Bureau of Mines
Special Publication

LIST OF BUREAU OF MINES PUBLICATIONS AND ARTICLES

January 1, 1985, to December 31, 1989

With Subject and Author Index

Compiled by Staff, Office of Public Information

UNITED STATES DEPARTMENT OF THE INTERIOR
1990

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UNITED STATES DEPARTMENT OF THE INTERIOR

Manuel Lujan, Jr., Secretary

BUREAU OF MINES

T S Ary, Director

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JANUARY 1, 1985, to DECEMBER 31, 1989

WITH SUBJECT AND AUTHOR INDEX

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INTRODUCTION

The Bureau of Mines was established in the public interest to conduct inquiries and scientific and technologic investigations concerning mining and the preparation, treatment, and utilization of mineral substances; to promote health and safety in the mineral industries; to conserve material resources and prevent their waste; to further economic development; to increase efficiency in the mining, metallurgical, quarrying, and other mineral industries; and to inquire into the economic conditions affecting those industries. The organic act of the Bureau, as amended by Congress and approved February 25, 1913, made it the province and duty of the Bureau of Mines to "disseminate information concerning these subjects in such manner as will best carry out the purposes of this Act."

In accordance with this directive, the Bureau reports the findings of its research and investigations in its own series of publications and also in articles that appear in scientific, technical, and trade journals; in proceedings of conventions and seminars; in reference books; and in other non-Bureau publications. The number of these reports, the wide range of subjects they cover, and the variety of mediums in which they appear make the kind of list and index presented in this special publication both necessary and valuable.

This issue of the Bureau of Mines List of Publications and Articles describes reports and articles published during the period January 1, 1985, to December 31, 1989. It supplements the 50-year list of Bureau publications issued from July 1, 1910, to January 1, 1960;[1] the 50-year list of articles by Bureau authors published outside the Bureau from July 1, 1910, to January 1, 1960;[2] the 5-year lists of publications and articles from January 1, 1960, to December 31, 1964,[3] from January 1, 1965, to December 31, 1969,[4] from January 1, 1970, to December 31, 1974,[5] from January 1, 1975, to December 31, 1979;[6] and from January 1, 1980, to December 31, 1984.[7]

[1] Available from National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, telephone 703/487-4650. NTIS publication number PB 295 062.
[2] Available from NTIS, publication number PB 295 432.
[3] Available from NTIS, publication number PB 295 481.
[4] Available from NTIS, publication number PB 198 112.
[5] Available from NTIS, publication number PB 252 843.
[6] Available from NTIS, publication number PB 82-145400.
[7] Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, GPO Stock No. 024-004-02188-8, $30; NTIS, publication number PB 89-234330.

BUREAU PUBLICATIONS

Some Bureau of Mines publications, including most Bulletins and the Minerals Yearbook, are sales publications; most other series are free or contain a substantial number of free publications. Because the price of sales publications varies, the price is indicated in the individual listing of any publication for which a charge is made. Prices listed are those set when the report was originally published; if no price is shown, the report was free.

Sales publications of the Bureau of Mines must be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, to whom orders should be sent directly. Sales publication purchases may be made by check or money order payable to the Superintendent of Documents, charged to a deposit account at the Government Printing Office, or charged on a VISA or MasterCard credit card.

An additional one-fourth of the current selling price of publication(s) ordered should be added on orders going to countries other than the United States or its possessions. Postage stamps and foreign money are not acceptable. When ordering publications by mail, please be sure to include your ZIP code. There is a minimum charge of $1 for each mail order.

Free publications of the Bureau of Mines may be obtained from Publication Distribution, Bureau of Mines, Cochrans Mill Road, P.O. Box 18070, Pittsburgh, PA 15236. Because of the limited editions, only 1 copy of any publication can be sent to the person applying and a maximum of 10 titles to any 1 applicant.

When Government Printing Office or Bureau stocks have been exhausted, the report may be available from the National Technical Information Service as described in the section entitled "Reports Available From the National Technical Information Service."

The following types or series of publications are issued by the Bureau of Mines.

Bulletins report the results of broad and significant projects or programs of scientific, historical, or economic research, or other investigations, including comprehensive and important mineral resource studies and compilations. Bulletins are usually prepared after all laboratory and field work has been completed, but they sometimes report a major phase of a larger or continuing investigation or research study. Bulletins rarely represent the first public report on the subject. As a rule, Bulletins encompass published work together with essential unpublished data and details.

Handbooks are instruction or information manuals designed to improve efficiency in the mineral industries or to promote the wise use of mineral resources. Based on research and the practical experience of Bureau and contractor personnel, Handbooks cover a wide range of subjects.

Reports of Investigations present the results of process research and investigations conducted by the Bureau at its research centers or laboratories, or in mines, quarries, smelters, plants, and other non-Bureau properties. Research conducted under contract to the Bureau that is deemed worthy of publication by the Bureau may be published in the Reports of Investigation series. Reports of Investigations differ from Bulletins in that they describe the principal features and results of individual experiments (single or multiple), minor research projects, or a significant coordinated phase of a major research project or program.

Information Circulars are concerned primarily with Bureau economic reviews and interpretative analyses. Information Circulars also cover surveys of mineral resources and related mining and operating activities, compilations of historical, statistical, and/or economic data on minerals, summaries of scientific and technical meetings and symposia, bibliographies, descriptions of new instrumentation and techniques, and descriptions of new industrial mining methods and metallurgical processes (as distinguished from those developed by the Bureau). Work done under contract to the Bureau that is deemed worthy of publication by the Bureau can be published in the Information Circular series.

Technology News is a succinct factsheet discussing new technologic developments from Bureau of Mines research programs that are of interest to the minerals industry. Technology News is issued as the need arises. For a free subscription to Technology News, write to Office of Technology Transfer, Bureau of Mines, Washington, DC 20241.

Mineral Issues are reports that identify and evaluate mineral policy issues to assist Government and private sector analysts and decisionmakers. Mineral Issues present mineral information in an analytically convenient form for the support of policy formulation and analysis; assess options to achieve mineral-related policy goals and provide an assessment of their economic, social, and environmental effects; examine specific issues of mineral economics using an accepted economics or operations research methodology; and/or assess the impact of Federal and State mineral-related policies.

Mineral Perspectives report on the mineral resources, industries, and related infrastructure of those foreign sources (individual countries or regions of the world) that assume major importance to our Nation's mineral needs.

Minerals Yearbooks summarize annually, on a calendar-year basis, the significant economic and technologic developments in the mineral industries. Three separate volumes are issued each year—Volume I, Metals and Minerals; Volume II, Area Reports: Domestic; and Volume III, Area Reports: International. Volume I presents, by mineral commodity, the salient statistics on production, trade, consumption, and other pertinent data. Volume II reviews the U.S. mineral industry by State and island possessions. Volume III presents the latest available mineral statistics for more than 150 countries and areas together with a review of the role of minerals in the economies of these nations. Chapters in these volumes are issued separately as preprints before the bound volumes are available.

Mineral Industry Surveys contain timely statistical and economic data on minerals. The surveys are designed to keep Government agencies and the public, particularly the mineral industry and business community, regularly informed of trends in the production, distribution, inventories, and consumption of minerals. Frequency of issue depends on the need for current data. Most of the reports are issued monthly, quarterly, or annually.

Mineral Commodity Summaries, an up-to-date annual summary of about 85 nonfuel mineral commodities, is the earliest Government publication to furnish estimates covering the previous year's nonfuel mineral industry data. It contains information on the domestic industry structure, Government programs, tariffs, and 5-year salient statistics.

Launched in 1989, the companion *State Mineral Summaries* provides estimated data and summaries of mineral activities at the State level; the summaries are prepared in cooperation with State geological surveys or related agencies.

At the end of 1989, the former *Minerals and Materials—A Bimonthly Survey* was replaced by a new periodical, *Minerals Today*. Providing readers with the latest information about developments, trends, and issues concerning the mining, processing, and use of minerals and materials, the new bimonthly is available by subscription through the Government Printing Office.

Special Publications comprise an omnibus category including publications ranging from popular-type pamphlets prepared for the general public to the Bureau's annual Research report.

Computer diskettes, tapes, and printouts are occasionally available containing mining and mineral data. A list of computer products available in early 1990 appears later in this publication.

LISTS OF BUREAU OF MINES PUBLICATIONS, JOURNAL ARTICLES, AND MOTION PICTURES

New Publications of the Bureau of Mines is a monthly list that gives titles and abstracts of publications, open file reports, and journal articles by Bureau authors. The list also tells where the reports can be obtained or inspected, and indicates the cost of the publication if it is for sale by the Superintendent of Documents at the U.S. Government Printing Office or by the National Technical Information Service.

Every 5 years the material from New Publications of the Bureau of Mines is compiled into an *indexed volume*, such as the present document. A list of previous indexed volumes appears on page 1.

Mineral Resource Films, Audiovisual Library, Bureau of Mines is a catalog of documentary-style films and videos produced in cooperation with major industrial sponsors for distribution by the Bureau of Mines to schools, libraries, and civic and professional organizations, and for broadcast on network-affiliated and independent cable television systems. These are professionally produced programs designed to inform viewers of the importance of minerals in our society, of how they affect every corner of our daily lives, and of the need for conservation of our finite natural resources. Most portray dramatic mining operations on the surface or underground;

the complex physical and chemical processes required to refine mineral values from today's low-grade ores; the manufacture of hundreds of products we use every day that are made possible by minerals; and the significance of minerals both now and to the economic, technological, and human challenges we will face in the future. All films and videos listed in this catalog are available on a short-term, free-loan basis to any responsible group or individual. Borrowers pay return postage only. Many of the films and videos in this series have won major national and international awards. Free catalogs can be obtained by writing Audiovisual Programs, Office of Public Information, Bureau of Mines, Washington, DC 20241.

Technology Transfer Films & Videos is a catalog of films and videos portraying the results of Bureau research projects that have been proven viable and are ready for transfer into industrial use. The films and videos are available on the same basis as the Mineral Resource Films described above. For a copy of the catalog, write to Office of Technology Transfer, Bureau of Mines, Washington, DC 20241.

ASSOCIATED DOCUMENTS

Although the material in the categories that follow is not published by the Bureau of Mines, it is listed and indexed in this publication as a service to those who may be interested.

Open File Reports are unpublished Bureau of Mines manuscripts, reports prepared for the Bureau under contracts, or material not in manuscript form, which the Bureau makes available for consultation at Bureau facilities; in the Natural Resources Library, U.S. Department of the Interior, Washington, DC; and/or for sale through the National Technical Information Service.

Mineral Land Assessments, a special open file report series, presents results of mineral investigations of areas studied by the Bureau of Mines. The results of these mineral investigations are to be incorporated in joint reports with the U.S. Geological Survey to provide information essential for determining the suitability of land for inclusion in the National Wilderness Preservation System.

Outside Publications are journal articles, papers in proceedings and transactions of symposia and society meetings, and other non-Bureau publications published by technical and trade journals, scientific organizations, and publishing houses.

The Bureau of Mines supports research at universities throughout the United States through 32 Mineral Institutes and 7 Generic Mineral Technology Centers. Research resulting from this support is reported in various media, as indicated under the heading *Mineral Institutes Reports.*

Patents issued to the Bureau are listed, with instructions on how to apply for permission to use such patents.

Reprints of Bureau of Mines publications that have been made available for purchase from the National Technical Information Service, U.S. Department of Commerce, are listed in the section "Reports Available From the National Technical Information Service."

DEPOSITORY LIBRARIES

Under the Depository Library Program established by Congress, Government publications are made available in designated depository libraries located in each State and congressional district to provide the general public with greater access to Government publications. Many of the depository libraries receive publications of the Bureau of Mines, and are thus a source for reports published by the Bureau when the publications are out of print. Generally, material more than 5 years old will no longer be available from the Bureau of Mines or Government Printing Office, although it may be available from the National Technical Information Service, as described later in this publication.

The following list contains the names and locations of depository libraries receiving various series of reports and documents issued by the Bureau of Mines; an asterisk preceding the name of a library indicates that it is one of the 50 Regional Depository Libraries, which receive copies of nearly all Government publications.

The figures in parentheses following the names of the libraries indicate the types of Bureau publications generally received on a regular basis by each library, according to the following code:

(1)Reports of Investigations and Information Circulars
(2)Bulletins
(3)Minerals Yearbooks

ALABAMA

Auburn–Auburn University, Ralph Brown Draughton Library (1, 2, 3).
Birmingham–Birmingham Public Library (1, 2, 3).
Birmingham-Southern College Library (2).
Jefferson State Junior College (3).
Samford University, Harwell G. Davis Library (3).
Fayette–Brewer State Junior College Library (1, 2, 3).
Florence–University of North Alabama, Collier Library (3).
Gadsen–Gadsen Public Library (3).
Huntsville–University of Alabama in Huntsville Library (3).
Jacksonville–Jacksonville State University Library (3).
Mobile–Mobile Public Library (3).
University of South Alabama Library (1, 2, 3).
Montgomery–Alabama Public Library Service (3).
*Auburn University at Montgomery Library (1, 2, 3).
Normal–Alabama Agricultural and Mechanical University, Drake Memorial Library (3).
Troy–Troy State University Library (3).
University–*University of Alabama Library (1, 2, 3).

ALASKA

Anchorage–Anchorage Municipal Libraries, Z. J. Loussac Public Library (3).
*U.S. Department of the Interior, Alaska Resources Library (1, 2, 3).
University of Alaska, Anchorage Library (1, 2, 3).
Fairbanks–University of Alaska, Elmer E. Rasmuson Library (1, 2, 3).
Juneau–Alaska State Library (2, 3).

ARIZONA

Coolidge–Central Arizona College, Instructional Materials Center (3).
Flagstaff–Northern Arizona University Library (1, 2, 3).
Glendale–Glendale Public Library (3).
Holbrook–Northern Pioneer College (3).
Mesa–Mesa Public Library (3).
Phoenix–Grand Canyon College, Fleming Library (3).
Phoenix Public Library (1, 2, 3).
Prescott–Yavapai College Learning Resource Center (2, 3).
Tempe–Arizona State University Library (1, 2, 3).
Arizona State University, College of Law Library (3).
Tucson–Tucson Public Library (3).
*University of Arizona Library (1, 2, 3).
Yuma–Yuma City-County Library (2, 3)

ARKANSAS

Arkadelphia–Ouachita Baptist University, Riley Library (2, 3).
Batesville–Arkansas College, Mabee Learning Resources Center (3).
Conway–Hendrix College, Olin C. Bailey Library (3).
Fayetteville–University of Arkansas Library (1, 2, 3).
Little Rock–*Arkansas State Library (1, 2, 3).
Central Arkansas Library System (3).
University of Arkansas at Little Rock Library (3).
University of Arkansas at Little Rock, School of Law and Pulaski County Law Library (3).
Magnolia–Southern Arkansas University, Magale Library (2, 3).
Monticello–University of Arkansas at Monticello Library (3).
Pine Bluff–University of Arkansas at Pine Bluff, Watson Memorial Library (3).
Russellville–Arkansas Tech University, Tomlinson Library (3).
State University–Arkansas State University, Dean B. Ellis Library (2, 3).
Walnut Ridge–Southern Baptist College, Felix Goodson Library (3).

CALIFORNIA

Anaheim–Anaheim Public Library (3).
Arcadia–Arcadia Public Library (3).
Arcata–Humboldt State University Library (1, 2, 3).
Bakersfield–California State College at Bakersfield Library (2, 3).
Kern County Library (1, 2, 3).
Berkeley–University of California at Berkeley, General Library (1, 2, 3).
Carson–California State University at Dominquez Hills, Educational Resources Center (3).
Carson Regional Library (3).
Chico–California State University, Chico Library (2, 3).
Claremont–Claremont College, Honnold Library (1, 2, 3).
Compton–Compton Library (3).
Culver City–Culver City Library (3).
Davis–University of California at Davis Library (1, 2, 3).
Downey–Downey City Library (3).
Fresno–California State University at Fresno Library (2, 3).
Fresno County Free Library (1, 2, 3).
Fullerton–California State University at Fullerton Library (2, 3).
Garden Grove–Garden Grove Regional Library (3).
Gardena–Gardena Public Library (3).
Hayward–California State University at Hayward Library (2, 3).
Huntington Park–Huntington Park Library, San Antonia Region (3).
Inglewood–City of Inglewood Public Library (2, 3).
Irvine–University of California at Irvine Library (1, 2, 3).
La Jolla–University of California at San Diego Library (3).
Lakewood–Angelo Iacoboni Public Library (3).
Lancaster–Lancaster Regional Library (3).
Long Beach–California State University at Long Beach Library (1, 2, 3).
Long Beach Public Library (1, 2, 3).
Los Angeles–California State University at Los Angeles, John F. Kennedy Memorial Library (1, 2, 3).
Los Angeles Public Library (1, 2, 3).
Loyola Marymount University, Charles Von Der Ahe Library (3).
Loyola University School of Law Library (3).
Occidental College, Mary Norton Clapp Library (2, 3).
University of California at Los Angeles Library (1, 2, 3).
University of Southern California, Doheny Memorial Library (1, 2, 3).
Montebello–Montebello Library (3).
Monterey Park–Bruggemeyer Memorial Library (3).
Northridge–California State University at Northridge, Oviatt Library (2, 3).
Norwalk–Norwalk Public Library (3).
Oakland–Oakland Public Library (1, 2, 3).
Ontario–Ontario Public Library (2, 3).
Palm Springs–Palm Springs Public Library (3).
Pasadena–California Institute of Technology, Millikan Memorial Library (1, 2, 3).
Pasadena Public LIbrary (1, 2, 3).
Pleasant Hill–Contra Costa County (3).
Redding–Shasta County Library (2, 3).
Redlands–University of Redlands, Armacost Library (2, 3).
Redwood City–Redwood City Public Library (3).
Reseda–West Valley Regional Branch Library (3).
Riverside–Riverside City and County Public Library (2, 3).
University of California at Riverside Library (1, 2, 3).
Sacramento–*California State Library (1, 2, 3).
California State University at Sacramento Library (1, 2, 3).
Sacramento Public Library (2, 3).
San Bernardino–San Bernardino County Library (1, 2, 3).
San Diego–San Diego County Library (3).
San Diego Public Library (1, 2, 3).
San Diego State University, Malcolm A. Love Library (1, 2, 3).
University of San Diego, School of Law Library (3).
San Francisco–Hastings College of Law Library (3).
San Francisco Public Library (1, 2, 3).
San Francisco State University Library (1, 2, 3).
University of San Francisco, Gleeson Library (2, 3).
San Jose–San Jose State University Library (1, 2, 3).
San Leandro–San Leandro Community Library (3).
San Luis Obispo–California Polytechnic State University Library (1, 2, 3).
San Mateo–College of San Mateo Library (3).
San Rafael–Marin County Free Library (3).
Santa Ana–Santa Ana Public Library (2, 3).
Santa Barbara–University of California at Santa Barbara Library (1, 2, 3).
Santa Clara–University of Santa Clara, Michel Orradre Library (3).
Santa Cruz–University of California at Santa Cruz Library (1, 2, 3).
Santa Rosa–Santa Rosa-Sonoma County Library (2, 3).
Stanford–Stanford University, Jonsson Library (1, 2, 3).
Stanford University, Robert Crown Law Library (3).
Stockton–Stockton and San Joaquin County Public Library (2, 3).
Thousand Oaks–California Lutheran College Library (2, 3).
Torrance–Torrance Public Library (3).
Turlock–California State College at Stanislaus Library (3).
Valencia–Valencia Library (3).
Vallejo–Solano County Library (2, 3).
Ventura–Ventura County Library (3).
Visalia–Tulare County Free Library (3).
Walnut–Mount San Antonio College Learning Resources Center (2, 3).
West Covina–West Covina Library (3).
Whittier–Whittier College, Bonnie Bell Wardman Library (3).

COLORADO

Alamosa–Adams State College Learning Resources Center (1, 2, 3).
Aurora–Aurora Public Library (3).
Boulder–*University of Colorado Libraries (1, 2, 3).
Colorado Springs–Colorado College, Charles Leaming Tutt Library (2, 3).
U. S. Air Force Academy (3).
Denver–Auraria Libraries (2, 3).
*Denver Public Library (1, 2, 3).
University of Denver, Penrose Library (1, 2, 3)
University of Denver, Westminster Law Library (3).
Water and Power Resources Service Library (3).

Fort Collins–Colorado State University Libraries (1, 2, 3).
Golden–Colorado School of Mines, Arthur Lakes Library (1, 2, 3).
Grand Junction–Mesa County Public Library (1, 2, 3).
Greeley–University of Northern Colorado, James A. Michener Library (1, 3).
Gunnison–Western State College of Colorado, Leslie J. Savage Library (1, 2, 3).
Lakewood–Jefferson County Public Library (3).
Pueblo–Pueblo Regional Library (1).
University of Southern Colorado Library (1, 2, 3).

CONNECTICUT

Bridgeport–Bridgeport Public Library (1, 2, 3).
University of Bridgeport, Law Library (3).
Danbury–Western Connecticut State College, Ruth A. Haas Library (2).
Enfield–Enfield Central Library (2, 3).
Hartford–*Connecticut State Library (1, 2, 3).
Hartford Public Library (3).
Trinity College Library (3).
University of Connecticut, School of Law Library (3).
Middletown–Wesleyan University, Olin Memorial Library (1, 2, 3).
New Britain–Central Connecticut State College Library (2, 3).
New Haven–Southern Connecticut State College, Hilton C. Buley Library (2, 3).
Yale University Library (2, 3).
New London–Connecticut College Library (3).
U. S. Coast Guard Academy (3).
Stamford–Ferguson Library (3).
Storrs–University of Connecticut, Wilbur Cross Library (1, 2, 3).
Waterbury–Post College, Traurig Library (3).
Silas Bronson Library (3).
West Haven–University of New Haven Library (3).

DELAWARE

Newark–University of Delaware, Morris Library (1, 2, 3).

DISTRICT OF COLUMBIA

Washington–George Washington University, Gelman Library (3).
Georgetown University Library (2, 3).
National Defense University Library (2).
U. S. Department of the Interior, Natural Resources Library (1, 2, 3).
U. S. Department of State Library (2).
U. S. Department of Treasury Library (2).

FLORIDA

Boca Raton–Florida Atlantic University, S. E. Wimberly Library (1, 2, 3).
Clearwater–Clearwater Public Library (3).
Daytona Beach–Volusia County Public Library (3).
De Land–Stetson University, DuPont-Ball Library (3).
Fort Lauderdale–Broward County Main Library (1, 2, 3).
Nova University, Law Center Library (3).
Fort Pierce–Indian River Community College (3).
Gainesville–*University of Florida Libraries (1, 2, 3).
Jacksonville–Jacksonville Public Library System, Haydon Burns Library (1, 2, 3).
Jacksonville University, Swisher Library (3).
Lakeland–Lakeland Public Library (3).
Melbourne–Florida Institute of Technology (3).
Miami–Florida International University, North Miami Campus Library (3).
Miami-Dade Public Library System (2).
Orlando–University of Central Florida Library (1, 2, 3).
Palatka–St. James River Community College Library (3).
Pensacola–University of West Florida, John C. Pace Library (3).
Port Charlotte–Charlotte County Library System (3).
St. Petersburg–St. Petersburg Public Library (3).
Sarasota–Selby Public Library (3).
Tallahassee–Florida Agricultural and Mechanical University, Coleman Memorial Library (2, 3).
Florida State Library, R. A. Gray Building (3).
Florida State University, Robert Manning Strozier Library (1, 2, 3).
Tampa–Tampa Public Library (1, 2, 3)
University of South Florida Library (1, 2, 3).
Winter Park–Rollins College, Mills Memorial Library (3).

GEORGIA

Albany–Albany Dougherty Public Library (3).
Americus–Georgia Southwestern College, James Earl Carter Library (1, 2, 3).
Athens–*University of Georgia Libraries (1, 2, 3).
Atlanta–Atlanta Public Library (2, 3).
Atlanta University (3).
Emory University, Robert W. Woodruff Library (2, 3).
Georgia Institute of Technology, Price Gilbert Memorial Library (1, 2, 3).
Georgia State Library (3).
Georgia State University (1, 2, 3).
Augusta–Augusta College, Reese Library (1, 2, 3).
Brunswick–Brunswick-Glynn County Regional Library (3).
Carrollton–West Georgia College Library (2, 3).
Columbus–Columbus College, Simon Schwob Memorial Library (3).
Dahlonega–North Georgia College, Stewart Library (2, 3).
Dalton–Dalton Junior College Library (3).
Macon–Mercer University, Walter F. George School of Law Library (3).
Marietta–Kennesaw College Library (3).
Milledgeville–Georgia College at Milledgeville, Ina Dillard Russell Library (3).
Savannah–Chatham-Effingham-Liberty Regional Library (3).
Statesboro–Georgia Southern College (1, 2, 3).
Valdosta–Valdosta State College Library (3).

HAWAII

Hilo–University of Hawaii at Hilo Libraries (3).
Honolulu–Hawaii State Library System (3).
*University of Hawaii Library (1, 2, 3).
Laie–Brigham Young University–Hawaii Campus, Joseph F. Smith Library (3).

IDAHO

Boise–Boise Public Library and Information Center (1, 2, 3).
Boise State University Library (1, 2, 3).
Idaho State Law Library (3).
Idaho State Library (1, 2, 3).
Caldwell–College of Idaho, Terteling Library (2, 3).
Moscow–*University of Idaho, College of Law Library (3).
University of Idaho Library (1, 2, 3).
Nampa–Northwest Nazarene College, Riley Library (1, 2, 3).
Pocatello–Idaho State University Library (1, 2, 3).
Rexberg–Ricks College, David O. McKay Library (1, 2, 3).
Twin Falls–College of Southern Idaho Library (2, 3).

ILLINOIS

Carbondale–Southern Illinois University at Carbondale, Morris Library (1, 2, 3).
Carlinville–Blackburn College, Lumpkin Library (2, 3).
Carterville–Shawnee Library System (3).
Champaign–University of Illinois Law Library (3).
Charleston–Eastern Illinois University, Booth Library (3).
Chicago–Chicago Public Library (1, 2, 3).
Chicago State University Library (3).
De Paul University Law Library (3).
Field Museum of Natural History Library (1, 2, 3).
Galvin Library, Doctoral Department (3).
Illinois Institute of Technology, Kent College of Law Library (3).
Loyola University of Chicago, E. M. Cudahy Memorial Library (3).
Northeastern Illinois University Library (3).
University of Chicago Law Library (3).
University of Chicago Libraries (1, 2, 3).
University of Illinois at Chicago Circle Library (1, 2, 3).
Decatur–Decatur Public Library (3).
De Kalb–Northern Illinois University, Founders Memorial Library (1, 2, 3).
Edwardsville–Southern Illinois University, Lovejoy Memorial Library (1, 2, 3).
Elsah–Principia College, Marshall Brooks Library (3).
Evanston–Northwestern University Library (1, 2, 3).
Freeport–Freeport Public Library (3).
Galesburg–Galesburg Public Library (3).
Jacksonville–MacMurray College, Henry Pfeiffer Library (3).
Kankakee–Olivet Nazarene College, Benner Library (3).
Lake Forest–Lake Forest College, Donnelley Library (2, 3).
Lisle–Illinois Benedictine College, Theodore Lownik Library (3).
Macomb–Western Illinois University Library (1, 2, 3).
Moline–Black Hawk College Learning Resource Center (3).
Monmouth–Monmouth College, Hewes Library (3).
Mount Carmel–Wabash Valley College Library (2, 3).
Normal–Illinois State University, Milner Library (1, 2, 3).
Oak Park–Oak Park Public Library (2, 3).
Oglesby–Illinois Valley Community College, Jacobs Memorial Library (1, 3).
Palos Hills–Moraine Valley Community College Library (3).
Peoria–Bradley University Library (2, 3).
Peoria Public Library (1, 2, 3).
River Forest–Rosary College, Rebecca Crown Library (3).
Rockford–Rockford Public Library (3).
Romeoville–Lewis University Library (2, 3).
Springfield–*Illinois State Library (1, 2, 3).
Streamwood–Poplar Creek Public Library (3).
Urbana–University of Illinois Library (1, 2, 3).
Wheaton–Wheaton College Library (3).
Woodstock–Woodstock Public Library (3).

INDIANA

Anderson–Anderson College, Charles E. Wilson Library (3).
Anderson Public Library (3).
Bloomington–Indiana University Law Library (3).
Indiana University Libraries (1, 2, 3).
Crawfordsville–Wabash College, Lilly Library (3).
Evansville–Evansville and Vanderburgh County Public Library (1, 2, 3).
Indiana State University at Evansville Library (1).
Fort Wayne–Indiana University-Purdue University at Fort Wayne Library (3).
Public Library of Fort Wayne and Allen County (1, 2, 3).
Gary–Indiana University, Northwest Library (2, 3).
Greencastle–DePauw University, Roy O. West Library (1, 2, 3).
Hammond–Hammond Public Library (3).
Hanover–Hanover College Library (2, 3).
Huntington–Huntington College (3).
Indianapolis–Butler University, Irwin Library (2, 3).
*Indiana State Library (1, 2, 3).
Indiana University-Purdue University at Indianapolis Library (2, 3).
Indianapolis-Marion County Public Library (1, 2, 3).
Kokomo–Indiana University at Kokomo Library (3).
Lafayette–Purdue University Library (1, 2, 3).
Muncie–Ball State University Library (2, 3).
Muncie-Center Township Public Library (3).
New Albany–Indiana University Southeast Library (1, 2).
Notre Dame–University of Notre Dame, Memorial Library (1, 2, 3).
Rensselaer–St. Joseph's College Library (2, 3).
Richmond–Earlham College, Lilly Library (2, 3).
Wayne Township Library, Morrisson-Reeves Library (2, 3).
South Bend–Indiana University at South Bend Library (3).
Terre Haute–Indiana State University, Cunningham Memorial Library (2, 3).
Valparaiso–Valparaiso University, Moellering Memorial Library (1, 3).

IOWA

Ames–Iowa State University Library (1, 2, 3).
Cedar Falls–University of Northern Iowa Library (3).
Council Bluffs–Free Public LIbrary (3).
Iowa Western Community College, Hoover Media Library (3).
Davenport–Davenport Public Library (1, 2, 3).
Des Moines–Drake University, Cowles Library (2, 3).

Public Library of Des Moines (3).
Dubuque–Carnegie-Stout Public Library (3).
Grinnell–Grinnell College Library (3).
Iowa City–University of Iowa Law Library (3).
*University of Iowa Libraries (1, 2, 3).
Lamoni–Graceland College, Frederick Madison Smith Library (3).
Mason City–North Iowa Area Community College Library (3).
Mount Vernon–Cornell College, Russell D. Cole Library (1, 2, 3).
Orange City–Northwestern College, Ramaker Library (3).
Sioux City–Sioux City Public Library (3).

KANSAS

Atchison–Benedictine College, North Campus Library (3).
Colby–Colby University Community College, H. F. Davis Memorial Library (3).
Emporia–Emporia State University, William Allen White Library (2, 3).
Hays–Fort Hays State University, Forsyth Library (1, 3).
Hutchison–Hutchison Public Library (3).
University of Kansas School of Law Library (3).
Manhattan–Kansas State University Library (2, 3).
Pittsburg–Pittsburg State University Library (2, 3).
Salina–Kansas Wesleyan University, Memorial Library (3).
Shawnee Mission–Johnson County Library (3).
Topeka–Kansas State Library (3).
Washburn University of Topeka, School of Law Library (3).
Wichita–Wichita State University Library (2, 3).

KENTUCKY

Barbourville–Union College, Abigail E. Weeks Memorial Library (3).
Bowling Green–Western Kentucky University, Helm-Cravens Library (2, 3).
Danville–Centre College of Kentucky, Grace Doherty Library (3).
Frankfort–Kentucky Department of Library and Archives (3).
Kentucky State University, Blazer Library (2, 3).
State Law Library (3).
Highland Heights–Northern Kentucky University, W. Frank Steeley Library (1, 2, 3).
Lexington–*University of Kentucky Library (1, 2, 3).
University of Kentucky Law Library (3).
Louisville–Louisville Free Public Library (3).
University of Louisville, Ekstrom Library (2, 3).
Morehead–Morehead State University, Johnson Camden-Julian Carroll Library (1, 2, 3).
Murray–Murray State University Library (1, 2, 3).
Owensboro–Kentucky Wesleyan College Library (3).
Richmond–Eastern Kentucky University, John Grant Crabbe Library (1, 2, 3).

LOUISIANA

Baton Rouge–Louisiana State Library (3).
*Louisiana State University, Middleton Library (1, 2, 3).
Eunice–Louisiana State University at Eunice, LeDoux Library (2, 3).
Hammond–Southeastern Louisiana University, Linus A. Sims Memorial Library (3).
Lafayette–University of Southwestern Louisiana Libraries (1, 2, 3).
Lake Charles–McNeese State University, Frazer Memorial Library (1, 2, 3).
Monroe–Northeast Louisiana University, Sandel Library (2, 3).
Natchitoches–Northwestern State University of Louisiana, Watson Memorial Library (3).
New Orleans–Loyola University Library (3).
New Orleans Public Library (2, 3).
Southern University in New Orleans (3).
Tulane University of Louisiana, Howard-Tilton Memorial Library (1, 2, 3).
Pineville–Louisiana College, Norton Memorial Library (3).
Ruston–*Louisiana Tech University, Prescott Memorial Library (1, 2, 3).
Shreveport–Louisiana State University in Shreveport Library (1, 2, 3).
Shreve Memorial Library (1, 2, 3).
Thibodaux–Nicholls State University, Ellender Memorial Library (1, 2, 3).

MAINE

Augusta–Maine State Library (2, 3).
Brunswick–Bowdoin College Library (2, 3).
Castine–Marine Maritime Academy, Nutting Memorial Library (3).
Lewiston–Bates College Library (2, 3).
Orono–*University of Maine at Orono, Raymond H. Fogler Library (1, 2, 3).
Portland–Portland Public Library (2, 3).
University of Maine Law Library (3).
Presque Isle–University of Maine at Presque Isle Library (3).
Waterville–Colby College Library (2, 3).

MARYLAND

Annapolis–U. S. Naval Academy, Nimitz Library (2, 3).
Baltimore–Enoch Pratt Free Library (1, 2).
Johns Hopkins University, Milton S. Eisenhower Library (1).
Beltsville–U. S. Department of Agriculture, National Agricultural Library (3).
College Park–*University of Maryland, McKeldin Library (1, 2).
Rockville–Montgomery County Department of Public Libraries (2).
Salisbury–Salisbury State College, Blackwell Library (2).

MASSACHUSETTS

Amherst–Amherst College Library (2, 3).
University of Massachusetts at Amherst, Goodell Library (1, 2, 3).
Boston–Boston College, Thomas P. O'Neill, Jr., Library (2, 3).
*Boston Public Library (1, 2, 3).
Brandeis University Library (3).

Harvard College Library (3).
Massachusetts Institute of Technology Libraries (1, 2, 3).
Northeastern University, Dodge Library (2, 3).
State Library of Massachusetts (3).
Suffolk University Law Library (3).

Brookline--Public Library of Brookline (3).

Chicopee--College of Our Lady of the Elms (3).

Lowell--University of Lowell, Alumni-Lydon Library (3).

Medford--Tufts University Library (2, 3).

North Dartmouth--Southeastern Massachusetts University Library (1, 2, 3).

North Easton--Stonehill College, Cushing-Martin Library (3).

Springfield--Springfield City Library (3).
Western New England College Law Library (3).

Wellesley--Wellesley College Library (3).

Williamstown--Williams College Library (3).

Worcester--Worcester Public Library (3).

MICHIGAN

Albion--Albion College, Stockwell Memorial Library (3).

Allendale--Grand Valley State College Library (1, 2, 3).

Ann Arbor--University of Michigan, Harlan Hatcher Library (1, 2, 3).

Bloomfield Hills--Cranbrook Institute of Science Library (3).

Dearborn--Dearborn Department of Libraries, Henry Ford Centennial Library (3).
Henry Ford Community College Library (3).

Detroit--*Detroit Public Library (1, 2, 3).
Mercy College of Detroit Library (3).
University of Detroit Library (3).
University of Detroit, Law Library (3).
Wayne State University, G. Flint Purdy Library (1, 2, 3).

Dowagaic--Southwestern Michigan College (3).

East Lansing--Michigan State University Library (3).

Farmington--Oakland Community College, Martin L. King Learning Resources Center (3).

Flint--Flint Public Library (3).
University of Michigan at Flint Library (3).

Grand Rapids--Calvin College and Seminary Library (3).
Grand Rapids Public Library (3).

Houghton--Michigan Technological University Library (1, 2, 3).

Jackson--Jackson District Library (3).

Kalamazoo--Kalamazoo Public Library (3).
Western Michigan University, Dwight B. Waldo Library (1, 2, 3).

Madison Heights--Madison Heights Public Library (3).

Marquette--Northern Michigan University, Olson Library (1, 2, 3).

Mount Pleasant--Central Michigan University Library (2, 3).

Muskegon--Hackley Public Library (3).

Port Huron--St. Clair County Library System (3).

Rochester--Oakland University, Kresge Library (3).

Royal Oak--Royal Oak Public Library (3).

Saginaw--Hoyt Public Library (3).

Sault Sainte Marie--Lake Superior State College (3).

Traverse City--Northwestern Michigan College, Mark Osterlin Library (3).

University Center--Delta College Library (3).

Ypsilanti--Eastern Michigan University Library (1, 2, 3).

MINNESOTA

Bemidji--Bemidji State University, A. C. Clark Library (3).

Blaine--Anoka County Library (3).

Collegeville--St. John's University, Alcuin Library (3).

Cottage Grove--Washington County Library (3).

Duluth--Duluth Public Library (3).

Eagen--Dakota County Library (3).

Edina--Southdale Hennepin Library (2, 3).

Mankato--Mankato State University Library (1, 2, 3).

Minneapolis--Minneapolis Public Library (2, 3).
*University of Minnesota, Wilson Library (1, 2, 3).

Moorhead--Moorhead State University Library (3).

Morris--University of Minnesota at Morris Library (3).

Northfield--Carleton College Library (2, 3).
St. Olaf College, Rolvaag Memorial Library (3).

St. Cloud--St. Cloud State University Library (1, 3).

St. Paul--Hamline University, School of Law Library (3).
Minnesota Historical Society Library (3).
St. Paul Public Library (2, 3).
University of Minnesota, St. Paul Campus Library (3).

St. Peter--Gustavus Aldophus College Library (2).

Winona--Winona State University, Maxwell Library (3).

MISSISSIPPI

Cleveland--Delta State University, W. B. Roberts Library (3).

Hattiesburg--University of Southern Mississippi Library (1, 2, 3).

Jackson--Millsaps College, Millsaps-Wilson Library (3).
Mississippi College, School of Law (3).
Mississippi Library Commission (3).

Lorman--Alcorn State University Library (2, 3).

Mississippi State--Mississippi State University, Mitchell Memorial Library (1, 2, 3).

University--*University of Mississippi Library (1, 2, 3).

MISSOURI

Cape Girardeau--Southeast Missouri State University, Kent Library (2, 3).

Columbia--University of Missouri at Columbia Library (1, 2, 3).

Fulton--Westminster College, Reeves Library (3).

Jefferson City--Missouri State Library (3).

Joplin--Missouri Southern State College Library (3).

Kansas City--Kansas City Public Library (2, 3).
University of Missouri at Kansas City Library (1, 2, 3).

Kirksville--Northeast Missouri State University, Pickler Memorial Library (3).

Liberty--William Jewell College Library (3).

Maryville--Northwest Missouri State University, Owens Library (1, 2, 3).

Rolla--University of Missouri at Rolla Library (1, 2, 3).

St. Louis--Maryville College Library (3).
St. Louis County Library (2, 3).
St. Louis Public Library (1, 2, 3).
St. Louis University, Pius XII Memorial Library (1, 2, 3).

University of Missouri at St. Louis, Thomas Jefferson Library (1, 2, 3).
Washington University, John M. Olin Library (1, 2, 3).
Springfield–Southwest Missouri State University Library (1, 2, 3).
Drury College, Walker Library (3).
Warrensburg–Central Missouri State University, Ward Edwards Library (1, 2, 3).

MONTANA

Billings–Eastern Montana College Library (1, 2, 3).
Bozeman–Montana State University Library (2, 3).
Butte–Montana College of Mineral Science and Technology Library (1, 2, 3).
Technology Library (1, 2, 3).
Havre–Northern Montana College (3).
Helena–Carroll College Library (3).
Montana State Library (1, 2, 3).
Missoula–*University of Montana, Mansfield Library (1, 2, 3).

NEBRASKA

Blair–Dana College, C. A. Dana-Life Library (3).
Fremont–Midland Lutheran College Library (3).
Kearney–Kearney State College, Calvin T. Ryan Library (2, 3).
Lincoln–*Nebraska Library Commission (3).
University of Nebraska, D. L. Love Memorial Library (1, 2, 3).
Omaha–Creighton University, Alumni Memorial Library (3).
Omaha Public Library, W. Dale Clark Branch (1, 2, 3).
University of Nebraska at Omaha Library (1, 3).
Wayne–Wayne State College, U. S. Conn Library (3).

NEVADA

Carson City–Nevada State Library (1, 2, 3).
Las Vegas–Clark County Library District (3).
University of Nevada at Las Vegas, James R. Dickinson Library (1, 2, 3).
Reno–Nevada State Historical Society (3).
*University of Nevada Library (1, 2, 3).
Washoe County Library (2, 3).

NEW HAMPSHIRE

Concord–New Hampshire State Library (1, 2, 3).
Durham–University of New Hampshire (1, 2, 3).
Hanover–Dartmouth College, Baker Memorial Library (1, 2, 3).
Manchester–Manchester City Library (3).
New Hampshire College, Shapiro Library (3).
Nashua–Nashua Public Library (3).

NEW JERSEY

Bayonne–Bayonne Free Public Library (2, 3).
Bloomfield–Bloomfield Public Library (2, 3).
Bridgeton–Cumberland County Library (3).
Camden–Rutgers University at Camden Library (3).
East Brunswick–East Brunswick Public Library (3).
East Orange–East Orange Public Library (3).
Elizabeth–Elizabeth Public Library (3).
Glassboro–Glassboro State College, Savitz Learning Resource Center (2, 3).
Hackensack–Johnson Free Public Library (3).
Jersey City–Jersey City Public Library (3).
Jersey City State College, F. A. Irwin Library (3).
Lawrenceville–Rider College Library (3).
Madison–Drew University, Rose Memorial Library (3).
Mahwah–Ramapo College of New Jersey Library (3).
Mount Holly–Burlington County Library (3).
New Brunswick–New Brunswick Free Public Library (3).
Rutgers University Library (1, 2, 3).
Newark–*Newark Public Library (1, 2, 3).
Rutgers University, State University of New Jersey, John Cotton Dana Library (1, 2, 3).
Passaic–Passaic Public Library (3).
Plainfield–Plainfield Free Public Library (2, 3).
Ponoma–Stockton State College Library (1, 2, 3).
Princeton–Princeton University Library (2, 3).
Red Bank–Monmouth County Library, Eastern Branch (3).
Rutherford–Fairleigh Dickinson University, Messler Library (3).
South Orange–Seton Hall University, McLaughlin Library (3).
Teaneck–Fairleigh Dickinson University, Teaneck Campus Library (2, 3).
Toms River–Ocean County College Learning Resources Center (2, 3).
Trenton–New Jersey State Library (3).
Trenton Free Public Library (3).
Union–Kean College of New Jersey, Nancy Thompson Library (3).
Wayne–Wayne Public Library (3).
West Long Branch–Monmouth College, Guggenheim Library (3).
Woodbridge–Free Public Library of Woodbridge (3).

NEW MEXICO

Albuquerque–*University of New Mexico, Zimmerman Library (1, 2, 3).
Hobbs–New Mexico Junior College, Pannell Library (1, 3).
Las Cruces–New Mexico State University Library (3).
Las Vegas–New Mexico Highlands University, Donnelly Library (3).
Portales–Eastern New Mexico University Library (1, 2, 3).
Santa Fe–*New Mexico State Library (1, 2, 3).
New Mexico Supreme Court Law Library (3).
Silver City–Western New Mexico University, Miller Library (1, 3).
Socorro–New Mexico Institute of Mining and Technology Library (1, 2, 3).

NEW YORK

Albany–*New York State Library (1, 2, 3).
State University of New York at Albany Library (2, 3).
Auburn–Seymour Library (3).
Binghamton–State University of New York at Binghamton/Glenn G. Bartle Library (1, 2, 3).
Brockport–State University of New York College at Brockport, Drake Memorial Library (1, 2, 3).

Bronx–Fordham University Library (3).
Herbert H. Lehman College Library (3).
State University of New York Maritime College Library (3).
Brooklyn–Brooklyn College Library (3).
Brooklyn Public Library (3).
Pratt Institute Library (3).
Buffalo–Buffalo and Erie County Public Library (1, 2, 3).
State University of New York at Buffalo, Charles B. Sears Law Library (3).
State University of New York at Buffalo, Lockwood Library (1, 2, 3).
Canton–St. Lawrence University, Owen D. Young Library (1, 2, 3).
Corning–Corning Community College, Arthur A. Houghton, Jr., Library (3).
Cortland–State University of New York College at Cortland, Memorial Library (3).
Delhi–State University Agricultural and Technical College Library (3).
East Islip–East Islip Public Library (3).
Elmira–Elmira College, Gannett-Tripp Learning Center (3).
Flushing–Queens College Library (2, 3).
Garden City–Adelphi University Library (3).
Genesco–State University of New York College at Genesco, Milne Library (1, 2, 3).
Greenvale–C. W. Post Center of Long Island University, B. Davis Swartz Memorial Library (2, 3).
Hamilton–Colgate University Library (1, 2, 3).
Hempstead–Hofstra University Library (3).
Ithaca–Cornell University Library (1, 2, 3).
Jamaica–Queens Borough Public Library (1, 2).
St. John's University Library (3).
Mount Vernon–Mount Vernon Public Library (3).
New Paltz–State University of New York College at New Paltz Library (2, 3).
New York–Benjamin N. Cardozo Law School Library (3).
City University of New York, City College Library (1, 2, 3).
Columbia University Libraries (1, 2, 3).
Cooper Union Library (3).
New York Law Institute Library (3).
New York Public Library, Astor Branch (3).
New York Public Library, Lenox Branch (1, 2, 3).
New York University Law Library (3).
New York University Library (2, 3).
Yeshiva University, Pollack Library (3).
Newburgh–Newburgh Free Library (3).
Niagara Falls–Niagara Falls Public Library (3).
Oakdale–Dowling College Library (3).
Oneonta–State University of New York, College at Oneonta, James M. Milne Library (2, 3).
Oswego–State University of New York, Penfield Library (2, 3).
Plattsburgh–State University of New York College at Plattsburgh, Benjamin F. Feinburg Library (2, 3).
Potsdam–Clarkson University Library (1, 2, 3).
State University of New York College at Potsdam Library (1, 3).
Poughkeepsie–Vassar College Library (3).
Purchase–State University of New York College at Purchase Library (3).
Rochester–Rochester Public Library (2, 3).
University of Rochester Library (1, 2, 3).
Saratoga Springs–Skidmore College Library (3).
Schenectady–Union College, Shaffer Library (2, 3).
Southampton–Southampton College Library of Long Island University (3).
Sparkhill–St. Thomas Aquinas College (3).
Stony Brook–State University of New York at Stony Brook, Main Library (1, 2, 3).
Syracuse–Syracuse University Library (1, 2, 3).
Onondaga County Public Library System (3).
Troy–Troy Public Library (1, 2, 3).
Uniondale–Nassau Library System (2, 3).
Utica–State University of New York College of Technology, Utica-Rome Library (3).
Utica Public Library (3).
White Plains–Pace University Law Library (3).
Yonkers–Sarah Lawrence College Library (3).
Yonkers Public Library (3).
Yorktown Heights–Mercy College (3).

NORTH CAROLINA

Asheville–University of North Carolina at Asheville, D. Hiden Ramsey Library (3).
Boone–Appalachian State University Library (1, 2, 3).
Buies Creek–Campbell College, Carrie Rich Memorial Library (3).
Charlotte–Public Library of Charlotte and Mecklenburg County (3).
University of North Carolina at Charlotte, Atkins Library (1, 2, 3).
Cullowhee–Western Carolina University, Hunter Library (1, 2, 3).
Davidson–Davidson College Library (3).
Durham–Duke University, William R. Perkins Library (1, 2, 3).
North Carolina Central University, James E. Shepard Memorial Library (3).
Elon College–Elon College Library (3).
Greensboro–North Carolina Agricultural and Technical State University, F. D. Bluford Library (2, 3).
University of North Carolina at Greensboro, Walter Clinton Jackson Library (3).
Greenville–East Carolina University Library (1, 2, 3).
Pembroke–Pembroke State University, Mary H. Livermore Library (1, 3).
Raleigh–North Carolina Department of Cultural Resources State Library (3).
North Carolina State University, D. H. Hill Library (1, 2, 3).
Rocky Mount–North Carolina Wesleyan College Library (3).
Wilmington–University of North Carolina at Wilmington, William M. Randall Library (1, 2, 3).
Wilson–Atlantic Christian College Library (2, 3).
Winston-Salem–Forsyth County Public Library (3).
Wake Forest University, Z. Smith Reynolds Library (3).

NORTH DAKOTA

Bismarck–North Dakota Historical Society (3).
North Dakota State Library (3).
Veterans Memorial Public Library (3).
Dickinson–Dickinson State College Library (3).
Fargo–Fargo Public Library (3).

North Dakota State University Library (1, 2, 3).
Grand Forks–*University of North Dakota, Chester Fritz Library (3).
Minot–Minot State College, Memorial Library (1, 2, 3).
Valley City–Valley City State College Library (3).

OHIO

Ada–Ohio Northern University, J. P. Taggart Law Library (3).
Akron–University of Akron, Bierce Library (1, 2, 3).
Alliance–Mt. Union College Library (1, 3).
Athens–Ohio University Library (1, 2, 3).
Bluffton–Bluffton College, Musselman Library (3).
Bowling Green–Bowling Green State University Library (2, 3).
Canton–Malone College, Everett L. Cattell Library (3).
Cincinnati–Public Library of Cincinnati and Hamilton County (1, 2, 3).
University of Cincinnati Library (1, 2, 3).
Cleveland–Case Western Reserve University, Freiberger Library (1, 2, 3).
Cleveland Heights-University Heights Public Library (3).
Cleveland Public Library (1, 2, 3).
Cleveland State University, Cleveland Marshall College of Law Library (3).
Cleveland State University Library (1, 3).
John Carroll University, Grasselli Library (3).
Columbus–Capital University Library (3).
*Ohio State Library (1, 2, 3).
Ohio State University Library (1, 2, 3).
Public Library of Columbus and Franklin County (3).
Dayton–Dayton and Montgomery County Public Library (1, 2, 3).
University of Dayton, Roesch Library (2, 3).
Wright State University Library (2, 3).
Delaware–Ohio Wesleyan University, L. A. Beeghly Library (1, 2, 3).
Elyria–Elyria Public Library (2, 3).
Gambier–Kenyon College Library (3).
Granville–Denison University Library (3).
Kent–Kent State University Library (1, 2, 3).
Marietta–Marietta College, Dawes Memorial Library (1, 3).
Marion–Marion Public Library (3).
Middletown–Miami University-Middletown, Gardner-Harvey Library (2, 3).
New Concord–Muskingum College Library (3).
Oberlin–Oberlin College Library (2, 3).
Oxford–Miami University Library (1, 2, 3).
Rio Grande–Rio Grande College, Jeanette Albiez Davis Library (3).
Steubenville–Public Library of Steubenville and Jefferson County (3).
Tiffin–Heidelberg College, Beeghly Library (3).
Toledo–University of Toledo Library (1, 2, 3).
Westerville–Otterbein College, Courtright Memorial Library (3).
Wooster–College of Wooster, Andrews Library (2, 3).
Youngstown–Public Library of Youngstown and Mahoning County (3).
Youngstown State University Library (1, 2, 3).

OKLAHOMA

Ada–East Central State University, Linscheid Library (3).
Alva–Northwestern Oklahoma State University Library (3).
Bethany–Bethany Nazarene College, R. T. Williams Library (3).
Durant–Southeastern Oklahoma State University Library (3).
Edmond–Central State University Library (3).
Enid–Enid Public Library (3).
Norman–University of Oklahoma Law Library (3).
University of Oklahoma Libraries (1, 2, 3).
Oklahoma City–Metropolitan Library System (3).
Oklahoma City University Library (3).
*Oklahoma Department of Libraries (1, 2, 3).
Shawnee–Oklahoma Baptist University (3).
Stillwater–*Oklahoma State University Library (1, 2, 3).
Tahlequah–Northeastern Oklahoma State University, John Vaughan Library (3).
Tulsa–Tulsa City-County Library (1, 2, 3).
University of Tulsa, McFarlin Library (1, 2, 3).
Weatherford–Southwestern Oklahoma State University, Al Harris Library (3).

OREGON

Ashland–Southern Oregon State College (2, 3).
Corvallis–Oregon State University (1, 3).
Eugene–University of Oregon (1, 2, 3).
Forest Grove–Pacific University (3).
La Grande–Eastern Oregon State College (1, 3).
McMinnville–Linfield College, Northrup Library (3).
Monmouth–Western Oregon State College (3).
Portland–Lewis and Clark College (3).
Library Association of Portland (2, 3).
*Portland State University (1, 2, 3).
Salem–Oregon State Library (1, 2, 3).
Willamette University (3).

PENNSYLVANIA

Allentown–Muhlenberg College (3).
Altoona–Altoona Public Library (3).
Bethlehem–Lehigh University (1, 2, 3).
Bradford–University of Pittsburgh (3).
Carlisle–Dickinson College, Boyd Lee Spahr Library (2, 3).
Dickinson School of Law, Sheely-Lee Law Library (3).
Cheyney–Cheyney State College, Leslie Pinckney Hill Library (3).
Erie–Erie Public Library (3).
Greenville–Thiel College, Langenheim Memorial Library (1, 2, 3).
Harrisburg–*State Library of Pennsylvania (1, 2, 3).
Haverford–Haverford College (3).
Hazleton–Hazleton Public Library (2, 3).
Indiana–Indiana University of Pennsylvania, Rhodes R. Stabley Library (3).
Johnstown–Cambria County Library System, Glosser Memorial Library (1, 2, 3).
Lancaster–Franklin and Marshall College (1, 2, 3).
Meadville–Allegheny College, Pelletier Library (1, 2, 3).
Millersville–Millersville State College, Ganser Library (3).

New Castle–New Castle Public Library (3).
Newtown–Bucks County Community College (3).
Norristown–Montgomery County-Norristown Public Library (3).
Philadelphia–Drexel University (1, 2, 3).
Free Library of Philadelphia (1, 2, 3).
Temple University, Paley Library (1, 2, 3).
University of Pennsylvania (1, 2, 3).
Pittsburgh–Carnegie Library of Pittsburgh (1, 2, 3).
La Roche College, John J. Wright Library (3).
University of Pittsburgh, Hillman Library (1, 2, 3).
Pottsville–Pottsville Free Public Library (2, 3).
Reading–Reading Public Library (2, 3).
Scranton–Scranton Public Library (3).
Shippensburg–Shippensburg State College, Ezra Lehman Memorial Library (3).
Swarthmore–Swarthmore College (3).
University Park–Pennsylvania State University (1, 2, 3).
Villanova–Villanova University Law Library (3).
Warren–Warren Library Association (3).
Waynesburg–Waynesburg College (2, 3).
Wilkes-Barre–King's College (2).
Williamsport–Lycoming College (3).
Youngwood–Westmoreland County Community College (3).

RHODE ISLAND

Providence–Brown University (1, 2, 3).
Providence College, Phillips Memorial Library (2, 3).
Providence Public Library (3).
Rhode Island College, James P. Adams Library (3).
Warwick–Warwick Public Library (3).
Westerly–Westerly Public Library (3).

SOUTH CAROLINA

Charleston–College of Charleston (3).
The Citadel Library (3).
Clemson–Clemson University Library (1, 2, 3).
Columbia–South Carolina State Library (1).
University of South Carolina (1, 2, 3).
Conway–University of South Carolina, Coastal Carolina College, Kimbel Library (3).
Due West–Erskine College, McCain Library (3).
Florence–Florence County Library (3).
Francis Marion College, James A. Rogers Library (3).
Greenville–Furman University (1, 2, 3).
Greenville County Library (3).
Rock Hill–Winthrop College, Dacus Library (3).
Spartanburg–Spartanburg County Public Library (3).

SOUTH DAKOTA

Aberdeen–Northern State College (3).
Brookings–South Dakota State University, H. M. Briggs Library (2, 3).
Pierre–South Dakota State Library (3).
Rapid City–South Dakota School of Mines and Technology Library (1, 2, 3).
Sioux Falls–Augustana College, Mikkelsen Library (3).
Sioux Falls Public Library (3).
Spearfish–Black Hills State College (2, 3).
Vermillion–University of South Dakota, I. D. Weeks Library (3).

TENNESSEE

Bristol–King College (3).
Chattanooga–Chattanooga-Hamilton County Bicentennial Library (1, 2, 3).
Clarksville–Austin Peay State University, Woodward Library (1, 2, 3).
Cleveland–Cleveland State Community College (3).
Cookeville–Tennessee Technological University, Jere Whitson Memorial Library (1, 2, 3).
Jefferson City–Carson-Newman College (3).
Johnson City–East Tennessee State University, Sherrod Library (1, 2, 3).
Knoxville–Knoxville-Knox County Public Library (2, 3).
University of Tennessee at Knoxville (1, 2, 3).
Martin–University of Tennessee at Martin (3).
Memphis–Memphis-Shelby County Public Library (2, 3).
Memphis State University (1, 2, 3).
Murfreesboro–Middle Tennessee State University (3).
Nashville–Public Library of Nashville and Davidson County (3).
Tennessee State Library and Archives (1, 2, 3).
Tennessee State University Library (3).
Vanderbilt University Library (1, 2, 3).
Sewanee–University of the South, Jessie Ball DuPont Library (2, 3).

TEXAS

Abilene–Abilene Christian University, Margaret and Herman Brown Library (2, 3).
Hardin-Simmons University (3).
Arlington–University of Texas (1, 2, 3).
Austin–*Texas State Library (1, 2, 3).
University of Texas, Perry-Castenada Library (1, 2, 3).
University of Texas, Lyndon B. Johnson School of Public Affairs Library (2, 3).
University of Texas Law Library (3).
Beaumont–Lamar University, Gray Library (1, 2, 3).
Brownwood–Howard Payne University, Walker Memorial Library (3).
Canyon–West Texas State University Library (1, 2, 3).
College Station–Texas A & M University (1, 2, 3).
Commerce–East Texas State University (1, 2, 3).
Corpus Christi–Corpus Christi State University (3).
Dallas–Dallas Public Library (1, 2, 3).
Southern Methodist University, Fondren Library (1, 2, 3).
Denton–North Texas State University (2, 3).
Edinburg–Pan American University (3).
El Paso–El Paso Public Library (3).
University of Texas (1, 2, 3).
Fort Worth–Fort Worth Public Library (1, 2).
Texas Christian University, Mary Couts Burnett Library (1, 2, 3).
Galveston–Rosenburg Library (3).
Houston–Houston Public Library (1, 2, 3).
North Harris County College (3).
Rice University, Fondren Library (1, 2, 3).
South Texas College of Law (3).
University of Houston (1, 2, 3).

University of Houston, Clear Lake City Library (3).
Huntsville–Sam Houston State University (3).
Irving–Irving Public Library System (3).
Kingsville–Texas A & I University (1, 2, 3).
Laredo–Laredo Junior College, Harold R. Yeary Library (3).
Lubbock–Texas Tech University Law Library (3).
*Texas Tech University Library (1, 2, 3).
Nacogdoches–Stephen F. Austin State University, Steen Library (1, 2, 3).
Richardson–University of Texas at Dallas Library (1, 2, 3).
San Angelo–Angelo State University Library (3).
San Antonio–St. Mary's University, Academic Library (2, 3).
San Antonio Public Library (1, 2, 3).
Trinity University (1, 2, 3).
University of Texas (1, 2, 3).
San Marcos–Southwest Texas State University (3).
Victoria–Victoria College-University of Houston (3).
Wichita Falls–Midwestern State University, Moffett Library (3).

UTAH

Ephraim–Snow College (3).
Logan–*Utah State University, Merrill Library (1, 2, 3).
Ogden–Weber State College (2, 3).
Provo–Brigham Young University, Law Library (3).
Brigham Young University, Lee Library (1, 2, 3).
Salt Lake City–University of Utah, Law Library (2, 3).
University of Utah, Marriott Library (1, 2, 3).
Utah State Library (3).

VERMONT

Burlington–University of Vermont, Bailey Library (1, 2, 3).
Castleton–Castleton State College, Calvin Coolidge Library (3).
Johnson–Johnson State College, John Dewey Library (3).
Lyndonville–Lyndon State College, Samuel Reed Hall Library (3).
Middlebury–Middlebury College Library (2, 3).
Montpelier–Vermont Department of Libraries (3).
Northfield–Norwich University (3).
South Royalton–Vermont Law School Library (3).

VIRGINIA

Charlottesville–*University of Virginia, Alderman Library (1, 2, 3).
Chesapeake–Chesapeake Public Library (3).
Emory–Emory and Henry College Library (2, 3).
Fairfax–George Mason University Library (1, 2, 3).
Fredericksburg–Mary Washington College, E. Lee Trinkle Library (3).
Hampden-Sydney–Hampden-Sydney College, Eggleston Library (3).
Harrisonburg–James Madison University, Madison Memorial Library (3).
Hollins College–Hollins College, Fishburn Library (3).
Lexington–Virginia Military Institute, Preston Library (2, 3).
Washington and Lee University (3).
Norfolk–Norfolk Public Library (3).
Old Dominion University Library (2, 3).
Petersburg–Virginia State College, Johnston Memorial Library (3).
Richmond–University of Richmond, Boatwright Memorial Library (2, 3).
Virginia Commonwealth University, James Branch Cabell Library (2, 3).
Virginia State Library (1, 2, 3).
Salem–Roanoke College Library (3).
Williamsburg–College of William and Mary, Swem Library (1, 2, 3).
Wise–Clinch Valley College, John Cook Wyllie Library (1, 2, 3).

WASHINGTON

Bellingham–Western Washington University, Wilson Library (1, 2, 3).
Cheyney–Eastern Washington University Library (1, 2, 3).
Ellensburg–Central Washington University Library (1, 2, 3).
Everett–Everett Public Library (3).
Midway–Highline Community College (3).
Olympia–Evergreen State College (3).
*Washington State Library (1, 2, 3).
Port Angeles–North Olympic Library System (3).
Pullman–Washington State University (1, 2, 3).
Seattle–Seattle Public Library (1, 2, 3).
University of Washington (1, 2, 3).
Spokane–Gonzaga University School of Law Library (3).
Spokane Public Library (1, 2, 3).
Tacoma–Tacoma Public Library (1, 2, 3).
University of Puget Sound, Collins Memorial Library (2, 3).
Vancouver–Fort Vancouver Regional Library (3).
Walla Walla–Whitman College, Penrose Memorial Library (2, 3).

WEST VIRGINIA

Athens–Concord College Library (3).
Bluefield–Bluefield State College (1, 3).
Charleston–Kanawha County Public Library (3).
West Virginia Library Commission (1, 2, 3).
West Virginia Supreme Court Law Library (1).
Elkins–David and Elkins College (3).
Fairmont–Fairmont State College (2, 3).
Glenville–Glenville State College, Robert F. Kidd Library (3).
Huntington–Marshall University Library (1, 2, 3).
Institute–West Virginia State College (3).
Morgantown–*West Virginia University (1, 2, 3).
Salem–Teikyo University (1).
Shepherdstown–Shepherd College (3).

WISCONSIN

Appleton--Lawrence University, Seeley G. Mudd Library (2, 3).
Beloit--Beloit College (3).
Eau Claire--University of Wisconsin, William D. McIntyre Library (2, 3).
Fond du Lac--Fon du Lac City-County Library Service (3).
Green Bay--University of Wisconsin (1, 2, 3).
La Crosse--La Crosse Public Library (3).
University of Wisconsin, Murphy Library (2, 3).
Madison--Madison Public Library (2, 3).
*State Historical Society Library (1, 2, 3).
University of Wisconsin Memorial Library (3).
Milwaukee--*Milwaukee Public Library (1, 2, 3).
University of Wisconsin (1, 2, 3).
Oshkosh--University of Wisconsin, Forrest R. Polk Library (1, 2, 3).
Platteville--University of Wisconsin (1, 2, 3).
Racine--Racine Public Library (3).
Ripon--Ripon College (3).
River Falls--University of Wisconsin, Chalmer Davee Library (3).
Sheboygan--Mead Public Library (3).
Stevens Point--University of Wisconsin (1, 2, 3).
Superior--Superior Public Library (3).
University of Wisconsin, Jim Dan Hill Library (2, 3).
Waukesha--Waukesha Public Library (3).
Wausau--Marathon County Public Library (3).
Whitewater--University of Wisconsin (2, 3).

WYOMING

Casper--Natrona County Public Library (1, 2, 3).
Cheyenne--*Wyoming State Library (1, 2, 3).
Gillette--Campbell County Public Library (1, 2, 3).
Laramie--University of Wyoming, Coe Library (1, 2, 3).
University of Wyoming, Law Library (3).
Riverton--Central Wyoming College Library (1, 3).
Rock Springs--Western Wyoming Community College (2, 3).
Sheridan--Sheridan College, Griffith Memorial Library (1, 2, 3).

PUERTO RICO

Mayaguez--University of Puerto Rico (1, 2, 3).
Ponce--Catholic University of Puerto Rico Library (3).
San Juan--University of Puerto Rico (1, 2, 3).

MINERAL INDUSTRY SURVEYS

Mineral Industry Surveys contain statistical and economic data on various mineral commodities. These reports are issued at regular intervals so that information on mineral commodities may be made available quickly and in a convenient form. Most of the data contained in these reports appear in permanent form in the Bureau of Mines Minerals Yearbook. Single copies of Mineral Industry Surveys may be obtained from Publication Distribution, Bureau of Mines, Cochrans Mill Road, P.O. Box 18070, Pittsburgh, PA 15236. Mineral Industry Surveys dealing with various mineral commodities will be forwarded regularly if application is made to Mailing Lists, MS 9800, Bureau of Mines, Washington, DC 20241. Preliminary annual data are published as soon as possible after the close of each calendar year and comprise statistics that are later printed in permanent form in the Minerals Yearbook. Preliminary annual area reports also contain data on mineral production by State, and final figures are published in Volume II of the Minerals Yearbook.

MONTHLY

Aluminum.
Cement.
Chromium.
Cobalt.
Copper (periodically includes copper sulfate).
Gold and Silver.
Gypsum.
Iron and Steel Scrap.
Iron Ore.
Lead.
Lime.
Manganese.
Molybdenum.
Nickel.
Phosphate Rock.
Silicon.
Sodium Compounds.
Sulfur.
Tin.
Tungsten.
Vanadium.
Zinc.

QUARTERLY

Abrasives.
Antimony.
Bauxite.
Cadmium.
Feldspar.
Fluorspar.
Magnesium.
Mercury.
Platinum-Group Metals.
Sand and Gravel, Construction.
Stone, Crushed.
Titanium.

SEMIANNUALLY

Ferroalloys.
Phosphate Rock.
Potash.
Stone, Dimension.

ANNUALLY

Abrasives.
Arsenic.
Asbestos.
Barite.
Bismuth.
Boron
Bromine
Cadmium
Cement.
Clays.
Columbium and Tantalum.
Diamond, Industrial.
Diatomite.
Explosives.
Fluorspar.
Gallium.
Garnet.
Gem Stones.
Graphite.
Gypsum.
Iodine.
Iron and Steel.
Iron and Steel Scrap.
Iron and Steel Slag.
Iron Oxide Pigments.
Lime.
Mercury.
Mica.
Molybdenum.
Perlite
Phosphate Rock.
Potash
Pumice and Pumicite.
Rhenium.
Salt.
Sand and Gravel, Construction.
Sand and Gravel, Industrial.
Selenium.
Stone, Crushed.
Stone, Dimension.
Sulfur.
Talc and Pyrophyllite.
Tellurium.
Thallium.
Thorium.
Tungsten.
Vermiculite.

SPECIAL PERIODIC PUBLICATIONS

The following publications are issued to assist producers and consumers of mineral commodities, policymakers, mineral industry experts, and the general public to keep abreast of developments in the mineral industries.

Mineral Commodity Summaries, an annual publication, is the earliest Government publication to furnish estimates of the previous year's nonfuel mineral industry data. Most of the estimates are based on 9 months' data. The publication contains information on the domestic industry structure, Government programs, tariffs, and 5-year salient statistics for a number of minerals and metals. Single copies of the current issue may be obtained from Publication Distribution, Bureau of Mines, Cochrans Mill Road, P.O. Box 18070, Pittsburgh, PA 15236.

State Mineral Summaries were launched in 1989 to give comparable data for each State. Single copies of the current issue may be obtained from Publication Distribution, Bureau of Mines, Cochrans Mill Road, P.O. Box 18070, Pittsburgh, PA 15236.

Minerals Today replaced the former bimonthly *Minerals and Materials* at the end of 1989. It contains both feature articles on the minerals scene and brief articles about recent developments, announcements of coming events, etc. A subscription publication, *Minerals Today* may be ordered from the Superintendent of Documents, Government Printing Office, Washington, DC 20402; initial price was $13 per year ($16.25 foreign), and ordering code was 5069.

Technology News factsheets covering recent Bureau research are available by free subscription from the Office of Technology Transfer, Bureau of Mines, Washington, DC 20241.

MINERALS YEARBOOKS

The Minerals Yearbook, published in three volumes, discusses the performance of the worldwide minerals industry during the year and provides background information to assist in interpreting developments during the year being reviewed. The complete volumes are sold by—

Superintendent of Documents
Government Printing Office
Washington, DC 20402

When Government Printing Office stocks have been exhausted, the volume may be available from the National Technical Information Service, as described in the section entitled "Reports Available from the National Technical Information Service."

Individual chapters of the current Minerals Yearbook can be obtained without charge from—

Publication Distribution
Bureau of Mines
Cochrans Mill Rd., P.O. Box 18070
Pittsburgh, PA 15236
or call 412/675-4338.

Volume I of the Minerals Yearbook contains chapters on virtually all metallic and nonmetallic mineral commodities important to the U.S. economy. In addition, it contains a statistical summary chapter, a chapter on mining and quarrying trends, and a chapter discussing the statistical surveying methods used by the Bureau of Mines.

Volume II contains chapters on the mineral industry of each of the 50 States, the U.S. island possessions in the Pacific Ocean and the Caribbean Sea, and the Commonwealth of Puerto Rico. This volume also has a statistical summary.

Volume III contains the latest available mineral data on more than 150 foreign countries and discusses the importance of minerals to the economies of these nations. A separate chapter reviews the international minerals industry in general and its relationship to the world economy.

1984 MINERALS YEARBOOK

Volume I. Metals and Minerals, prepared by the staff of the Bureau of Mines. 1985. 75 ch. 1034 pp. This volume of the Minerals Yearbook, covering metals and minerals, contains 72 commodity or commodity group chapters with data on approximately 90 minerals that were obtained as a result of the mineral information gathering activities of the Bureau of Mines. In addition, the volume contains a chapter on mining and quarrying trends, a chapter discussing the statistical surveying methods used by the Bureau of Mines, and a statistical summary. GPO Stock No. 024–004–02155–1. $29.

Volume II. Area Reports: Domestic, prepared by the staff of the Bureau of Mines. 1986. 52 ch. 669 pp. This volume of the 1984 Minerals Yearbook contains chapters on the mineral industry of each of the 50 States, the U.S. island possessions in the Pacific Ocean and the Caribbean Sea, and the Commonwealth of Puerto Rico. A statistical summary is also included in this volume. GPO Stock No. 024–004–02163–2. $24.

Volume III. Area Reports: International, 1984, prepared by the staff of the Bureau of Mines. 1986. 91 ch. 1079 pp. This volume of the 1984 Minerals Yearbook contains the latest available mineral data on more than 130 foreign countries and discusses the importance of minerals in the economies of these nations. A separate chapter reviews the international minerals industry in general and its relationship to the world economy. GPO Stock No. 024–004–02162–4. $35.

1985 MINERALS YEARBOOK

Volume I. Metals and Minerals, prepared by the staff of the Bureau of Mines. 1987. 75 ch. 1104 pp. This volume of the 1985 Minerals Yearbook, covering metals and minerals, contains 72 commodity or commodity group chapters with data on approximately 90 minerals that were obtained as a result of the mineral information gathering activities of the Bureau of Mines. In addition, this volume contains a chapter on mining and quarrying trends, a chapter discussing the statistical surveying methods used by the Bureau of Mines, and a statistical summary. GPO Stock No. 024–004–02175–6. $36.

Volume II. Area Reports: Domestic, prepared by the staff of the Bureau of Mines. 1987. 52 ch. 635 pp. This volume of the 1985 Minerals Yearbook contains chapters on the mineral industry of each of the 50 States, the U.S. island possessions in the Pacific Ocean and the Caribbean Sea, and the Commonwealth of Puerto Rico. A statistical summary is also included in this volume. GPO Stock No. 024–004–02184–5. $23.

Volume III. Area Reports: International, prepared by the staff of the Bureau of Mines. 1987. 90 ch. 1127 pp. This volume of the 1985 Minerals Yearbook contains the latest available mineral data on more than 150 foreign countries and discusses the importance of minerals in the economies of these nations. A separate chapter reviews the international minerals industry in general and its relationship to the world economy. GPO Stock No. 024–004–02179–9. $36.

1986 MINERALS YEARBOOK

Volume I. Metals and Minerals, prepared by Staff, Bureau of Mines. 1988. 75 ch. 1075 pp. This volume of the 1986 Minerals Yearbook, covering metals and minerals, contains 72 commodity or commodity group chapters with data on approximately 90 minerals that were obtained as a result of the mineral information gathering activities of the Bureau of Mines. In addition, this volume contains a chapter on mining and quarrying trends, a chapter discussing the statistical surveying methods used by the Bureau of Mines, and a statistical summary. GPO Stock No. 024–004–02197–7. $36.

Volume II. Area Reports: Domestic, prepared by Staff, Bureau of Mines. 1988. 52 ch. 546 pp. This volume of the 1986 Minerals Yearbook contains chapters on the mineral industry of each of the 50 States, the U.S. island possessions in the Pacific Ocean and the Caribbean Sea, and the Commonwealth of Puerto Rico. A statistical summary is also included in this volume. GPO Stock No. 024–004–02202–7. $22.

Volume III. Area Reports: International, prepared by Staff, Bureau of Mines. 1988. 90 ch. 1135 pp. This volume of the 1986 Minerals Yearbook contains the latest available mineral data on more than 150 foreign countries and discusses the importance of minerals in the economies of these nations. A separate chapter reviews the international minerals industry in general and its relationship to the world economy. GPO Stock No. 024-004-02199-3. $37.

1987 MINERALS YEARBOOK

Volume I. Metals and Minerals, prepared by Staff, Bureau of Mines. 1989. 75 ch. 990 pp. This volume of the 1987 Minerals Yearbook, covering metals and minerals, contains 72 commodity or commodity group chapters with data on approximately 90 minerals that were obtained as a result of the mineral information gathering activities of the Bureau of Mines. In addition, this volume contains a chapter on mining and quarrying trends, a chapter discussing the statistical surveying methods used by the Bureau of Mines, and a statistical summary. GPO Stock No. 024–004–02206–0. $42.

Volume II. Area Reports: Domestic, prepared by Staff, Bureau of Mines. 1989. 52 ch. 439 pp. This volume of the 1987 Minerals Yearbook contains chapters on the mineral industry of each of the 50 States, the U.S. island possessions in the Pacific Ocean and the Caribbean Sea, and the Commonwealth of Puerto Rico. A statistical summary is also included in this volume. GPO Stock No. 024–004–02210–8. $19.

Volume III. Area Reports: International, prepared by Staff, Bureau of Mines. 1989. 88 ch. 1164 pp. This volume of the 1987 Minerals Yearbook contains the latest available mineral data on more than 150 foreign countries and discusses the importance of minerals in the economies of these nations. A separate chapter reviews the international minerals industry in general and its relationship to the world economy. GPO Stock No. 024–004–02209–4. $39.

COMPUTER PRODUCTS

CP 1. Analysis of Natural Gases, 1917-1989. The Bureau of Mines has been conducting annual analyses of natural gases for their helium content since 1917. In addition to various publications compiling this information, it has been made available on magnetic tape through the National Technical Information Service, Springfield, VA 22161; 703/487-4650. The tape referenced above was available as PB 90-501503; however, the tape is updated early each year and prospective purchasers should contact NTIS for current availability and ordering information.

CP 2. Primary Aluminum Plants, Worldwide, Part One—Details, by Staff, Bureau of Mines. Part one of this two-part Bureau of Mines report, which is updated annually, details the location, ownership, and sources of energy and aluminum raw materials for most foreign and domestic primary aluminum plants. Tables give production capacities for each plant for the past 3 years and the present year and production capacity projections for the next 4 years. A special remarks section highlights important developments that could affect present or future production at individual plants and the timing of planned changes in capacity. The publication is based on current data collected by the Bureau from a variety of domestic and foreign sources. Up-to-date, comprehensive information on the world's aluminum producers will help professionals in both Government and industry spot trends that could affect domestic supplies of this essential industrial commodity. This computer printout can be ordered from the Chief, Division of Finance, Bureau of Mines, Denver Federal Center Bldg. 20, Denver, CO 80225. Checks or money orders should be made payable to the Bureau of Mines. Please do not send cash or postage stamps. Please include your ZIP code. Part one, $15.

CP 3. Primary Aluminum Plants, Worldwide. Part Two—Summary, by Staff, Bureau of Mines. Part two of this two-part Bureau of Mines report, which is updated annually, will be of interest to people who are interested only in capacity data. In this section, worldwide production capacities by plant and country are summarized for the past 3 years and the present year and projected for the next 4 years. This printout can be ordered from the Chief, Division of Finance, Bureau of Mines, Denver Federal Center Bldg. 20, Denver, CO 80225. Checks or money orders should be made payable to the Bureau of Mines. Please do not send cash or postage stamps. Please include your ZIP code. Part two, $5.

CP 4. Cost Estimating System. The CES is a PC software program used to produce quick and reliable estimates of capital and operating costs for mining and mineral beneficiation facilities in any location in the world. The software is the computerized version of the two-volume U.S. Bureau of Mines Cost Estimating Handbook (Information Circulars 9142 and 9143). CES was developed in Lotus 1-2-3 (Release 2.0 or higher) and affords the user the capability to manipulate available geographic data, spatial geometry characteristics, and engineering judgment in an automated manner. For further information, contact the Chief, Branch of Minerals Availability, Bureau of Mines, Washington, DC 20241; 202/634-1144. The material is sold by the National Technical Information Service, Springfield, VA 22161; 703/487-4650. NTIS order numbers are PB 88-246590 for the documentation and PB 88-246582 for the diskette. As NTIS prices change from year to year, prospective purchasers should contact NTIS for current ordering information. See also CP 12.

CP 5. Availability of Federally Owned Minerals for Exploration and Development in Western States: New Mexico: 1988. This Bureau of Mines database contains the raw and interpreted data on Federal land status and known deposit areas that were collected and processed for the New Mexico Inventory of Land Use Restraints Program Study. Size—Micro (MS-DOS Based); language dBase III. For further information, contact Donald Barnes, 202/634-1044. The material is sold by the National Technical Information Service, Springfield, VA 22161; 703/487-4650. NTIS order numbers are PB 89-228878 for the documentation and PB 89-228860 for the diskettes. As NTIS prices change from year to year, prospective purchasers should contact NTIS for ordering information. See also OFR 28-89.

CP 6. KARDEX. This database contains engineering data for all operating mines in Alaska. Size—Micro (IBM); language—DBase III; contact Gary Sherman, 907/364-2111.

CP 7. MILS. This database contains identification and location information for approximately 200,000 mineral locations in the United States. It includes undeveloped, operational, and abandoned sites. Language—ASCII; contact John Henry, 303/236-5207.

CP 8. MINES-DATA. Late in 1989 a computer bulletin board service was introduced by the Bureau of Mines; as of June 1990 coverage included aluminum, bauxite, beryllium, bismuth, cadmium, chromium, copper, gallium, gold and silver, iron and steel scrap, lead, magnesium, mercury, molybdenum, platinum-group metals, silicon, thallium, thorium, tin, titanium, vanadium, and zinc. To access the system, call 202/634-4637. For information on how to use the service, call 202/634-9632 and leave a message for the systems operator.

CP 9. PC/ADIT. The Advanced Deposit Information Tracking (ADIT) system is a fast, easy-to-use PC version of the minicomputer-based Minerals Availability System (MAS) database. PC/ADIT contains site-specific information on over 3,000 mineral operations with an emphasis on operations located in the United States and other market economy countries. It covers 34 commodities representing those most significant in terms of value, tonnage, and import reliance. PC/ADIT menus guide the user through a criteria selection process in order to sort the data by location, commodity, company, or several other criteria. Help keys explain the criteria, while choice keys provide a list of options within a criteria category. Since the ADIT database resides within the PC, sorts are relatively fast, usually taking a minute or less. The PC/ADIT software is available for IBM or IBM-clone PC's. The software and database require about two megabytes of hard disk memory. For further information, contact the Chief, Branch of Minerals Availability, Bureau of Mines, Washington, DC 20241; 202/634-1144.

CP 10. MAS data base printouts. Listings of operations in the Minerals Availability System (MAS) database are available upon request to the Chief, Branch of Minerals Availability, Bureau of Mines, Washington, DC 20241; 202/634-1144. The MAS database, located on a minicomputer, contains comprehensive engineering and economic data on mineral operations throughout the world. The data are used in mineral availability evaluations and other analytic applications. Standard computer printouts contain one-liner information on operation name, operator, owner, location, primary product, and byproducts. More comprehensive printouts can be tailored to specific requests. Data can be sorted on almost any field, usually by location or product. Public access to the data base is limited to data that are not company proprietary.

CP 11. International Mining Cost Index. The IMCI was developed for the Cost Estimating System (see CP 4) to translate foreign currency mine production costs into U.S. dollar costs and to update costs over time. The IMCI consists of 12 cost indexes representing costs through the life of a mineral operation from development through production. Indexes are available for labor, both construction and mining, plant and equipment, steel, timber, fuel, explosives, tires, construction materials, chemicals, transportation, and electricity. The IMCI covers 95 countries, including the United States. For further information, contact the Chief, Branch of Minerals Availability, Bureau of Mines, Washington, DC 20241; 202/634-1144.

CP 12. Cost Estimating System Handbook for Small Placer Mines. The Bureau of Mines developed a method for estimating capital and operating costs associated with the exploration, mining, and processing of valuable minerals from placer deposits. The cost-estimating method is documented in Information Circular 9170, and a diskette based on the material is also available. For further information, contact the Chief, Western Field Operations Center, Bureau of Mines, East 360 Third Ave., Spokane, WA 99202; 509/353-2712. See also CP 4.

CP 13. Network Model. The Network Model is a world mineral market model that uses optimization methods in the analysis of short-term issues. Its use is twofold: (1) to determine the optimal mix of production levels in a given economic climate, and (2) to determine optimal trade flow patterns on a region-by-region basis. To date, network models have been developed on a commodity-specific basis. The phosphate network model is complete. Models for chromium and aluminum are in development. This item is not fully available to the public because of proprietary considerations, etc. Agencies with a need to consult it should contact the

Chief, Branch of Minerals Availability, Bureau of Mines, Washington, DC 20241, 202/634-1144, describing the intended use.

CP 14. SDIAS: Supply Disruption Impact Analysis System. This analytical system is designed to provide users with a useful tool for evaluating the economic impacts of a mineral supply disruption. It is available to academics and students at colleges and universities nationwide. For further information, contact the Chief, Branch of Economic Analysis, Bureau of Mines, Washington, DC 20241; 202/634-1036.

OP 15. MINSIM. The MINe SIMulator is a discounted cash flow rate-of-return (DCFROR) model used by the Bureau of Mines to evaluate the economics of a mineral recovery operation. A MINSIM evaluation combines reserve tonnage and grade estimates and the associated capital and operating costs (exploration, acquisition, infrastructure, mining, milling, etc.) with information about financial and tax conditions to simulate the DCFROR that can be expected over the life of the mine. MINSIM is available in two PC versions, one in Lotus 1-2-3 and the other in Fortran. Both use tiered menus which direct the user through the evaluation process. For further information, contact the Chief, Branch of Minerals Availability, Bureau of Mines, Washington DC 20241; 202/634-1144.

CP 16. Minerals Property Evaluation at the Early Exploration Stage. As part of the Bureau of Mines efforts in evaluation of mineral potential on federally managed lands, a software package (PREVAL) used to evaluate the potential economics of a mineral property from selection of mining method through year-by-year cash flow analysis has been developed. The software was developed on a Lotus 1-2-3 spreadsheet and should be available to the public by late 1990. This presentation covers all of the basic criteria necessary to systematically evaluate the economics of a mineral property, explains which criteria have been included in the Bureau's software, and describes generalized analytical techniques. Evaluation criteria include mine and mill selection, mine life optimization, capital and operating cost estimation, material balances; transportation, smelting and refining, commodity pricing, and economic analysis. Sensitivity analysis can also be performed to help identify the items that have the most impact on property economics. All this can be accomplished when very little is actually known about a mineral property, but a thorough knowledge of the assumptions and limitations within PREVAL is necessary. For further information, contact the Chief, Intermountain Field Operations Center, Bureau of Mines, Denver Federal Center, Bldg. 20, Denver, CO 80225; 303/236-0421.

CP 17. OPMHS/2: A Computer Simulation Model for Surface Mine Reclamation Planning. This computer program is a modified and updated version of the Open Pit Materials Handling Simulator (OPMHS) first developed in 1971, and modified in 1975. The present (1985) version provides a direct link between the geology and reserves system, incorporating a flexible method of describing various equipment, locations, sequence of operations, place changes, and interactions between these elements to allow for study of mining equipment selection, mining method analysis, and reclamation planning. Research was done under contract J0295005 by Pennsylvania State University. A nine-track, 800BPI, EBCDIC, odd-parity tape is sold by the National Technical Information Service (NTIS), Springfield, VA 22161, 703/487-4650, as PB 87-204863 (computer tape plus four volumes of documentation; price code T08; contact NTIS for current price). To order documentation separately, see below:

CP 17A. Volume I—Ore Reserve Estimation, by R. V. Ramani and E. Diaz. This volume describes the development of a geological model for surface mine planning, detailing the most common ore body modeling techniques and presenting a geostatistical alternative to these techniques. 207 pp. 23 figs. NTIS: PB 87-204871; paper copy price code A10.

CP 17B. Volume II—Dragline Model, by R. V. Ramani and S. Bandopadhyay. This volume describes the types of mining methods the program is able to simulate and the type of predictions that can be made using it. 271 pp. 30 figs. NTIS: PB 87-204889; paper copy price code A12.

CP 17C. Volume III—Mine Coordinate Generator System, by R. V. Ramani and E. K. Albert. This volume describes the Mine Coordinate Generator System in its role as an interface between the Geology and Reserves System described in Volume I and the Open Pit Materials Handling Simulator Version 2 (OPMHS/2) described in Volume IV. 31 pp. 2 figs. NTIS: PB 87-204897; paper copy price code A03.

CP 17D. Volume IV—User's Manual for OPMHS/2, by R. V. Ramani and E. K. Albert. This volume details the features of the computer program, its operation, and its applications in surface mining. 369 pp. 28 figs. NTIS: PB 87-204905; paper copy price code A16.

CP 18. Computer Program for Planning Mine Ventilation and Predicting Real-Time Spread of Contaminants. To provide mine operators with a method of using a personal computer to plan mine ventilation and to determine the spread of contaminants on a real-time basis, the Bureau of Mines adapted a mainframe mine ventilation computer program for personal computer use. For additional information, contact Daniel Ng, Bureau of Mines, Pittsburgh Research Center, P.O. Box 18070, Cochrans Mill Rd., Pittsburgh, PA 15236-0070; 412/675-6751.

CP 19. MULSIM/BM: A Structural Analysis Computer Program for Mine Design. The Bureau of Mines developed MULSIM/BM, an improved computer program listing the boundary-element approach for geomechanical analysis of mine plans in single or multiple coal seams. In addition, an interactive graphics mesh generator program was written to accompany MULSIM/BM. For information about diskettes containing this program, contact Nicholas R. Kripakov, Bureau of Mines, Denver Research Center, Denver Federal Center Bldg. 20, Denver, CO 80225; 303/236-0765. A nine-track computer tape containing the program is sold by the National Technical Information Service, Springfield, VA 22161, 703/487-4650; NTIS order number is PB 88-129465. As NTIS prices change from year to year, prospective purchasers should contact NTIS for current ordering information.

CP 20. SUBPRO. The subsidence prediction model was developed using field data acquired from 17 monitoring sites in the Northern Appalachian Coalfield. The model incorporates the novel use of a variable subsidence coefficient. A computer program has been developed that permits use of the model on a personal computer. The program requires input information that is readily available and does not require the user to have a knowledge of subsidence theory. The program output includes subsidence, inclination, and curvature developed along a line extending from the centerline of the mined-out panel to a point beyond the unmined rib. The program also gives an estimate of the horizontal strains developed along this line. For further information, contact Paul Jeran, Bureau of Mines, Pittsburgh Research Center, P.O. Box 18070, Cochrans Mill Rd., Pittsburgh, PA 15236-0070; 412/675-6530.

CP 21. DRUMPRO for Longwalls. This program provides longwall operators with advice on longwall drum design. The program analyzes and diagnoses drum design problems by examining drum design parameters for obvious flaws, seam conditions, and loading performance during cutting. Documentation on how to use the program is on the diskette in a DOS text file. Also a DOS text file is present for assisting the user with diagnosing and correcting user problems. The program diskette(s) can be ordered free of charge from Fred Kissell, Pittsburgh Research Center, P.O. Box 18070, Cochrans Mill Rd., Pittsburgh, PA, 15236-0070, 412/892-6679; blank diskette(s) are required.

CP 22. DUSTPRO for Continuous Miners. This program provides site-specific advice on the application of dust control techniques for continuous mining operations. The system provides advice on basic dust control procedures and offers other refined approaches if compliance cannot be achieved using basic measures. Documentation on how to use the program is on the diskette in a DOS text file. Also a DOS text file is present for assisting the user with diagnosing and correcting user problems. The program diskette(s) can be ordered free of charge from Fred Kissell, Pittsburgh Research Center, P.O. Box 18070, Cochrans Mill Rd., Pittsburgh, PA, 15236-0070, 412/892-6679; blank diskette(s) are required.

CP 23. DUSTPRO for Longwalls. This program providas site-specific advice on the application of dust control techniques for longwall mining operations. The system analyzes and diagnoses dust control problems and recommends corrective measures to reduce dust. Documentation on how to use the program is on the diskette in a DOS text file. Also a DOS text file is present for assisting the user with diagnosing and correcting user problems. The program diskette(s) can be ordered free of charge from Fred Kissell, Pittsburgh Research Center, P.O. Box 18070, Cochrans Mill Rd., Pittsburgh, PA, 15236, 412/892-6679; blank diskette(s) are required.

CP 24. METHPRO. This knowledge-based expert system is designed to provide a solution to the problem of determining the optimum methane control strategy for underground coal mines. The system considers both naturally existing conditions such as coalbed gas content and mining-induced conditions such as type of mining. Data files are maintained where appropriate, and facts, regulatory requirements, and rule-of-thumb are available to provide solutions. The validity of the system has been checked and verified based on actual case histories. Documentation on how to use the program is on the diskette in a DOS text file. Also a DOS text file is present for assisting the user with diagnosing and correcting user problems. The program diskette(s) can be ordered free of charge from Fred Kissell, Pittsburgh Research Center, P.O. Box 18070, Cochrans Mill Rd., Pittsburgh, PA, 15236-0070, 412/892-6679; blank diskette(s) are required.

CP 25. Sealed Gob Assistant. This program examines seals and abandoned areas of coal mines. It provides an in-depth analysis of air exchange in sealed gobs. It also supplies projected yearly gas leakage values, recommendations to minimize leakage across seals, and recommendations on control measures for spontaneous combustion and/or methane. Documentation on how to use the program is on the diskette in a DOS text file. Also a DOS text file is present for assisting the user with diagnosing and correcting user problems. The program diskette(s) can be ordered free of charge from Fred Kissell, Pittsburgh Research Center, P.O. Box 18070, Cochrans Mill Rd., Pittsburgh, PA, 15236-0070, 412/892-6679; blank diskette(s) are required.

CP 26. SSPEC: Personal Computer Calculation of Ideal Equilibria Concentrations for Stainless Steel Pickling Solutions. To improve the efficiency of stainless steel pickling (chemically cleaning) operations by providing the industry with a quick and convenient method to estimate pickling solution behavior, the Bureau of Mines developed a mathematical model that provides quick and convenient information regarding ideal equilibria concentrations of the various cations and anions in the pickling solution. SSPEC requires a PC with a math coprocessor, 256 kilobytes of memory, and 1 disk drive; a printer is recommended. For further information about SSPEC, contact J. B. Stephenson or G. L. Horter, Bureau of Mines, Rolla Research Center, P.O. Box 280, 1300 Bishop Ave., Rolla, MO 65401; 314/364-3169.

CP 27. Phosphate Flotation Expert System. This program takes 10 readings from remote sensors in the plant (data file for demonstration) and compares them with accepted values, within a given range. The program prompts the user to enter a visual determination of the quality of the product streams (low, OK, high). Based on the sensor readings and the quality of the products, the program identifies problem areas, prompts the user to check various operating conditions in the plant, and suggests appropriate changes. For further information, contact Technology Transfer Officer, Bureau of Mines, Tuscaloosa Research Center, University of Alabama Campus, P.O. Box L, Tuscaloosa, AL 35486-9777; 205/759-9434.

CP 28. Fuzzy Logic Controller; Matrix Method. A rule-based fuzzy logic controller (FLC) using matrices to represent membership sets was developed to control a liquid level vessel. The controller accepts the current height of the liquid and the true rate of change in height and outputs the appropriate change in height. The advantage in using matrices to represent membership sets is that it conforms closely to fuzzy logic theory. The disadvantage is that the inputs are quantized. For further information, contact Technology Transfer Officer, Bureau of Mines, Tuscaloosa Research Center, University of Alabama Campus, P.O. Box L, Tuscaloosa, AL 35486-9777; 205/759-9434.

CP 29. Flotation Kinetics Model. The program calculates the flotation response using data containing the fluid velocity profile, power consumption, bubble size distribution, and particle size distribution. The flotation rate constants and the flotation response with time are calculated. For further information, contact Technology Transfer Officer, Bureau of Mines, Tuscaloosa Research Center, University of Alabama Campus, P.O. Box L, Tuscaloosa, AL 35486-9777; 205/759-9434.

CP 30. Velocity Profile Measurements. Program supervises data gathering for electrochemical velocity measurements of a fluid. The calibration and measurement sequence is controlled to make the measurements and prompt the technician to change the electrode position. The program converts the voltage measurements to fluid velocity and stores it in a database. For further information, contact Technology Transfer Officer, Bureau of Mines, Tuscaloosa Research Center, University of Alabama Campus, P.O. Box L, Tuscaloosa, AL 35486-9777; 205/759-9434.

CP 31. PB-Program. The program was written specifically to determine species of lead present in ground and surface water compositions existing at a site being investigated by the Bureau of Mines Tuscaloosa Research Center. Therefore only Na, Ca, Mg, Mb, Fe, Pb, and S (as SO_4 valence-2) were considered. These comprised about 99.9 pct of the compositions; lead was the only trace element considered. The program was written in BASIC for use on a PC and requires 19,300 bytes. Associated with the computational program was a data-input program requiring 3,000 bytes. Each data set used about 300 bytes. The program contained 25 ionization constants, 11 solubility products, and 5 stability constants with each constant named from the chemical formula involved. All constants were calculated from free energy data in Wagman et al.'s National Institute of Standards and Technology table of chemical and thermodynamic properties. Values of dissociation, stability constants, and solubility products are contained in the program. Initial concentrations of all ions in their usual valences are set equal to total concentrations from chemical analyses. Mass balance equations are used to calculate the concentrations of ions by iteration from their initial values. The ionic strengths are calculated from the concentrations of species, and activity coefficients are calculated by the Davies equation. All constants were corrected for activities and reused in determining species concentrations. Soluble species concentrations were corrected for concentrations of precipitated insoluble species. For further information, contact Technology Transfer Officer, Bureau of Mines, Tuscaloosa Research Center, University of Alabama Campus, P.O. Box L, Tuscaloosa, AL 35486-9777; 205/759-9434.

CP 32. Computer Vision Sensor. The main part of the computer vision system is the processing subsystem. The main purpose of the processing software is to correctly identify the percentages of different minerals and the background in an image. Three different methods are used to find the percentages. The first method is a thresholding technique; if the current pixel in the image is above or below the threshold, then consider it as part of the target information. The second method is the use of a variance combined with the thresholding technique; the variance of the current pixel is found by using the surrounding eight pixels. The last method is the use of a low-pass filter combined with the thresholding technique; the low-pass filter eliminates the noise in the image. For further information, contact Technology Transfer Officer, Bureau of Mines, Tuscaloosa Research Center, University of Alabama Campus, P.O. Box L, Tuscaloosa, AL 35486-9777; 205/759-9434.

CP 33. Factor Analysis. The factor analysis program was designed with two objectives in mind: (1) to eliminate error and/or noise from data and (2) to help in predicting data. The first objective was met by using the factor analysis technique described in "Factor Analysis in Chemistry" by E.D. Malinowski and D.G. Howery (Wiley, 1980). The second objective was met by using principal-components regression described in "Partial Least-Squares Regression, A Tutorial" by P. Galadi and B.R. Kowalski (Analytica Chimica Acta, v. 185, 1986, pp. 1-17). For further information, contact Technology Transfer Officer, Bureau of Mines, Tuscaloosa Research Center, University of Alabama Campus, P.O. Box L, Tuscaloosa, AL 35486-9777; 205/759-9434.

CP 34. Curve Fitting Using a Genetic Algorithm. Genetic algorithms (GA's) are search techniques based on the mechanics of natural genetics. A GA was employed to fit curves to a given set of data. Three types of curves were involved: a least-squares curve fit to a straight line, parabola, and the Ree-Eyring equation. For further information, contact Technology Transfer Officer, Bureau of Mines, Tuscaloosa Research Center, University of Alabama Campus, P.O. Box L, Tuscaloosa, AL 35486-9777; 205/759-9434.

CP 35. Fuzzy Logic Controller for a Liquid Level System. A fuzzy logic controller (FLC) is a system for controlling a process based on fuzzy logic. FLC's have been used to control many processes. The one drawback of using FLC's is the selection of the membership functions that give meaning to fuzzy linguistic variables. The general process for selecting membership functions cannot always guarantee optimum performance. A genetic algorithm was employed to learn membership functions for an FLC designed for a liquid-level vessel. For further information, contact Technology Transfer Officer, Bureau of Mines, Tuscaloosa Research Center, University of Alabama Campus, P.O. Box L, Tuscaloosa, AL 35486-9777; 205/759-9434.

CP 36. Improved Fuzzy Process Control of Spacecraft Autonomous Rendezvous. A fuzzy logic controller (FLC) was developed to control a mathematical model simulating the autonomous rendezvous of a spacecraft. The problem with FLC's is that the selection process for choosing membership functions does not always yield optimum performance. A genetic algorithm was employed to learn more efficient membership functions. For further information, contact Technology Transfer Officer, Bureau of Mines, Tuscaloosa Research Center, University of Alabama Campus, P.O. Box L, Tuscaloosa, AL 35486-9777; 205/759-9434.

CP 37. Dielectric Properties Data Acquisition. There are several programs written to operate together to automate data retrieval and storage from a Hewlett-Packard HP8753A Network Analyzer. The information acquired from the network analyzer is stored in usable data format for later retrieval into programs designed to calculate dielectric property data. For further information, contact Technology Transfer Officer, Bureau of Mines, Tuscaloosa Research Center, University of Alabama Campus, P.O. Box L, Tuscaloosa, AL 35486-9777; 205/759-9434.

CP 38. Generic in Situ Leach Copper Mining Cost Model. The program is a menu-driven cost model that may be used to estimate costs for commercial-scale in situ mine designs for copper oxide deposits. This model permits the user to make cost inputs and other operational inputs that are converted to mine design elements. Outputs that are generated include specific design parameters and capital and operating costs. Other outputs include a pretax selling price or discounted cash flow rate of return and a discounted cash flow table. For further information, contact Joseph Pugliese, Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Ave. South, Minneapolis, MN 55417; 612/725-4569.

CP 39. BOMSPS. BOMSPS was developed for the manipulation and analysis of individual acoustic signals. Operations such as gain control, muting, normalization, polarity change, randomization, scaling, shifting, stacking, smoothing, and windowing account for the basic time-domain operations available. Higher order time-domain enhancement capabilities involve convolution, deconvolution, autocorrelation, and cross-correlation. Frequency-domain attributes such as the real and imaginary transform, relative amplitude, power, and phase spectra can be determined. Frequency-domain filter capabilities permit the investigator to employ a half sine or cosine window, notch, bandpass, high-cut or low-cut filter, while interactively defining the rolloff of either a linear or cosine taper. Calculation of time-domain trace attributes such as the quadrature, instantaneous amplitude, and instantaneous phase is also available. For further information, contact Technology Transfer Officer, Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Ave. South, Minneapolis, MN 55417; 612/725-4562. A related publication, Information Circular 9242, BOMSPS: Bureau of Mines Signal Processing Software; Concepts, Expressions and Tutorial, is available from the National Technical Information Service, Springfield, VA 22161; 703/487-4650; NTIS order number is PB 90-224981. As NTIS prices change from year to year, prospective purchasers should contact NTIS for current ordering information.

CP 40. Computer Modeling Continuous Miner Cutting Systems for Dust Generation. The Cutting System Model (CSM) program has been developed to analyze relative dust generated by a continuous miner. This interactive program provides relative dust, cutting forces, and production values for any given set of mining machine parameters, specific seam conditions, and operator-controllable parameters. Expanded versions of the program provide a dynamic evaluation of the effects of bit wear, over time, on production. The program provides operators with the option of looking at proposed changes in the cutting system before the system is shut down. With this program an operator can evaluate, in advance, the potential effect of any change, saving actual machine down time and production loss. The program has been tested against field data to validate the techniques used. Excellent correlation has been found between the model and field test data. Operational. For further information, contact Technology Transfer Officer, Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Ave. South, Minneapolis, MN 55417; 612/725-4562.

CP 41. Computer Modeling of Dust and Forces for Longwall Mining Systems. The Cutting System Model (CSM) program has been developed to analyze relative dust generated by a double-drum, ranging-arm, longwall shearer. This interactive program provides relative dust, cutting forces, and production values for any given set of mining machine parameters, specific seam conditions, and operator-controllable parameters. Expanded versions of the program provide a dynamic evaluation of the effects of bit wear, over time, on production. The program provides operators with the option of looking at proposed changes in the cutting system before the system is shut down. With this program an operator can evaluate, in advance, the potential effect of any change, saving actual machine down time and production loss. The program has been tested against field data to validate the techniques used. Excellent correlation has been found between the model and field test data. For further information, contact Technology Transfer Officer, Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Ave. South, Minneapolis, MN 55417; 612/725-4562.

CP 42. CSM: Computer Evaluation of Coal Cutting With Rotary Drum Miners. To provide mine operators with a means for evaluating dust generation and bit wear effects on production without costly and extensive underground testing, the Bureau of Mines developed personal-computer-based cutting system models (CSM's) that simultaneously evaluate machine, coal seam, and mine-operator-controlled parameters for their interactive effects on dust generation, bit wear, and production by either a longwall shearer or a continuous miner. For further information, contact Bruce D. Hanson, Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Ave. South, Minneapolis, MN 55417; 612/725-4782.

CP 43. LFIRE. LFIRE is used in conjunction with a network of fire detection devices in an underground mine to specify the network branch in which a fire is located. For further information, contact Technology Transfer Officer, Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Ave. South, Minneapolis, MN 55417; 612/725-4562.

CP 44. MFIRE: Mine Fire and Ventilation Simulator. MFIRE is a mine fire and ventilation simulator. It is capable of solving routine ventilation network problems and also analyzing networks under the influence of thermal disturbances such as fires or cooling stations. In addition, MFIRE calculates the concentration and time-dependent spread of contaminants in a mine ventilation network. Unlike other network models, MFIRE can analyze both steady-state and transient conditions. For further information and/or a FORTRAN diskette, contact Linn Laage, Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Ave. South, Minneapolis, MN 55417; 612/725-4624 or 612/725-4500.

CP 45. TILTCALC. The Bureau of Mines is studying foundation response to mine subsidence for the development of economic mitigation and repair techniques. For monitoring foundations and ground movements, commercially available tiltmeters are being evaluated for use as a cost-effective monitoring technique. The tiltmeter system consists of a portable sensor, digital indicator, and tiltplate. Readings are obtained by aligning the sensor on the tiltplate in four orthogonal directions; thus, tilts are obtained in all four directions as a function of the sine of the angle that the tiltplate makes with the horizontal. To facilitate data reduction, a menu-driven, interactive computer program was written that executes the tedious tilt calculations suggested by the manufacturer. The tiltmeter program allows the user to build or modify files containing readings from the field. It calculates tilt angle and direction from the input, stores them in files, and displays graphs of scaled vectors showing magnitude and direction of tilt relative to time and position of the tiltplate. The program is written in BASIC using low-resolution graphics and will run on most personal computers. For further information, contact Larry Powell, Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Ave. South, Minneapolis, MN 55417; 612/725-3469.

CP 46. ACIM (Accident Injury Indicator Model). From the MSHA accident statistics, ACIM assigns a cost estimate to each reported accident and provides a fast retrieval capability. The cost elements included are loss in personal income, compensation of wages from State, Federal and union funds for disabling injuries, benefits for injuries resulting in death or permanent disability, medical treatment and hospital care, immediate and postaccident losses as a result of a fatality or amputation injury, and finally investigation of a fatal accident. Current information on the software can be obtained by writing or calling Donald Chi, Bureau of Mines, Pittsburgh Research Center, P.O. Box 18070, Cochrans Mill Rd., Pittsburgh, PA 15236-0070; 412/892-6502.

CP 47. BOMTOM. Developed by the Bureau of Mines as a means for analyzing seismic crosshole data to predict and monitor the flow of leach solution during in situ mining, BOMTOM (Bureau of Mines Tomographic Reconstruction) performs tomographic analysis of seismic travel time data to reconstruct a two-dimensional representation of seismic velocities. It uses the simultaneous iterative

reconstruction technique (SIRT) with straight ray paths. Velocity is assumed constant within rectangular pixels. Source and receiver positions can be in any configuration. It is efficient in use of memory and execution speed and can be run on an XT computer. Comments in the source code specify data formats. Bureau of Mines Report of Investigations 9159 describes the program and lists the source code. BOMTOM provides special constraints to help obtain unique solutions with crosshole data. (Crosshole data without constraints cannot provide a unique solution.) Optional constraints include upper and lower velocity limits, fixed velocities at the boreholes, and others. Uniqueness can be tested by varying the pattern of the initial velocity guesses for the pixels to start the iterative solution procedure. A unique solution will be independent of the initial velocity guesses. For further information, contact Technology Transfer Officer, Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Ave. South, Minneapolis, MN 55417; 612/725–4562.

CP 48. Longwall Production Simulator. The Longwall Production Assistant is a flexible, user friendly simulator developed to investigate and evaluate the most efficient changes an operator can make to a longwall system. The simulator uses a continuous modeling strategy between all system components (shearer, face conveyor, shields) to allow for continuous interactive performance monitoring between these components. The simulator also allows the user total control over the shearer's mining sequence, providing the user with the ability to optimize standard mining practices and to simulate creative mining methods. The user conducts computer experiments by changing system parameters and running the simulator to determine the effect on production. The user can then best evaluate the most efficient changes for production optimization. For additional information, contact John Organiscak, Bureau of Mines, Pittsburgh Research Center, P.O. Box 18070, Cochrans Mill Rd., Pittsburgh, PA 15236–0070; 412/892–6675.

CP 49. ALPS: Analysis of Longwall Pillar Stability. The Bureau of Mines has developed a method for longwall pillar design that can predict the strength of longwall pillar systems as well as the loading that will be applied during all phases of longwall mining. For additional information and a diskette, contact Christopher Mark, Bureau of Mines, Pittsburgh Research Center, P.O. Box 18070, Cochrans Mill Rd., Pittsburgh, PA 15236–0070; 412/892–6522.

CP 50. Accident Data Analysis (ADA). The ADA program developed by the Bureau allows the user to access mine accident data for both coal and metal for any year or combination of years back to 1975. Any subset of data may be selected, stored, and analyzed for relevant patterns in risk and frequency distributions. This program has proven very valuable in planning mine safety research programs. For further information, contact Elaine Cullen, Bureau of Mines, Spokane Research Center, East 315 Montgomery Ave., Spokane, WA 99207-2291; 509/484–1610.

CP 51. Longwall Production Assistant. This program is a user-friendly simulator to investigate the most efficient changes an operator can make to a longwall mining system. Continuous modeling between the shearer and face conveyor identifies material flow bottlenecks. Cut sequence is defined through a coordinate system to provide the user with total control of the shearing machine. Documentation on how to use the program is on the diskette in a DOS text file. Also a DOS text file is present for assisting the user with diagnosing and correcting user problems. The program diskette(s) can be ordered free of charge from Fred Kissell, Pittsburgh Research Center, P.O. Box 18070, Cochrans Mill Rd., Pittsburgh, PA, 15236–0070, 412/892–6679; blank diskette(s) are required.

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When Bureau stocks have been exhausted, the report may be available from the National Technical Information Service, as described in the section entitled "Reports Available From the National Technical Information Service."

HB 1–87. Guidelines for Dust Control in Small Underground Coal Mines, by Ed Divers, Natesa Jayaraman, Steve Page, and Robert Jankowski. 1987. 32 pp. 10 figs. This Bureau of Mines handbook presents guidelines for controlling dust in underground room-and-pillar coal mines. The dust-control techniques represented are primarily directed toward cost-effectiveness for the operators of small mines facing tightened Federal regulations due to excessive respirable quartz dust. Emphasis is placed on the latest developments in ventilation and water sprays for continuous mining, auger, and conventional mining sections.

HB 1–89. Methane Control in Tunneling, by Fred N. Kissell. 1989. 16 pp. 8 figs. This U.S. Bureau of Mines handbook presents guidelines for preventing methane gas explosions during tunnel construction. It conveys technology and practice from the coal mining industry, which has been safely dealing with methane gas emissions for many years. Emphasis is placed on assessing the hazard potential, on ventilation principles, on monitoring for gas, and on what can go wrong in practice.

BULLETINS

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When Government Printing Office or Bureau stocks have been exhausted, the report may be available from the National Technical Information Service, as described in the section entitled "Reports Available From the National Technical Information Service."

B 675. Mineral Facts and Problems, 1985 Edition, by Staff, Bureau of Mines. 1985. 956 pp. This one-volume encyclopedia comprising 78 commodity chapters and an explanatory introduction contains comprehensive information on metals and nonmetals. Commodity chapters cover such topics as industry structure, reserves and resources, technology, uses, supply-demand relationships, byproducts and coproducts, strategic considerations, economic and operating factors, problems, and outlook and forecasts to 2000. GPO Stock No. 024-004-02152-7. $30.

B 677. Thermodynamic Data for Mineral Technology, by L. B. Pankratz, J. M. Stuve, and N. A. Gokcen. 1985. 355 pp. Thermodynamic data on the elements, oxides, sulfides, halides, and selected hydrides, carbides, nitrides, carbonates, sulfates, silicates, and miscellaneous compounds were reviewed, evaluated, and compiled at the Bureau of Mines. Values for C_p°, S°, H_{298}°, ΔHf°, and ΔGf° are given in tabular form. A brief thermodynamic background and a number of examples and applications are presented. GPO Stock No. 024-004-02141-1. $16.

B 678. Sulfur Construction Materials, by W. C. McBee, T. A. Sullivan, and H. L. Fike. 1985. 31 pp. 45 figs. This Bureau of Mines bulletin summarizes both Government and private sector research related to the use of sulfur in construction materials through 1984. Byproduct sulfur has been investigated for use in concretes, coatings, and paving materials as part of a Bureau research program to utilize abundant minerals. Material properties, mixture design procedures, and applications for these materials are described. GPO Stock No. 024-004-02149-7. $1.50.

B 679. Pacific Manganese Nodules: Characterization and Processing, by Benjamin W. Haynes, Stephen L. Law, David C. Barron, Gary W. Kramer, Riki Maeda, and Michael J. Magyar. 1985. 44 pp. 9 figs. The Bureau of Mines conducted research to provide technical information needed to devise waste management plans for the processing of manganese nodules. Studies included summary descriptions of Pacific manganese nodules, process options and flowsheets, methods for characterizing nodules and their tailings, and results of analyses of laboratory and pilot plant generated tailings. This information is the result of a cooperative research effort of the Bureau of Mines and the National Oceanic and Atmospheric Administration (NOAA), with NOAA providing funding and the Bureau conducting the research. A summary of the extensive literature review is provided for manganese nodule mineralogy, chemistry, processing techniques, and methods of analyses. Characterizations and analyses of laboratory-generated tailings and slags are given, as well as the results of the leaching studies on these waste materials. Leachability was determined by three standard leachate tests—the Environmental Protection Agency (EPA) extraction procedure (EP) toxicity test, the American Society for Testing and Materials shake extraction test, and the U.S. Army Corps of Engineers-EPA seawater elutriant test. While the wastes generated in the laboratory may not be entirely representative of those to be generated in full-scale plants, results of these studies provide a positive indication that commercial recovery of cobalt, copper, manganese, and nickel from manganese nodules would be environmentally acceptable.

B 680. Investigation of Fire and Explosion Accidents in the Chemical, Mining, and Fuel-Related Industries—A Manual, by Joseph M. Kuchta. 1986. 84 pp. 87 figs. This Bureau of Mines manual is oriented to the technical needs of an investigation of fire or explosion accidents and includes various practical and theoretical information that is needed in analyzing accidents or evaluating conditions that might lead to an accident. It is applicable to accidents in the chemical, mining, transportation, and other fuel-related industries. Specific procedures for conducting an accident investigation are outlined, and various guidelines are given for developing the fire or explosion evidence. Ignitability, flammability, and physiochemical data are presented for over 500 combustible gases, liquids, and solids; empirical and theoretical expressions are also given for extrapolating the behavior of combustible-oxidant-diluent systems to various environmental conditions. In addition, various data pertinent to damage analysis are summarized to facilitate the task of the investigator in developing plausible accident scenarios. GPO Stock No. 024-004-02167-5. $4.50.

B 681. Dewatering of Mineral Waste Using the Flocculant Polyethylene Oxide, by B. J. Scheiner, Annie G. Smelley, and D. A. Stanley. 1985. 18 pp. 19 figs. This bulletin summarizes the results of Bureau of Mines investigations of a technique for dewatering clay waste that consists of flocculation with polyethylene oxide (PEO) followed by screening of the resulting flocs. Results of laboratory tests and small- and large-scale field tests are described. The PEO dewatering technique has been applied to clay wastes from phosphate, coal, bentonite, and potash operations and to tailings from uranium, talc, and mica mining operations. Fundamental studies to determine the mechanism of PEO interaction with clay particles are also described. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

B 682. Recovery of Tungsten From Searles Lake Brines by an Ion-Exchange Process, by P. B. Altringer and others. 1985. 47 pp. 23 figs. Searles Lake, CA, contains the largest known domestic tungsten resource. The brines in this near-dry lake bed, located in the Mojave Desert 130 mi northeast of Los Angeles, contain an estimated 135 MMlb of tungsten. However, the low concentration of tungsten (0.080 g/L WO_3) in the supersaturated brine makes selective tungsten extraction very difficult. Although many brine chemicals are extracted from the lake, tungsten recovery was an elusive goal prior to Bureau of Mines development of an ion-exchange technique. This publication describes the Bureau process, the Searles Lake resource, general problems associated with tungsten recovery, Bureau research objectives, the synthesis of ion-exchange resins, the development of a two-stage ion-exchange tungsten extraction and concentration procedure, product recovery and purification, and provides an economic evaluation. Flowsheets for recovering three products (calcium tungstate, sodium tungstate, and tungstic oxide) are presented and evaluated, as well as a summary of the research effort and potential applications.

B 683. Resource Recovery From Municipal Solid Waste, by Martin H. Stanczyk and Roger S. DeCesare. 1985. 31 pp. 34 figs. As part of its mission to investigate and encourage recovery and recycling technologies, the Bureau of Mines studied the feasibility of recovering metal and nonmetallic

mineral values from municipal solid waste. This bulletin reviews Bureau research conducted primarily between 1966 and 1979, which covered various aspects of recycling municipal solid waste and included operation of both a municipal incinerator residue and a raw (unburned) refuse continuous-separation pilot plant. The report describes the products recovered from incinerated and raw refuse and research in upgrading, refining, and/or utilizing the various metal and mineral products. The data are based on approximately 100,000 lb of residues and nearly 1 million lb of raw refuse processed in the pilot plants. Products recovered from incinerator residue included 20 to 30 wt pct ferrous metals, 2 to 3 wt pct nonferrous metals, and 30 to 40 wt pct glass; products from raw refuse included 4 to 8 wt pct ferrous metals, less than 1 wt pct nonferrous metals, 4 to 17 wt pct glass, and 63 to 83 wt pct combustibles. Use of the Bureau's technology at commercial plants in the United States and abroad is briefly described.

B 684. Bureau of Mines Research on Recycling Scrapped Automobiles, by K. C. Dean, J. W. Sterner, M. B. Shirts, and L. J. Froisland. 1986. 46 pp. 31 figs. Discarded automobiles represent the greatest single resource of reusable metals, plastics, and rubber in the United States. This report presents results of Bureau of Mines research, conducted from 1965 to 1983, on separating and recovering useful materials from the scrapped hulks, using old and new metallurgical techniques combined with standard scrapyard methods. The Bureau determined the materials composition of three composite cars designated as circa 1960, mid-1970's and early 1980's, and used these cars to study smokeless incineration and hand-sorting techniques. In studies on treating rejects from automobile shredders, the Bureau designed a process that included air classification, water elutriation, magnetic separation, handpicking, and heavy-medium separation, and also investigated cryogenics and liquation. Complete recovery of copper and other metals was economically made by hand and tool dismantling, leaching, or selective melting of starters and generators. Techniques are also discussed for plastic recovery and waste tire treatment. GPO Stock No. 024–004–02166–7. $2.75.

B 685. Dielectric Separation of Minerals, by C. E. Jordan and G. V. Sullivan. 1986. 17 pp. 25 figs. The fundamental properties of dielectric separation were studied to provide insight into the design and operating characteristics of a dielectric separator. Force equations on mineral particles were derived and evaluated experimentally. Responses to variations in the electrical voltage and frequency, feed rate, particle size, dielectric fluid, and dielectric constant were tested theoretically and experimentally, using a 5-cm-diam dielectric separator. High-dielectric mineral recovery was proportional to the calculated effective dielectric force volume that surrounded each drum-electrode wire. Electrode spacing was the most sensitive design parameter; spacing of less than 0.4 cm was required for a good separation. Dielectric separation was effective for separating minerals with dielectric constants that differed by approximately 2 or more. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

B 686. The Citrate Process for Flue Gas Desulfurization, by W. I. Nissen, L. Crocker, L. L. Oden, and others. 1986. 69 pp. 47 figs. As part of its program to provide technology for reducing undesirable environmental impacts of mineral processing operations, the Bureau of Mines developed the citrate process for desulfurizing industrial stack gases that contain from 0.1 to 2 vol pct SO_2. In this regenerable flue gas desulfurization process, SO_2 is absorbed from cleaned and cooled industrial flue gas with a citric acid-sodium citrate solution. The absorbed SO_2 is subsequently reacted with H_2S to precipitate marketable elemental sulfur and regenerate the solution for recycle. Laboratory investigations of process parameters provided information for designing larger scale continuous operations. Information gathered from operation of two pilot plants, one at a copper smelter and one at a lead smelter, confirmed the laboratory results. Data were obtained for design and construction of a commercial-sized demonstration plant at the George F. Weaton Power Station, Monaca, PA. A preliminary operation of the plant was demonstrated under a cost-sharing Bureau-industry contract. This bulletin describes the citrate process and gives results of the laboratory, pilot plant, and demonstration plant studies, as well as corrosion investigations. GPO Stock No. 024–004–02169–1. $3.75.

B 687. Methane Control Research: Summary of Results, 1964-80, by Maurice Deul and Ann G. Kim. 1988. 174 pp. 211 figs. This bulletin summarizes the work conducted under the Bureau of Mines methane control research program during the years 1964 to 1979. This research effort was directed toward improving existing methods and developing alternative methods of reducing the explosion hazard during mining. The research was performed in three general areas: (1) basic factors that control the emission of methane into coal mines, (2) methane control during mining, and (3) methane drainage in advance of mining. Topics discussed in this bulletin include the magnitude of the methane problem; the equipment and instruments developed; the geological, chemical and physical parameters that control the movement of methane in coalbeds; the direct method of determining gas content; the estimates of gas content from adsorption data; and methane drainage through shafts, through horizontal boreholes, through vertical boreholes, or through slant holes. Improvements in ventilation, control of methane in gob areas, and water infusion are also discussed, as is the potential use of coalbed methane as a supplement to natural gas supplies. This bulletin provides a comprehensive source of information on the accomplishments of the Bureau's methane control research program, on the technology developed, and on the direction of further research. GPO Stock No. 024-004-02200-1. $9.50.

B 688. Utilization and Stabilization of Mineral Wastes, by K. C. Dean, L. J Froisland, and M. B. Shirts. 1986. 46 pp. 34 figs. The Bureau of Mines, following passage of the Solid Waste Disposal Act of 1965, was authorized to conduct research on methods for utilizing, stabilizing, or reclaiming mineral wastes. This report summarizes laboratory research conducted by the Bureau and cooperative field studies made with the mineral industry to reduce the environmental impacts of air and water pollution deriving from mineral wastes. Utilization research showed that both dry-press and steam-cured building bricks and ceramic tile could be made from copper mill tailings and other discarded mineral wastes. Sponge iron was produced from steel mill and amination industry wastes, and valuable mineral products were extracted from such diverse sources as flue dusts and uranium tailings. Mineral wastes were combined with agricultural and/or sewage wastes to make artificial soils that have the potential of resolving several disposal problems by production of a useful commodity. Physical, chemical, and vegetative stabilization methods were evaluated, singly and in combination, for reclamation potential on copper, uranium, lead-zinc, and asbestos tailings. Suitable methods were developed in the laboratory for overcoming major adverse conditions of these wastes such as salinity, heavy metal toxicity, acidity, basicity, lack of nutrients and organics, and unstable surfaces. Field testing of these methods was performed on a variety of mineral wastes. Costs for the various stabilization and utilization procedures developed were also determined.

B 689. Thermodynamic Properties of Sulfides, by L. B. Pankrantz, A. D. Mah, and S. W. Watson. 1987. 427 pp. Thermodynamic data on the sulfides were reviewed, evaluated, and compiled at the Bureau of Mines Albany Research Center. Values for Cp°, S°, $H^\circ - H^\circ_{298}$, $-(G^\circ - H^\circ_{298})/T$, ΔHf°, ΔGf°, and log Kf are given in tabular form. Cp°, $H^\circ - H^\circ_{298}$, ΔHf°, and ΔGf° are also expressed algebraically. GPO Stock No. 024–004–02173–0. $21.

B 690. Bureau of Mines Development of Titanium Production Technology, by J. L. Henry, W. W. Stephens, D. D. Blue, and J. H. Maysilles. 1987. 120 pp. 82 figs. The development and status of technology for producing titanium from U.S. resource materials are summarized in this Bureau of Mines report. Commercially feasible processes and investigations of alternative procedures are reviewed in order to identify techniques that could make existing operations more effective or

areas in which future research may lead to the development of new production methods. Procedures are described for producing concentrated titanium dioxide from starting materials such as sands, massive deposits, and mineral processing residues containing rutile, ilmenite, and perovskite; producing and purifying titanium tetrachloride from concentrated rutile, ilmenite, and titaniferous slags; reduction of titanium tetrachloride to titanium sponge metal using metallic magnesium or sodium; purifying and consolidating titanium sponge and scrap by arc melting or induction melting techniques; purifying sponge, scrap, and alloys by molten salt electrorefining; and electrowinning titanium from chloride salts. GPO Stock No. 024-004-02174-8. $6.

B 691. Lithium and Its Recovery From Low-Grade Nevada Clays, by L. Crocker, R. H. Lien, and others. 1988. 37 pp. 24 figs. The Bureau of Mines investigated processes for recovering a marketable lithium product from the montmorillonite-type clays of the McDermitt caldera. The clay deposit, located on the Nevada-Oregon border, is estimated to contain over 3 million short tons of lithium. Limestone-gypsum roasting and selective chlorination proved most successful for extracting lithium from the clays; 80-pct Li recovery was achieved using either technique. With both processes, lithium silicate in the clay was converted to a water-soluble compound—either lithium sulfate or lithium chloride. The lithium was then recovered as a carbonate by water leaching the calcine, concentrating the leach solution by evaporation, and precipitating the lithium with soda ash. The operating costs for the limestone-gypsum roast process were estimated at $2.02/lb Li_2CO_3; selective chlorination operating costs were estimated at $3.85/lb Li_2CO_3. The current selling price of Li_2CO_3 is about $1.50/lb. A detailed flowsheet, material balance, and process evaluation are presented for the limestone-gypsum roast process. In addition, lithium reserves and resources are discussed and the McDermitt clays are described.

B 692. An Appraisal of Minerals Availability for 34 Commodities, by Staff, Bureau of Mines. 1987. 300 pp. 47 figs. The Bureau of Mines has developed a policy support capability to perform availability analyses for 34 mineral commodities, which has required the development and integration of data bases, evaluation procedures, and analytic systems used to estimate mining and mineral processing costs and to perform commodity-wide economic analyses. Geologic, engineering, and economic evaluations of approximately 2,900 major mines, deposits, and mineral processing plants in market economy countries provide the basic data for the availability studies. The amounts and estimated extraction costs of known resources of each commodity are typically indicated via availability and capacity curves. This report includes an introduction, which details the methodologies and assumptions of the availability analyses, and 29 commodity chapters—aluminum through tungsten. GPO Stock No. 024-004-02190-0. $19.

PATENTS

These patents, which may be used by any U.S. citizen or organization without royalty payment upon authorization by the U.S. Department of the Interior, were developed by Bureau scientists or under contracts with the Bureau. Application should be made to—

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1985

P 1-85. Short Range Trapped Miner Locator. William E. Webb and Ronald H. Church. U.S. Pat. 4,491,971, Jan. 1, 1985.

P 2-85. Extensible Brattice Support System for Mine Face Ventilation. Edward F. Divers, John C. LaScola, and Robert G. Behers. U.S. Pat. 4,494,894, Jan. 22, 1985.

P 3-85. Machine for Mixing and Injecting Water and Grout Into a Roof Bolt Hole. Robert E. Simpson. U.S. Pat. 4,497,578, Feb. 5, 1985.

P 4-85. Self-Adjusting Cap Lamp Bracket. Andrew B. Cecala and Jon C. Volkwein. U.S. Pat. 4,530,112, July 23, 1985.

P 5-85. Non-Incendive Rock-Breaking Explosive Charge. Richard J. Mainiero. U.S. Pat. 4,537,133, Aug. 27, 1985.

P 6-85. Recovery of Titanium From Perovskite Using Sulfuric Acid Leaching. Monte B. Shirts, Dale A. Martin, and Allan E. Petersen. U.S. Pat. 4,552,730, Nov. 12, 1985.

P 7-85. Electrolytic Production of Precious Metals. Kenneth P. V. Lei, Judith A. Eisele, and Gene E. McClelland. U.S. Pat. 4,554,058, Nov. 19, 1985.

P 8-85. Recovery of Titanium From Perovskite by Acid Sulfation. Monte B. Shirts, Dale A. Martin, and Allan E. Petersen. U.S. Pat. 4,562,049, Dec. 31, 1985.

1986

P 1-86. Passive Encoder for Range Knobs. William H. Schiffbauer. U.S. Pat. 4,567,763, Feb. 4, 1986.

P 2-86. Bonding of Metallic Glass to Crystalline Metal. Brent W. Madsen. U.S. Pat. 4,568,014, Feb. 4, 1986.

P 3-86. Use of Soluble Additives To Improve High Temperature Properties of Alumina Refractories. Arthur V. Petty, Jr. U.S. Pat. 4,568,652, Feb. 4, 1986.

P 4-86. Separation of Lithium Chloride From Impurities. Lawrence E. Schultze, Donald J. Bauer, and Ronald M. Arington. U.S. Pat. 4,588,565, May 13, 1986.

P 5-86. Biaxial Pressure Sensor. Richard A. Allwes. U.S. Pat. 4,596,151, June 24, 1986.

P 6-86. Detached Rock Evaluation Device. David R. Hanson. U.S. Pat. 4,598,588, July 8, 1986.

P 7-86. Mine Type Roof Bolt Load Measurement Process. Bernard J. Steblay. U.S. Pat. 4,601,207, July 22, 1986.

P 8-86. Alloy Coating Method. Gerald R. Smith and John E. Allison, Jr. U.S. Pat. 4,601,795, July 22, 1986.

P 9-86. Method for Soldering Aluminum and Magnesium. Wilbert L. Falke, Agnes Y. Lee, and Leander A. Neumeier. U.S. Pat. 4,613,069, Sept. 23, 1986.

P 10-86. Process for Producing Chlorine From Ferric Chloride. Richard S. Olsen and Glenn C. Brown. U.S. Pat. 4,615,874, Oct. 7, 1986.

P 11-86. An Electrolytic Cell and Methods Combining Electrowinning and Electrochemical Reactions Employing a Membrane or Diaphragm. Gerald R. Smith and William R. Thompson. U.S. Pat. 4,627,899, Dec. 9, 1986.

1987

P 1-87. An Apparatus for Controlling the Divergence of a Collimated Abrasive Water Jet. George A. Savanick, Walter G. Krawza, and Steve Connors. U.S. Pat. 4,663,893, May 12, 1987.

P 2-87. Gas Content Determination of Evaporite Formation Using Acoustic Emissions During Dissolution. Gerald L. Finfinger, Roger L. King, and Thomas E. Marshall. U.S. Pat. 4,679,435, July 14, 1987.

P 3-87. Constant Current, Fast and Float Rate, Variable Hysteresis Battery Charger. Bernard J. Steblay. U.S. Pat. 4,686,443, Aug. 11, 1987.

P 4-87. Metal Alloy Identifier. William D. Riley and Robert D. Brown, Jr. U.S. Pat. 4,692,875, Sept. 8, 1987.

P 5-87. Acid Mine Water Aeration and Treatment System. Terry E. Ackman and John M. Place. U.S. Pat. 4,695,378, Sept. 22, 1987.

P 6-87. Electrode Assembly for Molten Metal Production From Molten Electrolytes. James E. Murphy and Michael F. Chambers. U.S. Pat. 4,707,239, Nov. 17, 1987.

P 7-87. An Abrasive Water Jet Rock Drill. Walter G. Krawza, George A. Savanick, and Steven W. Connors. U.S. Pat. 4,708,214, Nov. 24, 1987.

1988

P 1-88. Recycling Superalloy Scrap by Vapor Phase Embrittlement. Henry E. Hilliard. U.S. Pat. 4,718,939, Jan. 12, 1988.

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P 4-88. Isolectric Drilling To Enhance Rate and Prolong Bit Life. Sanaa E. Khalafalla, William H. Engelmann, and John E. Pahlman. U.S. Pat. 4,765,415, Aug. 23, 1988.

P 5-88. Stereoscopic/35mm Camera Slide Bar. Edward A. Barrett, Marion B. Molchen, and Henry J. Kellner. U.S. Pat. 4,768,049, Aug. 30, 1988.

P 6-88. A Method of Measuring the Hazardous Surface Accumulations of Explosive or Toxic Dusts. Michael J. Sapko and Henry E. Perlee. U.S. Pat. 4,793,710, Dec. 27, 1988.

P 7-88. Formation of Tungsten Monocarbide From a Molten Tungstate-Halide Phase by Gas Sparging. John M. Gomes, Andrea E. Raddatz, and Elizabeth G. Baglin. U.S. Pat. Re. 32,612 (reissue of U.S. Pat 4,489,044), Feb. 23, 1988.

1989

P 1-89. Determining Inert Content in Coal Dust/Rock Dust Mixture. Michael J. Sapko and Jack A. Ward, Jr. U.S. Pat. 4,799,799, Jan. 24, 1989.

P 2-89. Production of Titanium Nitride, Carbide and Carbonitride Powders. Charles F. Davidson, Monte B. Shirts, and Donna D. Harbuck. U.S. Pat. 4,812,301, Mar. 14, 1989.

P 3-89. Enhancement of Titanium-Aluminum Alloying by Ultrasonic Treatment. John G. Groetsch, Jr., Timothy H. Elkins, Jr., and Charles A. Sorrell. U.S. Pat. 4,847,047, July 11, 1989.

P 4-89. Gauge for In Situ Measurement of Borehole Diameter. Clarence D. Babcock and George J. Schneider. U.S. Pat. 4,852,262, Aug. 1, 1989.

P 5-89. Separation of Metal Halides Using Supercritical Fluid. William Kent Tolley and Bruce Whitehead. U.S. Pat. 4,853,205, Aug. 1, 1989.

P 6-89. Process for Acid Leaching of Manganese Oxide Ores Aided by Hydrogen Peroxide. James P. Allen and Richard R. Corwin. U.S. Pat. 4,872,909, Oct. 10, 1989.

P 7-89. Recovery of Arsenic From Ores and Concentrates. Charles M. Flynn, Jr., and Thomas G. Carnahan. U.S. Pat. 4,888,207, Dec. 19, 1989.

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1985

SP 1–85. Availability of Land for Mineral Exploration and Development in Southeastern Alaska, 1984, by William S. Roberts. 1985. 34 pp. 20 figs. The Bureau of Mines has initiated a program to determine the availability of land for mineral exploration and development in Alaska. Researchers involved in this program are comparing land availability, based on ownership and government policies and regulations, to the distribution of known mineral deposits and terranes. This report on southeastern Alaska presents the findings of the first of six regional studies that will cover the State. The study consisted largely of data compilation and analysis using various mapping techniques. Summary land availability data are presented on copies of U.S. Geological Survey quadrangles at a scale of 1:500,000. Five categories of land availability were identified: open to mineral exploration and development (approximately 9.4 million acres, or 38% of the 24.8-million-acre study area), open but with possible use restrictions (4.2 million acres, or 17%), selected (0.5 million acres, or 2%), patented (0.74 million acres, or 3%), and formally closed to mineral exploration and development (10 million acres, or 40%). Of the 1,187 known mineral deposits in the study area, approximately 38% are on land in the open category. Mineral terranes comprise approximately 6.7 million acres, or 27% of southeastern Alaska. Approximately 34% of these terranes are on open land. GPO Stock No. 024–004–02158–6. $5.25.

SP 2–85. Bureau of Mines Research 1985. A Summary of Significant Results in Mineral Technology and Economics, compiled and edited by Jerald R. Pederson. 1985. 124 pp. 61 figs. This publication highlights significant studies in the areas of mining research, minerals and materials research, minerals information, mineral data analysis, and helium operations that were conducted during the past fiscal year at Bureau of Mines facilities and offices. A listing of principal officials, a location map of field facilities, and a selected bibliography of publications and patents issued on Bureau developments during the past 3 years are provided.

SP 3–85. Availability of Federal Land for Mineral Exploration and Development in Western States: Colorado, 1984, by Richard A. Beach, Arthur W. Gray, Eileen K. Peterson, and Clark A. Roberts. 1985. 40 pp. 13 figs. The Bureau of Mines inventoried and classified Federal land in Colorado to show its availability for mineral exploration and development, determined areas of the State that are favorable for deposits of certain minerals, and compared Federal land availability with mineral favorability to demonstrate the extent of restricted Federal land in favorable areas. Colorado has 24.7 million acres of Federal land (37.2% of the State). About 5.22 million acres of Federal land is favorable for selected metallic and nonmetallic minerals, of which 78.3% is available and 21.7% is unavailable or severely restricted. About 2.63 million acres is favorable for uranium (and partly for vanadium); 72.4% is available and 27.6% is unavailable or severely restricted. About 7.02 million acres is favorable for and 9.90 million acres more is permissible for (capable of containing) oil and gas; 73.9% is available and 26.1% is unavailable or severely restricted. About 6.31 million acres is favorable for coal, 1.02 million acres for oil shale, and 0.25 million acres for the aluminum minerals alunite and dawsonite; as of July 1, 1984, all Federal land not already leased for these minerals is unavailable. Part of the available Federal land is subject to less stringent restrictions. GPO Stock No. 024–004–02157–8. $7.

1986

SP 1–86. Mineral Position of the United States: The Past Fifteen Years. The 1985 Annual Report of the Secretary of the Interior Under the Mining and Minerals Policy Act of 1970, by Staff, Bureau of Mines. 1986. 45 pp. 12 figs. In addition to describing the performance of the nonfuel mineral industry during 1985, this report reviews the changes that have taken place in the Nation's mineral position since the passage of the Mining and Minerals Policy Act of 1970. Changes in mineral demand and foreign competition for world markets are analyzed, and responses of Government and industry to these changes are discussed.

1987

SP 1–87. Bureau of Mines Research 1986. A Summary of Significant Results in Mineral Technology and Economics, compiled and edited by Jerald R. Pederson. 1986. 131 pp. 42 figs. This publication highlights significant studies in the areas of mining research, minerals and materials research, minerals information, mineral data analysis, and helium operations that were conducted during the past fiscal year at Bureau of Mines facilities and offices. A listing of principal officials, a location map of field facilities, and a selected bibliography of publications and patents issued on Bureau developments during the past 3 years are provided.

SP 2–87. Availability of Land for Mineral Exploration and Development in North-Central Alaska, 1985, by Robert G. Bottge. 1986. 37 pp. 16 figs. The Bureau of Mines is engaged in a program to determine the availability of land for mineral exploration and development in Alaska. Researchers are comparing land availability, based on ownership and Federal and State laws and policies, to the distribution of known mineral deposits and terranes. Six regional studies, consisting of extensive data compilation and analysis using mapping techniques, will cover the State. This study encompassed 54.6 million acres in north-central Alaska. Based on the data collected, the researchers divided the land in the study area into 3 availability categories and 15 subcategories. In July of 1985, 18.8 million acres of the study area were available for mineral exploration and development, 6.1 million acres were available with restrictions, and 29.7 million acres were unavailable. Much of the land that is currently classified as unavailable is likely to be reclassified; however, more than half of the unavailable land is Federal land considered to be permanently unavailable to mining. About 21.7 million acres in the study area are underlain by mineral terranes (assemblages of related rocks likely to contain mineral deposits with a similar genesis). Of this total, more than 5.7 million acres are available to mineral entry, 2.1 million acres are available with restrictions, and 13.9 million acres are unavailable. GPO Stock No. 024–004–02176–4. $2.25.

SP 3–87. Availability of Land for Mineral Exploration and Development in South-Central Alaska, 1985, by Robert G. Bottge and Michael J. Northam. 1986. 45 pp. 23 figs. The Bureau of Mines investigated the availability of the land in south-central Alaska for exploration and mineral development of locatable minerals under State or Federal laws. The land ownership for an area of nearly 72.5 million acres in south-central Alaska was divided into 3 availability categories and 15 subcategories. In July 1985, 31.0 million acres of the

study area were available for mineral exploration and development, 6.2 million acres were available with restrictions, and 35.3 million acres were unavailable. About 23.6 million acres in the study area are underlain by mineral terranes. About 9.9 million of the 23.6 million acres are available for mineral entry, 2.4 million acres are available with restrictions, and 11.3 million acres are unavailable. While much of the land currently classified as unavailable will be reclassified once it is conveyed to the State or to Native corporations, about 22% of the unavailable lands underlain by mineral terranes are now Federal parks, preserves, wildlife refuges, wild and scenic rivers, and military lands, all of which are considered permanently unavailable for mineral exploration and development. GPO Stock No. 024–004–02182–9. $2.75.

SP 4–87. Availability of Land for Mineral Exploration and Development in Northern Alaska, 1986, by Kenneth M. Maas. 1987. 34 pp. 35 figs. The Bureau of Mines inventoried the land availability for mineral exploration and development in northern Alaska and compared this land with known mineral terranes and mineral deposits to quantify the potential for favorable location of mining claims for metalliferous mineral deposits. This report includes thirty-three 1:500,000-scale maps that depict land availability, and the accompanying text and tables relate availability acreage to areas of favorable mineral terranes. Three categories of land availability and ownership are identified, along with 12 subcategories of land status. Available land comprises approximately 14.5 million acres or 16% of the 90.3-million-acre study area; land available with restrictions accounts for 7.5 million acres or 8%; and unavailable land encompasses 68.3 million acres or 76%. Mineral terranes underlie 37.8 million acres or 42% of the study area; 5.3 million acres or 14% are available for mineral location, 2.8 million acres or 7% are available with restrictions, and 29.7 million acres or 79% are unavailable. There are 500 known mineral deposits or occurrences within the study area. This includes 271 lode deposits, of which 171 lie within a recognized mineral terrane and 55 are on available land. The remaining 229 are placer deposits. GPO Stock No. 024–004–02185–3. $8.50.

SP 5–87. Availability of Federally Owned Minerals for Exploration and Development in Western States: Arizona, 1986, by Robert A. McColly and Neal B. Anderson. 1987. 27 pp. 5 figs. This Bureau of Mines report compares the availability of federally owned minerals in Arizona with lands considered favorable for discovery of mineral resources to determine the extent to which Federal mineral lands in such areas have been withdrawn by legal action or restricted by management practice. Of particular concern are restraints on Federal lands in areas identified as highly favorable for occurrences of valuable mineral deposits. Excluding Indian lands held in trust by the Federal Government, about 32 million acres, or 44%, of Arizona's mineral estate is federally owned. This total includes lands with partial Federal mineral ownership. Approximately 16.5 million acres, or 52% of these lands, are available for location or lease. This includes 496,000 acres, or 62%, of the lands highly favorable and 2.6 million acres, or 57%, of the lands moderately favorable for locatable minerals in Arizona. All other Federal mineral lands are either withdrawn or restricted and reflect a wide range of purpose, authority, and impacts on mineral exploration and development. GPO Stock No. 024–004–02191–8. $3.25.

SP 6–87. List of Bureau of Mines Publications and Articles, January 1, 1980, to December 31, 1984. With Subject and Author Index, compiled by Staff, Branch of Editorial Services. 1987. 640 pp. This issue of the List of Bureau of Mines Publications and Articles describes reports and articles published during the period January 1, 1980, to December 31, 1984. Abstracts are included for each item in a regular Bureau series such as Bulletins, Handbooks, Information Circulars, Mineral Issues, Mineral Perspectives, Reports of Investigations, and Special Publications, as well as for contract and unpublished reports such as Open File Reports, Mineral Institutes Reports, and Mineral Land Assessments. This volume also contains a listing of Patents issued to the Bureau of Mines during the period, with instructions on how to apply for permission to use them; information for ordering out-of-stock publications from the National Technical Information Service; a comprehensive listing of depository libraries and regional depository libraries where out-of-print publications can be found; and descriptions of articles written by Bureau employees that have been published in outside journals. GPO Stock No. 024–004–02188–8. $30.

1988

SP 1–88. Technical Highlights, Mining Research, 1987, by Staff, Bureau of Mines. 1988. 142 pp. Research programs at the Bureau of Mines have made notable progress since 1970. This report highlights many significant research results that are already available for use by the industry, as well as other work that is expected to be ready in the near future. The document focuses on accomplishments in the program areas of respirable dust; physical and chemical agents; ground control; industrial hazards; mine-disaster prevention; explosives; technology for mining coal, metals and nonmetal materials; controlling mine wastes, and conserving land resources. Despite the many accomplishments cited in the report, changing mining conditions—such as deeper and thinner deposits with less stable formations—continue to dictate the need for improvements in existing mining processes. The Bureau is addressing these needs by conducting research into new and radical approaches such as automation, robotics, remote sensing and solution mining. GPO Stock No. 024–004–02198–5. $11.

SP 2–88. Bureau of Mines Research 87. A Summary of Significant Results in Mineral Technology and Economics, by Staff, Bureau of Mines. 1988. 93 pp. This publication highlights significant studies in the areas of mining research, minerals and materials research, minerals information, mineral data analysis, and helium operations that were conducted during the past fiscal year at Bureau of Mines facilities and offices. An organizational chart, and a selected bibliography of publications and patents issued on Bureau developments during the past 3 years are provided.

SP 3–88. Issues & Needs of the Mining Industry. A Bureau of Mines Perspective, by Staff, Bureau of Mines. 1988. 28 pp. This report identifies some of the major technological hurdles that need to be overcome and provides some insight into the research approaches underway or plans to remove these obstacles to a state-of-the-art mining industry in this country. The long-term, high-risk aspects of this effort are being addressed by the Bureau of Mines with support by the mining industry. Such studies have long been the role of the Bureau. New methods to exploit coal and mineral deposits in a safe and healthful manner, in situ mining of valuable minerals, protection of the environment against pollution and subsidence, and, perhaps most important of all, the wise conservation and utilization of natural resources are examples of areas in which initial Bureau research and development can and must help the United States maintain a strong mining industry. The Bureau is committed to serve as the principal agent through which the great mineral potential of this nation can be realized and our international status as a mineral producer be assured.

SP 4–88. Availability of Federally Owned Minerals for Exploration and Development in Western States: Oregon, 1984, by Warren D. Longwill. 1988. 27 pp. 4 figs. The U.S. Bureau of Mines inventoried Federal lands in the State of Oregon and classified them in detail, section by section, according to their availability for mineral exploration and development as affected by legal status and agency management practices. The Bureau determined areas of the State having past mineral production and/or known metallic mineral resources and areas favorable for coal, oil, gas, and geothermal resources, and prepared maps that spatially compare the availability of Federal mineral land with these mineral areas to demonstrate the extent of restrictions to mineral entry. Oregon contains 62.1 million acres, of which 33.9 million acres, or 55 pct, is Federal mineral land. About 2.3 million acres of Federal land is favorable for selected metallic mineral deposits, of which 64 pct is available, 13 pct is restricted, and 23 pct is unavailable. Of the 21.1 million acres of Federal leasable land favorable for oil and gas, 68 pct is available, 11 pct is restricted, and 21 pct is unavailable. Of the 146,720 acres favorable for coal, approximately 71 pct is available, 13 pct is restricted, and 16 pct is unavailable. Federal leasable land favorable for geothermal resources amounts to 458,968 acres, of which 42 pct is available, 34 pct is restricted, and 24 pct is unavailable.

1989

SP 1–89. Availability of Land for Mineral Exploration and Development in Southwestern Alaska, 1986, by Kenneth M.

Maas. 1988. 35 pp. 33 figs. The Bureau of Mines inventoried the land in southwestern Alaska to classify ownership and availability and compared this land with known mineral terranes and mineral deposits. This report discusses and quantifies the potential for favorable location of mining claims for metalliferous (locatable) mineral deposits. Of the nearly 24 million acres that constitute the study area, approximately 3.6 million acres or 17% are available for mineral location, 3.4 million acres or 14% are available with restrictions, and 17 million acres or 71% are unavailable. Mineral terranes are known to underlie about 7.8 million acres or 33% of the study area; 3 million acres or 38% occur on land available for mineral location, 1.3 million acres or 17% occur on land available with restrictions, and 3.5 million acres or 45% occur on unavailable land. The State of Alaska has opened over 91% of its land in the study area to mineral location; in comparison, the Federal Government allows mineral location on 0.07% of the land under its jurisdiction. There are 117 known mineral deposits or occurrences within the study area, including 77 lode deposits and 40 placer deposits. Of the 41 lode deposits occurring within a mineral terrane, 2 occur on available land.

SP 2-89. Availability of Land for Mineral Exploration and Development in Western Alaska, 1986, by Robert G. Bottge. 1988. 47 pp. 40 figs. The Bureau of Mines has engaged in a program to determine the availability of land for mineral exploration and development in Alaska. Land availability, based on ownership and Federal and State laws and policies, is compared with mineral terranes and mineral deposits. This is the fifth of six regional studies, which cover the State with a comprehensive set of maps and data compilations. This study covers an area of 112.3 million acres in western Alaska. In July 1986, 41.0 million acres, 37% of the study area, were available for mineral exploration and development; 14.6 million acres, 13%, were available with restrictions; and 56.7 million acres, 50%, were unavailable. Nearly 65% of the unavailable land is classified as national parks, preserves, wildlife refuges, and wild and scenic rivers. Of the 34.0 million acres of mineral terranes that underlie the study area, 12.9 million acres, 38%, are available for exploration and development; 3.6 million acres, 11%, are available with restrictions; and 17.5 million acres, 51%, are unavailable.

SP 3-89. Crushed Stone and Sand and Gravel Production by State Districts 1985-1986, by Valentin V. Tepordei, Olga E. Valdes, and Kim B. Shedd. 1989, 109 pp. 52 figs. To provide more and better information that can be released to the public without compromising individual company data, a new reporting system has been developed by the U.S. Bureau of Mines for reporting crushed stone and sand and gravel production within each State. The new system, implemented for the first time with the publication of the 1985 crushed stone production data, subdivides 40 States into several districts by grouping adjacent counties on which the reporting system is based. In defining the districts, factors like location and number of aggregate producers, size and location of markets, existing road systems, locations of major industries, and Standard Metropolitan Statistical Areas were considered. Consequently, most of the districts represent a market area and include more than three crushed stone or sand and gravel producers, thus allowing the publication of more production information. This publication provides a complete set of tables with production information for crushed stone and sand and gravel by districts for the 40 States in which the districting system was implemented; in the other 10 States the limited number of companies or low level of production precluded implementation of the system.

SP 4-89. U.S. Bureau of Mines Research 88. A Summary of Significant Results in Mineral Technology and Economics, by Staff, Bureau of Mines. 1989. 125 pp. This publication highlights significant studies in the areas of mining research, minerals and materials research, minerals information, mineral data analysis, and helium operations that were conducted during the past fiscal year at Bureau of Mines facilities and offices. Organizational data and a selected bibliography of publications and patents issued on Bureau developments during the past 3 years are provided. GPO Stock No. 024-004-02207-8. $12.

SP 5-89. Availability of Federally Owned Minerals for Exploration and Development in Western States: New Mexico, 1987, by Arthur W. Gray, Neal B. Anderson, Richard A. Beach, and Robert A. McColly. 1989. 32 pp. 11 figs. The U.S. Bureau of Mines inventoried Federal land availability for mineral exploration and development in New Mexico as affected by legal status and agency management practices. To illustrate the impact that such restrictions have on the mineral industry, the Bureau also determined areas having past and present mineral production and/or mineral resources and compared these areas spatially with the availability of Federal mineral lands. About 33.4 million acres, or 43 pct, of New Mexico's mineral estate is federally owned. Of this, about 2.1 million acres is highly or moderately favorable for selected locatable mineral deposits, of which 61 pct is available, 6 pct is moderately restricted, and 33 pct is unavailable or severely restricted. Of the approximately 8.4 million acres favorable for oil and gas, 74 pct is available, 12 pct is restricted, and 14 pct is unavailable. Of the 4.1 million acres favorable for coal, 79 pct is available, 6 pct is restricted, and 15 pct is unavailable. About 2.2 million acres of land is favorable for geothermal resources, of which 76 pct is available, 11 pct is restricted, and 13 pct is unavailable.

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MP. Mineral Industries of Europe and the U.S.S.R., by Staff, Bureau of Mines. 1984. 143 pp. 12 figs. This Bureau of Mines report presents a summary review of the mineral industries of 26 European countries and the U.S.S.R. Mineral production, international mineral trade, and the role of minerals within each country and in terms of world supply are reviewed in text and tables. The principal mining companies are listed, along with their locations and capacities. Basic information is presented on labor, energy, and infrastructure relative to the mineral industries. Maps for each country show the generalized locations of major mineral deposits, petroleum sources, and processing or refining plants. The maps also show major roads, railways, pipelines, and ports that are important to mineral transportation and trade. GPO Stock No. 024–004–02139–0. $5.

MP. Zaire, by George A. Morgan, Kevin Connor, and Ben A. Kornhauser. 1985. 36 pp. 12 figs. Zaire is the world's largest producer of cobalt and diamond and fifth in mine production of copper. Copper is the country's most important product, accounting for 43% of the value of all exports and providing byproducts of cobalt, zinc, cadmium, gold, silver, and sulfur. Mineral industry exports provide 86% of Zaire's foreign exchange and a third of its gross domestic product. The industry's labor force is 10% of the industrial work force. The country's geologic heritage of ancient mineralized rock is the source of its mineral wealth and remains to be further developed. Information available to the Bureau of Mines indicates that output of gold, tin, and tin byproducts has declined owing to exhaustion of easily minable ore and deterioration of production facilities. Resources remain for exploitation but will require much capital and new infrastructure. The rugged environment, isolation of scattered deposits, and inadequate reinvestment may have lost some resources for development indefinitely. Low copper prices and higher cost for energy and transportation are balanced by relatively low wages and by Government and international financial assistance. GPO Stock No. 024–004–02153–5. $1.75.

MP. Mineral Industries of the Middle East, by Staff, Branch of Africa and the Middle East, Division of International Minerals. 1986. 65 pp. 32 figs. This Bureau of Mines report presents a summary of the mineral industries of the 16 countries in the Middle East. Countries in this region differ widely, from those heavily endowed with hydrocarbon resources but with limited nonfuel resources, such as Saudi Arabia, Kuwait, and Qatar, to those heavily mineralized countries with limited petroleum reserves, such as Turkey, and to those with little mineral activity of any kind, such as Lebanon. Base maps and tables show the location and salient features of each country's mineral and petroleum industries. The text highlights the important aspects of mineral supply and trade, mineral policy, industry structure, labor, energy, and the outlook for future developments in the industry. Infrastructure of importance to the mineral industry of each country, including railways, roads, and pipelines, is included on each map. Photographs of some operations are included. GPO Stock No. 024–004–02161–6. $3.50.

MP. Mineral Industries of Australia, Canada, and Oceania (Including a Discussion of Antarctica's Mineral Resources), by Charles L. Kimbell, Travis Q. Lyday, and Harold R. Newman. 1985. 69 pp. 43 figs. This Bureau of Mines report gives the mineral industry highlights of two of the world's major mineral producing countries, Australia and Canada, and seven Pacific island nations or territories—Fuji, New Caledonia, New Zealand, Papua New Guinea, Republic of Nauru, Solomon Islands, and Vanuatu. The mineral resources of Antarctica are also discussed. Because of the size of the Australian and Canadian mineral industries, summary reviews are presented for each of the States, Provinces, or Territories. The most current information available from all nations is given on major minerals or mineral commodity production, share of world production, and reserves. Reported also are significant mining companies, locations and capacities of their main facilities, and their share of domestic production. Other information is provided on mineral related trade with the United States, government mineral policy, energy production-consumption and trade, the mining industry labor force, and prospects for the mineral industry. Maps show the locations of selected mineral deposits, oilfields and gasfields, mines, and processing facilities including iron and steel plants, nonferrous smelters and refineries, and cement plants, as well as infrastructure pertinent to the mineral industry. GPO Stock No. 024–004–02160–8. $6.

MP. Mineral Industries of Latin America, by Staff, Branch of Latin America and Canada, Division of International Minerals. 1988. 134 pp. 34 figs. This Bureau of Mines report provides a general summary of the most important elements of the mineral industries of 37 countries forming the entire Latin American region, including Mexico and all the Caribbean countries. Within the Latin American nations, the mineral industry, which includes hydrocarbon resources, ranges from being a very important sector in Bolivia, Brazil, Chile, Mexico, Peru, and Venezuela to being of almost no consequence to the economies of the countries such as Paraguay or on the islands in the Lesser Antilles. Base maps and tables show the location and most important aspects of each country's mineral and petroleum industry and related infrastructure. The text covers mineral output, trade, and policy, and includes the structure of the mineral industry presented in a table form. The text of each country description concludes with an Outlook section, which presents a prognosis of pending developments. Photographs of various mineral industry installations are included throughout the report. GPO Stock No. 024–004–02194–2. $7.

MP. Mineral Industries of the Far East and South Asia, by Staff, Branch of Far East and Australia, Division of International Minerals. 1988. 128 pp. 8 figs. plus unnumbered maps and photographs. This Bureau of Mines report presents a summary review of the mineral industries of 26 countries in the Far East and South Asia. The review includes a section on each country, which has a text narrative and a base map. The narrative and accompanying tables provide information on mineral reserves and production, mineral supply and international trade position, trade with the United States, the role of minerals within the economy of each country, local mineral policy, the structure of the industry (including a listing of major operating companies with their locations and capacities), industry labor, infrastructure as it relates to the mineral industry, and energy status. An outlook section for each country briefly assesses the future prospects for the mineral industry in that country. Base maps provide information on land area, population, and location of major mineral deposits and facilities: mines, oil and gas fields, and processing plants, including iron and steel works, nonferrous smelters and refineries, and cement plants. The maps also show major roads, pipelines, railways, and ports important to mineral transportation and trade. GPO Stock No. 024–004–02205–1. $10.

REPORTS OF INVESTIGATIONS

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RI 8888. Overlap Probability for Short-Period-Delay Detonators Used in Underground Coal Mining, by T. S. Bajpayee, Richard J. Mainiero, and J. Edmund Hay. 1985. 18 pp. 6 figs. The Bureau of Mines investigated coal-mine-type short-delay electric detonators marketed by three domestic manufacturers to determine the accuracy of delays and the probability of overlap between adjacent delay periods. The Winzer index was computed and compared with the probability of overlap. A close agreement between the Winzer criterion and overlap probability was demonstrated. A permissible blasting unit capable of delivering a maximum firing energy of 4.0 J and a digital oscilloscope were used to measure the delay time with an accuracy of ±0.25 ms. Another oscilloscope and a pulse transformer were used to record firing current. Experimental data indicated negligible overlap probability in detonators of shorter delay periods: periods 1 to 4, which correspond to 25 to 250 ms. However, a significant probability of overlap was detected in some detonators of longer delay periods: periods 5 to 9, which correspond to 300 to 500 ms.

RI 8919. Wear and Corrosion of 12 Alloys During Laboratory Milling of Phosphate Rock in Phosphoric Acid Waste Water, by D. J. Singleton and R. Blickensderfer. 1985. 16 pp. 7 figs. Erosion-corrosion of 12 alloys in phosphoric acid waste water was studied by the Bureau of Mines. Tests were conducted on oblate spheriods or cylindrical specimens in 12- and 60-cm-diam ball mills by grinding phosphate rock in gypsum pond water with a starting pH of 1.6. For comparison, tests were conducted while grinding phosphate rock in plain water. Static corrosion tests in gypsum pond water also were conducted. For all alloys, the wear by erosion-corrosion (milling with gypsum pond water) was greater than the sum of erosion (milling with water) plus static corrosion. Erosion-corrosion wear was about 1,500 to 3,000 mils per year (mpy) for the alloyed white cast irons, 1,000 to 1,400 mpy for commercial steel ball material and type 316 stainless steel, and 600 to 900 mpy for nickel-base alloys and a high-manganese, nitrided stainless steel. Alloy costs per unit of phosphate rock processed favor a low-alloy, high-carbon steel or a high-manganese, nitrided stainless steel.

RI 8920. Upgrading Domestic High-Iron Chromite Concentrates by Carbonyl Extraction of Excess Iron, by A. Visnapuu and W. M. Dressel. 1985. 17 pp. 6 figs. The Bureau of Mines has upgraded high-iron domestic chromite concentrates by a carbonyl process. The upgraded chromite concentrates show as much as 10 wt pct higher Cr_2O_3 content and up to a threefold increase in the Cr:Fe ratio, compared with the starting concentrates. The high-iron chromites were first reduced to convert the iron oxides to the metal, and then treated with CO at elevated pressures and low temperatures to convert part of the metallic iron fraction to iron pentacarbonyl. Carbonylation was accelerated by the addition of H_2S in small quantities. The iron pentacarbonyl was extricated from the concentrate in the pressure reactor during carbonylation by a CO sweep through a pressure-reducing valve and passed through a decomposer at atmospheric pressure to convert it back to iron metal and CO. CO pressure, temperature, promoter trends, and other factors enhancing iron pentacarbonyl formation are presented.

RI 8921. Compaction Criteria for Metal and Nonmetal Tailings, by C. M. K. Boldt. 1985. 27 pp. 20 figs. The Bureau of Mines studied the compaction characteristics of metal and nonmetal tailings. Densities of the tailings and zone of compaction influence, compactive effort, and cost of equipment are related to changes in the factor of safety for specific grain-sized tailings and embankment configurations. Field testing was accomplished in two distinct phases. The first phase investigated the effectiveness of using a nuclear gauge on metal and nonmetal tailings to produce rapid, instantaneous measurements of moisture content, wet density, and dry density. The results of the nuclear gauge testing are presented in chapter 1. Chapter 2 presents a comparison of the compactive effectiveness of three different pieces of construction equipment on a coarse-grained metal tailings pond. The three pieces of equipment chosen for study were a D8H track-mounted dozer, a D500 rubber-tired dozer, and a SP848 vibratory smooth-drum compactor.

RI 8922. Recovering Zinc-Lead Sulfide From a Geothermal Brine, by L. E. Schultze and D. J. Bauer. 1985. 10 pp. 7 figs. The Bureau of Mines devised a technique to recover a Zn-Pb concentrate from a geothermal brine. More than 99 pct of the Zn and Pb was precipitated by treating the brine with H_2S and controlling the pH with lime. Recycle of the sulfide precipitates increased crystal size and resulted in easily filterable products. A typical sulfide precipitate contained 53 pct ZnS, 8 pct PbS, 24 pct MnS, and 15 pct FeS. Addition of sulfide as FeS or CaS was not effective in precipitating Zn and Pb, but Zn in the brine was selectively removed with a strongly basic ion-exchange resin. A proposed flowsheet for metals recovery is discussed.

RI 8923. The Phase Relationship of Talc and Amphiboles in a Fibrous Talc Sample, by Robert L. Virta. 1985. 11 pp. 5 figs. The Bureau of Mines examined a fibrous talc sample from the Gouverneur talc district of New York by transmission electron microscopy (TEM) and polarized light microscopy to determine the mineralogical relationship of the fibrous talc to the amphibole present in the sample. Two amphiboles, anthophyllite and tremolite, were present in the sample. Tremolite occurred as a separate mineral phase, which was blocky in habit. Only a few composite tremolite-talc grains were observed. Anthophyllite, however, was present only in the fibrous talc grains. Microdiffraction study of the fibrous talc grains containing anthophyllite showed that the anthophyllite was intermixed with the talc on a fine scale and that there was a crystallographic relationship between the talc and anthophyllite lattices in the fibrous talc grains. A mechanism similar to the process that forms biopyriboles could explain the structural defects, the fibrous habit of the talc, and the structural relationship between the talc and anthophyllite in the fibrous talc grains. Because of these characteristics, phase contrast microscopy and a provisional TEM technique for monitoring asbestos exposure would not distinguish between fibrous talc and fibrous amphiboles. TEM techniques employing electron diffraction and energy-dispersive X-ray analysis are recommended to positively identify the fibrous phases for regulatory purposes.

RI 8924. Comparative Laboratory Evaluation of Resin-Grouted Roof Bolt Elements, by John R. Bartels and Deno M. Pappas. 1985. 20 pp. 7 figs. In laboratory testing, the Bureau of Mines established criteria by which common resin-grouted roof

bolting systems can be evaluated and compared. Ultimate strength and stiffness were determined for nontensioned full-column, point-anchor, tensioned full-column, and debondable resin-grouted bolts, and for variations on full-column bolts. Bolt performances were compared using the performance of the ¾-in full-column resin-grouted bolt as the standard. New and innovative systems can also be qualitatively compared against this standard. Since the medium into which a resin-grouted bolt is installed is one of the most important parameters affecting bolt performance, various host mediums were used in the testing: sandstone, concrete, simulated coal, simulated shale, and plaster. Bolt performances expected in other mediums can be inferred from the response patterns obtained in these mediums. Results indicate several functional differences among bolt types. Where resistance to shear is important, point-anchor bolts may outperform nontensioned full-column bolts at a lower cost. In medium- to soft-strength rock, tensioned full-column bolts perform best. Also, varying the resin-steel ratio seems to have little effect on the properties of a full-column bolt, when proper resin mixing is ensured.

RI 8925. Device for In Situ Measurement of Coal-Cutting Forces, by James C. Church. 1985. 25 pp. 19 figs. The Bureau of Mines devised and demonstrated a portable linear-cutting tester that directly measures and records the in situ cutting forces required of continuous-mining machine picks to cut coal in underground mines. It requires only two operators to transport and operate the tester, which can be assembled and operated through a complete test cycle within a single mine work shift. This report reviews the factors considered in the design and development of the tester and the results of its system verification testing at coal mine sites.

RI 8926. Mathematical Simulation of Automated Metabolic Breathing Simulator and Self-Contained Self-Rescuer, by John C. Edwards. 1985. 18 pp. 9 figs. The Bureau of Mines developed a mathematical model that describes the interaction of an automated breathing and metabolic simulator, or lung, with a self-contained self-rescuer that is supplied compressed oxygen. The model can be used to predict the gas partial volumes of O_2, N_2, and CO_2 in the lung and in the self-rescuer breathing bag for a prescribed metabolic state that characterizes the lung. Nonlinear rate equations are used to describe the temporal evolution of the gas partial volumes. A numerical procedure was established with a FORTRAN computer program to solve these equations, which correspond to a given metabolic state. Examples are presented of applications of the model to predict bag volume and bag oxygen concentration changes with time when the bag is controlled by an automated breathing simulator. Under certain restrictive conditions, the model equations can also be used to analytically predict the time required for the bag to reach a maximum or minimum volume. The model equation in this latter case was extended to transitions between metabolic states, with transitions described as exponential growth or decay processes.

RI 8927. Cobalt Recovery From Copper Leach Solutions, by T. H. Jeffers and M. R. Harvey. 1985. 12 pp. 3 figs. Significant amounts of cobalt, a strategic and critical metal, are present in readily accessible spent copper leach solutions; for example, recovery of cobalt at two major U.S. copper operations could produce about 1,300,000 lb Co annually, about 13 pct of domestic consumption. However, techniques such as solvent extraction and precipitation have not proven cost effective in separating and recovering the cobalt from these low-grade domestic sources. The Bureau of Mines has devised a procedure using a chelating ion-exchange resin to extract cobalt from a pH 3.0 copper leach solution containing 30 mg/L Co. Cyclic tests in 4-ft-high by 1-in-diam columns gave an average cobalt extraction of 95 pct when 65 bed volumes of solution were processed at a flow rate of 4 gpm/ft² of resin area. After an impurity scrub, eluates contained, in grams per liter, 0.4 Co, 0.2 Ni, <0.001 Cu, 1.3 Fe, 2.8 Zn, and 0.008 Al. Solvent extraction procedures to remove impurities, reject nickel, and concentrate cobalt produced a cobalt sulfate solution containing 80 g/L Co, 0.05 g/L Ni, and not more than 1 mg/L Cu, Fe, Zn, or Al. Based on data from commercial electrowinning operations, this solution appears suitable for production of metallic cobalt.

RI 8928. Large-Scale Dewatering of Phosphatic Clay Waste From Northern Florida, by Annie G. Smelley and B. J. Scheiner. 1985. 9 pp. 3 figs. The Bureau of Mines is testing a dewatering technique for phosphatic clay waste that will recover a portion of the water lost using conventional waste disposal methods and produce solids suitable for land reclamation. The technique utilizes a flocculant, polyethylene oxide (PEO), that forms strong, stable flocs that can be dewatered on a static screen followed by further dewatering on a rotary screen. In field tests conducted in northern Florida, clay wastes containing a nominal 2.5 pct solids have been consolidated to greater than 20 pct solids. The rate at which PEO-treated material continues to dewater in a mine cut also was monitored. Preliminary results indicate that PEO-treated material will dewater to 30 pct solids in 140 days. Pretreatment of phosphatic clay waste with lime and H_2O_2 was shown to improve the dewatering technique for problem clay wastes. Research at the Tuscaloosa Research Center is carried out under a memorandum of agreement between the Bureau of Mines, U.S. Department of the Interior, and the University of Alabama.

RI 8929. Ground Control Study of a Mechanized Longwall Coal Operation in West Virginia, by Paul H. Lu. 1985. 34 pp. 36 figs. This Bureau of Mines report summarizes the analysis and evaluation of the field measurement results of a comprehensive ground control study conducted in a mechanized longwall coal mine in West Virginia. Emphasis is placed on the three basic ground control parameters: ground pressure, ground movement, and geomechanical properties. Specific topics include premining ground pressures, front-abutment pressure in the longwall panel, histories of pillar loading, differential roof-strata movement and bed separation, differential floor strata movement, entry roof-to-floor convergence, in situ moduli of rigidity of coal seam and roof and floor strata, and mechanical properties of coal and coal measures rocks.

RI 8930. Hydrogen Chloride Sparging Crystallization of the Chloride Salts of Cobalt, Manganese, and Nickel, by D. E. Shanks and E. G. Noble. 1985. 19 pp. 13 figs. The Bureau of Mines investigated the effects of HCl concentration and solution temperature on the solubility and crystal form of the chlorides of Co, Mn, and Ni when sparged with HCl gas at temperatures of 20°, 40°, and 60° C. Increasing HCl concentration in solution caused the chlorides of Co, Mn, and Ni to crystallize (salt out) because of the common ion effect. The salting-out crystallization was most effective for $NiCl_2$, which had a solubility of 0.7 pct at 20° C and maximum HCl concentration. $CoCl_2$ salted out to a minimum solubility of 9.4 pct at 20° C and 22 pct HCl concentration and increased in solubility at greater HCl concentrations because of the formation of chloride complexes. $MnCl_2$ was intermediate in behavior. The effect of temperature on solubility was greatest for $CoCl_2$ and least for $NiCl_2$, 15 and 7 pct change, respectively, over the temperature range of 20° to 60° C. The salted-out chlorides of cobalt and nickel formed the hexahydrates and those of manganese formed the tetrahydrate in saturated metal chloride solutions at 20° C and low concentrations of HCl. Increasing the temperature or the HCl concentration caused a loss in waters of hydration. At 60° C, the salted-out crystals of $NiCl_2$ formed the tetrahydrate in HCl concentrations up to 18 pct and dihydrate at higher concentrations, while cobalt and manganese chlorides formed the dihydrates, even in water.

RI 8931. Deposition of Nickel-Cobalt Alloys by Controlled-Potential Electrolysis, by J. L. Holman and L. A. Neumeier. 1985. 17 pp. 10 figs. The Bureau of Mines is

conducting research to improve technology for the recovery of strategic and critical metals, such as cobalt, nickel, and chromium, that are lost in bulk and particulate superalloy-type scrap because it has not been possible to process mixed contaminated scrap efficiently. The research approach involves melting and casting mixed superalloy scrap into soluble anodes for electrodeposition of Ni-Co alloys by controlled-potential electrolysis. The initial experimental results described in this report are from electrolytic tests using alloy anodes cast from elemental nickel, cobalt, and chromium, the main constituent metals of superalloys. Baseline data and operating parameters are necessary for Ni-Co and Ni-Co-Cr alloys before detailed experiments can be conducted on the more complex superalloy scrap. This basic research assessed the effects of cathode potential, SO_4:Cl electrolyte ratio, electrolyte pH, stirring rate, deposition time, cathode current density, and chromium concentration on cathode current efficiency, alloy deposit composition, and deposition potential at a cell temperature of 55° C.

RI 8932. Spectral Characteristics of Grinding Sparks Used for Identification of Scrap Metals, by W. D. Riley, B. W. Dunning, Jr., and D. M. Soboroff. 1985. 13 pp. 11 figs. The Bureau of Mines is conducting research on methods for the rapid identification and sorting of mixed scrap metals and alloys so that domestic scrap resources can be fully utilized. One method, spark testing, is the examination of the pattern of sparks that results when a metal or alloy is ground on an abrasive wheel. This technique requires experienced sorters. Bureau researchers have shown that spectrophotometric methods can be used in lieu of the highly skilled sorter. The spectra of mild steel, a high-strength low-alloy steel, several stainless steels, and four nickel-base alloys have been measured. Differences in the spectra that are sufficient for identification are apparent.

RI 8933. Comparison of Rotary and In-Hole Motor Techniques for Drilling Horizontal Boreholes in Coal, by S. J. Kravits, A. Sainato, and G. L. Finfinger. 1985. 33 pp. 21 figs. This Bureau of Mines report describes and compares the procedures, capital investments, and operating costs of rotary and in-hole motor drilling techniques used to drain methane gas from the Pittsburgh Coalbed in an underground mine located in southwestern Pennsylvania. A timestudy was conducted during the drilling of each of two boreholes, and the data were collected to serve as a base for comparing drilling procedures and operating costs. Findings indicate that drilling with an in-hole motor offers four advantages over rotary drilling; namely, an increase in drilling productivity, fewer worker-hours required, ease of maintaining vertical and horizontal bit trajectory, and less expensive drilling cost per foot of borehole.

RI 8934. Minimizing Lead Contamination in Copper Produced by Solvent Extraction-Electrowinning, by T. H. Jeffers and R. D. Groves. 1985. 11 pp. 2 figs. The Bureau of Mines conducted a laboratory investigation of copper electrowinning from electrolytes produced by solvent extraction. The purpose of the research was to gain a better understanding of the fundamental relationship between copper electrowinning conditions, anode corrosion, and cathode purity. Processing variables were evaluated in a cyclic semicontinuous system in which the depleted electrolyte was used to strip copper from loaded organic extractant. For the production of high-quality copper cathodes, the electrolyte was dosed with cobalt and stripped of organic solvent extraction reagent. An optimum cobalt addition of 60 ppm, and removal of the entrained extractant with activated carbon provided the best conditions for electrowinning copper containing the least amount of lead and controlling anode corrosion. As little as 13 ppm of the entrained organic extractant, LIX 64–N, significantly accelerated anode corrosion. However, the addition of 1,000 ppm of organic diluent kerosine did not affect anode corrosion. After cobalt dosing and removing the entrained extractant, cathodes containing less than 2 ppm lead were consistently electrowon at widely varied current densities, electrolyte copper and acid concentrations, and temperatures. Dosing of the electrolyte with selected impurities including magnesium, aluminum, manganese, and iron did not affect the cathode purity. However, 0.05 g/L of chloride ions markedly increased anode corrosion and the subsequent transfer of lead to the cathode copper.

RI 8935. Adding Steam To Control Dust in Mineral Processing, by Andrew B. Cecala, Jon C. Volkwein, and Edward D. Thimons. 1985. 9 pp. 6 figs. The Bureau of Mines performed tests to compare the effectiveness of steam and of water sprays to reduce respirable dust levels at mineral processing plants. By applying 0.22 wt pct water vapor as steam to product material, a 64-pct respirable dust reduction was recorded. By applying the same amount of moisture with water sprays, only a 25-pct dust reduction was recorded. By increasing the moisture content up to 0.5 pct using water sprays, the dust reduction was increased to 55 pct, which was still less than the dust reduction achieved by adding less than half that amount of water in the form of steam.

RI 8936. Field Evaluations of Magnesium Oxide in Deep-Bed Filtration, by Daniel N. Tallman and Joseph E. Schiller. 1985. 11 pp. 3 figs. To provide technology for achieving more efficient water filtration systems for the mineral industry, the Bureau of Mines performed demonstration filtration tests at three iron ore mines and one steel mill. A comparison of equivalently sized magnesium oxide (MgO) and sand filters showed that MgO had a higher capacity and could operate at higher filtration rates than sand. In demonstration tests when alum ($AlK(SO_4)_2$) was the coagulant, suspended solids breakthrough occurred even though the pressure across the filter (head loss) was 7 psig or less. Under these circumstances, the MgO demonstrated 20 to 100 pct greater filtration capacity, defined in terms of the volume of water filtered before breakthrough. When an organic flocculant was used at one location, head loss was the run-limiting factor; the filters essentially plugged without any solids breakthrough.

RI 8937. Pull and Creep Tests on Gypsum-Bonded Roof Bolts, by J. S. Hansen and S. J. Gerdemann. 1985. 36 pp. 22 figs. To improve mine safety, the Bureau of Mines has conducted a search for better materials and systems to anchor roof bolts. This report describes a study on the ability of a gypsum-based anchoring medium to withstand short- and long-term loads. Results showed that 2-ft-long bolts anchored with gypsum that was injected as plaster slurry at a 0.370 water-cement ratio and cured for 10 min sustained pull test loads equal to the ultimate strength of the bolt steel (about 37,000 lb). For comparison, the minimum required capacity is 17,600 lb. Long-term loads of 15,500 lb were sustained with estimated 10-yr movement of less than ½ in. Two-foot-long bolts anchored with gypsum installed in a cartridge in which the water was contained in tiny capsules sustained a pull test load of about 30,300 lb at a 0.319 water-cement ratio and 10-min cure time. At a 0.288 water-cement ratio, load capacity was about 37,000 lb. The lower capacities of cartridge-installed bolts resulted primarily from the remnants of the water-wax capsules. Above 10,000 lb, creep movement of cartridge-grouted bolts appears excessive, but longer bolts may be capable of resisting creep better.

RI 8938. Laboratory Processing and Characterization of Waste Materials From Manganese Nodules, by Benjamin W. Haynes, David C. Barron, Gary W. Kramer, Riki Maeda, and Michael J. Magyar. 1985. 16 pp. 1 fig. This Bureau of Mines report describes the laboratory processing of manganese nodules and the results of tailings characterization obtained during the cooperative program with the Department of Commerce's National Oceanic and Atmospheric Administration and the Bureau. Five technically feasible first-generation nodule processing methods were operated at bench scale to

generate sufficient tailings and slags for physical and chemical analyses. A description is given for the laboratory operation of the individual unit operations of each process. The laboratory-generated tailings and slags were tested for physical properties, mineral content, elemental and ion content, and leachability for all five processes. The results of leachate testing using the Environmental Protection Agency (EPA) extraction procedure (EP) toxicity test, the American Society for Testing and Materials shake extraction test, and the EPA-U.S. Army Corps of Engineers seawater elutriant test showed very low to negligible leaching of metals from the tailings and slags. Results of the EP toxicity test demonstrated that the wastes are nonhazardous as defined in the Resource Conservation and Recovery Act (Public Law 94–580).

RI 8939. Assessment of Phosphogypsum as a Constituent of Aggregate Material, by A. May, J. R. Cobble, and J. W. Sweeney. 1985. 21 pp. 14 figs. Florida has accumulated about 400 million tons of phosphogypsum, a mineral process waste generated in the production of fertilizer, and is adding 30 million tons to this annually. To minimize storage of this waste and reduce potential environmental effects, the Bureau of Mines conducted research into utilizing the phosphogypsum, by identifying and developing high-volume uses for this material. Admixtures of phosphogypsum, fly ash, and lime that could produce a coarse aggregate suitable for road construction were investigated. Using phosphogypsum with asphalt, cement, cement-kiln dust, silica, clays, and oxychlorides to produce aggregate was also examined. This report is based upon work done under an agreement between the Bureau of Mines, U.S. Department of the Interior, and the University of Alabama.

RI 8940. Hydrometallurgical Treatment of Electronic Scrap To Recover Gold and Silver, by H. E. Hilliard, B. W. Dunning, Jr., D. A. Kramer, and D. M. Soboroff. 1985. 20 pp. 8 figs. The Bureau of Mines investigated hydrometallurgical procedures for concentrating precious metals from a mechanically processed metal fraction of obsolete military electronic scrap. Feed material for the leaching procedures described in this report was the high-tension-separated metal concentrate obtained as a fraction from mechanically processing partially stripped electronic units. Initial pretreatment with a 20-wt-pct NaOH solution solubilized most of the aluminum. After washing, the resulting residue was incinerated to destroy any organics attached to metal particles. The incinerated residue was leached with 20-vol-pct H_2SO_4 solution using two methods, countercurrent pressure and ultrasonic-aided leaching, to solubilize the base metals, predominantly copper. Silver was recovered from the base metal leach residue using 50-vol-pct HNO_3, and gold contaminated with several percent palladium was recovered from the silver leach residue using aqua regia. The impure silver and gold plus palladium products represent about 1.5 wt pct of the high-tension-separated metal concentrate. Included is a three-step process evaluation study of mechanical processing of general electronic scrap and two hydrometallurgical procedures for leaching high-tension-separated metallic concentrates obtained from the mechanical processing step. Process evaluation concluded that only mechanical processing is economically viable.

RI 8941. Analysis for Impurities in Helium Using the Helium Ionization Detector, by Charles A. Seitz. 1985. 30 pp. 19 figs. This Bureau of Mines report describes a chromatographic method for analyzing impurities in helium that utilizes a helium carrier gas containing 25 to 30 ppm Ne. An example of the effect of trace amounts of nitrogen, methane, and moisture on the detector's response is shown. The added neon in the carrier does away with irregularities of the analysis that were experienced when the carrier contained up to 3 ppm Ne. The addition of 25 to 30 ppm Ne causes a loss of sensitivity, but the remaining sensitivity is adequate for routine analyses. The high-neon carrier allows positive and more linear responses for eight impurities: neon, hydrogen, argon, oxygen, nitrogen, methane, carbon dioxide, and ethane. Neon concentration levels of 0.02 to 125 ppm in helium carrier gases were studied. The high-neon carrier has been in successful routine use in Bureau of Mines helium facilities since October 1981.

RI 8942. Application of Cast-On Ferrochrome-Based Hard Surfacings to Polystyrene Pattern Castings, by J. S. Hansen, R. R. Jordan, S. J. Gerdemann, and G. F. Soltau. 1985. 37 pp. 24 figs. To advance technology that can help conserve critical materials, the Bureau of Mines investigated a cast-on hard-surfacing technique that improves wear resistance and confines alloy additions to wear-prone surfaces. Wear-resistant material in powdered form is applied on a polystyrene pattern, the pattern is embedded in a mold of unbonded sand, and the wear-resistant material is transferred to a casting surface at the time of pouring. For low-stress abrasion, surfacings derived from high-carbon ferrochrome had higher wear resistance than did commercially available weld-deposited hard facings. The microstructure of the surfacings was typical of hypoeutectic white iron containing M_7C_3-type carbides. Free carbon added to the ferrochrome powder produced more M_7C_3 carbides than did material contained in surfacings made from ferrochrome alone, and improved the wear resistance. Several white iron powders with greatly reduced chromium contents also produced white iron surfacings containing M_7C_3 carbides. One surfacing derived from white iron powder had wear resistence equal to that of weld-deposited hard facings. Among the parameters investigated, surfacing thickness was found to have a major influence on solidification, diffusion of elements out of the surfacing, microstructure, and wear resistance. The results of field tests on bucket-wheel excavator teeth and plowshares with cast-on hard surfacing are given.

RI 8943. Strengthening Low-Alloy Magnesium Sheet by Strain Softening and Annealing, by M. M. Tilman, R. L. Crosby, and L. A. Neumeier. 1985. 13 pp. 6 figs. The Bureau of Mines conducted research to determine the feasibility of strengthening experimental magnesium-base sheet alloys by strain softening induced by controlled cold rolling followed by selective heat treatment. Relatively small alloying additions having potential for producing strain softening were selected from metals that are readily available. Tensile properties comparable to minimum properties of the most commonly used magnesium-base sheet alloy AZ31B, in the H24 condition (strain-hardened and partially annealed), were obtained in an Mg-1MM (mischmetal)-0.5Mn alloy after strain-softening rolling followed by heat treatment. Tensile properties of the experimental alloys in certain conditions are also compared with minimum tensile properties of other standard magnesium sheet alloys. Incidental to the principal objectives, apparent superplastic behavior was observed in three experimental magnesium-base alloys containing MM, MM plus manganese, and MM plus zirconium.

RI 8944. Flocculation of Metal Oxide and Hydroxide Minerals With Cross-Linked Starches Containing Chelating Groups, by S. C. Termes and R. L. Wilfong. 1985. 17 pp. 14 figs. To help develop the basis for new fine-particle separation methods, the Bureau of Mines has investigated the use of cross-linked starches containing four chelating groups—carboxylate, iminodiacetate, diethanolamine, and xanthate—as flocculants for selected metal oxide and hydroxide mineral fines. It was found that those starches capable of interacting with the mineral surface by a chemisorption mechanism (as indicated by zeta potential measurements) produced the highest recoveries and grades of the metal oxide or hydroxide when flocculated from a binary mixture with quartz. The effects of pH, dispersing agent, stirring rate, stirring time, and starch dosage on selective flocculation were studied for binary mixtures of hematite and chromite with quartz. Floc strength becomes important in achieving maximum recoveries by mechanical postflocculation separations.

RI 8945. Determination of Tungsten and Associated Elements in Natural Brines and Related Process Solutions by Inductively Coupled Plasma Spectrometry, by M. M. Jones and A. B. Whitehead. 1985. 9 pp. 1 fig. Natural brines are potential domestic resources of minerals. The brines of Searles Lake, CA, for example, contain an estimated one-fourth of our current reserve of tungsten. A key to Bureau of Mines research to recover this critical mineral is the ability to quantitatively measure concentrations of particular constituents in the large number of brine samples and process solutions produced under a multiplicity of test conditions. This paper describes procedures used to determine arsenic, boron, phosphorus, silicon, and tungsten in these solutions by simultaneous inductively coupled plasma spectrometry. A variable internal standard method was used to compensate for tungsten interference on the other analytes in tungsten concentrates, and matching standards were used to determine tungsten in raw brine. Other solutions were analyzed using normal techniques. Analytes were determined down to 1 mg/L with an average precision of 2.5 pct relative standard deviation. Accuracy, estimated using synthetic solutions and by comparsion with values obtained by other methods, averaged about 2.5 pct. The methods were rapid, required little sample preparation, and provided the needed sensitivity.

RI 8946. Fire Tests of Five-Gallon Containers Used for Storage in Underground Coal Mines, by F. J. Perzak, T. A Kubala, and C. P. Lazzara. 1985. 35 pp. 29 figs. The Bureau of Mines conducted a study to develop a standard fire test for 5-gal containers used for storing combustible fluids in underground coal mines. A standard test method was developed that evaluates the performance of the container in a 4-min tray fire. Bureau investigators used the standard test method to evaluate several types of closed 5-gal plastic and metal cans in outdoor tests. Each can tested contained 1 gal of non-fire-resistant (NFR) hydraulic oil. A container failed the test if it lost its contents in any of seven trials. Contents spilled either as a result of thermal rupture or melting. Fewer than 10 pct of the metal containers failed this criterion, but all the plastic containers failed. The metal container failures were usually due to tipping over during pressure relief, which spilled the NFR oil. Replacing the NFR oil in the container with kerosene resulted in failure of more than 30 pct of the metal containers. The standard tests and preliminary tests showed that plastic containers are not equivalent to metal containers in their ability to contain combustibles such as lubricants and greases in a fire. For solvents and lubricants more volatile than NFR hydraulic oil, approved metal safety containers are recommended.

RI 8947. Vanadium Extraction From Idaho Mudstones, by M. Hayashi, I. L. Nichols, and J. L. Huiatt. 1985. 13 pp. 7 figs. The Bureau of Mines conducted laboratory studies on Idaho mudstones to examine techniques for extracting vanadium. Recovery of vanadium from low-grade sources could contribute to future vanadium production and reduce reliance on imports. An Idaho mudstone surface sample containing 0.30 pct V_2O_5 and an underground sample containing 0.21 pct V_2O_5 were used in the extraction tests. Leaching of the surface sample for 18 h at 80° C with the addition of up to 1,000 lb/ton H_2SO_4 recovered 70 pct of the vanadium. However, leaching of the underground sample under the same conditions recovered only 47 pct. By adding 15 wt pct NaCl and roasting the samples at 750° C for 2 h, followed by leaching with 800 lb/ton H_2SO_4, vanadium extractions were increased to 78 pct from the surface sample and 83 pct from the underground sample. Water leaching of samples roasted at 750° C for 4 h with a 25-wt-pct NaCl addition yielded about 60 pct of the vanadium from both surface and underground samples. Autoclave leaching at 200° C for 3 h with 1,000 lb/ton H_2SO_4 extracted 97 pct of the vanadium from the surface sample and 86 pct from the underground sample. An exploratory solvent extraction investigation to purify and concentrate vanadium in the leach solution using several organic reagents was also conducted.

RI 8948. Analysis of Sampling Variance From Certain Platinum and Palladium Deposits in Alaska, by James C. Barker, Dana L. Thomas, and Daniel B. Hawkins. 1985. 26 pp. 13 figs. The analytical variability encountered when sampling for platinum-group metals (PGM) was statistically evaluated during a 1983 study by the Bureau of Mines and the University of Alaska. Sampling procedures were designed to systematically incorporate commonly used reconnaissance exploration techniques under actual field conditions. Analytical variability was evaluated at each procedural step. Analytical data from each sample from a single deposit grouped relatively well around the calculated mean for that deposit. Standard deviations did not exceed 43 pct of the mean for any of the deposits; more commonly, the deviation was about 25 pct. Statistical treatment of the data by analysis of variance indicated the most important source of error is selection of the sample site. Two or more replicate samples appear necessary to adequately quantify the PGM content. Secondly, significant variation occurs during preparation of a pulverized split for fire assay. The optimum sample size was in the 11-lb range; larger samples did not appreciably reduce variability. Smaller samples generally indicated a higher degree of variability. Evaluation of the sample method suggested the common grab sample, if carefully taken, is a useful indicator of the general range of PGM concentration but potentially includes a considerable margin of error.

RI 8949. Chlorine-Oxygen Leaching of a Low-Grade Zinc Sulfide Flotation Concentrate, by G. A. Smyres and T. G. Carnahan. 1985. 10 pp. 7 figs. The Bureau of Mines conducted laboratory studies to determine the feasibility of chlorine-oxygen leaching for treating low-grade zinc sulfide flotation concentrates. Recovery of zinc sulfides by flotation from complex fine-grained sulfide ores is substantially higher in low-grade bulk sulfide concentrates than in the high-grade cleaned concentrates required for smelter feed. However, there is no commercial process in the United States for the treatment of low-grade bulk zinc sulfide concentrates. Leaching experiments using reactors of 500-mL and 1-gal capacity were conducted on a bulk concentrate containing 19.3 pct Zn, 35.6 pct Fe, and 39.4 pct S. The effects of pressure, temperature, and percent solids on extraction were investigated. The chlorine-oxygen leaching procedure showed promise for treating the concentrates. Zinc extractions of 95 pct or more were obtained by leaching at 50 pct solids in the temperature range of 100° to 120° C. Zinc extractions by leaching with chlorine followed by oxygen at reactor pressures of 50 to 100 psig were independent of pressure.

RI 8950. Rock Stability Analysis Using Acoustic Spectroscopy, by D. R. Hanson. 1985. 21 pp. 27 figs. This Bureau of Mines study examines the acoustic vibrational spectra of rock slabs in the range from 0 to 5,000 Hz. The power spectra of so-called drummy rocks were found to be diagnostically enhanced in the range from 200 to 1,000 Hz. Comparison of the power in this band with that in a band from 3,000 to 3,500 Hz provides a quantitative measure of rock stability. A prototype field instrument was designed, constructed, and field tested. This battery-powered instrument computes the power contained in the two frequency bands mentioned, compares the magnitude of these two quantities, and displays a number that is related to the detachment of the block tested. Field tests show that this instrument is capable of giving reliable measurements of block stability under conditions of noise and dust that would seriously degrade the accuracy of normal sounding techniques.

RI 8951. Electrochemical Conditioning of a Mineral Particle Bed Electrode for Flotation, by J. E. Gebhardt, N. F. Dewsnap, and P. E. Richardson. 1985. 10 pp. 8 figs. External control of the electrochemical potential of a bed of mineral particles has been investigated by the Bureau of Mines as a method for controlling particle interaction with organic collec-

tors and thus, flotation response. A cylindrically shaped, 200- to 300-g bed of sulfide mineral particles was used as the working electrode to examine the potential distribution in the bed. The dissolved oxygen concentration of the electrolyte had a significant effect on the potential profile across the mineral bed. Low oxygen levels were necessary to achieve uniform electrochemical potential distributions. Flotation separation of a chalcocite-pyrite mineral mixture by controlled potential was achieved using ethylxanthate, but the flotation behavior of the chalcocite and pyrite from the mixture does not follow the flotation behavior of the individual minerals. That is, the presence of another sulfide mineral alters the flotation behavior with ethylxanthate. Galvanic interaction due to mineral-to-mineral contact between chalcocite and pyrite contributes to differences in the recovery. Chalcocite dissolution products had a deleterious effect on pyrite flotation by activating flotation below -0.1 V (saturated calomel electrode) and depressing flotation above -0.1 V. Pyrite dissolution products had no effect on chalcocite flotation.

RI 8952. A Technology for Integrity Testing of In Situ Leach Mining Wells Using a System of Inflatable Packers, by Jon K. Ahlness, Stephen C. Gould, and Michael G. Pojar. 1985. 14 pp. 8 figs. The Bureau of Mines investigated technologies for testing the integrity of in situ leach mining wells, as required by environmental regulations. To test for leaks, inflatable packers were used to seal the well casing. Laboratory testing determined that the packers could contain a casing pressure up to 50 to 60 psi (345 to 414 kPa) less than the packer inflation pressure. Single- and double-packer configurations were successfully field tested in 32 wells ranging from 500 to 530 ft (153 to 162 m) in depth. A rigid pipeline and a hoist truck were used to run the packers in and out of the wells for the double-packer tests, which averaged 2¼ h each. In an effort to decrease the time of the rigid-pipe double-packer test, a self-contained trailer-mounted test system was designed and built. It utilizes a winch and steel cable to run the packers in and out of the well and high-pressure nylon tubing for packer inflation. This system was successfully field tested in eight wells averaging 650 ft (198 m) in depth and resulted in a time savings of 13 pct and an operator-hour reduction of 42 pct.

RI 8953. Removal of Magnesia From Dolomitic Southern Florida Phosphate Concentrates by Aqueous SO_2 Leaching, by J. P. Hansen, B. E. Davis, and T. O. Llewellyn. 1985. 11 pp. 6 figs. The Bureau of Mines has investigated the SO_2 leaching of MgO from high-MgO-bearing Florida phosphate concentrates. The SO_2 was effective in leaching some of the MgO from three phosphate concentrates; flow rate of the SO_2 and leach time were major factors in determining the amount of MgO leached. Calcining the samples, then grinding to minus 200 mesh, and elevating the leach temperature gave only small increases in the amount of MgO leached. The research also showed that some of the MgO was so intimately associated with the phosphate mineral that it could not be removed by SO_2 leaching. This amounted to about 0.6, 0.7, and 1.0 pct MgO in three leached residues. The calculated heads for the three concentrate samples averaged 1.4, 1.1, and 1.5 pct MgO, respectively, before leaching. This report is based upon work done under a memorandum of agreement between the Bureau of Mines, U.S. Department of the Interior, and the University of Alabama.

RI 8954. Ground-Penetrating Radar for Strata Control, by Ronald H. Church, William E. Webb, and James R. Boyle, Jr. 1985. 16 pp. 13 figs. As part of the Bureau of Mines health and safety research program in strata control, a ground-penetrating radar (GPR) system capable of penetrating approximately 10 ft into the mine roof has been devised to identify anomalistic conditions. The GPR system consists of a transmitter with carrier frequencies of 250, 500, and 1,000 MHz, utilizing a dipole antenna, and a receiver, consisting of a dipole antenna fed into a sampler with a time base housed in a storage oscilloscope. A computer was utilized for data acquisition and data processing. Data analysis by computer enhancement revealed recognizable return radar signatures from the middle man rock and main roof of the test site. These stratigraphic anomalies can be cataloged for recognizable features, which from the past history of the mine may have been shown to create strata control problems. Early recognition of such features could lead to immediate corrective actions and result in the saving of lives. This report is based upon work done under a memorandum of agreement between the Bureau of Mines, U.S. Department of the Interior, and the University of Alabama.

RI 8955. Coal Mine Air Tempering: Effectiveness, Design, and Roof Support, by Gary P. Sames. 1985. 20 pp. 12 figs. Shale roof deterioration in coal mines, caused by ventilation air humidity fluctuations, is a common ground control problem. Shale roof deterioration often results in increased accidents, decreased production, inadequate ventilation, and increasing operating costs in maintaining haulage roads and airways. The results of Bureau of Mines research indicate that air tempering entries are an effective method of controlling deterioration prone shales. Some of the conclusions and recommendations drawn from Bureau research include (1) moisture sensitive shales will react adversely to moisture gains and losses, (2) the majority effect of specific humidity fluctuations can be concentrated in and absorbed by tempering entries, (3) tempering entry panels should be located as near to the main intake as possible, (4) tempering panels should be designed for a conservative recovery and provide a minimum of 20- to 30-min air residence time, (5) ventilation and escapeway requirements must be considered early in panel design, and (6) an efficient support and sealant plan can increase the life expectancy of a tempering panel.

RI 8956. Fiber Reinforcement of Sulfur Concrete To Enhance Flexural Properties, by B. W. Jong, W. C. McBee, K. L. Rasmussen, and T. A. Sullivan. 1985. 12 pp. 8 figs. The Bureau of Mines studied reinforcement of sulfur concretes using glass, polyester, and aramid fibers. The objective of this research was to determine the feasibility of fiber-reinforcing the sulfur concrete to enhance the flexural properties. Optimum fiber sulfur concrete compositions were formulated with a cement-to-fiber ratio of 9.0:1 for glass-fiber and polyester-fiber sulfur concretes and 12.1:1 for aramid-fiber sulfur concretes. Test samples were prepared using techniques developed by the Bureau of Mines. Flexural strength values of up to 50 pct of compressive strength values were achieved with fiber additions. With non-fiber-reinforced sulfur concrete, the values ranged up to 20 pct. The impact strength and fracture toughness of sulfur concretes were increased significantly by reinforcement with glass or with aramid fiber and were adversely affected by use of polyester fiber. Strain tolerance was doubled and failure mode was shifted from catastrophic to noncatastrophic type by adding glass fiber. The glass-fiber and aramid-fiber sulfur concretes are resistant to acid corrosion and have proved durable in freeze-thaw cycles. This laboratory and field evaluation has shown that fiber reinforcement of sulfur concrete is feasible and that it enhances the flexural properties.

RI 8957. Defluorination of Byproduct Zinc Concentrates, by R. B. Prater, Jr., V. R. Miller, and E. R. Cole, Jr. 1985. 13 pp. 2 figs. The Bureau of Mines conducted research to separate the F from byproduct Zn concentrates obtained from fluorspar (CaF_2) production, as part of the Bureau's effort to devise efficient, environmentally acceptable technology for recovering Zn from resources considered undesirable by Zn producers. Sulfuric acid (H_2SO_4) was found to be effective in F removal, while ammonium carbonate [$(NH_4)_2CO_3$] was not. The most important variables for reducing the necessary residence time were found to be temperature and agitation. Optimum leaching conditions were 75° C and 500 r/min for 2 h at 40 pct solids with 0.2 g acid per gram of concentrate, which resulted in a 98.3-pct F extraction. Zinc losses during F removal were in the range of 2 to 3.3 pct. Other elements such as Fe, Cd, Ca, and Cu were also partially dissolved. About 93 pct of the F was removed from the leach solution by neutralization and

precipitation with calcium hydroxide [$Ca(OH)_2$]. Additional treatment might be necessary to limit the buildup of soluble elements in the recycled leach solution.

RI 8958. Recovery of Zircon From Investment Casting Molds, by C. W. Smith and T. O. Llewellyn. 1985. 9 pp. 4 figs. The Bureau of Mines conducted physical and chemical beneficiation studies on three samples of waste investment casting molds to devise a method to liberate and recover zircon. Rod mill grinding, autogenous attrition grinding, and caustic leaching were liberation methods investigated. Flotation, gravity separation, and caustic leaching and sizing were recovery methods investigated. Flotation techniques produced concentrates containing up to 74.2 pct zircon with a zircon recovery of 53.4 pct. Gravity concentration produced concentrates containing up to 98.6 pct zircon; however, recovery of the zircon was only 57 pct. Caustic leaching and sizing produced concentrates containing up to 98 pct zircon with attendant recoveries of 81 pct. This report is based upon work done under a memorandum of agreement between the Bureau of Mines, U.S. Department of the Interior, and the University of Alabama.

RI 8959. Bulkheads and Drains for High Sandfill Stopes, by R. L. Soderberg and R. A. Busch. 1985. 14 pp. 11 figs. Large open stopes mined by vertical crater retreat or sublevel stoping are sometimes backfilled with uncemented sand tailings to support the stope walls and alleviate rock bursts. The failure of bulkheads in two different mines prompted a research project at the Bureau of Mines to prevent a recurrence of these failures. A series of laboratory tests with gravel drains and sand filters was conducted to measure the bulkhead pressures when adequate drainage was maintained. Results showed that bulkhead pressure was reduced to near zero while drains were in operation, as compared with full hydrostatic pressure when drains were blocked or drainage was restricted. A relatively simple, light, free-draining bulkhead was shown to be adequate.

RI 8960. Separation of Cast and Wrought Aluminum Alloys by Thermomechanical Processing, by R. D. Brown Jr., F. Ambrose, and D. Montagna. 1985. 12 pp. 4 figs. There are techniques for separating aluminum alloys from mixed scrap, but there are no efficient ways to separate wrought aluminum from cast aluminum. This Bureau of Mines report describes a novel technique for separating mixed aluminum alloy scrap into cast and wrought aluminum alloy fractions. The technique, which uses conventional heating, fragmentizing, and screening equipment, exploits differences in the mechanical properties of cast and wrought aluminum alloys at elevated temperatures. The cast alloys become brittle at high temperatures owing to intergranular melting of regions of eutectic composition. This melting begins to occur as the solidus temperature for each alloy is reached. Solidus temperatures for casting alloys generally range from 520° to 580° C, but are above 600° C for most wrought alloys. Thus, the casting alloys are easily fragmented while the wrought alloys remain ductile in the proper temperature range. Starting with a mixture containing approximately 80 pct cast and 20 pct wrought alloys, fractions of 100 pct cast and 98 pct wrought have been produced.

RI 8961. Electrolytic Reduction of Cobalt in Ammoniacal Leach Solutions, by Gary L. Hundley, R. E. Siemens, and Thomas A. Phillips. 1985. 20 pp. 6 figs. The Bureau of Mines has devised and demonstrated an ammoniacal sulfate leach process for recovering nickel and cobalt from low-grade domestic laterites. Solvent extraction of cobalt, one of the process steps, requires the reduction of hexammine complexes of Co^{3+} to Co^{2+} in an ammoniacal leach solution. Previously, reduction was accomplished using cobalt metal shot in a column. This report presents experimental results and an economic evaluation comparing two alternate techniques with the shot column: (1) an electrolytic reduction cell with an extended surface area cathode and (2) direct electrowinning from purified leach solution using a cell with a fluid bed cathode. The second alternative eliminates the conventional solvent extraction-electrowinning steps. The costs of the three methods, based on the requirements of a proposed commercial-sized plant, including all unit operations, were determined by the Bureau's process evaluation group. The operating costs for the shot column, $1.19/kg Co, and for electrolytic reduction, $1.20/kg, are essentially the same, but the cost of direct electrowinning, $3.77/kg Co, would eliminate this method as a practical alternative. The capital cost of approximately $14.4 million for reduction in a shot column is much higher than the approximately $4.4 million for electroreduction.

RI 8962. Volume Expansion of Acidproof Brick Exposed to 20 Wt Pct HCl at 90° C, by James P. Bennett and Timothy A. Clancy. 1985. 7 pp. 3 figs. In this Bureau of Mines study, portions of four acidproof bricks (two red shale and two fireclay) were exposed to 20 wt pct HCl at 90° C for periods of 30 days. Three different techniques were selected to determine volume expansion of these materials after exposure. Linear expansions ranging from about 0.02 to 0.12 pct were noted from Ta pin and dilatometer measurements. The use of strain gauges to measure expansions was not successful. The red shale and fireclay bricks with the lowest apparent porosities had the lowest expansions. Expansion data obtained by direct measurement of samples exposed for 30-day periods or by dilatometric measurement of autoclaved samples exposed for 2 h were comparable. This suggests the use of an accelerated autoclave exposure procedure for determining volume expansion effects of ceramic materials in acid environments. This report is based upon work done under a memorandum of agreement between the Bureau of Mines, U.S. Department of the Interior, and the University of Alabama.

RI 8963. Improved Shearer-Clearer System for Double-Drum Shearers on Longwall Faces, by Natesa I. Jayaraman, Robert A. Jankowski, and Fred N. Kissell. 1985. 11 pp. 11 figs. This report describes recent improvements the Bureau of Mines made in the design of its shearer-clearer water-spray system for dust control on longwall shearer faces. The improvements were based on findings from a field survey of six mines and laboratory test results. The report includes information on installation and use of the improved shearer-clearer system and describes a field installation and 3-week underground test of the system. The improved shearer clearer, like its predecessor, reduces dust concentrations in the shearer operator's walkway by splitting the airflow on the upwind side of the shearer and confining the dust cloud to the face side of the shearer. The improved shearer-clearer system utilizes more practical-mounting locations for the water sprays and requires less water consumption. In the underground test, the improved system maintained the clean-air split in the walkway up to 40 ft downstream from the shearer. To further improve dust suppression, cooling-water manifolds were relocated into the loading zone. The laboratory and underground tests showed that the improved shearer-clearer system and the techniques described can significantly reduce the respirable dust exposure of shearer operators from shearer-generated dust.

RI 8964. Influence of an Organic Polymer in Ball-Mill Grinding of Quartz, Dolomite, and Copper Ore, by A. R. Rule, A. J. Fergus, and C. B. Daellenbach. 1985. 12 pp. 15 figs. Research was done by the Bureau of Mines to determine the effect of a low-molecular-weight polymer on wet grinding of quartz, dolomite, and a copper ore. A 5-in ball mill equipped with a torque sensor for precise measurement of input energy was used for batch grinding tests. Grinding parameters were determined from size distribution data on the feed material and ground product. Zeta potential measurements were made to determine the effect of the polymer on the surface properties of the three materials, and a viscometer was used to measure the effect of the polymer on slurry viscosity. The addition of the polymer caused a sharp increase in the negative value of the

zeta potential for all three materials, indicating that pronounced adsorption was taking place. At a constant slurry percent solids, addition of the polymer caused a similar reduction in slurry viscosity for each material. For quartz, dolomite, and the copper ore, grinding efficiency, as measured by kilogram of product per kilowatt hour passing a given screen size, was not affected by the addition of the polymer. However, the lowering in slurry viscosity caused by addition of the polymer permits grinding at a higher slurry percent solids.

RI 8965. Influence of Chelating Reagents on Leaching of Copper Ore, by Larry A. Haas and Terry L. Hebble. 1985. 12 pp. 11 figs. A major problem encountered in dump leaching operations is the plugging of both the dump and the piping by precipitated iron compounds. Bureau of Mines research to obtain basic data on agitation leaching and dump leaching methods has shown that the addition of organic chelating reagents can significantly enhance the lixiviant permeability through the ore and the concentration of the metal values in the liquor. For example, the addition of 5 g/L citric acid (CA) to a conventional sulfuric acid lixiviant almost doubled the fluid flow rate through 5-cm-diameter laboratory columns containing copper ore. After 185 h of percolation leaching, the metal concentrations with (and without, in parentheses) CA were 1.7 (1.5) g/L Cu, 200 (70) ppm Mn, 160 (40) ppm Al, and 6 (3) ppm Co. The enhancement of metal concentrations with chelating reagents such as CA was confirmed by determining the solubility of several metal ions as functions of pH and chelating reagent concentration. When ferric ions became insoluble at pH values above 3, the concentrations of other ions also decreased. The addition of chelating reagents kept iron, as well as the other dissolved metals, in solution even at pH values as high as 5. Citric acid was a more effective chelating reagent than gluconic acid, oxalic acid, or sodium lignin sulfonate.

RI 8966. Using Solvent-Impregnated Carbon To Recover Copper From Oxidized Mill Tailings, by T. H. Jeffers and R. D. Groves. 1985. 7 pp. 1 fig. The Bureau of Mines conducted laboratory tests to devise a procedure for extracting copper from low-grade discarded mill tailings. A solid extractant consisting of an organic solvent extraction reagent adsorbed on granular activated carbon was investigated and proved to be satisfactory for extracting copper directly from leach pulps. When this material was used in a cyclic leaching, stripping, and electrowinning process, 95 pct of the acid-soluble copper was recovered from oxidized mill tailings. The weathered tailings contained 0.24 pct Cu (total) and 0.20 pct acid-soluble Cu. The copper was recovered as cathodes containing, in parts per million, 1.6 Pb, 3.6 Fe, 0.5 Sb, 1.5 Al, 1.9 Mn, and <1 Mg.

RI 8967. Recovery of Lithium From a Montmorillonite-Type Clay, by R. H. Lien. With an Appendix on Process Economics, by D. A. Kramer. 1985. 26 pp. 13 figs. The Bureau of Mines investigated a roast-leach process for recovering a marketable lithium product from a montmorillonite-type clay deposit located on the Nevada-Oregon border. The clay sample treated in the investigation contained 0.6 wt pct Li. The lithium recovery process consisted of several unit operations. The lithium silicate compounds in the clay were converted to Li_2SO_4 by roasting a pelletized mixture of clay, limestone, and gypsum at 900° C in a direct-gas-fired rotary roaster. Water-leaching the calcine at 40 pct solids extracted the Li_2SO_4. Lithium recovery from the leach solution involved concentrating the solution by evaporation, adding Na_2CO_3 to the concentrated solution to precipitate Li_2CO_3, and filtering the slurry to obtain the product. The product filtrate was recycled to the evaporator following a crystallization step. About 80 pct of the lithium in the clay was recovered as 99-pct-pure Li_2CO_3. Process operating costs were estimated at $2.12/lb Li_2CO_3 produced; the current Li_2CO_3 selling price is $1.48/lb. Raw materials accounted for 30 pct of the total operating cost.

RI 8968. Laboratory Tests of Spalling, Breaking, and Abrasion of Wear-Resistant Alloys Used in Mining and Mineral Processing, by R. Blickensderfer and J. H. Tylczak. 1985. 17 pp. 7 figs. Laboratory wear testing was conducted by the Bureau of Mines on a variety of typical wear-resistant alloys used in mining and mineral-processing equipment to establish their relative spalling and abrasion resistance. Test specimens in the form of 75-mm-diam balls were subjected to repeated impacts until they broke, spalled excessively, or received several hundred thousand impacts. Pin specimens removed from the balls were evaluated for high-load abrasive wear. The alloys included commercial forged steels, cast steels, manganese steels, and four types of white cast iron, with a range of heat treatments. The effects of hardness and microstructure on impact wear and abrasive wear are discussed. The data should help mine operators select the compositions and heat treatments that best suit service conditions.

RI 8969. Blast Vibration Measurements Near and On Structure Foundations, by David E. Siskind and Mark S. Stagg. 1985. 20 pp. 20 figs. Blasting near structures often involves measurement of vibrations for the assessment of damage potential. Several methods of measurement are in use worldwide, but there is no consensus as to which methods are technically sufficient and yet practical for all situations. This Bureau of Mines study examined five methods of vibration transducer placement to determine the best method for monitoring blasting vibrations. The methods examined were burial in soil next to the structure; attachment to the foundation at ground level, to the basement floor, or to a surface slab; and burial at a distance from the structure in undisturbed soil. Typical surface mine production blasts were used as vibration sources. With the exception of the basement floor measurements and some of the distant measurements, waveforms were similar and amplitudes were generally within 10 to 30 pct. The low-frequency part of the wave (5 to 10 Hz) was particularly uniform in measurements obtained by all five methods. Differences in peak values were mostly from the minor shifts in phase of the high-frequency components, which are of less significance to structural response and potential damage than the low-frequency waves (5 to 20 Hz). Shallow surface burial resulted in good signal detection and the least chance of mechanically induced error.

RI 8970. Recovery of Platinum, Palladium, and Gold From Stillwater Complex Flotation Concentrate by a Roasting-Leaching Procedure, by E. G. Baglin, J. M. Gomes, T. G. Carnahan, and J. M. Snider. 1985. 12 pp. 2 figs. The Bureau of Mines devised a procedure for selectively extracting platinum-group metals (PGM) and gold from Stillwater Complex flotation concentrate. The Stillwater Complex is the only major U.S. PGM resource. Development of a suitable extraction technique will contribute to its exploitation. The concentrate was roasted at 1,050° C to convert host base-metal sulfides to oxides and the PGM from sulfide minerals to their elemental states. The roasted concentrate was preleached with dilute sulfuric acid to remove easily soluble gangue minerals. After preleaching, the concentrate was slurried with 6*M* HCl and leached at ambient temperature and pressure with a strong oxidizing agent. Hydrogen peroxide, chlorine, sodium hypochlorite, nitric acid, and a persulfate salt were the oxidants investigated. The two-stage leaching scheme extracted up to 97 pct of the platinum, 92 pct of the palladium, and 99 pct of the gold from the roasted concentrate. The base metals were not solubilized and reported to the residue. No attempt was made to devise a procedure to recover the copper and nickel because they comprise less than 5 pct of the value of the concentrate. Viable techniques for recovering the precious metals from the pregnant solution were sulfide precipitation, cementation with nickel, or adsorption on activated carbon.

RI 8971. Measurement of Air Velocity in Mines, by Edward D. Thimons and Jeffrey L. Kohler. 1985. 26 pp. 5 figs.

This Bureau of Mines investigation addressed two primary issues of air velocity measurement in mines: the determination and use of correction factors, and the development of guidelines for the selection of a suitable site at which the measurements should be taken. Other facets of the investigation included a comparison of measurement methods and devices, and aircourse cross-sectional area measurement. The study consisted of theoretical, laboratory, and in-mine investigations. The measurement devices included in the experimental phase were vane anemometer, vortex shedding anemometer, a prototype thermoanemometer, smoke tube, and oil of wintergreen sprayer. The measurement methods included single-point centerline, timed-point traverse, continuous traverse for the anemometers, and various distances and cloud positions for the smoke tube and oil of wintergreen devices. The study resulted in guidelines for measurement site selection that are applicable to most in-mine situations. It also showed that the use of correction factors is problematic. There are many potential pitfalls and there are cogent arguments against using certain correction factors. However, generalized correction factors were developed that can be successfully applied in routine ventilation work, provided that their use is properly understood.

RI 8972. Field Measurement and Finite-Element Modeling of Circular and Rectangular Shaft Shapes in the Coeur d'Alene Mining District, Idaho, by Michael J. Beus and Samuel S. M. Chan. 1985. 23 pp. 24 figs. This Bureau of Mines report describes a field experiment involving the sinking of two test shafts to directly compare the deformational behavior of circular and rectangular shapes. Results show that the circular shape is less sensitive to geologic discontinuities and applied stress field. Also, the rectangular shape is subject to a variety of behavioral modes, including beam bending and buckling. Geologic discontinuities around circular and rectangular shapes influence displacement significantly. Simple, two-dimensional elastic finite-element modeling, simulating circular and rectangular shapes in a biaxial stress field, shows that the structural response of a shaft is largely controlled by geologic structure. Consideration of anisotropy may be required for realistic analysis of a deep shaft.

RI 8973. Electrochemical Determination of Thermodynamic Properties of MnF_2 and CoF_2, by Seth C. Schaefer. 1985. 8 pp. 3 figs. The Bureau of Mines investigated the standard Gibbs energies of formation, $\Delta Gf°$, for MnF_2 (manganese difluoride) and CoF_2 (cobalt difluoride). High-temperature galvanic cells employing CaF_2 (calcium difluoride) as the solid electrolyte were used to measure the open-circuit potentials for the cell reactions

$$Mn(c) + NiF_2(c) = MnF_2(c) + Ni(c)$$

and

$$Co(c) + NiF_2(c) = CoF_2(c) + Ni(c).$$

Combination of the standard Gibbs energy changes for these reactions with the standard Gibbs energy of formation of NiF_2 yielded the following:

$$\Delta Gf°(MnF_2) = (-203{,}008 + 30.96T) \pm 560 \text{ (745.7–1,078.3 K)}$$

and

$$\Delta Gf°(CoF_2) = (-159{,}090 + 32.13T) \pm 420 \text{ (769.5–1,026.8 K),}$$

where $\Delta Gf°$ is expressed in calories per mol (1 cal = 4.184 J) and T is expressed in kelvins. The standard enthalpies of formation $\Delta Hf°$, derived by the third-law method, are

$$\Delta Hf°_{298}(MnF_2) = -204{,}633 \pm 560 \text{ cal/mol}$$

and

$$\Delta Hf°_{298}(CoF_2) = -161{,}166 \pm 420 \text{ cal/mol.}$$

RI 8974. Laboratory Evaluation of Spray-Applied Rigid Urethane Foams, by Robert J. Timko, Mervin D. Marshall, and Edward D. Thimons. 1985. 18 pp. 14 figs. The objectives of this research were to examine and to document the laboratory performance of several brands of rigid urethane foam. Eighteen brands, produced by thirteen manufacturers, were examined. All testing was performed in a laboratory under controlled conditions. Preliminary laboratory tests included flame spread evaluations, flame penetration, ignition temperatures, air permeability, and adhesion. Having established arbitrary cutoff values, the original 18 candidates were narrowed to 8. More specialized tests followed. The effects of water immersion and dry aging on flame spread performance and other physical properties were then examined. This Bureau of Mines report was written to provide information for those concerned with using rigid urethane foam as a sealant. Its intent is to describe the various laboratory evaluations performed and to delineate the performance of each candidate. This report neither promotes nor discourages the use of rigid urethane foams. It presents results that will enable those responsible for using or enforcing the use of rigid urethane foams in underground mines to make informed decisions.

RI 8975. Determination of Alpha Quartz Particle Distribution in Respirable Coal Mine Dust Samples and Reference Standards, by C. W. Huggins, S. N. Johnson, J. M. Segreti, and J. G. Snyder. 1985. 7 pp. The objective of this Bureau of Mines research was to compare the size distribution of respirable quartz collected at coal mines with that of several reference standards used to quantify quartz in coal mine dust samples. Particle size measurements were made on 23 samples and 4 reference standards using a scanning electron microscope in the backscatter electron mode of operation, interfaced with an image analysis system. The Mine Safety and Health Administration provided the 23 respirable coal mine dust samples, which were collected at surface and underground coal mines in 7 States. The accumulated particle size measurements indicate three of the reference standards, minus 5-μm Min-U-Sil, minus 5-μm Supersil, and NBS 1878, would be preferred over the fourth, Silver Bond B, for quantitative quartz determinations in coal mine dusts by X-ray diffraction and infrared spectrometry.

RI 8976. Structural Design Considerations for Deep Mine Shafts. Analysis of Circular, Rectangular, and Elliptical Openings, by S. S. M. Chan and M. J. Beus. 1985. 37 pp. 30 figs. The Bureau of Mines has investigated the structural aspects of shafts and support systems using the finite-element technique. In situ field measurements in deep, vein-type metal mines show that rock stresses are often higher in the horizontal direction than the vertical, and unequal in the horizontal plane. These data and laboratory and field-determined physical properties were used as input to analytical studies. Various design and construction parameters were investigated to determine the effect on shaft stability. Rectangular shafts were studied in detail to determine the effects of applied stress ratio, shaft orientation and dimension, influence of interbedded quartzite and argillite, and rock fracturing. Various support systems were analyzed, including concrete lining, timber, and steel sets. Circular configurations were investigated to evaluate yield zones and liner thickness. Elliptical shafts and time effects were briefly evaluated to illustrate shape and time effects and demonstrate the methodology. It is shown that the magnitude, direction, and ratio of applied stress and rock mass anisotropy are keys to determining shaft stability. A realistic conceptual framework was developed with which to examine the rock and support interaction in deep mine shafts. Structural analysis techniques overcome some of the historical difficulties with shaft design by defining the field data requirements and structural sensitivity of various design and construction parameters.

RI 8977. Extraction of Chromium From Domestic Chromites by Alkali Fusion, by Gary L. Hundley, D. N. Nilsen, and R. E. Siemens. 1985. 14 pp. 7 figs. The Bureau of Mines has devised a procedure to recover chromium chemicals from

low-grade domestic chromites, which contain silicon and aluminum impurity levels that are too high to permit processing by present industrial processes. The Bureau procedure consists of reacting chromite with molten sodium hydroxide (NaOH) under oxidizing conditions to form sodium chromate (Na_2CrO_4). The reaction product is leached with methanol to remove the majority of the unreacted sodium hydroxide, then with water to remove the sodium chromate and the remainder of the sodium hydroxite. The sodium chromate product is recovered by evaporative crystallization from the aqueous solution. This report presents results of laboratory tests to determine the optimum fusion conditions and the chromium extractions obtained from several domestic chromite concentrates. These concentrates are from a variety of sources, including the Stillwater Complex in Montana, Kanuti River-Caribou Mountain, Red Bluff Bay, Kenai Peninsula, and Kodiak Island areas in Alaska, deposits in northern California, and a nickel-cobalt laterite from southern Oregon. All of these concentrates were successfully treated by the Bureau procedure. The best chromium extractions obtained for each of these materials ranged from 69.5 to 98.9 pct.

RI 8978. Pressure Leaching Alumina From Raw Kaolinitic Clay Using Hydrochloric Acid, by Dwight L. Sawyer, Jr., and Theodore L. Turner. 1985. 18 pp. 7 figs. The Bureau of Mines studied alumina extraction from uncalcined, kaolinitic clay at temperatures from 100° to 250° C using 20- or 27-wt-pct-HCl concentrations and with an acid-to-clay ratio of from 0.8 to 1.4 times stoichiometric. Autogenous digestion pressures ranged from atmospheric pressure to about 900 psia. Extraction of 96 pct of the alumina was obtained by HCl leaching at temperatures and leaching times that varied from 100° C for 120 h to 200° C for 15 min. Hydrochloric acid stoichiometry of the reaction $Al_2O_3{\cdot}2SiO_2{\cdot}2H_2O + 6HCl \rightarrow 2AlCl_3 + 2SiO_2 + 5H_2O$ was studied at different temperatures and leaching times in a 750-mL tetrafluoroethylene-polymer-lined autoclave. A combination of high temperature and 20 wt pct excess HCl promoted rapid and almost quantitative extraction of alumina (99 pct in some tests). Additional Bureau data obtained with 35-mL tantalum bombs and leaching tests with added fluoride are also provided. At high temperatures, the addition of fluoride did not result in a significant improvement over HCl alone and was deleterious to the filtering properties of the digest residue.

RI 8979. Computer Program To Relate Dust Generation to Drum-Type Coal Mining Machines, by Wallace W. Roepke, Bruce D. Hanson, and Robert L. Schmidt. 1985. 30 pp. 5 figs. The Bureau of Mines has developed an interactive computer program that enables mine operators and others to identify the effect of cutting system changes on relative dustiness at the face. The program, which simultaneously evaluates machine parameters, coal seam parameters, and operator-controllable parameters, was developed for use on any microcomputer using BASIC programming language. The program allows the user to change one or more of the cutting system parameters at a time to see how these changes affect relative dustiness. A complete program listing and flowchart are included along with operating instructions and sample outputs. An example showing how to use the program is also included.

RI 8980. High-Temperature Properties of Magnesia-Refractory Brick Treated With Oxide and Salt Solutions, by James P. Bennett. 1985. 11 pp. 5 figs. The Bureau of Mines investigated the effect of refractory oxide additions, introduced in soluble form, on the high-temperature properties of 90- and 98-pct-MgO brick. Brick samples were soaked in solutions containing Al, Ca, Cr, Co, Fe, Mg, Mn, Mo, Ni, Si, Sr, Sn, Ti, or Zr ions. Additions to 98-pct-MgO brick did not generally result in statistically significant property improvements. Statistically significant improvements were noted in hot modulus of rupture (MOR), slag resistance, and spalling resistance of the 90-pct-MgO brick for additions of Al, Mg, or Sn. High-temperature performance of treated 90-pct-MgO refractories was equal to or approached that of 98-pct-MgO brick. The marked improvements due to tin were obtained with additions of only 1.14 wt pct SnO_2. This report is based upon work done under a memorandum of agreement between the Bureau of Mines, U.S. Department of the Interior, and the University of Alabama.

RI 8981. Fracture Zone Dewatering To Control Ground Water Inflow in Underground Coal Mines, by Robert D. Schmidt. 1985. 84 pp. 27 figs. This Bureau of Mines investigation focuses on the identification and control of ground water inflow problems that occur in the active sections of underground Appalachian coal mines. A fracture inflow survey of eight underground mines was conducted. Three types of mine fracture intercepts were identified that are typical of wet section mining conditions. A mine in Preston County, WV, was selected as the site for a fracture zone dewatering experiment. Fracture trace analysis was used to site dewatering wells in a fracture valley setting ahead of mine development. The design, implementation, and results of this dewatering experiment are presented. A hydrology simulator was also developed and applied to the fracture zone flow problem at the field site. The model uses a semianalytic, boundary integral technique to simulate fracture zones as discrete regions of high average permeability. Comparisons are made between simulated and actual dewatering results. This investigation suggests that fracture zones are responsible for the sudden release of stored ground water, which often occurs as mining sections advance beneath fracture valley topography. It is concluded, therefore, that dewatering operations that are designed to intercept the component of ground water that is stored in fracture zones will be most effective in controlling infiltration to active mine sections.

RI 8982. Hot Acid Leaching of Vanadium From Western Phosphate Beneficiation Tailings, by D. G. Collins, J. H. Russell, and A. R. Rule. With an Economic Evaluation by Thomas A. Phillips. 1985. 18 pp. 9 figs. As part of its effort to develop ways to maximize resource recovery, the Bureau of Mines investigated the extraction of vanadium from Western phosphate beneficiation tailings with H_2SO_4 and/or H_3PO_4. Dissolution of the vanadium was accomplished by digesting a mixture of acid and a 50-pct-solids, tailings-water slurry. In the most effective method investigated, vanadium and phosphorus were leached by digesting the slurry at a constant boiling temperature (100°–110° C) in a stirred reactor. In batch tests, maximum vanadium dissolution was 95 pct. In continuous-circuit tests designed to further evaluate vanadium dissolution at constant boiling temperature in a continuously stirred reactor, vanadium dissolution ranged from 70 to 85 pct. An economic evaluation of the process demonstrated that H_2SO_4 consumption is the major cost factor. Based on the value of the vanadium product with no allowance for a phosphate product, the cost of producing the V_2O_5 is more than twice its value. The potential for profit would depend upon the value of the phosphate fertilizer produced from the impure H_3PO_4 remaining after vanadium extraction.

RI 8983. Conical Bit Rotation as a Function of Selected Cutting Parameters, by Carl F. Wingquist, Bruce D. Hanson, Wallace W. Roepke, and Theodore A. Myren. 1985. 18 pp. 8 figs. The Bureau of Mines is engaged in research to evaluate the effects of cutter bit wear at coal mine faces. This paper addresses one element of conical bit wear, bit rotation. A discussion on mounting configuration and bit forces and their effects on rotation is presented. The effects on rotation and bit forces of bit attack angle, cutting depth, and skew are determined for two types of conical bits during linear cutting of sandstone-inclusive rock. The results indicate that a 10° negative skew angle and 35° attack angle produce the maximum

rotation of 17.5° for each foot of cutting. Data on bit rotation and bit forces are presented in an appendix.

RI 8984. Plasma-Sprayed Iron-Base Wear-Resistant Coatings Containing Titanium Diboride, by J. F. McIlwain and L. A. Neumeier. 1985. 18 pp. 15 figs. Cobalt-base hardfacing alloys used for wear resistance consist almost entirely of metals largely imported into the United States. As part of an overall research program to help alleviate this foreign dependency, the Bureau of Mines has been investigating an iron-base alloy system as a potential replacement for cobalt-base alloys for some uses. To ascertain the melting ranges, thermal analyses were made of cast heats of alloys containing, in weight percent, 59–61 Fe, 16–19 Cr, 8–9 Ni, 1 Mn, 1 W, 1 Mo, 0.5 Cb, 0.6 Si, 0.3 C, and 0–12 stoichiometric TiB_2. Powder alloys within this range of composition, prepared by mechanical alloying, were sized and applied to mild steel test coupons by nontransferred-arc plasma spraying. The resulting thin coatings were >95 pct dense, with bond strengths of 35 MPa and hardness of 400 to 840 diamond pyramid hardness. Abrasive and adhesive wear test data were compared to those of a plasma-sprayed cobalt-base alloy. A range of boride contents resulting in most promising properties was determined for further research.

RI 8985. Methane Control on Longwalls With Cross-Measure Boreholes (Lower Kittanning Coalbed), by F. Garcia and J. Cervik. 1985. 17 pp. 19 figs. The cross-measure borehole technique has been shown by the Bureau of Mines to be an effective method of controlling methane liberated by fracturing the roof strata in longwall gobs where overburden is less than 750 ft (229 m). Boreholes are drilled into roof strata before mining operations affect the roof strata. Longwall mining fractures the roof strata and releases methane from source beds. Surface exhausters or vacuum pumps are used to draw the gas to the surface through an underground pipeline and vertical exhaust hole. The captured methane is thus prevented from entering the mine's ventilation system. About 71 pct of the methane produced by longwall mining in the Lower Kittanning Coalbed was captured by the cross-measure boreholes. Borehole spacing is an important factor affecting the performance of the technique. Interference tests and measurements of methane flows in return air indicate that borehole spacing in the Lower Kittanning Coalbed should be limited to about 200 ft (61 m) except on the first 600 ft (183 m) of the longwall where spacing should be reduced to about 100 ft (30 m) to capture the large quantities of methane released when the first large roof fall occurs. Comparisons between measured and calculated gas pressure differentials on boreholes indicate borehole length can be reduced from 280 to 140 ft (85 to 43 m), which reduces drilling costs significantly. Additional experimentation is necessary to verify the calculations.

RI 8986. Measuring Formation Pressures and the Degree of Gas Drainage in a Large Coalbed Gas Drainage Field, by David C. Oyler and Paul B. Stubbs. 1985. 15 pp. 8 figs. The Bureau of Mines and United States Steel Corp. are conducting a joint project to monitor formation pressures at a large (23-well) coalbed gas drainage field near Oak Grove, AL. Three monitor holes were drilled in late 1981, and pressure monitoring began in December 1981. The Bureau of Mines direct method was used to obtain gas content data from cores taken in the monitor holes. Comparison of the 1981 gas content data from the monitor holes with initial gas content values obtained from the production wells in 1977 indicates a 50-pct reduction in adsorbed gas content inside the pattern and a 29-pct reduction at one point 500 ft outside the pattern. The combination of pressure and gas content data has also allowed an in situ isotherm curve, relating the formation pressure to adsorbed gas content, to be developed for the area of the production wells. From the current rate of pressure decline (1 lbf/in² per month), the observed changes in gas content, and the isotherm curve, it appears that most of the early gas production came from within the pattern, but since 1981 (and possibly earlier) most of the gas produced has been migrating to the wells from outside the pattern area.

RI 8987. Reducing Hazards in Underground Coal Mines Through the Recognition and Delineation of Coalbed Discontinuities Caused by Ancient Channel Processes, by Carla A. Kertis. 1985. 23 pp. 19 figs. Because coalbed discontinuities often pose serious economic and safety problems in underground coal mines, criteria were documented for the recognition and prediction of discontinuities in advance of mining. Pennsylvanian strata in Indiana and Armstrong Counties, PA, were deposited as part of fluvio-deltaic complexes with channel-phase sandstones as the predominant type of coalbed discontinuity. Coalbed isopach maps constructed for this study delineated numerous want areas (areas of no coal) with elongate to linear geometries. A comparison of coalbed isopach and corresponding sandstone isolith maps of the study area revealed many examples of a thick-sandstone, thin-subjacent-coalbed relationship. Nearly 60 pct of the want areas in the study area were found to lie subjacent to thick (>20 ft [6 m]) sandstone accumulations. In addition to erosion of the coalbed, channels may contribute to coalbed splitting, coalbed thinning over paleotopographic highs, abnormal coalbed thicknesses, and deterioration of coal quality. If these features are considered, then approximately 80 pct of all interruptions in the economic coalbeds in this area result from channel activity. By using the criteria developed in this study and described in this Bureau of Mines report, the occurrence of coalbed discontinuities may be predicted and anticipated in advance of mining.

RI 8988. Electrical Ignition Energies and Thermal Autoignition Temperatures for Evaluating Explosion Hazards of Dusts, by Martin Hertzberg, Ronald S. Conti, and Kenneth L. Cashdollar. 1985. 41 pp. 27 figs. The Bureau of Mines measured the energy requirements for the spark ignition in air of Pittsburgh seam bituminous coal dust, lycopodium spores, and polyethylene powder with a 1.2-L furnace and 8-L and 20-L chambers. Thermal autoignition temperatures of the same dusts were measured in the 1.2-L furnace. Electrical ignition requirements are given in terms of both effective spark gap energies, ϵ_{eff}, and stored circuit energies, $\frac{1}{2} CE^2$. The measured order of electrical ignitability for the three dusts is consistent with the data of other researchers; however, the absolute values are systematically higher, probably because of higher flow and turbulence levels in the chambers used and lower electrical efficiency in the circuit used here. The temperature dependence of the lean limit of flammability for lycopodium was measured with the 1.2-L system, and those measurements confirm the applicability of the modified Burgess-Wheeler law to a dust. Owing to experimental complexities, the minimum ignition energies for dusts may not reflect intrinsic flammability behavior. However, some valuable information may be obtained from the relative ignition energies of various dusts at ambient and elevated temperatures. In addition, the concept of minimum electrical ignition energies for homogeneous gas mixtures is reevaluated theoretically.

RI 8989. Electrostatic Sensitivity, Strength, and No-Fire Current of Short-Delay Detonators, by T. S. Bajpayee, R. J. Mainiero, and J. E. Hay. 1985. 9 pp. 3 figs. The Bureau of Mines evaluated short-delay coal mine detonators manufactured by three domestic companies for electrostatic sensitivity, strength, and no-fire current level. Electrostatic sensitivity was studied in pin-to-pin and pin-to-case modes employing 10-kV potential. Strength of detonation was measured in the Bureau's underwater test facility. No-fire current was measured using a constant-current power supply unit. Test procedures and experimental data are included.

RI 8990. Procedures for Determining Support of Excavations in Highly Yielding Ground, by J. D. Dixon, M. A. Mahtab, and T. W. Smelser. 1985. 19 pp. 15 figs. This Bureau of Mines report describes the results of an investigation for developing and applying procedures for stabilizing excavations openings in highly yielding ground. The approach developed in this report involves nonlinear modeling of the progressive relaxation of the zones of rock mass around the excavations opening where Coulomb criterion of failure is exceeded.

Stresses are calculated by using a computer code; Coulomb-failure condition is examined for both intact rock and joints (using strength parameters ϕ and c). The rock mass in the failed zones is relaxed by reducing the Young's modulus of the rock based on an empirical formulation that is a function of the shape of the opening and the extent of the failed zone. In addition, the material in the failed zone is assigned reduced strength parameters ϕ' and c'. The limiting (or convergent) relaxed zone is obtained through an iterative process by manually changing the rock modulus and the strength parameters between iterations. Support pressures are computed by applying forces normal to the excavation surface. The approach is applied to the analysis of stability and support requirements for an entry in a longwall coal mine.

RI 8991. Solubilities of Chloride Salts of Alkali and Alkaline-Earth Metals When Sparged With Hydrogen Chloride, by E. G. Noble, D. E. Shanks, and D. J. Bauer. 1985. 17 pp. 13 figs. The effects of hydrogen chloride (HCl) concentration and temperature on the solubility and hydration state of the alkali chlorides LiCl, NaCl, and KCl and the alkaline-earth chlorides, $MgCl_2$, and $CaCl_2$ were investigated by the Bureau of Mines. Saturated aqueous solutions of the chlorides were sparged with HCl gas at temperatures of 20°, 40°, and 60° C. Increased HCl concentration caused decreased salt solubility because of the common ion effect. Aqueous solubilities for the chlorides of Ca, Li, Mg, K, and Na ranged from 42.6, 45.2, 35.2, 25.5, and 26.1 pct, respectively, at 20° C to 56.9, 49.4, 37.6, 31.0, and 27.0 pct, respectively, at 60° C. In solutions sparged to HCl saturation, solubilities for these chlorides ranged from 22.4, 26.5, 3.0, 1.3, and 0.05 pct, respectively, at 20° C to 53.2, 48.8, 28.3, 2.6, and 0.8 pct, respectively, at 60° C. The solubilities of LiCl and $CaCl_2$ in HCl solution were high because HCl solubility is low in these solutions. The chloride salts of Ca, Li, and Mg formed hydrates, which depended on temperature and HCl concentration. Monohydrates for LiCl, tetrahydrates and hexahydrates for $MgCl_2$, and dihydrates, tetrahydrates, and hexahydrates for $CaCl_2$ were obtained.

RI 8992. Exhaust Ventilation of Deep Cuts Using a Continuous-Mining Machine, by Jon C. Volkwein, S. K. Ruggieri, C. McGlothlin, and Fred N. Kissell. 1985. 16 pp. 15 figs. The Bureau of Mines, Foster-Miller, Inc., and Beaver Creek Coal Co. have evaluated the ability of a new system to ventilate a 40-ft-deep cut. A remote-control continuous-mining machine, in a 7-ft-thick seam, with exhausting brattice was fitted with an improved sprayfan system plus additional forward and reverse pointing sprays. Static and dynamic tests using tracer gas were conducted in a full-scale model and underground to measure the effectiveness of exhaust face ventilation for various deep-cutting mine and spray configurations. When compared to a 10-ft primary ventilation brattice, the extended-cut spray system consistently provided better face ventilation at all configurations up to and including a 40-ft brattice setback. The system also provided good dust protection and visibility for the machine operator. Another safety advantage is the elimination of the need to set temporary roof supports to maintain the ventilation brattice.

RI 8993. Effects of Water on Coal Cutting Forces and Primary Dust Distribution, by Wallace W. Roepke and Theodore A. Myren. 1985. 14 pp. 5 figs. Research to evaluate the lubricity effects achieved by spraying water on the cutting bit of a mining machine or spraying water on the coal during cutting has shown that neither practice affects cutting forces, as had been believed. However, when water was supplied to the cutting zone axially through the bit at 3,000 to 5,000 psi pressure, tangential cutting forces were reduced an average of 30 pct at a 1-in depth of cut while normal bit forces were reduced an average of 65 pct. Lower normal forces mean reduced bit wear, faster advance with greater depth of cut, and fewer coal fines.

RI 8994. Thermodynamic Properties of $CoS_{0.89}$, $CoS_{1.33}$, and CoS_2, by J. M. Stuve, R. P. Beyer, and R. R. Brown. 1985. 11 pp. 1 fig. In this Bureau of Mines investigation, the low-temperature heat capacities of polycrystalline phases corresponding to the sulfide compounds $CoS_{0.89}$, $CoS_{1.33}$, and CoS_2 were measured by adiabatic calorimetry within the nominal temperature range 5 to 300 K. The derived absolute entropies S°_{298} were 10.36 ± 0.02, 12.96 ± 0.03, and 16.31 ± 0.03 cal·mol^{-1}·K^{-1}, respectively, assuming third-law behavior. In addition, the standard enthalpy of formation ΔHf°_{298} of $CoS_{0.89}$ was determined by bromine solution calorimetry. The derived value of ΔHf°_{298} was -50.63 ± 2.1 kcal·mol^{-1}, based on the ΔHf°_{298} of CoO. This result is considerably more negative than previously published formation values based on high-temperature gas equilibrium studies.

RI 8995. Recovery of Metal Values From Copper Converter Flue Dust, by F. J. Palumbo, R. L. Marsh, and R. C. Gabler, Jr. 1985. 10 pp. 5 figs. Effective recycling or disposal of flue dusts is a continuing problem for copper, brass, and bronze smelters. Over 300,000 short tons (st) of dust is generated annually by U.S. secondary copper, brass, and bronze smelters. The Bureau of Mines has developed an alkaline leach method for recovering metal values from copper converter flue dust containing zinc, tin, lead, and copper. The dust was leached with a hot solution of ammonium chloride and ammonium hydroxide to solubilize ZnO. All of the tin (as SnO_2) and the metallic copper, lead, and zinc, as well as possible insoluble compounds of each, report to the residue. Dissolved copper and lead salts are removed from the leachate by cementation with granular zinc. Zinc oxide is precipitated by diluting the leachate with water. The tin-rich (9.8 pct) residue has a ready market. The cement product is recyclable to the smelting operation. The ZnO is at least 97 pct pure and has potential marketability.

RI 8996. The Effects of a Retreating Longwall on a Three-Entry Gate Road System, by Richard A. Allwes, Jeffrey M. Listak, Gregory J. Chekan, and Daniel R. Babich. 1985. 19 pp. 18 figs. The Bureau of Mines conducted an in-mine case study on two consecutive three-entry gate road systems designed in accordance with the stiff-yield pillar design concept. This Bureau study was conducted in order to further develop technology that will improve the health and safety aspects of longwall mining. Support loading and strata activity were monitored to determine the effects of retreat longwall mining on the gate road ground control system. Analyses of pillar stress and roof bolt loading histories revealed that headgate roof support elements experienced cumulative loading throughout the life of the longwall panel. Tailgate pillar loadings had significantly different histories from the loading histories of the headgate pillars. Stress relief occurred in the tailgate pillars following the passage of the longwall face. Moreover, the stiff-yield pillar design, with the abutment pillar placed adjacent to the working panel when part of the headgate system, provided effective ground control in that no major roof falls or roof problems were experienced in the headgate or tailgate systems during longwall mining.

RI 8997. Utilization of Simulated Coal Gases for Reducing Iron Oxide Pellets, by Larry A. Haas, John C. Nigro, and Robert K. Zahl. 1985. 14 pp. 12 figs. The Bureau of Mines is investigating the use of complex gas mixtures, such as would be produced by coal gasification, for reducing iron oxide pellets. A semiempirical model was developed to predict a priori the reduction rate of an iron oxide pellet in a laboratory tube furnace with simulated coal gases at a total pressure of 1 atm. The model uses partial pressures of H_2, CO, CO_2, CH_4 (methane), water vapor, and a temperature-dependent term to predict the rate of reaction. The reduction rate (weight loss per unit of time) was determined with a thermogravimetric apparatus in the temperature range of 800° to 1,100° C. The ranking of the reductants, in order of decreasing reducing potential, is H_2, CO, and CH_4 at temperatures between 800° and 1,000° C; however, CH_4 became a better reductant than CO at

1,100° C. Water vapor did not decrease the reduction rate as much as did CO_2. Carbon deposition was observed at temperatures below 1,000° C with gas mixtures with high CO and low H_2 concentrations. With low-Btu gas at 900° C, over 90 pct of the iron oxide was reduced to iron in less than 3 h. This compares with a reduction time of 1.5 h with medium-Btu gas and 1 h with reformed natural gases.

RI 8998. Fiber Dimensions of Crocidolites From Western Australia, Bolivia, and the Cape and Transvaal Provinces of South Africa, by Kim B. Shedd. 1985. 33 pp. 5 figs. The Bureau of Mines measured fiber dimensions on crocidolites (riebeckite-asbestos and magnesioriebeckite-asbestos) from the world's four crocidolite mining regions. The objective of the study was to determine whether there are measurable morphological differences between crocidolite fibers that correlate with the high reported incidence of mesothelioma in miners and mill employees in the Cape Province of South Africa and Western Australia, as compared with little or no reported incidence of this cancer in the Transvaal Province of South Africa or Bolivia. Fiber dimensions measured with the scanning transmission electron microscope showed that crocidolites from Western Australia and the Cape Province have more thin fibers than crocidolites from Bolivia and the Transvaal Province.

RI 8999. Hydrochloric Acid-Oxygen Leaching and Metal Recovery From a Copper-Nickel Bulk Sulfide Concentrate, by G. A. Smyres, K. P. V. Lei, and T. G. Carnahan. 1985. 17 pp. 10 figs. The Bureau of Mines investigated a HCl-O_2 leaching procedure to recover Cu, Ni, and Co from a low-grade bulk sulfide flotation concentrate prepared from the Duluth gabbro complex. Since the Duluth gabbro complex is the largest known and unexploited Ni resource in the United States, the development of options for extracting the metal values from the flotation concentrate of this domestic resource is necessary. Conditions were determined for producing a pregnant solution low in Fe to facilitate recovery of the metal values. Leaching experiments were conducted at 15 pct solids, 100° to 120° C, 0.2 to 0.3 g HCl per gram concentrate in a 50-gal reactor pressurized to 50 psig with O_2. Base metal extractions from the concentrate were, in percent, 90 to 92 Cu, 99 Ni, 97 to 99 Co, and 0.1 Fe. Precious metals extractions were erratic and unpredictable; at best their extractions were, in percent, 55 Au, 90 Ag, 40 Pt, and 45 Pd. The reaction time at 120° C was 0.5 h. The use of compressed air instead of O_2 as the oxidant was also investigated. Solvent extraction using LIX 622 was used to remove Cu from the pregnant solution. Cementation on Cu was tested for precious metals recovery, while sulfide precipitation was used to produce a Ni-Co product. A conceptual flowsheet for treating the Duluth gabbro concentrate is proposed.

RI 9000. Recent Developments in Spray Cooling of Deep Mines, by Edward D. Thimons, John F. McCoy, and John R. Marks. 1986. 10 pp. 7 figs. This report describes in detail four water spray coolers designed for cooling deep underground mines and discusses the performance of three of them in deep-mine field tests. The four spray coolers were designed and built as part of a Bureau of Mines program to investigate direct-contact (warm air to cool water) spray cooling systems. A single-stage cooling unit was tested in a New Mexico uranium mine, and a two-stage cooler and a three-stage cooler were tested in a South Dakota gold mine. To date, all three coolers have performed well under in-mine conditions and have required only minimal maintenance. Tests on a fourth cooler, a three-stage unit, are under way, but have not been completed.

RI 9001. Calamity Hollow Mine Fire Project. (In Five Parts.) 5. Excavation and Evaluation of the Fire Zone, by K. E. Soroka, R. F. Chaiken, L. E. Dalverny, and E. F. Divers. 1986. 25 pp. 26 figs. The Bureau of Mines has demonstrated a new technological approach that utilizes controlled in situ combustion to bring fires in abandoned coal mines and waste banks under control. This new technology involves the accelerated combustion of "waste" coals in situ under controlled ventilation conditions, which allows for total management of the combustion products, including utilization of the heat produced. This concept could significantly lower the costs for reducing the environmental and public safety hazards associated with waste coal fires and lead to the conversion of a coal waste to a coal resource. The Burnout Control technique was demonstrated at the site of an abandoned coal mine fire in Allegheny County, PA. Following a 4-month continuous operation of Burnout Control, a novel water injection-fume exhaustion technique was utilized to "rapidly" cool the underground heated zones before the 1½-acre fire site was excavated and backfilled. Observations and interpretations made during excavation relative to fire propagation and quench efficiency are described. Pillar and entry layout, burn regions along entries, roof, and pillars, and degrees of coking of pillars were observed. Borehole temperatures greater than 200° C (392° F) correlated with observed burned and/or coked regions. Water injection-fume exhaustion lowered strata temperature to an average of 160° C (320° F) resulting in minimal gas outbursts and only two local instances of flaming combustion during excavation. The excavation analysis supports the effectiveness of both Burnout Control and water injection-fume exhaustion techniques for control of fires in abandoned coal mines.

RI 9002. Producing Chlorination-Grade Feedstock From Domestic Ilmenite—Laboratory and Pilot Plant Studies, by G. W. Elger, J. B. Wright, J. E. Tress, H. E. Bell, and R. R. Jordan. 1986. 24 pp. 10 figs. The Bureau of Mines investigated the conversion, at both laboratory and pilot plant scale, of a low-grade ilmenite to chlorination-grade feedstock that could substitute for imported rutile used to produce titanium tetrachloride. The concentrate was derived from the Tahawus, NY, lode deposit of ilmenite-magnetite in rock that contains anorthosite and gabbro. Charges of the ilmenite concentrate, containing 46.6 wt pct TiO_2 blended with soda ash, were carbothermically reduced in an electric arc furnace, which separated most of the iron and left a high-titanium slag. However, the slag contained Ca, Mg, and Mn constituents that rendered the material unsuitable for continuous chlorination by causing plugging problems. After being ground and pelletized, the slag was reacted with SO_2 and air at 700° to 900° C, which selectively converted the harmful impurities to soluble compounds that were removed in a subsequent water or dilute HCl leach. In laboratory tests, the combined levels of harmful impurities were decreased from 5 to as low as 0.5 wt pct in leached slags. In pilot plant tests, leached slags sulfated at a rate of 10 lb/h averaged 85.5 wt pct TiO_2 with pertinent impurity levels averaging 1.86 wt pct. The leached slag was successfully chlorinated in a laboratory fluidized-bed reactor at 950° C to extract titanium as $TiCl_4$.

RI 9003. Large-Scale Laboratory Drag Cutter Experiments in Hard Rock, by R. J. Morrell, D. A. Larson, and D. E. Swanson. 1986. 18 pp. 8 figs. The Bureau of Mines conducted a series of laboratory experiments to test a cutting technique for hard rock using large-scale drag cutters. Cutting experiments were performed on rocks ranging in compressive strength from 10,000 to 27,000 lb/in^2, using large drag cutters from 3 to 6 in in width. The tests were conducted on a special test apparatus, called a ripper tester, which made a curvilinear cut across the rock sample while measuring the cutting force acting on the drag cutter. The cutting method that evolved from these experiments is called ripper cutting, and its energy efficiency appears superior to all other large-scale mechanical fragmentation techniques. In addition, the method created very little dust, and the wear on the bits was negligible. A fragmentation system based on ripper cutting was then devised, and a large-scale test device was fabricated to allow full-scale laboratory testing of the system. The results of these tests will be published in future Bureau reports.

RI 9004. Evaluation of a Ground Penetrating Radar System for Detecting Subsurface Anomalies, by Ronald H.

Church and William E. Webb. 1986. 21 pp. 18 figs. The Bureau of Mines tested a ground penetrating radar (GPR) system in the central Florida phosphate district to determine the feasibility of utilizing GPR technology for subsurface cavity detection. The test area is located in karst topography where sinkhole development is prevalent. State regulations require subsurface drilling of damsites to identify underground anomalies; however, this method is not totally accurate in locating subsurface cavities that could lead to sinkhole development. An electromagnetic method of identifying anomalous subsurface conditions could reduce or eliminate the possibility of dam failure due to sinkhole development. The Bureau devised a GPR system that successfully penetrated over 50 ft of overburden and gave recognizable radar return signals characteristic of a rock-cavity interface. This research at the Tuscaloosa Research Center was carried out under agreements between the Bureau of Mines, U.S. Department of the Interior, and the University of Alabama and the Florida Institute of Phosphate Research.

RI 9005. Microwave Drying of Fine Coal, by David P. Lindroth. 1986. 12 pp. 5 figs. The objective of this research by the Bureau of Mines was to determine the technical feasibility and associated pilot data for drying minus ¼-in coal with microwave energy at a frequency of 2.45 GHz. The drying data were obtained experimentally on three coal types: bituminous, subbituminous, and lignite. The experiments were performed with a custom-designed conveyorized microwave oven having a continuous power capability of 12 kW. Drying efficiencies near the theoretical maximum of 1.54 kg of water per kilowatt hour of energy input were achieved for two coals and two sizes; overall drying efficiencies averaged 77 pct.

RI 9006. Performance Characteristics of Large-Capacity Face Ventilation Systems for Oil Shale Mining, by Edward D. Thimons, Carl E. Brechtel, Marv E. Adams, and Joseph F. T. Agapito. 1986. 15 pp. 11 figs. The performance of two large-capacity ventilation systems was compared through tests conducted in a large dead-end heading at a pilot oil shale mine in Colorado. Sulfur hexafluoride (SF_6) tracer gas was used to measure the performance of the two systems: a freestanding jet fan and a reversible fan with rigid duct. The tracer gas was used to simulate the production of mine air pollutants, including blasting pollutants, hot diesel emissions, free methane from surrounding strata, and methane desorbing from muck piles. The test room was 55 ft wide, 30 ft high, and 320 ft long. The performance of the two fans was similar, but the jet fan used less power. The tests showed that either system could provide effective ventilation during oil shale mining.

RI 9007. Investigation of Similarities Between Methane Drainage Potential of Utah's Sunnyside Coalbed and Eastern U.S. Coalbeds, by Gregory M. Molinda, Thomas M. Kohler, and Gerald L. Finfinger. 1986. 10 pp. 7 figs. The Bureau of Mines has completed an investigation of the effectiveness of methane drainage in the Lower Sunnyside Coalbed at Kaiser Steel Corp.'s Sunnyside No. 1 Mine in Utah. Most of the previous attempts to drain methane gas using long horizontal holes were conducted in the Eastern Coal Province. From the high degree of success realized in these efforts and the large body of knowledge gained from associated research, it seemed natural to extend the technology to western coalfields. Previous work had indicated that properties affecting gas drainage were variable in the Sunnyside Coalbed. In an attempt to characterize these properties, four degasification holes were drilled from the outside entries of an advancing section. The holes were drilled to lengths of 780, 1,680, 1,315, and 1,047 ft and produced initial flow rates of 50,000, 180,000, 340,000, and 240,000 ft^3/d, respectively. A total of over 300 million ft^3 of commercial-quality gas has been removed from the Sunnyside Coalbed. The four holes have reduced face emissions by 78 pct.

RI 9008. Delayed Blasting Tests To Improve Highwall Stability—A Final Report, by Virgil J. Stachura, Larry R. Fletcher, and Michael A. Peltier. 1986. 12 pp. 14 figs. The Bureau of Mines conducted a series of delayed blasting experiments at a Barbour County, WV, contour coal mine that resulted in smoother highwalls. The highwalls were smoother owing to reduced overbreak (excessive rock breakage beyond the excavation limit) and were inherently safer owing to reduced likelihood of rockfall. The experiments were directed at reducing overbreak without special drilling or significant additional cost. Reduced overbreak was accomplished by increasing the highwall hole delays, which changed the effective delay pattern geometry and the direction of burden movement. Three test combinations of blast delays were used in the highwall holes: (1) 50 ms longer than the nominal design, (2) 100 ms longer than nominal, and (3) 50 and 100 ms longer in the two rows of holes nearest the highwall. The mine's nominal blast design was a flat V pattern with 17-ms surface delays between holes, 42-ms surface delays between rows, and 200-ms in-the-hole delays. All three test designs produced highwall improvements, compared with results using the nominal design, with occasional exceptions because of geologic variations. Observations and terrestrial photogrammetry showed that the delay changes produced generally smoother vertical profiles with less loose material.

RI 9009. Geotechnology in Slate Quarry Operations, by Noel N. Moebs, Gary P. Sames, and Thomas E. Marshall. 1986. 38 pp. 37 figs. This report summarizes a Bureau of Mines study on the use of geotechnology to identify and reduce ground control hazards at slate quarry operations in eastern Pennsylvania. The major ground control hazard is falling rock, attributed to weathered bedding plane faults, which weaken quarry highwalls. It was demonstrated that these faults can be detected outside of the quarry perimeter using surface resistivity measurements. Falls of ice from quarry highwalls constitute a second major hazard, which requires water diversion as a basic control method. In situ stresses seemingly cause only minor problems in slate extraction although they could interact with developed stresses and lead to failure of barriers between quarries. Pull tests showed that rockbolts anchor firmly in slate and should prove effective in securing loose rock.

RI 9010. An Improved Analyzer for Determining Helium-4 in Parts-Per-Billion Range, by Charles A. Seitz and Philip W. Holland. 1986. 7 pp. 2 figs. The Bureau of Mines has modified its parts-per-billion helium-4 analyzer to improve the analytical capabilities of the instrument. The modifications resulted in the following improvements: (1) The analytical precision of the instrument for 10 consecutive analyses was improved to ± 1 ppb at the 5,000-ppb helium-4 level, (2) the helium-4 sensitivity was increased almost tenfold, and (3) the minimum detectable limit for helium-4 was improved to 0.5 ppb. The modifications made to improve the instrument included replacing the ion-source control circuit with a direct-current solid-state design, controlling the temperature of the ion source, stabilizing and reducing the pumping rate of the vacuum system, and optimizing peak integration.

RI 9011. Corrosion Resistance of Selected Ceramic Materials to Sulfuric Acid, by James P. Bennett. 1986. 11 pp. 3 figs. The Bureau of Mines is investigating the acid resistance of ceramic materials to identify construction materials for emerging technology in chemical and metallurgical processes. Eight commercial ceramic materials were evaluated: two red shale, two fireclay, one silicon carbide, one silica, one carbon, and one high-alumina. Samples were exposed to 10 wt pct H_2SO_4 at 50° C and 10, 30, 50, 70, and 90 wt pct H_2SO_4 at 90° C for time periods of 110 days. Statistically significant changes in cold crushing strength were observed in the silicon carbide and carbon materials. Weight changes and the leach rate of Al, Ca, Fe, K, Mg, Na, Si, and Ti were also monitored. The most severe corrosion conditions were at 90° C and 30 to 50 wt pct H_2SO_4 for the acidproof and at 10 wt pct H_2SO_4 for the acid-resistant materials. The silica and the high-alumina materials were the

most acid-resistant, followed by the higher density red shale and fire clay. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

RI 9012. High-Purity, Fine-Particle Boron Nitride Powder Synthesis at -75° to 750° C, by Rustu S. Kalyoncu. 1986. 9 pp. 3 figs. Nonoxide ceramics with improved high-temperature properties could substitute for high-temperature alloys and reduce the Nation's dependence on imports of Cr, Co, Ni, and Mn. To meet this objective, the Bureau of Mines conducted research to synthesize ultrafine reactive boron nitride (BN) powders. BN powders were prepared at temperatures ranging from -75° to 750° C. Low-temperature reactions (-75° to 200° C) between boron halides and N compounds led to formation of elemento-organic compounds that were thermally decomposed to ultrafine (approximately 100- to 150-Å particle size) reactive BN powders. BN powders were also prepared through the reaction of a low-melting inorganic B compound (boric acid, borax) with an organic N compound (carbimide and thiocarbimide) in N_2 and/or ammonia (NH_3) atmospheres at temperatures between 500° and 750° C. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

RI 9013. Comparisons Between Cross-Measure Boreholes and Surface Gob Holes, by T. W. Goodman and J. Cervik. 1986. 14 pp. 21 figs. The Bureau of Mines conducted studies to compare the effectiveness of the cross-measure borehole system with that of surface gob holes on two successively mined retreating longwalls in the Lower Kittanning Coalbed. Only the cross-measure system was in operation on panel A; on panel B, both systems were in operation. In addition, the cross-measure boreholes on panel B were drilled parallel to the face, whereas those on panel A were drilled at a 45° angle with respect to the longwall axis. The studies show that the cross-measure system captured 71 pct of the methane generated by longwall mining on panel A. On panel B, the surface gob hole dominated over the cross-measure system for about 700 ft (213 m) after it was intercepted. Beyond that point, the cross-measure system dominated. About 93 pct of the methane generated on panel B was captured by the two systems. Cross-measure boreholes that were drilled parallel to the face were as effective as boreholes oriented 45° with respect to the longwall axis. In addition, they were shorter and required less drilling time. Comparison between observed gas pressure differentials in boreholes and calculated values indicate that boreholes can be shortened further to 140 ft (43 m). Additional studies are needed to verify these calculations.

RI 9014. Seasonal Variation in Respirable Dust Concentration in U.S. Coal Mines, by Nevin Greninger, Welby Courtney, and Edward Divers. 1986. 7 pp. 4 figs. The Bureau of Mines examined the possibility of a seasonal variation of respirable dust concentration in U.S. coal mines. The first step was to review company and MSHA-inspector dust samples that had been collected during the past several years in 14 selected mines for compliance purposes. Results indicated severe scatter in data; most standard deviations of the dust concentrations measured in winter and summer months were comparable in magnitude with the mean values of dust concentrations for the seasons. Therefore, a detailed statistical analysis was conducted. At the 90% confidence level, the company samples of three mines had winter means 0.15 to 0.54 mg/m^3 higher than the summer means; six mines had negligible seasonal variations; and five mines had winter means that ranged from higher to lower than the summer means. Inspector data, however, were too sparse for analysis. In view of both the low frequency of occurrence of a seasonal effect and its wide scatter in several of the mines, the study was ended with the conclusion that seasonal variation in respirable dust levels, in general, is an insignificant factor.

RI 9015. A Short-Term Evaluation of Compressible Stoppings Used in Trona Mines, by R. J. Timko. 1986. 14 pp. 12 figs. In an attempt to reduce the damage to ventilation stoppings caused by strata convergence, many mines are now using new stopping construction techniques that include compressible materials. This Bureau of Mines study concentrated on compressible stoppings in use in underground trona mines, all of which had overburden in excess of 1,000 ft. This overburden depth, in conjunction with the relatively soft floor in trona mines, has commonly created excessive floor heave throughout mined-out entries. Five different compressible stopping assemblies were examined: metal, wood, a wood-polyisocyanurate hybrid, and "small" and "large" expanded polystyrene (EPS) blocks. Testing was done in both elliptical and rectangular openings, and both rigid urethane foam (RUF) and a mortar-based sealant were used in different tests—for sealing either the perimeter (and joints) or the entire stopping face. Results showed that the EPS stoppings sealed with RUF were superior in prevention of air leakage in the mine openings evaluated. EPS has the advantage of being capable of being cut to any size and shape required. The mortar-based sealant was susceptible to degradation, especially around perimeter interfaces with the mineral surface, because of the hygroscopic nature of trona.

RI 9016. Large-Scale Dewatering of Phosphatic Clay Waste From Polk County, FL, by D. R. Brooks, B. J. Scheiner, A. G. Smelley, and J. R. Boyle, Jr. 1986. 8 pp. 4 figs. The Bureau of Mines has tested a dewatering technique for phosphatic clay waste. The technique utilizes a flocculant, polyethylene oxide (PEO), that forms strong, stable flocs that can be dewatered on a static screen followed by further dewatering on a rotary screen or trommel. In field tests conducted in central Florida, clay wastes containing approximately 4 pct solids have been consolidated to greater than 20 pct solids. The rate at which PEO-treated material continues to dewater in a mine cut was also monitored. Preliminary results indicate that PEO-treated material will dewater to 30 pct solids in 80 days. Pretreatment of phosphatic clay waste with lime lowers the PEO dosage required for dewatering. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

RI 9017. Triboelectric Effects on Polyethylene Methane Drainage Pipelines, by A. A. Campoli, J. Cervik, and R. L. King. 1986. 14 pp. 20 figs. The Bureau of Mines performed laboratory experiments to evaluate the triboelectric effect of particulate-laden gas streams on polyethylene pipe at various velocity, humidity, dust-size, and dust-load conditions. Charges in excess of 10 kV were produced on the outside and inside surfaces of laboratory pipe samples when exposed to 40 pct relative humidity (RH) gas stream containing coal dust. However, no charges were produced in laboratory tests that duplicated the over 75 pct RH and dust-free gas streams found in working underground pipelines. Bare copper wire, which is wound around the polyethylene pipe in a 1-ft (31-cm) spacing and grounded, eliminated the charge on the outside surface of the pipe, but not on the inside of the pipe surface.

RI 9018. High-Temperature Relative Enthalpies and Related Thermodynamic Properties of $Na_2Ti_6O_{13}$, by M. J. Ferrante. 1986. 6 pp. 1 fig. Relative enthalpies of high-purity disodium hexatitanate ($Na_2Ti_6O_{13}$) were measured at the Bureau of Mines to provide new thermodynamic data needed to advance the technology of materials. Measurements from 298.15 to 1,478 K were made by drop calorimetry with a copper block. Tabulated values are listed for the standard relative enthalpy, heat capacity, entropy, and Gibbs energy function between 298.15 and 1,500 K. Enthalpy data are also given in equation form and are combined with thermodynamic data from the literature to derive values of standard enthalpies of formation, Gibbs energies of formation, and logarithms of the equilibrium constants of formation. Similar calculations were made for the reaction of Na_2O with TiO_2.

RI 9019. In Situ FT-IR Studies of Reactions of Activated Sphalerite With Aqueous Solutions of Potassium Ethylxanthate, by S. C. Termes and P. E. Richardson. 1986. 11 pp. 14 figs. The Bureau of Mines has used Fourier transform infrared spectroscopy (FT-IR) to study in situ reactions of aqueous solutions of potassium ethylxanthate with Cu(II)- and Pb(II)-activated sphalerite plates, in which the plates were both the infrared-transparent windows and the reacting surfaces. A copper (I) ethylxanthate formed predominantly with Cu(II)-activated sphalerite, regardless of the activation time. The products formed on Pb(II)-activated sphalerite depended on the activation times; a short activation time (30 min) yielded a lead ethylxanthate-like product, but a long activation time (90 min) yielded a considerable amount of dixanthogen.

RI 9020. Calcium Chloride-Oxygen Leaching and Metals Recovery From an Arsenical Copper-Cobalt Concentrate, by G. A. Smyres, R. L. Kral, K. P. V. Lei, and T. G. Carnahan. 1986. 21 pp. 9 figs. A $CaCl_2$-O_2 leaching procedure and metal-recovery method for treating an arsenical Cu-Co sulfide concentrate was developed by the Bureau of Mines as an alternative to smelting, which is no longer considered an environmentally acceptable method for treating arsenic-containing ores. The procedure involved leaching in a $CaCl_2$ solution with $CaCO_3$ for 96 h at 26 pct solids (concentrate and $CaCO_3$), 115° C, and a pressure of 50 psig (345 kPa) with oxygen. More than 98 pct of the cobalt and 97 pct of the copper were extracted, and 99.98 pct of the arsenic and 99.9 pct of the iron remained in the leached residue. A filtration rate of 2.9 gal/(ft²•h) [118 L/(m²•h)] and a cake formation rate of 36 lb/(ft²•h) [172 kg/(m²•h)] were obtained by filtering reacted pulp at 100° C. More than 99 pct of the copper in the pregnant solution was extracted as $CuCl_2$ by solvent extraction with a new copper extractant. Copper was stripped from the loaded organic with a sulfate-chloride solution, which was used as the anolyte for electrowinning of copper in a membrane cell. Copper plate produced was more than 99.99 pct pure and required 0.81 (kW•h)/lb Cu [1.78 (kW•h)/kg Cu]. Cobalt sulfide was precipitated at pH 3 with $Ca(HS)_2$.

RI 9021. Flocculation and Dewatering of Montmorillonite Modified by Ion Exchange, by D. A. Stanley and B. J. Scheiner. 1986. 10 pp. 10 figs. The Bureau of Mines is investigating a method of dewatering flocculated fine-particle waste that involves treating the waste with a high-molecular-weight polymer such as polyethylene oxide (PEO) followed by dewatering on a static screen and/or in a trommel. Dilution of the polymer solution used for dewatering and use of the ion-exchanged form of the montmorillonite clay were found to be major factors determining the amount of polymer required to dewater clay-containing slurries. The amount of polymer, A, required to dewater ion-exchanged montmorillonite can be described by the equation, $A^n = kC + b$, where n, k, and b are empirical constants and C is the concentration of the polymer solution used for dewatering. Clays that require large amounts of polymer for dewatering also dewater to a lower solids content. The concentration of the polymer solution is important because it affects the radius of the polymer coil in solution and hence its ease of transfer to a bridging configuration by shear. The constant, n, a function of the charge to hydrated radius of the exchange ion, relates to the strength of the bond between the polymer and the surface of the clay through a water bridge. The constant k is related to the hydrated radius for sodium or to the unhydrated radius for the other exchange ions. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

RI 9022. Recovery of Silver, Gold, and Lead From a Complex Sulfide Ore Using Ferric Chloride, Thiourea, and Brine Leach Solutions, by R. G. Sandberg and J. L. Huiatt. 1986. 14 pp. 12 figs. The Bureau of Mines investigated a hydrometallurgical procedure to recover gold, silver, and byproduct lead from a complex lead-zinc sulfide ore. A ferric chloride ($FeCl_3$) preleach, at 40° C in 6 h, extracted about 50 pct of the zinc and formed insoluble silver and lead chlorides. Subsequent acid thiourea leaching, for 1 to 3 h at 40° C, extracted about 85 pct of the gold and silver. Lead chloride was solubilized from the remaining residue with NaCl brine solution at 55° C in 1 h. Lead metal was recovered from the brine solution in an electrolytic cell with an anion permselective membrane at a current efficiency of 95 pct and current density of 100 A/m². Spent $FeCl_3$ leach solution was reoxidized in the anode compartment at a current efficiency between 75 and 95 pct.

RI 9023. Reclaiming Heavy Metals From Wastewater Using Magnesium Oxide, by D. N. Tallman, J. E. Pahlman, and S. E. Khalafalla. 1986. 13 pp. 7 figs. The electrokinetic properties of MgO have been utilized to simultaneously filter suspended solids and remove trace amounts of dissolved heavy metals from synthetic mine water. Greater than 95 pct removal of metals from influent at neutral pH containing 1 to 6 mg/L of dissolved Cd, Cu, Mn, Ni, and Zn can be routinely achieved by filtering through a granular bed of MgO at flow rates typical of rapid sand filtration (0.3 cm/s). Filtrate concentrations of most metals can be maintained below 0.1 mg/L for 160 bed volumes or more loading. The more mobile metals (those with larger solubility products) are more difficult to remove, and are strongly bonded to the MgO granules so that chemical stripping with chelating agent is required to clean the bed. Less mobile ions are easily removed by the filter and are effectively stripped by conventional filter backwashing. The fraction of metals recovered by chemically stripping the loaded MgO filters correlates to the zero points of charge of the metals. This process may be applicable to removal and recovery of trace amounts of heavy metals in mine drainage that is partly neutralized by liming. Also, since many of these metals are critical and strategic, the technique can be adapted not only to recycle process water from mineral and milling waste streams, but also to reclaim their metal values.

RI 9024. Solubility of Anhydrous $AlCl_3$ in $TiCl_4$ and VCl_4, by Dennis A. Hansen and Davis E. Traut. 1986. 8 pp. 7 figs. The solubility of anhydrous aluminum chloride in solutions of titanium tetrachloride and vanadium tetrachloride was determined as part of a research project by the Bureau of Mines to make a homogeneous alloy sponge of titanium, vanadium, and aluminum. Solubility curves were established using an autoclave at 75°, 100°, 125°, and 150° C. The solubility of $AlCl_3$ in $TiCl_4$ is 0.2 wt pct at 75° C; it increases to 18.3 wt pct at 150° C. The data concur with data from earlier researchers of this binary system for 75° to 125° C. For the VCl_4-$AlCl_3$ binary system, the solubility of $AlCl_3$ is 0.1 wt pct at 75° C, increasing to 1.6 wt pct at 150° C. For the $TiCl_4$-$AlCl_3$-VCl_4 ternary system, the solubility of $AlCl_3$ decreases from the values found with a pure $TiCl_4$-$AlCl_3$ system to the lower values found with a pure VCl_4-$AlCl_3$ system at the respective temperatures.

RI 9025. Recovery of Vanadium, Uranium, and Phosphate From Idaho Phosphorite Ores, by J. C. Judd, R. G. Sandberg, and J. L. Huiatt. 1986. 15 pp. The Bureau of Mines investigated the recovery of vanadium, uranium, and phosphorus from low-grade phosphorite ores and concentrate by leaching with H_2SO_4. Samples containing 0.12 to 0.23 pct V_2O_5, 0.009 to 0.012 pct U_3O_8, and 18 to 30 pct P_2O_5 were treated by batch-agitation leaching, roasting followed by acid leaching, salt-roasting followed by acid leaching, and leaching under pressure. Maximum recoveries using leaching alone ranged from 78 to 98 pct of the V_2O_5 and 74 to 88 pct of the U_3O_8. Leaching under pressure resulted in extractions of 88 to 95 pct of the V_2O_5 and 84 to 89 pct of the U_3O_8. Leaching following roasting—with or without NaCl—produced extractions of 97 to 99 pct of the V_2O_5 and 86 to 91 pct of the U_3O_8. Depending on the technique(s) employed, phosphate extractions ranged from 89 to 99 pct. Solvent extraction laboratory tests were conducted to selectively recover vanadium and uranium values from acid leach solutions. An average of 95 pct of the U_3O_8 was recovered using di(2-ethylhexyl)phosphoric acid, plus trioctylphosphinic oxide. Essentially all of the V_2O_5 was recovered with

octylphenyl acid phosphate plus isodecanol. The phosphate remained in the raffinate.

RI 9026. Effects of Millisecond-Delay Intervals on Vibration and Airblast From Surface Coal Mine Blasting, by John W. Kopp and David E. Siskind. 1986. 44 pp. 38 figs. A major concern with blasting at surface mines is generation of ground vibrations and airblast and their effects on nearby residences. This Bureau of Mines report looks at the use of millisecond delays in blast design and their effect on the resulting ground vibrations and airblast. A total of 52 production blasts were instrumented and monitored at a surface coal mine in southern Indiana. Arrays of seismographs were used to gather time histories of vibrations and airblast. The data were analyzed for peak values of vibration and airblast and for frequency content. Various delay intervals were used within and between rows of blastholes. Delay intervals within rows were 17 and 42 milliseconds (ms) and those between rows ranged from 30 to 100 ms; these intervals are equivalent to 0.5 and 1.3 ms/ft within rows and 1.2 to 4.3 ms/ft between rows. Subsonic delay intervals within rows reduced airblast by 6 dB. Large delay intervals between rows reduced the amplitude of ground vibrations; their frequency depended primarily upon the geology of the minesite.

RI 9027. Shield Mechanics and Resultant Load Vector Studies, by Thomas M. Barczak and Robert C. Garson. 1986. 43 pp. 54 figs. The term "resultant load vector" is defined as the representation of the forces applied to a longwall roof support element by strata activity through a single, quantifiable measure of support resistance. The relatively complex kinematics of the shield structure prohibit determination of support resistance simply from the summation of leg forces. In the research reported in this Bureau of Mines study, the mechanics of the shield structure were evaluated, and a technique was developed whereby the resultant shield loading could be determined by instrumenting supports with pressure transducers and strain gauges to measure leg, canopy capsule, and lemniscate link forces. This technique has been laboratory tested in the Bureau's Mine Roof Simulator. Functional relationships among variables were assessed, and confidence intervals were established for prediction of the resultant load vector parameters. Resultant load measurements were taken on five instrumented shields on an active longwall face in Colorado. Results were analyzed and found to be consistent with shield mechanics and anticipated roof behavior. Benefits to be derived from this research, future efforts, and long-range goals are discussed.

RI 9028. Recovery of Fluorite and Byproducts From Fish Creek Deposit, Eureka County, NV, by F. W. Benn, D. G. Foot, Jr., and J. L. Huiatt. 1986. 13 pp. 13 figs. The Bureau of Mines investigated flotation methods for recovering fluorite and byproducts from two samples of the Fish Creek deposit in Eureka County, NV. The preferred method for treating a fluorite-beryllium sample included (1) fluorite rougher and cleaner flotation, (2) desliming at 20 μm, (3) muscovite flotation, (4) silicate flotation, (5) sodium hypochlorite wash of silicate concentrate, and (6) beryllium rougher and cleaner flotation from the silicate concentrate. Laboratory results showed that over 94 pct of the fluorite was recovered in a recleaner concentrate containing 98 pct CaF_2. Beryllium flotation produced concentrates containing in excess of 5 pct BeO with recoveries over 70 pct. The preferred method used for a fluorite-mica sample consisted of (1) fluorite rougher and cleaner flotation, (2) desliming at 20 μm, and (3) mica flotation using an anionic-cationic collector system. Laboratory results showed that 84 pct of the fluorite was recovered in a recleaner concentrate containing 96 pct CaF_2. Mica flotation produced a concentrate containing 95 pct mica at 85-pct recovery.

RI 9029. Waveform Analysis of Electric Furnace Arcs as a Diagnostic Tool, by Thomas L. Ochs, Alan D. Hartman, and Stephen L. Witkowski. 1986. 19 pp. 14 figs. The Bureau of Mines is investigating the fundamental behavior of electric arcs in electric-furnace operations. The electric arc is a poorly understood phenomenon. If the arc in a steelmaking furnace can be more carefully controlled, it should be possible to increase heat transfer to the melt, reducing both electrical and acoustical noise. As a first step toward a better understanding of the arc, voltage and current signals from operating furnaces were analyzed. The results of the initial analysis show that instrumentation used in monitoring and controlling furnaces, such as meters and strip-chart recorders, gives incomplete or erroneous information to the operator and leads to less than optimal control. Advanced instrumentation and analysis techniques, such as the waveform analysis used in these investigations, can improve the understanding of operation and the control of electric furnaces. This report describes the instrumentation and the numerical analysis methods used and compares these methods with standard metering and recording techniques.

RI 9030. Correlating Abrasive Wear to Alloy Additions in Low-Alloy Steels, by J. H. Tylczak. 1986. 14 pp. 8 figs. The Bureau of Mines studied the effect of alloy additions on abrasive wear of low-alloy steels. A dry-sand, rubber-wheel abrasion test apparatus using ASTM G65–81 procedure B was used for the abrasive wear tests. Eighty-six material heat-treatment combinations were abrasion tested. Results of these tests were analyzed statistically using regression analysis to see if additions of Cr, Mn, Mo, Ni, Si, Al, Cu, and S were significant in affecting the abrasive wear rate of low-alloy steels. Regression analysis was also used to confirm hardness and C affect on the abrasive wear rate of these steels. It was found that for all the steels taken as a group, increased amounts of Mn significantly reduced the wear rate, while increased amounts of Mo and Si increased the wear rate. Analysis also confirmed previous research done by others, that increasing hardness and amounts of C reduced the wear rate. For the hardened steels taken as a class, only increasing amounts of C and Mn reduced the wear rate, while increases in Si increased the wear rate. In the class of unhardened steels, increases in C, Mn, and S reduced the wear rate, whereas increases in Mo increased the wear rate. The steels with the best resistance to wear were two hardened experimental steels similar to AISI 1055 and AISI 1078.

RI 9031. Gas Equilibrium in Sealed Coal Mines, by Charles D. Litton. 1986. 13 pp. 8 figs. This Bureau of Mines report presents new concepts and procedures that have been derived for determining ambient equilibrium conditions in sealed coal mines. In particular, these concepts address problems usually encountered in determining the return of a mine to ambient temperature levels after it has been sealed due to a fire. These concepts are applied to six sealed mine fire incidents with good agreement.

RI 9032. Removal of Alkalies From Portland Cement Kiln Dust, by R. D. Wilson and W. E. Anable. 1986. 10 pp. 8 figs. Ten to twelve million tons of dust is produced by cement kilns annually in the United States, resulting in a serious waste disposal problem. The Bureau of Mines investigated two alkali volatilization methods for converting this dust into materials for making portland cement and a useful potassium product. Portland cement kiln dust was found to be composed of finely ground cement raw materials ($CaCO_3$ and SiO_2) having a layer of alkali sulfate (K_2SO_4 and Na_2SO_4). In this form, it cannot be directly recycled to cement kilns because concrete is weakened by a reaction between the alkali and the aggregate. Portland cements with 28-day strengths above 5,000 psi were produced from low-alkali residues using sintering and melting methods. For nearly complete removal of alkalies, primarily potassium sulfate, from cement kiln dust, a temperature above 1,300° C and a reducing atmosphere were required.

RI 9033. Measurement of Coal-Cutting Forces Underground With the In-Seam Tester, by Laxman S. Sundae.

1986. 16 pp. 9 figs. The Bureau of Mines designed, fabricated, and is using an in-seam tester for in situ determination of coal cutting forces. This report describes the results of field tests conducted in the Pocahontas No. 3 and Upper Freeport seams to obtain peak and mean cutting forces during coal cutting with several bit geometries, including radial and point attack bits currently used on drum-type machines. Comparisons were also made between new and worn bits, and by using data obtained from a Bureau-modified chisel bit. The test results show that longwall plough cutting (horizontal cuts) in bony coal bands (shale) requires greater than three times the cutting force for the same cuts in a vertical direction. When no bony coal is present, the cutting forces required to make horizontal and vertical cuts are equal. Worn bits require four to five times more cutting and normal force than new or undamaged bits. Normal force increased drastically for the worn chisel bit. Peak force encountered in making independent cuts was found to be approximately three times higher than that required to make interactive cuts using a spacing-to-depth-of-cut ratio of 2. Both rake and clearance angles were found to have a significant effect on normal and cutting force.

RI 9034. Experimental Nickel-Cobalt Recovery From Melt-Refined Superalloy Scrap Anodes, by J. L. Holman and L. A. Neumeier. 1986. 17 pp. 6 figs. The Bureau of Mines is conducting research to recover strategic and critical metals such as Ni, Co, and Cr from mixed contaminated superalloy scrap. One approach being studied involves melt refining of superalloy scrap to produce anodes for electrolytic deposition of Ni-Co alloy. This melt refining of superalloy turnings is described based on melt-oxidation and oxidation-carburization experiments that use roasted superalloy grinding sludge to supply the O needed to oxidize Cr and other readily oxidized elements to the slag. Controlled melt-carburization subsequent to oxidation improved the metal phase recovery of Ni and Co to sell over 90 pct and decreased electrolytic solubility of Cr, Mo, and W by carbide formation. Electrolytic refining experiments were conducted using a controlled-potential mode (preset cathode potential). Data show effects of Fe and Cr impurities, cation concentration, electrolyte pH, SO_4-Cl electrolyte ratio, temperature, cathode potential, and cation-selective membrane use on current efficiency, current density, and deposit composition. Disposition of Ni, Co, Cr, Mo, W, and Fe is compared for melt-oxidized versus oxidized-plus-carburized anodes. Deposits containing >97 pct Ni + Co (major impurity Fe) have been routinely obtained from scrap anodes. Research is continuing to improve deposit quality in sustained deposition and to recover Cr and other metals from refining slags and anode sludges.

RI 9035. Measurement of Dielectric Properties of Minerals at Microwave Frequencies, by W. E. Webb and R. H. Church. 1986. 8 pp. 7 figs. This report describes a method the Bureau of Mines devised for measuring the dielectric constant and loss tangent of low-loss minerals at microwave frequencies. Determination of these properties makes it possible to predict the effects of using microwave heating in potential processing applications. The method uses a test cell and a radio-frequency impedance analyzer with automated data acquisition and analysis. In this initial phase of microwave heating research, the Bureau measured dielectric constants and loss tangents at frequencies between 100 MHz and 1 GHz. The objective was to establish a reliable data base for use in predicting the effects of microwave heating on minerals. Comparison with previously measured data showed the Bureau's measurement method to be accurate to within ±3 pct. This report describes the method and discusses the preliminary results of the Bureau's investigations. Typical comparative data are included. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

RI 9036. An Infrared Examination of Ion-Exchanged Montmorillonite Treated With Polyethylene Oxide, by Steve W. Webb, D. A. Stanley, and B. J. Scheiner. 1986. 16 pp. 13 figs. The Bureau of Mines is researching a new technology for dewatering clay suspensions that consists of flocculation by high-molecular-weight polyethylene oxide (PEO) polymer and subsequent removal of water from the flocs via a trommel. The minimum amount of PEO required to dewater the clays depends on the ions adsorbed on the surface of the clay particles. Infrared studies were performed on clays with Li^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}, Ba^{2+}, or Sr^{2+} adsorbed, with and without adsorbed PEO, to develop data to aid in understanding the dewatering mechanism. Hydroxyl stretching modes between 3,400 and 3,250 cm^{-1}, associated with water adsorbed on the clay, showed changes in intensity proportional to the ionic charge-to-radius ratio; that is, the ionic potential. In addition, a water-bending vibration of adsorbed water at 1,630 cm^{-1} showed variations associated with water desorption. The data are consistent with changes in adsorption of PEO resulting from variation of the acidity of water coordinated with the exchange ions, induced by the variation in field strength of the ions with the ionic potential. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

RI 9037. Using Barriers To Reduce Dust Exposure of Longwall Face Workers, by Robert A. Jankowski and Charles A. Babbitt. 1986. 10 pp. 9 figs. Through laboratory and underground studies, the Bureau of Mines has evaluated the use of passive barriers (dust shields) to help confine dust generated by longwall shearers to the face area. Laboratory studies focused first on selection of the optimum barrier design—a simple, gobside barrier (made of conveyor belting) coupled with a headgate splitter arm—to prevent the dust cloud from entering the walkway at the headgate end of the shearer when cutting tail to head. Further laboratory testing was done to determine whether using passive barriers in combination with different water-spray dust-reduction methods, including the shearer-clearer system developed by the Bureau, would improve dust reduction over that from using the water sprays alone. It was found that the combination of gobside passive barriers plus the full shearer-clearer system was most effective, and surmised that this would be especially useful in thicker seams. However, underground testing revealed that the shearer-clearer system alone was 35 pct more effective in reducing dust contamination than when used with the gobside passive barriers, and far more effective than using passive barriers with a conventional water spray system. For such an effective system as the shearer-clearer, the reduction in available space over the top of the machine actually impeded system performance; this was shown in both eastern and western mines. But when used with comparatively inefficient water spray systems, the passive barriers, used in combination with a headgate splitter arm, provide considerable help in reducing dust levels in the walkway.

RI 9038. Testing Materials for Support-Wall Construction, by Kenneth E. Hay and Joanne L. Johnston. 1986. 11 pp. 8 figs. The Bureau of Mines collected coal and coal waste aggregate material from two different mine sites to determine their strength characteristics for use in concrete. The concrete would be placed underground as support walls for ground control in adverse conditions or unique mining applications. A standard mix design was established for a "wet" mix using a water-to-cement (w/c) ratio of 1.0 to facilitate pumping into place. Later, material was collected from four more mine sites and used to make 2- by 2- by 2-ft test blocks with the same w/c ratio. A pullout cone device and borehole shear tester were used to determine the in situ material strength of the test blocks. These techniques will provide a simple and quick way of determining support wall strength in an underground environment. Test results from the pullout cone device showed a good correlation of 0.98 to test cylinder compressive strengths of the same mix. Results of the borehole shear tester were inconclusive.

RI 9039. High-Temperature Relative Enthalpies of V_2O_5, by M. J. Ferrante and R. V. Mrazek. 1986. 7 pp. Relative enthalpies of V_2O_5 from 298.15 to 1,101.0 K were measured at

the Bureau of Mines to provide data needed for the advancement of mineral technology. Enthalpies were measured with a copper-block calorimeter. A sharp melting point was found at 951 K, with Δ_m° = 15.690 kcal/mol for the standard enthalpy of melting. Tabulated values are given at selected temperature increments between 298.15 and 1,500 K for the standard relative enthalpy ($H^\circ - H_{298}^\circ$), heat capacity (C_p°), entropy (S°), and Gibbs energy function $[-(G^\circ - H_{298}^\circ)/T]$. Standard relative enthalpies are also given in equation form and combined with data from the literature to derive values of standard enthalpies of formation and Gibbs energies of formation.

RI 9040. Direct Measurement of Longwall Strata Behavior: A Case Study, by Jeffrey M. Listak, John L. Hill III, and Joseph C. Zelanko. 1986. 19 pp. 19 figs. The Bureau of Mines has conducted a rock mechanics study to monitor deformation of near-seam strata above a longwall panel in the Pittsburgh Coalbed. The primary goal was to determine the height of caving immediately behind advancing longwall face supports. This study, although site specific, provides information on the caving mechanism associated with longwall extractions so that strata behavior and its interaction with longwall face supports can be better understood. Two holes were drilled, approximately 550 ft apart along the centerline of a longwall panel, from the surface to the coalbed approximately 650 ft below. Various downhole geotechnical instruments were used to monitor strata deformation. In addition, surface elevation surveys were conducted to differentiate between surface and subsurface activity. This report discusses the caving characteristics of the strata as the longwall panel approached and passed beneath the boreholes. Physical property data are also presented to demonstrate the relationship between caving behavior and local geology. Data show that immediate caving of strata above the longwall face occurred at a height less than 23.5 ft and that strata behavior above longwall extractions is highly dependent upon lithology, with major disturbances occurring at weak lithologic zones.

RI 9041. Deposition of Respirable Coal Dust in an Airway, by Welby G. Courtney, Lung Cheng, and Edward F. Divers. 1986. 10 pp. 7 figs. Because of the inherent safety problem associated with the deposition of airborne respirable dust onto the floor and other airway surfaces, the Bureau of Mines investigated the rate of reduction of airborne respirable dust in an airway due to deposition of the particles onto the surfaces of the airway. The effects of relative humidity and air velocity on the deposition rate were examined. It was found that the deposition rate was comparable in magnitude with the Stokes sedimentation rate and that it was independent of relative humidity. However, near the dust source the deposition rate depended significantly upon the air velocity, with such dependence decreasing with increasing distance from the dust source. In addition, the size distribution of the airborne particles was approximately constant along the first 300 ft of the airway, indicating that it was not merely the larger (heavier) particles that were being deposited. These results suggest that deposition, though comparable with the Stokes sedimentation rate in magnitude, does not follow a simple Stokes-type process, and that the process of deposition remains to be explained.

RI 9042. Calcium Sulfide Precipitation of Mercury From Gold-Silver Cyanide-Leach Slurries, by W. W. Simpson, W. L. Staker, and R. G. Sandberg. 1986. 8 pp. 3 figs. During cyanidation of mercury-bearing gold-silver ores, significant amounts of mercury are extracted. The presence of mercury decreases gold loading and increases mercury stripping time on activated carbon, complicates fire refining of the gold cathodes, and creates a potential health hazard. Addition of calcium sulfide (CaS) to the cyanide leach slurry precipitates the solubilized mercury but also some silver. The Bureau of Mines investigated silver loss during CaS precipitation of mercury. Addition of 0.1 lb CaS per short ton ore to a mercury-bearing gold-silver ore precipitated both mercury and silver. However, if copper was added with CaS, or if the ore contained copper, much of the silver loss was prevented. Addition of 235 ppm Cu with 0.1 lb/st CaS, prior to carbon-in-pulp adsorption, resulted in 89- to 97-pct, 80- to 91-pct, and 0-pct adsorption of the solubilized gold, silver, and mercury, respectively, on the activated carbon.

RI 9043. Electrochemical Determination of Thermodynamic Properties of $NiCr_2O_4$ and $CoCr_2O_4$, by Seth C. Schaefer. 1986. 11 pp. 7 figs. This report describes a Bureau of Mines investigation into the standard Gibbs energies of formation ΔGf°, for $NiCr_2O_4$ (nickel chromite) and $CoCr_2O_4$ (cobalt chromite). High temperature galvanic cells employing stabilized ZrO_2 (zirconia) as the solid electrolyte were used to measure the open-circuit potentials for the cell reactions, and equilibrium oxygen pressures for the $Ni\text{-}Cr_2O_3\text{-}NiCr_2O_4\text{-}O_2$ system, were determined from the electromotive force (emf) measurements.

RI 9044. Evaluation of Bearing Plates Installed on Full-Column Resin-Grouted Bolts, by Stephen C. Tadolini and Bryan F. Ulrich. 1986. 12 pp. 13 figs. The Bureau of Mines conducted field investigations in two underground mines to determine the actual loads to which bearing plates were subjected when installed in conjunction with full-column resin-grouted bolts and the roof movements generated by the applied loads. Measured loads indicate that the bearing plate is an integral part of the support system. Vertical displacement gauges installed to monitor roof displacements in the test sites show that the highest degrees of loading occur in conjunction with the largest amounts of movement.

RI 9045. Wood Crib Fires in a Ventilated Tunnel, by Margaret R. Egan and Charles D. Litton. 1986. 18 pp. 10 figs. This Bureau of Mines report presents results from experimental studies on wood crib fires in an intermediate-scale fire tunnel. Gas concentrations, smoke particle characteristics, heat release rates, and ventilation rates were determined. These measurements form a data base for wood, which can be used with previous analyses for coal and future studies of other mine combustibles, to comprehend the potential hazards of these materials in underground mine fires. A knowledge of the combustion products emitted from these materials will benefit fire detection and control. Results show the changes in burning rate and heat release rate produced by different crib configurations and ventilation rates. Also included are the effects that the burning rate has on smoke characteristics and gas production.

RI 9046. Longwall Shearer Performance Using Water-Jet-Assisted Cutting, by P. D. Kovscek, C. D. Taylor, H. Handewith, and E. D. Thimons. 1986. 15 pp. 12 figs. The Bureau of Mines equipped a longwall shearer with a water-jet-assisted mechanical cutting system to determine the effect of the high-pressure sprays on machine performance, airborne dust levels generated, and size of particles formed. Testing was conducted on a simulated coal block (coalcrete) while cutting at a water pressure of 190 psi and at water-jet-assisted pressures ranging from 1,000 to 6,000 psi. The shearer motor energy used by the shearer while cutting coalcrete was determined for each cutting condition. Results indicate that the motor energy required by the shearer for each ton of material cut did not vary significantly as the water pressure was increased. Results of dust measurements recorded near the cutting drum indicate that at water pressures above 3,000 psi, dust reductions up to 85 pct were achieved compared with cutting with conventional sprays. Analysis of the particle size distribution during cutting showed that increasing the water pressure resulted in increased median particle size. In light of these results, various mechanisms for water-jet-assisted cutting are discussed.

RI 9047. Effect of Alloying Elements on Oxidation of Low-Chromium Alloys, by Je M. Oh. 1986. 12 pp. 18 figs.

The Bureau of Mines is conducting research to determine the high-temperature oxidation resistance of substitute stainless steels (SS) containing two less strategic elements, Al and Si, instead of Cr. Chromium is considered to be a critical and strategic metal. Although the Cr content was reduced to 8 wt pct, the alloys showed better oxidation resistance than did 304 SS containing 18 wt pct Cr. Specifically, the alloys that contained Fe-8Cr-16Ni with combinations of Al and Si showed excellent oxidation resistance even at temperatures up to 1,000° C. In this study, the effects of the alloying elements on oxidation kinetics and morphology of oxides were investigated using a Cahn Rg electrobalance, scanning electron microscopy, an energy-dispersive X-ray analyzer, X-ray diffraction, and an electron microprobe. Aluminum and silicon additions in combination were more effective in providing oxidation resistance than either element was alone.

RI 9048. A Statistical Determination of Spark Ignition Safety Factors in Methane, Propane, and Ethylene Mixtures in Air, by James C. Cawley. 1986. 15 pp. 13 figs. The Bureau of Mines conducted an investigation to statistically determine the mean current or voltage for resistive, inductive, and capacitive circuits that would cause spark ignitions in 8.3% methane-air, 5.3% propane-air, and 7.8% ethylene-air mixtures. Each mean ignition current or voltage was determined on the basis of 100 trials. Each trial consisted of 400 revolutions, 200 in each polarity, at 80 rpm of the standard breakflash apparatus. In general, spark ignition curves published in UL 913 for resistive and inductive circuits represent approximately the mean current values determined in this study, while published capacitive circuit values in methane are considerably less than the mean voltage values from this study, especially for a capacitance of less than 100 μF. For resistive and inductive circuits, spark ignitions were obtained at currents considerably below those in the published curves, but this study was not optimized to find minimum ignition values. This report defines "safety factor" as applied to intrinsic safety testing as the energy ratio of the mean values of ignition current or voltage for two test gases. The safety factors presented in this report are not constant with voltage or current and, therefore, are not recommended for use.

RI 9049. Fracture Geometries in Three Ore Bodies Mined by Undercut Caving as Determined From Oriented Drill Core and Scanline Mapping, by Louis A. Panek and Michael T. Melvin. 1987. 82 pp. 63 figs. Block caving, a low-cost method of mining large low-grade deposits, has the potential for application to a larger class of mineral deposits than has been attempted heretofore, provided that quantitative methods can be developed to predict the span required to induce caving and the size distribution of the caved fragments. Prerequisite to employing a numerical method of structural analysis to evaluate the stability or failure of the rock mass in the vicinity of an excavation are the specifications of rock mass strength and fracturing (jointing). This Bureau of Mines report characterizes the fracturing geometries in three ore bodies that are mined by undercut-cave methods, utilizing data that were generated by measurements on oriented diamond drill cores and along multiple scanlines on underground exposures. Procedures employed for data acquisition and for data analysis are described in detail. Numerous polar equal-area plots of fracture orientation and histograms of fracture spacing, obtained by Bureau-developed codes FRACTAN and GDIST, are presented. Fracture-trace-length estimates are derived from the multiple-scanline mapping measurements, a new procedure.

RI 9050. A Method for Locating Abandoned Mines, by R. G. Burdick, L. E. Snyder, and W. F. Kimbrough. 1986. 27 pp. 15 figs. The problems presented by old mine workings affect both present-day mining and land development. An automated method of locating these old mines from the surface using electrical resistivity techniques was developed earlier under a Bureau of Mines contract. Subsequent Bureau research has refined the techniques and expanded the area of study to a variety of geologic provinces. During this research, six mining areas in the United States were investigated with the Bureau's automated resistivity method. This report describes the mining areas involved and the results of the resistivity investigations, which showed a high rate of success in detecting old mines. It also describes the field measurement techniques and data analysis procedures.

RI 9051. Self-Contained Self-Rescuer Field Evaluation: First-Year Results of 5-Year Study, by N. Kyriazi, J. G. Kovac, J. Shubilla, W. Duerr, and J. Kravitz. 1986. 12 pp. 10 figs. A joint effort by the Bureau of Mines and the Mine Safety and Health Administration, U.S. Department of Labor, was undertaken to determine how well self-contained self-rescuers (SCSR's) deployed in accordance with Federal Regulations (30 CFR 75.1714), held up in the underground environment. This report presents findings regarding laboratory-tested breathing apparatus from the first year of a 5-yr program as well as other related findings. The SCSR's were tested on human subjects and on a breathing and metabolic simulator. These results indicate that the apparatus, if well-treated, perform as expected except for manufacturing defects or quality control problems, which are identified. However, when the apparatus are carried in and out of the mine every day and stored at the working section, they may suffer abuse that can be extreme. Physical signs of abuse, unless extremely obvious, frequently are not detected by the miners or the mine operators; this poses a danger to a potential user in case of emergency. Recommendations include improved training in inspection procedures.

RI 9052. Steam-Induced Volatilization of Silica From Refractories, by L. Y. Sadler III and E. G. Davis. 1986. 10 pp. 7 figs. The Bureau of Mines conducted a study to determine the loss in weight of silica (SiO_2) volatilization from low-alumina (Al_2O_3) refractories used as hot face liner materials in such process equipment as coal gasifiers, synthesis gas transfer lines, and ammonia plant secondary reformers. Small specimens of 80- and 40-pct-Al_2O_3 brick and 95-pct-SiO_2 brick were exposed to steam in high-pressure furnaces at pressures of up to 1,000 psig and temperatures up to 1,400° C for periods ranging up to 120 h. Weight losses from the 40-pct-Al_2O_3 brick after 40 h of exposure were highest, 2.75 pct at 1,400° C and 1,000 psig. The rate of weight loss had dropped to near zero after 80 h of exposure at all temperatures. No relationship between total silica content of the specimen and weight loss could be established nor did scanning electron microscopic examination of the specimens before and after exposure identify specific regions (e.g., surface) suffering a disproportionate share of the silica loss. It was concluded that minor silica volatilization is likely to occur, if at all, at temperatures of less than 1,000° C and pressures below 1,000 psig, and that low-alumina refractories should be used as dry-ash coal gasifier hot face linings.

RI 9053. Particle Size Distribution of Quartz and Other Respirable Dust Particles Collected at Metal Mines, Nonmetal Mines, and Processing Plants, by Charles W. Huggins and Gail T. Meyers. 1986. 8 pp. The primary objective of this Bureau of Mines research was to measure the size distribution of respirable quartz collected at metal mines, nonmetal mines, and processing plants to select the best reference standard for use in quantifying quartz in mine and plant dust samples. The secondary objective was to size all the nonquartz particles collected at the same sites. Particle size measurements were made on 29 samples using a scanning electron microscope in the backscatter mode of operation, interfaced with an image analysis system. The Mine Safety and Health Administration, Denver, CO, provided the 29 samples, which were collected at mines and processing plants in 19 States. The accumulated particle size measurements indicate that NBS 1878, minus 5-μm Min-U-Sil, and minus 5-μm Supersil would be preferred over Silver Bond B as reference standards for most quantitative determinations by X-ray diffraction and infrared spectrometry. The respirable dust samples collected at sand plants, however,

would be better served by a new reference standard having a quartz particle size distribution of approximately 2.2 μm, as none of the four existing reference standards matched closely with them. Commercially available NBS 1878 and minus 5-μm Min-U-Sil could be used as reference standards for 28 of the 29 samples studied in this investigation.

RI 9054. Firing Delay Characteristics of Instantaneous and Seismic Detonators, by T. S. Bajpayee, Richard J. Mainiero, and J. Edmund Hay. 1986. 10 pp. 4 figs. This report describes an evaluation by the Bureau of Mines of the firing delay and interval of commercially available instantaneous and seismic detonators considered for use with nonincendive sheathed explosive rock-breaker charges. Detonators manufactured by three domestic companies were evaluated. Time measurements were based on the principle of detecting ionization at the detonation front. High-resolution digital oscilloscopes and twisted-pair ionization probes were integral parts of the experimental setup. Firing delays and firing intervals were measured using 3 different test procedures: (1) 3 detonators in series with a 100-ft-long 16-gauge firing line fired by a 20-shot permissible blasting machine, (2) 2 detonators in series fired by a 20-shot blasting machine through a total circuit resistance of 25 ohms, and (3) 2 detonators in series fired by a 20-shot permissible blasting machine through a total circuit resistance of 150 ohms.

RI 9055. Hydrometallurgical Process for Producing Lead and Elemental Sulfur From Galena Concentrates, by Agnes Y. Lee, Ann M. Wethington, and Ernest R. Cole, Jr. 1986. 13 pp. 6 figs. The Bureau of Mines has developed an effective hydrometallurgical method to recover high-purity Pb metal and elemental S from galena concentrates. This low-temperature process eliminates S gases and Pb emissions, in contrast to the current high-temperature smelting technology. The method consists of (1) oxidative leaching with H_2O_2, PbO_2, and waste fluosilicic acid at 95° C to produce a solution of $PbSiF_6$ and a residue containing elemental S, (2) electrowinning the $PbSiF_6$ solution at 35° C to produce 99.99 pct Pb metal and H_2SiF_6, and (3) solvent extraction to recover S, leaving a residue containing Cu, Ag, and other metal values. Spent electrolyte was recycled repeatedly, with impurity buildup controlled by controlling the leach parameters.

RI 9056. Strata Interactions in Multiple-Seam Mining—Two Case Studies in Pennsylvania, by Gregory J. Chekan, Rudy J. Matetic, and James A. Galek. 1986. 17 pp. 22 figs. The Bureau of Mines, in an effort to improve planning and development in coal mining, is investigating strata interactions associated with mining of multiple coalbeds. Two common interactions that occur between adjacent coalbeds are subsidence and pillar load transfer. The study described involves underground observations and measurements conducted at two Pennsylvania mines, each affected by one of these interactions. At the mine affected by subsidence, measurements show that undermining had little effect on upper mine pillar stability, but had a more severe effect on the development and maintenance of entries. Roof-to-floor measurements recorded over four times more convergence in entries developed over gob as compared with entries developed over support pillars in the lower mine. At the mine affected by pillar load transfer, initial in situ measurements have shown the existence of a pressure arch in the lower workings. Prior research has shown that arch interaction between two adjacent openings can create stress concentrations in the innerburden. Underground measurements and results obtained from both mine sites correlate with theoretical and photoelastic multiple-seam models, and eventually these field data will serve to refine model accuracy. Further study of multiple-seam interaction mechanisms will lead to improved mine planning, increased resource conservation, and a safer working environment.

RI 9057. Thickening Fine Coal Refuse Slurry for Rapid Dewatering and Enhanced Safety, by Bill M. Stewart, Ronald R. Backer, and Richard A. Busch. 1986. 12 pp. 5 figs. To decrease the potential for fine coal waste slurry impoundment failures, the Bureau of Mines investigated a new disposal technique. The fine coal waste slurry is rapidly thickened (i.e., dewatered) and deposited on a slightly sloping surface. To accomplish rapid dewatering, a chemical flocculation system using polymers was developed to treat the fine coal waste slurry stream. The fine solids formed flocs, settled from suspension, and rapidly released excess water. During the last 5 days of the field test, slurry flowing at rates from 498 to 675 gal/min with a specific gravity range of 1.15 to 1.33 was successfully treated and dewatered. During this period, untreated slurry had an average moisture content of 227.4 pct (30.7 wt pct solids). The effectiveness of the dewatering system was determined by monitoring the moisture content of the deposited waste with respect to time. Sixty-five hours after ending the field test the average moisture content was 54.9 pct (64.5 wt pct solids); 68 days after the field test the average moisture content was 28.8 pct (78.0 wt pct solids).

RI 9058. Oxidative Thermal Degradation of PVC-Derived, Fiberglass, Cotton, and Jute Brattices, and Other Mine Minerals. A Comparison of Toxic Gas and Liquid Concentrations and Smoke-Particle Characterization, by Maria I. DeRosa and Charles D. Litton. 1986. 13 pp. 10 figs. The Bureau of Mines performed experiments to determine concentrations of toxic gases and liquids, and smoke-particle diameters and diameter-concentrations evolved during degradation of PVC-derived brattice with and without nylon-woven fabrics, fiberglass, cotton, and jute brattices, and other mine materials. The samples were exposed in a 20-L chamber at temperatures of 150° to 450° C, with a chamber airflow of 10 L/min; 27.3 cm^3/s of which was directed into a submicrometer-particle detector-analyzer. During the degradation of PVC-derived brattice, large concentrations of hydrogen chloride (TLV, 5 ppm; STEL, 100 ppm) evolved at a temperature as low as 200° C. The minimum toxic load of 3.1 mg or 40 ppm in 50 L of dilution air, with 0.1-g weight loss, may be reached at a mine face with 314,000 L of dilution air, at the 5th min, during which less than 1 kg of brattice undergoes combustion. Fiberglass, cotton, and jute brattices, pine wood dust, and coal dust showed small concentrations of carbon monoxide evolving during early stages of combustion. Hydrogen cyanide gas evolved from the PVC-derived, nylon-reinforced brattice; at a later stage of combustion, large concentrations of carbon monoxide and dense smoke evolved from all PVC-derived brattices. Experiments to characterize smoke particles showed that marked differences exist in particle diameter-concentrations among the materials.

RI 9059. Thermal Gravimetric Analysis of Pyrite Oxidation at Low Temperature, by J. E. Pahlman and G. W. Reimers. 1986. 12 pp. 8 figs. Spontaneous oxidation and combustion of sulfides and resultant fires are serious problems in underground mines. The Bureau of Mines has conducted fundamental thermal gravimetric analysis (TGA) research to determine the mechanisms and factors governing the rate of low-temperature pyrite oxidation, and to identify possible inhibitors to spontaneous oxidation and combustion. The mechanism of low-temperature pyrite oxidation was found to be topochemical, meaning that the oxidation process is controlled by the chemical reaction at the interface between pyrite (FeS_2) and iron sulfate ($FeSO_4$). An activation energy of 8.9 kcal/mol FeS_2 was obtained for oxidation of minus 500-mesh pyrite in an atmosphere of 60 vol pct water vapor and 40 vol pct O_2. Water-vapor content of the atmosphere was found to be the critical factor in the rate of spontaneous oxidation of pyrite, with a water-vapor content greater than 20 vol pct needed for accelerated oxidation. An atmosphere of pure oxygen resulted in negligible oxidation. The rate of pyrite oxidation is also greatly affected by the particle size of pyrite. Pyrite-oxidation rate increased drastically for particles less than 40 μm. Room-temperature pyrophoric behavior was observed for freshly ground unoxidized pyrite (55 pct minus 5 μm) upon exposure to air. Addition of water-adsorbing materials such as activated alumina (Al_2O_3) decreased the rate of pyrite oxidation.

RI 9060. Clay Veins: Their Occurrence, Characteristics, and Support, by Frank E. Chase and James P. Ulery. 1987. 19 pp. 17 figs. Clay veins found in coal mines have caused numerous injuries and fatalities. These structures plague all phases of mining, including entry development, pillar recovery, and panel extraction. Clay veins also increase production costs and may disrupt or halt mining. These detrimental aspects have prompted the Bureau of Mines to investigate the physical characteristics of and roof instability problems associated with clay veins. This was accomplished by observing and mapping clay veins in surface and underground mines. The occurrence and origins of clay veins were also investigated to determine predictive capabilities. The investigators found that clay veins normally occur in more stable, less rapidly subsiding coal basins. Clay veins result when tensile stresses develop fissures that are later infilled. These fissures can be propagated by compactional processes and/or tectonic stresses during and subsequent to coalification. The Bureau also found that associated faults, fractures, and slickenside planes commonly parallel clay veins and disrupt the lateral continuity of the immediate and, sometimes, main roof. When clay veins parallel or subparallel the direction of face advance, the roof is segmented into cantilever beams, causing unstable conditions. Consequently, the strata on either side of the clay veins should be bolted and strapped together to form a beam.

RI 9061. Method Factors For Anemometer Measurement at Pipe Outlets, by F. Garcia and J. Cervik. 1987. 10 pp. 8 figs. Gob holes are routinely used by the mining industry to vent methane from gobs and to prevent it from entering the mine ventilation system. In some cases, flows from gob holes are measured by centering an anemometer on the end of a discharge pipe. these measurements are erroneous and tend to be high by as much as 30 pct. The Bureau of Mines determined method factors (correction factors) for anemometer measurements taken in this manner. Method factors for 4-, 6-, and 8-in (10.2-, 15.2-, and 20.3-cm) ID pipe are 0.68, 0.71, and 0.78, respectively. Comparisons between horizontal and vertical flows indicated no significant change in method factors. Consequently, the method factors for horizontal pipe flows can be applied to vertical upward flows.

RI 9062. Coal Mine Hazard Detection Using In-Seam Ground-Penetrating-Radar Transillumination, by Maureen M. Foss and Richard J. Leckenby. 1987. 27 pp. 28 figs. Underground coal mining is hazardous due to changing geological conditions. One geophysical method showing promise for in-seam hazard detection is ground-penetrating radar (GPR). The Bureau of Mines recently completed preliminary studies to demonstrate the feasibility of using GPR for in-seam hazard detection. Investigations included air and coal tests for the purpose of checking equipment accuracy, coal penetration, and other factors such as the effects of receiver orientation. Further investigations involved using both a short pulse and a new prototype synthetic-pulse system to locate a clay vein in a coal seam using transillumination. Data were gathered on multiple travel paths, and a back projection processing technique was then used to create a tomographic image using the calculated velocities. A computer model of the same coal seam was subsequently processed using the same tomographic technique, and the results were compared with those of the actual data. Analysis of the tomographic images shows the presence of the clay vein, although its boundaries are unclear due to the tomography method used. Results of these preliminary studies show that GPR is feasible for use in in-seam hazard detection and point the direction that future research should take. A need has been shown for research involving more sophisticated tomography techniques, transmission studies on thicker coal seams, and reflection studies using the synthetic-pulse system.

RI 9063. Methane Contents of Oil Shale From the Piceance Basin, CO, by S. J. Schatzel, D. M. Hyman, A. Sainato, and J. C. LaScola. 1987. 32 pp. 23 figs. The Bureau of Mines determined the gas contents of 135 oil shale samples obtained from approximately 630 ft of core drilling. Drilling was done within a projected mining zone of the Cathedral Bluffs Mine, located in the Piceance Basin of western Colorado. Methane contents were determined by the modified direct method, which can measure the volumes of several gases released from or reacted with mine rock without destructive sample treatment. Over the duration of the test, nitrogen was largely unreactive, CO_2 increased slightly, oxygen decreased markedly, and methane increased more than the total increase of all contained gases. The gas volumes were normalized per unit sample mass and are given in cubic centimeters per gram. Common time indices for test duration of 3, 40, and 125 days were used to compare methane desorption among samples. The means of the sample populations for these indices were 0.0316, 0.114, and 0.195 cm^3/g, respectively. These quantities are lower than those reported in a Bureau emissions study at the Horse Draw Mine in the Piceance Basin. Oil shale samples that were gas enriched beyond the mean methane contents frequently contained bitumens and pyrite.

RI 9064. Thermodynamic Properties of Two Manganese Silicates, Pyroxmangite and Fowlerite, by K. O. Bennington, R. R. Brown, H. E. Bell, and R. P. Beyer. 1987. 22 pp. 7 figs. The thermodynamic properties of two manganese silicates pyroxmangite and fowlerite (zincian rhodonite) were experimentally determined by the Bureau of Mines. The standard enthalpies of formation were determined by hydrofluoric acid (HF) solution calorimetry, the low-temperature heat capacities by adiabatic calorimetry, and the high-temperature heat capacities by differential scanning calorimetry over the range 322 to 1,372 K. These experimentally determined values were combined with data from the literature to calculate the Gibbs energies and equilibrium constants of formation over the temperature range of the measurements. Standard enthalpies, Gibbs energies, and equilibrium constants of formation are given as a function of temperature from both the elements and the constituent oxides.

RI 9065. Preparation of Titanium Feedstock From Minnesota Ilmenite by Smelting and Sulfation-Leaching, by R. H. Nafziger and G. W. Elger. 1987. 13 pp. 1 fig. As part of its program to help decrease the dependency of the United States on foreign imports of nonfuel minerals and to devise technology for the efficient and economic use of domestic resources, the Bureau of Mines smelted and sulfation-leached an ilmenite from northern Minnesota. The objective was to assess the feasibility of preparing chlorination-grade titanium feedstock. The concentrate was smelted with woodchips, coke, and soda ash in 91-kg- and 1-metric ton (mt)-capacity electric arc furnaces to form Ti-rich slag and commercial-grade pig iron. The slag contained from 67 to 77 wt pct titanium oxides and from 1.8 to 7.2 wt pct iron. Sulfation occurred in a 4.5-kg/h moving-bed reactor using SO_2-air mixtures at temperatures of 800° to 850° C to form soluble salts of the Ca, Mg, Mn, and Na impurities, which cause plugging of fluidized-bed chlorinators. Subsequently, the sulfated slag was leached in acid to remove the soluble sulfates. The final product from small-scale testing contained up to 95.5 wt pct TiO_2, a minimum of 0.6 wt pct Fe, and a minimum total of 0.3 wt pct of the four impurities of interest. The final product meets charge specifications for chlorination. However, more large-scale testing is necessary. This report is based upon work performed under a Memorandum of Agreement between NICOR Mineral Ventures and the Bureau of Mines.

RI 9066. Pillar Load Transfer Associated With Multiple-Seam Mining, by R. J. Matetic, G. J. Chekan, and J. A. Galek. 1987. 23 pp. 25 figs. The Bureau of Mines, as part of a program to improve mine planning and development, is currently investigating the effects of pillar load transfer, which can impact mining operations within a multiple-seam configuration. At two minesites where such ground interactions were present, the Bureau performed a complete geological analysis

and installed and monitored instrumentation to gather pertinent data on rock mechanics. Overburden depth varied dramatically in the vicinity of the study area and reached a maximum at the study site; innerburden thickness was less than a pillar width (40 to 45 ft); heaving was experienced in both mines where sandstone and/or shale floor units were observed; overlays of the mine layouts show pillars were not totally superpositioned; a maximum of 5 in of roof to floor convergence was measured; and pressure readings indicated pillar core loading only and increased to a maximum of 7,000 psig over instrument setting pressure.

RI 9067. Bolt Anchorage With Gypsum-Plaster Water Capsule Cartridges, by J. E. Fraley and M. O. Serbousek. 1987. 23 pp. 29 figs. Full-column anchored resin bolts were first used in underground mines in 1972. These bolts appear to improve support in many roof bolt applications, as indicated by the use of about 30 million resin bolts in 1980. In the mid-1970's, Bureau of Mines investigators began looking for a substitute for resin because of its short supply and rapidly increasing price. The investigators selected accelerated gypsum plaster ($CaSO_4 \cdot \frac{1}{2}H_2O$), which becomes gypsum ($CaSO_4 \cdot 2H_2O$) when mixed with water. Gypsum makes an effective alternate grout material because it hardens quickly, is readily available, and is inexpensive in comparison with other cementitious materials. The Bureau received a patent (U.S. patent 4,096,944) for a system combining water capsules (wax-encapsulated water) with plaster into cartridges resembling resin cartridges. This report presents the results of tests conducted by the Bureau on the plaster, the water capsules, and their combined use in cartridges. The tests were designed to determine how the gypsum-plaster water capsule bolting system performs and what happens in the hole while the bolt is being inserted through the cartridge. The test results indicate that water capsule plaster cartridges are a workable alternative to resin cartridges under normal or dry conditions.

RI 9068. Damping Properties of Selected Steels and Cast Irons, by A. Visnapuu, R. W. Nash, and P. C. Turner. 1987. 15 pp. 5 figs. Excessive noise and high vibration are inherently associated with equipment used in the mining, extraction, and processing of mineral resources. High vibration degrades structural components, often leading to catastrophic failure and loss of productivity, and excessive noise can result in permanent hearing loss. In order to foster efficient utilization of the Nation's mineral resources and minimize occupational hazards associated with mineral processing, the Bureau of Mines investigated the relationship between the microstructures of carbon and alloy steels and cast irons and their damping capacities (ability to absorb vibration). Researchers measured damping capacity and other properties and investigated the effects of carburizing, spheroidizing, and annealing. The investigators found that in carbon and alloy steels, rounded colonies of fine-grained pearlite in a ferrite matrix correlate well with low damping capacity. Steel microstructures that exhibit sharp-faceted pearlite in ferrite matrix and partially or fully spheroidized cementite in ferrite show considerably higher damping. In cast irons, the lowest damping capacity is associated with nodular graphite microstructure, and the specific damping capacity (SDC) increases as the graphite microstructure progresses from nodular to compacted to flake. Predominant ferrite in cast irons is also associated with good damping. SDC data are presented for selected carbon and alloy steels and cast irons.

RI 9069. Fugitive Dust Control for Haulage Roads and Tailing Basins, by Keith S. Olson and David L. Veith. 1987. 38 pp. 20 figs. During 1982 and 1983, the Bureau of Mines concentrated its fugitive dust control research on haulage road dust suppression by newer chemicals relatively unknown in the mineral industry, innovative dust control designs for haulage trucks, chemical tailing basin stabilization, and combined chemical and vegetation tailing basin stabilization. Relatively unknown dust suppression chemicals and innovative aerodynamic modifications to haulage truck fender designs were tested on a Minnesota sand and gravel operation haulage road. Magnesium chloride salt at 95-pct control efficiency and a petroleum derivative at 70-pct control efficiency were effective in suppressing dust generated by haulage vehicles; however, none of the fender modifications were successful. Commonly used dust suppressant chemicals were tested on a Minnesota taconite tailing basin to reduce the dust lift-off during the spring and fall dry seasons. The most successful chemical was lignin sulfonate with a seasonal cost of less than $200 per acre to achieve 90-pct dust control. When chemical treatments for immediate dust control were combined with revegetation for permanent control, the most promising chemical treatment based on vegetation response was lime-neutralized lignin sulfonate.

RI 9070. Fine Grinding of Coal by the Turbomilling Process, by E. G. Davis. 1987. 8 pp. 3 figs. As a result of interest by the U.S. Department of Energy, the Bureau of Mines conducted studies on comminution of bituminous coal to the 2-μm particle size range using the Bureau-developed turbomill. Both "plant-grind" size (80 pct minus 75 μm) and microsize (minus 10 μm) coal can be produced in a single step with the Bureau's turbomill. In 15 min, minus 2.4-mm coal milled in water with steel shot was reduced to 65 pct minus 75 μm and 26 pct minus 2 μm, with an energy requirement of 139 kW·h/mt coal. Plant-grind size coal milled in water, with Ottawa sand as the milling medium, was reduced to more than 45 pct minus 2 μm in 15 min, at 175 kW·h/mt. Plant-grind coal milled with steel shot was reduced to 57 pct minus 2 μm in 15 min, at 138 kW·h/mt. When diesel fuel was substituted for water, the milling of the coal was less effective and less energy efficient. Keeping the pulp dispersed was critical. Without an effective dispersant, the slurry became very viscous and increased the milling time, which resulted in higher energy requirements, low heat dissipation, and poor grinding efficiency.

RI 9071. Capability Evaluation of the Radial-Axial Splitter, by S. J. Anderson and D. E. Swanson. 1987. 30 pp. 19 figs. To define the capabilities of a nonexplosive excavation concept, the Bureau of Mines conducted reduced-scale laboratory tests of a mechanical excavation tool called a rock splitter. The splitter investigated was capable of applying combinations of radial and axial loads to rock when placed in a predrilled hole. Experiments conducted with the tool in concrete, limestone, and granite proved it capable of excavating all three materials. Break geometry in these three materials was the same, which encourages the prediction of performance in all rocks. The design of the radial-axial loading splitter's feather components significantly affected the tool's performance. It appears the design of this in-hole component should be tailored for the rock to be excavated.

RI 9072. Continuous Flotation Testing To Recover Cobalt From Missouri Lead Ores, by W. L. Cornell, A. M. Wethington, D. C. Holtgrefe, and F. H. Sharp. 1987. 11 pp. 8 figs. The Missouri lead ores are the only domestic sources of cobalt presently being mined and processed for other materials. They represent the best short-term solution for meeting up to 13 pct of the Nation's strategic and critical cobalt needs from domestic sources. Presently, the cobalt is lost as an impurity in the copper, lead, and zinc concentrates and in the mill tailings because the technology to recover it with minimum impact on present production does not exist. This paper presents results of research, built upon earlier Bureau of Mines laboratory research, to enumerate the problems encountered in cobalt recovery from the copper concentrate under actual mill conditions; to present alternative solutions to these problems; and finally, to describe the best available technology for cobalt recovery within the imposed constraints. Mineralogical analyses showed the cobalt present as a distinct mineral phase, predominately siegenite, amenable to a physical separation method such as froth flotation. Flotation was chosen for

recovery because of easy adaptation by the mills. Unit processes of grinding, conditioning and flotation were studied individually and in concert, and a series of continuous tests were run based on the parameters developed to obtain engineering data for subsequent economic analysis. Overall cobalt grades of 3.00 wt pct at a recovery of 64.0 pct were achieved.

RI 9073. Analysis of Rock Chips Produced During Water-Jet-Assisted Cutting, by A. N. Styler and E. D. Thimons. 1987. 14 pp. 10 figs. As part of its water-jet-assisted rock cutting research, the Bureau of Mines has initiated a study into the mechanism of rock fragmentation by water-jet-assisted mechanical tools. The objective of this research is to increase coal extraction efficiency by seeking an improved understanding of the synergistic relationship between mechanical cutters and water jets, enabling the design of more effective cutterheads. Rock chips collected during laboratory traverse speed jet-assisted cutting tests were analyzed with respect to the size distribution of the chips and the forces measured during cutting. As the water-jet pressure was increased, the size distribution of the product became coarser with V-face-type cutting tools producing less fine material than conical cutting tools. Fracture mechanics theory accounted for less than 10 pct of the energy consumed during fragmentation of the rock. The energy consumed by processes other than rock breakage decreased with the use of water jets and increasing advance rate.

RI 9074. High-Temperature Relative Enthalpies and Related Thermodynamic Properties of CuI, by M. J. Ferrante, R. V. Mrazek, and R. R. Brown. 1987. 10 pp. 1 fig. Relative enthalpies of cuprous iodide (CuI) were measured at the Bureau of Mines to provide thermodynamic data for the advancement of mineral technology. Enthalpy measurements between 298.15 and 1,396.3 K were made with a copper-block drop calorimeter. The temperatures of transition were measured by differential scanning calorimetry. Reversible transitions were determined at 643 K with a standard enthalpy of transition (ΔH°_{tr}) = 0.74 kcal/mol, at 679 K with a ΔH°_{tr} = 0.65 kcal/mol, and at 868 K with a standard enthalpy of fusion (ΔH°_m) = 1.895 kcal/mol. Tabulated values are listed at selected temperature increments from 298.15 to 1,600 K for the standard relative enthalpy ($H^\circ - H^\circ_{298}$), heat capacity (C_p°), entropy (S°), and Gibbs energy function $[-(G^\circ - H^\circ_{298})/T]$. The enthalpy data are also given in the form of equations and combined with thermodynamic data from other investigations to derive values of standard enthalpies of formation (ΔHf°), Gibbs energies of formation (ΔGf°), and logarithms of the equilibrium constants of formation (log Kf).

RI 9075. Arch Canopy Design Procedure for Rehabilitation of High-Roof-Fall Areas, by Richard A. Allwes, C. P. Mangelsdorf, and Deno M. Pappas. 1987. 51 pp. 45 figs. This Bureau of Mines report presents a procedure for the design of an arch canopy for use in rehabilitating a high-roof-fall area. Only dynamic line loading of an unbackfilled arch canopy at its crown is considered, and the procedure does not account for an asymmetrical loading condition. The evaluation of whether an arch canopy is suitable for a particular installation depends on many variables, including in-mine conditions and the engineering properties of the structure. However, a general evaluation can be based on a comparison of the arch's maximum crown deflection and a prescribed allowable crown deflection. The design procedure is based on the concept that when an arch canopy is subjected to impact loading at its crown and deflects from its unloaded state to maximum crown deflection, the structure absorbs strain energy, both elastic and plastic. As a result, this strain energy can be calculated from a static load-displacement diagram for the structure. The significance of this design procedure is that it gives mine personnel an analytical tool to select an arch canopy to meet the dimensional and functional requirements of a mine entry and a prescribed allowable crown deflection.

RI 9076. Calculating Fire-Throttling of Mine Ventilation Airflow, by Charles D. Litton, Maria DeRosa, and Jing-Shu Li. 1987. 21 pp. 13 figs. Tests were conducted in an intermediate-scale fire tunnel and a large-scale fire gallery to determine the effects of fires on the ventilation flow. Results of these tests were applied to a full-scale mine fire conducted in the Bruceton Experimental Mine with very good agreement. The analysis predicts a limit fire size, dependent only upon the passageway dimensions, below which ventilation reductions are significant and independent of fire size. For larger fires a simplified theory, based upon the measurement of CO_2 concentrations, was found to be valid. Continuous monitoring of CO_2 can also provide significant information relative to the fire hazards that result.

RI 9077. Acoustic Emission Monitoring of Fracture Development, by Sterling J. Anderson and Peter L. Ruzzi. 1987. 15 pp. 13 figs. Through the use of nondestructive testing techniques, the Bureau of Mines is pursuing a goal of improving the efficiency of the rock excavation process. Toward this end, 44 laboratory tests were conducted to identify a practical method of monitoring fracture development in rock, as caused by an excavation tool. An acoustic emission (AE) transducer was used to monitor the test samples as they were loaded. The signal from this instrument was recorded in real time along with the radial and axial loads generated by the fracturing device. Through the review of these signals on a common-time base, it was possible to see the relationship between the developing fracture and the loading conditions. As a part of the posttesting investigations, samples that were incompletely fractured were sawn and ground to expose the fractures. Visual examination of these samples allowed approximations to be made of the total surface created. Surface area approximations were also made for the completely fractured samples. Quantitative analyses of the AE signals were conducted for comparisons with the calculated surface areas.

RI 9078. Low-Frequency Vibrations Produced by Surface Mine Blasting Over Abandoned Underground Mines, by David E. Siskind, Virgil J. Stachura, and Michael J. Nutting. 1987. 58 pp. 58 figs. Bureau of Mines researchers assisted the U.S. Office of Surface Mining by studying complaint-producing blasting vibrations resulting from an active surface mine operating over abandoned mine workings beneath the surface mine and the nearby town of Blanford, IN. Bureau researchers analyzed over 500 blasting records collected by the Peabody Coal Co. and the Indiana Department of Natural Resources over a period of 9 months at 7 Blanford residences. To characterize generated and propagated seismic waveforms, the Bureau set up two extended instrument arrays and monitored five production and two specially fired single-charge blasts. Ground vibrations were of high amplitude and dominated by unusual and more structure response-producing low frequencies (4-8 Hz) than in previous studies at other sites. These conditions resulted primarily from the geologic structure as the vibration propagating medium. Either the natural horizontal layering and/or extensive horizontal room-and-pillar network underlying the region were trapping seismic energy and determining its character. Blast designs were partly responsible, with high level casting and complex multidelayed blasts producing wave interaction and constructive reinforcement. The traditional 8-ms criteria for separating charge weights per delay appears insufficient for this low-frequency site.

RI 9079. Spontaneous Combustion Studies of U.S. Coals, by Alex C. Smith and Charles P. Lazzara. 1987. 28 pp. 17 figs. This report describes laboratory studies conducted by the Bureau of Mines on the spontaneous combustion of U.S. coals. Approximately 11 pct of U.S. underground coal mine fires are attributed to spontaneous combustion. The relative self-heating tendencies of 24 coal samples were evaluated in an adiabatic heating oven. Minimum self-heating temperatures (SHT's) in the oven ranged from 35° C for a lignite and

high-volatile C bituminous coal, to 135° C for two low-volatile bituminous coals. An empirical expression was determined predicting a bituminous coal's minimum SHT in the adiabatic oven based on the coal's dry ash-free oxygen content. Several factors that can affect the self-heating process were also evaluated. The self-heating tendency of a coal increased when the coal was dried and exposed to humidified air, and was dependent on the particle size and oxygen concentration of the air. A new moderate-scale apparatus is described, in which the self-heating tendencies of larger coal samples, 3 kg, can be evaluated. The minimum SHT's of two coals were determined, and the results were in good agreement with those found in the adiabatic oven. Finally, results of a test in the moderate-scale apparatus indicated a strong dependence of the self-heating rate of a low rank coal on the moisture content of the air.

RI 9080. Stemming Ejection and Burden Movements From Small Borehole Blasts, by John W. Kopp. 1987. 15 pp. 12 figs. Stemming is used in blasting operations to help contain explosive gases as long as possible. Stemming can reduce airblast, improve fragmentation, and reduce the chances of hot explosive gases igniting methane and dust explosions in underground mines. Stemming is required in underground coal mines but is generally not used in underground metal and nonmetal mines. Some underground metal and nonmetal mines are classified as gassy and can require special blasting procedures such as the use of stemming to insure the safety of miners. The types and amounts of stemming material that are desirable in underground metal and nonmetal mine blasting to ensure good or improved fragmentation while containing the hot gases are largely unknown. This Bureau of Mines research examined the effectiveness of differing lengths of stemming by measuring stemming ejection times as related to burden movement. With properly stemmed blasts, stemming is contained until some burden movement has occurred. Test blasts at two surface limestone quarries were evaluated using high-speed photography. For the conditions of these tests, a stemming length of at least 26 charge diameters was found to prevent premature stemming ejection. In tests with stemming lengths of 16 charge diameters, the stemming was effective but there was early venting of hot gases through fractures in the rock. Further testing with other rock types, hole diameters, explosive types, and stemming materials as they affect incendivity is recommended.

RI 9081. Assessment of Longwall Roof Behavior and Support Loading by Linear Elastic Modeling of the Support Structure, by Thomas M. Barczak and W. Scott Burton. 1987. 7 pp. 8 figs. Longwall roof behavior is characterized by strata displacements in both the face-to-waste (horizontal) and roof-to-floor (vertical) directions. The roof support structure provides resistance to this motion by translation of these displacements into vertical and horizontal support loading. Observations indicate that the shield reacts with both a vertical and horizontal force to uniaxial convergence (displacement). However, there are different magnitudes depending on whether the displacement is vertical or horizontal. This makes it possible to use supports as monitors of strata activity and loading. The Bureau of Mines examined this behavior using a linear elastic model of the support structure with two degrees of freedom. Vertical and horizontal load reactions were related to associated displacement actions of the strata. This was done by determining the stiffness of the shield under controlled vertical and horizontal displacement motions in the Bureau's mine roof simulator. This report provides example predictions of strata convergence and isolation of horizontal support loading due to vertical roof convergence using the linear elastic shield model. The report also examines efforts to determine strata behavior by direct measurement of support displacement.

RI 9082. Cobalt and Nickel From Lead-Smelter Matte: Purification of Leach Liquor, by R. B. Prater, Jr., and Robert M. Doerr. 1987. 24 pp. 7 figs. Research by the Bureau of Mines includes efforts to devise means for maximum recovery of critical and strategic metals from primary and secondary domestic resources. As part of that effort, the Bureau developed a hydrometallurgical process to recover Co, Ni, and Cu from Missouri lead-smelter matte. The process includes leaching with H_2SO_4 plus MnO_2 as an oxidizing agent, liquor purification, selective precipitation of CuS, (Co,Ni)S, and $MnCO_3$, and crystallization of Na_2SO_4. This report is concerned primarily with liquor purification, in which As and Fe are removed from the leach liquor by pH adjustment and filtration. Two variations of the purification step are described. One variation provides liquor containing <1 mg/L As and Fe but requires two solid-liquid separations. The other is achieved with only one solid-liquid separation but leads to a lower degree of purification.

RI 9083. Effects of Stimulation Treatments on Coalbeds and Surrounding Strata. Evidence From Underground Observations, by William P. Diamond and David C. Oyler. 1987. 48 pp. 53 figs. Stimulated vertical boreholes are an effective means of removing gas from coalbeds in advance of mining. This Bureau of Mines report examines the coal mine roof damage potential of stimulation treatments. Twenty-two Government-sponsored stimulation treatments have been mined through to determine the effects on the coalbed and roof strata. Vertical fractures in the coalbed were discernible for most treatments, and horizontal fractures were present for about half of the stimulations. Sand-propped vertical fractures were usually short in lateral extent. Evidence of stimulation fluid movement could generally be traced beyond the maximum extent of sand-filled fractures when fluorescent paint was added to the treatment fluids. The maximum lateral extent for a sand-filled vertical fracture was 416 ft, and a paint-coated vertical fracture extended 630 ft. Horizontal fractures were generally found within bedding planes, most commonly on top of the coalbed. The maximum lateral extent for a horizontal fracture was 265 ft at a coalbed depth of 630 ft. Horizontal fractures have been found to occur as deep as 1,145 ft. Penetration of strata overlying coalbeds was observed in nearly half of the treatments intercepted. Most of these occurrences have been interpreted to be penetrations into preexisting joints. No roof falls or adverse mining conditions were encountered that could be attributed to the stimulations.

RI 9084. Recovery of Cobalt From Spent Copper Leach Solution Using Continuous Ion Exchange, by T. H. Jeffers, K. S. Gritton, P. G. Bennett, and D. C. Seidel, with an appendix on process economics by Thomas A. Phillips. 1987. 17 pp. 7 figs. Significant amounts of cobalt are present in readily accessible spent copper leach solutions. The Bureau of Mines investigated the feasibility of extracting cobalt from these solutions in a multiple-compartment ion-exchange (MCIX) column. The effects of aqueous flow rate, resin flow rate, column height, and compartment height on cobalt extraction were determined. Cobalt extractions of 92 pct or higher were achieved at solution flow rates of up to 5.5 gpm/ft^2 of column cross-sectional area and an aqueous-to-resin flow ratio of 40:1. Overall cobalt extraction increased as the column height increased, but cobalt extraction per unit of length was more efficient in 8- and 12-ft columns than in an 18-ft column. Solvent extraction procedures were utilized to purify and concentrate the MCIX column eluates and produce a cobalt sulfate solution containing 70 to 80 g/L Co. Metallic cathodes containing over 99 pct Co were electrowon from this solution. Zinc, nickel, and copper byproducts were also recovered during processing of the ion-exchange eluates. Estimated total capital cost for a commercial-scale plant processing 10,000 gpm of a spent leach solution containing 26 ppm Co was $29.9 million. With credits for zinc, nickel, and copper byproducts, the estimated net operating cost was $9.36/lb Co.

RI 9085. Fire Tests of Rigid Plastic Ventilation Ducts, by F. J. Perzak, C. P. Lazzara, and T. A. Kubala. 1987. 15 pp. 12 figs. The Bureau of Mines conducted a flammability study

of plastic ventilation ducts. Six rigid 16-in-diam fiberglass-reinforced plastic ducts from five manufacturers were examined using laboratory-scale, large-scale, and full-scale fire tests. The laboratory-scale tests included the American Society for Testing and Materials E162 radiant panel test, the E2863 oxygen index test, and the standardized small-scale flammability test (S^3FT) developed by the Mine Safety and Health Administration, U.S. Department of Labor, and replicated by the Bureau of Mines. Ten-foot lengths of the same ducts were also subjected to a large-scale vertical fire test, and 20- to 30-ft lengths were tested in a full-scale in-mine fire test at the Bureau's Lake Lynn Laboratory mine. The data from the laboratory-scale radiant panel test and oxygen index test indicated that the ducts were fire-resistant. However, five of the six ducts failed the S^3FT and vertical fire tests, and four of the ducts failed the full-scale in-mine tests with flame propagation rates that ranged from 3 to 10 ft/min. The results indicate the need for improved fire-resistant plastic ducts. The good agreement between the S^3FT results and the vertical and full-scale tests show that the S^3FT provides a good indication of the flammability of fiberglass-reinforced plastic ducting under realistic fire conditions.

RI 9086. A Laboratory Comparison of Drag Cutting Methods in Hard Rock, by S. J. Anderson, R. J. Morrell, and D. A. Larson. 1987. 12 pp. 8 figs. The Bureau of Mines compared three methods of rock cutting using drag cutters under controlled laboratory conditions. The methods tested were the conventional drag cutting method used on continuous miners, the kerf-core method used on some boring machines, and an experimental method called ripper cutting. All three methods were tested in blocks of Indiana and Kasota limestone. The results of this testing showed ripper cutting to be 30 to 40 pct more energy efficient than both the conventional and the kerf-core methods in Kasota limestone and 35 pct more efficient than the kerf-core method in Indiana limestone. The conventional method was, however, 9 pct more energy efficient than the ripper method in Indiana limestone. These results are considered promising, and more tests are planned with the ripper cutting system.

RI 9087. Recovery of Critical Metals by Carbonyl Processing, by A. Visnapuu and L. C. George. 1987. 18 pp. The Bureau of Mines investigated carbonyl processing techniques for the recovery of the critical metals Ni, Co, Mn, and Cr from domestic primary and secondary sources. In most cases, the source materials require reductive precarbonylation treatment to metallize the contained Fe, Ni, and Co compounds to render them reactive with CO. The critical metals were recovered either by direct conversion to the respective carbonyls or as upgraded products by carbonyl removal of an undesirable metal. Best metal-to-metal carbonyl conversion was under CO pressure, from 80 atm upward, and at 140° C. Carbonylation was accelerated by the addition of H_2S in small quantities. CO pressure, temperature, promoter and pretreatment trends, and other factors enhancing metal carbonyl formation are presented.

RI 9088. Indices of Mine Safety Resulting From the Application of the Poisson Distribution to Mine Accident Data, by J. C. Kerkering and P. C. McWilliams. 1987. 31 pp. 1 fig. The Bureau of Mines used mathematical reliability theory to define, for use in the mining industry, the concepts of risk, safety, reliability, hazard, and mean time between accidents. In this report, the definitions are explained theoretically and illustrated by application to actual underground mine accident data extending over a 9½-year period. The theoretical development proceeds along two parallel analytical paths. For each line of reasoning, the data are presumed to be independent. If they are not, the analysis stops, although there are interesting implications when dependency is demonstrated. The first method uses the elapsed times between accidents as the basic data. These elapsed times are fitted to a negative exponential distribution function using least squares and yielding the function parameter, P_1. The P_1 is used to form the Poisson distribution function for the data, which is then used to define the safety-related concepts. The second method uses the maximum likelihood estimator to formulate a Poisson distribution function for the data. The function is tested for adequacy by a goodness-of-fit test; if the fit is acceptable, the Poisson function is used to define the concepts. Both methods were applied to the data base, yielding nearly identical results.

RI 9089. Extended Bumper Designs for Large Haulage Trucks, by Stephen A. Swan. 1987. 28 pp. 28 figs. This Bureau of Mines report discusses research to analyze and evaluate extended bumper systems in order to determine the degree of protection provided to equipment operators in the event of rear-end collisions between off-road rear-dump haulage trucks. The basic characteristics of rear-end collisions were determined, and a detailed analysis of the collision dynamics was performed to identify the magnitude and direction of impact loads, the amount of energy that must be absorbed during impact, and the major factors that affect the outcome of a collision. Separate bumper designs were developed to facilitate attachment to four 170-st-capacity haulage truck frame types.

RI 9090. Effects of Barium-Based Additive on Diesel Exhaust Particulate, by H. William Zeller. 1987. 40 pp. 29 figs. The Bureau of Mines performed laboratory research to determine the effects of a barium-based fuel additive on diesel particulate emissions. The test engine was typical of types used to power underground coal mining equipment. Test parameters consisted of baseline measurements without additive, three fuel additive concentrations, and five steady-state engine loads, all at 1,200 r/min. Additive effects on soot mass concentration, opacity, particle size distribution, volatile fraction, and NO_x emissions were determined. Important findings are as follows: Using the manufacturer's recommended additive concentration increased the gravimetrically measured mass of particulate by 30 to 80 pct at four of the five steady-state load conditions. Soot measurements by optical methods did not agree with those by gravimetric techniques, for additive-treated fuels. The additive reduced volatile hydrocarbons adsorbed on filter deposits by up to 50 pct. At most engine loads, carbon particulate was also reduced. About 40 pct of the barium added to the fuel was accounted for in the exhaust. The health implications for miners were considered, but no firm conclusions were drawn or recommendations made because the results are for steady-state conditions, which may not be representative of real-world operation of diesel-powered equipment underground.

RI 9091. Three-Dimensional Shield Mechanics, by Thomas M. Barczak and W. Scott Burton. 1987. 23 pp. 9 figs. This Bureau of Mines report describes research on developing technology to utilize shields as roof load monitors. Three-dimensional equations of static equilibrium are presented for a generic two-legged longwall shield. The equations are presented in the most general form, assuming a force and moment vector at each reaction by rigid-body analysis of the shield mechanics. The resulting system of equations was found to be indeterminate to a very high degree. A three-dimensional solution to measurement of the resultant reaction on the canopy by the strata activity and shield response required the elimination of several forces or moments that were thought to be nonparticipating or to not significantly affect overall shield mechanics. Required measurements for solution of the equilibrium equations were leg, canopy capsule, and lemniscate link forces. Two-dimensional analysis, which considered forces acting only in the roof-to-floor and face-to-waste plane, was also provided by reduction of the three-dimensional equations.

RI 9092. Effects of Ancient Stream Channel Deposits on Mine Roof Stability: A Case Study, by David K. Ingram and Frank E. Chase. 1987. 33 pp. 35 figs. The Bureau of Mines conducted underground mapping and rock strength tests to describe and analyze mine roof conditions surrounding ancient stream channel deposits (paleochannels) in the Pittsburgh Coalbed in southwestern

Pennsylvania. Paleochannels in the study mine consist of sandstone and/or siltstone and affect the Pittsburgh Coalbed through erosion and/or differential compaction. Differentially compacted sediments within and adjacent to channel deposits caused slip planes, faults, clay-dike faults, clastic dikes (clay veins), coalbed rolls, and slumped structures. Paleochannels can be predicted by recognizing these features and associated sediments, which allows for modification of long- and short-term mine planning and development. Mine entries located beneath the paleochannel deposits exhibit less stable roof conditions than entries with normal (nonchannel) roof. Paleochannel deposits comprise only one-fourth of the mapped study area: however, they contain one-half of the hazardous roof. This study determined that rock strength evaluations must be accompanied by underground observations. Suggested remedial support techniques include angled and/or longer tensioned bolts, steel mats or crossbars, steel sets or cribbing, and roof trusses.

RI 9093. Selective Elution of Mercury, Silver, and Gold From Strong-Base Anion-Exchange Resins, by W. L. Staker and R. G. Sandberg. 1987. 9 pp. 2 figs. The Bureau of Mines investigated methods for selectively eluting mercury, silver, and gold from strong-base anion-exchange resins, including Rohm and Haas resins IRA–430 and 900, and Dow Chemical resins 21K, SMA–1, and SBR. Resins were typically loaded to 145 oz/st of each metal. Loaded resins were eluted with H_2SO_4, NaCl–HCl, NaOCl, and $NaClO_4$ solutions. The resins tested had similar elution characteristics for mercury and precious metals. The best selective elution scheme was achieved by eluting in a column with 2*N* H_2SO_4 to recover 99 to 100 pct Hg, with 200 g/L NaCl in 1*N* HCl to recover 99 to 100 pct Ag, and with 2*M* $NaClO_4$ to recover 79 to 89 pct Au.

RI 9094. Leaching of Phosphate Values From Two Central Florida Ores Using H_2SO_4-Methanol Mixtures, by G. M. Wilemon and B. J. Scheiner. 1987. 9 pp. 5 figs. The Bureau of Mines conducted preliminary investigations on the use of an acid-alcohol leaching technique for recovering phosphate values from phosphate matrices. H_2SO_4 and methanol were used as the leaching agents. Starting-matrix particle size and acid-apatite ratio were found to significantly affect the efficiency of phosphate leaching. Phosphate extractions of more than 80 pct were obtained when minus 200-mesh ore was used and the acid-apatite ratio was 8:1 or more. The iron and aluminum oxide impurities (R_2O_3) present in the crude acid products were monitored, and R_2O_3-P_2O_5 ratios are reported. Phosphate extractions in excess of 80 pct also were obtained when phosphatic clay wastes were leached. Typically, leach slurries filtered using test leaf filters exhibited filtration rates of 100 lb/(h·ft²) or more.

RI 9095. A Critique of the Dust Explosibility Index: An Alternative for Estimating Explosion Probabilities, by M. Hertzberg. 1987. 24 pp. 3 figs. This Bureau of Mines report proposes a new methodology for estimating industrial dust explosion hazards in terms of three probabilities or cofactors: The dispersion of the dust, the existence of a flammable dust concentration, and the presence of an effective source of ignition. This method or rationale is proposed as a replacement for the "explosibility index" that was first suggested 25 yr ago, but which, by consensus among leading researchers in the field, is now outdated. This report presents a detailed critique of the deficiencies of that old, material-oriented index, and develops the logical rationale for its replacement by an approach that is better suited for quantitative hazard evaluations. A variety of such evaluations are illustrated that show how a quantitative prediction of explosion frequencies can be obtained from laboratory measurements and operating conditions in a given industrial facility. The method has some pitfalls, particularly as they relate to the correlation of events or their randomness. These are discussed, as well as the method's other limitations and uncertainties. This work is intended to provide a beginning to a quantitative approach to explosion hazard assessment. To that end, a new method is proposed for estimating thermal ignition in terms of the measured laboratory autoignition temperature of a dust, its relationship to the operating temperature, and its distribution within a given industrial system.

RI 9096. Water Infusion for Coal Mine Dust Control: Three Case Studies, by John J. McClelland, John A. Organiscak, Robert A. Jankowski, and B. Rao Pothini. 1987. 17 pp. 9 figs. This Bureau of Mines report discusses recent applications of water infusion technology to control dust in U.S. coal mines and presents recommended guidelines for determining coal seam infusibility. The techniques required to use water infusion are presented in detail. A Bureau case study indicated that water infusion reduced dust levels by 68 pct along a longwall plow face, bringing this section into compliance with the 2.0-mg/m³ Federal dust standard. Similar studies conducted by Occidental Research Corp. under a Bureau contract show that water infusion at two longwall double-drum shearer operations produced dust reductions ranging from 38 to 50 pct. Water infusion was found to be cost effective, averaging 5 cents per ton.

RI 9097. Effects of Turbomilling Parameters on the Comminution of α-SiC, by Jesse L. Hoyer. 1987. 9 pp. 4 figs. A Bureau of Mines turbomill was evaluated for use in the production of high-purity, ultrafine α-SiC powders suitable for advanced ceramics that could substitute for high-temperature alloys containing critical materials such as chromium, cobalt, and nickel. The effect of milling parameters, such as type of dispersant, temperature, pH, and gas environment, on the milling of α-SiC was studied. The addition of dispersants improved the grindability of α-SiC. Of the six dispersants studied, the best results were obtained with Marasperse N–22. Grinding efficiency was also increased when the α-SiC was milled in a basic slurry and at an elevated temperature. Gas environments did not appear to affect grinding of α-SiC. Optimum grinding efficiency was obtained at 50° C in a slurry at pH 9.5 with Marasperse N–22 as the dispersant. Under these conditions, minus 100- plus 200-mesh α-SiC was ground to 80 pct less than 1 μm in 4 h. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

RI 9098. Shield-Loading Studies at an Eastern Appalachian Minesite, by Thomas M. Barczak and Stephen J. Kravits. 1987. 81 pp. 37 figs. A primary objective of the Bureau of Mines geomechanics research program is to develop a better understanding of support behavior and interaction of supports with the strata so that supports can be more closely engineered to the geological conditions in which they are employed. Four longwall shield supports were instrumented with an eight-transducer instrumentation array to measure leg, canopy capsule, and compression lemniscate link forces from which resultant shield loading was determined. The instrumented supports were monitored over a 4-month period, producing over 75 shield cycles of resultant shield loading. Resultant loading is the true measure of support resistance, providing both roof-to-floor and face-to-waste support reactions as well as the location of the reaction on the shield canopy. Observed roof support reactions were analyzed, with particular emphasis on horizontal shield loading, since it is the least understood design parameter. Average, peak, and change in shield loading during the mining cycle are discussed. Correlations among data parameters are examined, as is the distribution of support loading at the headgate and midface. Conclusions are drawn as to the effectiveness of the shield support at this installation. Recommendations are made for further research needs.

RI 9099. Flotation of Silicon Carbide From Waste Sludges, by C. W. Smith, T. O. Llewellyn, and G. V. Sullivan. 1987. 6 pp. 1 fig. The Bureau of Mines conducted laboratory beneficiation tests on four samples of waste granite sludge to devise a method of recovering silicon carbide (SiC). Froth flotation using creosote as a collector in an alkaline circuit resulted in concentrates containing over 91 pct SiC from each of

the samples. Recoveries ranged from 43.1 to 86.6 pct. Single-stage flotation of sample A using a column flotation cell produced a concentrate containing 92.0 pct SiC with a recovery of 71.4 pct. Flotation using petroleum sulfonate as a collector in an acid circuit resulted in a concentrate containing 95 pct SiC from one of the waste granite products with a recovery of 97.5 pct. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

RI 9100. Solubilities of Sideronatrite and Ferrinatrite in the System $Na_2SO_4 - Fe_2O_3 - H_2SO_4 - H_2O$, by C. M. Flynn, Jr., and J. A. Eisele. 1987. 17 pp. 5 figs. The solubilities of sideronatrite [$Na_2Fe(OH)(SO_4)_2 \cdot 3H_2O$] and ferrinatrite [$Na_2Fe(SO_4)_2 \cdot 3H_2O$] were determined by the Bureau of Mines in the Na_2SO_4-Fe_2O_3-H_2SO_4-H_2O system at 25°, 40°, 60°, and 90° C. The solution compositions investigated ranged from Na^+-Fe^{3+} mol ratios of 0.5 to >100 (Na_2SO_4 saturation) and H^+-SO_4^{2-} mol ratios of 0 to 1.0. The results are presented in the form of contour plots. The solubilities were determined by seeding supersaturated solutions of known composition with the specified solid phase to precipitate a substantial amount of solid. Water was then added in small portions to the solution until the last portion of the solid dissolved. Equilibration times at 25°, 40°, 60°, and 90° C were 2 days, 1 day, 8 to 16 h, and 2 to 4 h, respectively. The accuracy of the solubility data is estimated to be 1 to 2 pct. Low iron solubilities of <0.36 pct $Fe_2(SO_4)_3$, or 1 g Fe/kg solution, were obtained in solutions containing at least 8 pct Na_2SO_4 in the absence of H_2SO_4 or a total of at least 36 to 38 pct Na_2SO_4 + H_2SO_4 at high acidity. The filterability and density of sideronatrite and ferrinatrite in comparison with other iron compounds are reported. These compounds are suitable vehicles for iron removal in Na_2SO_4- rich solutions. Additional solubility data on the Na_2SO_4-H_2SO_4-H_2O system were also obtained.

RI 9101. Borehole (Slurry) Mining of Coal, Uraniferous Sandstone, Oil Sands, and Phosphate Ore, by George A. Savanick. 1987. 39 pp. 27 figs. This paper reviews advances in the art of borehole (slurry) mining made by the Bureau of Mines from 1974 to 1980. The design of a prototype borehole-mining tool (BMT) developed by the Bureau of Mines is presented along with production data, reclamation data, and an application of the BMT to the mining of coal, uraniferous sandstone, oil sands, and phosphate ore. The BMT was first used near Wilkeson, WA, where steeply pitching metallurgical coal was mined at 8 st/h from a depth of 25 to 75 ft. Next, 940 st of uraniferous sandstone was mined at 8 st/h from a depth of 75 to 100 ft in Natrona County, WY. One thousand short tons of oil sands was mined in Kern County, CA, at the rate of 14 st/h from a depth of 110 to 150 ft in 1979. Most recently, 1,700 st of phosphate ore was produced at 25 st/h from deep (230- to 250-ft) deposits in St. Johns County, FL. Progressive improvements were made in the borehole mining technique. These include the use of the hydrostatic head of a water-filled borehole for roof support and the development of methods to survey and backfill mined-out cavities.

RI 9102. Accurate Directional Borehole Drilling: A Case Study at Navajo Dam, New Mexico, by S. J. Kravits, A. Sainato, and G. L. Finfinger. 1987. 25 pp. 20 figs. This report describes a project conducted by the Bureau of Mines in which the accurate directional drilling of a borehole was demonstrated with the objective of intercepting a designated target. The project was conducted at Navajo Dam in northern New Mexico at the request of the Bureau of Reclamation. Borehole survey and drill logs are provided in an appendix. The trajectory of the demonstration borehole was designed to intercept a 5-ft-radius target at the final or "punchout" distance of 885 ft. The elevation of the borehole at this distance was within the target; the borehole punchout coordinates were 8.81 ft southwest of the target. As a result of the demonstrated accuracy, the Bureau of Reclamation has contracted the accurate drilling of boreholes as long as 600 ft from the inside of a short tunnel, to control water seepage in the right abutment. This resulted in a substantial cost savings compared to the original plan of constructing a longer tunnel and drilling 150-ft boreholes.

RI 9103. Zeta Potential Control for Simultaneous Enhancement of Penetration Rates and Bit Life in Rock Drilling, by William H. Engelmann, Pamela J. Watson, Patrick A. Tuzinski, and John E. Pahlman. 1987. 18 pp. 7 figs. In pursuit of innovative methods to improve mining productivity, the Bureau of Mines is investigating the use of inorganic salts as drilling fluid additives for penetration enhancement. Laboratory diamond drilling tests were performed on Westerly Granite with aluminum chloride solutions and on Sioux Quartzite with aluminum, aluminum nitrate, calcium, sodium, and zirconium chloride solutions as drilling fluid additives. These drilling results were compared with the average drilling performance using distilled, deionized water on Sioux Quartzite (12 replicate tests) and Westerly Granite (3 replicate tests). Maximum increases in penetration per given time and bit life were obtained when drilling with zero point of charge (ZPC) concentration solutions of each additive. For Sioux Quartzite, maximum increases in penetration and bit life ranged from 96 to 115 pct and 64 to 99 pct, respectively. For Westerly Granite, maximum increases in penetration of 155 and 165 pct and bit life of 109 and 136 pct were obtained at or near ZPC aluminum chloride concentrations of quartz (7.3×10^{-7} mol/L $AlCl_3$) and alkali feldspars (1.1 to 1.5×10^{-6} mol/L $AlCl_3$), respectively. This simultaneous increase in penetration per time together with extended bit life should result in increased productivity and reduced bit costs.

RI 9104. The Character of Five Selected LANDSAT Lineaments in Southwestern Pennsylvania, by Noel N. Moebs and Gary P. Sames. 1987. 25 pp. 31 figs. Five LANDSAT lineaments in the coal mining region of southwestern Pennsylvania were investigated by the Bureau of Mines to determine their geologic character, relation to subsurface conditions, and the means of discriminating one from another. The investigation included earth resistivity and very low frequency electromagnetic traverses, soil moisture sampling, and a correlation with coal mine roof conditions. The lineaments could not be detected by the methods used, suggesting that they might be a surface phenomenon unrelated to subsurface geologic structures or roof stability in coal mine workings beneath.

RI 9105. Fumes From Shielded Metal Arc Welding Electrodes, by J. F. McIlwain and L. A. Neumeier. 1987. 18 pp. 8 figs. The Bureau of Mines has investigated fumes generated by selected welding electrodes used in mines in order to help determine their relative health hazard potential. Fumes were generated and collected in an enclosed chamber for subsequent generation rate and chemical constituent determination. Shielded metal arc electrodes from the following groups were tested: AWS types E308–16 and E310–16 stainless steel, ECoCr-A Co-Cr hardfacing alloy, ENiCI Ni, an Mn-Cr buildup alloy, E7018 carbon steel, and E11018–M low-alloy steel. Flux-cored wire electrodes of this last group also were tested. Fume generation rates and the chemical composition of the fumes were measured. From these data, exposure indices were determined, which give a relative measure of the health hazards potential of using the electrodes. The effect of welding onto buildup alloy layers on the fume composition also was examined for five of the higher alloy groups.

RI 9106. An Investigation of Crack Propagation With a Wedge Indenter To Improve Rock Fragmentation Efficiency, by D. A. Larson, R. J. Morrell, and J. F. Mades. 1987. 28 pp. 26 figs. The Bureau of Mines conducted basic experiments to study the process of crack propagation with a wedge indenter. The work was conducted under plane stress conditions in a hard, brittle limestone. The purpose of these experiments was to first gain an understanding of the basic crack propagation process under a sharp indenter, and second, to determine how the crack propagation process could be used to improve mechanical fragmentation systems. Three methods of rock fracture with the wedge indenter were investigated in this program. These were the confined indentation tests, the unconfined splitting tests, and the edge chipping tests. The confined indention tests represent worse case conditions for crack growth, and formed the lower bound on fracture efficiency. The unconfined splitting tests represented best case conditions and fixed the upper bound of fracture efficiency. The edge chipping tests represented an idealized fragmentation process based exclusively upon the highly efficient fracture propagation process. Edge chipping achieved a specific energy of 25 in·lbf/in^3 compared with conventional drag cutters, which required a specific energy of at least 2,385 in·lbf/in^3. Thus edge chipping is up to 100 times

more efficient than conventional drag cutting. Because of these promising results, more work is planned with the fracture propagation process in three dimensions.

RI 9107. A Photographic Method for Determining Mineral Reflectances in Underground Mines, by Alan G. Mayton. 1987. 14 pp. 8 figs. The Bureau of Mines conducted a study to (1) determine from laboratory tests the feasibility of a photographic method for determining reflectances that may be applied to measuring in-mine mineral reflectances and (2) formulate a procedure for collecting and analyzing the data. The method uses a 35-mm camera with automatic flash and a gray-scale reflectance standard to collect on film reflectivity data in underground mineral mines. After the film is processed, the data on the photographic prints are analyzed in the laboratory with a photometer. Test results show that the photographic method can provide values of reflectance within ±5 pct of full scale (full scale = 100 pct). The method's usefulness for determining reflectivity values within similar limits of absolute percent error at the lower end of the scale, however, has not been completely resolved by the study and consequently warrants further investigation. The method offers an acceptable means for collecting and analyzing reflectivity data for reflectivities at the higher end of the scale, i.e., 50 pct or above; it should be used with caution when reflectivity values are below 50 pct. Four films were evaluated; all gave relatively satisfactory results.

RI 9108. Field Measurement of Rock Displacement During Sinking of a Deep Rectangular Shaft, by J. K. Whyatt and M. J. Beus. 1987. 12 pp. 11 figs. The Bureau of Mines, under a cooperative agreement with Callahan Mining Corp., measured rock displacement at the 4,750-ft level of the 5,100-ft-deep rectangular, timbered Caladay Shaft in northern Idaho. Displacements were measured with multiple-position borehole extensometers installed 4 ft above the face and timber extensometers installed with the timber sets. This report presents the displacement data along with preliminary, qualitative observations of rock behavior. The measured displacements showed an instantaneous response to shaft sinking and significant time dependency. The relative magnitudes of displacement measured at the shaft walls were heavily influenced by local geologic structure and distance from the shaft bottom.

RI 9109. Mechanical Behavior of Coal Measure Rocks: Elastic-Inelastic Behavior, by Sathit Tandanand and Richard E. Thill. 1987. 27 pp. 21 figs. A safe working environment can be provided for underground coal miners through implementing new ground control technology. To devise a practical method for stability design of underground rock structures in coal mines, the Bureau of Mines has examined the time-independent behavior of coal measure rocks in uniaxial and triaxial compression tests. These rocks exhibit work hardening before failure. Their stress-strain relationship can be expressed by a hyperbolic equation similar to that for soils. The behavior of rocks at failure can be regarded as the limit of work hardening. To simplify the stability design for temporary rock structures, rock behavior may be idealized as perfectly plastic for stability analysis of roof, ribs, and floor in underground coal mines, although such idealization does not strictly represent the real inelastic behavior of rocks.

RI 9110. Recovery of Phosphate From Florida Phosphate Slimes, by B. E. Davis, E. G. Davis, and T. O. Llewellyn. 1987. 13 pp. 4 figs. The Bureau of Mines conducted tests on samples of two Florida phosphate slimes to devise a technique to recover phosphate currently discarded because of its fine size. A flotation technique was devised to recover the phosphate contained in two fractions of each slime: the plus 37-μm fraction and the plus 20-μm fraction. The technique involved conditioning the flotation feed with sodium silicate and a fatty acid-fuel oil emulsion, floating a rougher phosphate concentrate, and cleaning the concentrate in two cleaner stages with sodium silicate added to each for gangue depression. Concentrates containing 21.0 to 32.3 pct P_2O_5 were produced with recoveries of 68.1 to 84.2 pct of the P_2O_5 contained in the flotation feed. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

RI 9111. The Effect of Different Natural Flake Graphite Additions on the High-Temperature Properties of a Dolomite-Carbon Refractory, by James P. Bennett. 1987. 12 pp. 11 figs. The Bureau of Mines investigated the role of imported natural flake graphite in dolomite-carbon refractories used in steelmaking processes. Fundamental engineering data were obtained to enable the evaluation of substitute materials. Changes in oxidation resistance (2,000° F), hot strength (2,750° F), and deformation under load (2,750° F) caused by 10-wt-pct additions of five different kinds of natural flake graphite and increasing quantities (0 to 30 pct) of a 90-pct-carbon natural flake graphite were studied. Results indicated that carbon purity of 10-wt-pct-graphite additions did not influence hot strength deformation under load. When the quantity of 90-pct-carbon graphite addition varied between 0 and 30 wt pct in a dolomite-carbon brick, hot strength was highest and deformation under load lowest with 10-wt-pct additions. As hot strength test temperature was increased from 500° to 2,750° F, the strength difference observed between 0- and 30-wt-pct additions of a 90-pct-carbon graphite became smaller. Additions of a boron-treated graphite caused significantly higher strength and lower deformation under load at high temperatures, while an addition of ball clay significantly reduced strength and increased deformation. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

RI 9112. Bit Wear-Flat Temperature as a Function of Depth of Cut and Speed, by C. F. Wingquist and B. D. Hanson. 1987. 15 pp. 8 figs. As part of an ongoing study to determine how the wear of mining tools affects dust generation, the Bureau of Mines has measured bit temperature rise during cutting of abrasive rock. Radial bit wear-flat temperatures generated by linear cutting in Berea Sandstone were measured as a function of cutting depth and speed. Depths of cut (DOC) were ⅛, ¼, and ½ in, and cutting speeds were 10, 40, and 80 in/s, respectively. Temperature sensing was accomplished by emplacement of a miniature thermocouple into the center of the wear flat. Temperatures observed ranged from 200° to 500° C. Correlation between depth and temperature was weak. Temperature increased linearly with speed at ½-in DOC, but data taken at ⅛- and ¼-in DOC produced inconclusive results. The results indicated that, at least for deeper cuts (½ in), bit temperature, and therefore wear, can be reduced by lowering the cutting speed.

RI 9113. Gas Content Determinations of Salt Samples Using Acoustic Responses, by Thomas E. Marshall and Gerald L. Finfinger. 1987. 10 pp. 5 figs. The Bureau of Mines has developed a practical methodology for determining occluded gas contents of domal rock salt samples. The method, which is portable and fieldworthy, provides results in 5 min or less and does not require a laboratory environment or specially trained personnel to obtain meaningful results. The results can be used to identify gas-enriched zones, and thus may aid mine operators in production planning or ventilation design. The test method is based on the relationship between gas content and the acoustic response of salt samples as they are dissolved in water. The relationship is defined by an equation, and the results are repeatable. The equation was derived by testing a series of rock salt samples collected from domal salt mines in Louisiana.

RI 9114. Probability of Resistive Spark Ignition Caused by Very Low Currents, by James C. Cawley. 1987. 11 pp. 9 figs. The Bureau of Mines has empirically determined ignition probability versus current for resistive circuits in an 8.3% methane-air atmosphere. Simple ignition probability, defined as the number of ignitions divided by the total number of sparks, was determined, and the corresponding currents were recorded. The experiment was designed to minimize the probability of not observing an ignition that should occur during a series of tests. For resistive circuits in 8.3% methane-air mixtures, the experimental results indicate that ignition was not achieved below 2,000 mA at 20 V dc, 350 mA at 30 V dc, 150 mA at 40 V dc, and 175 mA at 50 V dc. The simple probability of ignition corresponding to these currents is estimated to be, respectively, 1.0×10^{-6}, 1.7×10^{-7}, 3.0×10^{-7}, and 1.0×10^{-5}. The ignition mechanism seems to break down below this point, implying that a threshold current value exists below which spark ignition does not occur.

RI 9115. Effects of Composition and Processing Variables on Transverse Rupture Strength and Hardness of Nickel-Alloy-Bonded Titanium Carbide, by G. T. Fisher II, L. L. Oden, and G. Asai. 1987. 25 pp. 12 figs. The material requirements of carbide cutting tools for machining steel and cast iron are dependent on tungsten carbide (WC) bonded with Co, with additions of TaC and TiC. The Bureau of Mines is conducting

research to devise substitute materials, based on Ni-alloy-bonded TiC, for C-5-grade cutting tool applications. This substitution would result in less dependence on foreign sources for Co, Ta, and W, and use of lower cost materials. In this preliminary study, the Bureau investigated the effects of composition and processing variables on the transverse rupture strength and hardness of Ni-alloy-bonded TiC to identify compositions that exhibit promising mechanical properties. Further systematic modification of these compositions by solid-solution strengthening additions would subsequently be evaluated to obtain cutting tool materials with requisite properties and performance for C-5 applications. Compositions for evaluation were prepared by a powder metallurgy method of cold-pressing and liquid-phase sintering. Complementary analysis of compositions included chemical analysis, X-ray diffraction, energy-dispersive X-ray spectroscopy, and density measurements. Based on results of this investigation, promising compositions were determined to be 59.37TiC-25Ni-5Mo-10.63Mo_2C, 59.68TiC-25Ni-3.33Mo-1.77Mo_2C-6.67W-3.55WC, and 59.35TiC-25Ni-1.67Mo-3.54Mo_2C-3.33W-7.1WC.

RI 9116. Sampling, Characterization, and Evaluation of Midwest Clays for Iron Ore Pellet Bonding, by Larry A. Haas, Jeffrey A. Aldinger, Rolland L. Blake, and Stephen A. Swan. 1987. 44 pp. 10 figs. The Bureau of Mines, in cooperation with three Minnesota agencies (Department of Natural Resources, Geological Survey, and the Iron Range Resources and Rehabilitation Board), investigated the potential of using glacial lake clay from Minnesota, as well as other areas, as a binder for iron ore pellets. The best clay-characterizing procedures for predicting binder effectiveness were the cation exchange capacity using the methylene blue method and the plate water absorption test. The best clay binder was found in the Red River Valley. However, compared to a typical western bentonite at the 0.5-pct-addition level, addition of about 2 pct Minnesota clay was required to obtain comparable unfired (green) pellet strengths. Soda ash addition only slightly improved the binding properties of Minnesota clay, but considerable improvement was obtained by the addition of a small quantity of water-absorbing organic coumpounds. For example, with a mixture of 0.5 pct Minnesota clay or paint rock and 0.1 pct pregelatinized starch, the unfired and fired physical pellet properties were about the same as with 0.5 pct of typical western bentonite. The reduction rate at the 40-pct reductior level and the percentage of plus 6.3-mm particles from the reduction disintegration index test were also about the same.

RI 9117. Analysis of Cutter Roof Failure Inducted by Clastic Dikes in an Underground Coal Mine, by Eric R. Bauer and John L. Hill III. 1987. 23 pp. 29 figs. Cutter roof failure, a ground control problem that frequently results in massive roof failure, is common in coal mines of the Northern Appalachian Coal Basin, causing delays in production and posing a safety hazard to mine personnel. The Bureau of Mines is conducting research on the causes of cutter roof failure to gain a basis from which to predict and prevent its occurrence, and to support such roof when failure occurs or is imminent. Research conducted at the Greenwich Collieries North and South Mines in central Pennsylvania revealed a correlation between the presence of clastic dikes and formation of cutter roof failure. The research consisted of in-mine mapping of geologic and deformational features, rock pressure monitoring, core recovery and evaluation, and in situ stress measurement. It was found that roof failure increased in areas where the occurrence of clastic dikes was most frequent, especially where two or more clastic dikes intersect. Staggering of crosscuts prevented the extension of cutters and deterred the occurrence of large falls extending over several breakthroughs. In additon, trusses and cribbing were effective in stabilizing clastic dikes and inhibiting the development of cutter roof failure when employed immediately or shortly after mining.

RI 9118. Analysis of the Oxidation of Chalcopyrite, Chalcocite, Galena, Pyrrhotite, Marcasite, and Arsenopyrite, by G. W. Reimers and K. E. Hjelmstad. 1987. 16 pp. 8 figs. Conditions in the underground mine environment can cause self-heating of sulfide ores as a result of exothermic oxidation reactions, which may result in mine fires. This Bureau of Mines report describes thermal analyses of finely ground chalcopyrite, chalcocite, galena, pyrrhotite, marcasite, and arsenopyrite to characterize their responses under oxidizing conditions. Thermal gravimetric analysis and differential thermal analysis were used in the temperature range 100° to 500° C. Chalcopyrite showed an initial weight gain due to formation of sulfates, a weight loss caused by ignition of iron sulfide to iron oxide, and a final weight gain, indicating the conversion of copper sulfide to sulfate. Chalcocite did not ignite in the temperature range studied but exhibited a rapid weight gain because of the rapid conversion of copper sulfide to sulfate. Likewise, galena failed to ignite but underwent a steady weight gain when oxidized in a moist atmosphere, showing conversion of lead sulfide to sulfate below the ignition point. Marcasite underwent a rapid weight loss, indicating ignition, at 200° C. Moisture in the oxidizing atmosphere lowered the ignition point of marcasite and arsenopyrite but not that of pyrrhotite. All the sulfides exhibited exothermic behavior at temperatures below the ignition point.

RI 9119. Pioneering Studies on the Flotation of Corundum From a Montana Gneiss, by C. W. Smith and T. O. Llewellyn. 1987. 4 pp. The Bureau of Mines conducted laboratory-scale beneficiation tests on a sample of corundum gneiss from Montana to devise a method for beneficiating corundum for use as a substitute for refractory-grade bauxite. A flotation process utilizing petroleum sulfonate as the collector in an acid circuit was devised. Results showed that two flotation schemes each produced a concentrate exceeding the national stockpile specifications for calcined bauxite. From a feed containing 28 pct corundum, concentrates containing up to 92.5 pct alumina (Al_2O_3) were produced with a corundum recovery of 78.5 pct. This report is based upon work done under an agreement between the University of Alabama and the Bureau of Mines.

RI 9120. Numerical Prediction of Cobalt Sorption in a Continuous Ion-Exchange Column, by K. S. Gritton and T. H. Jeffers. 1987. 13 pp. 12 figs. The Bureau of Mines investigated the feasibility of numerically modeling the sorption of cobalt, a vulnerable strategic and critical metal, from spent copper leach solutions in a multiple-compartment ion-exchange (MCIX) column. Equilibrium resin loadings, cobalt-sorption kinetics, and resin-fluidization characteristics were determined in simple laboratory tests, and a numerical model was developed to predict cobalt extraction and the MCIX-column resin inventory based upon the test results. The model was implemented on a microcomputer to approximate the solution to the set of differential equations that govern model performance. Results compared very well with data from 12 pilot-scale MCIX-column experiments. The average difference between predicted and actual cobalt extractions was 3.2 pct; the maximum difference was 9.3 pct. The actual and predicted resin inventories differed by an average of 5.8 pct, and the maximum difference was 12.0 pct.

RI 9121. Column Length Criteria for Resin Bolting in Evaporites, by W. C. Smith and R. M. Stateham. 1987. 20 pp. 22 figs. This Bureau of Mines report discusses how pull-test data can help establish polyester resin column length criteria for roof bolts in evaporite minerals. The study evaluates the effectiveness of partial to full columns of resin in anchoring 4-ft, No. 6, grade 40 rebar roof bolts in potash, salt, trona, gypsum, and borate mine roofs. Pull tests were performed on over 600 roof bolts in 11 evaporite mines. Column lengths ranging from 6 to 48 in (fully grouted) were evaluated for each test site. In general, comparative results among all test sites indicate that pull-out loads in excess of 10 tons (force) were attained with resin-grouted bolts having 13 to 75 pct less than a full column of polyester resin. Ten tons (force) of load-carrying capability compared favorably, in terms of strength, with the calculated yield strength of the rebar used in the tests, which was 8.8 tons (force). The site-specific nature of each test site, due to the unique combinations of geology, mine-induced stresses, and other unknown parameters, prevented the establishment of valid generic column-length criteria. For these reasons, data to evaluate resin-column-length effectiveness are best obtained on a mine-specific basis.

RI 9122. Silver-Catalyzed Oxidative Leaching of an Arsenical Copper Sulfide Concentrate, by K. P. V. Lei and T. G. Carnahan. 1987. 14 pp. 8 figs. The Bureau of Mines investigated a silver-catalyzed oxidative procedure for leaching an arsenical copper sulfide concentrate containing 10 pct As and 32 pct Cu. Currently, there are no environmentally safe means to treat arsenical copper concentrates in the United States. Leaching was conducted in a 2-L autoclave reactor. The effects of catalyst concentration, O_2 pressure, temperature, and H_2SO_4, Cu, As, and Fe concentrations in the leaching solution on extractions of metals from the concentrate were determined. The best leaching conditions for extracting 95 pct Cu and As and less than 21 pct Fe were 260 g/L concentrate, 0.007 mol/L (1.0 g/L) AgCl, 3.0 mol/L (294 g/L) H_2SO_4, 100° C, 60 psig O_2, and 6 h. Copper as $CuSO_4 \cdot 5H_2O$ was recovered by crystallization from the

pregnant solution. Arsenic, as As_2O_3, was recovered from the copper mother liquor by solvent extraction, with tributyl phosphate, SO_2 reduction of As^{5+} to As^{3+} in the strip solution, and crystallization of the As^{3+}. The silver catalyst was recovered by contacting the leached residue with a brine solution. A conceptual scheme is proposed for treating arsenical copper sulfide concentrates.

RI 9123. Large-Scale Testing of the Ripper Fragmentation System, by David A. Larson, Roger J. Morrell, and David E. Swanson. 1987. 18 pp. 9 figs. This is the second in a series of Bureau of Mines reports that describe experiments designed to devise an efficient, economic mechanical fragmentation technique for hard rock. The previous study described the development of the ripper cutting technique to successfully cut hard rock with 3- to 6-in-wide drag cutters. This study was conducted to test the ripper cutting technique at full scale using 9-in-wide drag cutters. The experiments were conducted with a special test device that cut shallow, 6- by 6-ft openings in 9,200-lbf/in^2 compressive-strength concrete blocks. The tests showed that ripper cutting can excavate large-scale openings of the type required by the mining industry at a production rate that outperforms the conventional drill-blast technique. Moreover, the system can produce openings of various sizes and shapes, is simple to operate and maintain, and produces very little dust or noise during operation. The system appears to meet all of the criteria for a successful hard-rock mining machine.

RI 9124. Development of Rapid-Setting Inorganic Grouts, by J. E. Fraley and J. E. Bevan. 1987. 20 pp. 8 figs. This report describes the preliminary results of a Bureau program to develop and test an inexpensive grout for full-column support of roof bolts. Various inorganic grouts were tested in both cartridge and slurry form. Tests were also performed on methods of water packaging and on the effect of fillers on the grout strength. Results showed that some grouts had poor early strength and exceptional mid- to long-term strength. Laboratory tests have shown that rapid-setting inorganic grout could be an economical replacement for resin bolts if the short-term strength could be increased. Further development to improve its early strength would need to be tested in the laboratory and underground to prove its potential for the mining industry.

RI 9125. Nonferrous Waste as a Source of Zinc for Electrogalvanizing, by E. R. Cole, Jr., M. Dattilo, and T. J. O'Keefe. 1987. 20 pp. 12 figs. One objective of Bureau of Mines recycling research is to devise technology that enables recovery of metals and minerals from wastes. From October 1982 through September 1985, researchers at the Bureau and at the University of Missouri—Rolla (contract H0222002) investigated the use of nonferrous flue dust with varying Zn contents (11 to 66 pct) as a source of Zn for electrogalvanizing steel wire. The waste dusts used were from a secondary Cu smelter, a brass smelter, a Pb smelter, and a water treatment plant. The dusts were leached in H_2SO_4, and the leach solutions were treated to make electrolyte for electrogalvanizing steel wire using soluble Zn anodes. Cyclic voltammetry was used in an innovative method to evaluate the quality of the electrolytes used for electrogalvanizing. After electrogalvanizing, the wire was drawn on a laboratory draw bench to simulate industrial practice. Corrosion resistance was measured by a number of electrochemical techniques and by the standard ASTM salt-spray tests. After successful bench-scale tests, the process was demonstrated in an industrial pilot plant. Results indicate that nonferrous flue dusts can be used as a source of Zn for electrogalvanizing if certain impurities are either partially or completely removed from the starting electrolyte.

RI 9126. Dual Leaching Method for Recovering Silver and Manganese From Domestic Manganiferous Silver Deposits, by John E. Pahlman, Charles A. Rhoades, and Peter G. Chamberlain. 1987. 8 pp. 3 figs. The Bureau of Mines has conducted research on a dual leaching method that offers the potential for the economic recovery of the silver and manganese contained in some domestic manganiferous silver deposits. The method consists of an initial leach of manganese with aqueous sulfur dioxide (SO_2) followed first by a neutralization rinse, and then by a second leach with cyanide solution for the extraction of silver. Refractory silver in these ores was either (1) intimately associated with the manganese, (2) chemically resistant to cyanide leaching, or (3) rendered inaccessible to cyanide leach solution by the surrounding manganese mineralization. Less than 10 pct of the silver was extracted when minus 2.5- plus 1.3-cm ore pieces were leached directly with cyanide. However, extractions of 25 to 82 pct of the silver and 65 to 96 pct of the manganese were attained in laboratory column-leach tests using the dual leaching method on equivalent-sized ore pieces from seven domestic deposits.

RI 9127. In Situ Comparison of Radial and Point-Attack Bits, by L. S. Sundae and T. A. Myren. 1987. 15 pp. 6 figs. The Bureau of Mines conducted a series of tests to compare the cutting forces required by radial and point-attack bits when making similar cuts. Three radial and four point-attack bits were tested in two coal mines using the Bureau's in-seam tester to measure coal-cutting forces in situ. Tests were also conducted to investigate the effects of weathering and cleating. The test results show that in each case, at a specific clearance angle, the radial bits required less tangential and much less normal force than the point-attack bits. The resultant of the cutting forces for some types of cut was 50 pct less at mine 1 for radial cuts compared to cuts with the best point-attack bit, and 40 pct less at mine 2. There was some difference between the three types of radial bits tested, but it was not as significant as the difference between each type of point-attack bit. Cutting coal perpendicular to the cleat planes required less cutting and normal force than the same type of cuts parallel to the cleat planes. Test results showed no effect due to weathering on cutting force data. Cutting parallel increased forces only because cuts were made in the rock band.

RI 9128. Physical Properties and Mechanical Cutting Characteristics of Cobalt-Rich Manganese Crusts, by D. A. Larson, S. Tandanand, M. L. Boucher, M. S. Olson, R. J. Morrell, and R. E. Thill. 1987. 35 pp. 19 figs. The Bureau of Mines conducted research to develop preliminary engineering data necessary if the cobalt-rich manganese crusts that occur in the Exclusive Economic Zone of the Hawaiian Archipelago are to be mined. The research was divided into the following sections: (1) physical, mineralogical, and chemical descriptions, (2) mechanical property testing, such as compressive strength, tensile strength, and a rippability index, and (3) mechanical cutting characteristics, including average and peak cutter forces, the specific energy, and cuttings size distribution. Section 1 utilized microscope, X-ray powder diffractometer, and electron microprobe analyses. Section 2 utilized standard mechanical property testing techniques. Section 3 utilized a converted planer mill with full-size coal cutters to fragment the crust and substrate samples. The manganese crust samples were mainly manganese and iron oxides and hydroxides with an average cobalt content of 1 pct and had a nucleus or substrate of rock or sediment. The significant results shown by the mechanical property and cutting tests are that the crust and all but two types of substrates (basalt and trachyte) are weak materials and easily cut with standard drag cutters. The crusts are generally comparable to medium-hard coal in strength and in their resistance to cutting.

RI 9129. Avoiding Anchorage Problems With Resin-Grouted Roof Bolts, by Howard C. Pettibone. 1987. 28 pp. 11 figs. Mine safety personnel reported occurrences of excessive "glove-fingering" and other problems with resin-grouted roof bolt installations. To study these problems, the Bureau of Mines designed a test plan to (1) obtain baseline information on several resin cartridges and (2) investigate the variables involved in the installation of a resin bolt. Three brands of resin representative of those used in the industry in January 1983 were selected for cartridge evaluation. The installation variables selected for study were the method of installation, the hole depth, and the hole annulus. These variables were studied by installing a series of bolts in concrete blocks using different values for each variable. Results of the research show that overspinning the resin may cause problems, but they can be avoided by using the spin times recommended by manufacturers. Excessive glove-fingering is not a problem if the manufacturer-recommended installation procedures are followed.

RI 9130. Utilization of Scrap Preheating and Substitute Slag Conditioners for Electric Arc Furnace Steelmaking, by G. W. Elger, R. H. Nafziger, J. E. Tress, and A. D. Hartman. 1987. 26 pp. 6 figs. The Bureau of Mines investigated the preheating of continuously fed, fragmented ferrous scrap charges by furnace offgases and the utilization of substitutes for imported fluorspar to condition electric steelmaking slags. Three types of continuous scrap charging procedures were investigated to determine electrical energy consumption in a 1-st (short ton) electric arc furnace. Cold and preheated scrap charges were continuously fed at rates averaging 37.5 and 43.7 lb/min, respectively. The feed rate varied appreciably from test to test owing to hangup of the scrap in the charge bin. Approximately 7 pct less electrical energy was consumed in melting scrap preheated to 840° to 1,110° F by furnace offgases than in melting cold scrap. Overall energy consumptions were 888 kW•h/st for cold scrap, 829 kW•h/st for preheated scrap, and 637 kW•h/st for conventional backcharged scrap. Stack gases from scrap preheating averaged 120° F and a flow rate of 1,615 standard cubic feet per meter (scfm) compared with 220° F and 1,302 scfm for cold-charged scrap. Slag conditioners tested included synthetic fluorspar, boric acid, hydroboracite, used aluminum potlining wastes and aluminum anode tailing wastes, and Sorelflux B. The boron-containing conditioners fluidized the slags the best, followed in order by the conditioners containing fluorine and titanium.

RI 9131. Time-Dependent Behavior of Coal Measure Rocks: Adsorption Rate and Strength Degradation, by Sathit Tandanand. 1987. 18 pp. 12 figs. This report presents a Bureau of Mines study on the time-dependent behavior of coal measure rocks for future implementation in stability analysis and safety evaluation of in-mine rock structures. This initial study focused on moisture adsorption rate and strength degradation of shales in Pennsylvanian coal-bearing strata in the Illinois Basin. A reaction of clay minerals in Illinois shales with atmospheric water vapor was hypothesized as the adsorption and strength degradation mechanism. Part of energy exchange between shales and the environment was attributed to a free energy controlled by pore pressure of the rock and partial pressure in the environment. The relationships between adsorption versus time and strength degradation versus moisture content were derived and correlated with the experimental data. Partial saturation at various levels of relative humidity occurs within approximately 2 weeks at room temperature. The strength of shales tested decreases linearly with increasing moisture content. When the moisture exceeds 7 pct of the dry weight, these Illinois shales become unstable. To this end, the moisture content is a good predictor of rock strength for shales.

RI 9132. Mathematical Model of Absorption of Carbon Dioxide by Rescue Breathing Apparatus Scrubber, by John C. Edwards. 1987. 9 pp. 5 figs. The Bureau of Mines developed a mathematical model for analysis of the impact of scrubber bed length, porosity, and gas flow rate on the absorption of CO_2 in a breathing apparatus. The model accounts for the decrease in available absorbent through chemical conversion. The predicted efflux of CO_2 from a canister containing LiOH compared favorably with measured values reported elsewhere. It was determined from a computational study that the time for breakthrough of CO_2 at a prescribed level is nearly directly proportional to bed length and inversely proportional to gas flow and porosity.

RI 9133. Coreduction of $TiCl_4$, $AlCl_3$, and VCl_4 To Produce Titanium Alloy Sponge, by Davis E. Traut, G. J. Slavens, and Dennis A. Hansen. 1987. 17 pp. 8 figs. $TiCl_4$, $AlCl_3$, and VCl_4 were coreduced simultaneously via a Kroll-type magnesium reduction to form an alloy sponge as part of a research effort by the Bureau of Mines to produce titanium alloy powder. Reduction temperatures of 750°, 850°, and 950° C, a range of chloride feed rates from 34 to 152 lb/(ft²•h), and crucible diameters of 7¾ and 10¼ in were tested. Microprobe analyses using a 40-μm-diam spot showed no effect on alloy microhomogeneity (distribution of Al and V in the Ti, considered critical as a powder property) owing to changes in process variables within these ranges. Statistical analysis of these data for alloy sponge indicated greater variation in the chemical composition (Al and V) than that found in commercial Ti-6Al-4V plate or Plasma Rotating Electrode Process powder. Therefore, a one-step approach to powder, such as grinding the Ti alloy sponge, would not produce a powder product of acceptable chemical homogeneity. An approach that homogenized the sponge, such as with a melting step, would produce an acceptable powder product with respect to chemical homogeneity.

RI 9134. Reduction in Frictional Ignition Due to Conical Coal-Cutting Bits, by Lung Cheng, Aldo L. Furno, and Welby G. Courtney. 1987. 10 pp. 4 figs. The Bureau of Mines conducted laboratory tests to investigate the ease of frictional ignition with frozen (nonrotating) conical bits cutting into sandstone. The number of strikes with a new bit to obtain ignition of a combustible methane-air environment was measured. Tests were made with bits tipped with both tungsten carbide and steel at several bit attack angles (angle between bit axis and sandstone surface) and initial tip angles (included angle at the tip of the new bit). Carbide-tipped bits required more strikes for ignition than steel-tipped bits by a factor of 7 to 10. With a carbide-tipped bit, the number of strikes for ignition increased by a factor of about 3 if the bit attack angle increased by 10° or if the initial tip angle decreased by 10°. During use, abrasive wear of the frozen bit caused a flat surface to form at the tip of the bit, thereby decreasing the tip angle. As the attack angle increased, however, the new bit involved a smaller wear-flat area whereby abrasive wear was decreased.

RI 9135. Linear Load-Transfer Mechanics of Fully Grouted Roof Bolts, by M. O. Serbousek and S. P. Signer. 1987. 17 pp. 16 figs. The load-transfer mechanics of fully grouted roof bolts in coal mines have been investigated in laboratory and analytical studies. The purpose of this Bureau of Mines research is to increase understanding and better interpret data from routine field pull tests and to develop a numerical model of a grouted bolt that can be used in a global computer model of a mine roof. Analytical studies using closed-form solutions and finite-element techniques were compared to experimental results. Laboratory work includes variation of bolt length, hole diameter, and grout type. Pull tests were performed on 4-, 2-, and 1-ft bolts in holes of 1- and 1-⅜-in diam. Both polyester resin and inorganic grouts were used as the anchorage medium. Strain gauges were installed on the bolts at several locations to observe the rate of load transfer from the bolt through the grout to the rock mass when a force was applied at the bolt end using standard jack pull testing procedures and equipment. The average anchorage length of 4- and 2-ft bolts was 22 in. Grout type and hole size variations did not produce a significant effect on the rate of load transfer from the bolt to the rock.

RI 9136. Size Scaling of Gas Explosions: Bruceton Experimental Mine Versus the Lake Lynn Mine, by M. J. Sapko, E. W. Weiss, and R. W. Watson. 1987. 23 pp. 19 figs. Single-entry gas explosion characteristics for the Bruceton Experimental Mine (BEM) are compared to those occurring in the larger geometries of the new Lake Lynn Mine (LLM) within the Lake Lynn Laboratory. (All three are Bureau of Mines facilities.) Scale factors and boundary conditions for the BEM and the larger entries of the LLM are reviewed in some detail using representative data for pressure, flame, and wind velocity in the two mines. Measured pressure histories for gas explosions at the BEM are compared with data for comparable explosions in the larger cross section of the LLM. The time evolution for flame-front displacement can be characterized by a general expression that relates gas concentration and length of flammable volume. The course of the explosion development and its destructive power are dependent upon the development of turbulence in the unburned flammable mixture into which the flame propagates. The results of this study indicated that pressure profiles in the larger cross section are maintained to much larger distances even though the flame front is accelerated less rapidly in a comparable entry length of smaller flammable volume.

RI 9137. Electrokinetic Densification of Solids in a Coal Mine Sediment Pond—A Feasibility Study (In Two Parts). 2. Design of an Operational System, by R. H. Sprute, D. J. Kelsh, and S. L. Thompson. 1988. 75 pp. 27 figs. The Bureau of Mines conducted a feasibility study and designed an operational system for consolidating waste coal sludge in a 110-acre pond by applying direct current between buried and floating electrodes. Consolidation would reduce the sludge to half its present volume, thereby extending the working life of the pond as well as creating a safe, stable impoundment. The project was conducted by the Bureau under an agreement with the Washington Irrigation and Development Co. (WIDCO), located near Centralia, WA. Part 1 of this report, published as Report of Investigations 8666 in 1982, covers the results of laboratory tests at the Bureau's Spokane Research Center and of a small-scale field test at

WIDCO's coal preparation plant. Test results show the process is efficient and cost-effective when power is applied at low current density. Part 2 (this paper) describes a detailed design for an electrokinetic system to dewater WIDCO's 110-acre pond with a 27.4-acre electrode array. Densification of the inactive sludge pond will require 3.6 yr of treatment for a total cost of $1,450,000. The study and design are site specific, but design procedures and analyses are sufficiently detailed to serve as a guide for applying the process to any sludge pond.

RI 9138. Recovery of Cobalt and Copper From Complex Sulfide Concentrates, by R. O. Dannenberg, P. C. Gardner, S. R. Crane, and D. C. Seidel. 1987. 20 pp. 13 figs. The Bureau of Mines conducted laboratory investigations with the objective of developing an alternative process for recovering cobalt and copper from complex sulfide concentrates. Processes currently used depend largely upon precipitation techniques to remove impurities and recover cobalt from sulfate liquors prepared by oxidative pressure leaching of the sulfide concentrates. The Bureau conducted bench-scale research on a process for treating cobaltite concentrates, comprising (1) oxidative pressure leaching, (2) jarosite precipitation followed by H_2O_2 oxidation and pH control to remove iron and arsenic, (3) copper solvent extraction with a mixed hydroxyoxime-amine extractant, (4) copper electrowinning from recirculating acidic strip liquor, (5) selective cobalt extraction from copper solvent extraction raffinate with a phosphinic acid extractant, and (6) electrowinning of cobalt from a recirculating weak acid strip liquor. Overall cobalt and copper recoveries were 91.7 and 84.1 pct, respectively. Electrowon products assayed 99.8 pct Co and 99.89 pct Cu.

RI 9139. Removal of Copper From Molten Ferrous Scrap: Results of Laboratory Investigations, by L. L. Oden and G. W. Elger. 1987. 10 pp. The Bureau of Mines has studied a number of processes to remove Cu from molten steel scrap with the objective of determining if any of the laboratory methods studied warranted in-depth research investigations. Experimental approaches included oxidizing Cu from steel containing other metals that form stable mixed oxides with Cu (Al, Cr, Fe, Mn, Mo, and V), injecting the same metals as oxides to simplify the mechanism of complex oxide formation, partitioning Cu into alkali or alkaline earth silicate slags or oxide-moderated sulfides, and co-removing Cu and S by injecting active compounds of Ca and Mg. The most promising tests, producing nearly 0.3 pct Cu in the slag, used Ar injection of K_2O-moderated Na_2S–FeS below the surface of molten steel containing about 0.6 pct Cu and protected by a CaO–SiO_2 slag; however, in-depth research investigations currently are not felt to be warranted.

RI 9140. Recovery of Mercury From Concentrates by Cupric Chloride Leaching and Aqueous Electrolysis, by J. E. Murphy, H. G. Henry, and J. A. Eisele. 1987. 9 pp. 6 figs. The Bureau of Mines developed a hydrometallurgical method for recovering mercury metal from mercury sulfide concentrates. Sulfide flotation concentrate from the McDermitt Mine was leached in a cupric chloride solution at 80° C. The redox potential of the solution was maintained at 850 mV during leaching by chlorine sparging. Mercury extractions exceeded 99 pct in 3 h of leaching. After leaching, the pH of the solution was increased from 1 to 4.5 to precipitate copper as atacamite. The pregnant solution, typically containing 100 g/L Hg, was sent to electrolysis to produce high-purity mercury metal and chlorine for recycle. In a 200-A electrolytic cell operated for 24 h, current efficiency was 99 pct, and the energy requirement was 0.9 kW·h/lb of mercury produced. Mercury removal from the waste stream was also investigated. Iron or zinc cementation, sulfide precipitation with H_2S, and activated carbon adsorption all decreased the mercury concentration from 10 g/L to 0.01 mg/L, which is less than the Environmental Protection Agency limit on wastewater of 0.02 mg/L.

RI 9141. Critical-Load Studies of a Shield Support, by Thomas M. Barczak and David E. Schwemmer. 1987. 15 pp. 12 figs. One of the primary goals of Bureau of Mines research is to reduce the cost of coal mining by improving the efficiency of longwall supports. One method of achieving this goal is the optimization of stress distribution within the support structure, resulting in a lower overall weight, more fully stressed shield. However, before stress optimization can be initiated, load conditions must be defined that cause maximum stress in the various support components. A finite-element model of a longwall shield was used to identify these critical load conditions. These load conditions were then evaluated in the Bureau's mine roof simulator by instrumentation of a longwall shield and measurement of strains in each of the shield components. The critical (canopy-base contact) load conditions were identified that can cause structural failure at less than rated shield (hydraulic yield) capacity. Comparisons were made between full-contact and partial-contact load conditions. Other parameters investigated included the stiffness of the contact material, changes in shield geometry, rate of load application, and effects of horizontal constraint. Conclusions were drawn regarding the structural integrity of the major shield components and potential for stress optimization.

RI 9142. Prediction of Surface Deformations Over Longwall Panels in the Northern Appalachian Coalfield, by Vladimir Adamek, Paul W. Jeran, and Michael A. Trevitz. 1987. 19 pp. 16 figs. This paper describes the Bureau of Mines development of a novel subsidence prediction methodology suitable to the mining and geologic conditions in the Northern Appalachian Coal Region. It describes the computation of vertical and horizontal movements, inclination, curvature, and horizontal strains. The substance of this method is the separation of the effects of lithology by introducing a correlation between hypothetically homogeneous overburden and existing lithologic conditions, while providing for different mining conditions such as underground geometry and overburden thickness. The effects of lithology have been expressed in the form of a variable subsidence coefficient within the subsidence trough. The subsidence coefficient is considered a constant for other predictive methods. Field data from 16 test sites at 11 Bureau longwall panel studies were used in the analysis. For each panel, the characteristics of the variability of the subsidence coefficient were defined. Regression analysis of the subsidence coefficients from all test sites on their locations relative to the edges of their respective panels yielded a third-degree polynomial equation. Results from additional longwall panel studies not included in the regression analysis were used to prove the validity of this method. To facilitate the use of this precalculation methodology, a computer program was written in BASIC for use on a personal computer.

RI 9143. Protective Structures for Low-Coal Shuttle Car Operator, by John R. Bartels, August J. Kwitowski, and William D. Mayercheck. 1987. 22 pp. 16 figs. This report discusses the Bureau of Mines efforts to develop partial protective structures for operators of low-coal shuttle cars. In coal seams 48 in high or less, full-coverage canopies are generally difficult or may be impossible to implement on high-speed face equipment owing to the restrictions they impose on the operator's vision and comfort. Limited coverage is one alternative that provides an acceptable level of operator protection in thin-seam applications were conventional full-coverage canopies cannot be used. Three possible limited-coverage design scenarios (roll bars, sliding canopies, and flip-top canopies) were designed, fabricated, and evaluated for low-coal shuttle cars. All three designs were determined to be feasible and desirable for low-coal shuttle car application.

RI 9144. Rigid-Body and Elastic Solutions to Shield Mechanics, by Thomas M. Barczak. 1987. 20 pp. 16 figs. This report describes Bureau of Mines research to develop methods to evaluate loading on longwall roof supports to permit better design and more efficient utilization of these structures in compliance with the geological conditions in which they are employed. The resultant vertical and horizontal force acting on the canopy of a shield can be determined, either from a statically determinate solution assuming rigid-body mechanics and elimination of certain unknowns, or from an elastic solution by analysis of the load-displacement relationship of the shield structure. A two-dimensional rigid-body model is presented that determines resultant shield forces by measurement of leg, canopy capsule, and lemniscate link forces. An elastic solution is presented in the form of an elastic stiffness model with two degrees of freedom, which describes the load-displacement relationship from the stiffness of the shield structure as determined in the Bureau's Mine Roof Simulator (MRS). The ability of both models to determine resultant forces acting on the shield canopy are evaluated from full-scale tests in the MRS. More advanced numerical models are also discussed as part of the Bureau's continuing effort in the evaluation of roof support structures.

RI 9145. Characterization of Ketchem Dome Tin Prospect, East-Central Alaska, by D. C. Dahlin, L. L. Brown, and J. D.

Warner. 1987. 11 pp. 7 figs. The Bureau of Mines investigated the Ketchem Dome tin prospect in east-central Alaska to evaluate the tin resource. The studies included field investigations, mineralogical characterization, and concentration of the tin-bearing minerals. The tin mineralization consists of cassiterite (SnO_2), which occurs as grains disseminated in a greisen (quartz-mica) matrix. A bulk sample from the largest and best-developed greisen vein exposed at Ketchem Dome contained 0.51 pct Sn. Concentration of the cassiterite by gravity table methods resulted in a product that contained 56 pct of the tin at a grade of 41.4 pct Sn. The mineralization exposed at Ketchem Dome is typical of greisen found in the area and elsewhere in interior Alaska.

RI 9146. Analytical Methods for Determining Products From Thermal Decomposition of Aluminum Nitrate Nonahydrate, by A. Adams and P. A. Romans. 1987. 6 pp. 3 figs. The Bureau of Mines determined the composition of the vapors liberated during thermal decomposition of aluminium nitrate nonahydrate. Small samples were heated from room temperature to 550° C with initial heating rates from 50° to 200° C/min. Gases were rapidly swept away from the heated chamber with Ar and subjected to immediate analysis in order to minimize reaction between the components. In addition to H_2O, four N-containing compounds were identified: HNO_3, NO_2, NO, and N_2O. N_2 could not be determined in the presence of the nitrogen oxides, and attempted separation from the oxides led to the formation of more nitrogen. Relative amounts of each component were found to vary over a period of time; however, total amounts measured with different heating rates were reasonably constant and were typically as follows: 84.2 pct HNO_3, 7.1 pct NO_2, 4.3 pct NO, and 4.2 pct N_2O. HNO_3 and NO were determined from chemical reactions with a permanganate solution, N_2O was measured with a mass spectrometer, and NO_2 was measured with a spectrophotometer. Details of the methods used are described. Since NO_2 and NO can readily be converted to HNO_3, about 96 pct of the N from the decomposition can be recovered as HNO_3.

RI 9147. Case Evaluation of a Surface Seismic Reflection Technique for Delineating Coalbed Discontinuities, by Gregory M. Molinda and David K. Ingram. 1988. 28 pp. 18 figs. Coalbed discontinuities historically have been hazardous to mining as well as obstructions to efficient production. An effective means of mapping these features is needed in order to plan safe and efficient mine development. This Bureau of Mines report discusses the use of surface seismic techniques for this purpose. At a southwestern Pennsylvania mine, a system of coalbed discontinuities (paleochannels) was accurately mapped by the Bureau of Mines using borehole log methods and underground observation. This site was chosen to test the value of a high-resolution surface seismic reflection technique for coalbed mapping. A statistical study performed at this mine indicated that the probability of accurately delineating this paleochannel system with conventional borehole methods was remote. A total of 1.47 miles of high-resolution seismic survey, comprised of four seismic profiles, was conducted in known and suspected coalbed discontinuity areas. Several test holes were drilled on the seismic lines in order to evaluate the interpretations. It was found, based on these and other existing boreholes, that it is possible to predict these discontinuities. Paleochannel washouts were correctly predicted in several instances but in other instances were either incorrectly predicted or not predicted in areas of known discontinuities.

RI 9148. Leakage and Performance Characteristics of Large Stoppings for Room-and-Pillar Mining, by Edward D. Thimons, Carl E. Brechtel, Marvin E. Adam, and Joseph F. T. Agapito. 1988. 17 pp. 13 figs. This report presents a Bureau of Mines study comparing the construction costs, leakage measurements, and predicted performance of different types of large stoppings built and tested in a room-and-pillar oil shale mine. The six full-sized structures (30 ft high by 55 ft wide) included both permanent and temporary stoppings and were fabricated using materials ranging from structural steel to coated brattice cloth. Leakage across each stopping was measured at differential pressures ranging up to 1.0 in w.g., using both the brattice window method and sulfur hexafluoride (SF_6) tracer gas. Blast air pressures resulting from a full-scale face blast of approximately 1,800 lb of ammonium nitrate-fuel oil (ANFO) explosives were measured across two of the stoppings, and the pre- and post-leakage rates were compared for all the stoppings.

Overall performance of the stoppings for production applications was evaluated using an operational model of a two-panel oil shale mine. Different combinations of temporary and permanent stoppings were evaluated based upon ventilation performance and construction and operating costs.

RI 9149. In Situ Horizontal Stress Determinations in the Yampa Coalfield, Northwestern Colorado, by D. L. Bickel and D. A. Donato. 1988. 43 pp. 27 figs. This report presents a Bureau of Mines study intended to determine if horizontal stress trends exist and if the stresses can be projected for improved mine design in a selected coalfield. The horizontal stresses were determined in three mines in the Yampa Coalfield and one mine in the adjacent Danforth Hills Coalfield of northwestern Colorado. Stresses were determined from stress-relief measurements using a three-component borehole deformation gauge and overcoring techniques developed by the Bureau. A least-squares method of calculating the average rock stress components in the horizontal plane was performed. Physical properties of the rock from the test sites are also included. For the Yampa Coalfield, the maximum horizontal compressive stress in the floor ranged from 363 to 1,956 psi, and the maximum horizontal compressive stress in the roof ranged from 235 to 875 psi. For the Danforth Hills Coalfield, the maximum horizontal compressive stress in the floor ranged from 360 to 1,494 psi, and the maximum horizontal compressive stress in the roof was 1,033 psi. Results indicated a trend of low horizontal stresses in the Yampa Coalfield that have not impacted ground control conditions in mines less than 1,000 ft deep.

RI 9150. Leaching of Domestic Manganese Ores With Dissolved SO_2, by John E. Pahlman and Sanaa E. Khalafalla. 1988. 15 pp. 9 figs. The Bureau of Mines conducted column-leaching tests on 25 domestic Mn ores to determine the feasibility of extracting Mn by in situ or heap leaching with dissolved sulfur dioxide (SO_2) solutions. The ores tested were obtained from deposits in Arizona, Arkansas, California, Colorado, Maine, Minnesota, Nevada, and South Dakota. Dissolved SO_2 was found to be effective for leaching Mn; extractions greater than 90 pct were obtained with solution application rates of 1 mL/min from uncalcined, minus 2.5- plus 1.3-cm ore pieces. Leaching these ores with solutions containing only 5-wt-pct SO_2 and no added H_2SO_4 resulted in Mn being selectively extracted over Fe except when Fe was present as goethite or siderite. Ca solubilization was inhibited by controlling the solution application rate (1 mL/min). The rate of leaching was found to be principally dependent upon the rate at which the leaching solution can penetrate the ore, since the solubilization of Mn upon contact with SO_2 was observed to be rapid. Despite low water permeabilities of the ores (as low as 10^{-2} to 10^{-4} darcy), greater than 90 pct of the Mn was extracted from even the largest ore pieces tested (approximately 10 cm in diameter). It appears, therefore, that leaching Mn opens up the pores, allowing penetration of the leach solution into the ore pieces.

RI 9151. Cost Comparison of Gob Hole and Cross-Measure Borehole Systems To Control Methane in Gobs, by Eugene C. Baker, Fred Garcia, and Joseph Cervik. 1988. 23 pp. 6 figs. The capital investment and operating costs of two methane-control systems used during longwall mining operations are compared in this Bureau of Mines report. Costs are given for a surface gob hole drainage system and an underground cross-measure borehole drainage system to control methane gas in gobs in four coal mining areas—central Pennsylvania, northern West Virginia, southern Virginia, and northern Alabama. Present-worth analysis is used to determine the more cost-effective alternative in each location. The alternatives have equal lives and provide the same service based on a minimum rate of return of 15 pct. In central Pennsylvania and northern West Virginia, the gob hole system is more cost effective than the cross-measure system, by 10 and 18 pct, respectively. In southern Virginia and northern Alabama, the cross-measure system is more cost effective, by 29 and 38 pct, respectively. Costs for other locations must be developed on a case-by-case basis.

RI 9152. Laboratory Assessment of Alternative Longwall Stabilization Materials, by Deno M. Pappas. 1988. 14 pp. 7 figs. The objective of this Bureau of Mines investigation was to identify and evaluate alternative binder materials for use in stabilizing and consolidating highly fractured roof along longwall faces and gate roads. The desirable characteristics of a stabilization material were defined, and an extensive search was conducted to find materials satisfying these characteristics. Of 20 materials originally scruti-

nized, 9 were chosen for laboratory analyses. The laboratory tests evaluated bond strength and tensile strength under both dry and wet conditions. An optimum material was not found. The laboratory analyses indicated two possible candidate materials for longwall stabilization: high-aluminous cement and two-component epoxy; however, the tensile strength of the high-aluminous cement was mediocre, and the epoxy cement is toxic, flammable, and fairly expensive. The potential market demand for an effective and economical stabilization material is discussed in the appendix.

RI 9153. Electrodewatering of Bayer Muds—Laboratory Studies, by Elizabeth G. Baglin and Synthia M. McIntosh. 1988. 10 pp. 4 figs. Research was conducted by the Bureau of Mines to determine the feasibility of using electrokinetic densification to dewater Bayer process red mud, magnetic black mud prepared by pressure digestion of red mud in the presence of ferrous sulfate, and magnetic black mud formed by simulated Bayer digestion of Jamaican bauxite with added ferrous sulfate. Tests showed that the solids content of presettled muds could be increased from 25 pct to approximately 40 to 48 pct by gravity draining followed by electrodewatering for approximately 48 h. Electrodewatering may not be practical because of increased reagent and processing costs and because the muds must be thoroughly washed prior to electrodewatering to remove dissolved ions and decrease mud conductivities.

RI 9154. Stiffness Characteristics of Longwall Shields, by Thomas M. Barczak and David E. Schwemmer. 1988. 14 pp. 15 figs. The stiffness characteristics of longwall shields were investigated in this Bureau of Mines study. Since longwall strata activity is characterized by roof-to-floor and face-to-waste displacements, a model with two degrees of freedom was used to describe the load-displacement relationship of the shield structure. The model considers the support as an elastic body and relates horizontal and vertical resultant forces acting on the support to associated displacements as a function of the stiffness of the support structure. Stiffness coefficients under full canopy and base contact configurations were determined by controlled displacement loading of longwall shields in the Bureau's Mine Roof Simulator. Three two-legged longwall shields of different manufacture were investigated. The stiffness characteristics of these shields were evaluated relative to two parameters, namely, shield height and setting pressure. The test results indicate a reduction in shield stiffness for increasing height. Setting pressure was found to have less of an effect on shield stiffness, producing only a slight increase in stiffness as setting pressure increased. Similar trends were observed for all three shields, indicating a similarity in stiffness characteristics for shields of the same basic configuration.

RI 9155. Measurement of Incombustible Content of Coal Mine Dust Samples, by N. Greninger, W. Courtney, and H. Lang. 1988. 14 pp. 6 figs. The Bureau of Mines conducted a laboratory study of the measurement of the water and rock dust (RD) contents of synthetic mine-type coal dust (CD) mixtures using a commercial unit for measuring water content and several prototype radiometric units for measuring the RD content. The RD content ranged from 50 to 100 wt pct and the added water (AW) ranged from 0 to 15 wt pct. The total water (TW) content (intrinsic (IW) and AW) of a small dust sample could be readily measured automatically by essentially untrained personnel using a commercial unit. The RD content of a sample containing only IW could readily be measured by moderately trained personnel using several radiometric units. With gamma-ray devices, about 300 g of sample is needed. With the improved beta-ray device, about 25 g of sample is needed. With dry mine dust samples, the estimated RD error range is 0.8 to 2.3 pct for gamma-ray devices and 0.5 to 1.0 pct for beta-ray devices. However, the radiometric measurement of RD content was questionable if the dust mixture also contained AW or if it was uncertain whether the dust mixture contained AW.

RI 9156. Solubilities of Bromide Salts of Aluminum, Cobalt, Lead, Manganese, Potassium, and Sodium When Sparged With Hydrogen Bromide, by E. G. Noble and D. E. Shanks. 1988. 19 pp. 15 figs. The effects of HBr concentration and temperature on the solubility and hydration state of $AlBr_3$, $CoBr_2$, $PbBr_2$, $MnBr_2$, KBr, and NaBr were investigated by the Bureau of Mines. Saturated aqueous solutions of the Al, Pb, K, and Na bromides were sparged with HBr gas at 20°, 40°, and 60° C, and saturated solutions of Co and Mn bromides were sparged at 20° C. Increased HBr concentration caused decreased salt solubility because of the common ion effect for all the investigated bromides except $PbBr_2$. Aqueous solubilities at 20° C were, in percent, 51.7 for $AlBr_3$, 53.2 for $CoBr_2$, 1.1 for $PbBr_2$, 59.6 for $MnBr_2$, 39.5 for KBr, and 47.4 for NaBr. At 60° C, the solubilities were, in percent, 53.3 for $AlBr_3$, 2.2 for $PbBr_2$, 46.0 for KBr, and 53.8 for NaBr. Solubilities in solutions sparged to HBr saturation at 20° C were, in percent, 0.5 for $AlBr_3$, 42.0 for $CoBr_2$, 32.2 for $PbBr_2$, 21.0 for $MnBr_2$, 0.6 for KBr, and 0.3 for NaBr. At 60° C, the solubilities at HBr saturation were, in percent, 1.8 for $AlBr_3$, 41.4 for $PbBr_2$, 1.3 for KBr, and 0.4 for NaBr. $CoBr_2$ precipitated out to a minimum solubility of 27.2 pct at 28.7-pct-HBr concentration. Further increases in HBr concentration increased $CoBr_2$ solubility because of the formation of bromide complexes. $PbBr_2$ increased in solubility as HBr concentration increased.

RI 9157. Permeability and Corrosion Resistance of Reinforced Sulfur Concrete, by W. R. Wrzesinski and W. C. McBee. 1988. 13 pp. 10 figs. This report presents the findings from a 1-yr Bureau of Mines program in which sulfur concrete reinforcing materials were tested and evaluated to determine their resistance to corrosion. It also summarizes the permeation characteristics of sulfur concrete and the exemplary performance of precast, reinforced sulfur concrete structures in various industrial environments. The Bureau is furthering the development of sulfur concrete technology as part of a larger effort to find uses for the Nation's plentiful sulfur resources in construction materials. Sulfur concrete is a corrosion-resistant material that can be used in acid and salt environments where conventional materials fail. Penetration of corrosion-inducing agents is minimized because of the low permeation characteristics of sulfur concrete.

RI 9158. Potential for Recovery of Rutile and Other Byproducts From Western Copper Tailings, by E. G. Davis, G. V. Sullivan, and W. E. Lamont. 1988. 19 pp. 5 figs. The Bureau of Mines studies tailings samples from 11 large-scale western copper operations to determine the potential for recovery of rutile and other critical and strategic minerals. Up to 15 pounds per short ton (lb/st) TiO_2 was found in these samples; however, only 9 to 44 pct of the TiO_2 was liberated rutile. For one sample, gravity preconcentration, grinding, and flotation recovered 34 pct of the TiO_2 in a 54.8-pct-TiO_2 concentrate. Over 0.38 lb/st W was found in some of the tailings samples. Scheelite was identified as the major W mineral. Nine of the eleven samples contained about 0.02 to 0.18 lb/st Co. Pyrite was the principal Co-bearing sulfide mineral, with Co contained in about one-fifth of the pyrite grains. Up to 30 pct of the Co was concentrated in a bulk sulfide flotation concentrate.

RI 9159. A Tomographic Computer Program With Constraints To Improve Reconstructions for Monitoring In Situ Mining Leachate, by Daryl R. Tweeton. 1988. 70 pp. 18 figs. The Bureau of Mines is investigating possible applications of geophysics to monitor leachate during in situ mining. Tomographic reconstruction of seismic or electromagnetic crosshole data appears applicable. The tomographic program BOMTOM (Bureau of Mines tomography) was written and then used to investigate reconstructions with synthetic travel time data. The calculations confirmed that without constraints, crosshole data do not provide unique solutions. The solution is not determined solely by the data, but is also influenced by the velocity guesses starting the iterative solution procedure. The effectiveness of constraints in combatting nonuniqueness was examined. The requirement that the velocity not vary laterally at the top and bottom of the pixel grid was effective. This constraint is realistic when the top and bottom of the grid represent dry and saturated regions, respectively. Limiting the maximum velocity improved reconstructions, but may not be applicable in practice. BOMTOM uses the simultaneous iterative reconstruction technique with straight ray paths. The program is efficient in use of memory, and can be run on a personal computer. A source code in FORTRAN is listed. A source code in BASICA and compiled executable codes in both languages are available from the Bureau's Twin Cities Research Center.

RI 9160. Feasibility of CO_2 Monitoring To Assess Air Quality in Mines Using Diesel Equipment, by J. Harrison Daniel. 1988. 81 pp. 12 figs. Diesel-engine exhaust emissions are a major concern in underground mines. Engine operating mode and condition, mine environment, and

operator's habits all influence emission concentration and composition. It is not practical to measure each exhaust pollutant in underground mines; therefore, a monitoring methodology is required. This Bureau of Mines report investigates the feasibility of a monitoring methodology that uses carbon dioxide (CO_2) as an indicator of mine air quality. The methodology includes (1) establishing pollutant-to-CO_2 ratios for in-service equipment, (2) estimating pollutant concentrations from the ratios and in-mine CO_2 measurements, and (3) using an air quality index (AQI) to combine the pollutants into a single number that indicates the associated health hazards. For the methodology to be valid, the pollutant-to-CO_2 ratios must remain constant if engine operating conditions do not significantly change. However, because of the complex dynamics of the fuel injection system, the fuel-air combustion process, and the engine speed-load governing system, the pollutant-to-CO_2 ratios may vary during repetitive, but transient engine speed and load operation. These transient effects were investigated. In addition, the influence of changing engine conditions due to engine maladjustment, and a practical means to evaluate engine condition were investigated to advance the methodology. The laboratory investigation determined that CO_2 is an effective indicator of engine exhaust pollutants. It was shown that the exhaust concentrations of carbon monoxide, carbon dioxide, oxides of nitrogen, hydrocarbons, and particulate matter do not significantly vary among repetitive, but transient engine speed and load duty cycles typical of in-service equipment. Based on an AQI and threshold limit values, particulate matter exhibited the greatest adverse effect on air quality. Particulate mass was separated into volatile (organic soluble fraction) and nonvolatile (insoluble carbon fraction) components. Because of particulate concentrations, the engine operating conditions of overfueling and advanced injector timing had greater adverse effects on air quality than the conditions of retarded injector timing, intake air restriction, and Federal certification specifications. An exhaust smoke analysis that could be performed by mine workers to evaluate engine condition was proved ineffective.

RI 9161. Effect of Load Rate on Wood Crib Behavior, by Thomas M. Barczak and David E. Schwemmer. 1988. 11 pp. 6 figs. The effect of load rate on the load-carrying capabilities of wood cribs is investigated in this Bureau of Mines study. The modulus of deformation (stiffness) of wood crib blocks has been shown to increase with increases in rates of load application, causing larger load reactions for increases in convergence rates. Since wood cribs are tested in the laboratory at convergence rates that are orders of magnitude faster than typically would occur underground, wood cribs tested in the laboratory will react larger loads than the same cribs would react underground for the same displacement. Tests conducted in the Bureau's mine roof simulator on green wood crib blocks indicate that the increase in stiffness for increasing load rates diminishes at displacement rates beyond 0.1 in/min, making crib load nearly independent of load rate for rates faster than 0.1 in/min. Seasoned wood specimens were not as consistent in load-rate dependency. Some possible explanations of observed load-rate behavior on wood crib specimens are also postulated in this paper.

RI 9162. Roof Truss Contact Forces, by J. H. Stears and M. O. Serbousek. 1988. 20 pp. 18 figs. Increasing use of Birmingham and other roof trusses prompted a Bureau of Mines study of support forces produced on a mine roof by these members. Equations, obtained from laboratory and field tests, are given for calculating the contact forces between the roof strata and a typical truss. Actual contact forces for a specific truss are difficult to estimate because of variable friction loss at the contact points. A finite-element analysis, using typical contact forces, indicated that trusses have a negligible effect on the stress field in massive, competent roof strata. The effectiveness of trusses in supporting broken rock strata was not analyzed. However, experience has shown that trusses are effective in supporting incompetent roof.

RI 9163. Measurement and Control in Industrial Processes Using an Analog-to-Digital Telemetry System, by P. J. McDonough, A. E. Isaacson, and J. H. Maysilles. 1988. 24 pp. 25 figs. The Bureau of Mines designed and tested a hardware-software system for measuring on-line corrosion rates of materials in a rod mill in operation. Currents ranging from 10^{-6} to 10^{-3} A and potentials in 1-mV increments were converted to a digital signal. The digitized data were frequency-modulated and transmitted from a rotating ball mill to an FM receiver, where they were decoded by computer and then processed in real time using assembly language software. This design approach would allow accurate measurement and control of systems where signals of small amplitude and large ranges are present.

RI 9164. Effect of Fluoride Inclusions on Induction-Slag-Melted Ti-6Al-4V Alloy, by J. I. Paige. 1988. 11 pp. 6 figs. The effect of fluoride inclusions on the properties of titanium produced from the Bureau of Mines developed induction slag melting process is of concern to members of the titanium industry. The objective of the research was to determine the effect of CaF_2 inclusions on the properties of titanium and its survival rate during melting. The data were obtained from single-induction-slag-melted ingots prepared with the normal addition of 4 pct and also with 2- and 1-pct additions of CaF_2 slag. The results of this effort showed that the mechanical properties of single-induction-slag-melted Ti-6Al-4V alloy exceed the minimum values specified in Aerospace Materials Specification for Titanium Alloy Bars and Forgings AMS4928H, but these materials are much more notch sensitive in fatigue than normal Ti-6Al-4V alloy titanium. First and second vacuum-arc remelts of single-induction-slag-melted ingots fragmented and increased the number of inclusions, while reductions in the amount of flux resulted in an upward trend in the spatial distance between pores in an x-y plane.

RI 9165. Preparation of Ammonium Paratungstate From a Sodium Tungstate-Sodium Chloride Phase, by A. E. Raddatz, J. M. Gomes, and T. G. Carnahan. 1988. 10 pp. 6 figs. Previous Bureau of Mines research has shown that tungsten ores containing as little as 40 pct WO_3^{2-} can be processed by a high-temperature molten-salt extraction technique to produce a tungstate-bearing sodium chloride phase with 99 pct W recovery and little impurity contamination. The objective of this work was to demonstrate that the tungstate-bearing sodium chloride phase can be a suitable feed material for preparing ammonium paratungstate (APT) by a modification to the present industrial solvent extraction process. A combined crossflow-countercurrent flow solvent extraction technique to extract tungsten is presented. APT produced by this new technique contained 88.6 pct WO_3^{2-} and the following impurities, in percent: MnO_2, 0.0007; MoO_2, 0.017; P_2O_5, <0.010; and SiO_2, 0.012. Implementation of this processing technique would improve tungsten recovery from concentrates and simplify processing operations.

RI 9166. Determining Corrosion Rates in Industrial Ore Grinding Environments, by A. E. Isaacson, P. J. McDonough, and J. H. Maysilles. 1988. 25 pp. 20 figs. Bureau of Mines researchers developed and tested equipment to measure corrosion rates on a commercial-scale mill. Bench-scale experiments were designed for duplicating ore grinding conditions closely enough so that realistic rate determinations could be made in laboratory tests. Rates measured in a laboratory system compared favorably with those measured in the field. Cast steel was found to have corrosion rates in a copper mill and laboratory test cell of 22 and 21 mpy, respectively. Corrosion was found to account for less than 5 pct of the total grinding media wear in the operations studied.

RI 9167. Na_2CrO_4 From Domestic Chromite Concentrates by an Alkali-Fusion Method, by Gary L. Hundley, R. E. Mussler, R. A. Holmes, and R. S. Olsen. 1988. 12 pp. 3 figs. The Bureau of Mines has devised a procedure to recover chromium chemicals from concentrates derived from low-grade domestic chromites. These domestic chromites contain silicon and aluminum impurities at levels that are too high to permit processing by present industrial processes. The Bureau procedure consists of reacting chromite with molten NaOH under oxidizing conditions to form sodium chromate (Na_2CrO_4). The reaction product is leached with methanol to recover the majority of the unreacted NaOH, then with water to extract the Na_2CrO_4 and the remainder of the NaOH. The Na_2CrO_4 product is recovered by evaporative crystalization from the aqueous solution. This report presents laboratory results of studies to determine the optimum leaching conditions for the reaction products of several domestic chromite concentrates. Results of solution purification and crystallization studies are also presented. The concentrates are from a variety of sources including the Stillwater Complex in Montana, Red Bluff Bay and the Kenai Peninsula in Alaska, and a Ni-Co laterite from southern Oregon. Sodium chromate crystals were produced that contained less than 0.01 pct NaOH.

RI 9168. Factors Affecting Strength and Stability of Wood Cribbing: Height, Configuration, and Horizontal Displace-

ment, by Thomas M. Barczak and Carol L. Tasillo. 1988. 23 pp. 26 figs. The Bureau of Mines is conducting research to optimize the capability of mine roof supports so that the selection and design of these supports are compatible with the conditions in which they are to be employed. This report describes a study that investigates three parameters influencing the load-carrying capability of wood crib supports: height, configuration, and horizontal displacement. Four crib heights, four parallelogram configurations, and three ratios of horizontal-to-vertical displacements were tested on full-scale wood crib supports in a mine roof simulator. Test results indicated a reduction in load-carrying capability for increases in crib height. Increasing the contact area by changing the intersecting angle between crib blocks to form parallelogram configurations provided a slight increase in load-carrying capability for the first 10 or 12 in of vertical convergence, after which the cribs became more unstable, resulting in significantly less load-carrying capability. Horizontal displacements did not appreciably affect the load-carrying capability of wood crib supports for the range of vertical displacements (less than 10 in) likely to be encountered underground. This report documents these tests and postulates some explanations of failure mechanics for the observed behavior.

RI 9169. Coal Particle Pyrolysis Mechanisms and Temperatures, by Martin Hertzberg, Isaac A. Zlochower, and John C. Edwards. 1988. 39 pp. 26 figs. This Bureau of Mines report analyzes diverse observations of the rates and mechanisms for the pyrolysis and devolatilization of coal and polymethylmethacrylate (PMMA). New data are presented for PMMA, together with new morphological evidence for the microscopic structure of the pyrolysis and devolatilization wave front in coals. It is concluded that there is no substantive evidence to support the traditional viewpoint that the pyrolysis and devolatilization rate process occurs isothermally, under chemical rate control; or is described realistically by a classical, unimolecular Arrhenius function of temperature. Instead, the reaction process occurs as a highly nonisothermal, heat-flux-driven, pyrolysis and devolatilization wave front, whose speed of propagation is predictable by internal heat transport constraints. Except for the complication of its char-layer residue, whose increasing thickness insulates the pyrolysis wave front from the heat source flux that drives it, both coal and PMMA behave similarly during pyrolysis and devolatilization. For PMMA, decomposition occurs at a temperature of 350° to 550° C; for coal it occurs at 450° to 600° C. There is no evidence that the reactant temperature ever exceeds those values regardless of the source temperature to which the samples are exposed.

RI 9170. Detection of Roof Instability by Monitoring the Rate of Movement, by Hamid N. Maleki and James R. McVey. 1988. 12 pp. 10 figs. Cooperative efforts by the Bureau of Mines and Agapito & Associates, Inc., Grand Junction, CO, achieved the research objective of showing that data from measurements of the rate and change in rate of mine roof movement can be effective in detecting roof instability. Several instruments and techniques have been used to monitor roof movement and to detect imminent roof caves during pillar robbing. Early detection of unstable conditions can provide time either to withdraw personnel and equipment or to allocate supplemental support to prevent injury or downtime. Critical convergence rates were determined both manually and electronically. The detection of critical rate of movement has been shown to be an effective tool in ground control efforts.

RI 9171. Beach Characteristics of Mine Waste Tailings, by C. M. K. Boldt. 1988. 24 pp. 12 figs. The Bureau of Mines surveyed waste disposal sites at 18 metal and nonmetal mines and conducted laboratory and full-scale field tests to determine the effects of tailings deposition techniques on physical properties of tailings pond beaches. Survey data included measurements of beach slopes, descriptions of deposition techniques, and measurements of beach physical properties taken at various distances from the point of discharge. Laboratory tests involved depositing two types of tailings, each with different grain-size distributions, into a settling trough and determining the resultant physical properties of settled materials along the length of the beach. Side confinement and the closeness of the water pool to the point of deposition caused the laboratory results to be inconclusive. Full-scale field deposition tests conducted at the tailings pond of a cooperating mine showed that there were similarities in relationships between exit velocities of tailings slurry and physical properties of the settled tailings on the beach.

RI 9172. Computer-Assisted Mine Design Procedures for Longwall Mining, by N. P. Kripakov, L. A. Beckett, D. A. Donato, and J. S. Durr. 1988. 38 pp. 24 figs. The Bureau of Mines has developed a unique new mine design procedure to determine the changing static load distributions imposed on underground support structures during the mining cycle. The procedure reduces the complexities associated with analyzing a three-dimensional problem. A combination of the multiple-seam displacement-discontinuity model and a two-dimensional finite-element window model produces refined results for a specific area of interest by assuming displacement compatability between models. Input to the procedure includes the geometry of mined-out areas in up to two adjacent seams, the rock mass characteristics of the surrounding geology, the in situ stress conditions, and the mining sequence. The displacement-discontinuity program calculates expected loadings for mine structures affected by the mining cycle and/or by overlying or underlying seams. Pseudoelastic finite-element analysis using a yield-factor approach determines the stability of coal pillars by simulating the degree and extent of progressive rib failure and subsequent load transfer. Application of the procedure is demonstrated on a field problem. Induced stress changes predicted from the numerical model analysis are in reasonably good agreement with stress measurements obtained from an instrumented chain pillar affected by remnant workings in an upper seam.

RI 9173. Loading Characteristics of Pillars in Multiple-Seam Mining Operations, by G. J. Chekan and R. J. Matetic. 1988. 19 pp. 16 figs. The Bureau of Mines, in an effort to improve resource conservation, mine planning, and development, is currently investigating the loading behavior of pillars in multiple-seam developments. The simultaneous mining of two or more coalbeds may cause instability between room-and-pillar operations, resulting in an interaction known as pillar load transfer. Although pillars may be adequately designed for single-seam mining, the development of a second seam may complicate loading conditions in both operations. If pillars are not adequately designed to contend with this load transfer, failure of the mine structure may result. To improve multiple-seam development and pillar design, the Bureau studied the loading characteristics of pillars in three separate multiple-seam operations. In all three cases, instrumented pillars recorded increasing pressure after development of the second seam. Increases in the average pillar pressure ranged from 7 to 110 pct over predicted overburden loads. An analysis of pillar loading before and after second-seam mining indicates that the ratio of overburden to innerburden thickness is a critical factor influencing load transfer. Based on this relationship, safety factors for case study pillars are calculated and alternative design considerations are discussed.

RI 9174. Evaluation of Water-Jet-Assisted Drilling With Handheld Drills, by P. D. Kovscek, C. D. Taylor, and E. D. Thimons. 1988. 20 pp. 14 figs. The Bureau of Mines has tested a low-thrust water-jet-assisted rotary drill. This work was performed to evaluate the performance of a water-jet-assisted drill operated at thrust levels typical of a handheld manual-thrust operation. Prior work by the Bureau had indicated that using water-jet-assist with high-thrust drilling applications would increase drilling rate. Small-diameter holes were drilled in five different types of rock. Thrust and water pressure were varied as the drill rate was monitored. The test results indicate that drilling rates increase with increasing water pressure and thrust. The water jet has more effect on reducing the specific energy when drilling in the harder rocks than in softer rocks. Variation in drill rate for a given rock sample is attributable primarily to the material heterogeneity within the sample. One rock type (Greenwich sandstone) could not be drilled efficiently with the water-jet-assisted drill.

RI 9175. Critical Conditions for Ignition and Propagation of Mine Fires, by C. C. Hwang and C. D. Litton. 1988. 35 pp. 15 figs. The Bureau of Mines made time-dependent calculations to determine the size of a stationary-source fire within a ventilated duct (or passageway) necessary to ignite a combustible duct liner. The objective of this work was to gain more understanding of what occurs in duct fires and to determine critical conditions for ignition and propagation of mine fires. Heat transfer to the combustible surface includes both convective and radiated components, while the heat is conducted into the combustible and reradiated to the surroundings. The combustible is assumed to ignite when the net heat transfer to its surface is

sufficient to raise the surface temperature to some minimum temperature, defined as the ignition temperature. A nondimensional parameter, which characterizes the source-fire intensity in the presence of ventilation flow, emerges as a parameter for a criterion of the critical conditions. The results of these calculations indicated that the minimum fire size necessary for ignition increases with the ventilation rate and duct cross section. These results are compared with experimental results obtained from fires in a 0.8- by 0.8- by 11-m-long duct and a full-scale gallery (2.4- by 2.4- by 65-m). Agreement between the theory and the experiment is good.

RI 9176. Comparative Study of Pillar Load Transfer Associated With Multiple-Seam Mining, by R. J. Matetic and G. J. Chekan. 1988. 20 pp. 20 figs. The Bureau of Mines, as part of a program to improve mine planning and development, is currently investigating the effects of pillar load transfer, which can impact mining operations within a multiple-seam configuration. A comparative study was performed at two separate mine sites. The objective of this study was to compare two mines, each affected by this pillar load transfer mechanism, and to show how this interaction affected underground workings by installing and monitoring underground instrumentation. At mine site A, where the overburden was 1,000 ft, the innerburden thickness was less than a pillar width (40 to 45 ft), overlays of the mine layout show pillars were not superpositioned, excessive roof to floor convergence was measured, and pressure readings indicated pillar core loading only. At mine site B, the overburden was approximately 555 ft, the innerburden thickness was approximately 105 ft, overlays of the mine layout show pillars were superpositioned, minimal roof to floor convergence was measured, and pressure readings indicated a skin loading only.

RI 9177. Horizontal Trajectories of Rotary-Drilled Holes, by Tobias W. Goodman and Joseph Cervik. 1988. 11 pp. 14 figs. This Bureau of Mines report investigates the horizontal trajectory of boreholes drilled in coalbeds using the rotary drilling technique. Test holes drilled in coalbeds showed that the path of a borehole in the horizontal plane depends on drilling assembly configuration, drill bit rotation, and coalbed geologic features. An assembly that contained an 18-ft (5.5-m) long drill collar and two centralizers had the best horizontal stability evidenced by trajectories that deviated less than 16 ft. (4.9 m) from a target at 1,000 ft (305 m). Removal of one of the centralizers resulted in a loss of control of hole trajectory in the horizontal plane. Generally, holes tended to turn to the right, presumably because of right-hand rotation of the bit. Deviations from the original bearing line were as much as 200 ft (61 m) or more at a depth of 1,000 ft (305 m).

RI 9178. Evaluation of Refractories for Aluminum Recycling Furnaces, by E. G. Davis. 1988. 8 pp. 8 figs. Under a memorandum of agreement with Reynolds Metals Co., Richmond, VA, the Bureau of Mines studied the problem of corundum formation on refractory linings in aluminum recycling furnaces. A laboratory test was developed for evaluating refractories in contact with molten recycled aluminum and identifying the mechanism of corundum formation. A test apparatus was designed and constructed to evaluate the performance of refractory samples. Corundum mechanism formation studies indicated that corundum forms on refractories when there is metal penetration. Once corundum forms, it acts as a wick allowing the molten aluminum to move to the surface where it is oxidized, thus causing further growth of the corundum. Phosphoric acid treatment or a spinel mortar coating prevented corundum formation on the 70- and 90-pct-Al_2O_3 refractories.

RI 9179. A Method for Predicting Equilibrium Values in the Solvent Extraction of Copper in Ammoniacal Systems, by D.N. Nilsen, J. H. Russell, and R.L. Rickel. 1988. 32 pp. 6 figs. A mathematical modeling method was developed by the Bureau of Mines for the prediction of the principal equilibrium species in the solvent extraction of copper. The use of models for predicting the amount of metal extracted can reduce the amount of experimental work required to characterize a system for purposes such as optimization studies. Models were developed for the extraction of copper from ammoniacal sulfate and carbonate solutions with commercially available extractants commonly used by industry. Results from laboratory shakeout tests compared well with predictions of the equilibrium concentrations of copper and pH values. For example, the loading of copper onto the solvent was predicted for most cases within ±5 pct of the measured values, and the pH to within ±0.1 pH unit in sulfate systems and ±0.2 pH unit in carbonate systems. Both mechanistic and empirical extraction equations were developed from laboratory data for copper and ammonia. The empirical-based models were slightly more accurate than the mechanistic-based models. Industrial-level concentrations of the aqueous and organic constituents were used in this work. Independent variables included copper concentration, ionic strength, and initial pH of the aqueous phase; extractants, diluents, and their concentration in the organic phase; and temperature.

RI 9180. Effect of Shearer Web Depth on Dust Generation and Methane Liberation, by J. A. Organiscak, D. M. Doyle-Coombs, and A. B. Cecala. 1988. 11 pp. 9 figs. The Bureau of Mines recently investigated dust generation and methane liberation during half- and full-web cutting at a double-drum shearer longwall face. This study was conducted to ascertain the health and safety aspects of wider web shearing at longwalls. Results from these underground tests showed that deeper web cutting reduced dust generation and methane liberation per ton of coal mined, while significantly improving shearer production rates. When cutting with the airflow (head-to-tail cut pass) full-web cutting decreased dust generation per ton by 16 pct at the shearer and 6 pct at the tailgate, with an increase in shearer production rate of 72 pct. Methane liberation per short ton also decreased by 36 pct at the shearer and 22 pct at the tailgate. Full-web cutting against the airflow (tail-to-head cut pass) decreased dust generation per ton by 41 pct at the shearer and 37 pct at the tailgate over half-web cutting, with an increase in shearer production rate of 61 pct. Methane liberation per ton also decreased by 35 pct at the shearer and 41 pct at the tailgate. These improvements for full-web cutting are a reflection of improved cutting efficiency (less dust and methane produced from cutting) and less new face area exposed per ton of coal mined (less methane liberated from face per short ton of coal mined).

RI 9181. Leaching Gold-Silver Ores With Sodium Cyanide and Thiourea Under Comparable Conditions, by J. A. Eisele, A. H. Hunt, and D. L. Lampshire. 1988. 7 pp. There is currently much interest in how extraction of gold and silver from ores with acidic thiourea solution compares with extraction using alkaline cyanide solution. Agitation leaching tests were performed by the Bureau of Mines on 14 precious metal ores using sodium cyanide (NaCN) and thiourea [$(NH_2)_2CS$] as extractants. The objective was to compare the results of the two extractants. NaCN was used at a concentration of 2 g/L with and without H_2O_2 as an oxidant. $(NH_2)_2CS$ was used at concentrations of 2 and 20 g/L, and the solution potential was controlled at 390 to 420 mV standard hydrogen electrode (Eh) with $Fe_2(SO_4)_3$. With both reagents at 2-g/L extractant levels, NaCN extracted more gold and silver than $(NH_2)_2CS$ from all of the ores. At 20 g/L $(NH_2)_2CS$ compared with 2 g/L NaCN, $(NH_2)_2CS$ extracted more gold than NaCN from two ores, the same amount from one ore, and more silver from one ore. NaCN extracted more gold than $(NH_2)_2CS$ from 10 ores and more silver from 4 ores.

RI 9182. Strain Energy as a Basis for Optimizing Roof Truss Installations in Bedded Roof, by C. P. Mangelsdorf. 1988. 24 pp. 13 figs. When the finely bedded shale frequently encountered over coal seams experiences a separation, the material below the separation must behave like a beam or plate in that it must resist both bending and shear. Because of the weakness in interlaminar shear inherent in such strata, shear deflections that are usually ignored in isotropic beam theory may account for a significant part of the total roof sag. Similarly, when a roof truss is installed in such a roof the upward displacement reducing the sag will have components due to shear as well as bending. Questions asked by mine operators about the installation of roof trusses frequently deal with optimum position, slope, and initial tension of the inclined chords. This Bureau of Mines report examines the effects of those chord parameters on the strain energy of both shear and bending and offers optimum values that will minimize the total strain energy of the immediate roof. Design charts are provided, several design examples are included, and the results are compared with current practice. The effects of in situ stresses are investigated and are shown to be equivalent to an additional load on the beam.

RI 9183. Probability of Spark Ignition in Intrinsically Safe Circuits, by James C. Cawley. 1988. 15 pp. 14 figs. This report presents results of recent Bureau of Mines research to establish the probability of spark ignition as a function of current (or voltage, for capacitor circuits) for resistive, inductive, and capacitive circuits in 8.3-pct methane-air atmospheres. The data presented quantify the explosion hazard created when low-power electronic devices catastrophically fail

in an explosive mine atmosphere. Previous literature dealt with levels of probability between 10^{-3} and 10^{-4}. This report extends the probability data to levels as low as 10^{-7}. This study has verified that when the probability of ignition, p_i, is plotted on a log-log coordinate system versus the current (or voltage), a continuous, straight-line relationship is formed. An interesting result that can be statistically hypothesized is that at some low level of igniting current the ignition process ceases altogether.

RI 9184. Effects of Various Longwall Chain Pillar Configurations on Gate Road Stability, by J. M. Listak, J. C. Zelanko, and T. M. Barton. 1988. 17 pp. 15 figs. The Bureau of Mines conducted a field study to assess the performance of various chain pillar configurations in terms of gate road entry stability. Vibrating wire stressmeters (VWS's) were installed in four consecutive gate road chain pillars. Field data collected during panel retreat were analyzed to gain a better understanding of the mechanics of vertical load redistribution in gate road chain pillars as it relates to ground control problems. Several different pillar configurations were investigated including abutment-yield and yield-abutment-yield designs. VWS data indicate that average pillar loads were lower and appeared to stabilize when an abutment-yield pillar arrangement was utilized. Data analyses also support the occurrence of severe roof and pillar deterioration that was visually observed in the tailgate entries during panel extraction.

RI 9185. Dimensional Changes of Select Ceramic Materials Exposed to HCl, HNO_3, and H_2SO_4 Acid Environments, by J. P. Bennett and M. A. Maginnis. 1988. 10 pp. 3 figs. The Bureau of Mines investigated the dimensional changes of ceramic materials exposed to acid environments to evaluate construction materials for emerging technology in chemical and metallurgical processes. Six commercial ceramic materials (two red shale, two fireclay, one silica, and one silicon carbide (SiC)) were exposed to H_2O, 20 and 30 wt pct HCl, 40 and 60 wt pct HNO_3, and 10 and 50 wt pct H_2SO_4 at temperatures from 50° to 90° C for 300 days. Linear expansions ranged from a low of −0.02 pct for the silica to a high of 0.45 pct for the red shale. A general ranking of the volume expansion of the materials tested (from high to low) is as follows: high-porosity red shale A and fireclay B >> low-porosity red shale B and fireclay A > silicon carbide and silica. A general ranking (largest to smallest) of the effect of exposure environments is HCl > H_2SO_4, HNO_3 > H_2O. An autoclave test method was evaluated. Data obtained from 8- to 24-h exposures were compared with data obtained from the 300-day exposures. The relative expansion trends were similar, indicating that this method could be used as an accelerated test.

RI 9186. Investigation of Methane Occurrence and Outbursts in the Cote Blanche Domal Salt Mine, Louisiana, by Gregory M. Molinda. 1988. 21 pp. 17 figs. The Bureau of Mines conducted an investigation into the occurrence of outbursts of salt known to be responsible for explosions, fatalities, and damage in domal salt mines. The purpose of the investigation was to develop a basis for predicting these outbursts based on geologic and associated physical properties of salt. The investigation was conducted at the Cote Blanche salt mine in southern Louisiana. Because outbursts are the primary mode of methane emission into the mine, more than 80 outbursts, ranging in size from 1 to 50 ft in diameter, have been mapped. These outbursts generally are aligned and elongate parallel to the direction of salt layering. More than 200 salt samples, both random and selected, were tested for methane content. It was found that outburst zones are well correlated with high methane content. Detailed mapping also revealed that the zones are well defined, with salt crystal size abruptly increasing upon entry into the zone. The intensity of folding and kinking of the salt layering within the outburst zone also appears to increase. An interbedded sand layer occurring throughout the mine does not appear to be a significant source of methane. However, fine-grained salt may be related to outburst occurrence.

RI 9187. Foundation Response to High-Extraction Mining in Southern Illinois, by Larry R. Powell, Theodore L. Triplett, and Ronald E. Yarbrough. 1988. 54 pp. 37 figs. The Bureau of Mines, in cooperation with the Illinois Mine Subsidence Insurance Fund, instrumented and monitored the response of two foundations to ground movements induced by subsidence from high-extraction retreat mining in southern Illinois. The objective was to study the interaction between the ground surface and a foundation during a subsidence event to enhance the understanding of the mechanisms that produce subsidence effects in structures. This study measured the response of two differently constructed foundations to subsidence, evaluated the capability of the instrumentation and monitoring program to detect and track foundation and ground movements, and provided data for developing mitigative techniques to reduce foundation damage and formulate economic repair strategies. The instrumentation and monitoring plan successfully measured the response of the foundations to the subsidence-induced ground movements. Both foundations showed a tendency to cantilever when ground movements were rapid. Curvature developed in the footings as shown by differential vertical displacements and differential tilts. All measured displacements and observed damage indicate deformation was caused by a combination of bending and torsion. The difference in performance of the two foundations indicates that mitigative measures can reduce the effects of subsidence on residential foundations.

RI 9188. Horizontal and Vertical Load Transferring Mechanisms in Longwall Roof Supports, by Thomas M. Barczak and David E. Schwemmer. 1988. 24 pp. 23 figs. This report describes a study that examined load transfer mechanics in longwall shield supports as part of the Bureau of Mines research program to optimize support design and utilization. The objectives of this study were to determine the contribution of the leg cylinders and the caving shield-lemniscate assembly towards full shield vertical and horizontal load resistance capability and to determine how the interaction of these members affects overall shield response. Load-displacement characteristics of the leg cylinders and the caving shield-lemniscate assembly, independent of the full shield, were evaluated from controlled displacement tests in the Bureau's mine roof simulator, and responses were compared with full shield responses to identify load transfer mechanics. It is concluded from this research that the participation of the caving shield-lemniscate assembly significantly affects the response of the shield support. It is likely that the caving shield-lemniscate assembly is not participating fully in current shield designs because of translational freedom in the numerous pin joints. It is also concluded that the shield will respond differently to different boundary conditions resulting from interaction with the strata. This report describes load transfer mechanics of shield supports and the implication of these research findings on shield design and utilization.

RI 9189. Relationship Between Horizontal Stresses and Geologic Anomalies in Two Coal Mines in Southern Illinois, by David K. Ingram and Gregory M. Molinda. 1988. 18 pp. 15 figs. In situ horizontal stresses were measured to determine the influences of geologic anomalies on the regional horizontal stress field in two coal mines in southern Illinois. Stress measurements were obtained near a normal fault having a 121-ft displacement at the AMAX Wabash Mine and a large coalbed want at the Kerr-McGee Galatia No. 5 Mine. Horizontal stress measurements were completed using a Bureau of Mines borehole deformation gauge. The average maximum and minimum horizontal compressional stresses at the Wabash Mine were 1,400 and 800 psi, with the direction of maximum stress ranging from N 78° W to N 83° E. At the Galatia No. 5 Mine, the averages were 1,500 and 500 psi, with the direction of maximum stress ranging from N 85° E to N 75° E. Generally, the geologic anomalies appear to have no dramatic effect on the regional horizontal stresses. However, subtle differences between stress measurements suggest an influence by the fault zone at the Wabash Mine. The larger anisotropic stress conditions at the Galatia No. 5 Mine could be responsible for the increase in kink zones and directional roof failures.

RI 9190. Recovery of Cobalt From Spent Copper Leach Solutions—Improved Elution and Impurity Removal Techniques, With Revised Process Economics, by P. G. Bennett and T. H. Jeffers. 1988. 9 pp. 2 figs. The Bureau of Mines developed a process using ion exchange to recover cobalt from spent copper leach solutions. A preliminary economic evaluation of the process indicated that about one-third of the capital cost was attributed to the total resin inventory, and one-third of the operating cost was required for reagents to remove iron from the ion-exchange eluates. An agitated Pachuca elution system was investigated in place of a fixed-bed elution system. The Pachuca system reduced the resin inventory by 27 pct when compared with the fixed-bed elution system. Processing fresh spent copper leach solution reduced the resin

inventory by 20 pct and resin iron loading by 80 pct. Reagent requirements for removing iron from the eluates were decreased because less iron was extracted. The Pachuca system, along with processing fresh spent copper leach solution, reduced the total resin inventory by 47 pct. A revised cost evaluation of the cobalt recovery process was obtained to determine the effects of these process modifications. The estimated total capital cost for a plant processing 10,000 gpm of spent copper leach solution containing 26 ppm Co was $23.1 million. With credits for nickel, zinc, and copper byproducts, the estimated net operating cost was $5.10/lb of cobalt.

RI 9191. Selective Electrowinning of Mercury From Gold Cyanide Solutions, by S. A. N. Sheya, J. H. Maysilles, and R. G. Sandberg. 1988. 13 pp. 16 figs. Many gold-bearing ores in the Western United States also contain small amounts of mercury. The presence of mercury creates potential pollution and health hazards during several steps in gold processing. An investigation was undertaken by the Bureau of Mines to develop techniques for removing mercury from cyanide mill solutions by selective electrowinning to reduce the potential hazards. Sixty-five percent of the mercury was selectively electrowon from synthetic carbon strip solution at applied potentials of 1.00 to 1.50 V when using a mercury-coated platinum or copper plate cathode. Increasing the active surface area by using mercury-coated copper wool resulted in up to 96 pct of the mercury being electrowon from mill carbon strip solutions that contained 1.9 to 20 ppm Hg, 20 to 345 ppm Au, and 0.35 to 39.5 ppm Ag. About 98 pct of the silver was electrowon with the mercury onto the mercury cathode. Gold extraction ranged between 0 and 20 pct. Results of the investigation showed that choice of cathode material was critical to the success of the process. Selectivity was not achieved using uncoated steel wool cathodes.

RI 9192. Rapid (Grab) Sampling During Full-Scale Explosions—Microscopic and Analytical Evaluation, by Ronald S. Conti, Isaac A. Zlochower, and Michael J. Sapko. 1988. 17 pp. 15 figs. The Bureau of Mines has developed a system using a high-speed electropneumatic mechanism for the rapid (grab) sampling of dusts and gases during an explosion. The sampling system consists of an aluminum housing that incorporates two 30-cm³ preevacuated glass vials with rubber septums. Upon actuation, the sampling probe needle is driven through the septum with a pressurized air pulse, filling the tube with gas and dust from the mine explosion. After a predetermined time, the sampling probe needle is retracted by a second high-pressure air pulse to its normal (quiescent) state, allowing the sampling tube to reseal. The onset and the duration of sampling are independently variable and controlled by a time-delay relay package. This technique enables the monitoring of pyrolysis-charring in coal particles and the generation and combustion of the pyrolysis vapors in both large- and small-scale explosions. The following results were obtained from full-scale dust explosion tests at the Bureau of Mines Lake Lynn Laboratory: (1) Gas sampling of the leading edge of the flame front shows the large concentration changes, characteristic of the flame front; (2) gas samples taken entirely in the flame zone consist of pyrolysis and combustion products with very low residual oxygen; and (3) the particles collected in the flame zone show signs of extensive pyrolysis and charring.

RI 9193. Preliminary Evaluation of the Relationship of Bit Wear to Cutting Distance, Forces, and Dust Using Selected Commercial and Experimental Coal- and Rock-Cutting Tools, by Matthew N. Plis, Carl F. Wingquist, and Wallace W. Roepke. 1988. 63 pp. 33 figs. This report describes the initial results of long-range research on bit life conducted by the Bureau of Mines. Three commercial bit designs—a round-nose radial, 60° conical, and 90° conical with tungsten carbide (WC) inserts—and five experimental bits were tested. Four of the experimental bits were radial designs using polycrystalline diamond compact (PDC) inserts. The fifth was a 90° conical with an oversize WC insert. Bits were worn on a high-silica sandstone typical of coal mine roofs. The bits were mounted on a 34-in-diam drum section that provided a bit speed of 565 ft/min. Cutting forces were measured on a modified vertical slotter using a three-axis force dynamometer and recorded on an FM magnetic tape recorder. Changes in cutting forces, bit weight, and airborne dust due to gradual abrasive wear and catastrophic insert failure are presented. Tabulated and graphed data, photographs of the progression of bit wear, and selected qualitative visual and auditory observations of the bits taken throughout the experiment are found in the appendixes. The results show that bit life ranged from approximately 16,000 ft for the WC round-nose radial bit to over 125,000 ft for a PDC round-nose radial. Performance, in terms of bit life, cutting forces, wear rate, frictional sparking, machine vibration, and noise, was in general best with the PDC bits, followed by the rotating WC bits, with the nonrotating WC bits (round-nose radial and locked 60° conical) being the worst. The results show variations in the included tip angles of new conical bits have an insignificant influence on bit performance when the effects are averaged over the life of the bit. In addition, new bits were generally found to entrain more primary respirable dust for a given cutting distance than wornout bits. It is hypothesized that this is due to the difference in frictional behavior between new and worn bits. The results from these tests are being used in the Bureau's cutting system model.

RI 9194. Dielectric Properties of Low-Loss Minerals, by R. H. Church, W. E. Webb, and J. B. Salsman. 1988. 23 pp. 13 figs. As part of the research effort on investigating the effects of microwave energy upon the chemical and physical properties of different minerals and ores, the Bureau of Mines has conducted basic research into identifying those properties of minerals that are affected by microwave energy, namely, the dielectric constant and loss tangent. These properties were determined utilizing the theory of microwave propagation in a coaxial waveguide filled with a dielectric material and measuring the input impedance with an RF impedance analyzer that operates from 1 MHz to 1 GHz. By knowing the microwave frequency and filling the waveguide with a powdered mineral, the dielectric properties of the mineral sample were determined. From these dielectric properties, theoretical microwave heating characteristics of each mineral could be calculated. These same mineral samples were then irradiated by a 915-MHz 30-kW variable power microwave oven, and dielectric heating studies were performed. A comparison of the theoretical heating characteristics and the results from actual dielectric heating studies was conducted to evaluate the dielectric property measurements on each mineral. This report presents the results of the Bureau's research in identifying the dielectric properties of low-loss minerals according to the mineralogical classification scheme along with their irradiation studies. Though far from complete, this study represents some of the more frequently encountered low-loss minerals.

RI 9195. Geologic Factors Influencing the Gas Content of Coalbeds in Southwestern Pennsylvania, by James P. Ulery. 1988. 26 pp. 20 figs. A Bureau of Mines geologic study of Pennsylvanian and Permian coalbeds in southwestern Pennsylvania was undertaken to determine the effects of coalbed geology and petrology on in situ coalbed gas contents. Data were obtained from 18 coreholes from parts of four 7.5′ quadrangles in southwestern Washington and northwestern Greene Counties, and from a single corehole in Westmoreland County. A total of 88 samples from 24 coalbeds were collected for direct-method testing to determine gas content. The samples were also analyzed for petrographic composition, chemical composition, and vitrinite reflectance values. Corehole information was used to generate isopach maps and geologic cross sections useful in data interpretation. Results of the investigation show that coalbed gas content is related to vitrinite reflectance, but not to petrographic composition. Gas contents are also influenced by other geologic factors such as roof rock lithology and competency, and location with respect to local fold structure.

RI 9196. Inhibition of Spontaneous Combustion of Coal, by Alex C. Smith, Yael Miron, and Charles P. Lazzara. 1988. 16 pp. 9 figs. This report describes laboratory studies conducted by the Bureau of Mines to evaluate the effectiveness of 10 additives to inhibit the self-heating of coal. Aqueous additive solutions were applied to a bituminous coal with a high spontaneous combustion potential, and the minimum self-heating temperatures (SHT's) of the dried coal-additive mixtures were determined in the Bureau's adiabatic heating oven. The relative effectiveness of the additives was determined by the observed changes in the minimum SHT's of the mixtures, or by the time required for the sample temperature to reach 150° C, compared with the untreated coal and a coal-water blank. Sodium nitrate, sodium chloride, and calcium carbonate were found to be the most effective inhibitors, followed by ammonium dihydrogen phosphate, calcium chloride, ammonium chloride, sodium acetate, and potassium chloride. Two additives, sodium formate and sodium phosphate, promoted the self-heating process. Differential scanning calorimetry experiments on the coal-additive

mixtures showed that reactions occurred between the coal and some of the additives, but these reactions did not influence the self-heating process.

RI 9197. Pallet Loading Dust Control System, by Andrew B. Cecala and Anthony Covelli. 1988. 12 pp. 7 figs. The Bureau of Mines has developed a pallet loading dust control system designed to lower the dust exposure of workers during the bag stacking process at mineral processing facilities. The system makes bag stacking much easier because the pallet height remains constant throughout the entire bag stacking cycle through the use of a hydraulic lift table. The system uses a push-pull ventilation technique to capture the dust generated during bag stacking. A low-volume, high-velocity blower system operating at approximately 150 cfm blows a stream of air over the top layer of bags on the pallet. The blower system is composed of two 3-in air jets (approximately 1,200-ft/min velocity) directed toward an exhaust system on the opposite side of the pallet. As these air jets travel across the pallet, they entrain the dust generated during bag stacking. The exhaust ventilation system pulls approximately 2,500 cfm of air and dust through the exhaust hood. This exhaust air can then be dumped into a baghouse ventilation system, or filtered before being discharged outside the mill. During a laboratory evaluation, a 70-pct dust reduction was recorded for the bag stacker. The system was then evaluated in an actual working environment. The first field evaluation was performed at a silica sand operation in which one worker performed the entire loading and bag stacking process. This worker's dust exposure was lowered 76 pct when using the new pallet loading system. The second field evaluation showed only moderate dust reduction, but this was mainly attributed to an overriding problem associated with background dust and the cleanliness of the bags. From both the ergonomic and production standpoint, the system was well received by both the workforce and plant management.

RI 9198. Case Study of the Effects of Longwall Mining Induced Subsidence on Shallow Ground Water Sources in the Northern Appalachian Coalfield, by J. S. Walker. 1988. 17 pp. 14 figs. The Bureau of Mines monitored surface subsidence and water level fluctuations in 10 shallow observation wells above a series of four adjacent longwall panels in southwestern Pennsylvania, for about 4 yr. This study attempted to correlate the changes in the water levels within the observation wells to the measured vertical and horizontal ground movements associated with subsidence. Results of this study indicate that the fluctuation of the water levels appears to be a function of the well location relative to the mine layout and the proximity of mining. Wells are generally unaffected by mining of a preceding panel unless they are located within the angle of draw for that panel. Wells located at the centerline of a longwall panel exhibit the greatest fluctuation and head loss. This relationship may be related to the strain developed by the advancing longwall face. The water levels in the wells monitored fell at the greatest rate when the ground surrounding the well was in tension. The rate of the decline decreased as the dynamic development of the strains was changing from tension to compression. The water levels were found to be near the premining level before the ground was subject to maximum compressive strain. Nine of the ten wells investigated recovered to their premining water level after mining was completed.

RI 9199. Metal Recovery From Secondary Copper Converter Dust by Ammoniacal Carbonate Leaching, by Robert C. Gabler, Jr., and Jack R. Jones. 1988. 8 pp. 2 figs. Effective recycling or disposal of flue dusts is a continuing problem, particularly for secondary smelters treating low-grade Cu scrap. The Bureau of Mines investigated a variety of flue dust treatment approaches and demonstrated the technical feasibility of a bench-scale alkaline method that includes leaching, cementation, precipitation, and roasting. Flue dust was leached at room temperature with an alkaline solution of $(NH_4)_2CO_3$ and NH_4OH to solubilize ZnO and Zn metal. Some copper, lead, tin, and most of the zinc were dissolved in the leach step. Copper, lead, and tin were recovered in the cement product. The Zn in the filtrate was precipitated by pH adjustment to neutral using CO_2 injection. The Zn salt was filtered from solution and roasted to give high-purity ZnO. The leach residue, enriched from 4.3 to 10.4 pct Sn, could find a ready market; the metallic cement product can be recycled back to the copper converter; and the high-purity ZnO product can be sold in several markets, leaving no material for disposal. The possibility for recycling of reagents, lower energy demand, and low environmental impact make this method economically and environmentally attractive for recycling secondary copper smelter flue dusts.

RI 9200. Use of Lignochemicals and Humic Acids To Remove Heavy Metals From Process Waste Streams, by John E. Pahlman and Sanaa E. Khalafalla. 1988. 9 pp. 7 figs. The Bureau of Mines investigated the feasibility of removing heavy metals from mineral-process waste streams by precipitation with lignochemicals and humic acids. Lignochemicals are byproducts from the paper industry, while humic acids are obtained by caustic treatment of peat, subbituminous coal, and lignite. These high-molecular-weight organic materials have many functional groups, which can coordinate and form innercomplex salts with heavy metals that are crystalline precipitates. Filtering of a humic-acid- or lignochemical-treated solution or waste stream containing these precipitates removes the heavy metal sequestrates. Tests were conducted with two lignochemical samples, three humic acid samples, lime (CaO), and sodium hydroxide (NaOH) in which increasing amounts of these additives were reacted with 50 mL of solution containing Fe^{3+}, Al^{3+}, Cr^{3+}, Pb^{2+}, Cu^{2+}, Cd^{2+}, Zn^{2+}, Co^{2+}, Ni^{2+}, Mn^{2+}, and Hg^{1+}. At the appropriate pH, greater than 90- and 99-pct removal was achieved for these 11 heavy metal ions from the 10- and 100-ppm solutions, respectively, using lignochemicals and humic acids. Removal efficiency with these organic materials is better than that with CaO, especially for the more toxic ions, Hg^{1+}, Cd^{2+}, and Pb^{2+}. Unlike the precipitates formed with NaOH or CaO, those with lignochemicals and humic acids are compact and noncolloidal. The volume of their sludge is sharply lower than that of the finely dispersed lime or soda precipitates; thus, their removal in settling tanks or by simple filtration is enhanced.

RI 9201. Techniques To Increase Water Pressure for Improved Water-Jet-Assisted Cutting, by P. D. Kovscek, C. D. Taylor, and E. D. Thimons. 1988. 10 pp. 16 figs. High-pressure streams of water, known as water jets, can be used to improve the cutting efficiency of mechanical bits. During prior testing by the Bureau of Mines, the cutting performance of a longwall shearer, equipped for water-jet-assisted cutting, was evaluated. The performance of the shearer did not improve while using water jet assist because the pressure of the water delivered to the rock surface was inadequate. The study, described in this report, resulted in a determination of the major cause of water pressure loss on the shearer, and an evaluation of the techniques for increasing the water pressure at the rock surface. The results show that the major pressure loss, which occurred between the nozzle and rock surface, is directly affected by the amount of fluid turbulence that develops just upstream from the nozzle. Preventing a sudden change in the direction of the flow channel can increase the stagnation pressure as much as 400 pct. Smoothing the surface of the flow channel in the shearer bit block would increase the stagnation pressure delivered to the rock surface by 35 pct.

RI 9202. Control of Airborne Respirable Dust in the Face Area With Water Sprays Using a Full-Scale Laboratory Model, by Lung Cheng and Welby G. Courtney. 1988. 11 pp. 3 figs. This report presents the results of a Bureau of Mines laboratory investigation of the effect of water sprays in reducing respirable dust that escaped the face area of a full-scale wooden model of a mine entry containing a wooden model of a ripper-type continuous mining machine and exhaust brattice. Areas examined were (1) the general effectiveness of a low-pressure water spray system mounted on top of the mining machine boom, a high-pressure spray system mounted under the boom, and the combined top- and bottom-spray systems, and (2) the effect of these three spray systems on the capture of coal dust particles of different sizes. Dust was injected into a sump cavity at the face. Airborne respirable dust concentration was measured behind the brattice with a personal sampler and cyclone, and particle size distribution was measured with a cascade impactor. When used alone, the top-spray system captured about 55 pct of the respirable dust in the face area and the bottom-spray system captured 60 pct; the capture efficiency of each system is decreased when they are used simultaneously. From a mass-concentration viewpoint, each spray system preferentially captures larger dust particles.

RI 9203. Computer Modeling of Dust and Forces for Longwall Mining Systems, by B. D. Hanson and W. W. Roepke. 1988. 24 pp. 7 figs. An interactive computer program has been devel-

oped by the Bureau of Mines which enables the user to identify the effect of cutting system changes on relative dust generation for longwall shearer drums. The program simultaneously evaluates machine and coal seam parameters, and those parameters which the user can control. The user can change one or more of these parameters at a time to determine their effect on relative dust generation, cutting forces, and/or cost. The program is written in the BASIC programming language. A complete program listing is included along with user instructions and sample outputs. This program is a more comprehensive version of the relative dustiness index (REDI) program described in Bureau Report of Investigations 8979.

RI 9204. Chromium Recovery From High-Temperature Shift Cr-Fe Waste Catalyst, by A. M. Stubbs and B. W. Jong, With an Appendix on Process Economics by M. J. Magyar. 1988. 10 pp. 3 figs. The Bureau of Mines has devised a procedure to selectively extract and recover chromic oxide (Cr_2O_3) from waste high-temperature shift catalysts that contain approximately 6 pct Cr and 62 pct Fe, both in oxide form. The Bureau's procedure consists of roasting the waste catalyst with sodium hydroxide (NaOH) or sodium carbonate (Na_2CO_3), followed by water leaching. The chromium from the leach liquor was recovered utilizing an oxidation-reduction reaction with pH adjustment to form a hydrous chromic oxide ($Cr_2O_3 \cdot XH_2O$) precipitate. The roast-leach procedure produced chromium extractions greater than 89.7 pct, with product recovery in excess of 99 pct from the leach liquor. The costs of the NaOH and Na_2CO_3 roast processes, including sizing and equipment-related recommendations, were determined by the Bureau's Office of Process Evaluation. The economic evaluation indicates that producing a Cr_2O_3 product, at the present time, is not competitive with the present-day cost of imported chromites. The estimated average operating cost for both processes was $5.44/lb of recovered Cr_2O_3 concentrate. However, this procedure offers a potential alternative to the disposal of this waste through landfill.

RI 9205. Subsidence Due to Undermining of Sloping Terrain: A Case Study, by Paul W. Jeran and Vladimir Adamek. 1988. 10 pp. 9 figs. Subsidence over a series of longwall panels undermining sloping terrain in southwestern Pennsylvania was monitored to verify the Bureau of Mines subsidence prediction model for the northern Appalachian coal region. Comparison of the field data to model output shows close agreement. Vertical movements over each panel ceased with the mining of the adjacent panel. Horizontal movements were significantly affected by topographic slope. The distributions of horizontal strains over each panel were similar, with a zone of compression occurring over the center of each panel. The zones of compression were flanked by zones of tension toward the rib. The magnitudes of the tensions were affected by the slope. The strains developed at the completion of each panel were not significantly altered by the mining of subsequent panels.

RI 9206. Model of Coal Dust Explosion Suppression by Rock Dust Entrainment, by John C. Edwards and Kathleen M. Ford. 1988. 17 pp. 4 figs. The Bureau of Mines developed a mathematical model to calculate the aerodynamically induced lifting of coal and rock dust from a composite deposition on a mine entry floor and the subsequent transport of the dust ahead of the propagating combustion zone of a coal dust explosion. For a series of experimental explosibility tests approximated by combustion zones that expand at a constant flame velocity, the mass fraction of airborne rock dust ahead of the flame front, as well as the mass fraction overtaken by the combustion zone, was calculated. A statistical analysis of the theoretical results demonstrated with a high level of confidence that the propagating and nonpropagating test samples belonged to separate populations. This analysis was further supported by an independent model of the average temperature over the combustion zone.

RI 9207. Fire Endurance of Mine Stoppings, by D. Ng, C. P. Lazzara, K. E. Mura, and C. Luster. 1988. 19 pp. 25 figs. A facility to evaluate the fire endurance of mine stoppings was constructed by the Bureau of Mines in the multiple-entry section of the Bruceton (PA) Experimental Mine. Stoppings up to 6 by 8 ft can be tested in a manner simulating mine conditions. The stopping is subjected to a 70-min liquid fuel tray fire with an energy output of 75,000 Btu/min. The stopping and adjacent areas are instrumented with thermocouples and heat flux gauges. Data acquisition is by an automatic data logger capable of continuously recording over 100 channels of information. Two 8-in-thick concrete block stoppings and a galvanized steel stopping were tested. A crack developed on the fire-side surface of the block stoppings where the flames were most intense. However, the temperatures of the unexposed surfaces of the stoppings never exceeded 80° C and the surfaces were undamaged. The steel stopping retained its structural integrity during the test. The temperature of the unexposed steel surface reached 500° C, but combustible materials located 1 ft from the surface did not ignite. A 3/4-in-thick coating of construction plaster was applied to the fire side of the previously tested uncoated steel stopping. The quantity of heat energy transmitted across this coated metal stopping was reduced approximately 50 pct. All stoppings prevented the passage of flame and smoke.

RI 9208. Instructional Mode and Its Effect on Initial Self-Contained Self-Rescuer Donning Attempts During Training, by C. Vaught, M. J. Brnich, and H. J. Kellner. 1988. 11 pp. 2 figs. The purpose of this Bureau of Mines study was to assess the impact of four different instructional modes upon trainees' ability to don self-contained self-rescuers. The modes, designed to deliver the same prepractice instruction, were a computer-based training program, a structured lecture, a live demonstration, and a step-by-step hands-on talk-through. Two hundred forty-one subjects were assigned to groups that received their initial self-rescuer donning instruction by one of the four modes. The trainees' performances were then assessed using a number of different measures. It was found that delivery mode had a moderate initial influence upon how well people performed.

RI 9209. Closed Loop Control for a Continuous Mining Machine, by John J. Sammarco. 1988. 17 pp. 12 figs. As part of a project to automate coal extraction, computer control of a continuous mining machine test bed has been developed and tested by the Bureau of Mines. A computer system and control software were developed for accurate positioning of the conveyor elevation and swing, stabilizer jack, gathering head, and shear elevation. Tramming actions are also controlled by the computer. The computer system was designed to access data from sensors installed on a continuous miner and to interface with the existing control circuits of the miner. Testing in free space was used to characterize the operation of the machine. From this information, control algorithms were written and stored in the computer. The ability to control each function of the continuous miner with a high degree of accuracy and stability was successfully demonstrated in a series of tests in free space and in mining a block of simulated coal. In the mining of simulated coal, the cutting drum was instructed to position the shearer at the top of the block and shear down to the bottom under closed-loop control. The cutting drum came within 0.27 in of the top and within 0.49 in of the bottom of the block for this shearing test.

RI 9210. Hydrometallurgical Recovery of Critical Metals From Hardface Alloy Grinding Waste: A Laboratory Study, by L. D. Redden, R. D. Groves, and D. C. Seidel. 1988. 31 pp. 27 figs. As part of the Bureau of Mines program to reduce U.S. reliance on foreign suppliers of strategic and critical metals, research was conducted to improve technology for the recovery of critical metals from hardface alloy grinding waste, a form of superalloy scrap. This report describes a hydrometallurgical process that demonstrated on a laboratory scale that 79 pct of the chromium, 97 pct of the cobalt, 99 pct of the manganese, 99 pct of the nickel, and 90 pct of the tungsten could be recovered in chemical form from hardface alloy grinding waste. The process involved deoiling the grinding waste, followed by chloride-based dissolution of the deoiled material. A high-grade calcium tungstate ($CaWO_4$) product was recovered from the resultant leach residue by caustic leaching and precipitation. Iron, cobalt, manganese, and nickel chlorides were sequentially recovered from the leach liquor by solvent extraction. Amine extractants were used to extract the iron, cobalt, and manganese; decanal oxime was used to extract the nickel. Market-grade cobalt chloride ($CoCl_2$), manganese chloride ($MnCl_2$), and nickel chloride ($NiCl_2$) products could be produced directly from the resultant strip liquors. The final raffinate was a relatively pure chromic chloride ($CrCl_3$) solution that compared favorably with commercial solutions.

RI 9211. Vacuum Induction Melting of Ti-6Al-4V Alloy in a Cold Crucible, by J. I. Paige. 1988. 6 pp. 2 figs. The effect of fluoride inclusions on the properties of titanium produced from the

Bureau of Mines-developed induction slag melting process is of concern to the titanium industry. The objective of the research was to determine the effect of removing the nonconductive molten calcium fluoride (CaF_2) slag used as an insulator between the titanium and the segmented copper crucible. The data were obtained from single-induction-melted ingots prepared with no CaF_2 insulating slag and an ingot prepared with the normal addition of 4 pct CaF_2 slag. The results showed that the mechanical properties of single-induction-slag-melted and annealed Ti-6Al-4V alloy exceed the minimum values specified in "Aerospace Materials Specification for Titanium Alloy Bars and Forgings AMS4928H." High-cycle, tension-tension fatigue testing yielded similar results. The data from 44 of the 45 specimens were contained within the typical scatter band for fatigue data on wrought Ti-6Al-4V alloy. Although the removal of the insulating slag is a desirable change, the data from the specimens with the previously standard 4 pct slag addition showed no detrimental effect from the slag inclusions.

RI 9212. Anticollision Systems for Large Mine-Haulage Trucks, by Russell E. Griffin. 1988. 14 pp. 8 figs. With the development of larger mine-haulage trucks in recent years, the visual field of the driver has diminished correspondingly. Specifically, the operator's lack of direct vision in the right front area and directly to the rear constitutes a serious hazard to personnel in nearby small utility vehicles. Recently developed electronic technology has made it possible to supplement the use of mirrors and fresnel lenses to warn the operator of specific collision dangers in the truck's blind areas. This Bureau of Mines report describes the results of a coordinated contract and in-house research program to develop and test in-mine prototype electronic systems to detect the presence of smaller vehicles within the blind areas of large mine-haulage trucks. Each system utilized transmitters installed on the smaller vehicles and receivers installed on the haulage trucks. Transmitting techniques tested included both low- and high-frequency radio waves. On-vehicle testing established the engineering feasibility of each approach. Further private sector product development to improve reliability and reduce system costs is recommended. Mining companies should consider the advantages of each type of system.

RI 9213. Fe-Ni-Cr Alloys for Coatings and Electroforms, by J. E. Allison, Jr., and G. R. Smith. 1989. 13 pp. 14 figs. As part of a Bureau of Mines research program to conserve critical and strategic metals, an aqueous electrodeposition method for preparing stainless-steel-type coatings was studied. Chromium powder (averaging 3-μm diam) was suspended in a ferrous-nickelous sulfate electroplating bath and occluded in the electrodeposited Fe-Ni alloy matrix. Subsequent heat treatment of the resulting composite coating formed the ternary alloy. The occlusion process was affected by the quantity of Cr powder suspended in the electrolyte and by the microstructure and composition of the electrodeposited matrix. Coatings containing up to 21 wt pct Cr were deposited from an electrolyte containing 20 vol pct suspended Cr powder. Heat treatment at 1,100° C for 8 h homogenized the composite coating. Deposition of 44Fe36Ni20Cr alloy coatings (250 μm thick) on AISI 1020 carbon steel rods, followed by heat treatment, provided complete protection of the carbon steel during exposure to a boiling 65-pct-HNO_3 solution. Corrosion rates of 0.6 ± 0.4 mm/yr for the coating in the boiling HNO_3 approximate that of 304 stainless steel. Practically shaped electroforms have been prepared by the coating method.

RI 9214. Comparison of Aerial and Ground Surveying of Subsidence Over an Active Longwall, by John C. LaScola. 1988. 12 pp. 9 figs. The Bureau of Mines repeatedly surveyed a grid of monuments over an active longwall mine panel in southwestern Pennsylvania during a 1-yr period. Both conventional ground surveying techniques and photogrammetry were used. The objective of this investigation was to compare elevation measurements of subsidence obtained from aerial and ground survey methods under dynamic ground conditions. The results of a statistical analysis of the survey data show that the mean of the differences between 372 matched pairs of elevation measurements was 0.20 ft (61 mm) with a 95-pct-confidence interval of 0.05 ft (15 mm). The mean of the absolute values of the differences was 0.38 ft (116 mm) with a 95-pct-confidence interval of 0.04 ft (12 mm). Ninety-five percent of the absolute values of the differences were less than 1.11 ft (338 mm).

RI 9215. Instrumentation and Modeling of the North 140 Section of Magmont Mine, Bixby, MO, by D. R. Tesarik and R. W. McKibbin. 1989. 30 pp. 39 figs. An instrumentation and numeric modeling study was conducted by the Bureau of Mines at the Magmont Mine in Bixby, MO. An isolated section of this room-and-pillar mine was monitored with borehole and closure extensometers during a pillar recovery program to determine stress redistribution. In situ stress measurements were taken in the rib before pillar extraction began. Sample cores from the boreholes were taken for analysis of the properties of the host rock in the laboratory. The extensometers recorded no measurable displacements during most of the operation. Two-dimensional, finite-element; three-dimensional, finite-element; and three-dimensional displacement discontinuity codes were used to model the area of study. The finite-element models were run with two initial stress conditions, i.e., stress due to gravity only and stress obtained by in situ measurements. Horizontal stresses in the models reduced the calculated factor-of-safety in the mine back by up to a factor of 10, but did not have a significant effect on calculated pillar stability.

RI 9216. Supercritical CO_2 Solubility of $TiCl_4$, by W. K. Tolley and L. S. Tester. 1989. 11 pp. 5 figs. The Bureau of Mines is testing supercritical fluids as solvents to selectively extract valuable components from complex matrices. Materials recovered during supercritical fluid extraction are often highly purified. Using laboratory apparatus designed specifically for supercritical fluid research, Bureau researchers have measured the solubility of titanium tetrachloride ($TiCl_4$) in supercritical, liquid, and gaseous carbon dioxide (CO_2). CO_2, a commonly used supercritical fluid, is inert, inexpensive, and nontoxic. Supercritical CO_2 formed a single phase with $TiCl_4$ at 45°C and 1,500 psig. When the solution was heated at constant pressure beyond 55°C, $TiCl_4$ precipitated from the fluid. Results showed that $TiCl_4$ solubility in supercritical CO_2 is not controlled by the vapor pressure of the solute.

RI 9217. Methods of Evaluating Explosive Reactivity of Explosive-Contaminated Solid Waste Substances, by T. S. Bajpayee and Richard J. Mainiero. 1989. 5 pp. 3 figs. The Bureau of Mines has developed test procedures and criteria for evaluating explosive reactivity of explosive-contaminated solid waste substances generated by U.S. Army ammunition plants. These substances are produced as explosive-contaminated sludge from wastewater treatment plants, residues from the burning of munitions and explosives on open ground, and residues from deactivation furnaces. The characterization of explosive reactivity is a prerequisite for disposal of such waste materials, which may be contaminated with primary explosives, propellants, or pyrotechnic materials. The Bureau has proposed two tests for this purpose. These tests were developed to evaluate the explosive reactivity as defined in Title 40, Code of Federal Regulations (CFR), part 261.23(a)(6) and (7). These are the Bureau's gap and internal ignition tests, which determine the sensitivity to shock and thermal stimuli, respectively. This report also includes gap and internal ignition reference data for typical blasting agents, high explosives, propellants, and marginally reactive substances. These reference data were used to establish test criteria. The Bureau has evaluated over 400 samples of contaminated soil, sludge, and burning residues using these two test methods.

RI 9218. Thermal Characteristics of Energized Coal Mine Trailing Cables, by M. R. Yenchek and P. G. Kovalchik. 1988. 12 pp. 16 figs. The Bureau of Mines conducted research to determine the relationship between current load and temperature rises in coal mine trailing cables. Six low-voltage, unshielded, portable power cables were continuously and intermittently loaded with direct current of various magnitudes. Temperature rises within and on the cables were measured with thermocouples, and the data were recorded with a computer. Thermal time constants were calculated, which fixed the periods of the duty-cycle tests. Relationships between average temperature at the conductor-insulation interface and current load were established. The steady-state and intermittent currents that produce a 90° C average conductor-insulation temperature were then determined. Comparisons with Insulated Cable Engineers Association (ICEA) steady-state ratings revealed that 10 to 25 pct more current than recommended ICEA ampacities is required to reach rated insulation temperature. Examination of the maximum intermittent temperatures attained showed that autoignition of coal dust and burn injuries to personnel handling the cable would not be concerns if the temperature at the conductor-insulation interface averaged 90° C.

RI 9219. Computer Simulation of Face Ventilation To Dilute High Methane Concentrations Developed by Blasting Oil Shale, by C. E. Brechtel and E. D. Thimons. 1989. 7 pp. 7 figs. Cooperative research efforts by the Bureau of Mines and Agapito & Associates, Inc., Grand Junction, CO, used a one-dimensional, finite-element computer model to simulate turbulent mass transfer in face ventilation of oil shale mines. The objective was to study the dilution of methane released by rubbled oil shale during blasting. A methane release rate function was developed from the back-analysis of field measurements, and the finite-element model was calibrated using tracer gas characterization data from tests of full-scale face ventilation systems.

RI 9220. Two-Leg Longwall Shield Mechanics, by Thomas M. Barczak and David E. Schwemmer. 1989. 34 pp. 36 figs. This Bureau of Mines report investigates shield mechanics by describing the elastic response and interaction of shield components to applied vertical and horizontal displacements for various canopy and base contact configurations. This research provides information on generalized shield mechanics, which is applicable in describing the behavior of all two-leg shield supports. Utilizing mechanics of materials concepts and known kinematic relationships for two-leg shield supports, free-body diagrams are constructed for each shield component illustrating internal axial, shear, and bending moment responses required to maintain equilibrium for each load case evaluated. Predicted shield (component) responses are verified by controlled displacement of instrumented longwall shields in the Bureau's mine roof simulator. Conclusions drawn from these analyses indicate shield structural responses are significantly dependent upon canopy and base contact configurations. Applied displacements also significantly affect shield responses. Horizontal displacement produces different responses than those produced by vertical displacements. The direction of horizontal displacement is also significant in evaluating shield response. Applications of shield mechanics to in situ support monitoring are also discussed. An objective of this research program is to establish unique shield responses to identify in situ load conditions.

RI 9221. Basic Parameters of Conveyor Belt Cleaning, by C. A. Rhoades, T. L. Hebble, and S. G. Grannes. 1989. 19 pp. 19 figs. The spillage that accumulates under conveyor belt lines presents a possible fire and explosion hazard to mine personnel, especially to those who must clean up the spillage. The U.S. Bureau of Mines conducted research to reduce this hazard by identifying and investigating the parameters affecting the efficiency of conveyor belt cleaning. The amount of material carried back under the conveyor and the wear rates of metal cleaning blades decreased with increasing blade-to-belt pressure to a limiting value, after which the carryback and wear rates remained essentially constant. The optimum blade-to-belt pressure was found to be 11 to 14 psi for the research conveyor system. Greater pressures increased the blade-belt friction without improving either cleaning or blade life. The modes of blade wear were three-body abrasion and slurry erosion caused by the sand-lime test mixture. Wear rates were reduced by increasing the metal hardness, optimizing the pressure, and removing conveyor belt imperfections. Corrosion was not observed to affect the wear of various steels in tests of less than 34 h. The results of this study should allow mine operators to run their conveyors under conditions that will maximize cleaning and minimize equipment wear.

RI 9222. Acid Sulfation of Alunite, by L. J. Froisland, M. L. Wouden, and D. D. Harbuck. 1989. 12 pp. 11 figs. The U.S. Bureau of Mines conducted laboratory studies on sulfuric acid (H_2SO_4) digestion of alunite [$KAl_3(SO_4)_2(OH)_6$] as a means for treating domestic deposits of this mineral. Digesting alunite ore in boiling H_2SO_4 at concentrations of 88-wt-pct acid or higher breaks down the alunite and permits a convenient separation of potassium and aluminum. The digestion reaction is a complex sulfation reaction occurring in two stages. In this reaction, the potassium component extracts into the H_2SO_4 for eventual recovery as potassium sulfate (K_2SO_4) in a separate unit operation. Aluminum is left as acid-insoluble aluminum sulfate [$Al_2(SO_4)_3$], which can be extracted by a 95° C water leach. Additional purification of $Al_2(SO_4)_3$ produced in this study is needed to meet cell-grade alumina (Al_2O_3) purity specifications. Extraction and separation of potassium and aluminum from the alunite ore were consistently above 90 pct.

RI 9223. Respirable Dust Sources and Controls on Continuous Auger Mining Sections, by J. Drew Potts, Robert A. Jankowski, and George Niewiadomski. 1989. 8 pp. 6 figs. The U.S. Bureau of Mines identified respirable dust sources and controls on four continuous auger mining sections, two with relatively low dust levels and two with high levels. Factors adversely affecting dust levels included auger equipment design, continuous haulage, and low seam height. Dust controls included ventilation practices and spray systems. Maximizing airflow seemed to reduce dust levels most. Air leakage and shock loss can be reduced by constructing stoppings with brushed-on mortar containing fiberglass and by keeping areas between curtains and ribs free from obstructions and storing equipment not essential for face activities in outby crosscuts. Curtain configuration, setback distance, and installation can also affect dust levels. Use of both blowing and exhausting curtains is the most effective configuration. Setbacks from the face should not exceed 15 ft. Installing brattice curtains at least 5.5 ft from ribs, when entries are 26 ft wide, minimizes velocity head. Installing curtains tightly against the mine roof and floor helps maintain a forward airflow movement in the center of the mine heading; curtain overlap can create a tighter seal. The wet-auger spray system also effectively controls dust, provided the mine is already exercising good ventilation practices.

RI 9224. Foundation Response to Subsidence-Induced Ground Movements: A Case Study, by Jeffrey S. Walker and John C. LaScola. 1989. 12 pp. 12 figs. The purpose of this U.S. Bureau of Mines effort was to determine if ground movement caused by mining-induced subsidence is directly transferred to a structure and, if so, how that transfer takes place. Four concrete block walls with foundations were constructed and monitored over an active longwall panel. Three of the walls were located perpendicular to the direction of mining in zones where maximum inclination, maximum tension, and maximum curvature were predicted to occur. The fourth wall was constructed along the centerline of the panel, parallel to the direction of mining. All of the walls and the surrounding ground surface were instrumented with conventional survey monitoring points and extensometer stations to observe the vertical and horizontal movements. The fourth wall instrumentation also included continuously recording tilmeters. The results of this investigation indicate that these simple structures respond to subsidence in a similar manner as the ground surface. This suggests that once the transfer mechanism is more fully defined, prediction models can be developed to accurately estimate the effect of mining on surface structures.

RI 9225. Causes and Control of Coal Mine Bumps, by K. Y. Haramy and J. P. McDonnell. 1988. 35 pp. 37 figs. Coal mine bumps involve the violent, rapid failure of coal and rock around a mine excavation. Deep coal mines with strong roof and floor rocks and high-stress conditions frequently experience face and rib bumps. The bump problem is becoming more severe as mining depth increases, prompting efforts to control high stress in advance of mining. This Bureau of Mines report presents a review of the most widely used methods to detect and destress high-stress zones along coal faces and an investigation of stress-related bump problems and destressing techniques at a cooperating mine. Geotechnical instrumentation and microseismic methods were used to better understand bump occurrences in underground coal mines. Laboratory tests of the drilling-yield method for high-stress detection were conducted to determine the correlation between the volume of cuttings obtained and the magnitude of the applied stress at various confining pressures. A three-dimensional, multiple-seam computer modeling program, MULSIM, was used to evaluate the effectiveness of stress-relief methods. Modeling results indicate that dangerously high-stress areas can be controlled by either proper planning or destressing. Proper mine planning guidelines and destressing methods such as volley firing, hydraulic fracturing, and auger drilling are discussed.

RI 9226. Comparative Study of Blasting Vibrations From Indiana Surface Coal Mines, by David E. Siskind, Steven V. Crum, Rolfe E. Otterness, and John W. Kopp. 1989. 41 pp. 35 figs. The U.S. Bureau of Mines performed a comparative study of nine sites at eight surface coal mines to determine if the presence of near-surface underground abandoned workings resulted in the generation of adverse long-duration, low-frequency blast vibrations. Six of the nine sites had underlying workings, and two had thick layers of low-velocity unconsolidated surface material. Extended seismic arrays were used to identify the vibration characteristics within a few tens of feet of the blasts and also as modified by the propagating

media at distances over 1 mile. Production blasts and specially fired single-charge blasts allowed the determination of natural ground frequency and the influence of initiation delay timing. Vibration amplitudes from the production blasts at all sites exceeded historical norms, particularly at the greater distances. This contrasts with the near-normal results from single-charge blasts. Apparently, between-hole time delays were insufficient to separate vibrations from adjacent charges for the low-frequency waves present. Single-charge tests showed that the propagating media produced low-frequency, ground-roll-type surface waves at nearly all sites. Large blasts at such sites could produce an unacceptable risk of vibration-induced cracks in nearby structures.

RI 9227. Zero-Surface-Charge-Controlled Drilling for Enhanced Penetration and Extended Bit Life, by John E. Pahlman, William H. Engelmann, Patrick A. Tuzinski, and Pamela J. Watson. 1989. 18 pp. 8 figs. The U.S. Bureau of Mines has continued its investigation of chemical additive drilling fluids that produce a zero surface charge (ZSC) on a rock to better define the boundary conditions of the phenomenon. Laboratory drilling tests were performed on Minnesota taconite, Tennessee marble, and Sioux Quartzite using diamond-impregnated coring bits or tungsten carbide spade bits. Drilling fluids were made from chemical additives such as inorganic salts, cationic surfactants, cationic polymers, acids, or nonionic polymers in either distilled, deionized water, mine pond water, mine well water, or tap water. These additives were tested below, at, and above their respective ZSC concentrations. Penetration and bit life improvements obtained with ZSC concentration solutions ranged from 88 and 56 pct, respectively, to over 650 pct and over 400 pct, respectively, for the additives tested. Polyethylene oxide (PEO) was found to be the best additive for ZSC-controlled drilling because a continuous range of PEO solution concentrations produced the enhanced ZSC-controlled drilling performance.

RI 9228. Microseismic Data Analysis of Failure Occurrence in a Deep, Western U.S. Coal Mine: A Case Study, by Richard O. Kneisley. 1989. 16 pp. 13 figs. Microseismic activity observed both in the laboratory and underground indicates that a quiet period, associated with the closure of existing fractures and strongly influenced by coal seam microstructure, occurs prior to coal bumps. Field studies conclude that coal mine bumps occur against a background of this so-called microseismic calm. This Bureau of Mines report summarizes microseismic activity associated with face bumps and floor bursts in a deep, western U.S. coal mine. Results conclude that while bumps are often accompanied by panel-wide increases in microseismic activity, bumps are not only preceded by a localized decrease in activity, but occur within these quiet zones. The results of this study concluded that microseismic activity may be applicable to the global detection of potential bump-prone zones, but that future studies are necessary to confirm these findings and to improve the techniques for evaluating stress control effectiveness.

RI 9229. Intercomparison of North American Radon Progeny Measurement Methods and Equipment, by T. H. Davis and R. F. Holub. 1989. 7 pp. Twelve laboratories from the Western United States and Canada participated in radon progeny intercomparison measurements at the U.S. Bureau of Mines radon calibration facility in March 1987. The participants intercompared grab-sampling and automated equipment methods at high and low concentrations of radon progeny and condensation nuclei. The objective of this intercomparison was to determine if the measurement procedures and equipment of the North American facilities are equivalent. The sampling results showed good agreement among all participants. The standard deviation for the working level measurements was less than 3.5 pct for 1.70 working level (WL) and less than 8.8 pct for 0.21 WL. This relatively good agreement was achieved by using alpha standards calibrated by the National Bureau of Standards and by closely checking and monitoring airflows.

RI 9230. Effectiveness of Organic Binders for Iron Ore Pelletization, by Larry A. Haas, Jeffrey A. Aldinger, and Robert K. Zahl. 1989. 21 pp. 10 figs. The U.S. Bureau of Mines investigated the use of organic binders as substitutes for bentonite in agglomerating iron ore concentrate. Over 30 organic binders were evaluated at several dosage levels in laboratory tests. The binder groups producing the greatest green pellet strengths were natural gums (guars), carboxyl methyl celluloses, and gelled starches. The non-gelled and alkalized starches, starch acrylic copolymers, wood-related products, and dairy products were less effective but better than bentonite. The highest wet pellet drop numbers were obtained with binders that had a medium plate water absorption value (>500 and <10,000) in distilled water and a high slurry viscosity (>75 cP) at 6 pct solids. The highest dry compressive strengths were obtained with binders that gave the highest adhesive tensile strength (>4 kg/cm^2) on iron oxide lap-joint substrates. Pellets with 0.1 pct organic binder had lower compressive strengths and reduction disintegration indices than those with 1 pct bentonite, but higher reduction rates. Pellets with carboxyl methyl cellulose and gelled starch had higher softening temperatures than those with bentonite. Overall, the most promising binder is gelled starch. Its price makes it more cost effective than carboxyl methyl cellulose, and its pellets have metallurgical properties superior to those of bentonite pellets.

RI 9231. In Situ Measurements and Preliminary Design Analysis for Deep Mine Shafts in Highly Stressed Rock, by M. P. Board and M. J. Beus. 1989. 46 pp. 39 figs. The U.S. Bureau of Mines, under a cooperative agreement with Hecla Mining Co., conducted a rock mechanics study at four widely spaced horizons in a deep mine shaft in northern Idaho. The objective of the project was to measure and analyze rock deformation and lining behavior during construction of a deep shaft in a high in situ stress field within an isotropic rock mass. Rock mass displacements were monitored with multiple-position borehole extensometers. Liner stress and strain were measured with concrete pressure cells and embedment strain gauges. This report discusses the general trends and magnitudes of data from the four test sites, and relates the data to a proposed anisotropic constitutive model for the rock mass. A design procedure is then outlined for specifications of liner thickness and support installation sequences for future shaft sinking.

RI 9232. Improved Method for Determination of Helium-4 in Helium-3 by Mass Spectrometry, by Samuel R. M. Burton and David E. Cornelius. 1989. 7 pp. 3 figs. This U.S. Bureau of Mines report describes a method for determining parts per million (ppm) of helium-4 (He-4) in helium-3 (He-3) to an accuracy of ±5 pct by mass spectrometry. Gravimetrically prepared primary standards were used for the calibration of a Dempster 180° magnetic sector mass spectrometer. A comparison between a 2.49 pct He-4 in hydrogen mixture and a 2.49 pct He-4 in He-3 mixture shows that He-3 can be replaced with hydrogen as a diluent for standards with comparable mass spectrometry sensitivities for He-4. Using hydrogen as a diluent allows analysis of He-3 samples for He-4 when He-3 for preparation of standards is not available and also conserves the rare He-3 isotope. Standards of He-4 in H_2 were prepared for calibration of the mass spectrometer for quantitative determinations of He-4 in the 2- to 100-ppm range. A minimum detectable limit of 2 ppm He-4 is obtained by this method.

RI 9233. Respirable Dust Generation: Comparison of Continuous and Conventional Mining Methods When Excavating Rock in Coal Mines, by John A. Organiscak. 1989. 9 pp. 6 figs. The U.S. Bureau of Mines recently conducted an investigation into the amount of respirable and quartz dust generated while mining rock in coal mines by continuous and conventional methods. The study was made at two mines that use both continuous and conventional mining. Results show that continuous mining produces 1.2 to 3 times more respirable dust, and 6.7 to nearly 15 times more quartz dust than conventional mining.

RI 9234. Capillary Wetting Response of Coal After Exposure to Ambient Air Atmosphere, by H. W. Kilau and J. E. Pahlman. 1989. 27 pp. 22 figs. The U.S. Bureau of Mines examined the wettability of bituminous and subbituminous coals before and after exposure to ambient air atmosphere, as part of an ongoing project investigating the coal-wetting abilities of surfactant solutions intended for the suppression of dust during coal mining operations. Exposure periods were generally 7 days or less, and the changes in wetting response were measured with a capillary penetration apparatus. Wetting solutions tested included a nonionic surfactant, two anionic surfactants, and pure distilled water. After exposure, higher ranked bituminous coals treated with nonionic surfactant solution and pure water showed increased wettability, but lower ranked subbituminous coals showed decreased wettability. With the anionic surfactants, the coals demonstrated opposite responses. The wettability changes appeared to be related to the coal moisture content. These changes may be amplified by specific, but incompletely understood, interactions between surfactant polar groups, absorbed water, and the coal surface.

RI 9235. Separation and Recovery of Metals From Zinc-Treated Superalloy Scrap, by P. D. Laverty, G. B. Atkinson, and D. P. Desmond. 1989. 16 pp. 15 figs. The U.S. Bureau of Mines treated mixed and contaminated superalloy scrap by pyrometallurgical and hydrometallurgical methods to separate and recover metal values. Best results were obtained by leaching Zn-treated or atomized scrap with HCl–O_2 at 95° C and 50 psig O_2. This resulted in dissolving approximately 98 pct of the Al, Co, Cr, Cu, Fe, Mn, Ni, and Zn while rejecting over 98 pct of the Mo, Nb, Ta, Ti, W, and Zr as an insoluble refractory residue. Chlorine was successfully substituted for HCl to leach Zn-treated scrap but was unsuccessful for leaching atomized scrap. The leaching solution was treated by pH adjustment and hydrothermal precipitation at 200° C for 4 h to remove Al, Cr, Fe, and other contaminants as a filterable precipitate. Recovery of Co and Ni would be accomplished by solvent extraction and electrowinning. Chromium recovery as a ferroalloy was demonstrated.

RI 9236. Structural Stability and Oxidation Resistance of Substitute Alloys With Various Cr and Mn Levels, by Je M. Oh and Max L. Glenn. 1989. 11 pp. 8 figs. The U.S. Bureau of Mines is conducting research on the oxidation resistance and structural stability of Fe–(0–8)Cr–(0–16)Ni–(0–16)Mn–3.5Si–1Al alloys as potential substitutes for high-Cr stainless steels. Oxidation tests were conducted in air over the temperature range of 600° to 900° C for up to 1,000 h. Microstructures were analyzed at room temperature after hot rolling. The oxidation properties and the structural stability were found to be greatly affected by the Cr and Mn levels. Although substitution of Mn for Ni increased the oxidation rate, the Mn helped to stabilize the austenitic microstructure. Decreasing the Cr content or increasing the Mn content produced higher oxidation rates and earlier oxide spalling. In this study, reaction kinetics, oxide morphologies, and microstructure of the alloys were investigated using scanning electron microscopy, energy-dispersive X-ray analysis, X-ray diffraction, and electron microprobe analysis.

RI 9237. Evaluation of High-Pressure Front-Mounted Water Jets for Frictional-Ignition Suppression, by C. D. Taylor and A. L. Furno. 1989. 8 pp. 7 figs. The U.S. Bureau of Mines conducted a laboratory study to determine what effect use of water-jet-assisted cutting has on frictional-ignition suppression. A single bit with a steel tip, installed on a rotating drum, repeatedly made 22-in-long cuts in a block of Berea sandstone. The drum was operated in an enclosure that contained an explosive methane-air mixture. High-pressure front-mounted water jets operating at 2,000 to 5,000 psig and low-pressure rear-mounted sprays operating at 80 psig were used; the number of ignitions that occurred with each type of spray was compared. The rear-mounted spray was more effective for preventing frictional ignitions than the front-mounted water jet.

RI 9238. Rotary Drilling Techniques Used in the Beckley Coalbed, by Tobias W. Goodman. 1989. 11 pp. 11 figs. The U.S. Bureau of Mines used a contact drilling strategy with short-collared assemblies in order to rotary drill long horizontal methane drainage holes in the Beckley Coalbed near Glen Daniel, WV. By decreasing the thrust and increasing the rotation of the drill bit when in contact with the roof and floor rock, assemblies with 1-ft (0.3-m), 10-ft (3-m), and 14-ft (4.3-m) long collars were made to deflect and stay in the coalbed. Successful application of this procedure resulted in holes drilled full length in coal with the original assembly including bit. The test assemblies deflected away from the original bearings of the holes during drilling and arced. Four holes were drilled to depths ranging from 478 ft (145.7 m) before the strategy was developed, to 4,034 ft (1,230 m) when the strategy was applied. Total length of the holes in coal was 8,590 ft (2,618 m). After 577 days the total methane captured by the holes was 221,600,000 ft³ (6,276,000 m³). The methane flow rate peaked at 805,000 ft³/d (22,798 m³/d), then decreased to stabilize at 670,000 ft³/d (18,974 m³/d) after 6 months.

RI 9239. Evaluation of Moderately High-Pressure Water-Jet Assist Applied to Single Drag Bit Tools, by J. L. Thompson, E. D. Thimons, and R. J. Timko. 1989. 11 pp. 5 figs. The U.S. Bureau of Mines conducted a water-jet-studies program using a single-bit, in-seam test unit to determine effects of a moderately high-pressure (up to 10,000 psi) water-jet-assisted cutting system on rock weakening. The in-seam test unit was used to obtain cutting force data in tangential, normal, and side force directions. Conical continuous miner and radial longwall miner bits were used to penetrate test samples of coalcrete, Berea sandstone, and Indiana limestone with unconfined compressive strengths of 4,600, 8,000 and 10,000 psi, respectively. Depth of cut in the coalcrete tests was 1 in, with 2-in cut spacing (2:1 ratio). Because of cutting equipment and instrumentation limitations, the Berea sandstone and Indiana limestone were cut using a 0.5-in depth of cut and 2-in spacing (4:1 ratio). Bit velocity was maintained at 25 ft/min for both bits. Each specimen and bit type was tested using 0.3-, 0.6-, 0.8-, and 1.0-mm-diam nozzles and water-jet pressures of 2,500, 5,000, 7,500, and 10,000 psig. Water-jet-assisted cutting decreased average resultant conical and radial longwall bit cutting forces 6.4 and 8.4 pct in coalcrete, 5.5 and 1.4 pct in Berea sandstone, and 2.0 and 5.5 pct in Indiana limestone. Slight reductions of power requirements resulting from water-jet assist were ascertained during these experiments.

RI 9240. Performance of a Novel Bump Control Pillar Extracting Technique During Room-and-Pillar Retreat Coal Mining, by Alan A. Campoli, David C. Oyler, and Frank E. Chase. 1989. 40 pp. 46 figs. Retreat pillar mining concentrates stresses on workings directly outby gob areas, which can result in coal mine bumps. The development of bump-control design criteria by the U.S. Bureau of Mines was furthered by data from a novel bump control mining method at the Olga Mine, McDowell County, WV. The pillar splitting, retreat mining system induced large pillar pressure increases and roof-to-floor convergence. Roof-to-floor convergence monitoring proved to be a valuable tool in evaluating the pillar splitting mining method and localized destressing techniques. Maximum strain energy storage in chain pillars appears to have occurred just prior to the first of four split cuts. At that point a 15-ft-wide, highly fractured perimeter confined the core of the 55- by 70-ft pillars, permitting the pillar core to support tremendous pressures. Splitting the chain pillars into two 17.5- by 70-ft wings removed the confinement load, resulting in pillar yield. Thus, the pillar splitting mining method successfully redistributed the weight of the roof away from the pillar line. Shot fire and auger drilling destressing techniques augmented the pillar splitting mining method by redistributing the weight of the roof.

RI 9241. Calamity Hollow Mine Fire Project (In Five Parts). 2. Operation of the Burnout Control System, by Robert F. Chaiken, Louis E. Dalverny, and Ann G. Kim. 1989. 35 pp. 25 figs. During the period from January to May 1982, the U.S. Bureau of Mines carried out a continuous field test of the Burnout Control process for controlling abandoned mined-land fires. In this process, the rate of burning of an underground mine fire is accelerated through the action of a suction fan, which pulls and collects hot combustion gases from the mine while causing air to flow over the fire. Burnout Control thus controls the emission of heat and fumes from the mine fire, and produces sufficient thermal power to run a small electrical generation plant. Previous reports in this five-part series have described the design, construction, and instrumentation of the Burnout Control system at Calamity Hollow, Allegheny County, PA, and the quenching and excavation process by which the fire was cooled and finally extinguished after this particular experimental field test. This report, which completes the full description of the Calamity Hollow Coal Mine Fire Project, summarizes in detail various aspects of the operational phase of the field test. It includes a chronology of events, a discussion of the technical data, and a summary of results. Despite mechanical and operational problems, the field trial at Calamity Hollow demonstrated that Burnout Control is a viable method of controlling an abandoned mine fire.

RI 9242. Surface Fracture Development Over Longwall Panels in South-Central West Virginia, by David K. Ingram. 1989. 18 pp. 17 figs. The development of large open surface fractures over mined-out coal longwall panels is the focus of this U.S. Bureau of Mines report. The research concentrates on defining the fracture characteristics and their controlling variables. The investigation was conducted at two mines in south-central West Virginia. All but one of the fractures are subparallel to the trend of the underlying longwall panel. One fracture is perpendicular to the trend of a longwall panel. Overall length of the fractures ranges from 60 to 900 ft. In cross section they are V-shaped, ranging from a couple of inches to 25 ft in width at the surface, but narrowing as they increase in depth. Fracture depth varies from a few inches to over 50 ft into bedrock. A vertical fracture or joint plane was observed in the bedrock at several open zones along the fractures. All of the fractures vary in elevation and do not parallel surface contours. The fractures are aligned with local joint trends, they correlate with longwall development, and they are situated in an increased tensional area over the mined-out longwall panels. These observations indicate that the

fractures are tensional openings along preexisting joint planes possibly triggered by longwall mining.

RI 9243. Backfill Properties of Total Tailings, by C. M. K. Boldt, P. C. McWilliams, and L. A. Atkins. 1989. 21 pp. 8 figs. This U.S. Bureau of Mines report presents a study of three typical tailings samples as potential cemented backfill in underground mines. The testing series was unique in that the pulp densities of the samples were all above 75 pct solids. Test results included dry density; slump; percent settling after 28 days of curing; tensile strength after 28, 120, and 180 days of curing; and unconfined compressive strengths after 7, 28, 120, and 180 days of curing. The physical properties of the various test mixtures were further analyzed using linear and nonlinear statistical methods to produce correlations and mathematical equations. Physical properties were used to determine the influence of mix additives and as input for numerical modeling studies of backfill. The mathematical relations were used as a predictive tool in determining the suitability of various materials as backfill.

RI 9244. Effect of Sulfide Minerals on Ferrous Alloy Grinding Media Corrosion, by A. E. Isaacson. 1989. 19 pp. 12 figs. The U.S. Bureau of Mines determined the effect of common sulfide minerals on the corrosion rates of various types of ferrous alloy grinding media. Data obtained from this study will aid in determining the contribution of any electrochemical reactions between sulfide minerals and grinding media to the total grinding media consumption. Common sulfide minerals used in this study were chalcopyrite, galena, and sphalerite. In the presence of oxygen, chalcopyrite was found to increase the corrosion rate, galena was found to decrease the corrosion rate, and the effect of sphalerite was dependent upon the type of grinding media. Possible electrochemical reactions of these minerals in the presence of grinding media are suggested.

RI 9245. Computer Modeling of Continuous Miner Cutting Systems for Dust Generation, by B. D. Hanson and W. W. Roepke. 1989. 21 pp. 6 figs. The U.S. Bureau of Mines has developed an interactive computer program that enables the user to identify the effect of cutting system changes on relative dust generation and forces for continuous miner drums. The program simultaneously evaluates machine and coal seam parameters, and those parameters that the user can control. One or more of these parameters may be changed to determine their individual or collective effect on relative dust generation and cutting forces. The program is written in the BASIC programming language. A complete program listing is included along with user instructions and sample outputs.

RI 9246. Underground Coal Mine Track Inspection and Cleaning Vehicle, by Richard L. Unger. 1989. 34 pp. 35 figs. The U.S. Bureau of Mines has designed, fabricated, and tested a prototype track maintenance vehicle for underground coal mines. The vehicle uses a stiff rotating brush to clean the track so that a visual inspection is possible. It is also equipped to measure track gauge and cross-level. The objective of this report was to describe the track maintenance vehicle and detail the results of investigations into present underground track inspection procedures and cleaning technologies, which led to the development of the prototype. Recommendations are made concerning the integration of components of this prototype vehicle into current track cleaning and inspection systems used in underground mines.

RI 9247. Effects of Abandoned Multiple Seam Workings on a Longwall in Virginia, by Gregory J. Chekan, Rudy J. Matetic, and David L. Dwyer. 1989. 15 pp. 17 figs. In order to reduce waste and improve resource conservation, mine planning, and development, the U.S. Bureau of Mines is investigating multiple seam interactions associated with longwall mining. Longwall gate entry and panel stability have been influenced by previous mining in coalbeds above and below a mine in Virginia that operates in the Lower Banner Coalbed. Directly superjacent, approximately 115 ft, the Upper Banner Coalbed has been partially worked by room-and-pillar mining. Directly subjacent, approximately 730 ft, the Tiller Coalbed has been worked by partial room-and-pillar retreat mining. The study mine has experienced problems during development of gate entries in areas of overmining and undermining. It is anticipated that stress fields associated with adjacent mining may further affect gate entry stability and face advancement during the extraction of the longwall panel. To assess overmining and undermining effects on ground stability, the Bureau gathered geotechnical information at the site. Headgate entries and pillars were instrumented and monitored to study loading behavior as the longwall face approached and passed potential problem areas. Measurements indicate that although increases in average pillar pressure were greater than predicted values, previous mining in adjacent coalbeds had little effect on headgate stability.

RI 9248. Assessment of Experimental Longwall Recovery Rooms for Increasing Productivity and Expediting Equipment Removal Operations, by Eric R. Bauer, Jeffrey M. Listak, and Mike Berdine. 1989. 20 pp. 23 figs. The U.S. Bureau of Mines, in cooperation with a southwestern Pennsylvania coal mining company, Beth-Energy Inc., Mine No. 60, Eighty-Four, PA, recently assessed the feasibility of using predriven recovery rooms (open entry recovery) when longwall mining to increase the productivity of the coal extraction process. Two recovery entries, one 200 ft long and another 600 ft long, were supplementally supported with bolts, channels, and wire mesh, and either fly ash-cement piers or fiber cribs, then mined into by the longwall face. The recovery entries showed little deterioration as the supports provided adequate resistance to the front abutment loading. Compared with conventional recovery methods, the fullface recovery room allowed for panel extraction to be completed nearly 17 days faster and reduced face equipment move time by 1-1/2 days. The potential productivity increase accompanying recovery rooms is greater than the cost of supporting a fullface recovery room. The fullface recovery room provided over 18 additional production days and the opportunity to mine nearly 68,400 st of coal per year per panel mined.

RI 9249. An Improved Method for Determining Helium in Water, by Philip W. Holland. 1989. 9 pp. 3 figs. The U.S. Bureau of Mines has developed an improved method for determining dissolved helium in water in the concentration range of 4.0×10^{-8} to 270×10^{-8} cm³ He (STP)/cm³ H_2O. The method is a modification of a previously reported method that was developed for analyzing surface and subsurface waters in geochemical survey work. Water samples are collected in 500-cm³ stainless steel cylinders, and the dissolved gases in a sample are extracted into an evacuated cylinder of equal volume. After addition of 30 psig of nitrogen containing less than 2 ppb helium to the extracted gases, the resulting mixture is analyzed for helium using a helium-tuned mass spectrometer. The helium content of the water sample is determined from an empirical calibration that is established by analyzing standard solutions of helium in water. The accuracy of the method is ± 7 pct for helium-in-water concentrations above 10×10^{-8} cm³ He (STP)/cm³ H_2O.

RI 9250. Primary Gas Toxicities and Smoke Particle Characteristics During a Two-Stage Combustion of Mine Conveyor Belts: Development of a Test Parameter, by Maria I. DeRosa and Charles D. Litton. 1989. 13 pp. 12 figs. The U.S. Bureau of Mines performed experiments to determine if the primary gas toxicities evolved during the early (~300° C) and later (≥400° C) combustion stages of mine conveyor belts could be predicted by a smoke particle characteristic. The experiments were conducted in an approximately 20-L furnace at set furnace temperatures of 150°, 250°, and 1,000° C, with a furnace airflow of 10 L/min. The variables studied, as a function of time, included hydrogen chloride and carbon monoxide concentrations, the average smoke particle diameter (d_p) and number concentration (n_p), and the product of the average smoke particle diameter and concentration ($d_p n_p$). Other variables included the sample and furnace temperatures and the sample mass weight loss. Results show that the inverse of the smoke particle diameter-concentration product ($1/d_p n_p$) correlates directly with the hydrogen chloride and carbon monoxide toxicities released in large quantities during the early and later stages of combustion.

RI 9251. Tungsten and Gold Recovery From Alaskan Scheelite-Bearing Ores, by J. N. Greaves, W. R. McDonald, and J. H. Maysilles. 1989. 16 pp. 10 figs. Investigations were conducted by the U.S. Bureau of Mines to develop flowsheets for the recovery of tungsten and gold from four Alaskan scheelite-bearing ores. Basic gravity concentration and cyanide leach tests were performed on all samples. About 46 pct of the tungsten and 30 pct of the gold from one sample were recovered in a gravity concentrate containing 24 pct WO_3 (tungstic oxide) and 119 troy ounces per short ton (tr oz/st) Au. Froth flotation of the gravity concentrate resulted in separate tungsten and gold products with grades of 38 pct WO_3 and 2,720 tr oz/st Au and recoveries of 60 and 97 pct, respectively. Additional gold was recovered from the gravity and flotation tailings by cyanidation. Overall recoveries of tungsten and gold from this sample were 28 and 94 pct, respectively. A flowsheet with mill design

parameters was developed that consisted of (1) free gold and scheelite recovery by gravity methods and froth flotation and (2) fine-grained gold recovery by cyanide leaching of reground gravity and flotation tailings, followed by a carbon-in-pulp (CIP) circuit. Data were developed from the Bond mill work index, gold and tungsten flotation, conventional and high-rate thickening, cyanide leaching, and CIP adsorption tests.

RI 9252. Recovery of Principal Metal Values From Waste Hydroprocessing Catalysts, by B. W. Jong, S. C. Rhoads, A. M. Stubbs, and T. R. Stoelting, With an Appendix on Process Economics by Thomas A. Phillips. 1989. 27 pp. 16 figs. The U.S. Bureau of Mines investigated anhydrous chlorination and caustic-acid leaching processes to recover Ni, Co, Mo, and W from waste hydroprocessing catalysts. In batch laboratory-scale equipment, the chlorination process extracted 61 to 99 pct of the metals. Final recovery was 65 to 99 pct. The caustic-acid leaching process extracted 81 to 98 pct of the metals. Final recovery was 36 to 99 pct. Chlorination processing included roasting, chlorination, hydrolysis of metal chlorides for recovering Mo or W, water leaching of Ni or Co from the spent charge, purification, and solvent extraction or precipitation of Ni or Co from the purified solutions. Caustic-acid leach processing included NaOH leaching, solvent extraction of Mo or W from the NaOH leach liquor, H_2SO_4 leaching of the NaOH leach residue, purification, and solvent extraction or precipitation of Ni or Co from the purified solution. The estimated fixed capital cost for a commercial-scale plant processing 39,000 lb/d of waste Ni-Mo-Al catalyst was $8 million for the chlorination process and $9.6 million for the caustic-acid leaching process. The estimated operating cost was about $0.20 and $0.40 per pound of the waste catalyst, respectively, for the two processes.

RI 9253. Relationships Between Annulus Thickness and the Integrity of Resin-Grouted Roof Bolts, by Bryan F. Ulrich, William J. Wuest, and Raymond M. Stateham. 1989. 13 pp. 8 figs. If resin-grouted roof bolts are not installed correctly, mine roof reinforcement can be affected, and roof falls can result. A bolt installation variable that is readily controlled by the mine operator is annulus thickness. The objective of this U.S. Bureau of Mines investigation was to study the effect of annulus thickness variations on the integrity of 3/4-in-diam resin-grouted bolts. Forged-head test bolts, 2 and 1 ft long, were installed in concrete blocks that had been drilled with 1-, 1-1/8-, 1-1/4-, 1-3/8-, and 1-1/2-in-diam bits. Standard pull tests were performed; then the concrete was broken away from the bolts so that grout mix quality could be inspected. It was found that the optimum annulus thickness is 1/8 in (1-in-diam drill hole), and as annulus thickness increases from the optimum, there is a corresponding decrease in grout mix quality, effective grout ratio, and axial stiffness.

RI 9254. X-Ray Fluorescence Analysis of Superalloy Leach Liquors Using a Thin-Film Technique, by R. D. Govier. 1989. 8 pp. 5 figs. The U.S. Bureau of Mines has developed a thin-film X-ray fluorescence technique to rapidly determine Cu, Ni, Co, Fe, and Cr in superalloy leach liquors. Total analysis time per sample was less than 15 min, as opposed to several hours for traditional wet chemical methods. Precision and accuracy were checked by replicate analyses of solutions similar in composition to leach liquors, whose analyte concentrations were well known. Coefficients of variation for all elements were found to be less than 2 pct. With the exception of the results for Fe, all relative errors of estimation were also found to be less than 2 pct. Bulk liquids are not introduced into the spectrometer; thus, the potential for damage to the instrument by leakage of corrosive liquids is eliminated.

RI 9255. Heat-Resistant Steels Containing 8 Pct Cr, by D. E. Larson. 1989. 9 pp. 6 figs. The U.S. Bureau of Mines investigated Fe-base alloys containing 8 pct Cr with Ni, Al, and Si additions as substitutes for standard AISI Type 304 stainless steel (SS) in high-temperature oxidizing applications. The objective of this study was to reduce the amount of Cr required to make an austenitic stainless steel while retaining satisfactory workability, mechanical properties, and oxidation resistance. Alloys prepared in this investigation had a composition of Fe-8Cr-1Mn-0.07C with varying amounts of Ni, Al, and Si. A minimum of 10 pct Ni was required to achieve an austenitic composition. The microstructures of the austenitic alloys were very susceptible to room-temperature, deformation-induced martensitic transformations. When the alloys were cold-worked or stressed, the materials had far greater tensile strengths than Type 304 SS at room temperature. At higher temperatures, tensile strengths and workability of several of the alloys were comparable to that of Type 304 SS. Although martensitic transformation caused the room-temperature properties of the experimental alloys to be quite different than those of Type 304 SS, the superior oxidation resistance and similar hot workability of several alloys encourage their use as replacements for Type 304 SS.

RI 9256. Characterization of the Sheep Creek Pb-Zn-Ag-Sn Prospect, North-Central Alaska Range, by W. K. O'Connor, D. C. Dahlin, and J. D. Warner. 1989. 15 pp. 9 figs. The U.S. Bureau of Mines investigated the Sheep Creek prospect in the north-central Alaska Range to evaluate the Pb, Zn, Ag, and Sn resources. The studies included field investigations, mineralogical characterization, and concentration tests. Mineralization at Sheep Creek consists of disseminated, banded, and massive pyrite, sphalerite, and galena. Tin occurs as grains of cassiterite (SnO_2) in the quartz-mica matrix and within pyrite and sphalerite grains, and Ag occurs in solid solution within the galena. Three bulk surface samples and two sets of core samples were collected at the Sheep Creek prospect for this study. Gravity concentration yielded products with up to 30 pct Sn, and the best result was a product that recovered 52 pct of the Sn at a grade of 22 pct Sn. Bulk sulfide flotation yielded products that recovered up to 89 pct of the Zn, 73 pct of the Pb, and 75 pct of the Ag, but grades were relatively low; selective flotation would significantly increase the grades.

RI 9257. Utilization of Papermill Sludges as Binders for Iron Ore Concentrate, by Larry A. Haas, Jeffrey A. Aldinger, and John C. Nigro. 1989. 28 pp. 12 figs. The U.S. Bureau of Mines, in cooperation with the Iron Range Resources and Rehabilitation Board, investigated the potential of using northeastern Minnesota papermill waste sludges as a binder for Mesabi Range iron ore (taconite) concentrate. Sludges from five different commercial papermill waste treatment operations were evaluated in laboratory tests. Except for the coarsest sludge, all were fairly easy to blend with the taconite concentrate using conventional mixing methods. The coarsest sludge had to be reslurried at 2 pct solids before adding it to the concentrate in order to obtain pellets without visible sludge clumps. Drying and grinding the sludges made them less effective as binders because of a lower degree of rehydration. On a dry weight equivalent basis, twice as much raw sludge binder was required to obtain similar pellet physical properties as with bentonite; however, the pellets made with raw sludge had superior metallurgical properties. Over 30 pct higher reduction rates and over 150° C higher softening temperatures were obtained with sludge binder than with bentonite. Sludge D, which had the lowest fiber and the highest alkali metal content, resulted in the lowest reducibility enhancement. Even though more raw sludge was required than bentonite, the sludges have virtually no value, and therefore may provide a cost-effective additive binder for producing improved metallurgical-quality pellets. Large-scale testing has not been done to confirm these laboratory results.

RI 9258. Alkaline Oxidative Leaching of Gold-Bearing Arsenopyrite Ores, by P. Bhakta, J. W. Langhans, Jr., and K. P. V. Lei. 1989. 12 pp. 7 figs. The U.S. Bureau of Mines developed an alkaline oxidative pretreatment leaching procedure to increase the recovery of gold from arsenopyrite (FeAsS) ores. The best solution compositions for arsenopyrite dissolution were determined using cyclic voltammetry and chronocoulometry. Initial arsenopyrite dissolution occurred at, −0.20 V versus standard hydrogen electrode (SHE) in a sodium hydroxide (NaOH) solution. Leaching of a high-grade arsenopyritic ore containing, in percent, 28.2 As, 25.3 Fe, 19.9 total S, and 1.0 Sb and, in troy ounces per short ton, 1.6 Au and 5.5 Ag resulted in >90 pct As extraction at 100° C, 40 psig O_2, 4 h, and 2 M NaOH solution in a 2-L autoclave. Cyanidation of the leach residues resulted in 90 to 93 pct Au and 60 to 80 pct Ag extractions, compared with only 5 and 15 pct, respectively, without the pretreatment. The procedure was further tested by leaching a low-grade gold ore and a bulk sulfide flotation concentrate prepared from it. Cyanidation of the leach residues resulted in 70 pct Au and 31 pct Ag extraction. The NaOH leachate was partially regenerated by precipitating the arsenate as calcium arsenate [$Ca_3(AsO_4)_2$] and the sulfate as barium sulfate ($BaSO_4$).

RI 9259. Impact of Water Sprays on Scrubber Ventilation Effectiveness, by Jon C. Volkwein and Travis S. Wellman. 1989. 12 pp. 11 figs. The U.S. Bureau of Mines conducted a study to

assess the impact of a directional water spray system on a unique single-inlet dust scrubber on a low-profile mining machine. Tests were conducted in a full-scale model mine using a continuous mining machine. Tracer gas was introduced at the face and concentrations of the tracer gas were monitored at the face and in the return. Various parameters tested included mining position, depth of cut, brattice setback, and combinations of scrubber, and directional or symmetrical sprays. Results indicated that either water spray configuration improved the ventilation effectiveness of the scrubber by a factor of 2 to 3. Average face ventilation effectiveness (FVE) values for all testing of the scrubber and directional sprays were 0.95, versus 0.37 for a standard 20-ft blowing curtain without sprays. No FVE values were less than the standard 20-ft blowing results.

RI 9260. Effect of Energy and Impact Direction on Coal Fragmentation, by Jon I. Voltz. 1989. 16 pp. 4 figs. The U.S. Bureau of Mines has conducted fundamental coal fragmentation studies to evaluate the effects of impact energy and direction of bedding planes on dust generation, size distribution, and impact-output energy relationships. Product size distributions were obtained for the fragmented samples by screening to minus 150 mesh. The minus 150-mesh fines were analyzed with a light-scattering photometer with a measurement range of 176 to 1.9 μm. Increased input energy produced a significant increase in the weight of plus 3/8-in material for impact perpendicular to the bedding planes. No significant trend was observed for parallel impact. Impact direction had little influence on dust size distribution and input versus output energy relationships. As expected, total airborne dust measured at time of impact and percent particulates below 11 μm in size generally increased with increased input energy for both directions of impact. Energy used for sample fragmentation increased with increased energy input.

RI 9261. Abrasive-Enhanced Water-Jet Drill for Hard Rocks, by George A. Savanick and Walter G. Krawza. 1989. 10 pp. 8 figs. The U.S. Bureau of Mines has patented and transferred to industry an abrasive-enhanced water-jet rock drill. This drill incorporates three novel components: a collimator, jet deflectors for cutting clearance, and an unpressurized swivel, which rotates at 1,000 rpm while passing 20 gpm of an abrasive slurry flowing at 1,000 ft/s. Drilling occurs through the action of a 10,000-psi, 20-gpm water jet into which is entrained 22 lb/min of abrasives. The pumps, hoses, and fittings are those commonly used in the water-jet-cleaning industry. Only inexpensive, common sandblasting abrasives are used. This drill can cut through hard rocks with moderate-pressure jets; e.g., rocks with a compressive strength of 73,000 psi can be drilled with a 10,000-psi abrasive jet. In addition to drilling holes, the drill can cut deep, narrow kerfs; collar a hole at any angle; drill through rubble; and chamber holes. The development of the abrasive jet drill is a significant advance in the state of the art of hard-rock drilling. The Government of the United States has licensed the abrasive jet drill patent to Weatherford Water Jetting Systems.

RI 9262. Primary Gas Toxicities and Smoke Particle Characteristics During Combustion of Mine Brattices: Development of a Test Parameter, by Maria I. De Rosa and Charles D. Litton. 1989. 13 pp. 9 figs. The U.S. Bureau of Mines performed experiments to determine if primary gas toxicities that evolve during the early (~300°C) and later (≥400°C) combustion stages of polyvinyl chloride and chlorinated brattices could be predicted by a smoke particle characteristic, which could be used as a simple and inexpensive test parameter. The experiments were conducted in an approximately 20-L furnace at set furnace temperatures of 250° and 1,000°C, for 14-min duration, with an airflow through the furnace of 10 L/min. The variables studied, as a function of time, were the hydrogen chloride (HCl) and carbon monoxide (CO) concentrations, sample and furnace temperatures, the sample mass weight loss, the average smoke particle diameter (d_g) and number concentration (n_o), and the product of the average smoke particle diameter and concentration ($d_g n_o$). Results show that the inverse of the smoke particle diameter-concentration ($1/d_g n_o$) correlates directly with the primary gas toxicities evolved during both stages of combustion.

RI 9263. Use of an In-Seam Tester To Determine Effects of Bit Type on Primary Dust Generation, by Laxman S. Sundae. 1989. 13 pp. 7 figs. A U.S. Bureau of Mines designed and fabricated in-seam tester, retrofitted with a dust shroud, was used to establish a respirable dust index (RDI) and to determine cutting forces from a variety of bit types in four coal mines and a salt mine. Results from cutting tests at four coal mines showed that radial bits required the lowest cutting force and the least specific energy. Generally, for each conical bit the RDI and cutting force increased when the included bit tip angles increased from 70° to 90°. During field tests it was not possible to measure the total quantity of respirable dust produced by each cut; therefore, attempts were made to determine the amount of dust that became airborne from each test cut. The test results show that the quantity of airborne respirable dust is very erratic and cannot be related to bit type. Two statistical methods were employed to analyze RDI, but no correlation was found between the RDI and bit type. Despite scatter in test results for RDI, significant difference was found in RDI generated in four coal seams. In general, RDI increased with increased cutting force.

RI 9264. Alumina Recovery From Copper Dump Leaching Liquors Using a Supported Liquid Membrane, by S. P. Sandoval and L. E. Schultze. 1989. 14 pp. 13 figs. The U.S. Bureau of Mines investigated the separation of aluminum from copper dump leaching liquors using a supported liquid membrane. Aluminum was selectively transported through porous polypropylene impregnated with di (2-ethylhexyl) phosphoric acid in an aliphatic diluent. The effects of variables, such as solution composition, temperature, and extractant concentration, were measured with a three-level fractional factorial experimental design. Experimental results were used to derive equations for predicting transport rates for aluminum, iron, and copper. The major variables influencing aluminum transport were solution temperature, feed solution pH, aluminum concentration in the feed solution, and extractant concentration. Copper and iron transport rates were almost zero when aluminum transport rates were high. Measured aluminum transport rates under the best conditions of 55° C, pH 3.0, 16 g/L Al^{3+}, and 65 pct extractant solution confirmed the predicted value of 210 $\mu g/(cm^2 \cdot h)$. Transport rates for iron and copper were less than 5 $\mu g/(cm^2 \cdot h)$ under these conditions. Aluminum was recovered from the stripping solutions by sparging with gaseous hydrogen chloride to crystallize aluminum chloride hexahydrate, which was calcined to alumina. Sparging crystallization regenerated the stripping acid for recycle.

RI 9265. Continuous Flotation Testing To Recover a Bulk Sulfide Concentrate From Missouri Lead Ore Tailings, by W. L. Cornell and D. C. Holtgrefe. 1989. 7 pp. 8 figs. The Missouri Pb ores are the only domestic Co resource being mined and processed for other metals; therefore, they present a viable short-term opportunity for Co production. Lead, zinc, and copper concentrates are produced from the ore. The Cu concentrate can contain up to 30 pct of the Co and the Pb concentrate up to 15 pct of the Co. Since Co is detrimental to the processing of the Zn concentrate, the remainder of the Co is rejected to the tailings. The tailings can contain as much as 50 pct of the Co originally present in the mined ore. Researchers at the U.S. Bureau of Mines have successfully tested on a continuous basis a process that recovers a bulk sulfide concentrate from mill tailings. The concentrate contains up to one-half of the Co and from 50 to 90 pct of the Pb, Zn, and Cu. Concentrate weight represents 10 pct or less of the total tailings.

RI 9266. Structural Uses and Placement Techniques for Lightweight Concrete in Underground Mining, by Eugene H. Skinner. 1989. 31 pp. 38 figs. The U.S. Bureau of Mines conducted experiments on the use of lightweight concrete in the density range of 100 lb/ft^3 for liners in underground mines. Three test sections were completed: a monolithic, portal-type structure with integral walls and arch constructed aboveground; an underground test section constructed in a mine drift using plywood forms; and a second section constructed in a drift using an air-supported formwork. The lightweight concrete in the two underground test sections was placed using piston pumps and a slickline. Fiber reinforcement was added to the concrete in the mine sections without any apparent problems with either pumping or placement of the concrete. In another experiment, the Bureau and Hecla Mining Co., Mullan, ID, used lightweight concrete in the density range of 25 lb/ft^3 to replace timber blocking in a raise preparation structure. Other experiments are described in which low-density, lightweight concrete blocks were produced for mine ventilation doors, stoppings, and barricades. Other mine uses reviewed include pillars and collapsing beams. An advantage of low-density concrete is that it will display up to 50 pct deformation at a constant yield stress. These innovative concepts in deformable concrete lining systems will aid mine operators by decreasing capital and maintenance costs, increasing the available space in underground haulageways, and providing productivity gains and improved resource recovery in the

soft, caving, squeezing, or bursting ground conditions often found in deep mines.

RI 9267 Hillseam Geology and Roof Instability Near Outcrop in Eastern Kentucky Drift Mines, by Gary P. Sames and Noel N. Moebs. 1989. 32 pp. 39 figs. This U.S. Bureau of Mines study was conducted in eastern Kentucky drift mines as part of an ongoing research program to characterize the outcrop barrier zone. "Hillseams" were identified as the dominant geologic cause of roof instability unique to the outcrop barrier zone, with many roof fall injuries and fatalities attributed to them. Hillseam is the eastern Kentucky miners term for weather-enlarged tension joints that occur in shallow mine overburden where surface slopes are steep. Hillseams are most conspicuous within 200 ft laterally of a coalbed outcrop and under 300 ft or less of overburden. Hillseams form by stress relief, and therefore tend to parallel topographic contours and ridges. They can intersect at various angles, especially under the nose of a ridge, and create massive blocks or wedges of roof prone to failure. Examples of hillseams are described in both outcrop and coal mine roof to establish their geologic character and contribution to roof failure.

RI 9268. Effect of Metal Impurities on Adsorption of Gold by Activated Carbon in Cyanide Solutions, by S. A. N. Sheya and G. R. Palmer. 1989. 7 pp. 3 figs. The U.S. Bureau of Mines performed batch equilibrium contact experiments to examine the ability of activated coconut-shell carbon to adsorb various metal cyanide complexes. Tests were also conducted to determine the effect these cyanide complex impurities might have on the adsorption of gold by the activated carbon. Metal cyanide species included in the investigation were antimony, arsenic, cadmium, calcium, cobalt, gold, iron, mercury, nickel, silver, thallium, and zinc. Tests were made over a pH range of 6.4 to 12.5. The carbon exhibited a preference for gold adsorption over other metals present in solution. In the absence of gold, the metal cyanide complexes were adsorbed; adsorption generally decreased with increasing pH. However, calcium and thallium adsorptions increased with increasing pH, while arsenic and iron were not adsorbed at any pH.

RI 9269. Noise Test Report: Handheld Pneumatic Rotary Drill, by Robert R. Stein and William W. Aljoe. 1989. 11 pp. 4 figs. Using an automated drill test fixture, the. U.S. Bureau of Mines measured the sound power levels produced by a small, pneumatic, rotary roof drill. A series of tests were conducted to determine (1) the relative effectiveness of several drill muffling schemes and (2) the relationship between drill sound power and pneumatic power supplied to the drill. The influence of rotation rate (i.e., airflow) and feed thrust on the penetration rate of the drill was also noted.

RI 9270. Evaluation of Water-Jet-Assisted Cutting Capability on Longwall Shearers, by C. D. Taylor, E. D. Thimons, and P. D. Kovscek. 1989. 14 pp. 13 figs. The U.S. Bureau of Mines evaluated water-jet-assisted longwall shearers in full-scale laboratory tests and underground. Both test programs showed that use of high-pressure water did little to reduce the shearer motor energy required to maintain a given cutting rate. However, three other major benefits were achieved with the use of water-jet-assisted cutting. At 1,800 psi, respirable dust levels were reduced about 80 pct compared with the dust levels of the conventional water spray system operating at 340 psi. Operating at higher pressures required for water-jet assist also resulted in an increase in the average size of coal cut, which translates into a decrease in product fines. Finally, although no controlled measurements of bit wear as a function of water pressure were made, mine personnel reported that the shearer bits lasted longer when water-jet-assisted cutting was used.

RI 9271. Collimated Abrasive Water-Jet Behavior, by David E. Swanson. 1989. 43 pp. 30 figs. The U.S. Bureau of Mines undertook a basic investigation of collimated abrasive water-jet behavior because a more complete understanding of the fundamental process may lead to further technical advances. Laboratory experiments used 2-mm water-jet nozzles and new entrainment apparatus to analyze collimated abrasive water jets operating under varied conditions. Maximum water pressure was 69 MPa to permit use of conventional hoses with a burst-to-operating-pressure ratio of 4. Nozzle and induction line pressures, abrasive induction rates, and jet reactive thrust forces were recorded for each operating condition. Average jet velocity and power were determined from component mass flow rates and reactive thrust force measurements. Relative velocity and cross-sectional distribution of abrasive particles were determined using impact analysis techniques. Other jet characteristics were determined photographically. Properties of free water jets, collimated water jets, and collimated air-water jets were determined for comparison.

RI 9272. Mechanical and Physical Properties of Particulate Composites in the System Titanium Nitride-Alumina-Aluminum Nitride, by K. J. Liles. 1989. 7 pp. 6 figs. The U.S. Bureau of Mines evaluated the physical properties of ceramic particulate composites made from titanium nitride (TiN), alumina (Al_2O_3), and aluminum nitride (AlN) as part of a program to meet the high-performance demands on structural materials for new and emerging technologies. Samples containing from 20 to 80 wt pct TiN were pressed and fired, and their composition, Vickers hardness, modulus of rupture (MOR), and fracture toughness were determined. X-ray diffraction and scanning electron microscope (SEM) analyses showed that, depending on the amount of TiN added, the microstructure of the samples consisted of either a titanium-aluminum-oxynitride (TiAlON) particulate in a spinel matrix or a spinel particulate in a TiAlON matrix. The best results of the physical tests were achieved on a mixture of 40 wt pct TiN, 30 wt pct Al_2O_3, and 30 wt pct AlN. Sintering aids were added in 1- and 3-mol-pct increments to the 40-30-30 mixture to determine their effect on microstructure and physical properties. Results of an analysis of variance on a 4 by 4 factorial analysis showed significant effects on density, MOR, and Vickers hardness.

RI 9273. Physical and Computer Modeling of Roof Bolt Systems, by S. M. Dar, T. W. Smelser, and H. C. Pettibone. 1989. 59 pp. 55 figs. The U.S. Bureau of Mines constructed a full-scale model of a 15-ft-wide coal mine entry to use in combination with finite-element analyses to investigate roof support systems and various types of roof bolts. The objective was to enhance understanding of the fundamental mechanics of the interaction between rock and supports and the relative integrity of bolted mine roof as a function of roof bolt type, length, spacing, and tension, and the basic characteristics of the roof strata. The laboratory test results, when correlated with computer simulations using finite-element analysis and underground verification tests, should provide a basis for designing safer, more cost-effective roof control systems and help to establish guidelines for employing fully grouted resin and mechanically anchored bolting systems. The background for this research, the research approach, the methods and equipment employed, and the results are described in this report.

RI 9274. Determining the Relative Toxicity and Smoke Obscuration of Combustion Products of Mine Combustibles, by Maria I. De Rosa and Charles D. Litton. 1989. 11 pp. 7 figs. Combustible materials, when burned, produce toxic gases and smoke, which may vary dramatically from one material to another, with resultant different total toxicity and smoke obscuration levels. This U.S. Bureau of Mines report presents smoke property data acquired for a variety of mine combustibles and shows that there exists a correlation between the smoke properties, the relative toxicity, and the smoke obscuration levels of those combustibles tested. These correlations can be used to devise simple, standard tests for determining the toxic and smoke obscuration hazards of mine materials during fire.

RI 9275. Effect of Natural Flake Graphite and Carbon Fiber Additions on High-Temperature Properties of Dolomite-Carbon Refractories, by James P. Bennett. 1989. 16 pp. 12 figs. The U.S. Bureau of Mines investigated the role of imported natural flake graphites in dolomite-carbon refractories used in steelmaking processes and evaluated carbon fibers as a potential substitute. Varying quantities (1.5–30 pct) of natural flake graphite and carbon fibers were added to test samples. The effect of the additions on modulus of rupture (75°–2,750° F), deformation under load (2,750° F), and air-slag-metal resistance (3,000° F) was studied. Carbon purity of natural flake graphite additions did not influence hot strength, deformation under load, or air-slag-metal resistance. When the quantity of 90-pct-carbon graphite addition varied between 0 and 30 wt pct, hot strength was highest, deformation under load lowest, and air-slag-metal wear the least at 10 wt pct. As test temperature increased from 500° to 2,750° F, the hot strength difference became less. Carbon fiber additions were limited to 1.5 pct in dolomite-carbon brick. At this level, physical properties were generally comparable to those obtained with natural flake graphite, but were below values obtained with 10-pct-flake-graphite additions. Carbon fibers are not considered a satisfactory substitute for natural flake graphite.

RI 9276. Control of Diesel Particulate Matter in Underground Coal Mines, by W. F. Watts, Jr., K. B. Baumgard, B. K. Cantrell, and K. L. Rubow. 1989. 11 pp. 6 figs. The U.S. Bureau of Mines has conducted research on methods to reduce and to measure diesel particulate matter (DPM) aerosols in underground coal mines. One objective of this report is to present findings from an investigation of the DPM reductions obtained by an engine-mounted integrated control system consisting of a dry system (DS) and a diesel particulate filter (DPF). Another objective is to present results from the use of a size-selective personal sampler to measure DPM concentrations in an underground coal mine. Bureau laboratory tests of the integrated dry system and diesel particulate filter (DS–DPF) have shown that DPM emissions can be reduced up to 97 pct with little change in gaseous emission concentrations. The DS–DPF is undergoing certification tests conducted by the Mine Safety and Health Administration (MSHA). Subsequent to passing all safety requirements, it will be tested in an underground coal mine. A baseline survey of DPM concentrations and aerosol size distributions in a cooperating mine was completed in August 1988. A prototype DPM personal sampler was tested during this survey. Based on results from this test, an improved unit has been developed. This unit is scheduled for extensive field testing by MSHA in 1989.

RI 9277. Recovery of Lead and Silver From Plumbojarosite by Hydrothermal Sulfidation and Chloride Leaching, by N. P. Gallagher and K. P. V. Lei. 1989. 9 pp. 6 figs. The U.S. Bureau of Mines investigated a hydrothermal sulfidation (HTS) and chloride leaching procedure to recover lead and silver from plumbojarosite. The plumbojarosite, generated during pressure-oxidative leaching of zinc concentrate in a commercial operation, contained, in percent, 25.4 Pb, 18.8 Fe, 1.4 Zn, 29.5 sulfate (SO_4^{2-}), 3.2 elemental sulfur (S°), 13.4 total S, and 7.4 tr oz/st Ag. The HTS was conducted in an autoclave and converted the plumbojarosite into amorphous iron oxide and liberated the Pb and Ag as sulfides (S^{2-}). The best operating conditions were 50 g of plumbojarosite and 7 pct S° (2.04 g S° added) in 500 mL of 2.0-mol/L NH_3 at 150° C for 1 h. The sulfidation product contained, in percent, 37 Pb, 28 Fe, 2 SO_4^{2-}, 7 total S, and 11.2 tr oz/st Ag. Flotation of the sulfidation product was conducted at pH 3 with 15-pct pulp density and 2.4 lb/st of isopropyl xanthate as collector. The flotation concentrate contained 43 pct Pb, 25 pct Fe, and 13 tr oz/st Ag. $FeCl_3$ leaching of the sulfidation product in a resin kettle extracted 98 pct Pb and 97 pct Ag from the sulfidation product, and HCl–O_2 leaching in a shaker glass bottle extracted 99 pct Pb and 98 pct Ag. Both leach residues met the Environmental Protection Agency's Toxicity Characteristic Leaching Procedure (EPA–TCLP) standards for nonhazardous wastes. The HTS and chloride leaching procedure is a potentially effective method for detoxification of plumbojarosite-bearing residue from the zinc pressure-leaching circuit.

RI 9278. Effects of Al Additions on Sulfidation Resistance of Some Fe–Cr–Ni Alloys, by J. S. Dunning and S. C. Rhoads. 1989. 19 pp. 7 figs. The objective of this research by the U.S. Bureau of Mines was to determine the effects of Al additions on the sulfidation resistance of Fe–Cr–Ni alloys. A series of Fe–Cr–Ni alloys with and without additions of 4 pct Al were tested in a wet S vapor atmosphere at 677° C. A study of the morphology and composition of corrosion scales indicated a different corrosion mechanism for Al-free alloys compared with Al-containing alloys. Aluminum-containing alloys formed a compact, tightly adherent layer at the metal-scale interface that reduced corrosion rates by a factor of 3 to 10 compared with that of Al-free alloys. The thin, adherent Al-containing scale limited inward diffusion of O and S to the base metal and outward diffusion of Ni from the base metal. Aluminum-containing alloys formed a three-layer scale in oxidizing-S environments, while Al-free alloys formed a less protective two-layer scale.

RI 9279. Yielding Steel Posts, by J. P. Dunford and L. N. Henton. 1989. 19 pp. 13 figs. This U.S. Bureau of Mines report describes the development of a yielding steel post for underground mine support. The report covers concept development, laboratory tests, modifications, and field evaluations. The objective of this work was to develop a stiff support member capable of both supporting high loads and yielding when excessive amounts of mine entry closure were present. The 6- to 7-ft steel post was designed to yield nearly 2 ft while maintaining a 45-ton (force) load. The post is a three-piece unit consisting of top and bottom telescoping legs and a separate foot bracket. It develops its load-carrying characteristics when the lower pipe, with an attached interference ring, is forced into the larger top pipe. Laboratory tests were used to determine critical loads and post performance for various post lengths. Field tests showed that the posts could perform in actual mining conditions. The post has the ability to provide support in highly yielding ground and also, because of its slender profile, enhance ventilation and provide more area for travelways and escapeways. The design is simple enough to allow for fabrication at most mine shop facilities.

RI 9280. Leakage Across a Bituminous Coal Mine Barrier, by Noel N. Moebs and Gary P. Sames. 1989. 18 pp. 16 figs. The U.S. Bureau of Mines is conducting research on many topics relating to the hazards of coal mining, increased production, and protection of the environment. One area of research that has received scant attention in recent years is that of water inflows, probably because few fatalities in the United States have been attributed to them. As mining goes deeper, the problem of water inflow could increase dramatically because of adjacent or overlying mines in which huge water pools are impounded. Inaccurate mine maps and ineffective barriers can constitute a serious problem for operators from both gradual inflows and sudden inrushes of water. This report describes a wide but ineffective barrier that permitted an average 240-gpm inflow to a developing mine from an adjacent mine. The anomalous geologic structure that facilitated this leakage is described, demonstrating that size, alone, is no assurance against serious leakage. Some recommendations for managing serious water inflow are included.

RI 9281. Fire and Explosion Hazards of Oil Shales, by Staff, U.S. Bureau of Mines. 1989. 63 pp. 54 figs. This U.S. Bureau of Mines publication presents the results of investigations into the fire and explosion hazards of oil shale rocks and dust. Three areas have been examined: the explosibility and ignitability of oil shale dust clouds, the fire hazards of oil shale dust layers on hot surfaces, and the ignitability and extinguishment of oil shale rubble piles.

RI 9282. Pressure Monitoring and Observed Effects of Mining at the Oak Grove, AL, Coalbed Degasification Pattern, by David C. Oyler. 1989. 27 pp. 16 figs. The U.S. Bureau of Mines and the United States Steel Corporation evaluated the progress of methane drainage at the Oak Grove, AL, degasification pattern. Coalbed pressures were monitored between December 1981 and November 1985. Formation pressures, in the lower bench of the Mary Lee Coalbed, were reduced from 400 lbf/in²(ga) in 1977 to 50 lbf/in²(ga) in November 1985. Gas contents of coal cores obtained from monitor wells were compared with coalbed gas contents measured in 1976. Data indicated a 48- to 56-pct reduction within the pattern and a 29-pct reduction at a point 500 ft outside the pattern. The effect of the advance of a section of the Oak Grove Mine on changes in gas and water production rates in the pattern was evaluated. Gas production increases were noted in 12 wells; water production decreases were noted in 6. The times of initial influence indicate the presence of a zone of high permeability within the pattern. This zone correlates well in orientation and location with a fracture zone mined through at the mine. The existence of such fracture zones could have a significant effect on productivity of individual coalbed methane wells.

RI 9283. Field Evaluation of Three Longwall Pillar Systems in a Kentucky Coal Mine, by Timothy M. Barton and Christopher Mark. 1989. 13 pp. 16 figs. The U.S. Bureau of Mines is conducting research to assess the effectiveness of different chain pillar designs in maintaining gate entry stability. A particular concern is ground control for deep-cover longwalls located at depths in excess of 1,000 ft. The study described in this report was performed in two experimental sections in one longwall headgate section which contained three different pillar designs. Two of the designs used conventional abutment pillars, while the third was a total-yielding pillar system. Both of the test areas were located under 1,800 ft of cover. The purpose of this study was to evaluate the effectiveness of these three pillar designs for gate road stability. As the longwall mined passed the test areas, Bureau engineers monitored entry convergence, roof sag, and changes in roof quality. The study indicated that the all-yield system performed nearly as well as the better of the two abutment pillar systems, but all three designs would have failed to provide acceptable stability for second panel mining without considerable artificial support.

RI 9284. Primary Gas Toxicities and Smoke Particle Characteristics During Combustion of Mine Ventilation Ducts: Development of a Test Parameter, by Maria I. De Rosa and Charles D. Litton. 1989. 11 pp. 9 figs. The U.S. Bureau of Mines performed experiments to determine if the primary gas toxicities evolved during the early (~300° C) and later (≥400° C) combustion stages of

chlorinated polyester-reinforced mine ventilation ducts could be predicted by a smoke particle characteristic, for the development of a test parameter. The experiments were conducted in an approximately 20-L furnace, at 14-min durations at set furnace temperatures of 250° and 1,000° C, with an airflow through the furnace of 10 L/min. The variables studied, as a function of time, were the hydrogen chloride (HCl), carbon monoxide (CO), carbon dioxide (CO_2), and oxygen (O_2) concentrations, furnace temperatures, the sample mass weight loss, the average smoke particle diameter (d_s) and average number and concentration (n_s), and the product of the average smoke particle diameter and concentration ($d_s n_s$). Results show that the inverse of the smoke particle diameter-concentration product ($1/d_s n_s$) correlates directly and significantly with the primary gas toxicities evolved during both early (HCl) and later (CO) stages of combustion.

RI 9285. Well Point Dewatering of Phosphatic Clays, by C. W. Smith and J. T. McLendon. 1989. 11 pp. 8 figs. The U.S. Bureau of Mines conducted research to determine the effect of ground water control on the dewatering of phosphatic clay wastes. Two storage impoundments were constructed. One impoundment was surrounded on three sides with a series of well points (shallow vertical wells) to lower the ambient water table, and the second impoundment served as a control. Ground water was pumped from the area surrounding the test impoundment for a period of 490 days. A constant pumping rate of 60 gal/min resulted in a water table drawdown of 13 ft, approximating the bottom of the impoundment. At the end of the test period percent solids in the test impoundment was 35 pct, while in the control impoundment percent solids was only 26.8 pct. Percent solids of greater than 30 pct is required for capping and final reclamation using fertile overburden.

RI 9287. A Simplex-Method-Based Algorithm for Determining the Source Location of Microseismic Events, by Jennifer S. Riefenberg. 1989. 12 pp. 5 figs. The U.S. Bureau of Mines conducts basic and applied research related to predicting, eliminating, and/or controlling rock bursts in underground hard-rock mines and coal bumps in underground coal mines. An important element in this research is the development of a reliable and efficient microseismic source location technique. This report presents the results of a Bureau study to develop and evaluate a new algorithm to locate microseismic events based on the Simplex method, a powerful linear programming technique. The technique was tested on both field data and simulated data. Microseismic event source locations obtained with this new Simplex-based algorithm were shown to have less error than those locations obtained using a least squares method. It was concluded that the Simplex approach to source location of microseismic events can be used effectively in microseismic monitoring.

RI 9289. Effects of Structural Faults on Ground Control in Selected Coal Mines in Southwestern Virginia, by Gregory M. Molinda and David K. Ingram. 1989. 25 pp. 28 figs. Large structural faults create serious ground control hazards, as well as adversely affect coal mine production. Two faults related to the Pine Mountain overthrust sheet in Buchanan County, VA, were investigated by the U.S. Bureau of Mines to determine their effect on ground control and to develop recognition criteria for prediction. Five underground mines encountering these faults were visited and mapped for structural information. This information, along with surface mapping, indicated that the Pistol Gap and Keen Mountain Faults show right-lateral, strike-slip faulting and bedding planes slippage, which can be projected linearly and vertically. These fault zones are up to 200 ft wide, with coalbed offsets up to 18 ft vertically, coalbed swags (depressions) up to 15 ft, and roof falls up to 20 ft high. Recognition criteria include bedding plane slips, coalbed offsets, fault gouge, coalbed swag (depressions or synclines), and disturbed bedding. These recognition criteria will help an informed operator realize that many sudden coalbed discontinuities are related to larger geologic events (in this case thrust faulting) and can be projected linearly and vertically. Ground control strategies include mine designs that minimize fault exposure. Mining plans can be adjusted based on type and extent of fault movement.

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When Government Printing Office or Bureau stocks have been exhausted, the report may be available from the National Technical Information Service, as described in the section entitled "Reports Available From the National Technical Information Service."

IC 8990. Chromite Deposits Along the Border Ranges Fault, Southern Alaska. (In Two Parts.) 1. Field Investigations and Descriptions of Chromite Deposits, by Jeffrey Y. Foley and James C. Barker. 1985. 58 pp. 27 figs. Chromite deposits along the Border Ranges Fault in southern Alaska were investigated by the Bureau of Mines. This report, part 1 of a two-part series, describes the deposits. Part 2 describes the mineralogy and the results of metallurgical tests. Fieldwork began in 1981 and continued through 1983. Ninety-four subeconomic podiform chromite deposits in eight mafic-ultramafic complexes were investigated. Previously unreported chromite deposits at Red Mountain on Kenai Peninsula, on Kodiak Island, and near Tonsina are described. Deposits range in size from less than a thousand tons to over 1.25 million tons of contained chromic oxide (Cr_2O_3). Grades range from about 5 to 10 pct chromite. Excluding all deposits more than 10 miles from tidewater or existing roads and all deposits containing only chemical- or refractory-grade chromite, about 2,200,000 tons of Cr_2O_3 are contained in 41 hard-rock deposits. A placer deposit contains an additional 556,000 tons. These 42 deposits constitute a subeconomic indicated and inferred reserve sufficient to meet the Nation's chromite demands for about 4 yr, or the metallurgical industry's demands for over 5 yr, at 1981 consumption rates.

IC 8991. Chromite Deposits Along the Border Ranges Fault, Southern Alaska. (In Two Parts.) 2. Mineralogy and Results of Beneficiation Tests, by D. C. Dahlin, D. E. Kirby, and L. L. Brown. 1985. 37 pp. 5 figs. To identify and characterize potential domestic chromium resources, the Bureau of Mines investigated podiform chromite deposits along the Border Fault in southern Alaska. Part 1 of this two-part report describes an extensive field investigation and preliminary resource evaluation studies by the Bureau's Alaska Field Operations Center. This paper, part 2, describes the mineralogy of 38 samples that were collected from low-grade deposits in the Chugach Mountains, on the Kenai Peninsula, and on Kodiak Island, and presents the results of laboratory batch beneficiation tests designed to concentrate the chromite. The samples are peridotites and chromitites that consist primarily of variable amounts of chromite, olivine, and serpentine. They were beneficiated by a sequence of grinding, sizing, and gravity concentration operations. Twenty-four high-chromium or marginal high-chromium chromite concentrates, six high-iron or marginal high-iron chromite concentrates, and five submarginal concentrates were produced with chromium recoveries that ranged from 37 to 95 pct. Three very low-grade samples were not beneficiated. These results indicate that several of the deposits may be significant chromium resources. Potential precious metals association with the chromite was also investigated. Analysis of these samples indicates that the chromite deposits are not good platinum sources.

IC 8996. Cabs and Canopies for Underground Coal Mining Equipment. Proceedings: Bureau of Mines Technology Transfer Symposium, Charleston, WV, June 22, 1983, compiled by William W. Aljoe. 1985. 90 pp. 84 figs. This publication contains eight papers presented at a Bureau of Mines Technology Transfer Symposium in Charleston, WV, on June 22, 1983. Five of the papers describe the results of Bureau-sponsored research on cabs and canopies for low-coal underground mining equipment. The other papers describe the efforts of three underground coal mining equipment manufacturers (FMC, JOY, and Lee-Norse) in the area of cab and canopy design.

IC 8997. Automated Temporary Roof Support (ATRS) Systems for Roof Bolting Machines. Proceedings: Bureau of Mines Technology Transfer Symposium, Charleston, WV, June 23, 1983, compiled by William W. Aljoe. 1985. 77 pp. 89 figs. This publication contains 10 papers presented at a symposium on ATRS systems in Charleston, WV, on June 23, 1983. Included are papers by MSHA Technical Support (Roof Control), West Virginia Institute of Technology, the Bureau of Mines, and seven roof bolter manufacturers and/or designers of ATRS systems. These papers summarize the most recent developments in ATRS technology and can serve as a guide to potential designers, developers, and users of ATRS systems.

IC 8998. Inverted Pyramid-Shaped Plugs for Closing Abandoned Mine Shafts—Galena, KS, Demonstration Project, by W. M. Dressel and John S. Volosin. 1985. 14 pp. 14 figs. This Bureau of Mines report describes a shaft closure demonstration project in which 11 inverted pyramid-shaped plugs were used to plug abandoned open mine shafts in Galena, KS. The inverted pyramid-shaped forms, fabricated from steelplate, were designed so that the inverted base would be larger, by 4 ft on a side, than the approximate size of the shaft opening at the surface residuum-solid rock interface. After the surface openings of the shafts were trimmed with a backhoe, the steel forms, complete with reinforcing, were lowered into the openings and filled with concrete; the remaining portions of the openings above the plugs were backfilled to slightly above the surrounding surface level with waste rock and soil. Location and elevation monuments were installed for a long-term evaluation of the success of the project.

IC 8999. Video-Supplemented Task Training at the United States Steel Corp. Minntac Mine, Mt. Iron, MN, by D. T. Couillard, B. C. Nelson, and R. R. Tomassoni. 1985. 9 pp. 6 figs. Video technology is becoming an important tool for many designers of industrial training programs. This report describes how trainers at the Minntac Mine, Mt. Iron, MN, have developed videocassettes of safe job procedures (SJP) for training miners assigned to perform unfamiliar work tasks. All steps necessary for videocassette production, from idea to finished product, as well as the required equipment and prices, are listed and/or briefly explained. Minntac officials believe that the SJP videocassettes have contributed significantly to a reduction in mine accidents.

IC 9001. Laboratory Wear Testing Capabilities of the Bureau of Mines, by R. Blickensderfer, J. H. Tylczak, and B. W. Madsen. 1985. 36 pp. 20 figs. The laboratory wear testing capabilities of the Bureau of Mines are described. Wear tests are used to support the Bureau's research efforts toward reducing the wear of equipment used for mining and minerals processing and any wear involving a loss of strategic or critical materials. The emphasis is on abrasive wear because it accounts for most of the wear losses that occur in mining and minerals processing equipment. Spalling wear, caused by repetitive impact in grinding equipment, also is included. Ten abrasive wear tests, including high-stress and low-stress and two-body and three-body conditions, are described: dry-sand, rubber-wheel abrasive wear; Taber Abraser; abrasion resistance of refractory materials; dry-particle erosive wear; elevated-temperature, dry-particle erosive wear; low-angle slurry pot;

jaw crusher gouging wear; ball mill wear; pin-on-drum abrasive wear; and high-speed impact gouging. Two repetitive impact tests are described: ball-on-block impact-spalling and ball-on-ball impact-spalling. Test equipment, procedures, and specimens are described, and typical test results are presented and discussed.

IC 9002. Production of High-Purity Gold From Zinc Precipitates and Steel Wool Cathodes by Hydrometallurgical Refining, by G. E. McClelland, M. D. Wroblewski, and J. A. Eisele. 1985. 11 pp. 2 figs. The Bureau of Mines investigated chemical methods for producing high-purity gold from precious-metal-bearing zinc precipitates and steel wool cathodes. Precious-metal-bearing zinc precipitates and steel wool cathodes are unrefined products from conventional cyanidation and heap leaching-cyanidation operations. The zinc precipitates contained 14.40 pct Au and 0.35 pct Ag. The precious-metal-bearing steel wool cathodes contained 20.65 pct Au and 4.84 pct Ag. The precipitates and cathodes were treated with dilute acid to solubilize the silver and/or base metals. The gold-bearing residue was leached in dilute aqua regia to solubilize the gold. High-purity gold was precipitated from the aqua regia solution with oxalic acid, sulfurous acid, sodium bisulfite, and gaseous sulfur dioxide. The leaching-precipitation experiments recovered 99.9 pct of the gold. The gold precipitates ranged in fineness from 997 to 999 fine. The chemical refining method provides a viable technique for the smaller operator to produce high-purity gold without using pyrometallurgical refining methods.

IC 9003. Effect of Turbulence on Vortex-Shedding Air-Velocity Transducers, by A. F. Cohen. 1985. 13 pp. 11 figs. When location guidelines are followed in choosing sites for fixed-point velocity transducers for use in underground coal mine monitoring, mine air turbulence intensities <11% are generally expected at those sites. The objective of this Bureau of Mines investigation was to determine the effect of turbulence intensities <11% on vortex-shedding sensors and transducers. Measurements were made at velocity levels of interest for underground coal mine monitoring use (≈200, ≈500, ≈1,000, ≈1,500 ft/min). The effect of grid-produced turbulence intensities (2% to ≈14%) on the output of vortex-shedding air-velocity transducers was less than ±10%.

IC 9004. The Bureau of Mines Noise-Control Research Program—A 10-Year Review, by William W. Aljoe, Thomas G. Bobick, Gerald W. Redmond, and Roy C. Bartholomae. 1985. 85 pp. 67 figs. This report summarizes the Bureau of Mines noise-control research program from 1972 to 1982. Each segment of the mining industry—underground coal, underground hardrock, surface mining, and processing plants—has different noise-control problems because of vast differences in working procedures, equipment, and workplace design. The Bureau has identified the most serious noise problems in each segment and has developed strategies for attacking these problems. This publication points out the need for noise control in the mining industry, discusses Federal regulations governing worker exposure to noise, and describes the Bureau's overall approach to mining noise-control research. It traces the history of noise overexposure in each segment of the mining industry and discusses the major noise sources. It provides detailed information on noise-control research efforts in the Bureau's major areas of emphasis, including the results of these efforts. Finally, the report discusses the Bureau's future role in research on mining noise control, emphasizing the need to expend more effort on long-term in-house investigations into the noise problems that have been identified in past programs as the most serious ones.

IC 9005. Dust Control in Bag-Filling Operations, by Jon C. Volkwein and Richard D. Gaynor. 1985. 21 pp. 12 figs. The Bureau of Mines and many member companies of the Industrial Sand Association have been working in several areas to reduce personal exposure to respirable dust. Areas investigated include ventilation, modification of hardware, moisture addition to the product, and improved housekeeping practices. Ventilation systems have been devised and shown to contain 100 pct of a tracer gas released within the hood. An industrial clean air island has been developed and shown to reduce dust levels 90 pct at the operator's position. Modification of hardware on a bag-filling machine has been demonstrated to reduce dust 83 pct at the machine operator's lapel. This particular development has been termed a significant advancement in the state of the art of bag filling by industry representatives. Addition of moisture to dried product materials has been tested with results showing dust reductions of 90 pct are possible. Control of the moisture-addition method still needs refinement and costs may be prohibitive. Dust sampling results clearly show the benefits of housekeeping practices such as building cleaning and vacuum sweeping. Rotation of work schedules is also effective for reducing personal exposure.

IC 9006. Safety Aspects of Pneumatic Transport, by E. T. Bowers. 1985. 37 pp. 4 figs. Pneumatic conveying of coal underground is not widely used in the United States, although it is becoming increasingly popular in Great Britain, the Federal Republic of Germany, and South Africa. The question of safety has been raised repeatedly: Will the system be prone to dust or gas explosions, and if so, can it withstand such occurrences safely? The work reported here was done under a Bureau of Mines contract and deals with the safety aspects of pneumatic transport of underground coal, as well as the hazards inherent in more conventional haulage systems. Included are three designs for different applications of pneumatic haulage: off-loading a continuous-mining machine on a room-and-pillar section, vertical hoisting through a 1,200-ft shaft, and off-loading a tunnel-boring machine driving a 2,000-ft tunnel.

IC 9007. Subsidence Information for Underground Mines—Literature Assessment and Annotated Bibliography, by A. J. Fejes, R. C. Dyni, J. A. Magers, and L. B. Swatek. 1985. 86 pp. The purpose of this Bureau of Mines report is to provide mining industry personnel and regulatory authorities with a subsidence-reference list and annotated bibliography that will aid them in locating subsidence information and in developing their own subsidence information sources. Over 700 references are listed in the Bureau's subsidence information center bibliography; approximately 600 of these references were obtained for assessment. Of these 600 references, 167 were selected to be rated, categorized, and annotated. All literature referenced in this report was published prior to 1984. Table 1 is a cross-referenced index that classifies and rates selected references with respect to specific keywords. References are rated not on quality of content but rather on applicability to given subject areas. Appendix A is an annotated bibliography of the references listed in table 1 and provides further information on each article to aid the user in selecting articles for specific areas of subsidence technology. Appendix B is a copy of the subsidence information center bibliography.

IC 9008. Analysis of Dredge Safety Hazards, by Stephen A. Swan. 1985. 14 pp. 16 figs. Bureau of Mines research has not included analyses of mining dredge safety since 1948. Because of the increasing use of dredges, 63 fatal accidents and several hundred nonfatal injury accidents involving dredges were examined. Also, 31 working dredges and 3 dredge manufacturers were visited to acquire qualitative information. Drowning accidents represented 59 pct of the fatalities and are delineated in detail. Also, countermeasures against other hazards are discussed.

IC 9009. Rollover Protective Structures (ROPS) Inspection and Maintenance Guide, by Stephen A. Swan, Dennis C. Jones, and Kazimir Niziol. 1985. 15 pp. 18 figs. Bureau of Mines researchers have collected and evaluated rollover protective structures (ROPS) for more than 10 yr. ROPS and falling object protective structures (FOPS) are required on specified mining

machines under regulations of the Mine Health and Safety Administration (MSHA). Both ROPS and FOPS are required on mining machines used in surface coal mines and surface areas of underground coal mines (30 CFR 77.403 and 77.413a), and ROPS are required on mining machines used in metal and nonmetal mining operations (30 CFR 55, 56, and 57.9–88). This illustrated manual provides mine safety personnel, MSHA inspectors, and original-equipment manufacturers with guidelines and a checklist for inspecting ROPS being used in the field. The manual discusses specific requirements of the MSHA regulations and minimum inspection and maintenance checks for ensuring compliance with those regulations. An easily reproducible checklist is provided as an aid to the inspection of ROPS.

IC 9010. Mining Health and Safety In-House and Contract Research in Fiscal Year 1985, by Staff, Bureau of Mines. 1985. 19 pp. This publication summarizes the research (in-house and contract projects) programmed by the Bureau of Mines for fiscal year 1985 (October 1, 1984-September 30, 1985) under its Health and Safety Technology Program. The objective of these projects is to provide an ordered and sequenced advance toward the Bureau's overall goal of providing the systems technology required to create a more healthful and safer working environment for the Nation's mining and minerals processing workers.

IC 9011. A Summary of Current and Historical Federal Income Tax Treatment of Mineral Exploration and Development Expenditures, by Phillip N. Yasnowsky. 1985. 13 pp. In this Bureau of Mines report, the Federal income tax treatment of mineral exploration and development expenditures is summarized, and changes in the tax treatment of these expenditures since 1951 are detailed and analyzed. Although no attempt is made to establish causal relationships, major tax changes favorable to exploration and development activities did occur in 1951 and 1966 when the Nation was engaged in military actions and the economy was expanding. More recent changes have been unfavorable to exploration and development and were parts of major tax reform efforts.

IC 9012. Cobalt Availability—Market Economy Countries. A Minerals Availability Program Appraisal, by C. P. Mishra, C. D. Sheng-Fogg, R. G. Christiansen, J. F. Lemons, Jr., and D. L. De Giacomo. 1985. 33 pp. 24 figs. The Bureau of Mines performed a study of the availability of cobalt from market economy countries. The study entailed the detailed analysis of 97 deposits which contain 3.9 billion lb of cobalt at the demonstrated level; in 94 of the deposits cobalt is recovered as a byproduct, and in 3 it is considered the primary product. Since 97 pct of all recoverable cobalt is derived as a byproduct from copper and nickel deposits, the report focused on these two sources. At an assumed market price of $0.89/lb for copper, $3.45/lb for nickel, $475/tr oz for platinum, and $7/lb for cobalt, 1,330 million lb of cobalt at the demonstrated level are potentially available. This total includes 1,105 million lb of cobalt from copper properties, 190 million lb from nickel, 29 million lb from platinum, and 6 million lb from primary cobalt. This analysis indicates that the production cost for 589 million lb of cobalt can be totally covered by the revenues obtained from the other metals produced. The impacts of increases in capital investment and energy costs are also discussed.

IC 9013. Overcoring Equipment and Techniques Used in Rock Stress Determination (An Update of IC 8618), by David L. Bickel. 1985. 27 pp. 27 figs. Stress-relief techniques and instrumentation have been developed through many years of research in the Bureau of Mines and successfully used to determine the in situ state of stress in rock. This report describes the Bureau's three-component borehole deformation gauge and the drilling equipment and accessories used with it. Operation and calibration procedures for the deformation gauge are discussed in detail, along with site selection and overcoring procedures. Information and references included in this publication provide a guide to the Bureau's overcoring method for determining rock stress.

IC 9014. Remedial and Strata Replacement Techniques on Longwall Faces—A Report on the State of the Art, by Robert S. Dalzell and Ernest A. Curth. 1985. 29 pp. 24 figs. Following the introduction of roof shields to the U.S. longwall mining scene in 1975, the number of shield faces (faces supported by shields) has increased steadily, and the occurrence of accidents associated with ground control inadequacies at longwall operations has shown a downward trend. However, ground control problems in longwall mining still exist. New mining systems, however efficient, have run afoul of roof control. Shield faces have suffered extended stoppages because of roof cavities. In this report, the Bureau of Mines addresses the problem of longwall roof control. The report presents a review of foreign remedial and strata replacement techniques for longwall faces and evaluates their potential for domestic application. The technology reviewed includes meshing, chemical rock stabilization, cribbing, strain-absorbent modules, inflatables, synthetic foams, and monolithic fills.

IC 9015. Mining Deep Ocean Manganese Nodules. Description and Economic Analysis of a Potential Venture, by C. Thomas Hillman and Burton B. Gosling. 1985. 19 pp. 3 figs. This Bureau of Mines report describes an investigation of factors influencing economic viability of a proposed system to mine and process manganese nodules. The system consists of hydraulic dredging and ammonia leach processing designed to recover three metals: nickel, copper, and cobalt. A ferromanganese recovery plant is a considered option. Annual capacity is 3 million dry metric tons nodules. Aftertax rates of return (ROR's) of only 7.38 and 6.63 pct are predicted for three- and four-metal base scenarios, respectively. Sensitivity analyses indicate that variations in commodity prices, metal recoveries, and deposit grades produce similar incremental changes in ROR. Estimated cumulative effects of price variations are greatest. While three-metal operations generally yield higher predicted returns, potential increases in manganese price and process recovery could make four-metal operations most profitable. Maximum variations in both capital costs and three-metal operating costs result in ROR changes of about 25 pct. In contrast, four-metal ROR's exhibit variations to 70 pct. Even so only a best case analysis, utilizing favorable variations in all categories tested, generated ROR's approaching a level thought necessary to trigger company interest. Consequently, it is concluded that nodule mining will not take place in the foreseeable future without significant financial incentives.

IC 9016. Improved Stench Fire Warning for Underground Mines, by William H. Pomroy and Terry L. Muldoon. 1985. 33 pp. 41 figs. This report describes Bureau of Mines research that led to the design, prototype fabrication, and successful proof-of-concept testing of an improved stench fire-warning system for underground noncoal mines. Stench systems are the most widely used means of warning miners in underground noncoal mines of fires or other emergencies. A stench system alerts miners that an emergency condition exists by injecting an odorant into the mine air. Although stench warning systems have been used successfully for over 60 yr, present systems suffer several serious shortcomings, including odorant toxicity, unreliability of warnings, widely varying stench concentrations, and others. In 1980, the Bureau began a research program to upgrade the stench warning system. The resultant system overcomes the deficiencies of existing systems by substituting tetrahydrothiophene for the commonly used ethyl mercaptan stench odorant, and through the use of a specially designed stench injector. The improved injector reliably meters stench fluid into either ventilation-air or compressed-air streams at a precisely controlled rate. Prototype hardware has been fabricated and proof-of-concept tested under both laboratory and in-mine conditions.

IC 9017. Recognizing Signs of Excessive Loading in Underground Coal Mines, by Eric R. Bauer. 1985. 30 pp. 38 figs. This Bureau of Mines publication describes and illustrates the physical signs of excessive loading on mine roof supports, installations, and openings. It is designed to assist mine personnel in recognizing potentially hazardous ground conditions, by emphasizing the preliminary effects of developing unstable ground. Increased worker awareness can be expected to reduce the injuries and fatalities resulting from falls of roof, rib, and face.

IC 9018. Airflow Evaluations of Four Flow-Controlled Personal Sampling Pumps, by R. P. Vinson, K. L. Williams, and G. H. Schnakenberg, Jr. 1985. 25 pp. 18 figs. The Bureau of Mines conducted a series of tests to determine how well the Bendix BDX 60, the Gilian HFS 113U, the MSA Fixt-Flo, and the Spectrex PAS-3000 dust sampling pumps control the flow rate at 2 L/min. These tests were performed because users need to know the performance characteristics of sampling pumps to select the pump that best satisfies their sampling requirements. Long-term (6- to 8-h) flow stability at various backpressures was examined in relation to the flow control tolerance of ±5% of the flow, the level imposed by Federal regulations; four of the five Bendix pumps did not meet the criterion for this test, which was passed by all other pumps tested. Flow control recovery times were measured at transient backpressures; all pumps evaluated met the criterion for this test. The low-flow indicators of the sampling pumps were tested; only two Bendix pumps and one Gilian pump met the criterion of indicating a flow change greater than ±5%. In the pulsation flow measurement test all of the pumps passed, with pulsating flows greater than 20 Hz. The Bureau also evaluated the manuals accompanying the sampling pumps. All were judged adequate except the Spectrex manual, which was judged poor.

IC 9019. Factors Affecting Respirable Dust Generation From Longwall Roof Supports, by John A. Organiscak, Jeffrey M. Listak, and Robert A. Jankowski. 1985. 19 pp. 11 figs. The Bureau of Mines conducted a survey of eight shearer longwall operations to identify factors that affect respirable dust generation from longwall roof supports. The longwalls surveyed were in coal seams located in different geographic regions of the United States. Data were collected on mining (geologic) conditions, support design, operational characteristics, and amount of respirable dust generated from roof supports. Analysis indicated that mining conditions are the main factors that affect the generation of dust during roof support movement. Both roof strength and depth of cover above the coal seam showed relationships with the amount of support dust generated. Several practices are currently employed to effectively control roof support dust; however, some of these controls are limited. More research and development is needed to improve dust control technology for longwall roof supports.

IC 9020. Design of Bulkheads for Controlling Water in Underground Mines, by Gregory J. Chekan. 1985. 36 pp. 19 figs. This Bureau of Mines report presents three methods for designing bulkheads to impound water underground: (1) thin and thick plate design; (2) South African plug design; and (3) single and double bulkhead seal design. Related areas critical to the long-term effectiveness of underground water impoundments are also addressed. These include bulkhead anchorage, concrete specifications and placement, the grouting of permeable strata, and the sizing of barrier pillars. A case study involving hydrostatic tests conducted on a single bulkhead seal constructed in the Safety Research Coal Mine of the Bureau's Pittsburgh Research Center is presented in an appendix.

IC 9021. A Low-Cost FSK Modem Network for Polled Communication Systems, by Richard A. Watson. 1985. 23 pp. 17 figs. A frequency-shift keying (FSK) modulator-demodulator (modem) network has been devised for the Bureau of Mines mine-monitoring systems. This network permits an unlimited number of remote stations to communicate with one central station over the same pair of wires. The network operates at a speed of 4,800 baud (bits per second) at distances up to 5 miles. This report describes the development and operation of the modems. The theory of operation, schematic diagrams, and printed cricuit board layouts are provided. Although the modems were built for a specific application, a more general use is discussed whereby the network would operate with a typical serial channel format.

IC 9022. Field Trials of a Portable Microseismic Processor Recorder, by John P. Coughlin and Clinton D. Sines. 1985. 8 pp. 4 figs. The Bureau of Mines has tested a portable microseismic processor recorder at the Galena Mine, Wallace, ID, both in an environmentally controlled enclosure and, with minimal protection, in a working area of the mine. In both trials the device demonstrated effective and reliable data acquisition capabilities.

IC 9023. Bulk Mineralogy and Geochemistry of Selected Alaskan Chromian Spinel Samples, by William S. Roberts. 1985. 13 pp. 8 figs. As part of the Bureau of Mines critical and strategic minerals program in Alaska, 34 high-purity chromium spinel samples were analyzed for trace and major element geochemistry and mineralogy. The samples were analyzed by X-ray diffraction, X-ray fluorescence, and chemical techniques. Systematic differences in chemistry are evident when samples collected from the Chugach Mountains and their related extension are compared with chromian spinel samples collected from interior Alaska. Compared with the Chugach samples, the interior Alaska samples have higher average amounts of Al_2O_3, Fe_2O_3, TiO_2, and NiO, have lower average amounts of FeO and Cr_2O_3, and exhibit greater dispersion in values. Considerable mineralogical variability of chromian spinel exists between and within individual Alaskan chromite-bearing ultramafic complexes. Of 34 samples analyzed, 25 samples are magnesiochromite, 5 are chromite, 3 are spinel, and 1 is hercynite. As a group, the interior Alaska samples have a smaller average unit cell dimension than the Chugach group of samples. The chemical and mineralogical differences between the two groups of samples can be attributed to different genetic histories and may have implications for locating chromian spinel deposits amenable to standard beneficiating techniques.

IC 9024. Feasibility of Water Diversion and Overburden Dewatering, by Noel N. Moebs and Michael L. Clar. 1985. 68 pp. 18 figs. The Bureau of Mines studied the feasibility of water diversion and overburden dewatering for underground coal mines in the Appalachian region. All relevant published literature pertaining to the occurrence and control of surface and ground water in underground coal mines was reviewed, and the impacts of mine water with respect to health and safety, production, environment, and costs were assessed and are described in this report. The report also identifies the sources of water inflow into underground coal mines, and gives a summary description and evaluation of techniques that can be used to reduce the amount of water entering these mines. Engineering practices currently used by operation coal mines in the Appalachian region to prevent the movement of ground and surface water into active coal workings were reviewed and are summarized. Major emphasis has been placed on the identification of geologic and hydrologic conditions of the site, the water control methods used, and an evaluation of their technical and cost effectiveness.

IC 9025. Tungsten Availability—Market Economy Countries. A Minerals Availability Program Appraisal, by T. F. Anstett, D. I. Bleiwas, and R. J. Hurdelbrink. 1985. 51 pp. 36 figs. The Bureau of Mines estimated the potential availability of tungsten from 57 mines and deposits in 19 market economy countries. The tungsten resources of China and the U.S.S.R. were also estimated. This resulted from an evaluation of

tonnage-cost relationships indicating the quantity of tungsten available as ammonium paratungstate (APT), artificial and natural scheelite, and ferrotungsten at various average total costs of production including 0- and 15-pct rates of return on invested capital. The evaluated deposits contain 1.2 million metric tons (t) of recoverable WO_3, of which approximately 52,000 t of APT can be produced at the January 1983 market price of $5.37/lb, 89,000 t of natural and artificial scheelite at a market price of $3.63/lb, and 1,700 t of ferrotungsten at $5.61/lb of tungsten. An annual availability analysis indicates that by the early 1990's new deposits discoveries, development of known prospects, or expansions of producing mines will be necessary to meet projected tungsten demand.

IC 9026. Primary Lead and Zinc Availability—Market Economy Countries. A Minerals Availability Program Appraisal, by G. R. Peterson, K. E. Porter, and A. A. Soja. 1985. 44 pp. 25 figs. To determine the availability of lead and zinc from demonstrated resources, the Bureau of Mines evaluated 235 mines and deposits in 31 market economy countries. Of the 235 mines and deposits evaluated for this study, 186 were evaluated as zinc operations, 30 as lead operations, and 19 as copper operations. Demonstrated lead-zinc resources of market economy countries in 1981 were approximately 4.3 billion metric tons (t) of ore containing 221 million t of zinc and 97 million t of lead. Of these amounts, approximately 154 million t of zinc and 70 million t of lead are estimated to be recoverable. The analyses indicate that demonstrated resources in market economy countries should be sufficient to satisfy projected demand for primary lead and zinc through the balance of the century. The U.S. lead industry will continue to have a comparative advantage over the rest of the world industry, barring any drastic increase in the cost of compliance with pollution control regulations. It appears that the comparative disadvantage faced by the U.S. zinc industry will probably intensify owing to the relative quantity of lower cost zinc resources in other countries, especially Canada, Australia, Mexico, and Peru. GPO Stock No. 024-004-02144-6. $2.

IC 9027. Control of Acid Mine Drainage. Proceedings of a Technology Transfer Seminar, by Staff, Bureau of Mines. 1985. 61 pp. 41 figs. Acid mine drainage can be controlled by water treatment, retardation of the pyrite oxidation reaction system, or enhanced prediction that allows preventive action to be taken. The Bureau of Mines is conducting research in each of these areas; the results of this research are summarized in the eight papers that comprise this volume. Fieldwork to evaluate overburden analysis, alkaline injection, and bactericidal control of acid formation is described, along with two new inexpensive methods to treat acid mine water. These papers were prepared for an acid mine drainage technology transfer meeting held in Pittsburgh, PA, on April 3 and 4, 1985.

IC 9028. Helium Resources of the United States, 1983, by Richard D. Miller. 1985. 17 pp. 6 figs. The helium resources base of the United States was estimated by the Bureau of Mines to be 961 Bcf as of January 1, 1983. These resources are divided into four categories in decreasing degree of assurance of their existence: (1) helium in storage and in proved natural gas reserves, 271 Bcf, (2) helium in probable natural gas resources, estimated at 202 Bcf, (3) helium in possible natural gas resources, estimated to be 351 Bcf, and (4) helium in speculative natural gas resources, which makes up the remaining 137 Bcf. These helium resources are further divided into depleting, nondepleting, and stored classifications. The depleting resources are those associated with natural gas fields that are, or will be, produced for the natural gas they contain. All of the helium in potential (probable, possible, and speculative) natural gas resources is included in this classification. These depleting resources are estimated to contain 789 Bcf of the total helium resource base. Helium resources contained in nondepleting natural gas resources, those in shut-in, abandoned, or otherwise nonproducing natural gas fields, are estimated to total 134 Bcf. There is 38 Bcf of helium in storage in the Federal Government-owned Cliffside Gas Field near Amarillo, TX.

IC 9029. Continuous Radiation Working-Level Detectors, by R. F. Droullard and R. F. Holub. 1985. 20 pp. 23 figs. The Bureau of Mines has used gross alpha and gross beta detectors to continuously measure radiation working levels for a number of years. During this time, improvements have been made in the design and performance of continuous working-level (CWL) detectors. This report discusses the improved designs and some of the operating principles and applications of CWL detectors in the measurement of radon daughter products in mines and dwellings.

IC 9030. Design and Operation of Four Prototype Fire Detection Systems in Noncoal Underground Mines, by William H. Pomroy and Robert E. Helmbrecht. 1985. 25 pp. 24 figs. Fires in underground metal and nonmetal mines pose a threat to the safety of underground miners and to the productive capacity of this Nation's mines. Contaminated air (smoke, carbon monoxide, and other products of combustion) is the primary life safety hazard created by a mine fire. The most reliable defense against the hazard posed by the rapid spread of contaminated air underground is early warning fire detection and rapid evacuation. This Bureau of Mines report describes the design and operation of four prototype early warning fire detection systems, for underground noncoal mines, presently undergoing prolonged in-mine testing by the Bureau. The systems are described within the context of the underground mine environment.

IC 9031. Computer Program for Calculating Gravimetric Primary Standard Gas Mixtures, by Ernest W. Loya. 1985. 38 pp. The Bureau of Mines has developed a computer program for calculating the composition of gravimetric primary standard gas mixtures. The Fortran IV program applies corrections due to buoyancy variations of the cylinder and inaccuracies of the balance weights. The program also determines the statistical error due to the sensitivity and precision of the balance and applies the analytical error of the weighed gases.

IC 9032. Improved Fire Protection for Underground Fuel Storage and Fuel Transfer Areas, by William H. Pomroy and Guy A. Johnson. 1985. 19 pp. 21 figs. The potential for large-scale fires in underground fuel storage and fuel transfer areas prompted the Bureau of Mines to study fire hazards in these areas and devise improved fire safety technology for use in these areas. This report describes the Bureau's research to characterize and quantify fire hazards in fuel storage and fuel transfer areas, develop guidelines for safe and efficient fueling system design, prepare specifications for automatic fire sensing and suppression systems for these areas, test prototype systems in the laboratory and in underground mines, and perform cost-effectiveness evaluations of the devised technology.

IC 9033. Metallurgical Effects of Impurities in Recycled Copper Alloys, by Harry V. Makar and William D. Riley. 1985. 19 pp. 9 figs. As part of a continuing research program for conserving domestic mineral resources, the Bureau of Mines is investigating new and improved scrap identification techniques to improve sorted mixed scrap purity. This report focuses on various classes of wrought and cast copper alloys produced with recycled scrap. Based on a survey of the literature, principal alloys, such as the brasses and bronzes, are examined with respect to impurity elements and their effects on metallurgical behavior. Effects of elements such as lead, antimony, iron, chromium, and aluminum are discussed. The metallurgical effects described include hot shortness, fire cracking, and undesirable phase transformations.

IC 9034. Agglomeration and Heap Leaching of Finely Ground Precious-Metal-Bearing Tailings, by G. E. McClel-

land, D. L. Pool, A. H. Hunt, and J. A. Eisele. 1985. 11 pp. 10 figs. During the 1970's the Bureau of Mines investigated a particle agglomeration technique for improving the flow of leaching solution through heaps of clayey or crushed, low-grade gold-silver ores. This technology has been adopted on a broad scale by the precious-metal-processing industry. This report presents information on the application of agglomeration technology to finely ground precious-metal-bearing tailings. Two commercial operations that have benefited from agglomeration technology are discussed. The technology is cost effective because of decreased leach times and improved precious metal recoveries.

IC 9035. Principal Deposits of Strategic and Critical Minerals in Nevada, by N. T. Lowe, Russell G. Raney, and John R. Norberg. 1985. 202 pp. 28 figs. This Bureau of Mines publication presents salient deposit information in abstract form on 119 principal mineral deposits in the State of Nevada. Commodity coverage addresses 17 critical and strategic commodities that appear to have commercial production potential in the State. The core of the deposits described is taken from those properties evaluated under the Bureau of Mines Minerals Availability Program (MAP); additional deposits are included to provide a more complete coverage. Institutional and infrastructure factors affecting mineral development are also discussed. GPO Stock No. 024–004–02151–9. $7.50.

IC 9036. Asbestos Availability—Market Economy Countries. A Minerals Availability Program Appraisal, by T. F. Anstett and K. E. Porter. 1985. 21 pp. 15 figs. The Bureau of Mines evaluated the potential availability of chrysotile, amosite, and crocidolite asbestos from 42 properties in market economy countries. This resulted in the development of tonnage-cost relationships indicating the quantity of grades 3 through 7 asbestos at various average total costs of production at 0% and 15% rates of return on invested capital. The availability of grades 2 and 8 was also evaluated, but since each is produced at only one property, no analytical results were given. Total demonstrated recoverable chrysotile fiber potentially available of grades 3 through 7 from the 42 properties evaluated follow: 1.59 million t, 21.00 million t, 16.74 million t, 15.54 million t, and 19.27 million t, respectively. The total amount of crocidolite is 1.69 million t. Owing to the good potential for discovery and development of new deposits, long-term availability of fiber of all three types is not in jeopardy. However, many of the crocidolite properties evaluated in the northern Cape crocidolite field of South Africa have relatively small demonstrated resources, and new deposits will have to be exploited by the late 1990's to sustain projected levels of production.

IC 9037. Critical and Strategic Minerals in Alaska. Tin, Tantalum, and Columbium, by J. Dean Warner. 1985. 19 pp. 1 fig. Alaska contains many critical and strategic minerals that are scarce in the conterminous United States. Among these are tin, tantalum, and columbium. This Bureau of Mines report summarizes available data on the production, reserves, and occurrences of these minerals in Alaska. Alaska produces about 200,000 lb of tin per year, with historical production since 1901 estimated to have totaled 5,830,600 lb. Measured, indicated, and inferred tin reserves total over 140,000,000 lb. Much of the tin production has been from the placer mines of the western Seward Peninsula; however, most of the reserves are in that area's lode deposits. Alaskan tin occurrences are part of a belt of tin mineralization that extends along the western coast of North and South America. The Alaskan portion of this "tin belt" comprises placer occurrences and lode occurrences of five major types: greisen, vein, skarn, pegmatite, and volcanogenic massive sulfide. Greisen and vein occurrences are the most abundant, but skarn deposits have historically been the most economically important. Columbium and tantalum have not been produced in Alaska; however, they may be recoverable as byproducts of tin, tungsten, gold, or uranium mining. Approximately 135,000 lb of columbium oxide (Cb_2O_5) are inferred within the Tofty placer deposits in the Manley Hot Springs district.

IC 9038. Mercury Availability—Market Economy Countries. A Minerals Availability Appraisal, by C. P. Mishra, D. R. Wilburn, D. G. Hartos, C. D. Sheng-Fogg, and R. C. Bowyer. 1985. 18 pp. 10 figs. The Bureau of Mines investigated the availability of mercury from 22 deposits in market economy countries. The 15 significant deposits evaluated have demonstrated resources of approximately 25 million metric tons of ore containing 5.3 million flasks of mercury and account for more than 85 pct of the demonstrated resources for market economy countries. Using data gathered as part of its Minerals Availability Program, the Bureau determined the mercury production potential of each deposit. At a January 1984 mercury market price of $300 per flask, the deposits evaluated could economically produce an estimated 2.5 million flasks of mercury from six mines operating at the time of this study; no mercury is available at this price from nonproducing operations. At $600 per flask, approximately 4.5 million flasks of mercury are available. For production costs up to $300 per flask, operating mines could supply mercury at the current production rate of 114,000 flasks per year until 1988, when the amount of mercury available from these deposits would decrease. This decline could be offset by the development of resources currently reported at the identified level (17 million flasks) at much higher production costs. GPO Stock No. 024–004–02148–9. $1.

IC 9039. Chemically Enhanced Drilling. An Annotated Tabulation of Published Results, by Pamela J. Watson and William H. Engelmann. 1985. 53 pp. This report presents a Bureau of Mines literature survey that provides a data base useful for current and future studies in the area of chemically enhanced drilling and cutting. Publications describing laboratory testing and field studies of drilling and cutting with chemical additives are reviewed. Significant results are summarized and tabulated by rock or material type and also by chemical additive, with extensive references. Selected studies related to fluid-enhanced processing or material testing are summarized in the appendixes. GPO Stock No. 024–004–02150–1.

IC 9040. Environmental Issues Related to Mineral Development in the Stillwater Complex, MT, by Michael T. Nigbor, Stephen R. Iverson, and Paul C. Hyndman. 1985. 33 pp. 20 figs. This Bureau of Mines publication identifies the significant environmental issues associated with the potential development of strategic and critical minerals in the Stillwater Complex, MT. The Stillwater Complex contains deposits of Cr, platinum-group metals (PGM), and Ni. Issues that must be addressed prior to minerals development include the effects mining, milling, and smelting will have on the land, water, and air, and methods of minimizing the environmental impacts.

IC 9041. Improved Underground Rerailing Apparatus, by John R. Bartels. 1985. 8 pp. 6 figs. This report discusses an improved method for rerailing underground railcars devised in a joint effort by the Bureau of Mines and Hoesch MFD. This improved method utilizes a lightweight hydraulic ram with hand-pump activation to move a bridge-mounted roller carriage in conjunction with steel-reinforced air-lift bags. This method provides a lightweight portable system in which only two workers are required to perform the mine car rerailing operation. Because of the very narrow confines in underground mines, use of overhead cranes and other surface rail techniques is not possible. This new system is designed for very low profile work, and provides the necessary lifting force from lightweight compressed-air bottles.

IC 9042. Mine Subsidence Control. Proceedings: Bureau of Mines Technology Transfer Seminar, Pittsburgh, PA, September 19, 1985, compiled by Staff, Bureau of Mines. 1985.

56 pp. 44 figs. This publication contains four papers presented at a seminar on mine subsidence control held in Pittsburgh, PA, on September 19, 1985. The seminar was designed to keep the mineral industry informed of new technology developed by the Bureau of Mines that permits reliable and accurate prediction of mine subsidence. The papers describe actual field studies undertaken by the Bureau to monitor surface subsidence over longwall panels. Topics discussed include the effects of subsidence on water table levels, the development of subsidence precalculation methodology suitable for use with the specific lithological conditions of the Pittsburgh coalbed, an engineering comparison of technologies used in surveying for longwall mine subsidence, and a comparison of the process of subsidence over two different longwall panels.

IC 9043. Phosphate Resource Potential for Borehole Mining in the Southeastern Coastal Plain, by George H. Popper, Douglas J. Godesky, and James J. Giambra. 1985. 20 pp. 7 figs. The Bureau of Mines has evaluated the extent of phosphate resources available for recovery by the experimental borehole mining method in the Southeastern Coastal Plain of the United States. Phosphate resources at overburden depths greater than 30 m are, as a rule, currently unsuitable for recovery through conventional mining methods because of economic, environmental, or technical considerations. In the identified deposit areas, borehole mining operations are projected to yield a more favorable rate of return and to be environmentally more desirable than conventional surface mining. Borehole mining resource estimates presented in this study are preliminary and designed to serve as a basis for future resource evaluations, as the current data base is relatively sparse and incomplete. The resulting resources have, therefore, been classified as hypothetical and speculative and are subject to updating as additional exploratory data become available. Hypothetical and speculative resources amenable to borehole mining are estimated to total about 385 billion metric tons (mt) of phosphate matrix with a minimum in situ grade of 5 pct P_2O_5. With projected borehole mining capabilities and current conventional beneficiation procedures, this resource would make available approximately 64 billion mt of phosphate rock product at an estimated grade of 30 pct P_2O_5.

IC 9044. Molybdenum Availability—Market Economy Countries. A Minerals Availability Appraisal, by C. M. Palencia. 1985. 30 pp. 11 figs. The Bureau of Mines evaluated the potential availability of molybdenum resources from 88 mines and deposits that account for more than 90 pct of the demonstrated resource base in market economy countries (MEC's). For each property, tonnage-cost relationships were developed that indicate the molybdenum potentially available at different average production costs, including a 15-pct rate of return on invested capital. From the 23 MEC primary deposits, 2.5 billion lb Mo was determined to be potentially available at a price of $4/lb, rising to 4.7 billion lb Mo at $8/lb. Copper price-molybdenum tonnage relationships were developed for those mines and deposits from which molybdenum can be recovered as a byproduct of copper production. This analysis showed that another 3.4 billion lb Mo is potentially available based on a copper price of $0.75/lb, rising to 4.3 billion lb Mo at $1.00/lb. The United States has been the world's largest molybdenum supplier since 1924. Its remaining resources are sufficient to meet the domestic demand of 57 million lb/yr Mo (averaged for a 10-yr period) through the end of the century. Production from primary domestic mines was suspended during most of 1983 because of oversupply of materials. A major concern is the cheap molybdenum byproducts from foreign copper operations in which employment and the need for hard currency override economics in meeting production goals. GPO Stock No. 024-004-02154-3. $1.50.

IC 9045. Water-Jet-Assisted Cutting. Proceedings: Bureau of Mines Open Industry Meeting, Pittsburgh, PA, June 21, 1984, compiled by Charles D. Taylor and Robert J. Evans. 1985. 86 pp. 94 figs. Greater mining productivity requires a more efficient cutting process. The cutting force available from today's mining machines has been optimized with respect to machine size and weight. Researchers have shown that when employing water-jet-assisted cutting, bit forces and drum torques can be reduced significantly, which may allow mining machines to become lighter and more efficient. The Bureau of Mines has initiated a program to develop a water-jet-assisted rotary cutting system using the conventional bit assisted by a directed water jet operating at moderate pressures (3,000 to 10,000 psi). This water-jet-assisted cutting system has the potential to improve cutting efficiency without increasing machine horsepower or water usage (beyond what is presently used for dust control) or requiring fundamental changes in mining practice. In addition to improvements in productivity, other anticipated benefits of water-jet cutting include reduced generation of respirable dust, elimination of frictional ignitions, increased bit life, reduced fines, and fewer machine vibrations. The papers presented at this open industry meeting discuss the development of water-jet-assisted cutting technology and future application of this technology to a variety of mining techniques including roof drilling and longwall mining.

IC 9046. Analyses of Natural Gases, 1984, by B. J. Moore and John E. Hamak. 1985. 102 pp. 1 fig. This Bureau of Mines publication contains analyses and related source data for 276 natural gas samples from 23 States. All samples except four were collected during calendar year 1984. Those four samples were collected earlier, but releases granting permission to publish were not received until 1984. All samples were obtained and analyzed as part of Bureau of Mines investigations of the occurrences of helium in natural gases of countries with free market economies. This survey has been conducted since 1917. The analyses published herein were made by the mass spectrometer and chromatograph. The results of these investigations are published annually to make the information available to the petroleum industry and the general public. Twenty-eight publications have presented the results of 13,957 gas analyses made prior to 1984. The first three bulletins contain analyses and related source data on 5,218 gas samples collected from 1917 through 1960; these bulletins have been supplemented annually by information circulars containing 8,453 analyses of samples collected since 1960.

IC 9047. Lightweight Fiberglass Feed Leg for Hand-Held Pneumatic Percussion Rock Drills, by Ellsworth R. Spencer. 1985. 6 pp. 5 figs. A lightweight fiberglass feed leg for hand-held pneumatic percussion rock drills has been fabricated and tested by the Bureau of Mines. Its lighter weight facilitates easier handling of the rock drill apparatus, thereby reducing the potential for back injury to the driller and increasing drilling productivity. Current hand-held feed leg drills of the same class are 50 pct heavier than the Bureau-devised feed leg drill, which is comprised of a reduced-noise drill and the fiberglass feed leg. In-mine tests of the fiberglass leg showed that its performance and cost are comparable to those of standard aluminum feed legs.

IC 9048. Literature on the Revegetation of Coal-Mined Lands: An Annotated Bibliography, by David L. Veith, Kenneth L. Bickel, Roger W. E. Hopper, and Michael R. Norland. 1985. 296 pp. 1 fig. This Bureau of Mines bibliography of U.S. and Canadian literature pertaining to revegetating coal-mined lands contains 805 references published from 1977 to 1984. Each reference is evaluated by keywords, providing the reader with a means of rapidly sorting through the references to locate only those dealing with the coal mining region and subject of interest. All references are annotated. Other sources of information are given, including Office of Surface Mining and State reclamation agencies and other published bibliographies.

IC 9049. Earth Grounding Beds—Design and Evaluation. Proceedings: Bureau of Mines Technology Transfer Seminars, Pittsburgh, PA, June 25, 1985, and Reno, NV, June 27,

1985, compiled by Staff, Bureau of Mines. 1985. 24 pp. 12 figs. Recent Bureau of Mines research in earth grounding safety is documented in three separate papers. First, guidelines for the design of a 5-ohm borehole ground are presented. Next, an inexpensive practical means to construct a low-resistance bed in high-resistivity soil is described. Finally, a procedure that employs a commercial resistivity meter to measure shock potentials around grounded objects is explained step-by-step. These papers complement the material presented at an earlier technology transfer seminar and published as IC 8767.

IC 9050. Research on the Reliability of Mine Electrical Equipment: A Status Report, by Dean H. Ambrose. 1985. 14 pp. 7 figs. This Bureau of Mines publication summarizes the status of mine electrical equipment reliability research. Failure rate data were estimated from theoretical, laboratory, and field studies. Tables are presented listing reliability characteristics of molded-case circuit breakers, undervoltage relays, ground check monitors, cables, motors, and control circuitry. Application of failure rate data is shown in tables listing maintenance scheduling intervals of components and components that are most sensitive to the probability of hazardous voltages on power distribution systems in the mines. Complete, accurate, and appropriate failure rates on mine equipment are of the utmost importance for reliability evaluations.

IC 9051. An Overview of Research on Explosionproof Enclosures, by L. W. Scott and M. R. Yenchek. 1985. 18 pp. 8 figs. This report presents an overview of explosionproof (X-P) enclosure research being conducted by the Bureau of Mines. This report emphasizes the increasing importance of research related to the safety considerations of X-P enclosures used in underground coal mines. Selected topics are included that summarize results of research in the areas of electrical clearances, reliability of enclosures with windows, safety factors in X-P enclosures, potting materials, performance tests for X-P enclosures, protection against high-voltage explosions, and innovative X-P devices.

IC 9052. Determining Face Methane-Liberation Patterns During Longwall Mining, by Andrew B. Cecala, Robert A. Jankowski, and Fred N. Kissell. 1985. 9 pp. 9 figs. As deeper seams are continually mined, methane liberation will continue to increase and must be monitored effectively. To effectively monitor and develop appropriate control technology, methane-liberation patterns must be known. The Bureau of Mines recently completed a study to identify specific patterns of face methane liberation during longwall mining. Both of the longwall faces surveyed had high methane liberation rates. At one longwall face, most of the methane was liberated during cutting of coal by the shearer mining machine. At the second face, a significant portion of methane was emitted from the face and floor. An effective methane-monitoring system would be different for each longwall panel because of the differences in how the gas is released along the face.

IC 9053. Ground Control Instrumentation—A Manual for the Mining Industry, by Eric R. Bauer. 1985. 68 pp. 68 figs. This Bureau of Mines manual is intended to provide a better understanding of ground movement and the technology available for measuring it. The manual deals with convergence, strata separation, lateral roof movement, stress, and support load in underground mines. The instruments that measure these ground control parameters are described in detail. Step-by-step procedures for selecting the appropriate instrument are presented, which consider such factors as approximate cost, installation procedures, data collection, and data interpretation. An instrument selection worksheet is provided to facilitate the instrument selection process. Actual instrument case studies and a list of instrument suppliers are presented in the appendixes.

IC 9054. Technological Alternatives for the Conservation of Strategic and Critical Minerals—Cobalt, Chromium, Manganese, and Platinum-Group Metals: A Review, by Russell J. Foster. 1985. 53 pp. 1 fig. This Bureau of Mines review focuses on the extent to which technologically and economically feasible programs in substitution, improved processing practices, including recycling, and design can achieve conservation of cobalt, chromium, manganese, and platinum-group metals, and thus reduce U.S. vulnerability to interruptions of supply. In addition, supply-side options—domestic and foreign resources, ocean minerals, and stockpiles—are identified. The report consolidates four major studies on these strategic and critical minerals sponsored entirely or partially by the Bureau in the last few years. These studies have been updated with further information from the recent literature. GPO Stock No. 024–004–02156–0. $2.25.

IC 9055. Corrosion of Roof Bolt Steels in Missouri Lead and Iron Mine Waters, by M. M. Tilman, A. F. Jolly III, and L. A. Neumeier. 1985. 9 pp. 6 figs. As part of ongoing research to improve mine safety, the Bureau of Mines conducted research on the corrosion of friction rock stabilizer steels in five Missouri lead and iron mine waters. Electrochemical corrosion tests, including evaluation of pitting tendency, were performed on two types of high-strength, low-alloy (HSLA) steels and galvanized steel in four Missouri lead mine waters and one Missouri iron mine water. The tests were conducted at in-mine water temperatures in both air-saturated and deaerated waters. Static, weight-loss corrosion tests were also conducted on HSLA steel specimens in the five Missouri mine waters for a 2,900-h duration at average in-mine water temperatures and air-dissolved oxygen contents of 6 to 7 ppm. Corrosion rates determined by the weight-loss tests were roughly comparable with rates determined electrochemically in deaerated waters containing 0.3 to 0.5 ppm dissolved oxygen content. Passivation of specimen (nongalvanized) surfaces in air-saturated waters resulted in very low electrochemically determined corrosion rates. Pitting tendency was generally higher for both HSLA steels in air-saturated waters than in deaerated waters. Galvanized steel generally exhibited higher tendency to pitting in the deaerated waters than in the aerated mine waters.

IC 9056. Quartz Dust Sources During Overburden Drilling at Surface Coal Mines, by S. D. Maksimovic and S. J. Page. 1985. 7 pp. 2 figs. The Bureau of Mines identified and evaluated major sources of quartz dust during overburden drilling at a surface coal mine. The relative contribution of each source to the total dust hazard was estimated, using personal gravimetric and instantaneous dust-sampling devices. No attempt was made to determine actual dust generation rates. The major sources of dust at the drill rig during dry drilling operations were the collector dump, drill shroud leakage, and drill stem seal leakage. These sources contributed 90 pct of the respirable dust and 89 pct of the respirable quartz dust generated during drilling. The collector dump cycle (21.6 pct of total drilling time) accounted for 38 pct of the respirable dust and 41 pct of the respirable quartz dust, with peak dust concentrations reaching 68 mg/m^3. Shroud and drill stem leakage contributed 28 and 24 pct of the respirable dust and 32 and 16 pct of the respirable quartz dust, respectively. A dragline and second drill rig contributed the remaining 10 pct of dust and 11 pct of quartz dust. Gravimetric dust samples collected inside the drill cab and outside, near the cab door, averaged 1.65 and 1.43 mg/m^3, respectively, with 6 pct respirable quartz.

IC 9057. Evaluation of Sensitive Ground Fault Interrupters for Coal Mines, by Michael R. Yenchek and Melvin N. Ackerman. 1985. 15 pp. 14 figs. Contacts with energized conductors are a major cause of electrocutions in underground coal mines. Sensitive ground fault interrupters (GFI's) installed on in-mine three-phase ac utilization circuits would probably

prevent the majority of these deaths. A sensitive GFI is a protective device that detects and interrupts small deadly ground currents in the milliampere range before those currents can cause ventricular fibrillation in humans. Commercially available three-phase sensitive GFI's have not been specifically designed for application in coal mines. The Bureau of Mines therefore tested three commercial GFI models to determine their worthiness for mine power systems. GFI design and construction, transient immunity, reliability, and time-current characteristics were evaluated in laboratory tests. No commercial device was found suitable for mine use without design modifications. The tests results will serve as a basis for the development of a mineworthy sensitive GFI in ongoing Bureau research.

IC 9058. Anchorage Capacities in Thick Coal Roofs, by Stephen C. Tadolini. 1986. 13 pp. 14 figs. The anchorage capacity of four types of bolting systems was investigated in two mines with thick coal roofs. In conjunction with the in-mine tests, a simple axisymmetric finite element computer program was developed. Both the field and computer results indicated that thick coal roofs can be effectively supported entirely by the coal member.

IC 9059. Precious Metals Recovery From Low-Grade Resources. Proceedings: Bureau of Mines Open Industry Briefing Session at the National Western Mining Conference, Denver, CO, February 12, 1986, compiled by Staff, Bureau of Mines. 1986. 56 pp. 32 figs. This information circular describes research the Bureau of Mines has conducted to improve technology for recovering precious metals from low-grade resources. Many of the reported findings are recent, and some of the work described is ongoing. Topics discussed include cyanidation of carbonaceous gold ores to enhance gold recovery, a new method for precipitating mercury during cyanide leaching of gold ores, a staged heap leaching process to generate suitable solutions for direct electrowinning of gold, and use of anion-exchange resins to recover gold from cyanide solutions, and precious metals recovery from electronic scrap.

IC 9060. Fluorspar Availability—Market Economy Countries and China. A Minerals Availability Appraisal, by Catherine C. Kilgore, Sandra R. Kraemer, and James A. Bekkala. 1985. 57 pp. 22 figs. The Bureau of Mines investigated the availability of fluorspar (CaF_2) from 36 U.S. and 50 foreign mines and deposits in 13 countries. Only 6 U.S. properties are considered to be economic, as 29 domestic deposits were found to have an average total cost of production that was uneconomical at a break-even (0-pct) discounted-cash-flow rate of return (DCFROR). The 50 foreign properties evaluated represent at least 85 pct of demonstrated fluorspar resources located in market economy countries and China. All evaluated foreign operations were found to be economic to marginally economic in January 1984 dollars when compared against published prices for each country. Reserves for 56 properties totaled 97 million metric tons (mt) (recoverable CaF_2) from demonstrated ore resources of 344 million mt that contained 123 million mt CaF_2. The average total cost needed to cover all costs over the life of each operation was determined for all recoverable fluorspar products. Comparisons of mining, beneficiation, and transportation costs per metric ton of fluorspar concentrate illustrate advantages between countries. Of the three countries with the greatest fluorspar production, China, with its high-grade, low-cost operations, had the lowest weighted-average total cost of production ($38/mt concentrate). Mexico was next, at $54/mt concentrate, and benefited in U.S. dollar terms from the devaluation of the peso. The Republic of South Africa needed an average of $90/mt of concentrate to cover all costs of production at its large low-grade deposits.

IC 9061. Titanium Minerals Availability—Market Economy Countries. A Minerals Availability Appraisal, by R. J. Fantel, D. A. Buckingham, and D. E. Sullivan. 1986. 48 pp. 29 figs. The Bureau of Mines investigated the resource availability of titanium minerals from 63 mines and deposits in 12 market economy countries. These mines and deposits contain, at the demonstrated resource level, an estimated 438 million metric tons (mt) of titanium dioxide (TiO_2) in the minerals rutile, ilmenite, leucoxene, and anatase. An additional 314 million mt of TiO_2 is available from inferred resources. If all titanium minerals and other recovered heavy minerals are sold at total costs at least equal to the January 1984 market prices, approximately 200 million mt of contained TiO_2 could be recovered in total. In terms of mineral concentrates, this equals approximately 11 million mt of rutile concentrate, 187 million mt of ilmenite concentrate, 3 million mt of leucoxene concentrate, 13 million mt of synthetic rutile concentrate (in addition to the ilmenite), and 89 million mt of titanium slag. The study indicates that world resources of low-cost rutile are declining. In order to maintain future supply for high-grade titanium resources, alternate sources will need to be developed, which may include higher cost rutile mines, Brazilian anatase deposits, increased production from slag operations, or more synthetic rutile capacity from ilmenite resources, which are abundant. GPO Stock No. 024-004-02159-4. $2.25.

IC 9062. Microcomputer-Based Instrumentation System for Monitoring Ground Support in a Deep Mine Shaft, by J. K. Whyatt and E. L. Hardin. 1986. 88 pp. 18 figs. This report describes a microcomputer-based instrumentation system for structural monitoring of the circular, concrete-lined Silver Shaft in northern Idaho. The 1-ft-thick concrete lining and surrounding rock mass were instrumented with a total of 12 multiple-point borehole extensometers, 16 pressure cells, 22 concrete embedment strain gauges, and 12 thermistors. The instruments were distributed among four test sites and installed immediately above the shaft bottom during sinking at the 2414, 4063, 5191, and 5955 levels. Limited access to the instruments prompted the development of a microcomputer-based remote data acquisition system that could be operated from the surface. The system scanned the instruments on a programmed schedule, printed out reduced data, and stored the data for plotting and recall. Data acquisition from off-site and uploading of data to mainframe computers were accomplished by the addition of modems to the basic system. The system is suitable for use in monitoring the structural behavior of any deep mine opening, especially in harsh operating environments and where access is limited.

IC 9063. Computer Simulation of Oxygen Requirements for Evacuating Miners, by John C. Edwards and Glenn N. Grannemann. 1986. 42 pp. 1 fig. The Bureau of Mines developed a mathematical model to predict the oxygen requirements for a miner evacuating a mine. The model accounts for variations in the miner's escape speed with mine airway height, and for the empirically determined expressions for the weight-specific oxygen uptake rate for upright walking, stooped walking (duck-walking), and crawling. A Fortran computer program that is user oriented was prepared based upon the model's constitutive equations. Specific instructions for utilizing the program, as well as applications to miner evacuation from a mine, are presented.

IC 9064. Short-Delay Blasting in Underground Coal Mines, by Richard J. Mainiero and Harry C. Verakis. 1986. 12 pp. 9 figs. The Bureau of Mines has conducted research to determine whether the total elapsed delay time for blasting bituminous coal in underground mines could be safely expanded beyond the present 500-ms limitation without igniting a methane or methane-coal dust atmosphere. The results indicated that the increase of total delay from 500 to 1,000 ms had no detectable effect on safety relative to incendivity as long as permissible practices were observed in all other aspects. Research was also conducted to evaluate the safety of 18-in hole spacing for delay blasting in coal relative to misfires. For a variety of permissible explosives, misfires were observed for

about 50 pct of the holes at 18-in spacing. Based on this observation, the Bureau has recommended that the new regulations prohibit hole spacings of less than 24 inches in underground coal mines. Misfires were also observed for 24-in spacing, but the number of misfires and test shots was too small to support any firm conclusions.

IC 9065. Evaluation of Safety Shutoff Valve System on Methane Gas Pipelines Under Mine Fire Conditions, by Patrick A. Kinek, Thomas E. Marshall, and Gerald L. Finfinger. 1986. 7 pp. 4 figs. The purpose of this investigation was to evaluate the integrity of the existing shutoff valves and actuators used under high-temperature conditions in the Bureau of Mines' horizontal borehole methane drainage pipeline system and to determine the potential for improvement in the system. In the field tests, both firesafe ball valves and standard brass ball valves were initially subjected to a 30-min pan fire without thermal protection. Neither valve could maintain line pressure beyond 11 min in a fire that reached temperatures between 500° and 700° C. Based on the test results, it was concluded that the brass ball valve used in the Bureau's methane drainage pipeline system can be retrofitted with an inexpensive "fire bag" to substantially increase its integrity under mine fire conditions.

IC 9066. Longwall Roof Support Technology in the Eighties. A State-of-the-Art Report, by Ernest A. Curth and Jeffrey M. Listak. 1986. 43 pp. 36 figs. It took only 9 years from the first appearance of roof shields on the U.S. longwall mining scene to the present predominance of shield faces. An apparent consequence is the welcome downward trend in accidents related to failures in longwall ground control. The report addresses load prediction, the effects of shield geometry on support loads, factors contributing to ground control, and related techniques. The Bureau of Mines took an active part in the evolution of longwall mining, including developing one of the first shield faces in 1975, the first lemniscate-type shields in 1976, the Mine Roof Simulator completed in 1980, the first shields in steeply pitching coalbeds in 1981, and the first multilift working of a thick coalbed in 1982. The information offered in this state-of-the-art report will assist in establishing criteria for roof support selection.

IC 9067. Results of Direct-Method Determination of the Gas Content of U.S. Coalbeds, by W. P. Diamond, John C. LaScola, and D. M. Hyman. 1986. 95 pp. 1 fig. In 1972, the Bureau of Mines developed a direct-method test for measuring the gas content of virgin coal core samples for coal mine health and safety considerations. Since that time, approximately 1,500 coal samples from more than 250 coalbeds in 17 States have been collected for gas content determination. The gas content data, when combined with geologic and engineering studies, can be used as a basis for a preliminary estimate of mine ventilation requirements, and to determine whether methane drainage in advance of mining should be considered. The data are also critical in delineating coalbed resources and in utilization feasibility studies. This report makes the Bureau's extensive data base of gas content data more readily available to the coal and gas industries. The data are presented in tabular form, alphabetically by coalbed name and by State. The components of the total gas content (lost, desorbed, and residual gas) are given. Location (State and county), sample depth, coalbed or formation name, and coal rank are included for geographic and geology identification.

IC 9068. Dust Reduction Capabilities of Five Commercially Available Bag Valves, by Andrew B. Cecala, Anthony Covelli, and Edward D. Thimons. 1986. 10 pp. 6 figs. The dust-reduction capabilities of five commercially available bag valves were evaluated by the Bureau of Mines for use in mineral processing plants. The five valves were made of (1) standard paper, (2) polyethylene, (3) extended polyethylene, (4) double trap (paper), and (5) foam. The valves were evaluated at a mineral processing plant during the bag loading, conveying, and pallet loading process. For the overall process, the extended polyethylene valve was the most effective at reducing product blowback, and resulted in lower dust concentrations for bag-generated dust. When compared to the standard paper, it gave a 62-pct reduction in respirable dust at the bag operator location, and a 66-pct reduction at the bag stacker location. The cost of the extended polyethylene valve is less than 1 cent per bag higher than that of the standard paper valve. The high dust reductions and slight cost increase make it an attractive choice for the mineral processing industry.

IC 9069. Aluminum Fluxing Salts: A Critical Review of the Chemistry and Structures of Alkali Aluminum Halides, by Charles A. Sorrell, John G. Groetsch, Jr., and D. M. Soboroff. 1986. 37 pp. 38 figs. This Bureau of Mines publication reviews the structural characteristics of crystalline phases and phase equilibria data for the system NaCl-KCl-$AlCl_3$-NaF-KF-AlF_3, which encompasses a large number of molten salt fluxes currently used in aluminum recycling. Its purpose is to provide guidelines for research into the relationships between molten salt compositions and their physical properties, notably vapor pressures, densities, surface tensions, and viscosities, knowledge of which is essential to maximizing fluxing efficiencies and metal recovery and minimizing hazardous emissions and disposal problems. In addition, this report describes experimental determinations of subsolidus compatibility relationships in the system, which is of the quaternary reciprocal type, containing 12 different stable 4-phase assemblages in the solid state. The compatibility diagram serves to define the important compositional planes across which important changes in properties are likely to occur.

IC 9070. Gold Availability—World. A Minerals Availability Appraisal, by Paul R. Thomas and Edward H. Boyle, Jr. 1986. 87 pp. 37 figs. The Bureau of Mines evaluated the long-term cost and availability of primary gold production from 135 mines and deposits worldwide. Collectively, the evaluated countries represent 93 pct of world gold production. Total recoverable gold available (as of January 1984) from a subset of 111 significant producing mines and developing deposits in 13 market economy countries (MEC's) is estimated at 810 million tr oz. The Republic of South Africa is estimated to account for 87 pct of total recoverable gold. The United States and Canada account for 4 and 4.5 pct of the total, respectively. Eighty-three percent of total recoverable gold is available at a constant 1984 break-even price of $400/tr oz, and 70 pct is available at $300/tr oz. South Africa accounts for 90 pct of the gold available at $400/tr oz or less. Major conclusions are that (1) South Africa should remain the largest world producer through the year 2000, (2) annual MEC output in 2000 should not be significantly different than current output given constant 1984 gold prices of more than $300/tr oz, and (3) there may be a significant decline in production after 2010 in the absence of major new discoveries and continued development of new mines to offset the depletion of the South African mines. GPO Stock No. 024–004–02164–1. $4.50.

IC 9071. Economic Evaluation of an Electrolytic Process To Recover Lead From Scrap Batteries, by Thomas A. Phillips. 1986. 19 pp. 2 figs. This publication is an economic evaluation of the Bureau of Mines electrolytic process for recovering lead from scrap lead-acid batteries. In this process, scrap batteries are crushed and separated into metal and sludge fractions. The metal fraction is cast as anodes and electrorefined. Lead in the sludge fraction is converted to lead carbonate by reaction with an ammonium carbonate-ammonium bisulfite solution. The lead carbonate is then dissolved in a fluosilicic acid electrolyte from which pure lead metal is electrowon. A cost estimate is presented for a plant capable of processing 10,000 scrap batteries per day. The fixed capital cost for this plant is estimated to be $14 million on a fourth quarter 1984 basis. Operating costs are estimated to be $0.15/lb Pb recovered. Assuming a lead selling price of $0.17/lb, the interest rate of return on investment after taxes is 11 pct. A lead selling

price of about $0.21/lb is needed to obtain a 20 pct interest rate of return.

IC 9072. Ground Subsidence and Structural Damage Over an Abandoned Room-and-Pillar Coal Mine at Hegeler, IL, by Gennaro G. Marino, James W. Mahar, Larry R. Powell, and Richard E. Thill. 1986. 24 pp. 21 figs. The Bureau of Mines and the University of Illinois investigated surface characteristics and damage to structures from mine subsidence over a room-and-pillar coal mine in Hegeler, IL. Data on three adjacent subsidence sags and associated structural damage were collected, summarized, and evaluated. The subsidence sags developed over a 10-year period and took place above a modified room-and-pillar operation mining the Herrin (No. 6) coal at a depth of 130 to 135 ft. Surface vertical displacements of 3.0 to 3.5 ft resulted from extracting 6.1 to 6.4 ft of coal. Ground movements associated with sag formation severely damaged three houses and a radio station building, broke numerous utility lines, and structurally distorted three radio transmission towers. The radio station was remodeled and the towers repaired, but the three houses were subsequently demolished. Surface waters collecting in the subsidence depressions caused failure of radial ground transmission systems. The following subsidence profile characteristics were determined at the radio station and one of the houses, respectively: profile slopes, 0.02 and 0.07; maximum curvatures, 2.3×10^{-4} ft^{-1} and 3.0×10^{-4} ft^{-1}; and angular distortions, 6.6×10^{-3} and 62.0×10^{-3}. Although the house was more severely damaged than the radio station, both structures are classified as severely to very severely damaged.

IC 9073. Underground Coal Mine Lighting Handbook. (In Two Parts.) 1. Background, compiled by W. H. Lewis. 1986. 42 pp. 60 figs. This Bureau of Mines report and its companion report (Information Circular 9074) have been prepared as a complete reference on underground coal mine lighting. This report discusses the fundamentals of light and its interrelationship with the visual process. The purpose of the report is to insure an understanding of the numerous complex and interrelated factors that must be considered to design and implement a mine lighting system that will satisfy human needs for good vision and comfort. Topics include history, objectives, and technical considerations of coal mine lighting; light physics; light and vision relationships; and disability and discomfort glare.

IC 9074. Underground Coal Mine Lighting Handbook. (In Two Parts.) 2. Application, compiled by W. H. Lewis. 1986. 89 pp. 79 figs. This Bureau of Mines report and its companion report (Information Circular 9073) have been prepared as a complete reference on underground coal mine lighting. This report discusses system design criteria and procedures, data and specifications to aid in selection of suitable mine lighting hardware, and guidelines for system installation and maintenance. Topics include light measuring techniques and instruments, illumination regulations for underground coal mine environments and equipment, lamps and ballasts, available mine lighting hardware, design and evaluation of coal mine illumination systems, and installation and maintenance of a mine lighting system.

IC 9075. Field Tests of a Model Health and Safety Program for the Mining Industry, by Robert H. Peters and Louis Schaffer. 1986. 36 pp. 17 figs. The objective of the project described in this report was to design and field test a model health and safety program at a coal mining company and a gold mining company. The model program was implemented primarily by providing training on loss control, accident investigation, and the operation of mobile equipment, and by providing technical assistance to help solve health and safety problems. Data were obtained from company records on occupational injuries, illnesses, accidents, and "near misses"; and through direct observation of employees performing a large number of randomly selected jobs. At the coal mine, employees were observed five times over a 15-month period. At the gold mine, employees were observed six times over a 16-month period. During the study, the percentage of sampled jobs containing one or more safety deficiencies decreased from 74.3 pct to 36.6 pct at the coal mine and from 86.4 pct to 19.1 pct at the gold mine. Work on this project was performed by Woodward Associates, Inc., under a Bureau of Mines contract.

IC 9076. Coal Mine Roof Instability: Categories and Causes, by Noel N. Moebs and Raymond M. Stateham. 1986. 15 pp. 14 figs. Coal mine roof failure is categorized according to character, trend, or pattern of occurrence. Two principal categories of failure are proposed—geology related and stress related. Geology-related failure includes both lithology and structure. Each of several subcategories reflects the probable cause of failure and thereby provides a basis for the selection of appropriate techniques for reducing the incidence of failure. These control techniques, depending on local conditions, may include supplementary support, destressing, reduction of mine air humidity, or a change in the customary support methods.

IC 9077. Dust Control on Longwall Shearers Using Water-Jet-Assisted Cutting, by C. D. Taylor, P. D. Kovscek, and E. D. Thimons. 1986. 9 pp. 6 figs. The Bureau of Mines equipped a longwall shearer with a water-jet-assisted cutting system and measured dust levels during the cutting of a simulated coal block. The block was cut dry at a conventional water spray pressure of 190 psi and with water-jet-assisted cutting pressures ranging from 1,000 to 6,000 psi. At water pressures of 3,000 psi and higher, dust concentrations were reduced by as much as 85 pct via water-jet-assisted cutting in comparison with conventional water sprays. This reduction was achieved without any increase in the water flow rate.

IC 9078. Surface and Underground Coal Mine Equipment Population, 1982, by Michael G. Pojar. 1986. 25 pp. 3 figs. This Bureau of Mines report estimates the population of the principal types of machinery in use by the coal mining industry during 1982 in surface and underground mines. Estimates were arrived at using 1976 coal equipment population estimates as baseline data with modifications made for new mine development, expansion, and closure occurring during 1976–82. Estimates were broken down into 3 regions that included all 26 coal-producing States. Modifications made to the baseline data were computed using (1) actual equipment information when available and (2) equipment information hypothesized from representative generic mine models, which were predicated on mine size and mine method. Roughly half of the equipment fleet at new or expanding coal operations was known; the remainder was hypothesized. The mine models used to generate equipment information are included in this report, along with the hypothesized equipment use data. The equations and various factors used to determine the equipment adjustments for mine closings, new mine openings, and small coal mine operations are also identified.

IC 9079. Improved Backup Alarm Technology for Mobile Mining Equipment, by Guy A. Johnson, Russell E. Griffin, and Linneas W. Laage. 1986. 19 pp. 16 figs. Despite the use of warning alarms to alert miners to the backward movement of large mining equipment, miners still are injured too frequently in backup accidents. Currently approved backup alarm technology consists of continuous sounding alarm systems. New technology has developed a warning system that initiates an alarm only if there is an object close behind the vehicle. This advancement eliminates constant exposure to the alarm because a warning is given only in case of a potential collision. Adoption of this development can improve safety and reduce damage, especially for front-end loaders. It will also eliminate a source of nuisance noise in urban and residential areas. This Bureau of Mines report describes the general characteristics of infrared light, ultrasonic wave, and Doppler radar technology as used for backup alarms, and reviews the testing of the most promising detection devices.

IC 9080. Economic Evaluation of Horizontal Borehole Drilling for Methane Drainage From Coalbeds, by Eugene C. Baker, Roy H. Grau III, and Gerald L. Finfinger. 1986. 18 pp. 3 figs. The potential profitability of a horizontal borehole drilling program for recovering methane gas in an Alabama coalbed for 6 yr in advance of mining is estimated in this Bureau of Mines report. A cash flow analysis based on estimated capital investments, annual operating costs, and the selling price of methane gas was used to determine the net income and net cash flow for each year of operation. Subsequently, the annual net cash flows were capitalized to determine the discounted cash flow rate of return. Findings indicate that a 25.08-pct interest rate of return on investment could be realized from the sale of methane gas in excess of 3 billion ft^3 during the years 1985 through 1990 at a minesite price of $2.25/Mft^3$.

IC 9081. Thermodynamic Properties of Selected Metal Sulfates and Their Hydrates, by Carroll W. DeKock. 1986. 59 pp. Thermodynamic data for selected metal sulfates were critically evaluated and compiled as part of the Bureau of Mines program to provide a scientific base for use in developing new technology and predicting the feasibility of new processes. Values for $Cp°$, $S°$, $H° - H°_{298}$, $-(G° - H°_{298})/T$, $\Delta Hf°$, $\Delta Gf°$, and log Kf as functions of temperature are given in tabular form. Thermodynamic data were compiled for Ag_2SO_4, $Al_2(SO_4)_3$, $Al_2(SO_4)_3 \cdot 6H_2O$, $BaSO_4$, $BeSO_4$, $BeSO_4 \cdot 2H_2O$, $BeSO_4 \cdot 4H_2O$, $CaSO_4$, $CaSO_4 \cdot 1/2H_2O$, $CaSO_4 \cdot 2H_2O$, $CdSO_4$, $CdSO_4 \cdot H_2O$, $CdSO_4 \cdot 8/3H_2O$, $2CdO \cdot CdSO_4$, Cs_2SO_4, $In_2(SO_4)_3$, K_2SO_4, $KAl(SO_4)_2$, $KAl(SO_4)_2 \cdot 12H_2O$, Li_2SO_4, $Li_2SO_4 \cdot H_2O$, $MgSO_4$, $MgSO_4 \cdot H_2O$, $MgSO_4 \cdot 2H_2O$, $MgSO_4 \cdot 4H_2O$, $MgSO_4 \cdot 6H_2O$, $MgSO_4 \cdot 7H_2O$, Na_2SO_4, $Na_2SO_4 \cdot 7H_2O$, $Na_2SO_4 \cdot 10H_2O$, $(NH_4)_2SO_4$, $NH_4Al(SO_4)_2$, $NH_4Al(SO_4)_2 \cdot 12H_2O$, $PbSO_4$, Rb_2SO_4, Tl_2SO_4, and $Zr(SO_4)_2$. GPO Stock No. 024–004–02168–3. $3.25.

IC 9082. Mineral Consumption Forecasting: Standardizing and Comparing Forecasts, by John B. Bennett. 1986. 17 pp. 2 figs. This Bureau of Mines report presents a method of standardizing forecasts of mineral consumption that attempts to resolve the problems caused by the use of different data bases, different definitions of minerals consumption, and different base years for making projections. Using this method, forecasts of U.S. and world mineral consumption, in the year 2000, for nine commodities (aluminum, chromium, cobalt, copper, manganese, nickel, tin, tungsten, and zinc) are standardized and compared. Also, selected forecasts or associated growth rates are used to generate implied values of consumption for 1980–83, which are then compared with actual values of consumption for 1980–83. The economic growth predictions underlying these forecasts are examined, and some general conclusions are drawn. A description of each methodology used to generate these forecasts is given in an appendix. GPO Stock No. 024–004–02165–9. $1.50.

IC 9083. Subsidence Investigations Over Salt-Solution Mines, Hutchinson, KS, by Robert C. Dyni. 1986. 23 pp. 21 figs. The Bureau of Mines in cooperation with the Solution Mining Research Institute conducted surface and subsurface investigations over five solution-mined salt cavities in the Hutchinson, KS, area. The purpose of these investigations was to determine the mechanisms that lead to the formation of sinkholes above collapsed solution cavities. Of the five salt-solution cavities investigated, four had collapsed and produced sinkholes prior to the time of the investigations; the fifth cavity was considered stable. Exploratory drilling and coring operations were conducted at all five sites; surface stability monitoring was conducted at three of them. The results of these studies indicate that excessive dissolution at the salt-shale contact of each collapsed cavity produced large, unsupported roof spans that ultimately exceeded the structural integrity of the overburden. The stable cavity was not exposed to excessive dissolution at the salt-shale contact; this limited the roof span and ensured a stable cavity. The data also show that surface settlement in the vicinity of the two surface-monitored sinkholes continued for approximately 7 years after the sinkholes formed, indicating that the rubble piles of the collapsed cavities were undergoing gradual consolidation. This report is based upon work done under an agreement between the Solution Mining Research Institute and the Bureau of Mines.

IC 9084. Potash Availability—Market Economy Countries. A Minerals Availability Appraisal, by D. E. Sullivan and N. Michael. 1986. 32 pp. 23 figs. The Bureau of Mines investigated the availability of potash from 68 mines and deposits in 12 market economy countries (MEC's) containing, at the demonstrated resource level, approximately 11.7 billion metric tons (mt) of potash in assay terms of contained K_2O as used by industry as a standard of comparison for the different forms of potash. These resources include almost 190 million mt in the United States, 9.63 billion mt in Canada, approximately 430 million mt in Western Europe (France, Federal Republic of Germany, Italy, Spain, and the United Kingdom), 1.24 billion mt in the Middle East (Israel and Jordan), and over 220 million mt in other countries (Brazil, Chile, and the Congo). This analysis has determined that future production of potash in MEC's will most likely continue to be from the large resources associated with producing operations in Canada. Based solely on the demonstrated resources included in this study, potash mining in the United States would decline while overseas production from MEC's can continue into the next century at near current production levels. However, timely development of new or inferred resources would offset any such decline. Producing mines in Canada have the resources to increase and maintain increased production well into the next century. For U.S. potash users, Canada is a long-term stable and secure source.

IC 9085. Columbium Availability—Market Economy Countries. A Minerals Availability Appraisal, by Frederick W. Miller, R. J. Fantel, and D. A. Buckingham. 1986. 20 pp. 17 figs. The Bureau of Mines has investigated the availability of columbium from 19 deposits (3 producers and 16 nonproducers) in 7 market economy countries (MEC's). Brazil has the largest recoverable columbium resource, possessing approximately 2.39 million metric tons (Mmt), or 69 pct of the MEC total (3.47 Mmt). The Western Hemisphere countries of Brazil, Canada, and the United States contain 3.14 Mmt of recoverable columbium or 90 pct of the MEC total. Columbium recovered as a byproduct of tin mining is not included as part of MEC resources in this study. Currently producing mines are Araxa and Catalao in Brazil, and Niobec in Canada. These three mines have 2.42 Mmt of recoverable resources or approximately 69 pct of the MEC total. It is estimated that these mines, operating at full capacity, could satisfy cumulative MEC demand (based on an annual growth rate of 5.1 pct) for the next 20 yr. The United States is totally dependent upon foreign sources for its columbium supply. The majority of U.S. columbium is imported from Brazil in the form of steelmaking-grade ferrocolumbium. Canada has been the sole source of pyrochlore concentrates since Brazil discontinued exports in 1981. The United States also imports small (but important) quantities of columbium as columbite concentrates from Nigeria and Brazil, as columbite contained in tin slags from Thailand and Malaysia, and as synthetic concentrates from the Federal Republic of Germany.

IC 9086. Tin Availability—Market Economy Countries. A Minerals Availability Appraisal, by D. I. Bleiwas, Andrew E. Sabin, and G. R. Peterson. 1986. 50 pp. 21 figs. The Bureau of Mines determined demonstrated tin resources and costs associated with tin production in order to evaluate the potential for tin production from 18 market economy countries. Data were collected from tin producers, in most cases during on-site visits. The analyses evaluated the relative economic and resource position of 146 mines, deposits, or regions in January 1984 dollars. The demonstrated resource of recoverable tin within the nations studied is approximately 2.8 million metric tons. Of this total, over 73 pct is recoverable from the Southeast Asian countries of Malaysia, Thailand, and Indonesia, which in

1983 accounted for almost 60 pct of the world's tin production. Brazil has joined the Southeast Asian countries as a major low-cost, high-volume supplier of tin and is likely to continue to expand its production. Given the 1984 market structure, over 60 pct of the tin in demonstrated resources was economically recoverable. Historically, the International Tin Council has helped maintain relatively stable tin prices through a buffer stock and sales quotas. In late 1985, exhaustion of buffer stock funds led to suspension of tin trading on the world's major tin metal exchanges.

IC 9087. Chromium-Chromite: Bureau of Mines Assessment and Research. Proceedings of Bureau of Mines Briefing Held at Oregon State University, Corvallis, OR, June 4–5, 1985, compiled by Charles B. Daellenbach. 1986. 141 pp. 70 figs. This briefing was sponsored by the Bureau of Mines to summarize ongoing and recently completed chromium-chromite research and resource assessment activities by the Bureau. Through the series of 18 presentations compiled herein, Bureau personnel covered a wide range of topics including U.S. chromite and chromium trends and usage patterns; foreign and domestic resources; and research activities on mineral characterization and beneficiation, chemical and pyrometallurgical processing of chromite and chromium-bearing wastes, new low-chromium alloy and coating substitutes, corrosion- and oxidation-resistant stainless steels, and chromium-containing refractories.

IC 9088. Reliability Prediction for Computerized Mine-Monitoring Systems, by Raymond M. Kacmar and Edward F. Fries. 1986. 13 pp. 17 figs. This report presents the Bureau of Mines research on the hardware reliability prediction for two Bureau monitoring projects. The basic concepts of reliability predictions are introduced along with the reliability models and assumptions used for this particular evaluation. The results of the reliability predictions are for ground-fixed and naval-sheltered environments.

IC 9089. Impact of Background Sources on Dust Exposure of Bag Machine Operator, by Andrew B. Cecala and Edward D. Thimons. 1986. 10 pp. 10 figs. The Bureau of Mines has recorded a number of different background dust sources that significantly contaminate the air breathed by bag machine operators. These background sources, observed at five different plants over the past 2 years, can expose bag machine operators to more significant dust concentrations than the filling process itself. To keep bag operator exposure within acceptable dust levels established by the Mine Safety and Health Administration, U.S. Department of Labor, the significance of these background sources must be realized, and the sources must be identified and controlled. The purpose of this work is to identify common background dust sources and show the significant effects that they have on the bag operator's overall dust exposure.

IC 9090. Primary Silver Availability—Market Economy Countries. A Minerals Availability Appraisal, by E. H. Boyle, Jr., G. R. Peterson, and P. R. Thomas. 1986. 36 pp. 14 figs. The Bureau of Mines has evaluated the potential availability of silver from 436 mines and deposits in 41 market economy countries (MEC's) comprising 5 major economic categories of deposits: predominantly silver deposits and predominantly zinc, lead, copper, and gold deposits. This study evaluated the long-term cost and availability of primary silver production from 53 producing and 13 nonproducing predominantly silver properties in 11 MEC's and estimated the total recoverable silver from 370 properties as a coproduct or byproduct of zinc, lead, copper, or gold production. This study resulted in estimates of a demonstrated resource of 5.99 billion tr oz of recoverable silver as of January 1984. Of this total, 23.5 pct is in the 66 mines and deposits classified as predominantly silver properties. The largest quantity of recoverable silver, 43.9 pct, lies in the 121 properties classified as predominantly zinc, with 26.5 pct in 120 properties classified as predominantly copper, 4.1 pct in 21 predominantly lead properties, and 2.0 pct in 108 predominantly gold properties. At current silver prices, the economics of silver production favor silver that is a byproduct or coproduct of zinc, lead, copper, or gold, and much of the silver production in the United States from the predominantly silver mines is at an economic disadvantage in comparison with silver production in other countries. GPO Stock No. 024–004–02171–3. $2.25.

IC 9091. Placer Gold Sampling In and Near the Chugach National Forest, Alaska, by Robert B. Hoekzema and Steven A. Fechner. 1986. 42 pp. 19 figs. The Bureau of Mines and U.S. Geological Survey completed a 4-yr (1979–82) mineral appraisal of the Chugach National Forest (CNF), AK. This report summarizes the Bureau's placer gold studies in the CNF. Placer mining from the mid-1890's through 1982 produced an estimated 133,800 oz of gold, of which two-thirds was produced prior to 1920. As much as 6,800 oz of placer gold was produced from 1979 to 1982. Most production came from Crow, Canyon, and Resurrection Creeks. Five types of placer gold deposits were identified in the CNF: (1) alluvial placers, (2) bench placers, (3) eluvial placers, (4) glacial placers, and (5) marine placers. Placer sampling indicated a potential for gold production from alluvial and bench placers associated with historically mined drainages such as Crow, Canyon, Resurrection, Sixmile, and Mills Creeks and from unmined drainages including the Avery, Kings, Snow, Copper, and Tasnuna Rivers and several smaller streams throughout the CNF. Results of fineness tests indicated that gold from the CNF ranges from 455 to over 950 fine. Subsequent investigations in drainages with anomalous placer sample values also identified previously unknown lode mineralization.

IC 9092. Application of Employee Turnover Research Findings to the Mining Industry, by Robert H. Peters. 1986. 29 pp. 1 fig. Several significant problems associated with employee turnover among underground miners are described in this Bureau of Mines report. Although a vast amount of research has been conducted on turnover among employees in nonmining industries, there has never been an attempt to empirically investigate the causes of turnover among underground miners. This report presents the results of empirical research on employee turnover in other industries and describes and critiques the research methods that have been used to investigate turnover. Using the findings on employee turnover in other industries and known data about miners and the mining industry, a conceptual model of the factors that cause turnover among miners was generated. This model, which is expected to provide a basis for later empirical studies, is presented. Several recommendations for controlling miner turnover are also presented.

IC 9093. Development of a Protective Operator Compartment for a Thin-Seam Mobile Bridge Carrier, by August J. Kwitowski and Robert J. Gunderman. 1986. 27 pp. 61 figs. This Bureau of Mines report summarizes the development of a protective operator compartment for a new generation thin-seam mobile bridge carrier. The developed compartment is commercially available and is currently employed on approximately 15 bridge carriers used in the mining industry. The design of the compartment, which employed human factors engineering and small- and full-scale mockup models, is fully described. Details of the compartment's fabrication, evaluation, and demonstration in a commercial low-seam coal mine are also provided.

IC 9094. Cutter Roof Failure: An Overview of the Causes and Methods for Control, by John L. Hill III. 1986. 27 pp. 34 figs. The Bureau of Mines is conducting research on the causes and methods for control of cutter roof failure in underground coal mines. This hazardous ground control problem exposes miners to the danger of falling roof rock and frequently results in massive roof failure. This report outlines

the probable causes of cutter roof failure, which are based on field investigations, numerical model analysis, and in-mine observations. Traditional methods of control are presented, as well as innovative methods based on mining concepts developed during earlier years of coal mining history. The report can be useful to a mine operator for assessing the causes of cutter roof failure on a site-by-site basis and for predicting the probability of its occurrence. A process is presented for selecting an optimum control method that includes both traditional and innovative control techniques for each of the various causes of cutter roof failure.

IC 9095. Safe Cleaning of State of Maine Filters Using EDTA-Type Chelating Agents, by John E. Pahlman and Daniel N. Tallman. 1986. 12 pp. 9 figs. An increasing number of gold and silver mining operations are employing cyanide solutions to effectively dissolve silver and gold from finely disseminated ores. Many of these operations use small, packaged processing systems like the State of Maine filter system, which employs zinc precipitation of gold and silver. Solution-clarifying filters in these systems become blinded with calcium carbonate ($CaCO_3$) scale and require frequent (every 2 to 10 days) dismantling of the filter units for acid cleaning. This is a hazardous operation as it is not compatible with the alkaline cyanide leach solutions and may result in the evolution of toxic hydrogen cyanide (HCN) gas during cleaning and during any accidental acid spill. The Bureau of Mines has investigated an alternative, nonacidic method of cleaning blinded State of Maine filters that employs ethylene-diamine-tetraacetic-acid (EDTA) type chelating agents to dissolve the scale. In situ cleaning of a 150-st/d State of Maine filter with EDTA-type chelating agents was successfully demonstrated. Greater than 90 pct of the $CaCO_3$ scale was removed in about 10 min with circulation of 31 L of 2.5-pct-EDTA solution through the filter unit. The EDTA cleaning method not only eliminates the cyanide hazard in filter cleaning but is advantageous from the standpoint of operating costs and productivity.

IC 9096. Analyses of Natural Gases, 1985, by B. J. Moore and Stella Sigler. 1986. 182 pp. 1 fig. This publication contains analyses and related source data for 517 natural gas samples from 25 States and 1 foreign country. Of the total samples, 298 were collected during calendar year 1985; the remainder were collected earlier, but releases granting permission to publish were not received before 1985. All samples were obtained and analyzed as part of Bureau of Mines investigations of the occurrences of helium in natural gases of countries with free market economies. This survey has been conducted since 1917. The analyses published herein were made by mass spectrometer and chromatograph.

IC 9097. Bureau of Mines Research Into Reducing Materials-Handling Injuries, by Richard L. Unger and Thomas G. Bobick. 1986. 22 pp. 14 figs. The Bureau of Mines entered into a cooperative agreement with an eastern Kentucky coal mining company to comprehensively redesign the flow of equipment and supplies throughout its underground mines. Items were tracked from delivery to the warehouse and from surface storage areas to their final usage locations underground. Three underground mines were visited, and a great variety of tasks were videotaped for subsequent laboratory analysis. Of particular interest were tasks that required manual handling of the supplies or equipment components. Activities such as handling daily supplies (concrete blocks, rock dust, and crossbeams) and handling or lifting the continuous miner power cable were determined to be the most hazardous. Recommendations to the company included redesigned surface storage areas to facilitate the use of forklift vehicles to load the underground supply cars. Designs were also developed for different mechanical-assist devices to help in unloading the supply cars underground and to handle equipment maintenance tasks underground. Additionally, the videotapes of the underground manual handling tasks became the basis for simulating those activities in controlled laboratory conditions. This testing will contribute to developing guidelines for proper lifting techniques for low-seam coal mines.

IC 9098. Antimony Availability—Market Economy Countries. A Minerals Availability Appraisal, by C. M. Palencia and C. P. Mishra. 1986. 20 pp. 8 figs. The Bureau of Mines studied the potential availability of primary antimony (Sb) from demonstrated resources in 21 mines and deposits in market economy countries (MEC's). Twelve of these properties were evaluated as producers and nine as nonproducers. The 21 studied properties contain 499,600 mt Sb as demonstrated resources, of which 304,000 mt is recoverable as antimony metal; another 973,500 mt Sb is contained in inferred resources. Recoverable antimony from demonstrated U.S. deposits is only 10,700 mt, just 3.5 pct of the MEC total. Domestic production of primary antimony from operating mines has averaged only 561 mt/yr over the 10-yr period 1975–84. This represents just over 5 pct of total U.S. consumption of primary antimony, which averaged 11,081 mt/yr during the same period. The United States will thus continue to rely on imported ores and/or concentrates, antimony oxides, and metal to satisfy domestic industrial requirements. At production costs up to $1.15/lb Sb, 110,000 mt of refined antimony is potentially available from 10 of the 21 studied properties. At $2/lb, 294,000 mt Sb is available, and at $3/lb, the total rises to 304,000 mt Sb available from all evaluated producers of refined antimony.

IC 9099. Surface Subsidence Over Longwall Panels in the Western United States—Monitoring Program and Final Results at the Price River Coal Co. No. 3 Mine, Utah, by Alan J. Fejes. 1986. 21 pp. 20 figs. As part of its mine subsidence research program, the Bureau of Mines and the American Electric Power Co. cooperated on a study, conducted at the Price River Coal Co. No. 3 Mine, directed toward developing the capability to estimate the surface subsidence resulting from longwall mining in a geologic, topographic, and mining environment common to coalfields in the Western United States. Subsidence was monitored at the No. 3 Mine over two adjacent longwall panels. The subsidence study area was reduced when the two planned panels were reduced in length because of equipment failure and a mine fire. Subsidence was measured for 21 months. Subsidence continued for 6 months after mining had been completed. A maximum of 2.2 ft of subsidence occurred over the two longwall panels mined at an overburden depth ranging from 800 to 1,500 ft.

IC 9100. Beryllium Availability—Market Economy Countries. A Minerals Availability Appraisal, by Audrey A. Soja and Andrew E. Sabin. 1986. 19 pp. 16 figs. The Bureau of Mines investigated beryllium resources, production methods, and production costs to estimate the quantity of beryllium available for future use. Eight mining districts and 12 deposits are included in the study; lack of data precluded the evaluation of resources from 6 nonproducing and undeveloped deposits. The study revealed that demonstrated beryllium-bearing resources should be sufficient to meet domestic needs and those of other market economy countries (MEC's) well into the 21st century. Total demonstrated beryllium-bearing in situ resources from MEC's are estimated at 118 million metric tons (Mmt) of ore containing approximately 33,000 mt beryllium metal. Approximately 111 Mmt ore containing 29,000 mt beryllium was included in the cost analysis and availability sections of this study. Three Brazilian districts currently produce beryl ore, and one domestic company, Brush Wellman Inc., produces bertrandite ore. Brush Wellman Inc. owns and operates the only MEC facility in the Western Hemisphere for extracting beryllium values from beryl and bertrandite and is the beryllium industry's only fully integrated corporation.

IC 9101. Domestic Consumption Trends, 1972–82, and Forecasts to 1993 for 12 Major Metals, by Staff, Bureau of Mines, U.S. Department of the Interior, and Basic Industries Sector, U.S. Department of Commerce. 1986. 34 pp. 17 figs.

Consumption and intensity of use trends for 12 metals, by industrial end use, were estimated for 1972 through 1982 by the Bureau of Mines and U.S. Department of Commerce. The trends were then forecast through 1993 using standard statistical methods. The intensity of use measures selected is the quantity of metal consumed per constant dollar output of a specific industrial sector. The metals studied were aluminum, chromium, cobalt, copper, lead, manganese, nickel, the platinum-group metals, tin, titanium, tungsten, and zinc. Average annual growth rates for the following 4 of the 12 metals increased from 1972 to 1982 as follows: aluminum, 1.00%; platinum-group metals (consisting of platinum, palladium, and iridium), 8.83%; titanium, 7.82%; and tungsten, 6.09%. Consumption for the remaining eight metals decreased at average annual rates ranging from 0.58% (copper) to 5.37% (manganese). GPO Stock No. 024-004-02170-5. $2.

IC 9102. Lithium Availability—Market Economy Countries. A Minerals Availability Appraisal, by D. I. Bleiwas and J. S. Coffman. 1986. 23 pp. 7 figs. The Bureau of Mines determined the costs associated with lithium production (in various products) from demonstrated resources in seven market economy countries (MEC's). This analysis evaluated the relative economic and resource position of 16 mines or deposits, including 6 producers and 1 (Bernic Lake) operating at pilot scale. The demonstrated resource of recoverable lithium within the deposits studied is approximately 2.2 million metric tons. Virtually all known MEC resources and production were covered, including resources in Chile (59 pct of the total), the United States (13 pct), Australia (11 pct), Canada (10 pct), and Bolivia, Zaire, and Zimbabwe (combined 7 pct). In addition, the large potential of lithium-enriched brines is assessed, especially those in the Atacama Basin, Chile, where production began in 1984. The lithium resource consists of lithium in spodumene, brines, and to a small extent lepidolite and petalite. Most MEC lithium trade originates from the United States, though development of brine deposits in Chile, and potential development in Bolivia, could threaten the U.S. position. Economic analysis indicated that all lithium being recovered from producing properties could be produced at less than the published market price, and that MEC resources from these properties are adequate to supply any foreseeable demand.

IC 9103. Uranium Occurrences in the Northern Darby Mountains, Seward Peninsula, AK, by Jeffrey Y. Foley and James C. Barker. 1986. 27 pp. 13 figs. In 1980, the Bureau of Mines investigated the northern Darby Mountains on the Seward Peninsula, AK, for radioactive mineral deposits. Uranium is concentrated in silicified shear zones in biotite quartz monzonite of the Darby pluton. The shear zones are best exposed in steep, narrow, avalanche gullies; they are characterized by radiometric anomalies and by uranium and thorium geochemical anomalies. Radiometric and geochemical anomalies are also found over altered biotite quartz monzonite where there are no visible shear zones. The radiometric and uranium anomalies are often spatially, but apparently not genetically, associated with alkaline mafic and felsic dikes. Similar geochemical and radiometric anomalies over disclosed altered zones and geochemical anomalies in sediments downstream from the altered zones indicate that additional areas may also be favorable targets for uranium deposits. Analyses of panned, heavy mineral concentrates show no significant concentrations of uranium or thorium in resistant heavy minerals. This indicates that radioactive elements in the Darby pluton are concentrated in soluble, nonresistant minerals that may constitute a recoverable uranium resource.

IC 9104. Tin Reconnaissance of the Kanuti and Hodzana Rivers Uplands, Central Alaska, by James C. Barker and Jeffrey Y. Foley. 1986. 27 pp. 13 figs. The Bureau of Mines evaluated the tin development potential of the uplands between the Kanuti and Hodzana Rivers from 1978 through 1980. Chemical and petrologic data indicate that local granitic intrusions are generally similar to "tin granites" that contain tin deposits elsewhere. The tin mineral cassiterite (SnO_2) was identified in chlorite-rich greisen from the Sithylemenkat pluton. Greisen zones are located near the intersections of high-angle, linear structural features, and samples contain up to 0.23 pct Sn. One bedrock exposure of greisen is 10 to 15 ft wide. Although some lode mineralization is present, the deeply eroded nature of the region suggests larger tin-bearing cupolas may have existed prior to erosion. Extensive stream gravel deposits have not been affected by glaciation, and potential exists for placer tin deposits. Especially favorable is a large semiclosed basin drained by the Kanuti Kilolitna River. Heavy mineral concentrates collected from surface alluvium in the Kanuti Kilolitna River valley contained up to 51.2 pct Sn (0.02 to 0.4 lb/yd^3 Sn), up to 5 pct W, up to 0.4 pct Cb(Nb), and up to 0.1 pct Ta. The concentration of heavy minerals is expected to increase with depth. Detailed mapping and extensive surface and subsurface sampling will be needed to quantify the mineral development potential of the lode and placer tin deposits in the uplands.

IC 9105. A Columbium-Bearing Regolith on Upper Idaho Gulch, Near Tofty, AK, by J. Dean Warner, C. L. Mardock, and D. C. Dahlin. 1986. 29 pp. 20 figs. In 1984, as part of a project to evaluate Alaskan occurrences of certain critical and strategic minerals, the Bureau of Mines investigated a columbium-bearing regolith on upper Idaho Gulch, near Tofty, AK. The regolith is derived from weathering of a dolomitic marble and consists mostly of iron oxide minerals with accessory apatite, zircon, xenotime, rutile, monazite, and the columbium minerals aeschynite, columbite, and ilmenorutile. Two regolith lenses contain 340,000 lb of columbium resources at an average grade of 0.07 pct. Calculated composite concentrates from two regolith samples (approximately 200 lb each) contained 53 and 57 pct of the columbium at grades of 0.97 and 0.86 pct, respectively. In each case the grade could be improved to 1.1 pct Cb with a sacrifice of 9-pct recovery. The regolith's mineralogy, trace-element geochemistry, and similarity to descriptions of other columbium-enriched regoliths suggest that the underlying marble may be a carbonatite. The lack of associated alkalic igneous rocks and the stratiform nature of the regolith, however, may be interpreted as evidence for sedimentary origin of the marble. The marble and regolith are a lode source for some of the minerals in the Idaho Gulch placer deposit.

IC 9106. Availability of Elemental Sulfur and Pyrite Concentrate—Market Economy Countries. A Minerals Availability Appraisal, by D. A. Buckingham. 1986. 16 pp. 12 figs. Engineering and economic evaluations were performed by the Bureau of Mines on 14 Frasch sulfur, 1 native sulfur, and 21 metal sulfide operations in 11 market economy countries. The evaluation included discounted-cash-flow, rate-of-return economic analyses at 15 pct to determine the average total cost of production of these two commodities and the potential availability of elemental sulfur (S) and pyrite concentrate. The Bureau evaluated the potential availability of elemental sulfur and pyrite concentrate. Approximately 279 million metric tons (Mmt) of pyrite concentrate at 46 pct S is potentially recoverable from 422 Mmt of in situ metal sulfide ore. Nearly 89 pct of the total pyrite concentrate is available at an average total cost of production below the January 1984 pyrite concentrate market price ($43/mt). About 185 Mmt S is potentially recoverable from 253 Mmt of in situ elemental sulfur. About 99 pct of this sulfur is available at an average total cost of production below its January 1984 market price ($131/mt).

IC 9107. Company Towns Versus Company Camps in Developing Alaska's Mineral Resources, by Robert Bottge. 1986. 19 pp. 10 figs. When a company develops a mineral property in a remote area of Alaska, it must consider how best to house its personnel. This Bureau of Mines report examines the economics of two options: company towns and company

camps. The price required to maintain a 15% discounted-cash-flow rate of return (DCFROR) was derived for hypothetical 1,000-st/d cut-and-fill mines and 50,000-st/d open pit mines located in three different regions of the State. One set of hypothetical mines utilizes a townsite; the other utilizes a relatively new concept, a fly-in camp or commuting operation, in which two shifts of employees operate the mine and all associated facilities for 1 week before being replaced by a second crew. The study shows that operating costs were higher for mines employing the commuting option than for mines having a company town because of the additional wages paid for overtime hours; however, the price required to obtain a 15% DCFROR for the single-product copper concentrate, f.o.b. the mill site, was significantly lower owing to the lower investment costs for the camp-type operation. The economic advantage for those mines utilizing the camp increases from south to north and from the coast toward the interior.

IC 9108. Water-Jet-Assisted Roadheaders, by Robert J. Timko, Bradley V. Johnson, and Edward D. Thimons. 1986. 11 pp. 13 figs. Water-jet-assisted cutting involves the use of a mechanical cutting bit in combination with a high-pressure water jet directed just in front of the bit tip. Such a jet can offer benefits in terms of improved cutting, reduced dust and fines, and improved bit wear. The Bureau of Mines, through a contract with the British National Coal Board, has researched the use of water-jet-assisted cutting on roadheaders. After several engineering design problems were overcome, this program led to the successful underground testing of these roadheaders. Today, more than 60 water-jet-assisted roadheaders are in operation around the world, and numerous others are on order. This paper details the evolution of these machines and the benefits to be gained by their use.

IC 9109. Evaluating Ventilation Parameters of Three Coal Mine Gobs, by R. J. Timko, F. N. Kissell, and E. D. Thimons. 1986. 16 pp. 5 figs. The Bureau of Mines used sulfur hexafluoride (SF_6) tracer gas to evaluate the effectiveness of gob ventilation and/or sealing practices at three coal mines, each having different problems associated with their mined-out areas. The purpose of these ventilation studies was to better understand whether current techniques employed for ventilation or sealing are successful at minimizing the potential for gob fires and explosions. The work performed at each mine is discussed: One is a longwall operation that uses ventilation to carry off hazardous gases, and two are room-and-pillar operations, each with far different concerns, that seal off the gobs to isolate them from the main mine ventilation. In all cases, employment of the Bureau's SF_6 tracer gas technique resulted in answers to questions raised by the mine operators concerning the effectiveness of their gob ventilation or sealing practices in preventing mine fires.

IC 9110. Development of an Automated Breathing and Metabolic Simulator, by Nicholas Kyriazi. 1986. 17 pp. 17 figs. The Bureau of Mines has been developing breathing and metabolic simulator technology since 1970. Breathing simulation has been widely achieved throughout the world and used in the testing of open-circuit breathing apparatus, but satisfactory metabolism stimulation has not been achieved. This situation required that the testing of closed-circuit breathing apparatus, which are the only type used in mines, be done using human test subjects. The goal was a machine that could accurately simulate both the breathing and the metabolic functions of a human being for testing of closed-circuit breathing apparatus. The advantages of using such a machine instead of a human being for testing respiratory protective devices lie in its ability to quantify metabolic input, its repeatability, and the lack of a need to deal with the vagaries of human subjects. This report describes the breathing and metabolic simulators that have been developed and used by the Bureau over the past 15 yr.

IC 9111. Availability of Rare-Earth, Yttrium, and Related Thorium Oxides—Market Economy Countries. A Minerals Availability Appraisal, by T. F. Anstett. 1986. 19 pp. 11 figs. The Bureau of Mines estimated the potential availability of rare-earth oxides (REO), including yttrium and thorium, which is also contained in the rare-earth bearing minerals monazite and bastnasite, from 38 properties in market economy countries (MEC's). Only nine of the properties evaluated produce or would produce REO as the primary product; the others contain REO as a byproduct, chiefly from mineral sands operations recovering rutile, ilmenite, and zircon. Nearly 77% (2,578,000 mt) of the total 3,355,000 mt of recoverable REO evaluated is from producing properties. It is estimated that 21% (705,000 mt) of this total is from properties that could not realize a positive rate of return at the January 1984 market prices for the recovered commodities. At production capacities assumed for this evaluation, the amount of REO potentially available from producers ranges from an estimated 46,500 mt in 1986, to a peak of 50,900 mt in 1992, to 49,900 mt by the year 2000. Total MEC production in 1984 was estimated at 40,700 mt. Assuming demand does not increase sharply, producing properties can continue to fulfill overall REO demand through at least the end of this century.

IC 9112. Magnesium Availability—Market Economy Countries. A Minerals Availability Appraisal, by D. R. Wilburn. 1986. 24 pp. 9 figs. The Bureau of Mines investigated the potential availability of magnesium from 45 properties in market economy countries (MEC's). The 38 significant deposits evaluated have demonstrated resources of approximately 29 billion short tons (st) magnesium-bearing material containing 416 million short tons (MMst) magnesium oxide (MgO). Using data it gathered, the Bureau determined the magnesium production potential for each property including a 15-pct rate of return on invested capital. Total and annual availability assessments for the next 30 yr were completed for magnesium (Mg) metal, dead-burned MgO, and caustic calcined MgO. At a January 1984 market price of $1.34/lb Mg metal, the properties evaluated could economically produce an estimated 13 MMst Mg metal. At a market price of $400/st nonmetal magnesium product, these properties could economically produce 109 MMst deadburned MgO and 43 MMst caustic MgO. These properties could produce approximately 301,000 st Mg metal, 3.0 MMst deadburned MgO, and 430,000 st caustic MgO annually at current full production levels and 1984 market prices until at least the year 2000. Total 1984 MEC production assessed in this study was 153,000 st Mg metal and 4.3 MMst nonmetallic MgO products.

IC 9113. Evaluation of Selected Lode Gold Deposits in the Chugach National Forest, Alaska, by Robert B. Hoekzema, Steven A. Fechner, and Joseph M. Kurtak. 1987. 62 pp. 32 figs. This Bureau of Mines report describes the history, characteristics, distribution, and mineral development potential of 21 lode gold deposits in or near the Chugach National Forest (CNF), AK. It includes findings from a 4-yr (1979 to 1982) mineral evaluation of the CNF conducted by the Bureau and the U.S. Geological Survey. This evaluation, undertaken to provide the U.S. Forest Service with mineral resource data for use in making decisions on land use, included site-specific mapping and sampling of more than 200 lode gold deposits. The data presented here were compiled from the findings of this 4-yr evaluation and from existing literature. Fourteen of the 21 lode gold deposits described in this report contain a combined identified resource of 117,750 short tons (st) averaging 0.55 oz/st Au and 0.2 oz/st Ag. Two mineralized felsic dikes in the Summit Lake-Palmer Creek area contain a combined identified resource of 18 million st grading 0.02 oz/st Au and 0.16 oz/st Ag. Identified resources were not determined for the remaining five deposits because of a lack of information.

IC 9114. Dust Controls To Improve Quality of Longwall Intake Air, by John A. Organiscak, Robert A. Jankowski, and Jonathan S. Kelly. 1986. 8 pp. 8 figs. The Bureau of Mines has recently completed a program to identify and evaluate various methods that address control of dust generated outby

the longwall mining face. Dust generated by the stageloader-crusher, the panel belt, and the intake roadway can be long-term throughout the shift, contributing significantly to the dust exposure of all face workers. Dust control techniques were identified and tested at a number of longwall mining sections located in diverse geological conditions across the United States. Dust controls investigated include (1) methods that eliminate the sources of intake dust contamination—homotropal ventilation, (2) methods to limit the amount of respirable dust released into the intake airstream—improved water application and the use of curtains and enclosures, and (3) methods to clean the contaminated air prior to delivery to the mining face—scrubber systems. Usually they can be implemented at a low cost and can be very effective. This report describes each technique and its application and presents the resulting conclusions.

IC 9115. Barite Availability—Market Economy Countries. A Minerals Availability Appraisal, by Joseph S. Coffman and Catherine C. Kilgore. 1986. 25 pp. 16 figs. The Bureau of Mines investigated the availability of barite ($BaSO_4$) from 35 U.S. and 41 non-U.S. mines and deposits in 17 market economy countries (MEC's). This evaluation assesses the availability of mud-grade barite and concentrates consumed by the chemicals and fillers industries. The demonstrated resources defined in this analysis totaled 130 million metric tons (Mmt) of barite (contained $BaSO_4$), yielding a potential 115 Mmt of recoverable barite concentrates. At the 1984 MEC production rate, the evaluated resources would last about 30 yr; however, this would include production costs of up to $100/mt concentrate. An average price needed to cover all costs of production over the life of each operation was determined for both mud-grade and chemical- and filler-grade barite products. Including a 0-pct discounted-cash-flow rate of return, regional weighted-average total production cost ranged from $38/mt for barite concentrates in Asia to $71/mt for U.S. operations. Transportaton costs have the greatest impact, contributing up to 60 pct of the total cost of production. Rail transportation costs from the mines to U.S. markets are generally significantly higher than ocean shipping rates on imports.

IC 9116. Thick-Seam Mining in the Western United States—Geological Considerations, by D. L. Borek. 1986. 18 pp. 7 figs. Thick coal seams are common in the Western United States. Many seams are over 50 ft thick (some are over 200 ft thick) and are too deep to extract using surface methods. Currently, such deposits are developed using standard "eastern" mining methods which only extract a few feet of total seam thickness, often rendering the remaining coal unminable with current technology. Novel methods that increase thick-seam recovery have been developed and are currently being used in Europe. These methods—high-face single-pass and multislice longwall, longwall caving, and hydraulic mining—have great potential for use in the United States. Successful use of these methods is an objective of the Bureau of Mines. Their use requires, among other things, a full evaluation of geologic features common to thick coals. The objective of this report is to present and summarize those features that will affect the introduction of the methods into thick-seam mines in the Western United States. The geologic elements delineated are three-dimensional configuration of the seam, cleat development, joints and fractures, roof and floor lithology, and faulting.

IC 9117. Transformer Fluid Fires in a Ventilated Tunnel, by Margaret R. Egan. 1986. 13 pp. 4 figs. The Bureau of Mines subjected three commercially available brands of transformer fluid to a series of combustion studies. The experiments were conducted in the intermediate-scale fire tunnel, which was designed to simulate environmental conditions in underground mines. The work was divided into three phases. In phase one, the brands were compared for gas production, smoke characteristics, and combustion yields. In phase two, the production constants of transformer fluids and other fuels were compared for the rate of formation of gas and smoke as a function of fire size. In phase three, several diameters of liquid-pool fires were compared in terms of fire size and burning rate. These transformer fluid measurements will be added to the existing coal and wood data that can be used as a basis of comparison for future studies of other mine combustibles. Further research into the combustion product emissions from combustible materials found in underground mines will lead to improved and realistic fire detection and suppression systems.

IC 9118. Face Ventilation for Oil Shale Mining, by Edward D. Thimons, Carl E. Brechtel, Marvin E. Adam, and Joseph F. T. Agapito. 1986. 22 pp. 12 figs. This Bureau of Mines report presents expected levels of air pollutants in the face areas of oil shale mines, based upon data collected by the authors and previous investigators. Ventilation requirements to maintain these pollutant levels below their threshold limit values and Federal and local mine air quality standards are discussed. Two practical face ventilation systems are discussed in terms of actual in-mine test experience.

IC 9119. Evaluation of the TEOM Dust Monitor, by K. L. Williams and R. P. Vinson. 1986. 16 pp. 8 figs. The Bureau of Mines tested a prototype tapered-element oscillating microbalance (TEOM) dust monitor for measuring respirable coal mine dust. The monitor uses the inertial behavior of a vibrating element to measure the mass of sampled dust. Tests were performed to determine variability, drift, the effect of humidity, placement of collection filter, and element orientation during analysis, and comparability with gravimetric measurements of respirable coal dust. Variability was about 1.6 μg. Over about 26 h at 46 pct relative humidity, drift was very slightly negative. When the relative humidity was increased to 78 pct, all units showed a total positive change less than 40 μg over about 70 h. Filter placement variation on the tapered element resulting from inconsistent sizing of the filter mounting bases caused significant error (up to 0.2 mg). In practice, calibration of the system for each new filter will eliminate that error. Orientation of the element during analysis did not introduce significant error, but care is necessary when mounting the canister that houses the element to avoid damping oscillation of the element. Dust tests were performed in an aerosol chamber using coal dust. Measurements made by the TEOM dust monitor agreed to within 10 pct of simultaneous measurements by gravimetric personal samplers.

IC 9120. Fuse Wire Arc Tester, by Peter G. Kovalchik. 1987. 9 pp. 8 figs. To compare the viability of the new fuse wire arc test (FWAT) as a substitute for the comparative tracking index (CTI) for determining surface resistance to electrical tracking, the Bureau of Mines constructed a fuse wire arc tester and undertook a detailed testing program for testing insulating materials used on explosion-proof enclosures. This report describes the Bureau's apparatus, the two methods (CTI and FWAT), and the results of the Bureau's testing, showing comparisons of the FWAT with the CTI. Results showed strong correlation between the two methods, as all specimens tested that had CTI ratings of 400 V ac rms and above passed the 10-test sequence with the FWAT, whereas all specimens with lower CTI ratings failed, with the number of tests to failure corresponding roughly to the descending CTI rating order.

IC 9121. International Regulation of Diesel Engine Use Underground: A Country-By-Country Synopsis, by Robert W. Waytulonis and Debra J. Johnson. 1987. 69 pp. Mining regulations pertaining to the use of diesel engines were solicited by the Bureau of Mines from foreign countries with mining operations. Responses were received from 27 countries, U.S. regulations were reviewed, and those parts pertaining to the use of diesel engines in underground mining were synopsized according to the following subject categories: types of engines permitted, testing and certification procedures, fuel quality

specifications, emission control requirements, procedures and frequency of testing exhaust gases, mine air quality and quantity (ventilation) requirements, procedures for testing mine air quality and quantity, and noise standards. All categories except the types of engines permitted and testing and certification procedures are summarized in tables. Contacts are provided for each country to facilitate inquiries concerning regulation revisions or interpretation.

IC 9122. Flake and High-Crystalline Graphite Availability—Market Economy Countries. A Minerals Availability Appraisal, by Catharine T. Fogg and Edward H. Boyle, Jr. 1987. 40 pp. 19 figs. The Bureau of Mines investigated the availability of flake and high-crystalline natural graphite from 4 domestic and 25 foreign mines and deposits in 11 market economy countries. Demonstrated resources were estimated to be 95 million metric tons (Mmt) containing 5.61 Mmt of recoverable flake and high-crystalline graphite products. Fifty-five percent (3.17 Mmt) of the total recovered product is estimated to comprise plus 100-mesh (150-μm) flake products and "lump" and "chip" high-crystalline products, designated as "graphite A" in this study; 45 pct (2.44 Mmt) of the total is minus 100-mesh (150-μm) flake products and "dust" high-crystalline products, designated as "graphite B." Total production costs, including all costs needed over the life of each operation, were determined at a 0- and 15-pct discounted-cash-flow rate of return (DCFROR) for both graphite A and graphite B products. For a 15-pct DCFROR, 1.74 Mmt (54.9 pct) of the graphite A products is available at $600/mt or less and 2.13 Mmt (67.2 pct) is available for $800/mt or less. For the same DCFROR, 1.08 Mmt (44.3 pct) of the graphite B is available at $200/mt or less, and 1.71 Mmt (70 pct) is available at $325/mt or less. No domestic resources were determined to be economic at present prices. A sensitivity analysis of the relative economics of the Alabama graphite deposits under various operational parameters is presented in an appendix. All evaluations are in January 1984 dollars.

IC 9123. Placer Gold Deposits of the Eagle Trough, Upper Yukon River Region, Alaska, by James C. Barker. 1986. 23 pp. 10 figs. Gold placer deposits along the upper Yukon River, in the region between the river villages of Circle and Eagle, were investigated by the Bureau of Mines. The investigation was conducted intermittently between 1976 and 1985 as part of an evaluation of mineral resources on lands proposed for inclusion in the National Park System. At least 230,000 troy ounces of gold has been produced in the region, principally from Woodchopper, Coal, and Fourth of July Creeks. The placers are underlain by, or occur downstream of, early Tertiary sediments that have been deposited in the Eagle Trough. Strike-slip displacement along the Tintina Fault is responsible for creation of the trough and may have been a factor in the formation of the present placers. Placers were found to have a close spatial correlation to certain altered fault lineaments of the Tintina Fault trench. Placer concentrates contain several different textural forms of gold, suggesting multiple origins. Geological studies and a survey of 162 panned concentrates throughout the region indicated previously unreported sites of placer gold, and potential exists for the discovery of additional placer and lode gold. Because of nearly continuous soil and vegetation cover, further evaluation of the region will require subsurface sampling.

IC 9124. Mined Land Subsidence Impacts on Farmland With Potential Application to Illinois: A Literature Review, by David L. Veith. 1987. 16 pp. 3 figs. This report summarizes a Bureau of Mines review of selected literature on the effects of subsidence due to high-extraction underground coal mining on farmland areas. The data are presented for consideration in evaluating the subsidence effects due to similar mining techniques on the prime farmland areas of Illinois. In Illinois the ground water level in the glacial drift is only 2 to 15 ft below the nearly flat to gently rolling ground surface. The main subsidence concern is flooding, as caused by the lowering of the ground surface, and the subsequent effects on crop production. Positive drainage must be maintained in the farmlands, and the need exists for extensive regional planning by the mining and agricultural industries to maximize short- and long-term production from both efforts. The Bureau is cooperating with the State of Illinois to develop basic information necessary for such planning.

IC 9125. Respirable Dust Levels in Coal, Metal, and Nonmetal Mines, by W. F. Watts, Jr., and D. R. Parker. 1987. 23 pp. 1 fig. In 1980 the Bureau of Mines developed the Mine Inspection Data Analysis System (MIDAS). MIDAS is a computerized, industrial hygiene data base capable of statistically analyzing environmental data collected in coal and noncoal mines and mills by Mine Safety and Health Administration (MSHA) inspectors or mine operators. The objectives of this report are to describe the current contents of MIDAS, to report analyses of coal and noncoal mine respirable dust samples collected by MSHA inspectors, and to evaluate the proposed change in the metal and nonmetal respirable dust standard from a formula based upon the percentage of quartz identified in the sample to 100 $\mu g/m^3$ of respirable quartz. Based on samples collected by MSHA inspectors, changing the noncoal respirable dust standard would result in 4 pct fewer samples with dust concentrations exceeding the standard. Analysis of respirable coal dust data collected by MSHA inspectors showed that mines with longwall plows or shears had the highest geometric mean concentrations (1.64 and 1.29 mg/m^3, respectively). Mine operations using continuous rippers outnumbered longwall mine operations about 10 to 1 and had a geometric mean concentration of 0.66 mg/m^3.

IC 9126. Hose Safety During High-Pressure Water-Jet Cutting, by C. D. Taylor, J. L. Thompson, H. J. Handewith, and E. D. Thimons. 1987. 9 pp. 7 figs. Flexible hoses with rated working pressures up to 40,000 psi are used when high-pressure water jets are employed to cut rock or improve the performance of mining machines. Hose failures at such high pressures can result in serious injuries to workers. The Bureau of Mines used fatigue and burst tests to investigate the failure modes of high-pressure hoses at their rated working and burst pressures. Fatigue failure, at rated working pressures, occurred when the inner liner of the high-pressure hose broke, allowing water to seep through the wire wrapping, although the reinforcement wires did not break. At the burst pressure, all hoses failed catastrophically when the reinforcement wires broke. Low-pressure hoses placed over the high-pressure hoses for safety failed to contain water released by catastrophic failure.

IC 9127. Human Factors Contributing to Groundfall Accidents in Underground Coal Mines: Workers' Views, by Robert H. Peters and William J. Wiehagen. 1987. 24 pp. 1 fig. This report presents findings from a Bureau of Mines study on barriers that may prevent miners from correcting and avoiding groundfall hazards. Such barriers stem from four basic types of problems: (1) inability to recognize groundfall hazards, (2) inability to correct groundfall hazards, (3) lack of motivation to search for groundfall hazards, and (4) lack of motivation to correct groundfall hazards. Data are presented that summarize the views of miners, section supervisors, and mine inspectors about the contribution of these barriers to groundfall accidents and what they think should be done to reduce the frequency of injuries sustained by falls of roof and rib. The report also includes a summary of miners' responses concerning their recent experiences with groundfall accidents, along with industrywide statistics on accidents and injuries caused by groundfalls in underground coal mines.

IC 9128. Iron Ore Availability—Market Economy Countries. A Minerals Availability Appraisal, by Judith L. Bolis and James A. Bekkala. 1987. 56 pp. 34 figs. The Bureau of Mines estimated the potential availability of iron ore from 129 domestic and foreign mines and deposits in 25 market economy

countries. The availability of four products on a total and regional basis was determined from demonstrated resources of 75.3 billion lt. From the resources evaluated there are a total of 18.6 billion lt of sinter fines, 4.9 billion lt of lump ore, 14.7 billion lt of pellets, and 820 million long tons (MMlt) of pellet feed potentially available at a 15-pct discounted-cash-flow rate of return (DCFROR), f.o.b. port. On a regional basis, at or below a total cost of $0.26 per iron unit there are 1.7 billion lt, 2.8 billion lt, and 186 MMlt of sinter fines potentially available from Brazil, Australia, and Africa, respectively. There are 825 MMlt of lump ore from Brazil and 1.4 billion lt from Australia potentially available at or below a total cost of $0.24 per iron unit. There are 2.1 billion lt of pellets potentially available from the United States at or below a total cost of $0.80 per iron unit, while 442 MMlt are potentially available in Brazil at or below $0.38 per iron unit. South America has 208 MMlt of pellet feed potentially available at or below a total cost of $0.28 per iron unit. While the resources of iron ore are more than adequate to satisfy demand, the future of the iron ore industry is very dependent upon changes in the world economy, and on the domestic scene, changes in the domestic steel industry and steel imports.

IC 9129. Analyses of Natural Gases, 1917–85, by B. J. Moore and Stella Sigler. 1987. 1197 pp. 1 fig. This publication contains 14,242 analyses of gas samples from oil and gas wells and natural gas pipelines in 40 States and 24 foreign countries. These gas samples were collected during the period 1917–85 as part of the Bureau of Mines survey for helium occurrences. The gas analyses contained herein were made by several methods over the period covered. Analytical work on samples collected early in the period was done on the Orsat apparatus. The one-cut apparatus and four-cut fractional distillation equipment were added later. A mass spectrometer was acquired in 1949 and used for all gas analyses made after that time. From 1917 to 1978, helium analyses were made on special helium analytical equipment designed and built by the Bureau of Mines Helium Operations Laboratory. In 1978, this apparatus was replaced in the quantitative helium analysis work by a gas chromatograph. GPO Stock No. 024–004–02172–1. $35.

IC 9130. Helium Resources of the United States, 1985, by Richard D. Miller. 1987. 17 pp. 4 figs. The helium resources base of the United States was estimated by the Bureau of Mines to be 1,070 Bcf as of January 1, 1985. These resources are divided into four categories in decreasing degree of assurance of their existence: (1) helium in storage and in proved natural gas reserves, 280 Bcf, (2) helium in probable natural gas resources, estimated at 243 Bcf, (3) helium in possible natural gas resources, estimated to be 287 Bcf, and (4) helium in speculative natural gas resources, which makes up the remaining 260 Bcf. These helium resources are further divided into depleting, nondepleting, and stored classifications. The depleting resources are those associated with natural gas fields that are, or will be, produced for the natural gas they contain. Almost all of the helium in potential (probable, possible, and speculative) natural gas resources is included in this classification. These depleting resources are estimated to contain 900 Bcf of the total helium resource base. Helium resources contained in nondepleting natural gas resources, those in shut-in, abandoned, or otherwise nonproducing natural gas fields, are estimated to total 133 Bcf. There is 37 Bcf of helium in storage in the Federal Government-owned Cliffside Gas Field near Amarillo, TX.

IC 9131. Foreign Direct Investment in the U.S. Minerals Industry, by Louis J. Sousa, Elizabeth H. Yaremchuk, and Annette P. Graham. 1987. 24 pp. This Bureau of Mines report examines aggregate trends in foreign direct investment in the U.S. mining and mineral processing industries between 1977 and 1984, and provides an analysis of foreign investment in several major mineral commodity industries. In 1984, 11.1 pct of total employment in the U.S. minerals industry was at firms that were U.S. affiliates of foreign firms. In 1985, the proportion of U.S. capacity held by foreign investors in nine major mineral commodity industries was as follows: steel, 5 pct; silver, 16 pct; lead, 18 pct; aluminum, 25 pct; zinc, 26 pct; copper, 30 pct; cement, 32 pct; gold, 44 pct; and ferroalloys, 56 pct. Almost 90 pct of the total foreign investment in the U.S. minerals industry was accounted for by eight countries—Canada, the United Kingdom, France, Federal Republic of Germany, Switzerland, Japan, Australia, and the Republic of South Africa. The most fundamental reason behind the growth in foreign investment in the U.S. minerals industry has been that an increasing proportion of U.S. mineral firms and assets have been for sale, while foreign mineral companies have been the ones most willing and able to purchase these firms and/or their assets. While the growth in foreign ownership in the minerals industry has not been without controversy, it has helped save jobs, reduce the minerals trade deficit, and—from the national defense perspective—maintain the Nation's overall mineral and metal self-sufficiency at reasonably high levels. In the absence of domestic buyers, foreign investors have helped to maintain a viable domestic minerals industry.

IC 9132. A Statistical Analysis of Metal and Nonmetal Mine Fire Incidents in the United States From 1950 to 1984, by Shail J. Butani and William H. Pomroy. 1987. 41 pp. 8 figs. This Bureau of Mines publication presents a statistical analysis of official U.S. Mine Safety and Health Administration metal and nonmetal mine fire reports from 1950 through 1984, plus accounts of selected nonreportable fires (less than 30 min and no injury) and opinion data on fire hazards from mine safety directors. Fires were analyzed by time trends, ore type, ignition source, burning substance, location in mine, equipment involved, means of detection, duration, number of injuries and fatalities, mining method, and successful extinguishing agent. The leading ignition sources were electricity in underground fires and engine heat in reported surface fires. The most frequent burning substance was combustible liquids for all nonreportable fires, reported surface fires, and reported underground fires from 1978 to 1984. For underground fires reported prior to 1978, timber was the leading burning substance. Mobile equipment was the type most frequently involved in both underground and surface fires. Underground fires occurred most often in haulageway or drift areas, and reported surface fires occurred most often in plant and mill buildings, while most nonreportable surface fires occurred in other areas. The most common method of extinguishment were water hose lines for reported fires and dry chemical hand-portable extinguishers for nonreportable fires.

IC 9133. Estimation of Remaining Lode Gold Endowment in Selected Mining Districts of Alaska, by Gary Sherman. 1987. 22 pp. 10 figs. The Bureau of Mines estimated the remaining lode gold endowment of eight mining districts in Alaska using historic production data. A logarithmic model of cumulative tonnage of ore processed versus cumulative grade was applied to the following districts: Chichagof, Fairbanks, Homer, Hope-Seward, Juneau, Ketchikan, Prince William Sound, and Willow Creek. To assess the remaining endowment, a computerized production data base was compiled from Bureau records. These data were aggregated in 5-yr intervals for each district. Data were sorted in order of declining grade, and log cumulative grade was plotted against log cumulative tonnage. Linear regression was performed on the data for each district. The linear equation for each curve was used to predict remaining endowment at a limiting mining grade. Based on conservative extrapolation of the grade-tonnage curves, a substantial total endowment of 8,415,100 tr oz of gold remains in the eight districts. The districts with the greatest remaining endowment are the Juneau, Chichagof, Fairbanks, and Willow Creek Districts.

IC 9134. Mining Applications of Life Support Technology. Proceedings: Bureau of Mines Technology Transfer

Seminar, Pittsburgh, PA, November 20, 1986, compiled by Staff, Mining Research. 1987. 57 pp. 46 figs. The Bureau of Mines has conducted considerable research to improve life support technology for underground mining applications. This proceedings volume presents several new developments that may help increase the chances of mine workers in surviving underground disasters. Several papers address the performance of present self-contained self-rescuers (SCSR's) and provide proposed guidelines for the design and testing of a second-generation SCSR. Improvements in the safety and effectiveness of mine rescue and recovery operations are described, including the design of a low-profile breathing apparatus and a rescue team helmet.

IC 9135. Surface Mine Blasting. Proceedings: Bureau of Mines Technology Transfer Seminar, Chicago, IL, April 15, 1987, compiled by Staff, Bureau of Mines. 1987. 114 pp. 88 figs. The Bureau of Mines has sponsored a comprehensive research program to enhance the safe, effective, and efficient use of blasting technology by the mining industry. Recent research results of the surface mine blasting program were presented at a seminar on April 15, 1987, in Chicago, IL. Many of the topics discussed at the seminar are presented in this proceedings. The new research described in these papers includes computer monitoring of rock motion, the influence of blast delay times on rock fragmentation, blasting effects on Appalachian water wells, blast vibration measurement near structures, and the reduction of accidents through improved blasting safety.

IC 9136. Survey of Nuisance and Biologically Active Dusts in Metal and Nonmetal Mines, by P. J. Watson, D. Tallman, and J. E. Pahlman. 1987. 20 pp. 3 figs. The objective of this study was to prioritize the potential risks nuisance and biologically active dusts and fumes present in metal and nonmetal mines. This was accomplished by ranking numerical values derived from a matrix formula calculation that took into account dose, mine population, and sampling size. Data used in these calculations were obtained from the Mine Inspection Data Analysis System (MIDAS). The dusts determined to have the highest risk potential were quartz respirable particulates, mine dust, cristobalite respirable particulates, welding fume components, and nuisance respirable dust. Other dusts and fumes that were not ranked in this study, owing to small sampling population, but which show a potential risk, include asbestos, talc, hydrogen cyanide, organic compound dusts, arsenic, metal dusts, and metal and nonmetal fumes.

IC 9137. Eastern Coal Mine Geomechanics. Proceedings: Bureau of Mines Technology Transfer Seminar, Pittsburgh, PA, November 19, 1986, compiled by Staff, Bureau of Mines. 1987. 89 pp. 79 figs. The Bureau of Mines is establishing design criteria for effective roof support systems and is developing technology to improve mine planning and design. Geologic studies, surface and underground mine monitoring, and laboratory evaluations were conducted. The seven papers in this proceedings Information Circular present results of several investigations. Addressed are problems existing in both longwall and multiple-seam mines. Discussions include the effect of dewatering at a longwall mine site in the Pittsburgh coal seam and the effect of chain pillars on subsidence. Other results are measurement and characterization of longwall rock mass movement and an integrated design for stability in multiple-seam mining.

IC 9138. MgO Filtration Research, by D. N. Tallman and J. E. Pahlman. 1987. 32 pp. 9 figs. The Bureau of Mines has completed 4 yr of deep-bed filtration research comparing the efficiencies of granular magnesium oxide (MgO) and conventional filter sand in single- and dual-medium filters when filtering mineral-processing and mine waters. Bench and field evaluation tests were conducted using water types ranging from synthetic suspensions of asbestos, kaolin, metal hydroxides, and milled sand to process waters from magnetite beneficiation, iron ore flotation, granite cutting, and a steel mill. Even though the turbidity reductions were similar, MgO filters were found to be advantageous when filtering water pretreated with alum because the volume throughput before breakthrough (turbidity >1 nephelometric turbidity unit) was much more for the MgO filter than for the sand filter. Reduced head loss owing to the greater porosity of the MgO filter beds is potentially the most beneficial advantage in employing MgO as the filter medium, especially when filtering water pretreated with polymer flocculants. Granular MgO (periclase) is durable and can be backwashed like sand. It is compatible with anthracite in a dual-medium filter and apparently is not poisoned by dissolved metals in the process water. No single solid-removal mechanism could be identified for the improved filtration observed with granular MgO.

IC 9139. An Analysis of Off-Highway Haulage Truck Maintenance and Repair Accidents, 1978–84, by Dennis A. Long. 1987. 15 pp. 6 figs. The size of off-highway trucks has increased substantially over the last decade, bringing about a radical change in truck maintenance practices and procedures. As a result, surface mine maintenance mechanics today are faced with the increased hazards of working with larger and heavier tools and components and doing repairs at greater heights, thereby exposing them to a higher potential for serious injury or death. Not surprisingly, the number of accidents involving truck maintenance mechanics is significantly increasing. The Bureau of Mines has assessed the haulage truck maintenance safety problem, analyzing maintenance-accident data over the period 1978–84 in terms of personnel, job activities, truck components and systems, tools involved, and truck design. This assessment, based on the review and interpretation of 1,225 haulage truck maintenance accident reports, identified major factors contributing to these accidents. Overall, young inexperienced workers are involved in most accidents. A typical maintenance accident involves a male mechanic under 33 yr old, with less than 5 yr job experience.

IC 9140. Natural and Synthetic Zeolites, by Robert A. Clifton. 1987. 21 pp. 19 figs. This Bureau of Mines report discusses the mineralogy of zeolites, the properties that make them commercially valuable, the conditions of formation of both natural and synthetic zeolites, and present and potential markets.

IC 9141. Diesels in Underground Mines. Proceedings: Bureau of Mines Technology Transfer Seminar, Louisville, KY, April 21, 1987, and Denver, CO, April 23, 1987, compiled by Staff, Bureau of Mines. 1987. 165 pp. 97 figs. The goal of the Bureau of Mines diesel engine research program is to reduce exhaust emissions and minimize the risk of fires and explosions caused by the use of diesel-powered equipment in underground mines. This program has led to a fundamental understanding of the problems and to solutions that allow diesel equipment to be used safely and effectively. This volume contains reports of the presentations made at the Bureau Technology Transfer Seminar on Diesels in Underground Mines given in Louisville, KY, and Denver, CO, on April 21 and April 23, 1987. It also contains three reports of related research, not presented at the seminar, which highlight the significant achievements of a joint U.S.-Canadian research program on diesel emission control technology for underground mines. Topics covered in this volume include discussions of industrial hygiene problems associated with the use of diesels, accident statistics, fire and explosion control systems, measurement of diesel pollutants, emission control techniques including engine maintenance, fuel additives, diesel particulate filters, and ventilation of diesel sections. An alternative to diesel power, the hydrogen-powered mine vehicle, is also described.

IC 9142. Bureau of Mines Cost Estimating System Handbook (In Two Parts). 1. Surface and Underground Mining, compiled by Staff, Bureau of Mines. 1987. 631 pp. 208 figs. This Bureau of Mines report was prepared to assist in the preparation of prefeasibility-type estimates for capital and operating costs of mining of various types of mineral occurrences using current technology. The handbook provides a convenient costing procedure based on the

summation of the costs for the unit processes required in any particular mining or mineral processing operation. The costing handbook consists of a series of costing sections, each corresponding to a specific mining unit process. Contained within each section is the methodology to estimate either the capital or operating cost for that unit process. The unit process sections may be used to generate, in January 1984 dollars, costs through the use of either costing curves or formulae representing the prevailing technology. Coverage for surface mining includes dredging, quarrying, strip mining, and open pit mining. The underground mining includes individual development sections for drifting, raising, shaft sinking, stope development, various mining methods, underground mine haulage, general plant, and underground mine administrative cost. This system can be used for estimating cost data for an undeveloped deposit or for checking or verifying mining costs from a developed deposit, with a minimum amount of background information. GPO Stock No. 024-004-02195-1. $30.

IC 9143. Bureau of Mines Cost Estimating System Handbook (In Two Parts). 2. Mineral Processing, compiled by Staff, Bureau of Mines. 1987. 566 pp. 201 figs. This Bureau of Mines report was prepared to assist in the preparation of prefeasibility-type estimates for capital and operating costs of beneficiation of various types of mineral occurrences using current technology. The handbook provides a convenient costing procedure based on the summation of the costs for the unit processes required in any particular mining or mineral processing operation. The costing handbook consists of a series of costing sections, each corresponding to a specific mineral processing unit process. Contained within each section is the methodology to estimate either the capital or operating cost for that unit process. The unit process sections may be used to generate, in January 1984 dollars, costs through the use of either costing curves or formulae representing the prevailing technology. The mineral processing handbook includes individual cost estimation sections for unit operations associated with comminution, beneficiation, solid-liquid separation, hydrometallurgy, and special applications as well as infrastructure and plant general and administrative costs. When using this system for estimating cost data for a mineral processing facility or for checking or verifying processing costs from an existing facility, a minimum amount of background information is necessary. GPO Stock No. 024-004-02196-9. $27.

IC 9144. Spontaneous Combustion Fire Detection for Deep Metal Mines, by William H. Pomroy. 1987. 25 pp. 19 figs. Spontaneous combustion fires involving high-sulfide-content ores are a relatively infrequent yet serious safety hazard in mining. They are also the cause of lengthy mine shutdowns because they typically occur in areas of a mine where abundant fuel material is present but which are inaccessible for fire fighting. This Bureau of Mines report describes research to design, fabricate, and test in the laboratory and field a system that warns of spontaneous combustion fires in metal mines. Overall performance of the detection system was found to be satisfactory in that the system was capable of reliably detecting low levels of combustion products believed to indicate the preflaming stage of spontaneous combustion in metal mines. Installation of similar systems in mines with a high risk of spontaneous combustion is recommended. Principal operating problems and recommended corrective actions are also discussed.

IC 9145. Human Engineering and Human Resources Management in Mining. Proceedings: Bureau of Mines Technology Transfer Seminar, Pittsburgh, PA, July 7–8, 1987; St. Louis, MO, July 15–16, 1987; and San Francisco, CA, July 21–22, 1987, compiled by Staff, Bureau of Mines. 1987. 170 pp. 54 figs. The Bureau of Mines human factors research program is directed toward reducing accidents and improving the overall efficiency of the person-machine environment interface found in surface and underground mines. The focus of the human factors program is to insure that sound knowledge is available concerning human capabilities and limitations, and that this knowledge is applied to the design of mining equipment, work tasks, and management procedures. The papers presented in these proceedings summarize some of the recent Bureau research in human factors. The papers focus on two broad areas: human resource issues and human engineering of equipment, tools, and work procedures found in mines.

IC 9146. Surface Testing and Evaluation of the Monorail Bridge Conveyor System, by Robert J. Evans, William D. Mayercheck, and Joseph L. Saliunas. 1987. 35 pp. 36 figs. The monorail bridge conveyor (MBC) is a prototype continuous face haulage system that was surface tested and evaluated by the Bureau of Mines. The MBC consists of a series of cascading belt bridge conveyors suspended from roof-supported monorail track. Tests were conducted to determine MBC haulage capability, maneuverability, power consumption, and reliability using rigid and chain-suspended monorail track installations. Subsequent modifications to improve operation and reliability made during surface testing are described. Mining plans were devised to show potential MBC installations for room-and-pillar, longwall development, and shortwall mining sections. Compatibility tests were conducted with the Bureau's prototype hopper-feeder to provide additional surge capacity and lump-breaking capability. Results from the surface test program, along with modifications to improve system operation and reliability, indicate that the MBC has the potential to perform successfully in an in-mine trial.

IC 9147. Economic Evaluation Methodology, by Frank A. Peters. 1987. 21 pp. 7 figs. This description of process evaluation techniques used by the Bureau of Mines for studying proposed processing techniques has been prepared to provide those interested in using these studies with an understanding of the methodology. The methods used for preparing both capital and operating cost estimates are described. Each step in preparing the evaluations is described. Types of equipment costs are shown, and factors used in the estimates are defined. Uses of the estimates are suggested, and several examples are included. The accuracy of various types of estimates is discussed, along with an explanation of the reason for selecting the type used in the Bureau's process evaluation studies.

IC 9148. Reducing Dust Exposure of Workers During Bag Stacking in Enclosed Vehicles, by Andrew B. Cecala, Anthony Covelli, and Edward D. Thimons. 1987. 13 pp. 6 figs. The Bureau of Mines has evaluated a number of ventilation systems for potential application in lowering the dust exposure of workers who stack bags of mineral product material in enclosed vehicles. Workers who stack these bags in enclosed vehicles usually have the highest dust exposure among all workers in processing plants. This is because dust liberated while the vehicle is being loaded has no means of exiting the vehicle or being diluted with fresh air so that dust concentrations increase to substantial levels. Laboratory-scale testing was performed in a railcar to compare the effectiveness of a number of different ventilation systems in reducing the bag stacker's dust exposure. The most effective system was taken into the field to optimize its performance. The final and recommended system exhausted about 2,000 cfm through 10-ft-long, 12-in-diam fiberglass tubing located 3.5 ft past the slinger at a 6.5-ft height so as to not interfere with the bag stacker's job. A 6-in-diam tube exhausted approximately 300 cfm at the snake conveyor-slinger transfer point to capture the dust generated there. With this system, dust reductions in and around the bag stacker ranged between 65 and 95 pct when loading both 50- and 100-lb bags of product into railcars and trailer trucks.

IC 9149. Coal Mine Bumps: Five Case Studies in the Eastern United States, by Alan A. Campoli, Carla A. Kertis, and Claude A. Goode. 1987. 34 pp. 42 figs. This Bureau of Mines study was conducted to obtain a better understanding of the coal mine bump problem and its effect on underground coal mining in the Eastern United States. To accomplish this, information was collected on the geologic conditions, mining techniques, and engineering parameters at five bump-prone mines. Two geologic conditions have been found to cause the occurrence of bumps in the Eastern United States: (1) relatively thick overburden and (2) extremely rigid strata occurring immediately above and below the mine coalbed. Additionally, the probability of bump occurrence is increased by certain mining practices that concentrate stresses during retreat mining in areas where geologic conditions are conducive to bumps. Mining plans that permit the development of pillar line points or long roof spans that project over gob areas should be

avoided because these features may contribute to the occurrence of bumps.

IC 9150. The Impact of Advanced Materials on Conventional Nonfuel Mineral Markets: Selected Forecasts for 1990–2000, by Ronald F. Balazik and Barry W. Klein. 1987. 18 pp. The introduction of "high-tech" materials such as new polymer composites presents significant competitive challenges and opportunities in conventional mineral markets. Moreover, rapid advances in materials science are critical to the resolution of important economic and strategic issues, including national competitiveness and import dependence. This Bureau of Mines study examines the displacement of conventional nonfuel mineral materials by certain new materials, specifically advanced plastics and ceramics. Analyses of substitution by plastics are conducted for five major U.S. industrial sectors: motor vehicle manufacturing, aerospace applications, building and construction, packaging, and heavy machinery production. Based on interviews with more than 60 scientists, executives, and other professionals engaged in materials development and sales, forecasts of substitution by plastics during the 1990's are made for aluminum, steel, and glass. In addition to these forecasts, study findings identify key factors that will influence the emergence of advanced materials in the next decade. GPO Stock No. 024–004–02186–1. $1.50.

IC 9151. Roof and Rib Fall Accident and Cost Statistics: An In-Depth Study, by Deno M. Pappas. 1987. 20 pp. 15 figs. The purpose of this Bureau of Mines study of U.S. roof and rib (roof-rib) accident statistics and related accident costs is to define current accident trends (1980–84) associated with fatal and nonfatal roof-rib fall accidents. Data were retrieved from a data base containing all recorded U.S. mining accidents, then sorted and normalized utilizing a computer software program. The statistics indicate that roof-rib accidents have significantly declined in the 5-yr study period. Moreover, they indicate that there have been increases and/or patterns of roof-rib accidents associated with specific mine characteristics such as seam height, mine size, geographic location, and seasonal variation. Also, roof-rib injury characteristics produced pattern changes involving worker activity, lost workdays, types of injury, and severity of injury. A conservative estimate indicates that there has been a 30% adjusted increase in the cost of a roof-rib accident over the 5-yr study period.

IC 9152. Remote Sensing of Mine Waste, by C. M. K. Boldt and B. J. Scheibner. 1987. 43 pp. 26 figs. This report summarizes five separate Bureau of Mines contract studies on the use of aerial photogrammetry, satellite transmission of in situ instrumentation information, and satellite imagery to monitor and update mine waste embankment data. The equipment used, methods applied, results, recommendations, and cost analyses are presented along with a bibliography of related investigations.

IC 9153. Assessment and Determination of Illumination Needs for Operators of Mobile Surface Mining Equipment, by Alan G. Mayton. 1987. 37 pp. 21 figs. The Bureau of Mines conducted one of the most extensive studies on surface mine illumination to date to assess the illumination needs of mobile surface mining machinery with respect to the visual tasks required of machinery operators. Field investigations were performed at 22 surface mining operations (coal and metal-nonmetal) within several mining regions of the United States. Visibility and illumination were measured for 159 visual tasks performed by equipment operators on or near 57 surface mining machines, including draglines, shovels, blasthole drills, bulldozers, loaders, haul trucks, graders, scrapers, and several service-type vehicles. The report shows that illumination and/or visibility could be improved for various visual tasks and makes recommendations for these improvements. Moreover, the report describes the various equipment studied, gives details of the instruments and measuring techniques used, and presents equations to calculate the luminance and illuminance levels suggested for performing mining tasks. Tables are presented that compare values of illumination computed for workers in the 25- and 50-yr age groups. Appendixes to the report include a glossary of terms, abbreviations, symbols, and calibration and analysis procedures.

IC 9154. Computer Modeling of the Effect of Mine-Fire-Induced Ventilation Disturbances on Stench Fire Warning System Performance, by Linneas Laage, William Pomroy, and Thomas Weber. 1987. 12 pp. 1 fig. Underground mine fires can significantly influence mine ventilation airstreams, in some cases throttling or even reversing airflows. As a result, the performance of a metal and nonmetal mine stench fire warning system, which depends on the ventilation to carry the vital warning signal, under fire conditions is different from performance under nonfire conditions. The safety of underground miners can be jeopardized if the warning signal is delayed. This Bureau of Mines report describes research to investigate fire and stench warning system interactions. A computer model is presented that permits quantitative analysis of stench warning signal delays as a function of fire location and intensity. The results of a case study involving computer simulations of stench distribution in a hypothetical mine network subject to various fire exposures are also discussed. This case study illustrates a technique for identifying the areas within a mine that are subject to unacceptable warning signal delays, thereby enabling preemptive action by mine personnel, such as redeployment of stench injectors.

IC 9155. A Review of the Mechanisms of Gas Outbursts in Coal, by David M. Hyman. 1987. 11 pp. 3 figs. Outbursts are sudden and violent releases of gas and coal that result from a complex function of geology, stress regime, and gas pressure and content. The Bureau of Mines has reviewed methods for prediction and mitigation of such outbursts in use worldwide as an aid in selecting the proper techniques for use in specific mine environments. Outburst-prone coal may be distinguished from normal coal by its sorption-desorption velocity. Three types of methods used to characterize the kinetics of sorption-desorption are described; all are based on the ability of outburst-prone coal to release, through desorption, methane or carbon dioxide much more rapidly than normal coals. Other prediction methods, based on borehole samples, are also described. Various mitigation methods described and evaluated include (1) working the least stressed, less disturbed, lowest gas content seam in multiple-seam areas; (2) mine opening geometry; (3) inducer shot firing; (4) water infusion; (5) localized stress relief using boreholes or by cutting a reliever slot in the longwall face; and (6) other gas drainage methods.

IC 9156. Domestic Secondary Lead Industry: Production and Regulatory Compliance Costs, by R. Craig Smith and Michael R. Daley. 1987. 18 pp. 16 figs. The Bureau of Mines conducted a study of production costs for the secondary lead industry and determined costs for present, pending, and proposed environmental legislation. Operating costs for smelters by capacity groups range from 16.8¢/lb to 19.6¢/lb of refined lead. Present regulatory compliance costs for these groups range from 2.2¢ to 2.4¢/lb. Pending compliance costs can add 3.5¢/lb of refined lead, and proposed regulations could add another 1.3¢/lb. The individual capital costs necessary to comply with pending environmental regulations are estimated to be $1.8 million for small smelters and $10.4 million for large smelters. Proposed regulations could require additional expenditures from $1.9 million for small smelters to $4.9 million for large smelters. These cost estimates, based on average 1985 dollars, indicate that pending and proposed legislation will add significantly to capital and operating costs of the secondary lead industry. These regulatory compliance costs may result in a loss of up to 40 pct of secondary lead production capacity. GPO Stock No. 024–004–02180–2. $1.50.

IC 9157. Suggested Minimum Performance Specifications for Underground Coal Mine Environmental Monitoring Systems, by J. H. Welsh, A. E. Cohen, and J. E. Chilton. 1987. 39 pp. 2 figs. This Bureau of Mines report presents guidelines to be considered in the design, installation, and operation of environmental mine monitoring systems in underground coal mines so as to enhance safety in the U.S. mining industry. A review of the current status of mine monitoring in the United States is also provided.

IC 9158. International Mining Cost Indexation System. Indexes for 96 Countries, by D. E. Sullivan, P. R. Thomas, and E. H. Yaremchuk. 1987. 52 pp. The Minerals Availability Program of the Bureau of Mines conducts cost evaluations of current and potential mineral operations in the United States and foreign countries. The International Mining Cost Indexation System (IMCI) allows

data of different time periods within a country to be updated to a common base year for analytical purposes. The IMCI comprises 12 factor cost indexes and an exchange rate series for 96 market economy countries, denominated in both local and U.S. currency. The IMCI for each country contains 12 time series indexes that measure the average annual rate of change in the cost of factor inputs to the mining industry within that country. Mining industry factor cost indexes include wages, plant and equipment, construction and mining materials, power and transportation, and other measures considered to comprise the majority of capital and operating costs. Cost data or proxies are collected in local currency. Index series within each country are constructed separately and indexed on a 1975 base year. The local currency index is converted to a U.S.-dollar-based currency index using an exchange ratio. GPO Stock No. 024-004-02181-1. $1.25.

IC 9159. Corrosion of Friction Rock Stabilizer Steels in Underground Coal Mine Waters, by A. F. Jolly III and L. A. Neumeier. 1987. 14 pp. 2 figs. In an effort to better predict the useful service life of friction rock stabilizer mine roof bolts in coal mine environments, the Bureau of Mines has evaluated the corrosion resistance of stabilizer steels in air-saturated and deaerated waters from seven Eastern and Midwestern underground coal mines. Accelerated electrochemical corrosion tests were used to estimate corrosion rates for the two high-strength, low-alloy (HSLA) steels used to fabricate Split Set stabilizers and for galvanized steel. Long-term static-immersion weight-loss tests were also conducted with the HSLA steels. Corrosion rates developed from the weight-loss tests (steady-state air dissolution) were roughly comparable to rates determined from electrochemical testing in aerated waters. Although the highest rates occurred in waters with the highest chloride contents, rates in the other waters were low ($\leq$2.0 mpy) and exhibited little correlation to the widely varied chloride contents of the waters. The generally low corrosion rates are attributed in part to the tendency to deposit a protective $CaCO_3$ film, reflecting susceptibility to carbonate precipitation as indicated by positive Langelier (saturation) index values for the waters. With one exception, corrosion rates for the galvanized steel were $\leq$2.0 mpy. Rates with aerated waters were higher than those with deaerated waters. Pitting tendencies of the steels were also estimated.

IC 9160. Lead Reduction in Ambient Air: Technical Feasibility and Cost Analysis at Domestic Primary Lead Smelters and Refineries, by Richard D. Smith, Orville A. Kiehn, David R. Wilburn, and Robert C. Bowyer. 1987. 50 pp. 5 figs. The Bureau of Mines evaluated the emission control methods, including the capital investments and operating cost, necessary for further reducing lead levels in ambient air at the Glover, Herculaneum, and Buick smelter-refineries in Missouri and the East Helena, MT, smelter. The U.S. Environmental Protection Agency has proposed more stringent lead in ambient air standards than those currently in effect. This report presents theoretically achievable lead emission reductions and estimated capital and operating costs. Lead emission inventories theoretically can be reduced from 1985 levels by 2,421 lb/d at the three Missouri operations by containing and filtering fugitive emissions within structural enclosures and baghouses. The aggregated capital and operating costs in 1986 dollars using conventional environmental and workplace technologies are estimated to be $250,014,100 and $18,507,800, respectively. Estimated total incremental cost is $0.063/lb as refined lead. Additional regulatory costs attributable to Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, workplace standards are included since proposed environmental controls may otherwise degrade workplace conditions. Continuous drossing is evaluated as an alternative to conventional OSHA controls. Substituting continuous drossing for conventional workplace technology results in an estimated aggregated capital and operating costs of $258,344,800 and $15,719,600, respectively. Estimated total incremental cost is $0.062/lb as refined lead. For comparison, the average open market price of refined lead during the first quarter of 1986 was $0.184/lb.

IC 9161. Causes of Coal Miner Absenteeism, by Robert H. Peters and Robert F. Randolph. 1987. 45 pp. 1 fig. This report describes several significant problems associated with absenteeism among underground coal miners. The vast empirical literature on employee absenteeism is reviewed, and a conceptual model of the factors that cause absenteeism among miners is presented. Portions of this model were empirically tested by performing correlational and multiple regression analyses on data collected from a group of 64 underground coal miners. The results of these tests are presented and discussed.

IC 9162. Performance Evaluation of Two Light-Scattering Dust Monitors, by R. P. Vinson and K. L. Williams. 1987. 13 pp. 7 figs. The Bureau of Mines evaluated two real-time light-scattering dust monitors by measuring their response to Pittsburgh Seam coal dust and Arizona road dust (ARD). Both monitors—the PDS–1, a personal dust sensor, and the PCD–1, a digital dust indicator—are made in Japan by Sibata Scientific Ltd. Tests were conducted inside a laboratory aerosol chamber designed to maintain a uniform spatial distribution of the test dust. PDS–1 and PCD–1 measurements of concentrations for each test dust were averaged over 4–h test periods and compared with simultaneous gravimetric measurements. Both dust monitors responded linearly with mass concentration with both coal dust and ARD. However, the linear response of the PDS–1 differed from that of the PCD–1 for both dusts.

IC 9163. True Flammable Gas Detecting System, by J. E. Chilton and T. Kubala. 1987. 11 pp. 15 figs. The Bureau of Mines has developed a portable flammable gas detecting system for estimating the flammable gas concentrations in a mine containing one or more combustible gases at concentrations up to 100 vol pct. With this portable detecting system, mine rescue or recovery personnel can quickly determine if they are working in a potentially explosive gas atmosphere and either leave the area or make appropriate changes in the fresh air ventilation of the mine to render the area safe. The detecting system uses a commercial, intrinsically safe, flammable gas detector with a range from 0 to 5 vol pct methane (CH_4). The flammable gas detector has a catalytic heat-of-combustion sensor that can detect all flammable gases that would be encountered in a mine including methane (CH_4), ethane (C_2H_6), carbon monoxide (CO), and hydrogen (H_2). To determine the mine gas concentration, the rescue worker dilutes a sample with fresh air carried within the detecting system. The concentration of the diluted sample is then measured with the permissible flammable gas detector. The actual mine gas concentration is calculated from the product of the indicated diluted gas concentration and the system dilution ratio using a pocket calculator or the nomograph on the side of the unit.

IC 9164 Water-Jet-Assisted Drag Bit Cutting in Medium-Strength Rock, by J. E. Geier, M. Hood, and E. D. Thimons. 1987. 10 pp. 6 figs. This Bureau of Mines report reviews hypotheses for the mechanism by which water jets reduce the specific energy of cutting for drag bits. Several of these hypotheses are shown to be inconsistent with published evidence and new observations. The notion of a limiting cutting speed, above which water jets would be incapable of rendering assistance, is shown to be improbable. The hypothesis that seems most plausible is that specific energy reductions are mainly due to the erosion of crushed materials from in front of the bit. This hypothesis leads to a prediction that, for a given rock type and jet-bit configuration at a constant depth of cut, the reduction in bit forces should be a function of dW/dx, the jet energy spent per unit length of cut. This dependence upon dW/dx is shown to be consistent with other workers' results.

IC 9165. Fire Doors for Noncoal Mines, by Kenneth L. Bickel and William H. Pomroy. 1988. 22 pp. 15 figs. During an underground mine fire, the importance of controlling the spread of smoke and toxic gases with suitable ventilation structures has been proven. However, under certain conditions, control of the propagation of the fire itself may be even more critical in insuring a safe mine evacuation. Fire doors offer the means for accomplishing both objectives. In 1978, the Bureau of Mines initiated research to evaluate the state of fire-door technology and develop and test a fire door suitable for large openings (10 by 12 ft or larger) in noncoal underground mines. This report discusses current fire-door technology in the context of the underground mine environment and the design, fabrication, lab testing, and in-mine field testing of a mineworthy fire door. This door has a 1.5-h fire resistance rating and limits temperature rise across the door to 250° F during the first 30 min of fire exposure.

IC 9166. Test Apparatus for Measuring Sound Power Levels of Drills, by William W. Aljoe, Robert R. Stein, and Roy C. Bartholomae. 1987. 35 pp. 25 figs. This Bureau of Mines report describes in detail the design and operation of a test apparatus for measuring the sound power levels of drills used by the mining indus-

try. The two major components of the test apparatus are a computer-controlled automated drill test fixture (ADTF) and a 45,000-ft³ reverberation chamber that houses the ADTF. Design specifications and performance capabilities of the ADTF and the reverberation room are given. Initial test results for three types of drills—a pneumatic percussion drill, a hydraulic percussion drill, and a pneumatic rotary drill—are given to illustrate the types of experiments that can be conducted with the test apparatus.

IC 9167. Analyses of Natural Gases, 1986, by B. J. Moore and Stella Sigler. 1987. 101 pp. 1 fig. This publication contains analyses and related source data for 274 natural gas samples from 20 States. Of the total samples, 269 were collected during calendar year 1985; the remainder were collected earlier, but releases granting permission to publish were not received before 1986. All samples were obtained and analyzed as part of Bureau of Mines investigations of the occurrences of helium in natural gases of countries with free market economies. This survey has been conducted since 1917. The analyses published herein were made by mass spectrometer and chromatograph.

IC 9168. MULSIM/BM—A Structural Analysis Computer Program for Mine Design, by Les A. Beckett and Rudy S. Madrid. 1988. 302 pp. 10 figs. The Bureau of Mines has developed MULSIM/BM, an improved computer program using the boundary-element approach for geomechanical analysis of mine plans in single or multiple coal seams. This Information Circular presents the improved features of the MULSIM/BM program. The four major improvements are (1) ability to specify up to 26 material property sets, (2) a new material model capability for gob and inserted materials such as packwalls or cribs, (3) ability to model a large area with a grid of undivided blocks and to subdivide only a specified fine-mesh portion of these blocks into elements, and (4) specification of extraction ratios for the undivided blocks. In addition, an interactive graphics mesh generator program was written to accompany MULSIM/BM. A complete user's guide and program listings are included. The MULSIM/BM and mesh generator programs are available on tape from the National Technical Information Service.

IC 9169. Coal Combustion in a Ventilated Tunnel, by Margaret R. Egan. 1987. 13 pp. 2 figs. The Bureau of Mines experimentally burned Pittsburgh Seam coal and other combustible materials found in mines in order to obtain a better knowledge of their emission products. These experiments were conducted in the Bureau's intermediate-scale fire tunnel, which simulates environmental conditions in underground mines. Smoke characteristics, gas concentrations, mass loss, and ventilation were measured. From these values, heat-release rates, particle sizes, obscuration rates, combustion yields, and production constants were calculated. This information was sought as part of a comprehensive study of combustible materials that will ultimately advance the design of more efficient fire detection and suppression systems. The coal combustion measurements presented in this report, together with previous analyses of wood and transformer fluid fires, form a data base by which future studies of other mine combustibles can be compared.

IC 9170. Cost Estimation Handbook for Small Placer Mines, by Scott A. Stebbins. 1987. 94 pp. 9 figs. In 1974 the Bureau of Mines began a systematic assessment of U.S. mineral supplies under its Minerals Availability Program. To aid in this program, a technique was developed to estimate capital and operating costs associated with various mining methods. Subsequently, it was noted that few provisions were made for estimating the costs of small-scale mining and milling methods typically associated with placer mining. Accordingly, this publication presents a method for estimating capital and operating costs associated with the exploration, mining, and processing of placer deposits. GPO Stock No. 024–004–02183–7. $4.75.

IC 9171. Surface Testing and Evaluation of the Hopper-Feeder-Bolter, by Robert J. Evans, William D. Mayercheck, and Joseph L. Saliunas. 1988. 39 pp. 33 figs. The Hopper-Feeder-Bolter (HFB) is a prototype multifunctional machine designed to improve productivity by minimizing continuous miner place changes. It is designed primarily to work beside a two-pass continuous miner, bolting on one side and then place changing to bolt the other side while simultaneously providing a surge car and lump breaker located directly behind the continuous miner. Surface testing was conducted at the Bureau of Mines Mine Equipment Test Facility to evaluate overall system performance and reliability. Tests were conducted to evaluate place changing, tramming, lump breaking, roof bolting, drawbar pull, conveying, temporary roof-support capacity, lighting, and noise. Surface test results indicate the HFB is ready to be tested and evaluated underground in a production mode.

IC 9172. Geologic Conditions Affecting Coal Mine Ground Control in the Western United States, by Gary P. Sames and Robert B. Laird. 1988. 30 pp. 33 figs. The Bureau of Mines recently initiated a study of geologic features that contribute to roof instability in western U.S. underground coal mines. The purpose of the study is to provide information for use in ground control planning and safety hazard reduction in that region, where mining activity has been increasing. Hazardous geologic conditions were surveyed in selected underground coal mines in Utah and Colorado, and both depositional and structural features were identified as potential ground hazards. Although the conditions found do not differ in kind from hazardous geologic conditions in the Eastern United States, they do differ in intensity of occurrence and relative importance. Three depositional features dominate where unstable roof occurs in western underground coal mines: paleochannel deposits, crevasse splay deposits, and flood basin deposits. Three structural features identified as hazardous, but not so widespread or common as the depositional hazards, are faulting, jointing, and igneous intrusions. This survey establishes a foundation for future studies aimed at reducing and preventing ground control accidents in western coal mines.

IC 9173. Investigation of Dust Sources and Control Technology for Longwall Plow Operations, by John J. McClelland and Robert A. Jankowski. 1988. 10 pp. 5 figs. The Bureau of Mines conducted a study of longwall plow operations to identify dust sources and existing control technology. Three longwalls employing either the high-speed overtaking or conventional method of mining were surveyed. Principal operating parameters and on-site dust control technology at the time of each survey are described. Short-term gravimetric and instantaneous sampling results are discussed in detail. The relationship between longwall dust levels and dust control technology was examined.

IC 9174. Review of Membrane Technology for Methane Recovery From Mining Operations, by F. Garcia and J. Cervik. 1988. 6 pp. 2 figs. Recent advances in the commercial separation of gases using membranes have renewed interest in the possibility of applying this technology to the recovery of methane (CH_4) from mining operations. This Bureau of Mines report briefly reviews the history of the development of membranes for gas separation, the theory of how they work, and their application to the separation of methane from air and associated problems. However, methane-air mixtures are difficult to separate with membranes because of pertinent gas couples, O_2–N_2, O_2–CH_4, and N_2–CH_4, have poor separation characteristics, as indicated by their separation factors of about 3 or less. Even if these separation factors were substantially higher, there is doubt that methane could be recovered economically from the low concentrations in mine ventilation exhaust (2 vol pct or less). The exhaust pressures are not sufficient for adequate separation. The power cost of compressing these mixtures would far exceed the value of the methane recovered. New discoveries could make separation of gob hole methane-air mixtures practical. These mixtures have much higher concentrations of methane (from 30 to 100 vol pct); however, for safety reasons, treatment would be limited to gob gas with 60 vol pct CH_4 or more.

IC 9175. Steel in Motor Vehicles—A 35-Year Perspective, by J. Weinberg, K. L. Harris, and G. White. 1987. 15 pp. 7 figs. This Bureau of Mines report presents data on the changes in the use of steel in motor vehicles over the past 35 yr. Sources of supply of steel for the automotive sector have shifted from almost all domestic in the 1950's to about 50% domestic and 50% foreign in the 1980's. Downsizing, design changes, and substitution of lighter weight materials to achieve energy efficiency also contributed to the market loss of the domestic steel industry. Although plastics and aluminum have displaced some steel in motor vehicles over the years, heavy low-carbon steel is now being replaced most rapidly by lightweight high-strength steel. If the percent of domestic steel used in motor vehicles had not declined since 1950, domestic industry would have

supplied 9.3 million more short tons of steel than it supplied in 1985. Downsizing and design changes accounted for 43% of the loss; steel imports, 32%; and substitution of plastics and aluminum, 25%. In 1985, the total value of market share lost by U.S. steel producers was $5.1 billion, of which $1.6 billion was lost to foreign steel producers and automobile manufacturers. Through aggressive marketing and increased efficiency, however, the domestic steel industry may be able to recapture some lost markets, as applications for high-strength steels expand, and as foreign-owned automotive plants in the United States provide fresh sales opportunities. GPO Stock No. 024-004-02192-6. $1.25.

IC 9176. Processing Technologies for Extracting Cobalt From Domestic Operations, by C. E. Jordan. 1988. 24 pp. 12 figs. Domestic cobalt resources are relatively large, but low grade. The full potential for cobalt production from domestic sources is at least 19.4 million lb of cobalt per year exclusive of offshore resources. A summary of the cobalt processing technologies for the major domestic resources is presented in this Bureau of Mines report. The processing technologies for the Blackbird, Madison Mine, Duluth Gabbro, iron ore pyrite, laterites, and manganese sea nodules are nearly complete, but the economics are not favorable. Research on these resources should be limited to approaches that promise to cut the total processing costs by at least 50 pct. The most promising sources of cobalt are the spent copper leach solutions and siegenite from the Missouri lead ores. Research on cobalt processing from these two sources needs to be completed.

IC 9177. Selected Significant Mineral Deposits in Alaska, A Minerals Availability System Overview, by Donald W. Baggs, Michael J. Northam, Mark P. Meyer, and Kenneth M. Maas. 1988. 124 pp. 9 figs. This Bureau of Mines publication presents a summary of mining activity in Alaska, as well as institutional and infrastructural factors affecting mineral development in Alaska. Salient information on 67 significant mineral deposits in the State of Alaska is presented in abstract form. The deposits covered are those whose principal commodity is 1 of 20 commodities that appear to have commercial production potential within the State. Many of the deposits described are properties evaluated under the Bureau's Minerals Availability Program; additional deposits are included for more complete coverage. The appendix provides reference information on 214 additional significant mineral deposits. GPO Stock No. 024-004-02178-1. $8.

IC 9178. A Catastrophe-Theory Model for Simulating Behavioral Accidents, by William E. Souder. 1988. 19 pp. 9 figs. Behavioral accidents are a particular type of accident. They are caused by inappropriate individual behaviors and faulty reactions. Catastrophe theory is a means for mathematically modeling the dynamic processes that underlie behavioral accidents. Based on a comprehensive data base of mining accidents, a computerized catastrophe model has been developed by the Bureau of Mines. This model systematically links individual psychological, group behavioral, and mine environmental variables with other accident causing factors. It answers several longstanding questions about why some normally safe behaving persons may spontaneously engage in unsafe acts that have high risks of serious injury. Field tests with the model indicate that it has three important uses: It can be used as an effective training aid for increasing employee safety consciousness; it can be used as a management laboratory for testing decision alternatives and policies; and it can be used to help design the most effective work teams.

IC 9179. Probe-Hole Drilling: High-Stress Detection in Coal, by John P. McDonnell and Khamis Y. Haramy. 1988. 11 pp. 8 figs. Coal mine bounces and bursts are major problems facing U.S. mine operators. Bounces and bursts have the potential to inflict severe injury on mining personnel, damage equipment, and cause mine closures. High-stress conditions, at or near the working face, are the common denominator in the burst problem. If mine operators can locate high-stress and potentially burst-prone zones, they can then use stress-relief methods to control the burst condition. One method of locating the high-stress zone is the probe-hole-drilling or drilling-yield method. Probe-hole drilling is used frequently in Europe, the U.S.S.R., and Japan as a means for locating potential burst zones. Consequently, the Bureau of Mines performed tests in the laboratory and in a deep, burst-prone western mine to analyze probe-hole drilling. The in-mine method, very simply, involves drilling a hole into the coal seam and measuring the volume of cuttings obtained. A certain volume of cuttings can be expected from a certain diameter and length drill hole. A significant increase in the volume of cuttings means the zone around that particular hole is highly stressed. In-mine use of the drilling yield method has shown it to be a useful tool for locating highly stressed and potential burst zones. Results from laboratory testing confirm that high stress applied tri-axially to a cube specimen will cause a significant increase in the volume of cuttings from a small-diameter drill hole in the specimen.

IC 9180. Tin Occurrences Near Rocky Mountain (Lime Peak), East-Central Alaska, by J. Dean Warner, D. C. Dahlin, and L. L. Brown. 1988. 24 pp. 13 figs. In 1984 and 1985, as part of its critical and strategic minerals studies, the Bureau of Mines investigated lode and placer tin occurrences near Rocky Mountain (Lime Peak), in east-central Alaska. The lode occurrences consist of mineralogically complex, generally fault-controlled veins, and contain an average of approximately 0.05 pct Sn, as cassiterite. Beneficiation testing of two bulk samples of the vein material produced concentrates containing 65 and 59 pct of the total tin values at grades of 0.35 and 13.9 pct, respectively. Although as much as 30 million short tons (MMst) of mineralized rock containing up to 20 MMlb Sn may be present, the grade of these occurrences is too low to be considered economic at this time. Trace amounts of cassiterite were also identified in surface samples of glacial outwash gravels collected along North Fork Preacher Creek, which partially drains the area of tin lode deposits near Lime Peak. Low tin grades in the samples do not account for the former erosion of a large volume of lode tin mineralization from near Lime Peak; higher tin grades may be present in gravels closer to bedrock.

IC 9181. Coal Extraction, Transport, and Logistics Technology for Underground Mining, by Robert J. Evans and William D. Mayercheck. 1988. 81 pp. 88 figs. The Bureau of Mines is sponsoring a variety of long-term, high-risk research to advance state-of-the-art technology in U.S. underground coal mining. This report reviews the status of many Bureau projects that support fundamental underground coal mining operations; the project areas include cutting coal from the solid (extraction), hauling coal from the face (transport), and activities that sustain daily operations (logistics). Innovative equipment and technology have been developed, with these major objectives: to significantly improve coal mine productivity, to further advance coal recovery and personal safety within the mining industry, and to reduce the time needed to develop longwall panels. The majority of the prototype equipment covered in this report either has undergone or will undergo comprehensive evaluation at Bureau surface test facilities so that performance and reliability can be improved before the equipment is tested and evaluated in a working section underground.

IC 9182. Human Factors in Mining, by Mark S. Sanders and James M. Peay. 1988. 153 pp. 130 figs. There is a growing awareness among mining professionals that the human factor plays a significant role in safety and productivity. Since the 1960's, the science of human factors, or ergonomics, has been making inroads into the mining industry, and a considerable amount of research has documented human-factor-related mining problems and solutions. This Bureau of Mines report is directed toward summarizing the application of human factors to improving safety, productivity, and the general physical and psychological working conditions of miners and toward familiarizing the readers with the role of human factors in the mining industry and the benefits that can accrue by systematically applying available human factors principles and data.

IC 9183. Mine Drainage and Surface Mine Reclamation (In Two Volumes). I. Mine Water and Mine Waste. Proceedings of a Conference Sponsored by the American Society for Surface Mining and Reclamation, the Bureau of Mines, and the Office of Surface Mining Reclamation and Enforcement, Pittsburgh, PA, April 19-21, 1988, compiled by Staff, Bureau of Mines. 1988. 413 pp. Mine waste and mine reclamation are topics of major interest to the mining industry, the government and the general public. There were nine sessions (50 papers) that dealt with the geochemistry, hydrology and problems of mine waste and mine water, especially acid mine drainage. These comprise Volume 1. The nine sessions (43 papers) that

dealt with reclamation and restoration of disturbed lands, as well as related policy issues, are included in volume 2. Volume 2 also contains the ten papers that pertained to control of subsidence and mine fires at abandoned mines. Poster session presentations are, in general, represented by abstracts; these have been placed in the back of both volumes.

IC 9184. Mine Drainage and Surface Mine Reclamation (In Two Volumes). II. Mine Reclamation, Abandoned Mine Lands and Policy Issues. Proceedings of a Conference Sponsored by the American Society for Surface Mining and Reclamation, the Bureau of Mines, and the Office of Surface Mining Reclamation and Enforcement, Pittsburgh, PA, April 19–21, 1988, compiled by Staff, Bureau of Mines. 1988. 401 pp. Mine waste and mine reclamation are topics of major interest to the mining industry, the government and the general public. There were nine sessions (50 papers) that dealt with the geochemistry, hydrology and problems of mine waste and mine water, especially acid mine drainage. These comprise Volume 1. The nine sessions (43 papers) that dealt with reclamation and restoration of disturbed lands, as well as related policy issues, are included in volume 2. Volume 2 also contains the ten papers that pertained to control of subsidence and mine fires at abandoned mines. Poster session presentations are, in general, represented by abstracts; these have been placed in the back of both volumes.

IC 9185. Mine Safety Education and Training Seminar. Proceedings: Bureau of Mines Technology Transfer Seminar, Pittsburgh, PA, May 17, 1988; Beckley, WV, May 19, 1988; St. Louis, MO, May 24, 1988; and Reno, NV, May 26, 1988, compiled by Staff, Bureau of Mines, 1988. 124 pp. Education and training research is a major component of the Bureau of Mines human factors research program. The goal of human factors research is to enhance human performance for the purpose of improving both safety and the profitability of the minerals industries. This is achieved through the design of mining equipment, work tasks, management procedures, and development of human resources. This proceedings volume presents several new developments that are helping to improve the quality and efficiency of health, safety, and occupational skills training in the mining community. Several papers address the issue of how to teach and assess miner abilities to deal with underground mine emergencies. Other papers examine practical procedures for defining and cost-justifying the integration of structured training and other performance improvement strategies to enhance the proficiency of the work system.

IC 9186. Rock Burst Research and the Coeur d'Alene District, by Terry McMahon. 45 pp. 29 figs. This Bureau of Mines report describes the rock burst problem and measures being taken for its alleviation in the deep underground mines of the Coeur d'Alene Mining District in northern Idaho. The geologic features that contribute to rock bursting in that area are discussed and briefly compared with similar features in other burst-prone mining districts throughout the world. Early investigations to understand and control rock bursting are reviewed, and the mechanics of bursting are discussed in terms of the seismic events that produce them. Sources of strain energy, rock failure mechanisms, and the conditions necessary for the release of seismic energy are covered in detail. Rock burst research in the Coeur d'Alene District is described. Included are discussions of the microseismic method as both a research tool and as a rock burst monitoring system, rock destress blasting and preconditioning methods for rock burst control, and stoping methods currently being developed to reduce rock burst hazards.

IC 9187. Phosphate Availability and Supply: A Minerals Availability Appraisal, by R. J. Fantel, R. J. Hurdelbrink, D. J. Shields, and R. L. Johnson. 1988. 70 pp. 34 figs. The Bureau of Mines investigated the resources, costs, capacities, market relationships, and short- and long-run supply of phosphate rock and phosphoric acid. The 206 mines and deposits evaluated in 30 market economy countries contain an estimated 35.1 billion mt of recoverable phosphate rock (demonstrated resource level). U.S. resources are sufficient to satisfy the domestic and export markets for phosphate products well beyond the year 2000. Because of resource depletion at current producers, however, new properties (with higher cost levels) need to be developed if U.S. production levels are to be maintained. Existing worldwide capacity can satisfy expected demand through the early 1990's. Expansion at existing mines or low demand growth could mean that no new property development will be needed before the late 1990's. Worldwide, almost $8 billion could be required for development of new phosphate rock properties between now and the year 2000, given 3-pct annual growth in demand. Most properties that could develop in the 1990's would require price increases of 20 to 50 pct to break even. To earn a 15-pct rate of return on investment, prices must rise to nearly double the present level of $24 to $29 per metric ton. GPO Stock No. 024–004–02203–5. $3.75

IC 9188. Analyses of Natural Gases, 1987, by B. J. Moore and Stella Sigler. 1988. 74 pp. 1 fig. This publication contains analyses and related source data for 191 natural gas samples from 22 States and 1 foreign country. Of the total samples, 182 were collected during calendar year 1987. The remainder were collected earlier, but releases granting permission to publish were not received before 1987. All samples were obtained and analyzed as part of Bureau of Mines investigations of the occurrences of helium in natural gases of countries with free market economies. This survey has been conducted since 1917. The analyses published herein were made by mass spectrometer and chromatograph.

IC 9189. Helium Resources of the United States, 1987, by Richard D. Miller. 1988. 17 pp. 5 figs. The helium resources base of the United States was estimated by the Bureau of Mines to be 1,040 Bcf as of January 1, 1987. These resources are divided into four categories in decreasing degree of assurance of their existence: (1) helium in storage and in proved natural gas reserves, 265 Bcf, (2) helium in probable natural gas resources, 228 Bcf, (3) helium in possible natural gas resources, 320 Bcf, and (4) helium in speculative natural gas resources, 227 Bcf. These helium resources are further divided into depleting and nondepleting, with the helium in storage being in a separate classification. The depleting resources are those associated with natural gasfields that are, or will be, produced for the natural gas they contain. Almost all of the helium in potential (probable, possible, and speculative) natural gas resources is included in this classification These depleting resources are estimated to contain 951 Bcf of the total helium resource base. Helium resources contained in nondepleting natural gas resources, i.e., those in shut-in, abandoned, or otherwise nonproducing natural gasfields, are estimated to total 53 Bcf. There is 36 Bcf of helium in storage in the Federal Government-owned Cliffside Gasfield near Amarillo, TX.

IC 9190. Surface Testing and Evaluation of the Conveyor Belt Service Machine, by Jasinder S. Jaspal and Lawrence F. Miller. 1988. 32 pp. 24 figs. In underground room-and-pillar mining methods, the sectional conveyor belts are extended or retracted periodically to maintain shuttle car tramming distance to a minimum. A conventional conveyor belt extension or retraction is a heavy, arduous job that, if mechanized, has the potential to improve productivity and safety. To reduce the burden of heavy work of this activity and mechanize it, the Bureau of Mines developed a conveyor belt service machine (CBSM) through a research contract with Tractor MBA. The CBSM is a self-contained, battery-powered, rubber-tired vehicle capable of handling, storing, and transporting conveyor belting, wire rope, and associated belt structures in seams as low as 48 in. Belt extensions and retractions are accomplished by moving the tailpiece of a belt conveyor with the CBSM to the next position while dispensing or retrieving the belt, wire rope, and associated belt structures. The CBSM improves the belt extensions and retractions by making them easier and faster, and it utilizes fewer workers. The CBSM was surface tested at the Bureau's Mining Equipment Test Facility to evaluate its performance and reliability. Modifications were made to the CBSM to correct deficiencies found during surface testing.

IC 9191. Behavioral Accident Simulator Computer Program User Guide and Technical Reference Manual, by William E. Souder. 1988. 33 pp. 1 fig. The behavioral accident simulator (BAS) is a computer program that can be used to simulate accident situations. It demonstrates how the potential to have an accident grows or diminishes as a result of changes in various environmental, organizational, and behavioral factors. It calculates the number of fatalities that may result from various conditions and graphically displays these data. The BAS is useful for studying systems of accident causes, for demonstrating the various ways to diminish fatalities, and for training employees. This Bureau of Mines report provides the detailed instructions needed to use the BAS.

IC 9192. Characterization of the 1986 Coal Mining Workforce, by Shail J. Butani and Ann M. Bartholomew. 1988. 76 pp. 3

figs. In 1986, the Bureau of Mines conducted a probability sample survey, Mining Industry Population Survey, to measure such employee characteristics as occupation; principal equipment operated; work location at the mine; present job, present company, and total mining experience; job-related training during the last 2 yr; age; sex; race; and education. The population estimates are necessary to properly analyze the Mine Safety and Health Administration (MSHA) injury (includes illness and fatality data) statistics; that is, to compare and contrast injury rates for various subpopulations in order to identify those groups that are exhibiting higher than average injury rates. This report uses the survey's results to characterize the U.S. coal mining workforce from March through September 1986.

IC 9193. Characterization of the 1986 Metal and Nonmetal Mining Workforce, by Shail J. Butani and Ann M. Bartholomew. 1988. 69 pp. 3 figs. In 1986, the Bureau of Mines conducted a probability sample survey, Mining Industry Population Survey, to measure such employee characteristics as occupation; principal equipment operated; work location at the mine; present job, present company, and total mining experience; job-related training during the last 2 yr; age; sex; race; and education. The population estimates are necessary to properly analyze the Mine Safety and Health Administration (MSHA) injury (includes illness and fatality data) statistics; that is, to compare and contrast injury rates for various subpopulations in order to identify those groups that are exhibiting higher than average injury rates. This report uses the survey's results to characterize the U.S. metal and nonmetal mining (includes metal, stone, sand and gravel, and nonmetal industries) workforce from March through September 1986.

IC 9194. Surface Subsidence Over Longwall Panels in the Western United States—Final Results at the Deer Creek Mine, Utah, by Frederick K. Allgaier. 1988. 17 pp. 12 figs. This report presents the final data from a 5-yr Bureau of Mines study designed to determine the surface subsidence characteristics resulting from longwall coal mining in a geologic environment common to the Western United States. It includes a description of the geologic setting of the study site, the mine plan, measurement techniques, and results of the monitoring program. Measured subsidence values were obtained over four adjacent longwall panels. Major subsidence characteristics such as longitudinal and transverse profiles, angles of draw, time-related subsidence development, and critical width are discussed. The maximum subsidence value of 5.8 ft was 68 pct of the mining thickness. The average angle of draw was 30°. Subsidence at the center of the first panel continued for 46 months following undermining. The lengths of the longwall panels precluded a definitive determination of the critical width and maximum possible subsidence.

IC 9195. New Steelmaking Technology From the Bureau of Mines. Proceedings of an Open Industry Briefing Held in Association With the Electric Furnace Conference, December 8, 1987, Chicago, IL, compiled by Staff, Bureau of Mines. 1988. 73 pp. 50 figs. This report is a proceedings of a briefing sponsored by the Bureau of Mines at which Bureau personnel presented findings from their research efforts to improve steelmaking techology currently used in the United States. The papers contained in this report address many areas of concern to the iron and steelmaking industry. Among these are improving arc stability in electric arc furnaces, preheating ferrous scrap to reduce energy consumption, fluorspar substitutes in steelmaking, basic steelmaking refractories, corrosion of iron-based materials, improvements in stainless steel acid pickling processes, recycling of stainless steel dusts and other wastes, and use of wastes as a source of zinc for electrogalvanizing.

IC 9196. Water Use in the Domestic Nonfuel Minerals Industry, by Choon Kooi Quan. 1988. 62 pp. 40 figs. Water availability is essential for mining and minerals processing. To provide government and industry with recent data for water use planning and management, the Bureau of Mines canvassed a number of U.S. producers of nonfuel minerals to determine their water use in 1984. Data were analyzed and compared with previously published data in order to examine historical trends in water utilization in the nonfuel minerals industry and to estimate water requirements in the year 2000. Total water use in the domestic nonfuel minerals industry during 1984 was estimated at 2,267 billion gal, of which 571 billion gal was new water and 1,696 billion gal recirculated water. The largest users of water were the phosphate rock, iron ore, copper, sand and gravel, and crushed stone industries, together accounting for almost 90 pct of total used. More than one-half of all water was used in Florida, Michigan, and Minnesota. In the year 2000, total water use will amount to an estimated 2,679 billion gal, of which 810 billion gal will be new water and 1,869 billion gal recirculated water. Most of this water would be used in producing the foregoing suite of minerals. GPO Stock No. 024-004-02201-9. $3.25.

IC 9197. Effectiveness of Catalytic Converters on Diesel Engines Used in Underground Mining, by B. T. McClure, K. J. Baumgard, and W. F. Watts, Jr. 1988. 13 pp. 3 figs. Oxidizing catalytic converters are sometimes used by underground mine operators as an emission control device to reduce odor, hydrocarbon (HC), and carbon monoxide (CO) emissions from diesel equipment. The objectives of this report are to quantitatively assess the effects of catalytic converters on diesel exhaust emissions and to make recommendations for their use. Information in this report is from a literature survey and contract research supported by the Bureau of Mines. Catalytic converters are effective in reducing CO, HC, and odors when the exhaust temperature is high enough so that the converter remains above 250° C. Converter temperature is dependent upon engine duty cycle. Catalytic converters increase sulfate emissions and slightly increase oxides of nitrogen (NO_x) emissions. If low-sulfur fuels are not used, the increase in sulfate and nitrogen dioxide (NO_2) emissions can offset any advantages of the catalytic converter as measured by the emissions quality index (EQI). In addition, in vitro bioassays have shown that catalytic converters produce soluble organic compounds, which have increased mutagenic activity with respect to untreated exhaust. Based upon criteria recommended by a joint Canadian-United States research panel, catalytic converters should only be used in special circumstances in underground mines. Vehicles equipped with catalytic converters should operate under moderate to heavy load conditions, and use fuel with a sulfur content less than 0.1 pct.

IC 9198. A Testbed for Autonomous Mining Machine Experiments, by William H. Schiffbauer. 1988. 20 pp. 7 figs. The Bureau of Mines is conducting research that is aimed at making the mining industry more efficient in terms of both productivity and the health and safety of the worker. As part of this research the Bureau of Mines has integrated a testbed composed of computer and related peripheral hardware to form an intelligent base for performing autonomous mining machine experiments. Although this particular application was configured for use on a Joy 16 CM mining machine, its generic structure facilitates its attachment to a variety of mining machine types. The multitasking multiuser computer can be set up for other applications by changing a bubble memory cartridge. The Joy 16 CM implementation includes 96 digital input-output (I–O) ports, 32 analog inputs, 8 analog outputs, 2 serial data channels, and 1 printer port. Operation of the machine can be performed either through a local terminal or remotely through a modem hookup. This report describes a testbed for autonomous mining machine experiments (TAMME)—its hardware, software, and complete system integration—so that it can be used as a foundation for other applications.

IC 9199. Mining and Reclamation of a Central Florida Forested Wetland: A Case Study, by James R. Boyle, Jr. 1988. 24 pp. 19 figs. The Bureau of Mines initiated a program to address short- and long-term objectives of wetlands restoration as a option for reclamation of lands mined for phosphate. The short-term objectives were to identify a suitable wetland test site, initiate an extensive premining monitoring plan, develop an acceptable mining plan, and recontour and revegetate the test site. These goals were accomplished using a unique combination of expertise provided by Federal and State agencies and private industry. A 6.5-ha forested wetland with an associated streambed was offered by private industry as the test site. A premining monitoring program was established and carried out from May 1982 to October 1983. A control site was established to determine ecological changes unrelated to mining. Clearing and mining began in October 1983 and were completed in April 1984. Grading and streambed restoration were completed in February 1986. Revegetation of the site was completed in February 1987. The program to meet the long-term objective of postmining monitoring is described.

IC 9200. Integrated Compartment-Machine Design for Low-Coal Shuttle Cars, by John R. Bartels, August J. Kwitowski,

and William D. Mayercheck. 1988. 18 pp. 14 figs. This Bureau of Mines report describes the development of a preliminary design for a novel, protected, cab-shuttle car for use in working seam heights down to 40 in. Because of the severe restrictions imposed by low-coal operation, Mine Safety and Health Administration (MSHA) regulations only require canopy protection on shuttle cars operating in seam heights of 42 in or greater. MSHA routinely grants variances for canopy use in seams 48 in high or less. The design was generated by giving the operator needs equal priority as related to machine performance parameters. Cab-shuttle car concepts that led to the recommended design are described, along with criteria and testing used to evaluate their potential effectiveness.

IC 9201. Characterization of the 1986 Metallic Mining Workforce, by Shail J. Butani, and Ann M. Bartholomew. 1988. 36 pp. In 1986 the Bureau of Mines conducted a probability sample survey, Mining Industry Population Survey, to measure such employee characteristics as occupation; principal equipment operated; work location at the mine; present job, present company, and total mining experience; job-related training during the last 2 yr; age; sex; race; and education. The population estimates are necessary to properly analyze the Mine Safety and Health Administration injury (includes illness and fatality data) statistics; that is, to compare and contrast injury rates for various subpopulations in order to identify those groups that are exhibiting higher than average injury rates. This report uses the survey's results to characterize the U.S. metallic mining workforce from March through September 1986. Similar reports have been published for the stone, sand and gravel, and nonmetallic mining industries, as well as for the entire metal and nonmetal mining (includes metallic, stone, sand and gravel, and nonmetallic industries) sector and the coal mining sector.

IC 9202. Characterization of the 1986 Stone Mining Workforce, by Shail J. Butani and Ann M. Bartholomew. 1988. 37 pp. 6 figs. In 1986 the Bureau of Mines conducted a probability sample survey, Mining Industry Population Survey, to measure such employee characteristics as occupation; principal equipment operated; work location at the mine; present job, present company, and total mining experience; job-related training during the last 2 yr; age; sex; race; and education. The population estimates are necessary to properly analyze the Mine Safety and Health Administration (MSHA) injury (includes illness and fatality data) statistics; that is, to compare and contrast injury rates for various subpopulations in order to identify those groups that are exhibiting higher than average injury rates. This report uses the survey's results to characterize the U.S. stone mining workforce from March through September 1986. Similar reports have been published for the metallic, sand and gravel, and nonmetallic mining industries, as well as for the entire metal and nonmetal mining (includes metallic, stone, sand and gravel, and nonmetallic industries) sector and the coal mining sector.

IC 9203. Characterization of the 1986 Sand and Gravel Mining Workforce, by Shail J. Butani and Ann M. Bartholomew. 1988. 37 pp. In 1986 the U.S. Bureau of Mines conducted a probability sample survey, Mining Industry Population Survey, to measure such employee characteristics as occupation; principal equipment operated; work location at the mine; present job, present company, and total mining experience; job-related training during the last 2 years; age; sex; race; and education. The population estimates are necessary to properly analyze the Mine Safety and Health Administration injury (includes illness and fatality data) statistics; that is, to compare and contrast injury rates for various subpopulations in order to identify those groups that are exhibiting higher than average injury rates. This report uses the survey's results to characterize the U.S. sand and gravel mining workforce from March through September 1986. Similar reports have been prepared for the metallic, stone, and nonmetallic mining industries, as well as for the entire metal and nonmetal mining (includes metallic, stone, sand and gravel, and nonmetallic industries) sector and the coal mining sector.

IC 9204. Characterization of the 1986 Nonmetallic Mining Workforce, by Shail J. Butani and Ann M. Bartholomew. 1988. 37 pp. 6 figs. In 1986 the Bureau of Mines conducted a probability sample survey, Mining Industry Population Survey, to measure such employee characteristics as occupation; principal equipment operated; work location at the mine; present job, present company, and total mining experience; job-related training during the last 2 yr; age; sex; race; and education. The population estimates are necessary to properly analyze the Mine Safety and Health Administration (MSHA) injury (includes illness and fatality data) statistics; that is, to compare and contrast injury rates for various subpopulations in order to identify those groups that are exhibiting higher than average injury rates. This report uses the survey's results to characterize the U.S. nonmetallic mining workforce from March through September 1986. Similar reports have been prepared for the metallic, stone, and sand and gravel mining industries, as well as for the entire metal and nonmetal mining (includes metallic, stone, sand and gravel, and nonmetallic industries) sector and the coal mining sector.

IC 9205. Emission Products From Combustion of Conveyor Belts, by Margaret R. Egan. 1988. 12 pp. 3 figs. A series of experiments were undertaken by the Bureau of Mines to determine the emission products of several types of conveyor belting and other combustible materials found in mines. These experiments were conducted under intermediate-scale, simulated mine conditions to determine smoke characteristics and gas concentrations. From these determinations, heat-release rates, particle sizes, obscuration rates, combustion yields, and production constants were calculated. Three types of belts were investigated: chloroprene, also known as neoprene (NP); polyvinyl chloride (PVC); and styrene-butadiene rubber (SBR). The belts were designated as ignitable or self-extinguishing depending on the length of the burning time and the subsequent combustion products. Under these experimental conditions, the SBR belts were the easiest to ignite. The PVC and NP belts tended to self-extinguish within a few minutes after ignition, but were still capable of maintaining a brief flaming period. These conveyor belt combustion results are compared with previous analyses of wood, transformer fluid, and coal fires. Together they form a data base by which findings from future experiments with other mine combustibles can be compared.

IC 9206. Recent Developments in Metal and Nonmetal Mine Fire Protection. Proceedings: Bureau of Mines Technology Transfer Seminars, Denver, CO, October 18-19; Detroit, MI, October 20-21; Las Vegas, NV, November 1-2; and Spokane, WA, November 3-4, 1988. 1988. 82 pp. 56 figs. Great strides have been made in recent years to reduce the disaster potential of underground mine fires. However, mines can still be caught unprepared for a fire emergency. Fires can grow too large before they are detected, warning systems can be too slow and uncertain to reliably signal the danger, and suppression systems can be inadequate to extinguish the flames. New mining systems and equipment may create unanticipated fire hazards, and new materials may generate highly toxic combustion products. This report contains papers that summarize recent significant developments from the Bureau of Mines mine fire protection research program relating to these problems. Certain of these findings are also applicable to surface mining operations. The papers fall into the general categories of fire detection and instrumentation, fire warning, fire suppression, diesel equipment, spontaneous combustion, and toxicity analysis of combustion products.

IC 9207. A Seal Breaching Operation in Quinland Coal Mine: A Case Study, by Diane M. Doyle-Coombs and Randy Hansford. 1988. 21 pp. 9 figs. In late July 1985, air samples from a sealed portion of the Quinland coal mine in West Virginia showed the presence of carbon monoxide (CO). Mine Safety and Health Administration (MSHA) personnel concluded that a fire was burning behind the seals. Since an imminent danger existed, the mine operator was given a closure order. The gases behind the seals were monitored, and almost 2 million ft^3 of carbon dioxide (CO_2) gas was pumped into the sealed area to stabilize the environment. Sixteen days after the closure order was issued, MSHA allowed the mine to return to production. Approximately 1 yr later, mine management submitted a seal breaching request to MSHA in order to drive a set of entries to further develop the mine. The Bureau of Mines established a sampling strategy and monitored gases from behind the sealed area during the breaching operation until the atmosphere was safe. This report is an account of the seal breaching conducted by the mine, MSHA, and the Bureau. The logistics of this event, the sampling strategy, and the equations applied could be used by the mining industry in future breachings or mine recovery operations. Time to reenter the area was calculated by using the methane (CH_4) concentrations sampled at the discharge of the seals. Tracer gas was used to verify the ventilation flows through the area.

IC 9208. Gallium and Gallium Arsenide: Supply, Technology, and Uses, by Deborah A. Kramer. 1988. 25 pp. 8 figs. As part

of the Nation's growing concern with the competitiveness of U.S. firms in the world economy, especially with respect to advanced materials, the Bureau of Mines assessed the actual and potential recovery and manufacturing capabilities for gallium and gallium arsenide (GaAs). GaAs has advanced from a laboratory curiosity to a material with important "high-tech" applications within only the last few years, and although protected North American gallium supplies are currently considered adequate, consumption could grow to the point that this assessment would need reevaluation.

IC 9209. Rollover Protective Structure (ROPS) Performance Criteria for Large Mobile Mining Equipment, by Stephen A. Swan. 1988. 15 pp. 11 figs. Certain types of mobile surface mining equipment are required to be equipped with rollover protective structures (ROPS) capable of protecting the operator in case of a rollover accident. The Bureau of Mines has developed ROPS performance criteria for wheeled front-end loaders. This report reviews the development of rollover test procedures and subsequent testing of ROPS for 52,000-, 286,000-, and 390,000-lb gross vehicle weight (GVW) loaders. The program consisted of both dynamic (roll) and static tests to assist in the development of the ROPS performance criteria. Each test included extensive instrumentation and photographic documentation to fully evaluate the performance of the ROPS. Data summarizing side, longitudinal, and vertical force and deflections are included. The data indicate that for loaders in excess of 240,000 lb, GVW, a side force-to-mass ratio of 1.0 and an energy-to-mass ratio of 6.0 appear to be adequate criteria to protect an operator in the event of a 540° rollover. For smaller machines, Society of Automotive Engineers (SAE) J1040 performance criteria provide adequate protection. Longitudinal loading, though not addressed in previous ROPS performance criteria, was shown to be a potentially significant factor in ROPS failure. Longitudinal loading and energy criteria equal to 80 pct of side loading criteria are recommended.

IC 9210. Application of Stereoscopic (3-D) Slides to Roof and Rib Hazard Recognition Training, by Edward A. Barrett, William J. Wiehagen, and Robert H. Peters. 1988. 15 pp. 10 figs. The ability to recognize visual cues commonly associated with roof and rib hazards is fundamental to the prevention of groundfall accidents. The perceptual skills that miners possess to visually search and assess hazardous ground conditions differ considerably. This U.S. Bureau of Mines report summarizes recent investigations on the use of stereoscopic (3-D) slides as a training aid for improving the ability of miners to recognize the various geologic and mining-induced irregularities that cause groundfalls. The feasibility of using 3-D slides for training and their effectiveness for representing roof and rib hazard conditions are discussed. Information is presented on equipment and procedures for creating a 3-D slide program that can be updated by mine trainers. Recommendations are made on selection of 3-D equipment and on the use of 3-D slides for training miners to recognize roof and rib hazards.

IC 9211. Predicting the Failure of Electric Motors, by Gerald T. Homce. 1989. 15 pp. 13 figs. A system capable of monitoring a mine electrical power system to detect incipient electrical component failure could significantly improve power system safety and availability. The Bureau of Mines funded a contract with The Pennsylvania State University (Penn State) to establish the theoretical and technical framework for such a system. This report briefly outlines the contract, reviewing related Bureau and Penn State work prior to its award, and describes support work carried out by the Bureau. The main focus of the report is on research efforts by Penn State and subsequent results. An existing algorithm for incipient-failure detection and classification was studied, and recommendations are made to improve its performance. In addition, mathematical models of cable-connected motor systems and deteriorating motors were developed and implemented on computers. These models and laboratory tests were used to study and document relationships between component deterioration and electrical terminal effects. The project was supported by the U.S. Navy, and the nature of its interest in the application of failure prediction techniques is also included.

IC 9212. Material Handling Devices for Underground Mines, by Ernest J. Conway and Richard L. Unger. 1989. 48 pp. 51 figs. This report presents engineering drawings for six material handling devices for underground coal mines. The devices were designed under a U.S. Bureau of Mines program to reduce injuries from material handling during mine and equipment maintenance. The six devices are scoop-mounted lift boom, swing-arm boom, heavy-component lift-transport, mine mud cart, container-workstation vehicle, and timber car. Each device is described briefly, and recommendations are made concerning the design of new devices.

IC 9213. Strontium—Uses, Supply, and Technology, by Joyce A. Ober. 1989. 15 pp. 3 figs. This U.S. Bureau of Mines report attempts to present a complete picture of the state of the international strontium industry, including end uses, world resources, chemical production, supply-demand relationships, and Government programs. Strontium is produced from an ore, celestite, which is found in several countries; dominant producers are Mexico, Spain, and Turkey. The United States does not mine celestite domestically, but nearly 100 pct of its imports come from Mexico. Because of the good relationship between the two countries, and their close geographic proximity, there is little concern over the stability of supply for the foreseeable future. Major end uses for strontium include color television faceplate glass, permanent ceramic magnets, and pyrotechnics. GPO Stock No. 024-004-02208-6. $1.25.

IC 9214. Framework for Autonomous Navigation of a Continuous Mining Machine: Face Navigation, by Donna L. Anderson. 1989. 23 pp. 11 figs. The first section of this U.S. Bureau of Mines report includes a discussion of the navigational tasks performed by operators of mobile mining equipment, with the focus on the navigational information and guidance techniques required by continuous mining machine operators. Some previous research and attempts in remote and autonomous navigation of continuous mining machines are mentioned. Issues of research in autonomous navigation of various other mobile robots are presented, with attention focused on their applicability to a continuous mining machine navigating in the mining environment. Conclusions are stated on methods of automating the navigational tasks of a continuous mining machine, and a decision to concentrate initial attempts on the tasks of autonomous face navigation is defended. The second section of this report includes a presentation of the Bureau's proposed solution for autonomous face navigation of a continuous mining machine, which includes the employment of a mobile roof support as a reference for guidance in the face area, and a navigational guidance system for the continuous mining machine.

IC 9215. Mine Ventilation Computer Code for Personal Computers, by Daniel Ng. 1989. 33 pp. 1 fig. The U.S. Bureau of Mines-Michigan Technological University mine ventilation mainframe program was successfully adapted for execution in a personal computer (PC). The hardware requirement can be as modest as 256 kilobytes (Kb) of random access memory (RAM) and two floppy disk drives. A version compiled for a PC possessing 512 Kb RAM has arrays dimensioned to accommodate 512 separate mine airways and junctions, and it contains all the features and capabilities of the original version. It has successfully analyzed all the ventilation networks tested, including a very large commercial mine (404 airways, 237 junctions, and 5 fans). In all cases the PC version produced practically identical results as obtained from the mainframe computer. In all respects, the PC version performed the same as the mainframe version with the exception of execution speed. When a numerical coprocessor is employed, execution time can be reduced by more than 50 pct. As an aid to the user of the PC version, a data base management program was developed using a commercially available data base management language to automate data entry and management.

IC 9216. In Situ Leach Mining. Proceedings: Bureau of Mines Technology Transfer Seminars, Phoenix, AZ, April 4, and Salt Lake City, UT, April 6, 1989, by Staff, Bureau of Mines. 1989. 107 pp. 87 figs. As part of its research on advanced mining technology, the U.S. Bureau of Mines emphasizes studies on in situ leach mining. This research enables the Bureau to develop technical information that can allow mining companies to adopt in situ leach mining methods. Research results should help to remove the technical and economic barriers currently hindering the development of commercial in situ leach mining operations. This report contains papers summarizing results of Bureau research on various aspects of in situ leach mining. A featured topic is the cooperative field experiment of the Bureau and Santa Cruz Joint Venture in a copper deposit near Casa Grande, AZ. Discussions include an overview of the entire

project, cost modeling, environmental permitting, laboratory core-leaching experiments, petrographic studies, and an evaluation of the geologic structure in the region. In addition, papers describe hydrologic modeling and geophysical studies of solution flow during leaching. Preliminary geochemical modeling studies are also summarized. A final paper describes a nonionic chemical additive with potential for significantly reducing the high costs of drilling in in situ leach mining.

IC 9217. Practical Considerations in Longwall Face and Gate Road Support Selection and Utilization, by Thomas M. Barczak, David E. Schwemmer, and Carol L. Tasillo. 1989. 22 pp. 32 figs. The U.S. Bureau of Mines has been conducting research to optimize the design and utilization of mine roof support systems. An objective of these efforts is to evaluate the mechanical and structural responses of various mine roof support systems under simulated load conditions in the Bureau's mine roof simulator. Underground studies are also made to evaluate the in situ behavior of support structures. The purpose of this report is to document practical applications for longwall face and gate road supports that have resulted from these studies. This report is not intended to be an all-inclusive manual on every aspect of support utilization, but it does provide a comprehensive assessment of practical considerations relating to the mechanical and structural behavior of these support systems. Forty-six recommendations are made to provide assistance to mine operators in the testing, selection, and utilization of longwall face and gate road supports. Many of these recommendations offer innovative solutions to everyday problems faced by mining personnel in the control of ground in longwall mining.

IC 9218. Bureau of Mines Geotechnical Centrifuge Research—A Review, by Paul C. McWilliams. 1989. 19 pp. 8 figs. The U.S. Bureau of Mines has, primarily through its contract program, used large-scale centrifuges to determine design criteria for tailings embankments. The centrifuge runs were made at two installations, the University of Cambridge, Cambridge, England, and Sandia National Laboratories, Albuquerque, NM. The major problems considered were as follows: slope stability of embankments, modeling erosion and seepage, use of the phreatic surface level to ascertain the validity of centrifuge modeling, and the effects of compaction and weathering on a tailings embankment. This report summarizes the results of the four test series conducted at University of Cambridge and Sandia National Laboratories. A review of prior centrifuge applications to mining problems is included. Consideration is given to future centrifuge application to mining problems in both soil and rock mechanics.

IC 9219. Reducing Miner Absenteeism, by Robert H. Peters, Mark R. Clingan, and Robert F. Randolph. 1989. 27 pp. 9 figs. The U.S. Bureau of Mines has prepared this report on strategies for maintaining high job attendance among underground coal miners because high absenteeism is a threat to miners' safety and seriously hampers productivity. A substantial number of research studies on the effectiveness of various strategies for reducing absenteeism among the employees of nonmining industries have been reported in the literature. These strategies have aimed at improving job attendance through one or more of the following: (1) improving employment procedures, (2) overcoming problems that adversely affect one's ability to attend work, and (3) increasing miners' motivation to attend work. Many of these strategies appear applicable to the mining industry, and are reviewed in the first half of this report.

The second half of this report describes how one could develop and implement a program for maintaining high attendance at underground coal mines. The steps include measuring and evaluating attendance levels, formulating attendance goals and an absenteeism policy, developing and implementing an attendance promotion program, and periodically going through the preceding steps (known as recycling).

IC 9220. The Talc Industry—An Overview, by Robert L. Virta. 1989. 11 pp. 1 fig. This U.S. Bureau of Mines paper discusses the structure of the talc industry, talc production, processing of talc ore, applications and demand for talc, and the outlook for the talc industry.

IC 9221. Safety Evaluations of Longwall Roof Supports, by Thomas M. Barczak. 1989. 17 pp. 17 figs. State-of-the-art longwall roof supports provide effective strata control, but failures of these support systems still occur. To identify failure mechanisms and the impact these failures have on the safety of the support system, the U.S. Bureau of Mines has been conducting research on shield mechanics in the Bureau's unique mine roof simulator, as well as field studies of in situ support loading and investigations of longwall failures. Three types of failures are discussed: (1) inadequate support capacity, (2) structural failure, and (3) instability. Hypothetical situations with proposed courses of action and case studies of actual longwall failures are described. This information is intended to assist the Mine Safety and Health Administration and industry mining personnel in safety evaluations of longwall roof support systems.

IC 9222. Position and Heading Determination of a Continuous Mining Machine Using an Angular Position-Sensing System, by Donna L. Anderson. 1989. 8 pp. 7 figs. This U.S. Bureau of Mines report describes a system to determine the position and heading of a continuous mining machine during the maneuvers required at the face area of a mine. The system consists of commercially available angular position sensors and a computer interface developed and tested at the Bureau. The sensors employed are laser-based scanning devices that report the angular location of retroreflective targets within their 90° field of view. The targets are mounted on the continuous mining machine; the laser scanners are mounted on an external reference structure. The computer interface consists of a single-board computer-controller programmed to gather and process the angular position information, and to calculate the machine's position and heading relative to the reference structure. A sensor fusion algorithm will be incorporated into the computer interface programming to increase the accuracy and reliability of the system.

IC 9223. Intrinsically Safe 5-V, 4-A Rechargeable Power Supply, by John J. Sammarco. 1989. 11 pp. 8 figs. The U.S. Bureau of Mines has developed a regulated, intrinsically safe, rechargeable power supply for portable electronic equipment for underground use. The regulated output is ideal for microprocessor power requirements and is suited for operation in hazardous environments. Two rechargeable, sealed batteries are contained within the power supply. Provisions are made to use an external source of power if these batteries fail. Provisions are also made to charge these internal batteries when needed. The circuit is composed of three main circuits: the main regulator circuit, the input protection circuit, and the output protection circuit. The main regulator circuit provides remote voltage sensing, current sensing, fault monitoring, and internal thermal protection. The input protection circuit checks for excessive input current and low battery conditions. The output protection circuit contains two overvoltage detection devices. Schematics, a parts list, and a calibration procedure are provided to enable readers to fabricate the power supply.

IC 9224. Effects of Environmental Stressors on Vigilance Performance, by J. C. Duchon and S. D. Hudock. 1989. 17 pp. 2 figs. The U.S. Bureau of Mines is conducting human factors research for the purpose of reducing accidents and improving the person-machine interface found in surface and underground mining operations. Miners are exposed to a variety of environmental stressors, e.g., extreme heat, noise, vibration, and adverse illumination, throughout the workday. Exposure to these environmental stressors has been noted in the literature to affect performance of vigilance tasks. Since impaired performance of vigilance tasks can lead to industrial accidents, further investigation of the effects of environmental stressors on human performance is warranted. A brief description of the environmental conditions present in the mining workplace is followed by a review of experiments dealing with the effects of environmental stressors on vigilance task performance. The applicability of past research to actual mining operations is considered.

IC 9225. Analyses of Natural Gases, 1988, by J. E. Hamak and Stella Sigler. 1989. 66 pp. 1 fig. This publication contains analyses and related source data for 165 natural gas samples from 21 States and 1 foreign country. Of the total samples, 155 were collected during calendar year 1988. The remainder were collected earlier, but releases granting permission to publish were not received until 1988. All samples were obtained and analyzed as part of U.S. Bureau of Mines investigations of the occurrences of helium in natural gases of countries with free market economies. This survey has been conducted since 1917. The analyses published herein were made by mass spectrometer and chromatograph.

IC 9226. A Computer Program To Rapidly Screen Explosion-Proof Enclosures, by Frank T. Duda. 1989. 84 pp. 10 figs. A U.S. Bureau of Mines interactive FORTRAN computer program can screen explosion-proof enclosures intended for underground service. The program incorporates information and criteria to assist enclosure manufacturers and Mine Safety and Health Administration (MSHA) personnel by providing a first-order approximation of rectangular explosion-proof enclosure characteristics prior to actual certification testing. The program uses information and data that can be retrieved automatically during program execution. The program also performs the calculations for a series solution algorithm and various equations to evaluate the enclosure for both a static internal pressure and an internal explosion. The program writes the intermediate and final calculations and information concerning the status of the screening process to a summary file on a floppy disk. One data base contains MSHA certification requirements given in the Code of Federal Regulations (30 CFR 18). A second data base contains material properties of acceptable construction materials and weld joint efficiencies. A series algorithm determines bolt and cover stresses for a simply supported rectangular cover with arbitrary bolt locations. Limit and yield line analysis is used to calculate the strength of body panels.

IC 9227. Computer-Assisted Continuous Coal Mining System—Research Program Overview, by George H. Schnakenberg, Jr. 1989. 15 pp. 6 figs. Automation of coal mining activities at the face offers improvements in worker safety, health, and productivity. Introduction of integrated computer-sensor systems to current mining machines will enable these machines to perform some of the most hazardous tasks through supervised teleoperation. The U.S. Bureau of Mines is pursuing the development of the enabling technology necessary to achieve this goal. The research program consists of both basic and applied research, each focused on the fundamental issues of computer and sensor technologies. Short-term research is directed to providing computer-assisted, remote supervisory operation of present underground equipment; the long-term goal is the development of progressively more intelligent mining systems. The research program includes a review of robotic machine and autonomous vehicle technologies and of current mining technology, which provides a base for developing innovative mining methods; research in navigation and guidance technology, emphasizing control of a continuous mining machine; research on coal-rock interface sensing technology for horizon control, and rib thickness control in highwall mining; the development of computer systems and hierarchical architectures for real-time control; and development of expert systems for machine system fault diagnostics and predictive maintenance. This report presents a brief background and the current status for each of these research areas.

IC 9228. Surface Testing and Evaluation of the Multiple-Unit Continuous Haulage System, by Jasinder S. Jaspal, Lee A. Erhard, and William D. Mayercheck. 1989. 60 pp. 47 figs. Most of the underground coal in the United States is mined via room-and-pillar mining methods with continuous miners. These machines operate intermittently because they have to wait for shuttle cars to interchange positions. To overcome this discontinuity in shuttle car haulage and to realize the full production potential of continuous miners, the U.S. Bureau of Mines developed a multiple-unit continuous haulage (MUCH) system through a research contract with Jeffrey Mining Machinery Div. (JMMD). The MUCH system consists of 12 rubber-tired vehicles and a bridge conveyor. The rubber-tired vehicles are connected by a unique mechanical linkage system to form a 250-ft train. The mechanical linkage permits the vehicles to track-retrack the preceding vehicle in both inby and outby directions. The cut coal cascades from one vehicle to another until it is discharged on the section conveyor belt. The MUCH system provides continuous haulage to the continuous miner. The MUCH system was initially surface tested by JMMD. Subsequent extensive testing was conducted by the Bureau at its test facilities at Bruceton, PA. Deficiencies found during testing were corrected. This report summarizes initial tests by JMMD and subsequent extensive tests and evaluation by the Bureau.

IC 9229. Study of Zeta Potential for Material Particles in Chemical Additive Solutions, by Pamela J. Watson and Patrick A. Tuzinski. 1989. 34 pp. 5 figs. A novel technique has been employed by the U.S. Bureau of Mines to determine the zeta potential of particles for a far-reaching series of material types in a wide variety of baseline waters, both alone and with many different chemical additives. The materials tested ranged from naturally occurring Sioux Quartzite and Tennessee marble to commercially produced magnesium oxide bricks. The waters tested ranged from ultrapure distilled, deionized water to municipal tap water and mine-site water. The chemical solutions tested included inorganic additives, such as aluminum chloride (AlC_3) and sodium chloride (NaCl); organic additives, such as dodecyltrimethyl ammonium bromide (DTAB); and nonionic polymers, such as polyethylene oxide (PEO). The results of precise zeta potential determinations have application in a large number of laboratory studies as well as in various mining and processing operations.

IC 9230. A Method for the Calibration of Class 2 and Class 4 Standards of Mass, by Nabil A. Bibawy. 1989. 14 pp. 1 fig. The U.S. Bureau of Mines has established a method for the calibration of class 2 and class 4 standards of mass using a procedure from designs developed by the National Institute of Standards and Technology (NIST). This method produces a weight calibration that is within 1.0 pct of the balance sensitivity. A set of four 1-kg weights yielded a standard deviation of 3.25 mg compared to $\pm$2.91 mg balance sensitivity. The method employs the use of a high-accuracy balance to measure the difference between a set of weights calibrated by NIST and the set to be calibrated. The error of the balance is included in the error for each weight calibrated.

IC 9231. Advanced Guidelines for Performance Testing of Two-Legged Longwall Shields, by Thomas M. Barczak. 1989. 149 pp. 42 figs. This U.S. Bureau of Mines report is intended to assist coal mine operators in the selection of longwall supports by providing advanced guidelines for performance testing and standardized test documentation to facilitate support comparisons. These advanced guidelines culminate in a series of proposed tests to evaluate (1) support resistance characteristics, (2) stiffness characteristics, (3) leg mechanics, (4) stability, (5) load transfer mechanics, and (6) structural integrity. The Bureau has conducted extensive studies on shield mechanics to identify boundary conditions that induce loading in support components, which is often not included in current testing techniques. This report discusses influential parameters that affect support behavior and provides insight into how components are loaded and what conditions produce the most severe loading. Testing philosophies and techniques in both active and static frames are discussed. Proper methods for determining support resistance are described, and instrumentation requirements for advanced performance testing are provided.

IC 9232. Review of Recent Research on Organizational and Behavioral Factors Associated With Mine Safety, by Robert H. Peters. 1989. 38 pp. This report presents a literature review conducted by the U.S. Bureau of Mines. The review summarizes what has been learned from recent empirical studies of the relationship between mine safety and characteristics of miners, mine management, and mining companies. The review is based on literature published in the United States from 1976 to 1988. In addition to summarizing the empirical findings, this report discusses the implications and limitations of these studies, and gives recommendations for improving mine safety. An annotated bibliography section appears in the appendix.

IC 9233. A Personal Miner's Carbon Monoxide Alarm, by J. E. Chilton and C. R. Carpenter. 1989. 12 pp. 11 figs. Underground miners may be exposed to hazardous quantities of toxic gases, such as carbon monoxide (CO), generated from mine fires or explosions. Every underground miner is required to carry a filter self-rescuer (FSR), which when operated will remove CO from the miner's breathing air. In addition, every underground miner must have a self-contained self-rescuer (SCSR) near the worksite that will supply breathing oxygen. In many situations, miners do not know when to don either rescuer since they do not know if there is a fire in the mine, nor do they carry instrumentation necessary for the detection of the toxic, colorless, and odorless fire product CO. If each miner carried a personal CO alarm, which would respond to high concentrations of CO, the miner would then be alerted when to don either the FSR or SCSR and exit the mine. A prototype personal miner's CO alarm called PEMCOAL was developed by the U.S. Bureau of Mines. The PEMCOAL unit is small enough to be carried on a miner's belt, has a flash lamp visual alarm, requires no calibration for use, and uses a chemical sensor that changes color by reaction with trace quantities of CO. The chemical sensor was tested at concentrations of CO from 10 to 1,000 ppm, at temperatures from 5°

to 40° C, and with several potential mine gas interferents. The PEMCOAL alarm times were sufficiently fast to warn miners before they are exposed to hazardous quantities of CO.

IC 9234. Development and Testing of a Pneumatic Scraper Blade for Conveyor Belt Cleaning, by C. A. Rhoades, S. G. Grannes, and T. L. Hebble. 1989. 12 pp. 14 figs. A major contributor to the problem of short life expectancy for blade-type conveyor belt cleaners is uneven wear along the blade edge. Uneven wear results in the formation of channels in the blade edge, which allow material to be carried back between the blade and the belt. In an effort to reduce the uneven wear problem, the U.S. Bureau of Mines has studied the mechanisms responsible for effective belt cleaning. From this study emerged a design for a cleaner blade that would greatly reduce uneven edge wear. The design consists of a standard cleaner blade incorporating air passages that allow for the expulsion of air along that part of the blade edge in contact with the conveyor belt surface. The results of 18-h tests indicated that the expulsion of air on the blade edge prevents scratches from developing into deep grooves. These tests showed the effective blade cleaning life can be extended 25 times using the pneumatic cleaning blade, compared with solid metal cleaning blades.

IC 9236. Cleaning, Disinfecting, and Sterilizing Self-Contained Self-Rescuer Mouthpiece Assemblies Used in Hands-On Training, by Michael J. Brnich, Jr., and Henry J. Kellner, Jr. 1989. 7 pp. This U.S. Bureau of Mines report addresses issues involved in using a limited number of training apparatus to give hands-on self-contained self-rescuer (SCSR) training to a succession of miners, and provides guidance regarding methods for minimizing the spread of infectious diseases. Procedures used for preventing the spread of infectious organisms in dentistry, cardiopulmonary resuscitation (CPR) training, and scuba training are examined. The sanitizing methods of three organizations that require individuals to insert the mouthpiece as part of the SCSR donning sequence are discussed. It was found that each of these organizations was able to render the mouthpiece assemblies microbe free simply and inexpensively.

IC 9237. Ultra-High-Purity Silicon for Infrared Detectors: A Materials Perspective, by Clark R. Neuharth. 1989. 13 pp. 8 figs. To assess the supply status of ultra-high-purity silicon for national defense needs, the U.S. Bureau of Mines conducted a general study of the availability of materials and processing technology for silicon used in the manufacture of infrared (IR) detectors from raw materials to the highly advanced device state. The United States possesses all of the raw materials and processing technology for IR detector-grade silicon production, but does not produce at all of the processing stages on a regular basis. Consequently, the United States continues to rely on foreign sources for some of these critical materials.

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When Government Printing Office or Bureau stocks have been exhausted, the report may be available from the National Technical Information Service, as described in the section entitled "Reports Available From the National Technical Information Service."

MI. The Chromium Industry of the U.S.S.R., by Vasilii V. Strishkov and Walter G. Steblez. 1985. 33 pp. 8 figs. As a major world producer and exporter of chromite, the U.S.S.R. possesses sufficient chromite reserves to meet its long-term requirements. Recent declines in Soviet chromite production growth and in exports have raised the issue of the U.S.S.R.'s prospective future as a world supplier. This Bureau of Mines report provides a description of the salient characteristics of the U.S.S.R. chromium industry including the raw material base, mining and processing facilities, foreign trade, and policies and programs controlling its operations, and outlook for the future.

MI. Mineral Issues—1987, by Staff, Bureau of Mines. 1987. 43 pp. 8 figs. This Bureau of Mines publication contains articles on five topics of current interest to the mining and minerals community: mine waste regulations, the impact of new developments in advanced materials, the implications of the restricted use of Federal land for mineral-related activities, mineral supplies from South Africa, and the lending practices of international financial institutions.

MI. The Manganese Industry of the U.S.S.R., by Vasilli V. Strishkov and Richard M. Levine. 1987. 39 pp. 7 figs. This Bureau of Mines report on the Soviet manganese industry presents information on reserves, mining, technology, ferroalloy production, trade, and consumption. It examines the Soviet manganese industry from its historical origins to the present and provides an outlook for the future. This report demonstrates that in all likelihood the Soviet manganese industry will experience increased difficulty. Although the U.S.S.R. is the world's largest producer of manganese ore, its reserves of high-grade ore are being depleted, resulting in the need to import ore in recent years and, in 1987, to contract to engage in a joint venture that would enable it to import Brazilian ferromanganese. Furthermore, at the same time that high-grade manganese ore reserves were being depleted, the Soviets rapidly expanded electric-furnace ferromanganese production capacity, thereby increasing the need for high-grade manganese concentrate. Soviet production in the future will probably be based on extensive reserves of the lower grade carbonate ore, for which the Soviets have not yet mastered the necessary processing technology. In addition, Soviet consumption of manganese in steelmaking per ton of steel produced is more than double the amount consumed in industrially advanced countries. The U.S.S.R.'s future supply of manganese of domestic origin will depend on both mastering the technology for processing the lower grade carbonate ore and on introducing improvements in mining, beneficiation, ferroalloys production, and steelmaking to reduce manganese consumption.

MI. Quantifying the Economic Potential of Undiscovered Mineral Resources: A Case Study of Kantishna Hills, Alaska, by Loring P. White, Barbara A. White, and John T. Dillon. 1987. 24 pp. 5 figs. The Bureau of Mines and the Alaskan Division of Geological and Geophysical Surveys have jointly developed a methodology to quantitatively assess the potential for undiscovered but economically recoverable minerals within a mineralized terrane or region. This methodology, referred to as ROCKVAL, provides a rigorous procedure for disaggregating the assessment problem into a set of technical judgments that focus on and capture the important geologic, engineering, and economic factors affecting the occurrence and economic viability of mineral resources. The procedure requires geologists and engineers to express their knowledge and opinions in terms of standard geologic and engineering parameters, which are then combined in a simple grade-tonnage format to generate quantitative estimates of regional resource potential. The methodology further provides for the explicit incorporation of uncertainty in the values of the geologic parameters; thus, the assessments are expressed as probability distributions and directly indicate the limitations in the data base and knowledge of the region. Assuming 1983 prices, the total gross recoverable value of mineral resources in the Kantishna Hills area was estimated to range from $375 million to $1,260 million at the 90% confidence level.

MI. The Tungsten Industry of the U.S.S.R., by George A. Rabchevsky. 1988. 50 pp. 12 figs. This Bureau of Mines study indicates that the Soviet Union is the world's second largest mine source of tungsten and the world's largest consumer of this strategic commodity. Nonetheless, because of security considerations, the Soviets have published little in the way of official statistical data on tungsten mining, processing, trade, and consumption. This study, one of a series of detailed reports on selected commodities in the Soviet Union, summarizes the contents of a wide variety of Russian language technical literature and other materials. These served as the basis for the compilation of statistical tables presenting estimates of salient statistics on reserves, production, trade, and apparent consumption of tungsten in the U.S.S.R. from the inception of tungsten mining in the early 1900's through 1986. By far the greatest emphasis is placed on reserves, mining, beneficiation, and consumption of Soviet tungsten deposits and ores therefrom, and on trade in ores and concentrates. Some material also has been included on the downstream tungsten industry, that is, the production and trade in ferrotungsten and other materials. This emphasis is directly related to the volume of material available in Soviet sources on these topics. In addition to the Russian language sources used, other source materials have been utilized where they have proven useful or essential to developing a comprehensive picture. The study substantially revises previously published Bureau of Mines estimates of Soviet tungsten production for a number of years, utilizing source materials that were not previously available or evaluated. GPO Stock No. 024-004-02204-3. $4.75.

MI. Mineral Issues — 1989. Competitiveness and Regulation. 1989. 84 pp. 18 figs. *Mineral Issues—1989* is the latest in a series of reports that discuss issues and problems of the mineral sector of the U.S. economy. The Bureau of Mines believes that these issues are important and should be part of any debate that seeks to address mineral and mineral material problems. The policy options are included for discussion purposes only and do not imply recommendations or positions of the Bureau of Mines, the Department of the Interior, or the Administration. In the last year, Bureau of Mines analysts have related many issues to two general themes: competitiveness and Government regulation. The seven papers in *Mineral Issues—1989* explore the issues and problems in the context of these two themes.

OPEN FILE REPORTS

An open file report is an unpublished Bureau of Mines report that has been made available as reference material. Any open file report may be inspected during working hours at the locations indicated but may not be removed, except that the Natural Resources Library, U.S. Department of the Interior, Washington, DC 20240, can usually supply copies on interlibrary loan. For further information, contact the library, 202/343-5815.

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The following key explains the symbols indicating the locations where the open file reports can be consulted.

AD/I&A	Associate Director—Information and Analysis, USBM, Washington, DC (replaces AD/MDA and AD/MI).
AD/RES	Associate Director—Research, USBM, Washington, DC (replaces AD/MMR and AD/MR).
AFOC/A	Alaska Field Operations Center, USBM, Anchorage, AK.
AFOC/F	Alaska Field Operations Center, USBM, Fairbanks, AK.
AFOC/J	Alaska Field Operations Center, USBM, Juneau, AK.
ALRC	Albany Research Center, USBM, Albany, OR.
DOI	U.S. Department of the Interior.
DRC	Denver Research Center, USBM, Denver, CO.
IFOC	Intermountain Field Operations Center, USBM, Denver, CO.
LIB	Natural Resources Library, DOI, Washington, DC.
MSHA	Mine Safety and Health Administration, Arlington, VA.
NMH&SA	National Mine Health and Safety Academy, Beckley, WV.
OSM	Office of Surface Mining Library, DOI, Washington, DC.
PRC/B	Pittsburgh Research Center, USBM, Pittsburgh, PA.
RERC	Reno Research Center, USBM, Reno, NV.
RORC	Rolla Research Center, USBM, Rolla, MO.
SLRC	Salt Lake City Research Center, USBM, Salt Lake City, UT.
SRC	Spokane Research Center, USBM, Spokane, WA.
TCRC	Twin Cities Research Center, USBM, Twin Cities, MN.
TURC	Tuscaloosa Research Center, USBM, Tuscaloosa, AL.
USBM	U.S. Bureau of Mines.
WFOC	Western Field Operations Center, USBM, Spokane, WA.

Other abbreviations such as AVRC and PRC/P, appearing in the earlier listings, refer to Bureau facilities that have since been closed.

1985

OFR 1–85. Grinding Aids and Transport in Comminution, by Douglas W. Fuerstenau. Oct. 1984. 51 pp. 15 figs. This report presents the results of an investigation of comminution in ball mills. Two topics involved with particulate transport and grinding kinetics in mills were investigated, and the results were analyzed in terms of phenomenological and/or analytical models. First, the effect of liner design and configuration on material transport through tumbling mills was studied. Using laboratory-scale apparatus, a comparison of the transport parameters in drums and mills fitted with angular square lifters (ASL) was made with drums and mills fitted with conventional bar lifters. The holdup of material in the ASL drum at any feed rate was less in the forward-spiraling than in the reverse-spiraling operation, whereas the Peclet (Pe) number was found to be independent of the spiraling direction. Comparison of the conventional bar mill with that of the ASL mill showed slight difference in the holdup but Pe is essentially the same for the two types of mills. Second, part of the research was concerned with the role of polymeric chemical additives in improving mill performance. Published data on fine particle production in wet grinding were analyzed as a function of the specific energy consumed by the mill with and without grinding aids. The main advantage from polymeric grinding aids is probably to increase the mill productivity by permitting operation at higher solid-liquid ratios, but there is no energy saving. Preliminary experimental results showed that at high solid-liquid ratios, the slurry viscosity in the mill is high enough to cause the balls to stick to the mill shell and thereby tend to act as a flywheel that consumes less energy. Research done under grant G1125149 to University of Utah. Available for reference at the following facilities: AD/MMR, ALRC, AVRC, LIB, RERC, SLRC, and TURC. Copies of this report will not be available for purchase.

OFR 2(1)–85. Cost Survey for Radon Daughter Control by Ventilation and Other Control Techniques: Volume I, by C. H. Bloomster, W. I. Enderlin, J. K. Young, and J. A. Dirks. Aug. 1984. 235 pp. 2 figs. The costs of ventilation for underground uranium mines to meet the existing radiation exposure standard were estimated for 14 mines, representing over half of the underground uranium production in the United States. All of the mines used the room-and-pillar system of mining, all were in sedimentary formations, and mine depth ranged from 300 to 2,700 ft. Using the information obtained from the mines, the costs were estimated for meeting more stringent exposure standards using dilution ventilation only, and other control methods in combination with dilution ventilation. A theoretical engineering analysis of the ventilation system requirements that would be needed in each mine to comply with the more stringent standards was performed. The Harris and Bales equation was used to estimate the increased airflow required to achieve the lower mine average working levels that were needed to meet the more stringent standards. Projected costs for meeting the more stringent standards were based on the increased capital and operating costs of the higher capacity ventilation systems. Two mines were analyzed to determine the cost-effectiveness of other control methods (i.e., sealants, bulkheads, and filtration), in combination with dilution ventilation. Research done under contract J0215033 by Battelle, Pacific Northwest Laboratories. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–152932; paper copy price code A11.

OFR 2(2)–85. Cost Survey for Radon Daughter Control by Ventilation and Other Control Techniques: Volume II. Radon Emissions From Underground Uranium Mines, by C. H. Bloomster, P. O. Jackson, J. A. Dirks, and J. W. Reis. Sept. 1984. 102 pp. 6 figs. This study estimated (1) radon and radon daughter emissions from underground uranium mines; (2) the reduction in radon that would be released to the surface by using control techniques such as bulkheads, sealants, backfilling, and positive pressure ventilation; (3) the cost for radon and radon daughter removal from total exhaust air; and (4) total radon and radon daughter discharge for lower occupational exposure limits. For 13 large underground uranium mines, estimated yearly radon emissions from each ranged from 900 to 3,400 Ci. The estimated age of air emitted from the mines ranged from 11 to 37 min. Potential radon removal methods for the total mine exhaust were evaluated. The cost of these methods was prohibitive. Diurnal and seasonal changes may affect radon emission over short periods of time, but do not affect the total emissions over the long run. Radon and radon

daughter emissions would be little changed by increased ventilation requirements needed to achieve lower occupational exposure limits. The concentrations in the exhaust would be lower, but the total release would be the same. Research done under contract J0215033 by Battelle, Pacific Northwest Laboratories. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–152940; paper copy price code A06.

OFR 3(1)–85. Caving Mine Rock Mass Classification and Support Estimation. Volume I—Final Report, by Robert A. Cummings, Francis S. Kendorski, and Z. T. Bieniawski. Jan. 1984. 197 pp. 45 figs. A rock mass classification system was developed to recommend drift support requirements in block caving mines. The development follows a 2-yr program incorporating field observations of support practice and performance in rocks of different classes at several U.S. block caving mines. Popular rock mass classification systems presently in use for tunneling were applied at various field sites and were evaluated for conformance with caving mine support requirements and for general utility to caving mine operations. The developed system accepts readily obtainable engineering and geologic data to yield a rational estimate of support requirements. This report describes the background and development of the system. Research done under contract J0100103 by Engineers International, Inc. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–154144; paper copy price code A09.

OFR 3(2)–85. Caving Mine Rock Mass Classification and Support Estimation. Volume II—Manual, by Robert A. Cummings, Francis S. Kendorski, and Z. T. Bieniawski. Jan. 1984. 74 pp. 12 figs. A rock mass classification system was developed for support estimation in mines using block caving methods. The developed system accepts readily obtainable geotechnical properties and mining geometry to develop a rating that permits recommendations for drift support in block caving mines. The method is intended to be used for planning and estimating purposes and for preliminary support design. This report explains the organization and nature of the system, its derivations, details of required input data, methods for assessing the data and for developing rock mass ratings, and techniques for selecting the most appropriate mine support recognizing mine requirements and desired stability. A worked example is provided. Research done under contract J0100103 by Engineers International, Inc. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–154151; paper copy price code A04.

OFR 4–85. Copper, Lead, Zinc, Gold, and Silver Waste Disposal Activities and Practices in the United States, by Luis V. Coppa. Nov. 1984. 195 pp. 47 figs. This Bureau of Mines report is an inventory of the amount and type of mill tailings created from the lode-mine commodities (copper, lead, zinc, gold, and silver) on a State and county basis between the years 1911 and 1981. The report contains tables and base maps cataloging the amounts of tailings created in each county on a decade basis. Mine waste and mill tailings disposal practices and technological advances and changes in the milling are discussed. Also included is a discussion of the material content typical to tailings produced from these five commodities. Research done by Division of Minerals Availability. Available for reference at the following facilities: AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–154706; paper copy price code A09.

OFR 5(1)–85. Evaluation of Dust Sources and Control Techniques for Conventional Mining. Vol. I—Field Studies, by S. J. Rodgers. Mar. 1983. 59 pp. 26 figs. This report presents the results of in-mine studies to determine the severity of dust sources in conventional mining operations. Three underground coal mines were surveyed using gravimetric samplers and continuous dust monitors, and two mines were surveyed using only monitors. Data on dust control methods were acquired during the survey. The results indicated that cutting, drilling, and loading out were the dustiest operations during a conventional mining cycle. Roof bolting, shot firing, and product transport were less severe dust sources. Research done under contract J0100012 by MSA Research Corp. Available for reference at the following facilities: AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–153328; paper copy price code A04.

OFR 5(2)–85. Evaluation of Dust Sources and Control Techniques for Conventional Mining. Vol. II—Guidelines, by S. J. Rodgers. Mar. 1983. 70 pp. 30 figs. This report presents guidelines on methods of dust control in conventional coal mining operations. The normal mining cycle and equipment used in a room-and-pillar conventional section are described. Main ventilation, section ventilation, and face ventilation are discussed in detail. Proper installation of line brattice, maintenance of proper airflows at the face, and split ventilation are stressed. The effects of maintaining the end-of-the-line brattice near the face are described. The advantages and disadvantages of blowing and exhausting face ventilation are presented, and the use of water sprays on cutter bars and loading machines is described. The design of a nonclogging water spray system developed under a Bureau of Mines contract is presented. Other methods of reducing dust exposure are discussed and include alternative procedures for shot firing and administrative controls. Research done under contract J0100012 by MSA Research Corp. Available for reference at the following facilities: AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–153336; paper copy price code A04.

OFR 6–85. Research To Improve Health and Safety Programs in the Mining Industry. Volume II, by Louis Schaffer and Donna Atchison. Apr. 1983. 197 pp. 15 figs. The objectives of this research were to determine whether a model health and safety program could be defined in terms that would enable its application to mines of all types, and, if such a model program could be defined, to determine through evaluations in two mining companies whether it would achieve measurable improvements. This report describes the literature and field research that preceded the model definition. Research done under contract H0308076 by Woodward Associates, Inc. Available for reference at the following facilities: AD/MR, DRC, LIB, MSHA, NMH&SA, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 85–151017; paper copy price code A09.

OFR 7–85. Optimization and Test of Water Spray Coolers, by J. F. McCoy, K. S. Heller, J. W. Valentine, and A. J. Erickson. July 1984. 71 pp. 32 figs. As mining develops into deeper and hotter regions, the safety and health of miners require that the workspace be cooled. Toward this end, a high-performance, low-maintenance, nominal capacity 5,000-cfm spray cooler was developed. Further, a series of four 25,000-cfm nominal capacity spray coolers were built and mine tested with satisfactory results. The coolers exceeded the desired operational specifications. Although performance degrades slightly with extended use and virtually no maintenance, they operate at satisfactory performance levels under these conditions. Research done under contract H0395058 by Foster-Miller, Inc. Available for reference at the following facilities:

AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–152460; paper copy price code A04.

OFR 8–85. A Tungsten-Rich Porphyry Molybdenum Occurrence at Bear Mountain, Northeast Alaska, by James C. Barker and R. C. Swainbank. Oct. 22, 1984. 64 pp. 15 figs. In 1983, the Bureau of Mines investigated an occurrence of molybdenum and tungsten near Bear Mountain in northeastern Alaska. A mineralized area defined by greater than 600 ppm molybdenum in soils over approximately 100 acres is underlain by an altered complex of rhyolite porphyry, intrusive breccia, and rhyolite porphyry dikes. Soil with at least 500 ppm tungsten also defines an area partially coincident with the molybdenum area. These values are approximately equivalent to 0.1 pct MoS_2 and 0.06 pct WO_3. Soil samples also indicate low-grade niobium (columbium) enrichment. Rock samples from the Bear Mountain occurrence contained 0.1 to 0.8 pct molybdenum and 0.06 to 0.6 pct tungsten. Although sulfide minerals have been leached, the tungsten mineral wolframite comprising both the huebnerite and ferberite end members was identified in rocks and placer concentrates. Zonation between a higher level, silica-rich, wolframite-topaz zone and a lower level, central molybdenum-rich, gossan zone with lower tungsten values is evident. Research done by Alaska Field Operations Center. Available for reference at the following facilities: AD/MDA, AFOC/A, AFOC/F, AFOC/J, ALRC, LIB, SLRC, and WFOC. Copies of this report will not be available for purchase.

OFR 9–85. Mineral Investigation of the Iditarod-George Planning Block, Central Kuskokwim River Area, Alaska, by Mark P. Meyer. 1984. 232 pp. 7 figs. In 1983, the Bureau of Mines conducted a literature search and a 10-day field reconnaissance for the Bureau of Land Management to identify mineralized areas in the Iditarod-George Planning Block in southwestern Alaska. Mineral deposits in the area include (1) lode mercury-antimony, (2) lode gold-silver, (3) lode antimony, (4) lode molybdenum, (5) lode copper-lead-zinc, (6) gemstone(?), (7) placer gold, (8) placer mercury, (9) placer tungsten, (10) coal, (11) oil and gas, and (12) sand and gravel. A geothermally active area was noted. During the literature search, 7 lode mines, 15 placer mines, 10 lode prospects, 9 lode occurrences, 10 placer prospects, 12 placer occurrences, 2 coal prospects, 1 gemstone(?) occurrence, and 1 sand and gravel pit were identified. In addition to the literature data, stream sediment and rock samples were taken to identify the presence of minerals and elements and to delineate the mineralized areas. Fourteen areas contain anomalous concentrations of several elements: 12 areas contain anomalous concentrations of 1 element, 2 contain coal, 2 have potential for oil and gas, and 1 is geothermally active. All stream valleys contain sand and gravel. Metals of possible economic interest found in the samples include antimony, chromium, cobalt, copper, gold, lead, manganese, mercury, molybdenum, nickel, tin, titanium, and tungsten. Placer deposits contain gold, mercury, and tungsten. Deposit grades and reserves were not established. Research done by Alaska Field Operations Center. Available for reference at the following facilities: AD/MDA, AFOC/A, AFOC/F, AFOC/J, and LIB. Copies of this report will not be available for purchase.

OFR 10–85. Subsurface Leaching of Pyritic Coal Mine Spoils and Contaminant Migration, by Jeffrey P. Schubert. Dec. 1984. 122 pp. 12 figs. A site in northeastern Illinois underwent surface mining for coal in 1943 and was reclaimed by the State of Illinois in 1972–73. Additional soil amendments and seed were applied to the spoil surface in 1975–80. Studies in 1975–78 had shown that the surface spoil materials and five final-cut lakes at the site were quite acidic and the lakes contained high concentrations of sulfate and dissolved metals. Surface runoff water from monitoring plots in 1976 were only moderately acidic and the mean concentrations of most dissolved metals and sulfate in the runoff waters were less than 25% of the concentrations found. By 1980, vegetation had become well established over most of the mined areas; however, the five final-cut lakes remained acidic. The purpose of this study was to determine the physical and geochemical subsurface conditions of the spoil materials, the hydrologic flow system within the spoils, and the magnitude of acidic spoil leachate migration into the lakes and into the wetland prairie north of the minesite. Research done under grant G1115173 to Southern Illinois University—Carbondale. Available for reference at the following facilities: AD/MR, DRC, LIB, OSM, PRC/P, SRC, and TCRC. Copies of this report will not be available for purchase.

OFR 11–85. Characterization and Beneficiation of Bitumen-Free Domestic Tar Sands, by Paulette B. Altringer, P. J. McDonough, and P. T. Brooks. Sept. 1982. 16 pp. 1 fig. The Bureau of Mines conducted a study to determine if residues from fractional distillation represent a potential source of mineral values. A literature review and discussions with tar sand specialists failed to disclose the mineralogical nature of residues remaining after bitumen extraction. To develop this information, pilot plant tar sand residues or toluene-cleaned tar sands from 23 deposits were examined. The nature of the residues was determined by standard mineralogical methods, and the chemical compositions were determined by X-ray and inductively coupled plasma spectroscopy. None of the sands or concentrates examined contained sufficient valuable minerals to be economically important. Research was done by the Salt Lake City Research Center of the Bureau of Mines. Available for reference at the following facilities: AD/MMR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–185791; paper copy price code A02.

OFR 12(1)–85. An Evaluation of the Fire and Explosion Hazards of Oil Shale Mining and Processing. Volume 1: Analytical Studies and Accident Scenarios, by R. B. Crookston, M. T. Atwood, R. E. Williams, and M. D. McGuire. July 15, 1983. 268 pp. 59 figs. The objectives of this research were to identify and evaluate potential fire and explosion hazards in oil shale mining and processing by laboratory testing to provide recommendations for mitigation and safety monitoring and to establish a basis for regulation. A series of scenarios were developed describing hypothetical fire and explosion incidents that might occur in oil shale mining. The objectives were achieved through the following accomplishments. (1) It was found that fire and explosion properties of oil shale increase with oil shale richness and decreasing particle size. (2) Data from dust loading studies in several mines showed that the total potential yield of combustibles was about one-tenth the amount required to fuel a propagating explosion. (3) Aging of oil shale dusts over a period of several years reduces the content of volatile combustibles and the corresponding fire and explosion properties. (4) Data and information from the completed program indicate that the hazard of dust explosions is less severe than the hazard of fire in mine muck piles. Laboratory data were used to relate fire and explosivity properties of oil shales to those of coals and other carbonaceous materials and to assist in the identification and evaluation of potential hazardous situations that may be encountered in oil shale mining and processing. Research done under contract J0275001 by Tosco Corp. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–165492; paper copy price code A12.

OFR 12(2)–85. An Evaluation of the Fire and Explosion Hazards of Oil Shale Mining and Processing. Volume 2: Data Summary of Anvil Points Raw Shale Waste Pile Combustion, by R. B. Crookston and M. D. McGuire. July 15, 1983. 144 pp. 42 figs. The objectives of this investigation were to gather combustion data on a raw shale pile and to monitor product gases. The internal temperatures and the gaseous products of a combusting raw oil shale pile on the surface at a Colorado oil shale mine were monitored from August 1979 to July 1980. The internal pile temperatures and gas concentration data collected were summarized, pictures were taken for the record, and observations were made to provide information on the origin, occurrence mode, progression, and paths of the combustion events. Research done under contract J0275001 by Tosco Corp. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–165959; paper copy price code A07.

OFR 12(3)–85. An Evaluation of the Fire and Explosion Hazards of Oil Shale Mining and Processing. Volume 3: Oil Shale Mine Dust Program, by R. B. Crookston and M. D. McGuire. July 15, 1983. 74 pp. 13 figs. The objective of this report was to present a summary of the oil shale mine dust programs that were conducted to assess the explosivity hazard of settled mine dust and to compare the results with those obtained in a previous study. Settled dust samples were taken from three Colorado underground oil shale mines and analyzed. The volatile-combustible concentrations were calculated and compared with the minimum nominal explosive concentration determined by the Bureau of Mines. The dust concentrations sampled were found to be well below the minimum nominal explosive concentrations. Research done under contract J0275001 by Tosco Corp. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–165967; paper copy price code A04.

OFR 13–85. Design, Build and Test an Air Cleaning System for Working Level Control in Uranium Mines, by W. E. Schroeder, T. L. Muldoon, and C. Babbitt. June 1984. 79 pp. 30 figs. The health hazard from radon-222 byproducts, radon daughters, will be increasingly difficult to control by dilution with primary ventilation as the uranium industry digs farther and deeper for ore of diminishing grade. One solution is removal of daughters from air at the workplace by filtering out respirable-size dust particles to which most daughters attach. This report describes design and testing of a filtration unit that reduces the working level in ventilating air 95% on an airflow of 10,000 cfm. Buildup of dust on the filter is controlled by periodic back-pulsing, so that the unit can operate for an extended period without changing elements. Differential pressure across the unit at rated flow remains below 3 in water gauge after 6 simulated months of use. The effectiveness of the self-cleaning action was satisfactory under a contaminant loading that was 43% diesel smoke. Back-pulsing was able to control filter loading or buildup to a degree even under 100% diesel. The report describes testing of the filter medium and filter unit in both an experimental and an active mine and concludes with an analysis of the prototype design. Research done under contract J0292017 by Foster-Miller, Inc. Available for reference at the following facilities: AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–164846; paper copy price code A05.

OFR 14–85. Geotechnical Validation of Pre-Dug, Backfilled Egress Concept, by N. Barton, D. Bush, and K. Bakhtar. June 1983. 179 pp. 102 figs. Large-scale tests were conducted on quartzitic gravel and crushed sandstone to investigate pertinent geotechnical properties for backfill support of egress shafts. Such shafts are envisaged for rapid launching of deep-based missiles. The backfill support is designed to resist shaft closure under dynamic loading and must also drain rapidly to a lower catch chamber to allow launching. Large-scale tilt shear tests were performed to measure the internal shear strength of the two backfill materials. Shaft filling and emptying tests were conducted in a 12-ft-deep, 3-ft-diam model section of shaft drilled in sandstone. One-half of the model was smooth bored, the other half was rough surfaced to represent drill and blast surfaces. Vertical and horizontal pressure cells indicated that stress only built up during the first 1 to 1½ diam of filling, owing to the high sidewall friction of 38° for the rough shaft and 31° for the smooth shaft. Interface sliding tests were performed to confirm these figures. Static and dynamic deformation tests were also performed and indicated moduli as high as 56,000 psi, which will give excellent shaft support. Both the shaft support characteristics and the ease of emptying of gravel look particularly promising. Research done under contract J0133917 by Terra Tek, Inc. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–163608; paper copy price code A09.

OFR 15–85. A Study of Subsidence From Multiple-Seam Coal Mining, by John D. Rockaway and Alphonse C. Van Besien. Jan. 11, 1984. 23 pp. The objective of this study was to define the parameters that contribute to the development of subsidence from multiple-seam coal mining and evaluate subsidence estimation techniques using data from an existing site. An extensive literature search and review of precalculation methods available suggested that the Stealth Program, developed by Science Application, Inc., had considerable potential for predicting multiple-seam mining subsidence. Results of the search for documented case histories of subsidence from multiple-seam mining revealed that either the full extent of the subsidence is unknown or the contribution of one or both seams is not available. Research done under contract J0225021 by University of Missouri—Rolla. Available for reference at the following facilities: AD/MR, DRC, LIB, OSM, PRC/B, SRC, and TCRC. Copies of this report will not be available for purchase.

OFR 16–85. Detection of Potential Inundation Hazards by Overwater Seismic Methods, by John J. Miller, Robert A. Speirer, M. W. Lee, and A. H. Balch. Aug. 20, 1984. 48 pp. 29 figs. The objective of this investigation was to map fault trends adjacent to underground coal mine workings overlain by a shallow body of water. The nature of the lake bottom was found to act as a wave guide and reverberative mechanism so that water bottom multiples obscured all reflections from depth. This occurrence was proved by the application of extensive computer modeling programs to the data that removed all reverberative energy and left no primary reflections. To predict the phenomena prior to conducting the survey would have required extensive seismic experimentation. Although the main objective was not achieved, possible solutions to overcome water bottom multiples generated in this environment are presented in the recommendations section of this report. Research done by Denver Research Center and U.S. Geological Survey. Available for reference at the following facilities: AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 17–85. Solid Solubility of Sulfur in Transition Metal Oxides and Stability of Sulfates Relevant to Roasting Processes, by Zeynal Karakus. Dec. 1984. 65 pp. 16 figs. In this study, two types of sulfur equilibration experiments were conducted using either a conventional thermal gravimetric analysis (TGA) technique or a horizontal tube furnace apparatus. Samples were equilibrated with flowing SO_2-O_2 gas mixtures of 58% or 10% SO_2. The experiments were (1) the investigation of the extent of solid solution of sulfur in ZnO,

NiO, CuO, and Fe_2O_3 over a wide range of temperature, and (2) studies of compound or solid solution formation between binary sulfate mixtures of Fe-Zn, Cu-Zn, Ni-Zn, Fe-Cr, and Cd-Zn by TGA. There was no appreciable solid solution and/or compound formation indicated from any of the mixtures of two different sulfates investigated, except for $ZnSO_4$-$CdSO_4$, which exhibited compound formation. Research done under grant G1125129 by University of Missouri—Rolla. Available for reference at the following facilities: AD/MR, ALRC, LIB, OSM, and RORC. Copies of this report will not be available for purchase.

OFR 18–85. Materials Evaluations in an Experimental Blast Furnace, by P. L. Woolf. Dec. 1984. 59 pp. 1 fig. The objectives of this study were to improve blast furnace practice, expand and develop understanding of the operation and theory, quantify the effects of changes, and explore the limitations of operability. Under cooperative agreements between the Bureau of Mines and North American steel companies, seven evaluation tests with blast furnace iron-bearing burden materials were conducted in Bruceton, PA. The effects of pellet strength, fines in the burden, decreasing slag volume, pellet size, eliminating stone with superfluxed sinter, and eliminating stone by prefluxing the pellets were determined. Fluxed pellets and fluxed sinter made with the same ore fines were compared. This report describes the results of the seven tests. Research done under contract J0134049. Available for reference at the following facilities: AD/MMR, AFOC/J, ALRC, AVRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC and WFOC. Order ONLY from NTIS: PB 85–172989; paper copy price code A04.

OFR 19–85. Decomposition of Potassium Ethyl Xanthate in an Aqueous Solution, by J. K. Winter, I. L. Nichols, and J. L. Huiatt. Nov. 1984. 20 pp. 6 figs. One Bureau of Mines goal is to contribute advanced technology to the domestic minerals industry. Research at the Salt Lake City (UT) Research Center is focused on the decomposition of potassium ethyl xanthate (KEX) in an aqueous solution. KEX is a reagent used for flotation of sulfide minerals in mineral beneficiation processes. Recycling of these decomposition products through waste water processing in minerals beneficiation plants may result in a loss of process efficiency. Evaluation of the data showed decomposition of KEX was a first-order reaction, with a decomposition rate over four times as fast at pH 6 as at pH 10. When about 99% of the KEX decomposed at pH 6, the major decomposition products were ethyl alcohol (C_2H_5OH) and carbon disulfide (CS_2). When about 99% of the KEX decomposed at pH 10, the major decomposition products were C_2H_5OH, carbonate (CO_3^-), and hydrosulfide (HS^-). The HS^- produced would be presumed to be oxidized by dissolved oxygen from the air to other sulfur species. Available for reference at the Salt Lake City Research Center. Copies of this report will not be available for purchase.

OFR 20–85. Development of Engineering and Cost Data for Foreign Titanium Properties, by George E. Aiken. Aug. 1982. 40 pp. 2 figs. The objective of this investigation was to obtain engineering profiles and cost data on foreign titanium mines and potential projects throughout the world. After identification as significant world reserves and resources, international titanium deposits were visited. Estimated quantity and quality determinations of in situ minerals were made as well as technical descriptions of operating and future potential new operations. Capital and operating costs were estimated for all reported currently operating and potential future operations. The impact of associated byproduct production was addressed, downstream raw material processing was reviewed, and appropriate costs were developed. Research done under contract J0215037 by Kaiser Engineers, Inc. Available for reference at the following facilities: AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–172997; paper copy price code A03.

OFR 21–85. Conservation and Substitution Technology for Critical Metals in Bearings and Related Components for Industrial Equipment and Opportunities for Improved Bearing Performance, compiled by Allen G. Gray and Robert T. Nash. 1984. 446 pp. 174 figs. The purpose of this workshop was to identify available technologies and opportunities for new technologies in conservation, substitution, and displacement of critical and strategic metals in bearings systems. Equally significant objectives were considerations of technologies in materials processing and design to extend the life of bearings and related components. Also considered was the value of an organized effort to gather and develop information for a data base on substitution and conservation technology for chromium and other critical metals that would be available as a contingency measure in the event of a crisis in supply. All findings and candidate recommendations developed in the workshop were summarized and are presented. Research done under agreement C0134055 by Vanderbilt University. Available for reference at the following facilities: AD/MMR, ALRC, AVRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–176246; paper copy price code A19.

OFR 22–85. Development of a Rapid, Position-Sensitive X-Ray Diffraction Device for Silica Analysis, by J. Fitzpatrick and E. Wardzala. Mar. 15, 1984. 79 pp. 38 figs. The objective of this study was to design and fabricate a device with few or no moving parts that could acquire desired X-ray data in a short period of sampling time. A rapid, position-sensitive X-ray diffraction device (based on a parafocusing X-ray geometry and utilizing an X-ray sensitive, phosphor-coated, linear diode array) was developed. The smallest loading of quartz powder consistently detectable with the device was found to be 28.8 $\mu g/cm^2$. Loadings as small as 5.8 $\mu g/cm^2$ were detected, although not consistently. The device was found to be limited mainly by sample distribution on the substrate filter rather than the total sample weight. Research done under contract H0387002 by University of Denver. Available for reference at the following facilities: AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 23–85. Comprehensive Planning for Strip Mining Reclamation in Dry Regions With Emphasis on Water Harvesting, by John L. Thames. Sept. 1984. 64 pp. 6 figs. The benefits of water harvesting as an alternative to conventional reclamation were demonstrated on the Peabody Coal mines in northeast Arizona. The project produced food crops for 4 years and demonstrated that a catchment-to-crop area ratio of about 2.5:1 was sufficient to obtain sufficient water from the 11-in annual precipitation to produce garden and fruit varieties in quantities equal to or exceeding national production averages. The economic returns exceeded those of the conventional practice of returning the mine area to rangeland by at least tenfold. Subsidence of the regraded spoil was the only major problem in maintaining the system. Although water harvesting systems have the potential of providing high economic returns and greater social benefits, as demonstrated by this project, they are presently at variance with strip mining regulations. Research was done under contract J0205042 by the University of Arizona School of Renewable Natural Resources. Available for reference at the following facilities: LIB, OSM, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 85–185759; paper copy price code A04

OFR 24–85. Feasibility of a Machine Mounted Scrubber System for Ventilating Coal Mine Working Faces, by George Halfinger, Jr. June 1984. 117 pp. 35 figs. Underground testing was carried out to determine the effectiveness of a machine-mounted scrubber system for ventilating the face during deep cutting. A continuous miner equipped with an integral flooded-bed dust scrubber system was instrumented. Methane and respirable dust data were collected at brattice

setbacks of 25 ft (standard), 35 ft, and 50 ft (blowing ventilation) during production shifts. Results showed that a suitable machine-mounted scrubber system can adequately ventilate the face at brattice setbacks up to 50 ft. No deterioration in ventilation performance was observed as brattice setbacks were increased from 25 to 50 ft. The scrubber system effectively controlled face methane levels at large setbacks, although some increase in respirable dust levels at the operator cab was noted at setbacks greater than 25 ft. The use of the scrubber system consistently improved intake airflow (as measured at the curtain mouth) by an average of 29%. Research was done under contract J0199080 by Ingersoll-Rand Research, Inc. Available for reference at the following facilities: AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–185742; paper copy price code A06.

OFR 25–85. Development of an Automated Breathing Metabolic Simulator (ABMS), by Larry L. Wischhoefer and Stephen D. Reimers. Jan. 1984. 51 pp. 13 figs. The automated breathing metabolic simulator (ABMS) is a machine capable of performing almost any physiologically appropriate respiratory simulation. Since the first ABMS was delivered to the Bureau of Mines in 1973, efforts have been made to refine the systems and components that make up the ABMS, including the breathing simulator module, the gas analysis module, and the supervisory controller, each of which is capable of stand-alone operation. To improve the equipment and to develop simulation criteria and parameters, testing and modification of the ABMS has been continuing since 1980. Changes have been made to the phase I design plan and performance specifications. Future improvements based on current experience are recommended, and test results of full-scale testing conducted in November 1983 on several types of breathing apparatus are reported and illustrated. Research was done under contract J0100098 by Reimers Consultants. Available for reference at the following facilities: ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–185247; paper copy price code A04.

OFR 26–85. Sensitive Ground-Fault Protection for Mines. Phase I. Alternating-Current Utilization, by L. A. Morley, F. C. Trutt, and T. Novak. Sept. 28, 1984. 90 pp. 34 figs. This report covers research and development of ground-fault relays for use on low-voltage alternating-current utilization circuits in mining. Sensitive relaying employs very low pickup levels such that, when used in conjunction with very high resistance grounding, the exposure of a human to ventricular fibrillation is significantly reduced. To delineate the desired relay characteristics, the report reviews and updates previous research in this area. The critical relay component for sensitive ground-fault relays has been found to be the current transformer. Electronics for two prototype relays—an analog relay and a digital relay—have been produced through the research, and information is presented so that either may be duplicated. Research was done under contract J0134025 by the Pennsylvania State University. Available for reference at the following facilities: AD/MR, DRC, LIB, MSHA, NMH&SA, PRC/B, PRC/P, SRC, and TCRC. Order ONLY from NTIS: PB 85–185767; paper copy price code A05.

OFR 27–85. Laser Velocimeter Study of Methane Roof Layers, by J. F. Driscoll and Tzong Hsi Chen. June 1983. 77 pp. 24 figs. Laser velocimeter measurements were made to quantify the mixing between a simulated roof layer and ventilation air in a model mine. A model mine was built and the effect of the following were measured: Reynolds number, Richardson number, air speed, layer thickness, gas density, turbulence intensity, and mixing length. A turbulence model was used to explain the data. Increasing the Reynolds number promoted mixing, causing vortices to break down into more efficient, fine-scaled turbulence. Decreasing the Richardson number also promoted mixing; Richardson numbers less than 0.3 resulted in complete mixing. Turbulence intensity increased as the Richardson number decreased. The velocimeter system was assembled and made operational for methane roof layer studies in the Bruceton Experimental Mine. Engineering drawings were provided and optics were aligned. Computer programs for data acquisition and an instruction manual were also provided. Research was done under contract J0199094 by the University of Michigan, Department of Aerospace Engineering. Available for reference at the following facilities: DRC, LIB, MSHA, NMH&SA, PRC/B, PRC/P, SRC, and TCRC. Order ONLY from NTIS: PB 85–185809; paper copy price code A05.

OFR 28(1)–85. Standardization of Controls for Roof Bolter Machines. Volume I. Executive Summary, by Ernest J. Conway, William W. Elliott, and Richard Curtin. Oct. 1983. 22 pp. The objective of this study was to propose standardized arrangements for controls in roof bolters. Roof bolting is the most dangerous work in underground coal mines. It is expected that standardized control arrangements would increase safety, minimize training requirements, and promote productivity. This report provides a human factors analysis of roof bolter controls. Standards for control design are suggested. These include the adoption of design criteria such as functional grouping of controls; sequencing controls according to order of operation; standardizing control motion directions; and standardizing actuation force requirements, control sizes, and interspacing. The proposed control arrangements were reviewed by roof bolter manufacturers and MSHA roof control experts; the responses were favorable. Detailed designs for the proposed standardized controls were developed. Research was done under contract H0292007 by the Canyon Research Group, Inc. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–185775; paper copy price code A02.

OFR 28(2)–85. Standardization of Controls for Roof Bolter Machines. Volume II, by Ernest J. Conway, William W. Elliott, and Richard Curtin. Apr. 15, 1983. 88 pp. 16 figs. The objective of this study was to propose standardized arrangements for controls in roof bolters. Roof bolting is the most dangerous work in underground coal mines. It is expected that standardized control arrangements would increase safety, minimize training requirements, and promote productivity. This report provides a human factors analysis of roof bolter controls. Standards for control design are suggested. These include the adoption of design criteria such as functional grouping of controls; sequencing controls according to order of operation; standardizing control motion directions; and standardizing actuation force requirements, control sizes, and interspacing. The proposed control arrangements were reviewed by roof bolter manufacturers and MSHA roof control experts; the responses were favorable. Detailed designs for the proposed standardized controls were developed. This report summarizes major tasks performed and significant findings. Research was done under contract H0292007 by the Canyon Research Group, Inc. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–185783; paper copy price code A05.

OFR 29(1)–85. Physiological Responses of Miners to Emergency. Volume I—Self-Contained Breathing Apparatus Stressors, by Eliezer Kamon, Scott Deno, and Max Vercruyssen. Oct. 2, 1984. 32 pp. This report summarizes completed research pertaining to the reaction of human subjects exposed to self-contained breathing apparatus stressors during escape conditions (resistance breathing, CO_2 breathing, hot air breathing, and static facepiece positive pressure breathing) and the development of an automated breathing and metabolic simulator. Volume I contains summaries of the studies

performed. Research was done under contract J0100092 by the Pennsylvania State University. Available for reference at the following facililties: AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85-186831; paper copy price code A08.

OFR 29(2)-85. Physiological Responses of Miners to Emergency. Volume II—Appendices, by Eliezer Kamon, Scott Deno, and Max Vercruyssen. Oct. 2, 1984. 181 pp. 46 figs. This report summarizes completed research pertaining to the reaction of human subjects exposed to self-contained breathing apparatus stressors during escape conditions (resistance breathing, CO_2 breathing, hot air breathing, and static facepiece positive pressure breathing) and the development of an automated breathing and metabolic simulator. Volume II, the appendixes, contains detailed descriptions of the studies performed. Research was done under contract J0100092 by the Pennsylvania State University. Available for reference at the following facililties: ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85-186849; paper copy price code A09.

OFR 30-85. Small-Scale Detinning of Municipal Solid Waste Magnetics, by C. L. Kusik, P. Tsantrizos, J. Valentine, S. C. Malhotra, and F. Harrison. Mar. 1983. 75 pp. 1 fig. The objectives of this study were to assess the need for small-scale detinning technology suitable for municipal solid waste (MSW) ferrous scrap and to determine the technical feasibility of various processes that might meet this need. A comprehensive review of existing detinning processes for tin-plated steel was made, and new concepts on small-scale detinning technology were reviewed. Economic evaluations of processes and concepts when adapted to MSW magnetics were undertaken. The principal findings of the study were as follows: (1) Conventional detinning technology is not adequate to process MSW magnetics on a small scale; (2) it is unlikely that nonupgraded MSW magnetics can be detinned economically; and (3) if the MSW magnetics are upgraded to nearly eliminate nonmetallic tramp materials, they can be detinned on a small scale economically by a number of processes with modifications to treatment vessels including alkali chemical oxidation, acid chemical oxidation, and alkali electrolysis. Research done under contract J0113039 by Arthur D. Little, Inc. Available for reference at the following facilities: ALRC, AVRC, LIB, RERC, SLRC, and TCRC. Copies of this report will not be available for purchase.

OFR 31-85. Reconnaissance Investigation of Tin Occurrences at Rocky Mountain (Lime Peak), East-Central Alaska, by P. Jeffrey Burton, J. Dean Warner, and James C. Barker. Nov. 9, 1984. 44 pp. 6 figs. Preliminary reconnaissance in the Rocky Mountain (Lime Peak), AK, area by the Bureau of Mines and the University of Alaska indicates the Lime Peak pluton is a composite intrusion comprising at least three plutonic phases cut by two sets of north-trending dikes. Numerous occurrences of fault-controlled, tin-bearing greisen have been identified. The greisen is composed of quartz, chlorite, sericite, and minor amounts of fluorite, tourmaline, topaz, pyrite, chalcopyrite, and molybdenite; samples contain between 60 and 1,560 ppm tin. Because there has been no systematic sampling, the extent of the mineralization is unknown. Stream sediments and panned concentrate samples contain anomalous metal concentrations over a region that is generally coincident with outcrops of the Lime Peak pluton. Two anomalous drainage areas in addition to several isolated samples comprise the larger anomalous region. Anomalous concentrations of tin, tungsten, columbium (niobium), and thorium occur in sediment or panned concentrate samples collected from streams draining the Lime Peak summit whereas anomalous concentrations of lead, zinc, uranium, thorium, copper, tin, and beryllium occur in samples from streams draining the northeastern periphery of the pluton. Research done by Alaska Field Operations Center. Available for reference at the following facilities: AFOC/J, ALRC, IFOC, LIB, RERC, and WFOC. Copies of this report will not be available for purchase.

OFR 32-85. Preliminary Investigation of Acid Leachable Tin Mineralization, Western Seward Peninsula, Alaska, by Thomas C. Mowatt and Uldis Jansons. Dec. 20, 1984. 14 pp. 3 figs. Chemical and petrographic studies were carried out on selected tin-bearing rock samples of contact-metasomatic origin from the Cassiterite Creek and Brooks Mountain areas, Seward Peninsula, AK. The tin content of rocks ranged from 0.39 to 8.9 pct. Leaching with a 20-pct hydrochloric acid solution released from 19.3 to 67.9 pct of the tin. Cassiterite was not observed in the rock samples. The results are significant with regard to tin recovery and reserve delineation in these and similar occurrences. Part of this leachable tin may be associated with metasomatic borate minerals. Research done by Alaska Field Operations Center. Available for reference at the following facilities: AD/MDA, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 33-85. A Copper-Cobalt Occurrence in the Cape Krusenstern Area, Northwestern Alaska, by James C. Barker and William S. Roberts. Dec. 14, 1984. 22 pp. 6 figs. An occurrence of copper mineralization with minor cobalt and traces of gold and silver was found in the Cape Krusenstern National Monument, AK, during critical and strategic mineral investigations by the Bureau of Mines. The occurrence consists of subangular sulfide-quartz boulders found in the drainage of Rabbit Creek and one similarly mineralized, poorly exposed vein outcropping. The mineralized boulders are up to at least 3 ft wide. Chip and grab samples generally contained 0.5 to 6.7 pct copper with associated cobalt ranging from trace to 0.153 pct. The mineralization is suggestive of silicified shear zones in green to gray phyllites believed to be part of the Late Devonian to Early Mississippian Endicott Groups. Further trenching and soil sampling necessary to assess this occurrence are not possible within the monument. This occurrence and reports of other mineralization in the area suggest a general favorability for mineralization in the Cape Krusenstern area. Research done by Alaska Field Operations Center. Available for reference at the following facilities: AFOC/J, ALRC, IFOC, LIB, RERC, and WFOC. Copies of this report will not be available for purchase.

OFR 34-85. Gallium and Germanium Potential in Alaska, by Steven A. Fechner. 1985. 12 pp. 1 fig. As part of its critical and strategic minerals program, the Bureau of Mines is conducting a study of the gallium and germanium potential in Alaska. Gallium and germanium are produced as byproducts from the processing of aluminum, zinc, coal, phosphate, and copper ores. Through literature research and geochemical analyses of selected mineral samples, 22 properties were identified as having high gallium or germanium concentrations. The potential for gallium and/or germanium in Alaska is currently unknown because of insufficient data. The study indicates that the most likely sources are from Alaska's large massive sulfide and coal deposits, but more sampling of all possible sources is needed. Research done by Alaska Field Operations Center—Anchorage. Available for reference at the following facilities: AFOC/A, AFOC/F, AFOC/J, and LIB. Copies of this report will not be available for purchase.

OFR 35-85. Productivity of Parent Materials on Mined Prime Farmlands Using Alternative Sources of Organic

Materials Compared to Topsoil Replacement, by J. H. Jones and F. J. Olsen. Jan. 1985. 25 pp. 6 figs. This research compared the parent materials of loess, glacial till, and a soil mixture of the B and the underlying C_1 loess and C_2 glacial till horizons with the B horizon replacement. Animal manure, green manure, and a forage grass-legume "organic building" crop were incorporated into the surface of each rooting medium to compare with topsoil replacement. The objectives of the study were to (1) characterize the physical and chemical properties of the selected parent materials, (2) determine soil moisture regimes for each selected rooting medium during the growing seasons, (3) evaluate alternative organic amendments incorporated in the surface of the selected parent materials compared with topsoil replacement, and (4) determine the suitability of selected parent materials on prime farmlands as a replacement for suggested B horizon as rooting mediums for corn and soybeans. In the 1984 growing season, the rainfall was somewhat higher and better distributed and the temperatures were lower than in the 1982 and 1983 production seasons. Thus, the corn yields were much higher in 1984 for the glacial till soil materials. The other three soil materials were used during the growing season by a coal company for their mining operations. However, the crop yield trends on the glacial till soil material can be extrapolated to the other three soil materials. Research done under grant G1115174 by Southern Illinois University—Carbondale. Available for reference at the following facilities: AD/MR, DRC, LIB, OSM, PRC/B, SRC, and TCRC. Copies of this report will not be available for purchase.

OFR 36–85. Development of a Planter for Direct Seeding of Trees in Surface Mine Reclamation, by L. G. Wells and T. W. Richards. Feb. 15, 1985. 15 pp. 2 figs. Provisions in the Surface Mining Control and Reclamation Act of 1977 have renewed interest in reforestation of mined land. In response, the University of Kentucky is conducting reforestation research on surface mines in Kentucky. A commercially available no-till row planter was modified for use in direct seeding of hardwood tree species. A pneumatic seed metering system was designed, fabricated, and mounted on the planter frame. Removable modules were fabricated with cells of different sizes coresponding to the various sizes of tree seeds being tested. A centrifugal fan, powered by an auxiliary variable-speed hydraulic motor, was utilized to develop seed metering vacuum. The planter unit was also modified by enlarging the furrow opening disk penetration and adding a 46-in parabolic upper tine ahead of the furrow opening disks. In tests conducted during May 1984, the planter performed satisfactorily on regraded sandstone and shale spoil material with an established vegetative cover. The metering device delivered approximately 95% of expected seed density when operated on a mild slope at a relatively slow speed using red oak seed. During fall of 1984, the metering device was tested under simulated conditions of varying terrain slope and field speed using various hardwood tree species. Metering efficiencies of 97% were achieved for pin oak seeds at 2.0 mph and 50% slope. For red oak, 97% efficiency was achieved at 2.5 mph and 50% slope. Unsatisfactory performance was noted during tests of larger seed, namely bur oak and black walnut. A redesign of seed cell configuration is expected to result in satisfactory metering of bur oak, whereas preprocessing of black walnut seeds to smooth rough seed exterior will probably be required. Research done under grant G1134121 by University of Kentucky. Available for reference at LIB and OSM. Copies of this report will not be available for purchase.

OFR 37–85. Analysis of Recharge to an Underground Lead-Zinc Mine, Coeur D'Alene Mining District, Idaho, by Joel A. Hunt. Oct. 1984. 91 pp. 16 figs. This project was directed toward delineation of reclamation alternatives, based on an understanding of the characteristics of ground water recharge near the Bunker Hill Mine in the Coeur d'Alene mining district in Idaho. A variety of field techniques were used to identify areas of rapid infiltration and to investigate the ground water flow system associated with the upper portion of the mine in the Milo Creek drainage. The techniques include installation of piezometer nests, dye tracing, surface resistivity, dye dilution, spring surveys, and hydrochemical analyses. Sites of direct infiltration into the mine were located that include mine workings directly below perennial streams, intersections between streams and faults, and a caved area adjacent to an ephemeral stream. The results indicate that recharge through these sites is not as rapid as suggested by previous studies. Inflow to the underground workings from the ground water flow system around the margin of the mine may account for more mine water than sites of direct infiltration. Recharge control at areas of direct infiltration could result in a net decrease in the quality of acid drainage from the Bunker Hill Mine. Research was done under grant G1125132–1651 by the University of Idaho. Available for reference at the following facilities: AD/MR, LIB, SRC, and TCRC. Copies of this report will not be available for purchase.

OFR 38–85. Integration, Compilation, and Computer Programming for Engineering and Geological Data for the Title III Information System, by Alan D. Smith, James C. Cobb, Richard A. Smath, and Konstanty F. Unrug. Dec. 1984. 50 pp. 12 figs. The objective of this project was to develop a computer-based information system for geotechnical data related to surface mining and reclamation. More than 1,000 tests (slake durability, direct shear, Brazilian tensile, punch shear, and ultimate and compressive strengths) were performed on coal mine overburden rocks described by the three-digit code for cored rocks by Ferm and Weisenfluh. As a result, baseline data for the strength and weatherability of selected overburden rocks were collected and organized by rock type and engineering test for the Title III Information System. Statistical methods applied to the data base were multiple linear regression, hypothesis testing, power analysis, stepwise regression, and model building. The analyses provided estimates of relationships between the engineering test results and the geologic characteristics. Statistically significant relationships were found among slake durability index, mean and standard deviation of punch shear, mean and standard deviation of Brazilian tensile, uniaxial compressive strength derived from the diametral and axial point-load tests, and overburden lithology. Research done under grant G1134121 by University of Kentucky. Available for reference at AD/MR and LIB. Copies of this report will not be available for purchase.

OFR 39–85. Characterization of Surface Area and Porosity in Coal by Gas and Vapor Adsorption, by P. J. Reucroft and H. Patel. Mar. 1985. 27 pp. 8 figs. The objective of this investigation was to directly measure and evaluate any swelling effects that may be caused by CO_2 and other gases used in adsorption studies. Dilatometric studies were carried out on three coal specimens (KCER 7122, KCER 7259, and KCER 7463) in various gaseous environments. The KCER 7463 sample showed the maximum length increase to date (0.50%). This corresponds with a volume increase of 1.31%. Volume increases on the order of 9.2% would account for the surface areas usually found by CO_2 adsorption on coal. However, the dilatometric studies have generally not reached equilibrium even after 280 h of exposure to CO_2. The 1.31% volume increase value is thus probably a lower limit; a higher value should be obtained at equilibrium. A distinct effect of carbon content was observed on the swelling behavior. Results of these three coals indicate that a lower carbon content correlates with a higher degree of swelling. The order of swelling was KCER 7259 < 7122 < 7463. Research done under grant G1134121 by University of Kentucky. Available for reference at AD/MR and LIB. Copies of this report will not be available for purchase.

OFR 40–85. Evaluating Rigid Foams for Construction and Repairing Mine Stoppings, by M. D. Marshall. Oct. 1984. 151 pp. 12 figs. Twenty-seven commercially available rigid foam materials were tested to delineate those most

suitable for use as a sealant in underground mine stoppings. The rigid foam industry was surveyed for possible candidates based on published properties, cost, and application equipment. Using a process that recognized those properties of rigid foams that were important for use as mine stopping materials, laboratory tests reduced the initial listing to two. Flammability, air permeability, and mode of application comparisons played major roles in the selection process, with adhesion and cost comparisons being minor factors. Standard ASTM tests were employed where applicable. In-mine tests were conducted on the final two candidates, using them as the main air barrier and as a joint and perimeter sealant for ventilation stoppings in a nonmetal mine. Research was done under contract J0308006 by MSA Research Corp. Available for reference at the following facilities: DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, SRC, and TCRC. Order ONLY from NTIS: PB 85–187656; paper copy price code A08.

OFR 41–85. Economic Feasibility of Tighter Quality Control of Clean Coal Output Through Additional Sampling, by E. L. Gillenwater and G. T. Lineberry. Nov. 30, 1984. 61 pp. 5 figs. The objective of this study was to determine whether altering the coal sampling program by differing sampling decision rules would result in tighter quality control of a preparation plant's clean coal output, and if so, to determine whether it would be economically feasible. The basic consideration is the product gain possible and the increased cost of sampling and analyses. To aid in the analyses, a computer model was developed. By applying systematic decisions to sampling frequencies, based on results of previous sample analyses by use of the Markovian chain theory and other statistical and mathematical techniques, new sampling schemes can be modeled and compared using economic considerations. Through this method, it may be found that for a typical plant, overall economics can be improved by altering the sampling program, most likely by requiring additional sampling. Effects of premiums and penalties, as well as sampling and analytical costs on plant economics, are included. Research done under grant G1134121 by University of Kentucky. Available for reference at AD/MR and LIB. Copies of this report will not be available for purchase.

OFR 42–85. Modeling the Performance of Sediment Detention Ponds: Volume 2. The Basin Model Based on Advection-Diffusion and Reactor Mixing Concepts, by B. N. Wilson, B. J. Barfield, and D. G. Colliver. Mar. 1985. 217 pp. 66 figs. The objective of this investigation was to present an algorithm that would model the movement of sediment in detention ponds. The cornerstone of the algorithm is the coupling of reactor theory concepts with advection-diffusion processes. Reactor theory concepts are used to (1) determine residence times of sediment particles and (2) to calculate mixing in the horizontal plane. Advection-diffusion processes are used to model the settling characteristics and turbulent diffusion of sediment. Also incorporated in the model is a bed scour routine based on the statistical properties of turbulent lift forces. Empirical coefficients for the bed scour routine are evaluated by using previously published results. Research done under grant G1134121 by University of Kentucky. Available for reference at LIB and OSM. Copies of this report will not be available for purchase.

OFR 43–85. Sampling and Analytical Results of a Mineral Reconnaissance in the Selawik Hills Area, Northwestern Alaska, by James C. Barker. Dec. 14, 1984. 67 pp. 7 figs. In 1980, the Bureau of Mines and the Bureau of Land Management made a mineral reconnaissance in the Selawik Hills area of northwestern Alaska. The Selawik Hills are partially underlain by three Cretaceous alkaline complexes that have given rise to uranium and thorium mineral occurrences locally associated with columbium, fluorite, and rare-earth elements. Anomalous uranium occurs in altered zones in syenite that contains xenotime, zircon, fluorite, thorianite, and an unidentified columbium-uranium-titanium mineral found by microprobe examination; quartz vein systems associated with altered tectonic lineaments; and slightly uraniferous lamprophyre dikes. A low-grade occurrence of uranium in carbonaceous sandstone also was found within Tertiary coal-bearing sediments. Multiple thin seams of lignitic coal exposed in two outcroppings indicate that the sedimentary basin north of the Selawik Hills contains coal deposits of unknown extent. The uranium and thorium occurrences in igneous rock and the uranium at the adjacent sedimentary series both warrant further investigation. Detailed sampling, mapping, and geophysics followed by core drilling would be needed to estimate the economic significance of these occurrences. Research was done by the Alaska Field Operations Center of the Bureau of Mines. Available for reference at the following facilities: AFOC/A, AFOC/F, AFOC/J, ALRC, IFOC, LIB, RERC, and WFOC. Copies of this report will not be available for purchase.

OFR 44–85. Mineral Sampling in the Western Portion of the Sound Study Area, Chugach National Forest, Alaska, by Mark P. Meyer and Steven A. Fechner. Dec. 19, 1984. 104 pp. 9 figs. Eight previously reported prospects, eight previously unreported mineral occurrences, and one placer occurrence were located, mapped, and sampled by the Bureau of Mines during the 1979–82 Roadless Area Review and Evaluation II mineral appraisal of the western portion of the Sound study area of the Chugach National Forest, AK. Copper, lead, gold, silver, nickel, cobalt, fluorite, and arsenic were found in the north-northeast to north-northwest trending shear zones, veins, felsic dikes, and granitic intrusives in Tertiary Orca Group metasedimentary rocks. Previous unreported mineralization was in Long Bay, Wells Bay, and Miners River, as discovered. Of special interest were higher concentrations of lead, fluorine, and arsenic that had been previously reported in the Orca Group. Research done by Alaska Field Operations Center. Available for reference at the following facilities: AD/MDA, AFOC/A, AFOC/F, AFOC/J, ALRC, AVRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 45–85. Platinum and Palladium in Some Mafic/Ultramafic Rocks From the Rabbit Creek Area in the Noatak Quadrangle, Alaska, by Thomas C. Mowatt and Uldis Jansons. Dec. 21, 1984. 27 pp. 4 figs. Preliminary Bureau of Mines studies of mafic igneous rocks collected from the Rabbit Creek area, northwestern Alaska, indicated concentrations of platinum and palladium in five of eight samples analyzed. The samples represent boulders and cobbles of mafic-ultramafic rocks from this locality. They are not from outcrop. Petrologically, the samples are crudely to well layered and are troctolitic ± gabbroic in character, with primary igneous mafic minerals strongly altered. Small patches of interstitial sulfide minerals, including chalcopyrite, bornite, pyrrhotite, pyrite, and covellite, are associated with these altered zones and elsewhere through the specimens. Copper values ranged from 0.1 to 0.3 pct in samples analyzed semiquantitatively; nickel, cobalt, and chromium contents are low. Chemical, mineralogic, and petrographic relationships suggest that the rocks of similar character outcropping in northwestern Alaska could also be considered as prospective for concentrations of platinum, palladium, and copper. Research was done by the Alaska Field Operations Center of the Bureau of Mines. Available for reference at the following facilities: AD/MDA, AFOC/J, ALRC, IFOC, LIB, RERC, SRC, and WFOC. Order ONLY from NTIS: PB 85–195451; paper copy price code A03.

OFR 46–85. Mine Power System Safety and Reliability Improvement—Part I, by Herman W. Hill, Jr., and E. Keith Stanek. Nov. 1981. 186 pp. 70 figs. This report summarizes research into the root causes of failures in mine power systems that impact safety and reliability. Abnormally low fault currents owing to arcing faults, self-excited systems, and fallen trolley wires are examined and quantified. The

reliability of components that are critical for safety is studied, as well as reliability of components that are crucial to the mining process. Failure rates are found through in situ tests, accelerated life tests, studies of mine maintenance, and fault-tree analysis. Reliability data are used to predict fatalities and lost-time accidents through computer-aided fault-tree analysis. Analytical support tasks reported include the determination of trailing-cable ampacities under cyclic loading and the measurement of connected ground beds. Research was done under contract J0199119 by West Virginia University. Available for reference at the following facilities: AD/MR, DRC, LIB, MSHA, NMH&SA, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 85–200962; paper copy price code A09.

OFR 47–85. Development of a Remote Coal Dust Deposition Rate Monitor, by P. W. Runstadler, Jr., P. K. Dutta, R. W. Hatfield, and R. Tenenbaum. Dec. 1983. 123 pp. 11 figs. This report describes the design, development, and manufacture of a monitoring system to continuously monitor the buildup of float coal dust and rock dusting materials in coal mine workings. A readout and special switch module can monitor up to 10 coal dust sensors, displaying the dust load directly in milligrams per square centimeter with a sensitivity of 0.5 mg/cm^2. The readout is a microprocessor-based unit, MSHA approved, and is rugged, portable, accurate, and easy to use and read. The sensors collect dust on a disk and measure the dust loading using vibrating wire technology. Ten dust sensors and two readout and switch station units were built, performance tested, and calibrated. The hardware was delivered to the Bureau of Mines for further evaluation and in-mine testing. Research was done under contract J0188058 by Creare Products Inc. Available for reference at the following facilities: AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–199784; paper copy price code A06.

OFR 48–85. Methods and Criteria for Producing a Photographic Core Logging Manual for the Pittsburgh Basin, by John C. Ferm and G. C. Smith. Jan. 5, 1983. 59 pp. 29 figs. Although continuous rock coring has long been practiced in the Eastern Coalfield of the United States, much potentially important information is lost owing to incomplete or confusing core description. A solution to this problem is presented in the form of a field manual containing color photographs of commonly occurring rock types. To prepare such a manual, specific procedures have been developed for selecting cores for sampling, sampling individual cores, and categorizing core samples on the basis of readily recognized criteria. In addition, a system of numeric designation has been developed for rock core to aid in rapid recording and assist in computer input, storage, and retrieval. Research was done under contract J0188115 by the University of South Carolina and the University of Kentucky. Available for reference at the following facilities: AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 49–85. Development of the Hydrotransport Boost Pump, by Leslie S. Rubin, Robert L. Cardenas, Mackenzie Burnette, John Roberge, and Andrew Harvey. Dec. 1984. 255 pp. 34 figs. A ventilated helical boost pump was developed that can handle varying flow rates and/or solids concentrations while operating at a single rotational speed and without computer-assisted feedback controls. The boost pump developed and briefly tested during this program was designed to accomodate flows suitable for a 3-in-diam pipeline. The boost pump's ventilated design provides the automatic pressure regulation needed to meet the system's requirements for supporting transient pipeline flow. A maximum discharge pressure of 120 psi was achieved at an operating speed of 3,000 rpm. The boost pump efficiency at maximum discharge pressure was 65 pct. Coal flow rates of up to 1,000 lb/min were successfully processed with a nonshrouded single vane impeller. Further redesign is required to develop a shrouded impeller that can be combined with stationary wear rings to minimize impeller wear. Research was done under contract J0133934 by Foster-Miller, Inc. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS; PB 85–203776; paper copy price code A12.

OFR 50–85. Preliminary Feasibility Study of a Ground Modification System for Egress Tunnel Construction, by D. C. Wakefield, J. W. Curran, and E. L. Foster. Feb. 1984. 202 pp. 30 figs. A preliminary systems concept and feasibility study of a ground modification system for egress through rubble has been made. The rubble environment has been postulated to include rock particles ranging in size from gravel to tens of feet in principal dimension. A system has been conceptualized that would store grout components at a safe (deep) level, transfer them to the heading, and inject them into the rubble ahead of the tunnel boring machine (TBM). Crushed muck from the TBM may be stowed in the larger cavities to reduce total grout requirements. Available grouts appear to have many of the properties needed for proper functioning in rubble. The system employs a stinger, a steel tube 15 in. in diameter, which extends through the center of the cutterhead out to a maximum of 35 ft. It carries its own motor and tricone bit and other equipment needed for carrying out the grout injection process. Control of grout envelope position is sensed by geophysical instrumentation and controlled from a remote booth. The preliminary study indicates that the system is feasible, although more detailed studies are recommended. Research was done under contract J0133918 by UTD Corp. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, PRC/P, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 51–85. Underground Mine Monitoring and Control Testing Criteria, by R. S. Nutter, R. S. Chapman, A. M. Kissel, C. A. Winkelmann, and W. R. Voltz. June 30, 1984. 156 pp. 42 figs. The proliferation of computer-based monitoring and control systems for underground coal mines has created the need for criteria to be used in evaluating the performance of these systems. This report contains the findings and conclusions of research on the development of test criteria for monitoring and control systems. The design of a test facility for control systems performance measurement of monitoring and control systems is presented. Tests were conducted and the results were used to develop recommended criteria. The implementation of the test facility, test conclusions, and resultant objectives are described in the executive summary. The appendix presents the detailed design of test facility hardware and software. Research was done under contract J0113057 by West Virginia University. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–228864; paper copy price code A08.

OFR 52–85. Minerals Availability Chromium Deposit Abstracts, by William L. Rice. Apr. 1985. 349 pp. This Bureau of Mines open file report on chromium is one of a series of minerals availability commodity deposit abstracts. Nonconfidential information from the Minerals Availability Program data base covering domestic and foreign chromium properties and deposits has been abstracted for use in this report. Abstracts include applicable data on location, published reserves and resources, geology, mine and beneficiation systems, and operation information. Research was done by the Western Field Operations Center of the Bureau of Mines. Available for reference at the following facilities: AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–202257; paper copy price code A15. $26.50.

OFR 53–85. Development of Engineering and Cost Data for Foreign Antimony and Barite Properties, by Vas P.

Kenyen and W. Joseph Schlitt. Oct. 1984. 31 pp. This report summarizes work done while profiling 52 antimony and barite companies, mines, and/or deposits in 20 market economy countries, exclusive of the United States. The profiles include current geological, engineering, and economic data on deposits that represent 85 pct of the production potential for these two commodities. In addition to summarizing the information collected, the report describes the methods used to gather and evaluate the data. Research was done under contract J0225017 by Brown & Root Development, Inc. Available for reference at the following facilities: AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–202984; paper copy price code A03.

OFR 54–85. Standard Test Criteria for Evaluation of Underground Fire Detection Systems—Final Report (Including Phase IV), by Jeffrey S. Newman and Mohammed M. Khan. Oct. 1984. 217 pp. 14 figs. This report presents a summary of the results of a four-phase program conducted to evaluate underground fire detection systems. The major accomplishments of this program are (1) quantification and prediction of the distribution of fire products in a mine passageway; (2) quantification of "equivalent protection" by fire detectors as contained in title 30 of the Code of Federal Regulations; (3) definition of detection criteria; (4) design of a detector test program for determining detector spacing requirements; (5) design, construction, operation, and calibration of a fire test apparatus for evaluating mine fire detectors; (6) quantification of several mine fire sources; (7) evaluation of several fire detector types including heat, CO and CO_2 gas, and ionization smoke detectors; (8) development of generalized spacing criteria for mine fire detectors; and (9) development of performance specifications. Research was done under contract H0113017 by Factory Mutual Research Corp. Available for reference at the following facilities: AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–204170; paper copy price code A10.

OFR 55–85. Video Display of Mine Environments, by Duane L. Abata. Dec. 1984. 230 pp. 20 figs. This work deals with the development of a computer graphics software package that will (1) display multicolor graphics of mine ventilation schematics and other representative illustrations for a real-time data acqusition system under development by the Bureau and (2) utilize the Bureau-owned "Minefire and Ventilation Code" for display of ventilation and contamination predictions. The software package has been written to operate on a 64K, Z-80 based microprocessor-computer. The project has been divided into two phases or tasks. The first phase deals with the development of the graphics software. The second phase deals with the retrofit of the Minefire and Ventilation Code to the Z-80 microprocessor-computer. Research was done under contract H0212024 by the Michigan Technological University. Available for reference at the following facilities: AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–203826; paper copy price code A11.

OFR 56–85. Petroleum Geology of Kentucky, by R. G. Shepherd and S. F. Greb. Mar. 1985. 449 pp. 102 figs. The petroleum geology of Kentucky is characterized by shallow pools of limited extent and production, by reservoirs of early Paleozoic age, by both stratigraphic and structural traps, and by future potential. In 1983, Kentucky was third nationally in number of oil and gas exploration wells drilled, ranking behind only Texas and Kansas. A publicly available summary report reviewing the petroleum geology of Kentucky had not been produced since the early 1940's. The research in this report is designed to update earlier works and to summarize the current information available related to petroleum in Kentucky. Research was done under grant G1134121 by the University of Kentucky. Available for reference at LIB. Copies of this report will not be available for purchase.

OFR 57–85. Simulation of Compaction by Equipment in Overburden Replacement Operations, by L. G. Wells. Feb. 15, 1985. 25 pp. 5 figs. A combined stress-strain model for predicting soil compaction due to wheel traffic was developed based on a method for predicting stress distribution within the soil, as well as the development of a log-linear relationship between porosity, applied stress, and moisture content. A computer model that simulates equipment traffic patterns during overburden replacement operations utilized the combined stress-strain model to predict overburden compaction. Model predictions were compared with measured overburden densities determined by field measurements in a study of large surface mines in the Midwestern United States that were originally characterized as prime farmland. Simulated levels of bulk density in subsoil and topsoil materials were in relatively good agreement with the field measurements, which corresponded to a variety of soil types, equipment types, and vehicle generation patterns. Research was done under grant G1134121 by the University of Kentucky. Available for reference at LIB and OSM. Copies of this report will not be available for purchase.

OFR 58–85. A Pilot Program for Underground Mine Rescue and Emergency Program Utilizing Cooperative Resources, by James H. McCutchan. Sept. 1984. 36 pp. The operators of small and remote underground mines must comply with the Federal Mine Safety and Health Administration regulation requiring them to train and maintain mine rescue teams. The alternative is for the operators to contract with established teams within 2 hours travel time of their mine. Many of these remote operations are too far from established teams and have too few employees to make up the necessary teams. Many cannot comply with the regulation either from a personnel or an economic standpoint. The concept of a volunteer mine rescue program was researched and developed by the Office of the Arizona State Mine Inspector under contract J0100125. This program, with the assistance of the mining industry and volunteer rescue organizations, has planned and instituted a statewide volunteer mine rescue organization. The trained and equipped volunteers are stationed throughout the State and can respond to a mine emergency within the time constraints. Available for reference at DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 85–215754; paper copy price code A03.

OFR 59–85. Shuttle Car Operator Training System, by N. Seidle. June 1984. 84 pp. 15 figs. This report describes the design, development, and manufacture of a shuttle car operator training system. The training system, including a program of instruction, (1) is economically feasible; (2) addresses accident data and specific causes of accidents; (3) includes an aerospace quality simulator of sufficient fidelity to teach and develop manipulative skills, recognition of and response to hazards, and routine and emergency procedures; (4) is designed to significantly reduce the severity and frequency of accidents especially during the operator's first year; and (5) is designed to significantly improve the performance of the trainee compared to the standard learning curve. Research was done under contract H0272039 by ORI, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–215788; paper copy price code A05.

OFR 60–85. Correct Shortcomings During Trial of Shotcrete Lining System and Demonstrate Lining System, by International Ground Support Systems, Inc. Oct. 1983. 502 pp. 98 figs. This report describes the redesign, development, and field demonstration of a remote shotcrete lining system capable of operating in shafts and mines from 8 to 16 ft in diameter at depths up to 1,000 ft. Included with the engineering and technical description of the system is a comprehensive technology package with information on ancillary equipment, materials selection procedures, mix-design data, a quality control and assurance program, selection and training of

personnel, and the organizational aspects required to operate the entire system. The report concludes with details of a successfully completed borehole lining operation at the Nevada test site. An irregular 104-in-diam borehole was lined with shotcrete at the rate of 4.8 ft/h for an 8- to 9-in thickness and 20 ft/h for a 2- to 3-in thickness. Research was done under contract J0233908. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 61–85. Haulage Truck Training System, by Kristine Krupp and Jane Applegate. Dec. 1983. 224 pp. 60 figs. This report documents the research and development efforts that were undertaken to design, develop, implement, and validate a haulage truck training system for the surface mining industry. The results of this effort were a complete haul truck training system and an on-board simulator of abnormal conditions, which is used in the haul truck as a training aid to simulate abnormal and emergency conditions. The training system and simulator were validated at three U.S. minesites. The conclusions from these validation efforts were that the system and simulator provide a flexible training system that can be used in diverse mine environments and adapted to various training needs with relative ease. Research was done under contract J0387221 by Woodward Associates, Inc. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–215762; paper copy price code A10.

OFR 62–85. Evaluation and Demonstration of Underhand Stoping To Control Rock Bursts, by D. D. Bush, W. Blake, and M. P. Board. Dec. 1982. 191 pp. 76 figs. Based on the results of this study, the underhand cut and fill stoping method, with mass destressing, is an effective method for controlling rock bursts and falls of ground for deep mining in the Coeur d'Alene mining district. The procedure can be utilized to pull highly stressed pillars by converting from conventional overhand stoping methods or used as a primary recovery system. During the demonstration, only one minor rock burst occurred, with no injuries. The system facilitates accurate placement of vertical boreholes for effective mass destressing. Each mining cut is filled with cemented sandfill overlying a timbered mat that forms the back for the succeeding cut. For this demonstration, a cemented fill was mixed on the surface and piped to the stope. Costs for pillar recovery by this method are comparable and are considered cost effective over conventionally timbered overhand mining as a pillar recovery method. Research was done under contract H0292013 by Terra Tek, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–216489; paper copy price code A09.

OFR 63(1)–85. Types, Causes, and Effects of Instability Phenomena in Reclaimed Spoils at Two Surface Coal Mines in Western North Dakota, by Gerald H. Groenewold and Chris M. Halvorson. June 1983. 98 pp. 40 figs. Monitoring of reclaimed surface mine spoils at the Indian Head and Center Mines showed three forms of instability: area wide settlement, localized collapse, and piping. Over 200 survey markers were installed at the two mines and monitored from 1977 through 1982. Area wide settlement at the Indian Head Mine averaged 3 cm over 3 yr. Some movement was missed because survey monuments were installed a year after spoils placement. Settlement at the Center Mine averaged 12 cm over 3 yr; most settlement occurred in the first 15 months. These data indicate that settlement time should be provided before structures are built on spoils or settlement monitored during construction. Localized collapse was observed at both mines. The contractor determined the cause to be the thawing and subsequent compaction of frozen spoils contoured with a bulldozer. All collapse features ended within 15 months of the contouring completion. The largest feature seen was 15 m long and 3 m deep. Piping was observed at the Indian Head study site. Piping features reached a maximum diameter of 3 m and were typically 0.5 to 1 m in diameter. They typically first appeared after a rainstorm as small openings through the topsoil and underlying spoils. Drainage into the pipes enlarged the opening. Piping appears to be controlled by a combination of physical and chemical conditions in the soil. Near-surface sodic spoils that shrink and swell more than non-sodic soils may increase infiltration and subsequent piping formation. Development of piping continued up to 6 yr after contour completion; piping can be a severe long-term stability problem. This volume summarizes the results of the study. Research was done under contract J0275010 by the North Dakota Geological Survey. Available for reference at LIB and OSM. Copies of this report will not be available for purchase.

OFR 63(2)–85. Types, Causes, and Effects of Instability Phenomena in Reclaimed Spoils at Two Surface Coal Mines in Western North Dakota. Appendices, by Gerald H. Groenewold and Chris M. Halvorson. June 1983. 320 pp. 31 figs. Monitoring of reclaimed mine spoils at the Indian Head and Center Mines showed three forms of instability: area wide settlement, localized collapse, and piping. Over 200 survey markers were installed at the two mines and monitored from 1977 through 1982. Data indicate that settlement time should be provided before structures are built or settlement monitored during construction. Localized collapse was observed at both mines, and piping was observed at the Indian Head study site. This volume consists of appendixes containing marker data. Research was done under contract J0275010 by the North Dakota Geological Survey. Available for reference at LIB and OSM. Copies of this report will not be available for purchase.

OFR 64(1)–85. In Situ Leaching and Solution Mining: State of the Art and Recommended Research. Summary Report—Phase I, by Phillip M. Wright. Oct. 1983. 175 pp. 11 pp.

In situ leaching and solution mining, relatively new techniques for mining and recovering mineral commodities, have shown desirable attributes such as low front-end costs, low overall capital investment, rapid startup, and favorable environmental considerations. This study was undertaken to obtain a comprehensive evaluation of the state of the art and to develop a coordinated research program toward solving the major technological problems confronting the industry. A task force considered four major topics: geological characterization leaching chemistry, fracturing (rubblization), and solution flow. Major problems appear to be (1) lack of adequate methods to fracture and/or rubblize deep ore bodies cost effectively for leaching; (2) lack of knowledge in fundamental leaching chemistry that would permit predicting such factors as mineral dissolution, precipitation, absorption, and ion exchange; and (3) fluid flow measurement and prediction. Research was done under contract J0113094 by the University of Utah Research Institute. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 64(2)–85. In Situ Leaching and Solution Mining: Evaluation of State of the Art. Bibliography, by University of Utah Research Institute. July 1983. 128 pp. This bibliography contains approximately 2,000 references to articles of interest in in situ leaching and solution mining. For convenience in use, it is divided by topic into nine separate sections: general references, chemistry, fracturing and rubblization, fluid flow, copper, uranium, precious metals, biologic leaching, and nonmetallics. Some references occur in more than one section to make the search for a specific topic or author easier. More than 300 of the more important articles have been read, and a brief review of each is included to help users of this bibliography determine the potential utility of these articles to their particular problems. Research was done under contract J0113094. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 64(3)–85. In Situ Leaching and Solution Mining: Evaluation of State of the Art. Appendix 1—Geologic Characterization, by Jeffrey B. Hulen, William C. Larson, William P. Nash, Richard L. Nielsen, Dennis L. Nielsen, and Phillip M. Wright. Jan. 1983. 162 pp. 12 figs. Geologic characterization of a deposit prior to leaching or solution mining includes determination of at least the following items in enough detail to be able to specify in a quantitative fashion how each will affect the proposed operation: (1) location and configuration of the deposit; (2) distribution and nature of ore mineral within the deposit; (3) distribution and nature of gangue mineral within the deposit; (4) distribution and nature of natural porosity and permeability; (5) distribution of ore and gangue minerals relative to natural fluid pathways; and (6) state of stress, regional and local. This report looks at each of these items in detail. Research was done under contract J0113094 by the University of Utah Research Institute. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 64(4)–85. In Situ Leaching and Solution Mining: Evaluation of State of the Art. Appendix 2—Chemistry, by Michael Adams, John A. Apps, Regina M. Capuano, David R. Cole, Charles L. Kusik, Donald Langmuir, and Milton E. Wadsworth. Jan. 1983. 346 pp. 63 figs. This report describes the state of the art of chemistry as it applies to in situ mining. Some of the topics covered are electrolytic solutions, dissolved gases, solid-liquid equilibria, adsorption and ion exchange, kinetics of ore minerals, kinetics of matrix minerals, kinetics of adsorption and ion exchange, biologic leaching, and experimental leaching studies. Research was done under contract J0113094 by the University of Utah Research Institute. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 64(5)–85. In Situ Leaching and Solution Mining: Evaluation of State of the Art. Appendix 3—Fracturing and Rubblization, by Dennis V. D'Andrea, Wayne O. Ursenbach, Howard M. Wells, and Stephen R. Winzer. Jan. 1983. 79 pp. 3 figs. Present knowledge of explosive applications is inadequate for extrapolation into in situ mining environments. Lack of scientific understanding and description of the fundamental mechanisms of rock fracture under explosive loading and of the propagation of high-energy impulses through rock makes design impossible of computer and other sophisticated models to simulate the process. Explosives and initiation systems available today are too imprecise to allow the kind of millisecond control of timing that will be necesary to execute cost-effective, confined in situ blasts. The major problem is enhancement of permeability at depth. To sustain an economically viable operation, adequate, well-distributed permeability in rock at depth is necessary for solutions to circulate directly to ore minerals for rapid chemical kinetics. A summary of the state of the art of fracturing and rubblization is presented. Research was done under contract J0113094 by the University of Utah Research Institute. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 64(6)–85. In Situ Leaching and Solution Mining: Evaluation of State of the Art. Appendix 4—Fluid Flow Management, by Steven E. Follin, Larry W. Lake, Subir Sanyal, Ronald C. Schroeder, Devraj Sharma, and Phillip M. Wright. Jan. 1983. 134 pp. 13 figs. This report describes the state of the art of fluid flow management as it applies to in situ mining. Some of the topics covered are hydrologic characterization; mathematical modeling; well testing, drilling, and completion; tools and instrumentation; and well field design and management. Research was done under contract J0113094 by the University of Utah Research Institute. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 65–85. Recommendations for Minimal Luminance Requirements for Metal and Nonmetal Mines, by J. O. Merritt, T. J. Perry, W. H. Crooks, and J. E. Uhlaner. Aug. 1983. 236 pp. 45 figs. The primary objective of this research program was to recommend ranges of minimum luminance for safety in underground metal and nonmetal mining. Visual tasks critical to safety were identified and rank ordered. Realistic, full-scale dynamic task simulations encompassing the most important visual components of the critical tasks were installed in a large simulated workspace. Five trained observers performed the six simulated mining tasks under varying levels of luminance. Over 13,000 measurements of visual task performance were used in developing minimum luminance recommendations for the on-foot underground worker and the mobile equipment operator. Research was done under contract J0318022 by Perceptronics, Inc. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–215689; paper copy price code A11.

OFR 66–85. Development of Foreign Economic Indices, Phase II Update for Australia, by Edgar M. Chavez. Aug. 1984. 77 pp. 6 figs. This report presents the development and updating of economic indices for Australia for the period from 1970 through 1983; the phase I report covered the period 1970 through 1981. Factor input costs in the mining sector were described by 12 index time series: (1) mining wages, (2) construction wages, (3) equipment and repair costs, (4) bits and related steel, (5) timber and lumber, (6) fuel, (7) powder and blasting agents, (8) tires, (9) construction materials, (10) industrial materials, (11) transportation, and (12) electrical power. The indices were developed primarily for use in the Bureau of Mines Minerals Availability Program in assessing the worldwide availability of nonfuel minerals. These indices combined with weight factors being developed by Bureau personnel will be used to perform updates of all costs relating to the mining industry. Research was done under contract J0225001 by Phoenix Associates, Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–216448; paper copy price code A05.

OFR 67–85. Development of Foreign Economic Indices, Phase II Update for Bolivia, by Robert Smith. May 1984. 56 pp. This report presents the development and updating of economic indices for Bolivia for the period from 1970 through 1983; the phase I report covered the period 1970 through 1981. Factor input costs in the mining sector were described by 12 index time series: (1) mining wages, (2) construction wages, (3) equipment and repair costs, (4) bits and related steel, (5) timber and lumber, (6) fuel, (7) powder and blasting agents, (8) tires, (9) construction materials, (10) industrial materials, (11) transportation, and (12) electrical power. The indices were developed primarily for use in the Bureau of Mines Minerals Availability Program in assessing the worldwide availability of nonfuel minerals. These indices combined with weight factors being developed by Bureau personnel will be used to perform updates of all costs relating to the mining industry. Research was done under contract J0225001 by Phoenix Associates, Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–216158; paper copy price code A04.

OFR 68–85. Development of Foreign Economic Indices, Phase II Update for Canada, by Edgar M. Chavez. May 1984. 79 pp. 12 figs. This report presents the development and updating of economic indices for Canada for the period from 1970 through 1983; the phase I report covered the period 1970 through 1981. Factor input costs in the mining sector were described by 12 index time series: (1) mining wages, (2) construction wages, (3) equipment and repair costs, (4) bits and related steel, (5) timber and lumber, (6) fuel, (7) powder and blasting agents, (8) tires, (9) construction materials, (10)

industrial materials, (11) transportation, and (12) electrical power. The indices were developed primarily for use in the Bureau of Mines Minerals Availability Program in assessing the worldwide availability of nonfuel minerals. These indices combined with weight factors being developed by Bureau personnel will be used to perform updates of all costs relating to the mining industry. Research was done under contract J0225001 by Phoenix Associates, Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–216455; paper copy price code A05.

OFR 69–85. Development of Foreign Economic Indices, Phase II Update for Chile, by Alice Chieruzzi. May 1984. 57 pp. This report presents the development and updating of economic indices for Chile for the period from 1970 through 1983; the phase I report covered the period 1970 through 1981. Factor input costs in the mining sector were described by 12 index time series: (1) mining wages, (2) construction wages, (3) equipment and repair costs, (4) bits and related steel, (5) timber and lumber, (6) fuel, (7) powder and blasting agents, (8) tires, (9) construction materials, (10) industrial materials, (11) transportation, and (12) electrical power. The indices were developed primarily for use in the Bureau of Mines Minerals Availability Program in assessing the worldwide availability of nonfuel minerals. These indices combined with weight factors being developed by Bureau personnel will be used to perform updates of all costs relating to the mining industry. Research was done under contract J0225001 by Phoenix Associates, Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–216463; paper copy price code A04.

OFR 70–85. Development of Foreign Economic Indices, Phase II Update for Greece, by Robert Smith. Dec. 1984. 64 pp. This report presents the development and updating of economic indices for Greece for the period from 1970 through 1983; the phase I report covered the period 1970 through 1981. Factor input costs in the mining sector were described by 12 time index series: (1) mining wages, (2) construction wages, (3) equipment and repair costs, (4) bits and related steel, (5) timber and lumber, (6) fuel, (7) powder and blasting agents, (8) tires, (9) construction materials, (10) industrial materials, (11) transportation, and (12) electrical power. The indices were developed primarily for use in the Bureau of Mines Minerals Availability Program in assessing the worldwide availability of nonfuel minerals. These indices combined with weight factors being developed by Bureau personnel will be used to perform updates of all costs relating to the mining industry. Research was done under contract J0225001 by Phoenix Associates, Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–215655; paper copy price code A04.

OFR 71–85. Development of Foreign Economic Indices, Phase II Update for Guatemala, by Robert Smith. May 1984. 61 pp. This report presents the development and updating of economic indices for Guatemala for the period from 1970 through 1983; the phase I report covered the period 1970 through 1981. Factor input costs in the mining sector were described by 12 index time series: (1) mining wages, (2) construction wages, (3) equipment and repair costs, (4) bits and related steel, (5) timber and lumber, (6) fuel, (7) powder and blasting agents, (8) tires, (9) construction materials, (10) industrial materials, (11) transportation, and (12) electrical power. The indices were developed primarily for use in the Bureau of Mines Minerals Availability Program in assessing the worldwide availability of nonfuel minerals. These indices combined with weight factors being developed by Bureau personnel will be used to perform updates of all costs relating to the mining industry. Research was done under contract J0225001 by Phoenix Associates, Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–215853; paper copy price code A04.

OFR 72–85. Development of Foreign Economic Indices, Phase II Update for Morocco, by Edgar M. Chavez. Jan. 1984. 68 pp. This report presents the development and updating of economic indices for Morocco for the period from 1970 through 1983; the phase I report covered the period 1970 through 1981. Factor input costs in the mining sector were described by 12 index time series: (1) mining wages, (2) construction wages, (3) equipment and repair costs, (4) bits and related steel, (5) timber and lumber, (6) fuel, (7) powder and blasting agents, (8) tires, (9) construction materials, (10) industrial materials, (11) transportation, and (12) electrical power. The indices were developed primarily for use in the Bureau of Mines Minerals Availability Program in assessing the worldwide availability of nonfuel minerals. These indices combined with weight factors being developed by Bureau personnel will be used to perform updates of all costs relating to the mining industry. Research was done under contract J0225001 by Phoenix Associates, Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–216471; paper copy price code A04.

OFR 73–85. Development of Foreign Economic Indices, Phase II Update for Philippines, by Robert Smith. May 1984. 63 pp. 1 fig. This report presents the development and updating of economic indices for the Philippines for the period from 1970 through 1983; the phase I report covered the period 1970 through 1981. Factor input costs in the mining sector were described by 12 index time series: (1) mining wages, (2) construction wages, (3) equipment and repair costs, (4) bits and related steel, (5) timber and lumber, (6) fuel, (7) powder and blasting agents, (8) tires, (9) construction materials, (10) industrial materials, (11) transportation, and (12) electrical power. The indices were developed primarily for use in the Bureau of Mines Minerals Availability Program in assessing the worldwide availability of nonfuel minerals. These indices combined with weight factors being developed by Bureau personnel will be used to perform updates of all costs relating to the mining industry. Research was done under contract J0225001 by Phoenix Associates, Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–216141; paper copy price code A04.

OFR 74–85. Development of Foreign Economic Indices, Phase II Update for South Africa, by Alice Chieruzzi. May 1984. 72 pp. This report presents the development and updating of economic indices for South Africa for the period from 1970 through 1983; the phase I report covered the period 1970 through 1981. Factor input costs in the mining sector were described by 12 index time series: (1) mining wages, (2) construction wages, (3) equipment and repair costs, (4) bits and related steel, (5) timber and lumber, (6) fuel, (7) powder and blasting agents, (8) tires, (9) construction materials, (10) industrial materials, (11) transportation, and (12) electrical power. The indices were developed primarily for use in the Bureau of Mines Minerals Availability Program in assessing the worldwide availability of nonfuel minerals. These indices combined with weight factors being developed by Bureau personnel will be used to perform updates of all costs relating to the mining industry. Research was done under contract J0225001 by Phoenix Associates, Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–215671; paper copy price code A04.

OFR 75–85. Development of Foreign Economic Indices, Phase II Update for Syrian Arab Republic, by Robert Smith. July 1984. 56 pp. This report presents the development and updating of economic indices for the Syrian Arab Republic for the period from 1970 through 1983; the phase I report covered the period 1970 through 1981. Factor input costs in the mining sector were described by 12 index time series: (1) mining wages, (2) construction wages, (3) equipment and repair costs, (4) bits and related steel, (5) timber and lumber, (6) fuel, (7) powder and blasting agents, (8) tires, (9) construction materials, (10) industrial materials, (11) transportation, and (12) electrical

power. The indices were developed primarily for use in the Bureau of Mines Minerals Availability Program in assessing the worldwide availability of nonfuel minerals. These indices combined with weight factors being developed by Bureau personnel will be used to perform updates of all costs relating to the mining industry. Research was done under contract J0225001 by Phoenix Associates, Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–215663; paper copy price code A04.

OFR 76–85. Development of Foreign Economic Indices, Phase II Update for Zambia, by Alice Chieruzzi. May 1984. 76 pp. 1 fig. This report presents the development and updating of economic indices for Zambia for the period from 1970 through 1983; the phase I report covered the period 1970 through 1981. Factor input costs in the mining sector were described by 12 index time series: (1) mining wages, (2) construction wages, (3) equipment and repair costs, (4) bits and related steel, (5) timber and lumber, (6) fuel, (7) powder and blasting agents, (8) tires, (9) construction materials, (10) industrial materials, (11) transportation, and (12) electrical power. The indices were developed primarily for use in the Bureau of Mines Minerals Availability Program in assessing the worldwide availability of nonfuel minerals. these indices combined with weight factors being developed by Bureau personnel will be used to perform updates of all costs relating to the mining industry. Research was done under contract J0225001 by Phoenix Associates, Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–215648; paper copy price code A05.

OFR 77–85. Development of Foreign Economic Indices, Final Contract Report, Phase I and II, by Phoenix Associates, Inc. Sept. 1984. 16 pp. This final report contains an overview of the project for developing foreign economic indices, details of the project output, project challenges and problems, and a summary of major accomplishments. Factor input costs in the mining sector of 95 countries were described by 12 index time series: (1) mining wages, (2) construction wages, (3) equipment and repair costs, (4) bits and related steel, (5) timber and lumber, (6) fuel, (7) powder and blasting agents, (8) tires, (9) construction materials, (10) industrial materials, (11) transportation, and (12) electrical power. The indices were developed primarily for use in the Bureau of Mines Minerals Availability Program in assessing the worldwide availability of nonfuel minerals. These indices combined with weight factors developed by Bureau personnel will be used to perform updates of all costs relating to the mining industry. Research was done under contract J0225001. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–215697; paper copy price code A02.

OFR 78–85. Maps Summarizing Land Availability for Mineral Exploration and Development in Southeastern Alaska, 1984, by William S. Roberts. 1984. 16 maps. Map compilations of land availability for mineral exploration and development in southeastern Alaska are based on the distribution and types of land status and areal relationship to mineral terranes and mineral deposits. Five categories of land availability were identified: open, open with possible use restrictions, selected, patented, and closed land. Compilation results of the five land availability categories are presented at a scale of 1:250,000. The mineral deposits, a total of 1,187 as compiled by the Bureau of Mines Minerals Availability System, are located on the maps for reference purposes. A tabulation of the names and principal commodities for each deposit is included adjoining each map. The maps include the following quadrangles: Atlin, Bradfield Canal, Craig, Dixon Entrance, Juneau, Ketchikan, Mount Fairweather, Mount St. Elias, Petersburg, Port Alexander, Prince Rupert, Sitka, Skagway, Sumdum, Taku, and Yakutat. Available for reference at AFOC/J, AFOC/F, and AFOC/J. Copies of these maps will not be available for purchase.

OFR 79–85. Strategic and Critical Materials Program Annual Report, by R. E. Chaney. May 1984. 281 pp. 109 figs. This report summarizes the research on the Strategic and Critical Materials Program tasks between May 1983 and April 1984. The work is divided into two areas: (1) production technologies and (2) conservation-substitution technologies. Production technologies, tasks directed at developing advanced extraction technologies, include biologically-assisted minerals processing, metal-gas reactions and thermal plasmas, and dehydration of aluminum chloride hexahydrate. Conservation-substitution technologies, tasks directed toward establishing the technical processing base that will permit the use of advanced materials, include joining of rapidly solidified alloys (RSA), joining of silicon nitride-based ceramics, and nondestructive evaluation of ceramic and RSA joints and materials. Research was done under contract J0134035 by the Idaho National Engineering Laboratory. Available for reference at AD/MMR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS; PB 85–216026; paper copy price code A13.

OFR 80–85. Radionuclides Technology, by Arpad E. Torma. Mar. 1985. 49 pp. 6 figs. This study has demonstrated the applicability of hydrochloric acid-containing brine solutions in the extraction of uranium and radionuclides from a low-grade ore. The method combines the advantages of hydrochloric acid and neutral brine solution leachings. The presence of brine in the leach solution improved the extraction of radionuclides from the ore, and final extractions as high as 97% uranium, 75% thorium-230, 96% radium-226, and 65% lead-210 were obtained. In this process, all the radioactive isotopes are extracted simultaneously. Uranium can be extracted selectively from the solution by solid ion exchange, for example, followed by the selective recovery of radium-226, then the other radionuclides. Research was done under grant G1125132 by the New Mexico Institute of Mining and Technology. Available for reference at AD/MMR and LIB. Copies of this report will not be available for purchase.

OFR 81–85. Subsurface Structure and Hydrocarbon Occurrence, Heidelberg-Sand Hill Graben System, Southeast Mississippi, by J. Keith Bowman and Maurice A. Meylan. Apr. 1985. 113 pp. 36 figs. The subsurface structure and hydrocarbon distribution of the Heidelberg-Sand Hill Graben System have been determined, utilizing 575 electric logs, existing field studies, and proprietary seismic data. This graben system, located on the eastern side of the Mississippi Salt Basin, extends for about 60 miles in a NNW-SSE direction from Jasper County to Green County, MS. The objectives of this research were threefold. Subsurface faults that comprise the Heidelberg-Sand Hill Graben System were delineated and portrayed on cross sections, structure maps, and isopach maps, providing a regional picture of the structural attitudes and sedimentation histories of the oil-prolific Mesozoic sediments. The structural locations of the known hydrocarbon accumulations in the Heidelberg-Sand Hill producing fields were examined to compare trap styles. The fault-hydrocarbon accumulation relationships were generalized to develop a model that can serve as an analog for future exploration. Research was done under grant G1134128 by the University of Southern Mississippi. Available for reference at LIB. Copies of this report will not be available for purchase.

OFR 82–85. Development of Engineering and Cost Data for Foreign Tin Properties, by R. L. Denny and D. J. Ottley. Dec. 1983. 53 pp. This report summarizes efforts in the development of engineering and cost data for tin properties in 12 foreign countries. The number and description of the various technical reports prepared and submitted are outlined. The evolving mines-deposits list and the accompanying criteria classifications are explained along with the verifications-

justifications for adding or deleting specific mines or deposits. Included are tabulated summaries of property data including reserves-resources, assays, production, and operating costs. Research was done under contract J0225004 by Davy McKee Corp. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–215838; paper copy price code A04.

OFR 83–85. A Comparison of the Effects of Various Soil Handling Equipment on the Density of Prime-Farmland Subsoils, by C. Steve Albrecht. June 30, 1984. 269 pp. 76 figs. The primary objective of this study is to evaluate the influences of different equipment systems on prime farmland subsoil compaction due to surface mining in the Midwest. The basis for this research effort centers on four major experiment designs: (1) comparison of soil bulk density values for three distinct equipment systems (i.e., scraper, bucket-wheel excavator, and end-dump haulback) evaluated on the same general soil types; (2) evaluation of the effects of soil replacement in repeated lifts using scrapers; (3) presentation of bulk density values representing soil compaction for four equipment systems (i.e., bucket-wheel excavator, dragline, scraper, and end-dump haulback) on four separate minesites in the Midwest; and (4) development of a prediction analysis model for subsoil bulk density following reclamation based on equipment characteristics and a statistical evaluation of texture. Research was done under contract J0225007 by Kenwill, Inc. Available for reference at AD/MR, DRC, OSM, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 85–241016; paper copy price code A13.

OFR 84–85. Development of Engineering and Cost Data for Foreign Columbium, Tantalum, Mercury, and Molybdenum Properties, by Pincock, Allen & Holt, Inc. Feb. 1985. 20 pp. This report outlines the number of deposits and country reports submitted for the four commodities studied in this contract. The initial and final deposit reports are listed in separate tables with explanations for the addition or deletion of specific deposits. Problems experienced during the course of the project are outlined. Separate sections are devoted to the discussion of comments and recommendations for future Minerals Availability Program studies, industry trends, and cost estimation methodology. Research was done under contract J0225022. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–215325; paper copy price code A02.

OFR 85–85. Desilicated Kaolin for High Alumina Refractories, by R. K. Koch, Davis E. Traut, and Jack L. Henry. 1985. 27 pp. 3 figs. The Bureau of Mines studied, on a limited basis, the preparation of high-alumina refractory-grade material from domestic kaolin clay as a substitute for refractory-grade bauxite. After calcination to remove water of hydration, the crushed clay was desilicated by a NaOH-KOH aqueous solution leach then dealkalized by a hydrochloric acid wash. Alternative desilication leaches with NaOH and KOH individually proved less effective. Alternative dealkalization with carbonic acid was also tested but proved unsuccessful. Substantial removal of iron and partial removal of titanium was effected by high-temperature hydrochlorination prior to desilication, but this might prove economically unfeasible. A typical final product after processing contained, in wt pct, 81.5 Al_2O_3, 11.2 SiO_2, 4.6 TiO_2, 0.3 Fe_2O_3, 0.15 K_2O, and 0.12 Na_2O. Refractory evaluation of this material indicated a pyrometric cone equivalent value of 36 to 37 and a modulus of rupture value of 105 psi at 1,400° C, both values being lower than desired. Further reduction of the titania content was suggested to attain adequate refractory properties. Available for reference at AD/MMR, ALRC, AVRC, RERC, RORC, SLRC, and TURC. Copies of this report will not be available for purchase.

OFR 86(1)–85. A Demonstration of Longwall Mining, by John R. Janes. Nov. 1983. 105 pp. 55 figs. The objective of this research was to introduce a workable longwall mining system into the Illinois No. 6 seam. Earlier attempts at longwall mining in the Illinois Basin had failed owing to inadequate ground control by chock-type roof supports available in the 1960's. As a result of a cost-sharing agreement between the Bureau of Mines and the Old Ben Coal Co. in 1975, longwall mining was demonstrated in Old Ben No. 24 Mine. The use of shield-type roof supports instead of chock-type roof supports appears to be the major factor contributing to successful roof control. Some of the advantages of shield-type roof supports are the short span of exposed roof, quickly applied support, stability of the structure, and full shelter for face personnel. The longwall at Old Ben No. 24 Mine was experimental in nature. Longwall productivity surpassed that of room-and-pillar mining, but not to a spectacular degree; however, subsequent longwalls at Old Ben Coal Co. mines were five times more productive. Research was done under contract J0333949 by Old Ben Coal Co. Available for reference at DRC, LIB, MSHA, NMH&SA, PRC/B, SRC, and TCRC. Copies of this report will not be available for purchase.

OFR 86(2)–85. A Demonstration of Longwall Mining—Appendix, by Dames & Moore. Nov. 1983. 371 pp. 190 figs. The objective of this research was to introduce a workable longwall mining system into the Illinois No. 6 seam. This appendix contains the results of the premining investigation in which the groundwork was done to select a roof support system. The premining investigation included (1) an analysis of bearing capacity of roof and floor rock in the vicinity of the projected longwall area, (2) a geological study comprising rock strata and faulting information, (3) a summary of previous longwall attempts, and (4) stress analysis on chock-type roof supports salvaged from a longwall face abandoned in 1967. Recommendations from the premining investigation led to the selection of shield-type roof supports. The primary advantage of the shields compared with chock-type powered support is greater stability. Shield-type roof supports are a three-jointed, kinematically determinate system that can easily advance while the canopy is in contact with the roof. All other powered support systems are four-jointed, kinematically indeterminate, and require holding springs or other devices for stability. Research was done under contract J0333949 to the Old Ben Coal Co. Available for reference at DRC, LIB, MSHA, NMH&SA, PRC/B, SRC, and TCRC. Copies of this report are not available for purchase.

OFR 87–85. Survey of Rollover Protective Structures (ROPS) Field Performance, by Jack L. Woodward. Nov. 1980. 131 pp. 32 figs. Analyses of rollover accidents were conducted and rollover protective structure (ROPS) test data were reviewed to determine whether ROPS provide adequate operator protection. It was found that ROPS generally exceed structural performance requirements and do reduce the number of injuries and deaths due to rollovers on mining and construction machines. It was also determined that the severity of rollovers vary widely between different types of machines, that quality control during ROPS fabrication is very important, and the chances of surviving a rollover are enhanced substantially by wearing a seat belt. Research was done under contract J0285022 by Woodward Associates, Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–246189; paper copy price code A07.

OFR 88–85. Demonstration of Shield-Type Longwall Supports at Kaiser Steel Corporation's No. 1 Mine, Utah, by P. M. Hawley and M. Hood. May 1983. 50 pp. 13 figs. The performance of approximately 115 shield supports employed in 2 panels at Kaiser Steel's Sunnyside No. 1 Mine is described. These Hemscheidt 320 HSL caliper-type shields were installed originally at Kaiser Steel's York Canyon Mine as a demonstration program and later were transferred to Sunnyside. This report describes the rehabilitation of the shields prior to their installation at the second mine and the mining experience using these supports. The findings show that, in general, the shield

supports were able to perform adequately in the wide range of seam heights (from about 6 ft to about 10 ft) within each panel. Some problems were experienced with roof stability immediately ahead of the supports (the only strata control problem experienced with these units); this may be attributable to the movement of the roof canopy away from the face, an inherent feature of caliper units. Overall, the supports functioned well. During the trials, a 24-hour production record was set with 20,384 tons mined. Throughout the mining of both panels, high production and productivity were maintained. Although mining conditions are not directly comparable between these panels and an adjacent panel that was mined with chock supports, the peak productivity was between 20 and 55 pct higher in the panels where shields were employed. Research was done under contract J0233912 by the Kaiser Steel Corp. Available for reference at AD/MR, DRC, LIB, MSHA, NMH&SA, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 85–240406; paper copy price code A04. $11.95.

OFR 89–85. Development of a Closed Circuit TV Borehole Probe, by Douglas Talley. Sept. 1984. 22 pp. 9 figs. This report describes a 4-in-diam borehole probe that contains a low light level television camera, magnetic compass, light illumination source, bottom-water detector sensor, and a point angle sensor. The camera viewing angle is at a right angle to the probe's body. All data from the sensor are multiplexed into the closed-circuit camera video for transmission on a single 50-ohm coaxial cable to a surface control unit. Likewise, control of the probe's power, zoom lens, focus, panning, and aperture is accomplished via a downlink multiplexed on the same cable. Research was done under contract H0308041 by the Design Engineering Laboratories, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–240414; paper copy price code A02. $9.95.

OFR 90–85. Biomechanical and Work Physiology Study in Underground Mining Excluding Low Coal, by M. M. Ayoub, J. L. Selan, C. L. Burford, K. Intaranont, H. P. R. Rao, J. L. Smith, D. K. Caddel, W. M. Bobo, N. J. Bethea, and H. Chang. July 1984. 211 pp. 15 figs. In this project, a biomechanical and work physiology study of underground mines (excluding low coal) was conducted to generate data to be utilized in equipment and job design. Anthropometric, strength, physical work capacity, and nutritional intake measurements were collected on miners. Energy expenditure and postural data were collected on mining tasks to identify those tasks that were demanding. Male underground miners were not significantly different from comparison populations in terms of anthropometric characteristics, but they were significantly stronger. Females were heavier and larger in terms of circumferential measurements than comparison populations and were stronger. Both males and females were generally rated low in terms of aerobic capacity, and their nutritional intake did not appear to be adequate in terms of daily energy expenditure or recommended dietary allowances. Daily energy expenditures for mining jobs appeared to be reasonable in terms of percentage aerobic capacity, but this was due largely to travel and down time. Several mining tasks imposed stressful postures on miners. Recommendations based on the data collected are made. Research was done under contract J0308058 by the Institute for Ergonomics Research, Texas Tech University. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 85–243566; paper copy price code A10. $22.95.

OFR 91–85. Trailing-Cable Construction Improvements. Development of a Conductive-Rubber Shielded Trailing Cable, by L. A. Morley and J. N. Tomlinson. Mar. 1985. 54 pp. 18 figs. A prototype flat three-conductor number 6 AWG G-GC shuttle-car trailing cable has been fabricated in an SHD configuration using a conductive-rubber shield material with volume resistivity of 32 ohm-cm. Resistances measured through the shield, between a penetrating object and the cable grounding conductor, are 1,000 ohms or less. The conductive rubber can be easily stripped from the insulated conductors, which is important for splicing. An SHC splicing approach appears to be practical and effective. In-mine evaluation with high-sensitivity ground-fault relaying is recommended. Research was done under contract J0338001 by the Pennsylvania State University. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–239978; paper copy price code A04.

OFR 92–85. Respirable Dust Measurement, by Virgil A. Marple and Kenneth L. Rubow. Mar. 1984. 154 pp. 75 figs. The objective of this research was to conduct characterization, evaluation, and/or calibration studies of instrumentation used for measuring the quantity of respirable dust in mining atmospheres. Initially, this work involved the upgrading and detailed evaluation of the aerosol test chamber and the development of impactors with respirable classification characteristics. These were used as standards in the chamber for measuring the quantity of respirable dust based on either the American Conference of Governmental Industrial Hygienist or British Medical Research Council respirable dust criteria. A program was then conducted to calibrate several photometers. In addition, the mass sensitivity of the GCA RAM-1 photometer to water droplets in the respirable size range was determined. Three additional studies were also made in this program: (1) An experimental study was performed to ascertain the effect of crosswind, cyclone orientation, and particle size on particle sampling and penetration through the 10-mm Dorr-Oliver cyclone. (2) A theoretical study was conducted to refine the theory used to predict the particle collection characteristics of impactors. (3) Filter samples with known quantities of diesel and coal particles were produced and delivered to the Bureau of Mines for testing a Raman scattering analysis technique to discriminate diesel particles in the presence of coal dust. Research was done under contract J0113042 by the University of Minnesota Particle Technology Laboratory. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–245843; paper copy price code A08.

OFR 93–85. Sulfur Extraction From Elemental Sulfur-Bearing Materials, by B. P. Herve, B. R. Eichbaum, J. E. Murphy, and R. G. Sandberg. 1985. 11 pp. 8 figs. The Federal Bureau of Mines devised two high-temperature solvent extraction techniques to recover elemental sulfur from a leached residue generated from leaching a lead concentrate with ferric chloride and sodium chloride. The procedures are similar except for the mechanisms by which the sulfur is extracted from the residue, and the temperatures to which the extractants are cooled to induce sulfur solidification. One method uses an organic liquid carrier to melt sulfur out of the residue, and the other uses an organic liquid for its properties as a solvent for sulfur. In the carrier procedure, leached residue and carrier were mixed and heated at atmospheric pressure to above the melting point of sulfur. The hot slurry was filtered to separate the solids from the filtrate, which was a mixture of the carrier and liquefied sulfur. The filtrate was cooled to 110° C and filtered again to separate the solidified sulfur product from the carrier. Sulfur recovery was 61 pct and purity was at 99.9 pct. In the carrier-solvent procedure, the sulfur-loaded filtrate was cooled to 20° C rather than 110° C to precipitate dissolved sulfur. Sulfur recovery was 93 pct and purity was 99.9 pct. For both procedures, the reclaimed extractants were suitable for reuse. Research was done at the Reno Research Center of the Bureau of Mines. Available for reference at AD/MMR, ALRC, AVRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–101680; paper copy price code A02.

OFR 94–85. Sorption of Lithium From a Geothermal Brine by Pelletized Mixed Aluminum-Lithium Hydrous Ox-

ides, by L. E. Schultze and D. J. Bauer. 1985. 19 pp. 13 figs. An inorganic ion exchanger was evaluated by the Bureau of Mines for recovering lithium from geothermal brines. The ion exchanger or sorbent was mixed hydrous oxide of aluminum and lithium that had been dried at 100° C. The dried precipitate was pelletized with a sodium silicate binder to improve flow rates in sorption tests. The sorbent was loaded to 2 mg Li/g of pellets, and sorption from the solution was independent of the concentrations of Ca, Fe, Mn, and Zn. Manganese and zinc were sorbed by the pellets but did not suppress lithium sorption. Lithium was desorbed with water, but none of the washing solutions investigated removed entrained brine without stripping lithium. The complex nature of the sorption mechanisms is discussed. Research was done at the Bureau of Mines Reno Research Center. Available for reference at AD/MMR, AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 85–245686; paper copy price code A02.

OFR 95–85. Low Temperature Processes for Production of Non-Equilibrium Materials, by G. L. Messing, T. J. Gardner, and R. Roy. June 1984. 44 pp. 12 figs. The influence of salt precursor on the characteristics of MgO powders synthesized by the evaporative decomposition of solutions (EDS) technique is presented. Thermal analysis results are used to determine the decomposition path for the $Mg(C_2H_3O_2)_2{\cdot}4H_2O$, $MgCl_2{\cdot}6H_2O$, $Mg(NO_3)_2{\cdot}6H_2O$, and $MgSO_4$ salts. MgO powders with surface areas ranging from 30 to 150 m^2/g have been prepared from the acetate and nitrate precursors. The decomposition of the chloride and sulfate precursors is incomplete during EDS as a result of kinetic limitations imposed by the high heating rate (≅300° C/sec) associated with the EDS process. Generally, the particle morphology consists of large aggretates for powders produced from the chloride, nitrate, and sulfate precursors. However, fine, dispersed submicrometer particles are formed from the acetate precursor. This difference is attributed to the fragmenting of the dried acetate salt aggregate during the exothermic decomposition of the acetate salt, whereas the dried salt aggregate structure persists for the other precursors, with strong MgO crystalline aggregates forming owing to localized sintering following salt decomposition. The thermal analysis results and the powder characteristics demonstrate that these differences in particle morphology are a direct result of the decomposition path of the precursor salt. Research was done under contract J0225003 at the Pennsylvania State University. Available for reference at AD/MMR, ALRC, AVRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 85–245173; paper copy price code A03.

OFR 96–85. Resource Recovery of Strategic and Other Metals From ECM and EDM Operations, by L. J. Holcombe, G. B. DeWolf, L. O. Edwards, and R. F. Klausmeier. Sept. 1984. 92 pp. 9 figs. The development and widespread use of electrochemical machining (ECM) and electrical discharge machining (EDM) have created a new source of heavy metal sludges. These sludges often contain large quantities of strategic metals, including chromium and nickel; however, there was not a great deal of compositional uniformity. The presence of cobalt in ECM sludges was not uncovered, but cobalt was present in some EDM sludges. The quantity of EDM sludge generated was significantly less than the volume of ECM materials produced. The ECM and EDM wastes were evaluated on a dry basis nickel content in order to select the best available technology for extracting nickel and possibly cobalt from these materials. Two methods are proposed: (1) the dried hydroxide approach, where the dry material would be sold to a toll company for its nickel content, and (2) the ammoniacal leach-solvent extraction approach, which would recover nickel sulfate and possibly cobalt and copper metals as cementation products. Research was done under contract J0145013 by the Radian Corp. Available for reference at AD/MMR, ALRC, AVRC, LIB, MSHA, PRC/B, RERC, RORC, SLRC, and TURC. Copies of this report will not be available for purchase.

OFR 97–85. Critical and Strategic Minerals Investigations in Alaska: Chromium, by Jeffrey Y. Foley, James C. Barker, and Lawrence L. Brown. May 1985. 54 pp. 7 figs. The Bureau of Mines investigated chromite deposits and occurrences in Alaska between 1979 and 1984 as part of the Bureau's critical and strategic minerals program. Beneficiation and mineralogical characterization tests were performed on 68 samples. Chromite-bearing ultramafic rocks occur in eight regions in Alaska. An estimated 3,414,000 to 4,266,000 tons of chromite oxide (Cr_2O_3) in high-chromium and high-iron chromite are contained in 132 subeconomic podiform-type deposits and 1 placer deposit. In most cases, minesite beneficiation would be required to produce shipping-grade concentrates. In the Chugach trend, an inferred reserve base is comprised of 2,800,000 tons of Cr_2O_3 in 42 deposits that are all within 10 miles of tidewater or existing transportation routes. Most of these are indicated reserves (1,812,000 tons) contained in the newly discovered Turner stringer zone and Windy River placer deposit at Red Mountain and inferred reserves at the Halibut Bay complex on Kodiak Island. Between 576,000 and 1,394,000 tons of high-chromium chromite are contained in 70 less accessible deposits in the remote western Brooks Range. The Rampart, Yukon-Koyukuk, and Alaska Range trends and the southeast Alaska region contain deposits with minor production potential. Chromite also occurs in southwest Alaska and in the Yukon-Tanana uplands, but no significant deposits are known and no reserves were estimated. Available for reference at AD/MDA, AFOC/A, AFOC/F, AFOC/J, ALRC, LIB, and RERC. Copies of this report will not be available for purchase.

OFR 98–85. Flotation of Pyrochlore From Powderhorn District, Colorado, Ore, by E. Morrice and G. M. Martinez. 1985. 15 pp. 5 figs. An investigation was undertaken by the Bureau of Mines to devise a flotation method for concentrating the pyrochlore in a Powderhorn, CO, ore (0.43 pct Cb_2O_5). The technique involved regrinding and flotation of pyrochlore from a rougher tailing product obtained by flotation of the biotite and apatite gangue. Cocoamine acetate and hydrofluosilicic acid were used in the pyrochlore flotation step that produced a rougher concentrate containing 17 pct of the feed, assaying 1.21 pct Cb_2O_5 and representing 47 pct columbium recovery. Tests on the rougher concentrate to float a cleaner concentrate yielded a 2.62-pct-Cb_2O_5 product at a recovery of 22.6 pct of the columbium in the ore. Fine grinding was used to liberate the pyrochlore from the gangue minerals and, as such, resulted in the generation of slimes that contributed to problems in flotation. Yet, the flotation technique investigated indicates that flotation has potential as a beneficiation method for the Powderhorn, CO, ore. Research was done at the Reno Research Center of the Bureau of Mines. Available for reference at AD/MMR and LIB. Order ONLY from NTIS: PB 86–101912; paper copy price code A03.

OFR 99–85. Blast Furnace Operation With Oxygen-Enriched Unheated Blast Air, by P. L. Woolf. Mar. 1985. 24 pp. Three trials with oxygen-enriched unheated blast air are described. The trials were conducted in the Bureau of Mines experimental blast furnace located in Bruceton, PA. In the first trial, moisture was added to the oxygenated blast. The second and third trials were conducted with natural gas injection. The test was basically a feasibility study; the practice was demonstrated to be feasible and also have possible advantages over hot blast operation. The testwork was conducted in 1964 and 1965 as part of a continuing study of ironmaking technology in cooperation with several North American steel companies. Research was done under contract J0134049. Available for reference at AD/MMR, AFOC/J, ALRC, AVRC, DRC, IFOC, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–101854; paper copy price code A02.

OFR 100–85. Detection of Potential Inundation Hazards by Overwater Seismic Methods, by John J. Miller,

Robert A. Speirer, M. W. Lee, and A. H. Balch. Aug. 1984. 48 pp. 29 figs. The Bureau of Mines and the U.S. Geological Survey conducted a joint overwater seismic study at Rend Lake, IL, in the fall of 1980. The objective was to map fault trends adjacent to underground coal mine workings overlain by a shallow body of water. The nature of the lake bottom was found to act as a wave guide and reverberative mechanism so that water bottom multiples obscured all reflections from depth. This occurrence was proved by the application of extensive computer modeling programs to the data, which removed all reverberative energy and left no primary reflections. Research was done under contract H0292033 by the U.S. Geological Survey. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 101–85. Trailing Cable Maintenance Improvements—Splice Training, by L. A. Morley and J. N. Tomlinson. Sept. 1984. 27 pp. The report summarizes prior research on underground trailing cable splices leading to the current project on videotape and hands-on training for mine mechanics. A videotape was produced for splicing three-conductor flat cable and was used in training 22 miners in three 2-hour training sessions. Recommendations for improving the videotape and instruction procedures are presented. Research was done under contract J0338002 at The Pennsylvania State University. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–113396; paper copy price code A03.

OFR 102–85. Satellite Monitoring for a Coal Waste Embankment, by F. J. Prokoski, J. T. Byrne, Jr., and D. J. Bryant. Sept. 1984. 45 pp. 29 figs. The COALSTAR Project, which operated from November 1981 to December 1982, was a research and development project aimed at providing a reliable and inexpensive means of monitoring various waste site conditions via the Geostationary Operational Environmental Satellite (GOES) system. The GOES system provides data transfer from unattended isolated sites where neither power nor telephone lines exist. The reliability and resolution of the data received while using the satellite link were excellent; however, the site instrumentation gave considerable trouble. The disastrous failure of a large coal waste embankment in 1972 led the Bureau of Mines to undertake a comprehensive program to reduce the likelihood of recurrence. Part of this program involved the installation of instruments to monitor the stability of a specially selected embankment near Montcoal, WV. Initially, the instruments were monitored by normal telephone lines and used normal commercial power from the local utility. The project described here was initiated to replace this monitoring system with an unmanned, solar-powered data collection system that transmitted data via satellite to a central computer facility. The satellite data network is the National Earth Satellite Service of the National Oceanic and Atmospheric Administration. Research was done under contract H0212017 by Energy Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 103–85. The Safe Handling of Materials in Bins, by M. D. Marshall. Nov. 1984. 59 pp. 23 figs. This handbook is for the engineer or person responsible for the storage and removal of material from bins and silos in the minerals industry. The objective of the handbook is to prevent bin-related accidents by eliminating problems that require workers to enter bins. It provides basic information on handling materials so that knowledgeable decisions can be made on bin design and accessories to minimize flow stoppages. Materials are classified in terms of their flowability, and bin design and accessories are suggested for each classification. A method for classifying a material is also given, and the various types of material flow aids are reviewed. Safety around bins is the basic theme of the handbook. Federal regulations are reviewed, and additional suggestions are presented to prevent bin accidents. New equipment for releasing material hangups is reviewed. Research was done under contract H0318008 by MSA Research Corp. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–137122; paper copy price code A04.

OFR 104–85. Development of Safer Methods To Clean Down Storage Bins, by M. D. Marshall. Nov. 1984. 39 pp. 7 figs. A survey showed that there were 24 bin-related fatalities in the 5-year period from 1975 to 1979 in the minerals industry. Only four victims wore safety belts and only one of these had a second person attending his lifeline, as mandated by Federal safety regulations. Not one victim observed the three main Federal safety regulations governing work in and around bins. A study was conducted on the force necessary to pull victims partially buried in sand and limestone. Recommendations are made on procedures and safety equipment that can minimize bin-related accidents. A handbook, directed to the plant engineer responsible for bin design and safety, was also issued detailing bin designs and flow-aid accessories as a function of the flowability of the stored material to better maintain material flow from bins. A comprehensive table of the flowability of many materials produced in the minerals industry is presented, and simple procedures are given for determining the flowability of materials if not available. Research was done under contract H0318008 by MSA Research Corp. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–111234; paper copy price code A03.

OFR 105–85. Mine Particulate Size Characterization, by R. W. Welker, W. Eisenberg, R. A. Semmler, and G. J. Yucuis. Jan. 1982. 207 pp. 6 figs. A technique was developed for sampling and analyzing airborne dusts in diesel-operated underground metal and nonmetal mines. Samples were taken using personal respirable samplers, operated as area samplers, and an 11-stage cascade impactor. Real-time particle size distribution and concentration measurements were made with a quartz crystal microbalance cascade impactor and a portable electrical aerosol analyzer. The materials characterized were minerals (by X-ray diffraction), elements (by X-ray fluorescence), particle size distribution and concentration (gravimetrically), and organic constituents (by high-performance liquid chromatography). The method was used to characterize dusts generated at the chute pulling operations on the main haulage level of an underground tungsten mine. Analysis showed that respirable dust concentration ranged from 0.8 to 2.3 mg/m^3. It consisted of silica (3% to 7%), organic constituents from diesel exhaust (0.11 to 0.31 mg/m^3 equivalent airborne concentration), and mineral dust (39% to 100%). The remainder was diesel exhaust particles. It was concluded that size selective sampling may be used to estimate the ratio of diesel exhaust to nondiesel dusts in the respirable fraction. Research was done under contract J0199086 by IIT Research Institute. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–142163; paper copy price code A10.

OFR 106(1)–85. Cost-Effectiveness of Dust Controls Used on Unpaved Haul Roads. Volume I—Results, Analysis, and Conclusions, by Keith D. Rosbury and Robert A. Zimmer. Dec. 1983. 139 pp. 17 figs. The basic objective of this project was to determine the cost-effectiveness of dust controls used on unpaved mine haul roads. Field testing was conducted at three surface coal mines (two in Wyoming, one in southern Illinois) for a total of 20 weeks. The highest control efficiency measured for a chemical dust suppressant, 82 pct, was for calcium chloride 2 weeks after application. Generally, however, the control efficiencies hovered in the 40 to 60 pct range over the

first 2 weeks after application, and then decreased with time. After the fifth week, the limited number of data points suggests a control efficiency of less than 20 pct. Composite watering data were fairly uniform. Watering once per hour resulted in a total suspended particulate control efficiency of approximately 40 pct. Doubling that application rate increased the control effectiveness by about 15 pct to 55 pct. Chemical dust suppressants (primarily salts and lignons) can be shown to be more cost-effective than watering under some conditions. Data summaries and the analysis of data are contained in volume I. Volume II contains basic data. Research was done under contract J0218021 at PEDCo Environmental, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–115201; paper copy price code A07.

OFR 106(2)–85. Cost Effectiveness of Dust Controls Used on Unpaved Haul Roads. Volume II—Data, by Keith D. Rosbury and Robert A. Zimmer. Dec. 1983. 169 pp. The basic objective of this project was to determine the cost-effectiveness of dust controls used on unpaved mine haul roads. Field testing was conducted at three surface coal mines (two in Wyoming, one in southern Illinois) for a total of 20 weeks. The highest control efficiency measured for a chemical dust suppressant, 82 pct, was for calcium chloride 2 weeks after application. Generally, however, the control efficiencies hovered in the 40 to 60 pct range over the first 2 weeks after application, and then decreased with time. After the fifth week, the limited number of data points suggests a control efficiency of less than 20 pct. Composite watering data were fairly uniform. Watering once per hour resulted in a total suspended particulate control efficiency of approximately 40 pct. Doubling that application rate increased the control effectiveness by about 15 pct to 55 pct. Chemical dust suppressants (primarily salts and lignons) can be shown to be more cost-effective than watering under some conditions. Data summaries and the analysis of data are contained in volume I. Volume II contains basic data. Research was done under contract J0218021 at PEDCo Environmental, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–115219, paper copy price code A08.

OFR 107(1)–85. Methane Modeling—Predicting the Inflow of Methane Gas Into Coal Mines. Volume 1—Final Report, by F. C. Schwerer, E. R. Bollinger, A. M. Pavone, and H. R. Kokal. Dec. 1984. 238 pp. 99 figs. A two-dimensional, numerical, mathematical model has been developed to predict methane influx into coal mines under a variety of mining conditions. A set of time-dependent, partial differential equations for two-phase Darcy flow in a porous medium was developed. The equations comprehend various microscopic flow phenomena and time- and pressure-dependent adsorption and desorption of methane. One-dimensional models were expanded to two-dimensional models by appropriate geometric modification of the basic equation set. Numerical solutions were obtained with an implicit method-of-lines technique. Boundary conditions corresponding to the appropriate mining system can be selected. The model and solution procedure are coded in a structured dialect of FORTRAN, and a preprocessor is included for adaptation to popular computer systems. To obtain data for comparison with the model, methane measurements were made in three coal mines in the Eastern United States to encompass a range of gas contents, porosities, permeabilities, coal rank, and mining methods. Results of the simulation of methane emission during advance of the mining face following idle periods were in general agreement with observed values. Volume 1 contains the final report and summary, methane measurement data, mathematical components, and simulation demonstrations. Research was done under contract J0333952 by the United States Steel Corp. Available for reference at ALRC, AVRC, DRC, LIB, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–116878; paper copy price code A11.

OFR 107(2)–85. Methane Modeling—Predicting the Inflow of Methane Gas Into Coal Mines. Volume 2—Computer Source Codes, by F. C. Schwerer, E. R. Bollinger, A. M. Pavone, and H. R. Kokal. Dec. 1984. 362 pp. 33 figs. A two-dimensional, numerical, mathematical model has been developed to predict methane influx into coal mines under a variety of mining conditions. A set of time-dependent, partial differential equations for two-phase Darcy flow in a porous medium was developed. The equations comprehend various microscopic flow phenomena and time- and pressure-dependent adsorption and desorption of methane. One-dimensional models were expanded to two-dimensional models by appropriate geometric modification of the basic equation set. Numerical solutions were obtained with an implicit method-of-lines technique. Boundary conditions corresponding to the appropriate mining system can be selected. The model and solution procedure are coded in a structured dialect of FORTRAN, and a preprocessor is included for adaptation to popular computer systems. To obtain data for comparison with the model, methane measurements were made in three coal mines in the Eastern United States to encompass a range of gas contents, porosities, permeabilities, coal rank, and mining methods. Results of the simulation of methane emission during advance of the mining face following idle periods were in general agreement with observed values. Volume 2 contains a guide to the computer program, flowcharts, and source codes. Research was done under contract J0333952 by the United States Steel Corp. Available for reference at ALRC, AVRC, DRC, LIB, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–116886; paper copy price code A16.

OFR 108–85. Development of Environmentally Attractive Leachants. Volume III, Geochemical Flow Modeling, by Robert S. Schechter, Larry W. Lake, and Mark P. Walsh. Mar. 1985. 336 pp. 38 figs. This report describes the development and application of PHASEQ/FLOW, a geochemical flow simulator capable of describing the dynamic changes in chemical composition of an aqueous solution during flow in a permeable medium. The solution components can react through intraaqueous reactions, redox, precipitation, or dissolution. The assumption of local thermodynamic equilibrium ensures maximum generality with respect to the number of species and components possible; however, the fluid flow itself is limited to one dimension. The report describes several applications: generic batch equilibria, flowing equilibria, uranium roll-front deposition, and roll-front leaching. Research was done under contract H0232016 at The University of Texas at Austin. Available for reference at AFOC/J, ALRC, AVRC, DOI, DRC, IFOC, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–110285; paper copy price code A15.

OFR 109–85. Advancement of Cab and Canopy Design and Use in Coal Mines, by W. W. Aljoe and K. L. Whitehead. Aug. 1981. 306 pp. 83 figs. The use of protective canopies can result in canopy roofing and/or serious restrictions to operator comfort and vision. To document this experience, a field study was conducted of cab and canopy design and application that resulted in a catalog of 164 canopy designs. An analysis of field data showed no simple relationship between working height and canopy-related problems. The relationship also involves (1) machine frame height, (2) mine floor undulations, (3) operator compartment dimensions, and (4) canopy design and location on the machine. Data analysis indicates (1) present technology does not always permit successful application of canopies in working heights below 42 inches and (2) development of satisfactory low-coal canopies is doubtful. The basic conclusion of the study is that future research and development studies should be directed at development of alternative protection systems and remote mining methods. Research was done under contract J0199005 by Bituminous Coal Research, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC.

Order ONLY from NTIS: PB 86–153574; paper copy price code A14.

OFR 110–85. Improved Oxygen Sources for Breathing Apparatus—Final Report, by Peter C. Wood and Theodore Wydeven. Aug. 1983. 160 pp. 23 figs. This report describes research directed toward the preparation of chemical oxygen (O_2) sources that exhibited improved O_2 storage and reaction characteristics when compared with potassium superoxide (KO_2). The initial focus of the research was the preparation of calcium superoxide ($Ca(O_2)_2$) by the disproportionation of calcium peroxide diperoxyhydrate. The $Ca(O_2)_2$ was characterized by chemical, thermal, and X-ray analyses. Several methods for scaling up the $Ca(O_2)_2$ synthesis process were studied. Next, the reactivity of $Ca(O_2)_2$ toward humidified carbon dioxide (CO_2) was evaluated and was compared with that of KO_2 under flow-test conditions approximating those existing in portable breathing apparatus. The reactivities of mixtures of KO_2 and $Ca(O_2)_2$ or lithium peroxide toward humidified CO_2 were also studied. Finally, an analysis of two commercial, KO_2-based, self-contained self-rescuers was conducted to determine the potential weight and volume savings that would be possible if $Ca(O_2)_2$ or a mixture of KO_2 and $Ca(O_2)_2$ were used as a replacement for KO_2. Research was done under contract H0242047 by the National Aeronautics and Space Administration Ames Research Center. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: N 85–35623; paper copy price code A08.

OFR 111–85. Interagency Comparison of Respirable Quartz Analysis, by C. W. Huggins, K. B. Shedd, J. G. Snyder, H. W. Lang, and T. F. Tomb. July 1985. 67 pp. 3 figs. An interagency investigation was conducted to compare results from five laboratories using infrared spectroscopy and X-ray diffraction techniques to quantitatively determine the quartz content of respirable coal mine dust. The importance of using a quartz standard having the same particle size distribution as the samples analyzed is underscored for both analytical methods. High-temperature ashing techniques in sample preparation were found to contribute to analytical error. Various factors in the preparation of quartz standards are examined, including quartz materials, matrix, and filter type. Laboratories taking precautions to minimize the effects of variation sources discovered during these investigations will be able to place greater confidence in their determinations of quartz in respirable dusts. Research was done at the Avondale Research Center. Available for reference at the following facilities: AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 112–85. Generalization of Medical and Health Compliance Research to Coal Mine Safety, by H. P. Cole, P. K. Berger, T. F. Garrity, C. D. Auvenshine, A. B. Szwilski, M. Hernandez, D. K. Blythe, and W. E. Lacefield. Feb. 1985. 206 pp. 1 fig. Methods for increasing compliance to medical and health regimens were reviewed along with similar research in industrial and mine safety. Principles abstracted from both areas suggest that compliance with health and safety practices is improved when (1) workers are cooperatively involved with management in setting safety goals and planning for their achievement, (2) the program has the support of workers, supervisors, and management, (3) specific tasks responsible for injuries are targeted, (4) company organizational policy, educational, and behavioral programs work together toward the same goals, (5) workers and supervisors are frequently informed about their degree of correct task performance, and (6) programs are monitored by the frequency of correct performance of targeted tasks (the means to lowered accident rates) rather than by lowered accident and injury rates themselves (the goals for safety programs.) Safety programs that incorporate these principles increase persons' adherence to specified health and safety practices and subsequently decrease injury rates. Research was done under contract P0333468 by the Institute for Mining and Minerals Research, University of Kentucky. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–138989; paper copy price code A10. $22.95.

OFR 113–85. Products of the Oxidative Thermal Degradation of Elastomeric Noise Abatement Materials and Woods, by K. L. Paciorek, R. H. Kratzer, J. H. Nakahara, D. H. Harris, and S. R. Ahmed. Apr. 1982. 152 pp. 81 figs. The primary objective of this program was to determine the toxic fume and fire hazards of elastomeric noise abatement materials with a limited effort expended on the evaluation of specific treatments applied to mine timbers. Under the conditions employed, the major toxic hazard for a dimethyl silicone rubber was formaldehyde; for both polyester and polyether urethanes and an acrylonitrile-butadiene-styrene resin, acrolein; for flame-retardant styrene-butadiene rubber compositions, hydrogen chloride; and for Pyresote-Firehold 10-Albi 144-treated timber, furfural. Of the materials studied, the flame-retardant styrene-butadiene rubbers presented the greatest toxic hazard. The generated data have been reduced to toxic load tabulations amenable to employment for potential hazard assessment. Research was done under contract J0395008 by Ultrasystems, Inc. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–160199; paper copy price code A08.

OFR 114–85. Development of a Roof Competence Tester, by J. B. Czirr. June 1985. 63 pp. 26 figs. A 4-year program was completed to develop a technique for measuring roof competence in underground coal mines. The preferred technique employs a tracer gas that is injected into a roof borehole drilled near the working face. The tracer gas performs the dual purpose of determining the pressure loss rate from the borehole and of marking the diffusion pattern of the escaping gas. The primary detection technique relies upon observation of the rate of pressure drop in a hole drilled in the roof strata under test. If this measurement indicates a significant probability of roof collapse, the gas diffusion pattern is outlined with the Leakgun tracer-gas detector. These two techniques provide a comprehensive method for predicting the relative probability of roof collapse in operating coal mines. Research was done under contract H0100088 by Minority Enterprise Service Associates Corp. Available for reference at ALRC, AVRC, DRC, LIB, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–135415; paper copy price code A04.

OFR 115–85. A Medium Frequency Wireless Communication System for Underground Mines, by Larry G. Stolarczyk. Sept. 1984. 221 pp. 64 figs. A medium-frequency (MF) wireless communication system for underground mines, a new telecommunication system, works on low loss electromagnetic wave propagation modes that allow it to provide quality radio communications almost anywhere in a mine. Tests show the MF system can provide improved safety and managerial control, increased productivity, better organizational teamwork, and reduced maintenance costs; furthermore, the MF system's unique design allows for easy installation at a minimum cost. This report covers (1) the MF design plan, (2) an overview of mine radio communications systems, (3) preparations needed for designing an MF system, (4) MF equipment, (5) MF installation, (6) MF design considerations, (7) MF design specifications, and (8) recommendations dealing with the system. Experiments in four mines are illustrated to demonstrate the success and viability of the MF system. The mines range from small (500 tons/day) to large (67,000 tons/day) capacity and represent several different mining methods. The MF wireless communication system represents an advancement in mining communication and the groundwork for other advanced mine systems. Research was done under contract

H0308004 by A.R.F. Products, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–134103; paper copy price code A11.

OFR 116–85. Demonstration of a Mine Shaft Fire and Smoke Protection System for Coal Mines, by Ralph B. Stevens. Mar. 1983. 294 pp. 54 figs. The goal of this research was to increase the safety of workers in underground coal mines by developing and in-mine testing a low-cost, available, and flexible fire safety system to reduce the spread of fire and contaminated air in or near mine shafts. The work detailed information on the magnitude of the hazard, industry acceptance of remote data acquisition systems, and alternative fire safety systems to meet four different mine profiles. A complete fire reporting system was designed, installed, and in-mine tested at a Midwest underground coal mine from April 1980 to March 1983. The surface-located master control unit provided analog displays of real-time sensor data and a printer graph-record of the last 24 hours of activity. Fire warning sensors included ionization particle sensors, electrochemical cell carbon monoxide (CO) analyzers, a solid-state CO analyzer, and continuous heat-sensitive wire sensors. Multiplex telemetry of data occurred on existing telephone lines and wireless radios from shafts up to a 5-mile distance. Four fire conditions occurred during in-mine testing that demonstrated the system's effectiveness. Evaluation of converting the system to meet MSHA approval is included. Research was done under contract H0100017 by ESD Corp. Available for reference at AD/MR, DRC, LIB, MSHA, NMH&SA, PRC/B, TCRC, and SRC. Order ONLY from NTIS: PB 86–146933; paper copy price code A13.

OFR 117–85. An Alternative Method To Evaluate Mine Ground System Safety, by W. L. Cooley, H. W. Hill, and M. L. Maberry. Feb. 1985. 138 pp. 57 figs. A significantly different method of evaluating mine ground system safety was investigated. The method measures touch and step potentials around ground beds and grounded equipment resulting from a series of extremely small simulated faults. The values are then scaled for a full-scale fault. The method should be particularly useful for large ground beds and under conditions where the ground bed cannot be isolated from the rest of the ground system in order to make traditional ground bed resistance measurements. Instrumentation for making the alternative measurements was evaluated under rigorous field conditions. A step-by-step procedure is proposed for evaluating a surface mine ground system. This procedure was subject to several field tests at eastern metal mines and nonmetal mines. The final evaluation procedure is written as a stand-alone document for use by MSHA inspectors and mine operating personnel and is included as an appendix to the report. Research was done under contract H0338023 at West Virginia University. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–130523; paper copy price code A07.

OFR 118–85. Development of Self-Contained Self-Rescuer and Enhanced Electrical Hazard Training Materials, by Michael J. Klishis. May 1985. 86 pp. 45 figs. It was the goal of this project to develop training materials specific to two areas of the mining industry: (1) safe use and care of the self-contained self-rescuers, and (2) awareness and avoidance of electrical hazards. This report describes the development of instructor's training modules for self-contained self-rescuers (OCENCO EBA 6.5, CSE AU 9A1, and PASS 700 E); a textbook, slide tapes, and accident case study scenarios for mine electricity; and a computer-based instructional package on mine electricity and electrical hazards. The report concludes that additional efforts are needed in mine training, and four recommendations are made: (1) tailor existing materials to fit specific minesites, (2) develop and evaluate computer-based instructional material, (3) develop parallel training materials for metal and nonmetal mines, and (4) develop additional training materials for preparation plants and surface areas of underground mines. Research was done under contract J0328045 at West Virginia University. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–138914; paper copy price code A05.

OFR 119–85. Multiplex Distribution System for Multichannel Pager Communications, by George C. Bowser and William M. Pulford. Dec. 1983. 42 pp. 7 figs. This report covers the development and prototype installation of the multiplex distribution system, which gives private communications capability to simple pager phones at minimum cost. This was accomplished by adding an applique to conventional pager-type telephones to allow them to communicate and interact with a multiplex distribution unit that serves as a miniature private branch exchange. Through this mechanism, the pager phones are able to receive and generate private calls without the expense of a complete multiplex telephone unit at every location. A special commercial telephone interface unit was also developed that allows outsiders to call directly to any pager in the mine and allows mine personnel to call any 1 of 10 preset outside telephone numbers. Research was done under contract H0318010 by Catalyst Research Corp. and Microcom Design, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–137130; paper copy price code A03.

OFR 120–85. Retrofit Noise Control of Underground Load-Haul-Dump Machines, by Mathew N. Rubin. July 1984. 110 pp. 65 figs. The primary objective of this work was to extend the noise control technology developed under earlier projects to a wider range of load-haul-dump models to evaluate the general applicability of these techniques. Noise control treatments were designed, fabricated, and installed on three load-haul-dump machines (two 2-yd^3 models and one 8-yd^3 model) selected as demonstration machines for this project. The machines were evaluated either in production mines or at the Bureau's Lake Lynn Mine. The results indicate that it is possible to achieve overall noise reductions of between 4 and 8 dB using these techniques. Engine cooling and seal design were determined to be important design issues in such treatments. Research was done under contract H0395041 by Lake Shore, Inc. and Bolt Beranek and Newman, Inc. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–145810; paper copy price code A06.

OFR 121–85. Deviation Control for Bored-Raise Pilot Holes, by Nicholas P. Callas. Dec. 1981. 109 pp. 6 figs. This report presents research results obtained in the investigation of deviation control of boreholes in the rotary drilling process. The approach taken in this research is the passive method of placing stabilizers in the bottom-hole assembly to control deviation. Extensive use was made of the drill string mechanics theories of Lubinski and Woods. Analog, digital, and hybrid solutions to a variety of boundary value problems were investigated to determine the best models for bottom-hole assemblies. Field drilling data were analyzed, and the results obtained from various models were compared with the actual drilling results. Various accomplishments of this work have been published in Bureau of Mines Information Circular 8891. Research was done under contract J0285005 by the Department of Mathematics, Colorado School of Mines. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–147196; paper copy price code A06.

OFR 122–85. Abstracts of Publications and Reports From Coal Mining Technology Research, by Richard S.

Fowkes and Cynthia A. Mytrysak. Aug. 1984. 202 pp. This report contains abstracts describing articles, papers, and reports dealing with the contract research results of the Coal Mining Technology Research Program. The report is divided into four major areas: (1) general, (2) underground mining, (3) surface mining, and (4) mine systems. The underground mining section is subdivided into mine planning, mine development, production systems, and logistics. The surface mining section is subdivided into mine planning, production systems, logistics, and reclamation. Within each category, projects are listed chronologically from the earliest to the latest publication. Research was done at the Bureau of Mines Pittsburgh Research Center. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–139003; paper copy price code A10.

OFR 123–85. Instrumentation for Remotely Detecting the Placement of Injected Backfill Material, by M. J. Waller, B. G. Stegman, and P. J. Huck. July 1982. 130 pp. 17 figs. Methods of blind backfilling to prevent surface subsidence over abandoned mines have been demonstrated in both flooded and dry workings in recent years. These systems, developed from methods to combat mine fires, involve the injection of slurries containing crushed mine refuse, fly ash, or other material available in large quantities nearby, which are not desired on the surface. A major drawback of all current backfilling methods is the difficulty of monitoring the location and behavior of the injected material underground. The expense of drilling many boreholes to permit physical confirmation of slurry distribution essentially reduces the amount of surface that can be protected, and the drilling itself has negative impacts on surface activities and installations. The objective of this program has been to develop conceptual systems for blind backfill monitoring that will require fewer boreholes and give better definition than is currently possible. Proof-of-concept tests on two recommended systems were conducted in the field. Research was done under contract J0295061 by Earthtech Research Corp. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–139011; paper copy price code A07.

OFR 124–85. Cost Benefit Analysis of Low-Coal Cabs and Canopies, by P. D. Lindahl and K. L. Whitehead. Nov. 1983. 144 pp. 5 figs. A cost benefit analysis was conducted by comparing the industry cost to install protective structures on low-coal face equipment with the benefits paid for injuries and/or fatalities considered preventable by the use of these structures. The industry costs were based on estimates by original equipment manufacturers and rebuild shops for installing protective structures on new and rebuilt face equipment. The accident benefits were based on evaluations performed by the Bureau of Mines Accident Cost Indicator Model. Industry-wide population data were developed on low-coal face equipment and injuries and/or fatalities preventable with protective structures. The results of the analysis are to be used as a tool by the Bureau of Mines in determining the feasibility of continuing development of cab and canopy technology for low-coal equipment. Research was done under contract J0199005 by Bituminous Coal Research, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–138930; paper copy price code A07. $16.95.

OFR 125–85. Development of Modular Irrigation Systems for Reclaimed Strip Mined Lands Incorporating Mycorrhiza Inoculations Trials, by A. Uiga, J. A. Kinkead, and W. K. Ostler. Dec. 1984. 150 pp. 29 figs. The U.S. Bureau of Mines funded a project that addressed objectives concerning irrigation of native plants and inoculation of native plants with vesicular-arbuscular mycorrhizal (VAM) fungi. The specific irrigation objectives were (1) to demonstrate the performance capabilities of solid-set irrigation for reclaimed mineland conditions and (2) to demonstrate and evaluate three irrigation concepts under two separate water supply conditions. The VAM inoculations were to assess irrigation benefits in establishing VAM relationships for transplanted native species. Following the seasonal demonstration (May to September 1983) at three separate minesites, conclusions were made that apply to the six-State Western mining industry. The demonstration sites were located in Montana, Wyoming, and New Mexico. Positive conclusions were reached for (1) the use of soil moisture sampling with or without irrigation and (2) the selection of solid-set sprinklers as the irrigation method. The conclusions about the irrigation concepts and strategy were mixed because of the short-term (one season) nature of the project. No conclusions could be reached for the VAM inoculations because the study time was too short. Research was done under contract H0222004 by Sherman and Kinkead Consulting Engineers, Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–154119; paper copy price code A08.

OFR 126–85. Improved Skips, Guide Alignment, Dynamics, and Economics, by F. A. Penning. Feb. 1985. 315 pp. 126 figs. A comprehensive study of high-speed hoisting in deep shafts was conducted. The study (1) demonstrated the practicality of lightweight skips, (2) developed a guide alignment measuring system, (3) identified the factors affecting skip-guide, skip-rope dynamic interaction, and (4) presented the economic benefits of using lightweight skips. Two lightweight cylindrical skips, one of aluminum and one of fiberglass, were designed, fabricated, and tested. A self-contained guide alignment measuring system was conceived, fabricated, tested, and used to make field measurements in an operating shaft. A computer program (SKIP II) was used to find the effect of misaligned guides for any size skip, empty or full, at any speed. An economic analysis of lightweight cylindrical hoists focused on the impacts on capital and operating costs in hoist plant and rope life. Research was done under contract H0282013 by the Colorado School of Mines. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–152006; paper copy price code A14.

OFR 127–85. Through-the-Earth Electromagnetic Trapped Miner Location Systems. A Review, by Walter E. Pittman, Jr., Ronald H. Church, and J. T. McLendon. Oct. 1985. 57 pp. In its role of providing technical assistance to the mining industry, the Bureau of Mines Tuscaloosa Research Center has conducted research to develop trapped miner location systems that would aid in locating miners trapped by underground mining disasters. Efforts to produce electromagnetic systems for the location of trapped miners underground and to communicate with them were surveyed, from the 1920's to 1981. Theoretical studies of through-the-earth electromagnetic transmissions are described as well as studies of the electrical characteristics of various rocks, minerals, and soil. Several trapped miner location systems are reviewed including the Westinghouse systems, the DEVELCO system, and an automated three-dimensional location system, and the phase difference of arrival technique. Tangential research relevant to trapped miner location systems is described. A comprehensive bibliography covering all aspects of trapped miner, through-the-earth electromagnetic location, and communications systems is appended. Research was done at the Bureau of Mines Tuscaloosa Research Center. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 128–85. Development of Prototype Quiet Hard Rock Stoper Drill—Volume I, by Piyush K. Dutta and William

N. Patterson. Feb. 1985. 62 pp. 27 figs. This report describes the design, development, and manufacture of a prototype quiet hard-rock stoper drill and results of its field tests. It is shown that the stoper drill noise level can be reduced from 118 dBA to below 100 dBA by using this design. The design concept of this drill is based on a valveless independent rotation system and use of an integral muffler and pivot mount. The drill was manufactured in a standard commercial drill manufacturing setup and organization. The design and production technology proved that commercially viable quiet drills can be made available for mine use. Research was done under contract H0113034 by Creare Products Inc. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86-139722; paper copy price code A04.

OFR 129-85. Refinement and Evaluation of Basic Longwall Dust-Control Techniques, by J. A. Kost, J. F. Colinet, and G. A. Shirey. Feb. 1985. 251 pp. 37 figs. The contract objective was to evaluate the effectiveness of available dust-control technology for double-drum shearers. Eight underground surveys were conducted to evaluate drum design, drum spray nozzle locations, ranging-arm sprays, water quantity, wetting agents, and cutting techniques. The final report is made up of eight dust-control technique reports, each discussing details of the individual mine surveys. Research was done under contract J0318093 by BCR National Laboratory. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 130(1)-85. High Reliability Miner Hydraulic System. Volume I—Part I, by Staff, Fluid Power Research Center, Oklahoma State University. Feb. 1983. 270 pp. 102 figs. Research was conducted to develop methods for improving the reliability of hydraulic systems in underground coal mining equipment. Major causes of poor reliability were (1) poor overall system design, (2) poor component contamination tolerance, (3) poor system filtration, and (4) poor maintenance practices stemming from a lack of defined maintenance procedures and enforcement of same. Volume I—Part I describes the development of a computer model to aid in hydraulic system evaluation, the design study of a prototype continuous miner-bolter, the contaminant sensitivity testing of pumps, and the evaluation of conduits, filters, cylinders and seals, fluids, and reservoirs. Research was done under contract J0333948 by the Fluid Power Research Center, Oklahoma State University. Available for reference at ALRC, AVRC, DRC, LIB, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: DE 83-010312; paper copy price code A12.

OFR 130(2)-85. High Reliability Miner Hydraulic System. Volume I—Part II, by Staff, Fluid Power Research Center, Oklahoma State University. Feb. 1983. 242 pp. 102 figs. Research was conducted to develop methods for improving the reliability of hydraulic systems in underground coal mining equipment. Major causes of poor reliability were (1) poor overall system design, (2) poor component contamination tolerance, (3) poor system filtration, and (4) poor maintenance practices stemming from a lack of defined maintenance procedures and enforcement of same. Volume I—Part II describes the evaluation of valves, the diagnosis of particulate contamination, the reliability analysis of selected hydraulic components of the conveyor and roof drill subsystems of a prototype continuous miner-bolter, and reliability analysis of common continuous miner hydraulic systems. Research was done under contract J0333948 by the Fluid Power Research Center, Oklahoma State University. Available for reference at ALRC, AVRC, DRC, LIB, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: DE 83-010313; paper copy price code A11.

OFR 130(3)-85. High Reliability Miner Hydraulic System. Volume II—Mining Hydraulics Manual, by Staff, Fluid Power Research Center, Oklahoma State University. Feb. 1983. 114 pp. 76 figs. Research was conducted to develop methods for improving the reliability of hydraulic systems in underground coal mining equipment. Major causes of poor reliability were (1) poor overall system design, (2) poor component contamination tolerance, (3) poor system filtration, and (4) poor maintenance practices stemming from a lack of defined maintenance procedures and enforcement of same. Volume II is a mining hydraulics manual containing information on hydraulic system design and the selection of hydraulic components, system fabrication aspects from the manufacturer's point of view, and hydraulic system operation and maintenance. Research was done under contract J0333948 by the Fluid Power Research Center, Oklahoma State University. Available for reference at ALRC, AVRC, DRC, LIB, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: DE 83-010314; paper copy price code A06.

OFR 131(1)-85. Optimal Multiple Seam Dragline Operating Procedures. Volume I: Dragline Simulation Models User's Manual, by C. D. Lee, Sun W. Chow, Harry Goforth, John W. Hughes, John A. Nowak, Ronny J. Sadri, and Mary S. Sredanovic. Apr. 1984. 424 pp. 151 figs. The dragline simulation model was designed to assist the mining engineer in finding an optimal combination of operating parameters for a given combination of physical parameters. This computer model simulates the digging, spoiling, walking, deadheading, and maintenance actions of a dragline and the removal of partings and interburdens by auxiliary equipment. It works with a three-dimensional representation of the operating pit to reflect the results of digging and spoiling. These volumes contain the results from the investigation of multiple-seam coal mining using draglines. Three different coal mining regions of the United States were visited to obtain data and provide examples of typical mining operations. Two operating mines were computer simulated during the study to validate the computer model and gain experience in the program's operation. Results indicate that most operating mines can benefit from computer simulation and subsequent implementation of computer-tested optimization procedures. Volume I consists of the user's manual for the dragline simulation model. Research was done under contract J0233903 by Fluor Engineers, Inc. Available for reference at ALRC, AVRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86-164282; paper copy price code A19.

OFR 131(2)-85. Optimal Multiple Seam Dragline Operating Procedures. Volume II: Appendices, by C. D. Lee, Sun W. Chow, Harry Goforth, John W. Hughes, John A. Nowak, Ronny J. Sadri, and Mary S. Sredanovic. Apr. 1984. 324 pp. 20 figs. The dragline simulation model was designed to assist the mining engineer in finding an optimal combination of operating parameters for a given combination of physical parameters. This computer simulates the digging, spoiling, walking, deadheading, and maintenance actions of a dragline and the removal of partings and interburdens by auxiliary equipment. It works with a three-dimensional representation of the operating pit to reflect the results of digging and spoiling. These volumes contain the results from the investigation of multiple-seam coal mining using draglines. Three different coal mining regions of the United States were visited to obtain data and provide examples of typical mining operations. Two operating mines were computer simulated during the study to validate the computer model and gain experience in the program's operation. Results indicate that most operating mines can benefit from computer simulation and subsequent implementation of computer-tested optimization procedures. Volume II consists of appendices containing computer printouts and programmer aids. Research was done under contract J0233903 by Fluor Engineers, Inc. Available for reference at ALRC, AVRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86-164290; paper copy price code A15.

OFR 132–85. A Borehole Probe for In Situ Neutron Activation Analysis, by J. A. Baicker, D. B. Lister, R. E. Marr III, and L. H. Goldman. June 1984. 119 pp. 29 figs. A prototype borehole probe for ore grade determinations by means of in situ neutron activation analysis was designed, built, and tested in a two-phase program. Phase I dealt with the design and fabrication of a borehole logging system for operation in 7.6 cm (3 in) diameter or larger boreholes. It consisted of a 5.06 cm (2 in) diameter borehole probe containing an intrinsic germanium detector, a canister-type solid cryogen cooling system, cooled field-effect transistor preamplifier, linear amplifier, high voltage supply, analog-to-digital converter, microprocessor-based multichannel analyzer, buffer memory, bidirectional cable link, power supplies, and a californium-252 neutron source. A surface support vehicle was designed and outfitted. A minicomputer system was constructed, and software was developed and tested. In phase II, the system was field tested at several minesites. The system was calibrated, tested, improved, and demonstrated in a variety of applications. Tests were performed at sites pertinent to uranium, iron, coal, copper, silver, and gold. Technical feasibility was demonstrated for all these applications except gold; the gold results were inconclusive. In situ neutron activation analysis using high resolution gamma ray spectrometry was found to be a potentially viable logging method for ore grade analysis under certain conditions. Research was done under contract H0262045 by Princeton Gamma Tech, Inc. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–150133; paper copy price code A06.

OFR 133–85. A Study of Design and Development of a Coal Injector for Coarse Slurry Transport, by Boyd Wise, Sam Bell, and Dennis Thompson. May 1985. 358 pp. 101 figs. A jet pump injector was developed and successfully tested, thereby demonstrating the feasibility of a jet injector for introducing coarse coal into an operating slurry face haulage system. In phase I, a variety of injection concepts were evaluated, and the jet pump was identified as best, owing to its simplicity, compactness, and performance potential. In phase IIA, subscale jet pump injector tests were conducted, and a computer model of a jet pump injector was developed whose performance predictions correlated well with subscale test results. In phase IIB, various system configurations were defined for integrating a jet pump injector into a fully operational underground coarse slurry face haulage system, further highlighting the feasibility and practicality of such a system. In phase III, a full-scale mobile haulage vehicle embodying a jet pump injector and coal sizing equipment was detail designed into a practical vehicle with attractive performance characteristics. More importantly, fully operational full-scale jet pump injector and feeder-breaker subassemblies were tested and proven successful in their ability to down-size coal to 3 inches in all three dimensions and to consistently provide slurry of 42% weight concentration at 6.4 t/min throughout under a wide range of operating conditions including zero to maximum feed rate within 5 s. Research was done under contract J0333920 by Ingersoll-Rand Research, Inc. Available for reference at AD/MR. AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–159464; paper copy price code A16

OFR 134–85. Report of Second Meeting on the Definitions and Scope of Nonfuel Mineral Production Statistics in America, by the Department of Scientific and Technological Affairs, Organization of American States. Sept. 1985. 130 pp. The purpose of the meeting described in this paper is to improve understanding of statistics on mineral production and processing collected and/or published by the participating countries—Argentina, Bolivia, Brazil, Canada, Colombia, Mexico, Peru, United States, and Venezuela. This report, a summary of the deliberations of the 2d Meeting on the Definitions and Scope of Nonfuel Mineral Production Statistics in America, held September 16–21, 1984, in Buenos Aires, Argentina, consists of two major sections. The first provides data for each participating country for 12 commodities, iron ore, manganese, copper, lead, zinc, gold, silver, molybdenum, tin, tungsten, fluorspar, and phosphate rock, as provided at the conference. The second part presents the data on each commodity into one or more summary tables, each on as nearly a standard basis as is possible. Explanatory text describes differences in definitions as necessary for understanding of the tabular material. Research was done under contract J0145048 by the Organization of American States. Available for reference at AD/MI and LIB. Order ONLY from NTIS: PB 86–144318; paper copy price code A07.

OFR 135–85. Strategic and Critical Materials Program Annual Report 1985, by R. E. Chaney. May 1985. 125 pp. 53 figs. This report summarizes the research on the Strategic and Critical Materials Program tasks conducted at the Idaho National Engineering Laboratory between May 1984 and April 1985. The work is divided into two areas: production technologies and conservation and/or substitution technologies. Production technologies, tasks directed at developing advanced extraction technologies, include biologically assisted minerals processing, metal-gas reactions and thermal plasmas, and dehydration of aluminum chloride hexahydrate. Conservation and/or substitution technologies, tasks directed toward establishing the technical processing base that will permit the use of advanced materials, include joining of rapidly solidified alloys (RSA), joining of silicon nitride-based ceramics, nondestructive evaluation of ceramic and RSA joints and materials, and substitute catalytic materials for platinum. Research was done under contract J0134035 at the Department of Energy Idaho National Engineering Laboratory. Available for reference at AD/MMR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–144540; paper copy price code A07.

1986

OFR 1–86. Distribution, Analysis, and Recovery of Gold From Kantishna Placers, Alaska, by Steven A. Fechner and Robert B. Hoekzema. 1986. 54 pp. 11 figs. In 1983, the U.S. Bureau of Mines, using contractors and conducting independent studies, evaluated the mineral resources of the Kantishna Hills area of Denali National Park and Preserve, south-central Alaska. Geological and engineering studies addressed types and abundance of mineralization, mineral development potential, and acquisition costs of mineral claims. The Bureau of Mines collected reconnaissance and site specific bulk placer samples to evaluate the mineral development potential of 27 drainages and analyze the size distribution of gravel and gold on 5 streams in the Kantishna Hills study area. Sizing studies conducted on five streams suggest that over 99% of the gold ranges from minus 6 to plus 70 mesh with the biggest percentage being plus 40 mesh in size. Recommended placer recovery plants on these streams should be designed to recover plus 70-mesh gold and classify gravels to minus 1 mesh in size prior to processing through a recovery device. Ten streams were rated as having high mineral development potential; 5 of these streams lack current mining activity. Available for reference at AD/MDA, AFOC/J, IFOC, LIB, AND WFOC. Copies of this report are not available for purchase.

OFR 2–86. Castings Made With Hard-Particle Dispersions and Facecoats, by J. C. Benz and J. S. Hansen. Oct. 1985. 23 pp. 4 figs. Ingots with hard-particle dispersions were produced by vacuum arc melting hollow steel cylinders containing compacted hard particles. Attempts to disperse Cr_3C_2, B_4C, or WC in AISI 4130 and 4340 steel resulted in the dissociation of these carbides and the formation of new phases within solid solutions containing the dissolved elements. TiC and TiB_2 additions remained intact as discrete particles dispersed throughout the matrix but failed to yield significantly increased wear resist-

ance. Cast-on hard facings were produced by casting AISI 4340 steel into investment molds with hard particles adhered to the mold inner faces. Using the lost-wax investment molding process, together with vacuum arc melting and cold-mold centrifugal casting, conical coal cutter bits of the type used on continuous mining machines were produced with cast-on hard facings. Essentially void-free and tightly bonded hard facings of Cr_3C_2, Cr_7C_3, and WC were achieved, but TiC, B_4C, and TiB_2 hard facings were marked by gas-related defects and discontinuous interfacial bonding. The chromium and tungsten carbide facings proved to be too thin to provide notable protection to substrates. Research was done by the U.S. Bureau of Mines Albany Research Center. Available for reference at ALRC, AVRC, LIB, PRC/B, RERC, RORC, SLRC, and TURC. Order ONLY from NTIS: PB 86–151875; paper copy price code A02.

OFR 3–86. Environmental and Occupational Health Regulations in the U.S. Lead Industry, by Carl W. Anderson, Paul T. Behum, and Frederick W. Miller. Jan 1986. 76 pp. 3 figs. This report presents a Bureau of Mines study of regulations pursuant to four major environmental and occupational health laws and the compliance problems of primary and secondary lead smelters and lead-acid battery manufacturers. Technical feasibility and difficulties in implementing and administering the following standards are addressed: (1) the Occupational Safety and Health Administration standards for occupational exposure to lead, (2) the Environmental Protection Agency (EPA) national ambient air quality standard for lead, (3) the EPA hazardous waste management regulations pertaining to recycling of lead, and (4) the EPA effluent limitations under the Clean Water Act and amendments. Although alternative technologies for lead production are emerging and engineering controls are available for retrofitting existing facilities, the economic viability and universal adaptability of these measures are uncertain. Additional pilot and demonstration plant tests may be required for new lead smelting and refining processes. Regulatory approaches in dealing with compliance problems on a plant-by-plant basis would be beneficial. Such an approach should consider the technical and economic feasibility of engineering controls on existing processes and take into account the level of development of new processes. Research was done by the U.S. Bureau of Mines Division of Minerals Policy and Analysis. Available for reference at AFOC/J, IFOC, LIB, PRC/B, and WFOC. Order ONLY from NTIS: PB 86–155686; paper copy price code A05.

OFR 4–86. Explosively Induced Fracture and Fragmentation in Copper Porphyry, by Navid Mojtabai. June 1984. 54 pp. 16 figs. Experiments were conducted to obtain an understanding of the nature and processes of rock fragmentation near a borehole in rock blasting. Ten controlled impact experiments on quartz monzonite were performed using the inclined-plane wave generator to induce a uniaxial compressive wave. Particle size distribution and microcrack density in quartz grains were determined as a function of stress levels (between 1.6 GPa (16 kb) and 7.3 GPa (73 kb)) and pulse durations (between 1.1 μs and 6.9 μs). Both shock pressure and pulse duration were shown to have a strong effect on both particle size and microcrack density. Although the effect of pressure is well recognized, the effect of pulse duration indicates that the ultimate fragmentation increases with the time of application of a plane wave pulse. At high pulse durations, both the degree of fragmentation and microcracking are more sensitive to change in pressure than at low pulse durations. The degree of fragmentation increases rapidly as the microcrack density is increased. Research was done under grant G1125149–3501 at the New Mexico Institute of Mining and Technology. Available for reference at AD/MR, LIB, and PRC/B. Copies of this report are not available for purchase.

OFR 5–86. Shock Wave Propagation and Attenuation in Quartz Monzonite Porphyry, by Kenrick H. Lee. Sept. 1985. 112 pp. 19 figs. The propagation and attenuation of shock waves in quartz monzonite were investigated to improve the understanding of the controlling parameters that influence shock wave characteristics and rock material behavior under shock loading. Four instrumented impact experiments were performed on quartz monzonite using a 4-in helium gas gun to induce a uniaxial compressive wave. Input shock pressures for the impact events ranged from 22 to 71 kb, and pulse durations ranged from 0.3 to 2.3 μs. A change in slope of the shock velocity versus particle velocity curve, observed at about 25 kb, is attributed to the onset of pore collapse. Shock data for quartz monzonite and other rocks reveal that the shock velocity versus particle velocity curve appears to shift downward with increasing porosity. The pressure versus volume Hugoniot curve is concave downward, which may also have resulted from the onset of pore collapse. The pulse attenuation rate is shown to decrease with pulse duration. Research was done under grant G1125149–3501 at the New Mexico Institute of Mining and Technology. Available for reference at AD/MR, LIB, and PRC/B. Copies of this report will not be available for purchase.

OFR 6–86. Second Generation Front-End Loader Stability Indicator, by Gilbert Wray and Jan Nazalewicz. Mar. 1985. 81 pp. 22 figs. This report describes the second stage in the development of a stability indicating system for use in minimizing the occurrence of front-end loader (FEL) rollovers in mining. The overall development proceeded in three phases: definition of FEL stability-instability characteristics; design of a first-generation stability indicator; and design of a simplified, second-generation stability indicator, which is covered by this report. Goals met by the final design include confirmation of a simplified methodology for detecting machine instability; the ability to be installed on new loaders during manufacture or on older loaders on a retrofit basis; and reliable, easily interpretable operation. Research was done under contract J0395074 by the Stevens Institute of Technology Davidson Laboratory. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–176419; paper copy price code A05.

OFR 7–86. Development and Assessment of New and Existing Canopy Technology to Lower Coal Seams, by Jack Mantel. June 1985. 101 pp. 42 figs. The goal of this investigation was to increase safety in low-seam underground coal mines through development and in-mine evaluation of a temporary roof support system for roof drills and floor-riding operator compartments for a loader and shuttle car. The program was performed in three phases. During phase I, state-of-the-art canopy technology was investigated, and preliminary design and mock-up evaluations were performed for temporary roof supports, single- and dual-boom bolters, and for transverse-mounted floor-riding canopies for a shuttle car and coal loading machine. The shuttle car and loader canopies were approved for further development, and the design, fabrication, testing, and certification were completed in phase II. In phase III, the Bureau of Mines furnished a shuttle car for use in the evaluation of the canopy for 45 shifts. The shuttle car canopy was evaluated at the Virginia Crews Coal Co. in West Virginia. Efforts to secure an evaluation site for the loader canopy were unsuccessful. Research was done under contract H0387026 by ESD Corp. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 8–86. Bag Machine Dust Controls and Bag Sealing, by T. L. Muldoon, J. W. Valentine, and M. Burnett. May 1985. 74 pp. 41 figs. The bagging of dry pulverized products using fluidized air packers creates severe respirable dust problems in many surface mining operations. During bag filling, excess air and product blows by the bag valve-nozzle interface. After bag ejection, dust blows out of the bag valve. During bag conveying and handling, dust is released from the bag valve and dirty bag surface. Overexposure of the bagging machine operator and bag handlers is common. This report describes the development and testing of a new dust control system for bagging machines. The system features a new bag clamp design to reduce product blowby during filling. A controlled vacuum system removes excess air from the bag before ejection, eliminating the problems after bag ejection and during conveying and handling. The system has shown significant reductions in dust exposure for both bag machine operators and bag handlers. These reductions are achieved with no significant effect on total mill productivity. Research was done under

contract H0318013 by Foster-Miller, Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–153558; paper copy price code A04.

OFR 9–86. Development of an Integrated System of Monitoring for the Detection of Imminent Subsidence, by Swapan Bhattacharya and Mandan M. Singh. Oct. 1985. 213 pp. 64 figs. Numerous instances of surface subsidence resulting from shallow, abandoned mine workings have been reported over a large portion of the anthracite coal region of northeastern Pennsylvania. This study presents a methodology for identifying sites within the anthracite region that have the potential for imminent subsidence, and proposes an integrated monitoring plan capable of detecting incipient subsidence prior to its surface manifestations. The site screening methodology is based on the premise that the monitoring sites should be located in areas characterized by high subsidence risk. A technique for assigning subsidence risks is presented. The integrated monitoring plan proposed involves the use of two surface geophysical methods (ground penetrating radar and electromagnetics) in combination with in situ displacement sensors. This selection is performed by progressive elimination of over 30 viable instrument alternatives. The selected instrumentation systems are fully described along with a conceptual plan for utilizing these methods in six selected monitoring sites within the study region. Finally, recommendations for the field testing and evaluation of the candidate instrument systems are provided. Research was done under contract J0134022 by Engineers International, Inc. Available for reference at AD/MR, LIB, OSM, PRC/B, and TCRC. Copies of this report will not be available for purchase.

OFR 10A–86. Compact Loader/Trammer for Underground Metal and Nonmetal Mines. General and Design Review, by Tom Tallone. Aug. 1985. 93 pp. 49 figs. In the majority of metal and nonmetal mining operations, narrow vein deposits are being mined with slusher hoists. This method of mucking is costly, owing in part to its inherent labor intense operation and to its inability to muck 100 pct of the deposits. Mechanized equipment would greatly improve the material handling in narrow vein mining and would dramatically reduce the operational cost. The compact loader/trammer, known as the minimucker, has been developed to increase productivity of the load-haul-dump portion of the typical narrow vein mining cycle. This is volume I of the final report, a general and design review of the program activity. Research was done under contract J0205037 by Foster-Miller, Inc. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–193414; paper copy price code A05.

OFR 10B–86. Compact Loader/Trammer for Underground Metal and Nonmetal Mines. Operation and Maintenance Manual, by Tom Tallone and Phil Quenzi. Aug. 1985. 28 pp. 24 figs. In the majority of metal and nonmetal mining operations, narrow vein deposits are being mined with slusher hoists. This method of mucking is costly, owing in part to its inherent labor intense operation and to its inability to muck 100 pct of the deposits. Mechanized equipment would greatly improve the material handling in narrow vein mining and would dramatically reduce the operational cost. The compact loader/trammer, known as the minimucker, has been developed to increase productivity of the load-haul-dump portion of the typical narrow vein mining cycle. This is volume II of the final report, an operation and maintenance manual for the minimucker. Research was done under contract J0205037 by Foster-Miller, Inc. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–193422; paper copy price code A03.

OFR 11–86. High-Pressure Distillation of Crude $ZrCl_4$, by R. L. Skaggs, J. Younghans, Daniel T. Rogers, and D. B. Hunter. Aug. 1983. 41 pp. 12 figs. A high-pressure fractionation column for separation of $HfCl_4$ and $ZrCl_4$ was built to evaluate the claims of a 1976 Japanese patent (76 65,093). A 35.5-in by ¾-in-ID stainless steel 316 column packed with Inconel 600 helices was operated at 40 kg/cm² (39 atm) pressure with reboiler and overhead condenser temperatures of 471° and 455° C, respectively. The total reflux operation produced $ZrCl_4$, with 800 mol ppm $HfCl_4$ in the reboiler and with 5.2 mol pct $HfCl_4$ in the overhead. A 4.7-in height equivalent to a theoretical plate was determined using a variable separation factor. Although column corrosion partially obscured the redistribution tendencies of impurities, uranium clearly stayed in the reboiler. Of the potential construction metals exposed during distillation, Inconel 625 and Hastelloy C-276 showed the least corrosion. Research was done at the U.S. Bureau of Mines Albany Research Center. Available for reference at AD/MMR, ALRC, AVRC, LIB, PRC/B, RERC, RORC, SLRC, and TURC. Order ONLY from NTIS: PB 86–158078; paper copy price code A03.

OFR 12–86. Wire Hoist Rope Tensile Fatigue Testing Machine, by Lee J. Raabe. Mar. 1984. 77 pp. 20 figs. A specialized loading system for tensile and fatigue testing of wire rope was constructed and installed in the U.S. Bureau of Mines Wire Rope Test Facility in Bruceton, PA. The computer-controlled closed-loop servohydraulic test system, which can apply up to 800,000 pounds of force on the rope while stretching it up to 30 inches, will be used in the development and verification of hoist rope retirement criteria for ropes in the 1- to 2½-in-diam range. Characteristics and capabilities of the system are discussed. Research was done under contract H0123016 by MTS Systems Corp. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–158029; paper copy price code A05.

OFR 13–86. Development of Environmentally Attractive Leachants. Volume IV, A Minitest of an In Situ Uranium Leach Solution, by Robert S. Schechter, Larry W. Lake, Terry R. Guilinger, Jonathan G. Price, and Patricia Bobeck. July 1985. 150 pp. 50 figs. A minitest of the new potassium chloride-potassium carbonate two-stage in situ uranium leach process has been carried out at the Intercontinental Energy Corp. Zamzow project site in south Texas. Substantial quantities of high concentration uranium were produced, indicating the viability of the leach solution. The test results yield information regarding the reservoir dispersivity, the average cation-exchange capacity of the formation, and the distribution coefficients describing cation-exchange reactions. The test also indicates permeability anisotropy and the existence of disturbed flow fields. Research was done under contract H0282016 at the University of Texas at Austin. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–158789; paper copy price code A08.

OFR 14–86. Development of Effective Face Ventilation Systems for Oil Shale Mining, by C. E. Brechtel, M. E. Adam, and J. F. T. Agapito. Oct. 1985. 148 pp. 24 figs. This project describes the design and testing of large face ventilation systems for oil shale mining. A design data base was generated by reviewing general industry practice, oil shale industry planning, and technical literature. Conceptual designs for seven different systems were developed and evaluated for suitability. A large, freestanding, jet fan and reversible fan with rigid duct were selected for fabrication and testing. The two systems were field tested in a dead-end heading 55 ft wide by 30 ft high and 320 ft long. System performance was optimized using measurements of airflow direction and air velocity. Total system performance was then measured using SF_6 tracer gas released to simulate blast fumes, hot diesel exhaust, methane layering, and methane from a blasted muckpile. Field testing indicated that both systems delivered similar performance. The jet fan offered some clear advantages because of its mobility, ease of operation, and lower power requirement. It also offered some functional advantages in ventilating for methane because of its high average velocity. Research was done under contract H0134033 by J. F. T. Agapito & Associates, Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB,

MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–159829; paper copy price code A07.

OFR 15–86. Characterization of Metal Hydroxy Silicate Dispersants, by Maurice C. Fuerstenau and John J. Fitzgerald. July 1984. 122 pp. 35 figs. Studies on the synthesis and characterization of aluminum hydroxy silicate polymers were undertaken using gel filtration chromatography, solid-state nuclear magnetic resonance spectroscopy, and other chemical analysis methods. The results of these investigations indicate that (1) hydrosols prepared at lower initial reactant concentrations at fixed Si-Al ratios produce higher levels of soluble Si-Al supernatant species, (2) hydrosols with a Si-Al ratio 6.66 to 1 contain the highest concentration of total and polymeric Al and Si in their corresponding supernatants, (3) the ratio of polymeric silicon to polymeric aluminum contents in supernatants from 6.66 to 1 hydrosols is between 7 and 9, and (4) aluminosilicate species of molecular weight range 500 to 2,000 exist in the hydrosol supernatants in addition to monomeric and polymeric silicates of a similar molecular weight range. Nuclear magnetic resonance studies of colloidal precipitates from these hydrosols are consistent with the soluble aluminosilicate and silicate species from supernatant studies. The nature and stoichiometry of the active species in a range of Si-Al hydrosols are discussed in conjunction with a chemical model of the reaction process used to prepare these systems. Research was done under contract J0123058 at the South Dakota School of Mines and Technology. Available for reference at ALRC, AVRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–181732; paper copy price code A06.

OFR 16–86. The Solubilization of Byproduct Molybdenum From Low-Grade Copper Materials, by Terry L. Hebble, Larry A. Haas, and George A. Dumont. 1983. 22 pp. 7 figs. The Bureau of Mines is investigating hydrometallurgical procedures for recovering byproducts from low-grade copper materials. This report discusses research involving the leaching of low-grade molybdenum-bearing copper ore. The molybdenum concentration found in sulfuric acid leachate from low-grade copper ores is typically very low (less than 2 ppm). Research was performed to determine conditions required to improve molybdenum solubilization. The variables studied were pH, oxidation-reduction potential, metal ion concentrations, and nature of oxidant type. In both basic and acidic (stirred) reactor tests, over 80 pct of the molybdenum was extracted at ambient temperature and pressure in 24 h (or less) with strong oxidizing reagents such as sodium hypochlorite in a basic medium or in a nitric-hydrochloric acid solution. With weaker oxidants, such as hydrogen peroxide and manganese dioxide, in sulfuric acid solution at pH 1, <2 pct of the molybdenum was extracted. With basic solutions and lean ore (0.03 pct Mo), a large quantity (210 times stoichiometric) of sodium hypochlorite was required to obtain 80 pct extraction in 24 h. The extractions at pH <1 or near 10 were dependent on the oxidizing power of the oxidant rather than the solubility limit of molybdenum. However, at about pH 3, the presence of 0.1 to 0.3 g/L ferric ions precipitated >80 pct of the molybdenum from a prepared solution while other metal ions common to dump leach liquor, such as copper, manganese, magnesium, and aluminum, removed <20 pct of the molybdenum. Therefore, in order to obtain high (80 pct) molybdenum extractions from copper ores, the pH of the leach must be <0.5 or approximately 10, and the initial oxidation-reduction potential of the lixiviant must be >0.8 V for acidic leaching. Research was done by the Bureau of Mines Twin Cities Research Center. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 17–86. Results of 1984 Bureau of Mines Site Specific Field Studies Within the Willow Creek Mining District, Alaska, by Joseph M. Kurtak. 1986. 17 pp. 4 figs. The Bureau of Mines conducted mineral investigations of specific sites in the Hatcher Pass area of the Willow Creek Mining District in Alaska during 1984. The Hatcher Pass area has produced over 400,000 oz of gold, mainly from lode deposits and some minor placer production. Out of approximately 40 properties in the area, 9 were visited, including several active operations. Random samples were collected for analysis and mineral identification. Discussions with local miners identified several problem areas concerning metallurgy, recovery, and mining feasibility. Research was done by the U.S. Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/J, IFOC, LIB, PRC/B, and WFOC. Order ONLY from NTIS: PB 86–163904; paper copy price code A02.

OFR 18–86. Improved Diffuser and Sprayfan Systems for Ventilation of Coal Mine Working Faces, by S. K. Ruggieri, T. L. Muldoon, C. Babbitt, and Ed Lee. July 1985. 292 pp. 95 figs. This report describes the laboratory development and testing of the improved sprayfan auxiliary ventilation system. The sprayfan system, based on the fact that water sprays can move air like small fans, consists of several spray manifolds strategically placed on continuous miners to direct intake air to the face and sweep contaminated air (methane and dust) across the face to the return. Water spray systems using sprayfan principles have been installed on more than 300 continuous miners. Although the improved sprayfan system operates on the same principles as the original sprayfan system, the layout and number of spray nozzles differ, providing additional water for dust suppression. A detailed description of the test facility, evaluation techniques, and system test results is provided in this report. The effect of methane monitor placement and instrument lag on the indicated methane reading was also assessed. The results of two major field evaluations of the improved sprayfan system are given. Research was done under contract J0113010 by Foster-Miller, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–168440; paper copy price code A13.

OFR 19–86. Improved Sprayfan System Installation Guide, by Steven K. Ruggieri, Chip Babbitt, and Jim Burnett. July 1985. 72 pp. 20 figs. This guide contains information on the (1) description and capabilities, (2) design, (3) installation, (4) operation, and (5) maintenance of the improved sprayfan auxiliary ventilation system. The improved sprayfan system is a modified water spray system that directs intake air to and across the front of a continuous miner to prevent buildup of methane gas and dust concentrations. Although the improved sprayfan system operates on the same principles as the original sprayfan system, the layout and number of spray nozzles differ, providing additional water for improved dust suppression. Underground tests, independent laboratory tests, tests by the Mine Safety and Health Administration, and independent installations by coal producers have confirmed the performance of the sprayfan system. More than 300 sprayfan systems are currently in operation in underground coal mines. Research was done under contract J0113010 by Foster-Miller, Inc. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–165065; paper copy price code A04.

OFR 20–86. Development of Prototype Quiet Hard Rock Stoper Drill—Volume II, by William N. Patterson. Dec. 1985. 37 pp. 10 figs. This report describes the design and testing of an improved quiet hard-rock percussion drill. The improved drill incorporates a tappetless design with independent rotation in a handheld drill weighing 50 lb. Laboratory and field testing in three mines were conducted. The testing showed improved drilling performance with no increase in measured noise levels over the first design. Research was done under contract H0113034 by Creare Products, Inc. Available for reference at

AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–165073; paper copy price code A03.

OFR 21–86. Development of Noise Control Technology for Jumbo Drills, by Piyush K. Dutta and William N. Patterson. May 1985. 67 pp. 35 figs. This report describes the design, development, manufacture, and incorporation of noise control features on a jumbo drill and the results of successful tests of this drill in surface and underground mines. The noise-reducing features developed under this program are applicable to future designs of jumbo drills that can be cost effectively manufactured and have the potential to reduce noise levels at the operator's position from 115-120 dBA to 95 dBA or less without a reduction of currently attainable drilling rates. Research was done under contract H0395025 by Creare Products, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–165081; paper copy price code A04.

OFR 22–86. Dissolution of Galena With Ferric Chloride and Nitrate, by Maurice C. Fuerstenau. Dec. 1984. 58 pp. 30 figs. The kinetics of leaching galena with ferric chloride and ferric nitrate have been examined as a function of ferric concentration, salt concentration, temperature, and particle size. Diffusivity of ferric complex ions was also established as a function of ferric chloride concentration and temperature. In the presence of 3*M* NaCl, leaching rate is controlled by product layer diffusion when ferric chloride is added as oxidant. With NaCl concentrations less than 3 mol/L, rate decreases with decreased NaCl concentration, and thus, rate is apparently not controlled by product layer diffusion. It is suggested that rate is controlled by lead chloride solubility at the reaction interface under these conditions. When ferric nitrate is added as oxidant, leaching rate is limited by chemical reaction control. An electrochemical model is presented. Activation energies are 8.1 and 11.3 kcal/mol in the ferric chloride and ferric nitrate systems, respectively. Research was done under contract J0215026 at the South Dakota School of Mines and Technology. Available for reference at AD/MMR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–169513; paper copy price code A04.

OFR 23–86. Zeolite Determination and Geothermometry Interpretations Associated With Buried Volcanic Rocks in Oil Fields in Northwestern Mississippi, by Daniel A. Sundeen. Feb. 1986. 22 pp. 4 figs. A study was conducted to confirm the presence of zeolites and determine the type of zeolite minerals associated with the subsurface volcanic province in Humphreys, Leflore, and Holmes Counties, northwestern Mississippi. The petrographic microscope and X-ray diffraction with the Gandolphi camera were the primary tools used to identify the minerals. The most abundant zeolite mineral was analcite. Natrolite and chabazite were both suspected as minor mineral components in several locations. Other minerals such as celestite, ankerite, and clay (illite type) were found in the process of looking for zeolites. The abundant presence of analcimite indicates that the temperature regime associated with volcanism is relatively low, probably no higher than 120° to 130° C, which is not enough heat to degrade hydrocarbons to a noncommercial state. Study results indicate that thermal contribution to the trapping system by past volcanic events in the area does not increase the risk of successful oil well drilling. Research was done under grant G1144128 at the University of Southern Mississippi. Available for reference at LIB. Copies of this report will not be available for purchase.

OFR 24–86. The Examination of Landsat, Gravity and Magnetic Anomalies as Indicators of Subsurface Hydrocarbon Accumulation Geophysical Correlations in West-Central Mississippi, by Larry D. Schutts and Gwynne A. Woodward. Sept. 1985. 78 pp. 19 figs. Recent analysis of near-infrared Landsat data has revealed the existence of five circular tonal anomalies in the vicinity of Belzoni in west-central Mississippi. One feature is located just southwest of an area that yielded modest amounts of Smackover Formation oil and gas. Each of the others may represent reservoirs associated with structures in the underlying Sharkey platform. Research was done under grant G1144128 at the University of Mississippi. Available for reference at LIB. Copies of this report are not available for purchase.

OFR 25–86. Tertiary Lignites of Kemper and Northern Lauderdale Counties, Mississippi, by Shair E. T. Rahaim, Jr. Oct. 1985. 109 pp. 21 figs. Samples of lignite from thin, tabular seams ranging from a few centimeters to almost 3 meters in thickness in Kemper and Lauderdale Counties, MS, were studied by proximate, petrographic, mineralogical, and grain size analyses. Proximate analysis of the samples indicates high moisture (30%), ash (63%), and volatile matter (21%), and low fixed carbon (12%) values. Grain size and mineralogical analyses indicate a predominance of sand-size quartz in the lignite. Petrographic analysis indicates that humodetrinite (37%) and gelinite (27%) are the major organic constituent particles. The inertinite macerals (19%), fusinite and semifusinite, are unusually high in these low-grade coal seams. The cellular macerals, textinite and ulminite, compose only 11%, and corpohuminite and exinite compose 5% of the lignite samples studied. The values from these analyses seem to indicate that the lignite was deposited in a deltaic environment influenced by fluvial and marine processes. The paleo-environment was dominated by herbaceous plants and wood from angiosperms and lacked significant amounts of conifers in the depositional area. Research was done under grant G1144128 at the University of Southern Mississippi. Available for reference at LIB. Copies of this report will not be available for purchase.

OFR 26–86. Development of the Claw Hammer Scaling Tool, by James D. Eklund. Dec. 1983. 25 pp. 8 figs. To improve safety, economy, and efficiency of scaling in underground metal or nonmetal mines, research was conducted to develop a combination prying-hammering tool for machine scaling. In the prototype claw-hammer assembly, a hydraulic impact hammer was used to drive the claw mechanism into the rock. After a bite was established, the loose rock could be removed using a hydraulically actuated prying motion. This tool combines the advantages of both impact and repair type scaling tools and provides versatility for use in most rock types. The prototype was subject to limited testing (1) to verify its operational functions and (2) to assess its potential capability in future underground testing. The prototype was first bench tested to hydraulically test the independent functions. It was then mounted on a backhoe boom for some preliminary field testing. Both claw and hammering functions operated successfully on concrete and quartzite boulders. Research was done under contract H0202025 by Battelle, Pacific Northwest Laboratories. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–169471; paper copy price code A03.

OFR 27–86. Domestic Consumption Trends, 1972-82, and Forecasts to 1993 for Twelve Major Metals, by U.S. Department of the Interior, Bureau of Mines staff, and U.S. Department of Commerce, Basic Industries Sector staff. January 1986. 158 pp. 45 figs. Domestic consumption and intensity of use trends for 12 metals, by industrial end use, were estimated for 1972 through 1982. The trends were then forecast through 1993 using standard statistical methods. The intensity of use measure selected is the quantity of metal consumed per constant dollar output of a specific industrial sector. The metals studied were aluminum, chromium, cobalt, copper, lead, manganese, nickel, the platinum-group metals, tin, titanium, tungsten, and zinc. Average annual growth rates for 4 of the 12 metals increased from 1972 to 1982 as follows: aluminum, 1.00%;

platinum-group metals (consisting of platinum, palladium, and iridium), 8.83%; titanium, 7.82%; and tungsten, 6.09%. Consumption for the remaining eight metals decreased at annual rates ranging from 0.58% (copper) to 5.37% (manganese). Available for reference at AFOC/J, IFOC, LIB, and WFOC. Copies of this report will not be available for purchase.

OFR 28–86. 1984 Sample Results for Bureau of Mines Site Specific Mineral Investigations Within the Yentna Mining District, Alaska, by Steven A. Fechner. May 1985. 53 pp. 6 figs. In 1984, the Bureau of Mines conducted mineral investigations of specific sites within the Yentna Mining District, in which 108 placer and rock samples were taken. Reconnaissance placer samples were collected from drainages in the Talkeetna, Susitna, and Yentna River basins. The highest placer gold values were found in the historic placer gold producing creeks of the Cache-Peters Creek area. Samples taken from an outcrop in the Middle Fork of Iron Creek in the Talkeetna Mountains contained previously unreported high lead, zinc, and silver values. Research was done by the U.S. Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 86–168838; paper copy price code A04.

OFR 29–86. Control of Respirable Quartz on Continuous Mining Sections, by J. F. Colinet, G. A. Shirey, and J. A. Kost. June 1985. 106 pp. 40 figs. This study evaluated sources of airborne quartz and research control methods that would assist underground mine operators in complying with respirable dust standards that had been reduced because of quartz in the dust exceeding 5%. The work involved (1) evaluating sources of quartz dust at the roof bolter work location, (2) evaluating the relationship between the quartz content of the coal and adjoining rock strata and quartz exposure at the roof bolter and continuous miner locations, and (3) conducting laboratory tests to determine performance parameters for roof bolter dust collector systems. Underground surveys were conducted. The continuous miner typically was the greatest source of quartz exposure for the miner and roof bolter operators when single-split ventilation was utilized. A statistically significant relationship between quartz content in face material and operator exposure was not determined; data suggested that mining equipment and procedures may be more critical. The lab tests indicated the use of dust hog-type bits, filter cartridges, maximized collector airflow, and reduced bit revolutions per minute should be utilized to minimize dust liberation at the roof bolter. Research was done under contract J0338033 by BCR National Laboratory. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–179546; paper copy price code A06.

OFR 30–86. Compact Service Hoist System for Underground Metal and Nonmetal Mines, by David J. Hoadley, Billy C. Brunelle, and John F. Healey. Dec. 1985. 139 pp. 7 figs. A semiautomatic, raise climber, compact service hoist system was designed for stope access in underground metal and nonmetal mines. Demonstrated capabilities of the system include a 1,000-lb payload capacity, control from the traveling cage and from up to three remote stations, and operation in vertical or inclined raises 3 ft in diameter and up to 300 ft in length at a travel speed of 50 ft/min. The system can be operated in crooked raises; the conveyance climbs two stationary wire ropes suspended down the raise. The drive unit is electrically powered, with power and control signals supplied to the drive unit through an umbilical cable also suspended down the raise. The system has been designed for portability, ease of installation, and minimum raise development. The hoist has been demonstrated successfully in an aboveground test tower. This report provides a detailed description of the hoist design and its demonstrated performance to date. Research was done under contract H0202019 by Foster-Miller, Inc. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–179991; paper copy price code A07.

OFR 31–86. Conveyor Belt Dust Control, by Vinit Mody and Raj Jakhete. July 1984. 410 pp. 92 figs. The belt conveyor is one of the major pieces of equipment for transferring bulk material in mining operations. However, considerable amount of respirable dust may be generated whenever the bulk material is loaded, dumped, or transferred. This report identifies and evaluates various dust control technologies applicable to belt conveyors and describes how an integrated systems approach can reduce dust emissions at a transfer point. Phase I of the program consisted of a literature search and a critical evaluation of various dust control technologies. The work established that a comprehensive approach to calculating exhaust volumes for dust collection systems does not exist. The parameters that affect the wet dust suppression efficiency were also reviewed. Based on the phase I work, bulk material handling systems and dry dust collection or wet dust suppression systems were designed and installed at a number of transfer points in a limestone processing facility, a surface mine selected as a field test site. Field test data were used to determine the validity of various exhaust volume calculations at the different transfer points. The field test data also formed the basis for the evaluations of the relative effectiveness of commercially available and wet dust suppression systems in controlling respirable dust emissions. Research was done under contract H0113007 by Martin Marietta Laboratories. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 32–86. Revegetation of Coal Strip Mine Spoils in Eastern Wyoming, by Marinus L. Wouden, Lawrence J. Froisland, Delwin L. Richards, Jr., and Monte B. Shirts. Jan. 1986. 18 pp. 3 figs. In the late 1970's, the Bureau of Mines began to examine the criteria for reestablishing vegetative cover on coal strip mine spoils near Glenrock, WY. A 9-acre plot, consisting of (1) spoils covered with topsoil, (2) spoils without topsoil, and (3) spoils treated with sewage sludge, was constructed. These plots were seeded with Tegmar intermediate wheatgrass (*Agropyron intermedium*), Fairway crested wheatgrass (*A. cristatum*), and Critana thickspike wheatgrass (*A. dasystachyum*). After 5 yr, the topsoil had about 70 pct plant coverage. Revegetated spoils, without topsoil addition, averaged approximately 30 pct plant coverage, and sewage sludge-treated spoils had about 45 pct plant coverage. Comparison of grass types showed that intermediate wheatgrass produced greater surface coverages. Research was done by the Bureau of Mines Salt Lake City Research Center. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 33–86. Geologic Factors Affecting Vibration From Surface Mine Blasting, by James W. Reil, Douglas A. Anderson, Andrew P. Ritter, Dennis A. Clark, S. R. Winzer, and A. J. Petro. Sept. 1985. 204 pp. 65 figs. A test series of small, precisely controlled and thoroughly monitored production blasts was conducted at two quarries. In each series, all variables except delay were kept constant, as much as practically possible. The first aim of the study was to determine the effect of local geology on ground vibration. The second aim was to test several hypotheses relating the effect of millisecond delay intervals to fragmentation and ground vibration. A resonant frequency of ground vibration was shown to be related to the thickness of the overburden, in accord with a model proposed by Gupta. Since the overburden geology creating this resonant vibration cannot usually be changed, two methods were tested to choose delays such that blast vibrations would destructively interfere. These methods were shown to be effective in modifying both the peak particle velocity and response spectra of ground vibration. The delay interval chosen

also affects fragmentation, primarily in massive rock, with an optimum relief between holes of 2 ms/ft. Strain gauge records indicate a possible mechanism consistent with this information. Research was done under contract H0222009 by Vibra-Tech Engineers, Inc. Available for reference at ALRC, AVRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86-175858; paper copy price code A10.

OFR 34-86. Dust Control Handbook for Longwall Mining Operations, by Glenn A. Shirey, Jay F. Colinet, and John A. Kost. May 1985. 223 pp. 56 figs. The objective of this contract was to prepare a detailed, readily usable handbook on dust control techniques for longwall mining operations. Information was gathered from available literature and through contacts with industry and government personnel. The handbook describes those methods of dust control applicable to today's longwall mining systems and contains sufficient design elements to assist operators with problems in testing or implementing new control procedures. Complete reference lists are presented at the end of each chapter to direct the reader to additional information. Research was done under contract J0348000 by BCR National Laboratory. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86-178159; paper copy price code A11.

OFR 35A-86. Underground High Volume Hydraulic Coal Mining. Volume I—Mid-Continent Resources, Inc., by R. G. Heers. June 1983. 141 pp. 19 figs. This report examines the technical and economic feasibility of hydraulically mining the 12- to 20-ft-thick Middle Bed coal seam at Mid-Continent Resources, Inc., near Carbondale, CO. The mining system permits the safe recovery of a seam that is too thick to be recovered by longwall methods. Dual rooms are developed straight up the 8° to 13° pitch. The bottom room, under top coal and supported by yieldable arches, serves as an intake and fluming room. The parallel room against the roof, supported by roof bolts, serves as a return air course and bleeder. The top coal and pillars are extracted by a jet of water directed by a monitor, eliminating the need for miners or machinery to work beyond a roof supported by yieldable arches. Pillar recovery and productivity are both improved over those of other systems. At the same time, safety is markedly enhanced by roof control with yieldable arches, remote control extraction of the top coal and pillars, elimination of electricity from the vicinity of the working face, and positive ventilation of the area being pillared. The study shows that it is highly feasible to produce 1.2 MMtpy clean coal by hydraulic mining with internal rates of return from 23% to 92%, based on a range of selling prices from $30 to $40 per ton and on the extent to which existing capital for shared facilities is charged against the hydraulic mine. Capital expenditures required for the hydraulic mine, including interest during construction, are estimated to be $18 million, and overall productivity is estimated to be 28 clean tons of coal per employee per shift. Research was done under contract J0233911 by B. C. Coal, Ltd., and R. G. Heers & Associates. Available for reference at ALRC, AVRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 35B-86. Underground High Volume Hydraulic Coal Mining. Volume II—Price River Coal Company Castlegate Mine, by R. G. Heers. June 1983. 152 pp. 29 figs. This report examines the technical and economic feasibility of hydraulically mining a 12- to 25-ft-thick coal lens in the A bed on the west side of Price River Coal Co. property in Carbon County, UT. Although the coal is hard and strong and pitches only 7° to 8°, hydraulic mining at a rate of 1,154,000 tpy was determined to be highly feasible using an induced caving system, using strata and abutment pressures in a controlled manner in causing coal breaking in the retreat mining faces. The coal would be developed by continuous miners in widely spaced dual rooms driven up the full pitch. About 83% of the production would be extracted from pillars and top coal by hydraulic monitors in the rooms, supported by yieldable aluminum arches. In the average seam thickness of 20 ft, it was estimated that the tonnage mined from arched headings would constitute only 3.4% of the total. Estimated average monitor production was over 1,500 tons per shift. The coal would be dewatered underground. Safety would be enhanced by controlling the roof and ribs with lightweight arches, remote controlled extraction of pillars and top coal, reduction of airborne dust, and positive ventilation of pillar faces. Both mining recovery and productivity would be improved over any other system used for such thick seams. With a selling price range of $25 to $35 per ton, free on rail, the estimated rate of return on the incremental capital of about $25 million would be 17% to 41%. Overall productivity would be 29.1 clean tons of coal per employee-day. Research was done under contract J0233911 by B. C. Coal, Ltd., and R. G. Heers & Associates. Available for reference at ALRC, AVRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 35C-86. Underground High Volume Hydraulic Coal Mining. Volume III—The Pittsburg & Midway Coal Mining Co. Kemmerer Coal Mine, by R. G. Heers. Sept. 1983. 137 pp. 25 figs. Hydraulic mining of the three thickest seams at Pittsburg & Midway Coal Mining Co.'s property at Kemmerer, WY, is technically and economically feasible because of the great thickness of the seams (30 to 90 ft), the 20° pitch, the absence of gas, the self-supporting top coal, and the low ash and sulfur content. Access to the coal seams is by 11,000-ft twin rock tunnels, declining on a 21° grade to a central underground dewatering station where the plus 14-mesh coal is screened off and conveyed out. The minus 14-mesh coal and spent water is pumped to the surface for cleaning and clarification. About 4,000 hp of hydraulic energy is provided to each of the three monitors, one in each seam. This energy, together with an induced caving system, is expected to produce over 1,400 tons of raw coal per monitor shift. Only 3% of the coal mined comes from development, which is accomplished by roadheader-type machines. Capital costs are estimated at $88 million including interest during construction, for a production of 3 MMtpy. The internal rate of return ranges from 18% to 27%, based on sales prices from $21 to $26 per ton, free on rail. Overall productivity is estimated at 42 tons per employee shift, and recovery is estimated at 60%. Extensive measures are provided for the prevention, detection, and control of spontaneous combustion. Safety is further enhanced by reduction of dust and by remote controlled extraction of top coal and pillars. Recovery and productivity are improved over those of any other underground mining method for such thick seams. Research was done under contract J0233911 by B. C. Coal, Ltd., and R. G. Heers & Associates. Available for reference at ALRC, AVRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 35D-86. Underground High Volume Hydraulic Coal Mining. Volume IV—Kocher Coal Company Porter Tunnel Mine, by R. G. Heers. June 1983. 131 pp. 24 figs. This report examines the technical and economic feasibility of hydraulically mining anthracite veins at Kocher Coal Co.'s Porter Tunnel Mine, in Schuylkill County, PA. Results show that if a market for 1.156 MMtpy of clean coal at prices ranging from $40 to $50 per ton, free on rail, can be obtained, hydraulic mining would provide internal rates of return ranging from 11% to 23%, respectively. Capital costs are estimated to be $73 million, including interest during construction. An underground station, constructed at the base of the reserves, would collect all of the natural ground water, process water, and production coal. The dewatered plus ½-mm coal would be conveyed out of the mine, with a dilute slurry of minus ½-mm coal and water pumped to the cleaning plant on the surface. Development headings, supported by roof bolt trusses, are advanced by drilling, blasting, and flushing out the broken coal. To aid

extraction by the high-pressure water jet, the pillars between sublevels are sized to partially crush under abutment pressure. Extraction of the pillars by jet eliminates the need for miners or machinery to work beyond a well-supported roof. Both pillar recovery and productivity are expected to be superior to those of other systems. At the same time, safety is markedly enhanced by improved roof control, remote control extraction of top coal and pillars, and elimination of dust. The productivity is estimated at 11.8 tons of clean coal per employee-day. Research was done under contract J0233911 by B. C. Coal, Ltd., and R. G. Heers & Associates. Available for reference at ALRC, AVRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 35E–86. Underground High Volume Hydraulic Coal Mining. Volume V—Frederic A. Potts & Co., Inc., by R. G. Heers. Sept. 1983. 137 pp. 26 figs. This report examines the technical and economic feasibility of hydraulically mining anthracite veins in Schuylkill County, PA. The Lykens Valley veins are 6.5 and 15 ft thick and dip 40° to 50°. This plan proposes a combination of induced caving and hydraulic monitoring. All development entries will be driven in rock by a tunnel boring machine. Parallel main levels will be developed on 250-ft centers in the hanging wall of each vein. The hydraulic monitor will extract the coal from drawpoints on 160-ft centers. Coal will be flumed to an underground dewatering station where the plus ½-mm coal will be dewatered and transported by conveyor to the preparation plan on the surface. The minus ½-mm coal and water, including the assumed 8,000 gpm of mine water inflow, will be pumped to the surface by plunger pumps. Miners and material transport will be provided by a suspended monorail system. One monitor will be operated, producing 883,000 clean tons per year. Productivity is estimated at 13.2 clean tons per employee-day. capital expenditures of $62 million, including interest during construction, are planned. At assumed selling prices of $40 to $50 per ton, free on rail, the discounted rate of return is 16% to 25%. Research was done under contract J0233911 by B. C. Coal, Ltd., and R. G. Heers & Associates. Available for reference at ALRC, AVRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 35F–86. Underground High Volume Hydraulic Coal Mining—Summary, by R. G. Heers. June 1983. 39 pp. This report is a summary of five sites, three bituminous and two anthracite, where hydraulic mining might be technically and economically feasible. The bituminous sites were the Mid-Continent Resources, Inc., mine near Carbondale, CO; the Price River Coal Co. Castlegate Mine near Helper, UT; and the Pittsburg & Midway Coal Mining Co. Kemmerer Coal Mine at Kemmerer, WY. The anthracite sites were the Kocher Coal Co. Porter Tunnel Mine and the Frederic A. Potts & Co., Inc., property, both located in Schuylkill County, PA. This volume contains a summary of each of the other five volumes and general remarks. The other volumes provide details about each site: a geological description of the reserves, the anticipated mining conditions, an estimate of the quantity of the reserves, the development and extraction method and necessary equipment, water system description, personnel requirements, estimated capital and operating costs, cash flow and rates of return for various selling prices, and environmental and socioeconomic considerations. Research was done under contract J0233911 by B. C. Coal, Ltd., and R. G. Heers & Associates. Available for reference at ALRC, AVRC, DRC, LIB, OSM, PRC/B, RERC; RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 36–86. Investigation and Control of Noise Generated During Coal Cutting, by Mark R. Pettitt. Aug. 1985. 138 pp. 70 figs. This report presents the results of an extensive research and development program to reduce the noise generated during coal cutting. The characteristics and magnitude of continuous miner coal cutting noise sources are defined. This work consisted of development of a simulated coal seam to facilitate aboveground coal cutting tests, noise measurements in a reverberant acoustic chamber during simulated mining operations of a continuous miner (cutting the simulated coal seam), and noise measurements in an underground coal mine during continuous miner operation. In-mine and laboratory test results were in excellent agreement for both A-weighted overall levels as well as A-weighted one-third octave band spectra. Methods to reduce coal cutting noise are presented. These methods take full advantage of the dynamic characteristics of the forces generated during coal cutting. Dynamic cutting force isolation was shown to be a very effective technique. Finally, a continuous miner was equipped with a cutter head that incorporated (among other design factors) cutting force isolation. Successful long-term, in-mine use of the cutter head demonstrated coal cutting noise at the operator's station of less than 90 dBA and 50% coal, 50% rock cutting of less than 93 dBA. Research was done under contract J0387229 by Wyle Laboratories. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–189008; paper copy price code A07.

OFR 37–86. Control of Respirable Quartz on Continuous Mining Sections, by Eric G. Kok, Roger F. J. Adam, and Robert A. Pimentel. Nov. 1985. 169 pp. 19 figs. Complying with reduced dust standards (that is, less than 2.0 mg/m^3) owing to quartz levels that exceed 5% is presently a critical problem for many continuous mining sections. Results are presented of research that was performed to determine the factors causing high levels of respirable quartz dust and to identify the major contributors to operator exposure. The significant sources of quartz dust are the drilling of the roof and the mining of the roof, floor, and rock bands. Both the miner and the bolter may be on a reduced standard, but compliance is easiest to achieve on the bolter, for which improvements in maintenance and operator practices are usually sufficient. At the miner, the problem is more elusive. Dust was produced not only by the cutting action but also by scooping, gathering, and loading operations. Research was completed to identify dust problem areas at the continuous miner. An analysis of the potential for research in a number of dust control research project areas is also presented. The research areas address the respirable quartz dust problem at continuous miners. Research was done under contract J0338078 by Ketron, Inc. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 38–86. On the Development of a Model-Based Control Strategy for Copper-Ore Flotation, by J. A. Herbst, R. Zaragoza, and O. A. Bascur. Feb. 1986. 70 pp. 13 figs. During the last decade, it has been established that conventional flotation control strategies based on classical control theory result in significant increases in grade, recovery, and operating cost savings. In the current report, description of an advanced model-based control philosophy is presented. The derivation and verification of a simplified flotation model is described. The implementation of a Kalman filter for estimation of unmeasured variables for input to controllers is discussed. Several control strategies using the model-based approach are described, emphasizing the nonlinear nature of the flotation plant. Expected trends in the implementation of such model-based flotation control strategies in the future are discussed. Research was done under contract J0215035 at the University of Utah. Available for reference at AD/MMR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–190170; paper copy price code A04.

OFR 39–86. Application of Mathematical Modeling to the Analysis of Ground Water Flow Patterns Near a

Deep Underground Mine, by Paul Frankel. Jan. 1986. 85 pp. 25 figs. The purpose of this study was to evaluate the relative importance that several major geologic structural features have on ground water potential distribution and their impact on abandonment practices of deep underground mines. The U.S.G.S. Modular Finite Difference Ground Water Flow Model was utilized in analyzing conditions at the Bunker Hill Mine near Kellogg, ID. Observations suggested that ground water flow near the Bunker Hill Mine is controlled by secondary hydraulic conductivity created by the existing structural features. The research suggests several ways to reduce inflow to mines through fault zones. Research was done under grant G1125132-1651 at the University of Idaho. Available for reference at AD/MR and LIB. Copies of this report will not be available for purchase.

OFR 40–86. The Electrowinning of Dilute Zinc Sulfate Solutions in a Fluidized Bed Electrochemical Reactor, by Richard Z. Squillace. Nov. 1985. 69 pp. 16 figs. A cylindrical, fluidized bed electrochemical reactor (FBER) was employed to electrowin dilute zinc sulfate solutions containing 2.5 to 15 g/L zinc. The planar electrodes used in the industrial electrowinning of zinc requires 50 to 65 g/L zinc. A low acid catholyte solution of 5 g/L is the maximum concentration necessary for the efficient recovery of zinc. The addition of 60 g/L of Na_2SO_4 electrolyte improved both the catholyte conductivity and current efficiency. The optimum current efficiency and current density were obtained using a particle size of plus 355 minus 500 μm and a bed width of 1.3 cm. At a zinc concentration of 15 g/L, the FBER could be operated at current densities and at volumetric reaction rates greatly exceeding that of a conventional planar electrowinning cell. Research was done under grant G1125132-1902 at the University of Nevada at Reno. Available for reference at AD/MMR, LIB, and RERC. Copies of this report will not be available for purchase.

OFR 41–86. Measurement and Construction of Dust Distribution Maps for Longwall Faces, by S. S. Peng and H. S. Chiang. Jan. 1986. 110 pp. 45 figs. This report describes the development of dust distribution maps to aid in the prevention of the production and spread of airborne dust. Air velocity and flow patterns were measured by velometers and smoke tubes positioned at the 3d or 5th support from the head entry T-junction, at the 11th and every 10th support thereafter, with the last station located at the tail entry T-junction. Moving and fixed real-time aerosol monitor surveys also measured respirable dust both near the shearer and the support advance. Airflow distribution along the longwall face differed among the five mines surveyed as well as from face to face within the same mine. The most important contributing factor seemed to be the air leakage conditions in the gob. Location of high dust concentrations are identified and the techniques to control them are discussed. Research was done under grant G1135142-5403 at West Virginia University. Available for reference at AD/MR, LIB, MSHA, PRC/B, and TCRC. Copies of this report will not be available for purchase.

OFR 42A–86. Optimizing Water Sprays for Dust Control on Longwall Shearer Faces, by S. K. Ruggieri, T. L. Muldoon, W. Schroeder, C. Babbitt, and S. Rajan. Oct. 1983. 156 pp. 83 figs. Effective control of respirable dust is one of the most serious problems associated with longwall mining in the United States. The major reason is that face workers work in the airstream downwind of the major dust source—the longwall shearer cutting drum. The major approach to dust control has been the increased use of water sprays for dust suppression. These sprays, however, can make conditions worse by creating turbulence and mixing, which forces the dust cloud into the operator's breathing zone. The air upstream of the shearer is clean. If this flow could be divided with one split confining and carrying away the dust cloud and the second split blowing over the operators, their dust exposures would be reduced. This report describes the laboratory development and field evaluation of a system that accomplishes this airstream split. The system combines the use of barriers and water sprays to split the airflow and to confine the dust cloud in the dirty split in the face side of the shearer. The system, known as the shearer clearer, has shown a 50% reduction in shearer-generated dust measured at the operators. Research was done under contract J0308019 by Foster-Miller, Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86-205408; paper copy price code A08.

OFR 42B–86. Optimizing Water Sprays for Dust Control on Longwall Shearer Faces—Design and Installation Manual, by S. K. Ruggieri and C. Babbitt. Oct. 1983. 79 pp. 33 figs. This user's manual contains the following practical information concerning improved water spray systems for dust control on longwall shearers: (1) description and capabilities, (2) design, (3) installation, (4) testing and modification, and (5) operation and maintenance. All of the systems and techniques described are aimed at reducing the respirable dust exposure of the shearer operators from shearer-generated dust sources. Information is provided on upgrading water supply systems, making more efficient use of cooling water and drum spray systems, and using a shearer clearer passive barrier system to control shearer dust. The shearer clearer is an improved water spray system that consists of strategically mounted water sprays and passive barriers (conveyor belting). The system reduces the dust concentrations in the operator's walkway by splitting the airflow on the upwind side of the shearer and confining the dust cloud to the face side of the shearer. All of the systems and techniques presented have been installed on operating longwalls and are practical and fieldworthy. Extensive underground evaluations, tests by MSHA, and independent installations by coal producers have confirmed the performance of the shearer clearer system. The system has shown reductions of 50% in shearer-generated dust measured at the operators' positions. Research was done under contract J0308019 by Foster-Miller, Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86-205416; paper copy price code A05.

OFR 43–86. Monitoring and Control of Mine Air Diesel Pollutants: Summary of Michigan Technological University Research, by J. H. Johnson and D. H. Carlson. June 15, 1985. 49 pp. 18 figs. This report references reports and publications from 1975 to 1985 that are related to the diesel underground mine air quality research undertaken by Michigan Technological University. Research results obtained on this contract are summarized in five different sections: (1) development of a systematic approach to monitoring, data analysis, and interpretation for diesel mine air quality control; (2) experimental evaluation of load-haul-dump (LHD) on-board air quality control systems; (3) development of a portable self-contained LHD tailpipe emissions measurement apparatus for NO_2, NO, CO, CO_2, and particulate matter; (4) quantitative analysis of diesel and coal particulate matter by laser Raman spectroscopy; and (5) development and application to detector tubes of a laboratory method to assess accuracy of occupational diesel pollutant concentration measurements. Research was done under contract J0199125 at Michigan Technological University. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86-204104; paper copy price code A03.

OFR 44–86. Research Study on Pillar Design for Vertical Crater Retreat (VCR) Mining, by William G. Pariseau. Oct. 1985. 233 pp. 112 figs. A 4-year study was conducted of the rock mechanics aspects of two underground hard-rock mine

study stopes: (1) Anaconda Minerals Co.'s Carr Fork Mine near Tooele, UT, and (2) Homestake Mining Co.'s Homestake Mine in Lead, SD. Large-diameter (6½-in) blastholes were an integral part of the stoping method at each mine. A true vertical crater retreat (VCR) method was used at the Homestake Mine, while a vertical bench mining method (VBM) was used at the Carr Fork Mine. Since there are no personnel in a VCR or VBM stope, all ground control including dimensioning of stopes and pillars and the layout of cable bolt assays or other artificial support must be done in advance of production blasting. Accordingly, the objective of the research study was the establishment of a procedure for optimizing stope and pillar sizes. The approach taken in each case was a combination of mine measurements of the study stope response to mining, laboratory testing for rock properties and in situ stress measurements of the premining stress field, and theoretical calculations of the study stope response to mining. All calculations were done with the UTAH-II finite element computer program. Simulation of the blasting sequence gave a correlation of 0.88 between measured and calculated extensometer readings (incremental relative displacement) at the Carr Fork Mine where over 30 instrumentation boreholes were used to monitor the test stope response. A correlation of 0.84 was obtained at the Homestake Mine where 19 instrumented boreholes were used for monitoring purposes. These high correlations validated the computer model and calibrated it for rock mass properties. The calibrated model was then used in parametric studies of alternative design layouts. Research was done under contract J0215043 at the University of Utah. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–210960; paper copy price code A11.

OFR 45–86. EM Rescue (Location) System for Deep Mines Phase II—Build and Test Breadboard Equipment, by F. B. Curry, T. C. Moore, L. H. Rorden, and I. D. Schleicher. Oct. 1984. 106 pp. 25 figs. The purpose of this program is to extend electromagnetic (EM) techniques for use in locating miners trapped in mines as deep as 1,000 m. A previously developed EM system is considered adequate for use in mines less than 300 m deep where it has a probability of detection of 54%. A system for deep mines must keep underground equipment simple and use extremely low frequencies (ELF), sensitive receivers, and noise cancellation. The proposed location method is based on vector field measurements from two or more static sensors and computation of source location by iterative techniques. During phase II, very sensitive search coil sensors were built and used in a separate test to verify the feasibility of atmospheric noise cancellation. A breadboard location system version without cancellation, which is a fieldable test bed to evaluate receiving and location functions, was tested and supplied. Very good results were achieved from the first in-mine test with the transmitter at a depth of 380 m. Research was done under contract J0199009 by Develco, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–215902; paper copy price code A06.

OFR 46–86. Auto-Track Bridge Conveyor Train for Continuous Face Haulage, by D. D. Durrett and D. T. Atkinson. Feb. 1986. 225 pp. 126 figs. The auto-track bridge conveyor train (ABCT) is a continuous haulage system designed for underground coal mines. The ABCT is made up of identical "units," each of which consists of a wheeled mobile bridge carrier and a bridge conveyor. Microprocessors located on each carrier enable the entire train to follow precisely a predetermined course along the section's haulage route with minimal operator control requirements. Sensors determine each carrier's position with respect to a signal cable. This cable is automatically deployed on the mine floor as the system advances behind the continuous miner. This report summarizes system design efforts, prototype testing, and subsequent redesign and prototype modifications. Research was done under contract J0333913 by Foster-Miller, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–239795; paper copy price code A11.

OFR 47A–86. A Quality Program Plan for Explosion-Proof Electrical Enclosures. Part 1—Final Technical Report, by William D. Dodge and P. A. Cox. Nov. 1984. 128 pp. 10 figs. A typical quality program plan is presented for explosion-proof (XP) electrical enclosures. A quality program plan is a document traditionally prepared by a manufacturer to describe the manner in which it intends to meet the quality requirements imposed on its product by contract, purchase order, or government agency provisions. The plan is suggested for manufacturers of XP enclosures that are to be certified by MSHA for mining use. The plan describes the quality system, organization, and implementing mechanisms that are to be applied in the manufacture and delivery of certified XP enclosures. Example forms and example procedures are included. Research was done under contract H0387009 by Southwest Research Institute. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–209509; paper copy price code A07.

OFR 47B–86. Thermally Induced Stresses in Explosion-Proof Electrical Enclosures With Windows. Part 2—Final Technical Report, by Stephen E. Stewart, F. D. Lin, and P. A. Cox. Nov. 1984. 119 pp. 75 figs. This report presents the solutions to linear transient thermal and stress analyses of explosion-proof enclosures used in underground mines. The results were used to assess the severity of certification tests for enclosure windows relative to possible loads occurring in the actual mine environment. Cast iron electric light enclosures with polycarbonate and glass windows were analyzed under steady-state thermal conditions (light burning) and for thermal shocks corresponding to an internal explosion (ignition of volatile mine gas) or external quenching (mine water spray system). Thermal shocks to the enclosure, caused by ignited gases or water spray, were applied via a series of load steps in the transient analysis. The temperature dependence of material properties and of the film heat transfer coefficients were included in the model. The work demonstrates that thermally induced stresses are strongly influenced by the way the window is mounted in the enclosure. It also shows that the MSHA Thermal Shock Tests, if performed on an unsupported lens (or window), produces lower stresses than the lens (or window) may experience in the mine environment. Research was done under contract H0387009 by Southwest Research Institute. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–209517; paper copy price code A06.

OFR 47C–86. A Design Guide for Explosion-Proof Electrical Enclosures. Part 3—Final Technical Report, by P. A. Cox and W. R. Schick. Dec. 1985. 353 pp. 53 figs. Guidelines are provided for the design of explosion-proof electrical enclosures that will meet MSHA certification requirements according to Part 18, Title 30, of the Code of Federal Regulations, and fulfill their intended service underground. The guide covers only those aspects of design that affect enclosure strength, ruggedness, endurance, and flame path, i.e., the enclosure ability to properly contain an internal explosion. Internal static and explosion pressures and external impact and thermal heating loads are treated, as well as the proper selection of materials and welding procedures. Research was done under contract H0387009 by Southwest Research Institute. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC,

SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–209525; paper copy price code A16.

OFR 47D–86. Testing of Adhesives and Polycarbonate Lenses in a Simulated Mine Environment. Part 4—Final Technical Report, by Charles H. Parr, Donald N. Weed, and P. A. Cox. Nov. 1985. 69 pp. 28 figs. A testing program was conducted to determine the suitability and reliability of adhesives and polycarbonate (PC) lenses for extended use in luminaires in mine environments. Polycarbonates were exposed, for periods up to 36 months, to four environments including ultraviolet light, humidity, intermittent water spray, and heat of either 180° F or 240° F in various combinations. Izod impact tests on the exposed lens material indicated that polycarbonate functions well under all 180° F environments and could be used with confidence for periods exceeding the test period, for as long as 10 years, with a suitable safety factor employed in design. The specimens exposed at 240° F showed decreased toughness after 24 months' exposure. Extrapolation of these data was deemed to be risky. A 462-day compatibility test between polycarbonate and six hydraulic fluids was run on stressed PC beams. One fluid caused beam breakage in less than 1 day, while three caused breakage at intermediate times. Two fluids exhibited essentially no effect on the PC when compared with a control. Epoxy and silicone adhesives were tested as lens adhesives and sealants. Three epoxy combinations tested showed low and erratic failure stresses. A room-temperature-cure silicone adhesive functioned extremely well for the time periods up to 36 months and temperatures up to 240° F. Research was done under contract H0387009 by Southwest Research Institute. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–209533; paper copy price code A04.

OFR 48–86. Noise Study of Longwall Mining Systems, by Mark R. Pettitt and Robert M. Slone, Jr. Jan. 1986. 169 pp. 91 figs. An investigation was conducted to identify and promote the application of noise control technology to future longwall mining machinery. Intensive noise and vibration data were acquired on a typical longwall shearing machine, and the highest noise levels were shown to radiate from the cutter drums. Shearing machine cutter drum noise control techniques that take advantage of the nature of the dynamic forces generated during coal cutting were developed. These include both structural redesign and force isolation techniques. A reduced noise cutter drum was developed that achieved a 5- to 6-dBA system noise reduction at the operator's position. Its operational performance was verified by a 6-month-long in-mine test. It was evident from the data that additional noise reduction could be achieved by treatment of the shearing machine hydraulics. Noise control of secondary sources was also investigated. A method of reducing full or empty stage conveyor noise (and continuous miner conveyor noise) by 5 to 10 dBA was demonstrated through isolation techniques. Underground mine durability testing, however, is yet to be demonstrated. Research was done under contract J0188072 by Wyle Laboratories. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–102257; paper copy price code A08.

OFR 49A–86. Evaluation and Improvement of Electrical Storm Warning Systems, by R. L. Johnson, W. M. Sherrill, J. D. Moore, and D. E. Janota. Nov. 1979. 107 pp. 36 figs. An analysis of mining explosive accident reports indicates a need for clear and ample warning of approaching electrical storms to reduce injuries and/or fatalities due to lightning-induced premature detonation. During the spring and summer of 1979, six lightning warning devices were comparatively evaluated at three test sites. The devices tested were (1) flash counter, (2) corona point, (3) radioactive probe, (4) field mill, (5) azimuth and range locator, and (6) triangulation locator. The test sites were chosen to provide system evaluation under varied thunderstorm conditions. The devices were tested at San Antonio, TX; Kennedy Space Center, Cape Canaveral, FL; and Langmuir Laboratory near Socorro, NM. Comparative performance evaluation is reviewed in terms of alarm reliability, false alarm, and failure to alarm probabilities. Improved lightning warning system requirements and methods of relating warning criteria to explosive hazard are discussed. Research was done under contract J0387207 by Southwest Research Institute. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–203619; paper copy price code A06.

OFR 49B–86. Evaluation and Improvement of Electrical Storm Warning Systems—Warning Parameter Study, by R. L. Johnson and W. M. Sherrill. Dec. 1981. 17 pp. 4 figs. The data acquired under phase 2 of the subject contract were analyzed to investigate whether the electric field strength and/or abrupt changes in the electric field could be used as device-independent parameters for a lightning warning safety specification. Although the data analyzed were device specific, the following conclusions were reached: (1) A safety specification based upon the electric field strength at a single point is ineffective; the specification must also include an area of coverage that implies the use of multiple sensors. (2) A safety specification based upon flash rate or relative magnitude of received atmospherics is ineffective owing to the large variability in the measurement parameter. (3) A safety specification based upon an indication of atmospheric electrical activity within a predetermined radius of the site is viable and does not attempt to solve the difficult problem of estimating the location of the activity. Research was done under contract J0387207 by Southwest Research Institute. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–203775; paper copy price code A02.

OFR 50–86. Results of 1984 Bureau of Mines Site Specific Mineral Investigations in the Valdez Creek Mining District, Alaska, by Mark P. Meyer. 1986. 29 pp. 2 figs. During 1984, the Bureau of Mines conducted site specific mineral investigations in the Valdez Creek Mining District, AK. This study included a literature search and reconnaissance level field investigations. The literature search identified 243 mines, prospects, and occurrences within the Valdez Creek Mining District. During the field reconnaissance, 19 samples were collected from 5 deposits: Denali Copper Prospect, Valdez Creek Placer Mine, Black Creek Gold Mine, Windy Creek Placer Prospect, and Timberline Creek Gold Mines. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 86–203858; paper copy price code A03.

OFR 51–86. Lode Platinum-Group Metals Potential of the Goodnews Bay Ultramafic Complex, Alaska, by D. D. Southworth and Jeffrey Y. Foley. Apr. 1986. 87 pp. 22 figs. In 1981, 1982, and 1983, the Bureau of Mines examined the potential for lode deposits of platinum-group metals (PGM) in the Goodnews Bay ultramafic complex, Alaska. The complex consists of the Red Mountain, Suzie Mountain, and Smalls River ultramafic bodies and displays concentric zoning of rock types similar to complexes in southeast Alaska, British Columbia, and the Ural Mountains in the U.S.S.R. Results of the study indicate that platinum is preferentially associated with chromite and magnetite in the dunite core of the complex, and palladium is preferentially associated with sulfide minerals in the outer clinopyroxene-rich zones. The most promising targets for PGM lode deposits are the chromite-rich dunite at the heads of Fox Gulch and Squirrel Creek and the iron-nickel and iron-copper

sulfide-bearing magnetite clinopyroxenite and hornblende-rich rocks outward of the dunite core, also found in the Fox Gulch-Squirrel Creek area. Significant placer reserves are present in the unmined, deeply buried placer ground in the lower Salmon River Valley and also in tailings from previous dredging. Research was done at the Bureau of Mines Alaska Field Operations Center. Available for reference at AD/MDA, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 52–86. Financing Foreign Development of Non-Fuel Mineral Resources: An Analysis of Loan Terms of International Financial Institutions vs. Those of Commercial Banks, by Price Waterhouse. May 16, 1986. 310 pp. 58 figs. This report presents the results of a study comparing loan terms for nonfuel mineral projects in developing countries from various international financial institutions (IFI's) and from private sector commercial sources. The study compares IFI and commercial loan terms for seven mineral projects in developing countries. The IFI's represented are the International Bank for Reconstruction and Development (World Bank), the International Finance Corporation, the Inter-American Development Bank, the Asian Development Bank, and the International Monetary Fund. In addition, the costs of financing for these mineral projects were compared with the costs of long-term debt to five large U.S. mineral producers. Research was done under contract J0156023 by Price Waterhouse. Available for reference at AD/MDA, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–247228; paper copy price code A14.

OFR 53–86. Dual Wavelength Light Sources, by R. T. Boos, W. D. Egan, R. A. Elliott, and R. K. DeFreeze. Oct. 1985. 160 pp. 37 figs. This report describes work done to develop a tunable, room-temperature diode laser source for a remote coal mine methanometer. A detailed evaluation showed that a broad area InGaAs/InP injection laser operating at approximately 1,650 nm could be suitable for a differential absorption light detection and ranging measurement of methane if the spectral bandwidth could be reduced by a factor of approximately 400. Consequently, an external grating cavity was designed and fabricated to reduce the bandwidth of the injection lasers. The optical design of an off-axis parabolic mirror grating cavity was developed using geometric optics to determine the physical parameters for the external cavity that would produce the desired spectral bandwidth of 0.2 cm^{-1}. The fabrication of this external resonator source is described, and its performance against the design criteria is evaluated. Apart from a smaller than desired methane absorption coefficient, the device met all design specifications. The low methane absorption coefficient was attributed to a larger than desired source linewidth, which was measured to be two to three times larger than the design value. An explanation of this excessive bandwidth based on coupled mode theory is presented. The unsatisfactory methane absorption coefficient of the external cavity diode laser source significantly detracts from its suitability for use in an instrument to remotely measure methane in coal mines. Research was done under contract H0123031 by Bethlehem Steel Corp. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–209483; paper copy price code A08.

OFR 54–86. Mineral Investigations in the Chugach National Forest, Alaska, by J. M. Kurtak and R. E. Jeske. Nov. 1984. 305 pp. 36 figs. The Bureau of Mines and the U.S. Geological Survey cooperatively studied the Chugach National Forest, Alaska, from 1979 to 1982 as part of the Roadless Area Review and Evaluation (RARE II) Program. The Bureau evaluated the mineral production potential of the area. This included literature and claim records research, field examination of all reported mines, prospects, and occurrences that could be located, followup of anomalous geochemical samples, and reconnaissance of terranes with little prospecting or mining history. This report covers the central 790,880 acres of the forest. Copper, with byproduct zinc, silver, and gold, has been the major metal produced from the study area as well as from the entire Chugach National Forest. The majority of the copper deposits are concentrated within basaltic rocks on Knight Island, but the major producers are hosted by sedimentary rocks on Latouche Island. Approximately 182.6 million lb of copper, 1.5 million oz of silver, and an unknown but substantial amount of gold were produced during a 30-year period. Currently no mines in the area are producing. Reserves with mineral production potential total 4.6 million tons, with grades of 1.6% copper, 0.30 oz silver/ton, and 0.04 oz gold/ton. Research was done at the Bureau of Mines Alaska Field Operations Center at Anchorage. Available for reference at AD/MDA, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 55–86. Improving the Performance of Tunnel, Raise and Shaft Boring Machines for Coal Mine Applications, by Levent Ozdemir. Mar. 1986. 178 pp. 64 figs. A 6-ft-diam laboratory tunnel, raise, and shaft boring machine was designed and constructed to carry out research investigations to enhance the performance of mechanical rock excavation equipment. The machine is operated with a computer control system and features extensive instrumentation to monitor and record various test parameters, including triaxial cutter forces, machine thrust, torque, revolutions per minute, and penetration rate. An extensive laboratory testing program has been conducted using this machine, demonstrating the feasibility of attaining high rates of penetration in various sedimentary geologies. Also, a large data base has been developed to serve as a basis for the improved design and performance of tunnel, raise, and shaft boring equipment. Research was done under contract J0133919 at the Colorado School of Mines. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–216678; paper copy price code A09.

OFR 56–86. Research on Water Proportioning for Dust Control on Longwalls, by Eric G. Kok and Roger F. J. Adam. Feb. 1986. 138 pp. 49 figs. Compliance with respirable dust standards is presently a critical problem in many longwall faces equipped with double drum shearers. Results are presented of research performed to increase the quantity and optimize the distribution of the water supplied to the shearer drums to control the shearer operator dust exposure. The effect on the total respirable dust produced by the shearer was also examined. During the research effort, a simple and inexpensive manually controlled valve system was designed and implemented on a shearer to distribute the water supplied to the shearer drums. Research showed that increases in water quantities are beneficial, but associated pressure increases may induce respirable dust boilover, thus negating potential advantages. Other essential parameters such as location of shearer operator, outside spray orientation, and air quantity were considered in the evaluation. Research was done under contract J0318096 by Ketron, Inc. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 57–86. Development of Rollover Protective Structures (ROPS) Performance Criteria for Large Mobile Mining Equipment, by John L. Dahle and Gary R. Gavan. Apr. 1985. 277 pp. 139 figs. This report documents the research efforts undertaken to design, construct, and test rollover protective structures (ROPS) and to develop ROPS perform-

ance criteria for large mobile mining machines. The following tests were conducted: two rollover tests of a 52,000-pound machine, two rollover tests and one static test of a 390,000-pound machine, and one rollover test of a 286,000-pound machine. The tests were conducted on a specially constructed hill with a slope of 35° and were designed to provide consistent and repetitious results. Each roll test was designed to provide a minimum of 540° of machine rotation about the longitudinal axis, allowing the ROPS to impact the slope twice. All tests included extensive instrumentation and photographic coverage to fully evaluate the performance of the ROPS. Using data obtained from the testing, as well as all other available rollover data in which ROPS loading and energy absorption characteristics were known, recommended performance criteria were developed, including side force and energy, longitudinal force, and vertical force. Research was done under contract H0292020 by Woodward Associates, Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–216066; paper copy price code A13.

OFR 58–86. Development of High Voltage Permissible Loadcenter, by D. Randolph Berry and Bobby Gillenwater. Feb. 1986. 136 pp. 48 figs. This report makes recommendations for new approval and testing criteria for high-voltage permissible loadcenters (transformer and switchgear, greater than 4,160 V) for underground U.S. mines and describes the development and testing of a prototype loadcenter to meet the criteria. The recommended criteria included new findings in several areas: minimum clearances between live conductors, special precautions for using organic insulators, tests for dielectric strength and electrical stress, and explosion testing. A research test program was conducted to evaluate the pressure rise caused by a high-energy arcing fault (10,000 A) with and without a simultaneous methane-air explosion inside the enclosure. The prototype loadcenter included a 1,250-kV•A, 7,200-V primary transformer inside a center compartment with separate, attached enclosures for high-voltage switchgear on one end and low-voltage distribution and protection on the other end. A comprehensive literature search was conducted, and a state-of-the-art review of research and industrial experience with high-voltage explosion-proof transformers is included. Research was done under contract H0308093 by Foster-Miller, Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–215803; paper copy price code A07.

OFR 59–86. Performance and Test Criteria for DC Fuses—Phase II, by Allan Levins. Aug. 1985. 113 pp. 20 figs. The objective of this research was the development of test criteria for direct current (dc) fuses used for protecting trailing cables in coal mines. Using data developed in an earlier study, a preliminary set of requirements for such fuses was established. Interested parties such as fuse manufacturers, mining equipment manufacturers, and mine operators were contacted and asked to comment on the preliminary requirements. Fuses were tested using these preliminary requirements, and the viability and reasonableness of the test procedure were judged. A meeting of representatives of fuse manufacturers, a mine operator, the Mine Safety and Health Administration, and the contractors for phases I and II of this effort was held. From the information gained to that date and the comments made at the meeting, final proposed test criteria for mine duty fuses were established. Research was done under contract J0328019 by Underwriters Laboratories Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–215811; paper copy price code A06.

OFR 60–86. Analysis of Miners' Job Attendance Behavior and Its Relationship to Miners' Accidents and Injuries—Final Report, by Paul S. Goodman. Oct. 1985. 278 pp. 49 figs. This report examines coal miner absenteeism and its relationship to accidents and injuries at underground mines. A total of 19 mines participated in various phases of this 3-year project. Miners at the participating mines ranged in number from 185 to 776. The data consisted of the mines' daily attendance records and detailed interviews with approximately 50 miners from each mine. The interviews contained questions about the miners' satisfaction with various on-the-job and off-the-job factors, their perceptions of the mines' absenteeism policies, the reasons or causes for their own absences, and the miners' demographic characteristics. Accident and injury data from six mines were used in parametric and multiple regression analysis of the absenteeism-accident relationship. The data represented activity during approximately 80,000 miner-days worked. Strategies for reducing absenteeism are discussed. Research was done under contract J0328033 by Carnegie-Mellon University. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–216306; paper copy price code A13.

OFR 61A–86. Investigation of Quartz Dust Sources and Control Mechanisms on Surface Coal Mine Operations. Volume I—Results, Analysis, and Conclusions, by Robert A. Zimmer and Stan R. Lueck. Mar. 1986. 72 pp. 7 figs. The basic objective of this study was to evaluate the sources of airborne quartz dust during removal of overburden at surface coal mines to which the highwall driller, drill helper, truck driver, and bulldozer operator are exposed. Testing was conducted at 11 mine locations. Both dry and wet control systems for overburden drills were evaluated at the various mines. The test results showed that both control systems are capable of achieving greater than 95% control under certain conditions. On dry systems, a nearly linear inverse relationship was found between shroud height and control efficiency. Control efficiencies ranged from 41% to 99% over the 0- to 27-in height range evaluated. Dry systems performed most efficiently when the shroud was positioned as close to the ground as possible. For wet systems, measured control efficiencies ranged from 9% at a water flow rate of 0.2 gal/min to 96% at 1.2 gal/min. Water flow rates greater than 1.0 gal/min were found to cause operational problems. Quartz concentrations of the respirable particulate ranged from below detectable limits to 13.6%. Quartz concentrations did not change appreciably by mine, by filter location, or with the use of control equipment. Data summaries and the analyses of data are presented in volume I. Research was done under contract J0348032 by PEI Associates, Inc. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–215852; paper copy price code A04.

OFR 61B–86. Investigation of Quartz Dust Sources and Control Mechanisms on Surface Coal Mine Operations. Volume II—Appendices, by Robert A. Zimmer and Stan R. Lueck. Mar. 1986. 370 pp. 2 figs. The basic objective of this study was to evaluate the sources of airborne quartz dust during removal of overburden at surface coal mines to which the highwall driller, drill helper, truck driver, and bulldozer operator are exposed. Testing was conducted at 11 mine locations. Both dry and wet control systems for overburden drills were evaluated at the various mines. The test results showed that both control systems are capable of achieving greater than 95% control under certain conditions. On dry systems, a nearly linear inverse relationship was found between shroud height and control efficiency. Control efficiencies ranged from 41% to 99% over the 0- to 27-in height range evaluated. Dry systems performed most efficiently when the shroud was positioned as close to the ground as possible. For wet systems, measured control efficiencies ranged from 9% at a water flow rate of 0.2 gal/min to 96% at 1.2 gal/min. Water flow rates greater than 1.0 gal/min were found to cause operational

problems. Quartz concentrations of the respirable particulate ranged from below detectable limits to 13.6%. Quartz concentrations did not change appreciably by mine, by filter location, or with the use of control equipment. Volume II contains basic data. Research was done under contract J0348032 by PEI Associates, Inc. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86-215860; paper copy price code A16.

OFR 62-86. Additives for Strengthening Backfill Materials in Steep Coal Seam Mining, by C. E. Brechtel, D. A. Thies, and J. R. Aggson. Sept. 1985. 116 pp. 22 figs. A testing program was conducted to design a cemented backfill for hydraulic placement in underhand cut-and-fill mining of a steeply dipping coal seam. The testing evaluated the use of three different backfill aggregates, locally available at the coal mine, with portland cement and five different pozzolans, including a Class F fly ash, a Class C fly ash, a cement kiln dust, and ground smelter slag. Both viscosity and uniaxial compressive strength of backfill mixtures with different pozzolan and portland cement contents were used to evaluate their suitability. Based upon the results of preliminary testing, an optimum mixture of alluvial sand with 6% portland cement and 10% Class F pozzolan was chosen for further compression testing. Research was done under contract J0245006 by J. F. T. Agapito & Associates, Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86-215894; paper copy price code A06.

OFR 63-86. Geologic Conditions Affecting Coal Mine Ground Control in the Western United States, by R. B. Laird, A. L. Amundson, G. J. Colaizzi, and L. M. Bithell. Dec. 1985. 200 pp. 63 figs. A comprehensive investigation was conducted into geologic features affecting coal mine ground control in western underground coal mines. This study involved a literature search for data on geologic features affecting coal mine ground control, western coal geology associated with specific geologic features, and MSHA roof fall information. Data on mining operations were collected through interviews with mining and research personnel. Selected mines were toured within 10 coalfields in Utah and Colorado. This final report summarizes western coal depositional environments and geological structures and describes mining and geology for the coalfields studied. All observed geologic features and conditions related to coal mine ground control are described in terms of their depositional or structural origin, morphology, diagnostic characteristics, associated adverse mining conditions, and roof control methods. Photographic documentation of these geologic features is included. Adverse geologic features and their locations are correlated with geological environments by coalfield to define their relative impact on mining operations. Comprehensive bibliographical data and selected MSHA roof fall data are also included. Research was done under contract J0145032 by Goodson & Associates, Inc. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86-217171; paper copy price code A09.

OFR 64-86. A Study of the Precipitation of Platinum From Dilute Aqueous Solution, by Harold Ray Jouett II. 1984. 55 pp. 7 figs. Hydrogen sulfide gas was used to precipitate platinum sulfide from a dilute aqueous platinum solution. The precipitation was carried out in a continuous mixed suspension, mixed product removal precipitator. The platinum sulfide precipitate formed a stable colloidal suspension. The average particle size was about 7 nm. The purpose of this research was to be able to control and predict the size distribution of particles formed during the platinum sulfide precipitation. A mathematical model based on a steady-state particle population balance that relates the particle size distribution to nucleation and growth kinetics and operating parameters was compared with experimental particle size distributions. The model did not predict the observed size distributions. A qualitative model based on the Brownian motion of the particles and their electrostatic interactions is proposed to explain the observed size distributions. Addition of electrolytes to the colloidal suspension of platinum sulfide caused the particles to flocculate and form large, easily filtered particles. The higher the cation valence, the more effective it was as a flocculating agent. The problem with using electrolytes as flocculating agents is that the metal cations contaminate the flocculated platinum sulfide particles. Research was done under grant G1125132-3209 at Iowa State University. Available for reference at AD/MMR, LIB, and RERC. Copies of this report will not be available for purchase.

OFR 65-86. Leaching of Platinum and Palladium From Spent Automotive Catalysts, by David R. Tyson. 1984. 42 pp. 7 figs. The rate of reaction and the extent of reaction were investigated for the dissolution of platinum and palladium from spent automotive catalysts. Empirical rate expressions were obtained from mass balances and the concentration-time data. The rate for both platinum and palladium was high at early stages of leaching and decayed rapidly up to about 110 min and 50 min, respectively. The rate remained very low after these times while proceeding to zero. The extent of reaction for both platinum and palladium was affected by leaching solution composition and bed height and/or catalyst weight. The extent of reaction for palladium increased for increasing ratios of $(HCl):(HNO_3)$ and decreasing bed heights. The extent of reaction for platinum increased for decreasing ratios of $(HCl):(HNO_3)$ and decreasing bed heights. The catalyst particle size did not appear to affect the extent of reaction for either platinum or palladium. Research was done under grant G1125132-1901 at Iowa State University. Available for reference at AD/MMR, LIB, and RERC. Copies of this report will not be available for purchase.

OFR 66-86. Extraction of Palladium(II) Using Cyanex 471 Extractant and Supported Liquid Membrane, by Reed Dee Walker. 1984. 59 pp. 9 figs. The purpose of this report is to describe the recovery of palladium from spent automotive palladium-platinum catalysts. A type of liquid membrane separation process for the separation and concentration of metals—supported liquid membrane—was used to separate and concentrate very low concentrations of palladium(II) in hydrochloric acid solution against its concentration gradient. Using Cyanex 471 as the carrier and to clarify the permeation mechanism of palladium through the membrane, the separation of dilute solutions of palladium(II) chloride was carried out by (1) liquid-liquid extraction and (2) the use of supported liquid membrane containing the mobile carrier. In both cases, the operating conditions were varied so that the effect of such variables as HCl concentration, Cyanex 471 concentration, stripping agent concentration, temperature, palladium concentration, and platinum(IV) addition to the feed solution could be studied. Research was done under grant G1125132-2901 at Iowa State University. Available for reference at AD/MMR, LIB, and RERC. Copies of this report will not be available for purchase.

OFR 67-86. Lead Reduction in Ambient Air: Technical Feasibility and Cost Analysis at Domestic Primary Lead Smelters and Refineries, by Richard D. Smith, Orville A. Kiehn, David R. Wilburn, and Robert C. Bowyer. May 1986. 75 pp. 5 figs. The Bureau of Mines evaluated the technology and capital investment and annual operating costs of emission control for further reductions of lead in ambient air at the Glover, Herculaneum, and Buick smelter-refineries in Missouri and the East Helena, MT, smelter. This study seeks to analyze the technology available to the domestic primary lead industry for attempting to further reduce lead emissions below 1985 levels.

Through enclosure of concentrate unloading and handling areas and all lead processing buildings, followed by venting these enclosures to the atmosphere through baghouses and the application of appropriate local controls, lead inventories can theoretically be reduced by 2,424 pounds per day from 1985 levels. Using conventional technology, aggregated additional capital costs of $250,014,000 and annual operating costs of $18,507,800 are estimated for the four operations, resulting in a total cost of $0.063 per pound of refined lead. Continuous drossing techniques would assist in meeting OSHA standards in process areas. Continuous drossing would increase capital and operating costs to $258,344,800 and $16,104,700, respectively, for a total cost of $0.062 per pound of refined lead. The open market price for refined lead for the first quarter of 1986 was $0.184 per pound. Research was done by the Bureau of Mines. Available for reference at AFOC/A, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–216447; paper copy price code A05.

OFR 68–86. Instrumented In-Mine Testing of the Bureau of Mines Low-RPM, Deep-Cutting Continuous Mining Machine, by James M. Burkes. Sept. 1982. 125 pp. 45 figs. The Federal Coal Mine Health and Safety Act of 1969 established maximum airborne respirable dust exposure levels for underground coal mines. In an effort to provide the knowledge needed to achieve compliance without reducing productivity, the Bureau of Mines has sponsored research oriented toward improving mining machines. This work has consistently shown that a deep-cutting, low-rpm (revolutions per minute) continuous miner can reduce respirable dust levels without production penalties. To provide the design data by manufacturers to produce versions of the deep-cutting machine, a prototype miner was instrumented and in-mine tests were conducted. The data acquisition system developed for this testing allowed real-time monitoring of selected machine parameters to include cutterhead bit forces, power levels, structural loads, and pressures. During the in-mine tests, these parameters were recorded for a wide range of operating conditions. Test variables were advance rate, bit lacing, and head rotary speed. Analysis of the test data was performed to quantify the characteristics in terms useful to the designers of continuous mining equipment. Peak, average, and root-mean-square values for power, torque, rpm, boom loads, and bit loads were computed. Research was done under contract H0282020 at Southwest Research Institute. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–216587; paper copy price code A07.

OFR 69–86. Development of a Water Jet Assisted Cutterhead for Coal Measure Rocks, by Levent Ozdemir. Apr. 1986. 95 pp. 46 figs. The results of a laboratory research program aimed at the development of a water jet assisted drag bit cutting system for coal mine applications are presented. Two types of drag bits, a conical and a plow bit, were tested in a hard sandstone rock with jet pressures of up to 20,000 psi. Jet locations investigated were in front of and behind the bits. For each jet mounting location, three jet impingement distances with respect to bit tip were tested. The closest jet impingement location to bit tip was found most effective, providing the greatest force reductions on the bit. Overall, significant bit force reductions up to 50 percent were obtained with jet assist. Also observed was a drastic reduction in airborne dust when jets were employed. Research was done under contract J0233900 at the Colorado School of Mines. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–217692; paper copy price code A05.

OFR 70–86. Maps Summarizing Land Availability for Mineral Exploration and Development in North-Central Alaska, 1985, by Robert G. Bottge. May 27, 1986. 14 maps. These maps show land within 14 Alaskan quadrangles (Bettles, Beaver, Fort Yukon, Black River, Tanana, Livengood, Circle, Charley River, Kantishna, Fairbanks, Big Delta, Eagle, Mount McKinley, and Tanacross) that was open to mineral exploration as of July 1, 1985. As many as 15 other land subclassifications are depicted, as well as restrictions, private lands, and land closed to mining. The mineral deposits plotted are based on the Bureau of Mines Minerals Availability System (MAS). Included are tables keyed to deposit numbers within each quadrangle identifying one or more mineral deposits within a 3-mile radius. The table also includes the MAS sequence number (to relate it to Bureau files), major commodities associated with the deposit, and an indicator of past production. Available for reference at AFOC/A, AFOC/F, and AFOC/J. Copies of these maps will not be available for purchase.

OFR 71–86. Maps Summarizing Land Availability for Mineral Exploration and Development in South-Central Alaska, 1985, by Robert G. Bottge. May 27, 1986. 21 maps. These maps show land within 20 Alaskan quadrangles (Healy, Mount Hayes, Talkeetna Mountains (2 maps), Gulkana, Nabesna, Lime Hills, Tyonek, Anchorage, Valdez, McCarthy, Lake Clark, Kenai, Seward, Cordova, Bering Glacier, Iliamna, Seldovia, Blying Sound, Middleton Island, and Icy Bay) that was open to mineral exploration as of July 1, 1985. As many as 15 other land subclassifications are depicted, as well as restrictions, private lands, and land closed to mining. The mineral deposits plotted are based on the Bureau of Mines Minerals Availability System (MAS). Included are tables keyed to deposit numbers within each quadrangle identifying one or more mineral deposits within a 3-mile radius. The table also includes the MAS sequence number (to relate it to Bureau files), major commodities associated with the deposit, and an indicator of past production. Available for reference at AFOC/A, AFOC/F, and AFOC/J. Copies of these maps will not be available for purchase.

OFR 72–86. Using ADA (Accident Data Analysis) in Mine Safety Research, by E. T. Bowers. June 1986. 111 pp. 7 figs. This report describes the Accident Data Analysis (ADA) computer program developed at the Spokane Research Center to provide a rapid broad-based analysis of mining accidents. Because the Bureau of Mines often needs this type of information for the development of viable research programs, the ADA program was written to access and analyze accident data available from the Labor Department's Mine Safety and Health Administration. This report describes the ADA program, the data it uses, and the potential value it has for planning mining research. Research was done by the Bureau of Mines Spokane Research Center. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 73–86. Research To Determine the Feasibility of Utilizing Employee Assistance Programs for the Mining Industry—Final Report, by Paul S. Goodman. Jan. 1986. 234 pp. 5 figs. This report examines the feasibility of employee assistance plans for the coal industry. Three issues are examined in detail. First, the prevalence of off-the-job factors such as alcoholism, drug abuse, and marital problems are examined in a sample of miners from the eastern, midwestern, and western underground coalfields. Then data were presented that examined the link between these off-the-job factors and behaviors critical to the mines such as absenteeism and turnover. Lastly, the effectiveness of the major employee assistance program in underground coal mining—the HELP Program—was examined. The report contains recommendations on whether coal mining companies should implement these programs and how these programs should be designed. Research was done under contract J0100069 at Carnegie-Mellon University. Available for reference at AD/MR, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–227089; paper copy price code A11.

OFR 74–86. Psychophysical Investigations of Discomfort and Disability Glare From Underground Coal Mine Illumination Systems, by K. L. Whitehead, P. Lindahl, R. Vincent, and C. Crouch. Oct. 1983. 252 pp. 52 figs. A literature search was conducted to identify current light-control technology and hardware that may be applicable on underground lighting systems to minimize disability and discomfort glare. No research dealing specifically with mine lighting was found, but abstracts on research considered potentially applicable are included in the report. Information on several commercial light-control products for use in controlling glare are also included. Vision tests conducted on 137 mine personnel to determine their discomfort and disability glare sensitivity indicate their sensitivity to disability glare is about the same as the general population. Miners' sensitivity to discomfort glare is 40% greater coming off-shift than when going on-shift. Tests on currently available mine lighting hardware showed none were satisfactory with respect to glare potential. Reflectivity measurements showed the average reflectivity of mine surfaces were 4.2% for coal, 8.3% for the roof, and 4.0% for the floor. Research was done under contract J0308090 by Bituminous Coal Research, Inc. Available for reference at ALRC, AVRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–226941; paper copy price code A12.

OFR 75–86. Development of a Reduced-Noise Auger, Cutting Head, by Mark R. Pettitt. Mar. 1983. 195 pp. 69 figs. Noise surveys conducted in underground coal mines have consistently indicated that auger mining machines subject the operator and helpers to excessive noise exposure. The machine cutting heads have been identified as the primary noise source. This report documents the research program conducted to (1) investigate the nature of the cutting head noise problem, (2) develop noise control concepts, (3) devise in-mine survivable techniques to implement the noise control concepts, and (4) build and demonstrate prototype reduced-noise auger miner cutting heads. The dynamic forces generated during coal cutting by the brittle fracture of coal are predominantly low frequency. The low-frequency (less than 1,500 Hz) structural response of the cutting head determines the noise radiated by the cutting head. The most feasible methods of reducing the cutting head low-frequency response are to increase both the structural stiffness and the low-frequency damping. A technique was devised to achieve these goals. The standard plate helix was replaced by a sand-filled hollow helix of triangular cross section, and the core diameter was increased with an attendant reduction in helix depth. Extended in-mine tests demonstrated the operational capability of the reduced-noise auger cutting heads. The simple noise control concepts are valid for all continuous miner cutting heads. The sand-filled hollow helix technique, which achieved a 10-dB(A) noise reduction for the auger, can be used on any helix-bearing cutting head. Research was done under contract H0188065 by Wyle Laboratories. Available for reference at ALRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–226933; paper copy price code A09.

OFR 76–86. South Africa and Critical Materials, by Staff, Division of Minerals Policy and Analysis. July 1986. 86 pp. 8 figs. In September 1985, the chairman of the Transportation, Aviation and Materials Subcommittee of the House of Representatives requested that the Director of the Bureau of Mines address the issue of South Africa and critical materials dependency in testimony before the subcommittee. Subsequent to the testimony, the Bureau has prepared a technical report focusing on the importance of South Africa and, in some cases, its neighboring countries as suppliers of six key materials: chromium, manganese, platinum-group metals, cobalt, gold, and vanadium. The report includes a qualitative analysis that examines the supply shortfall resulting from a potential disruption, options that are available for mitigating the impact and their likely effectiveness, and quantitative analyses that estimate the economic impacts in the chromium and manganese markets resulting from peacetime disruption scenarios specified by the subcommittee chairman. The concluding section treats the role and capabilities of the Bureau of Mines in dealing with mineral supply disruptions. Research was done by the Bureau of Mines Division of Minerals Policy and Analysis. Available for reference at AD/MDA, AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 86–236601; paper copy price code A05.

OFR 77–86. Silver Extraction From Marginal Resources, by H. J. Heinen, D. G. Peterson, and R. E. Lindstrom. 1975. 17 pp. 9 figs. Modification of conventional cyanidation processes are being investigated by the Bureau of Mines to develop more efficient methods of extracting silver values from mine wastes and low-grade and refractory ores. One technique developed involves the selective precipitation of silver as Ag_2S from cyanide solutions followed by recovery of residual gold values on activated carbon. Carbon-in-pulp cyanidation appears promising for processing slimy tailings with the development of an efficient technique for stripping silver from loaded carbon with alkaline ethanol solutions at ambient temperature and pressure. Salt roasting-cyanidation treatment of a refractory ore gave 88% silver extraction compared with 60% attained by conventional cyanidation. The chloridized calcine is amenable to percolation or heap leaching with dilute cyanide solution. Research was done by the U.S. Bureau of Mines Reno Research Center. Available for reference at AD/MMR, ALRC, AVRC, LIB, RERC, RORC, SLRC, and TURC. Order ONLY from NTIS: PB 86–245917; paper copy price code A02.

OFR 78–86. Belt Conveyor Maintenance Installation Procedures, by Svend Bue Rondum. Oct. 1982. 91 pp. 66 figs. This report includes a collection of data from mine companies and manufacturers derived from on-site visits as well as a mail survey. Analysis activity was directed at developing an understanding of currently used safety practices related to underground coal mine belt conveyors and formulating better safety practices. This activity led to the development of design criteria upon which both the hardware and the procedures manual were based. Hardware development consisted of the conceptualization of new and unique solutions to existing problems, followed by the successful design, fabrication, and in-mine testing of prototypes (saucer skid, armored level, controlled tensioning device, and turnbuckle tensioning wrench). On-site observations and in-depth discussions with all levels of mine personnel, together with information from equipment manufacturers, provided the necessary background for the conceptualization of this procedures manual. Research was done under contract J0215004 by Management Engineers Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

OFR 79–86. Capital and Operating Cost Estimating System Handbook for Alumina Refinery Facilities, by R. F. Neider. May 1985. 177 pp. 3 figs. This report provides the methodology for developing capital and operating costs related to an alumina refinery. The costs developed are for a mid-United States location with the methodology prepared to allow translation of costs worldwide. Also, costs for environmental and alternative unit processes are identified. Research was done under contract J0245003 by Raymond Kaiser Engineers Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 86–246568; paper copy price code A08.

OFR 80–86. Capital and Operating Cost Estimating System Handbook for Aluminum Smelter Facilities, by R. F. Neider. Aug. 1985. 196 pp. 6 figs. This report provides the methodology for developing capital and operating costs for aluminum smelter facilities. The costs developed are for a mid-United States location with the methodology prepared to

allow translation of costs worldwide. Also, costs for environmental and alternative unit processes are identified. Research was done under contract J0245003 by Raymond Kaiser Engineers Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 86–246576; paper copy price code A09.

OFR 81–86. Capital and Operating Cost Estimating System Handbook for Lead Smelting and Refining Facilities, by R. F. Neider. Apr. 1985. 282 pp. 6 figs. This report provides the methodology for developing capital and operating costs related to lead smelting and refinery facilities. The costs developed are for a mid-United States location with the methodology prepared to allow translation of costs worldwide. Also, costs for environmental, secondary smelting, and alternative technology processes are identified. Research was done under contract J0245003 by Raymond Kaiser Engineers Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 86–246592; paper copy price code A12.

OFR 82–86. Capital and Operating Cost Estimating System Handbook for Electrolytic Zinc Refining Facilities, by R. F. Neider. Sept. 1985. 199 pp. 6 figs. This report provides the methodology for developing capital and operating costs for electrolytic zinc refining facilities. The costs developed are for a mid-United States location with the methodology prepared to allow translation of costs worldwide. Also, costs for environmental and alternative unit processes are identified. Research was done under contract J0245003 by Raymond Kaiser Engineers Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 86–246584; paper copy price code A09.

OFR 83–86. Mine Hoist Electrical Systems Study. Volume I—Mine Hoist Electrical Systems Inspection Manual, by Joseph D. Cooper and Robert H. King. July 1985. 199 pp. 31 figs. This manual describes how to inspect and maintain mine hoist electrical systems. It includes daily, weekly, monthly, and annual checklists. Federal regulations pertaining to electrical inspection are reviewed. Inspection and maintenance of hoist drives, switchgear, sensing devices, and brake cars are described. Considerable information is provided on Lilly controllers. American National Standards Institute standards for mine elevator inspection are reviewed. Research was done under contract J0134006 by the Colorado School of Mines. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 86–235132; paper copy price code A09.

OFR 84–86. Development of Engineering and Cost Data for Foreign Magnesium Properties, by George E. Aiken. Sept. 1984. 32 pp. 3 figs. This report summarizes the objectives and methodology of a contract to obtain and record data on some 23 potential or operating foreign sited plants producing magnesia or magnesium products. These foreign plants were visited at location once they were established as significant factors in world magnesium markets. Individual resources or reserves of raw materials were established or estimated, and technical descriptions of existing or conceptual operations are described. Capital and operating costs were estimated for all properties profiled in the study. Research was done under contract J0225016 by Raymond Kaiser Engineers, Inc. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 86–236700; paper copy price code A03.

OFR 85–86. Preliminary Mine, Prospect, and Sample Location Maps and Descriptions, Juneau Gold Belt Area, by Earl Redman, William S. Roberts, Al Clough, and Joseph Kurtak. May 29, 1986. 68 pp. 5 figs. This report describes Bureau of Mines fieldwork that revealed the locations of numerous adits, shafts, and other old mine workings, many of which were previously unreported or misplotted on existing published maps of the Juneau Gold Belt portion of the Juneau Mining District, an area which has produced $157,000,000 worth of gold, silver, and lead since 1880. The Bureau examined approximately 85 mines, prospects, and occurrences during this study, interviewed local prospectors, claim owners, and geologists, and conducted an extensive literature search that included reports by the U.S. Geological Survey, the State of Alaska, and the Bureau of Mines, as well as unpublished private company reports. Research was done by the U.S. Bureau of Mines Alaska Field Operations Center at Anchorage, AK. Available for reference at AD/MDA, AFOC/J, IFOC, and WFOC. Copies of this report will not be available for purchase.

OFR 86–86. Development of the Capacity To Assess Occupational Noise Overexposure in the Mining Industry, by A. G. Galaitsis. Feb. 1986. 205 pp. 9 figs. The purpose of this work was to expand and improve the scope and accuracy of the method developed for the prediction of the number of workers overexposed to noise in the mining industry. A significant portion of the noise data were acquired during mine visits that took place in the course of this study. These data were obtained with time-resolved dosimeters, which among other things store a time history of the sampled noise for an 8-hour work period. The remainder of the noise data have been obtained from MSHA files and from other Bureau of Mines projects. The report reviews the prediction model, discusses the model's assumptions and approximations, describes the function of the developed software, offers typical examples on the use of the software, and includes plots of the newly acquired data records. Research was done under contract J0245001 by BBN Laboratories Inc. Available for reference at ALRC, AVRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87–106191; paper copy price code A10.

OFR 87–86. Summary of Surface Testing of the Umbrella Miner Concept and First Prototype Machine, by Richard B. Farrar. July 1986. 11 pp. The umbrella miner, a prototype continuous mining machine for simultaneous mining and bolting in a room-and-pillar coal mine, was designed and fabricated. This machine was tested on the surface at the Pittsburgh Research Center's mine equipment test facility during an 18-month period from September 1984 through February 1986. Surface testing of the umbrella miner first prototype unit showed the concept to have considerable potential for fulfilling the industry need for a mining machine that can simultaneously mine coal, bolt roof, and advance continuously from "break to break." However, a second-generation machine would have to be designed, fabricated, and tested before that potential could be realized. The first prototype umbrella miner, a highly experimental machine, experienced several major problems during surface testing. Chief among these were the inability to tram and maneuver dependably, the inconsistent operation of the hydraulically powered functions because of the complexity of the hydraulic system, and unreliability of the gathering head conveyor. Research was done under contract J0133926 by Fairchild International, Inc. Available for reference at ALRC, AVRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87–105789; paper copy price code A02.

OFR 88–86. Design, Construction and Mine Testing of a Device for Installing Cement-Grouted Roof Bolts, by Douglas W. Ounanian and Robert L. Cardenas. Apr. 1986. 130 pp. 31 figs. Inorganic cement grouts for roof bolting applications provide an alternative to resin-grouted bolts. Inorganic cement grout is nonflammable, nontoxic, and nonallergenic and offers the potential for significant savings over petroleum-based resin if it can be mixed and injected cheaply and reliably. This report describes the development and testing of a device that mixes on demand and injects cement-based grouts for roof bolting. The grout mix-inject system mixes dry cement with water to form

grout, pumps it into a delivery hose, and injects it into the roof bolt hole. The mixing and pumping system is based on a twin screw extruder. The geometry of the twin screws is such that the unit is self-cleaning. The injection is performed pneumatically, and no hardware is placed up the hole. The bolter-mounted device was developed through laboratory testing during which injections were made into simulated bolt holes drilled in concrete. The underground testing and evaluation program demonstrated the ability of the system to install competent cement-grouted roof bolts. Research was done under contract H0202027 by Foster-Miller, Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–106233; paper copy price code A07.

OFR 89–86. Distribution, Analysis, and Recovery of Placer Gold From the Porcupine Mining Area, Southeast Alaska, by Robert B. Hoekzema, Steven A. Fechner, and Tom Bundtzen. 1986. 49 pp. 14 figs. The Bureau of Mines (Bureau) and the Alaska Division of Geological and Geophysical Surveys (ADGGS) completed an evaluation of the placer resources of the Porcupine Mining Area near Haines, AK, during 1985. The Bureau sampled and evaluated the placer deposits, and the ADGGS mapped and geology and summarized the glacial geologic history of the area. This report summarizes the results of the study. Gold was discovered along the Klehini River in 1898. A gold rush ensued that resulted in the discovery of gold on Porcupine Creek and nearby drainages and that has produced 79,650 oz of raw placer gold, most prior to 1936. Three types of placer deposits occur in the area: (1) stream channel gravels, (2) bench placers, and (3) alluvial fans. Organic material from bench deposits were age dated from 2,100 to 2,700 years ago. Each of these deposit types was sampled to estimate resources, identify gold fineness, determine mineral development potential ratings for streams, and calculate optimum screening sizes for use in recovery plants. Identified resources include 932,000 yd^3 of gravel rated as having moderate or high mineral development potential. Bulk character studies of gravel from Lower Porcupine Creek indicate that washing plants should be designed to screen to minus 1 mesh and recover gold to plus 80 mesh. Gold fineness of 13 samples ranged from 669 to 902 and averaged 837. Research was done by the Bureau of Mines and the State of Alaska Division of Geological and Geophysical Surveys. Available for reference at AFOC/J, IFOC, and WFOC. Copies of this report will not be available for purchase.

OFR 90–86. Coal Injection in an Experimental Blast Furnace: A Comprehensive Report, by Philip L. Woolf. Aug. 1985. 58 pp. 6 figs. Blast furnace coal injection tests conducted by the Bureau of Mines in cooperation with a consortium of 22 steel companies in 1963–64 are described. These tests were part of a program of extensive investigation of auxiliary fuel injection in the Bureau's experimental blast furnace located at Bruceton, PA. Seventeen coal tests are described on various coals ranging from anthracite to subbituminous. Factors affecting maximum rates of the injection were studied. These included coal size, coal type, and oxygen enrichment. The effect of high sulfur content coal and the means to control metal sulfur were investigated. An epilogue briefly describing the commercial experience with coal injection from 1960 to the present has been included. Research was done under contract J0134049 by Philip L. Woolf. Available for reference at AD/MMR, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87–111159; paper copy price code A04.

OFR 91–86. History of the Juneau Gold Belt, 1869–1985: Development of the Mines and Prospects From Windham Bay to Berners Bay, by Earl Redman. 1986. 78 pp. 32 figs. This report chronicles the exploration and mining development history of the Juneau Gold Belt from the discovery of the first placer gold in 1869 to the reevaluation of the economic potential of the Alaska Juneau Mine in 1985. Using an outline form, historical information is given year by year for most of the mines and prospects in the Gold Belt. The report includes information about initial discoveries, timing of mine exploration, construction of mills, mining problems and closures, and pertinent general history. Research was done by the U.S. Bureau of Mines Alaska Field Operations Center at Juneau, AK. Available for reference at AD/MDA, AFOC/J, IFOC, LIB, PRC/B, and WFOC. Copies of this report will not be available for purchase.

OFR 92–86. Changes in Worldwide Demand for Metals, by Jack G. Faucett and Harry J. Chmelynski. Aug. 1986. 179 pp. 68 figs. Worldwide demand for metals has been analyzed to identify the important factors that explain differences in the level of demand among world countries. The per capita demand for steel, aluminum, copper, and total nonferrous metals has been investigated for 40 to 50 countries over a 22-year period. These countries have been further grouped into four world regions for purposes of making generalizations about the importance of these factors for countries in different stages of development and with dissimilar levels of per capita gross domestic product (GDP). Intercountry and intertemporal differences are explained largely by differences in per capita GDP and changes over time in per capita GDP, oil real prices, and to a lesser extent, metal real prices. The trend in world consumption is dramatically different in the last decade than the previous one. In 1962–73, per capita consumption increased in all areas and consumption intensity (consumption divided by GDP) increased in most areas. In 1973–84, per capita consumption fell in most areas and intensity fell dramatically, except in developing nations. Research was done under contract J0156030 by Jack Faucett Associates. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–119012; paper copy price code A09.

OFR 93–86. Monitoring Moisture Migration in the Vadose Zone Using Electrical Resistivity Techniques, by M. J. Waller, W. F. Kean, and H. R. Layson. Jan. 1986. 94 pp. 47 figs. Surface resistivity techniques were used at four field sites to monitor changes in apparent resistivities with variations in soil moisture content in the vadose zone. Apparent resistivity values were correlated with gravimetric moisture contents from soil samples taken at each site. Tensiometer readings were taken at two sites and correlated with the results of gravimetric moisture contents and apparent resistivities. Moisture at two of the sites was added by extensive watering; rainfall events were monitored at the other two sites. A recharge event at a dewatering program was monitored at a fifth site. A Ghosh-Koefed multilayer computing algorithm was used to derive true resistivities from bulk or apparent resistivities. An automated data acquisition system was developed to measure resistivity changes and to process the data in the field. These studies are the first to evaluate measurement of moisture migration in clay rich soils using surface resistivity techniques. Results indicate that surface resistivity techniques readily measure changes in moisture contents in the vadose zone in clay rich soils. Correlation of apparent and true resistivity values with gravimetric moisture contents is more complex and requires additional research. Research was done under contract H0245004 by EarthTech, Inc. Available for reference at AFOC/J, ALRC, AVRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–117842; paper copy price code A05.

OFR 94–86. Hydrologic Properties and Characteristics of Two Tailings Ponds, by R. L. Hoye and W. E. Thompson. Jan 1986. 163 pp. 72 figs. This report describes site investigations conducted at two tailings impoundments to develop baseline hydrological data for the evaluation of these waste management practices. The impoundments are associated with a lead mine and mill in Missouri and a gold mine and

mill in South Dakota. The overall objectives of the investigations were to estimate the rate of seepage, to evaluate water quality impacts, and to obtain a better definition of the hydrogeology in the immediate area of the dams. Water table contour maps were prepared, water balance calculations were made, pump tests were conducted, water quality samples were collected and analyzed, and pertinent existing data were assembled and evaluated. Results of the study were largely inconclusive with regard to determination of water quality impacts due to seepage and estimation of theoretical seepage rates by water balance calculation. They have, however, provided additional insight into understanding the complex hydrogeological systems at these sites. Research was done under contract H0222003 by PEI Associates, Inc. Available for reference at AD/MR and SRC. Copies of this report will not be available for purchase.

OFR 95–86. Availability of Strategic and Critical Minerals: Role of the Republic of South Africa, by Staff, Minerals Availability Program. Oct. 1986. 111 pp. 21 figs. Possible consequences of continuing internal political unrest and the imposition of foreign sanctions raise concerns about the traditional reliability of the Republic of South Africa (South Africa) as a major world supplier of important minerals. A recent Bureau of Mines technical report (Open File Report 76-86) examined the impact of temporary peacetime disruption scenarios for six key materials (chromium, cobalt, gold, manganese, platinum-group metals, and vanadium) and mitigating options. Because of South Africa's dominant producer position for these minerals (except for cobalt), expansion of primary production capacity outside of South Africa is not a short-term mitigative option. However, prospects of a longer term disruption would likely spur investment in capacity expansion in alternative market economy country (MEC) supply sources. This report identifies the resources, production costs, and burdens that would be placed on alternative MEC producers of chromium, cobalt, gold, manganese, and platinum-group minerals if South Africa's production were subject to a long-term disruption. When long-term supplies from South African deposits are discounted, more than a few years reserves were found only for cobalt and manganese. Even for these two minerals, higher sustained prices would be required to increase manganese production capacity and to support means of cobalt transportation not through South Africa. Research was done by the U.S. Bureau of Mines. Available for reference at AD/MDA, AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 87–119038; paper copy price code A06.

OFR 96–86. Flywheel-Powered Shuttle Car, by Donald Christofferson. Mar. 1986. 173 pp. 26 figs. This report documents the program conducted to demonstrate the application of a flywheel-powered propulsion system to underground mining shuttle cars. Such application can replace the present electrical trailing cable common to most shuttle cars and thereby eliminate those safety hazards, maintenance problems, and haulage route limitations inherent in the trailing cable. Described are the activities undertaken to specify and design a flywheel of optimum size, shape, and material; to identify the best concepts of input and output systems; and to achieve installation of the power package into a shuttle car. The resultant flywheel-powered shuttle car is an FMC Corp. Model 6L shuttle car, 6-ton capacity, 20-ton gross vehicle weight, powered by a flywheel system with 4.5-kilowatt-hour usable energy. The completed vehicle was delivered to the Bureau of Mines in Bruceton, PA, for testing and evaluation. Research was done under contract J0333911 by Engineered Systems & Development Corp. Available for reference at AD/MR, ALRC, AVRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87–119079; paper copy price code A08.

OFR 97–86. Evaluation of Mine Stopping Sealants and Squeeze Blocks, by M.D. Marshall. Aug. 1986. 78 pp. 7 figs. A survey and test program was conducted to establish from materials now in use or available the best sealants for concrete block stoppings and the value of squeeze blocks for stoppings with mine convergence. Mines were surveyed for sealants currently used, and commercial products were surveyed for new sealant materials. An in-mine evaluation showed that, within limits, poor stopping construction practices rather than sealants were the cause of leakage. Sealants were found that could be brushed on concrete blocks rather than troweled to produce stoppings twice the strength of mortared joint stoppings, and equal in strength to dry-stacked stoppings, both standard construction techniques. The brush-on technique and improved construction practices were proved on demonstration stoppings tested over a period of 1 year and are now recommended by the Bureau of Mines in a new handbook. Polystyrene boardstock was the most commonly used material for squeeze blocks and was considered by mines using squeeze blocks to be helpful in maintaining stopping integrity under mine convergence conditions. Alternative squeeze block materials with overall properties better than polystyrene were found. Research was done under contract J0395042 by MSA Research Corp. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–138806; paper copy price code A05.

OFR 98A–86. Human Resource Management Skills and Coal Mine Productivity—Final Report Volume I, by Paul S. Goodman, Marilyn S. Hersh, and Cynthia A. Zak. Mar. 1985. 92 pp. Volume I of this report presents the first national survey of miners' attitudes and opinions about their work. The goal is to present attitudinal data that bear on coal production. Interviews were conducted in 26 mines with 2,000 miners. High levels of cooperation were exhibited by management, union, and the employees. Data are presented about miners' attitudes about general aspects of their work such as pay, supervision, their jobs, etc. Another section of this report reviews opinions about specific aspects of work performance. Recommendations are presented. Research was done under contract J0133924 at Carnegie-Mellon University. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–138327; paper copy price code A05.

OFR 98B–86. Human Resource Management Skills and Coal Mine Productivity—Final Report Volume II, by Paul S. Goodman and Dennis P. Leyden. Mar. 1985. 78 pp. Volume II of this report explains reasons for the productivity differences in mining crews. The literature on group productivity is examined. Then a new approach to estimating productivity differences is proposed and estimated across seven different mines. The results indicate a fairly robust model in terms of explanatory power. Recommendations on how the model can be used as a managerial tool are presented. Research was done under contract J0133924 at Carnegie-Mellon University. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–138335; paper copy price code A05.

OFR 99–86. Development of Optimal Water Spray Systems for Dust Control in Underground Mines, by William E. Schroeder, Charles Babbitt, and Terry L. Muldoon. Sept. 1986. 146 pp. 60 figs. Water sprays have been used on continuous miners for many years for bit lubrication, for cooling, and for dust control. Although these sprays do suppress some dust, they can also increase operator dust exposure levels. The air-moving action of the sprays creates recirculation of the dust cloud into the fresh intake air, thus contaminating the operator's breathing zone. This phenomenon is called dust rollback and is caused by sprays with high reach operating at high pressure, particularly in working faces with low primary airflow. The airstream entering the working face is usually

clean. If rollback from the face can be minimized, the continuous miner operator can be supplied with clean air. This report describes the laboratory development and field evaluation of a new water spray system for continuous miners that minimizes rollback while maintaining adequate dust suppression. The system, called the Antirollback Water Spray System, uses flat fan sprays operating at low pressure to provide water more efficiently to the cutting zone without creating excessive air turbulence. The system has shown 40% to 50% reductions in continuous miner-generated dust measured at the operator. Research was done under contract H0199070 by Foster-Miller, Inc. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–141537; paper copy price code A07.

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OFR 1A–87. Assessment of Whole Body Vibration Levels of Coal Miners. Volume I: Whole Body Vibration Exposure of Surface Coal Mining Machine Operators, by P. J. Remington, J. Stahr, and D. A. Andersen. July 1983. 291 pp. 17 figs. Field measurements utilizing a seat pad accelerometer were made on 61 surface coal mining machines in order to quantify the vibration levels experienced by the operators. Those data were combined with information on the statistics of the operating times of those machines in order to compare the operator's vibration exposure to the criteria in ISO 2631, "A Guide for the Evaluation of Human Exposure to Whole Body Vibration." The comparison showed that about one-half of all surface coal mining machine operators can be expected to be exposed to vibration exceeding the fatigue-decreased proficiency criterion, whereas only on the order of 15% would be expected to experience vibration exceeding the exposure limit. Detailed exposure statistics are presented and the implications of the results are discussed. Research was done under contract J0308045 by Bolt Beranek and Newman Inc. Available for reference at AD/MR, ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87–144101; paper copy price code A13.

OFR 1B–87. Assessment of Whole Body Vibration Levels of Coal Miners. Volume II: Whole Body Vibration Exposure of Underground Coal Mining Machine Operators, by P. J. Remington, D. A. Andersen, and M. N. Alakel. Mar. 1984. 114 pp. 5 figs. Field measurements utilizing a seat pad accelerometer were made on 25 underground coal mining machines in order to quantify the vibration levels experienced by the operators. Those data were combined with information on the statistics of the operating times of those machines in order to compare the operator's vibration exposure to the criteria in ISO 2631, "A Guide for the Evaluation of Human Exposure to Whole Body Vibration." The comparison showed that about 30% to 40% of all underground coal mining machine operators can be expected to be exposed to vibration exceeding the fatigue-decreased proficiency criterion, whereas only 10% to 15% would be expected to experience vibration exceeding the exposure limit. The primary sources of the exposure are shuttle cars and possibly scoop trams. Detailed exposure statistics are presented, and the implications of the results are discussed. Research was done under contract J0308045 by Bolt Beranek and Newman Inc. Available for reference at AD/MR, ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87–144119; paper copy price code A06.

OFR 1C–87. Assessment of Whole Body Vibration Levels of Coal Miners. Volume III: Low Frequency Vibration Exposure and Seat Peformance, by Paul J. Remington. Nov. 1984. 66 pp. 30 figs. The field data gathered as part of the measurements described in Volumes I and II were reanalyzed in the low frequency regime (0.1 Hz to 1 Hz) where motion sickness normally occurs. These data were compared to the international standard "ISO 2631 Addendum 2: Evaluation of exposure to whole body z-axis vertical vibration in the frequency range of 0.1 to 1.0 Hz." For both underground mining machines and surface mining machines, the results showed that one would not expect motion sickness to be a severe problem. New field data were gathered on the vibration reduction performance of various seat designs found on surface coal mining machines. The vibration during normal operation was simultaneously measured on the seat using the standard seat pad accelerometer package described in the previous two volumes, and on the floor of the machine at the base of the seat. Preliminary indications are that the so-called high performance seats used for operator vibration reduction do not offer significant improvement over conventional seats. Research was done under contract J0308045 by Bolt Beranek and Newman Inc. Available for reference at AD/MR, ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87–144127; paper copy price code A04.

OFR 2–87. Development of a Passive Mine Roof Fall Warning Device, by Walter P. Haimberger and Carl R. Peterson. May 1983. 116 pp. 40 figs. This report describes the design and the laboratory and field testing of a passive, mechanical mine roof fall warning device. The device relies on the assumption that roof sag velocity (the velocity between the roof surface and some presumed stable horizon some distance into the roof strata) is an indicator of relative roof stability. A sag velocity above some locally determined threshold level suggests impending roof failure. This assumption has previously been empirically proven for several mining situations that are referred to in this work. Several concepts for the warning device are presented. The preferred (and most extensively field tested) solution employs a highly viscous dashpot that transduces the sag velocity into a force and is used to activate a spring preloaded latch indicator assembly. Latch preload is set equal to the force generated by the dashpot at the predetermined critical sag velocity. When this critical sag velocity is exceeded, the latch begins to open. If the sag velocity remains above the critical level for a sufficient length of time (determined by the latch stroke), the latch is tripped, and a visual warning is activated. Research was done under contract J0199067 at the Massachusetts Institute of Technology. Available for reference at DRC, LIB, MSHA, NMH&SA, PRC/B, and SRC. Copies of this report will not be available for purchase.

OFR 3–87. An Economic Reconnaissance of Selected Sand and Gravel Deposits in the U.S. Exclusive Economic Zone, by Staff, Bureau of Mines. Jan 1987. 113 pp. 31 figs. This report details the investigation of seven sand and gravel areas in the U.S. Exclusive Economic Zone because of their perceived potential for containing economically viable deposits. Based on preliminary resource and market analysis, three of these areas were judged to have favorable near-term potential for development. Additional engineering, cost, and financial analysis indicate that two of the three areas—offshore Boston, MA, and New York, NY—should be considered for near-term leasing. Recommendations concerning the two above areas, as

well as several other offshore areas, address the need for detailed market analysis, sample characterization studies to determine commercial suitability, and studies to refine cost and financial analyses. Research was done by the Bureau of Mines. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 87-172938; paper copy price code A06.

OFR 4-87. An Economic Reconnaissance of Selected Heavy Mineral Placer Deposits in the U.S. Exclusive Economic Zone, by Staff, Bureau of Mines. Jan. 1987. 122 pp. 42 figs. This report is one of two concerning selected deposits within the U.S. Exclusive Economic Zone. The objective of this study and the companion sand and gravel study is to aid the Minerals Management Service in their selection of specific offshore areas for consideration of near-term lease offerings. Three selected placer areas were investigated and evaluated using engineering and cost models. Sensitivity analyses were then performed in major physical and engineering parameters affecting the economic viability of mineral resources from these three locations. Research was done by the Bureau of Mines. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 87-172920; paper copy price code A06.

OFR 5-87. Mine Hoist Electrical Systems Study. Volume II—Data Analysis System Design Study, by P. J. A. Lever and F. R. Leffler. July 1985. 154 pp. 18 figs. Safe operation and system integrity are two important properties of a mine hoist electrical system. Previous methods used to assess these systems, though rare, have involved extensive downtime and have required skilled personnel. The recommended design considerations presented in this report are for a proposed automated system that will perform real-time measurements, calculations, and recordings of pertinent performance data. Included are equipment installation and test procedures to be used with the system. The report also contains descriptions of hoist performance criteria, and how they are to be collected. Research was done under contract J0134006 at the Colorado School of Mines. Available for reference at AD/MR, ALRC, DRC, LIB, MSHA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87-162327; paper copy price code A08.

OFR 6-87. Mine Hoist Electrical Systems Study. Volume III—Microprocessor Application Study, by C. Richard Groves. Feb. 1986. 92 pp. 3 figs. As the level of technology applied in the electrical measurement, control, and display portions of mine hoist systems continues to advance, the issues and concerns associated with the ramifications of the application of microprocessor technology on the safety-related aspects of these systems become paramount. This report addresses several aspects of these concerns. Beginning with discussions of microprocessor-based system architectures, the report addresses some existing and anticipated uses of this technology in mine hoist systems and discusses safety-related considerations associated with the areas of data derivation, control and display panels, and system reliability issues. The report concludes with electrical maintenance and inspection considerations associated with the safety assurance of microprocessor-based mine hoist systems. Research was done under contract J0134006 at the Colorado School of Mines. Available for reference at AD/MR, ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87-157459; paper copy price code A05.

OFR 7-87. Interaction of Radio Transmissions on Mine Monitoring and Control Systems, by Larry G. Stolarczyk. July 1985. 65 pp. 13 figs. This report describes the creation of an efficient method to determine if command, control, communication, and monitoring (3CM) equipment in coal, metal, and nonmetal mines is susceptible to radio frequency interference (RFI) from the medium-frequency (MF) radio communications system. A qualitative and quantitative RFI test plan was developed for in-mine and laboratory evaluation of the equipment. The laboratory testing was accomplished using the transverse electromagnetic wave (TEM) test chamber. Detailed information on the test plan and the TEM test chamber is included. During in-mine testing of the MF system, some underground equipment malfunctioned when the transmitter's radiating antenna was in close proximity. Electromagnetic compatibility (EMC) testing was done on three levels: component (circuit or box), subsystems, and system. Nine tables are included that show the results of testing various equipment for RFI. Research was done under contract J0123038 by A.R.F. Products, Inc. Available for reference at AD/MR, DRC, LIB, MSHA, NMH&SA, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 87-155032; paper copy price code A04.

OFR 8-87. Development of Recommended Criteria and Test Facilities for Acceptance of High-Voltage Permissible Loadcenters and Switchgear Enclosures, by Arlie B. Massey. Sept. 1986. 45 pp. 15 figs. This report makes refinements to criteria described in OFR 58-86. The criteria addresses the permissibility of high-voltage permissible loadcenters and switchgear enclosures in seven major areas: higher internal pressure design requirements, minimum free volume, minimum free distance, minimum electrical clearances between exposed electrical conductors, electrical creepage distances, use constraints for control transformers, and explosion test requirements. It also contains chapters on criteria selection rationale, a discussion on parts of the OFR 58-86 recommendations, and the design and construction of mobile test facilities. Research was done under contract J0333909 by the U.S. Department of Labor Mine Safety and Health Administration. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87-157434; paper copy price code A03.

OFR 9-87. Characterization of Subsidence Over Pillar Extraction Panels, by R. W. Bruhn and R. C. Speck. Mar. 1985. 222 pp. 77 figs. An investigation was made of ground response to pillar retreat mining in a 5.5-foot-thick seam at 600-foot depth at a site in northern West Virginia. This paper describes mining-related stress changes and movements at mine level, displacements within the overburden, and ground surface subsidence and ground water level variations. Hydraulic properties of the rock strata were found to change and water levels decline in certain deep-lying strata. Research was done under contract J0233920 by GAI Consultants, Inc. Available for reference at AD/MR, LIB, OSM, PRC/B, and TCRC. Copies of this report will not be available for purchase.

OFR 10-87. Maps Summarizing Land Availability for Mineral Exploration and Development in Northern Alaska, 1986, by Kenneth M. Maas. Dec. 18, 1986. 33 maps. These maps show land within 33 Alaskan quadrangles (Ambler River, Arctic, Baird Mountains, Barrow, Barter Island, Beechey Point, Chandalar, Chandler Lake, Christian, Coleen, De Long Mountains, Demarcation Point, Flaxman Island, Harrison Bay, Howard Pass, Ikpikpuk River, Killik River, Lookout Ridge, Meade River, Misheguk Mountain, Mount Michelson, Noatak, Philip Smith Mountains, Point Hope, Point Lay, Sagavanirktok, Survey Pass, Table Mountain, Teshekpuk, Umiat, Utukok River, Wainwright, and Wiseman) that was available for mineral exploration and development in northern Alaska in 1986. The mineral deposits shown on the accompanying overlays are identified in the Bureau of Mines Minerals Availability System (MAS). Available for reference at AFOC/A, AFOC/F, AFOC/J, and LIB. Copies of these maps will not be available for purchase.

OFR 11-87. Improved Stopping, Door, and Overcast Construction for Oil Shale Mines, by M. E. Adam, C. E.

Brechtel, and J. F. T. Agapito. June 1986. 186 pp. 28 figs. This report describes the construction and testing of large (30-ft-high by 55-ft-wide) stopping and overcast structures in an oil shale mine. The work was undertaken to develop construction techniques and cost data and to measure leakage rates on full-scale structures in an oil shale mine. A design data base was developed by reviewing industry practice, oil shale industry plans, and technical literature. Alternate layouts for room-and-pillar mining were examined to find ways to reduce the size and number of ventilation control structures. Six full-size stoppings and one overcast structure were built at the Colony Pilot Mine. Leakage rates were measured using both SF_6 tracer gas techniques and the "brattice window" method. The leakage was measured both before and after a full-scale face blast. Blast air pressure were measured across two of the stoppings. Cost and leakage data were used to evaluate the projected overall performance of various combinations of the stoppings in a two-panel oil shale mine. Research was done under contract J0145020 by J. F. T. Agapito & Associates, Inc. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–174918; paper copy price code A09.

OFR 12–87. Development and Validation of a Comprehensive Mine Rescue Team Training Program, by Ronald Althouse, George Lies, and William Moser. Aug. 1986. 80 pp. 2 figs. This report discusses the design and development of a comprehensive training program for Mine Rescue (MR) teams and a management tool for mine emergency preparedness. Approved by MSHA in 1984 to meet the requirements for 30 CFR, Part 49, the MR team training materials are user-ready, provide the principles and practices for both initial and advanced training, and supply MR teams with problem-solving activities. The Mine Emergency Preparedness Program (MEPP) is used by management as a tool in the preparation of company personnel for handling mine emergency operations such as mine fires, explosions, inundations, and other hazards that require a total response plan, and encompasses all of the steps from hazard recognition and containment to the involvement of teams in the rescue of survivors and the restoration of mining operations. As a completely new program, MEPP provides means for anticipatory planning of key initial steps in the development of procedures that can lead to swift, orderly, and effective response to a mine emergency. Currently available to the mining industry, these two resources can bolster the efforts of any mine to deal with underground emergencies, to promote planning, and prepare personnel for emergency actions. Research was done under contract J0308002 at West Virginia University. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–174512; paper copy price code A05.

OFR 13–87. Demonstration of MINOS Coal Clearance System at Barnes & Tucker Lancashire No. 20 Mine, by G. S. Beaumont. Aug. 1986. 361 pp. 29 figs. This report presents a demonstration in the use of a surface-based centralized computer control system for the remote monitoring and control of underground conveyors in a U.S. coal mine. The system selected for demonstration was the Dynalink Micro MINOS system manufactured by Hawker Siddeley Dynamics Engineering Ltd. The site selected was Barnes & Tucker Lancashire No. 20 Mine located near Carrolltown, Cambria County, PA. The system concept and operating and application software was designed and developed by the British National Coal Board. The report describes the selection of the site, specification of the system requirements, and the commissioning, operation, and evaluation of the system under typical U.S. mine operating conditions. Experience with the system, based primarily on the system reliability and performance of conveyor control, was favorable. Mine management personnel felt that the system had successfully achieved its objectives and were taken to expand monitoring and control to other activities. Research was done under contract J0133930 by the National Coal Board. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–171294; paper copy price code A16.

OFR 14A–87. Research Study To Determine the Applicability of New Methodologies in Mine Accident Investigation—Volume I, by Louis Schaffer. July 1986. 185 pp. 53 figs. This report describes the development, field testing, and evaluation of a new method of investigating mining accidents. Initial testing of these techniques began at five mines owned by two mining companies, followed by further evaluation data obtained from four surface and two underground mines operated by five additional companies. Altogether, there were 170 loss incidents investigated at the cooperating mines using the methodology under evaluation. These loss incidents included injuries, property damage accidents, production losses, and other events generally referred to as "near misses." Volume I of this report discusses the background research, the design of the methodology, and the preliminary field tests in Utah mines. Research was done under contract J0308008 by Woodward Associates, Inc. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and WFOC. Order ONLY from NTIS: PB 87–172219; paper copy price code A09.

OFR 14B–87. Research Study To Determine the Applicability of New Methodologies in Mine Accident Investigation—Volume II, by Louis Schaffer. July 1986. 127 pp. 41 figs. This report describes the development, field testing, and evaluation of a new method of investigating mining accidents. Initial testing of these techniques began at five mines owned by two mining companies, followed by further evaluation data obtained from four surface and two underground mines operated by five additional companies. Altogether, there were 170 loss incidents investigated at the cooperating mines using the methodology under evaluation. These loss incidents included injuries, property damage accidents, production losses, and other events generally referred to as "near misses." Volume II of this report discusses the field tests at the second group of mines, modifications made to the initial methodology, and the results of its implementation. Research was done under contract J0308008 by Woodward Associates, Inc. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–172227; paper copy price code A07.

OFR 15–87. Feasibility of Economic Zinc, Copper, Silver, and Gold Mining in the Porcupine Mining Area of the Juneau Mining District, Alaska, by Donald W. Baggs and Gary E. Sherman. Dec. 1986. 28 pp. 6 figs. This report describes economic mining feasibility studies conducted by the Bureau of Mines to estimate mining costs in the Porcupine mining area of the Juneau Mining District, southeastern Alaska. Investigations were conducted on the economics of three mineral deposit types: (1) massive sulfide deposits containing zinc, copper, and silver, (2) vein gold, and (3) disseminated gold. Cost estimates were developed using the Bureau of Mines Cost Estimating System. Discounted cash flow rates of return were calculated using the Bureau of Mines MINSIM (mining simulation) computer program. Three sets of metal prices were used in the study based on recent historical price information. Underground longhole stope mining of a massive sulfide deposit containing 25 pct zinc, 1 pct copper, and 68.6 g/mt silver was found to be economic at high metal prices at a quantity of 13,200,000 mt ore. Cut-and-fill mining of a 26,400,000 mt massive sulfide deposit was found to be economic at medium metal prices. Open pit mining of a similar deposit was found to be economic at medium metal prices and 26,400,000 mt ore, or at high metal prices and 6,600,000 mt ore. Underground mining of

a vein gold deposit was found to be economic at a grade of 17.1 g/mt medium metal prices and 1,320,000 mt ore. Open pit mining of a disseminated gold deposit was found to be economic at a grade of 1.71 g/mt medium metal prices and a quantity of 39,600,000 mt ore. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AD/MDA, AFOC/J, IFOC, LIB, PRC/B, and WFOC. Order ONLY from NTIS: PB 87–179198; paper copy price code A03.

OFR 16–87. In Situ Strength Characteristics of Coal Mine Floor Strata in Illinois, by Yoginder P. Chugh. Sept. 1986. 161 pp. 50 figs. This report presents data on bearing capacity and in-place shear strength characteristics of immediate floor strata. Plate load tests were conducted under as-mined and saturated and/or wet conditions. Borehole shear tests were conducted to determine cohesive strength, angle of internal friction, and failure envelope for floor strata at different depths. An attempt was made to correlate the above data with laboratory determined strength deformation characteristics and engineering index properties of floor strata from ongoing studies. The results indicate the nature of floor strata at the two mines to be very similar. Statistically significant correlations were observed for two sets of variables: (1) ultimate bearing capacity and deformation modulus, and (2) natural moisture content of floor in the 0- to 12-in depth range below the coal seam and ultimate bearing capacity. Attempts to correlate ultimate bearing capacity and cohesive strength of immediate floor strata determined from borehole tests and confined compression tests were generally unsuccessful. Research was done under contract J0256002 by Southern Illinois University. Available for reference at AD/MR, DRC, LIB, OSM, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 87–179008; paper copy price code A08.

OFR 17–87. Cost Estimation Handbook for Small Placer Mines, by Scott A. Stebbins. Mar. 1987. 130 pp. 4 figs. This report presents a method for estimating capital and operating costs associated with the exploration, mining, and processing of placer deposits. To ensure representative cost estimates, operational parameters for placer mining equipment and basic principles of placer mining techniques are detailed. Research was done by the Bureau of Mines Western Field Operations Center. Available for reference at AD/MDA, AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 87–181178; paper copy price code A07.

OFR 18–87. Control of Respirable Quartz Dust on Continuous Mining Sections, by L. D. Taylor, P. C. Thakur, and J. B. Riester. Dec. 1986. 67 pp. 20 figs. This report describes research by the Bureau of Mines and Conoco Inc. to identify the sources and distribution of quartz dust in underground coal mines and to evaluate various types of bits. The study found that the main source of respirable quartz dust was the continuous miner when cutting rock material. Other activities in the section, such as roof bolting operations, normally did not contribute significant amounts of quartz dust. One forward attack and nine conical bits were tested in the laboratory to determine the amount of dust generated and the energy requirement for each bit. The laboratory tests indicated that slender bits with narrow tip angles generated less dust with less energy than larger bits with wide tip angles. The forward attack longwall bit also performed better than most of the other test bits. Tests conducted underground found that the smaller bits and the longwall bits were prone to wear, resulting in higher dust levels. The larger conical bits were not affected to the same degree. Underground power consumption measurements did not distinguish between the power required by different bits. Research was done under contract J0338077 by Conoco Inc. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–181855; paper copy price code A04.

OFR 19–87. The Mineral Industry of Yugoslavia, by Staff, Division of International Minerals. Apr. 1987. 169 pp. 5 figs. This report contains a review of over 40 mineral commodities including metals, industrial minerals, and mineral fuels produced by Yugoslavia. Tables for each commodity or commodity group present the locations of production facilities, their capacities, methods and equipment used, and supply and disposition information. Yugoslavia's role in the European and international minerals market is discussed, and a historic context is also provided. Research was done by the Bureau of Mines. Available for reference at LIB and PRC/B. Order ONLY from NTIS: PB 87–184941; paper copy price code A08.

OFR 20A–87. Low-Cost Removal of Trace Metals From Copper-Nickel Mine Stockpile Drainage. Volume I—Laboratory and Field Investigations, by Kim A. Lapakko, A. Paul Eger, and James D. Strudell. Aug. 1986. 103 pp. 15 figs. This report describes a two-phase experimental program to examine the feasibility of removing trace metals (Cu, Ni, Co, Zn) from stockpile effluent using readily available materials in low-cost, low-maintenance systems. Volume I details the process, beginning with the first phase, a laboratory screening program using (1) batch experiments to screen wood chips, peat, till, tailings, zeolite, lime, and sponge iron, and (2) column experiments to select the most promising materials for field trials. Low-sulfide tailings were chosen for the second phase field testing to utilize both treatment beds and joint disposal bins. Saturated and unsaturated flow tailings treatment beds demonstrated the greatest removal efficiency for copper (95 and 89 pct) and lowest for nickel (9 and 24 pct). A model was developed for the unsaturated bed to express output flow at a given distance from the input as a function of input flow. In the joint disposal study, total discharge from waste rock was reduced 34 pct by the addition of tailings and 66 pct by the addition of tailings followed by revegetation. The associated reductions in trace metal mass release were 73 and 87 pct, respectively. The drainage from the bins incorporating tailings had lower trace metal concentrations and higher pH than the drainage from the controls. Research was done under contract J0205047 by the Minnesota Department of Natural Resources. Available for reference at ALRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87–186136; paper copy price code A06.

OFR 20B–87. Low-Cost Removal of Trace Metals From Copper-Nickel Mine Stockpile Drainage. Volume II—Trace Metal Sequestration by Peat, Other Organics, Tailings, and Soils: A Literature Review, by Kim A. Lapakko, James D. Strudell, and A. Paul Eger. Aug. 1986. 45 pp. This report describes a two-phase experimental program to examine the feasibility of removing trace metals (Cu, Ni, Co, Zn) from stockpile effluent using readily available materials in low-cost, low-maintenance systems. Volume II is a literature review of several low-cost materials that might be used for removing trace metals from stockpile drainage. The materials included peat, humic acid, fulvic acid, other organics, soils, and tailings. The methods employed in the investigations review ranged from laboratory experiments to field-scale studies. Trace metal removal mechanisms and capacities were addressed. Research was done under contract J0205047 by the Minnesota Department of Natural Resources. Available for reference at ALRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87–186144; paper copy price code A03.

OFR 21–87. Deserado Mine Computerized Monitoring and Control System Evaluation, by L. A. Eros and R. H. King. June 1986. 118 pp. 3 figs. This report describes the planning, installation, and evaluation of a microcomputer-based monitoring and control system at the Deserado Mine, an underground coal mine. Costs, benefits, problems, and management and labor perceptions are included, and recommendations

are provided for mine operators and monitoring system vendors considering future installations. Research was done under contract J0348003 by the Colorado School of Mines. Available for reference at AD/MR, ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87-188710; paper copy price code A06.

OFR 22–87. Conceptual Investigation of a Management Information System for Underground Coal Mines, by J. L. Kohler, R. V. Ramani, G. Koharchik, and R. Bhaskar. 1987. 191 pp. 15 figs. This report presents the results of an investigation into the development of a Management Information System (MIS) for underground coal mines. The intent of the project was to examine the information issues, various design aspects, and associated application concerns of an integrated monitoring MIS, such as the impact of this technology on safety. The work performed on this contract used mine ventilation as a prototypical example and concludes that a KBES formulation of an integrated monitoring MIS for coal mine management is feasible and desirable. The report is presented in five chapters and six appendices and describes ventilation MIS system requirements, the formulation of a knowledge-based expert system (KBES) structure to implement the integrated ventilation monitoring MIS system, and the health and safety implications of the system. The appendices present details of the KBES system application with an example using a ventilation simulator (PSU-MVS). Research was done under contract J0348005 by the Pennsylvania State University. Available for reference at AD/MR, AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87-188736; paper copy price code A09.

OFR 23A–87. Coarse Coal Hydrotransport Testing at the Hydraulic Transport Research Facility—2½- by 1½-Inch Clean Coal, 6-Inch Pipeline: R104, by Michael E. Henderson. Sept. 24, 1985. 90 pp. 13 figs. This six-volume report describes a series of coarse coal hydraulic transport tests performed at the Hydraulic Transport Research Facility at the Pittsburgh Research Center in Bruceton, PA. The primary objective of the research covered in this volume was to examine the performance of the 6-inch (150 mm) pipeline in transporting clean, 2½- by 1½-inch (63.5 mm by 38.1 mm) coal at velocities ranging from 5 to 20 ft/s (1.5 to 6.1 m/s) and concentrations ranging from 15 to 45 pct by weight. Head loss and deposition conditions for future system designs were quantified, and the effects of coal size distribution on hydraulic parameters, and the coal degradation rates caused by the pipeline and pumps, are also discussed. Research was done under contract J0333956 by Boeing Services International. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 23B–87. Hydraulic Transport Research Facility—Coal Degradation Report, by Michael E. Henderson, Timothy J. Matty, and Anna C. Stewart. Sept. 30, 1985. 288 pp. 104 figs. This six-volume report describes a series of coarse coal hydraulic transport tests performed at the Hydraulic Transport Research Facility at the Pittsburgh Research Center in Bruceton, PA. The primary objective of the research covered in this volume was to investigate the reduction in size of varying sizes of coal after transport through 6- and 12-inch pipeline. The particle size distribution data taken during these tests revealed a sharp degradation during the first pass through the system, followed by a decreasing rate of size change during subsequent passes, an effect apparently attributable to pump grinding. Research was done under contract J0333956 by Boeing Services International. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 23C–87. Coarse Coal Hydrotransport Testing at the Hydraulic Transport Research Facility—2-Inch by 0 Clean Coal, 12-Inch Pipeline: R203, by Michael E. Henderson. Sept. 27, 1985. 96 pp. 15 figs. This six-volume report describes a series of coarse coal hydraulic transport tests performed at the Hydraulic Transport Research Facility at the Pittsburgh Research Center in Bruceton, PA. The primary objective of the research covered in this volume was to examine the performance of the 12-inch (300 mm) pipeline in transporting clean, 2-inch by 0 (51 mm by minus 50 mm) coal at velocities ranging from 5 to 18 ft/s (1.5 to 5.5 m/s) and concentrations ranging from 15 to 55 pct by weight. Head loss and deposition conditions for future system designs were quantified, and the effects of coal size distribution on hydraulic parameters, and the coal degradation rates caused by the pipeline and pumps, are also discussed. Research was done under contract J0333956 by Boeing Services International. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 23D–87. Coarse Coal Hydrotransport Testing at the Hydraulic Transport Research Facility—2-Inch by 0 ROM Coal, 12-Inch Pipeline: R205, by Michael E. Henderson. Sept. 20, 1985. 72 pp. 11 figs. This six-volume report describes a series of coarse coal hydraulic transport tests performed at the Hydraulic Transport Research Facility at the Pittsburgh Research Center in Bruceton, PA. The primary objective of the research covered in this volume was to examine the performance of the 12-inch (300 mm) pipeline in transporting clean, 2-inch by 0 (51 mm by minus 50 mm) run-of-mine coal (ROM) coal at velocities ranging from 8 to 16 ft/s (2.4 to 4.9 m/s) and concentrations ranging from 25 to 55 pct by weight. Head loss and deposition conditions for future system designs were quantified, and the effects of coal size distribution on hydraulic parameters, and the coal degradation rates caused by the pipeline and pumps, are also discussed. Research was done under contract J0333956 by Boeing Services International. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 23E–87. Coarse Coal Hydrotransport Testing at the Hydraulic Transport Research Facility—2-Inch by 0 Clean Coal, 12-Inch Pipeline: R206, by Michael E. Henderson. Mar. 25, 1985. 88 pp. 16 figs. This report describes a series of coarse coal hydraulic transport tests performed at the Hydraulic Transport Research Facility at the Pittsburgh Research Center in Bruceton, PA. The primary objective of the research covered in this volume was to examine the performance of the 12-inch (300 mm) pipeline in transporting clean, 2-inch by 0 (51 mm by minus 50 mm) coal at velocities ranging from 5 to 18 ft/s (1.5 to 5.5 m/s) and concentrations ranging from 15 to 55 pct by weight. Head loss and deposition conditions for future system designs were quantified, and the effects of coal size distribution on hydraulic parameters, and the coal degradation rates caused by the pipeline and pumps, are also discussed. Research was done under contract J0333956 by Boeing Services International. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 23F–87. Coarse Coal Hydrotransport Testing at the Hydraulic Transport Research Facility—2-Inch by 0 Clean Coal, 6-Inch Pipeline: R121, by Michael E. Henderson. Apr. 24, 1985. 92 pp. 14 figs. This report describes a series of coarse coal hydraulic transport tests performed at the Hydraulic Transport Research Facility at the Pittsburgh Research Center in Bruceton, PA. The primary objective of the research covered in this volume was to examine the performance of the 6-inch (150 mm) pipeline in transporting clean, 2-inch by 0 (51 mm by minus 50 mm) coal at velocities ranging from 5 to

20 ft/s (1.5 to 6.1 m/s) and concentrations ranging from 15 to 45 pct by weight. Head loss and deposition conditions for future system designs were quantified, and the effects of coal size distribution on hydraulic parameters, and the coal degradation rates caused by the pipeline and pumps, are also discussed. Research was done under contract S0368000 by Boeing Services International. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 24–87. Products of the Oxidative Thermal Degradation of Mine Stoppings and Mine Reinforcing Materials, by K. L. Paciorek, R. H. Kratzer, J. H. Nakahara, and S. R. Ahmed. Dec. 1983. 133 pp. 63 figs. The primary objective of this program was to determine the toxic fume and fire hazard of materials used in the construction of mine stoppings and in the sealing and reinforcing of mine ribs and roofs. The materials investigated were silicone, phenolic, and isocyanate-based rigid foams, as well as epoxy and acrylate mine sealants. Of the rigid foams tested, the X–156 urethane foam presented the greatest toxic hazard based on toxie load values, and hydrogen chloride was the main toxic species evolved by this foam. In none of the isocyanate-based compositions was hydrogen cyanide the major component, but its contribution increased with temperature. Of the two mine sealants tested, the latex acrylic coating presented the greater toxic hazard; acetic acid was the main toxic species evolved. Research was done under contract J0395008 by Ultrasystems, Inc. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87–191854; paper copy price code A07.

OFR 25–87. Gases From Explosives Detonated in Underground Mines, by Meliton M. Garcia and Mark Malcomson. June 1986. 97 pp. 28 figs. This report describes the measurement and identification of the gases produced by explosives detonated under actual mining operations in an underground mine. A brief background about the nature of the problem and the objectives of this investigation are presented, as well as a brief summary of previous studies regarding gases produced in trace quantities and entrapped in the muck pile and surrounding mine rock. Also included are discussions of selected explosives, detailed descriptions of the test chamber, the mining procedures used to generate the gases, a description of the analytical instruments and procedures used to monitor and identify the gases, and a presentation of the experimental results, conclusions, and recommendations. Research was done under contract J0145008 by the University of Arizona. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–191805; paper copy price code A05.

OFR 26–87. Prediction of Mill Grindability Using Percussion Drilling Data, by W. A. Hustrulid and Y. C. Lo. Feb. 1987. 42 pp. 7 figs. This report presents the results of a preliminary examination of the relationship between grindability and percussive drillability in hard and soft rock. The research indicates that grindability increases along with drillability but in a nonlinear fashion owing to relative differences in the ratio between these two factors in soft and hard rock. It was also determined that the specific energy index for grindability is highly dependent upon the average particle size and size distribution of the materials. Research was done under grant G1125149–0801 by the University of Utah. Available for reference at AD/MMR and LIB. Copies of this report will not be available for purchase.

OFR 27–87. Results of 1985 Bureau of Mines Investigations in the Johns Hopkins Inlet-Margerie Glacier Area, Glacier Bay, Alaska, by Joseph M. Kurtak. 1985. 31 pp. 9 figs. This report describes the mineral investigations of specific sites in the Johns Hopkins-Margerie Glacier area. Approximately 17 square miles were mapped, and over 99 rock and placer samples were collected in an effort to determine possible extensions of known mineralization. Several rock samples contained anomalous copper and gold values, and anomalous gold was detected in several placer samples. The area has been found to contain copper, zinc, molybdenum, and gold, and has produced a total of approximately 7,100 oz of gold in the period 1938 to 1985. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, IFOC, LIB, and WFOC. Copies of this report will not be available for purchase.

OFR 28–87. Development of a Contaminant Diagnostic Monitor, by the staff of the Oklahoma State University Fluid Power Research Center. May 1983. 89 pp. 38 figs. This report describes the development of an on-board contaminant diagnostic monitor to continuously measure contaminant level in a mining machine. Several concepts were investigated, and it was found that a static spool-type sensor was the most reliable and accurate. Laboratory and field tests showed that an instrument based on this concept is capable of measuring contaminant levels and/or size distribution, depending on the configuration of the sensor. Moreover, this instrument can function on emulsions or homogeneous fluids, while current laboratory equipment can operate on homogeneous fluids only. Research was done under contract J0233926 by Oklahoma State University. Available for reference at ALRC, DRC, LIB, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87–203428; paper copy price code A05.

OFR 29–87. Sensitive Ground-Fault Protection for Mines. Phase II—Direct-Current Utilization, by J. L. Kohler, F. C. Trutt, and L. A. Morley. June 1986. 81 pp. 39 figs. This report for Phase II of Bureau of Mines Contract J0134025 describes the research and development of sensitive ground-fault relays for direct current utilization systems in mining. Sensitive relaying employs very low pickup levels so that, when used in conjunction with very high resistance grounding, the exposure of a human to ventricular fibrillation is significantly reduced. To delineate the desired relay characteristics, the report begins by reviewing previous research in this area, and a theory for the saturable transformer used to sense the fault current is presented. The design of the ground-fault relay is described in sufficient detail so that it may be duplicated, and the test procedures and results are given. Research was done under contract J0134025 by Pennsylvania State University. Available for reference at AD/MR, ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 87–203410; paper copy price code A05.

OFR 30–87. Development of a Methane Monitor Meeting the Bureau of Mines Intrinsically Safe Mine Monitoring System (ISMMS) Requirements, by T. Otagawa, S. Zaromb, and J. R. Stetter. Sept. 1984. 60 pp. 27 figs. This report describes the development, construction, and characterization of a low-current electrochemical methane sensor and monitor. Over 80 prototypes were built and evaluated in an attempt to optimize the various physical and chemical parameters that control the response characteristics of a sensor, and that would conform to Bureau standards. The report describes the experimental process in detail, and suggestions are given for future research. Research was done under contract H0233005 by Argonne National Laboratory. Available for reference at AD/MR, ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: DE 85–009663; paper copy price code A04.

OFR 31–87. Production and Testing of a Chromium-Free Heat-Treatable Alloy Steel, by Thomas B. Cameron. May 20, 1986. 66 pp. 26 figs. This report presents research in substitution technology for a chromium-free (Cr-free) alternate for 8620 steel. A Cr-free steel composition developed in an

earlier program was melted and cast, processed into carburized gears, and evaluated in comparison with an 8620 steel control group and an existing performance data base. An evaluation of processing characteristics indicated that the Cr-free steel could be substituted for 8620 in a gearing application with no change in process parameters. The performance of the Cr-free steel in the gearing tests was equivalent to, or slightly better than, both the 8620 control group specimens and the existing data base. Metallurgical characteristics of the Cr-free and 8620 steels were examined, and only minor differences were identified. Results from this investigation indicated that the Cr-free steel composition should be a suitable alternate for 8620 steel in a wide range of heat-treatable applications. Research was done under contract J0145009 by AMAX Materials Research Center. Available for reference at ALRC, LIB, and RORC. Order ONLY from NTIS: PB 87–214425; paper copy price code A04.

OFR 32–87. Geology of the McKinley Lake Gold Area, Chugach National Forest, South-Central Alaska, by Joseph M. Haney and Uldis Jansons. July 1987. 40 pp. 15 figs. This report describes the findings of a geologic survey of the McKinley Lake Gold Area of the Chugach National Forest. Mine workings in over 15 sq mi were mapped, the local mining history reviewed, mineral showings were sampled, and the origin of the gold deposits studied. Although potential zones of economic gold mineralization were not found, minor amounts of gold were detected in 52 pct of the 168 samples studied. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, IFOC, LIB, and WFOC. Copies of this report will not be available for purchase.

OFR 33–87. Thermal Recovery System for Reducing Mine Refrigeration and Energy Needs, by R. Cardenas, R. Torbin, and J. McCoy. May 1987. 184 pp. 59 figs. This report describes a project to evaluate alternative energy recovery systems. A turbine-generator system was selected, designed, installed, and operated at the Hecla Lucky Friday Mine. Performance data was collected indicating that actual system efficiency was close to predicted values. The system clearly demonstrated the usefulness of thermal energy recovery techniques and has operated successfully over a period of 1 year. Research was done under contract H0318053 by Foster-Miller, Inc. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–221149; paper copy price code A09.

OFR 34–87. Industry Assessment of MINOS Mine-Monitoring System, by F. du Breuill, J. C. Yingling, and K. L. Whitehead. Feb. 1987. 100 pp. 34 figs. This report describes the installation and operation of a computer-based belt-monitoring and control system at the Barnes & Tucker Coal Co. Mine No. 20 in Ebensburg, PA. The system installed was the National Coal Board's Mine Operating System (MINOS) coal transport monitoring and control system. The program objective was to document (1) the installation requirements for a conveyor control system, (2) the operating experience with the system, and (3) the impact of monitoring and control on mine operation. Analysis of the system operation indicates that monitoring and control did improve belt availability significantly and reduced downtime associated with belt delays. Economic analysis showed the increased belt availability would potentially result in significant production increase and excellent payback on the initial investment. The system performed satisfactorily, was well accepted by the work force, and did not increase the maintenance workload. Research was done under contract J0133922 by BCR National Laboratory. Available for reference at AD/MR, AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–227880; paper copy price code A05.

OFR 35–87. Systems Approach to Mine Fire Safety, by Jeffrey A. Shibe. Apr. 1987. 148 pp. 27 figs. This report describes a fire safety evaluation system to be used to determine combinations of widely accepted fire safety equipment and underground coal mine features to provide a level of safety equivalent to that required by the U.S. Code of Federal Regulations, Title 30, for underground coal mines. In this evaluation, equivalent safety performance is gauged in terms of overall level of safety provided rather than by a component-by-component comparison. Research was done under contract J0100053 by the National Bureau of Standards. Available for reference at AD/MR, AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 87–227898; paper copy price code A07.

OFR 36–87. Final Report of Stream Sediment, Float, and Bedrock Sampling in the Porcupine Mining Area, Southeast Alaska, 1983–1985, by Jan C. Still, Wyatt G. Gilbert, and Robert B. Forbes. Aug. 1987. 35 pp. 10 figs. This report describes a survey of 687 stream sediment, pan concentrate, soil, float, rubblecrop, and bedrock samples from the Porcupine mining area near Haines, AK. More than 460 of the 687 samples collected contained anomalous concentrations of one or more elements, indicating the possible presence of several deposit types. Types include zinc-silver-lead-barium volcanic- or sedimentary-hosted massive sulfide deposits, gold-silver or base metal vein deposits, and sedimentary-hosted large tonnage low-grade gold and gold-bearing copper cobalt skarn deposits. Stream sediment samples contained up to 62.25 parts per million (ppm) gold, 10 ppm silver, 1,810 ppm zinc, 2,800 ppm barium, 500 ppm tin, 300 ppm arsenic, 400 ppm nickel, and 30,000 ppm antimony. Bedrock and rubblecrop samples contained up to 24.83 ppm gold, 17.14 ppm silver, 13.4 percent zinc, 940 ppm cobalt, 47 percent barium, 500 ppm tin, 4 percent arsenic, 900 ppm bismuth, and 8,000 ppm antimony. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, IFOC, LIB, PRC/B, and WFOC. Copies of this report will not be available for purchase.

OFR 37–87. Demonstration of Longwall Mining in a Steeply Dipping Coal Seam, by Michael R. Kennedy and Larry M. Reschke. Jan. 1987. 82 pp. 26 figs. This report describes the demonstration of longwall mining in a seam dipping 27° to 34°. Equipment was selected on the basis of capability, compatibility, and cost. The longwall equipment operated very well on the steep pitch with an average equipment downtime of 21.9%. Coal handling outby the face was a problem that caused an additional downtime of 19.5%. Development for the panels proved to be the major problem in the economics of longwall mining on a steeply dipping seam. During the first 9 months of operation, the longwall averaged 71.9 tons per worker-shift (TPWS) and development averaged 0.6 TPWS, for an overall average of 14.1 TPWS. Had mining continued, timing of development would have been another major problem. Monitoring of subsidence, pillar stability, and shield loading was done in connection with mining, but little useful information was gained from the monitoring. Research was done under contract J0233923 by Snowmass Coal Co. Available for reference at LIB, MSHA, NMH&SA, OSM, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 88–102975; paper copy price code A05.

OFR 38–87. Light Sources for Fiber Optic Mine Lighting Systems, by M. C. Bleiweiss and G. J. English. Nov. 1986. 54 pp. 23 figs. This report describes the evaluation of various light sources for use in a fiber-optic lighting system for mining machines. Metal halide arc lamps were found to work best because of their resistance to damage from shock and vibration and the high luminance of the arc. Measurements were made of the percent transmission of the ½-inch-thick glass window and the fiber bundles, the total lumen output of the diffuser assembly with a known input, and the average surface luminance of the diffuser assembly. These data were then used to calculate the theoretical output of the system given an estimated input from the source. A prototype 55-watt, single-ended metal halide source was then developed. In order to provide greater efficacy and higher throughput through the fiber-optic cables, a variation of the lamp with thallium

iodide added to the fill was developed. The lamp was modified, and a ballast was developed to allow it to hot restrike. Research was done under contract H0232004 by GTE Lighting Products. Available for reference at AD/MR, ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 39–87. Cost Estimate for Dewatering Alaskan Placer Effluents With PEO, by Michael J. Magyar. Apr. 1987. 14 pp. 7 figs. This report contains a cost estimate of the Bureau of Mines process for dewatering Alaskan placer effluent streams with polyethylene oxide (PEO). In this process, effluent slurry is withdrawn from the placer plant pond system after a primary settling stage. A dilute PEO solution is injected into the slurry line to flocculate the fine, suspended solids. The flocculated solids are dewatered on a stationary screen. Clarified water is returned to the placer operation or discharged, while the 35% solids waste is pumped back into the mine cut. Cost estimates are presented for dewatering plants processing 1,000 gallons per minute of effluent slurry at three representative turbidity levels. Both the placer and the dewatering plants operate on the same 1-shift-per-day, 6-day-per-week schedule for the 100-day Alaskan operating season. Estimated fixed capital costs for these plants processing placer with effluent turbidities of 1,000, 3,000, and 5,000 nephelometric turbidity units are approximately $29,000, $31,000, and $34,000, respectively, on a fourth-quarter 1986 basis. Operating costs are estimated to be $0.34, $0.37, and $0.40 per thousand gallons of effluent slurry, respectively. Research was done by the Bureau of Mines. Available for reference at AD/MMR, ALRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, TURC, and WFOC. Order ONLY from NTIS: PB 88–106117; paper copy price code A02.

OFR 40–87. Experimental Studies of Dispersion and Transport of Respirable Dusts in Mine Atmospheres, by T. H. Ueng and Y. J. Wang. Mar. 1987. 162 pp. 75 figs. This report describes a study on dust dispersion around the face area in order to control dust concentrations. The effects of varying line brattice locations and air quantity changes were studied using methane and Arizona Road Dust to simulate respirable coal dust. Measurements were taken at 25 grid points for each brattice distance and air quantity combination both in the absence and presence of mine face machines. Test results are included, and concentration data are presented in a series of tables and figures. Research was done by West Virginia University under a subgrant to grant G1135142–5402 to Pennsylvania State University. Available for reference at AD/MR and LIB. Copies of this report will not be available for purchase.

OFR 41–87. Formation of Titanium Powder by Potassium Reduction of Titanium Salts, by Donna D. Harbuck, Aug. 1987. 20 pp. 3 figs. This report describes the investigation of a process to produce titanium powder directly from titanium salts. If successful, such a process could lower the cost and increase the use of titanium. In this study, K_2TiF_6, K_2TiF_5, and TiF_3 were reduced with potassium in the temperature range of 650° to 750° C. Under certain conditions, titanium powder 1.6 to 3.3 μm in size was produced. After leaching the product with a 0.1*M* HCl solution, powder with impurities as low as 0.04 pct potassium and 0.28 pct fluorine were obtained. However, oxygen levels of over 1 pct and the frequent formation of insoluble byproducts demonstrate the need for further research to make the powder suitable for powder metallurgy applications. Research was done by the Bureau of Mines Salt Lake City Research Center. Available for reference at AD/MMR, AFOC/J, ALRC, DRC, IFOC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88–114467; paper copy price code A02.

OFR 42–87. Effects of Stockpile Storage on Topsoil Characteristics in Arid Climates, by L. J. Froisland, W. K. Tolley, and M. B. Shirts. Apr. 1987. 4 pp. 4 figs. This report describes an investigation of the changes in soil characteristics in topsoil stockpiled during mining operations. Topsoil stockpiles in arid areas of New Mexico, Utah, and Wyoming were sampled over a 1- to 2-yr period to determine any changes in physical, chemical, or biological parameters in the top 15 ft of soil. Parameters examined in this study included soil moisture, pH, electrical conductivity, and cation exchange capacity; total nitrogen, organic carbon, carbon-to-nitrogen ratio, extractable potassium, and soluble phosphorus levels in the soil; general levels of bacteria activity in the soil; and productivity of the soil as measured by shoot yield in growth tests. Data were analyzed by multiple linear regression to determine possible effects of stockpile age and depth. Bacteria population counts, used as an indicator of general bacterial activity, was the only parameter found to be significantly correlated with stockpile age and depth at more than one site. Bacterial activity increased with depth at the two sites where it was measured. Activity increased with age at one site and decreased with age at the second. Significant changes in soil pH, electrical conductivity, and moisture were significantly correlated with stockpile age and depth at single sites. This study did not show significant, consistent deterioration in soil characteristics or growth yield of topsoil stored in stockpiles. Research was done by the Bureau of Mines Salt Lake City Research Center. Available for reference at AD/MMR, ALRC, LIB, OSM, RERC, RORC, SLRC, and TURC. Copies of this report will not be available for purchase.

OFR 43–87. A Prototype Hydride-Powered Underground Mining Vehicle, by Ned Baker and Frank Lynch. May 17, 1987. 36 pp. 20 figs. This report describes the development, construction, and testing of a hydrogen-fueled underground mining vehicle. A hydrogen burning engine and a hydride fuel system, both previously developed, were installed on a modified utility vehicle, together with the necessary controls. In tests and in actual use, the vehicle performance in terms of speed, acceleration, and gradeability exceeded that of the standard, unmodified vehicle. Research was done under contract H0202034 by EIMCO Mining Machinery International. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY for NTIS: PB 88–118864; paper copy price code A03.

OFR 44–87. Methods for the Selective Sampling of Diesel Particulate in Mine Dust Aerosols, by Virgil A. Marple, David B. Kittelson, Kenneth L. Rubow, and Ching-ping Fang. Oct. 1986. 94 pp. 27 figs. This paper describes an investigation into time-integrated and real-time methods for determining the diesel exhaust particulate concentration in underground mines, particularly coal mines. The microorifice uniform deposit impactor is recommended for obtaining the time-integrated measurement of the size distribution. The mass concentration of diesel exhaust particles can be obtained from the particle size distribution of mine aerosols. On a mass basis, diesel exhaust particles are primarily in the submicrometer size range while coal dust particles are larger. Size distribution measurements made in the laboratory and in three underground coal mines exhibited two distinct modes with the diesel exhaust particles in the smaller particle mode and the coal particles in the larger particle mode. The point of separation between the two modes occurred in the 0.7- to 1.0-μm size range. The separation was found to be independent of mass fraction of the diesel exhaust particles, particle concentration, and sampling site. Methods recommended for further consideration as real-time monitors of diesel exhaust aerosols in mines are photometers and filter pressure drop techniques. A preclassifier would be required in both cases to separate the larger dust particles from the sample. Research was done under contract J0145022 by the University of Minnesota. Available for reference at AD/MR, AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88–130810; paper copy price code A06.

OFR 45–87. A Study of RF Hazards at Low and Medium Frequencies to Blasting in Underground Coal Mines, by R. H. Thompson, J. G. Stuart, and W. W. Cipkins. Jan. 1985. 314 pp. 24 figs. This paper presents the preliminary safe distances for blasting wiring from typical electromagnetic sources. The distances are for underground coal mines and electromagnetic sources in the frequency range below 10 MHz. The distances are based on measurements performed at three locations in each of three coal mines. The measurement apparatus, measurement procedure, measurement results, and the rationale used in the calculation of the safe distances are all described. The safe distances presented are dependent on the measurement results and their interpretation. More measurements are clearly necessary to establish the validity of the suggested distances. Research was done under contract J0318023 by Franklin Research Center. Available for reference at AD/MR, AFOC/J,

ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-130097; paper copy price code A14.

OFR 46-87. Returning Coal Waste Underground, by John M. Popovich and Roger F. J. Adam. Apr. 1986. 256 pp. 10 figs. This report describes a system designed to return coal mine waste to the operating underground mine generating it. This system, which was installed and tested at a site operated by the Millers Cove Energy Co. Inc. in Lee County, VA, limits the size of the surface facilities and incorporates state-of-the-art hydraulic transport and backfilling technology and equipment to systematically backfill areas in the active mine. The cost of returning coal waste underground at the Millers Cove site was estimated at $0.67 per ton of marketable coal (1982 dollars), which is slightly higher than the surface disposal cost of $0.61 per ton of marketable coal (1982 dollars). The underground disposal costs do not include cost savings that could be realized in the preparation plant and treatment facilities at the surface. Preliminary tests of the system were conducted at the surface because funding restrictions prevented an in-mine trial. Research was done under contract J0133928 by Ketron, Inc. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-129333; paper copy price code A12.

OFR 47-87. Control of Diesel Exhaust Emissions in Underground Coal, by A. Stawsky, A. Lawson, H. Vergeer, B. Manicom, and W. Drummond. May 1987. 401 pp. 54 figs. This report describes an experimental survey of diesel emission aftertreatment control techniques, including water scrubbers, catalytic converters, exhaust gas recirculation, and soot filters. The use of two or more techniques in combination was tested for optimum control of all exhaust pollutants, and dynamometer data was developed for steady-state and computer-controlled simulated mines duty cycles operation of Deutz F6L-714 and F8L-413 engines. Exhaust quality indices were calculated from dynamometer data for comparisons among the control combinations examined. Research was done under contract H0199021 by Engelhard Corp. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-133673; paper copy price code A18.

OFR 48-87. Activities in Advanced Materials Definitions and Guidelines for the Office of Advanced Materials Coordination, by Charles A. Sorrell. Dec. 1987. 32 pp. This report presents the issues, goals, and principles of operation of the Bureau of Mines Office of Advanced Materials. Also included are a working definition of the term "advanced materials," a brief recent history of the materials, and an appendix containing a detailed functional and chemical classification system. Available for reference at AFOC/J, ALRC, DOI, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-149646; paper copy price code A03.

OFR 49-87. Juneau Gold Belt Area: 1986 Update, by Earl Redman, Ken Maas, Al Clough, and Joseph Kurtak. Nov. 1987. 41 pp. 1 fig. This report summarizes findings by the Bureau of Mines during the second year of the Juneau Mining District study. Fifty mines, prospects, and occurrences were examined, and 638 samples were collected for analysis. Metallurgical samples were collected from seven deposits, and preliminary tests of cyanide amenability have been completed for five of these. The simultaneous discovery by the Bureau and private industry of gold-bearing quartz veins cutting diorite gneiss recently exposed by the retreat of the Herbert Glacier is the most notable find in 1986, yielding gold values up to 7 oz/st. Research was done by Bureau of Mines Alaska Field Operations Center. Available for reference at AD/MDA, AFOC/J, LIB, IFOC, PRC/B, and WFOC. Order ONLY from NTIS: PB 88-147996; paper copy price code A03.

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OFR 1-88. Mineral Investigation of the Goodnews Bay Mining District, Alaska, by Steven A. Fechner. Dec. 1987. 230 pp. 12 figs. This report presents the results of site specific sampling in the Goodnews Bay Mining District in 1986. Approximately 70% of the mineral deposits in the district are located in two areas: Slate-Wattamuse Creek and Red Mountain. Placer deposits with high mineral development potential are located on Wattamuse and Cascade Creeks. Gold was found in rocks associated with the intrusive at the head of Wattamuse Creek. In the Red Mountain area, platinum-group metals (PGM) and gold were found in the Salmon River and its tributaries and along the beach from Platinum to Chagvan Bay. All of the eastern tributaries of the Salmon River that drain Red Mountain, and the beach along Kuskokwim Bay from Platinum to the Salmon River, have high mineral development potentials for small placer mining operations. The Salmon River has a high mineral development potential for a large operation. PGM and gold were found in the weathered dunite on Red Mountain and in the glacial deposits that compose the bluffs along the beach, proving that they are the sources of placer PGM and gold found in the streams and on the beach. Microprobe platinum-group analyses of placer PGM grains correlated well with the findings of the U.S. Geological Survey. Twenty-three platinum-group minerals were also identified. Available for reference at AFOC/J, IFOC, LIB, PRC/B, and WFOC. Copies of this report will not be available for purchase.

OFR 2-88. Dust Control Handbook for Minerals Processing, by Vinit Mody and Raj Jakhete. Feb. 1987. 220 pp. This report presents information on dust control engineering techniques for metal and nonmetal mineral processing. Dust prevention, formation, and control are examined, and wet and dry control systems, personal protection, testing methods, and costing methodologies are discussed. Prospective users of this handbook include maintenance foremen, plant engineers, mill supervisors, and safety directors. Research was done under contract J0235005 by Martin Marietta Corp. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-159108; paper copy price code A10.

OFR 3-88. Quality Improvement and Conservation of Copper Mill Waste Water, by Raymond O. Dannenberg and Paul C. Gardner. Dec. 1987. 35 pp. 13 figs. This report describes a series of laboratory and full-scale tests to develop a process for improving the flotation characteristics of lime-treated wastewater. Unknown substances in the wastewater reduced the flotation efficiency of the metal sulfides. An estimated annual loss of 795,000 lb Cu, 232,000 lb Mo, 5,625 tr oz Ag, and 617 tr oz Au would result from recycling the total flow from the lime treatment plant to the flotation mill in an effort to conserve water and reduce associated expense. The tests indicated that aeration or treatment with activated carbon significantly improved the water quality. The improvements in molybdenum recovery averaged 8 pct for aeration, 11 pct for activated carbon, and 16 pct for combined aeration and activated carbon. The combination of the two processes produced water quality as good as or better than that of normal feed water. Research was done by the Bureau of Mines Salt Lake City Research Center. Available for reference at AD/RES, ALRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, and TURC. Order ONLY from NTIS: PB 88-149737; paper copy price code A03.

OFR 4-88. Study on Titanium Chlorination Solid Wastes, by R. Krishnaswamy and N. H. Parker. Oct. 1987. 184 pp. 22 figs. This report presents the conceptual designs and the results of tests on processes used to recover titanium from solid waste. Recoveries of 80 to 88 pct of the titanium in the waste as a concentrate of 94 to 99 pct titanium dioxide were achieved, reducing the amount of final waste effluent to less than 40 pct of current quantities. It was estimated that a 1,000-lb/h plant, with an installed cost of $888,000,

would recover about 1,320 tons of titanium minerals a year, representing a revenue of $607,200. Allowing for operating expenses, return on investment would be 28 pct. The technical feasibility of pyrohydrolysis as an alternative final effluent treatment was established. Conceptual designs of pyrohydrolysis pelletization of concentrates, secondary chlorinator, and treatment of currently ponded tailings are presented. Overall treatment resulting in low quantities of inert, nontoxic, and nondusty final solid waste, reusable titanium mineral concentrates, and maximum recycle of process water is also discussed. Research was done under contract J0145046 by Krispar Technologies, Inc. Available for reference at ALRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-159801; paper copy price code A09.

OFR 5-88. Results of 1987 Bureau of Mines Placer Investigations of the White Mountains Study Area, Alaska, by Steven A. Fechner and Michael D. Balen. Jan. 1988. 158 pp. 13 figs. This report presents the results of a literature search and a site-specific sampling program of drainages in the White Mountains Study Area. The literature search identified 15 placer mineral properties, which were subsequently evaluated during this study. Of the 265 samples taken, physically separable quantities of gold were found in 49 samples collected from Beaver, Roy, Mascot, Nome, O'Brien, and Ophir Creeks, as well as from a tributary of American Creek. Nome and Beaver Creeks were found to have the highest gold values and were consequently rated as having high mineral development potentials for small size (100 to 500 yd^3/day) placer mining operations. Available for reference at AFOC/J, IFOC, LIB, PRC/B, and WFOC. Copies of this report will not be available for purchase.

OFR 6-88. Coal Interface Detector Investigation, by Richard P. Cislo. Nov. 1987. 215 pp. 46 figs. This report presents results of an evaluation of the effectiveness of the time domain Coal Interface Detector developed by the General Electric Co. (GE) under contract H0155120. The sensor utilizes differences in the time characteristics of shearer vibrations as sensed by an accelerometer mounted on the ranging arm to discriminate the cutting of coal and rock. Four identical time domain sensors were supplied by the Bureau for field evaluation. The performance of the time domain sensor was evaluated by an extensive field test and data collection program that included four longwall mines and a total of nine mine visits. The intent was to determine the sensor's applicability to a wide range of mining conditions and to document its limitations. Results of the extensive field tests indicate that shearer vibration data processed by GE's time domain signal processing algorithm cannot be used to reliably detect when the cutting drum crosses the coal-rock interface. Research was done under contract H0245008 by Wyle Laboratories. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-167499; paper copy price code A10.

OFR 7-88. Cobalt in Forsterite-Olivine Deposits of the Blue Ridge, North Carolina and Georgia, A Preliminary Investigation, by Mark L. Chatman. Dec. 5, 1986. 36 pp. 3 figs. This report presents the results of an evaluation of two forsterite-olivine deposits in the Blue Ridge physiographic province of the southeastern United States. Data from the Buck Creek deposit, Clay County, NC, and the Lake Burton deposit, Rabun County, GA, are compiled and evaluated. Both deposits contain 0.01% cobalt—about average cobalt concentration for ultramafic rocks, including forsterite-olivine. Because cobalt is a strategic metal with advanced materials applications and no domestic mine production of cobalt is underway, further consideration was given to cobalt in these forsterite-olivine deposits. There are 25 forsterite-olivine deposits in close proximity in the Blue Ridge containing 1 billion tons of potentially cobalt-bearing forsterite-olivine rock. Cobalt recovery is not feasible at the two deposits studied in detail, due to low cobalt concentrations and metallurgical concerns. The contained cobalt value at mid-1987 prices is about $1 per ton of forsterite-olivine and this cobalt is tied to primary silicate mineral bonds, requiring costly, unproven processing. Data suggest that cobalt occurrences in the other Blue Ridge forsterite-olivines are similarly restrained. Research was done by the Bureau of Mines Intermountain Field Operations Center. Available for reference at AD/I&A, AFOC/J, ALRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-209309; paper copy price code A03.

OFR 8-88. Supervisory Management Selection and Development, by Grant R. Brown, Michael G. Temple, William L. Dreifke, Kathleen Y. Knoeble, Denise E. Murphy, and David P. Gilfillan. July 1987. 183 pp. 9 figs. This report presents the results of a study examining the relationship between supervisor characteristics and performance in underground coal mines. The specific objectives of the research include: document tasks performed by first-line supervisors during a normal shift; explain why supervisors carry out their duties as they do; identify salient characteristics of effective first-line supervisors; and formulate criteria for selecting and developing candidate supervisors. To accomplish the study objectives, on-site observation and data collection was carried out at 13 underground mines in Illinois, Ohio, and Pennsylvania. One hundred thirty-eight first-line supervisors were observed during a full workshift and discussions with the supervisors and the mine superintendent were held during the course of the visit. The observational data from the study provide a detailed description of what supervisors do during their shift. The report begins with an introduction discussing the problem being studied and objectives of the research. The literature related to supervisor selection is then reviewed. The following section describes the research design including data collection procedures and statistical methodology used in the study. The next sections present the analysis of mine, section, crew, and supervisor characteristics. The report concludes with a discussion of the results of the study and recommendations concerning supervisor selection and development. Research was done under contract J0145025 by Ketron, Inc. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-208699/AS; paper copy price code A09.

OFR 9-88. Documentation for the Bureau of Mines Cost Estimating System on the Lotus 1-2-3 Worksheet, by Luis V. Coppa. January 1988. 87 pp. 36 figs. This report is the documentation of the computerized version of Bureau of Mines Information Circulars (IC) 9142 and 9143 entitled "Bureau of Mines Cost Estimating System Handbook (In Two Parts)." The computerized version of the Cost Estimating System (PC/CES) was developed using the Lotus 1-2-3 software package (Release 2.0 or above) for microcomputers. This programming essentially duplicates the information found in IC 9142 and 9143 and affords the user the capability to manipulate cost estimates in an automated manner not readily available through the Handbooks' format. Research was done by the Bureau of Mines Division of Minerals Availability. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-246590; paper copy price code A05. Note: DOI/SW/DK-88/009, BMINES: Cost Estimating System (for Microcomputers) is separately available from NTIS as PB 88-246582; code D01.

OFR 10-88. Distribution of Gold, Platinum, Palladium, and Silver in Selected Portions of the Bohemia Basin Deposits, Southeast Alaska (With an Appendix Section on Mirror Harbor), by Jan C. Still. Feb. 1988. 42 pp. 15 figs. This report presents results of a 1982 Bureau of Mines examination of the Bohemia Basin nickel-copper-cobalt deposits, located on the southeastern portion of Yakobi Island, to determine the potential for platinum-group metals, gold, and silver. The deposits are thought to be magmatic segregations in a zoned composite stock. Demonstrated resources, accessible by open pit mining, are 15.1 million tons averaging 0.37% nickel, 0.22% copper, and 0.02% cobalt. Bureau examination consisted of sampling surface outcrops, adits, and pits; and analysis of selected diamond drill hole samples for platinum-group metals, gold, and silver. Sixty samples were collected from surface outcrops and analyzed, and 185 samples from 5 diamond drill holes were analyzed. The highest gold, platinum, palladium, and silver values from the analysis of 245 surface and drill hole samples were 0.01 oz/ton gold, 0.006 oz/ton platinum, 0.004 oz/ton palladium, and 0.157 oz/ton silver; 94 of the 185 drill hole samples were analyzed for iridium, osmium, rhodium, and ruthenium, and none was detected. In general, most of the precious metal values were confined to the nickel-copper ore zones, with the highest values often coinciding with the highest nickel-copper values. Precious metals, except silver, are concentrated with copper and are potential low-grade metallurgical by-

products. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AD/I&A, AFOC/J, IFOC, LIB, PRC/B, and WFOC. Copies of this report will not be available for purchase.

OFR 11-88. A Review of Favorable Offshore and Coastal Depositional Sites for Platinum-Group Metals in the Goodnews Bay Mining District, Alaska, by Brian R. Zelenka. Feb. 23, 1988. 25 pp. 4 figs. This report describes mineral investigations conducted by the Bureau of Mines on geologic and depositional processes contributing to potential coastal and offshore platinum-group metal (PGM) placer deposits around the Goodnews Bay Mining District. The Bureau found that favorable environments for PGM along with gold and chromite enrichment include: (1) buried paleofluvial channels; (2) recent paleofluvial channels with little marine sediment overburden; (3) beach deposits, particularly in the upper swash zone and near back beach environments; (4) paleostrand lines; (5) shoal lag deposits inside the mouths of Goodnews and Chagvan bays; and (6) bases of far offshore tidal ridges which may represent reworked glacial deposits. Limited geologic and compositional (assay) data prevent determination of deposit size and grade of PGM mineralization for each deposit class. Future geologic sampling requirements for demonstration of identifiable offshore and beach PGM-bearing placers are discussed. Beach and offshore sampling programs conducted by the Bureau in 1986 will contribute additional information providing verification of specific deposit classes. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, and PRC/B. Order ONLY from NTIS: PB 88-210885; paper copy price code A03.

OFR 12-88. Trace Element Distribution Near Jasperoids in the Weepah Spring Wilderness Study Area, Lincoln and Nye Counties, Nevada, by Diann D. Gese. 1987. 45 pp. 8 figs. This report describes mineral investigations conducted by the Bureau of Mines as part of a study to further assess the possibility of gold occurring in the northwestern part of the Weepah Spring Wilderness Study Area, Lincoln and Nye Counties, Nevada. This area was identified in a previous study by the U.S. Geological Survey and the Bureau as having a "high potential" for undiscovered deposits of disseminated gold. The study consisted of the Bureau collecting 64 rock-chip samples, 4 from unaltered carbonate rocks to establish a local background the rest from jasperoid outcrops, and 117 stream-sediment samples. Gold, silver, antimony, arsenic, barium , and mercury contents of the samples were evaluated statistically. All the antimony, arsenic, and barium concentrations of the stream-sediment samples were plotted and then contoured to determine if any areas of anomalously high element concentrations existed within the study area. Some of the jasperoid samples contained low gold and silver concentrations and all contained anomalously high amounts of antimony, arsenic, barium, and mercury, elements commonly associated with disseminated gold and silver deposits in Nevada. Plotting and contouring the antimony, arsenic, and barium contents of the stream-sediment samples identified one area where all three elements were several times their background. Four other areas with anomalously high arsenic concentrations were also identified. The study identifies possible gold exploration targets in and near the wilderness study are. Research was done by the Bureau of Mines Intermountain Field Operations Center. Available for reference at AD/I&A, AFOC/J, IFOC, and WFOC. Order ONLY from NTIS: PB 88-208673/AS; paper copy price code A03.

OFR 13-88. 1985-1986 Mineral Investigations in the Southern Chilkat Range, Southeast Alaska, by Albert H. Clough and Terry J. Hayden. Dec. 1987. 25 pp. 4 figs. This report describes mineral investigations conducted by the Bureau of Mines during the 1985 and 1986 field seasons in the southern Chilkat Range of northern Southeast Alaska. These investigations were part of the Bureau's study of mineral resources in the Juneau Mining District. Field investigations included geologic mapping and sampling of known mines, prospects, and mineral occurrences in the study area. In addition, selected areas favorable for hosting mineral deposits were examined using geologic reconnaissance, geochemical sampling, and ground geophysics. During fieldwork, 179 geochemical samples were collected from 116 different locations. Analytical results of these samples defined polymetallic geochemical anomalies throughout the study area. Additionally, precious metal anomalies are broadly distributed in volcanic and clastic rocks, along with quartz veins, areawide. An area of special interest contains gold and base metal mineralization in interlayered volcanic and clastic rocks. This mineralized area crops out in mountainous terrain 3 miles to the west of Sullivan Island. All of the old mines in the area have moderate mineral development potential owing to their various grades of mineralization. The widespread occurrence of geochemical anomalies combined with favorable geology for volcanic and sediment hosted mineralization suggests the study area is favorable for economic mineral occurrences. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/J. Copies of this report will not be available for purchase.

OFR 14-88. Maps Summarizing Land Availability for Mineral Exploration and Development in Western Alaska, 1986, by Robert G. Bottge. Feb. 1988. Thirty-eight figures that appeared in the Bureau of Mines Special Publication "Availability of Land for Mineral Exploration and Development in Western Alaska, 1986," have been open-filed at the 1:250,000-scale size in the Anchorage, Fairbanks, and Juneau offices of the Bureau's Alaska Field Operations Center. These overlays show the availability of land within each quadrangle for mineral exploration and development as of July 1, 1986. As many as 15 land subclassifications may be depicted on each quadrangle, showing open land, land open with restrictions, private lands, and land closed to mining. The mineral deposits plotted on the overlays are based on the Bureau's Minerals Availability System (MAS). An adjoining table is keyed to the deposit numbers. The deposit numbers identify one or more mineral deposits within a 3-mile radius. The table shows the MAS sequence number (an identification number related to a Bureau file), major commodities associated with the deposit, and an indicator of past production. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, and AFOC/J. Copies of these maps will not be available for purchase.

OFR 15-88. Maps Summarizing Land Availability for Mineral Exploration and Development in Southwestern Alaska, 1986, by Kenneth M. Maas. Feb. 1988. These maps show the availability of land for mineral exploration and development as of September 1986. Availability is divided between the general headings of available, available with restrictions, and unavailable. As many as 14 categories of land status have been used to delineate the various degrees of availability for any quadrangle. The mineral deposits plotted on the overlays are identified from the Bureau of Mines Minerals Availability System (MAS) data base. The majority of the listings refer to locatable mineral deposits. A tabulation of the names and principal commodities for each deposit is included. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, and AFOC/J. Copies of these maps will not be available for purchase.

OFR 16-88. Shearer Mounted Dust Collector; Evaluation of Ventilated Cutting Drums, by Jonathan S. Kelly and Terry L. Muldoon. June 1987. 50 pp. 25 figs. This report describes the development and the underground evaluation of ventilated cutting drums, on a double ended ranging drum shearer. The ventilated drum uses high pressure (1,500 psi) water sprays to draw air (3,500 cfm) through 12 airmoving tubes mounted in the drum hub. The sprays draw dusty air from the face side of the drum, scrub the air, and discharge the clean air on the gob side of the drum against a deflector plate. During a 3-week underground evaluation, the cutting drums reduced shearer generated dust levels at the shearer operators position by 40%, at the shield operators downwind of the shearer by 55%, and at the tailgate by 55%. Cutting and loading performance of the drums were superior to the mine's conventional drums. After the evaluation, the mine continued to use the ventilated drums to finish mining the panel. During this 3 month period, there were no mechanical or seal failures demonstrating excellent system reliability. Research was done under contract J0387222 by Foster-Miller, Inc. Available for reference at ALRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-209200; paper copy price code A04.

OFR 17-88. Experimental Study of a Novel Jet Booster Pump, by Joseph M. Wetzel, T. Jackson, and D. W. Bintz. Dec. 1985. 39 pp. 11 figs. This report describes the evaluation of a new form of a low head, jet booster. The jet pump consisted of a constant

diameter pipe fitted with two wall jets energizing the flow and a constant area diffuser consisting of a slotted wall portion of the pipe where water and solid fines were withdrawn. The withdrawn water was pressurized and recirculated to the jets by an external centrifugal slurry pump, thus performing a pressure booster operation on the main line flow. The jet pump was evaluated in a 3 inch pipe recirculating flow facility. Extensive tests were conducted with water flow to evaluate and optimize performance characteristics. The best efficiency obtained was about 17%. Addition of solid particles to the flow in sizes up to 3/4 inch resulted in plugging of the screened diffuser for concentrations above 20% by weight. Coal particles were rapidly eroded to very small sizes due to the action of the high velocity side jets. Problems associated with the screened diffuser limit the pumps' usefulness. Research was done under contract J0333928 by the University of Minnesota. Available for reference at LIB and PRC/B. Order ONLY from NTIS: PB 88-208715/AS; paper copy price code A03.

OFR 18-88. Development and Testing of Ergonomically Improved Personal Flotation Devices for Dredge Operations, by Mark S. Sanders, Gregory S. Krohn, and Brian E. Shaw. Oct. 1985. 61 pp. 18 figs. This report describes the results of a study to develop and test improve Type V workvests for use on dredge operations. The goal was to design workvests that would be more comfortable to wear, would interfere less with task performance, and would better meet the needs of dredge workers. It was hypothesized that by attaining these goals, the resulting vests would be worn more often and would be kept buckled more of the time than traditional vests. The study involved three major phases. In Phase I, visits were made to dredge operations and a definition of the problem was developed. Problems with current vests were identified and working conditions and tasks surveyed. In Phase II, prototype vests were developed and laboratory tests were performed to assess comfort and interference. In Phase III, the prototypes were modified and field tested with actual dredge operators and workers. Research was done under contract J0387213 by Essex Corp. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRS, and TURC. Order ONLY from NTIS: PB 88-209317; paper copy price code A04.

OFR 19-88. Estimated Direct Economic Impacts of a U.S. Import Embargo on Strategic and Critical Minerals Produced in South Africa, by Marilyn Biviano, Richard Gillette, and Pamela Smith. Jan. 1988. 57 pp. Under Section 303 of the Comprehensive Anti-Apartheid Act of 1986 (P.L. 99-440) U.S. imports of products produced, manufactured, marketed, or exported by South African parastatal organizations are prohibited. Strategic and critical minerals that the President has certified to the Congress are essential for the economy or defense, and that are unavailable from reliable and secure suppliers, are exempt from this ban. Section 501(c) of the Act, however, introduces additional measures that could be undertaken, including the prohibition of strategic and critical material imports from South Africa. To assist the President and the Congress in determining the national implications of such a prohibition, at the request of the Department of State, the direct costs to this nation resulting from a U.S. embargo on South African strategic and critical minerals have been assessed by the Bureau of Mines. The minerals included in this analysis are platinum, palladium, and rhodium of the platinum-group metals; chromium (all forms of contained chromium); manganese (all forms of contained manganese); vanadium; titanium (rutile and rutile substitutes); and cobalt (that is transported through South Africa for export). NTIS: PB 89-102495; paper copy price code A04.

OFR 20-88. Personal Equipment for Low Seam Coal Miners: IX. Development and Testing of Knit Fabric Gloves, by Mark S. Sanders, Gregory S. Krohn, Jacqueline V. Downing, and Brian E. Shaw. Dec. 1985. 60 pp. 19 figs. This report discusses the development and testing of prototype gloves for underground mining work. An analysis of HSAC hand-finger injuries revealed three high-risk jobs: laborer, mechanic, and roof bolter. Laboratory tests of dexterity and protection were performed using six off-the-shelf gloves. Two prototype gloves were developed. Both were Kevlar-cotton blend knit gloves. One had polyvinyl "Ks" screened on the palm and fingers, and a hand pad sewn into the palm. The other prototype had the palm and fingers coated with a solid layer of polyvinyl and had no hand pad. Field tests revealed that the solid-coated gloves were preferred by workers, but that the polyvinyl melted when working with hot drill steels. Research was done under contract J0387213 by Essex Corp. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-209325; paper copy price code A04.

OFR 21-88. Personal Equipment for Low Seam Coal Miners: X. Improved Knee Pads, a Modified Design, by Mark S. Sanders and Brian E. Shaw. Mar. 1986. 23 pp. 6 figs. This report describes the development and field test to improve knee protection for underground coal miners working in low seam mines. In a previous phase of this contract (Sanders, 1982), experimental knee pads were developed and field tested. The field test revealed several design deficiencies with the knee pads, and suggestions for improving the design were made. The work summarized in this report, therefore, consists of modifying the design and method of fabrication of the knee pads originally described by Sanders (1982), and of field testing the improved design. The new prototype was shorter and wider than the original design, and used a neoprene pass-through strap design rather than a cloth strap molded into the pad itself. The new prototype was constructed by slush molding a hollow bladder that was then filled with foam. Initial reactions to the pads in the field test were very positive. However, after 2 months, the opinions about the new prototype became less positive. They were judged, generally, to be no better or worse than the pads usually worn by the field-test participants. Problems were encountered in the field with respect to durability. Water seeped into the inner cavity of many of the pads and caused the foam to deteriorate. It was concluded that it would not be cost-effective or feasible to significantly improve upon current commercially available knee pad designs. Research was done under contract J0387213 by Essex Corp. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-209333; paper copy price code A03.

OFR 22-88. Development of a Monorail Bridge Conveyor System, by Guenter F. Lehmann. 38 pp. 35 figs. This report summarizes the results of the development and testing of a prototype monorail suspended bridge conveyor (MBC) system as a method of continuous haulage in underground mining applications. Included are the results of full scale, surface and underground testing of the complete MBC system. Conclusions drawn from these results, together with recommended modifications, supports the viability of the MBC system. Research was done under contract J0333917 by Goodman Conveyor Co., Inc. Available for reference at AFOC/J, IFOC, LIB, MSHA, NMH&SA, PRC/B, and WFOC. Order ONLY from NTIS: PB 88-208707/AS; paper copy price code A03.

OFR 23-88. The Role of Nonfuel Minerals in the Nevada State Economy and the Counties of Elko, Eureka, Lander, Nye, and White Pine, by George M. Swisko. Dec. 1987. 54 pp. 17 figs. This report describes a Bureau of Mines program developed to determine the impacts of changes in the nonfuel mineral industries upon regional economies. As part of this program the Bureau examined the impacts on Nevada and several of its counties resulting from significant changes in nonfuel mineral production between 1981 and 1986. Regional input-output models for Nevada and the counties of Elko, Eureka, Lander, Nye, and White Pine were developed through IMPLAN, the U.S. Forest Service's economic impact model. These models generated multipliers to measure total impacts on employment, earnings, and indirect business taxes. From 1981 to 1986 gold and silver production in Nevada grew at a faster rate than the total production of all goods and services measured by the gross state product. Other nonfuel mineral production however declined, with direct employment and earnings losses offsetting the employment and earnings gains from increased gold and silver mining. These changes also generated indirect impacts on employment and earnings for other industries, which varied for each region according to population, industrial diversification, and the types of minerals mined. Findings show that several county economies are quite sensitive to changes in nonfuel mineral production. Research was done by the Bureau of Mines. Available for reference at AFOC/J, IFOC, LIB, RERC, and WFOC. Order ONLY from NTIS: PB 88-210919; paper copy price code A04.

OFR 24-88. World Demand for Fertilizer Nutrients for Agriculture, by Staff, Bureau of Mines. Apr. 1988. 88 pp. This

report presents the model used to develop future demand for fertilizer nutrients. The Bureau of Mines, through its minerals information program, prepares forecasts of future demand for mineral-based fertilizer raw materials for publication and for the use of Government policymakers. To facilitate the preparation of these forecasts, the Bureau contracted with Wharton Econometric Forecasting Associates to develop a model for projecting long-term and short-term demand for the primary fertilizer nutrients and raw materials. The contractor used the model to prepare a report with estimates of future demand up to 2010 on a worldwide and regional basis for nitrogen, phosphate, potash, sulfur, and phosphate rock. These estimates were based on projected trends in world population, harvests of major crops, harvested area, and fertilizer application rates. Historical data and projections are summarized, and the appendix presents additional data and projections in tabular and graphic formats. NTIS: PB 89-102537; paper copy price code A05.

OFR 25-88. Improved Canopy Air Curtain Systems, by Mark R. Engel, David F. Johnson, and Thomas D. Raether. Aug. 1987. 291 pp. 136 figs. The objectives of this report were to develop an improved canopy air curtain system for mining use. The canopy air curtain concept offers an inexpensive solution to dust protection of an individual worker while not interfering with the production process. The purpose of this contract was to apply canopy air curtain concepts to a wider variety of mining equipment and operations. The work was conducted in three phases: In Phase I canopy air curtains currently used in the mining industry were studied and concepts for mine mill air curtains were designed. During Phase II, canopy air curtains for retrofit on underground mining machines and enclosed cabs on surface mines were designed. The possibility of a gas purification module for protection from diesel contaminates was investigated. The air curtain for mine mill application was tested in the laboratory. During Phase III, the canopy air curtain for retrofit on underground mining equipment and the air-conditioned, partially enclosed cab were fabricated and laboratory tested. Results showed an 89 percent reduction in respirable dust under the canopy air curtain. Three mine mill systems were field demonstrated and showed dust reductions of 82.8 to 98.4 percent. In addition, field maintenance and mine worthiness of the systems were excellent. During Phase IV, the air-conditioned, partially enclosed cab system was field tested. Poor heat distribution and inadequate heating precluded dust testing of this unit in severe winter conditions. The retrofit canopy air curtain and the heat only partially enclosed cab systems were constructed and shipped to their respective field test sites for USBM evaluation. A cost and use study on cab air filtration systems used in the mining industry was also conducted. Research was done under contract J0318014 by Donaldson Company, Inc. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-210521; paper copy price code A13.

OFR 26-88. Grouting Efficiency in Vertical Shafts, by Robert A. Cummings and Madan M. Singh. Jan. 1987. 252 pp. 47 figs. This report presents a review of the state-of-the-art in grouting in vertical shafts. Case histories of various shafts recently sunk by conventional drill-and-blast techniques as well as blind-drilling have been studied and the results discussed. The existence of voids, their formation, detection, monitoring, and control during grouting are devoted special attention. The long-term performance of grouts was examined. The need for further research and investigations is documented. Research was done under contract J0156004 by Engineers International, Inc. Available for reference at ALRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-212790/AS; paper copy price code A12.

OFR 27-88. Feasibility Study of Placer Gold Mining in the White Mountains Area, Circle and Tolovana Mining Districts, Alaska, by Michael D. Balen. Apr. 1, 1988. 27 pp. 4 figs. This report describes a placer mineral resource assessment and mining feasibility study for the White Mountains Area north of Fairbanks, Alaska, in 1987. The mining feasibility study involved a cost analysis and cash flow determination for three types of placer mine models. The basic mine model design incorporated the use of dozers and loaders for material handling, vibrating screens and sluicing systems for ore processing, and gold saver type equipment for concentrate cleanup. Settling ponds were used in the mine design for effluent treatment. Data is presented graphically and in the form of third degree polynomial equations which can be used to estimate costs and cash flow for various configurations of ore reserves, mine design, and mining rate. The C-Type mine, which incorporates the use of mining equipment which is owned outright by the mine operator has the greatest economic viability. The C-Type mine model which is designed to operate at 1000 BCYD (bank cubic yards per day) for 6 years had the lowest breakeven RGV (recoverable gold value) threshold of $3.84/yd^3. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, IFOC, and WFOC. Order ONLY from NTIS: PB 88-210851; paper copy price code A03.

OFR 28-88. Potentially Critical Materials, by Russell J. Foster. Mar. 1988. 65 pp. 13 figs. In this Bureau of Mines report a selection process has identified 14 nonstockpiled materials (cesium, gallium, hafnium, indium, osmium, rhenium, rhodium, rubidium, ruthenium, scandium, selenium, tellurium, thallium, and zirconium) that are linked to the continuing evolution of high-technology fields such as electronics, catalysis, and energy, and that have limiting factors associated with domestic availability. A qualitative assessment of the "potential criticality" of these materials was made through a consideration of end uses, demand trends and forecasts, production, mineral reserves, byproduct status, alternative supply sources, substitution and conservation options, and recyclability. NTIS: PB 89-102271/AS; paper copy price code A04.

OFR 29-88. References to Coastal Mineral Occurrences (Other Than Mineral Fuels and Construction Materials) of Alaska, Indexed by Quadrangle, by Denise A. Herzog. Apr. 1, 1988. 308 pp. 1 fig. This report comprises a list of publications which discuss coastal geology and mineral deposits (other than mineral fuels and construction materials) in Alaska. This work was initially conducted for use in the Bureau of Mines Offshore Nome economic analysis. Publications have been indexed by topographic quadrangle and appear in the appendix of this report. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, IFOC, PRC/B, and WFOC. Order ONLY from NTIS: PB 88-210844; paper copy price code A14.

OFR 30-88. The Changing Role of the Nonfuel Mineral Industry in the State and Local Economies of Arizona (1981-1986), by Anthony M. Opyrchal, George M. Swisko, and Robert L. Adams. Apr. 1988. 45 pp. 8 figs. This report describes the changes in nonfuel mineral industry activity in Arizona and four of its counties between 1981 and 1986. Regional input-output models for Arizona and the counties of Gila, Greenlee, Pima, and Pinal were developed through IMPLAN, the U.S. Forest Service's economic impact model. These models generated multipliers to measure total impacts of changes in activity on employment, earnings, and indirect business taxes. From 1981 to 1983 metallic nonfuel mineral production in Arizona declined significantly. Production turned upward after 1983, but cost reductions, the introduction of new technology, and industry restructuring reduced direct employment and earnings over 50% each from their 1981 levels. These changes generated indirect impacts on employment and earnings for other industries in Arizona and the counties where the majority of production occurred. Findings show that county economies are quite sensitive to changes in nonfuel mineral production. Research was done by the Bureau of Mines. Available for reference at AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 88-210752; paper copy price code A03.

OFR 31-88. An Economic Evaluation of Selected Undiscovered Precious-Metal Deposits in the Tonopah Quadrangle, Nevada, by Thomas Gunther, Barbara White, Richard Gillette, and Robert Adams. May 1988. 32 pp. 7 figs. This report presents results of an evaluation of the potential for the production of gold and silver from undiscovered mineral deposits of five types—polymetallic vein, epithermal, polymetallic replacement, carbonate hosted, and hot spring—in the Tonopah Quadrangle, Nevada. It was completed as part of a continuing effort by the Bureau of Mines and the U.S. Geological Survey to develop and present mineral resource and potential supply information in a form that is more useful to decision-makers and analysts dealing with mineral-related policy and economic issues. An important part of this effort has been the development and application of techniques to provide quantitative (quantities and values) rather than qualitative (high, low) estimates of the

undeveloped and undiscovered portions of the mineral endowment of an area. The study merges existing geologic knowledge of the region with the economics of mining and milling using current technologies. Research was done by the Bureau of Mines. Available for reference at AD/I&A, AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 88-210950; paper copy price code A03.

OFR 32-88. Coal Mine Bump Monitoring, by J. M. Descour and R. J. Miller. Dec. 1987. 111 pp. 53 figs. This report describes the monitoring of microseismic activity maintained during several major phases of retreat mining in the 9 Right section of Olga Portal #2 coal mine in Caretta, West Virginia. Significant observations were made regarding mining, stress indications, stability problems and microseismic event occurrence. The first part of the analysis of microseismic data was focused on recognition of parameters and mechanics of an individual microseismic source as an element of instability development. Results of this analysis should also be useful for the development of a real-time microseismic data acquisition and processing system. The second part of the analysis was oriented to determine the correlation between areal and temporal event distribution, mining situation, and geological parameters to improve the reliability of a bump forecasting technique. In particular, the microseismic data provided very descriptive and unique images of areal and temporal development of instability which resulted in a major multiple bump occurrence on June 3, 1985. Microseismic data and other observations suggest that a nonuniform horizontal stress distribution in the roof and floor is probably responsible for most of the bump and roof instability problems. Mining is the main cause of the stress concentration around mine openings. The instability distribution is influenced by the joint system. The configuration of gob contours with respect to the joint system also needs to be considered. Research was done under contract J0245009 by the Colorado School of Mines. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-214309/AS; paper copy price code A06.

OFR 33-88. Design, Fabrication, and Testing of a Hopper-Feeder-Bolter, by Donald Giroux. Apr. 27, 1987. 69 pp. 65 figs. This report documents the design, fabrication, testing, and coal mine demonstration of a hopper-feeder-bolter during a four-phase program. The machine was designed to increase productivity and safety in underground room-and-pillar mining. It performed well as a hopper-feeder for continuous haulage during a coal mine demonstration. Testing in a simulated mine showed that the machine also has good roof bolting capability. Research was done under contract J0333940 by Engineered Systems & Development Corporation. Available for reference at AD/RES, AFOC/J, ALRC, DRC, IFOC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-213558; paper copy price code A05.

OFR 34-88. Development and Testing of a Variable Wall Miner Breadboard Prototype Unit, by Ronald J. Mathis, James M. Burkes, and Dan H. Weissling. Nov. 1987. 101 pp. 21 figs. This report describes and summarizes the operation characteristics of the Variable Wall Mining System (VWMS), the design methodology used to develop various working models, the surface testing of a 1/2-scale version of the VWMS, prediction of power requirements and performance potential of a full-scale system, and a critique of the VWMS concept, conclusions, and recommendations. Research was done under contract J0333951 by Southwest Research Institute. Available for reference at AD/RES, DRC, LIB, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 88-214317/AS; paper copy price code A06.

OFR 35-88. Prediction of Incipient Electrical-Component Failures, by Jeffery L. Kohler and Frederick C. Trutt. Sept. 17, 1987. 370 pp. 140 figs. This report presents the results of a research effort to predict incipient failure in electric-power-system components. The development of continuous monitoring techniques to detect an incipient failure would represent a significant improvement in system maintainability, availability and safety. This report describes the analytical and experimental aspects of the project. Mathematical models have been developed to study the behavior of cables and motors which are undergoing a deterioration process. These models allow a detailed study of the effect of deterioration on the component's terminal characteristics and performance. The efficacy of using negative-sequence monitoring as a reliable indication of deterioration has been established. Techniques for assessing the sensitivity of the prediction algorithm to component deterioration have been presented. An approach for modelling electrically-excited vibrations, and including these in the algorithm, has been presented. Research was done under contract J0338028 by the Pennsylvania State University. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-213590; paper copy price code A16.

OFR 36-88. Fundamental Studies on the Relationship Between Quartz Levels in the Host Material and the Respirable Dust Generated During Mining, Volume I: Experiments, Results and Analysis, by R. V. Ramani, J. M. Mutmansky, R. Bhaskar, and J. Qin. Sept. 1987. 179 pp. 152 figs. This report describes the results of a study into the relationship between quartz content in airborne dust and that in the material being cut in underground coal mines. This study included extensive experiments in operating mines for (1) documenting the amount of respirable dust generated, (2) measuring the quartz levels in host materials and airborne dust, (3) analyzing the size consist of the mined product, and (4) establishing the relationship between these various parameters. The results of the study indicate that the amount of dust airborne is a very small fraction of the total (<15 μm) and respirable (<7 μm) dust generated. The quartz contents in the total and respirable airborne dust are generally higher than those in the host material. Quartz content increases with decreasing size of airborne dust. Also, it appears that rock breaks into a different size distribution than coal. The source of quartz for the airborne dust appears to be the roof and the floor material rather than the coal seam itself. No general relationship is found between the Hardgrove Grindability Index and either the quartz content in the airborne dust or the amount of respirable dust. Extended descriptions of the experimental design, the experiments, data analyses and results are presented in this volume. The raw data, the data management computer program and the sampling and safety plan are presented in Volume 2. Research was done under contract H0358031 by the Pennsylvania State University. Available for reference at AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-214325/AS; paper copy price code A09.

OFR 37-88. Development of an Improved Permissible Miners' Caplamp, by Elio Ferreira and Allen Charkey. Feb. 1988. 86 pp. 45 figs. This report describes the design, and development work performed to reduce the volume and weight of the miners' caplamp battery, as well as a headpiece with a swivel mechanism containing a halogen bulb with two filaments. Work was also conducted in the development of a maintenance free battery. The design concept is based on non-sintered Ni-Cd technology, with an energy density of 22 Wh/lb. The caplamp system developed has been approved by the Mine Safety and Health Administration and can be manufactured for mine use. Research was done under contract J0188078 by Energy Research Corporation. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-213582; paper copy price code A05.

OFR 38-88. Feasibility of Economic Gold Mining in the Juneau Gold Belt Area of the Juneau Mining District, Alaska, by Gary E. Sherman and Donald W. Baggs. Jan. 1988. 16 pp. 3 figs. Preliminary economic mining feasibility studies were conducted by the Bureau of Mines to estimate mining costs in the Juneau gold belt area of the Juneau Mining District, southeastern Alaska. Investigations were conducted on the economics of two mineral deposit types: Berners Bay vein gold deposits and stockwork gold deposits containing gold, silver, and lead. Cost estimates were developed using the Bureau of Mines Cost Estimating System. Discounted cash flow return on investment (DCFROI) was calculated using the Bureau's MINSIM computer program. Underground mining of a Berners Bay vein gold deposit was found to be economic (15-pct DCFROI) at a recoverable metal value of $353.67/mt for a 100-mtpd shrinkage stoping mine with a 10-yr mine life, $324.76/mt for a 20-yr mine life, $136.63/mt for a 500-mtpd longhole stoping mine with a 10-yr mine life, and $127.50/mt for a 20-yr mine life. Block caving mining of a large stockwork gold deposit was found

to be economic at a recoverable metal value of $15.28/mt for a 18,000-mtpd mine with a 20-yr mine life. Research was done by the Bureau of Mines Alaska Field Opertions Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-221189/AS; paper copy price code A03.

OFR 39–88. Determining the Effects of Management Practices on Coal Miners' Safety, by Gregory H. Gaertner, Paul D. Newman, M. Shelley Perry, Gerald P. Fisher, and Kenneth Whitehead. Dec. 1987. 348 pp. 1 fig. A 3-year study of 10 mining companies and 62 underground coal mines was undertaken by the Bureau of Mines to determine the effects of management practices on coal miner safety. Site visits were made to all 10 companies, and a second visit was made to 8 of the 10 companies. Data collection procedures included interviews with company- and mine-level personnel, focus group interviews with foremen and hourly employees, content analyses of policies and procedures, and accident, injury, production, and productivity results from MHSA's HSAC data base for 1980 through 1986. Findings underline the importance of top management commitment to ensuring a safe, productive mining operation. In the sampled companies, a variety of practices were used by management to communicate safety priorities, although most companies focus on one or two mechanisms. Effective management practices include safety-productivity incentives, disciplinary policies for unsafe behaviors, and concerted efforts to investigate accidents and distribute the results of these investigations. Less effective mechanisms include repeater programs and rehabilitation clinics. The most effective management practices allow participative implementation, followup, and evaluation. They are also generally forcefully advocated by some well-positioned company official, not necessarily in the safety function. Research was done under contract J0156029 by Westat, Inc. Available for reference at AFOC/A, AFOC/F, AFOC/J, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-221445/AS; paper copy price code A15.

OFR 40–88. Changes in Domestic Demand for Primary Metals Due to Economic Growth, Technology Change, and Change in Composition of Final Demand, by Jack G. Faucett and Harry J. Chmelynski. July 1987. 93 pp. 22 figs. Metals consumption and production in the United States did not keep pace with economic growth from 1963 to 1983. For example, steel consumption per million dollars of real gross national product (GNP) decreased from 98 tons to 50 tons during this period, and nonferrous metals consumption decreased from $6,250 per million dollars of GNP in 1963 to $4,570 in 1983 (measured in 1975 constant dollars). This study, based on an interindustry analysis, identities and quantifies the contribution of three sources responsible for change in U.S. metals demand and, in turn, production between 1963 and 1982: Technological change, economic growth, and the composition of final demands. The results of the analysis show that technology was the most significant factor causing the production of ferrous metals and the production growth rate of nonferrous metals to decline during the study period. Research was done under contract S0178004 by Jack Faucett Associates. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-231584/AS; paper copy price code A05

OFR 41–88. Measuring Critical Mine Health and Safety Skills, by Henry P. Cole, Philip K. Berger, Charles Vaught, John V. Haley, Warren E. Lacefield, Ronald D. Wasielewski, and Launa G. Mallett. Mar. 1988. 202 pp. 18 figs. A series of studies are described that identify critical health and safety skills needed by underground coal miners for coping with mine emergencies. First aid and self-rescue and escape were selected as two broad performance domains that include many subordinate skills needed for preventing, recognizing, and coping with mine emergencies. The performance domains and their objectives were used to direct the development of simulation exercises that permit miners to experience mine emergencies in the safety of a training room. The exercises are based upon research with similar simulations for the training of flight crews and medical personnel in information gathering, judgment, and decision making skills. Exercise content is drawn from actual mine accident and disaster case studies. The exercises incorporate recent principles of cognitive psychology and instructional design. Initial studies in annual refresher training classes suggest the exercises are stimulating for miners and their instructors, easy to use and read, sufficiently complex and authentic to challenge experienced miners, and useful devices for both teaching and testing critical problem solving skills required for preventing and minimizing emergencies. Research was done under contract H0348040 by the University of Kentucky. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-231352/AS; paper copy price code A10.

OFR 42–88. Methods for Assessing Critical Nonroutine Mine Health and Safety Skills, by Henry P. Cole, Philip K. Berger, Charles Vaught, Warren G. Lacefield, Ronald D. Wasielewski, John V. Haley, and Shannon L. Price. Mar. 1988. 234 pp. 11 figs. A comprehensive review of published research was carried out to identify methods for teaching and assessing critical but nonroutine skills needed for coping with emergency situations. Specific methods for assessing critical skills proficiency in aviation, medicine, organization management, the military, and other industrial and technical workplaces are described. The potential application of these methods for teaching and assessing critical first aid and self-rescue and escape skills to underground coal miners in annual refresher training is explored. Research and development activities that may improve mine health and safety training are suggested; most of these research and development activities were completed later in the project. Research was done under contract H0348040 by the University of Kentucky. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 88-231360/AS; paper copy price code A11.

OFR 43–88. Results of 1987 Bureau of Mines Investigations in the Valdez Creek Mining District, Alaska, by Joseph M. Kurtak, Michael D. Balen, and Steven A. Fechner. June 1988. 80 pp. 3 figs. The Bureau of Mines is currently conducting a 4-yr mineral assessment of the 5.7-million-acre Valdez Creek Mining District in South-Central Alaska as part of its ongoing statewide mining district evaluation program. This report is a summary of the 1987 fieldwork, which included examining mines, prospects, and mineral occurrences in the study area. Placer gold has been the main metal produced in the area and totals 161,131 oz with the major production coming from the Valdez Creek Mine. Lode gold and silver production totals 1,581 oz and 8,617 oz, respectively, and comes mainly from the Golden Zone Mine. Varying amounts of other metals including copper, lead, zinc, molybdenum, antimony, chrome, nickel, cobalt, tin, tungsten, and platinum exist in the study area. Occurrences of industrial limestone and coal are also located within the study area. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, IFOC, LIB, PRC/B, and WFOC. Copies of this report will not be available for purchase.

OFR 44–88. Copper: List of Bureau of Mines Publications and Articles Through March 1988, compiled by Jean K. Moore. July 1988. 135 pp. This report contains copies of abstracts of Bureau of Mines publications and articles about or related to copper ores, copper materials, or copper-base products. The publications and articles described in the abstracts were compiled between 1910 and early 1988. Accompanying the list are an index, a page defining abbreviations used, a list of Regional Depository Libraries as published in the List of Bureau of Mines Publications and Articles, January 1, 1980, to December 31, 1984, a list of reports available from the National Technical Information Service (NTIS) with NTIS accession numbers and price codes, and another list of costs with GPO stock numbers. Work was done by the Bureau of Mines Division of Mineral Commodities. Available for reference at LIB and PRC/B. Order ONLY from NTIS: PB 88-234265/AS; paper copy price code A07.

OFR 45–88. Research on the Stability of an N_2O Metal Powder System, by R. H. Lien and D. C. Seidel. June 1988. 20 pp. 4 figs. The Bureau of Mines investigated nitrous oxide (N_2O) stability when used as a solvent for organic removal from metal powder surfaces. Both supercritical and subcritical conditions were studied. This investigation was prompted by the occurrence of a violent reaction when supercritical N_2O was being used to deoil a metal powder grinding waste sample that contained 20 to 25 wt pct cutting oil. Tests were conducted to determine the cause of the reaction and to define stability limits. Test data showed that the waste's oil fraction reacted violently with N_2O acting as an oxidizer; the metal powder acted as a promoter to reduce the ignition temper-

ature. Although the data were scattered, this temperature appeared to reach a minimum at a certain pressure (dependent on vessel and sample size). The minimum ignition temperature for a 0.64-g sample in a 72-cm³ vessel was 360° C at 200 psig. As the sample size increased, the ignition temperature decreased. For example, when the sample size was increased to 10 g, a reaction occurred at 240° C and 600 psig. Because of the variability of ignition temperature with pressure and sample size, safe operating conditions were not established. Overall, this research showed that extreme caution should be exercised when using N_2O in an organic or organic-metal system. Research was done by the Bureau of Mines Salt Lake City Research Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-234836/AS; paper copy price code A03.

OFR 46-88. Combining Laser Measurements With Backward Wave Techniques for Evaluation of Underground Openings, by G. L. Fitzpatrick, R. L. Skaugset, and T. J. Davis. Oct. 1987. 48 pp. 12 figs. A portable optical instrument for performing multispot laser vibrometry is described. The instrument is capable of measuring arrival times, surface motion frequency, and surface velocity and displaying these quantities in various useful ways. Sigma Research is currently pursuing the development of such optical measuring systems for the evaluation of structures in rock by noncontact interferometry methods. The goal of the work was to develop a portable tripod mounted measuring system which can be set up at arbitrary distances (up to 30 m) from a surface and project four in-line laser sample beams on this surface. A light-receiving telescope gathers the scattered light from these four spots, and provisions are made to mix this light with a reference beam from the laser. Four photodiodes are employed to determine the resultant interference signals which characterize the motion (particle velocity, frequency, amplitude) of the four illuminated spots on the surface under study. Information of this type can then be used to characterize the elastic or mechanical properties of the surface in question. In some cases (if more than four spots are involved) this surface information could be back-propagated to draw inferences about the *internal* state of the material volume bounded by this surface. Research was done under contract J0145075 by Sigma Technologies. Available for reference at AD/RES, AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-235080/AS; paper copy price code A04.

OFR 47-88. Determining the Effect of Incentive Programs on the Occurrence of Accidents, Injuries, and Productivity—Final Report, by Paul S. Goodman. Dec. 1987. 143 pp. 17 figs. This report examines the effectiveness of bonus plans in the coal industry. The analysis uses theoretical, literature review, and empirical approaches to determine the impact of bonus plans on safety and productivity in underground coal mines. The basic finding is that the modal bonus plan in underground coal mining does not have a major impact on productivity and safety indicators. The design of the plan, organizational factors, and the process of introducing the plan all contribute to its relative ineffectiveness. Strategies and options for designing effective plans are presented. Research was done under contract J0145012 by Carnegie-Mellon University. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-234257/AS; paper copy price code A07.

OFR 48-88. Instrumentation To Monitor Subsidence Associated With High Extraction Mining in the Illinois Basin, by Peter J. Huck and Swapan Bhattacharya. June 1988. 60 pp. 19 figs. Prime cropland and underground coal reserves constitute two significant natural resources in the State of Illinois. Utilization of both agricultural and mineral resources suggests the development of high-extraction mining methods which minimize damage to the overlying croplands. Several Illinois agencies have therefore instituted a program to study high-extraction mining methods in an effort to characterize surface damage caused by subsidence. In support of this program, Engineers International, Inc. undertook a program from the U.S. Bureau of Mines, Twin Cities Research Center, to select and emplace appropriate subsidence instrumentation over a high-extraction mine panel selected by the cooperating Illinois State agencies. This instrumentation was to provide subsidence data for both short-term and long-term subsidence and hydrological effects of mining. The emplaced instrumentation included multipoint borehole extensometers (MBPX), observation wells, piezometers, subsidence monuments, and control monuments to provide local horizontal and vertical control. A suite of laboratory tests was conducted on specimens recovered during drilling, and rock properties data were culled from published and Engineers International, Inc. file data. Research was done under contract H0256005 by Engineers International, Inc. Available for reference at DRC, LIB, OSM, PRC/B, and TCRC. Order ONLY from NTIS: PB 88-241922; paper copy price code A04.

OFR 49-88. Gold-Copper Mineralization of the Chilkat Peninsula and Islands, by Jan C. Still. May 1988. 39 pp. 15 figs. As part of a cooperative project during 1986 and 1987, personnel from the U.S. Bureau of Mines and State of Alaska Division of Geological and Geophysical Surveys studied the mineral development potential of the Chilkat Peninsula and Islands, AK, as part of the larger Juneau Mining District study. About four-fifths of the area is within the Alaska State Chilkat and Chilkat Islands State Parks and not open to mineral entry. This study located four new (or previously unreported) gold-copper prospects. One of these, the Road Cut prospect, was examined by trenching, drilling, and geophysics. While sufficient grades and tonnages were not delineated by this work to constitute an economic deposit, they are sufficient to encourage exploration for such in the prospect vicinity. Of 112 reconnaissance rock, stream sediment, and pan concentrate samples collected at scattered locations (not from prospects or occurrences) in the Chilkat Peninsula and Islands, 79 were anomalous in gold, silver, copper, or zinc. Newly discovered mineralization and anomalous reconnaissance sample values indicate that the Chilkat Peninsula and Islands could be an important target for the exploration of fault-controlled gold-copper deposits, but present land status prevents mineral exploration in most of the area. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, IFOC, LIB, PRC/B, and WFOC. Copies of this report will not be available for purchase.

OFR 50-88. Mineral Investigations in the Juneau Mining District, Alaska (Eagle River Area), by Joseph M. Kurtak and Kenneth M. Maas. June 1988. 147 pp. 65 figs. The Bureau of Mines Alaska Field Operations Center conducted a 4-yr (1985-88) mineral assessment of the Juneau Mining District in southeast Alaska as part of its ongoing statewide mining district evaluation program. Following an extensive literature search, the Bureau investigated mines, prospects, and mineral occurrences in the area. This report describes the results of Bureau work in the Eagle River area of the Juneau gold belt, a component of the Juneau Mining District comprising 87,000 acres between the Mendenhall Glacier and Berners Bay. Gold and silver have been the only metals having significant production from the area and occur mainly in quartz stringer and fissure-type veins hosted by phyllites, greenschists, greenstones, altered diorite dikes, and quartz diorite gneiss. Gold also occurs in several small placer deposits. Approximately 21,100 oz of gold and nearly 9,000 oz of silver were produced over a 60-yr period. Currently, the only mining activity consists of some exploration and minor placer gold production. Inferred and indicated lode gold resources having mineral development potential total approximately 796,000 tons with a weighted average grade of 0.22 oz/ton gold. Available for reference at AFOC/A, AFOC/F, AFOC/J, DRC, IFOC, LIB, and PRC/B. Copies of this report will not be available for purchase.

OFR 51-88. Development of Anthracite Open-Pit Haulage Systems, by Jordan A. Kinkead, Adrian Matthias, Ants Uiga, and G. J. Campbell. June 1986. 158 pp. 28 figs. The development and analysis of highly productive haulage systems for the anthracite industry in eastern Pennsylvania was completed in this work. A literature survey and field survey were completed for 10 haulage systems. A site scenario was developed for two mine sizes in eastern Schuylkill County, PA. The analysis showed a combined system, using rail cars and skip hoists (rail-hoist), to be the only viable alternative to a truck haulage system. The rail-hoist system provided variable cost savings for capital investment and operating costs, depending on the projected size of the mine. Research was done under contract J0333935 by Sherman and Kinkead Consulting Engineers, Inc. Available for reference at AD/RES, DRC, LIB,

OSM, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 88-246921/AS; paper copy price code A08.

OFR 52-88. In-Mine Development Testing of an Automated Extraction System, by Richard Rittenhouse and Dale Blohm. July 1983. 121 pp. 71 figs. This program was to develop a new base line system for automated continuous room-and-pillar-type mining. The primary requirement established for this machine is that the machine be capable of mining and bolting simultaneously. Additionally, this machine was to provide temporary and permanent roof control, have a productive full-face semi-automatic mining system, leave a clean entry outby the machine, provide maximum operator protection, provide effective dust suppression, and provide air scrubbing to restrict respirable dust to permissible levels. The machine has effectively demonstrated the ability to mine and bolt simultaneously. Additional aboveground operation, testing, and time studies are recommended to further verify the machine's abilities. Design improvements are recommended for future generation machines. These relate to marginal design areas, such as side loading on vent duct lift cylinders, that will not impair additional testing of the existing machine. Research was done under contract J0333946 by National Mine Service Co., Nashville Division. Available for reference at AD/RES, AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-245626/AS; paper copy price code A06.

OFR 53-88. Placer Platinum-Group Metals Offshore of the Goodnews Bay Ultramafic Complex, Southwest Alaska, by James C. Barker and Kathryn Lamal. July 1988. 60 pp. 24 figs. In 1981 and 1985-86, the Bureau of Mines conducted orientation studies of marine placer platinum-group metals (PGM). PGM are derived from the Goodnews Bay ultramafic complex, and magnetic surveys show that the complex extends offshore at least 4 miles. The present seafloor was an emergent foreland as recently as 8,000 yr ago. High-energy ocean processes are transporting and depositing sediment such that PGM-bearing materials are reworked and later masked by barren littoral drift. Exploration targets include placers formed since present transgression began and ancient marine and drowned fluvial deposits. Additionally, there is evidence of PGM solution transport and accretion. At least minor values of PGM in Recent lag-type placers and possible submarine strands are concentrated along an offshore scarp incised through glacial deposits into the preglacial surface between Flat Cape and Red Mountain. Other Recent PGM-bearing features include Flat Cape shoal, Chagvan Bay, Salmon River delta, and modern beaches. Ancient placers include possible north-south fluvial systems 2 to 3 miles offshore, a nearshore scarp 50 ft below sea level, and strands adjacent to projected ultramafic bedrock slopes. The existence of ancient placers is dependent on depth of glacial erosion. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AD/I&A, AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 88-251996/AS; paper copy price code A04.

OFR 54-88. Estimated Impacts on U.S. Gross National Product (GNP) and Employment Resulting From a U.S. Embargo on South African Platinum-Group Metal Supplies, by Marilyn Biviano, Stan Miller, and George Swisko. Sept. 1988. 14 pp. A follow-up to OFR 19-88, this report estimates the overall impact of a U.S. embargo on South African platinum-group metal supplies. Although no reduction in automobile production would be expected to result from embargoing platinum, embargoing rhodium would result in reduced automobile production and substantial GNP and employment losses, assuming no change in the current emission control requirements of the Clean Air Act. NTIS: PB 89-109235/AS; paper copy price code A03.

OFR 55-88. Impact of Existing and Proposed Regulations on the Domestic Lead Industry, by Raymond J. Isherwood, R. Craig Smith, Orville A. Kiehn, and Michael R. Daley. Aug. 1988. 33 pp. 5 figs. The Bureau of Mines has investigated the domestic primary and secondary lead smelting and refining industries to determine the economic impacts of existing and proposed environmental, health, and safety regulations. The impacts are assessed in terms of capital and operating costs for existing and alternative smelting-refining technologies. Industry response to regulatory implementation is estimated and quantified in terms of import value from lost lead production. For the primary lead industry, regulatory compliance may add up to 1.15 ¢/lb refined lead to operating cost for rehabilitated plants. Alternative smelting-refining methods could reduce net operating costs by as much as 4.36 ¢/lb refined lead. Capital expenditures would range from $750 to $1,000 per annual mt of smelter capacity. Secondary lead smelter operating costs would increase about 3.8 ¢/lb refined lead to comply with existing regulations. Capital expenditures would average about $124 per annual mt of smelter capacity. Implementation and enforcement of proposed regulations would result in closure of the primary lead industry and additional expenditures for compliance by the secondary lead industry. Enforcement of the most extreme proposed regulations would force the secondary lead industry to close. Research was done by the Bureau of Mines Intermountain Field Operations Center. Available for reference at AFOC/A, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-121743/AS; paper copy price code A03.

OFR 56-88. Improvement of Coal Mine Dust Incombustible Content Meter, by Pedro Lilienfield and Roger Stern. Jan. 1984. 81 pp. 11 figs. The objective of this program was to design, develop, and laboratory-test a breadboard-prototype version of a pocket-sized coal mine dust incombustibles content meter. This instrument was designed to assess the combustibility of coal mine dust deposited on mine surfaces, without the need for sample retrieval, by placing the sensing face of the device directly in contact with the surface of the dust layer. The operation of this instrument is based on the detection of gamma radiation backscattered by the dust layer under scrutiny. The design of the device was aimed at extreme compactness, incorporating a single-chip CMOS microprocessor. The sensing configuration is based on an americium-241 source and a cadmium-telluride gamma radiation detector. Automatic calibration using standard samples and a digital readout directly in percent incombustibles are designed to minimize operational complexity. Research was done under contract H0387001 by GCA Corp. Available for reference at DOI, MSHA, NMH&SA, and PRC/B. Copies of this report will not be available for purchase.

OFR 57-88. Vaporization Thermodynamics of the Aluminum-Silicon Carbides Al_4SiC_4 and Al_8SiC_7, by E. A. Johnson, L. L. Oden, and Arnold Adams. Sept. 1987. 17 pp. 2 figs. The vaporization thermodynamics of the aluminum-silicon carbides Al_4SiC_4 and Al_8SiC_7 were studied by the Bureau of Mines over the temperature range of approximately 1,500 to 1,700 K. Vapor pressures were measured by a Knudsen effusion-mass spectrometry technique in which powdered samples were effused from graphite crucibles through small orifices. For each compound, a total of six orifice diameters was tested to verify equilibrium within the cell. Experimental results are based on the following equations for incongruent decomposition: $Al_4SiC_4(cr) = 4Al(g) + SiC(\alpha,hex) + 3C(gr)$; $Al_8SiC_7(cr) = 8Al(g) + SiC(\alpha,hex) + 6C(gr)$. The observed vapor pressure-temperature relationships determined with a cell orifice area of 2.0×10^{-3} cm^2 for Al_4SiC_4 and 1.81×10^{-3} cm^2 for Al_8SiC_7 are $\text{Log } P = (-18{,}682/T) + 12.476$, for Al_4SiC_4 (1,550 to 1,643 K) and $\text{Log } P = (-19{,}308/T) + 12.421$, for Al_8SiC_7 (1,526 to 1,784 K), with P in pascals and T in kelvins. Third-law analysis of the data provided the following heats of formation: Al_4SiC_4, ΔH at 298.15 K = −50.0 kcal/mol; and Al_8SiC_7, ΔH at 298.15 K = −92.1 kcal/mol. Research was done by the Bureau of Mines Albany Research Center. Available for reference at AFOC/A, ALRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-118079/AS; paper copy price code A03.

OFR 58-88. The Potential Impact of Acid Rain Legislation on the Domestic Aluminum Smelting Industry. Oct. 1988. 14 pp. 7 figs. In this report estimates are presented of the impact of the passage of five recently proposed "acid rain" bills on electric utility costs for coal-burning utilities servicing the domestic aluminum smelting industry, and on the costs of production for affected aluminum smelters. As aluminum smelting is an energy-intensive industry, domestic increases in electricity prices could affect the industry's competitiveness. Energy costs in U.S. aluminum smelting are compared to aluminum smelting energy costs in the rest-of-the-

world. Governmental policies affecting these energy costs are discussed. Research was done by the Bureau of Mines Division of Policy Analysis. Available for reference at AFOC/A, ALRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-122345/AS; paper copy price code A03.

OFR 59-88. The Potential Impact of Acid Rain Legislation on the Domestic Aluminum Smelting Industry: Methodology and Documentation, by Donald R. Alvic. Oct. 1988. 59 pp. 2 figs. This report documents the methods and assumptions underlying the Bureau of Mines analysis of the potential impact of acid rain legislation on the domestic aluminum smelting industry. Research was done under contract J0178041 by the Energy, Environment, and Resources Center, University of Tennessee/Knoxville. Available for reference at AFOC/A, ALRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-122352/AS; paper copy price code A04.

OFR 60-88. Development of Face Decision Support System for Underground Coal Mines, by Roy S. Nutter, Y. V. Reddy, R. L. Grayson, M. Klishis, and others. Aug. 1988. 203 pp. 45 figs. An expert system advisor consultant to assist a coal mine section foreman is described in this report. The system is designed for an underground continuous miner section that is being specifically used for longwall development. The system provides three methods of operation that include normal operational mode for use underground, a training mode for use in training section foremen under controlled classroom conditions, and a demonstration mode that is free running. The Face Decision Support System (FDSS) is designed to interface with section environmental monitoring equipment and section production monitoring equipment that may appear in the future. This provides automated reprioritization of the section foreman's job list from the system. The system is written in LASER which is written in C and is operated under the UNIX operating system. The objective of the entire FDSS system is to ensure that no job or piece of information important to safety or to production is forgotten because of the immediate problems confronting the section foreman. Research was done under contract H0358020 by West Virginia University. Available for reference at AD/RES, ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 89-127617/AS; paper copy price code A10.

OFR 61-88. Improved Ventilation of Sealed Mine Gob, by Steven D. Wirch and D. Randolph Berry. Oct. 1988. 21 pp. 4 figs. Abandoned underground coal mine areas must either be sealed or ventilated to comply with Federal mine regulations. Ventilation of these abandoned areas is often impractical owing to roof falls and inadequate primary mine ventilation. If the area is sealed, a very complex ventilation system is set up, in which the gob "breathes" in and out owing to barometric pressure fluctuations. The Gob Assistant is a computer program (for use on IBM-compatible personal computers) which allows the prediction of air flows into and out of a sealed mine area. Gas flows with applicable control techniques are also modeled. This information is presented to the user, who will decide which control technique, or combination of techniques, will ultimately be applied. The Gob Assistant is an intelligent gob simulator that can reduce the guesswork involved in predicting the effects of sealing and control techniques before they are applied. This paper provides the fundamental principles upon which the Gob Assistant is based, verification of these principles, and an explanation of how these principles were integrated into the Gob Assistant. Research was done under contract J0308029 by Foster-Miller, Inc. Available for reference at AFOC/A, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-130520/AS; paper copy price code A03.

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OFR 1-89. An Overview of Bureau of Mines Research on Mineral Alterations in Supercritical Water, by J. M. Oestreich. Nov. 1988, 20 pp. 3 figs. Supercritical water (SCW) is being tested for commercial use in several organic extraction systems, but little work has been done on the extraction of metals from minerals. This lack of information prompted U.S. Bureau of Mines research into the SCW treatment of minerals. As a result, this research project is intended to serve mainly as a starting point for further experimentation. A simple flowthrough reactor was built out of high-pressure tubing and used to treat minerals with SCW at 400°C and 3,500 to 7,000 psi. The research produced four main conclusions: (1) carbonates of copper, iron, and lead convert to oxides; (2) most iron minerals showed alteration to oxides with some iron dissolution; (3) valuable trace elements including nickel, chromium, and others leached to some extent from sea minerals along with some calcium, iron, silicon, and sulfur; and (4) treatment of sulfides extracted elemental sulfur and resulted in several alteration reactions, though with the exception of cinnabar and the iron-bearing minerals, the metals in sulfides were mainly insoluble. Surface alterations on many of the minerals show significant changes have occurred in the minerals even when only minor extractions were detected. These surface effects may be very important when used in conjunction with flotation processes since the SCW treatment may selectively enhance or suppress a mineral's floatability. Research was done at the Bureau of Mines Salt Lake City Research Center. Available for reference at ALRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 89-164602; paper copy price code A03.

OFR 2-89. Sensitive Ground-Fault Protection for Mines. Phase III: Coordination-Free GFR's for AC Distribution, by F. C. Trutt, J. L. Kohler, H. Rotithor, L. A. Morley, and T. Novak. June 1988. 95 pp. 33 figs. This report concerns the research and development of a coordination-free relay for ground fault protection in mine power distribution systems. The dynamic nature of distribution systems used in coal mines makes it difficult to maintain coordination of the ground fault relays. Excessive clearing times under fault conditions are a direct result of poorly coordinated systems. This results in an increased risk of fire or electric shock. One result of this project is the development and demonstration of a technology that will eliminate the need to coordinate serial ground-fault relays while ensuring that any ground fault is cleared in a minimum amount of time. Research was done under contract J0134025 by the Pennsylvania State University. Available for reference at AD/RES, ALRC, DOI, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 89-143382; paper copy price code A05.

OFR 3-89. Research on Health Effects and Particle Characterization To Improve Silica Dust Control in Underground Coal Mines, by K. Weber, J. Tucker, L. Stettler, and W. Wallace. Sept. 1988. 337 pp. 84 figs. Silica particles are known to induce lung damage when inhaled. It has been known for many years that "pure" silica particles, when inhaled in large amounts, lead to an acute, deadly form of silicosis. Silica particles are part of the occupational exposure in coal mining. The National Coal Workers Autopsy Study was surveyed from 1971 to 1980, and silicosis was found to be present in 13 pct of the cases. Silica particle size determinations were made using 22 human lungs, and the geometric size distributions showed a mean of less than 1 μm. No acute silicosis cases were found. These small-sized respirable particles would have to be eliminated to prevent silicosis from occurring. The cytotoxic potential of silica quartz dust can be affected by respirable particle surface properties. This research investigated a method to characterize the surface elemental composition of quartz respirable particles that may be contaminated or occluded in mixed dust atmospheres. Also, a surface modification of quartz was investigated that significantly alters the cytotoxic potential without producing a readily measurable elemental composition change. Effects on particle hemolytic potential of boiling quartz dust in glass are quantitated. Research was done under interagency agreement H0358030 by the National Institute for Occupational Safety and Health. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, DOI, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC,

TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-142988; paper copy price code A15.

OFR4(1)-89. Generic In Situ Copper Mine Design Manual: Volume I, Executive Summary, by Donald H. Davidson, Ray V. Huff, Ralph E. Weeks, and John F. Edwards. Apr. 1988. 93 pp. This report summarizes the work conducted under Bureau of Mines contract J0267001 by Science Applications International Corp. between September 30, 1986, and February 29, 1988. The product of this work includes a manual for designing commercial-scale operations, a commercial-scale design for the Lakeshore Mine site (now the Cyprus Casa Grande Mine) near Casa Grande, AZ, and a unit cell field experiment design of the commercial operation; a commercial-scale design for the Santa Cruz site near Casa Grande, AZ, and a unit cell field experiment design based on the commercial operation design; and permeability and geophysical wireline test data obtained in existing coreholes SC-46 and SC-19 at the Santa Cruz site. Volumes II-V of the Final Report (Open File Reports 4(2)-89 through 4(5)-89) cover this work. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-148217/AS; paper copy price code A05.

OFR 4(2)-89. Generic In Situ Copper Mine Design Manual: Volume II, Draft Generic In Situ Copper Mine Design Manual, by Donald H. Davidson, Ray V. Huff, Ralph E. Weeks, and John F. Edwards. Apr. 1988. 454 pp. 39 figs. This report provides a systematic method for assessing the commercial feasibility of applying true in situ copper mining at a selected site. Procedures and algorithms are provided for developing design specifications and costs for well fields and a surface processing facility, and then conducting a discounted-cash-flow-rate-of-return cash flow analysis. This report also describes the environmental requirements to permit an in situ copper mining operation in Arizona, including procedures and monitoring and restoration requirements and costs. Also included are descriptions of tests to obtain site-specific input data that are required to conduct a commercial design. Research was done under contract J0267001 by Science Applications International Corp. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-148225/AS; paper copy price code A20.

OFR 4(3)-89. Generic In Situ Copper Mine Design Manual: Volume III, Lakeshore Field Experiment and Design of Commercial Scale Operation, by Donald H. Davidson, Ray V. Huff, Ralph E. Weeks, and John F. Edwards. Apr. 1988. 371 pp. 29 figs. This report provides the program plan, costs and schedule, and engineering design specification for an in situ copper leaching field experiment at the Lakeshore Mine (now the Cyprus Casa Grande Mine) in Casa Grande, AZ. The field experiment is based on a unit cell concept of direct scale-up to a commercial-scale design which was developed for this site using the algorithms and computer program contained in the Draft Generic In Situ Copper Mine Design Manual. The field experiment unit cell design includes integrated testing of two 5-spots and an SX-EW plant with supporting environmental permitting activities. The field experiment has a maximum capacity of 50 gpm and 1,095 tpy copper production. The unit cell consists of a plan area of 150 by 300 ft; 150-ft producer-to-producer spacing; well depth of 1,335 ft; leach interval of 180 ft averaging 0.88 pct copper. The time frame of the field experiment is 44 months at a cost of $14,340,723. Research was done under contract J0267001 by Science Applications International Corp. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-153282/AS; paper copy price code A16.

OFR 4(4)-89. Generic In Situ Copper Mine Design Manual: Volume IV, Santa Cruz Field Experiment and Design of Commercial Scale Operation, by Donald H. Davidson, Ray V. Huff, Ralph E. Weeks, and John F. Edwards. Apr. 1988. 385 pp. 31 figs. This report provides the program plan, costs and schedule, and engineering-design specifications for an in situ copper leaching field experiment at the ASARCO-Freeport McMoran Joint Venture Santa Cruz Site in Casa Grande, AZ. The field experiment is based on a unit cell concept of direct scale-up to a commercial-scale design which was developed for this site using the algorithms and computer program contained in the Draft Generic In Situ Copper Mine Design Manual. The field experiment unit cell design includes integrated testing of two 5-spots and an SX-EW plant with supporting environmental permitting activities. The field experiment has a maximum capacity of 50 gpm and 1,095 tpy copper production. The unit cell consists of a plan of 160 by 320 ft; 160-ft producer-to-producer spacing; well depth of 2,220 ft; leach interval of 322 ft averaging 0.70 pct copper. The time frame of the field experiment is 44½ months at a cost of $15,939,616. Research was done under contract J0267001 by Science Applications International Corp. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-153290/AS; paper copy price code A17.

OFR 4(5)-89. Generic In Situ Copper Mine Design Manual: Volume V, Field Testing at the Santa Cruz Site, by Donald H. Davidson, Ray V. Huff, Ralph E. Weeks, and John F. Edwards. Apr. 1988. 114 pp. 42 figs. This report describes the field tests conducted at the Santa Cruz Joint Venture Site (jointly owned by ASARCO Santa Cruz Inc. and Freeport Copper Co.) in Casa Grande, AZ. These tests were carried out in existing core holes SC-46 and SC-19 and include coring; water injection permeability measurements; geophysical wireline logging measurements of initial water saturation, porosity, and flow profile; and laboratory core leaching. The purpose of these tests is to provide supporting data for the commercial-scale operation and experiment designs. Coring and testing in SC-46 was conducted over the interval from 1,436 to 1,685 ft, and in SC-19 from 1,249 to 1,461 ft. Field test results indicate the following average properties: 1 md in SC-46 and 4 md in SC-19 with mud damage in the test interval, and 20 to 30 md in SC-19 where the test interval did not have mud damage; 8-pct porosity in SC-46 and 9-pct in SC-19; 100-pct water saturation in SC-46 and in SC-19. Preliminary laboratory core leaching data indicate that at 50-gpl sulfuric acid strength 10-gpl copper loadings are achieved at a net acid consumption of less than 3½ lb acid per pound of copper. These data are within the range of input parameters used to calculate the economics for the best mining scenario for the commercial design in Volume IV. Research was done under contract J0267001 by Science Applications International Corp. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-153308/AS; paper copy price code A06.

OFR 5-89. Tin Occurrences Associated With the Ohio Creek Pluton, Chulitna Region, South-Central Alaska, by J. Dean Warner and D. Dahlin. Jan. 1989. 29 pp. 7 figs. In 1984 and 1985, as part of its Alaskan critical and strategic minerals project, the Bureau of Mines mapped and sampled reported tin occurrences associated with the Ohio Creek pluton, in the central Alaska Range, south-central Alaska. The pluton is a composite intrusion with a core of moderately coarse-grained biotite granite and an outer zone of finer grained leucocratic muscovite granite. Tin mineralization, associated with silver, base metal, and tungsten values, occurs within the muscovite granite as cassiterite (SnO_2) within both quartz-muscovite greisen and arsenopyrite veins. Silver occurs within argentiferous galena and argentite (Ag_2S); tungsten is present in the Mn-rich wolframite mineral huebnerite ($MnWO_4$). Samples of arsenopyrite veins average 0.7 pct Sn over 0.5 ft, whereas samples of muscovite or quartz-muscovite greisen average 0.17 pct Sn over 1.0 ft. Metallurgical testing of three large samples of tin-mineralized greisen showed tin recoveries of 27 to 64 pct in table concentrates; respective grades of concentrates range from 39.4 to 72.1 pct Sn. A low-grade (0.06 pct Sn) zone near the pluton's upper contact containing numerous relatively closely spaced greisen-bordered arsenopyrite veins is inferred to contain a resource of approximately 1,250,000 lb Sn. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, IFOC, LIB, PRC/B, SLRC, and WFOC. Order ONLY from NTIS: PB 89-148431/AS; paper copy price code A03.

OFR 6-89. Columbium-, Rare-Earth-Element-, and Thorium-Bearing Veins Near Salmon Bay, Southeastern Alaska, by J. Dean Warner. Jan. 1989. 25 pp. 6 figs. In 1984 and 1985, the Bureau of Mines investigated radioactive carbonate veins near Salmon Bay, southeastern Alaska, for concentrations of columbium

and associated metals. The veins cut units of graywacke, conglomerate, argillite, and limestone and range in width from less than 1 in to greater than 10 ft and have a length ranging from less than 100 to greater than 1,000 ft. Mineralogy of the veins is complex and includes thorite, the rare-earth-element (REE) minerals monazite, parisite, and bastnaesite, and a columbium mineral that is speculated to be columbite. Gangue minerals include ankerite, dolomite, siderite, quartz, and albite. More than 70 veins were sampled, but only 3 contained elevated metal concentrations along a significant strike length. The three veins contain a combined indicated resource of 340,000 lb Cb, 2.2 MMlb REE, and 11,700 lb Th in 763,000 st of rock. The columbium resource is contained in one of the three veins that averages 840 ppm Cb over a width of 3.4 ft and a length of 1,200 ft. These resources are small compared to columbium, REE, and thorium resources elsewhere in the world. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, IFOC, LIB, PRC/B, and WFOC. Order ONLY from NTIS: PB 89-148423/AS; paper copy price code A03.

OFR 7-89. Concepts To Control Quartz Dust Exposure of the Continuous Miner Operator and Helper, by C. Babbitt, T. Muldoon, S. Rajan, S. Wirch, and J. Burnett. Dec. 1988. 174 pp. 53 figs. Reduced respirable dust standards are imposed on U.S. coal mines when the quartz content of the dust exceeds 5 pct. Improvements in analytical techniques for free silica have identified many mines with quartz dust problems, resulting in standards as low as 0.1 mg/m³ in severe cases. Traditional approaches to dust control often fail to allow standards below 2.0 mg/m³ to be met. On this contract, several control techniques were identified to reduce the dust exposures (including quartz) of the continuous miner operator and other face personnel, including (1) the use of higher water flow rates to reduce the quantity of dust generated during cutting, (2) improved spray systems, including more practical underboom sprays, to reduce dust generation, (3) improved cutting and loading practices to minimize regrinding when roof rock and midseam partings must be removed, (4) improved use of ventilation curtains to increase forward air velocity and reduce rollback by confining dust to the face area, and (5) improved spray systems to reduce dust from secondary sources, such as coal discharging into the shuttle car. This report describes the laboratory development, engineering analyses, and underground evaluations of these control techniques. Research was done under contract H0348031 by Foster Miller Inc. Available for reference at AFOC/A, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-155402/AS; paper copy price code A09.

OFR 8-89. A High Performance, Intrinsically Safe Data Acquisition System for Underground Use, by Robert J. Van Scoy. Dec. 1988. 52 pp. 35 figs. This report describes a portable, intrinsically safe data acquisition system designed specifically for use in underground coal mines. The system is designed for high resolution and stability, and can accept a wide variety of transducer types without modification or accessories. Input units may be easily added to the system to expand it to a maximum of 240 input channels. Up to one megabyte of measurement data can be recorded by the system's Data Logger, which uses internal solid-state memory. Stored data can be transferred directly via modem to a host computer or copied into another unit for transportation to the surface. A user-friendly menu system displayed on a hand-held terminal allows simple control of recording and data transfer functions. All system units are designed to meet drop-test, watertightness, and other environmental criteria to enhance reliability in field use. The report includes photographs of the equipment and plots of data taken in laboratory and field tests. It also discusses system design considerations, the electronic design of each system unit, and system firmware and documentation. Research was done under contract H0245009 by Serata Geomechanics, Inc. Available for reference at ALRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 89-163430/AS; paper copy price code A05.

OFR 9-89. Mine Demonstration of Longwall Dust Control Techniques, by B. Rao Pothini. July 1988. 136 pp. 39 figs. This report represents the results of in-mine demonstration of three dust control techniques for controlling respirable dust levels on shearer-longwall faces. The techniques were water infusion, foam spray, and reverse shearer drum rotation. The mines in which tests were conducted were in the Upper Freeport seam and Pocahontas No. 3 seam. Both gravimetric samples and GCA RAM-1 real time dust monitors were used for dust surveys. Dust control technology was reviewed, pertinent techniques were selected, and equipment was procured and demonstrated as part of the program. The results indicated that water infusion can be readily implemented; foam spray holds promise, but requires more work to be done; and reverse drum rotation is effective in select conditions. Research was done under contract J0318094 by Island Creek Corp. Available for reference at AFOC/A, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: DE 88-013182; paper copy price code A11.

OFR 10-89. Safety Evaluation of a Prototype Hydride Powered Underground Mining Vehicle, by Frank Lynch, Lars Olavson, and Ned Baker. May 1987. 130 pp. 42 figs. This study assesses the reliability, operability, and safety of a prototype underground mining utility vehicle fueled by hydrogen stored in a hydride fuel system. The assessment is based on data derived from (1) a severe offroad vehicle operational test, (2) simulated accidental hydrogen release tests, (3) a Fault Tree Analysis, and (4) a hazards and operability study. The study was limited to the vehicle proper and did not include underground refueling. On that basis it is concluded that no fundamental safety problems exist with respect to the vehicle and vehicle systems that would discourage the use of this type of mining vehicle. Research was done under contract H0202034 by EIMCO Mining Machinery International. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 89-164859/AS; paper copy price code A07.

OFR 11-89. Tin and Lead-Silver Mineralization in the Cosna River Region, Alaska, by Roger E. Burleigh. Mar. 1989. 19 pp. 7 figs. In 1987, as part of an Alaska critical and strategic minerals project, the Bureau of Mines evaluated an occurrence of tin and lead-silver mineralization in the Cosna River drainage near the Bitzshtini Mountains. Tin mineralization is found in dense gossan associated with concentrated quartz veining distributed along linear depressions bearing 140° across a thinly vegetated dome. Gossan grades to 2 to 3 pct Sn with anomalous levels of Ag, Pb, Zn, Sb, and As. Lead-silver mineralization (average 71 pct Pb, 91.3 oz/ton Ag) occurs nearby as podlike masses of galena associated with <1-ft-wide vuggy quartz veins with easterly orientations. Stibnite mineralization is locally present in the lead-silver prospect. Heavy mineral sampling of stream drainages and geologic reconnaissance traverses established a widespread distribution of tourmaline and delineated isolated areas anomalous in Sb, REE, Ag, Te, Th, Sn, W, U, and Pb. Regional geology and available airborne magnetic and radiometric surveys suggest that mineralization reflects hydrothermal activity distal to a buried pluton which possibly cores a portion of the Bitzshtini Mountains several miles to the south of the study area. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, IFOC, SLRC, and WFOC. Copies of this report will not be available for purchase.

OFR 12-89. The Potential Supply of Minerals From the White Mountains National Recreation Area and Part of the North Steese National Conservation Area, Alaska, by Barbara A. White, Thomas M. Gunther, Ralph Johnson, and Robert L. Adams. Feb. 1989. 355 pp. 34 figs. This report combines geologic, engineering, and economic analysis to estimate the quantity and value of minerals in undiscovered deposits in the White Mountains National Recreation Area and the Steese National Conservation Area in Alaska. The study was performed at the request of the Steese-White Mountains District Office, Bureau of Land Management, and will be used in a re-evaluation of current Resource Management Plans (RMP's). It was prepared by the Bureau of Mines, with geologic assessments from the U.S. Geological Survey, the Alaska Division of Geological and Geophysical Surveys, and the Bureau of Mines. The current RMP's restrict or prohibit access to eight types of mineral deposits. At mid-1987 prices, the effect of the RMP's is to reduce the expected quantity of gold produced by 112,000 ounces, with a market value of $50 million. At double these prices, the RMP's cause a reduction in the expected production of lead, zinc, and tantalum (100 pct), silver (96 pct), tin (94 pct), tungsten (25 pct), gold (22 pct), uranium (20 pct), and rare earth oxides (14 pct). This foregone min-

eral development will also result in a loss of direct and indirect economic benefits to the state and local economy. Research was done by the Bureau of Mines Division of Policy Analysis. Available for reference at AFOC/A, AFOC/F, AFOC/J, ALRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-168462/AS; paper copy price code A17.

OFR 13(1)-89. Mine Maintenance Material Handling: Volume I—Final Technical Report, by E. J. Conway, W. A. Elliott, and R. Unger. May 1988. 44 pp. 5 figs. This report describes background research and concept development on a project intended to design, construct, and evaluate devices to reduce the injury risk and manual effort associated with the handling of maintenance materials in underground coal mines. Project activities included a review of literature, previous research programs, and accident statistics; visits to mines for study and data collection; data analysis and specification development; and concept generation and evaluation. Five prototype manual material handling devices were then designed, fabricated, and transported to operating coal mines for field evaluation. Research was done under contract H0113018 by Canyon Research, Inc. Available for reference at AFOC/A, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-168967/AS; paper copy price code A03.

OFR 13(2)-89. Mine Maintenance Material Handling: Volume II—Prototype Device Specifications, by E. J. Conway, W. A. Elliott, and R. Unger. May 1988. 51 pp. 5 figs. This report describes background research and concept development on a project intended to design, construct, and evaluate devices to reduce the injury risk and manual effort associated with the handling of maintenance materials in underground coal mines. Project activities included a review of literature, previous research programs, and accident statistics; visits to mines for study and data collection; data analysis and specification development; and concept generation and evaluation. Five prototype manual material handling devices were then designed, fabricated, and transported to operating coal mines for field evaluation. Research was done under contract H0113018 by Canyon Research, Inc. Available for reference at AFOC/A, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-168975/AS; paper copy price code A04.

OFR 14-89. Soil Extractions for Determining Heavy Metal Bioavailability in Mining Waste, by William M. Schaefer and Troy Smith. Feb. 1989. 218 pp. 11 figs. Forage plots were established on agricultural lands contaminated by acid mining waste. The acid produced through oxidation of pyrite and other sulfides caused elevated solubility and plant availability of copper, zinc, and arsenic, which killed vegetation and polluted surface and ground water. Soil amendments including agricultural lime ($CaCO_3$), hydrated lime ($Ca(OH)_2$), phosphorus, and organic matter were used to reduce the toxicity of metals. Several acid-tolerant grasses were used to vegetate the amended soils. Various soil extraction techniques were used to see which best correlated with vegetation performance. The extractions corresponded to three "forms" of metals in soil, including soluble (water-saturation extract); plant-available, weakly adsorbed (DTPA extract); and total (HNO_3/H_2O_2 extract). Of the extractants tested, the DTPA levels appeared to correlate best with metal levels in plant tissue. The DTPA soil extractant serves as a useful tool in predicting potential phytotoxicity of mine waste materials. Research was done under contract J0278005 by Schafer and Associates. Available for reference at AD/RES, ALRC, DRC, LIB, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 89-190123/AS; paper copy price code A11.

OFR 15-89. Strategic Metals (Tantalum, Columbium, Beryllium) in Pegmatites of Copper Mountain, Fremont County, Wyoming: A Preliminary Report, by Mark L. Chatman. Mar. 1989. 72 pp. 4 figs. In 1987 and 1988, the Bureau of Mines evaluated pegmatites and granitic rocks on the south side of Copper Mountain, Fremont County, WY, primarily for the strategic metals tantalum, columbium, and beryllium. The United States relies on foreign imports for over 90 pct of the tantalum and columbium consumed annually, and has no major known tantalum deposit. Widely spaced reconnaissance sampling identified subeconomic tantalum resources in two pegmatites on Copper Mountain, amounting to 1.5 million st at grades of 0.02 to 0.03 pct Ta_2O_5 (tantalum pentoxide). Tantalum content is 0.8 million lb of Ta_2O_5, or about one-fifth of the total tantalum resources delineated in the United States. Tantalum recovery testing showed that 70-pct recovery is possible. Additionally, columbium and beryllium could be byproducts of tantalum mining. Tungsten, gold, silver, and copper, primarily in quartz veins, are not present in economic amounts. Sample assays suggest additional tantalum resources could be present in other pegmatites in the study area, but more sampling work is required to determine resources. Unsampled pegmatites on an adjacent 2 square miles of land should be examined. Discovery of more tantalum resources could help alleviate U.S. dependence on foreign imports. Research was done by the Bureau of Mines Intermountain Field Operations Center. Available for reference at AD/I&A, AFOC/A, ALRC, IFOC, LIB, PRC/B, SLRC, and WFOC. Order ONLY from NTIS: PB 89-214217/AS; paper copy price code A04.

OFR 16-89. Evaluation of Air Sprays and Unique Foam Application Methods for Longwall Dust Control, by Anthony W. Laurito and Madan M. Singh. Nov. 1987, 108 pp. 45 figs. The purpose of this study was to evaluate two novel dust control techniques for longwall mining sections. The two systems, foam and air sprays, were evaluated in the laboratory, and the foam system was field-tested in three operating mines. Dust reductions between 13 and 80 pct were achieved during the field evaluations of the foam dust suppression system. This report describes the laboratory investigations and the field evaluations of the foam system along with the results and conclusions. Research was done under contract J0318095 by Engineers International, Inc. Available for reference at AFOC/A, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-189922/AS; paper copy price code A06.

OFR 17-89. Lode Deposits, Prospects, and Occurrences of the Porcupine Mining Area, Southeast Alaska, by Staff, Bureau of Mines. 1 map. Map sheet showing the locations and commodities of the lode deposits, prospects, and occurrences of the Porcupine mining area. The area geology is also shown on the map sheet. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/J. Copies of the map will not be available for purchase.

OFR 18(1)-89. Research and Evaluation Methods for Measuring Nonroutine Mine Health and Safety Skills: Volume I. by Henry P. Cole, Launa G. Mallett, John V. Haley, Philip K. Berger, Warren E. Lacefield, Ronald D. Wasielewski, G. T. Lineberry, and Andrzej M. Wala. July 1988. 229 pp. 22 figs. Thirty-six simulation exercises designed to teach and assess problem-solving skills for coping with mine emergencies were developed and field-tested in annual refresher training classes in eight States. The exercises focus on first aid and self-rescue and escape situations. Previous research in the development of simulation problems for aviation, medical, and military personnel guided the development of the new exercises. The 4,000 miners in the field test samples averaged 37 years of age and 12 years of experience. Only 2.1 pct of the sample was female. Miners and their instructors rate the exercises highly in terms of their authenticity, relevance, and utility. Analysis of performance data suggests the exercises are valid, discriminate between persons with basic and advanced levels of training, and challenge most miners. The exercises deal with critical skills that should be learned to high levels of mastery, yet fewer than 30 pct of the miners in the samples achieved mastery scores at or above the 90-pct level. The low levels of mastery suggest (1) miners have little opportunity to practice judgment and decision-making skills in mine emergency situations because of the infrequent occurrence of these events and (2) working the simulation exercises in annual refresher training classrooms may contribute to miners' preparedness to cope with infrequently encountered mine emergencies. Research was done under contract H0348040 by the University of Kentucky. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 89-196646/AS; paper copy price code A11.

OFR 18(2)-89. Research and Evaluation Methods for Measuring Nonroutine Mine Health and Safety Skills: Volume

II: Appendices, by Henry P. Cole, Launa G. Mallett, John V. Haley, Philip K. Berger, Warren E. Lacefield, Ronald D. Wasielewski, G. T. Lineberry, and Andrzej M. Wala. July 1988. 348 pp. This appendix to open file report 18(1)–89 includes mine emergency simulation exercises, summary statistics for latent image exercises, computer programs for CAI forms for four simulation exercises, an instructor's guide to an efficient method for donning the SCSR, a videotape script for an efficient method for donning the Draeger SCSR, and the instructor's copy for Marvin R. Letcher First Aid Simulation. Research was done under contract HO348040 by the University of Kentucky. Available for reference at ALRC, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Order ONLY from NTIS: PB 89–196653/AS; paper copy price code A15.

OFR 19–89. Human Factors in Mining: An Annotated Bibliography, by Elaine G. Aiken and Richard S. Fowkes. Sept. 1987. 640 pp. This bibliography is a compendium of over 600 abstracts selected from a computerized data base called the Human Factors in Mining Search System (HFMSS), which was developed under the Human Factors Research Program at the Pittsburgh Research Center of the U.S. Bureau of Mines. HFMSS stresses all of the different areas of human factors or ergonomics as they have been or might be applied to mining. Each entry or abstract in HFMSS contains title of publication, author(s), source of the publication, date, page numbers, descriptive terms or keywords, and abstract (divided into purpose, procedure, and results). The bibliography is comprised of 10 sections each of which is preceded by a brief discussion of its contents: (1) anthropometrics, work physiology, manual materials handling, and back injuries, (2) equipment, (3) female miners and female workers, (4) human error and human reliability, (5) environmental factors (illumination, noise, thermal stress), (6) human factors, (7) psychological factors, (8) personal protective equipment and clothing, and hand-tools, (9) job or work design, task analysis, and organizational and management practices, and (10) training. An index lists key words and the numbers of those abstracts that contain that keyword in the Descriptive Terms field. Available for reference at DRC, LIB, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 89–195424/AS; paper copy price code A99.

OFR 20–89. A Thesaurus of Human Factors in Mining Terminology, by Elaine G. Aiken. July 1986. 86 pp. This thesaurus was developed to familiarize users of the Human Factors in Mining Search System (HFMSS) computerized data base with the keywords or descriptive terms associated with the discipline of human factors or ergonomics. HFMSS contains abstracts and other information on over 800 technical documents (contractor and Bureau of Mines reports, journal and seminar or conference papers). This thesaurus presents the over 1,500 keywords and descriptors in 4 different ways: (1) A thesaurus of the keywords and descriptors for retrieving publications under selected subject categories in the HFMSS system, (2) an alphabetized thesaurus of terms, (3) an indexed thesaurus of keywords and descriptors relating keywords to the number assigned to an abstract and thence to specific documents in HFMSS, and (4) an alphanumeric listing of documents. This publication can also serve as a source of information on the most commonly used terms in the field of human factors and as an aid in any literature search. Research was done by the Bureau of Mines Pittsburgh Research Center. Available for reference at DRC, LIB, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 89–195432/AS; paper copy price code A05.

OFR 21–89. User's Guide for the Human Factors in Mining Search System (HFMSS), by Richard S. Fowkes. Sept. 1987. 33 pp. The Human Factors in Mining Search System (HFMSS) is a computerized data base that provides human factors or ergonomics information relevant to mining that was obtained from journal articles, research reports, seminars, conferences, etc., in terms of 19 categories or subject areas. It is the only existing data base that stresses all of the fields of human factors as they have been or might be applied to mining. HFMSS uses the POISE-DMS-Plus data management system version 5.0 and the Digital Equipment Corp.'s VAX/VMS Operating System Version 4.7. The User's Guide is divided into several sections: (1) definitions of terms, (2) subject categories of HFMSS, (3) fields (title, author(s), keywords, abstract, etc.), (4) thesaurus of most common keywords, (5) how to search on one keyword, (6) how to search on two or more keywords, (7) displaying and/or printing retrieved records in either a brief or complete format, and (8) examples of retrieved records. HFMSS can be accessed by contacting the National Mine Health and Safety Academy, Informational Services Branch, P.O. Box 1166, Airport Road, Beckley, WV, 25802–1166; 304–256–3226. Research was done by the Bureau of Mines Pittsburgh Research Center. Available for reference at DRC, LIB, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 89–195416/AS; paper copy price code A03.

OFR 22–89. Magnetic Belt Cobbing Technology for Upgrading Coarse Taconite Ore, by M. G. Pojar, J. Arola, J. E. Moy, and J. M. Campbell. June 1987. 129 pp. 23 figs. The Bureau of Mines conducted magnetic belt cobbing field-scale research with the Inland Steel Mining Co. and the Minnesota Department of Natural Resources. Sixty-seven field tests were conducted on three iron ore types, ranging from 10 to 24 pct magnetic iron, and at two different ore sizes, namely the secondary crusher discharge (3 × 0 inches) and tertiary crusher discharge (1 × 0 inch). Field cobbing of the test materials produced an enriched iron ore concentrate and a low-grade reject material. Successful ore separation and enrichment occurred with both tertiary and secondary crusher feed stocks. Certain material types currently considered to be uneconomic were upgraded using the dry magnetic cobbing process to produce a millable ore concentrate. Best magnetic iron recoveries after cobbing ranged from approximately 78 to 95 pct for the tertiary feed and 50 to 95 pct for the secondary crusher feed. The tests indicate that the lean-grade ore types (LC2 and LC5) lend themselves to dry magnetic cobbing, producing an enriched concentrate with noticeable upgrading. Additionally, the coarser size of those lean ore types produced the higher grade magnetic iron. Additional testing under more optimum operating conditions is warranted to prove out the validity of incorporating dry cobbing technology into mining of lean-grade taconite ore. Available for reference at ALRC, DRC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, and TURC. Copies of this report will not be available for purchase.

OFR 23–89. Control of Diesel Exhaust Emissions in Underground Coal Mines—Fuel Modifications, by T. J. Callahan, T. W. Ryan III, H. E. Dietzmann, and C. B. O'Neal. Dec. 1988. 155 pp. 95 figs. The use of various alternative and modified fuels in diesel engines was investigated as a method for controlling particulate and oxides of nitrogen emissions. The effect of these fuels on the carbon monoxide and hydrocarbon emissions was also documented. The test fuels were screened using a Caterpillar 3304 diesel engine converted to single-cylinder operation. Selected fuels were subsequently evaluated using full-scale engine tests. Engine modifications were made to optimize the performance of the alternative fuel. Transient and steady-state emissions data are reported for the optimized and baseline engine. The effects of the transient operation of the engine on the exhaust emissions were investigated. A method was developed for predicting transient cycle exhaust emission based upon the cycle speed and torque profile and steady-state emissions data. Research was done under contract J0188157 by Southwest Research Institute. Available for reference at AD/RES, DRC, LIB, MSHA, NMH&SA, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 89–205157/AS; paper copy price code A08.

OFR 24–89. The Effects of Economic Growth, Technology Change, Consumption Pattern Change and Foreign Trade on Domestic Demand for Primary Metals, 1963–82, by Patricia R. Devine. Dec. 1988. 128 pp. 23 figs. This report expands an earlier study by Jack Faucett Associates (OFR 40–88) of the same title. Both reports are based upon an interindustry analysis from 1963 through 1982, during which time U.S. metals consumption and production did not keep pace with economic growth. The report discusses three sources of change: economic growth, technological change, and composition of final demand, as well as the relative importance of the individual components of final demand for metals.

The results show investment and personal consumption to be the most metal-intensive components of final demand, and technology change to be the major cause of decline in consumption growth during the study period. Technology change is defined as alterations in production processes resulting in more or less consumption of metal per unit of output, often because of material substitutions and design changes. A trade analysis shows the significance of import growth, particularly indirect imports (metal contained in imported goods) as a factor contributing to the reduced growth rate of domestic metal production. The effect of import growth is partially offset by indirect export growth, suggesting that continued increase of all U.S. exports can have a strong effect in reducing the negative trade

balance in metals. Research was done by the Bureau of Mines Division of Policy Analysis. Available for reference at AFOC/A, ALRC, DRC, IFOC, LIB, PRC/B, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Order ONLY from NTIS: PB 89-204002/AS; paper copy price code A07.

OFR 25-89. Low-Profile, Lightweight Rescue Breathing Apparatus, by John Wippler. Sept. 1988. 45 pp. 33 figs. A lightweight, low-profile compressed oxygen rescue breathing apparatus (RBA) for mine rescue missions was developed by the Survivair Division of Comasec, Inc., under contract to the Bureau of Mines. Cofunding this contract were the U.S. Fire Administration, U.S. Air Force, and U.S. Coast Guard. The apparatus is a positive pressure, closed circuit system with 2-h mission capability. The apparatus weighs 24 lb when fully charged. Weight and size reduction were realized by using lithium hydroxide (LIOH) for carbon dioxide (CO_2) management, a composite glass-fiber-wrapped aluminum cylinder for oxygen storage, and lightweight plastic materials for backpack and breathing bag construction. Constant positive pressure within the breathing circuit is maintained by a pilot-operated pressure demand regulator and spring-biased breathing bags. Research was done under contract H0123008 by Survivair, a Division of Comasec, Inc. Available for reference at LIB, PRC/B, MSHA, and NMH&SA. Order ONLY from NTIS: PB 89-208672/AS; paper copy price code A06.

OFR 26-89. Research To Determine the Contribution of System Factors in the Occurrence of Underground Injury Accidents, by Mark S. Sanders and Brian E. Shaw. Sept. 1988. 165 pp. 33 figs. A systems approach to accident investigation was applied to 338 underground mining accidents. A taxonomic model of contributing factors in accident causation was developed, and expert raters assessed the degree to which each factor played a role in each accident case. The model contained the following factors: management, physical environment, work task, equipment, social environment, perceptual-cognitive-motor (PCM) error of the injured employee and coworkers, worker characteristics of the injured employee and coworkers, and other miscellaneous factors. The report contains a literature review on the analysis and classification of human error, including the role of human error in accidents. Results indicated that 88 pct of the cases involved more than one causal factor. Injured employee PCM error was involved to some degree in 93 pct of the cases, and when involved, averaged about 33 (of 100) points of causality. The factor was considered a primary causal factor in almost 50 pct of the cases and a secondary causal factor in another 24 pct. Management was the second most important causal factor. It was considered a primary factor in 22 pct of the cases and a secondary factor in another 12 pct. Recommendations are presented and discussed. Research was done under contract J0348042 by Essex Corp. Available for reference at AD/RES, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, SRC, and TCRC. Order ONLY from NTIS: PB 89-219638/AS; paper copy price code A08.

OFR 27-89. Proceedings of the 23rd International Conference of Safety in Mines Research Institutes, Washington, DC, Sept. 11-15, 1989, compiled by Ethel T. Wallace and Thomas H. Koslosky. Sept. 1989. 1251 pp. The Proceedings of the 23rd International Conference of Safety in Mines Research Institutes contains 100 papers from 20 countries. The majority of the papers are published in English (original or translation); where an original text in a foreign language was made available, it follows the English version. In all cases, either the full text or an abstract appears in all five conference languages: English, French, German, Russian, and Chinese. Order ONLY from NTIS: PB 89-225262/AS; paper copy price code A09.

OFR 28-89. Database for Availability of Federally Owned Minerals for Exploration and Development in Western States: New Mexico 1988, by Arthur W. Gray, Robert M. Thompson, Clark A. Roberts, and Richard A. Beach. Dec. 1988. 18 pp. and computer diskettes. This Bureau of Mines report contains the raw and interpreted data on Federal land status and known mineral deposit areas that were collected and processed for the New Mexico Inventory of Land Use Restraints Program Study. Research was done by the Bureau of Mines Intermountain Field Operations Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 89-228860; computer product code D02. Note: The text describing this database was placed with NTIS as a separate item; PB 89-228878; paper copy price code A03.

OFR 29-89. Development of Containment Barriers Using Foaming Mud Cement, by A. Gray Clark, Michael R. Virta, and Gary J. Colaizzi. Feb. 1989. 184 pp. 90 figs. This report addresses a comprehensive laboratory investigation on the application of Foaming Mud Cement (FMC) in the construction of containment barriers. FMC is a proprietary family of cellular concrete mixes. Information was gathered through an extensive literature search on existing containment barrier construction methods and grout mixtures. Over 140 FMC mix designs were established incorporating different types and amounts of cement, fly ash, coarse and fine aggregate, reagents, and foams. Extensive laboratory testing was conducted to determine physical properties of FMC such as unconfined compressive strength, shear strength, flexural strength, permeability, and unit weight. Scale model construction was conducted on numerous containment barrier designs utilizing FMC. These scale models progressed from bench scale (1/10), to 1/4 scale, 1/2 scale, and full scale (8 by 20 ft). Photographic documentation of this construction is included. Laboratory and scale model construction data were evaluated to determine the technical merit and cost effectiveness of each construction sequence. Conceptual site demonstration program designs were established for both conventionally constructed and remotely constructed containment barriers. Other applications where FMC has been used and its potential uses are discussed. Conclusions and recommendations relative to the use of FMC in containment barrier design are presented. Comprehensive bibliographical data are included. Research was done under contract J0278002 by Goodson & Associates, Inc. Available for reference at AD/RES, DRC, LIB, MSHA, NMH&SA, OSM, PRC/B, and TCRC. Copies of this report will not be available for purchase.

OFR 30-89. Availability of Land for New Mineral Entry and Development in Alaska, A Summary Report, by Robert Bottge. May 1989. 24 pp. 17 figs. The Bureau of Mines has engaged in a program to determine the availability of land for new mineral entry and development in Alaska. Land availability, based on ownership and Federal and State laws and regulations, was compared to mineral terranes and mineral deposits to determine the likelihood of areas for additional discoveries. The results of the six regional studies are summarized in this report. This study covers the State of Alaska, an area of 378.2 million acres including surface land and water. In July 1986, 116.6 million acres (31 pct of the study area) were available for new claim location and development, 42.2 million acres (11 pct) were available with restrictions, and 219.1 million acres (58 pct) were unavailable. About one-third of the State (132.9 million acres) was open for new claim location and development. Thus only 10 pct of the State is both available and shows promise for development. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, and AFOC/J. Copies of this report will not be available for purchase.

OFR 31-89. Results of 1988 Bureau of Mines Investigations in the Valdez Creek Mining District, Alaska, by Michael D. Balen. 1989. 136 pp. 8 figs. The U.S. Bureau of Mines is currently conducting a 4-yr study to assess the mineral resources and the mineral development potential of the 5.7-million-acre Valdez Creek Mining District (VCMD) in south-central Alaska. The VCMD study is part of the Bureau's ongoing statewide mining district evaluation program. This report is a summary of the 1988 fieldwork, which involved collection of reconnaissance placer and rock samples and also sampling and examination of the mines, prospects, and mineral occurrences that were identified by literature research of the geology, exploration history, and mining history of the district. During the 1988 field season, Bureau personnel spent 11 weeks in the field, collected 1,006 rock and placer samples, and located, mapped, and sampled 106 of the known mineral occurrences. The Bureau visited 243 of the 250 known mineral occurrences during the project. Reconnaissance sampling for placer occurrences resulted in the identification of four previously unreported gold placer occurrences and five occurrences that contain detectable levels of platinum or palladium. Reconnaissance sampling for lode sources of base and precious metals resulted in the identification of five new lode gold-silver occurrences, two occurrences that contain elevated quantities of chromium, cobalt, nickel, palladium, and platinum, and one occurrence that contains elevated quantities of copper, molybdenum, and zinc. Research was done by the Bureau of Mines Alaska Field Operations Center. Available for reference at AFOC/A, AFOC/F, AFOC/J, IFOC, LIB, PRC/B, and WFOC. Copies of this report will not be available for purchase.

OFR 32–89. Automated Natural Gas and Crude Helium Measurement System, by Timothy R. Spisak. Nov. 1989. 74 pp. The U.S. Bureau of Mines—Helium Field Operations has developed an automated system to fulfill its natural gas and crude helium measurement requirements. The system provides current gas flow information, automatic system calibration, daily flow volumes, and a computer-user interface. Helium Field Operations has a total of 24 meter runs at 3 different points along the Bureau's crude helium pipeline. This report discusses the hardware and software used to measure the different flows. The software, entirely developed by Bureau personnel, is written in easy to understand Advance BASIC Language. The program calculates an incremental gas flow every 15 min in accordance with standards presented in the publication "Orifice Metering of Natural Gas-American Gas Association Report No. 3." Each morning, a personal computer is used to calculate, record, and print the 24-h gas volumes. Bureau personnel can access current gas flow information at any time to monitor crude helium flow. Through a series of straightforward menus, personnel can also change orifice plate constants, calibrate transmitter hardware, view stored flow data, and perform other functions. The Bureau's gas measurement system can be modified for use by any company with similar requirements. The appendix documents the software for a typical crude helium measurement system. Available for reference at AFOC/A, IFOC, LIB, and WFOC. Order ONLY from NTIS: PB 90–130097/AS: paper copy price code A04.

OFR 33–89. Columbium- and Rare-Earth Element-Bearing Deposits at Bokan Mountain, Southeast Alaska, by J. Dean Warner and James C. Barker. Nov. 1989. 196 pp. 31 figs. From 1984 through 1987, the Bureau of Mines investigated numerous prospects and new discoveries of columbium, rare-earth elements (REE), uranium, zirconium, and other metals associated with the multiphased peralkaline granite at Bokan Mountain, southeastern Alaska. This report summarizes the mineral evaluations and estimates indicated and inferred resources for those prospects containing significant tonnage and grade. Approximately 96.2 million lb Cb_2O_5 (43 pct of the tonnage at a grade exceeding 0.125 pct Cb_2O_5), 11.8 million lb U_3O_8, 27.9 million lb ThO_2, 133.0 million lb Y_2O_3, 637.6 million lb ZrO_2, and 241 million lb rare earth oxides (REO) are estimated to be contained within nine deposits totalling 37.8 million tons (at least 80 pct of resource tonnage also exceeds 0.5 pct Y_2O_3 + REO). Generally, half of the REO content is composed of the heavy yttrium subgroup. Several deposits also contain beryllium and tantalum; 2.1 million lb of Ta_2O_5 and 8.9 million lb of BeO were estimated. These estimates would likely be substantially increased with additional exploration. Four deposit types were investigated: shear zones and fracture-related deposits, pegmatites, mineralized dikes, and placers. Mineralized dikes contain most of the beryllium, columbium, tantalum, yttrium, zirconium, and REE resources, whereas shear zones and fracture-related deposits (Ross-Adams Mine) contain the principal uranium resource. Pegmatites are similarly mineralized, as are dike deposits, and contain low levels of gold. Placer potential is suggested, but no deposits were found. Available for reference at AD/I&A, AFOC/A, AFOC/F, AFOC/J, ALRC, IFOC, LIB, PRC/B, SLRC, and WFOC. Copies of this report will not be available for purchase.

OFR 34–89. Thin Wall Explosion-Proof Enclosures, by Nenad Marinovic. Sept. 1987. 152 pp. The main objective of this project was to investigate the feasibility of fabricating thin-walled, explosion-proof enclosures for high-voltage electrical equipment for use in underground coal mines. The thin-wall construction technique is to prestress the enclosure with an internal methane-air explosion, then remachine the mating surfaces of the flame path to the allowable tolerances. Test results indicate that the prestressed enclosures, which are considerably lighter in weight than conventional enclosures, can withstand significantly higher internal pressures without detrimental permanent deformation and subsequent venting of incendiary particles. In addition, the use of stainless steel foams as flame arresters in large explosion-proof enclosures was investigated. Test data indicate that the enclosure pressures can be easily limited to less than 10 psi, using "Retimet" for the explosion pressure vent. Research was done under contract 14–09–0070–1104–01 (JF470) by the Electrotechnical Institute of "Rade Koncar," Zagreb, Yugoslavia. Available for reference at AFOC/A, ALRC, DRC, IFOC, LIB, MSHA, NMH&SA, PRC, RERC, RORC, SLRC, SRC, TCRC, TURC, and WFOC. Copies of this report will not be available for purchase.

MINERAL LAND ASSESSMENT REPORTS

The following reports, part of a continuing series of Mineral Land Assessment reports, are available for consultation at the Bureau of Mines, Field Assessment and Evaluation Program Staff, Washington, DC, and at the Natural Resources Library, U.S. Department of the Interior, Washington, DC. Specific reports are also available at the field office indicated following their titles.

1985

MLA 1–85. Mineral Investigation of the Golden Valley Wilderness Study Area (BLM No. CDCA–170), San Bernardino County, California, by Richard S. Gaps. 1985. 26 pp. 4 figs. Western Field Operations Center, Spokane, WA.

MLA 2–85. Mineral Resources of the Little Lake Canyon (BLM No. CDCA–157), Owens Peak (BLM No. CDCA–158), and Owens Peak (BLM No. CA–010–026) Wilderness Study Areas, Inyo, Kern, and Tulare Counties, California, by J. Douglas Causey and Richard S. Gaps. 1985. 39 pp. 8 figs. Western Field Operations Center, Spokane, WA.

MLA 3–85. Mineral Investigation of the Bull Canyon Wilderness Study Area, Moffat County, Colorado, and Uintah County, Utah, by Terry J. Kreidler. 1985. 12 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 4–85. Mineral Investigation of the Chuckwalla Mountains Wilderness Study Area, California Desert Conservation Area, Riverside County, California, by Michael E. Lane. 1985. 148 pp. 14 figs. Intermountain Field Operations Center, Denver, CO.

MLA 5–85. Mineral Investigation of the Black Rock Wilderness Study Area, Graham County, Arizona, by George S. Ryan. 1985. 13 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 6–85. Mineral Resources of the Resting Spring Range Wilderness Study Area (BLM No. CDCA–145), Inyo County, California, by Michael S. Miller. 1985. 63 pp. 7 figs. Western Field Operations Center, Spokane, WA.

MLA 7–85. Mineral Investigation of the Eagle Mountain Wilderness Study Area, Pitkin County, Colorado, by Steven E. Kluender and Jeanne E. Zelten. 1985. 11 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 8–85. Minerals Investigation of Pond Mountain and Pond Mountain Addition RARE II Further Planning Areas, Carter County, Tennessee, by Richard F. Bitar, Paul T. Behum, Richard W. Hammack, and Mark L. Chatman. 1985. 54 pp. 13 figs. Intermountain Field Operations Center, Denver, CO.

MLA 9–85. Mineral Investigation of the Needle's Eye Wilderness Study Area, Gila County, Arizona, by George S. Ryan. 1985. 8 pp. 1 fig. Intermountain Field Operations Center, Denver, CO.

MLA 10–85. Mineral Resources of the Nopah Range Wilderness Study Area (BLM No. CDCA–150), Inyo County, California, by Charles Sabine and Ronald T. Mayerle. 1985. 33 pp. 4 figs. Western Field Operations Center, Spokane, WA.

MLA 11–85. Mineral Investigation of the Northern Part of the Washakie Wilderness and Nearby Roadless Areas, Park County, Wyoming, by Carl L. Bieniewski and R. Craig Smith. 1985. 26 pp. 10 figs. Intermountain Field Operations Center, Denver, CO.

MLA 12–85. Mineral Investigation of the Far South Egan Wilderness Study Area, Lincoln and Nye Counties, Nevada, by Steven E. Tuftin. 1985. 8 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

MLA 13–85. Mineral Resources of the Greenwater Valley Wilderness Study Area (BLM No. CDCA–148), Inyo County, California, by Richard L. Rains. 1985. 33 pp. 6 figs. Western Field Operations Center, Spokane, WA.

MLA 14–85. Mineral Resources of the Owlshead Mountains Wilderness Study Area (BLM No. CDCA–156), San Bernardino County, California, by Arel B. McMahan, William L. Rice, and Michael Sokaski. 1985. 21 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 15–85. Mineral Resources of the Panamint Dunes Wilderness Study Area (BLM No. CDCA–127), Inyo County, California, by Andrew M. Leszcykowski. 1985. 15 pp. 1 fig. Western Field Operations Center, Spokane, WA.

MLA 16–85. Mineral Investigation of the Cache La Poudre Wilderness, Larimer County, Colorado, by Jeanne E. Zelten. 1985. 24 pp. 7 figs. Intermountain Field Operations Center, Denver, CO.

MLA 17–85. Mineral Investigation of the Fishhooks Wilderness Study Area, Graham County, Arizona, by George S. Ryan. 1985. 8 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

MLA 18–85. Mineral Resources of the Inyo Mountains Wilderness Study Area (BLM No. CDCA–122), Inyo County, California, by Terry J. Close. 1985. 86 pp. 14 figs. Western Field Operations Center, Spokane, WA.

MLA 19–85. Mineral Investigation of the Weminuche Wilderness Additions, Hinsdale, La Plata, Mineral, and San Juan Counties, Colorado, by Stanley L. Korzeb and David C. Scott. 1985. 85 pp. 16 figs. Intermountain Field Operations Center, Denver, CO.

MLA 20–85. Mineral Investigation of the Mount Massive Wilderness, Lake County, Colorado, by John R. Thompson. 1985. 65 pp. 13 figs. Intermountain Field Operations Center, Denver, Co.

MLA 21–85. Mineral Investigation of the La Garita Wilderness Additions, Hinsdale and Saguache Counties, Colorado, by David C. Scott. 1985. 62 pp. 5 figs. Intermountain Field Operations Center, Denver, CO.

MLA 22–85. Mineral Investigations of the Arrasta Mountain Wilderness Study Area, La Paz, Mohave, and Yavapai Counties, and Peoples Canyon Wilderness Study Area, Yavapai County, Arizona, by Michael E. Lane. 1985. 37 pp. 12 figs. Intermountain Field Operations Center, Denver, CO.

MLA 23–85. Mineral Resources of the Carrizo Gorge Wilderness Study Area (BLM No. CA–060–025), San Diego County, California, by David A. Lipton. 1985. 14 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 24–85. Mineral Investigation of the Bull Gulch Wilderness Study Area, Eagle County, Colorado, by Steven E. Kluender and Jeanne E. Zelten. 1985. 11 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

MLA 25–85. Mineral Resources of the Mt. Stirling Wilderness Study Area (BLM No. 050–0401), Nye and Clark

Counties, Nevada, by Martin D. Conyac. 1985. 18 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 26–85. Mineral Investigation of Palisade Mesa and the Wall Wilderness Study Areas, Nye County, Nevada, by Richard F. Kness. 1985. 23 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 27–85. Mineral Resources of the Newberry Mountains Wilderness Study Area (BLM No. CDCA–206), San Bernardino County, California, by Charles Sabine. 1985. 13 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 28–85. Mineral Resources of the Hell's Half Acre Wilderness Study Area (BLM No. ID–33–15), Bingham and Bonneville Counties, Idaho, by Phillip R. Moyle and Richard A. Winters. 1985. 21 pp. 4 figs. Western Field Operations Center, Spokane, WA.

MLA 29–85. Mineral Resources of the Pinnacles Wilderness Contiguous Wilderness Study Area (BLM No. CA–040–303), San Benito and Monterey Counties, California, by Lucia Kuizon. 1985. 12 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 30–85. The Tungsten Queen Vein, Highland Ridge Roadless Area, White Pine County, Nevada, by S. Don Brown. 1985. 11 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 31–85. Mineral Resources of the White Rock Wilderness Study Area (NV–040–202) Lincoln County, Nevada, and Beaver and Iron Counties, Utah, by Diann D. Gese. 1985. 13 pp. 4 figs. Intermountain Field Operations Center, Denver, CO.

MLA 32–85. Mineral Resources of the Beaver Creek Wilderness Study Area, (CO–050–016), El Paso, Fremont, and Teller Counties, Colorado, by Terry J. Kreidler. 1985. 19 pp. 4 figs. Intermountain Field Operations Center, Denver, CO.

MLA 33–85. Mineral Investigation of the Sand Dunes Wilderness Study Area, Sweetwater County, Wyoming, by George S. Ryan. 1985. 17 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 34–85. Mineral Investigation of the Sierra Ancha Wilderness and Salome Study Area, Gila County, Arizona, by Thomas D. Light. 1985. 141 pp. 46 figs. Intermountain Field Operations Center, Denver, CO.

MLA 35–85. Mineral Resources of the South Pequop Wilderness Study Area, (BLM, NV–010–035), Elko County, Nevada, by Robert H. Wood II. 1985. 29 pp. 6 figs. Intermountain Field Operations Center, Denver, CO.

MLA 36–85. Mineral Resources of the Rodman Mountains Wilderness Study Area (BLM No. CDCA–207), Inyo County, California, by Lucia Kuizon. 1985. 16 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 37–85. Mineral Investigation of the South Reveille Wilderness Study Area, Nye County, Nevada, by John T. Neubert. 1985. 30 pp. 5 figs. Intermountain Field Operations Center, Denver, CO.

MLA 38–85. Mineral Resources of the High Rock Lake Wilderness Study Area, (BLM No. NV–020–007), Humboldt County, Nevada, by Terry R. Neumann and Terry J. Close. 1985. 14 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 39–85. Mineral Resources of Part of the Whipple Mountains Wilderness Study Area (CDCA–312), San Bernardino County, California, by Phillip R. Moyle and Peter N. Gabby. 1985. 50 pp. 10 figs. Western Field Operations Center, Spokane, WA.

MLA 40–85. Mineral Resources of the Weepah Spring Wilderness Study Area (NV–040–246), Nye and Lincoln Counties, Nevada, by Diann D. Gese and Albert D. Harris. 1985. 53 pp. 6 figs. Intermountain Field Operations Center, Denver, CO.

MLA 41–85. Mineral Resources of the La Madre Mountains Study Area (BLM No. 050–0412), Clark County, Nevada, by David A. Lipton. 1985. 14 pp. 3 figs. Western Field Operations Center, Spokane, WA.

MLA 42–85. Mineral Resources of the Parsnip Peak Wilderness Study Area (NV–040–206), Lincoln County, Nevada, by Diann D. Gese. 1985. 24 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 43–85. Mineral Resources of the Harquahala Mountains Study Area (AZ–020–095), La Paz and Maricopa Counties, Arizona, by John R. Thompson. 1985. 87 pp. 24 figs. Intermountain Field Operations Center, Denver, CO.

MLA 44–85. Mineral Resources of the Big Horn Mountains Wilderness Study Area (AZ–020–099), Maricopa County, Arizona, by Russell A. Schreiner. 1985. 29 pp. 5 figs. Intermountain Field Operations Center, Denver, CO.

MLA 45–85. Mineral Resources of the Blue Eagle Wilderness Study Area (NV–060–158/199), Nye County, Nevada, by Steven E. Tuftin. 1985. 22 pp. 6 figs. Intermountain Field Operations Center, Denver, CO.

MLA 46–85. Mineral Resources of the Gooding City of Rocks Study Areas, Gooding County, Idaho, by Phillip R. Moyle. 1985. 49 pp. 8 figs. Western Field Operations Center, Spokane, WA.

MLA 47–85. Mineral Resources of the North Fork Little Humboldt Study Area, Humboldt County, Nevada, by Andrew M. Leszcykowski. 1985. 8 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 48–85. Mineral Resources of the Battle Creek Wilderness Study Area, Owyhee County, Idaho, by Richard A. Winters. 1985. 10 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 49–85. Mineral Resources of the American Flats Wilderness Study Area (CO–030–217), Hinsdale and Ouray Counties, Colorado, by Brian J. Hannigan. 1985. 33 pp. 4 figs. Intermountain Field Operations Center, Denver, CO.

MLA 50–85. Mineral Investigation of the Chemehuevi–Needles Wilderness Study Area (AZ–050–004), San Bernardino County, California, by Michael E. Lane. 1985. 5 pp. 1 fig. Intermountain Field Operations Center, Denver, CO.

MLA 51–85. Mineral Resources of the Lower Burro Creek Wilderness Study Area (AZ–020–060), Mohave and Yavapai Counties, Arizona, by Russell A. Schreiner. 1985. 71 pp. 20 figs. Intermountain Field Operations Center, Denver, CO.

MLA 52–85. Mineral Investigation of the Honeycomb Buttes Study Area (WY–040–323), Fremont and Sweetwater Counties, Wyoming, by David C. Scott. 1985. 27 pp. 7 figs. Intermountain Field Operations Center, Denver, CO.

MLA 53–85. Mineral Resources of the Sacatar Meadow South Wilderness Study Area, Tulare and Inyo Counties, California, by Lucia Kuizon. 1985. 10 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 54–85. Mineral Resources of the Deep Creek–Owyhee River Study Areas, Owyhee County, Idaho, by Donald O. Capstick and Alan R. Buehler. 1985. 14 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 55–85. Mineral Resources of the Jacumba Study Area, Imperial County, California, by Edward L. McHugh. 1985. 27 pp. 3 figs. Western Field Operations Center, Spokane, WA.

MLA 56–85. Mineral Resources of the Buzzard Knob RARE II Study Area (No. 8–223), Rabun and Towns Counties, Georgia, by Mark L. Chatman. 1985. 40 pp. 6 figs. Intermountain Field Operations Center, Denver, CO.

MLA 57–85. Mineral Resources of the Anna Ruby RARE II Study Area (No. 8–225), White County, Georgia, by Mark L. Chatman. 1985. 20 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 58–85. Mineral Resources of the Laurel Fork RARE II Study Area (No. 8–274), Carter County, Tennessee, by Mark L. Chatman. 1985. 50 pp. 6 figs. Intermountain Field Operations Center, Denver, CO.

MLA 59–85. Mineral Resources of the Worm Creek Roadless Study Area, Bear Lake County, Idaho, by Richard L. Rains. 1985. 11 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 60–85. Mineral Investigation of the Cabezon Wilderness Study Area (NM–010–022), Sandoval County, New Mexico, by Steven E. Tuftin. 1985. 7 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 61–85. Mineral Investigation of the Fandango (NV–060–190) and Morey (NV–060–191) Wilderness Study Areas, Nye County, Nevada, by John R. McDonnell, Jr. 1985. 41 pp. 10 figs. Intermountain Field Operations Center, Denver, CO.

MLA 62–85. Mineral Resources of the Farlin Creek Study Area, Beaverhead County, Montana, by Steven W. Schmauch. 1985. 8 pp. 1 fig. Western Field Operations Center, Spokane, WA.

MLA 63–85. Mineral Resources of the Ruby Mountains Study Area, Madison County, Montana, by Steven W. Schmauch. 1985. 10 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 64–85. Mineral Resources and Occurrences in Part of the Frank Church–River of No Return Wilderness, Custer, Idaho, Lemhi, and Valley Counties, Idaho, compiled by James Ridenour. 1985. 211 pp. 29 figs. Western Field Operations Center, Spokane, WA.

MLA 65–85. Mineral Resources of the Black Rock Desert Wilderness Study Area, Humboldt County, Nevada, by Jerry E. Olson. 1985. 19 pp. 3 figs. Western Field Operations Center, Spokane, WA.

MLA 66–85. Mineral Resources of Part of the Bluebell (NV–010–027) and Goshute Peak (NV–010–033) Wilderness Study Areas, Elko County, Nevada, by S. Don Brown. 1985. 22 pp. 4 figs. Intermountain Field Operations Center, Denver, CO.

MLA 67–85. Mineral Resources of the Cinder Cones Wilderness Study Area, San Bernardino County, California, by Clayton M. Rumsey and Arel B. McMahan. 1985. 12 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 68–85. Mineral Resources of the Owyhee River Canyon Wilderness Study Area, Owyhee County, Idaho, by Peter N. Gabby. 1985. 15 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 69–85. Mineral Resources of the Worthington Mountains Study Area, Lincoln County, Nevada, by Robert H. Wood II. 1985. 47 pp. 11 figs. Intermountain Field Operations Center, Denver, CO.

MLA 70–85. Mineral Resources of the Browns Canyon Wilderness Study Area (CO–050–002), Chaffee County, Colorado, by Jeanne E. Zelten. 1985. 37 pp. 7 figs. Intermountain Field Operations Center, Denver, CO.

MLA 71–85. Mineral Investigation of the Ferris Mountains Wilderness Study Area (WY–030–407), Carbon County, Wyoming, by John T. Neubert. 1985. 55 pp. 11 figs. Intermountain Field Operations Center, Denver, CO.

MLA 72–85. Mineral Resources of the Burnt Lodge Wilderness Study Area, Phillips and Valley Counties, Montana, by J. Douglas Causey. 1985. 13 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 73–85. Mineral Resources of the Juniper Creek Study Area, Owyhee County, Idaho, by Donald E. Graham. 1985. 9 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 74–85. Mineral Investigation of Part of the Gila Lower Box Wilderness Study Area (NM–030–023), Grant and Hidalgo Counties, New Mexico, by George S. Ryan. 1985. 12 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

MLA 75–85. Mineral Resources of the Terry Badlands Study Area, Custer and Prairie Counties, Montana, by J. Douglas Causey. 1985. 18 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 76–85. Mineral Investigation of the Brasstown and Wolf Pen RARE II Areas, Towns and Union Counties, Georgia, by John A. Welsh, Jr. 1985. 31 pp. 4 figs. Intermountain Field Operations Center, Denver, CO.

MLA 77–85. Mineral Resources of the Little Owyhee River Wilderness Study Area, Owyhee County, Idaho, by Alan R. Buehler and Donald O. Capstick. 1985. 15 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 78–85. Mineral Resources of the West Potrillo/Mt. Riley Study Area (NM–030–052) and the Aden Lava Flow Wilderness Study Area (NM–030–053), Dona Ana and Luna Counties, New Mexico, by Diann D. Gese. 1985. 19 pp. 4 figs. Intermountain Field Operations Center, Denver, CO.

1986

MLA 1–86. Mineral Resources of the Antelope Creek Study Area, Phillips County, Montana, by J. Douglas Causey. 1986. 19 pp. 13 figs. Western Field Operations Center, Spokane, WA.

MLA 2–86. Mineral Resources of a Part of the Dos Cabezas Mountains Wilderness Study Area (AZ–040–065), Cochise County, Arizona, by Jeanne E. Zelten. 1986. 31 pp. 7 figs. Intermountain Field Operations Center, Denver, CO.

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MLA 3–86. Mineral Resources of the Cow Creek Wilderness Study Area, Blaine and Phillips Counties, Montana, by Michael S. Miller. 1986. 28 pp. 4 figs. Western Field Operations Center, Spokane, WA.

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MLA 5–86. Mineral Resources of the South Fork Owyhee River Study Areas, Owyhee County, Idaho, and Elko County, Nevada, by Ronald T. Mayerle and Peter N. Gabby. 1986. 15 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 6–86. Mineral Investigation of the Worley Ridge RARE II Area (08224), Rabun County, Georgia, by John T. Neubert. 1986. 17 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 7–86. Mineral Investigation of the Board Camp and Raven Cliff RARE II Study Areas, Lumpkin, Union, and White Counties, Georgia, by Robert H. Wood II and Robert A. Welsh, Jr. 1986. 32 pp. 3 figs. Intermoutain Field Operations Center, Denver, CO.

MLA 8–86. Mineral Investigation of the Rabun Bald (8–147) and Rand Mountain (8–148) RARE II Study Areas, Rabun County, Georgia, by Clay M. Martin. 1986. 48 pp. 6 figs. Intermountain Field Operations Center, Denver, CO.

MLA 9–86. Mineral Investigation of the Baboquivari Peak Wilderness Study Area (AZ–020–203B), Pima County, Arizona, by John R. McDonnell, Jr. 1986. 10 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

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MLA 11–86. Mineral Resources of the Yatahoney Creek Wilderness Study Area, Owyhee County, Idaho, by Andrew M. Leszcykowski. 1986. 9 pp. 2 figs. Western Field Operations Center, Spokane, WA.

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MLA 14–86. Mineral Resources of the Antelope Wilderness Study Area, Nye County, Nevada, by Frederick L. Johnson and David A. Benjamin. 1986. 16 pp. 6 figs. Western Field Operations Center, Spokane, WA.

MLA 15–86. Mineral Resources of the Lick Creek Roadless Study Area, Valley County, Idaho, by Michael C. Horn. 1986. 9 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 16–86. Mineral Resources of a Part of the Big Hatchet Mountains Wilderness Study Area (NM–030–035), Hidalgo County, New Mexico, by David C. Scott. 1986. 31 pp. 8 figs. Intermountain Field Operations Center, Denver, CO.

MLA 17–86. Mineral Investigation of the Antelope Wilderness Study Area (NM–020–053), Socorro County, New Mexico, by Stanley L. Korzeb. 1986. 6 pp. 1 fig. Intermountain Field Operations Center, Denver, CO.

MLA 18–86. Mineral Resources of the Indian Pass and Picacho Peak Study Areas, Imperial County, California, by Clayton M. Rumsey and Arel B. McMahan. 1986. 28 pp. 3 figs. Western Field Operations Center, Spokane, WA.

MLA 19–86. Mineral Investigation of the Southern Nantahala Wilderness Area, Rabun and Towns Counties, Georgia, and Clay and Macon Counties, North Carolina, by Brian J. Hannigan. 1986. 16 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

MLA 20–86. Mineral Resources of the Ojito Wilderness Study Area (NM–010–024), Sandoval County, New Mexico, by Steven E. Tuftin. 1986. 11 pp. 4 figs. Intermountain Field Operations Center, Denver, CO.

MLA 21–86. Mineral Investigation of the Jornada del Muerto Wilderness Study Area (NM–020–055), Sierra and Socorro Counties, New Mexico, by George S. Ryan. 1986. 12 pp. 4 figs. Intermountain Field Operations Center, Denver, CO.

MLA 22–86. Mineral Resources of the Owyhee Canyon Study Area, Malheur County, Oregon, by J. Mitchell Linne. 1986. 14 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 23–86. Mineral Resources of the Fish Creek Mountains Wilderness Study Area, Imperial County, California, by Harry W. Campbell. 1986. 22 pp. 4 figs. Western Field Operations Center, Spokane, WA.

MLA 24–86. Mineral Resources of the Roberts Wilderness Study Area, Eureka County, Nevada, by David A. Benjamin and Frederick L. Johnson. 1986. 27 pp. 10 figs. Western Field Operations Center, Spokane, WA.

MLA 25–86. Mineral Resources of the Park Range Wilderness Study Area, Nye County, Nevada, by Frederick L. Johnson and David A. Benjamin. 1986. 13 pp. 5 figs. Western Field Operations Center, Spokane, WA.

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MLA 75–87. Mineral Investigation of the Lost Spring Canyon (UT–060–131B) Wilderness Study Area, Grand County, Utah, by Diann D. Gese. 1987. 9 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

MLA 76–87. Mineral Resource Assessment of the Staubach Creek Area, Elkhorn Wilderness, Broadwater County, Montana, by Paul A. Pierce. 1987. 13 pp. 3 figs. Western Field Operations Center, Spokane, WA.

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MLA 81–87. Mineral Investigation of the East Cactus Plain Wilderness Study Area (AZ–050–017), La Paz County, Arizona, by Terry J. Kreidler. 1987. 10 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 82–87. Mineral Investigation of the Manzano Wilderness Study Area (NM–010–092), Torrance County, New Mexico, by S. Don Brown. 1987. 9 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

1988

MLA 1–88. Mineral Resources of the Mountain Lakes Wilderness Study Area, Klamath County, Oregon, by Richard A. Winters and Thomas J. Peters. 1988. 10 pp. 2 figs. Western Field Operations Center, Spokane, WA.

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MLA 9-88. Mineral Investigation of the Mount Tipton Wilderness Study Area (AZ-020-012/042) and Proposed Additions, Mohave County, Arizona, by Carl L. Almquist. 1988. 12 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 10-88. Mineral Resources of the Turtle Canyon (UT-060-067) and Part of the Desolation (UT-060-068A) and Floy (UT-060-068B) Canyons Wilderness Study Areas, Carbon, Emery, and Grand Counties, Utah, by John R. McDonnell, Jr. 1988. 50 pp. 6 figs. Intermountain Field Operations Center, Denver, CO.

MLA 11-88. Mineral Resources of a Part of the Muggins Mountains Wilderness Study Area (AZ-050-053A), Yuma County, Arizona, by Robert H. Wood II. 1988. 14 pp. 4 figs. Intermountain Field Operations Center, Denver, CO.

MLA 12-88. Mineral Investigation of the Owl Creek Wilderness Study Area (WY-010-104), Hot Springs County, Wyoming, by William Lundby. 1988. 10 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 13-88. Mineral Investigation of the Rimrock (NM-020-007), Little Rimrock (NM-020-009), Sand Canyon (NM-020-008), Pinyon (NM-020-010), and Petaca Pinta (NM-020-014) Wilderness Study Areas, Cibola County, New Mexico, by Brian J. Hannigan. 1988. 14 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

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MLA 18-88. Mineral Resources of the Carson-Iceberg Wilderness Study Area, Alpine County, California, by Michael S. Miller. 1988. 20 pp. 3 figs. Western Field Operations Center, Spokane, WA.

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MLA 26-88. Mineral Resources of the Gunnison Gorge Wilderness Study Area (CO-030-388), Delta and Montrose Counties, Colorado, by S. Don Brown. 1988. 26 pp. 6 figs. Intermountain Field Operations Center, Denver, CO.

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MLA 28-88. Mineral Investigation of the Bobcat Draw Badlands Wilderness Study Area (WY-010-126), Big Horn and Washakie Counties, Wyoming, by William Lundby. 1988. 16 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

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MLA 35-88. Mineral Investigation of a Part of the Mount Nutt Wilderness Study Area (AZ-020-024), Mohave County, Arizona, by Carl L. Almquist. 1988. 20 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

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MLA 44–88. Mineral Resources of the Eldorado Study Area, Clark County, Nevada, by J. Douglas Causey and Michael S. Miller. 1988. 48 pp. 8 figs. Western Field Operations Center, Spokane, WA.

MLA 45–88. Mineral Investigation of the Mancos Mesa Wilderness Study Area (UT-060-181), San Juan County, Utah, by Richard F. Kness. 1988. 24 pp. 4 figs. Intermountain Field Operations Center, Denver, CO.

MLA 46–88. Mineral Resources of the Ireteba Peaks Study Area, Clark County, Nevada, by J. Douglas Causey. 1988. 46 pp. 3 figs. Western Field Operations Center, Spokane, WA.

MLA 47–88. Mineral Investigation of the Fish Creek Canyon (UT-060-204), Mule Canyon (UT-060-205B), and Road Canyon (UT-060-201) Wilderness Study Areas, San Juan County, Utah, by Rodney E. Jeske. 1988. 18 pp. 1 fig. Intermountain Field Operations Center, Denver, CO.

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MLA 49–88. Mineral Resources of the Quinn RARE II Area, Lincoln and Nye Counties, Nevada, by John R. Thompson. 1988. 76 pp. 14 figs. Intermountain Field Operations Center, Denver, CO.

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MLA 1–89. Mineral Resources of the Black Mountains North (AZ-020-009) and Burns Spring (AZ-020-010) Wilderness Study Areas, Mohave County, Arizona, by John T. Neubert. 1989. 78 pp. 14 figs. Intermountain Field Operations Center, Denver, CO.

MLA 2–89. Mineral Resources of the Mohave Wash Wilderness Study Area (AZ-050-007C/048/020-052), Mohave County, Arizona, by John R. McDonnell, Jr. 1989. 40 pp. 14 figs. Intermountain Field Operations Center, Denver, CO.

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MLA 14–89. Mineral Resources of the Sand Dunes Additional (WY-040-307) and a Part of the Buffalo Hump (WY-040-306) Wilderness Study Areas, Sweetwater County, Wyoming, by John R. McDonnell, Jr. 1989. 16 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

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MLA 19-89. Mineral Investigation of a Part of the Mt. Pennell Wilderness Study Area (UT-050-248), Garfield County, Utah, by Diann D. Gese. 1989. 21 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 20-89. Mineral Resources of a Part of the Trigo Mountains Wilderness Study Area (AZ-050-023B), La Paz County, Arizona, by Robert H. Wood II. 1989. 51 pp. 9 figs. Intermountain Field Operations Center, Denver, CO.

MLA 21-89. Mineral Investigation of a Part of the Cougar Canyon Wilderness Study Area (UT-040-123/NV-050-166), Washington County, Utah, and Lincoln County, Nevada, by George S. Ryan. 1989. 8 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

MLA 22-89. Mineral Resources of the Sperry Creek Wilderness Study Area and Gold Creek Wilderness Study Area and Addition, Malheur County, Oregon, by Michael S. Miller. 1989. 71 pp. 4 figs. Western Field Operations Center, Spokane, WA.

MLA 23-89. Mineral Investigation of the White Canyon Study Area, Pinal County, Arizona, by David C. Scott and John R. McConnell, Jr. 1989. 20 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 24-89. Mineral Investigation of the Tabeguache Creek Wilderness Study Area (CO-030-300), Montrose County, Colorado, by David C. Scott. 1989. 9 pp. 1 fig. Intermountain Field Operations Center, Denver, CO.

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MLA 26-89. Mineral Resources of Parts of the Coal (UT-060-100C), Spruce (UT-060-100C1) and Flume (UT-060-100B) Canyons Wilderness Study Areas, Grand County, Utah, by Terry J. Kreidler. 1989. 20 pp. 4 figs. Intermountain Field Operations Center, Denver, CO.

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MLA 30-89. Mineral Resources of the Crack Canyon Wilderness Study Area, Emery County, Utah, by Terry J. Close. 1989. 94 pp. 15 figs. Western Field Operations Center, Spokane, WA.

MLA 31-89. Mineral Resources of the Diablo Mountain (Additional) Study Area, Lake County, Oregon, by Thomas J. Peters and Spencee L. Willett. 1989. 48 pp. 13 figs. Western Field Operations Center, Spokane, WA.

MLA 32-89. Mineral Resources of the Soda Mountain Wilderness Study Area, Jackson County, Oregon, by Thomas J. Peters and Spencee L. Willett. 1989. 24 pp. 14 figs. Western Field Operations Center, Spokane, WA.

MLA 33-89. Mineral Resources of the Adobe Town Wilderness Study Area (WY-030-401/408), Sweetwater County, Wyoming, by Richard F. Kness. 1989. 17 pp. 4 figs. Intermountain Field Operations Center, Denver, CO.

MLA 34-89. Mineral Investigation of Additional Parts of the Paria-Hackberry Wilderness Study Area (UT-040-247), Kane County, Utah, by John R. Thompson. 1989. 29 pp. 3 figs. Intermountain Field Operations Center, Denver, CO.

MLA 35-89. Mineral Resources of the Muddy Creek Wilderness Study Area, Emery County, Utah, by Terry R. Neumann. 1989. 112 pp. 29 figs. Western Field Operations Center, Spokane, WA.

MLA 36-89. Mineral Resources of the Sids Mountain Wilderness Study Area, Emery County, Utah, by David A. Lipton. 1989. 61 pp. 18 figs. Western Field Operations Center, Spokane, WA.

MLA 37-89. Mineral Resources of the Willow Creek Study Area, Harney and Malheur Counties, Oregon, by Thomas J. Peters and Richard A. Winters. 1987. 19 pp. 2 figs. Western Field Operations Center, Spokane, WA.

MLA 38-89. Mineral Investigation of the Oregon Buttes Wilderness Study Area (WY-040-324), Sweetwater County, Wyoming, by Michael E. Lane. 1989. 8 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

MLA 39-89. Mineral Resources of the San Rafael Reef Wilderness Study Area, Emery County, Utah, by Steven R. Munts. 1989. 106 pp. 19 figs. Western Field Operations Center, Spokane, WA.

MLA 40-89. Mineral Investigation of an Additional Part of the Mormon Mountains Wilderness Study Area (NV-050-161), Clark and Lincoln Counties, Nevada, by David C. Scott. 1989. 17 pp. 2 figs. Intermountain Field Operations Center, Denver, CO.

MINERAL INSTITUTES REPORTS

The mineral institutes program operates under Public Law 98–409 and under title III of Public Law 95–87. It is designed to improve the quality of mineral engineering research and education through support for research in mining, metallurgical processing, and related mineral sciences. The Bureau of Mines supports this research through annual allotment grants, matched by non-Federal funds, to mineral institutes at 31 universities throughout the United States and by research grants to these institutions to address specific mining and processing problem areas.

The following report describes research conducted under a research grant. Individual copies may be available from the authors of the paper at the university cited. Copies of this article are NOT available from the Bureau of Mines.

1985

MIR 1–85. An Analysis of the Geomechanical Factors Influencing Coal Mine Roof Stability in Appalachia, by M. Karmis and W. Kane. Ch. 18 in Second International Conference on Stability in Underground Mining, ed. by A. B. Szwilski and C. O. Brawner. (Proc. Conf., Lexington, KY, Aug. 6–8, 1984). Soc. Min. Eng. AIME, Littleton, CO, 1984, pp. 311–328. During this research, a detailed study of several mines in the southern Appalachian coalfields was undertaken to determine the most prominent geomechanical factors affecting roof stability and to evaluate their influence in promoting unstable ground conditions. To accomplish this task, the major geological and geomechanical features found to be detrimental to coal mine roof within the Appalachian basin were identified and mapped in four Virginia mines. Statistical processing by chi-square and regression analysis was used to determine the influence of geology, mine layout, and support methods on roof stability. It was found that some easily determined parameters can be successfully used to predict potentially unstable areas. A simplified roof classification system was developed based on these geomechanical parameters, which can be used to assess the stability of a particular roof type. A roof rating index was also devised capable of expressing the probability of a failure under a given set geomechanical condition. The research was done under grant G1125151 by Virginia Polytechnic Institute and State University.

MIR 2–85. Effects of *Thiobacillus Ferrooxidans* on Barium-Radium Sulfate in Uranium Mill Tailings, by J. Pérez, A. E. Torma, and I. J. Itzkovitch. Paper in Recent Progress in Biohydrometallurgy 1983. Associazione Mineraria Sarda, Iglesias, Cagliari, Italy, May 1983, pp. 643–656. The influence of bacteria, *Thiobacillus ferrooxidans*, on the stability of barium-radium sulfate precipitate present in treated synthetic and actual uranium mill tailings slurries was investigated. The radium-226 concentration was found to be lower in the inoculated leach suspensions than it was in the sterile controls. One explanation for this is the production of ferric sulfate and sulfuric acid by bacterial oxidation of pyrite contained in tailings. The excess of sulfate concentration resulted in a decrease in the dissociation of the barium-radium sulfate and as a consequence in the lowering of concentration of dissolved radium-226. The research was done under grant G1125132–3501 by New Mexico Institute of Mining and Technology.

MIR 3–85. Delineation of Abandonment Procedures for the Bunker Hill and Crescent Mines, Shoshone County, Idaho, by Kathleen M. Hampton. May 1985. 64 pp. 13 figs. The Bunker Hill and Crescent Mines are located in similar physical, geohydrologic, and geographic settings. The mines are only 3 miles apart and are connected physically by a crosscut drift. Flooding of the lower levels of both mines is expected to significantly reduce acid water production in those areas of the mines, although the mines are expected to fill with acid water because of the dissolution of oxidation products during the filling process. At least one mine pool volume of water is expected to require treatment after flooding. The levels of the Crescent Mine that are above the elevation of flooding are not expected to require the application of any special abandonment techniques upon mine closure because the drainage from the upper mine workings is good quality water. The presence of acid water in the upper workings of the Bunker Hill Mine does require the use of abandonment techniques to reduce water treatment costs after mine closure. Infiltration control, water diversion procedures, and partial flooding of the upper mine workings may be used to reduce acid water production in the upper mine levels. The research was done under grant G1125132 at the University of Idaho.

MIR 4–85. Analysis of Water Movement in an Underground Lead-Zinc Mine, Coeur d'Alene Mining District, Idaho, by Daniel L. Erikson. May 1985. 115 pp. 26 figs. Current National Pollutant Discharge Elimination System regulations require that acid mine drainage continue to be treated as long as the source exists, which makes acid mine drainage from abandoned mines a particular concern. One-time reclamation procedures should be sought as an alternative to perpetual treatment. An understanding of the ground water flow systems recharging a mine is necessary for the successful design and selection of reclamation alternatives. A large underground lead-zinc mine in the Coeur d'Alene mining district of northern Idaho produces an average discharge of about 3.4 cfs with a pH of 2.8 and zinc concentration of 120 mg/L. The mine is located in fractured quartzite and argillite. Analysis of hydrographs collected from selected portions of the internal drainage of the mine along with analysis of mine maps and geologic records suggest that flow in the aquifers surrounding the mine is controlled by fractures along major southeast-trending faults. The mine acts as a huge drain or well that stresses the system. Results suggest a hierarchial distribution of hydraulic conductivity that ranges from high in the southeast-trending fault systems to nil in the unfractured country rock bounded by the faults. Reclamation will probably be accomplished best by diversion of surface streams and interflow past the outcrops of the major faults or by underground measures to divert water from the faults before the water quality is degraded. The research was done under grant G1125132 at the University of Idaho.

MIR 5–85. Acid Water Implications for Mine Abandonment, Coeur d'Alene Mining District, Idaho, by John A. Riley. July 1985. 148 pp. 25 figs. An understanding of the ground water flow systems and the chemical reactions producing acid mine drainage is necessary for the successful design and selection of treatment procedures. The Bunker Hill Mine, a large underground lead-zinc mine developed in fractured quartzites, discharges an average of 3.4 cfs of poor quality water. The zinc concentration averages 116 mg/L and the average pH is 2.8. Acid is produced from the oxidation of pyrite. Flow and water quality at 22 underground sites were monitored for 18 months. The chemical reactions controlling the oxidation of pyrite are presented. The spatial and temporal distribution of water quality and metal loading are presented and discussed. Of the zinc load discharging from the mine, 64% is carried by 2.9% of the flow that originates in the upper levels of the mine. Hypothetical reclamation scenarios are presented

and discussed. Effective targeting of reduction of inflow to acid producing areas of the mine would improve significantly the quality of water discharging from the mine. The research was done under grant G1125132 at the University of Idaho.

MIR 6–85. Ideal Site Mixing in Solid Solutions, With an Application to Two-Feldspar Geothermometry, by Jonathan G. Price. July-Aug. 1985. 6 pp. 1 figs. The activity of end member i, α_i, in a solid solution can be defined as $\alpha_i = \alpha_i^{con} \gamma_i$, where γ_i is an activity coefficient describing the departure from ideal solution and α_i^{con} is the ideal contribution to activity. Statistical thermodynamics yields an explicit expression for α_i^{con} in terms of configurational entropy and mixing on sites. This general expression applies to binary, ternary, and complex multicomponent solid solutions. Applications of this expression to feldspars yields an adjustment of the two-feldspar geothermometer. Data in the system albite-orthoclase-anorthite-H_2O fit well enough to suggest that the proposed geothermometer is accurate to $\pm 50°$ C in the range of 650° to 900° C for coexisting plagioclase and alkali feldspar for which $0.15 < X_{Ab}^{Af} < 0.50$. The research was done under grant G1134148 at the University of Texas at Austin.

MIR 7–85. Summary of the Tectonic Development of Trans-Pecos Texas, by Christopher D. Henry and Jonathan G. Price. Oct. 1985. 8 pp. 2 figs. Basin and Range, and to a lesser extent Laramide, structures control the topography of the Trans-Pecos region. However, the area has experienced repeated deformation since the Precambrian. Major tectonic events occurred in the Precambrian, late Paleozoic, early to middle Mesozoic, late Mesozoic to early Cenozoic, and late Cenozoic. Structures and trends established in earlier events were later reactivated. Trans-Pecos structure is thus a summation of many events as illustrated in the accompanying map. The research was done under grants G5104028 and G1114037 at the University of Texas at Austin.

MIR 8–85. Origin of Silver-Copper-Lead Deposits in Red-Bed Sequences of Trans-Pecos Texas: Tertiary Mineralization in Precambrian, Permian, and Cretaceous Sandstones, by Jonathan G. Price, Christopher D. Henry, Allan R. Standen, and Jan S. Posey. Oct. 1985. 65 pp. 37 figs. Silver deposits occur in Precambrian, Permian, and Cretaceous red-bed sequences near Van Horn, TX. These deposits are geochemically similar and contain economically important quantities of silver, copper, and lead as well as anomalously high amounts of arsenic, zinc, cadmium, and molybdenum. Gold is not enriched. Primary minerals include chalcopyrite, tennantite-tetrahedrite, bornite, galena, sphalerite, acanthite, pyrite, marcasite, barite, and calcite. The deposits are dominantly steeply dipping veins. Strata-bound occurrences are near veins or closely spaced fractures. Structural evidence, including orientations of veins, relative ages of fractures, and relationships to major tectonic events in the region, suggests that the most likely time of mineralization was during late Basin and Range extensional deformation. Ore deposition probably occurred at least 18 million years after the period of voluminous silicic volcanism (38 to 28 million years ago) in the Trans-Pecos region. The hypothesis developed in this study on the origin of the veins involves a rise of moderate-temperature, moderately saline hydrothermal fluids along Basin and Range fractures and precipitation of metal sulfides in response to mixing with shallow ground water. This hypothesis has implications for exploration of additional deposits in Trans-Pecos Texas and elsewhere. The research was done under grant G1114037 at the University of Texas at Austin.

1986

MIR 1–86. Yield Pillar Simulation Using Physical Modeling, by Dwayne C. Kicker and Duk-Won Park. Ch. 35 in Rock Mechanics: Key to Energy Production, ed. by Howard L. Hartman (Proc. 27th U.S. Symposium on Rock Mechanics, Tuscaloosa, AL, June 23–25, 1986). Soc. Min. Eng. AIME, Littleton, CO, 1986, pp. 224–231. As the use of longwall mining increases in the United States, there is a need to better understand the stress redistributions indicative of this method. To control high stress concentrations, the yield pillar concept has been developed. A physical longwall mine model has been designed to study the effect of yield pillars in deep mining. The model includes sensitive stress measuring devices; a new excavating technique, and a new model material. This study includes the use of both regular and yield pillar systems and has successfully simulated the mode of stress change in chain pillars. The research was done under grant G1125151–0101 at the University of Alabama.

MIR 2–86. Stability Analysis of Entries in a Deep Coal Mine Using Finite Element Method, by Duk-Won Park and Nadim F. Ash. Min. Sci. and Technol., v. 3, 1985, pp. 11–20. Strain-softening behavior of rock and coal layers around a coal mine opening was simulated using a quasi-elastic approach that accounts for residual strength after failure. This simulation was achieved in such a way that material values were modified after each run, according to stress distribution, until the simulation reached an equilibrium condition. MSC/NASTRAN Finite Element Method program was used for the simulation. The effect of a yield system was analyzed in comparison with a regular pillar system. The results agreed with the field measurement in terms of stress distribution and floor heave. The research was done under grant G1125151–0101 at the University of Alabama.

MIR 3–86. Physical Model Study of a Longwall Mine, by Duk-Won Park and Dwayne C. Kicker. Min. Sci. and Technol., v. 3, 1985, pp. 51–61. In this study, a new physical model for longwall mining is developed combining features of the "sandbox" model with a new concept for excavation of mine openings using a special tool. The model is used to examine stress distributions around a longwall face in chain pillars, as well as in the panel. Reproducible results are obtained, which enable a successful simulation by the model of the mode of stress changes in chain pillars, and measurement of the development of panel front abutment. The research was done under grant G112515–0101 at the University of Alabama.

MIR 4–86. The Solubility and Stability of Scorodite, $FeAsO_4 \cdot 2H_2O$, by Patricia Martin Dove and J. Donald Rimstidt. Am. Mineral., v. 70, 1985, pp. 838–844. Scorodite is an orthorhombic iron arsenate commonly associated with arsenic-bearing ore deposits as a weathering product. This study investigated the mode of formation and persistence of scorodite in nature, and suggests that its presence controls the arsenate levels in waters draining from oxidizing arsenic-rich ores. Observations at the Brinton arsenic mine, Floyd County, VA, among other arsenopyrite deposits, show a close spatial relationship between arsenopyrite and scorodite. Analysis of the surface and ground waters at the Brinton arsenic mine site showed that scorodite seems to control maximum dissolved arsenate levels. This research was done under grant G1134151 at the Virginia Polytechnic Institute and State University.

MIR 5–86. Gahnite in the Metamorphosed Stratiform Massive Sulfide Deposits of the Mineral District, Virginia, U.S.A., by D. J. Sandhaus and J. R. Craig. Tschermaks Mineral. Petrogr. Mitt., v. 35, 1986, pp. 77–98. This paper describes the

analysis of 580 polished sections and 50 thin sections from samples and diamond drill cores from the mineralized zones of the Cofer, Arminius, Sulphur, and Julia stratiform sulfide deposits of Louisa County, VA. The presence of gahnite in these rocks and its potential as a exploration guide in the search for massive deposits of sulfide ore are also discussed. This research was done under grant G5105053 at the Virginia Polytechnic Institute and State University.

MIR 6–86. Rates of Reaction of Covellite and Blaubleibender Covellite With Ferric Iron at pH 2.0, by Carol Ann Walsh and J. Donald Rimstidt. Can. Mineral., v. 24, 1986, pp. 35–44. This study evaluates the rates of oxidation of covellite and blaubleibender (blue-remaining) covellite by Fe^{3+} at pH 2 in a batch reactor system to better understand the geochemical processes involved in second-cycle weathering of enriched zones of copper-bearing ore deposits. This research was done under grant G1134151 at the Virginia Polytechnic Institute and State University.

MIR 7–86. A Study of Roof Caving in the Eastern U.S. Coalfields, by Z. Agioutantis and M. Karmis. Paper in Proceedings of 5th Conference on Ground Control in Mining, Morgantown, WV, June 11–13, 1986, ed. by A. Wahab Khair and Syd S. Peng. WV Univ., 1986, pp. 134–146. This report describes caving and mass deformation characteristics above longwall panels including the effects of geological and geomechanical characteristics of the strata on the caving height and the bulking of the caved material, testing of the applicability of the various theoretical and empirical models of roof caving, and formulation of a numerical ground deformation model for nonelastic material behavior. This research was done under grant G1125151–5109 at the Virginia Polytechnic Institute and State University.

MIR 8–86. Temperature and Time Effects on the Closure of a Gravel Room in Permafrost, by Scott L. Huang. Bull. Assoc. Eng. Geol., v. 22, No. 1, Jan. 1985, pp. 53–65. Underground excavations in arctic and subarctic regions are subject to significant creep deformation, which are highly temperature and time dependent. The U.S. Army Cold Regions Research and Engineering Laboratory permafrost tunnel was monitored to investigate these dependencies. The creep behavior of the gravel room was described by a combined exponential and power relationship between closure rate, time factor, and ground temperature. For the long-term stability of an underground opening in frozen ground, the time effect upon the closure rate is secondary to the influence of temperature. The strata separation in the gravel roof of the tunnel opening was also studied. The partings were observed only during periods of high temperature and closure. The results of the study suggest that after consideration of factors such as ground temperature and time dependency, underground chambers in permafrost can be designed and utilized for long-term applications. This research was done under grant G1125151–0202 at the University of Alaska at Fairbanks.

MIR 9–86. Stability Study of CRREL Permafrost Tunnel, by Scott Lin Huang, Nolan B. Aughenbaugh, and Ming-Chee Wu. J. Geotech. Eng., v. 112, No. 8, Aug. 1986, pp. 777–790. This paper summarizes the results of a research project conducted at the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) permafrost tunnel. The relationships between the ground temperature, the roof span dimensions, and the vertical convergence rate of the CRREL tunnel correlate with a combined exponential and logarithmic model. The continuous deformation of the tunnel was primarily temperature dependent. In addition to the effect of temperature, the opening width also exhibited a strong influence on tunnel deformation. The span length gradually achieved a constant effect upon tunnel deformation as the opening width increased. The overburden thickness also exhibited an influence on convergence rate. This research was done under grant G1125151–0202 at the University of Alaska.

MIR 10–86. Estimation Practices for Reserves of Gold Deposits, by B. L. Kwa and P. Mousset-Jones. Paper in Proceedings of the Mining Latin America Conference, Santiago, Chile, Nov. 17–19, 1986. Inst. Min. Metall., 1986, pp. 201–219. This paper describes the problems mining and exploration companies have in estimating precious metal deposits, based on a questionnaire soliciting information on drill-hole spacing, mineral reserve estimation methods used, and sampling and assaying practices, as well as exploring the early investigative and defining stages of the industry. This research was done under grant G1125151–3252 at the University of Nevada—Reno.

MIR 11–86. Indicator Kriging Applied to a Gold Deposit in Nevada, U.S.A., by Boo Leong Kwa and Pierre Mousset-Jones. Paper in Ore Reservation Estimation Methods, Models, and Reality, ed. by M. David, R. Froidevaux, A. J. Sinclair, and M. Vallee (Proc. Symp., Montreal, Quebec, May 10–11, 1986). Can. Inst. Min. Metall., 1986, pp. 185–194. This report describes a case study utilizing geostatistical techniques carried out using ordinary linear kriging and indicator kriging. Blast hole data from seven benches of the Vantage One open pit of the Alligator Ridge Mine were used. In addition, indicator variants of the moving window and inverse distance weighting methods were also used. Generally, the indicator methods were found to have worked very well, with errors of 5 pct or less when estimated recoveries were compared with production figures. This research was done under grant G1125151–3252 at the University of Nevada—Reno.

MIR 12–86. A Comparison of Methods To Characterize Unsaturated Hydraulic Properties of Mill Tailings, by Mark B. Larson and Daniel B. Stephens. Paper in Proceedings of the Seventh Symposium on Management of Uranium Mill Tailings, Low-Level Waste and Hazardous Waste, Fort Collins, CO, Feb. 6–8, 1986, pp. 335–346. The purpose of this report is to discuss the results of extensive analyses on copper mill tailings sands to characterize saturated and unsaturated hydraulic conductivity and water content-pressure head relationships. These tailing characteristics were determined using various empirical methods, theoretical models, laboratory techniques, and field procedures. This research was done under grant G1125132–3202 at the New Mexico Institute of Mining and Technology.

MIR 13–86. Removal of Arsenic From Lead Smelter Speiss, by M. Peterson and L. G. Twidwell. J. Hazard. Mater., v. 12, 1985, pp. 225–229. This report describes the removal of arsenic from lead smelter speiss by volatilization techniques. This research was done under grant G1125132–3002 at the Montana College of Mineral Science and Technology.

MIR 14–86. Stability of Mineral Suspensions in the Absence and Presence of Collectors, Dispersants and Flocculants, by Z. Sadowski and R. W. Smith. Miner. and Metall. Process., Nov. 1985, pp. 217–222. The stabilities of finely divided mineral suspensions were determined as functions of pH and concentrations of polyethylene oxide, sodium ligninsulfonate, sodium dodecylsulfate, and sodium oleate. In addition, the electrokinetic potentials of the minerals were determined under identical pH and additive concentration conditions. Flocculation or dispersion of the suspensions is discussed in terms of both the amount and manner of adsorption at the appropriate solid-liquid interface as it is influenced by additive concentration and pH. This research was done under grant G1125132–3201 at the University of Nevada—Reno.

MIR 15–86. Electrokinetic Study of the Role of Modifying Agents in Flotation of Salt-Type Minerals, by R. W. Smith and David Shonnard. Am. Inst. Chem. Eng. J., v. 32, No. 5, May 1986, pp. 865–868. This report describes an investigation in elucidating, via an electrophoresis study, the role of sodium carbonate and lignin sulfonate in salt-type flotation separation. The assessment of the role of rare-earth

ions potentially dissolved from bastnaesite is also discussed. This research was done under grant G1123132–3201 at the University of Nevada—Reno.

MIR 16–86. A Comparison of Empirical/Theoretical, Laboratory, and Field Techniques in Evaluating Unsaturated Properties of Mill Tailings, by Mark B. Larson. M.S. Thesis, NM Inst. Min. and Technol., Socorro, NM, Aug. 1984. 287 pp. 115 figs. This report compares some of the empirical-theoretical, laboratory, and field techniques available to evaluate saturated hydraulic conductivity, soil moisture characteristic curves, and relative hydraulic conductivity. This research was done under grant G1125132–3502 at the New Mexico Institute of Mining and Technology.

1987

MIR 1–87. Compilation of Potassium-Argon Ages of Tertiary Igneous Rocks, Trans-Pecos Texas, by Christopher D. Henry, Fred W. McDowell, Jonathan G. Price, and Rebecca C. Smyth. Univ. TX Bur. Econ. Geol. Geol. Circ. 86–2. Univ. TX, Austin, TX, 1986, 34 pp. This report is a compilation of the results of the potassium-argon dating of the Tertiary volcanic field of Trans-Pecos Texas. Both published and unpublished data are included in the form of charts designed for the use of geologists already familiar with the igneous geology of the area, and obviously unreliable ages of samples are identified and briefly discussed. This research was done under grant G1144148 by the University of Texas at Austin.

MIR 2–87. The Van Horn Mountains Caldera, Trans-Pecos Texas: Geology and Development of a Small (10-km²) Ash-Flow Caldera, by Christopher D. Henry and Jonathan G. Price. Univ. TX Bur. Econ. Geol. Rep. Invest. 151, Univ. TX, Austin, TX, 1986, 46 pp. This report describes the development of the igneous rocks of the Van Horn Mountains, a small section of Trans-Pecos Texas, and attempts to determine the geologic processes and settings in that area that result in the existing ore deposits. This research was done under grants G1134148, G1124148, and G1144148 by the University of Texas at Austin.

MIR 3–87. Formation of Tourmaline-Rich Gem Pockets in Miarolitic Pegmatites, by David London. Am. Mineral., v. 71, 1986, pp. 396–405. This report compares fluid-inclusion data from pegmatites in San Diego, CA, and Kulam, Afghanistan, to identify the conditions under which gem pockets form. Miarolitic and massive rare-element pegmatites were found to crystallize under similar pressure-temperature conditions (2400 to 2800 bars and 425° to 475° C), and may also be controlled by the activities of alkali borate melt components. This research was done under grant G1154140 by the University of Oklahoma.

MIR 4–87. Magmatic-Hydrothermal Transition in the Tanco Rare-Element Pegmatite: Evidence From Fluid Inclusions and Phase-Equilibrium Experiments, by David London. Am. Mineral., v. 71, 1986, pp. 376–395. This report describes the evaluation of fluid inclusions in petalite, spodumene, eucryptite, and in coexisting quartz with respect to experimentally calibrated reaction relationships in the system $LiAlSiO_4$-SiO_2 to define the cooling path and fluid evolution of the rare-element pegmatite from the Tanco mine, at Bernic Lake, Manitoba, Canada. This research was done under grant G1154140 at the University of Oklahoma.

MIR 5–87. Simultaneous Determination of Chromium(VI) and Chromium(III) by Flame Atomic Absorption Spectrometry With a Chelating Ion-Exchange Flow Injection System, by Emil B. Milosavljevic, Ljiljana Solujic, John H. Nelson, and James L. Hendrix. Mikrochim. Acta, 1985, pp. 353–360. This paper describes an alternative approach to quantification of chromium(VI) and chromium(III). A chelating ion-exchange column is used to separate and preconcentrate chromium(III) from chromium(VI). The method presented utilized a single pump, single valve manifold, and uses a less expensive flame atomic absorption spectroscopy detector that allows for an increased sampling rate (120 analyses per hour) while sacrificing only slightly the limits of detection. This research was done under grant G1125132–3205 at the University of Nevada—Reno.

MIR 6–87. The Determination of In Situ Rock Thermal Properties and the Simulation of Climate in an Underground Mine, by P. Mousset-Jones and M. J. McPherson. Int. J. Min. and Geol. Eng., v. 4, No. 3, Oct. 1986, pp. 197–216. This paper describes the results of a continuing research project to investigate improved methods for predicting the underground climate in hot mines. The Homestake Gold Mine in South Dakota was the site for testing these methods, which are based on radial heat flow theory, to measure in situ values of the thermal conductivity and diffusivity of rock. The results verified that in situ thermal rock properties can differ considerably from those determined in the laboratory by a factor of two. This research was done under grant G1125151–3251 at the University of Nevada—Reno.

MIR 7–87. Use of Thiourea and Thioacetamide for Separation and Recovery of Heavy Metals From Mineral Treatment Waste Waters, by John H. Nelson, James L. Hendrix, Emil Milosavljevic. Paper in Proceedings of the International Symposium on Metal Speciation, Separation and Recovery, Chicago, IL, July 27–Aug. 1, 1986. IL Inst. Technol., 1986, pp. I–25—I–46. This report describes a study to test the effectiveness of using thiourea and thioacetamide to precipitate metals from wastewater and metallurgical process streams using two chloride leach washes and a sulfuric acid wash. Thiourea did not precipitate arsenic, whereas thioacetamide did precipitate it as a sulfide. It was found that most metals could be removed within the 96 to 99 pct range. This research was done under grant G1125132–3205 at the University of Nevada—Reno.

MIR 8–87. Igneous Geology of Trans-Pecos Texas. Field Trip Guide and Research Articles, by Jonathan G. Price, Christopher D. Henry, Don F. Parker, and Daniel S. Barker. Guidebook 23 of the 99th Annual Meeting of the Geological Society of America, San Antonio, TX, Nov. 6–9, 1986. Univ. TX, Austin, TX, 1986, 360 pp. This report is presented in the form of a guidebook to be used on a field trip to document the petrology and style of mildly alkaline magmatism in a continental arc tectonic setting by visiting several calderas. The guidebook contains a road log with detailed descriptions of stops at caldera structures and other examples of ancient volcanic activity in the Trans-Pecos region and nearby Mexico, and includes articles on current research concerning the igneous geology of the area covering such topics as field relations of pyroclastic rocks, rheology of peralkaline ash-flow tuffs and lava flows, magma mixing within intrusions, and the petrogenesis of silica-undersaturated and silica-oversaturated magmas. This research was done under grant G1144148 by the University of Texas at Austin.

MIR 9–87. Experimental Verification of the Use of Free-Energy Minimization Techniques for Modelling Complex

Sulfide Smelting, by Harry Eugene Flynn. Ph.D. Dissertation, Univ. MO—Rolla, Rolla, MO, 1987, 105 pp. This paper describes research into the use of free-energy minimization techniques as a method for modeling complex sulfide smelting. Model results were verified experimentally by smelting a variety of sulfide concentrates using a submerged lance technique where the matte, slag, and gas phases are in virtual equilibrium. Experiments were conducted at 1,523 K. It was found that a combination of the submerged lance technique with an equilibrium computer program was a useful way for estimating activity coefficients in systems where the volatility of species such as lead and zinc and their compounds make it difficult to determine activities using conventional experimental techniques. In addition, it was found that a chemical equilibrium program using activity coefficient expressions derived from simpler systems can be applied to complex sulfide smelting to determine the distribution of elements between the matte, slag, and gas phases. This research was done under grant G1125129 at the University of Missouri—Rolla.

MIR 10–87. Characterization of the Spatial Variability of Mill Tailings Hydraulic Properties: A Statistical and Geostatistical Analysis, by Gary D. Johnson. M.S. Thesis, NM Inst. Min. and Technol., Socorro, NM, Mar. 1987, 238 pp. This paper describes a study of an abandoned lead-zinc tailings impoundment in west-central New Mexico. The method of tailings deposition at this site was an upstreaming peripheral discharge system. Generally, this type of system produces a sedimentary structure that coarsens vertically upward and fines laterally away from the emitters. The use of galvanized thin wall samples (shelby tubes) recovered with the aid of a drilling rig was the most advantageous method of sampling. The samples were obtained from a cross section made up of horizontal transects at two given depths and six vertical transects. Hydraulic parameters tested included saturated hydraulic conductivity, porosity, moisture content-pressure head relationships, and particle size, and in situ moisture content was measured with a neutron-probe moisture meter. This research was done under grant G1125132 at the New Mexico Institute of Mining and Technology.

MIR 11–87. Linear Programming To Improve Raw Coal Blending: A New Twist to an Old Tool, by G. T. Lineberry and E. L. Gillenwater. Coal Prep., v. 4, 1987, pp. 227–239. This report describes a traditional linear programming technique to optimize raw coal blending for a given plant with known performance characteristics. The model matches raw coal feed rates to a plant's assumed optimum target feed, subject to quality and quantity constraints. The technique's usefulness is enhanced by a novel computer program for optimizing clean coal sampling frequency. This program analyzes a plant's current sampling scheme, models alternatives, and compares results. The user is presented a menu of feasible sampling schemes that can improve plant economics significantly. Adoption of these improved sampling programs provides the plant operator with a clearer view of the cleaning potential of the plant, permitting tighter quality control of clean coal output. This research was done under grant G1134121 at the University of Kentucky.

MIR 12–87. ZrO_2 Powders From Zirconium (IV) Carboxylates, by Fiona M. Doyle and Wumao Ye. J. Met., v. 39, No. 7, July 1987, pp. 34–37. This report describes the process by which zirconia powders can be produced by the hydrolysis of carboxylate solutions, which are readily prepared by solvent extraction. Polymeric, partially hydrolyzed zirconium carboxylate complexes develop during K_2SO_4 or water treatment at 200° C. Pure Zr solutions also give limited precipitation at 200° C, and extensive, rapid precipitation results when carboxylate solutions containing polymeric species were contacted with dilute HCl. This research was done under grant G1164106 at the University of California—Berkeley.

MIR 13–87. Electrochemical Interactions Between Mineral and Grinding Media and Their Effects on Flotation and Media Wear, by Roberto Luis Pozzo. Ph.D. Dissertation, Univ. MN, Minneapolis, MN, 1987, 155 pp. This report describes the electrochemical nature of mineral grinding media interactions in the wet grinding of one- and two-sulfide mineral ores with regard to the corrosive wear of the media and the flotation behavior of the minerals. Two iron sulfides (pyrite and pyrrhotite) and three types of steels (mild steel, high carbon forged steel, and austenitic stainless steel) were used to represent the sulfide minerals and the grinding media, respectively. Electrochemical measurements (rest and combination potentials, galvanic currents, and polarization behaviors) under abrasive and nonabrasive conditions were correlated with data from marked ball wear tests, Hallimond tube flotation tests, and with scanning electron photomicrographs and energy dispersive X-ray spectra. Corrosion currents obtained by superposition of polarization curves of sulfide mineral grinding media systems were in good agreement with corrosion currents estimated from ball wear data. It was also found that freshly abraded metallic debris particles generated by abrasive wear of the grinding media lowered the corrosive wear of the media by affecting the electrochemical behavior of the minerals. This effect was particularly strong on a magnetic mineral such as pyrrhotite. The adverse effect of mineral-grinding media interactions on the flotabilities of pyrite and of pyrrhotite in the single-mineral systems was partially reversed in a two-mineral grinding media combination. A parallelism was found between these flotability changes and the galvanic behaviors of the minerals in the two- and three-electrode systems. This research was done under grant G1125149–2702 at the University of Minnesota.

MIR 14–87. Effect of Metal Ions on the Stability and Zeta Potential of Barite Suspensions, by Z. Sadowski and R. W. Smith. Miner. and Metall. Process., May 1987, pp. 114–117. This report describes an investigation into the stability and electrokinetic behavior of barite suspensions in the presence of calcium, magnesium, ferrous iron, and aluminum ions. The presence of hydrolyzable metal ions was found to cause the zeta potential-pH curves to show two charge-reversal values that are dependent on the concentration of salt. This research was done under grant G1125132–3201 at the University of Nevada—Reno.

MIR 15–87. Solubility and Stability of Scorodite, $FeAsO_4 \cdot 2H_2O$: Reply, by J. Donald Rimstidt and Patricia M. Dove. Am. Mineral., v. 72, 1987, pp. 852–855. This report presents evidence that, although thermodynamically favored, ferric hydroxides do not form during the solution of scorodite owing to inhibition by the presence of arsenate. This permits the calculation of the congruent solubility product of scorodite. This research was done under grant G1164151 at the Virginia Polytechnic Institute and State University.

MIR 16–87. Gahnite in the Metamorphosed Stratiform Massive Sulfide Deposits of the Mineral District, Virginia, U.S.A., by D. J. Sandhaus and J. R. Craig. Tschermaks Mineral. und Petrogr. Mitt., v. 35, 1986, pp. 77–98. This report describes the examination and analysis of 580 polished sections and 50 thin sections from located samples and diamond drill cores that penetrated the mineralized zones and associated host rocks of four of the stratiform sulfide deposits—Cofer, Arminius, Sulphur, and Julia—of the Mineral District, VA. The polished sections were prepared and examined according to conventional techniques. Because many of the samples were originally selected for an examination of the ore mineralogy, there was a strong bias of samples to represent mineralized zones rather than the surrounding strata. Chemical analyses of gahnites and associated sulfide and silicate minerals were performed on an electron microprobe using synthetic sulfides and well-characterized natural grains of the following as standards: gahnite, fayalite, norbergite, tephroite, rutile, albite, orthoclase, and anorthite. Unit cell dimensions were determined using an automated Norelco diffractometer employing Ni-filtered CuK_α-radiation and using CaF_2 as an internal standard. Reflectance measurements

on the gahnite were performed at 460, 546, and 650 nm using a photometer with magnetite, galena, and pyrite reflectance standards calibrated against a primary Zeiss reflectance standard. This research was done under grant G5105053 by the Virginia Polytechnic Institute and State University.

MIR 17–87. The Electrowinning of Dilute Zinc Sulfate Solutions in a Fluidized Bed Electrochemical Reactor, by Richard Z. Squillace and Renato G. Bautista. Paper in Hydrometallurgical Reactor Design and Kinetics, ed. by Renato G. Bautista, Rolf J. Wesely, and Gary W. Warren (Proc. of The Metallurgical Society Annual Meeting, New Orleans, LA, Mar. 2–6, 1986). Metall. Soc. AIME, Warrendale, PA, 1986, pp. 373–387. This report describes the use of a cylindrical, fluidized-bed electrochemical reactor (FBER) to electrowin dilute zinc sulfate solutions containing 2.5 to 15 g/L zinc. The planar electrodes used in the industrial electrowinning of zinc requires 50 to 65 g/L zinc. A low acid catholyte solution of 5 g/L is the maximum concentration necessary for the efficient recovery of zinc. The addition of 60 g/L of Na_2SO_4 electrolyte improved both the catholyte conductivity and current efficiency. The optimum current efficiency and current density were obtained using a particle size of minus 500 plus 355 μm and a bed width of 1.3 cm. At a zinc concentration of 15 g/L, the FBER could be operated at current densities and volumetric reaction rates greatly exceeding that of a conventional planar electrowinning cell. This research was done under grant G1125132-1902 by the University of Nevada—Reno and Iowa State University.

MIR 18–87. Leaching Kinetics of Platinum and Palladium From Spent Automotive Catalysts, by David R. Tyson and Renato G. Bautista. Sep. Sci. and Technol., v. 22, Nos. 2–3, 1987, pp. 1149–1167. This report describes a study into the leaching kinetics of selected metals from automotive catalysts. Empirical rate expressions for both platinum and palladium were obtained from mass balances and concentration time data in a packed bed reactor using different (HCl):(HNO_3) leaching solution concentration ratios. The spent catalysts used in this study (minus 60 plus 70 mesh to minus 120 plus 140 mesh) were analyzed to be 3,791 parts per million (ppm) platinum and 1,306 ppm palladium. High initial rates for both platinum and palladium were obtained for the early stages of leaching and were followed by rapid decay up to about 110 minutes and 50 minutes, respectively. Typical concentrations in the leached solution were about 40 ppm Pt and 20 ppm Pd after about 5 hours for the experimental conditions used. The extent of reaction for platinum was in the 90-pct range while that of the palladium was in the 70-pct range. This research was done under grant G1125132-1901 at Iowa State University.

MIR 19–87. Analysis of Stress Waves Induced From Single Hole Stemmed Blasts, by Bryan W. Cowan, Francis O. Otuonye, and John B. Ligon. Min. Sci. and Technol., v. 5, 1987, pp. 83–88. This report describes a study of the effects of stemming on wave magnitude during blasting in underground mines. Two factors considered were the effects of changing the blast location on the face, and the repeated blasting on a single face. In addition, a laboratory study conducted on polymer models of a mine opening to compare stemmed and nonstemmed blasts showed that stemmed blasts produce lower energy waves than nonstemmed blasts. This research was done under grant G1154126 at Michigan Technological University.

MIR 20–87. Liquid-Liquid Extraction of Palladium(II) From the $PtCl_4$–$PdCl_2$–HCl–H_2O–Xylene–Cynanex 471 System, by Reed D. Walker and Renato G. Bautista. Paper in Proceedings of ISEC '86, Munich, Fed. Rep. of Germany, Sept. 11-16, 1986. Eur. Fed. Chem. Eng., Munich, Fed. Rep. of Germany, v. II, 1986, pp. 107–112. This report describes an investigation to determine the usefulness of Cyanex 471 in a liquid-liquid extraction process. Used as an extractant, Cyanex 471 was found to have potential in the separation of palladium(II) from chloride solutions containing platinum(IV) and palladium(III), a capability that could be exploited in the recovering of palladium(II) from spent automotive catalysts. This research was done under grant G1125132–1901 at Iowa State University.

MIR 21–87. Mined Land Reclamation and Development Potentials in Southwestern Virginia's Coal-Mining Region, by Carl E. Zipper. Land: Issues and Problems, No. 69. VA Coop. Exten. Serv., VA Polytech. Inst. and State Univ., Blacksburg, VA, June 1987, 4 pp. This report discusses the advantages of landform alteration methods of reclaiming coal mined land in southwest Virginia. This research was done under grant G1144151 at Virginia Polytechnic Institute and State University.

MIR 22–87. Natural Resources and Development: An Annotated Bibliography, ed. by William James and David Short. William S. Hein Co., Buffalo, NY, 1987, 297 pp. This book contains bibliographic references of legal literature concerning specific subject areas in the field of natural resources and development. Some topics included are air and marine pollution, the Clean Water Act, coal gasification, hazardous waste, energy conservation, and international oil concessions. This research was done under grant G1154121 at the University of Kentucky.

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MIR 1–88. Investigation of Some Alternatives to Timber Posts and Cribs, by Gavin J. Faulkner, Wenliang Tang, and Zhanjing Yu. Paper in Proceedings of the 5th Conference on Ground Control in Mining, Morgantown, WV, June 11–13, 1986, ed. by A. Wahab Khair and Syd S. Peng. WV Univ., 1986, pp. 62–72. This report presents some alternatives to timber posts and cribs used as temporary supports near the working face of underground mines. In addition to traditional props, other materials evaluated in this study include steel and steel-fiber reinforced-concrete props, as well as several new developments. The advantages and disadvantages of using these methods are discussed, and the performance factors considered include the mechanical behavior of the support, the technical feasibility of using it, and the cost to implement it. This research was done under grant G1125151–5107 by the Virginia Polytechnic Institute and State University.

MIR 2–88. Measurement of Superoxide Release From Single Pulmonary Alveolar Macrophages, by K. A. DiGregorio, E. V. Cilento, and R. C. Lantz. Am. J. Physiol., v. 252 (Cell Physiol. 21), 1987, pp. C677–C683. An electrooptical method was developed to quantify superoxide (O_2^-) release from single rat pulmonary alveolar macrophages (PAM) during adherence to the bottom of a culture dish. This was done by measuring the reduction of nitro blue tetrazolium (NBT) to a diformazan precipitate at 550 nm from videorecorded images of individual cells. Temporal changes in cell optical density, which are proportional to the mass of diformazan produced, were calculated from videophotometric measurements of the change in light intensity over individual cells. Total diformazan produced increased 78 and 126 pct with an increase in NBT from 0.5 to 1.0 and 2.0 mg/mL, respectively. Total diformazan produced and maximum rate of production among individual PAM varied two- to threefold, providing strong evidence for heterogeneity in O_2^- production. Specific inhibition of O_2^- production by superoxide dismutase, iodoacetate, and chlorpromazine significantly reduced the total diformazan produced and maximum rate of diformazan production. Hydrogen peroxide was not involved in NBT reduction, since catalase alone did not significantly change diformazan production. This novel method to quantify O_2^- release from single PAM should be valuable in analyzing heterogeneity and single-cell kinetics of O_2^- production, in assessing the effects of exposure of cells to particulates on O_2^- release, and in relating release to electrophysiological measurements. This research was done under grant G1135142–5408 by West Virginia University.

MIR 3–88. Study of Longwall Powered Support Pressures Under Static and Dynamic Conditions, by Gavin J. Faulkner.

Paper in Rock Mechanics: Key to Energy Production (Proc. 27th U.S. Symp. on Rock Mech., Univ. AL, Tuscaloosa, AL, June 23–25, 1986), ed. by H. L. Hartman. Soc. Min. Eng., Littleton, CO, 1986, pp. 347–351. Powered supports in longwall mines essentially operate under two conditions: static (nonworking) and dynamic (working). A variety of static conditions may exist in a mine. These may include a temporary stoppage of work for a few minutes or stoppage of work for days because of strikes or lack of demand for coal. Studies on pressure behavior were made during brief stoppages of work (few hours) as well as a long stoppage of work (2 weeks). In dynamic conditions, the pressure variation on supports is expected to follow a certain pattern. However, in many cases that does not happen. Pressure-time characteristics of each leg of the supports were studied. This paper discusses the research findings of the studies made on powered support pressure behavior under both static and dynamic conditions. This research was done under grant G1125151-5106, Virginia Polytechnic Institute and State University.

MIR 4-88. Sensitivity Analysis on Selected Input Parameters for Mine Climate Simulation Programs, by G. Danko, P. Mousset-Jones, and M. J. McPherson. Soc. Min. Eng. AIME preprint 88-159, 1988, 11 pp. This report describes ventilation and refrigeration for mine climate modification, which contributes significantly to the operating costs of a deep hot mine. Mine climate simulation programs can be used to minimize the impact of these costs. There are several computer codes available including CLIMSIM to assist in this work. Whichever simulation program is used, it is the mine ventilation engineer who must supply the input data. This paper raises and answers the following question, namely: what accuracy is required of the basic input parameters, in order for a certain precision to be obtained in the predicted air temperatures? In the first part of the paper a new approach is described to estimate the dry and wet bulb temperature of the airflow, either in a dry or wet roadway. The calculation procedure allows an arbitrary temperature change with time, using Duhamel's superposition solution. Matrix-vector representation is applied to simplify the computational structure. In the second part of the paper the sensitivities of the dry and wet bulb air temperatures are analyzed to the changes of the rock thermophysical properties, the heat transfer coefficient and the wetness factor. This research was done under grant G1125151-3251 by the University of Nevada—Reno and University of California—Berkeley.

MIR 5-88. Development of an Improved Method to Measure In Situ Thermal Rock Properties in a Single Drill Hole, by G. Danko, P. Mousset-Jones, and M. McPherson. Chapter 5 in Proceedings of the 3rd Mine Ventilation Symposium, University Park, PA, Oct. 12–14, 1987. PA State Univ., PA, 1987, pp. 33–41. This paper describes several methods of measuring in situ rock thermophysical properties. Among those existing in the literature, a particular measurement procedure was selected for further development. The measurement is based on creating a spherical temperature field in a drill hole using a point source heater of constant heat flux. The bivariate temperature distribution $\Theta(r,t)$ is measured at several points along the length of the drillhole, radius r from the heater and at particular time intervals (t). This research was done under grant G1125151-3251 by the University of Nevada—Reno and University of California—Berkeley.

MIR 6-88. Characterization of the Fluid-Dynamic Mixing of a Bottom Gas-Injected Channel Reactor Using Low-Temperature Modelling, by Jay Bernett Gassel. M.S. Thesis, Univ. MO, Rolla, MO, 1987, 118 pp. This report describes a study on variables influencing the mixing in a single-phase (30.5 × 60 × 606 cm) and a two-phase (20 × 40 × 200 cm) channel reactor model. Tracer and/or neutral density particle techniques were used to determine an eddy diffusivity, D_E, for the system(s). Three bubbler arrangements were investigated in the one-phase work. A separate apparatus was developed to withstand the corrosiveness of the tetrachloroethylene used in the two-phase work. Both the electrical conductivity tracer technique and the neutral density particle technique were shown to be feasible experimental techniques for determining an eddy diffusivity in the systems studied. Decreasing liquid depth or gas flow rate decreased the mixing in the systems. The bubble wall bubbler arrangement yielded higher D_E values and the central linear bubbler arrangement yielded lower values, relative to the single central bubbler arrangement. This was attributed to the directionality of the non-turbulent portion of the mixing energy. In the two-phase work, an upper phase was shown to decrease the mixing in the lower phase. Also, mixing in the upper phase was also lower than that expected, probably due to a more random mixing in this phase which resulted from surface energy effects on the gas phase at the liquid-liquid interface. This research was done under grant G1125129-2902 at the University of Missouri—Rolla.

MIR 7-88. Chemical and Thermal Zonation in a Mildly Alkaline Magma System Infiernito Caldera, Trans-Pecos Texas, by Christopher D. Henry, Jonathan G. Price, and Rebecca C. Smyth. Contrib. Mineral Petrol., v. 98, 1988, pp. 194–211. This report describes a study on postcollapse lavas of the Infiernito caldera grade stratigraphically upward from nearly aphyric, high-silica rhyolite (76% SiO_2) to highly prophyritic trachyte (62% SiO_2). Plagioclase, clinopyroxene, orthopyroxene, magnetite, ilmenite, and apatite occur as phenocrysts throughout the sequence. Sanidine, biotite, and zircon are present in rocks with more than about 67% SiO_2. Major and trace elements show continuous variations from 62 to 76% SiO_2. Modeling supports fractional crystallization of the observed phenocrysts as the dominant process in generating the chemical variation. This research was done under grant G1164148 at the University of Texas—Austin.

MIR 8-88. Thermodynamic Properties of Fe-Mg Titaniferous Magnetite Spinels, by Roy L. Hill and Richard O. Sack. Can. Mineral., v. 25, 1987, pp. 443–464. This report describes the experiments on reversed Fe–Mg exchange between olivine and Ti-rich magnetite [$(Mg,Fe)_2TiO_4 - (Mg,Fe)Fe_2O_4$] show that the distribution coefficient for the exchange reaction $\frac{1}{2}Mg_2TiO_4 + \frac{1}{2}Fe_2SiO_4 = \frac{1}{2}Mg_2SiO_4 + \frac{1}{2}Fe_2TiO_4$ varies from approximately 2.4 to 1.8 in the range 800–1400°C and suggest that Fe–Mg titanium-based spinel [$(Mg,Fe)TiO_{0.5}O_2$] exhibits small positive deviations from ideal mixing ($\leq$170 cal/mol) in this temperature range. Comparison of these results with those for aluminum-based spinels suggests that the Gibbs energy of the reciprocal reaction $MgAl_2O_4 + \frac{1}{2}Fe_2TiO_4 = FeAl_2O_4 + \frac{1}{2}Mg_2TiO_4$ is about 6.2 and 5.2 kcal/gfw at 1400 and 800°C, respectively. A thermodynamic formulation for R_3O_4 FeO–MgO–Fe_2O_3–TiO_2 spinels based on a second-degree Taylor expansion in terms of composition and cation-ordering variables is calibrated. It uses the above data in combination with homogeneous and heterogeneous equilibria for the Fe_2TiO_4–Fe_3O_4, Mg_2TiO_4–$MgFe_2O_4$, and Fe_3O_4–$MgFe_2O_4$ spinel binary joins. The resulting calculated activity-composition relations and cation-ordering schemes are in accord with available experimental data and petrological constraints. This model indicates that Mg and Fe^{2+} are more strongly ordered between tetrahedral and octahedral sites in titanium-based spinels than in ferric-iron-based spinels (with Mg^{2+} showing a tetrahedral preference relative to Fe^{2+} in both spinels) and predicts an approximately symmetrical miscibility gap for *Fd3m* Mg_2TiO_4–$MgFe_2O_4$ spinels ($T_c \sim 400$°C). Calculated activity-composition relations indicate that the activities of both dilute and concentrated components that exhibit temperature-dependent cation distributions are typically underestimated by themodynamic models that do not make explicit provisions for such cation ordering. A calibration for the olivine-spinel Fe–Mg exchange geothermometer is presented. This research was done under grant G114411 at Purdue University.

MIR 9-88. Heat Transfer in Mine Airways With Natural Roughness, by P. Mousset-Jones, G. Danko, and M. McPherson. Chapter 6 in Proceedings of the 3rd Mine Ventilation Symposium, University Park, PA, Oct. 12–14, 1987. PA State Univ., PA, 1987, pp. 42–52. This report describes the calculation of the sensible heat transfer between the rock surface and the flowing rate in an underground airway. There are only a few results available in the literature for the calculation of the convection in tunnels with naturally rough surfaces. Some of them are purely empirical, while others use a theoretical approach, based on the analogy between heat and momentum transfer, expressing the heat transfer coefficient as a function of the friction factor. A review and evaluation of these results are presented. The heat transfer equations obtained using the different assumptions, vary over a wide range, so that experimental results are needed to determine the formulae and constants applicable to mine airways. In situ measurements of the "physical" and "technical" heat transfer coefficient carried out in deep mines are described. The statistical distribution of the convective heat transfer coefficient on rough surfaces, as well as the re-

gression between the Nusselt and Reynolds numbers in the turbulent flow region, are presented. Radiative heat transfer between the surface and the moist air flowing in a duct of relatively large hydraulic diameter has been taken into account during evaluation. The results will be a definite refinement of those calculations presently used in mine climate simulation models. This research was done under grant G1125151-3251 at the University of Nevada—Reno and University of California—Berkeley.

MIR 10-88. Dikes in Big Bend National Park; Petrologic and Tectonic Significance, by Jonathan G. Price and Christopher D. Henry. Geol. Soc. America Centennial Field Guide—South-Central Section, Boulder, CO, 1988, pp. 435–440. This report describes localities for examining dikes in Big Bend National Park. The dikes in Big Bend National Park illustrate the petrologic variety and tectonic setting of Tertiary magmatism in Trans-Pecos Texas. Most igneous activity occurred between two major episodes in the tectonic history of western North America: (1) Late Cretaceous to early Eocene Laramide compression and (2) late Oligocene to recent Basin and Range extension. Volumetrically minor magmatism occurred during the initial stage of Basin and Range extension and perhaps during the final stage of Laramide deformation. The general geology of the park, including aspects of stratigraphy, structure, petrology, and geomorphology, is best described in the treatise by Maxwell and others (1967). The 1:62,500-scale geologic map in Maxwell and others' (1967) volume is also available at many stores in the Big Bend region as part of a nontechnical geologic guide to Big Bend by Maxwell (1968). The 1:250,000-scale geologic map by Barnes (1979) covers the southern part of the Trans-Pecos region. A field trip guidebook by Maxwell and Dietrich (1972) complements these publications. More recent studies have added considerably to our understanding of the tectonics, volcanic stratigraphy, and petrology of the region. Research results are summarized in guidebooks edited by Dickerson and Hoffer (1980), Dickerson and Muehlberger (1985), and Price and others (1986). In addition, details of the tectonic and magmatic history of the Trans-Pecos region are provided by Henry and Price (1984, 1985, 1986), Price and Henry (1984), and Price and others (1987). This research was done under grant G1154148 at the University of Texas—Austin.

MIR 11-88. Cryolite-Bearing and Rare Metal-Enriched Rhyolite, Sierra Blanca Peaks, Hudspeth County, Texas, by Jeffrey N. Rubin, Jonathan G. Price, Christopher D. Henry, and David W. Koppenaal. Am. Mineral., v. 72, 1987, pp. 1122–1130. This report describes the Round Top intrusion, one of five shallow rhyolite laccoliths in the Tertiary Trans-Pecos Texas magmatic province near Sierra Blanca, Texas, which was chemically modified by pegmatitic vapor-phase crystallization. Evidence of pegmatitic crystallization includes the presence of cryolite (Na_3AlF_6), Li-rich trioctahedral micas with variable Fe contents, rutilated quartz, and vapor-rich fluid inclusions defining quartz overgrowths on magmatic grains. The laccoliths are enriched in Li, Be, F, Zn, Rb, Y, Zr, Nb, Sn, REEs, and Th and are depleted in Mg, Ca, and Ti relative to typical calc-alkaline rhyolites. They are peraluminous, making them unusual among Trans-Pecos silicic igneous rocks, which are typically peralkaline or metaluminous. The presence of cryolite and the strong HREE enrichment, which may also be the result of vapor-phase crystallization, sets the Sierra Blanca rhyolites apart from otherwise chemically similar topaz-bearing rhyolites. Accessory biotite and Lirich micas are enriched in F, Mn, and Zn and are depleted in Mg and Ti. Rare metals are contained in part by bastnaesite(?), cassiterite, columbite, priorite(?), Nb-rich rutile, tantalite, thorite, HREE-rich xenotime, yttrocerite and yttrofluorite, and zircon. The rhyolites are the sources of F and Be in beryllium deposits in fluoritized limestones along the contacts with the laccoliths. This research was done under grant G1164148 at the University of Texas—Austin.

MIR 12–88. Air Temperature Calculation in Hot Airways: A Critique and a New Solution, by D. Danko, P. Mousset-Jones, and M. J. McPherson. Paper in Proceedings of the 1st Canadian Conference on Computer Applications in the Mineral Industry, Univ. Laval, Quebec, Canada, Mar. 7-9, 1988. Balkema, 1988, pp. 613–623. A general solution of the heat conduction in the infinite rock mantle is provided to allow air temperature change with time using the superposition technique and the nondimensional age function. Completely dry and wet surfaces are assumed, and the development of a computation algorithm is described to predict sensible and latent heat transfer in an airway developed in a homogeneous infinite solid. The model can be used with arbitrary temperature and moisture variation of the inlet air with time, while the variations can continuously adjust for changes with distance. Therefore the computation algorithm correctly handles the prehistory of the heat and moisture transfer and can be used when seasonal or periodic variation or a rapid continuous temperature increase, e.g., during mine fire simulation, occurs. This research was done under grant G1125151-3251 by the University of Nevada—Reno and University of California—Berkeley.

MIR 13–88. The Fuming of Lead and Germanium Sulfide, by J. P. Hager, R. Shanks and R. Z. Castro. Paper in Proceedings of the Flash Reactor Processes Conference (Salt Lake City, UT, June 15–17, 1988). Univ. UT, 1988, 23 pp. The vapor pressures of lead and germanium sulfide have been determined using a transpiration system where the sulfur potential in the carrier gas stream could be controlled. The results are represented by—

$$PbS(s) = PbS(g)$$
$$\Delta G^\circ = 49{,}400 - 30.98 \cdot T \text{ ; cal/g-mol (997–1,224 K);}$$
$$GeS(s) = GeS(g)$$
$$\Delta G^\circ = 37{,}650 - 36.78 \cdot T \text{ ; cal/g-mol (619–815 K).}$$

The vapor pressures are thought to be more accurate than those available previously. The PbS(g) pressures are approximately 12 pct lower and the GeS(g) pressures approximately 220 pct higher than those calculated from standard reference data sources. The experimental results have been used to calculate fume loading levels at different temperatures. In the presence of arsenic sulfide vapor the vapor pressure of PbS(s) was found to be enhanced, presumably due to the formation of a vapor complex species. The vapor complex species is proposed to be $PbAsS_2(g)$. The thermodynamic results for germanium sulfide have been used to investigate the feasibility of fuming germanium from slag by means of the reaction—

$$GeO_2(l) + 4\ CO(g) + SO_2(g) = GeS(g) + 4\ CO_2(g).$$

The calculated pressures of GeS(g) indicate that a flash reaction system, such as a flame reactor, would be ideally suited to such a fuming process. This research was done under grant G1125129-0851 at the University of Nevada—Reno.

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MIR 1-89. Health Hazards of Diesel and Electric Vehicles in an Underground Coal Mine, by Howald L. Hartman, Thomas Novak, and A. J. Gregg. Min. Sci. and Technol., v. 5, 1987, pp. 131-151. Results of an engineering assessment of potential health hazards, both air quality and noise, are reported for diesel and electric face-haulage equipment operating in the same underground coal mine. The effects of four parameters were investigated: (1) type of car, (2) number of cars, (3) sample location, and (4) airflow quantity. Instruments were chosen for integrated gas sampling (long-term detector tubes) that were reliable, reasonably priced, and suitable for routine use in the underground environment. Particulates and noise were measured instantaneously with direct-reading instruments. In the section using diesel ram cars, none of the shift-long measurements of carbon monoxide, carbon dioxide, particulates, or noise violated threshold limit values (TLV's). About 2 pct of the measurements of nitrogen dioxide and nitric oxide exceeded TLV's. Particulates were excessive only in the section using electric shuttle cars. When three rather than two diesel cars were used, emissions increased approximately proportionately. Of three locations sampled, in all instances, the discharge point consistently registered higher than the face and on board the cars, but there was only a poor correlation between diesel-emission concentrations and airflow quantity. Evidence was lacking of a significant health hazard due to diesels at the mine under study. Research was done under grant G1125151-0102 at the University of Alabama.

MIR 2-89. Comparative Performance Study of Diesel and Electric Face-Haulage Vehicles, by Thomas Novak, A. J. Gregg, and H. L. Hartman. Int. J. Min. and Geol. Eng., v. 5, 1987, pp. 001-017. Results of a performance study of diesel ram-dump cars and electric cable-reel shuttle cars, conducted at an underground coal mine in the Warrior Basin of Alabama, are presented. Time-study data, obtained over a 1-yr period, show that the average load and discharge times of the diesel cars are slightly less than those of the electric cars, while the average travel-loaded, travel-empty, in, and out speeds of the diesel cars are slightly greater. Computer simulations, based on frequency distributions from the cycle-time data, show average shift productions for both vehicle types to be very close for two-car and three-car configurations with a haul distance of two crosscuts. However, as the haul distance increases, the diesel cars outproduce the electric cars. Results of a maintenance-cost comparison are presented for the sake of general interest but should not be considered as fully comparable since the electric cars are approximately 3 yr older than the diesel cars. The results show preventive maintenance costs to be much greater for a diesel car on both per-month and per-ton bases, and the total maintenance cost for a diesel car to be significantly higher on a per-month basis, but significantly less on a per-ton basis. Research was done under grant G1125151-0102 at the University of Alabama.

MIR 3-89. Holographic Testing Method of Rock, by Duk-Won Park. Ch. 30 in Rock Mechanics: Key to Energy Production (Proc. 27th U.S. Symp. on Rock Mech., Tuscaloosa, AL, June 23-25, 1986). Soc. Min. Eng., Littleton, CO, 1986, pp. 192-199; J. Opt. Sensors, v. 1, No. 5, 1986, pp. 423-432. The most important information required for the engineering design of structures in rock is its inherent rock properties. Without adequate parameters on the rock property, high-quality engineering design cannot be expected. Many laboratory rock testing methods have been developed, but they are mostly for testing intact homogeneous rock without appreciable discontinuities. In reality, the intact rock properties do not represent the behavior of rock masses because rock masses include irregularities such as joints, cracks, interlayers, variations in mineral composition, etc. In general the type and intensity of the rock defects may be much more important than the type of rock that will be encountered. In situ rock testing can provide better information on rock parameters, but it takes a tremendous amount of effort, time, and cost. In recent years, numerical modeling techniques have been gaining popularity as a design tool for structures in rock bodies owing to the enormous progress in computer technology, but it is quite dangerous to use numerical techniques without having proper input data. To provide an adequate amount of input data, an extensive testing program may be required; thus major efforts in time and expenses are commonly spent. In this paper, a new rock testing method, which utilizes the principles of laser holographic interferometry, is introduced. This method requires only a few minutes to measure the modulus of elasticity and quality of a rock core sample, which does not have to be cut or ground. The Poisson's ratio can also be measured in a few minutes from a sliced rock specimen. Research was done under grant G1125151 at the University of Alabama.

MIR 4-89. Scale Up of Lifters in Ball Mills, by D. W. Fuerstenau and A.-Z. M. Abouzeid. Int. J. Miner. Proc., v. 15, 1985, pp. 183-192. Liner design and lifter geometry in tumbling mills are very important in comminution kinetics and energy consumption. In terms of the parameters of the batch grinding model, the breakage rate function decreases as lifter size increases while the breakage distribution function is independent of the lifter size. However, the specific energy consumption is not a function of lifter size. Reducing the lifter height from 2.54 cm to 0.32 cm increases the production from this mill by 37 pct. When the mill is operated without any lifters, the charge apparently slips inside the shell, resulting in lower breakage kinetics and higher energy consumption. Research was done under grant G11215149 at the University of California—Berkeley.

MIR 5-89. Grinding of Mixtures of Minerals: Kinetics and Energy Distribution, by D. W. Fuerstenau, A. M. Abouzeid, B. V. Velamakanni, and D. M. Deason. Paper in Proceedings 1. World Congress Particle Technology; Part II. Comminution. Nuremberg, 1986, pp. 415-426. In the mineral processing industry, the comminution unit operation accounts for a substantial portion of the total electrical energy utilized. This is due not only to the large tonnages of material handled but also to the inherently low energy efficiency of comminution. Since ball and rod mills are the conventional tumbling mills for fine grinding of ores, the overall thrust in comminution research has been directed toward understanding the performance characteristics of these systems in quantitative terms under various mill operating conditions. In most of the previous work in this area, only homogeneous single minerals have been used for analyzing and modeling the comminution kinetics. However, since ores are heterogeneous, it is necessary to ascertain whether these models are adequate for the comminution of heterogeneous or multicomponent feeds. In achieving this, research should be aimed at describing the grinding behavior of fully liberated mineral mixtures, which constitutes an important component of the overall problem of the comminution of complex ores. This paper deals with the results of an investigation of the effect of the composition of multicomponent feeds on the breakage kinetic parameters of the individual mineral components constituting the mixtures. We also attempted to delineate a framework to estimate the energy distribution between minerals being ground in the binary system. Research was done under grant G1125149 at the University of California—Berkeley.

MIR 6-89. The Comminution of Multicomponent Feeds Under Batch and Locked-Cycle Conditions: Kinetics, Simulation and Energy Distribution, by D. W. Fuerstenau and K. S. Venkataraman. Int. J. Miner. Proc., v. 22, 1988, pp. 105-118. The results of a detailed investigation of batch and locked-cycle dry grinding of quartz-calcite mixtures in a laboratory ball mill are presented. Batch grinding tests showed that the breakage rate function of the components is time-independent but composition-dependent and is normalizable with specific energy. Locked-cycle tests on the mineral mixtures revealed that approximately twenty-five 2-min cycles are required before the composition of the circuit product and the recycle material attains steady state. The circulating load, after steadily increasing during the first 15 cycles, continued to fluctuate over a narrow range. These findings indicate that industrial-scale grinding circuits may also have long transient periods as the grindability of the ore changes, and that circuits might be in transience perpetually. Research was done under grant G1125149 at the University of California—Berkeley.

MIR 7-89. Effect of Chemical Additives on the Dynamics of Grinding Media in Wet Ball Mill Grinding, by D. W. Fuerstenau, K. S. Venkataraman, and B. V. Velamakanni. Int. J. Miner. Proc., v. 15, 1985, pp. 251-267. Recent papers on the role of grinding aids in wet ball mills indicate that certain polymeric acids favorably act by altering pulp rheology, leading to improved production rates at high pulp densities. Analysis of recent data indicates that there can be an improvement in terms of the production of fine particles per unit time, but on the other hand, the production per unit of expended energy remains the same. Our experiments indicate that there is a critical pulp viscosity above which the grinding media tend to centrifuge because the balls cannot be detached from the mill wall during the time of rotation. Under these conditions the mill power draft decreases and a smaller amount of fines is generated. The polymeric additives are able to reduce the pulp viscosity to a value less than the critical value so that the balls no longer centrifuge and the mill draws full power. From an analysis of the force field acting on a ball inside the mill, this critical viscosity can be estimated and the results are in agreement with experiment. Research was done under grant G1125149 at the University of California—Berkeley.

MIR 8-89. The Effect of Polymeric Additives and Operating Conditions on Comminution in Wet Ball Mills, by D. W. Fuerstenau, K. S. Venkataraman, and B. V. Velamkanni. Paper in Proceedings 1. World Congress Particle Technology; Part II. Comminution. Nuremberg, 1986, pp. 515-528. Under certain conditions, the addition of small quantities of surface-active chemicals can improve the performance of energy-intensive comminution devices in dry and wet grinding. A recent report identified the development of grinding aids as an area that still requires detailed study. The central premise of this report is the well-known comminution dictum that "the energy required to achieve a certain degree of fineness has been and will continue to be the accepted measure of efficiency for a given size reduction task." However, most of the earlier investigations on the behavior of grinding aids did not interpret the results in terms of comminution energy. A second complication has been the widespread use of the air-permeability method to assess the specific

surface area of the comminuted product. This is unsatisfactory because air permeability does not detect reagglomeration phenomena. Both of these factors have complicated any attempt to understand the mechanism(s) by which these additives function in improving mill performance. Klimpel and coworkers' recent exhaustive work at Dow Chemical Co. showed that Dow's patented additive XFS 4272 effectively modifies the rheology of the slurry in the mill, resulting in the production of larger proportions of fines. Much of their work involved the batch grinding of taconite using a standardized procedure. Even though Klimpel's group collected the necessary data for presenting results pertaining to grinding energy, they did not present their results in terms of specific energy. Recently, our analysis of Katzer, Klimpel and Sewell's data on grinding taconite revealed that on the basis of grinding energy, the net amount of fines produced per kilowatt-hour was independent of the presence or absence of the additive. This means that there is hardly any beneficial effect of the additive in terms of the grinding energy expended per unit mass of the feed. This paper presents the results of a detailed investigation on how such operating variables as additive concentration, material holdup, and grinding time influence the grinding kinetics of dense suspensions in the presence and absence of two different polymeric additives. Grinding performance under the different operating conditions was evaluated in terms of the net production of minus 37-μm particles and the specific energy expended in the process. Research was done under grant G1125149 at the University of California—Berkeley.

MIR 9-89. Energy Split in Multicomponent Grinding, by P. C. Kapur and D. W. Fuerstenau. Int. J. Miner. Proc., v. 24, 1988. An energy split factor is defined as the ratio of energies expended when a unit mass of a mineral is ground in a mixture environment and ground alone for the same time interval. Provided the grinding path of a mixture component remains invariant in the two grinding modes and the mill power-breakage rate function correlation holds, the energy split factor can be computed from breakage rate functions or initial rates of production of fines or from data for top-size feed particles remaining unbroken as a function of time. The concept of energy split factor is highly useful for analyzing different aspects of mixture grinding. The principal implications of the analysis presented here lie in a rational and self-consistent integration of the energetics and kinetics of mixture grinding, and in the insight into hard and soft minerals interaction obtained by tracking the energy split factors of the constituents as a function of time. For illustration and verification, three sets of mixture grinding data have been employed: calcite-quartz and hematite-quartz, both in 1:1 volume ratio; and dolomite-hematite in four different compositions. Research was done under grant G1125149 at the University of California—Berkeley.

MIR 10-89. Effect of Lifter Shape and Configuration on Material Transport. Part I: In Rotating Drums, by K. S. Venkataraman and D. W. Fuerstenau. Powder Technol., v. 46, 1986, pp. 23–32. This paper presents the steady-state transport behavior of rotating drums fitted with (1) conventional bar lifters and (2) forward- and reverse-spiralling square lifters, when monosize hematite was fed through these devices. The steady-state holdup in the drum fitted with the forward-spiralling square lifters was less than that in the drum fitted with reverse-spiralling square lifters. However, the dimensionless residence time distributions (RTD's) for the drums were independent of the direction of spiralling of the lifters. Overall, the degree of mixing within the drum holdup, as revealed by the magnitude of the axial dispersion coefficient of the RTD's, was greater for the drums fitted with square lifters than for the drum fitted with conventional bar lifters. Between the forward- and reverse-spiralling configurations, the former showed a relatively greater degree of mixing. RTD's are discussed in this paper in terms of single-parameter models, and mechanistic explanations for the experimental observations are offered where appropriate. Research was done under grant G1125149 at the University of California—Berkeley.

MIR 11-89. The Influence of Polymeric Additives in the Rheology of Dense Slurries, by B. V. Velamakanni and D. W. Fuerstenau. Ch. in Flocculation in Biotechnology and Separation Systems, ed. by Y. A. Attia. Elsevier, 1987, pp. 211–223. When added beyond some limiting concentration, certain low-molecular-weight polyacrylates can significantly reduce the viscosity of dense suspensions. The present study summarizes the influence of three viscosity-lowering polymers on the rheology of hematite, dolomite, and quartz. The ability of a polymer to lower the viscosity of a suspension depends on the pH and the ionic strength, and has also been found to be system-specific. The implications of using different polymers as grinding aids in wet ball milling are also discussed. Research was done under grant G1125149 at the University of California—Berkeley.

MIR 12-89. Geology of the DeLamar Silver Mine, Idaho—A Volcanic Dome Complex and Genetically Associated Hydrothermal System, by Sid P. Halsor, Theodore J. Bornhorst, Matt Beebe, Kim Richardson, and William Strowd. Econ. Geol., v. 83, 1988, pp. 1159–1169. The DeLamar silver mine, located in southwest Idaho, produced over 17 million ounces of silver and 230,000 ounces of gold by bulk mining methods between 1977 and late 1987. The mine occurs within the Silver City rhyolite—an extensive and complex sequence of middle Miocene silicic volcanic flows and domes that unconformably overlie a thick pile of Miocene alkali olivine basalt. The basalt overlies Late Cretaceous granite which is correlative with the Idaho batholith. All three major rock types contain epithermal silver-gold veins, although rhyolites such as those at DeLamar are the only hosts for low-grade, large-tonnage mineralization. The DeLamar mine occurs within a sequence of six pervasively altered silicic volcanic units. From oldest to youngest these units have the following informal designations: (1) porphyritic latite, (2) quartz latite, (3) tuff breccia, (4) porphyritic rhyolite, (5) banded rhyolite, and (6) millsite rhyolite. The porphyritic rhyolite unit is spatially, temporally, and genetically related to silver-gold mineralization and is the principal host rock at DeLamar. This unit was emplaced as coalescing and overlapping lava domes and was preceded by cogenetic eruption of tuff breccia in the form of tuff rings. The emplacement of tuff rings and lava domes was controlled by structures related to a shallow level magma body and regional basin-and-range faulting. Onlap of banded rhyolite preceded hydrothermal activity and served as an important control on localizing ore deposition. The mineralogic character of ore and alteration at DeLamar is similar to adularia-sericite-type volcanic-hosted epithermal deposits, but the geologic setting is more like that of acid-sulfate deposits. Research was done under grant G1174126 at Michigan Technological University.

MIR 13-89. Effects of Temperature on Hydrocyclone Efficiency, by S. K. Kawatra, T. C. Eisele, D. Zhang, and M. Rusesky. Int. J. Miner. Proc., v. 23, 1988, pp. 205–211. Plant investigations and laboratory experiments have been conducted in order to study the effects of temperature on the classification efficiency of a cyclone. It was demonstrated that, under otherwise constant operating conditions, alterations in temperature produced a nearly linear change in d_{50c} size. However, the sharpness of the separation, as defined by the reduced efficiency curve, showed no dependence on temperature. Research was done under grant G1125149-2621 at Michigan Technological University.

MIR 14-89. Effect of Impact on the Grinding Media and Mill Liner in a Large Semiautogenous Mill, by A. K. Gangopadhyay and J. J. Moore. Wear, v. 114, 1987, pp. 249–260. The introduction of large semiautogenous mills to grind larger pieces of ore necessitates the use of large-diameter grinding balls. Grinding balls as large as 127 mm (5 in) in diameter are not rare. The increased height of fall of such grinding balls in these larger mills results in severe impact between the grinding balls and also between the grinding balls and the mill liners. The effects of this impact on the mill liner and the 127-mm-diameter grinding balls used in a 8.2-m-diameter semiautogenous mill were studied. It was observed that the repeated severe impacts resulted in the formation of adiabatic shear bands below the surface of both the mill liner and the grinding balls. Severe impact also resulted in fatigue failure of the mill liners and a phase transformation below the surface of the grinding balls due to the generation of high temperature. In smaller mills, using smaller grinding balls, considerable work hardening was observed beneath the surface of the grinding balls. The extent of the work hardening increased with increase in the ball and mill diameter. Research was done under grant G1125149-2702 at the University of Minnesota.

MIR 15-89. The Role of Abrasion and Corrosion in Grinding Media Wear, by A. K. Gangopadhyay and J. J. Moore. Wear, v. 104, 1985, pp. 49–64. A range of ferrous grinding media

compositions was subjected to laboratory marked-ball wear tests in an ongoing research program aimed at elucidating the responsible wear mechanisms during the grinding of minerals. Most of the wear data in this paper were obtained using a model quartz-pyrrhotite mineral slurry, but these have been supplemented, where appropriate, with a small amount of data from wear tests on taconite ore and a Cu-Ni gabbroic ore. The role of abrasive and/or corrosive wear was determined by comparing the wear rates that result under a range of grinding atmospheres, i.e., O_2, N_2, or compressed air, flushing through a laboratory mill of 8-in diameter coupled with examination of ball surfaces after grinding using scanning electron microscopy. Research was done under grant G1125149-2702 at the University of Minnesota.

MIR 16-89. Nature of Corrosive and Abrasive Wear in Ball Mill Grinding, by I. Iwasaki, R. L. Pozzo, K. A. Natarajan, K. Adam, and J. N. Orlich. Int. J. Miner. Proc., v. 22, 1988, pp. 345-360. Laboratory results of marked-ball wear tests are used to discuss the relative significance of corrosive and abrasive wear in wet grinding. The electrochemical mechanism was investigated by correlating the corrosive wear with the corrosion current obtained from polarization curves under abrasion. Slurry rheology governs the manner in which ground slurries coat grinding balls, thereby influencing not only the grinding efficiency but also abrasive wear. The effects of percent solids and a grinding aid are illustrated. Research was done under grant G1125149-2702 at the University of Minnesota.

MIR 17-89. Effect of Martensite and Austenite on Grinding Media Wear, by J. W. Jang, I. Iwasaki, and J. J. Moore. Wear, v. 122, 1988, pp. 285-299. Wear of martensitic and austenitic media in wet grinding of quartz plus 10 pct pyrrhotite under nitrogen, air, and oxygen environments was investigated when both phases were present in 440 °C martensitic stainless steel balls. As-received and heat-treated balls provided microstructures at their surfaces which ranged from 100 pct austenite to essentially all martensite. The marked-ball wear tests showed that the wear rate could be minimized by a suitable combination of austenite and martensite. A ball composed solely of hard martensite exhibited increased wear under an oxygen environment, while balls composed of soft austenite together with hard martensite exhibited decreased wear. A model of the wear mechanism in wet grinding with 440 °C martensitic stainless steel balls is proposed. Research was done under grant G1125149-2702 at the University of Minnesota.

MIR 18-89. Technical Note: Estimation of Corrosive Wear of Grinding Media by Electrochemical Measurements, by J. W. Jang, R. L. Pozzo, and I. Iwasaki. Corrosion Eng., v. 44, No. 11, Nov. 1988, pp. 836-838. The wear of grinding media in wet grinding accounts for a substantial portion of milling costs. Accordingly, how to identify the conditions that accelerate the corrosive wear and thereby minimize not only the wear, but also the adverse effect on flotation, has been the subject of continued investigation at the Mineral Resources Research Center, Minneapolis, MN. Electrochemical studies have shown that corrosion currents obtained by superposing the polarization curves of pyrrhotite and grinding media electrodes determined under abrasion (referred to as method 1) correlated well with the corrosion currents estimated from marked-ball wear tests (MBWT's). With this approach, however, since all of the ground pyrrhotite is not in contact with grinding balls at any given moment, the cathode-to-anode area ratio used to arrive at the total corrosion currents would probably be overestimated. A more conventional approach involves the extrapolation of the linear portions of the cathodic and anodic polarization curves of an electrode to a point where the two lines intersect. Polarization curves of a grinding media electrode determined under abrasion in ground ore pulps would represent the currents at the polarized media electrode influenced by the presence of electroactive mineral particles (referred to as method 2). Therefore, the corrosion current thereby determined may reflect the effect of the mineral particles in contact with the electrode on its corrosion rates. This study's purpose was to determine the corrosion currents using methods 1 and 2 and to compare the results with the corrosion currents calculated from the MBWT results. Research was done under grant G1125149-2702 at the University of Minnesota.

MIR 19-89. Factors Affecting Wear in Tumbling Mills: Influence of Composition and Microstructure, by J. J. Moore, R. Perez, A. Gangopadhyay, and J. F. Eggert. Int. J. Miner. Proc., v. 22, 1988, pp. 313-343. A large range of iron-carbon alloys were investigated under milling conditions. The alloy systems used included AISI 1020 mild steel, high-carbon low-alloy forged steel, forged martensitic stainless steel, forged austenitic stainless steel and NiHard, 20 pct chromium, 27 pct chromium, 30 pct chromium white cast irons. A range of mineral slurries was also used, including a corrosive copper-nickel sulfide ore, abrasive quartzite, taconite, molybdenite, and abrasive and corrosive quartzite-pyrrhotite combinations. These ranges of alloy systems and minerals provided suitable comparisons with respect to corrosive and/or abrasive conditions of the mineral slurry together with a suitable variation in microstructural constituents of the ball. Marked-ball wear tests were conducted under laboratory conditions in the main, but a small investigation aimed at identifying the importance of impact was also conducted using large industrial tumbling mills. Seven wear mechanisms were identified from examination of ball surfaces, using scanning electron microscopy. It was determined that wear rate was dependent upon a complex interaction of parameters involving microstructure, hardness ratio of the ball to the mineral, mineral slurry chemistry and pH and oxygen potential, ball mix, and size. Adiabatic shear bands were also found in balls which were used in the large industrial mill. A galvanic series of the minerals and grinding media materials was determined from electrochemical tests, indicating the tendency of each grinding material to corrosive wear. The effect of media composition and microstructure was also determined using a strain index method developed in this investigation. In all the tests conducted the harder grinding media produced the most efficient grinding. Wet grinding efficiency was found to be dependent on media hardness, while wear under wet grinding was much higher, in general, than that under dry grinding. With respect to mill size, it was found that the smaller laboratory mills tended to overemphasise corrosive wear compared with the larger laboratory mills. Research was done under grant G1125149-2702 at the University of Minnesota.

MIR 20-89. Effect of Pyrite and Pyrrhotite on the Corrosive Wear of Grinding Media, by R. L. Pozzo and I. Iwasaki. Miner. and Metall. Proc., Aug. 1987, pp. 166-172. A previous investigation showed that corrosion currents estimated from polarization curves for the pyrrhotite-grinding media system under abrasion correlated well with corrosion currents estimated from marked-ball wear test data by applying Faraday's law. Freshly abraded metal debris was magnetically attracted to pyrrhotite and lowered the rest potentials of the mineral particles, thereby affecting the corrosive wear. The investigation was extended to explore the interactions between a nonmagnetic sulfide mineral, pyrite, and abraded metal debris and their effects on the corrosive wear mechanism. The electrochemical behavior of a three-electrode system involving pyrrhotite, pyrite, and grinding media was also investigated as a first step toward elucidating the nature of interactions that occur in grinding complex sulfide ores. Research was done under grant G1125149-2702 at the University of Minnesota.

MIR 21-89. Pyrite-Pyrrhotite Grinding Media Interactions and Their Effects on Flotation and Media Wear, by R. L. Pozzo and I. Iwasaki. Paper in Electrochemistry in Mineral and Metal Processing II. Electrochem. Soc., 1988, pp. 66-83; J. Electrochem. Soc., v. 136, No. 6, June 1989, pp. 1734-1740. The electrochemistry of mineral-grinding media interactions in the wet grinding of one- and two-sulfide mineral ores is discussed with respect to the corrosive wear of the media and the flotation behaviors of the minerals. Electrochemical studies with mineral and steel electrodes under abrasive and nonabrasive conditions are correlated with the data from marked-ball wear tests, and from microflotation and laboratory batch flotation tests. Research was done under grant G1125149-2702 at the University of Minnesota.

MIR 22-89. Tectonic Controls on Orientation and Size of Epithermal Veins, by Jonathan G. Price, Sean T. Conlon, and Christopher D. Henry. Paper in Proceedings, North American Conference on Tectonic Control of Ore Deposits and the Vertical and Horizontal Extent of Ore Systems, ed. by G. Kisvarsanyi and S. K. Grant. Univ. MO—Rolla, Rolla, MO, 1988, pp. 36-46. Size and orientation of veins are complex functions of regional and local stress patterns, geochemistry of ore-forming fluids and wall rocks, and duration of hydrothermal activity. The hypothesis that regional tectonic stresses are major factors in determining the size and orientation of epithermal veins is supported by analyzing tonnage of epithermal ore deposits in the Western United States and Mexico as a function of vein strike and age. E- to NE-directed maximum princi-

pal compressive stress, $\sigma 1$, coupled with vertical and N- to NW-directed $\sigma 3$, imposed a preferred orientation of E- and NE-striking veins during and several Ma after Laramide deformation (Late Cretaceous to Eocene). The only examples of large-volume production from this period are Tayoltita and Cusihuiriachic, from which 24 Mt of ore have been produced. Extension began in the Basin and Range province at least as early as Late Oligocene and continues today. Stresses and styles of deformation changed about 10 Ma ago when $\sigma 3$ apparently shifted from ENE to WNW. Most epithermal veins in the U.S.-Mexican Cordillera formed from 30 to 10 Ma ago. Although there is much scatter in orientation, many veins preferentially strike N $\pm 35°$. Classic examples include the Comstock Lode, Cripple Creek, and Guanajuato, which collectively yielded more than 100 Mt of ore. The Pachuca district, which is anomalous in both size (90 Mt) and orientation (WNW), contains rocks correlative with two major volcanic belts of Mexico, the Oligocene Sierra Madre Occidental and the late Miocene to Recent Trans-Mexican. The Trans-Pecos region of far western Texas has several examples of rare early Oligocene epithermal veins. The region was undergoing weak compression during the voluminous igneous activity from 38 to 32 Ma ago. Hydrothermal solutions followed ENE-striking tectonic fractures into favorable strata to form silver-lead and mercury mantos rather than wide ore veins. The few precious metal veins that formed are relatively short and narrow and yielded less than 45 kt of ore. When crustal extension began in the region, about 30 Ma ago, silicic volcanism had subsided, and volumetrically minor alkaline basaltic magmatism apparently did not generate enough heat to sustain large hydrothermal systems. Regional tectonic stresses are dominant factors in the development of epithermal ore deposits. Veins preferentially develop perpendicular to regional $\sigma 3$. Because fractures are more likely to remain open during regional extension than during compression, regions with long periods of crustal extension and simultaneous voluminous igneous activity are favored for exploration. Research was done under grants G1154148, G1164148, and G1174148 at the University of Missouri—Rolla.

MIR 23-89. Heat, Mass and Impulse Transport Analogies for Underground Airways, by George Danko, Pierre Mousset-Jones, and Malcolm J. McPherson. Paper in Proceedings 4th International Mine Ventilation Congress, Brisbane, Australia, July 1988, 11 pp. Underground airways are characterized by irregular shape and uneven surfaces including large-scale natural roughness, fractures, and a superimposed sand roughness. Swirls in the grooves of the wall and separation because of the periodic variation of the open cross section, due to the blasting patterns, make it almost impossible to calculate average convective heat transfer computationally on the bases of the geometrical description of the surface. However, dimensionless friction factors can be used to characterize the surface effect of an airway, and an analogy between heat and momentum transfer can be applied to calculate an average convective heat transfer coefficient. The paper reviews the existing heat transfer analogies applicable for rough surfaces. A new heat transfer analogy, recently published by the authors and derived on the basis of more advanced similarity considerations, is discussed in more detail. The analogy between moisture transfer and convective heat transfer is also included, which is applicable for the calculation of the moisture transfer coefficient. For the test of the analogies a set of in situ measurement data was obtained in a hot deep mine. Over 100 local heat transfer coefficient readings were taken on the rock surface of a 9-m length of airway for each of four different velocities. These results produced an experimental relationship between the Nusselt and the Reynolds numbers, which shows acceptable agreement with the similarity equation derived theoretically. Velocity profiles were also measured along two diameters of nine cross sections of the airway for each of four different velocities. Research was done under grant G1125151-3251 at the Universities of Nevada—Reno and California—Berkeley.

MIR 24-89. Effect of Shape and Surface Factors on Flotation of Fine Calcite, by H. Lee and R. W. Smith. Paper in Proceedings of XVI International Mineral Processing Congress, ed. by E. Forssberg. Elsevier, 1988, pp. 1549-1559. Electrokinetic and flotation tests were performed on synthetic and naturally occurring calcium carbonates ranging in size from 0.1 to 40 μm. The materials possessed markedly different shapes. The synthetic materials were prepared by precipitation from solution. Flotation collectors used were sodium oleate and sodium tetradecylsulfate. Particle shape and electrokinetic characteristics of the particles had relatively little effect on flotation response. There was some minor difference in behavior between the naturally occurring material and the synthetic materials. There was a particle size effect on flotation. Of greatest importance, however, was how flocculated the flotation suspension visibly appeared, with best flotation corresponding to readily observable flocculation. Research was done under grant G1125132 at the University of Nevada—Reno.

MIR 25-89. Interaction of Dilute Fluoride Solutions With Acidic and Alkaline Soils, by Z. Yang and R. W. Smith. Paper in Light Metals 88, ed. by L. G. Boxall. TMS/AIME, 1988, pp. 725-729. The apparent solubility of fluorite in the presence of soils in the absence and presence of calcite and the abstraction (through either adsorption or reaction) of fluoride by soils from dilute aqueous streams was experimentally investigated. An acidic soil was more effective at removal of fluoride than were neutral or mildly alkaline soils. The equilibrium amount of fluoride in solution when 0.50 wt pct fluorite was added to the soils was substantially greater when the soils had been previously amended with 0.5 wt pct calcite. The results suggest that in general adding either lime or calcite to a soil will hinder uptake of fluoride by the soil. Research was done under grant G1125132-3202 at the University of Nevada—Reno.

MIR 26-89. The Reaction of Calcite With Dilute Fluoride Solutions, by Z. Yang and R. W. Smith. Paper in Water Resources Related to Mining and Energy—Preparing for the Future. Am. Water Resour. Assoc., 1987, pp. 427-438. Fluorides are sometimes used as modifying agents in mineral flotation concentrators. Thus, there is potential for substantial aqueous waste discharge of fluorides from the plants, albeit in dilute form. This paper investigates the interaction of calcite, a common carbonate rock mineral, with dilute HF and NaF solutions. When dilute HF solutions were reacted with calcite at different temperatures and the reaction studied as a function of time, under unstirred conditions, it was determined that the reaction followed an apparent second-order rate law. From Arrhenius and Eyring plots of the data it was found that the activation energies and enthalpies were intermediate in magnitude between solution diffusion control and solution reaction control of the reaction. When dilute NaF solutions were interacted with calcite, the reaction was much slower and appeared to be independent of temperature and obey an apparent first-order rate law. There was indication that an insoluble layer was forming on the calcite. From the kinetic data an attempt is made to elucidate the mechanisms of the dilute fluoride solutions-calcite interactions. Research was done under grant G1125132-3202 at the University of Nevada—Reno.

MIR 27-89. The Microbiological Extraction of Less Common Metals, by Arpad E. Torma. J. Metals, June 1989, pp. 32-36. A developing technology, the microbiological leaching of the less-common and rare metals has yet to reach commercial maturity. Still, although the data are preliminary in nature, the ultimate application of biotechnological principles may provide a potential solution for the valorization of many low-grade mineral resources. The development of these processes for large-scale commercial applications will create new opportunities and challenges for the research community and minerals processing industry. Research was done under grant G1184135 at the New Mexico Institute of Mining and Technology.

MIR 28-89. Gulf Coast Formation Waters as Potential Source Fluids for Cap Rock-Hosted Sulfide Mineralization, Hockley Dome, Texas, by William N. Agee, Jr. Paper in Transactions—Gulf Coast Association of Geological Societies, v. 38, 1988, pp. 561-568. Iron sulfides occur with lesser quantities of Zn, Pb, and Ag sulfides within anhydrite and calcite cap rocks at the Hockley salt dome near Houston, TX. Metal zonation patterns for Ag, Cd, Pb, and Zn in the anhydrite cap rock were evaluated to determine the nature and evolution of the metal reservoir. Gulf coast formation waters of different ages and host formations were examined as source fluids for cap rock mineralization. The assay data for the "H" line of drill holes on the southern perimeter of the dome indicate an overall increase of Zn relative to Pb downward in the anhydrite cap rock. Metal concentrations, expressed as Pb/(Pb + Zn) ratios, exhibit values that commonly range from 0.25 to 0.40 in the upper part of the holes; ratios less than 0.20 and commonly less than 0.10 are typical of the lower sections. Anhydrite cap rocks form by sequential underplating of anhydrite residue as the salt diapir is dissolved. Textural evidence indicates that some of the metal sulfides are stratiform deposits that precipitated at the salt-cap rock

contact as the anhydrite zone accumulated. Thus, the metal ratio data suggest that the sulfide-precipitating fluid became more Zn-rich during anhydrite cap rock accumulation. Metal-bearing brines have been identified in gulf coast oil wells and are believed to be the source of the metals in the salt dome cap rock deposits. Brines move updip out of the overpressured deep Gulf of Mexico basin via formational aquifers and major fault systems that serve as vertical pathways. $\delta^{34}S$ composition of sulfides at Hockley Dome suggests that brines from deeply buried Mesozoic carbonate formations may have been driven upward along growth faults and/or salt dome margins into the cap-rock-forming environment. The metalliferous formation waters responsible for cap rock mineralization likely originate from the Lower Cretaceous carbonate reservoirs. The apparent large-scale metal zonation suggests either variation in the metal source and/or evolution of a metal reservoir via rock-water interactions. Research was done under grant G1154146 at the University of Texas—Austin.

MIR 29-89. Geology and Tertiary Igneous Activity of the Hen Egg Mountain and Christmas Mountain Quadrangles, Big Bend Region, Trans-Pecos Texas, by Christopher D. Henry, Jonathan G. Price, and Donald E. Miser. TX Bureau of Economic Geology Rept. Inv. 183, 1989, 105 pp. Cretaceous sedimentary rocks and Tertiary intrusive, extrusive, and volcaniclastic rocks dominate the geology of the Hen Egg Mountain and Christmas Mountain quadrangles in the Big Bend region of Texas. The Cretaceous rocks consist of limestones, shales, mudstones, and sandstones that are host rocks for the Tertiary intrusions. This report focuses on the Tertiary intrusive and extrusive rocks. Research was done under grants G1154148 and G1164148 at the University of Texas—Austin.

MIR 30-89. Excursion 9A: Mid-Tertiary Silicic Alkalic Magmatism of Trans-Pecos Texas: Rheomorphic Tuffs and Extensive Silicic Lavas, by Christopher D. Henry, Jonathan G. Price, Don F. Parker, and John A. Wolff. NM BuMines & Miner. Resour. Memoir 46, May 1989, pp. 231-274. This trip provided an overview of the silicic, alkalic, and commonly peralkaline magmatism of Trans-Pecos Texas, particularly in the Davis Mountains and Big Bend National Park. Emphasis was on caldera development, a variety of pyroclastic deposits including strongly rheomorphic welded tuffs and unusually widespread silicic lavas. Two calderas illustrated contrasting styles of development and a wide variety of caldera-fill volcanic rocks and breccias. Much of the trip examined a group of rocks that have outcrop features of lava flows but areal extents and aspect ratios commonly associated with ash-flow tuffs; these include both true lavas and strongly rheomorphic tuffs, as well as some units of debatable origin. Research was done under grant G1144148 at the University of Texas—Austin.

MIR 31-89. Widespread, Lavalike Silicic Volcanic Rocks of Trans-Pecos Texas, by Christopher D. Henry, Jonathan G. Price, Jeffrey N. Rubin, Don F. Parker, John A. Wolff, Stephen Self, Richard Franklin, and Daniel S. Barker. Geol., v. 16, June 1988, pp. 509-512. Several silicic units of the Trans-Pecos volcanic field have outcrop and thin-section scale features of lava flows but areal extents and aspect ratios of ignimbrites. These voluminous rocks (up to hundreds of cubic kilometers per unit) are quartz trachytes to low-silica rhyolites (68 pct to 72 pct SiO_2). Lava flow features include flow banding and folding, elongated vesicles, and autobreccias and vitrophyres at the base and top of units. Pyroclastic flow features include sheetlike geometry, lateral extents up to 70 km, aspect ratios as low as 1:700, and areal extents up to 3,000 km^2. A few of these units are clearly rheomorphic ignimbrites, but others show no unambiguous evidence of a primary pyroclastic origin. Although no adequate explanation currently exists for the origin of the latter, we evaluate two end-member hypotheses: (1) they are ignimbrites in which extreme rheomorphism has obliterated primary internal features, and (2) they are highly viscous lavas with unusually high heat retention or effusion rates that allowed them to spread over great areas. Either origin requires a rock type and eruptive mechanism not commonly recognized. Research was done under grants G1164148 and G1174148 at the University of Texas—Austin.

MIR 32-89. Alkalic Rocks of Contrasting Tectonic Settings in Trans-Pecos Texas, by Jonathan G. Price, Christopher D. Henry, Daniel S. Barker, and Don F. Parker. Geol. Soc. America Spec. Paper 215, 1987, pp. 335-346. Alkalic rocks in Trans-Pecos Texas were emplaced in two distinctly different tectonic environments: one compressional (contractional) and one extensional. Rocks (Eocene and early Oligocene) of the older compressional environment can be divided into a western alkali-calcic belt and an eastern alkalic belt. The boundary between the two belts is parallel to the paleotrench that used to lie off the west coast of Mexico. The alkalic rocks were the most inland expression of subduction-generated volcanism. The predominance of east-striking dikes and veins and the orientation of en echelon dikes indicate igneous activity during residual compression remaining from Laramide deformation. As the dip of the subducting slab became gentler with time, calc-alkaline magmatism of Laramide age in Mexico graded eastward into the alkaline magmatism in Texas. Widespread extension and normal faulting began about 24 Ma in the Texas portion of the Basin and Range province. Between 24 and 17 Ma, alkalic basalts were extruded and intruded at several localities, dominantly as north-northwest-striking dikes. Both nepheline- and hypersthene-normative basalts occur in the extensional environment. Rocks of the compressional environment follow two major lines of differentiation: hypersthene-normative basalt to rhyolite and nepheline-normative basalt to phonolite. In contrast, rocks of the extensional environment are apparently limited to basalts. During contraction, magmas rising from the mantle probably formed chambers in which differentiation could occur. During extension, less differentiation occurred, either because tectonically dilated fractures permitted more direct rise of magma to the surface or because the volume of magma was too small. Basalts of the two contrasting tectonic settings are broadly similar in alkalinity and silica saturation. The basalts of the extensional environment are, however, generally richer in magnesium than are the basalts of the compressional environment. This difference is not simply a matter of degree of differentiation but is probably related to the different pressure-temperature regimes of the mantle from which the basalts originated. Research was done under grants G1134148 and G1144148 at the University of Texas—Austin.

MIR 33-89. A Petrographic and Geochemical Model for the Origin of Calcite Cap Rock at Damon Mound Salt Dome, Texas, U.S.A., by James D. Prikryl, Harry H. Posey, and J. Richard Kyle. Chem. Geol., v. 74, 1988, pp. 67-97. Calcite cap rock at Damon Mound, TX, consists of five calcite generations recognizable through standard petrography and cathodoluminescence. Stage-IA calcite formed by dissolution of anhydrite followed by calcite precipitation and was partly replaced by stage-IB calcite. Stage II formed above stage-IA and -IB substrates, either filling open voids or cementing breccia fragments. Stage-IIIA and -IIIB calcites fill late fractures that crosscut all previously formed generations. Microprobe analysis indicates that each calcite generation is geochemically distinct. Sr-Mg ratios indicate that calcite precipitated from variable proportions of formation water, meteoric water, and/or seawater. Wide variation in calcite fluid-inclusion compositions (1.0-9.4 eq.wt pct NaCl) indicates mixing of high-salinity water and low-salinity meteoric water. The single-phase nature of most fluid inclusions and the homogenization temperatures indicate that calcite precipitated at temperatures of $<70°$ C. Calcite $\delta^{13}C$-values range from -31.1 to -14.4 pct (PDB), generally decrease with depth, and are most similar to crude-oil $\delta^{13}C$-values. Calcite $\delta^{18}O$-values range from -7.6 to -4.8 pct (PDB), generally increase with depth, and are compatible with derivation from local meteoric water or formation water at high temperature. Late-stage calcite can be either isotopically heavier or lighter than adjacent early-stage calcite with regard to both carbon and oxygen, and because isotopic values vary with depth, it appears that fluid mixing is the mechanism most responsible for isotopic variations. Although $\delta^{13}C$- and $\delta^{18}O$-values of stage-I calcite are similar to adjacent stage-II and -III calcite, $^{87}Sr/^{86}Sr$ ratios of adjacent calcite pairs are generally different, indicating that each formed from different fluids or a fluid whose $^{87}Sr/^{86}Sr$ composition varied through time due to mixing. Isotopic modeling indicates that calcite cap rock formed from either of two fluid mixtures: (1) formation water and meteoric water between 40° and 80° C, the source of light carbon being either thermogenic CH_4 or liquid hydrocarbons; or (2) formation water, meteoric water, and seawater between 50° and 70° C with thermogenic CH_4 being the light carbon source. Sr was contributed by both anhydrite and fluid. Overall, it appears that calcite cap rock formed from top to base from mixtures of formation water, containing isotopically light carbon and heavy oxygen, and seawater and/or meteoric water, containing isotopically heavy carbon and light oxygen. During this progression the contributions of formation water increased at the expense of seawater and/or meteoric water. The correlation between $\delta^{18}O$ and $\delta^{13}C$ probably indicates that separate fluid pulses had different carbon abundances and/or

slightly different $\delta^{13}C$-values. Research was done under grant G1174148 at the University of Texas—Austin.

MIR 34-89. Field Evaluation of Starter N and Delayed Inoculation of *Lespedeza cuneata* Grown in Minesoil, by D. A. Bender, R. D. Morse, J. L. Neal, and D. D. Wolf. Plant and Soil, v. 109, 1988, pp. 109-113. A field study was conducted on freshly reclaimed surface-mined area to determine response of sericea lespedeza (*Lespedeza cuneata* [Dumont] G. Don.) to delayed rhizobial inoculation. Soybeans (*Glycine max* L.) were used as a control legume. Plots were inoculated with spray applications of rhizobial suspensions at seeding, cotyledon stage, or second trifoliate leaf stage, or not inoculated. Starter N at 0, 10, or 20 kg ha^{-1} was applied preplant in a factorial arrangement with inoculation timings. *G. max* was grown for 92 days and *L. cuneata* for 121 days. Starter N increased plant growth and total shoot N in both species. However, percent shoot N was found to increase only in *L cuneata.* Delaying inoculation had no significant effect upon total shoot N or percent shoot N accumulation in *L. cuneata.* Inoculation of *G. max* at planting produced greater plant growth and N accumulation than delayed inoculation treatments. Application of inoculum as a surface spray appeared to be an effective method for delayed inoculation, as evidenced by nodule formation. Lack of increased plant growth, regardless of time of inoculation, suggests that delayed inoculation does not improve establishment and growth of *L. cuneata* in minesoil. Research was done under grant G1164151 at Virginia Polytechnic Institute and State University.

MIR 35-89. Evaluation of Rhizobial Strains Nodulating *Lespedeza cuneata* for Improving N Input Into Minesoil Revegetation Systems, by Dave A. Bender, John L. Neal, and Ronald D. Morse. Commun. in Soil Sci. and Plant Anal., v. 20, Nos. 9-10, 1989, pp. 1033-1044. This study was designed to identify strains of *Bradyrhizobium sp. (lespedeza)* which could improve the plant performance and N status of *Lespedeza cuneata* (Dumont) G. Don (sericea lespedeza). Based upon preliminary screening for nodulation capability and acetylene reducing activity (ARA), six strains of rhizobia were chosen to be evaluated in the greenhouse for plant growth effects and N_2-fixing ability. The *L. cuneata* symbiosis with two strains, VPI 142 and VPI 163, resulted in the greatest plant growth, total N accumulation, and highest nodule nitrogenase activity (acetylene reduction activity). The high correlation (significant at the 1 pct level) of shoot dry weight with root dry weight ($r = 0.94$), nodule dry weight ($r = 0.92$), total shoot N ($r = 0.98$), total root N ($r = 0.92$), as related to nitrogenase activity of the nodule mass ($r = 0.71$), indicates that plant dry weight could be used as an easily determined measurement for screening isolates to be used with *L. cuneata.* The identification of efficient rhizobial strains capable of increasing N input should benefit revegetation systems using *L. cuneata* as the principal legume. Research was done under grant G1174151 at Virginia Polytechnic Institute and State University.

MIR 36-89. SALTY: A FORTRAN Program To Calculate Compositions of Fluid Inclusions in the System NaCl-KCl-H_2O. by R. J. Bodnar, S. M. Sterner, and D. L. Hall. Computers & Geosci., v. 15, No. 1, 1989, pp. 19-41. An algorithm for estimating compositions of fluid inclusions approximated by the NaCl-KCl-H_2O system has been developed using recently published data for phase equilibrium properties of vapor-saturated NaCl-KCl-H_2O solutions. The algorithm satisfactorily reproduces experimental results for all compositions in the ternary system and requires only the temperatures of two phase changes to calculate the total salinity and the NaCl/(NaCl + KCl) weight fraction of the inclusion fluid. The required input data are the temperatures at which the final two solid phases dissolve during heating. These data are obtainable easily during standard microthermometric analysis of the inclusions. Research was done under grant G1164151 at Virginia Polytechnic Institute and State University.

MIR 37-89. Ore Microscopic Studies Using the General Image Processing System (GIPSY), by J. R. Craig, R. M. Haralick, Roe-Hoan Yoon, Ting Chuen Pong, and Woo-Zin Choi. Paper in Physics of Minerals and Ore Microscopy: Proceedings of the 13th General Meeting of the International Mineralogical Association. Bulgarian Acad. Sci., 1986, pp. 223-232. Ore microscopy developed in the late 1800's and remained primarily a manually intensive art for many years. Since the 1950's there have been marked advances in the quantitative measurement of reflectance and, recently, in the quantitative evaluation of color. In the past 10 years there has also been a rapid increase in the use of automated image analysis systems. The pioneering work of Jones in Europe and Petruk in Canada has led to the recognition that these systems can supplement classical studies, provide a means of quantitative observation, and allow for the much rapider acquisition of data. The present paper discusses some of the applications and capabilities of the General Image Processing System (GIPSY) to ore microscopic studies in the Spatial Data Analysis Laboratory at Virginia Polytechnic Institute and State University. Research was done under grant 5115513 at Virginia Polytechnic Institute and State University.

MIR 38-89. Compositional Signatures in Some Appalachian Gold Occurrences, by J. R. Craig and T. N. Solberg. Paper in Physics of Minerals and Ore Microscopy: Proceedings of the 13th General Meeting of the International Mineralogical Association. Bulgarian Acad. Sci., 1986, pp. 213-222. The authors have analyzed several hundred gold particles from numerous central Appalachian localities and found an overall compositional range extending in fineness from 534 to 995 and with copper contents between 0 and 4.64 wt pct. There is a clear tendency for increased copper contents to correspond with higher fineness; thus copper contents are generally below 0.10 wt pct if fineness is less than 800 but may rise to more than 4 pct if fineness exceeds 900. The data presently available on several Central Appalachian gold occurrences reveal that the individual sites or districts have distinctive, though broad, signatures in terms of fineness and Cu content. Research was done under grant 5115513 at Virginia Polytechnic Institute and State University.

MIR 39-89. The Long Term Stability, Land-Use Potential and Erosivity of Surface Mined Lands Returned to Approximate Original Contour in the Central Appalachians, by W. Lee Daniels, Carl Zipper, and Jay Bell. Paper in Powell River Project Final Report. VA Tech., 1987, pp. 21-36. The requirement for return of mine spoil to "approximate original contour" (AOC) is quite controversial in the Appalachians. Many AOC backfills are unstable and prone to failure, particularly in excessively steep topography. Alternatives to AOC exist that are more stable, are environmentally and economically superior to complete AOC, and still eliminate the highwall, when properly constructed in appropriate locales. Widespread implementation of these alternative landforms would reduce sediment loss from mined areas. Research was done under grant G1144151 at Virginia Polytechnic Institute and State University.

MIR 40-89. Design of Lower Seam Longwall Operations in Multiple Seam Mining, by P. Forrest, C. Haycocks, and Y. Zhou. Paper in Proceedings, 7th International Conference on Ground Control in Mining. WV Univ., 1988. Based on the results of mathematical analysis, photoelastic modeling, and case studies, the mechanisms of longwall undermining interaction have been thoroughly investigated. The effects of using yield pillars in combination with rigid pillars in lower seam mine design have been found to provide significant improvement in ground conditions during undermining. Offsetting of columnized longwall panel entries relative to upper seam remnant structures has proven to be effective in alleviating adverse stress conditions. Research was done under grant G1125151 at Virginia Polytechnic Institute and State University.

MIR 41-89. Comparison of Fluid Inclusion Decrepitation and Acoustic Emission Profiles of Westerly Granite and Sioux Quartzite, by Donald L. Hall and Robert J. Bodnar. Techtonophysics, v. 168, 1989. Acoustic emissions recorded during slow heating of rocks at 1 atm have generally been attributed to intergranular stresses generated by differences in thermal expansion coefficients and elastic moduli of neighboring grains. These experiments have considered only the solid phases in analysis of the results, and little attention has been given to the role of intragranular or grain boundary fluid inclusions in initiating or facilitating fracturing. In principle, fluid inclusions may be thought of as a special case in which the "neighboring grains" are fluids rather than the usual solid mineral phases. The major differences are that (1) the number of inclusions per unit volume is usually 10^2 to 10^6 times greater than the number of mineral grains in that same volume and (2) the volume increase with temperature for most fluids is one to two orders of magnitude-greater for minerals. Thus, when fluid inclusion "grains" are considered, the absolute number of grain-to-grain contacts in a given sample volume is several orders of magnitude greater than if the inclusions are not considered. Further, the magnitude of the stresses between any two adjacent grains may be much higher if one of the "grains" is a fluid inclusion, owing

to the larger coefficient of the thermal expansion of the fluid relative to a solid phase. As a result, substantial overpressures may be generated at the fluid inclusion "grain"-mineral grain contact, during heating experiments. These overpressures result in brittle failure when the stress around the inclusion exceeds the local strength of the host crystal. In fluid inclusion terminology, this fracturing event is referred to as decrepitation. Samples of Westerly granite and Sioux quartzite were heated at 2° C/min in a gas-flow stage in order to determine the decrepitation profiles (number of decrepitations as a function of temperature) of these rocks. Decrepitation was monitored visually during heating experiments and was evidenced by the explosive loss of fluids from the inclusion during a fracturing event. Decrepitation produces microfractures which originate at decrepitated fluid inclusions and propagate outward into the surrounding mineral. Four different types of inclusions, based on room temperature phase ratios and distribution within the host phase, were noted in Westerly granite. Type 1 inclusions contain a single aqueous liquid, type 2 are two-phase, liquid-rich inclusions, type 3 are mostly one-phase fluid inclusions that occur in dense clusters in plagioclase, and type 4 are two-phase, moderate-density, H_2O-CO_2-"salt" inclusions. Type 5 inclusions are one-phase, aqueous liquid inclusions observed in Sioux quartzite. Fluid inclusions in Westerly granite decrepitate between 75° and 573° C with peaks at 275 to 300° C and 400 to 450° C. Type 4 inclusions in Westerly granite tend to decrepitate at lower temperatures (75 to 300° C) than other inclusion types. Initial fracturing of the quartz host surrounding type 1 inclusions (primary decrepitation) generally occurs over the range 100 to 400° C, and the fractures continue to propagate through the quartz (secondary decrepitation) during further heating from 400 to 573° C. Fluid inclusions in Sioux quartzite decrepitate between 188° and 573° C with a broad maximum at 250 to 450° C. Primary decrepitation generally occurs at 200 to 450° C, while secondary decrepitation occurs at 350 to 573° C in Sioux quartzite. Some small inclusions in both samples do not decrepitate until the quartz α-β transition temperature (573° C) is reached. Decrepitation profiles determined in this study display many similarities and differences when compared to previously published acoustic emission profiles of Westerly granite and Sioux quartzite. Owing to fundamental differences in the techniques used to measure acoustic emission and decrepitation, and the potentially different energies associated with the two events, it is unclear whether decrepitating fluid inclusions are recorded during acoustic emission studies. However, if decrepitating fluid inclusions are being recorded during acoustic emission measurements, then our results suggest that (1) decrepitation contributes more to low-temperature portions of acoustic emission profiles than to high-temperature portions for both Sioux quartzite and Westerly granite; (2) compared to Westerly granite, a larger percentage of acoustic emissions in the low-temperature decrepitation profile of Sioux quartzite is due to fluid inclusions; and (3) decrepitating fluid inclusions, not stresses generated by solid-solid interactions, cause the majority of intragranular fracturing in quartz below the temperature of the α-β transition in both these rocks. Research was done under grant G1164151 at Virginia Polytechnic Institute and State University.

MIR 42-89. Solving the Long-Term Mine Production Scheduling Problem by Mixed Binary Programming, by Jan West-Hansen and Subhash C. Sarin. First International Workshop on Project Management and Scheduling, Lisbon, July 11-14, 1988, 36 pp. Recognizing the complexity of coal mining management, e.g., the scarcity of financial resources and the high level of uncertainty, a mixed binary programming model has been developed as an aid for generating production schedules that maximize the associated net present value. The model is based on the definition of the mine layout as a precedence network, with the nodes representing mining sections. Heuristic solution procedures have been developed for producing good, though not necessarily optimal, solutions. In this paper, the problem is reviewed along with the general solution methods. Research was done under grant G1174151 at Virginia Polytechnic Institute and State University.

MIR 43-89. Crystal Chemistry of Tetrahedrite, by N. E. Johnson, J. R. Craig, and J. D. Rimstidt. Am. Mineralogist, v. 73, 1988, pp. 389-397. The crystal chemistry of tetrahedrite can be rationalized by considering the structure commonly written as $^{IV}M(1)_6{}^{III}M(2)_6[{}^{III}X^{IV}Y_3]_6{}^{VI}Z$ [where M(1) = Cu, Fe, Zn, Mn, Hg, Cd; M(2) = Cu, Ag; X = Sb, As, Bi, Te; Y and Z = S, Se] to be generally analogous to sodalite, i.e., a framework of corner-connected $M(1)Y_4$ tetrahedra forming a series of cavities that contain $ZM(2)_6$ octahedra rather than an interframework cation or anion as in sodalite. Adaptation of modeling techniques originally applied to sodalite-group minerals allows for the interpretation of the structural effects of composition on tetrahedrite that has been previously hindered by the lack of structural studies. Framework rotation (ϕ) is caused by the rotation of the framework tetrahedra about their 4 axes and is increased by increases in the M(1)-Y and X-Y bond lengths, but decreased by increases in the spinner-blade length. Distortion of framework tetrahedra is negligibly affected by the M(1)-Y bond length and greatly affected by the X-Y bond length. Increases in the spinner-blade length cause the distortion to decrease, then increase, implying a state of no distortion to the framework polyhedra at particular values of the spinner-blade length and ϕ. Because the structural effects of temperature, pressure, and composition are somewhat analogous in minerals, these results indicate that natural tetrahedrite composition may provide some indication of the thermal and baric conditions at the time of formation. Research was done under grant G1164151 at Virginia Polytechnic Institute and State University.

MIR 44-89. Characterization of a High-Efficiency Helium Microwave-Induced Plasma as an Atomization Source for Atomic Spectrometric Analysis, by Larry D. Perkins and Gary L. Long. Appl. Spectroscopy, v. 43, No. 3, 1989, pp. 499-504. Characterization studies of a He high-efficiency microwave-induced plasma, He-HEMIP, utilizing direct sample introduction with pneumatic nebulization for atomic emission and atomic fluorescence spectrometry, are presented. These studies include diagnostic measurements and analytical characterization of the 150-W He-HEMIP. Diagnostic measurements include excitation temperatures with the use of aqueous and organic nebulized thermometric species, electron number densities, and ionization temperatures for the plasma. The effect of sample uptake rate on the emission intensity is investigated. Ionization interferences are minimal, and phosphate interferences were found not to occur. In addition, the He-HEMIP is characterized as an atom source for metals and nonmetals with the use of atomic emission spectrometry and atomic fluorescence spectrometry. With AES, detection limits for metals and nonmetals are in the sub-ppm range. With AFS, detection limits for metals were determined to be in the low to sub-ppb range and were found to be not statistically different from those reported for HCL-ICP-AFS. Linear ranges for AES and AFS ranged from four up to five and one-half orders of concentrative magnitude. Research was done under grant G1174151 at Virginia Polytechnic Institute and State University.

MIR 45-89. Amperometric Method for Monitoring Anaerobic Respiration With Nitrous Oxide as the Terminal Electron Acceptor, by Kenneth D. Tucker and John L. Neal. Current Microbiology, v. 17, 1988, pp. 95-98. A commercially available Clark-type electrode with a platinum cathode, commonly used for monitoring oxygen uptake, may also be used to monitor respiration with N_2O. The disadvantages of this system include a high sensitivity to O_2, which may be overcome by excluding O_2, and sensitivity to acetylene. The advantage of the method is that it may be used to monitor directly the reduction of N_2O by respiring cells. Research was done under grant G1164151 at Virginia Polytechnic Institute and State University.

MIR 46-89. Growth and Respiration of *Bradyrhizobium japonicum* USDA 143 With Nitrous Oxide as the Terminal Electron Acceptor, by Kenneth D. Taylor and John L. Neal. Current Microbiology, v. 17, 1988, pp. 89-94. *Bradyrhizobium japonicum* USDA 143 grew chemoorganotrophically under anoxic conditions with exogenous N_2O as the sole terminal electron acceptor. Cell growth and dissimilatory N_2O reduction were significantly inhibited by C_2H_2 when either N_2O or N_2O plus NO_3^- served as terminal electron acceptor(s). Reduction of N_2O accounted for 20 pct of the energy for cell growth in cultures supplied with NO_3^- as the terminal electron acceptor. Nitrous oxide was produced stoichiometrically in cultures containing NO_3^- and C_2H_2, but cell growth was proportionately reduced when compared with cultures supplied with an equal amount of NO_3^-. Exogenous N_2O delayed the reduction of NO_3^- in cultures supplied with both electron acceptors. Direct amperometric monitoring of N_2O respiration showed a specific activity of 0.082 $\pm$ 0.004 μmole N_2O/min/mg cell protein, and azide inhibited cell respiration. Research was done under grant G1164151 at Virginia Polytechnic Institute and State University.

MIR 47-89. Computer Modeling of Yield Pillar Behavior Using Post-Failure Criteria, by G. Chen and M. Karmis. Pa-

per in Ground Control in Mining: Proceedings, 7th International Conference, August 3–5, 1988. WV Univ., 1988, pp. 116–125. The plastic increment theory was applied in a 2-D finite element model, and a generalized Von Mises yielding criterion adopted to simulate the progressive failure of coal pillars. Extensive underground monitoring was conducted, and the data were compared with the computer model, yielding promising results. Three different longwall entry layouts, including a stable (s-s) pillar system, a yield-stable-yield (y-s-y) pillar system, and a yield (y-y) pillar system, were investigated using the model developed. The yield-stable-yield system was considered to be the best of the designs studied in the case. A comprehensive parametric analysis was also performed. The triaxial factor and Poisson's ratio were found to be the most important material parameters affecting pillar yielding. Research was done under grant G1125151 at West Virginia University.

ARTICLES IN OUTSIDE PUBLICATIONS

The following are articles by Bureau of Mines personnel in non-Bureau publications that came to our attention. In addition to Bureau authors, this section may contain some non-Bureau coauthors. Copies of these articles are NOT available from the Bureau of Mines.

1985

OP 1–85. A Soldering System for Aluminum, by W. L. Falke, L. A. Neumeier, and A. Y. Lee. Weld. J., v. 64, No. 1, Jan. 1985, pp. 37–44. A method that permits the "soft" soldering of aluminum and aluminum alloys with standard tin-lead solders and fluxes was devised by the Bureau of Mines. The method employs the application of a thin nickel-copper alloy coating to the substrate prior to soldering. This alloy preplating enables the solders to readily wet and spread over the areas to be joined. With conventional technology, aluminum and aluminum alloys are extremely difficult to soft-solder because the tenacious surface oxide films prevent wetting and spreading of the solder. With the Bureau method, the aluminum substrate is mechanically or chemically cleaned to facilitate application of a minute layer of zinc that is subsequently applied with an electroless zincate solution. The nickel-copper-alloy (30 to 70 pct Ni) coating is then applied electrolytically over the zinc, using immersion-cell or brush-coating techniques. Development of acetate electrolytes has permitted deposition of the proper nickel-copper-alloy coatings. The coated areas can then be readily joined with conventional tin-lead solders and fluxes. The joints so formed are ductile, strong, and relatively corrosion resistant, and exhibit strengths equivalent to those formed on copper and brass substrates when the same solders and fluxes are used. The method also has been used to soft-solder magnesium alloys.

OP 2–85. Reactivation of Landslides by Surface Subsidence From Longwall Mining, by Anthony T. Iannacchione and Terry E. Ackman. Am. Assoc. Petrol. Geol. Bull., v. 68, No. 12, Dec. 1984, p. 1921. Subsidence research by the U.S. Bureau of Mines has identified and documented the occurrence of landslides over a longwall mining area in the Dunkard basin. Most of these landslides occurred in masses of slumped hummocky soil generally associated with limestone and claystone beds of the Washington and Greene Formations. Identification and characterization of this phenomenon are needed to model accurately the future effect of subsidence-related surface damage to postmining land use.

OP 3–85. Influence of Depositional Environment on Type and Probability of Encountering Coal-Bed Discontinuities, by Carla A. Kertis. Am. Assoc. Petrol. Geol. Bull., v. 68, No. 12, Dec. 1984, p. 1922. Predictive models that characterize coalbed discontinuities enable mine operators to be better judges of the size, geometry, and influence of these features in unmined portions of the coalbed. An analysis of depositional environments in initial geologic studies of prospective mine properties will indicate the specific types of coalbed discontinuities that can be anticipated.

OP 4–85. A Study of the Mechanisms of the Salt Catalyzed Carbochlorination of Kaolin, by Arne Landsberg and R. D. Wilson. Metall. Trans. B, v. 15B, Dec. 1984, pp. 695–700. Continuous weighing of kaolin during carbochlorination has been used to show the superiority of NaCl as a catalyst for increasing the reaction rate and selectivity at 625° to 650° C, and the possibility of using different types of carbon as a reductant. Initial distribution of NaCl in the kaolin was found to be of importance. A reaction mechanism involving the formation of $NaAlCl_4$ and alumina solubility in this salt is used to explain the effect of reactor configuration and kaolin particle geometry.

OP 5–85. Mössbauer Spectroscopy Used To Study the Removal of Iron From Clay, by A. Landsberg and R. D. Wilson. Metall. Trans. B, v. 15B, Dec. 1984, pp. 732–734. Domestic kaolinitic clay represents a vast, and accessible, potential source of aluminum that could conceivably be used to produce the refractory oxide, used as a substitute for imported bauxite, or used as a feed for the chlorination route to the metal. Long-range research efforts within the Bureau of Mines have pursued each of these concepts, and in each, the small amount of iron has been a major concern. Using Mössbauer spectroscopy, the Bureau has shown the chemical state of the contained iron before and after treating kaolin, and presents these analyses as a basis for judging the feasibility of iron removal by the treatments used here.

OP 6–85. Water-Powered Scrubber Aids Ventilation, by Steven J. Page, Bobby Hughes, and Stephen Monroe. World Min. Equip., v. 8, No. 12, Dec. 1984, pp. 67–69. A recent advance in dust collection on continuous mining machines has proven successful in reducing dust on blowing ventilation sections. The system is a water-powered scrubber built into the machine and has the advantages of not increasing machine height, no moving parts such as a fan, or filters to clog or clean. Airflow induction and scrubbing are accomplished simultaneously by water sprays. Using two units (one in the center of the machine and one in the left boom), the scrubber delivered 4,000 cfm of air at water pressures of 300 psi. Airflows of 9,000 cfm are possible at higher water pressures, and the collection system is compatible with left- or right-hand ventilation since it has a scrubber built into each side of the machine. Field test results showed that the scrubber system reduced dust by 67 pct on the immediate return air side of the machine and by 54 pct at the operator's position. Tracer gas tests indicate that the scrubber system significantly reduced the methane gas peaks, although it did produce a higher average entry methane concentration than if the scrubber were not used.

OP 7–85. Cogeneration of Power in the Underground Mining Industry, by E. D. Thimons, R. N. Torbin, and R. Cardenas. Paper in Proc. ASME Industrial Power Conf., Philadelphia, PA, Oct. 28–31, 1984, pp. 45–52. Cogeneration can be defined as any system that recovers energy that is normally lost, and converts it to useful shaft power. The U.S. Bureau of Mines has undertaken a program to evaluate the practicality of applying cogeneration principles to the incoming cooling and/or service water into deep mine shafts. Cogeneration, although quite commonly practiced in South African mines, has not found wide acceptance in the U.S. mining industry. The Bureau, through its contractor Foster-Miller, Inc., is proceeding with the design, installation, and operation of a demonstration cogeneration system to be operated in the Hecla Mining Co.'s Lucky Friday Mine, Mullan, ID. The objectives of the program are to verify the predicted energy savings resulting from the use of a turbine generator system to recover the available potential energy of the incoming water, to demonstrate the viability of the system hardware, and to promote the use of this technology throughout the U.S. mining industry. The demonstration system consists of an impulse turbine directly coupled to a 300-kW induction generator. The turbine is capable of operation of a range of flow from 16 to 47 L/s at a gross head of 915 m. The electrical power that is generated is fed into the mine power grid for internal

use. However, the output is metered and will in essence be "sold" to the local power company at their avoided energy cost.

OP 8–85. Demonstration Project for Application of High Head Turbines to Deep Underground Mining Operations, by R. N. Torbin, R. Cardenas, and E. D. Thimons. Paper in Proc. ASME 3d Symp. on Small Hydropower Machinery, New Orleans, LA, Dec. 9–14, 1984, pp. 165–170. The U.S. Bureau of Mines has undertaken a program to evaluate the value of energy recovery from incoming cooling and/or service water into deep mine shafts. Through its contractor, Foster-Miller, Inc., the Bureau is proceeding with the design, installation, and operation of a demonstration energy recovery system to be operated in the Hecla Mining Co.'s Lucky Friday Mine, Mullan, ID. The objectives of the program are to verify the predicted energy savings resulting from the use of a turbine generator system to recover the available potential energy of the incoming water, to demonstrate the viability of the system hardware, and to promote the use of this technology throughout the U.S. mining industry. Various types of energy recovery devices were considered including turbines, reverse running pumps, hydrotransformers, and high-pressure heat exchangers. The demonstration system will consist of an impulse turbine directly coupled to a 300-kW induction generator. The turbine is designed to operate over a range of flow between 16 and 47 L/s at a net head of 850 m. This paper discusses energy recovery principles in generic terms and indicates how they were applied to the Lucky Friday installation.

OP 9–85. Application of Vitrinite Reflectance To Interpret Gas Content, Maximum Depth of Burial, and Paleogeothermal Gradient of Coal Beds in Dunkard Basin, by James P. Ulery and Donald G. Puglio. Am. Assoc. Petrol. Geol. Bull., v. 68, No. 12, Dec. 1984, pp. 1929–1930. A thorough understanding of the interrelationship of the geologic history, thermal maturation, and petrographic characteristics of a coalbed is necessary to interpret its present methane content. Coalification of organic matter occurs contemporaneously with burial through the interaction of temperature and pressure during geologic time. In initial stages of coalification, pressure is an important factor in volume, pore, and moisture reduction. In later stages of coalification, temperature and duration of heating are more significant. During this period, methane and other gases are generated as coalification byproducts. The degree of coalification, referred to as rank or thermal maturity, is commonly measured by vitrinite reflectance. This value has been used by the Bureau of Mines to determine the rank of Permian and Pennsylvanian coalbeds from several boreholes in southwestern Pennsylvania. From these values, estimates of former depths of burial and coalification temperatures may be made.

OP 10–85. Effects of Clastic Dikes on Roof-Rock Stability in Central Pennsylvania Coal Mine, by John L. Hill III. Am. Assoc. Petrol. Geol. Bull., v. 68, No. 12, Dec. 1984, p. 1920. Clastic dikes are common in coalbeds of the Appalachian basin. Their presence often causes delays in mine production and poses safety hazards to mine personnel. The U.S. Bureau of Mines is conducting research on the occurrence and origin of clastic dikes and associated roof-rock instability, to gain a better understanding of the effect clastic dikes have on ground pressure around mine openings. Geologic mapping and pressure monitoring of clastic dikes at the Greenwich Collieries North Mine, Indiana County, PA, have provided insights to this problem.

OP 11–85. An Investigation of the Causes of Cutter Roof Failure in a Central Pennsylvania Coal Mine: A Case Study, by John L. Hill III and Eric R. Bauer. Ch. 62 in Rock Mechanics in Productivity, Protection (25th Symp. on Rock Mechanics, Chicago, IL, June 25–27, 1984), pp. 603–614. Bureau of Mines research in a coal mine of central Pennsylvania revealed a correlation between the occurrence of clastic dikes and formation of cutter roof failure. In-mine mapping of ground conditions showed an increase in roof failure in areas of high frequencies of clastic dikes. Rock pressure monitoring around clastic dikes registered the greatest amount of roof loading near the intersection of dikes with the rib. Load cells measuring horizontal pressure changes in the roof indicated that the greatest pressure changes were occurring perpendicular to entry headings when clastic dikes were present. Analysis of rock pressure monitoring showed that the roof behaved as two cantilever beams when severed by a clastic dike. Additional roof supports such as trusses and cribbing were found to effectively support the roof in areas of clastic dikes and prevent cutter roof failure. However, these methods were only successful when employed shortly after mining.

OP 12–85. New Developments in Materials Recycling by the U.S. Bureau of Mines, by Robert C. Horton and Charles B. Kenahan. Paper in Materials Substitution and Recycling (57th Meeting, Structures and Materials Panel, NATO-AGARD Conf. Proc. No. 356, Vimiero, Portugal, Oct. 14–19, 1983). NATO-AGARD reprint, Apr. 1984, pp. 15–1 — 15–24. The U.S. Bureau of Mines has been a strong advocate of materials recycling for over 50 years and has emerged as a world leader in the development of innovative recycling technology. Because recycling conserves mineral reserves, the Bureau considers the mineral-based waste products generated by industry and the consuming public as potential secondary mineral resources. This paper presents promising technical solutions to complex recycling problems such as recovery of cobalt, nickel, and chromium from superalloy scrap; the separation, recovery, and reuse of nickel and chromium from stainless and specialty steel wastes; precious metal recovery from electronic scrap; an environmentally acceptable method for recycling lead-acid batteries; recovery of nonferrous metals from scrap automobiles; and rapid scrap identification methods suitable for today's modern alloys.

OP 13–85. Concepts for Controlling the Quartz Dust Exposure of Coal Mine Workers, by Robert A. Jankowski, Robert E. Nesbit, and Fred N. Kissell. Paper in Proc. WV Univ. Coal Mine Dust Conf., Morgantown, WV, Oct. 8–10, 1984, pp. 126–136. Reduced standards resulting from exposure to coal mine dust containing more than 5% quartz are currently one of the most serious health compliance problems facing both the underground and the surface coal mining industry. In 1982, the Bureau of Mines initiated research to identify sources of quartz dust and means to allow mine operators to comply with more stringent standards. Results to date have identified the sources of quartz dust for both underground and surface operations from both a geological and an operational viewpoint. Control techniques involving improved dust scrubber systems, high-pressure sprays, improved spray systems, mining cycle modifications, and better roof bolter maintenance have been identified and evaluated. The Bureau is continuing in-house and contract research designed to allow mine operators to comply with the more stringent standards established to protect the health of the coal mining work force, without adversely affecting productivity.

OP 14–85. Evaluation of Homotropal Ventilation for Longwall Dust Control, by Jonathan S. Kelly and Robert A. Jankowski. Paper in Proc. WV Univ. Coal Mine Dust Conf., Morgantown, WV, Oct. 8–10, 1984, pp. 92–100. It has been found that a major problem in longwall mining is contamination of the face intake air. Using typical mining cycles and respirable dust data to analyze the potential impact of respirable dust exposures, homotropal ventilation as a possible cost-effective technique for reducing intake respirable dust contamination was investigated. The analyses showed respirable dust exposures on any cutting cycle could be reduced using homotropal

ventilation. During a tailgate-to-headgate cutting cycle, e.g., homotropal ventilation was predicted to reduce the shearer operator's exposure by 40 pct. After theoretically establishing the potential benefits of homotropal ventilation, researchers expanded the effort to (1) quantify the benefits and potential problems of homotropal ventilation with underground evaluations, (2) document the ventilation systems and mining techniques utilized by homotropal mines, and (3) provide technical information to the mining industry on the use of homotropal ventilation.

OP 15–85. Aluminum Recovery From Domestic Clay, by Arne Landsberg. Paper in Mining Convention Session Papers, Phoenix, September 24–26, 1984, Set. No. 10. Am. Min. Congr., Washington, DC, reprint 1984, 6 pp. Kaolinitic clays are potentially a vast domestic resource for aluminum. Utilization of this resource could decrease or eliminate the nearly complete dependence of the United States on foreign aluminum raw materials for this important metal. The Bureau of Mines conducted a research and development program to provide technology that would produce a feed of aluminum oxide from clay as a viable substitute for the Bayer alumina now produced from imported bauxite. In addition, the Bureau investigated the possibility of an anhydrous chloride route from clay to aluminum. This route included direct chlorination of clay, purification of the aluminum chloride product, and salt bath electrolysis of the purified aluminum chloride to the metal. The electrowinning step, now known as the Alcoa smelting process, has been commercially proven. Work is continuing on the direct clay chlorination and chloride purification steps to determine if the desired technology can be developed.

OP 16–85. Rock Mechanics Studies in a Mechanized Longwall Coal Mine, by Paul H. Lu. Ch. 12 in Stability in Underground Mining II (Proc. 2d Int. Conf. on Stability in Underground Mining, Lexington, KY, Aug. 6–8, 1984). Soc. Min. Eng. AIME, Littleton, CO, 1984, pp. 189–209. Methods and results of measuring three basic parameters for ground stability control — ground pressure, strata movement, and geomechanical properties of mine rock — are presented. It was found that these parameters can be measured in situ by simple and practical techniques with nonsophisticated and inexpensive instruments. Specifically, a drillhole dilation technique employing a cylindrical hydraulic borehole pressure cell (CPC) was used to determine the modulus of rigidity. Premining ground pressures were determined by pressure convergence tests with a combination of one CPC and two pre-encapsulated flat hydraulic borehole pressure cells (BPC) installed in a single drillhole. Abutment pressures and pillar loading were monitored with BPC. Differential strata movements and bed separations were measured with self-recording 10-anchor-point extensometers. Roof-to-floor convergence was measured with self-recording convergence meters. Some applications of these in situ-determined parameters to mine design and ground stability control are also discussed.

OP 17–85. Control of Acid Drainage From Fresh Coal Refuse: Food Preservatives as Economical Alternatives to Detergents, by Steven J. Onysko, Patricia M. Erickson, Robert L. P. Kleinmann, and Michael Hood. Paper in 1984 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation, Lexington, KY, Dec. 2–7, 1984, pp. 35–40. Water soluble detergents such as sodium lauryl sulfate (SLS), which can sorb to pyritic materials, have been successfully used by the mining industry for acid drainage prevention in coal refuse. Detergent control of acid drainage from refuse may be uneconomical, however, at sites where extensive rainfall or ground water movement results in rapid SLS washout. In this study, the performance of two alternative acid control chemicals, sodium benzoate and potassium sorbate, was compared with the performance of SLS in pilot-scale experiments with extensively leached, fresh coal refuse.

OP 18–85. The Influence of a Ceramic Particle Trap on the Size Distribution of Diesel Particles, by Kirby J. Baumgard and David B. Kittelson. Paper in Proc. Soc. Automot. Eng. Int. Congr. & Expo. on Diesel Particulate Control, Detroit, MI, Feb. 25-Mar. 1, 1985. SAE Tech. Pap. 850009, 1985, 12 pp. The Bureau of Mines sponsored research to determine the particle size distribution and concentration of submicrometer particles upstream and downstream of a ceramic particle trap mounted in the exhaust stream of a Caterpillar 3304 diesel engine. Particle size distribution and mass were measured with an electrical aerosol analyzer, a diffusion battery-condensation nuclei counter combination, and filters. The engine was operated at 1,400 and 1,800 rpm and three load conditions at each speed. In general, the collection efficiency of the trap was high, ranging from 89% to 96%. Size distribution analysis revealed that the trap was generally more efficient at removing particles smaller than 0.1 μm diam than larger particles. However, under certain conditions formation of nuclei downstream of the trap took place. This is probably associated with the penetration of hydrocarbon vapors through the trap that nucleate to form very fine particles as the exhaust is diluted and cooled. Particle concentration measurements during regeneration revealed significant transient particle generation. A large concentration peak of accumulation mode size particles appeared shortly after the onset of regeneration, followed by a broader peak of nuclei mode size particles. It is believed that the accumulation mode particles result from oxidation and breakup of particles deposited on the trap while nuclei mode particles result from nucleation of hydrocarbon vapors driven from the trap during regeneration.

OP 19–85. Sodium Zirconium Oxide: Molar Enthalpy of Formation at 298.15 K and Molar Heat Capacity From 5 to 1168 K, by R. P. Beyer, K. O. Bennington, and R. R. Brown. J. Chem. Thermodyn., v. 17, 1985, pp. 11–17. Part of the mission of the Bureau of Mines is to provide values of thermodynamic properties for minerals and related inorganic compounds. As part of this effort, the molar heat capacity of sodium zirconium oxide was measured from 5 to 305 K by adiabatic calorimetry and from 438 to 1,168 K by differential scanning calorimetry. The molar enthalpy of formation was determined by hydrofluoric-acid solution calorimetry. The molar enthalpy of formation at 298.15 K is $-(1{,}686.3 \pm 2.0)$ kJ·mol^{-1}. The values at 298.15 K of $C^\circ_{p,m}$, $\{S^\circ_m(T) - S^\circ_m(0)\}$, and $-\{G^\circ_m(T) - H^\circ_m(0)\}/T$ are 125.88, 125.50, and 54.88 J·K^{-1}·mol^{-1}, respectively. These functions are also calculated from 5 to 1,170 K.

OP 20–85. Heat Capacity of Aluminum Silicon Carbide (Al_4SiC_4) From 5.26 to 1047 K, by R. P. Beyer and E. A. Johnson. J. Chem. Thermodyn., v. 16, 1984, pp. 1025–1029. One of the goals of the Bureau of Mines is to provide thermodynamic quantities for minerals and related inorganic compounds. As part of this effort, the molar heat capacity of Al_4SiC_4 was measured by the Bureau from 5.26 to 301.5 K by adiabatic calorimetry and from 347 to 1,047 K by differential scanning calorimetry. The values at T = 298.15 K for $C^\circ_{p,m}$, $\{S^\circ_m(T) - S^\circ_m(0)\}$, $-\{G^\circ_m(T) - H^\circ_m(0)\}/T$, and $\{H^\circ_m(T) - H^\circ_m(0)\}$ are 145.07, 107.62, 40.66 J·K^{-1}·mol^{-1}, and 19.96 kJ·mol^{-1}, respectively. These properties are also reported from 5 to 2,000 K at convenient temperature intervals. The standard molar enthalpy of formation $\Delta_f H^\circ_m(Al_4SiC_4)$, calculated from Behrens and Rinehart's Knudson-effusion mass-spectrometric results, is $-(203.3 \pm 4.9)$kJ·mol^{-1} at 298.15 K.

OP 21–85. Longwall Dust Control by Water Infusion, by J. Cervik, A. Sainato, and E. Baker. Min. Eng., v. 37, No. 2, Feb. 1985, pp. 149–153; paper in Proc. Soc. Min. Eng. AIME Annu. Meeting, Atlanta, GA, Mar. 6–10, 1983. Soc. Min. Eng. AIME preprint 83–172, 5 pp. In Europe, water infusion is used widely to reduce generation of respirable dust during mining. Its use in the United States is limited to a few plow operations in the deeper parts of the Pocahontas No. 3 Coalbed.

The technology for infusing water into retreating longwalls is described, and results of a recent Bureau of Mines test in the Lower Sunnyside Coalbed demonstrated dust reductions ranging from 47% to 64%. Because water infusion increases moisture content of the coalbed, face air velocities in excess of 2.5 m/s (500 fpm) are possible, further diluting dust levels before dust entrainment occurs. An economic analysis shows a 23% reduction in operating costs when coal production is increased by changing from unidirectional to bidirectional mining with water infusion.

OP 22–85. Update on Recovering Lead From Scrap Batteries, by E. R. Cole, Jr., A. Y. Lee, and D. L. Paulson. J. Met., v. 37, No. 2, Feb. 1985, pp. 79–83. Previous work at the Bureau of Mines Rolla Research Center resulted in successful development of a bench-scale, combination electrorefining-electrowinning method for recycling lead from scrap batteries by using waste fluosilicic acid as electrolyte. This paper describes larger scale experiments. Prior attempts to electrowin lead failed because large quantities of insoluble lead dioxide (PbO_2) were deposited on the anodes at the expense of lead deposition on the cathodes. A major breakthrough was achieved with the discovery that PbO_2 formation at the anodes is prevented by adding a small amount of phosphorus to the electrolyte. The amount of PbO_2 formed on the anodes during lead electrowinning was less than 1% of the total lead deposited on the cathodes.

OP 23–85. Computer Simulation of Ventilation in Multilevel Mines, by John C. Edwards and Li Jing-shu. Paper in Mine Ventilation. Third International Congress, Harrogate, England, 1984, ed. by M. J. Howes and M. J. Jones (cosponsored by Inst. Min. and Metall. and Inst. Min. Eng., London, England, June 13–14, 1984). Stephen Austin/Hertford, London, England, 1984, pp. 47–51. A Bureau of Mines computer program was applied to a prediction of ventilation in a small-scale test mine and in a deep multilevel working mine. In both cases, temperature-induced natural ventilation and fan-driven, forced ventilation contributed to air movement; there was substantial agreement between predicted and measured airflow rates. It was demonstrated how the real-time capability of the program can be used to simulate the spread of a stench warning throughout a mine in which an emergency has occurred. A novel application of the program to an analysis of the methane depletion from a previously sealed gassy coal mine is also presented.

OP 24–85. Rock Stability Analysis by Acoustic Spectroscopy, by D. R. Hanson. Min. Eng., v. 37, No. 1, Jan. 1985, pp. 54–60; Soc. Min. Eng. AIME preprint 84–205, 1984, 7 pp. The acoustic vibrational spectra of impacted rock slabs were examined at the Denver Research Center, U.S. Bureau of Mines, in an attempt to characterize the behavior of partially detached mine roof rocks. The ultimate goal of this study was to develop a technique or instrument that could provide a quick, accurate, quantifiable measure of mine roof stability. The power spectra of unstable rock slabs were found to contain more energy in the range of 200 to 1,000 Hz than solid rock. Comparison of the power contained between 500 and 1,000 Hz with that between 3,000 and 3,500 Hz provided a quantitative measure of rock stability. A lightweight prototype field instrument was designed, constructed, and field tested. This battery-powered instrument computes the power contained in the two frequency bands, compares their magnitude, and displays a number related to the stability of the block tested. Field tests showed the instrument provided reliable measurements of block stability even under conditions of noise that would have seriously degraded the accuracy of the standard methods of roof sounding.

OP 25–85. Mining, by Barry W. Klein, Phillip N. Yasnowsky, and Annette P. Graham. Ch. 7 in U.S. Industrial Outlook 1985, Dep. Commerce, 26th ed., Jan. 1985, pp. 7–1—7–6. The mineral industry is expected to grow modestly in 1985, continuing the gradual improvement that began late in 1983. This chapter covers the mining of ores of such metals as iron, copper, gold, silver, and molybdenum (SIC 10) and the production of nonmetallic minerals such as stone, sand and gravel, clays, phosphate rock, salt, sulfur, and potash (SIC 14), but excludes fuels.

OP 26–85. Industrial Evaluation of Sulfur Concrete in Corrosive Environments, by W. C. McBee, T. A. Sullivan, and B. W. Jong. Min. Eng., v. 37, No. 1, Jan. 1985, pp. 37–44; paper in Proc. Soc. Min. Eng. AIME Fall Meeting, Salt Lake City, UT, Oct. 19–21, 1983. Soc. Min. Eng. AIME preprint 83–306, 11 pp. A sulfur concrete technology was developed by the Bureau of Mines, where chemically modified sulfur is used with suitable mineral aggregates to produce construction materials that are resistant to corrosion by acids and salts. This report presents a summary of the basic technology and results of testing the materials under actual operating conditions in 50 corrosive environments in 40 commercial plants. After 4 years of testing, there was essentially no evidence of material degradation or loss of strength. Regular concrete materials were attacked and, in some cases, completely destroyed under the same conditions. Testing is continuing to establish ultimate longevity and durability of the sulfur concretes. The materials are finding widespread applications in metallurgical, chemical, and fertilizer processing plants.

OP 27–85. Cross-Measure Borehole Technology for Gob Gas Control, by F. E. McCall, A. A. Campoli, J. Cervik, F. Burns, and P. Thakur. Min. Eng., v. 36, No. 12, Dec. 1984, pp. 1672–1676; paper in Proc. Soc. Min. Eng. AIME Annu. Meeting, Atlanta, GA, Mar. 6–10, 1983. Soc. Min. Eng. AIME preprint 83–161, 6 pp. Methane enters mine workings from adjacent strata and the mined coalbed. In longwall operations, the primary sources of methane are the coalbeds, sandstones, and shales that comprise the overlying strata. As shallower reserves of coal are depleted, new mines will be opened under deeper cover, where both the surrounding strata and the mined coalbed are likely to be more gassy. At present, ventilation and surface gob holes are common methods of controlling gob gas. Surface gob holes cannot always be drilled because mining may be under populated areas, topography may be too severe, or access to drilling sites may be denied. New methods of gob gas control need to be developed that are independent of the mine ventilation system and surface gob holes. This paper describes joint efforts by the U.S. Bureau of Mines and the mining industry to adapt European cross-measure borehole technology for methane drainage to retreat longwall mining in the United States.

OP 28–85. An Assessment of Fe-Mn-Al Alloys as Substitutes for Stainless Steels, by J. C. Benz and H. W. Leavenworth, Jr. J. Met., v. 37, No. 3, Mar. 1985, pp. 36–39. This paper details a study by the Bureau of Mines that examined the properties of Fe-Mn-Al alloys compared with austenitic stainless steels. Problems were encountered in melting, casting, and cutting the alloy. However, they could be easily hot worked, and they had good mechanical properties unless aged. Neither alloy tested exhibited good oxidation resistance during mild thermal cycling tests.

OP 29–85. Reducing Longwall Face Ignitions, by Andrew B. Cecala, John O'Green, Richard W. Watson, and Robert A. Jankowski. World Min. Equip., v. 9, No. 1, Jan. 1985, pp. 44–46. Methane ignitions are still one of the most serious hazards facing coal mine operators today. There have been a number of coal mine fatalities caused by methane ignitions over the past few years. Records from 1971 through 1980 indicate an average of approximately 50 recorded ignitions over the latter part of this period due, in part, to ignitions occurring on longwall panels where the high rate of extraction liberates methane at a higher rate. As mining continues to

expand to greater depths, it is estimated that methane levels will also increase.

OP 30–85. Controlling Coal Mine Bumps, by Claude A. Goode, Anthony Zona, and Alan A. Campoli. Coal Min., v. 21, No. 10, Oct. 1984, pp. 48–53. A coal bump or burst is defined as the instantaneous violent failure of a coal pillar from overstress. The causes of coal bumps are not well understood, although minor disturbances are a daily occurrence in bump prone seams. Lack of knowledge about coal bumps coupled with questionable mining practices can create disastrous consequences. This paper describes different coal bumps, discusses accidents caused by coal bumps, and presents preventive measures.

OP 31–85. Separation and Recovery of Cobalt From Copper Leach Solutions, by T. H. Jeffers. J. Met., Jan. 1985, pp. 47–50. Significant amounts of cobalt, a strategic and critical metal, are present in readily accessible copper recycling leach solutions. However, cost-effective technology is not available to separate and recover the cobalt from this low-grade domestic source. The Bureau of Mines has developed a procedure using a chelating ion-exchange resin to successfully extract cobalt from a pH 3.0 copper recycling solution containing only 30 mg/L cobalt. Cyclic tests with the commercial resin XFS–4195 in 4-ft-high by 1-in-diam columns gave an average cobalt extraction of 95% when 65 bed volumes of solution were processed at a flow rate of 4 gpm/ft^2. Elution of the cobalt using a 50-g/L H_2SO_4 solution yielded an eluate containing 0.5 g/L cobalt. Selective elution of the loaded resin and solvent extraction procedures using di-2-ethylhexyl phosphoric acid and Cyanex 272 removed the impurities and produced a cobalt sulfate solution containing 25 g/L cobalt.

OP 32–85. $2Al_4C_3$·SiC: A New Intermediate Phase in the Al-Si-C System, by B. L. Kidwell, L. L. Oden, and R. A. McCune. J. Appl. Crystallogr., v. 17, No. 6, 1984, pp. 481–482. All ternary intermediate phases in the Al-Si-C system reported to date lie on the join between Al_4C_3 and SiC, which are the only binary compounds in the Al-C and Si-C systems. The existence of Al_4C_3·SiC is well documented and Al_4C_3·2SiC has been reported. During an extensive study of phase relations in the ternary system at the Bureau of Mines Albany Research Center, Al_4C_3·SiC was confirmed, but Al_4C_3·2SiC was not. In addition, a new ternary intermediate phase, $2Al_4C_3$·SiC, was discovered, which is the subject of this communication.

OP 33–85. Measurements and Computer Analysis of Ventilation Airflow at the Lake Lynn Laboratory, by J. S. Li and J. C. Edwards. Ch. 66 in Computer Analysis of Ventilation Airflow (Proc. SME-AIME 1st Conf. on Use of Computers in the Coal Industry, WV Univ., Morgantown, WV, Aug. 1-3, 1983). Soc. Min. Eng. AIME, Littleton, CO, 1983, pp. 547–578. A prediction was made of the airflow at the Bureau of Mines Lake Lynn Laboratory with a ventilation computer program that accounts for fan-driven forced ventilation and temperature-induced natural ventilation. There was substantial agreement between measured and predicted airflow rates. The capability of the program is demonstrated as a planning aid for ventilation under emergency conditions in a multilevel coal mine. Smoke spread in a multilevel mine is analyzed following the occurrence of two events, the failure of the main exhaust fan and the development of a fuel-rich fire in a passageway.

OP 34–85. Continuous Ferric Chloride Leaching of Galena, by J. E. Murphy, B. R. Eichbaum, and J. A. Eisele. Paper in Proc. Soc. Min. Eng. AIME Annu. Meeting, Los Angeles, CA, Feb. 6-Mar. 1, 1984. Soc. Min. Eng. AIME preprint 84–124, 1984, 6 pp.; paper in Miner. and Metall. Process., v. 2, No. 1, Feb. 1985, pp. 38–42. The Bureau of Mines demonstrated ferric chloride leaching of galena concentrate on a continuous bench scale basis. Leaching was performed at 95° C (200° F) and with a contact time of 15 min. The ferric chloride leaching solution was continuously fed to a leaching tank at a constant rate for periods up to 45 h. In each test, a constant redox potential was maintained in the slurry exiting the leaching tank by controlling the concentrate feed rate. In the 45-h test, lead extraction exceeded 99.5%, and the lead chloride produced was 99.97% pure.

OP 35–85. Whole Body Vibration Exposure of Surface Coal Mining Machine Operators, by Paul J. Remington, Douglas W. Andersen, Gerald Redmond, and Roy Bartholomae. (Proc. SAE Int. Congr. & Expo., Detroit, MI, Feb. 27-Mar. 2, 1984). SAE Tech. Paper Series 840479, 1984, 10 pp. Field measurements utilizing a seat pad accelerometer were made on 61 surface coal mining machines in order to quantify the vibration levels experienced by the operators. Those data were combined with information on the statistics of the operating times of those machines in order to compare the operator's vibration exposure to the criteria in ISO 2631, "A Guide for the Evaluation of Human Exposure to Whole Body Vibration." The comparison showed that about half of all surface coal mining machine operators can be expected to be exposed to vibration exceeding the fatigue decreased proficiency criterion, whereas only 7% to 22% would be expected to experience vibration exceeding the exposure limit. Detailed exposure statistics are presented, and the implications of the results are discussed.

OP 36–85. Methane Drainage With Cross-Measure Boreholes on a Retreat Longwall Face, by Pramod C. Thakur, Stephen D. Lauer, and Joseph Cervik. Pres. at Soc. Min. Eng. AIME Fall Meeting and Exhibit, Salt Lake City, UT, Oct. 19–21, 1983. Soc. Min. Eng. AIME preprint 83–398, 13 pp.; also in Min. Eng., v. 37, No. 12, Dec. 1985, pp. 1375–1380. Methane drainage by cross-measure boreholes on retreat longwall faces can be a viable alternative to the vertical gob degas boreholes under favorable circumstances. This study, the first application of this technique in the Pittsburgh coal seam, was performed in a working mine in northern West Virginia. Fourteen small-diameter, inclined boreholes were drilled over a retreat longwall panel from gate roads, to intersect the overlying coal seams. All boreholes were manifolded to a pipeline and the gob gas was extracted by an exhaust fan on the surface. The methane capture ratio was poor at 7% to 18% at various stages of the longwall panel. A vertical gob degas borehole captured an additional 20% gas. Poor results were caused by premature failures of the cross-measure boreholes leading to air leakage. For better performance, the boreholes should be drilled from a point 30 to 45 m from the longwall pillar over the largest chain pillar, the standpipe should be grouted for at least 6 m, and the entry containing boreholes and the pipeline must be supported to ensure access for maintenance and the optimization of methane capture. Coursing the ventilation air around the longwall such that it forces methane-migration toward cross-measure boreholes can further improve methane capture. The optimum vertical inclination is 45° to 10°.

OP 37–85. Leaching Superalloy-Aluminum Intermetallic Compounds, by G. B. Atkinson and D. J. Bauer. Paper in Proceedings of the Second Conference on Management of Municipal, Hazardous, and Coal Wastes, ed. by S. Sengupta. U.S. Dep. Energy, DOE/METC/84–34, Sept. 1984, pp. 66–75. The Bureau of Mines investigated a method for increasing the leaching rate of bulk superalloy scrap to facilitate recycling and recovery of critical metals such as Ni, Co, and Cr. Three superalloys were investigated: cast nickel-base superalloy IN–738, wrought nickel-base superalloy Rene-41, and cast cobalt-base superalloy Mar–M–509. Superalloys melted with 20%, 30%, 40%, and 50% Al metal to form intermetallic compounds were easily crushed to a convenient particle size and dissolved rapidly in acid solutions. For example, leaching ½-in pieces of unalloyed IN-738 with excess 6*N* HCl at 95° C for 2 h dissolved about 0.5%, while leaching 10 g of minus 20-mesh 30% Al–70% IN-738 with excess 6*N* HCl at 95° C for 2 h dissolved 96.2%.

OP 38–85. Potash Recovery From Brines by Solar Evaporation and Flotation, by D. G. Foot, Jr., and J. L. Huiatt. Ch. 12 in Salts & Brines '85, ed. by W. J. Schlitt and W. C. Larson. Soc. Min. Eng. AIME, New York, 1985, pp. 119–133. The Bureau of Mines investigated methods of recovering potash values from process and waste brines. Laboratory pan evaporation of four chloride brines produced crude salts containing predominantly sylvite, halite, and carnallite. Six sulfate-chloride brines produced crude salts containing primarily schoenite, kainite, leonite, sylvite, carnallite, and halite. Potash grades ranged from 7.2% to 22.2% K_2O, and recoveries by crystallization ranged from 85% to 99%. Sylvite flotation from chloride evaporites with amine collector recovered 90% to 97% of the potash in a concentrate containing 54.3% to 60.3% K_2O. Fatty acid flotation of the high sulfate evaporite recovered 78% of the sulfate minerals in a 28%–K_2O concentrate. Flotation of the remaining chloride minerals with amine collector recovered 80% of the potash in a 59.7%–K_2O concentrate. Solar evaporation of 10,000 gal of brine recovered 99% of the potash in a crude evaporite containing 24.5% schoenite and 20% sylvite. Flotation in a 100-lb/h continuous flotation unit recovered over 95% of the potash in schoenite and sylvite concentrates containing 28% and 62.3% K_2O, respectively.

OP 39–85. Recovery of Fluorite and Byproducts From the Fish Creek Deposit, Eureka County, Nevada, by Donald G. Foot, Jr., Freddy W. Benn, and Jerry L. Huiatt. Paper in Physical Chemistry of Extractive Metallurgy, ed. by V. Kudryk and Y. K. Rao. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 251–262. Flotation methods were investigated for recovering fluorite and byproduct beryllium from the Fish Creek deposit of Nevada. The preferred method includes (1) fluorite rougher and cleaner flotation, (2) desliming at 20 μm, (3) muscovite flotation, (4) silicate flotation, (5) hypochlorite wash of silicate concentrate, and (6) beryllium rougher and cleaner flotation from the silicate concentrate. Laboratory results showed that over 94% of the fluorite was recovered in a concentrate containing 96% CaF_2. Beryllium flotation produced concentrates containing in excess of 5% BeO with recoveries over 70%. A 100-lb/h continuous flotation unit was constructed to demonstrate this procedure.

OP 40–85. Thermodynamic Properties of S–Fe–Co–Ni and Fe–Co–Ni Systems, by N. A. Gokcen and M. R. Baren. Metall. Trans. A, v. 16A, May 1985, pp. 907–911. The values of S activity in the liquid S–Fe–Co–Ni system were determined from unpublished equilibrium data for $H_2 + S$ (in alloy) = H_2S. The activity coefficient of S ranged from 0.387 to 1.896 and increased with increasing concentrations of Fe and Co. The published values for the activities in the binary systems Fe–Co, Fe–Ni, and Co–Ni were used to calculate the activities in the ternary Fe–Co–Ni alloys, and the results were expressed as a function of composition. This function was used with the activity coefficients of S in the binary metal solvents to express the activity coefficient of S in the ternary metal solvents as a function of mol fractions of Fe, Co, and Ni. The experimental values for S in Fe–Co–Ni agreed well with the calculated values based on the binary metal solvents, and this showed that all the activity values were consistent.

OP 41–85. An Electrochemical Study of Grinding Media Corrosion, by A. E. Isaacson and J. L. Huiatt. Paper 364 in Corrosion 85. Natl. Assoc. Corros. Eng., Houston, TX, 1985, 15 pp. The corrosion of carbon steel and high-chromium white iron grinding balls was investigated. Electrochemical measurements in an ultrasonic apparatus used to abrade the ball demonstrated that pyrite in a test slurry of pH 8 increased the corrosion rate of a steel ball from 27 mils per year (mpy) without pyrite to 80 mpy with pyrite. The rate depended upon pH and the metal-to-metal surface area ratio. When magnetite was substituted for pyrite, the rates were lower. Using an impactor apparatus to simulate grinding action, passivation rates on high-chromium iron balls in mill water were measured. At pH 2, passivation rates for 22%, 29%, and 31% Cr balls were statistically equal. At pH 5, 7, and 9, the passivation rates of the 31% Cr ball fell between those of the 22% and 29% Cr balls. Microstructural analyses indicated that the longer time for the 31% Cr ball, compared with the 29% Cr ball, was attributed to carbides that reduced the chromium content in the matrix. In a mill, the passivation layer may be removed faster than it is formed; consequently, passivation may have a minor effect in reducing corrosion.

OP 42–85. Discriminating Syndepositional Vs. Post-Depositional Coalbed Discontinuities, by Carla A. Kertis. Abstr. in Proc. PA Acad. Sci., v. 58, No. 1, 1984, p. 119. Processes that are contemporaneous with peat deposition create coalbed discontinuities that are clearly distinguishable from discontinuities that form post-depositionally. Syndepositional discontinuities are most commonly the result of scouring by ancient distributary channels. These breaks in the coalbed are recognized by several criteria: (1) absence or thinning of the coalbed, (2) numerous partings or binders, (3) decreased coal quality, (4) anomalous coal thicknesses immediately adjacent to the channel, and (5) rolls in the coalbed. Syndepositional discontinuities may also result from channel-bank slumping, growth of structural folds, and topographic irregularities in the peat swamp. Discontinuities generated after peat deposition commonly occur in conjunction with syndepositional discontinuities and include channel scouring and associated slumping, tectonic faulting, and the formation of clay veins. Syndepositional discontinuities created by distributary channel activity produce numerous warning signs, as mentioned, and can be predicted well in advance of mining. On the other hand, post-depositional discontinuities occur abruptly and give little advance notice of their presence. The problem associated with syndepositional discontinuities are more numerous.

OP 43–85. Imposing Hierarchical Data Structures on Commercial Software for Mining Applications, by John C. LaScola and David M. Hyman. Ch. 7 in Proceedings of SME-AIME Second Conference on the Use of Computers in the Coal Industry. Soc. Min. Eng. AIME, New York, 1985, pp. 49–55. Large amounts of data gathered during several projects requiring considerable amounts of repetitive computation and file organization are best represented logically by a tree or hierarchical structure. Much existing table-oriented software provides the computational, maintenance, and graphic capabilities, but lacks an inherently hierarchical data structure. The solution was to impose a dynamic hierarchical data structure onto a set of tables and graphs generated by a commercial decision-support software package. A general purpose procedure was written to produce a multileveled tree structure of subdirectories, where the names of the subdirectories describe the source of the data. The heart of this system is the use of table entries as nodes of a tree that point to the next level of branching until the actual data are finally reached.

OP 44–85. Bromine, by P. A. Lyday. Min. Eng., v. 37, No. 5, May 1985, pp. 463–465. This article is a brief overview of the bromine industry in 1984, covering production, use, Government developments, company developments, foreign activities, and outlook.

OP 45–85. Iodine, by P. A. Lyday. Min. Eng., v. 37, No. 5, May 1985, p. 473. This article is a brief overview of the iodine industry in 1984, covering U.S. developments, stockpile and imports, foreign developments, and outlook.

OP 46–85. Overview of Bureau of Mines Coal Mine Research, Part II, by John N. Murphy. Min. Technol., Dec. 1984, pp. 396–399. The article gives an overview of the Bureau of Mines conservation and development program. The mining technology section briefly describes research highlights in underground coal mining, room-and-pillar mining, longwall mining, improved cutting, and support systems. The resource conservation technology section describes various research

efforts in mine waste control, acid mine water drainage control, reclamation methods, restoration and revegetation, abandoned mine fire control, and surface stability.

OP 47–85. In-Plant Agglomeration and Recycling of Specialty Steelmaking Particulate Wastes, by Leander A. Neumeier and Marvin J. Adam. Paper in 4th International Symposium on Agglomeration, ed. by C. E. Capes. Bookcrafters, Inc., Chelsea, MI, 1985, pp. 421–431. The Bureau of Mines has devised a process for the in-plant recovery of about 90% of the chromium and molybdenum and well over 90% of the nickel and iron from stainless steelmaking electric-furnace dusts, argon-oxygen decarburization vessel dusts, mill scale, and oily swarf. Other metals such as manganese are also recovered. A key to the process is the blending of the mixed wastes with coke breeze reductant and binder and pelletizing the mixture with a drum or disk pelletizer. The mill scale and coke breeze are sized to minus 35 mesh. The other ingredients are fine and require no sizing. Small amounts of cement or bentonite can serve as binder. Such pellets, after drying, have sufficient strength for handling and adding to the furnace for metal recovery. Some silicon or aluminum furnace addition helps reduce chromium from the slag. The pellets can be smelted in all-pellet heats, but the recommended procedure is to charge the pellets to the production furnace in amounts up to 20% of the charge, or in proportion consistent with the waste generation rate, in lieu of part of the scrap normally charged. The technique is applicable to a variety of stainless steelmaking or related specialty steelmaking wastes.

OP 48–85. Prevention of Aggregate Formation During Oxidation Pressure Leaching, by A. E. Petersen. TMS Tech. Paper A85–22, Metall. Soc. AIME, Warrendale, PA, 1985, 15 pp. Sulfur-bound aggregates, formed during oxidation pressure leaching of pyritic concentrates, can cause severe operating difficulties. Laboratory scale research was conducted by the Bureau of Mines that resulted in a selective pressure-leach technique that solubilizes the metal values for recovery and prevents aggregate formation. The method primarily involves (1) avoiding pyrite overgrinding and (2) leaching with low partial pressures of oxygen. Data are presented for cobaltite-bearing concentrates from a domestic source. Over 90% of the cobalt and nickel were extracted, leaving unaggregated residues containing iron arsenates and pyrite.

OP 49–85. Chloride-Based Dissolution of Hardface Alloy Grinding Waste, by L. D. Redden, S. M. Giroux, R. D. Groves, and D. C. Seidel. TMS Tech. Paper A85–24, Metall. Soc. AIME, Warrendale, PA, 1985, 15 pp. Dissolution studies were undertaken by the Bureau of Mines to develop a method for digesting hardface alloy grinding waste as a first step in recovering the valuable constituents. A successful laboratory method was devised that included solvent degreasing and dissolution in hot hydrochloric acid sparged with chlorine gas. Although satisfactory dissolution was also achieved by leaching separately with hydrochloric acid or chlorine gas, these two leaching systems produced liquors not amenable to subsequent processing because of a high tungsten concentration. When the combination hydrochloric acid-chlorine gas leach was used, the tungsten precipitated almost quantitatively, producing a liquor suitable for cobalt, nickel, and chromium recovery.

OP 50–85. Titanium Recovery From Perovskite, by M. B. Shirts, L. J. Froisland, A. E. Petersen, and D. K. Steele. Ch. in Light Metals 1985, ed. by H. O. Bohner. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 1493–1503. Domestic perovskite ($CaTiO_3$) deposits represent a significant unutilized titanium resource. The Bureau of Mines investigated H_2SO_4–$CaTiO_3$ reactions at atmospheric pressure for converting the titanium to water-soluble sulfates. Batch studies were conducted in an agitator-equipped glass vessel to determine the effect of certain variables on the sulfation rate. The sulfation rate improved with increased acidity, temperature, and agitation, as well as with decreased particle size and percent solids. Under some conditions, over 98% of the titanium was rapidly converted to water-soluble sulfates. It appears that acid sulfation can provide a feasible first step in processing perovskite concentrates.

OP 51–85. The Phosphatic Clay Waste Problem—Flocculation as a Possible Solution, by B. J. Scheiner and Annie G. Smelley. Miner. Process. and Technol. Rev., v. 1, 1985, pp. 347–361. Flocculation of clay waste has produced dewatered material containing 11% to 27% solids depending upon the technique used. The Bureau of Mines polyethylene oxide dewatering sequence has been tested at four different minesites in Florida. Results obtained and reagent requirements varied depending upon the nature of the clay waste. Dewatered material containing up to 27% solids has been obtained, with 19% to 24% being typical. Also, it has been shown that the level of the water table is an important factor that affects the rate of consolidation of dewatered material when placed in a pit. Results strongly indicate that the clay waste at each mine is different, and in considering a solution to the problem of disposing of the clay waste, the site-specific nature of each mine must be considered.

OP 52–85. Mechanically Induced Dewatering of Ion-Exchanged Attapulgite Flocculated by a High-Molecular-Weight Polymer, by D. A. Stanley and B. J. Scheiner. Colloids and Surfaces, v. 14, No. 2, May 1985, pp. 151–159. The Bureau of Mines is investigating a dewatering technique that facilitates disposal of phosphatic clay wastes. The technique involves flocculation by high-molecular-weight polyethylene oxide (PEO) and mechanical deformation of the flocs in a trommel to release water. Field tests in central Florida determined that the ion-exchange form of the clay wastes affect their dewaterability. For this reason, the effect of sodium, potassium, calcium, magnesium, and aluminum exchange ions on the dewaterability of attapulgite slurries was investigated for PEO of both 5 and 8 million molecular weights. An empirical equation was developed that describes the dewatering of attapulgite with the polymer PEO.

OP 53–85. Cogeneration of Power at Deep U.S. Mines, by Robert N. Torbin and Edward D. Thimons. Eng. and Min. J., v. 186, No. 4, Apr. 1985, pp. 64–66. A program involving the cogeneration of power from incoming mine cooling water is being sponsored by the Bureau of Mines at the Lucky Friday Mine in northern Idaho. By U.S. standards, the Lucky Friday is a deep mine. The mine is equipped with 500 short tons of refrigeration capacity to service active underground workings. Using a turbine generator, the energy recovered from approximately 500 gal/min of cooling water piped from the surface to the 850 m level is now producing about 200 kW of electrical power at an overall system efficiency of 77%.

OP 54–85. Vitrinite Reflectance and Its Implications Regarding the Gas Content, Maximum Depth of Burial, and Paleogeothermal Gradient for Pennsylvania Coalbeds, Westmoreland Co., Pennsylvania, by James P. Ulery. Abstr. in Proc. PA Acad. Sci., v. 58, No. 1, 1984, p. 107. A commonly used indicator of coal rank is vitrinite reflectance. This value was used by the Bureau of Mines to determine the rank of Pennsylvania coalbeds from a borehole drilled along the axis of the Greensburg Syncline, Westmoreland County, PA. Thermal maturity of the coalbeds, as indicated by vitrinite reflectance, was found to relate directly to byproduct gas content. An estimate of the paleogeothermal gradient based on the Karweil nomogram for coalification indicates a significantly higher paleogeothermal gradient than had been proposed earlier. The estimated paleogeothermal gradient indicates a maximum depth of burial for the Allegheny coals of only 1.6 to 1.7 km.

OP 55–85. Characterizing and Discriminating Airborne Amphibole Cleavage Fragments and Amosite Fibers: Implications for the NIOSH Method, by Ann G. Wylie, Robert L. Virta, and Estelle Russek. Am. Ind. Hyg. Assoc. J., v. 46, No. 4, Apr. 1985, pp. 197–201. The method used by the National Institute for Occupational Safety and Health (NIOSH) for determining asbestos exposure in the mining environment involves using phase contrast microscopy to examine mineral particulates collected on air monitor filters. Particles are classified as asbestiform or non-asbestiform based on their size and length-to-width (aspect) ratio. The procedure works well when only fibers are present. In most non-asbestos mining operations, however, cleavage fragments are the most abundant airborne particulates. In this research, discriminate function analysis was applied to morphological data for airborne amphibole particulates to show that dimensional criteria could distinguish between amphibole asbestos and amphibole cleavage fragments. The data suggest that an appropriate definition of a regulatory fiber would be a particle longer than 5 μm with a width less than 3 μm and an aspect ratio of 20:1 or greater. Adoption of the 20:1 aspect ratio would greatly increase the precision of the NIOSH method.

OP 56–85. A Borehole Instrument for Measuring Mining-Induced Pressure Changes in Underground Coal Mines, by Eric R. Bauer, Gregory J. Chekan, and John L. Hill III. Paper in 26th U.S. Symposium on Rock Mechanics (SD School of Mines and Technol., Rapid City, SD, June 26-28, 1985). A. A. Balkema, v. 2, 1985, pp. 1075–1084. The Bureau of Mines Pittsburgh Research Center has been using a simple and inexpensive instrument for measuring mining-induced pressure changes in coal pillars and mine roof. The instrument, the borehole platened flatjack (BPF), is a copper flatjack (bladder) positioned between aluminum platens. It is calibrated in a simulated coal or coal measure rock medium prior to in-mine installation. Laboratory tests have shown the BPF to be repeatable and reliable and that the relationship between gauge pressure and strata pressure is dependent on the initial setting pressure. Field tests have shown that the BPF is easily installed and that it effectively indicates mine areas experiencing increasing or decreasing pressures.

OP 57–85. Recycling of Zinc Waste for Electrogalvanizing, by M. Dattilo, E. R. Cole, Jr., and T. J. O'Keefe. Conserv. & Recycling, v. 8, Nos. 3–4, 1985, pp. 399–409. Bureau of Mines researchers investigated the use of waste products containing zinc as a source of zinc for electrogalvanizing. Industrial wastes studied were lead smelter flue dust, wastewater treatment sludge, copper smelter flue dust, and brass smelter flue dust. After zinc extraction with sulfuric acid, the resultant solutions were partially purified and used to electrogalvanize 0.092-in-diam 1070 alloy steel wire, a common electrogalvanized product. The corrosion resistance of the electrogalvanized wire from the waste electrolyte was compared with electrogalvanized wire from relatively pure electrolyte prepared in the laboratory and electrogalvanized wire from an industrial electrogalvanizing plant. Corrosion rate measurements indicated that electrogalvanized wire obtained from waste electrolyte prepared from brass smelter flue dusts compared favorably with industrial electrogalvanized wire and electrogalvanized wire from the relatively pure electrolyte. The brass smelter flue dusts were chosen for more detailed studies. Impurities in the waste electrolyte caused some problems. Copper was undesirable because it passivated the soluble zinc anode. Other impurities such as cobalt and nickel were more tolerable but also slowly coated the anode. Owing to the ease of removal of copper by cementation, it posed no processing problem for electrogalvanizing. Successful completion of bench-scale work with brass smelter flue dusts led to large-scale trials at an industrial electrogalvanizing plant.

OP 58–85. Hot Air Breathing: Effects of Elevated Wet Bulb Temperatures on Tissue Temperatures of the Mouth, by Sean Gallagher, Max Vercruyssen, and N. Scott Deno. Am. Ind. Hyg. Assoc. J., v. 46, No. 6, June 1985, pp. 332–335. Six healthy young men breathed room air or one of nine hot humid air conditions on separate days for 1 hour while walking on a treadmill. Inspired wet bulb temperatures ranged from 18.9° (room air) to 49.3° C. Tissue temperatures in the mouth were measured by means of thermocouples placed on the tongue and hard palate. Analysis of variance on repeated measures showed significant increases in both tongue and hard palate temperatures as a result of increasing wet bulb temperatures; however, core temperature and heart rate were not affected. Ratings of subjective discomfort increased proportionally with increases in wet bulb temperature of the inspired air. It was concluded that wet bulb temperature of inspired air is a valuable measure to use in studying temperature responses of mouth tissues when inhaling hot humid air, particularly when investigating human tolerance levels in order to recommend Federal standards for the design of breathing apparatus.

OP 59–85. Mobile In-Pit Crushing—Product of Evolutionary Change, by E. M. Frizzell. Min. Eng., v. 37, No. 6, June 1985, pp. 578–580. Mobile in-pit crushing was first used in small limestone quarries with systems handling less than 1,102 short tons per hour. Since then, technology has advanced to include harder rock, including granite, copper ore, and waste rock. The mobile ability of these systems ranges from fully mobile units to fixed in-pit crushers including semimobile, movable, modular, and semifixed. Reasons for considering these systems include reduced cost, shorter haulage distance, more predictable future costs than trucks, more efficient energy use than trucks, and improvement in design to the point where mobile crushers are as reliable and rugged as stationary units.

OP 60–85. Partial Replacement of Chromium in Stainless Steel, by M. L. Glenn, S. J. Bullard, D. E. Larson, and S. C. Rhoads. J. Mater. for Energy Syst., v. 7, No. 1, June 1985, pp. 75–81. The Bureau of Mines conducted research on the partial replacement of chromium in stainless steel. The alloys examined contain 8 to 9 pct Cr, 11 to 14 pct Ni, and additions of up to 5 pct Mo, 2 pct Cu, and 2 pct V for corrosion-resistant applications and up to 5 pct Si and 2 pct Al for heat-resistant applications. Molybdenum additions enhanced the corrosion resistance to approach that of type 304 stainless steel (304SS) in phosphoric acid, nitric acid, citric acid, and acetic acid. Alloys with Si and Al additions had 800° C oxidation resistance superior to that of type 304SS. The stress rupture resistance of the best Si-Al alloys was comparable to that of type 304SS. The alloys had tensile properties typical of austenitic or martensitic stainless steels, depending on their structures. They exhibited greater tendency to hot crack during welding than did type 304SS. Additional levels of Ni, Mn, or C may be needed to stabilize an austenitic structure in these substitutes. Additions such as Mo, Si, and Al have potential to substitute for approximately one-half of the Cr in stainless steels for many applications.

OP 61–85. Statistical Thermodynamics of Electrons and Holes in Semiconductors, by N. A. Gokcen. J. Chem. Phys., v. 83, No. 3, Aug. 1, 1985, pp. 1240–1245. A statistical thermodynamic treatment is presented for the formation of electrons and holes in nondegenerate semiconductors, and for the accompanying standard changes in the Gibbs energy $\Delta G°$, entropy $\Delta S°$, heat capacity $\Delta C°$, and enthalpy $\Delta H°$. The treatment leads to the derivation of a new form of the variation of $\Delta G°$ with temperature; i.e., $\Delta G° - \Delta G°$ (at 0 K) $\equiv E_g - E_g$ (at 0 K) $= AT - BT \ln T$, where E_g is the forbidden band gap energy, and A and B are theoretically derivable constants, requiring relatively small adjustments for each semiconductor. Reliable data for Si, Ge, GaAs and GaP show that this equation and the derived properties $\Delta S°$, $\Delta C°$, and $\Delta H°$ are well represented as functions of temperature. The foregoing equation is also useful in predicting the temperature dependence of E_g from two values

of E_g at two different temperatures. The resulting interpretation of $\Delta G°$ indicates a distinct possibility that E_g is constant below a characteristic temperature close to 0 K.

OP 62–85. Use of Resource-Recovered Glass in Structural Clay Products, by H. Heystek, J. W. Schneider, and E. Aleshin. Resour. and Conserv., v. 12, 1985, pp. 1–12. Five different recovered glass samples were evaluated as additions to a commercial brick mix in amounts of 10, 15, and 20 wt pct. Based on the results, a large-scale plant test run of full-size brick containing 0, 10, and 15 wt minus 100-mesh ground glass was carried out. It was determined that the cost of crushing or grinding the waste glass amounted to about $3.85 per megagram and that a 10 wt pct addition of the ground glass reduced the firing temperature of the building brick about 40° C. Scumming, due to sulfates present in the ground glass, could be a problem and may require the addition of barium carbonate to a brick mix.

OP 63–85. A Computer-Implemented Coalbed Methane Model, by David M. Hyman and Peter A. Stahl. Ch. 47 in Proceedings of the SME-AIME Second Conference on the Use of Computers in the Coal Industry (Proc. Conf. Univ. AL, Tuscaloosa, AL, Apr. 15–17, 1985). Soc. Min. Eng. AIME, Littleton, CO, 1985, pp. 378–387. A computer-implemented methane model for coal mines has been developed and undergone preliminary field testing. The model, built under contract, considers two-phase (gas and water) porous medium flow in two horizontal dimensions with an optional vertical equilibrium effect. The changes in permeability and porosity of the coalbed due to mining-induced stresses are considered, as are the effects of gas slippage, flow regime, and fluid compressibility. Computer code exercises of the one-dimensional version of the methane model are presented, as well as a history-matching exercise with the results of prior Bureau of Mines in-mine research.

OP 64–85. The Application of Underground Mining Practices to Tunneling in Gassy Conditions, by Roger L. King. Ch. 29 in 1985 RETC Proceedings, Volume 1 (Rapid Excavation and Tunneling Conf., New York, NY, June 16-20, 1985). Soc. Min. Eng. AIME, Littleton, CO, 1985, pp. 482–487. The Bureau of Mines, in conjunction with the mining industry, over the past century has developed many techniques to safely handle the methane gas associated with the extraction of coal. The techniques include the detection and quantification of gas prior to mining, degasification or drainage (including predrainage from vertical and horizontal boreholes), and ventilation practices, all of which can readily be adopted by the tunneling industry.

OP 65–85. Flexible-Sulphur Concrete Materials, by W. C. McBee, B. W. Jong, and T. A. Sullivan. Paper in Proceedings of Sulphur-84 (Int. Conf., Calgary, Alberta, Canada, June 3–6, 1984). Sulphur Dev. Inst. of Canada, 1984, pp. 431–443. This report presents the development of technology for the preparation of densifiable sulfur concretes. Modified sulfur concretes were developed for use with suitable aggregates to prepare sulfur concretes that can be produced in commercial asphalt paving plants and laid and compacted with conventional asphalt paving equpment. Sulfur concrete materials were devised for use in areas where acid and salt corrosive solutions destroy construction materials currently used, including such uses as acid loading docks, floors, roadways, bridge decking, pipe, culverts, and as impervious liners for hazardous liquid storage ponds in metallurgical, chemical, and fertilizer plants.

OP 66–85. In-Plant Recycling of Specialty Steelmaking Particulate Wastes, by L. A. Neumeier and M. J. Adam. AFS Trans., v. 92, 1984, pp. 749–756. The Bureau of Mines has devised a procedure for recovering about 90 pct of the chromium and molybdenum and well over 90 pct of the nickel and iron from stainless steelmaking furnace dusts, swarf, and mill scale. Other metals such as manganese are also recovered. Initial laboratory results were confirmed and expanded to include a wide variation of stainless steelmaking waste mixtures. Later experiments included specialty steelmaking dusts other than from stainless steel. Significantly, the ease of technology transfer has been demonstrated by a number of industrial-sized (19-ton) commercial electric-furnace heats, in which the pelletized wastes represented some 10 to 20 pct of the furnace charge, replacing part of the normal scrap charge. Results of these successful large-scale trials are given. Cost evaluation indicates the procedure is economically attractive for stainless and other specialty steelmaking wastes.

OP 67–85. Semiconducting Characteristics of Galena Electrodes. Relationship to Mineral Flotation, by P. E. Richardson and C. S. O'Dell. J. Electrochem. Soc., v. 132, No. 6, June 1985, pp. 1350–1356. Electrochemical, interfacial capacitance, and surface photovoltage measurements have been used in a study of oxygen reduction and xanthate chemisorption on in situ cleaved natural and synthetic lead sulfide crystals. Electrodes cleaved in nitrogen-sparged 0.1*M* sodium tetraborate assume the flatband potential at the instant of cleavage, and thus the cleavage potential decreases with increasing bulk electron concentration. Highly n-type electrodes have a cleavage potential of $\simeq$ –0.6 V(saturated calomel electrode), and highly p-type electrodes have a value of $\simeq$ –0.2 V(saturated calomel electrode). The space charge is readily varied by applied potentials in the range –0.2V to –0.6 V. This report discusses the effect of the variable space-charge layer on oxygen reduction and xanthate chemisorption.

OP 68–85. The Flotation of Chalcocite, Bornite, Chalcopyrite, and Pyrite in an Electrochemical-Flotation Cell, by P. E. Richardson and G. W. Walker. Ch. in XVth International Mineral Processing Congress, Volume II, Flotation Hydrometallurgy (Proc. Conf., Cannes, France, June 2–9, 1985). Edition GEDIM, Saint-Etienne, France, 1985, pp. 198–210. The flotation of chalcocite, bornite, chalcopyrite, and pyrite has been studied in a microflotation cell in which the potential of a bed of the mineral particles could be controlled electromechanically. The ethylxanthate-induced flotation of each mineral is markedly dependent on electrochemical potential, with the recovery changing from 0 to 100 pct in potential intervals of $\simeq$0.2 V. The flotation edge occurs at more reducing potentials as the copper-to-iron ratio of the minerals increases. Linear sweep voltammetry and ultraviolet spectrophotometry were used to study the reaction mechanisms between the minerals and ethylxanthate. The hydrophobic entities appear to be the formation of metal-xanthate on chalcocite and bornite, dixanthogen on pyrite, and both species on chalcopyrite.

OP 69–85. The Outlook for Ceramic Research in the Bureau of Mines, by Murray A. Schwartz and William L. Miller. Am. Ceram. Soc., Bull., v. 64, No. 8, 1985, pp. 1094–95. Ceramic research in the Bureau of Mines is important because it contributes to the Bureau's mission of helping to conserve domestic resources, ensuring that U.S. industry has a continuing and adequate supply of raw materials, and reducing the Nation's dependence upon imported materials, especially those of a strategic nature. Current materials research includes substitution, development of long-service-life materials, development of improved materials for the mining and minerals processing industries, and recycling. As part of the overall materials research effort, ceramics will continue to have key roles as substitutes for critical and strategic materials, for improved resistance to corrosion and wear, and for refractories needed to withstand severe furnace environments. A major effort on nondestructive evaluation and joining technology for advanced ceramics is being conducted for the Bureau of Mines under contract.

OP 70–85. An Overview of Coal and Gas Outbursts, by Alan A. Campoli, Michael A. Trevits, and Gregory M. Molinda. Paper in Proceedings of the 2nd U.S. Mine Ventilation Symposium, ed. by Pierre Moussett-Jones. A. A. Balkema, 1985, pp. 345–351. An outburst in a coal mine environment is the rapid ejection of coal and gas from the face. Outbursts are caused by a combination of high coalbed gas pressure and structural stress, the load placed upon mine workings by the overburden. A review of the outburst problem in general is followed by a presentation of prediction and prevention techniques employed worldwide to mitigate outbursts.

OP 71–85. Experience with Cross-Measure Boreholes for Gob Gas Control on Retreating Longwalls, by J. Cervik, F. Garcia, and T. W. Woodman. Paper in Proceedings of the 2nd U.S. Mine Ventilation Symposium, ed. by Pierre Moussett-Jones. A. A. Balkema, 1985, pp. 123–129. The surface gob hole is a common auxiliary method of controlling gob gas during longwall mining in the United States. Because surface gob holes cannot always be drilled, the Bureau of Mines is conducting studies to modify and adapt European cross-measure borehole technology to U.S. retreating longwalls. Tests conducted where overburden is 650 ft (198 m) or less indicate up to 71% of the methane produced by the mining operation can be captured by a properly designed cross-measure system. Hole spacing should be limited to 200 ft (61 m) except on about the first 600 ft (183 m) of the longwall, where spacing should be reduced to 100 ft (30 m). More holes are necessary near the start of the longwall to capture the large quantities of methane released when the first large roof fall occurs and to prevent it from overloading the return air system.

OP 72–85. Extinguishment of Wasted Coal Fires: A Critical Review—New Directions, by Robert F. Chaiken. Paper in Proceedings of the National Symposium and Workshops on Abandoned Mine Land Reclamation, Bismarck, ND, May 21–22, 1984, ed. by Lynn L. Schloesser, Garth S. Anderson, Nirander M. Safaya, and David J. Thompson, 1984, pp. 457–484. Fires have occurred and are continuing to occur in residual coal in abandoned underground mines, refuse banks, and inactive deposits. Once established, these fires can smolder for many decades, resulting in emissions of toxic and obnoxious fumes to the atmosphere and destruction of property and coal resources. Conventional methods for extinguishing and/or controlling residual (or wasted) coal fires, such as sealing, digging out, isolation, quenching, and/or inundation, have been developed over the years, but their application is often costly and sometimes destructive or ineffective and they are hazardous in themselves. A review of these methods is presented along with an analysis of the technical and institutional problems associated with their successful application. For example, a major technical problem exists in identifying the location of subsurface heat sources and establishing measurable criteria as to when a fire is permanently extinguished. A major institutional problem occurs in evaluating project costs and setting aside adequate funds. Most often these two problems compound each other. Current research and development at the Bureau of Mines is attempting to resolve many of the problems with the conventional methods of fire control and extinguishment. The Bureau's research is innovative in that it is evaluating in new ways, "old" concepts for mine fire diagnostics, and in "old" ways, new concepts for fire control and extinguishment. The results obtained to date appear promising and are discussed along with plans for future work.

OP 73–85. The Use of High-Sulfur Coal in Copper Electrowinning, by J. R. Craynon and G. R. Smith. Processing and Utilization of High Sulfur Coals, Proceedings of the First International Conference on Processing and Utilization of High Sulfur Coals, ed. by Yosry A. Attia. Elsevier, Amsterdam, 1985, pp. 739–749. Research has been conducted to lower the energy requirement in copper electrowinning by replacing the anodic water oxidation reaction with a coal slurry oxidation system in a combined electrolysis cell. The cell, which employs a membrane to separate the two half-cells, was operated at 60° C at a cell voltage of approximately 0.5 V. This represents a 67-pct reduction in voltage from the 1.5 V required for conventional electrowinning. Using acetone washing and baking, the low-voltage electrolysis using the high-sulfur Pittsburgh No. 8 coal has been conducted for up to 102 h. Analytical results showed that the character of the coal remaining after electrolysis was only slightly lower in heat value while being significantly reduced in ash and sulfur content compared with the feed coal. Based upon the decrease in cell voltage, a decrease in the net cost of electrolysis energy could be achieved.

OP 74–85. Characterization of the Occurrence of Methane in Gulf Coast Domal Salt Mines, by Anthony T. Iannacchione and Steven J. Schatzel. Paper in Proceedings of the 2nd U.S. Mine Ventilation Symposium, ed. by Pierre Moussett-Jones. A. A. Balkema, 1985, pp. 353–360. Within the last 10 years, faster extraction rates, deeper mining levels, and "complete" mining of several salt dome levels contributed to the increased methane emission hazards, especially those associated with outbursts. The U.S. Bureau of Mines is actively involved in identifying the parameters governing these hazardous conditions, which may lead to a methane explosion. These parameters are better understood when the ranges of methane contents, emission rates, and the gas pressures are known. Data obtained in Louisiana domal salt mines have shown that variations in methane contents, emission rates, gas flows, and pressures are dependent upon the type of salt encountered. Normal production-grade pure salt was found to have a methane emission rate of less than 0.1 m^3/t and methane contents generally less than 0.1 $cm^3/100$ g. Emission rates from an adjacent anomalous zone ranged from 0.2 to 2.7 m^3/t and methane contents as high as 2.6 $cm^3/100$ g were determined. Extremely low gas flows and lack of pressure buildup were typical during drilling of exploration boreholes in normal salt. Gas flows of 0.33 L/sec and pressures of more than 6.2 MPa were observed from two boreholes when an anomalous zone was encountered. Localized permeability within this zone was observed by measuring tracer gas migration between two drill holes 7.3 m apart. Methane hazard characterization of a localized area within a Gulf Coast salt mine should consist of the following: (1) methane content determination, (2) mapping of geological features, (3) gas emission surveys, and (4) in situ tests of physical properties related to gas.

OP 75–85. U.S. Soda Ash Industry—The Next Decade, by Dennis S. Kostick. Min. Eng., v. 37, No. 10, Oct. 1985, pp. 1209–1212. Soda ash is known chemically as sodium carbonate, an important inorganic chemical. It has been produced for several centuries by processing certain vegetation and minerals. The U.S. soda ash industry has evolved from several small sodium carbonate mining operations in the West. Now, a nucleus of six companies produce about one-fourth of the world's annual soda ash output. U.S. producers currently dominate the world market. But certain international events are occurring that will reshape the domestic soda ash industry in the next decade.

OP 76–85. Oxidative Electrolysis Leaching of an Arsenical Copper Sulfide Concentrate, by K. P. V. Lei and T. G. Carnahan. Paper in Energy Reduction Techniques in Metal Electrochemical Processes, ed. by R. G. Bautista and R. J. Wesely. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 45–60. An oxidative electrolysis procedure for leaching an arsenical copper sulfide concentrate containing 28 pct Cu was investigated by the Federal Bureau of Mines. Leaching by electrolysis of the concentrate slurried in a sodium chloride solution was performed in a cell equipped with an ion-selective bimembrane to separate the anodic and cathodic reactions. The bimembrane consisted of a cation membrane facing the anode and an anion membrane facing the cathode. Oxidation by chlorine produced at the anode converted the concentrate to soluble metal ions,

arsenic acid, sulfate ion, and elemental sulfur. The effects of sulfide to sulfate conversion, current density, temperature, and sulfate concentration on metal extractions and energy requirements for operating the bimembrane cell were determined. Metal extractions of 95 pct were obtained at 50° C and an energy requirement ranging from 2.8 to 3.0 kW•h/lb of concentrate. A conceptual hydrometallurgical scheme to treat the arsenical sulfide concentrate is proposed.

OP 77–85. Column Flotation of Montana Chromite Ore, by J. D. McKay, D. G. Foot, Jr., and J. L. Huiatt. Soc. Min. Eng. AIME, preprint 85–335, 1985, 18 pp. The Bureau of Mines devised a column flotation technique using either fine or coarse bubbles and compared it with conventional flotation on a Montana chromite ore. On deslimed ore, fine-bubble column flotation produced a 44.7-pct-Cr_2O_3-grade rougher concentrate with 87-pct recovery, compared with 43.8- and 43.5-pct-Cr_2O_3-grade rougher concentrates with 85- and 77-pct recovery for coarse-bubble column flotation and conventional flotation, respectively. On undeslimed ore, coarse- and fine-bubble column flotation produced rougher concentrates containing approximately 41.5-pct-Cr_2O_3 with 95-pct recovery, exceeding conventional flotation which produced 35.6-pct-Cr_2O_3-grade concentrates with 87-pct recovery.

OP 78–85. Dewatering of Coal-Clay Waste at Paradise Steam Complex, by B. J. Scheiner. Paper in Processing and Utilization of High Sulfur Coals, ed. by Y. A. Attia. Elsevier, Amsterdam, 1985, pp. 395–405. The Bureau of Mines has investigated a dewatering technique for coal-clay waste that uses a flocculant, polyethylene oxide (PEO). This flocculant forms strong stable flocs that can be dewatered on either a hydrosieve screen or a combination of hydrosieve and trommel screens. A field test unit (FTU) was operated at a rate of 80 to 160 gal/min at a coal mine in western Kentucky at which coal-clay waste was dewatered first on a static screen, then on a trommel screen, to 50 pct solids using a polymer dosage of 0.12 to 0.15 lb/ton. The dewatered material continued to dewater, reaching 68 to 70 pct solids in 7 days when placed in a pond. The dewatered material was shown to be stable even when subjected to a heavy rainfall. Experiments were also made in which dewatered material was mixed with coarse waste from the preparation plant. A stackable mixture was obtained when four parts coarse waste was mixed with one part dewatered material.

OP 79–85. Recovery of Platinum, Palladium, and Gold From Stillwater Complex Flotation Concentrate by a Roasting-Leaching Procedure, by E. G. Baglin, J. M. Gomes, T. G. Carnahan, and J. M. Snider. Paper in Complex Sulfides—Processing of Ores, Concentrates and By-Products, ed. by A. D. Zunkel, R. S. Boorman, A. E. Morris, and R. J. Wesely. Metall. Soc. AIME, 1985, pp. 167–179. The Bureau of Mines devised a procedure for selectively extracting platinum-group metals (PGM) and gold from Stillwater Complex flotation concentrate. The concentrate was roasted at 1,050° C to convert base-metal sulfides to oxides and the PGM from sulfide minerals to their elemental states. The roasted concentrate was preleached with dilute sulfuric acid to remove soluble gangue minerals. After preleaching, the concentrate was slurried with 6*M* HCl and leached at ambient temperature and pressure with a strong oxidizing agent, such as hydrogen peroxide, chlorine, sodium hypochlorite, nitric acid, or persulfate salts. Up to 97 pct of the Pt, 92 pct of the Pd, and 99 pct of the Au were extracted from the roasted concentrate. The base metals were not solubilized and remained in the residue. The precious metals were recovered from the pregnant solution by sulfide precipitation, cementation with nickel, or adsorption on activated carbon.

OP 80–85. Impact of Horizontal Load on Shield Supports, by Thomas M. Barczak. Paper in Proceedings of the 4th Conference on Ground Control in Mining, Morgantown, WV, July 22–24, 1985, ed. by S. S. Peng and J. H. Kelley. WV Univ., 1985, pp. 50–57. A theoretical evaluation of the impact of horizontal load on shield support capacity is made from a static rigid body analysis of the shield structure. Parameters affecting horizontal support resistance are investigated for a typical two-leg shield design. Horizontal forces acting on a roof support element are found to be both roof-generated and shield-generated. The impact of shield-generated horizontal forces on roof strata is also discussed from a theoretical viewpoint in relation to desired ground control. A technique is described whereby horizontal loading of shield supports can be measured underground. Horizontal load measurements from two different longwall faces were found to be significant, ranging from 20 to 35 pct of measured vertical load.

OP 81–85. Resultant Load Vector Studies on Shield Supports, by Thomas M. Barczak. Paper in Proceedings of the 21st International Conference of Safety in Mines Research Institute, Sydney, Australia, Oct. 15–21, 1985. 5 pp. The resultant load vector represents the forces applied to a longwall roof support element by caving strata as a single, quantifiable measure of support resistance. A technique has been devised whereby the resultant load vector can be determined for shield supports by instrumenting the support with pressure transducers and strain gauges to measure leg, canopy capsule, and lemniscate link forces. The method has been evaluated in the Bureau's Mine Roof Simulator. Functional relationships among variables have been determined and confidence intervals established for predicting the resultant load vector parameters. Resultant load vector measurements for five shields on an active longwall face are consistent with shield mechanics and anticipated roof behavior.

OP 82–85. Characterization of the Performance of Large Capacity Face Ventilation Systems for Oil Shale Mining, by C. E. Brechtel, M. E. Adam, J. F. T. Agapito, and E. D. Thimons. Paper in Proceedings of the 2nd U.S. Mine Ventilation Symposium, ed. by Pierre Moussett-Jones. A. A. Balkema, 1985, pp. 517–529. The performance of two large capacity face ventilation systems was measured using sulfur hexafluoride tracer gas tests in a large dead-end heading at the Colony shale oil mine. The test room was 17 m wide by 9 m high and 98 m long. Testing compared the effectiveness of a free-standing jet fan and a reversible fan with a rigid duct. The jet fan performance was similar to the ducted system while using less power. Tracer gas was used to simulate the production of mine air pollutants including blasting fumes, hot diesel emissions, free methane from surrounding strata, and methane desorbing from rubblized shale. The tests showed that both systems could provide effective ventilation during oil shale mining.

OP 83–85. Determining Face Methane Liberation Patterns During Longwall Mining, by Andrew B. Cecala, Robert A. Jankowski, and Fred N. Kissell. Paper in Proceedings of the 2nd U.S. Mine Ventilation Symposium, ed. by Pierre Moussett-Jones. A. A. Balkema, 1985, pp. 361–367. As deeper seams are continually mined, methane liberation will continue to increase and must be monitored effectively. To effectively monitor and develop appropriate control technology, methane liberation patterns must be known. The Bureau of Mines recently completed a study to identify specific face methane liberation patterns during longwall mining. Two longwall faces were surveyed. Both had high methane liberation rates. At one longwall face, most of the methane was liberated during cutting of coal by the shearer mining machine. At the second face, a significant portion of methane was from total face and floor liberation. An effective methane monitoring system would be different for each longwall panel because of the differences in liberation.

OP 84–85. Clay Veins: Their Physical Characteristics, Prediction, and Support, by Frank E. Chase. Paper in Proceedings of the 4th Conference on Ground Control in Mining,

Morgantown, WV, July 22–24, 1985, ed. by S. S. Peng and J. H. Kelley. WV Univ., 1985, pp. 212–219. Clay veins, also referred to as clay or clastic dikes, have been responsible for numerous underground injuries and fatalities. These hazardous structures are also responsible for increased production costs during all phases of mining. For these reasons, the Bureau of Mines has investigated the physical characteristics of and roof instability problems associated with clay veins in order to make support and other mining recommendations. In addition, the occurrence and origins of clay veins were examined to determine whether or not the structures could be projected into unmined portions of the coalbed.

OP 85–85. Mine Stringent Dust Standards—Recent Compliance Statistics and Technology for Quartz Dust Control, by J. Harrison Daniel, Robert A. Jankowski, and Robert E. Nesbit. Paper in Proceedings of the Fall Meeting of Soc. Min. Eng. AIME, Albuquerque, NM, Oct. 16–18, 1985, pp. 186–197. More stringent dust standards, because of quartz in coal, have become a major compliance problem for the coal industry. Reducing quartz levels has become the major focus of the Bureau of Mines dust control research program. Results to date have identified both the sources of quartz and prospective control technology. Control techniques are being developed for both room-and-pillar and longwall mining underground operations. Techniques include changes in face ventilation, mining cycle modifications, and better roof bolting dust control.

OP 86–85. Recent Underground Observations of Intercepted Hydraulic Stimulations in Coalbed Methane Drainage Wells, by William P. Diamond and David C. Oyler. Soc. Min. Eng. AIME, preprint 85–335, 1985, 11 pp. The Bureau of Mines has been investigating several techniques, including the use of horizontal and vertical boreholes, to remove gas from coal in advance of mining. This paper provides historical observations and general conclusions based on 19 intercepted stimulation treatments and detailed observations on 5 recent interceptions in the Upper Freeport Coalbed, PA, and the Lower Kittanning Coalbed, WV.

OP 87–85. Microporosity in 304 Stainless Steel Films Prepared by Vapor Quenching, by Philip M. Fabis. Thin Solid Films, v. 128, Dec. 1985, pp. 57–66. Thin films of type 304 stainless steel compositions were direct current planar magnetron sputter deposited onto chilled and elevated temperature metallic and nonmetallic substrates within the thickness range from 40 nm to 3.5 μm. Bright field and dark field transmission electron microscopy and electron diffraction techniques were utilized to investigate the as-deposited thin films. A body-centered cubic microcrystalline grain structure was obtained through vapor quenching at substrate temperatures (deposition temperatures) between 77 and 473 K. The use of a defocus contrast technique and stereomicroscopy revealed a high density of intergranular and intragranular microvoids in all the films investigated. Microvoids were not observed in 304 stainless steel films sputter deposited by other investigators under similar conditions. Interconnected void networks did not exist in thicker regions of the film but were present in a "channel" in thinner film regions. Both the microcrystalline grain size and the void structures were influenced by the deposition temperature. In this study an attempt is made to evaluate the 304 stainless steel thin film microstructures in the light of their potential for protective coating uses.

OP 88–85. Preparation of Tungsten Carbide by Gas Sparging Tungsten Melts, by J. M. Gomes, A. E. Raddatz, and T. G. Carnahan. Paper in Tungsten: 1985. MPR Publ. Serv., Ltd., Shrewsbury, England, 1985, pp. 96–109; also in J. Met., v. 37, No. 12, Dec. 1985, pp. 29–32; and in Int. J. Refract. & Hard Met., v. 4, No. 4, Dec. 1985, pp. 177–181. The Bureau of Mines has devised a new technique for the preparation of tungsten monocarbide (WC) directly from ore concentrates by a two-step process. Wolframite or scheelite concentrates or mixtures of the two concentrates are decomposed in a $NaCl\text{-}Na_2SiO_3$ melt at 1,050° C. The melt forms two immiscible liquids. The upper halide-tungstate ($NaCl\text{-}Na_2WO_4$) phase contains 99% of the WO_3. The lower silicate phase contains 90% to 96% of the iron, manganese, and calcium oxides. After separating the two phases by decantation, the halide-tungstate phase is methane sparged to yield granular tungsten carbide. The WC is recovered from the reactor by decanting excess salt, cooling, water leaching, and scraping. The paper discusses results of research to establish operating variables, carbide harvesting procedures, selection of materials of construction, estimated cost of production, and physical properties of the WC product.

OP 89–85. An Overview of Water-Jet-Assisted Cutting at the Pittsburgh Research Center, by H. J. Handewith, R. J. Evans, and E. D. Thimons. Paper in Proceedings of the Third U.S. Water Jet Conference. Univ. of Pittsburgh, 1985, pp. 438–465. This paper presents an overview of the water-jet-assisted rock cutting research being conducted at the Bureau of Mines Pittsburgh Research Center. Findings indicate substantial reductions in airborne respirable dust using directed 3,000- to 9,000-psig water jets to assist mechanical cutting tools. In addition to dust reductions, there is a strong potential for longer cutting tool life attributed to jet lubrication and cooling of the cutting edge; reduced tool forces at the same depth of cut attributed to jet lubrication, precleaning of the tool path, and lubrication and propagation of mechanically induced rock cracks; and reduced occurrence of frictional ignitions attributed to jet cooling of both the cutting tool and rock surface. Research to date has established confidence in the concept of water-jet-assisted rock cutting, inferred some limitations, and highlighted specific areas requiring ongoing effort.

OP 90–85. Comparison of the Particle Size Distribution of Alpha Quartz in Respirable Coal Mine Dust Samples With Four Reference Standards, by C. W. Huggins, S. J. Johnson, J. M. Segreti, and J. G. Snyder. Paper in Proceedings of the 43rd Annual Meeting of the Electron Microscopy Society of America, ed. by G. W. Bailey. San Francisco Press, Inc., 1985, pp. 122–123. Particle size distribution of alpha quartz in respirable dust samples collected in 7 States from 9 underground and 14 surface coal mines in the Eastern United States were made by scanning electron microscopy and image analysis and compared with -5 μm Min-U-Sil, -5 μm Supersil, NBS 1878, and Silver Bond B reference standards. The accumulated particle size measurements indicated that three reference standards— -5 μm Min-U-Sil, -5 μm Supersil, and NBS 1878—would be preferred over the fourth, Silver Bond B, for quantitative quartz determinations in eastern coal mines by X-ray diffraction and infrared spectrometry.

OP 91–85. An Update of the Reduced Standards Problem and Overview of Improved Control Technology for Respirable Coal Mine Dust, by Robert A. Jankowski, Fred N. Kissell, and Robert E. Nesbit. Paper in Proceedings of the 2nd U.S. Mine Ventilation Symposium, ed. by Pierre Moussett-Jones. A. A. Balkema, 1985, pp. 151–167. Over 10 pct of active coal mine sections are on reduced dust standards owing to quartz, with an average applicable standard for the underground designated occupation at 1.2 mg/m³, while the applicable standard for the surface designated work position averages 0.8 mg/m³. It is estimated that by the end of the 1985 fiscal year over 15 pct of all coal mine workers will be affected by overexposure to respirable quartz and that a significant percentage of mining sections will be placed under more stringent dust standards. Studies have shown that the primary source of quartz dust on surface mining operations comes from dust escaping the collector system of the highwall drill. On underground operations, the primary source of quartz is the continuous mining machine, cutting roof, floor and rock partings in the seam. With the cooperation of industry and the Mine Safety and Health Administration, the Bureau of Mines has identified new or improved controls to reduce the amount of

airborne dust and dust rollback and developed procedures to correct the deficiencies of the roof bolter dust collector system. The Bureau has also initiated extensive research to control the quartz dust exposure of the continuous miner operator, to control quartz dust levels downwind of the continuous mining machine, and to identify novel concepts for reducing quartz dust in underground coal mines.

OP 92–85. Spark Testing in the Identification of Stainless Steel and Superalloy Scrap, by J. M. Larrain, W. D. Riley, and R. D. Brown, Jr. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 365–379. The Bureau of Mines is studying methods of identification of scrap that will lead to better segregation, conservation of strategic materials, and better utilization of existing resources. Spark testing—the visual examination of the spark stream generated when a metal is struck against a grinding wheel—has been used successfully for many years in the classification of alloy steels. Research using spectrophotometric methods to determine the characteristics of the light emitted by the sparks, and a minicomputer to recall and compare spark patterns is described. The utility of this instrumental method for the rapid identification of stainless steels and superalloys is discussed.

OP 93–85. Research Related to Safety of Mining Equipment in the U.S.A., by John N. Murphy. Paper in Proceedings of the Southern NSW Branch Convention, Inst. Min. Electr. and Min. Mech. Eng., Sydney, Australia, Nov. 2–4, 1985, 15 pp. The Bureau of Mines research program related to miner safety is divided into two principal areas: Health and Safety, and Mining Technology. Both programs address coal as well as metal and nonmetal problems, but this paper is limited to the safety research aspects of coal mining. By way of background, the Health and Safety Program addresses problems in underground and surface mines and the surface facilities associated with those mines. The Mining Technology Program focuses on problems relative to reducing the environmental impact of mining or past mining activities, and on problems of mine productivity and resource recovery. The emphasis of this paper will be directed toward recent accomplishments that are or will be available to industry in the near future.

OP 94–85. Remote Control Advances Safety, Productivity, by John N. Murphy, Am. Min. Congr. J., v. 71, No. 17, Sept. 18, 1985, p. 14. Improvements in miner safety as well as health can be realized through the use of remote control of mining machinery. Specific examples where remote control has enhanced health or safety of underground mining operations are reviewed, as well as projections on future applications. Several commercially available and prototype remote control systems are discussed.

OP 95–85. Remote Control Promises Safety and Productivity Gains, by John N. Murphy. Coal Min., v. 22, No. 10, Oct. 1985, pp. 38–42. Improvements in miner safety as well as health can be realized through the use of remote control of mining machinery. Specific examples where remote control has enhanced health or safety of underground mining operations are reviewed, as well as projections on future applications. Several commercially available and prototype remote control systems are discussed.

OP 96–85. Effects of Scrap Charges and Other Variables on the Quality of Iron Castings: A Progress Report, by R. H. Nafziger, R. F. Farrell, and P. J. Mikelonis. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 349–363. The cast-iron foundry industry has expressed concern regarding the quality of scrap used to prepare iron castings owing to the growth of alloy steel production and its influence on tramp element levels when recycled. Reliable and current information is unavailable on the amount of tramp elements contained in iron castings produced over a significant period of time. Accordingly, the Bureau of Mines is analyzing cast iron samples from the participating foundries throughout the United States on a quarterly basis under a Memorandum of Agreement between the Bureau and the American Foundrymen's Society. Each sample is analyzed for 28 elements to determine if the level of tramp elements in charge materials is changing over time. Preliminary results indicate that the type of furnace, the geographic location, and the size of the foundry did not significantly affect casting compositions. Owing to the variability of charge materials used, correlation of the analyses of the castings with charge compositions had not been possible. The data obtained are undergoing statistical analysis to determine significant differences among the chemical compositions as a function of time and foundry location.

OP 97–85. Gallium Extraction From Phosphorus Flue Dust by a Sodium Carbonate Fusion-Water Leach Process, by David L. Neylan, Claudia P. Walters, and Benjamin W. Haynes. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 727–733. Gallium extraction from waste material generated by high-temperature furnaces is being investigated as part of the Bureau of Mines recycling research program. The flue dust from the production of elemental phosphorus contains gallium at levels greater than in materials being processed for gallium by the aluminum and zinc industries. Gallium is present at levels of 300 to 900 ppm in phosphorus flue dust. If it were economically feasible to quantitatively extract the gallium available in this flue dust, it would meet current U.S. consumption. A combination soda fusion-water leach process is being developed to extract gallium from phosphorus flue dust and other waste materials. The procedure has extracted 80 pct of the gallium in optimization tests. Details of the laboratory-scale development are discussed together with the analytical procedure required to accurately determine gallium at the parts per million level.

OP 98–85. Access Concerns Spur Development, by John F. Papp. Am. Met. Mark.—Chromium, v. 93, No. 244, Dec. 19, 1985, pp. 8–13. Chromium is abundant, presently accessible, and relatively inexpensive. Accessibility has a political component. The world chromium reserve base is concentrated in the Republic of South Africa and Zimbabwe (previously called Rhodesia). Rhodesian chromium was embargoed from 1966 to 1972, making it politically inaccessible. South African chromium has always been politically accessible. Chromium reserve base concentration concerns consumers. The United States consumes chromium in the form of ferrochromium and chromium ore. International ferrochromium production capacity is of interest to the United States because this country is one of the traditional ferrochromium producers now experiencing declining capacity. Market economy countries are currently more vulnerable to a ferrochromium supply disruption than to a chromium ore supply disruption. Under the Trade Development Program, the U.S. Department of State encourages the development of foreign chromium deposits. Market economy countries are developing new ferrochromium production capacity and more efficient production processes.

OP 99–85. Sulphur Concrete Made From Metallurgical Wastes, by R. L. Rickel and D. M. Starrett. Sulphur Res. & Dev., v. 9, 1985, pp. 21–24. Proposed hydrometallurgical processing of sulfide ores may generate tailings that contain sizable amounts of elemental sulfur. The possible use of these waste tailings as a readily available source of low-cost raw materials in the preparation of sulfur concrete was studied by the U.S. Department of the Interior, Bureau of Mines. The study showed that the waste, with some pretreatment, could be combined with aggregate to yield a high-strength, corrosion-resistant sulfur concrete for use by the waste producer at its plant for floors, footings, pump bases, or retaining walls in areas where conventional concretes fail because of corrosion. Two process wastes were examined: the Duval Corp.'s Clear Process

residue and tailings from the ferric chloride leaching of galena ore, which has been pilot-plant-tested by the Bureau of Mines.

OP 100–85. An Overview of Explosion-Proof Enclosure Research, by Lawrence W. Scott. IEEE Trans. Ind. Appl., v. IA–21, No. 6, 1985, pp. 1552–1558. This paper presents an overview of explosion-proof enclosure research currently being conducted by the Bureau of Mines. It emphasizes the increasing importance of research related to the safety considerations of explosion-proof (XP) enclosures used in underground coal mines. Selected topics are included that summarize results of research in the areas of electrical clearances, reliability of enclosures with windows, safety factors in XP enclosures, potting materials, performance tests for XP enclosures, high-voltage explosion protection techniques, and innovative XP devices.

OP 101–85. Purification of Metals by Molten Metal Filtration, by Charles A. Sorrell, Henry E. Hilliard, and Darla J. Schrodt. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 503–517. The Bureau of Mines is studying methods for fractionating multicomponent metal scrap by filtration. This is to be accomplished by separation of liquid and solid phases consisting of (1) liquid and crystalline phases formed by addition of a component that reacts with one or more components in the liquid to form a compound with a high melting point, (2) liquid and crystalline assemblages equilibrated at constant temperature, and (3) liquid metals from fibers or particles in metal matrix composites. Equilibria in the systems Pb-Sb-Al, Al-Ti-B, Al-Si, and in superalloys are discussed. Data are given for purification of Pb-Sb alloys by formation and removal of AlSb, for purification of Al by formation of TiB_2, and for purification of Al by filtration of the Al-Si eutectic liquid from purified solid Al. Varieties of available filter media are described.

OP 102–85. Spray Cooling Developments, by Edward D. Thimons, John F. McCoy, and John R. Marks. Paper in Proceedings of the 2nd U.S. Mine Ventilation Symposium, ed. by Pierre Moussett-Jones. A. A. Balkema, 1985, pp. 599–606. As part of a Bureau of Mines program, four limited bulk water spray coolers were designed and built. The first of these coolers, a single-stage unit, was tested in the Mt. Taylor Mine near Grants, NM, before it closed. The remaining three coolers, a two-stage cooler and two three-stage coolers, were installed in the Homestake Gold Mine in Lead, SD. To date, all the coolers have performed well under in-mine conditions and have required only minimal maintenance. This paper details the design and performance of these coolers.

OP 103–85. Power Generation From Mine Refrigeration System, by Robert Torbin, Edward Thimons, and Steven Lautenschlaeger. Paper in Proceedings of the 2nd U.S. Mine Ventilation Symposium, ed. by Pierre Moussett-Jones. A. A. Balkema, 1985, pp. 589–597. The Bureau of Mines, as part of its Health and Safety Research Program, has investigated a technique for improving the performance of mine refrigeration systems. By converting the potential energy of the incoming water to electrical energy, rather than to heat energy, the water stays colder. This results in cooler mine temperatures and a healthier, more comfortable working environment for miners. A primary spinoff advantage resulting from this research is an energy savings from employing such a refrigeration technique. Recognizing the value of recoverable potential energy, the Bureau of Mines has undertaken a project to study the application of energy recovery techniques to the United States mining industry. To this end, the Bureau has contracted with Foster-Miller, Inc., of Waltham, MA, to investigate, evaluate, and demonstrate commercially available means of efficiently recovering the energy from any incoming cooling water source. This project has led to procurement, installation, and operation of a complete thermal energy recovery system. The test site is the Lucky Friday Mine, owned and operated by the Hecla Mining Co. of Wallace, ID. The Lucky Friday Mine is located in Mullan, ID, in the Coeur d'Alenes region of upper Idaho.

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OP 1–86. Precalculation of Subsidences Over Longwall Panels in the Northern Appalachian Coal Field, by V. Adamek and P. W. Jeran. Soc. Min. Eng. AIME, preprint 85–404, 1985, 17 pp. The specific lithological conditions over the Pittsburgh coalbed, highly resistive limestone and sandstone units with relatively shallow overburden, prevent the use of any predictive method as developed for European conditions. This paper describes the development of a subsidence precalculation methodology suitable to the mining-geological conditions in the Northern Appalachian Coalfield. It has been found that due to lithological conditions over the Pittsburgh coalbed, the subsidence coefficient varies within the area of the subsidence trough. This is different from the European conditions where the subsidence coefficient is considered to be a constant. The effects of lithology, in the form of a variable subsidence coefficient, have been separated for each test site by introducing a correlation between hypothetically homogeneous overburden and existing lithological conditions, while providing for different mining conditions. Field data from 11 Bureau longwall panel studies were used in the regression analysis. For each panel, the characteristics of the variability of the subsidence coefficient along individual profile lines were defined. Regression analysis of the subsidence coefficients from all test sites on the location relative to the edge of the panel has yielded a third degree polynomial equation with a coefficient of correlation of 0.9999. All sensitivity tests have shown good results.

OP 2–86. Treating Superalloy Scrap With Zinc To Increase Its Leaching Rate, by G. B. Atkinson and D. P. Desmond. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 337–348. The Bureau of Mines investigated technology for increasing the leaching rate of bulk superalloy scrap by treating the scrap with zinc. This technology would facilitate recycling contaminated superalloys and recovering critical metals such as Ni, Co, and Cr. Superalloys investigated were IN–738, a cast-nickel-base superalloy, and Mar–M–509, a cast-cobalt-base superalloy. Charges containing 80 pct Zn and 20 pct superalloy were heated to 900° C for 4 h in an argon atmosphere. The molten zinc dissolved the superalloy scrap, and the zinc was removed by vacuum distillation at 850° C for 4 h. The product was friable, contained less than 0.2 pct Zn, and more than 99.9 pct for the zinc was recovered. Leaching 5 g of product with excess 6*N* HCl at 95° C for 5 h dissolved 95 pct of the superalloy component metals.

OP 3–86. Sorting Techniques for Mixed Metal Scrap, by R. D. Brown, Jr., W. D. Riley, and D. M. Soboroff. Conserv. & Recycling, v. 9, No. 1, 1986, pp. 73–86. The U.S. Bureau of Mines is conducting research on methods for sorting and identifying mixed metal scrap so that this resource can be better utilized. A mechanical method for separating wrought

and cast aluminum scrap and instrumental methods for identifying mixed aluminum scrap and mixed high-value scrap are reviewed. New research on spark testing and field experience in high-value scrap sorting are discussed.

OP 4–86. Coal and Gas Outbursts: Prediction and Prevention, by Alan A. Campoli, Michael Trevits, and Gregory M. Molinda. Coal Min., v. 22, No. 12, Dec. 1985, pp. 42–44, 47. An outburst in a coal mine environment is the rapid ejection of coal and gas from the face. Outbursts are caused by a combination of high coalbed gas pressure and structural stress, created by the load placed upon mine workings by overburden. A review of the outburst problem in general is followed by a presentation of prediction and prevention techniques employed worldwide to mitigate outbursts.

OP 5–86. A Case Study of Ground Control Problems Related to Multiple Seam Mining in the Pittsburgh and Sewickley Coalbeds, by Gregory J. Chekan, Rudy J. Matetic, and James A. Galek. Soc. Min. Eng. AIME preprint 85–325, 1985, 10 pp. The Bureau of Mines, U.S. Department of the Interior, is currently investigating strata interactions associated with the mining of multiple coalbeds. Strata interactions due to subsidence are a result of undermining. This study involves underground investigations at a mine where room and pillar panels are actively being developed through an area of the Sewickley Coalbed that was subsided by undermining of the Pittsburgh Coalbed. Research to date indicates that undermining had little effect on upper mine pillar stability but had a more severe effect on the development and maintenance of entries. Roof-to-floor measurements recorded over four times more convergence in entries developed over gob as compared with entries developed over support pillars in the lower mine. Consequently, this has led to major roof falls in the active panels, resulting in considerable production delays and supplemental roof support costs.

OP 6–86. Concentrating a Complex Cobalt and Nickel Sulfide From Missouri Lead Ores by Continuous Froth Flotation, by W. L. Cornell, D. C. Holtgrefe, and F. H. Sharp. Paper in Complex Sulfides—Processing of Ores, Concentrates, and By-Products, ed. by A. D. Zunkel, R. S. Boorman, A. E. Morris, and R. J. Wesely. Metall. Soc. AIME, 1985, pp. 181–193. The Missouri lead ores are the only domestic sources of cobalt presently being mined and processed for other materials. They therefore represent the best short-term solution for meeting up to 20 pct of U.S. strategic and critical cobalt needs from domestic sources. At present, the cobalt is lost as an impurity in the Cu, Pb, and Zn concentrates and in the mill tailings. This paper presents research to enumerate the problems encountered in recovering cobalt from the copper concentrate on a continuous basis under actual mill conditions; to present alternative solutions to these problems; and finally, to describe what is presently the best available technology for cobalt recovery within the imposed constraints. Flotation was chosen as the method for recovery because of easy adaptation by the mills. In the best cases, when feeds in excess of 0.8 wt pct Co were encountered, cobalt recoveries in excess of 80 wt pct at grades as high as 8.2 wt pct were achieved. On average, however, cobalt recoveries of 60 wt pct at grades of 2.0 wt pct on feeds containing less than 0.4 wt pct would be typical.

OP 7–86. Recovery of Cobalt and Other Metal Values From Missouri Lead Ore Concentrator Tailings, by W. L. Cornell, D. C. Holtgrefe, and F. H. Sharp. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 675–682. Missouri lead ores are unique because they represent the only domestic cobalt resource that is presently being mined and processed. Lead, zinc, and copper concentrates are produced from the ore, and since cobalt is detrimental in these products, every effort is made to reject cobalt to the mill tailings. The tailings can contain as much as 45 pct of the cobalt originally present in the lead ore. Researchers at the Bureau of Mines Rolla Research Center used froth flotation to recover up to 65 wt pct of the cobalt and from 60 to 90 wt pct of the other valuable metals such as Ag, Cu, Pb, and Zn from the mill tailings. An augmented primary amine collector was used. Desliming of the pulp prior to flotation was not necessary. Improvement ratios range from 7 to 17 depending on the metal.

OP 8–86. Polarization and Corrosion of Electrogalvanized Steel—Evaluation of Zinc Coatings Obtained From Waste-Derived Zinc Electrolytes, by M. Dattilo. J. Electrochem. Soc., v. 132, No. 11, Nov. 1985, pp. 2557–2561. The corrosion of electrogalvanized 1070 steel wire has been investigated in molar quiescent ammonium chloride and ammonium sulfate under near-neutral conditions. Zinc coatings obtained from waste-derived electrolytes were evaluated versus coatings from relatively pure zinc electrolytes. The waste source of zinc was brass smelter flue dust. Corrosion rates were measured by Tafel line extrapolation and the polarization resistance technique. Values of the Tafel slopes and the corrosion currents were also compared with those for pure zinc (99.999%). Corrosion rates were found to be affected by the medium employed, pH, and bimetal diameter reduction (drawing). Drawn electrogalvanized steel displays higher values of the Tafel slopes than do the as-plated samples. The Tafel slopes are different from those obtained on pure zinc. This is assumed to be due to inhomogeneous surface features obtained from additive adsorption (during plating) and residual lubricants used in the drawing process as well as surface structure. The corrosion rates of electrogalvanized samples plated in the waste-derived zinc electrolytes were similar to the corrosion rates of samples plated in relatively pure zinc electrolytes. Therefore, wastes are a potential source of zinc for electrogalvanizing.

OP 9–86. Recycling Zinc From Flue Dust for Electrogalvanizing, by M. Dattilo, E. R. Cole, Jr., T. J. O'Keefe, R. A. Kosher, T. J. O'Keefe, Jr., and F. Chen. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 159–172. An objective of Bureau of Mines recycling research is to devise technology that enables the recovery of metals and minerals from wastes. In this report, researchers at the Bureau of Mines, U.S. Department of the Interior, and at the University of Missouri-Rolla investigated the use of the flue dusts containing zinc as a source of zinc for electrogalvanizing. After extraction of zinc with sulfuric acid, the resultant solution was partially purified and used to electrogalvanize 1070 alloy steel wire, a common electrogalvanized product. Bench-scale tests were successful, and a 400-lb coil of 1090 alloy steel wire was electrogalvanized in an industrial pilot plant. Corrosion performance and drawability of the coil plated in waste electrolyte compared favorably with that of a coil plated in industrial electrolyte.

OP 10–86. Electrogalvanizing Using Zinc Recovered From Nonferrous Smelter Dusts, by M. Dattilo, E. R. Cole, Jr., and T. J. O'Keefe. Conserv. & Recycling, v. 9, No. 1, 1986, pp. 55–66. An objective of the U.S. Bureau of Mines recycling research is to devise technology that enables the recovery of metals, minerals, and other values from waste products and thus promote the wise and efficient use of the resources of the United States. In line with this objective, Bureau researchers are investigating the use of waste products containing zinc as a source of zinc for electrogalvanizing. Industrial wastes used in this work were lead smelter flue dust, wastewater treatment sludge, copper smelter flue dust, and brass smelter flue dust. After zinc extraction with sulfuric acid, the resultant solutions were partially purified and used to electrogalvanize 0.234-cm (0.092-in.) diameter 1070 alloy steel wire, a common electrogalvanized product. The corrosion resistance of the electrogalvanized wire from waste electrolyte was compared with electrogalvanized wire from relatively pure

electrolyte prepared in the laboratory and with electrogalvanized wire from an industrial electrogalvanizing plant. Corrosion rate measurements indicated that electrogalvanized wire obtained from waste electrolyte prepared from brass smelter flue dusts compared favorably with industrial electrogalvanized wire and electrogalvanized wire from the relatively pure electrolyte. The brass smelter flue dusts were chosen for more detailed studies. Impurities in the waste electrolyte caused some problems. Copper was undesirable because it passivated the soluble zinc anode. Other impurities such as cobalt and nickel were more tolerable but also slowly coated the anode. Owing to the ease of removal of copper by cementation, it posed no processing problem for electrogalvanizing. Successful completion of bench-scale work with brass smelter flue dusts led to large-scale trials at an industrial electrogalvanizing plant.

OP 11–86. A Novel Technique for the Recovery of Coarse North Carolina Phosphate, by B. E. Davis, T. O. Llewellyn, and G. V. Sullivan. Soc. Min. Eng. AIME preprint 85–331, 1985, 6 pp; Miner. and Metall. Process., v. 3, No. 3, Aug. 1986, pp. 198–200. A technique was devised by the Bureau of Mines to recover coarse (plus 1.2 mm) North Carolina phosphate now discarded as waste. Concentration utilizes the difference in particle sphericity between the relatively flat calcite and the rounded phosphate pebbles. Sizing, treatment in a continuous hydraulic classification system, and grinding upgraded a 17.0-pct-P_2O_5 reject to 24.5 pct P_2O_5, with a phosphate recovery of 63 pct.

OP 12–86. Sensor Location Strategy for Minewide Environmental Monitoring, by Thomas J. Fisher and A. F. Cohen. Paper in Proceedings of the 21st International Conference of Safety in Mines Research Institutes, Sydney, Australia, Oct. 21–25, 1985, pp. 393–398. The decision to incorporate a mine monitoring system into a coal mine represents a commitment by management and engineering personnel to improve mine operations though innovative technology. The choice of monitoring transducers requires considerable planning and forethought so that the maximum benefits of whole mine monitoring can be realized. The intended use of the monitored data will often dictate specific locations for transducers, although in many cases technical constraints, imposed by transducers or measurand characteristics, will limit the choice of location. This paper presents some of the factors and considerations that should be examined prior to transducer installations. Some decision making procedures to help the system designer select appropriate locations are proposed. The paper includes a description of in-mine experimental programs being used to learn more about physical factors that influence transducer location and to further evaluate the procedures presented here.

OP 13–86. Distribution of Cr, As, Se, Ag, Cd, Ba, Hg and Pb in Pacific Ocean Ferromanganese Nodules, by Jane Z. Frazer, Benjamin W. Haynes, and Robert R. Sims, Jr. Wastes in the Ocean—Volume 5, Deep-Sea Waste Disposal, ed. by Dana R. Kester, Wayne V. Burt, Judith M. Capuzzo, P. Kilho Park, Bostwick H. Ketchum, and Iver W. Duedall. Wiley, 1985, pp. 260–270. Fifty-five bulk ferromanganese nodule samples from the Pacific Ocean were analyzed for total content of Cr, As, Se, Ag, Cd, Ba, and Hg. Concentrations of Pb and other metals had been determined previously for the same samples. Cadmium and barium are correlated positively with Mn, Ni, Cu, and Zn, and negatively with Fe, Co, As, and Pb. Cadmium seems to occur primarily in the 10 Å manganate phase of the nodules, whereas Ba occurs at least partly in the form of barite. Chromium probably occurs in the sediments incorporated within the nodules and is correlated positively with As and Si and negatively with Mn. Arsenic and mercury are correlated with Fe, and As is also correlated positively with Co and Pb and negatively with Mn, Ni, Cu, and Zn. Arsenic and mercury are associated presumably with the iron oxide phases. Like Co, they are especially concentrated in regions characterized by seamounts and may be of volcanic origin. Silver and selenium showed no clear trends. Concentrations of the toxic elements in nodules from the region between the Clarion and Clipperton Fracture Zones, where deep ocean mining is most likely to occur, can be compared with the maximum levels allowed by the U.S. Environmental Protection Agency (EPA) if a solid is not to be considered a toxic waste. Concentrations of Cr, Ag, and Hg are so low that they are of no environmental concern. Levels of As, Cd, and Ba are borderline; they could present a toxicity problem if they occurred in the rejects entirely in soluble form. Lead and selenium are observed in nodules in concentrations considerably higher than allowed by EPA for nonhazardous wastes. Since Se and Pb are the most likely elements to make the rejects toxic, further studies should pay particular attention to these elements.

OP 14–86. Partial Replacement of Chromium in Stainless Steel, by M. L. Glenn, S. J. Bullard, D. E. Larson, and S. C. Rhoads. Paper in New Developments in Stainless Steel Technology, ed. by R. A. Lula. Am. Soc. Met., Dec. 1985, pp. 99–105. The Bureau of Mines, U.S. Department of the Interior, conducted research on the partial replacement of chromium in stainless steel. The alloys examined contain 8 to 9 pct Cr, 11 to 14 pct Ni, and additions of up to 5 pct Mo, 2 pct Cu, and 2 pct V for corrosion-resistant applications, and up to 5 pct Si and 2 pct Al for heat-resistant applications. Molybdenum additions enhanced the corrosion resistance to approach that of type 304 stainless steel (304 SS) in H_3PO_4, HNO_3, citric acid, and acetic acid. Alloys with Si and Al additions had 800° C oxidation resistance superior to that of type 304 SS. The stress rupture resistance of the best Si-Al alloys was comparable to that of type 304 SS. The alloys had tensile properties typical of austenitic or martensitic stainless steels, depending upon their structures. They exhibited greater tendency to hot crack during welding than did type 304 SS. The research showed that additional levels of Ni, Mn, or C may be needed to stabilize an austenitic structure in these substitutes. The research also showed that additions such as Mo, Si, and Al have potential to substitute for approximately half the Cr in stainless steels for many applications.

OP 15–86. Electrolytic Removal of Tin From Can Scrap, by J. G. Groetsch, Jr., R. C. Gabler, Jr., and D. M. Soboroff. Conserv. & Recycling, v. 9, No. 1, 1986, pp. 15–22. Tin in the magnetic fraction of municipal solid waste (MSW) makes this material difficult to recycle to the steel industry. An electrolytic method using stannous fluoborate-fluoboric acid for removing tin was evaluated on a laboratory scale. Optimum concentrations of tin in the electrolyte and the effects of impurities such as aluminum, copper, iron, and lead on tin removal from the electrolyte were evaluated. Operating parameters were 60 to 65 g/L fluoboric acid and 20 to 30 g/L tin using stainless steel electrodes at a current density of 60 A/ft^2. Tests were run with clean tin cans and MSW magnetics with good results. The tin content of the MSW magnetics scrap was reduced from 0.18 to 0.017 wt % tin by reshredding, magnetic separation, and air classification, followed by electrolytic removal of the tin.

OP 16–86. The Relationship Between the Thermal Activity of Pyrite and the Rate of Acid Generation, by Richard W. Hammack. Paper in 1985 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation. Univ. KY, 1985, pp. 139–144. The thermal reactivity of pyrite in 33 overburden samples was evaluated by evolved gas analysis (EGA). Eight samples contained carbonaceous material; large exothermic effects resulting from the combustion of this material rendered EGA thermograms from these samples meaningless. EGA techniques and instrumentation capable of evaluating carbonaceous samples have been developed but were not available for this study. Therefore, the results of this study are based on 25 noncarbonaceous overburden samples.

OP 17–86. Characterization of Waste Materials From Manganese Nodule Processing, by Benjamin W.

Haynes, David C. Barron, Gary W. Kramer, Robert W. McKibbin, and Stephen L. Law. Paper in Marine Mining: A New Beginning—Conference Proceedings, July 18–21, 1982, Hilo, Hawaii, ed. by Peter B. Humphrey. State of Hawaii Marine Mining Program, 1985, pp. 116–140. In cooperation with several other Federal agencies, the U.S. Department of the Interior, Bureau of Mines, is investigating the composition of manganese nodule processing feed material and the possible reject waste material composition from several types of potential manganese processing options. In this study, both pilot plant and bench-scale-generated rejects are being studied for chemical composition and physical characterisitcs. This paper reports the results and estimates of reject waste material composition from five process types considered for first-generation manganese nodule processing. Particular emphasis is placed on two ammonia-based bench-scale processes.

OP 18–86. Reclamation of Metals From Magnet Alloy Grinding Sludge, by J. L. Holman and L. A. Neumeier. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 327–336. The Bureau of Mines has devised a procedure for treating cobalt-nickel-bearing magnet alloy grinding sludge to remove detrimental contaminants and produce an alloy powder for recycling. Sulfur contamination can result from use of elemental sulfur as fixturing cement for grinding. Carbon contamination results from residual oil and grinding-wheel debris. Since magnet alloys have low tolerances for these elements, they must be removed to low levels to render the metallics recyclable. The patented technique consists of (1) treatment with solvent to remove most of the sulfur and oil contamination, (2) drying, light grinding, sizing, and magnetic separation of a major portion of the grinding media, (3) controlled oxidation roasting to remove residual sulfur and carbon, and (4) hydrogen reduction of metal oxides. The powder product contained about 0.01 pct S, 0.06 pct C, and 30 pct Al_2O_3. When added to an experimental alnico melt, the alumina floated to the slag. Overall, >95 pct of the Co, Ni, and Fe and ~90 pct of the Cu were recovered from the starting sludge sample.

OP 19–86. Permselective Membrane Research for Stainless Steel Pickle Liquors, by G. L. Horter, J. B. Stephenson, and W. M. Dressel. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 467–475. Acid pickling of stainless steel annually generates approximately 30 million gallons of depleted nitric acid-hydrofluoric acid solutions as an undesirable byproduct. Disposal of these acid solutions significantly increases the cost of manufacturing stainless steel. Recent advances in ion-selective membrane technology have opened new avenues to economically regenerate these acid solutions as an alternative to disposal. Experimental work has indicated that an electrodialysis cell utilizing ion-selective membranes has potential for separating dissolved metals from depleted pickling acid solutions, allowing the acids to be regenerated for return to the pickling process.

OP 20–86. Fundamentals of Continuous Dielectric Separation of Minerals, by C. E. Jordan and G. V. Sullivan. Soc. Min. Eng. AIME preprint 85–383, 1985, 24 pp. The fundamental properties of the Bureau of Mines patented dielectric separator were studied to provide insight regarding its design and operating characteristics. Force equations for mineral particles were derived and evaluated experimentally. High dielectric mineral recovery was proportional to the calculated effective dielectric force volume that surrounded each drum electrode wire. Electrode spacing was the most sensitive design parameter, requiring less than 0.4-cm electrode spacing for a good separation. Operating characteristics and ore characteristics were investigated. With a dielectric constant difference as small as 2, good separations were made on a laboratory scale at energy consumption below 12 kw·h/mt.

OP 21–86. Treatment of Mine Water To Remove Manganese, by Robert L. P. Kleinmann, George R. Watzlaf, and Terry E. Ackman. Paper in 1985 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation. Univ. KY, 1985, pp. 211–217. The Bureau studied two novel approaches to the manganese problem. One was an inexpensive pipeline treatment system device known as the in-line aeration and neutralization system (ILS), which was developed by the Bureau to aerate and neutralize mine water. At three mines with influent Mn concentrations of 10 to 68 mg/L, use of the ILS reduced Mn concentrations to less than 2 mg/L at pH values of only 6.8 to 7.3. Another novel approach to mine water treatment is the construction of wetlands on mined sites. Results from ongoing tests indicate that this biological treatment can be engineered to optimize either iron or manganese removal. Moderate Mn concentrations (14 to 30 mg/L) have been reduced to 2 to 6 mg/L in constructed wetlands at four minesites in western Pennsylvania.

OP 22–86. Spoil Water Quality Variations at Two Regraded Surface Mines in Pennsylvania, by Kenneth J. Ladwig and Peter Campion. Paper in 1985 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation. Univ. KY, 1985, pp. 121–130. Field studies at two reclaimed surface mines in Pennsylvania were used to describe the hydrology and water quality within acid-producing spoil backfill. The study examined the relationsip between recharge source and water quality and empirically described the geochemical evolution of the spoil water.

OP 23–86. Assessment and Reclamation of an Abandoned Acid-Producing Strip Mine in Northern Clarion County, Pennsylvania, by Peter J. Lusardi and Patricia M. Erickson. Paper in 1985 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation. Univ. KY, 1985, pp. 313–321. The Pennsylvania Department of Environmental Resources and the Bureau of Mines are conducting a reclamation project aimed at controlling acid production at its source by surface application of high-quality limestone. The site of this project is a backfilled strip mine that discharges acidic water at three seepage areas. The site was reclaimed in May and June 1984 using 327 metric tons per hectare of high-quality limestone. The effect of the reclamation on water quality is currently being assessed in the last phase of the project. One year after reclamation, there has been no major improvement in the water quality in the wells and seeps. A sharp decrease in sulfate and acidity levels in two of the seeps occurred in late 1984; however, the improvement did not persist.

OP 24–86. End Uses of Boron Other Than Glass, by Phyllis A. Lyday. Ch. 17 in Borates: Economic Geology and Production, ed. by James M. Barker and Stanley J. Lefond. Soc. Min. Eng. AIME, 1985, pp. 255–264. The growth of the boron industry began when Marco Polo brought borax to Europe from Tibet in the 13th century. The paper is limited to uses other than glass, which account for approximately one-half of domestic consumption and cover a range of exotic uses. Depending on the concentration, boron can be both an explosive or a flameproofer and a fertilizer or a herbicide. Some of these uses require highly purified and concentrated forms of boron while other uses require only the crude ores. These nonglass uses include metallurgical fluxes, boron alloys, thermal neutron absorbers, bleaches, detergents, dyes, adhesives, nylon, and corrosion inhibitors.

OP 25–86. Electrolytic Preparation of Fe-Ni-Cr Alloys Using a Particle-Occlusion and Heat-Treatment Method, by G. R. Smith and J. E. Allison, Jr. J. Met., v. 37, No. 12, Dec. 1985, p. 55. As part of a research effort to conserve strategic and critical metals, the U.S. Department of the Interior, Bureau of Mines, has developed a modified aqueous electrodeposition method for preparing Fe-Ni-Cr alloy coatings and electroforms. This method involves mechanically suspending Cr powder (averaging 2 μm diam) in a ferrous-nickelous sulfate electroplating

bath and occluding the Cr particles in the electrodeposited Fe-Ni alloy matrix. Subsequent heat treatment of the resulting composite coating forms the ternary alloy. The occlusion process is affected by the quantity of Cr powder suspended as well as by the microstructure and composition of the electrodeposited matrix. The largest quantity of chromium is occluded when the electrodeposited matrix exhibits a dual-phase γ(Ni,Fe)-α(Fe,Ni) microstructure. Coatings with up to 20 wt pct Cr have been deposited from an electrolyte containing 20 vol pct suspended Cr powder. Heat treatment at 1,100° C for 8 h effectively homogenizes the composite coating. Alloys containing 55Fe-29Ni-16Cr produced by this method corroded at a rate of only 0.7 mm/yr during 240 h of exposure to boiling 65 pct HNO_3. Applicability of this method to the preparation of electroforms has also been demonstrated.

OP 26–86. Case Studies of Long-Term Methane Extraction From Coal, by Michael A. Trevits and Gerald L. Finfinger. Soc. Min. Eng. AIME preprint 85–333, 1985, 7 pp. In the course of Bureau of Mines research, various methods have been developed to remove gas in advance of, during, and subsequent to mining. Such methods include the drilling of horizontal or cross-measure boreholes from a mine opening, and vertical boreholes stimulated for drainage in advance of mining or for gob gas drainage. Techniques and equipment now exist that allow for the drilling of a borehole at any angle to the vertical (and even along an arc). Stimulation treatments have also been developed that provide for increased gas production capability. This paper briefly describes the long-term production history of five select gas drainage installations.

OP 27–86. Chlorination-Grade Feedstock From Domestic Ilmenite, by J. B. Wright, G. W. Elger, J. E. Tress, and H. E. Bell. Miner. and Metall. Process., Nov. 1985., pp. 198–202. This paper describes laboratory techniques and subsequent results of U.S. Bureau of Mines research to produce chlorination-grade feedstock from an abundant, low-grade, domestic, rock ilmenite ore. The research is part of the Bureau effort to devise technology that may help decrease U.S. dependence on imported raw materials. A rock ilmenite containing about 46 wt pct TiO_2 was smelted in an electric arc furnace with coke, woodchips, and Na_2CO_3 to separate most of the iron as pig iron and to form a low-iron, titanium-enriched slag. The slag was ground, pelletized, oxidized, and then sulfated with mixtures of SO_2 and air in a continuous 4.5- to 9.1 kg/h (10- to 20-lb/h) apparatus at 1,023 to 1,223 K (1,380° to 1,740° F). The sulfated slag, containing 60 pct to 65 pct TiO_2, was reground and leached in water at ambient temperature to decrease the combined levels of the troublesome calcium, magnesium, and manganese impurities from 7.0 to 1.7 wt pct. The final product was upgraded to about 84 wt pct TiO_2. This material is potentially suitable for chlorination in a fluidized-bed reactor. The most favorable results were achieved with leached slag sulfated at a feed rate of 4.5 kg/h (10 lb/h) and at temperatures of 1,073 to 1,123 K (1,470° to 1,560° F).

OP 28–86. Determination of Gallium in Phosphorus Flue Dust and Other Materials by Graphite Furnace Atomic Absorption Spectrometry, by David C. Barron and Benjamin W. Haynes. Analyst, v. 111, Jan. 1986, pp. 19–21. A simple, rapid method for the determination of gallium in inorganic matrices using Zeeman-corrected graphite furnace atomic absorption spectrometry (GFAAS) is described. The method uses an acid dissolution technique, $Mg(NO_3)_2$ as a matrix modifier, and the method of standard additions. The 294.4-nm wavelength is used to improve the signal-to-noise ratio without loss of sensitivity. Gallium was determined in phosphorus flue dust and also in coal fly ash, copper ore, and steelmaking flue dust. The procedure is used as an alternative to neutron-activation analysis (NAA) and as intermediate in sensitivity between flame atomic absorption spectrometry and NAA. A comparison of GFAAS and NAA results is presented.

OP 29–86. Dissolution Behavior of 304 Stainless Steel in HNO_3/HF Mixtures, by B. S. Covino, Jr., J. V. Scalera, T. J. Driscoll, and J. P. Carter. Metall. Trans. A, v. 17A, Jan. 1986, pp. 137–149. The dissolution behavior of type 304 stainless steel was studied in typical pickling environments in an effort to reduce the unnecessary loss of the critical metals nickel and chromium during the pickling process. Dissolution rates were determined for a 90-minute exposure to HNO_3/HF solutions ranging from 0.8 *M* to 3.5 *M* HNO_3 and 0.5 *M* to 2.6 *M* HF at 30°, 50°, 70°, and 90° C and containing 0 to 0.21 *M* dissolved Fe, Cr, or Ni. Dissolution rates increased as a function of increasing HNO_3 concentration from 0.4 *M* to 1.5 *M* HNO_3, decreased at higher HNO_3 concentrations, and increased with increasing HF concentration. Experiments to determine the effect of temperature on the dissolution reaction gave a lower activation energy for solutions with higher HNO_3 concentrations. The dissolved Fe and Cr decreased the dissolution rate of 304 stainless steel while dissolved Ni had essentially no effect. The Auger electron spectroscopy and X-ray photoelectron spectroscopy studies of films resulting from exposure to several HNO_3/HF solutions indicated that the fluoride did not penetrate the thin nonprotective films but remained on the outer surface of the film. The scanning Auger microscopy studies indicated that the fluoride was uniformly distributed over the surface. Both the dissolution and surface studies are consistent with a dissolution process that is controlled by reactions occurring either in solution or at the film-solution interface.

OP 30–86. An Elemental Description of Pacific Manganese Nodules, by Benjamin W. Haynes, Stephen L. Law, and David C. Barron. Mar. Min., v. 5, No. 3, Jan. 1986, pp. 239–276. A brief description of manganese nodule morphology and mineralogy is given, and detailed information on 74 elements in Pacific manganese nodules is presented. For the major elements and some minor and trace elements, the data are divided into four areas of the Pacific: the Clarion-Clipperton Fracture zone region, the mid-Pacific seamount region, other abyssal plain region (>3,000 m depth), and other seamount, ridge, and continental margin region (<3,000 m depth). For all 74 elements, data tables are presented, and for 21 elements, the data are broken down by area. Where only limited data are available for certain elements, the data are presented as a composite of the entire Pacific Ocean. The possible chemical form, mineral-element associations, and interelement correlations are given.

OP 31–86. Homotropal Ventilation for Longwall Dust Control, by Jonathan S. Kelly and Robert A. Jankowski. World Min. Int., v. 9, No. 12, Dec. 1985, pp. 24–26. U.S. longwall operators find compliance with federal respirable dust regulations difficult to achieve and maintain. Research has found that a major problem on many faces is contamination of the face intake air. Most U.S. longwall faces are currently ventilated from headgate to tailgate. Air is routed up one or more of the headgate entries, through a crosscut, and down the face to a return entry at the tailgate, causing intake air to become contaminated prior to entering the face. Results from this evaluation clearly showed the benefits of homotropal ventilation, as intake dust levels on the face were reduced by over 60% when compared with levels on the majority of longwall faces in the United States.

OP 32–86. New Laboratory Measurement Method for Water Spray Dust Control Effectiveness, by J. F. McCoy, W. E. Schroeder, S. R. Rajan, S. K. Ruggieri, and F. N. Kissell. Am. Ind. Hyg. Assoc. J., v. 46, No. 12, Dec. 1985, pp. 735–740. An innovative method for measuring dust reduction is presented. The approach involves measuring dust as it is introduced into a well-mixed chamber instead of into a tunnel. The technique is equivalent to measuring the product of airflow and dust reduction efficiency of scrubbers, filters, and electrostatic precipitators; it is especially convenient in evaluating the effectiveness of open water sprays. The method, which monitors the decay of dust concentration and is useful for both charged and uncharged water sprays, promises numerous benefits including the following: (1) Steady dust production is not required, (2) only single-point dust sampling is necessary,

and (3) only relative dust concentration accuracy is required. Laboratories engaged in dust control development for mines and mills are encouraged to consider adapting the measurement method for evaluating open sprays. A suitable mixed chamber can be designed, constructed, and operated with much less effort than a two-phase tunnel. Data for the dust reduction effectiveness of hydraulic and charged water sprays as well as a water-powered scrubber are presented.

OP 33–86. A Review of Techniques for Evaluating Mine Roof Competence, by E. R. Bauer and J. B. Czirr. Soc. Min. Eng. AIME preprint 86–44, 1986, 6 pp. A primary goal of Ground Control Research, Bureau of Mines, U.S. Department of the Interior, is to develop information that can be used by the mining industry to reduce accidents and fatalities due to failure of mine roof. A specific research objective is to determine methods to detect hazardous coal mine roof. This paper reviews the existing and experimental techniques and describes a recent Bureau of Mines contract research project that resulted in a simple technique and prototype instrument for evaluating mine roof competence.

OP 34–86. Treatment of Metalliferous Sulfides for Market, by Thomas G. Carnahan. Mar. Technol. Soc. J., v. 19, No. 4, 1985, pp. 62–64. Base metal sulfide deposits are known to exist in the Pacific Ocean and in the Red Sea. Sufficient data have been generated to allow a preliminary assessment of potential processing techniques. The coarse nature of the Pacific Ocean sulfide minerals indicates that conventional flotation will enable separate smelter-grade copper and zinc concentrates to be prepared. On-land smelting would produce these metals. The extremely fine-grained nature of the Red Sea deposits precludes preparation of smelter-grade flotation concentrates. The Red Sea concentrates would be treated for metals recovery by a chloride-based hydrometallurgical method.

OP 35–86. Control and Monitoring Via Medium-Frequency Techniques and Existing Mine Conductors, by Harry Dobroski, Jr., and Larry G. Stolarczyk. IEEE Trans. Ind. Appl., v. IA–21, No. 4, July-Aug. 1985, pp. 1087–1092. Medium-frequency (MF) techniques have been successfully applied to the problem of radio voice communications in both coal and metal and nonmetal mines. Long range is achieved by taking advantage of existing mine conductors that carry and propagate the signal over vast areas. It is very likely that in the near future such systems will become the preferred method for general mine communications. MF techniques can also be applied to the areas of in-mine control and monitoring. Preliminary work in this area is described. In a western mine, locomotives are being operated under MF remote control in a loading operation. In several eastern mines, MF has been evaluated as a method for monitoring the status of devices in remote areas of the mines. All control and monitor information uses existing mine conductors.

OP 36–86. Acid Mine Drainage From Inactive Eastern Coal Operations, by Patricia M. Erickson, Kenneth J. Ladwig, and Robert L. P. Kleinmann. Environ. Geochem. and Health, v. 7, No. 1, Mar. 1985, pp. 16–25. The most widely used technique for abatement of acid drainage from inactive surface mines and refuse disposal areas is revegetation of a soil cover applied to the waste material. Nonetheless, acid production often persists and, in some cases, limits establishment of vegetation. This paper reports on several field studies intended to determine the location of pyrite oxidation zones and migration pathways of oxidation products at inactive spoil and refuse sites. Oxygen required for pyrite oxidation is believed to be provided in the gaseous state from the atmosphere. Therefore, the oxygen concentration in unsaturated mine waste should provide an estimate of the weathering tendency in the local environment. Gas composition is currently being monitored in refuse and spoil at six sites. Barren refuse appeared to be oxygenated (>2% O_2) in a shallow zone extending less than 1 meter below the surface during most of the year. Preliminary data from coal spoil showed that oxygen can be available throughout the unsaturated thickness, even at a revegetated site. Gas composition varied vertically and laterally at a single site and also appeared to show seasonal dependence. Hydrologic factors are also important in acid production and transport. Discharge monitoring alone does not adequately describe the mass transport of acid products through the spoil. For example, at one reclaimed mine, the mean sulfate content in six monitoring wells ranged from 24% to 240% of the mean concentration at the discharge point. Sources of recharge and relative flow rates determine the contribution of a particular zone to overall discharge quality. These basic studies of acid production and transport indicate some shortcomings of standard reclamation practices at certain sites. This information will be used to develop alternative abatement technology designed to mitigate acid production at the source.

OP 37–86. Update on the Evaluation of Diesel Particulate Filters for Underground Mining, by A. Lawson, H. C. Vergeer, A. Stawsky, J. H. Daniel, and E. Thimons. Paper in the Proceedings of the 1986 SAE International Congress, Detroit, MI, Feb. 24–28, 1986, pp. 263–271. Results of a laboratory assessment of catalyzed ceramic diesel particulate filters (DPF's) are reported. Catalyzed DPF's are shown to substantially reduce diesel particulate emissions, carbon monoxide, and gaseous hydrocarbons, as well as particulate ignition temperatures. Sulfate production is discussed in relation to sulfates presently emitted into the mine environment. Field experience is reported on the application of the ceramic DPF to control diesel particulate emitted from underground diesel-powered vehicles. The vehicle has been operated in mine production service over typical load-haul-dump duty cycles. Field tests have been carried out using the filters assisted with both fuel additive and precious metal catalyst coating techniques. The structural integrity of the filter appears satisfactory with approximately 250 hours of field experience. Both manganese fuel additive and precious metal catalyst coating were shown to provide satisfactory regeneration assist. Exhaust backpressures over a 250-hour test were lower than the original exhaust system comprising an exhaust catalytic purifier and muffler in series.

OP 38–86. Biaxial-Loading Measurement for Mine-Pillar Stability Evaluation—Case Studies, by Paul H. Lu. Paper in the Proceedings of the International Symposium on Application of Rock Characterization Techniques in Mine Design, New Orleans, LA, Mar. 2–6, 1986. Soc. Min. Eng. AIME, Littleton, CO, 1986, pp. 142–151. This paper presents three case studies in which the biaxial loading was measured to evaluate the stability of longwall chain pillars. Integrity factor, defined as the ratio of the total pillar strength to the total pillar load, is the criterion for stability. The total pillar load is derived directly from the in situ measurement of vertical pressures. The total pillar strength is derived from the situ measurement of horizontal pressures and the confined compressive strengths of pillar material as determined in laboratory tests. Horizontal and vertical pressures in the pillar were measured with the Bureau of Mines, U.S. Department of the Interior, hydraulic borehole pressure cells.

OP 39–86. Crude Iodine Production—A Review of Processes, by P. A. Lyday. Ind. Miner., No. 222, Mar. 1986, pp. 65–66, 69–70, 73, 75–76. There have been three distinct but overlapping phases in the history of iodine processing. Phase 1, which began in 1817 and continued until 1959, involved iodine production from seaweed in France, Japan, Norway, Scotland, the United States, and the U.S.S.R. Phase 2 began in 1852 as byproduct production of iodine with natural sodium nitrate in Chile. Phase 3 began in 1854 with the production of iodine from brines in Java, Indonesia, and eventually in Italy, Japan, the United States and the U.S.S.R. The production of crude iodine has experienced many technical changes over the past 175 years. The changes in processing and production during these years will be discussed.

OP 40–86. Power From Mine Cooling Water, by Robert N. Torbin and Edward Thimons. Power Eng., v. 90, No. 3, Mar. 1986, pp. 27–28. The U.S. Bureau of Mines, as part of its Health and Safety Research Program, funded a research program to study the applicability of energy recovery techniques to the mining industry. Since much of the electric power consumed in the United States is generated by converting the energy from falling water, it is easy to conceive that water flowing down long, vertical pipelines into deep mines could be utilized in a similar manner by allowing the high-pressure water to operate a turbine at the bottom of the pipeline. An energy recovery system of this type can offer several advantages. Modern turbines can convert about 90% of the water's potential energy into useful shaft work. In using a turbine with an efficiency rate of 85%, the temperature rise of the water due to potential energy conversion is only 15% of the rise experienced with no turbine. Lower water temperature resulting from turbine usage can be expressed directly in tons of refrigeration (which becomes important to cooling the working environment in deep mines).

OP 41–86. Heat Capacity of Cadmium Oxysulfate From 5.16 to 300.7 K and Relative Enthalpy to 1001.5 K, by R. P. Beyer and M. J. Ferrante. J. Chem. Thermodyn., v. 18, 1986, pp. 365–370. The heat capacity of cadmium oxysulfate ($2CdO \cdot CdSO_4$) from 5.16 to 300.7 K was measured by adiabatic calorimetry and the relative enthalpy to 1001.5 K by copper-block drop calorimetry. A nonisothermal transition was observed over the temperature range 245 to 260 K with a peak at 253 K. The values at 298.15 K for $C^\circ_{p,m}$, $\{S^\circ_m(T) - S^\circ_m(0)\}$, $-\{G^\circ_m(T) - H^\circ_m(0)\}/T$, and $\{H^\circ_m(T) - H^\circ_m(0)\}$ are 193.67, 246.59, and 125.81 J · K^{-1} · mol^{-1}, and 36.01 kJ · mol^{-1}, respectively. These properties are also reported at convenient temperature intervals from 5 to 1000 K.

OP 42–86. Relative Importance of Abrasion and Corrosion in Metal Loss in Ball Milling, by J. Dodd, D. J. Dunn, J. L. Huiatt, and T. E. Norman. Miner. and Metall. Process., v. 2, No. 4, Nov. 1985, pp. 212–216. Corrosion studies in laboratory ball mills and grinding environment simulations produce corrosion rates and total metal removal rates much lower than those recorded in operating production ball mills. The corrosion component of ball metal loss in many mills probably represents less than 10% of the total loss, judging from AMAX Inc. experience and recent U.S. Bureau of Mines tests. Such small absolute losses are consistent with ball metal loss measured in production ball mill marked ball wear tests to determine effects of corrosion and abrasion resisting properties of alloys in operating mills. These indicate that metal hardness and microstructure determine relative metal loss rates of a given situation. The combination of ore characteristics and grinding process dynamics determine metal loss severity. Alloying for corrosion resistance and modification of the milling corrosion environment yield relatively small metal loss reductions. Alloying and heat treatment to produce high hardness and microstructures of high carbon martensite and, for cast irons M_7C_3 carbides, produce the lowest metal losses in typical wet grinding applications.

OP 43–86. Characterization and Measurement of Longwall Rock Mass Movement, by Jeffrey M. Listak, John L. Hill III, and Joseph C. Zelanko. Ch. 14 in Rock Characterization Techniques (Proc. SME-AIME Annu. Meeting, New Orleans, LA, Mar. 3–6, 1986). Soc. Min. Eng. AIME, Littleton, CO, 1986, pp. 133–141. This paper addresses the origins, directions, and magnitudes of loads imposed on longwall roof supports by the caving of the overlying strata. Physical property data are also presented to demonstrate the relationship between caving behavior and local geology. Analyses of data show that strata behavior above longwall extractions is highly dependent upon lithology with major disturbances occurring at weak zones. Information collected from this study is correlated with measurements taken from several other studies (i.e., shield support load measurements, pillar loading, and subsidence measurements) to provide a comprehensive description of the stress distribution and strata behavior associated with the extraction of a longwall panel.

OP 44–86. Anaerobic Extraction of Cobalt in a Pulse Column, by Larry R. Penner, Richard E. Siemens, and Gloria J. Galvan. Solvent Extr. and Ion Exch., v. 4, No. 2, Apr. 1986, pp. 345–360. The effects of excluding air (oxygen) from a cobalt solvent extraction circuit were studied for LIX 64N extractant. After solvent extraction of divalent cobalt from ammoniacal solutions with chelating extractants such as LIX 64N, the loaded Co-chelate is believed to oxidize to a stable trivalent complex that resists subsequent stripping with mineral acids. To improve stripping efficiency, cobalt was extracted and stripped in the absence of oxygen in pulsed, perforated-plate columns that were designed and constructed by the Bureau of Mines. When the ammoniacal cobalt(II) sulfate and LIX 64N solutions were purged, blanketed, and pulsed with argon, cobalt extraction exceeded 99%, and stripping with 1 vol % H_2SO_4 reached 98.5%. The stripped extractant was recycled to the extraction column with no loss of extraction efficiency in six passes through the circuit.

OP 45–86. Options in the HCl Process for the Production of Alumina From Clay, by D. E. Shanks, D. C. Thompson, R. M. Arington, G. L. Dan, and J. A. Eisele. Paper in Light Metals 1986, ed. by R. E. Miller. Metall. Soc. AIME, Warrendale, PA, 1986, pp. 25–33. The Bureau of Mines has conducted in-depth studies on the recovery of aluminum chloride hexahydrate and alumina from domestic kaolinitic clay. The original goal of the studies was to provide the technology for alumina production from domestic raw materials. Current research is focused on process modifications that would improve the economics of clay-HCl leaching and improve chances for transfer of the technology to commercial use. Options under investigation include direct leaching of raw clay, changes in leaching acid concentration and stoichiometry, decreased leaching duration, improved solid-liquid separations, elimination of solvent extraction for iron removal, and formation of basic aluminum chloride instead of aluminum chloride hexahydrate as an intermediate product. Implementation could decrease energy, equipment, and reagent costs by eliminating the calcination step, substituting filtration for thickening and washing circuits, and combining iron removal with aluminum chloride crystallization.

OP 46–86. Subsolidus Compatibility in the System NaCl-KCl-$AlCl_3$-NaF-KF-AlF_3, by Charles A. Sorrell and John G. Groetsch, Jr. J. Am. Ceram. Soc., v. 69, No. 4, Apr. 1986, pp. 333–338. The chemistry and properties of salts used as fluxes for recycling aluminum were studied. Many fluxing salts fall within the system NaCl-KCl-$AlCl_3$-NaF-KF-AlF_3, which has been shown to be a reciprocal system, with NaF-KCl, KCl-AlF_3, and NaCl-AlF_3 as the stable mixed-halide binaries. Twelve subsolidus compatibility tetrahedra were determined by X-ray analyses of samples heated in evacuated sealed tubes. X-ray measurements of quenched and annealed samples indicate that elpasolite, nominally K_2NaAlF_6, has a compositional range between 60 mol % Na_3AlF_6, 40 mol % K_3AlF_6 and 25 mol % Na_3Alf_6, 75 mol % K_3AlF_6. Improved X-ray powder data are given for $KAlF_4$, showing a previously reported structure to be essentially correct.

OP 47–86. The Flotation of Sulfide Minerals—Electrochemical Aspects, by R. Woods and P. E. Richardson. Ch. 9 in Advances in Mineral Processing—A Half-Century of Progress in Application of Theory to Practice, ed. by P. Somasundaran. Soc. Min. Eng. AIME, Littleton, CO, 1986, pp. 154–170. Selectivity in sulfide flotation arises from the nature of the interaction between collector species and the mineral surface. This takes place by a mixed potential mechanism involving separate electrochemical steps. The process that leads to a hydrophobic mineral surface is an anodic oxidation reaction that fixes the collector at the interface, and this is balanced by the cathodic reduction of oxygen. Studies carried out using solid and particulate bed electrodes have identified the hydrophobic

entity as a chemisorbed species, a metal-thiol compound, or a dithiolate, depending upon the collector, the mineral, and the solution composition. Recovery potential relationships have been determined for a number of single mineral systems, and the results correlate with electrochemical studies at electrodes. Studies on mineral mixtures have shown that the recovery is influenced by other components. Depressant action generally takes place by lowering the mixed potential below the flotation edge for the mineral. Self-induced flotation is also a function of potential.

OP 48–86. Acid Brick and Silica Brick, by James P. Bennett and William M. Eckert. Ch. 15 in Corrosion and Chemical Resistant Masonry Materials Handbook, ed. by Walter Lee Sheppard, Jr. Noyes Publ., Park Ridge, NJ, 1986, pp. 144–154. Physical properties, chemical resistance, temperature restrictions, volume expansion, and applications of acid brick (red shale and fireclay) and silica brick are contrasted. Tables and charts presenting the results of exposing both types of material to select acids are included.

OP 49–86. The Effect of Oxygen on the Open-Circuit Passivity of Fe–18Cr, by B. S. Covino, Jr., M. Rosen, T. J. Driscoll, T. C. Murphy, and C. R. Molock. Corros. Sci., v. 26, No. 2, Feb. 1986, pp. 95–107. Electrochemical studies were conducted to determine the critical amount of oxygen necessary to prevent corrosion by maintaining the open-circuit passivity of Fe–18Cr samples initially passivated at 0.6 V normal hydrogen electrode (NHE) in 1*N* H_2SO_4 solutions. Samples passivated at 0.6 V(NHE) and then released to open circuit in O_2-saturated (29.4 ppm O_2 dissolved) solution maintained a state of passivity. Samples passivated and released to open circuit in N_2-purged solution decayed to a state of active corrosion in 800 to 2,000 min. A passive state, however, could be maintained if O_2 were added to the N_2 flow so that a minimum of 1.7 ppm O_2 was present in solution. Furthermore, this critical amount of O_2 had to be added before open-circuit decay reached 0.45 V(NHE). Auger electron spectroscopy measurements indicated that following open-circuit stabilization of passivity by O_2 the percentage chromium in the film increased with increasing open-circuit potential. X-ray photoelectron spectroscopy measurements indicated that the film thickness decreased with increasing open-circuit potential.

OP 50–86. Dewatering of Red Mud, by G. D. Hood, G. M. Wilemon, D. A. Stanley, and B. J. Scheiner. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 655–664. A solid-liquid separation technique devised by the Bureau of Mines, U.S. Department of the Interior, was applied to red mud, the caustic-containing residue generated when alumina is extracted from bauxite by the Bayer process. Red mud obtained from Jamaican bauxite was dewatered in laboratory batch tests and small-scale continuous tests to develop an inexpensive method of washing the mud and recovering the valuable sodium aluminate and caustic. A number of high-molecular-weight polymers were evaluated, and a high-anionic powder polymer used in combination with a high-anionic, emulsion-type polymer proved to be most effective. In small-scale continuous tests using a baffled tube mixer to aid floc formation and a rotating trommel to dewater the solids, slurries with an initial concentration of 10 pct solids were dewatered to 27 pct solids using 0.20 kg of polymer per ton of dry solids. After the trommel treatment, the flocculated red mud was placed in a column fitted with a screen to allow released water to drain; after 15 days, the solids content increased over 40 pct.

OP 51–86. High-Purity, Fine Ceramic Powders Produced in the Bureau of Mines Turbomill, by Jesse L. Hoyer and Arthur V. Petty, Jr. Ceram. Eng. and Sci. Proc., v. 6, No. 9–10, Sept.–Oct. 1985, pp. 1342–1355. The Bureau of Mines turbomill is being evaluated for the production of ultrafine, high-purity, ceramic powders. Such highly reactive ceramic powders could contribute to improve performance of structural materials fabricated for use in severe conditions of temperature, pressure, and environment. The materials studied were alpha-silicon carbide (α-SiC), silicon nitride (Si_3N_4), titanium diboride (TiB_2), quartz (SiO_2), alumina (Al_2O_3), and zirconia (ZrO_2). The agglomeration characteristics of α-SiC and the effects of dispersing agents on agglomeration were also evaluated. Ultrafine α-SiC powders with an average diameter of 1.31 μm (51 pct <1 μm) were produced in 1 h in the Bureau's all-polymer turbomill. A sodium lignosulfonate was found to be the best dispersant for SiC powders, resulting in the least agglomeration and in negligible contamination from the milling process. Si_3N_4 powders were prepared from two different starting materials, each with a diameter of 55 μm. Milled powders had average particle sizes of 2.96 μm (20 pct <1 μm) after 1 h in the one case, and 2.09 μm (51 pct <1 μm) after 2 h in the other. TiB_2, with an average initial diameter of 35 μm, was reduced to 5.52 μm (2 pct <1 μm) in 1 h. SiO_2, ZrO_2, and Al_2O_3 (starting materials with average diameters of 30.52, 20.11, and 101. 74 μm) were ground to 3.44 μm (12 pct <1 μm), 3.09 μm (15 pct <1 μm), and 2.69 μm (28 pct <1 μm), respectively, in 1 h. Contamination of the powders produced in the turbomill was negligible, which is advantageous for high-temperature applications where purity is a primary concern.

OP 52–86. BN Powder Synthesis at Low Temperature, by Rustu S. Kalyoncu. Ceram. Eng. and Sci. Proc., v. 6, No. 9–10, Sept.–Oct. 1985, pp. 1356–1364. The Bureau of Mines has devised a laboratory technique for preparing ultrafine boron nitride (BN) powders through the formation of elemento-organic BN precursor compounds at low temperatures. Structural materials produced from such highly reactive powders may have applications in the severe conditions of temperature, pressure, and environment encountered in mining and mineral processing. The reactions of sodium borohydride ($NaBH_4$) with ammonium chloride (NH_4Cl) in an organic solvent such as chlorobenzene, ammonia (NH_3) with boron trichloride (BCl_3), and NH_4Cl with BCl_3 were studied at temperatures ranging from –75° to 200° C. All three reaction systems resulted in the formation of precursor compounds, the carbothermic decomposition of which yielded ultrafine amorphous BN powders.

OP 53–86. The Feasibility of Using Stereoscopic Photography To Improve Miners' Training on Groundfall Hazards, by Robert H. Peters. Paper in the Proceedings of the Fourth Annual Meeting of the Collegiate Association for Mining Education. Univ. MO-Rolla, Oct. 3, 1985, pp. 2–17. This paper describes Bureau of Mines research to determine the feasibility of using stereoscopic slides to improve miners' ability to recognize dangerous roof and rib conditions. In comparison to conventional slides, stereoscopic slides give the viewer a better perception of certain details such as the presence of cracks and gaps in the roof rock. Data were collected from mine safety and training personnel using structured interview guides and stereoscopic slides. The overwhelming majority of those interviewed indicated that stereoscopic slides are far superior to conventional slides for portraying groundfall hazards, and that their use as a training aid for underground coal miners is quite feasible.

OP 54–86. Formation of a Molybdenum Silicon Suboxide: Growth of SiO_2 Pegs, by James C. Rawers. J. Mater. Sci. Lett., v. 5, No. 5, May 1986, pp. 513–515. The high-temperature, long-term oxidation resistance of a low-chromium, silicon-molybdenum-iron alloy has been shown to result from the formation of a SiO_2 suboxide layer. This layer at the metal-oxide interface was observed by removing the substrate metal via chemical etching. Scanning electron micrographs of the oxide surface at the metal-oxide interface showed the presence of suboxide pegs extending into the substrate metal. A time sequence for the oxidation process of the alloy is presented.

OUTSIDE PUBLICATIONS

OP 55–86. The Flocculation of Fine Particles With Polyethylene Oxide: A Proposed Mechanism, by B. J. Scheiner and D. A. Stanley. Soc. Min. Eng. AIME preprint 86–75, 1986, 10 pp. The Bureau of Mines has developed a system for dewatering waste slurries by flocculating mineral particles with polyethylene oxide (PEO) and dewatering the resulting flocs on static and/or rotary screens. This paper discusses data obtained from dewatering, rheology, and ion-exchange experiments. A possible mechanism is postulated for the attachment of PEO to claylike particles through a water bridge with the intershell waters of the exchanged ion and the polymer.

OP 56–86. Recycling Zircon From Investment Casting Molds, by C. W. Smith, T. O. Llewellyn, and G. V. Sullivan. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 665–674. The Bureau of Mines, U.S. Department of the Interior, conducted physical and chemical beneficiation studies on three samples of waste investment casting molds to develop a method to liberate and recover zircon. Rod-mill grinding, autogenous attrition grinding, and caustic leaching were the liberation methods investigated. Flotation, gravity separation, and caustic leaching and sizing were the recovery methods investigated. Flotation techniques produced concentrates containing up to 74.2 pct zircon with a zircon recovery of 53.4 pct. Gravity concentration produced concentrates containing up to 98.6 pct zircon; however, recovery of the zircon was only 57 pct. Caustic leaching and sizing produced concentrates containing up to 98 pct zircon with attendant recoveries of 81 pct.

OP 57–86. Water Spray Cooler for Cooling Hot Working Environments in Mines, by E. D. Thimons, J. F. McCoy, and J. R. Marks. Paper 14 in Proceedings of Frigair 86 Conference, Pretoria, Republic of South Africa, Apr. 14–18, 1986, v. 1, 6 pp. The need for more efficient mine refrigeration equipment is greater than ever, as increasing numbers of U.S. mines are being operated at greater depths in order to reach minable ore deposits. The combination of high temperatures and high humidities encountered at these depths make a comfortable working environment difficult and expensive to maintain. Many ore bodies mined today could not be mined without cooling of the underground environment. Miners' safety, comfort, and productivity all suffer if air refrigeration needs are not satisfied. The water spray coolers described in this report are efficient and economical devices for dealing with the heat problem encountered in deep mines. Four limited bulk water spray coolers were designed and built. The first of these coolers, a single-stage unit, was tested in the Mount Taylor Mine near Grants, NM, before it closed. The remaining three coolers, a two-stage cooler and two three-stage coolers, were installed in the Homestake Gold Mine in Lead, SD. To date, all the coolers have performed well under in-mine conditions and have required only minimal maintenance. This paper details the design and performance of these coolers.

OP 58–86. Lessons Learned From First Impulse Turbine Installation in the U.S. Mining Industry, by E. D. Thimons and R. N. Torbin. Paper 25 in Proceedings of Frigair 86 Conference, Pretoria, Republic of South Africa, Apr. 14–18, 1986, v. 1, 7 pp. The Bureau of Mines, as part of its Health and Safety Research Program, has investigated a technique for improving the performance of mine refrigeration systems. By converting the potential energy of the incoming water to electrical energy rather than to heat energy, the water stays colder. This results in cooler mine temperatures and a healthier, more comfortable working environment for miners. A primary spinoff advantage resulting from this research is an energy savings from employing such a refrigeration technique. Recognizing the value of recoverable potential energy, the Bureau of Mines has undertaken a project to study the application of energy recovery techniques to the U.S. mining industry. To this end, the Bureau has contracted with Foster-Miller, Inc., of Waltham, MA, to investigate, evaluate, and demonstrate commercially available means of efficiently recovering the energy from any incoming cooling water source. This project has led to procurement, installation, and operation of a complete thermal energy recovery system. The test site was the Lucky Friday Mine, owned and operated by the Hecla Mining Co. of Wallace, ID. The system has now been successfully operating for 20 months.

OP 59–86. Sulphur Hexafluoride as a Mine Ventilation Research Tool—Recent Field Applications, by Robert J. Timko and Edward D. Thimons. J. Mine Vent. Soc. S. Afr., v. 39, No. 2, Feb. 1986, pp. 18–20. Sulfur hexafluoride (SF_6) is an odorless, colorless, nontoxic gas that has found acceptance as a tracer gas in research on ventilation patterns, measurement of air leak rates, respirable dust reductions due to bagging hood modifications, and the study of airflows relating to gob boreholes. Following a short review of the SF_6 sampling technique, this report describes recent Bureau of Mines projects in which SF_6 was used successfully as a tracer gas, enabling researchers to acquire representative data quickly and inexpensively.

OP 60–86. Sulfur Spray Coatings, by William C. McBee, Thomas A. Sullivan, and Harold L. Fike. Ch. 50 in Corrosion and Chemical Resistant Masonry Materials Handbook, ed. by Walter Lee Sheppard, Jr. Noyes Publ., Park Ridge, NJ, pp. 659–668. Sulfur spray materials have been developed as protective coatings for construction materials exposed to corrosive acid and salt environments. The development has included laboratory design and testing and the scale-up to large-scale field installations using special equipment and application techniques. Surface-bond construction using sulfur spray coatings has been shown to be technically feasible. Block buildings constructed by this method have structural properties exceeding those of buildings constructed with mortar joints.

OP 61–86. Polymer Concretes, by William C. McBee, Thomas A. Sullivan, and Harold L. Fike. Ch. 33 in Corrosion Resistant Masonry Materials Handbook, ed. by Walter Lee Sheppard, Jr. Noyes Publ., Park Ridge, NJ, pp. 392–416. Technology has been developed to prepare chemical-resistant construction materials. A modified-sulfur cement was developed in which sulfur is reacted with dicyclopentadiene and oligomers of cyclopentadiene to form a stable cement product. Mixture designs utilizing corrosion-resistant aggregates and modified-sulfur cements were developed to prepare stable sulfur concretes for use as corrosion-resistant materials of construction. Sulfur concretes were produced with excellent resistance to damage by most acid and salt environments, good mechanical strength properties, resistance to damage by freeze-thaw cycling, and coefficients of expansion compatible with those of other materials of construction such as portland cement concrete and reinforcing steel. The technology has been demonstrated on a commercial scale both in the manufacture of the modified-sulfur cement and in its utilization in producing sulfur concrete construction materials. Cooperative evaluation with industry on testing in corrosion environments indicated that sulfur concrete has the potential for widespread application in the chemical, metallurgical, and fertilizer industries.

OP 62–86. A New Construction Material To Consider—Sulphur Concrete, by K. W. Mlynarski and W. C. McBee. Navy Civ. Eng., v. 25, No. 4, Spring 1986, pp. 24–26. Corrosion-resistant sulfur concrete materials have been developed for use in acidic and salt environments where portland cement concrete (PCC) materials fail. Industrial testing has shown that these materials are durable in 50 different process environments. The materials exhibit excellent mechanical properties when compared with PCC. Sulfur concrete shows great promise for applications in the chemical, metallurgical, and fertilizer industries. Other potential use areas include marine environments and highway and bridge areas where salt corrosion is a problem.

OUTSIDE PUBLICATIONS

OP 63–86. Transmission Electron Microscopy of Rapidly Quenched Iron-Aluminum Sputter-Deposited Films, by L. D. McCormick, P. M. Fabis, and C. L. Chien. J. Non-Cryst. Solids, v. 81, 1986, pp. 155–161. Sputter-deposited Fe-Al alloys were studied with transmission electron microscopy (TEM), Auger electron spectroscopy, and selected area electron diffraction (SAD). The alloys were deposited with thicknesses of approximately 50 nm onto carbon-coated TEM grids. All samples were deposited by planar magnetron sputtering onto substrates held at liquid nitrogen temperature. The compositions studied were $Fe_{70}Al_{30}$, $Fe_{50}Al_{50}$, $Fe_{30}Al_{70}$, $Fe_{10}Al_{90}$ and Fe_5Al_{95}. The $Fe_{70}Al_{30}$ composition was polycrystalline body-centered cubic (bcc) with a lattice constant of 0.291 nm, and the Fe_5Al_{95} composition was polycrystalline face-centered cubic (fcc) with a lattice constant of 0.41 nm. The $Fe_{50}Al_{50}$ composition contained approximately 2 vol % bcc crystallites in an amorphous matrix. Both the $Fe_{30}Al_{70}$ and $Fe_{10}Al_{90}$ samples were amorphous to TEM and SAD. The amorphous alloys and the amorphous regions of the $Fe_{50}Al_{50}$ alloys display an "island-channel" structure that is detectable with TEM. The data indicate the presence of only three phases in this metastable system: polycrystalline bcc, amorphous, and polycrystalline fcc.

OP 64–86. Flocculation, by B. J. Scheiner. Min. Eng., v. 38, No. 5, May 1986, pp. 342–343. Publications in the field of flocculation as applied to mineral processing for the year 1985 are reviewed. Many of the theoretical factors effecting flocculation such as polymer dosage, mineral consumption, and charge density of the polymer were discussed. Also, new flocculation techniques for dewatering mineral processing waste are included in the review. The research conducted in 1985 has increased understanding of how polymers interact with minerals.

OP 65–86. Overview of the Bureau of Mines Subsidence Research Program, by Michael A. Trevitz, Roger L. King, and Bradley V. Johnson. Paper/Presentation No. 86 in the Proceedings of the 88th Annual General Meeting of the Canadian Institute of Mining and Metallurgy, Montreal, Canada, May 11–15, 1986, 14 pp. During the process of subsidence, the ground surface is changed as a result of the excavation of the underlying coal unit. The final surface profile is determined by a multitude of factors, such as extracted coal thickness, width of the opening, depth, overburden lithology, mine design, and mining method. An analysis of the typical subsidence profile reveals that almost every point of the surface over the mining area will be displaced both horizontally and vertically. Furthermore, mining operations have often been accused of causing local water wells to become dry or polluted. The impact on water can be of major proportions in such areas as the Western United States, where underground aquifers represent a major source of water for populated areas, and in the Midwest, where slight alterations in surface drainage could radically affect the agriculture industry. The Bureau of Mines Subsidence Research Program is focusing on providing the mine operator with the ability to predict surface movements and effects on ground water as a function of mining method and geologic context. The program is designed for coal basins where high mining activity may impact land use requirements. These areas have been delineated via consultations with industry and other Government agencies. Eventually, all coal basins and mining methods will be addressed. Data sets from several subsidence monitoring sites have been or are now being collected. Data sets are now available from the Eastern, Interior, and Rocky Mountain coal provinces for full-extraction mining methods (longwall and/or room-and-pillar with retreat mining). At select sites, shallow-aquifer monitoring wells have also been installed to observe the effects of subsidence on the ground water system. To date, an empirical model for subsidence prediction has been generated for the Northern Appalachian coal region. The applicability of this model to other coal regions remains to be tested.

OP 66–86. Design Procedure for Arch Canopies for Rehabilitation of High-Roof-Fall Areas, by Richard A. Allwes and C. P. Mangelsdorf. Paper in Proceedings of the Fifth Conference on Ground Control in Mining, Morgantown, WV, June 11–13, 1986, ed. by A. Wahab Khair and Syd S. Peng. WV Univ., 1986, pp. 51–61. This report describes an arch canopy design for rehabilitating a high-roof-fall area. This procedure is specifically developed for evaluating an unbackfilled arch canopy that is subjected to an impact load (roof fall). Only dynamic line loading of the arch canopy at its crown is considered, and the procedure does not account for an unsymmetrical loading condition. The evaluation of whether an arch canopy is suitable for a particular installation is dependent upon many variables, including in-mine conditions and the engineering properties of the structure. However, a general evaluation can be based upon a comparison of the arch's maximum crown deflection and a prescribed allowable crown deflection. A single spring-mass system is used as an idealized model to represent the dynamic behavior of the arch canopy at its crown. An energy approach is taken to determine the maximum crown deflection of an arch rather than solving a differential equation of motion derived from dynamic equilibrium. The design procedure is based on the concept that when an arch canopy is subjected to impact loading at its crown and deflects from its unloaded state to maximum crown deflection, the structure absorbs strain energy, both elastic and plastic. As a result, this strain energy can be calculated from a static load-displacement diagram for the structure. The significance of this design procedure is that it gives mine personnel an analytical tool to select an arch canopy to meet the dimensional and functional requirements of a mine entry, and a prescribed allowable crown deflection.

OP 67–86. Equations for the Analysis of Borehole Pressure Cell Data, by C. O. Babcock. Ch. 36 in Rock Mechanics: Key to Energy Production, ed. by Howard L. Hartman (Proc. 27th U.S. Symposium on Rock Mechanics, Tuscaloosa, AL, June 23–25, 1986). Soc. Min. Eng. AIME, Littleton, CO, 1986, pp. 233–241. Although hydraulic pressure cells in boreholes have been in extensive use since 1957, methods of data reduction have been slow to develop. Recent research indicates a linear relationship between cell pressure change and rock stress change. In this paper, the logarithm of the cell pressure is related to the stress change in seven elastic materials, and equations derived from this experiment to relate borehole pressure cell data from vertical and horizontal cells to biaxial ground stress changes are presented.

OP 68–86. Performance and Test Criteria for DC Fuses in Coal Mine Applications, by Tayfun Cataltepe, Eldon K. Stanek, Dennis O. Wiitanen, and Michael R. Yenchek. IEEE Trans. Ind. Appl., v. IA–22, No. 2, Mar.–Apr. 1986, pp. 352–359. A comprehensive study was made of direct current (dc) system parameters in coal mines to recommend performance and test criteria for dc fuses. Field tests were conducted in 10 coal mines in which transients were initiated on the dc system from which the parameters of the dc mine electrical power system could be determined. Data processing was done to fit an exponential curve to the field waveforms. From this data analysis finding, the dc system resistance, inductance, and time constant was possible. A survey of nationally recognized laboratories was conducted to establish that the recommended test criteria were practical. The development of test criteria for dc fuses used in mines was based on the measurement of parameters in the field, the survey of testing laboratories, literature searches, and laboratory tests. Methods to predict analytically the parameters measured in the field are discussed. A brief laboratory testing program was carried out to verify the practicality of the recommended criteria.

OP 69–86. Closing the Door on Dust, by Andrew B. Cecala and Terry Muldoon. Pit and Quarry, v. 78, No. 11, May 1986, pp. 36–37. Although bag technology is continually

improving, contamination from bags remains a significant source of dust exposure for workers. Most of the bag contamination is caused by the bag valve. Standard paper, polyethylene, extended polyethylene, double trap, and foam valves were tested for dust reduction capabilities during bag loading, conveying, and pallet loading at a mineral processing plant. When extended polyethylene valves were used, respirable dust at the bag operator location was reduced by 62%, while at the bag stacker location the reduction was 66%.

OP 70–86. Advances in Computerized Mine Monitoring and Control—Prospects for the Future, by T. J. Fisher and J. Durkin. Paper in Mining Productivity Through Reliability and Control. Volume 1. Technical Papers (Proc. Mining 85 Conference, Birmingham, England, June 23–25, 1985). Inst. Min. Eng., Birmingham, England, 1985, pp. 339–344. This paper describes recent advances in hardware and software used in U.S. monitoring systems and hypothesizes on developments from the field of artificial intelligence, such as expert systems, that may play an important role in future monitoring and control technology.

OP 71–86. Purification of Secondary Zinc Materials Contaminated With Chlorine, by J. P. Hager and J. F. Lemons, Jr. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 203–223.New process chemistry has been developed for the dechlorination roasting of secondary zinc materials. An experimental study has been undertaken on the use of gaseous ferric chloride [$Fe_2Cl_6(g)$] to enhance the volatilization of impurity chlorides and zinc chloride through the formation of gaseous complexes. The species $CdFe_2Cl_8(g)$, $PbFe_2Cl_8(g)$, and $ZnFeCl_5(g)$ have been identified and their thermodynamic properties determined. To provide a baseline for the measurement of vaporization enhancement through vapor complex formation, the vapor pressures of $CdCl_2$, $PbCl_2$, and $ZnCl_2$ were also determined. The thermodynamic data have been used to calculate the degree of visibility enhancement for different processing conditions. The results indicate that significant increases in vapor pressure are possible. An information base has been developed that should provide for further development and commercialization of the processing concept.

OP 72–86. Structural Stability of Coal Mine Entry Intersections—Case Studies, by K. Hanna, D. Conover, K. Haramy, and R. Kneisley. Ch. 74 in Rock Mechanics: Key to Energy Production, ed. by Howard L. Hartman (Proc. 27th U.S. Symposium on Rock Mechanics, Tuscaloosa, AL, June 23–25, 1986). Soc. Min. Eng. AIME, Littleton, CO, 1986, pp. 512–519. This paper describes a rock mechanics instrumentation program, data analyses, and a comparison of two case studies conducted at two underground mines, designated as "A" and "B," in the Illinois Coal Basin. The instrumentation plans and data collected during development and long-term monitoring of four-way intersections and adjoining entries are presented. Data analyses of premining and postmining roof stress, pillar loading, strata movement, roof bolt loading, and geologic features are included.

OP 73–86. Field Investigations of Roof and Pillar Stability in Coal Mine Intersections, by K. Hanna, J. Haramy, and D. Conover. Paper in Proceedings of Second Conference on Ground Control Problems in the Illinois Coal Basin, Southern Illinois University, May 29–31, 1985, ed. by Yoginder P. Chugh. Southern IL Univ., May 1985, pp. 76–83. This report describes a rock mechanics instrumentation program conducted in an underground coal mine in central Illinois. This research project was designed to provide a basic understanding of premining and postmining roof stresses, pillar loading, strata movement, floor heave, and bolt loading at coal mine intersections. The instrumentation plan, a description of the instruments installed in and around a four-way intersection, and the data obtained during the development of the intersection, are presented. Data collected include physical properties of coal and rock, strata lithology, strata movements, in situ stresses, mining-induced stresses, and roof bolt loading. An analysis of observations made and instrumentation results obtained during development and initial monitoring of the intersection is also presented.

OP 74–86. Effect of High Horizontal Stress on Coal Mine Entry Intersection Stability, by K. Hanna, K. Haramy, D. Conover, and D. Dopp. Paper in Proceedings of Fifth Conference on Ground Control Mining, Morgantown, WV, June 11–13, 1986, ed. by A. Wahab Khair and Syd S. Peng. WV Univ., 1986, pp. 167–182. This manuscript describes an extensive ground control study at the Inland Steel No. 2 Mine near McLeansboro, IL, conducted by the Bureau of Mines in cooperation with Inland Steel Coal Co. The mine experiences severe ground control problems primarily due to high horizontal stress, particularly at entry intersections. Mine experience has shown that reorienting mine entries, modifying the bolting pattern, and altering the mining sequence are effective in reducing the severity of roof falls and out-of-seam dilution. However, the frequency of roof falls has not been significantly reduced. This research project was designed to provide a thorough explanation of the intersection failure mechanism through combined analyses of company in-mine experience and Bureau field measurements. Stresses and deformations were monitored in a four-way intersection during all stages of development and were related to site observations and theoretical analyses.

OP 75–86. Floor Heave Analysis in a Deep Coal Mine, by K. Haramy and J. McDonnell. Ch. 75 in Rock Mechanics: Key to Energy Production, ed. by Howard L. Hartman (Proc. 27th U.S. Symposium on Rock Mechanics, Tuscaloosa, AL, June 23–25, 1986). Soc. Min. Eng. AIME, Littleton, CO, 1986, pp. 520–525. This paper presents an analysis of rapid floor heave in a deep western coal mine. The analysis is based on field measurements, laboratory data, and beam design theory. Factors affecting floor heave, such as mining-induced stress, mine opening size, entry orientation, mine geology, rock physical properties, and gas pressure, are considered. Examination of floor heave in the mine indicates that heaving is primarily caused by deformation of a soft floor member that is subjected to high mining-induced stress. Theoretical analysis of in situ floor stresses resulting from overburden loading indicates that floor failure will occur. The analysis is confirmed by visual observations of floor heave in the mine. Recommendations for mine layout and opening design to control rapid, massive floor heave under these conditions are also presented.

OP 76–86. Recovery of Cobalt From Spent Copper Leach Solution, by T. H. Jeffers, K. S. Gritton, and P. G. Bennett. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 609–621. Cobalt, used in jet engine parts, tool steels, and catalysts, is a strategic and critical metal. The United States depends primarily on cobalt imported from Africa, but the long-term stability of that source is questionable. However, significant amounts of cobalt are present in some readily accessible spent copper leach solutions. For example, recovery of cobalt from existing streams at two U.S. copper leaching operations would yield about 1,500,000 lb/yr of cobalt, or 13 pct of our 1983 domestic consumption. The Bureau of Mines has developed a procedure using continuous ion exchange to extract cobalt from spent copper leach solution containing only 26 to 30 ppm Co. The effects of aqueous flow rate, resin flow rate, and column height on cobalt extraction were investigated. Cobalt extractions of 92 pct or higher were achieved at solution flow rates of up to 5.5 gpm/ft^2 of column cross-sectional area, and an aqueous-to-resin flow ratio of 40:1. Overall cobalt extraction increased as the column height increased, but cobalt extraction per unit of length was more efficient in a 12-ft-high column than in an 18-ft column.

Solvent extraction procedures were utilized to purify and concentrate the ion exchange eluates and to produce a cobalt sulfate solution containing 80 g/L Co, 0.5 g/L Ni, and not more than 0.01 g/L Cu, Fe, Zn, or Al. Metallic cobalt cathodes containing over 99 pct Co were recovered by electrowinning this solution.

OP 77–86. Proposed Methods for Recovering Critical Metals From Spent Catalysts, by B. W. Jong and R. E. Siemens. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 477–488. The Bureau of Mines is investigating chlorination methods, various hydrometallurgical approaches, and pyrometallurgical roasting procedures to recover Ni, Mo, W, Cu, and Cr from spent hydroprocessing, hydrogenation, and high-temperature shift catalysts. Laboratory work to date has resulted in extraction of 73% to 99% of the metals from these wastes. Total processing schemes for recovering the metals have been proposed. Economic feasibility of the proposed processing schemes is being evaluated.

OP 78–86. An Overview of the Bureau of Mines Recycling Research, by Robert S. Kaplan. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 3-11. To meet its twin objectives of encouraging recycling and alleviating waste disposal problems associated with mineral and metallurgical processing, the Bureau of Mines conducts a varied and extensive research program. This program is conducted about 85 pct in-house and 15 pct in universities, colleges, and technical schools. Industrial input concerning program content is sought through contacts with trade associations, such as the National Association of Recycling Industries and the Institute of Scrap Iron and Steel, as well as with individual companies. Other sources of input include academia and other governmental organizations. The Bureau's program includes basic, long-range research to advance technology in recycling. Broad based input to this program results in real world needs being addressed.

OP 79–86. Reclaiming Heavy Metals From Wastewater With Magnesium Oxide, by S. E. Khalafalla, J. E. Pahlman, and D. N. Tallman. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 227–246. The unusual electrokinetic properties of the magnesium oxide aqueous interface has been utilized to make superior filters for suspended solids and precipitants for heavy metals in wastewater streams. While the electrocapillary maxima, or points of zero charge, for most oxides and hydroxides are at a pH of about 6 (range 2.5 to 10.5), that of MgO is around pH 12.4. Lippmann's theory of electrocapillarity and the thermodynamics of surfaces would predict MgO to be positively charged at pH values below 12.4, while most other solids surfaces are negatively charged at pH values above 6. An electrokinetic attractive force between unlike charges has been found to aid in the removal of asbestos fibers and other solid particulates from water. Likewise, the basicity at the MgO surface is strong enough to precipitate many of the heavy and hazardous metals encountered in wastewater streams. Because the embryonic metal precipitates are negatively charged, many of them cement to the MgO surface, thus forming more compact sludges and much denser residues than obtained with lime, the traditional precipitant. Regeneration of the MgO filter and/or precipitant by backwashing and chemical stripping with EDTA would allow for the recovery of heavy metals in concentrated form. Since many of these heavy metals are critical and strategic, the technique can be adapted not only to recycling process water from mineral and milling waste streams, but also to reclaim their metal values.

OP 80–86. Sodium Production, by Dennis S. Kostick. Sec. in Encyclopedia of Materials Science and Engineering, ed. by Michael B. Bever. MIT Press, v. 6 (R–S), 1986, p. 4465. Sodium, discovered by Davy in 1807, is a soft, chemically reactive metal with a density of 0.97 g cm^{-3} and a melting point of 97.8B C. Metallic sodium is currently produced by the electrolysis of molten sodium chloride in the Downs cell, a process that was patented in 1924. The cell contains an anode and a cathode chamber with collectors to recover the chlorine gas that is evolved. The Castner cell, used exclusively until the 1920's, produced metallic sodium by the electrolysis of sodium hydroxide. This technique is still used in some areas of the world.

OP 81–86. Triaxial-Loading Measurement for Mine-Pillar Stability Evaluation, by Paul H. Lu. Ch. 55 in Rock Mechanics: Key to Energy Production, ed. by Howard L. Hartman (Proc. 27th U.S. Symposium on Rock Mechanics, Tuscaloosa, AL, June 23–25, 1986). Soc. Min. Eng. AIME, Littleton, CO, 1986, pp. 379–385. This paper proposes a novel method, "integrity factor approach," of mine pillar stability evaluation based on in situ triaxial-loading measurement. The pillar integrity factor is defined as the quotient resulting from division of integrated total pillar strength across the critical dimension by the integrated total pillar load across the same dimension. The integrity factor is dynamic, while the conventional safety factor is static. With this approach, the pillar stability can be evaluated at any stage of mining progress during panel operation. It automatically considers the progressive failure of the pillar and postfailure strength without the need to clearly define the boundary between yielded and intact zones of the pillar. Based on two case studies, the integrity factor approach is shown to be a practical, effective technique for evaluating stability of conventionally designed pillars. It is suggested that a more realistic estimate of in situ pillar strength could be made based on the combination of in situ triaxial-loading measurements and laboratory true triaxial compression tests, rather than through the traditional combination of biaxial-loading measurements and conventional triaxial compression tests.

OP 82–86. Recovery of Chlorine From Ferric Chloride, by Richard S. Olsen. Paper in Recycle and Secondary Recovery of Metals, ed. by Patrick R. Taylor, Hong Y. Sohn, and Noel Jarrett. Metall. Soc. AIME, Warrendale, PA, 1985, pp. 771–783. Chlorination of ilmenite to produce titanium products results in large quantities of byproduct ferric chloride. This finely divided, deliquescent material is extremely corrosive and presents a difficult waste disposal problem. In particular, it is difficult to transfer accurately and reliably for processing in fluidized-bed operations for chlorine recovery. Compacting ferric chloride into hard, dense pellets reduces its tendency to pick up moisture and allows it to be easily fed into oxidation units where it can be converted to iron oxide and recyclable chlorine. Pelletizing also allows the incorporation of promoters such as sodium chloride and fuels such as carbon or metallic iron within the feed pellets. Bench-scale studies in fluidized-bed oxidation reactors are described and discussed. A product gas containing 80 pct chlorine was produced at 800○ C in a reactor where pelletized ferric chloride was fed to the bottom of a fluidized bed of iron oxide.

OP 83–86. A New Seismic Probe for Coal Seam Hazard Detection, by W. R. Peters, T. E. Owen, and R. E. Thill. Soc. Min. Eng. AIME preprint 85–312, 1986, 7 pp. An experimental hole-to-hole seismic probe system has been developed for use in coal measure geology as a means of determining the structural conditions of coal seams. The source probe produces a 500-joule electric arc discharge whose seismic wavelet has a spectrum in the 200 to 2,000 Hz frequency range. Low compliance hydrophones contained in the source probe as well as in a separate seismic detector probe are matched to the frequency range of the source. Both probes are constructed with 5.72-cm-diameter housings. The transducers in the probes are equipped with fluid-inflatable boots to permit operation in either wet or dry boreholes. Preliminary tests in vertical boreholes drilled 213 m apart in sedimentary rock formations

show reliable operation and useful seismic propagation measurements along horizontal and oblique paths up to 232 m in length. Because the seismic wavelet has an accurately repeatable waveshape, multiple shots and signal averaging techniques can be used to enhance the signal-to-noise ratio and extend the transmission distances.

OP 84–86. A Case History of Computer-Aided Lineament Analysis for Ground Control Planning, by D. C. Peters and R. A. Speirer. Paper in Proceedings of Fifth Conference on Ground Control in Mining, Morgantown, WV, June 11–13, 1986, ed. by A. Wahab Khair and Syd S. Peng. WV Univ., 1986, pp. 191–205. The Bureau of Mines has been researching remote sensing analysis of an underground coal mining area in Utah and computer-aided methods of defining ground control hazards in this mining area. As a result of these studies, a preliminary potential hazards map was developed for the test site. This map is based primarily upon a lineament (linear feature) analysis of Landsat satellite data. Other data used were paleochannel location data, resistivity data, and information from surface and underground field checking of the lineaments and ground control problems in the mine. Lineaments proved to be reliable indicators of hazardous areas, although the type and degree of hazard varies with different lineament trends and the presence of other conditions such as lineament intersections and intersections with other geologic structures or with paleochannels. Lineaments were observed to match faults, joints, and/or joint trends in the area. The paleochannel data, derived from drill-hole data, provided basic information about potentially hazardous areas in the mine by suggesting where paleochannels could cause instability in the roof rock. The ground control problem data served largely to define the relative degree of hazard associated with lineaments and the types of hazards encountered in the mine. Resistivity data helped confirm the presence of fractures where they were expected to occur both from surface geology and from the lineament data.

OP 85–86. Image Processing for Automatic Lineament Analysis, by D. C. Peters, R. A. Speirer, and S. H. Moll. Paper in Proceedings of Geotech '84, Denver, CO, October 10–12, 1984. Am. Inst. Prof. Geol., Denver, CO, 1986, pp. 88–91. This paper describes research by the Bureau of Mines on the use of remote sensing methods to evaluate potentially hazardous ground control conditions in underground mines. Computer processing of image and nonimage data is used to provide an estimate of potential mine hazards by identification of surface lineaments related to geologic structures. This approach to lineament analysis by computer involves a refinement of Landsat images to enhance linear information contained within the image data and to suppress nonlineament data. Since lineaments exhibit a moderate change in brightness compared with their surroundings, these contrasts can be ignored. The remaining data are enhanced to exaggerate the lineament information by applying a series of square, high-pass filters of different sizes (to enhance lineaments of different lengths), complex contrast stretches, and edge enhancement methods. Line-plotting of these individual readings produces a map of the existing faults and fractures.

OP 86–86. The Illinois-Bureau of Mines Cooperative Mine Subsidence Research Program, by Larry R. Powell and Paul B. DuMontelle. Paper in Proceedings of the Second Conference on Ground Control Problems in the Illinois Coal Basin, Carbondale, IL, May 29–31, 1985, ed. by Yoginder P. Chugh. Southern IL Univ., May 1985, pp. 13–17. This paper highlights past and present subsidence research projects within Illinois. The long-term research program developed and the management scheme devised to ensure efficient use of available research funds and expertise are presented. The program provides techniques for reliable subsidence prediction for both high-extraction mining, which results in immediate, planned subsidence, and room-and-pillar mining, in which no subsidence is anticipated.

OP 87–86. Use of Acoustic Velocity for Predicting Stress Under Uniaxial Compression, by K. S. Radcliffe, R. E. Thill, and J. A. Jessop. Soc. Min. Eng. AIME preprint 86–147, 1986, 11 pp. This report presents results for the first phase of an experimental program to study the feasibility of using acoustic velocity for predicting the state of stress in a rock mass. Compressional wave velocities were determined axially in cylindrical samples during uniaxial compression for several rock types conditioned in dry and water-saturated environments. Results indicate that in rocks containing compressible voids or cracks, substantial velocity change occurs with the application of stress in the lower (below 100 MPa) stress regime. The effect is normally nonlinear, however, and diminishes to asymptotic values when cracks or voids become closed, or with saturation. Empirical prediction equations were derived for each rock type by linear and nonlinear regression analyses, and correlation coefficients were calculated to determine the equations that best fit the stress-velocity data. The operational range for predicting stress using compressional wave velocity appears to be within the range of vertical stress expected in most shallow to intermediate depth mining operations (less than 1,000 m). Based on the experimental results to date and on theoretical considerations, it appears that the technology can be advanced to predict in situ stress based on acoustic P-wave velocity determinations in most mining situations.

OP 88–86. Pigments: Titania, Iron Oxides, and Other Minerals, by M. A. Schwartz. Sec. in Encyclopedia of Materials Science and Engineering, ed. by Michael B. Bever. Pergamon, Elmsford, NY, v. 5 (O–Q), 1986, pp. 3529–3531. This article describes the nature and characteristics of titania and iron oxide, the two most widely used pigment materials, as well as other pigment minerals that can be synthesized or that exist in nature. Processing techniques and uses for these pigments are included.

OP 89–86. Remote Sensing Applications for Improved Mine Design and Ground Control, by R. A. Speirer, D. C. Peters, L. P. Richardson, and T. C. Bettinger. Ch. 6 in Engineering Health and Safety in Coal Mining, ed. by A. Wahab Khair (Proc. SME-AIME Annu. Meeting, New Orleans, LA, Mar. 2–6, 1986). Soc. Min. Eng. AIME, Littleton, CO, 1986, pp. 45–59. The Bureau of Mines remote sensing researchers at the Denver, CO, Research Center have been investigating computerized methods to detect and map surface linear features called "lineaments" for ground hazard assessment in mines. Many of these lineaments at the test mine site were found to correlate to subsurface geologic discontinuities such as faults, fractures, and joints that intersect coal seams at depth. These features adversely affect the roof and rib integrity in underground mines, thus contributing to rock failures that may result in injuries to mine workers and loss of production. Advance knowledge of the existence of such hazardous geologic features can aid in mine planning and development.

OP 90–86. Influence of Lithology on Longwall Mining Subsidence, by S. Tandanand and L. R. Powell. Min. Eng., v. 36, No. 12, Dec. 1984, pp. 1666–1671. The U.S. Bureau of Mines assessed the geological effects on the ratio of maximum subsidence and extraction thickness, known as the subsidence factor, to develop a simple method for predicting the maximum subsidence. The study was restricted to the Northern Appalachian coal basin where data were collected from 13 coal mines. A model previously developed to relate the subsidence factor with the lithology and with the width and depth of working panels was used in the assessment. The result shows the possibility of determining maximum subsidence without resorting to a rigorous method.

OP 91–86. Effects of Water Saturation on Acoustic Wave Velocity, by R. E. Thill and J. A. Jessop. Soc. Min. Eng. AIME preprint 86–148, 1986, 13 pp. An ultrasonic, pulse-immersion apparatus and method are described for determining the effects of moisture on the dynamic elastic

properties of rock. The method provides an alternative approach for assessing the moisture sensitivity of rocks. Ultrasonic wave velocities are continuously monitored in immersed rock samples as a function of water absorption and time up to saturation. Moisture effects on compressional wave velocity vary as a function of the type of rock and the time and amount of water absorption. Regression analyses are used to curve-fit plots of the data and to derive empirical expressions for compressional wave velocity as a function of water content for different categories of rock. Results indicate that compressional wave velocity can be used to predict both the moisture content and its effect on strength and deformational properties of rock. These results have potential for detecting or monitoring bad roof conditions in situations where the mine rock exhibits strength degradation with moisture absorption.

OP 92–86. Foundation Response to Subsidence Induced by High Extraction Mining in Southern Illinois, by Theodore L. Triplett, Ronald E. Yarbrough, and Larry R. Powell. Ch. 42 in Rock Mechanics: Key to Energy Production, ed. by Howard L. Hartman (Proc. 27th U.S. Symposium on Rock Mechanics, Tuscaloosa, AL, June 23–25, 1986). Soc. Min. Eng. AIME, Littleton, CO, 1986, pp. 283–290. This paper describes the response of two foundations to ground movements induced by subsidence from a high-extraction retreat room-and-pillar operation in southern Illinois. The objective of this monitoring program was to study the interaction between the ground surface and a structure during a subsidence event. The monitoring instrumentation and techniques as they relate to the mining and site conditions are described, including the capability of a tiltmeter to detect and follow the tilt of the foundations caused by the mining subsidence sequence. Using data from this tiltmeter, the development of curvature in the foundations as they conform to the displaced ground surface is shown. This curvature is represented by differences in tilt as various points on the foundations, indicating a change in tilt over a horizontal distance. Also, even though subsidence damage has not been fully analyzed, preliminary observations of the cracks that formed in the foundations are reported.

OP 93–86. Instruments and Procedures for Monitoring Respirable Coal Mine Dust Concentrations, by Kenneth L. Williams. Paper in Proceedings of the Fifteenth Annual Institute on Coal Mining Health, Safety, and Research, VPI and State University, Blacksburg, VA, August 28–30, 1984, ed. by Michael Karmis, William H. Sutherland, J. Richard Lucas, David R. Forshey, and Gavin J. Faulkner. Dep. Min. and Miner. Eng., VPI and State Univ., Blacksburg, VA, 1986, pp. 115–130. This paper presents new information on the performance of the coal mine dust personal sampling unit, a brief description of some recently developed dust monitors, a summary of the most recent test results, and suggestions on how to best use respirable dust monitors, both new and old, in the mining environment.

OP 94–86. Leaching Aluminum-Superalloy Melts With Hydrochloric and Sulfuric Acids, by G. B. Atkinson and L. J. Nicks. Conserv. & Recycl. v. 9, No. 2, 1986, pp. 197–209. The Bureau of Mines investigated a method for increasing the leaching rate of bulk superalloy scrap to facilitate recycling and recovery of critical metals such as Ni, Co, and Cr. Superalloys were melted with 20%, 30%, 40%, and 50% Al to form intermetallic compounds. The melts were easily crushed to a convenient particle size and leached rapidly with hydrochloric and sulfuric acid solutions. Leaching ½-in pieces of scrap IN–738 with excess 6*N* HCl at 95° C for 2 h resulted in only 0.5% dissolution, whereas leaching 10 g of minus 20 mesh 30% Al-70% IN–738 with excess 6*N* HCl at 95° C for 2 h achieved a 96.2% dissolution.

OP 95–86. Bauxite, by Luke Baumgardner. Ceram. Bull., v. 65, No. 5, 1986, pp. 729–730. This paper reviews the consumption of domestic and imported calcined refractory-grade bauxite by U.S. refractory industries during 1985. Prices, quantities, and principal sources of refractory bauxite imports are also discussed.

OP 96–86. Bureau's Information Helps Industry Make Decisions, by V. Anthony Cammarota, Jr. Am. Min. Congr. J., v. 72, No. 12, July 1986, p. 7. The objective of the Bureau of Mines' information program is briefly described, and the publications are listed through which minerals data are disseminated. The data are used by government and industry for planning capital investments, setting stockpile policy, and for working with other international statistical organizations.

OP 97–86. Bismuth Production, by J. F. Carlin, Jr. Sec. in Encyclopedia of Materials and Science Engineering, ed. by Michael B. Bever. Pergamon, Elmsford, NY, v. 1 (A-Co), 1986, pp. 352–353. This article describes the byproduct nature of bismuth and its processing from copper and lead-based minerals into refined bismuth by the Betterton-Kroll and Betts electrolytic processes.

OP 98–86. Indium Production, by J. F. Carlin, Jr. Sec. in Encyclopedia of Materials and Science Engineering, ed. by Michael B. Bever. Pergamon, Elmsford, NY, v. 3 (F-I), 1986, p. 2285. This article discusses the production of refined indium from zinc ores and from various other source materials.

OP 99–86. Mercury Production, by L. C. Carrico. Sec. in Encyclopedia of Materials and Science Engineering, ed. by Michael B. Bever. Pergamon, Elmsford, NY, v. 4 (J-N), 1986, p. 2946. This article contains an overview of the mercury production process. Some of the topics addressed are mining, beneficiation, and a variety of recovery processes.

OP 100–86. The Mexico City Earthquakes. Mining Technology Applied to Rescue Efforts, by Harry Dobroski, Jr. Technotimes, June 1986, pp. 4, 13. On September 19, 1985, Mexico City was struck by a massive earthquake that measured 8.1 on the Richter scale. This was followed the next day by another quake registering 7.5. A team composed of personnel from the Bureau of Mines, the Office of Surface Mining, and the Mine Safety and Health Administration arrived in Mexico City on September 21, 1985, bringing with them a number of technologies developed for mining situations: (1) a miniature television camera borehole probe designed to investigate abandoned mines (2) a seismic detection system designed to locate trapped miners, and (3) an expertise in explosives. This paper describes the television probe and seismic system that were directly and indirectly involved in several successful rescues.

OP 101–86. Near Surface Elemental Concentration Gradients in Annealed 304 Stainless Steel as Determined by Analytical Electron Microscopy, by P. M. Fabis and B. S. Covino, Jr. Oxid. Met., v. 25, Nos. 5–6, 1986, pp. 397–407. Elemental concentration profiles in the near surface region of 304 stainless steel resulting from hot-band annealing have been investigated with scanning transmission electron microscopy-energy dispersive X-ray spectrometry. A severe Cr depletion in the top 100 nm of the steel surface was observed, and a Ni enrichment was present at depths less than 1 μm. The maximum Cr depletion depth, which was approximated by an error function relationship, was in excellent agreement with the Cr depletion depth maximum determined experimentally. The oxide-alloy interfacial Cr concentration projected from the parabolic depletion profile of the 304 stainless steel at depths greater than 400 nm was also in reasonable agreement with the calculated value. The oxide-metal interfacial (within 50 nm) Cr concentration determined experimentally was, however, substantially lower than the calculated values. Doping effects on the oxide defect structure were proposed to enhance the diffusive flux from the alloy surface region and to contribute to nonparabolic growth effects of the Cr depletion profile in this region during short-term annealing.

OUTSIDE PUBLICATIONS

OP 102–86. Beryllium Production, by K. L. Harris. Sec. in Encyclopedia of Materials and Science Engineering, ed. by Michael B. Bever. Pergamon, Elmsford, NY, v. 1 (A-Co), 1986, pp. 298-299. This article describes the fluoride and sulfate processes of extracting beryllium hydroxide from beryl.

OP 103–86. Overview of Rare-Earth Reserves and Worldwide Availability, by James B. Hedrick. Paper in Proceedings of the Eighth International Workshop on Rare-Earth Magnets and Their Applications and the Fourth International Symposium on Magnetic Anisotropy and Coercivity in Rare Earth-Transition Metal Alloys, Dayton, OH, May 6–9, 1985, ed. by Karl J. Strnat. Univ. of Dayton, OH, May 1985, pp. 365–376. This paper examines the growth in the use of rare-earth permanent magnets and its dependence on the availability of many of the lanthanide elements and yttrium (rare earths). Reserves and resources of rare earths, located throughout the world, are large relative to demand. Theoretical rare-earth supplies, based on the average rare-earth contents of producing reserves and theoretical processing and separation capabilities, are calculated to assess future rare-earth availability.

OP 104–86. Palladium Production, by J. H. Jolly. Sec. in Encyclopedia of Materials and Science Engineering, ed. by Michael B. Bever. Pergamon, Elmsford, NY, v. 5 (O-Q), 1986, p. 3381. This article briefly discusses the extraction of palladium and other platinum-group metals from nickel-copper and copper ores.

OP 105–86. Plutonium Production, by J. H. Jolly. Sec. in Encyclopedia of Materials and Science Engineering, ed. by Michael B. Bever. Pergamon, Elmsford, NY, v. 5 (O-Q), 1986, pp. 3582–3583. This article describes the extraction process used to recover plutonium from irradiated uranium fuels used in power reactors.

OP 106–86. Potassium Production, by J. L. W. Jolly. Sec. in Encyclopedia of Materials and Science Engineering, ed. by Michael B. Bever. Pergamon, Elmsford, NY, v. 5 (O-Q), 1986, p. 3859. This article discusses the production of potassium in the United States by the thermochemical distillation of potassium chloride with sodium.

OP 107–86. Thorium Production, by W. S. Kirk and R. V. Sondermayer. Sec. in Encyclopedia of Materials and Science Engineering, ed. by Michael B. Bever. Pergamon, Elmsford, NY, v. 7 (T-Z), 1986, p. 4991. This article describes the chemical processes involved in the extraction of thorium from monazite, a byproduct of the mining and processing of mineral sands.

OP 108–86. Development and Testing of a Water-Jet-Assisted Longwall Shearer, by Wilhelm J. Kogelmann and Edward D. Thimons. Paper in Proceedings of Longwall USA Conference, Pittsburgh, PA, June 24–26, 1986, pp. 277–304. This paper describes the design, manufacture, and testing of a 3,000- to 10,000-psi water-jet-assisted longwall shearer that can be retrofitted to existing standard machines. This shearer is the first of its kind to have a water jet associated with each bit, and it also features a phased water delivery system designed to minimize water usage.

OP 109–86. Soda Ash, by D. S. Kostick. Min. Eng., v. 38, No. 5, May 1986, pp. 365–366. This paper describes the changes in the use and consumption of soda ash owing to substitutes for this material in the glass container industry. Also discussed are the repercussions of corporate acquisitions and divestitures among U.S. soda ash companies.

OP 110–86. Gold, by J. M. Lucas. Min. Eng., v. 38, No. 5, May 1986, pp. 332–333. Despite the year's lower gold prices, exploration for gold and the development of new mines worldwide continued to expand during 1985. U.S. developments were highlighted by Nevada's continued dominance as both a gold producer and the focal point for gold exploration and mine development. Domestic gold consumption and gold trading activity on the nation's commodity exchanges declined from 1984 levels. Net imports of gold rose substantially during the year. Foreign gold developments included increased exploration, mine development, and production in many countries, especially Canada and Australia. The Republic of South Africa was again the world's largest producer with about 46% of the world total of over 47 million oz. World gold consumption increased over that of 1984. Gold mine production and gold consumption in the United States and the rest of the world was expected to increase through the end of the century.

OP 111–86. Production and Use of Precious Metals in 1985, by J. M. Lucas, R. G. Reese, Jr., and J. R. Loebenstein. Precious Met., v. 10, No. 6, June 1986, pp. 1–3. This article is an annual review of the world supply and demand for gold, silver, and platinum-group metals. It includes two tables that show general statistics on precious metals plus a breakdown of the usage of precious metals.

OP 112–86. Titanium Minerals, by L. E. Lynd. Min. Eng., v. 38, No. 5, pp. 368–369. Consumption and production of titanium concentrates, titanium dioxide (TiO_2) pigments, and titanium metal in 1985 are reviewed. Highlights include record high consumption of TiO_2 pigments, and plans for new or increased capacity for production of concentrates to meet the high TiO_2 demand.

OP 113–86. Electrochemistry of the Chalcocite-Xanthate System, by C. S. O'Dell, G. W. Walker, and P. E. Richardson. J. Appl. Electrochem., v. 16, No. 4, 1986, pp. 544–554. This paper describes the interactions between chalcocite and ethylxanthate when examined in an electrochemical-microflotation cell containing a particle-bed working electrode. Cyclic voltammetry has shown the formation of a chemisorbed product commencing at –0.5V versus saturated calomel electrode, with a bulk oxidation product, possibly cuprous xanthate, forming above –0.23V. Relating the charge passed on a potentiostated mineral bed after addition of xanthate to spectrophotometric changes in xanthate concentration suggested the presence of a fast chemical reaction and a charge transfer reaction. The strong correlation between flotation response and potential indicates that chemisorption of ethylxanthate produces a layer sufficiently hydrophobic for chalcocite flotation.

OP 114–86. Calcium Production, by J. W. Pressler. Sec. in Encyclopedia of Materials and Science Engineering, ed. by Michael B. Bever. Pergamon, Elmsford, NY, v. 1 (A-Co), 1986, pp. 481–482. This article describes the aluminothermal vacuum process of extracting calcium from high-purity limestone, and the uses of calcium in the refining and extraction of other minerals.

OP 115–86. Cadmium Production, by R. G. Reese. Sec. in Encyclopedia of Materials and Science Engineering, ed. by Michael B. Bever. Pergamon, Elmsford, NY, v. 1 (A-Co), 1986, pp. 467–468. This article discusses the process required to produce cadmium from fume and dusts collected from the pyrometallurgical processing of zinc-bearing ores or from the cadmium-enriched residues of certain electrolytic zinc operations.

OP 116–86. Silver, by R. G. Reese. Min. Eng., v. 38, No. 5, May 1986, pp. 333–334. This article is a review of the U.S. and world silver markets during 1985. Preliminary supply and demand data are presented, along with an overview of significant U.S. industry developments and the outlook for 1986.

OP 117–86. Cobalt Resources, by S. F. Sibley and W. S. Kirk. Sec. in Encyclopedia of Materials and

Science Engineering, ed. by Michael B. Bever. Pergamon, Elmsford, NY, v. 1 (A-Co), 1986, pp. 698–701. This article discusses the commercial applications of cobalt and the location of significant deposits around the world.

OP 118–86. Potential of Spent Catalysts as a Source of Critical Metals, by R. E. Siemens, B. W. Jong, and J. H. Russell. Conserv. & Recycl., v. 9, No. 2, 1986, pp. 189–196. Characterization and hydrometallurgical research was conducted by the Bureau of Mines to devise procedures for recovery of metals such as Co, Ni, V, W, Mo, Cr, Fe, Cu, or Zn from waste catalysts. The research effort was concentrated on recovery of metals from spent hydroprocessing, hydrogenation, and high-temperature shift catalysts. Results showed that 73% to 99% of the contained critical metals were extracted by a variety of processing approaches, including anhydrous chlorination, ammoniacal, acid, or caustic leaching, and Na_2CO_3 roasting followed by water leaching.

OP 119–86. Longwall Shearer Performance Using Water-Jet-Assisted Cutting, by C. D. Taylor, P. D. Kovscek, F. N. Kissell, and E. D. Thimons. Paper in Proceedings of Longwall USA Conference, Pittsburgh, PA, June 24–26, 1986, pp. 233–256; Paper in the Proceedings of the 8th International Symposium on Jet Cutting Technology, Durham, England, Sept. 9–11, 1986. BHRA, Cranfield, Bedford, England, 1986, pp. 93–102. The U.S. Bureau of Mines equipped a longwall shearer with a water-jet-assisted mechanical cutting system to determine the effect of the high-pressure sprays on machine performance, airborne dust levels generated, and size of particulates formed. Testing was conducted on a simulated coal block (coalcrete) while cutting at a water pressure of 190 psi and at water-jet-assisted pressures ranging from 1,000 to 6,000 psi. The shearer motor energy used by the shearer during cutting coalcrete was determined for each cutting condition. Results indicate that the motor energy required by the shearer for each ton of material cut did not vary significantly as the water pressure was increased. Results of dust measurements recorded near the cutting drum indicate that at water pressures above 3,000 psi, dust reductions up to 85 pct were achieved compared with cutting with conventional sprays. Analysis of the particulate size distribution formed during cutting showed that increasing the water pressure resulted in increased median particle size. In light of these results, various mechanisms for water-jet-assisted cutting are discussed.

OP 120–86. 1984 Crushed Stone Data, by Valentin V. Tepordei. Rock Prod., v. 88, No. 9, Sept. 1985, pp. 55–58. The data is in the form of a detailed map showing every county in the United States containing a crushed stone quarry. Statistics on crushed stone production by State are also included.

OP 121–86. Bureau of Mines Revises System, by Valentin V. Tepordei. Rock Prod., v. 88, No. 12, Dec. 1985, pp. 56–57, 84. This paper describes a new system for reporting aggregate production information by grouping adjacent counties into districts. This method of gathering information is expected to increase the number of producers in each reporting area and eliminate the confidentiality problem when statistics are revealed on a company-by-company basis.

OP 122–86. Biological Catalysis of the Oxidation of Iron(II) in Acid Mine Waters in a Sequencing Batch Suspended Film Reactor, by T. L. Theis, L. H. Ketchum, Jr., and W. H. Engelmann. Trans. Soc. Min. Eng. AIME, v. 276, 1984, pp. 1891–1899. The use of a suspended growth system of *Thiobacillus ferrooxidans* attached in a film to individual particles of bentonite and operated as a sequencing batch reactor is shown to be a practical way of oxidizing ferrous iron in acid mine drainage. This component, followed by limestone neutralization, is both a technically and economically feasible approach to treating these wastewaters, compared with existing and other proposed methods. The advantages, in addition to less expense, are greater safety, acceptable treatment at a lower pH, lower solids buildup, less danger of overtreatment, and greater flexibility in operational characteristics. In this paper, data on the continuous bench-scale operation of the system under a variety of conditions show sustained levels of oxidation in excess of 98%. Capital and operating costs are projected to be \$80/1,000 m^3 (\$80 per 35,000 cu ft) of wastewater.

OP 123–86. The Worldwide Availability of Gold, by P. R. Thomas, E. H. Boyle, Jr., and J. M. Lucas. Nat. Resour. Forum, v. 10, No. 1, Feb. 1986, pp. 39–50. This paper summarizes Bureau of Mines research relating to the state of the world gold industry. The authors discuss the world gold industry structure, resources, production, and the long-term cost and availability of primary gold production from producing mines and developing deposits in 13 market economy countries (MEC's). Total recoverable gold available from the evaluated mines and deposits is estimated at 819 million troy ounces. The Republic of South Africa is estimated to account for 87% of total recoverable gold. The United States and Canada account for 4% and 4.5% of the total, respectively. Eighty-three percent of total recoverable gold is available at a constant 1984 break-even price of \$400 per ounce. South Africa accounts for 90% of the gold available at \$400 per ounce or less. Gold resources in the Soviet Union and China are discussed but not evaluated. South Africa should remain the largest world producer until the year 2000, and annual MEC output in the year 2000 should not be significantly different from current output, given constant 1984 gold prices of more than \$300 per ounce.

OP 124–86. Productivity, Safety, and Environment—A Coordinated Approach for Improving Coal Mining Technology, by Lewis V. Wade and James J. Olson. Paper in Proceedings of the Illinois Mining Institute Annual Meeting, Springfield, IL, Oct. 31–Nov. 1, 1985, pp. 21–43. As part of its mission to help assure that the Nation has an adequate supply of minerals, the Bureau of Mines is conducting research to remove the obstacles to development of new, more productive mining methods. At the same time, these new technologies must assure the safety and health of the worker and allow extraction of the coal within the restrictions of existing and projected environmental regulations. The research program at the Bureau's Twin Cities Research Center (TCRC) in Minneapolis, MN, is structured to address all three aspects: productivity, health and safety, and environment. This paper summarizes current status of several TCRC projects that have particular relevance to the Illinois coal mining district.

OP 125–86. Noise-Controlled Longwall Shearer Cutting Head, by William W. Aljoe and Mark R. Pettitt. Paper in Progress in Noise Control, Volume I, ed. by Robert Lotz (Proc. 1986 International Conference on Noise Control Engineering, Cambridge, MA, July 21–23, 1986). Noise Control Found., Poughkeepsie, NY, 1986, pp. 321–326. A new noise-controlled longwall shearer cutting head is described, highlighting the design steps taken to reduce noise by increasing the stiffness of the helixes and face ring, and by the damping of the core. Test results include measurement of overall noise levels as well as at the lead-drum operator position, the reaction of miners to this new head, and its general performance in cutting coal.

OP 126–86. Behavioral Aspects of Roof/Rib Injuries—Implications for Training Utilizing Stereoscopic Photography, by Edward A. Barrett. Paper in Proceedings of Fifth Conference on Ground Control in Mining, Morgantown, WV, June 11–13, 1986, ed. by A. Wahab Khair and Syd S. Peng. WV Univ., 1986, pp. 213–220. This study is a report of experimental research on the use of stereoscopic (3-D) slides for presenting visual cues associated with hazardous roof and rib conditions. Compared with conventional slides, 3-D slides provide for significantly greater hazard recognition among both experienced and inexperienced miners. Details such as the presence of cracks and gaps in the surrounding rock are more accurately

and realistically perceived. Reaction to the 3-D slides by the mine training community has been positive, and it has been noted that they also stimulate trainees' overall interest.

OP 127–86. Noise of Chain Conveyors in Mining, by J. A. Burks and W. J. Peterson. Paper in Progress in Noise Control, Volume I, ed. by Robert Lotz (Proc. 1986 International Conference on Noise Control Engineering, Cambridge, MA, July 21–23, 1986). Noise Control Found., Poughkeepsie, NY, 1986, pp. 327–332. This paper describes research by the Bureau of Mines to identify and control the excessive noise of chain conveyors. The major noise source is the impact of the chain on the tail roller on the upper and lower decks. Abatement technology has emerged in the form of constrained layer damping for the conveyor decks, vibration isolation, and a reduction in structural discontinuities. A newly constructed conveyor test bed assembly was used to create and control a wide range of test conditions not possible in the operating environment of an underground mine. The effects of chain speed, the shape of the discontinuity, the type of chain, and chain tension on the noise level were investigated. It is anticipated that a model based on single impact analysis will be developed to predict noise level as a function of the various parameters under study. The advantages of a variable-speed conveyor were also explored.

OP 128–86. Changing Patterns in U.S. Nickel Consumption, by Peter G. Chamberlain. Paper in Industrial Applications of Nickel, Volume II, ed. by E. Ozberk and S. W. Marcuson (Proc. of 25th Annual Conference of Metallurgists—1986, Toronto, Ontario, Canada, Aug. 17–20, 1986). Can. Inst. Min. and Metall., Montreal, Quebec, Canada, 1986, pp. 193–215. Consumption trends in the U.S. nickel industry during the 1970's and 1980's are discussed, with a special emphasis on their impact on future predictions.

OP 129–86. Environmental Effects on Metallic Corrosion Products Formed in Short-Term Atmospheric Exposures, by D. R. Flinn, S. D. Cramer, J. P. Carter, D. M. Hurwitz, and P. J. Linstrom. Ch. 7 in Materials Degradation Caused by Acid Rain (ACS Symposium Series No. 318), ed. by Robert Baboian. Am. Chem. Soc., 1986, pp. 119–151. The Bureau of Mines has measured short- and long-term atmospheric corrosion damage on five metals and two metal-coated steel products at four sites in the east and northeast United States as part of the National Acid Precipitation Assessment Program to evaluate the effects of acid deposition on materials. The composition of the corrosion product on carbon steel, weathering steel, copper, zinc, and galvanized steel is relatively unchanged in 1- and 3-month exposures over a wide variety of environmental conditions. Spalling and runoff losses are observed on all metals. Massive reorganization of the corrosion film by a mechanism of cyclic dissolution and precipitation was observed on carbon steel, Cor-Ten A, zinc, and galvanized steel. Loss of corrosion product from zinc in runoff was a function of both dissolution in rain water and neutralization by hydrogen ion loading, with dissolution contributing to the greater portion of the loss.

OP 130–86. Reducing Methane Levels in Longwall Gobs, by F. Garcia and J. Cervik. Paper in Proceedings of Longwall USA Conference, Pittsburgh, PA, June 17–19, 1986, pp. 345–356. A test conducted in the Lower Kittanning Coalbed that indicates that up to 71 pct of the methane produced by a mining operation can be captured by a properly designed cross-measure system is described. The number, depth, spacing, and angle of boreholes is detailed, and methane flow at varying points during mining is discussed.

OP 131–86. A Subsidence Prediction Model for Longwall Mine Design, by Paul W. Jeran, Vladimir Adamek, and Michael A. Trevits. Paper in Proceedings of Longwall USA Conference, Pittsburgh, PA, June 17–19, 1986, pp. 102–112. It has been found that lithological conditions over the Pittsburgh Coalbed cause the subsidence coefficient to vary within the area of the subsidence trough. This precludes the use of European-developed predictive models, which are based upon a constant subsidence coefficient. Regression analysis of the distribution of subsidence coefficients from 11 Bureau of Mines, U.S. Department of the Interior, longwall panel studies on the location relative to the edge of the panel has yielded a third degree polynomial equation. This equation has been incorporated into a BASIC computer program for use on a personal computer that allows users with no previous knowledge of the theory of subsidence to predict vertical movements over typical longwall panels in the Northern Appalachian Coal Basin.

OP 132–86. Expert Reasoning Models Applied to Mine Geologic Data, by Roger L. King. Paper in Proceedings of the 3rd Conference on the Use of Computers in the Coal Industry, Morgantown, WV, July 28–30, 1986, pp. 65–70. The Bureau of Mines has been involved with gathering and interpreting geologic data for 75 years. This experience has led to a high level of expertise within the Bureau and a desire to make it more accessible to the mining industry. With the recent advances in the field of artificial intelligence over the past few years, it has become more feasible to consider transferring knowledge to computers. Knowledge-based expert systems, the most active branch of artificial intelligence today, are computer programs that seek to combine a knowledge base of domain facts with expert-level decision making to arrive at plausible solutions to a problem. The intent of this paper is to examine some of the expert-level decision making models or "inexact reasoning" processes to determine their applicability to mine geologic data. This paper will describe two models that are available for this task and will give examples of applying these models to mine geologic data.

OP 133–86. A New Method of Rock Stress Management With Hydraulic Borehole Pressure Cells, by P. H. Lu. Paper in Proceedings of the International Symposium on Rock Stress and Rock Stress Measurements, Stockholm, Sweden, Sept. 1–3, 1986, pp. 237–245. This paper presents basic principles and required instrumentation for rock stress measurements with Bureau of Mines hydraulic borehole pressure cells. Existing stresses and stress changes can be measured with the same instrumentation. Based on the elastic theories of plates and thick-walled cylinders, the magnitude of biaxial rock stresses existing in a rock mass can be determined by pressure convergence-divergence tests using a combination of one cylindrical and two encapsulated flat hydraulic borehole pressure cells installed in a single drill hole. Case studies are included to demonstrate the validity of the technique.

OP 134–86. Assessment of the Low Frequency Whole Body Vibration Exposure Levels of Coal Mining Machinery Operators, by Gerald W. Redmond and Paul J. Remington. Paper in Progress in Noise Control, Volume II, ed. by Robert Lotz (Proc. 1986 International Conference on Noise Control Engineering, Cambridge, MA, July 21–23, 1986). Noise Control Found., Poughkeepsie, NY, 1986, pp. 917–920. This paper explores the effects of low frequency vibrations (below 1 Hz) from heavy machinery in coal mines. Recordings of low-frequency vertical vibrations collected during earlier studies were used to determine whether exposure to these vibrations caused "motion sickness" in mining machine operators, and the probability of overexposure to these vibrations using a variety of equipment such as bulldozers, front-end loaders, and scrapers is presented.

OP 135–86. A Catastrophe Model of Behavioral Accidents, by W. E. Souder. Paper in Proceedings of 1985 IEEE International Conference on Systems, Man, & Cybernetics, Tucson, AZ, Nov. 12–15, 1986. Inst. Electr. and Electron. Eng., 1985, pp. 514–515. This paper describes the relationship between individual psychological, group behavioral, and en-

vironmental variables, as well as other accident causing factors, and answers several long-standing questions about why some normally safe behaving persons occasionally engage in unsafe acts having high risks of serious injury. Ways to reduce the number of accidents are also discussed.

OP 136–86. Concentric Drill Steels for Noise Reduction of Percussion Drilling, by Robert R. Stein and William W. Aljoe. Paper in Progress in Noise Control, Volume I, ed. by Robert Lotz (Proc. 1986 International Conference on Noise Control Engineering, Cambridge, MA, July 21–23, 1986). Noise Control Found., Poughkeepsie, NY, 1986, pp. 333–336. This paper describes the design and test results of a prototype concentric drill steel used to reduce noise in large drills. Operational advantages of concentric vs. conventional steel, and the problems in coupling performance, are also discussed.

OP 137–86. Thermodynamic Properties of Calcium Zirconate ($CaZrO_3$), by R. R. Brown and K. O. Bennington. Thermochim. Acta, v. 106, 1986, pp. 183–190. Characterized synthetic $CaZrO_3$ was used by the Bureau of Mines to determine the standard enthalpy of formation (ΔHf°_{298} = -424.58 ± 0.47 kcal mol^{-1}; -1776.43 ± 1.97 kJ mol^{-1}) and the standard enthalpy of formation from the oxides (ΔH°_{298} (from oxides) = -9.75 ± 0.11 kcal mol^{-1}; -40.78 ± 0.46 kJ mol^{-1}) at 298.15 K. This compound, easily prepared and characterized, is potentially useful for a calorimetric standard. The reaction scheme for hydrofluoric acid solution calorimetry does not require a reaction step adding liquid to the solvent.

OP 138–86. Column Flotation of Chromite and Fluorite Ores, by D. G. Foot, Jr., J. D. McKay, and J. L. Huiatt. Can. Metall. Q., v. 25, No. 1, Jan.-Mar. 1986, pp. 15–21. The Bureau of Mines investigated column versus conventional flotation of chromite and fluorite ores. Fine-bubble column flotation of deslimed chromite ore produced a 44.7% Cr_2O_3 rougher concentrate at 87.1% recovery, whereas conventional flotation produced a 40.4% Cr_2O_3 concentrate at 85.4% recovery. Column flotation of undeslimed chromite ore also produced results superior to those attained with conventional flotation. Column flotation of fluorite ore produced a 90.9% CaF_2 rougher concentrate at 86.8% recovery, compared with a 67% CaF_2 rougher concentrate at 90.4% recovery produced by conventional flotation.

OP 139–86. Computer Modeling To Evaluate the Effect of Cutting System Changes on Relative Dust Generation, by B. D. Hanson and W. W. Roepke. Paper in Proceedings of the Third Conference on the Use of Computers in the Coal Industry, Morgantown, WV, July 28–30, 1986, ed. by Y. J. Wang, R. Larry Grayson, and Richard L. Sanford. A. A. Balkema, 1986, pp. 235–239. Interactive computer programs are being developed by the Bureau of Mines that allow the user to analyze the effect of changes in cutting system parameters on relative dust generation. These programs are written in BASIC for use on microcomputers. Their interactive structure allows the user to evaluate the effect of parameter changes either collectively or individually. This paper describes the basic calculations used by the programs and their general use.

OP 140–86. A Subsidence Prediction Model for Longwall Mine Design, by Paul W. Jeran, Vladimir Adamek, and Michael A. Trevits. Ch. 1 in Mine Subsidence (Proc. of SME-AIME Annu. Fall Meeting, St. Louis, MO, Sept. 7–10, 1986). Soc. Min. Eng. AIME, Littleton, CO, 1986, pp. 3–8. It has been found that lithological conditions over the Pittsburgh Coalbed cause the subsidence coefficient to vary within the area of the subsidence trough. This precludes the use of European-developed predictive models, which are based upon a constant subsidence coefficient. Regression analysis of the distribution of subsidence coefficients from 11 Bureau of Mines, U.S. Department of the Interior, longwall panel studies on the location relative to the edge of the panel has yielded a third degree polynomial equation. This equation has been incorporated into a BASIC computer program for use on a personal computer that allows users with no previous knowledge of the theory of subsidence to predict vertical movements over typical longwall panels in the Northern Appalachian Coal Basin.

OP 141–86. Column Flotation of Montana Chromite Ore, by J. D. McKay, D. G. Foot, Jr., and J. L. Huiatt. Miner. and Metall. Process., Aug. 1986, pp. 170–177. The U.S. Bureau of Mines compared column flotation using either fine or coarse bubbles with conventional flotation on a Montana chromite ore. On deslimed ore, fine-bubble column flotation produced a 44.7% Cr_2O_3-grade rougher concentrate with 87% recovery, compared with 43.8% and 43.5% Cr_2O_3-grade rougher concentrates with 85% and 77% recovery for coarse-bubble column flotation and conventional flotation, respectively. On undeslimed ore, coarse-bubble and fine-bubble column flotation produced rougher concentrates containing approximately 41.5% Cr_2O_3 with 95% recovery, exceeding conventional flotation, which produced 35.6% Cr_2O_3-grade concentrates with 87% recovery.

OP 142–86. Mining for Lunar Base Support, by E. R. Podnieks and W. W. Roepke. Sec. in Ch. 7, Lunar Materials and Processes, in Lunar Bases and Space Activities of the 21st Century, ed. by W. W. Mendell. Lunar and Planet. Inst., Houston, TX, 1985, pp. 445–452. Mining and excavation technologies must be developed for the establishment of lunar bases that are capable of operating under the severe conditions of the lunar environment. The mining technology research needs for establishing a permanent lunar base utilizing lunar resources are outlined and briefly discussed in this paper. These requirements range from initial exploration needs to those required for gradually reaching full lunar base autarky. The extraterrestrial mining and excavation needs indicate that a multidisciplinary research effort must be initiated early in the lunar base program to provide timely research results for the subsequent development stages.

OP 143–86. Measurement and Analysis of Foundation Tilt Resulting From Mine Subsidence in Southern Illinois, by Larry R. Powell, Theodore L. Triplett, and Ronald E. Yarbrough. Paper in Proceedings of the Second Workshop on Surface Subsidence Due to Underground Mining, Morgantown, WV, June 9–11, 1986, pp. 142–152. The Bureau of Mines, in cooperation with the Illinois Mine Subsidence Insurance Fund, monitored the response of two foundations to ground movements induced by subsidence from high extraction mining in southern Illinois. The objectives of the monitoring program were to study the interaction between the ground surface and a foundation during a subsidence event and to determine the capability of the tiltmeter to detect and monitor subsidence movements. This paper describes the monitoring instrumentation and techniques as they relate to the mining and site conditions, and the capability of a tiltmeter to detect and follow the tilt of the foundations is also demonstrated.

OP 144–86. Electrochemical Determination of Thermodynamic Properties and X-Ray Diffraction Investigation of the Fe_3O_4-$ZnFe_2O_4$, by S. C. Schaefer and R. A. McCune. Metall. Trans. B, v. 17B, Sept. 1986, pp. 515–521. This paper describes the Bureau of Mines investigation into the thermodynamic properties of the Fe_3O_4-$ZnFe_2O_4$ solid solutions. Activities of Fe_3O_4 (magnetite) in solid solutions were determined with high-temperature electromotive force cells using stabilized ZrO_2 (zirconia) as the solid electrolyte. Partial and integral molar properties were derived for the Fe_3O_4-$ZnFe_2O_4$ system, and lattice parameter measurements of the Fe_3O_4-$ZnFe_2O_4$ solid solutions show a positive deviation from Vegard's law.

OP 145–86. Remote Mining Using Water for Ground Support, by Robert L. Schmidt and George A. Savanik. Paper in Proceedings of Fifth Conference on Ground Control in Mining, Morgantown, WV, June 11–13, 1986, ed. by A. Wahab Khair and Syd S. Peng. WV Univ., 1986, pp. 89–106. This paper examines the role of water as a ground support medium as

demonstrated by Bureau of Mines research on borehole mining of phosphate in St. Johns County, FL. A borehole mining tool incorporating a water jet nozzle and slurry eductor in a single downhole tool, and lowered through a borehole into the ore zone, eroded an underground cavity by the action of the water jet, simultaneously pumping the slurry to the surface. In addition to phosphate mining, the system has been sucessfully used in mining coal, oil sand, and uranium.

OP 146–86. Simple, Low-Cost Planar Flow Casting Machine for Rapid Solidification Processing, by M. T. Smith and M. Saletore. Rev. Sci. Instrum., v. 57, No. 8, Aug. 1986, pp. 1647–1653. This paper describes the design, fabrication, and operation of a relatively simple low-cost planar flow casting (PFC) machine optimized for small-batch processing. Several design features found beneficial to PFC process operation include (1) a ground nozzle stopper to retain the alloy charge during melting, (2) a remote, large-volume pressure vessel connected to the crucible gas system to reduce temperature-induced pressure fluctuations, and (3) the use of a nested induction coil that allows both the melt charge and the crucible reservoir to be located close to the cooling wheel. The results of several PFC process runs are provided showing typical values of the cooling wheel surface velocity, crucible ejection pressure, and crucible nozzle clearance gap. Examination of the rapidly solidified, Fe-based ribbons for thickness, dimensional uniformity, and atomic structure indicated that good quality glassy ribbon could be produced with proper selection of the controllable process variables. In addition, single-variable linear regression analysis was used to determine the effect of each process variable on the resulting ribbon thickness.

OP 147–86. Evaluation of Electrogalvanized Deposits From Zinc Wastes, by Vijay Srinivasan, Thomas J. O'Keefe, Ernest R. Cole, Vern R. Miller, and Rene Winand. Ch. 47 in Zinc '85, ed. by K. Tozawa (Proc. of International Symposium on Extractive Metallurgy of Zinc, Tokyo, Japan, Oct. 14–16, 1985). Min. and Metall. Inst. Japan, Tokyo, Japan, 1985, pp. 749–762. This paper describes the preliminary testing of various electrolytes made from waste materials using a range of processing conditions. Primary processing variables included acid concentration, steel substrate preconditioning, and electrolytic cell type. For comparison, deposits were also made from solutions prepared using french process zinc oxide. The morphology of the coatings was examined using scanning electron microscopy techniques.

OP 148–86. Wear of 12 Alloys During Laboratory Milling of Phosphate Rock in Phosphoric Acid Waste Water, by J. H. Tylczak, D. J. Singleton, and R. Blickensderfer. Miner. and Metall. Process., Aug. 1986, pp. 187–190. As part of its research on the wear of mining and mineral processing equipment, the U.S. Bureau of Mines evaluated the erosion-corrosion characteristics of 12 alloys in phosphoric acid waste water. Tests were conducted on 2- and 5-cm-diam specimens in 12- and 60-cm-diam ball mills by grinding phosphate rock in gypsum pond water with an initial pH of 1.6. For comparison, grinding tests also were conducted in tap water. Static corrosion tests in gypsum pond water also were carried out. For all alloys tested, the wear by erosion-corrosion was greater than the sum of erosion plus static corrosion. A low-alloy, high-carbon steel and a high-manganese, nitrated stainless steel were the most cost-effective materials.

OP 149–86. Hydrophobic Effects of Sulfur and Xanthate on Metal and Mineral Surfaces, by G. W. Walker, C. P. Walters, and P. E. Richardson. Int. J. Miner. Process., v. 18, 1986, pp. 119–137. The hydrophobic character of a variety of base-metal sulfides and gold has been examined in the presence of sodium hydrosulfide and potassium ethylxanthate. The degree of hydrophobicity induced by electrodeposition of sulfur and by electrochemical reaction between the minerals and ethylxanthate were determined by contact-angle measurements on polished surfaces and by flotation of mineral particles. During flotation, mineral-reagent interactions were followed by monitoring the solution composition spectrophotometrically. Results have shown that on gold and chalcopyrite the oxidation of hydrosulfide to molecular sulfur and the oxidation of ethylxanthate to dixanthogen produced hydrophobic surfaces; on pyrite, sulfur deposition was more effective than dixanthogen in producing a hydrophobic surface. Chalcocite, in contrast to gold, chalcopyrite, and pyrite, was found to react directly with ethylxanthate and hydrosulfide, but only the metal xanthate product was hydrophobic.

OP 150–86. A Case Study of Water Level Fluctuations Over a Series of Longwall Panels in the Northern Appalachian Coal Region, by J. S. Walker, J. B. Green, and M. A. Trevits. Paper in Proceedings of the Second Workshop on Surface Subsidence Due to Underground Mining, Morgantown, WV, June 9–11, 1986, pp. 264–269. This paper describes an investigation of water level fluctuation in five wells positioned over three consecutively mined longwall panels that was initiated in conjunction with an intensive subsidence monitoring program. The purpose of this work was to provide detailed information which could be used to predict certain hydrologic effects of longwall mining in the Northern Appalachian Coal Region. The results of this case study indicate that water level fluctuations in the local ground water system above longwall panels is associated with subsidence and that the static level will generally reestablish at or near the pre-mining elevation after mining is completed.

OP 151–86. The Molten Cyanide System for Electrodeposition of the Platinum-Group Metals, by Richard P. Walters and David R. Flinn. Paper in Precious Metals 1986, ed. by U.V. Rao (Proc. of the Tenth International Precious Metals Institute Conference, Lake Tahoe, NV, June 7–13, 1986). Int. Precious Met. Inst., 1986, pp. 439–443. Over the last two decades the Bureau of Mines had conducted several studies of the electrodeposition of platinum-group metals from a molten alkali metal cyanide bath. Bureau research has focused on producing platinum-group metal coatings on refractory metals and on more common structural materials. This research has shown that high-quality thick, adherent, and coherent deposits can be prepared. The methods used for electrolyte preparation, the parameters important in the deposition process, and some of the physical properties of the platinum coatings produced are presented in this paper. For in-depth discussions of specific topics, a bibliography of Bureau research is also included.

OP 152–86. U.S. Surface Coal Mine Mobile Equipment: Operator Noise Exposures and Noise Controls, by Roy C. Bartholomae and J. Alton Burks. Paper in Proceedings of the International Conference on the Health of Miners, Pittsburgh, PA, June 2–7, 1985, ed. by Robert W. Wheeler. Am. Conf. of Gov. Ind. Hyg., Cincinnati, OH, v. 14, 1986, pp. 575–590. The reduction of the noise exposure of operators of mobile surface mine equipment has been a primary objective of the Bureau of Mines. Approximately 25,000 mobile equipment operators in U.S. surface mines (45% of the operators) are overexposed to noise. These mobile machines include bulldozers, front-end loaders, haulers, shovels, draglines, trucks, scrapers, drills, and motor graders. Bulldozers and front-end loaders cause about two-thirds of the noise overexposures. The most cost-effective operator noise exposure control was determined to be acoustical cabs.

OP 153–86. Noise-Induced Hearing Loss—A Review, by Roy C. Bartholomae and Gerald W. Redmond. Paper in Proceedings of the International Conference on the Health of Miners, Pittsburgh, PA, June 2–7, 1985, ed. by Robert W. Wheeler. Am. Conf. of Gov. Ind. Hyg., Cincinnati, OH, v. 14, 1986, pp. 41–61. This paper provides an in-depth discussion on the ear and hearing loss, including references to many documented studies showing the deteriorative effects of high noise levels, and an in-depth discussion of the background and concept of the noise exposure damage risk criteria and noise

dose, which takes into effect noise levels and exposure times. Also discussed are the United States federal noise regulations pertaining to mining, the occupational noise problem (including references estimating that the future hearing-related compensations to U.S. workers will range from $3.4 billion to $20 billion), and the Bureau of Mines approach to mining noise control.

OP 154–86. Pitzer-Debye-Hückel Limiting Slopes for Water From 0° to 350° C and From Saturation to 1 kbar, by R. P. Beyer and B. R. Staples. J. Solution Chem., v. 15, No. 9, 1986, pp. 749–764. Using internationally recognized critical evaluations for the dielectric constant of water by Uematsu and Franck and the thermodynamic surface of water by Haar, Gallagher, and Kell, this paper presents values for the Pitzer-Debye-Hückel limiting slopes for osmotic coefficients, apparent molal enthalpies, apparent molal heat capacities, apparent molal volumes, molal compressibilities, and apparent molal expansivities from 0° to 350° C and from saturation to 1 kbar.

OP 155–86. Predicting Head Loss for Chunk Coal Slurry Transport, by Robert L. Cardenas, Mackenzie Burnett, and Anthony M. Briscoe. Paper in Advancements in Aerodynamics, Fluid Mechanics, and Hydraulics, ed. by R. E. A. Arndt, H. G. Stefan, C. Farell, and S. M. Peterson (Proc. of Specialty Conference of the Aerospace, Engineering Mechanics, and Hydraulics Divisions of the American Society of Civil Engineers, Minneapolis, MN, June 3–6, 1986). Am. Soc. of Civ. Eng., New York, NY, 1986, pp. 473–480. During research performed under a Bureau of Mines contract to develop a coarse coal injector, hydraulic transport data were gathered on pipeline head loss. These data have since been used to develop a combined sliding bed and heterogeneous flow model for predicting coarse (chunk) coal slurry head loss.

OP 156–86. The Vanadium-Nitrogen System: A Review, by O. N. Carlson, J. F. Smith, and R. H. Nafziger. Metall. Trans. A, v. 17A, Oct. 1986, pp. 1647–1656. This paper is a critical review of the available phase equilibria, crystallographic, and thermodynamic data for the vanadium-nitrogen system. Three nitride phases been identified and their crystal structures, ranges of homogeneity, and melting or decomposition temperatures determined. The solvus boundary for the vanadium-rich solid solution is placed at 3.8 at. pct N at 550° C and increases to 11 at. pct N at 1,500° C. A break in the solvus observed at 550° C is associated with the formation of a metastable phase, $V_{16}N$. Other metastable phases have been identified, but their exact stoichiometries and structures have not been unambiguously determined. The enthalpies and free energies of formation, heat capacities, and dissociation pressures for the subnitride and mononitride were evaluated and correlated.

OP 157–86. China, by E. Chin. Sec. in Mining Annual Review 1986, pp. 351–360. This article presents data on the minerals industry of China covering the shift from Government ownership to public ownership and its effect on production and trade in that country. Also included is a commodities review of metals, nonmetals, and fuels.

OP 158–86. Effects of Posture on Back Strength and Lifting Capacity, by Sean Gallagher and Thomas G. Bobick. Paper in Proceedings of The Human Factors Society 30th Annual Meeting, Dayton, OH, Sept. 29–Oct. 3, 1986, pp. 234–238. This paper describes a Bureau of Mines pilot study examining the effects of posture on back strength and maximum acceptable weight of lift (MAWL) on six healthy male subjects. Six back strength measurements (three static and three dynamic) were made while the subjects were kneeling and standing. In addition, these subjects (who were unaccustomed to lifting in these postures) volunteered to participate in a study of psychophysically determined MAWL in both postures. Results of the back strength tests showed a significantly lower peak torque per body weight output in kneeling versus standing back strength measurements for five out of six test comparisons. Subjective estimates of lifting capacity in the kneeling posture were significantly lower than those for the stooped posture. The results of tests of back strength and lifting capacity in these two postures provide useful information to consider in determining the physiological and psychophysical stresses imposed by these work postures.

OP 159–86. Longwall Dust Control: An Overview of Progress in Recent Years, by Robert A. Jankowski, Fred N. Kissell, and J. Harrison Daniel. Min. Eng., v. 38, No. 10, Oct. 1986, pp. 953–958. This paper reviews the progress of dust control in longwall coal mining in the United States, highlighting the development of the shearer clearer, drum spray water supply systems, and improved cutting sequence designs. Other control methods such as ventilation strategies, the proportioning of water to the drums, and the remote control of the shearer from less contaminated locations are also discussed.

OP 160–86. The Vapor-Liquid Equilibria of the Aluminum Chloride-Titanium Tetrachloride System, by H. C. Ko and A. Landsberg. Metall. Trans. B, v. 17B, Sept. 1986, pp. 609–610. As part of an overall investigation of the possibility of using domestic clay to produce aluminum via an energy saving chloride process, the Bureau of Mines has determined vapor-liquid equilibria for the system aluminum chloride-titanium tetrachloride. The system was studied over the entire composition range and at temperatures of 187° to 217° C in sealed vessels such that the total pressures were not known. Results indicate two azeotropes of approximately 20 and 95 wt pct aluminum chloride. These findings suggest difficulties in distillation separation of these two products of clay chlorination.

OP 161–86. Safer and More Productive Mining With a Computer-Controlled, Water-Jet-Assisted Longwall Shearer, by Wilhelm J. Kogelmann and Edward D. Thimons. Paper in Proceedings of the Second International Conference on Innovative Mining Systems, University Park, PA, Oct. 27–29, 1986, ed. by Lee Saperstein. Penn State Univ., PA, 1986, pp. 56–68. This paper describes the basics of water-jet-assisted cutting, design features of the shearer and the testing of its components such as high pressure water pumps, phased rotary water seals, bit-force-actuated water valves, and jet nozzles. Also, the water-jetting system and its layout in the longwall installation and the underground cutting trial is discussed in detail.

OP 162–86. Soviet Union, by Richard M. Levine. Sec. in Mining Annual Review 1986, pp. 455–463. This article presents data based on sources published in the U.S.S.R. concerning the geologic, technologic, and economic influences on the minerals industry in that country. A commodities review is also included.

OP 163–86. The Development of a Water-Jet-Assisted Shearer Loader, by K. Neinhaus, H. Weigelt, and E. D. Thimons. Paper 8 in the Proceedings of the 8th International Symposium on Jet Cutting Technology, Durham, England, Sept. 9–11, 1986. BHRA, Cranfield, Bedford, England, 1986, pp. 79–92. This paper describes the application of water-jet-assisted cutting on the shearer loader and some of the potential advantages to be achieved: improved cutting, little wear, reduction of the dust make, elimination of sparks, and a coarser material obtained due to a deeper cut.

OP 164–86. Bibliography on In Situ Mining of Metals, by Joseph M. Pugliese and William C. Larson. In Situ, v. 10, No. 3, Sept. 1986, pp. 277–311. As part of the Bureau of Mines in situ mining research program, the Twin Cities Research Center compiled a comprehensive bibliography for in situ mining of metals. The listing reported here emphasizes publications only (no patents) on in situ mining of metals published in 1978 and later. Three previous Bureau

publications (Bureau of Mines Information Circulars 8777, 8961, and 8969) include extensive bibliographies of pre-1978 in situ mining references. In this recent publication listing, each reference has been coded by topical acronyms shown under each reference. These acronyms, which are explained, provide an idea of what the reference covers and therefore represent an abbreviated subject summary.

OP 165–86. The Ambient Noise Floor in an Earcup of a Hearing Protector Worn by a Human Subject, by Gerald W. Redmond and J. Alton Burks. Paper in Proceedings of the International Conference on the Health of Miners, Pittsburgh, PA, June 2–7, 1985, ed. by Robert W. Wheeler. Am. Conf. of Gov. Ind. Hyg., Cincinnati, OH, v. 14, 1986, pp. 557–563. Hearing protective devices (HPD's) are necessary to control the noise exposure of miners when noise levels are in violation of Federal regulations and engineering or administrative controls cannot be implemented. However, standard laboratory performance measurements appear to overestimate the amount of protection a working miner may receive from HPD's. To more effectively evaluate hearing protector performance, the Bureau of Mines is investigating the basic parameters that influence the noise-attenuating properties of HPD's. Those parameters are being identified, and the degree to which they can be controlled under experimental conditions in the laboratory and field is being evaluated. With reasonable control over the stimulus and experimental parameters, it was possible to use a physical measurement procedure to predict the standard psychophysical method of evaluation in the laboratory. In attempting to adapt the method for use in the field, a high ambient noise level under the muff was observed. An experiment was designed to confirm and quantify the ambient noise level under an earmuff worn by a human subject. Preliminary analyses of the data tend to attribute the presence of the noise floor to human respiration and pulse. A discussion of the methods, results, and implications as to the effect of the noise floor on the physical measurement procedure will be presented.

OP 166–86. Whole Body Vibration Exposures of Coal Mining Machine Operators, by Gerald W. Redmond and P. J. Remington. Paper in the Proceedings of the International Conference on the Health of Miners, Pittsburgh, PA, June 2–7, 1985, ed. by Robert W. Wheeler. Am. Conf. of Gov. Ind. Hyg., Cincinnati, OH, v. 14, 1986, pp. 475–486. Field measurements utilizing a seat pad accelerometer were made on 61 surface coal mining machines and 25 underground coal mining machines in order to quantify the vibration levels experienced by the operators. Those data were combined with information on the statistics of the operating times of those machines in order to compare the operator's vibration exposure to the criteria in IS0 2631, A Guide for the Evaluation of Human Exposure to Whole Body Vibration. The comparison showed that about half of all surface coal mining machine operators can be expected to be exposed to vibration exceeding the fatigue decreased proficiency criterion, whereas only 15% would be expected to experience vibration exceeding the exposure limit. The comparison also indicated that about 30% to 40% of all underground coal mining machine operators can be expected to be exposed to vibration exceeding the fatigue decreased proficiency criterion and 10% to 15% would be expected to experience vibration exceeding the exposure limit. The primary sources of the exposure included scrapers, bulldozers, and loaders aboveground, and shuttle cars and possibly scoop trams underground. Detailed exposure statistics are presented and the implications of the results are discussed.

OP 167–86. A Mathematical Model To Predict the Potential Impact of Noise Control Measure on Reducing Miner Overexposures, by Robert W. Stephan, Gerald W. Redmond, and Roy C. Bartholomae. Paper in Proceedings of the International Conference on the Health of Miners, Pittsburgh, PA, June 2–7, 1985, ed. by Robert W. Wheeler. Am. Conf. of Gov. Ind. Hyg., Cincinnati, OH, v. 14, 1986, pp. 631–642. A statistical model is used to predict the number of miners overexposed to noise. A noise exposure probability is calculated for specific operator categories using information on mine worker population, exposure time, measured noise level of an associated piece of mining equipment, and the equipment duty cycle. In combination with information on equipment populations, the model can be used to rank-order the sources of miner overexposures. Also, by comparing noise levels of treated and untreated equipment, the model can be used to estimate the reduction in the number of overexposed miners and evaluate the impact of the control method. The prediction method has been computerized to facilitate the evaluation and comparison of various noise control treatments. The presentation includes a description of the prediction method and examples of its applications.

OP 168–86. Water-Jet-Assist for Rock Cutting, by Edward D. Thimons, Bradley V. Johnson, and Fred N. Kissell. Eng. Min. J., v. 187, No. 8, Aug. 1986, pp. 40–42. This paper describes recent research by the Bureau of Mines demonstrating that water-jet-assisted mechanical cutting can be useful under typical mining conditions.

OP 169–86. Thermal Analysis of Ion-Exchanged Montmorillonite, by S. W. Webb, D. A. Stanley, and B. J. Scheiner. Part. Sci. and Technol., v. 4, No. 4, Oct. 1986, pp. 131–142. As part of its program in mineral waste management, the Bureau of Mines has investigated the effect of ion exchange on the dewatering potential of clay minerals. Clays of the smectite group possess exchangeable cations to compensate for the overall net negative charge of the clay lattice. The ratio of the valence of the exchange cation to its ionic radius, referred to as the ionic potential, is indicative of the electrostatic influence that a given cation can exert on adjacent molecules. Differential scanning calorimetry and thermogravimetric analyses were performed on eight ion-exchanged montmorillonites (Li^+, Na^+, K^+, NH_4^+, Ca^{2+}, Ba^{2+}, Mg^{2+}, and Sr^{2+}). Results of these analyses indicate that the energy required to dehydrate the ion-exchanged montmorillonites and the associated dehydration water loss are directly related to the ionic potential of the exchange cation. Furthermore, the ordering influence of the exchange ion is responsible for different hydration states within the interlayer water.

OP 170–86. Heat Capacities of α-Cobalt Sulfate From 5.3 to 300.1 K, by Harry E. Bell and Richard P. Beyer. J. Chem. Eng. Data, v. 31, No. 4, Oct. 1986, pp. 381–383. As part of a U.S. Bureau of Mines effort to provide thermodynamic data on minerals and related inorganic compounds, the heat capacity of α-$CoSO_4$ was measured from 5.3 to 300.1 K by adiabatic calorimetry, thereby extending the range of existing measurements below 52 K. The heat capacity of α-$CoSO_4$ was measured previously from 52 to 296 K using an isothermal shield calorimeter.

OP 171–86. The Use of AC Impedence To Determine the Corrosion Rate of Electrogalvanized Steel, by Marion Datillo. Mater. Perform., v. 25, No. 11, Nov. 1986, pp. 18–22. This paper presents Bureau of Mines research into the corrosion rate of industrial electrogalvanized steel in deaerated molar ammonium sulfate by dc and ac electrochemical techniques as compared to solution analysis by atomic adsorption. An evaluation of the zinc coatings obtained in an industrial-scale test has shown that coatings obtained from a waste-derived electrolyte perform better than normal industrial coating. Impedance diagrams show that a slightly different frequency distribution is obtained for the two different coatings studied. The time dependence of the zinc corrosion rate can be monitored using impedance data over a frequency range of 0.1 to 11 Hz. Admittance plots provided the double-layer capacitance values, which indicate the presence or absence of surface corrosion products. The results show that electrochemical ac techniques can be applied to successfully determine the zinc corrosion rate of electrogalvanized steel in near-neutral media

and that waste sources of zinc are viable for electrogalvanizing steel.

OP 172–86. The Effect of Cathodic Treatment on the Anodic Polarization of Copper Sulfides, by J. E. Gebhardt, J. J. McCarron, P. E. Richardson, and A. N. Buckley. Hydrometall., v. 17, No. 1, Nov. 1986, pp. 27–38. Studies on the cathodic polarization behavior of copper sulfide electrodes have been conducted by the Bureau of Mines as part of an investigation of the simultaneous production of soluble copper at mineral anodes and soluble sulfur species at mineral cathodes by electrolysis in membrane cells. The application of a cathodic current to anodically polarized copper sulfide electrodes was used to reduce the surface product layer to either chalcocite or elemental copper. The effect of cathodic treatment was to allow additional anodic current application at low potential values. Low potentials would greatly improve the economics of a process based on these concepts. Rest potential and X-ray photoelectron spectroscopic data were used to help identify the surface product layers formed by anodic and cathodic treatment. A cyclic anodic-cathodic technique to achieve dissolution of copper sulfide minerals is suggested.

OP 173–86. Kinetics and Equilibria of the Pd-Cl System, by Arne Landsberg. J. Less-Common Met., v. 123, 1986, pp. 175–183. This study is a continuation of an attempt to characterize the interactions of chlorine and pure metals and to provide data that can be used when considering the compatibility of chlorine and other materials. Anomalies in the interactions of gold and of platinum with chlorine in an investigation of metal corrosion by chlorine, and the kinetics and equilibria of the similar Au-Cl and Pt-Cl systems were previously examined in detail in two papers from the Albany Research Center of the Bureau of Mines. This paper presents data and their interpretation demonstrating similarities between these systems and the interactions between palladium and chlorine.

OP 174–86. A Novel Technique for Dewatering Waste Slurries Containing Clay Particles, by B. J. Scheiner, A. G. Smelley, and D. A. Stanley. Paper in Flocculation Sedimentation and Consolidation, ed. by B. M. Moudgil and P. Somasundaran (Proc. of Engineering Foundation Conference, Sea Island, GA, Jan 27–Feb. 1, 1986). Eng. Found., 1985, pp. 549–564. The Bureau of Mines investigated a technique for dewatering clay waste consisting of flocculation with polyethylene oxide followed by screening of the resulting flocs. Results of laboratory tests as well as the results of small-scale and large-scale field tests are described in this paper. The procedure has been applied to clay wastes from phosphate, coal, bentonite, and potash operations and to the tailings from uranium, talc, copper, gold, silica, and mica mining operations.

OP 175–86. Musculoskeletal Injuries in Underground Mining, by Terrance J. Stobbe, Thomas G. Bobick, and Ralph W. Plummer. Paper in Proceedings of the International Conference on the Health of Miners, Pittsburgh, PA, June 2–7, 1985, ed. by Robert W. Wheeler. Am. Conf. Gov. Ind. Hyg., Cincinnati, OH, v. 14, 1986, pp. 71–76. Job-related musculoskeletal injuries are a continuing problem in all of industry. Mining is no exception. This paper presents an overview of the problem by summarizing strain and sprain injury data for underground mining. The data sources include both MSHA's accident statistics and individual company injury records.

OP 176–86. Application of FT-IR Spectroscopy for In Situ Studies of Sphalerite With Aqueous Solutions of Potassium Ethylxanthate and With Diethyldixanthogen, by S. C. Termes and P. E. Richardson. Int. J. Miner. Process., v. 18, 1986, pp. 167–178. This paper describes Fourier transform infrared spectroscopy used by the Bureau of Mines to study, in situ, the reaction of aqueous solutions of potassium ethylxanthate (KEtX) with copper-activated sphalerite. The use of a transmittance technique is possible for sphalerite because, besides being the reactive mineral surface, sphalerite is also an infrared-transparent material in the region where some of the characteristic vibrational bands of xanthates occur. Bands characteristic of copper(I) ethylxanthate were evident after 5 min of reaction between aqueous KEtX solutions and activated plates. The bands continued to grow as the reaction proceeded and were also present on dried surfaces after the reaction. Diethyldixanthogen dissociated on copper-activated surfaces, and bands characteristic of copper(I) ethylxanthate were detected on the surface of dried plates. No evidence for zinc(II) ethylxanthate formation with either unactivated or activated plates was obtained.

OP 177–86. First Impulse Turbine in the U.S. Mining Industry, by Robert Torbin, Robert Cardenas, and Edward Thimons. Paper in Proceedings of Waterpower '85, Las Vegas, NV, Sept. 25–27, 1985, ed. by Michael J. Roluti. Am. Soc. Civ. Eng., New York, NY, 1985, pp. 183–191. This paper describes a Bureau of Mines research project to investigate the improvements made in the operation of mine refrigeration systems when a thermal energy recovery system is incorporated. The project involved the use of an impulse turbine-generator system that extracts energy from the incoming cooling water. The shaft work performed by the turbine not only produces electricity, but reduces the thermal energy gain of the incoming water. The reduction in thermal gain is equivalent to the shaft work extracted by the turbine. The system has been operating for more than 9 months and has produced more than 800,000 kW-h of power.

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OP 1–87. Preventing Accidents in the Handling of Materials, by Thomas G. Bobick and Richard L. Unger. Paper in Proceedings of the Fourth Annual Meeting Collegiate Association for Mining Education, Rolla, MO, Oct. 3–4, 1985. Univ. of MO, Rolla, MO, 1985, pp. 106–130. This paper details research by the Bureau of Mines to redesign the flow of equipment and supplies in underground mines. Video tapes of underground manual tasks such as handling concrete blocks, rock dust, and cross beams, and lifting the continuous miner power cable, were made for use in simulating these activities under controlled laboratory conditions. Recommendations include the redesign of surface storage areas to facilitate the use of forklifts, and the design of mechanical-assist devices for loading underground.

OP 2–87. Human Factors Computerized Mining Information System, by Richard S. Fowkes. Paper in Proceedings of the Fourth Annual Meeting Collegiate Association for Mining Education, Rolla, MO, Oct. 3–4, 1985. Univ. of MO, Rolla, MO, 1985, pp. 131–147. This paper describes the Human Factors in Mining Search System (HFMSS), a computerized information retrieval system that extracts relevant human factors (or ergonomics) information from journal articles, research reports, seminars, and conferences in terms of 19 mining-related categories. Examples of these categories are biomechanics and work physiology, cost-benefit analysis, human error and human reliability, manual materials handling and back injuries, work design and task analysis, organizational and management practices, human factors, and training. Although the emphasis is on obtaining written material dealing directly with mining, in categories where little research has been done in mining, material from other fields that is considered of importance is also entered into the system. HFMSS is the only data base that stresses all of the different

areas of human factors as they have been or might be applied to mining, and will initially be used as a source of information for Bureau of Mines research, Bureau technology transfer, and MSHA.

OP 3–87. Back Injury Research at the U.S. Bureau of Mines Ergonomics Laboratory, by Sean Gallagher. Paper in Proceedings of the Fourth Annual Meeting Collegiate Association for Mining Education, Rolla, MO, Oct. 3–4, 1985. Univ. of MO, Rolla, MO, 1985, pp. 170–191. This paper describes research conducted at the Bureau of Mines Ergonomics Laboratory into the materials handling problems encountered in underground mines, with special emphasis on the unique stresses encountered by miners who must handle heavy materials in a stooped or kneeling position.

OP 4–87. Dewatering Fine Particle Waste Suspensions With Direct Current, by D. J. Kelsh and R. H. Sprute. Ch. 27 in Encyclopedia of Fluid Mechanics. Gulf Publ. Co., Houston, TX, v. 5, 1986, pp. 1171–1190. The phenomenon of electro-osmosis causes water to be drawn through a typical saturated soil by applying direct current between buried electrodes. This paper reviews work by the Bureau of Mines and others who have used electro-osmosis to dewater mining wastes. The theory of electro-osmosis is discussed along with dewatering efficiency and electrode reactions. The laboratory evaluation and results of several field applications by the Bureau of Mines are described for both metal mine wastes and coal sludge impoundments. Other commercial uses for the technology are noted, but evaluation of these applications was not attempted.

OP 5–87. Gold Dissolution in Chloride Solutions, by J. W. Langhans and K. P. V. Lei. Paper in Proceedings of The Reinhardt Schuhmann International Symposium on Innovative Technology and Reactor Design in Extraction Metallurgy, Colorado Springs, CO, Nov. 9–12, 1986, ed. by D. R. Gaskell, J. P. Hager, J. E. Hoffman, and P. J. Mackey. Metall. Soc. AIME, Warrendale, PA, 1986, pp. 259–271. The Bureau of Mines investigated the dissolution of gold in chloride solutions by cyclic voltammetry. Voltammograms of gold were obtained and provided a means of determining the effects of chloride concentration and different ionic species on the redox potentials and reaction rates for dissolving gold in $CaCl_2$ solutions. The potentials for gold dissolution ranged from 1.102 to 0.880 V standard hydrogen electrode in 0.01 to 8.0*N* $CaCl_2$ solutions, respectively. The dissolution rate was increased by increasing the chloride concentration and was further enhanced in chloride solutions containing hydrochloric acid, cupric, ferric, or cobaltic chlorides. The cyclic voltammetry data correlated to the results in the actual leaching of gold from a complex sulfide concentrate and a hydrometallurgical process residue in a chloride system.

OP 6–87. Analytical Chemistry Applied to the Exploration, Mining, and Processing of Materials, by Stephen L. Law. Sec. in Analytical Chemistry in the Exploration, Mining, and Processing of Materials, ed. by L. R. P. Butler. Blackwell Sci. Publ., Oxford, England, 1986, pp. 155–169. This paper reviews significant accomplishments by the Bureau of Mines in the application of analytical chemistry in solving problems in the areas of health and safety, environmental considerations, resource assessments, and minerals processing. Problems yet awaiting the help of the analytical scientist are given, and references to the published literature are provided where more detail can be obtained than is given in this discussion.

OP 7–87. Supercritical Fluid Extraction of Metal Values From Selected Minerals, by Michael J. Magyar, Franco E. Godoy, and Benjamin W. Haynes. Paper in Proceedings of The Reinhardt Schuhmann International Symposium on Innovative Technology and Reactor Design in Extraction Metallurgy, Colorado Springs, CO, Nov. 9–12, 1986, ed. by D. R. Gaskell, J. P. Hager, J. E. Hoffman, and P. J. Mackey. Metall. Soc. AIME, Warrendale, PA, 1986, pp. 1019–1027. Supercritical fluids (SCF) are being studied by the Bureau of Mines to determine the feasibility of selective metal extraction from various minerals and spent catalysts. Because supercritical fluids are dense gases rather than liquids, they offer the potential for high permeability and selective dissolution of mineral values. Supercritical SO_2, NH_3, H_2O, and H_2O_2 have been investigated as solvents. Static and flowthrough reactor systems were used at temperatures up to 500° C and pressures up to 10,000 psig to investigate metal extraction. Results showed limited extraction of metal values from manganese nodules, laterites, and sulfide minerals using anhydrous SO_2 or anhydrous NH_3 in the SCF state. Supercritical NH_3, modified with 30 pct H_2O_2 in H_2O, enhanced copper extraction from chalcocite. Using supercritical H_2O_2 solutions, selective chromium extraction was obtained from chromite and from chromium-bearing spent catalysts. Experimental procedures are discussed.

OP 8–87. Method for Prediction of Equilibrium Values in Practical Solvent Extraction Systems (Application to Ammoniacal-Copper Systems), by D. N. Nilsen, L. A. Powers, R. L. Rickel, and J. H. Russell. Paper in Proceedings of ISEC '86, Munich, Fed. Rep. of Germany, Sept. 11–16, 1986. Eur. Fed. Chem. Eng., 1986, pp. 455–462. This paper describes fundamental research into the equilibrium modeling of the solvent extraction of metals by the Bureau of Mines. As the first part of this research, the extraction of copper from ammoniacal solutions with LIX 64N was investigated. The primary goal of this research was to develop a mathematical model that could predict the equilibrium distribution of metal ions to within 5 pct of the actual concentrations. Additional goals of this effort were to develop a model that required only limited initial condition parameters and could accurately predict equilibrium values in practical situations; i.e., relatively high metal loading from high-ionic-strength solutions such as might be obtained in industrial leaching processes.

OP 9–87. Current State-of-the-Art of Diesel Emission Control—An Overview, by George H. Schnakenberg. Paper in Proceedings of the International Conference on the Health of Miners, Pittsburgh, PA, June 2–7, 1985, ed. by Robert W. Wheeler. Am. Conf. of Gov. Ind. Hyg., Cincinnati, OH, v. 14, 1986, pp. 233–243. The Bureau of Mines, the Canadian Center for Mineral and Energy Technology, and the Ontario Ministry of Labour have been working together for several years toward the reduction of diesel pollutants released into the underground mine air. Their studies have included the development of an in-mine air quality laboratory for the testing and development of particulate scrubbing devices for on-vehicle removal of diesel particulate matter, the investigation of the mutagenicity of diesel particulate matter collected underground, the development of the relationships among various gaseous and solid diesel pollutants, and various sampling and monitoring methods and strategies for the continual assessment of the effectiveness of exhaust control devices as used in practice. All of this work resulted in the perfection of two devices (a venturi scrubber and a ceramic flowthrough filter) for the removal of the particulate matter from the exhaust stream since it is this component which is thought to carry the potential long-term health hazard.

OP 10–87. Supported Liquid Membrane Separation of Aluminum From Copper Leaching Liquors, by L. E. Schultze, S. P. Sandoval, J. A. Eisele, and T. G. Carnahan. Paper in Proceedings of The Reinhardt Schuhmann International Symposium on Innovative Technology and Reactor Design in Extraction Metallurgy, Colorado Springs, CO, Nov. 9–12, 1986, ed. by D. R. Gaskell, J. P. Hager, J. E. Hoffman, and P. J. Mackey. Metall. Soc. AIME, Warrendale, PA, 1986, pp. 311–322. The Bureau of Mines investigated the separation of aluminum from copper dump leaching liquors using a supported liquid membrane. Aluminum was selectively transported through porous polypropylene impregnated with di(2-ethylhexyl) phosphoric acid in an aliphatic diluent. The effects of

variables such as solution composition, temperature, and extractant concentrations were measured with a three-level fractional factorial experimental design. Experimental results were used to derive equations for predicting transport rates for aluminum, iron, and copper. The major variables influencing aluminum transport were solution temperature, feed solution pH, aluminum concentration in the feed solution, and extractant concentration. Copper and iron transport rates were almost zero where aluminum transport rates were high. Measured aluminum transport rates under the best conditions of 55° C, pH 3.0, 16 g/L Al, and 65 pct extractant solution confirmed the predicted value of 223 μg/(cm²·h). Transport rates for iron and copper were less than 4 μg/(cm²·h) under these conditions.

OP 11–87. A Computer-Based Model of Machine Operator Compartments, by Richard L. Unger and James P. Rider. Paper in Proceedings of 1985 IEEE International Conference on Systems, Man, & Cybernetics, Tucson, AZ, Nov. 12–15, 1985. Inst. Electr. and Electron. Eng., 1985, pp. 147–153. The Bureau of Mines is developing a computer-based model of mining machine operator compartments to be used as both a research tool and as an aid to mining machine designers. Based on models now used in both the public and private sectors and on original software being developed by the Bureau, the model will perform reach assessment, visibility analysis, finite element analysis of canopy designs, illumination analysis (including both disability and discomfort glare ratings), and computation of an ingress-egress rating. The model will make extensive use of graphics to simplify data input and analysis. Two-dimensional orthographic projections of the machine and its operator compartment are digitized and the data rebuilt into a three-dimensional (3-D) representation. A 3-D mannequin is then used as the subject for the various analyses. Anthropometric data from either individual or any size population may be used. Outputs can be displayed both graphically and in a tabular form. In addition to its use in original machine design, the model should prove helpful as an accident investigation tool and for determining the effects machine modifications in the field will have on the critical areas of visibility and control reachability.

OP 12–87. The Evaluation of a Ceramic Diesel Particulate Filter in an Underground Mine Laboratory, by D. H. Carlson, D. Bucheger, M. Patton, J. H. Johnson, and G. H. Schnakenberg. Paper No. 6 in Ch. 1 of CIM Spec. V. 36, Heavy-Duty Diesel Emission Control: A Review of Technology, ed. by E. W. Mitchell. Can. Inst. Min. and Metall., 1986, pp. 92–131. This paper details the collection of diesel exhaust particulate from the instrumented Wagner ST5A load-haul-dump vehicle during a simulated ore loading and hauling operation. An evaluation of the exhaust included measurements to determine the effect of the Corning diesel particulate filter (DPF) on air quality, and the effect of operating variables and fuel additives on DPF regeneration. The results demonstrate the important effects of other mine particulate sources on the particulate collection efficiency. The effect of the diesel fuel sulfur content on potential reductions in ventilation air flow that can be realized as a result of the DPF airborne pollutant concentration reductions is also discussed.

OP 13–87. Organization, Objectives, and Achievements of a Three-Government Collaborative Program on Diesel Emissions Reduction Research and Development, by E. D. Dainty, E. W. Mitchell, and G. H. Schnakenberg, Jr. Paper No. 1 in Ch. 1 of CIM Spec. V. 36, Heavy-Duty Diesel Emission Control: A Review of Technology, ed. by E. W. Mitchell. Can. Inst. Min. and Metall., 1986, pp. 3–20. The historical development of the collaboration among three funding agencies—the U.S. Bureau of Mines (USBM), the Canada Centre for Mineral and Energy Technology (CANMET), and the Ontario Ministry of Labour (MOL)—is briefly discussed in this paper. Official collaboration began with the signing of a Memorandum of Understanding by all three governments to resolve a number of issues including (1) the use of a criterion by which to evaluate the comprehensive toxicity of the major components of diesel exhaust, and the consequent provision of a tool for ventilation prescription and engineering economic studies, (2) research and development to produce add-on exhaust hardware, and the study of other techniques to reduce emissions from diesel engines, (3) development of the means of measuring the impact of such devices on the underground environment for the benefit of regulatory agencies and mine operators, and (4) synthesis of the principles learned into an overall strategy to improve mine environments, reduce ventilation costs, increase productivity, and improve safety underground.

OP 14–87. Back Loading During Simulated Underground Materials Handling, by Sean Gallagher, Thomas G. Bobick, and William S. Marras. Paper in Proceedings of the Fall Industrial Engineering Conference, Boston, MA, Dec. 7–10, 1986. Inst. Ind. Eng., Boston, MA, 1986, pp. 116–122. This paper describes a study examining the effects of posture on back strength, lifting capacity, and electromyography (EMG) of muscles supporting the spine. Isometric and isokinetic assessments were obtained in both standing and kneeling postures, and the maximum acceptable weights of lift (MAWL) while stooping and kneeling were established for each posture.

OP 15–87. Interaction of Temperature and Humidity of Inspired Air on Tissue Temperatures of the Tongue and Hard Palate, by Sean Gallagher and Max Vercruyssen. J. Int. Soc. Resp. Prot., v. 4, No. 2, Apr.-June 1986, pp. 20–44. This paper describes the monitoring of the tongue and hard palate temperatures of six subjects via thermocouples while breathing hot, humid air and walking on a treadmill. The amount of change in mouth tissue temperature was used to determine maximum allowable temperature limits for self-contained breathing apparatus.

OP 16–87. Sulfur Concrete—A New Construction Material, by William C. McBee. Paper in Proceedings of the International Sulphur Concrete Symposium and Workshop, Washington, DC, Oct. 14–15, 1986. The Sulphur Inst., Washington, DC, 1986, pp. 31–37. This paper summarizes the results of research directed toward the development of sulfur concrete materials for use in corrosive chemical environments where conventional materials fail.

OP 17–87. Electrochemical Monitoring of Electrogalvanizing Solutions, by T. J. O'Keefe, S. F. Chen, E. R. Cole, Jr., and M. Dattilo. J. Appl. Electrochem., v. 16, No. 6, Nov. 1986, pp. 913–919. This paper describes the development of cyclic voltammetry techniques to monitor the active concentration of liquorice and other polarizing additives in zinc electrolytes. These additives impact on the quality of zinc coatings, which greatly improve corrosion resistance when used as a protective layer on steel.

OP 18–87. An Intelligent Remotely Operated Controller for Mining Machines, by W. H. Schiffbauer. Paper in Proceedings of the Third Conference on the Use of Computers in the Coal Industry, Morgantown, WV, July 28–30, 1986, ed. by Y. J. Wang, R. Larry Grayson, and Richard L. Sanford. A. A. Balkema, Accord, MA, 1986, pp. 223–233. This paper describes the development of a modular intelligent remotely operated controller (IROC) used in different applications with a variety of mining machines. Two computers are employed in this IROC system to control up to 48 machine-mounted devices, providing a safe and user-friendly means of operating continuous mining machines.

OP 19–87. Domestic Saprolites as Potential Substitutes for Refractory-Grade Bauxite, by Jack C. White. Ind. Eng. Chem. Res., v. 26, No. 1, Jan. 1987, pp. 7–11. This paper evaluates saprolites and gibbsitic sands of the Southeastern United States as potential sources of substitute refractory-grade bauxite (RGB). Material from this area did not prove

promising either in quantity or quality, and the production methods necessary to produce RGB would be expensive compared with those employed in Guyana or China, the current principal suppliers to the United States.

OP 20–87. A Newly Developed Computer Graphics System for the Display of Underground Mine Environments, by Duane L. Abata and Edward F. Fries. IEEE Trans. Ind. Appl., v. IA–23, No. 1, Jan.-Feb. 1987, pp. 9–14. A newly developed color computer graphics software package designed for the display of remote sensor information, such as underground air quality data, is discussed in this paper. The software also has trending, predictive ventilation, contaminant, and mine fire capabilities. The package utilizes a unique system of display indexing that provides a simple, efficient method of recalling a series of mine schematics detailing an underground operation and an alarm display, and an acknowledgment scheme that provides an effective method for identifying problem areas that may exist in the mine network. The package also permits the display of trend plots used to review a particular sensor value as a function of time over a period of several days. The software package has been written in Fortran and has been designed for use with a specific hardware system, although it can be modified for other hardware installations.

OP 21–87. Maintaining Filters, Bits Can Control Respirable Quartz Dust During Roof Drilling, by Edward F. Divers and Robert A. Jankowski. Coal Age, v. 92, No. 2, Feb. 1987, pp. 57–59. This paper demonstrates the way maintenance procedures for envelope- and cartridge-type filters can reduce the amount of quartz dust present in the atmosphere during roof drilling operations. In addition, shank- and hollow-type roof bits are compared, and their effectiveness at varying speeds is discussed.

OP 22–87. Bolt Faster, Cut Bit Costs in Hard Roof, by Edward F. Divers, John A. Organiscak, and Tiff Hilton. Coal Age, v. 91, No. 7, July 1986, pp. 54–55. This paper describes several means of improving roof bolting productivity and reducing bit costs in the presence of hard roof conditions. Bit selection, drilling parameters, and operating procedures for both dry and wet drilling systems are among the contributing factors discussed.

OP 23–87. Extractive Metallurgy of Ferromanganese Crusts From the Necker Ridge Area, Hawaiian Exclusive Economic Zone, by Benjamin W. Haynes, Michael J. Magyar, Franco E. Godoy. Mar. Min., v. 6, 1987, pp. 23–36. This paper describes preliminary metallurgical tests on a crust sample recovered from the Necker Ridge area of the Hawaiian Exclusive Economic Zone to determine potential processing alternatives. Three processes were chosen for use in the program: the Cuprion ammoniacal leach process, a high-temperature and high-pressure sulfuric acid leach process, and a smelting process. Test results from these three processes indicate that the sulfuric acid process and the smelting process give higher cobalt and nickel extraction than the Cuprion ammoniacal process. The sulfuric acid process extracted greater than 90% of the cobalt, nickel, and copper while rejecting most of the iron and manganese. The smelting process recovered 98% of the cobalt and nickel and 96% of the copper, rejecting 99% of the manganese and 18% of the iron in the initial smelting step. Tailings and slag generated in the processes were tested using the extraction-procedure toxicity test and were classified as nonhazardous under current regulations.

OP 24–87. Controlling of Thin-Seam Miner 500 Feet From the Face, by August J. Kwitowski, William H. Schiffbauer, and William D. Mayercheck. Paper in Proceedings of the Eighth West Virginia University International Mining Electrotechnology Conference, Morgantown, WV, July 30–Aug. 1, 1986. Univ. WV, 1986, pp. 80–85. This report summarizes work sponsored by the Bureau of Mines in the development of a remote operating system (ROS) for controlling a thin-seam continuous miner 500 feet or more distant from the extraction face. Details are provided on ROS subsystems including the continuous miner, video equipment, controls and displays, the electronic control system, and the operator station.

OP 25–87. The Application of Fiber Optics Technology to the Design of Mine Lighting Systems, by William H. Lewis. Paper in Proceedings of the Eighth West Virginia University International Mining Electrotechnology Conference, Morgantown, WV, July 30–Aug. 1, 1986, Univ. WV, 1986, pp. 12–21. This paper describes Bureau of Mines research and development of a new and innovative mine lighting system based on fiber optics technology. The new lighting concept offers significant advantages over conventional systems in the areas of both safety and long-term maintenance costs. An overview of Bureau research into the problems and limitations of present-day mine lighting systems is also presented.

OP 26–87. Quartz Dust Sources During Overburden Drilling At Surface Coal Mines, by Slavoljub D. Maksimovic and Steven J. Page. Paper in the Proceedings of the International Conference on the Health of Miners, Pittsburgh, PA, June 2–7, 1985, ed. by Robert W. Wheeler. Am. Conf. of Gov. Ind. Hyg., Cincinnati, OH, v. 14, 1986, pp. 361–366. This report describes the results of a Bureau of Mines study of the main quartz dust sources during overburden drilling at a surface coal mine. Respirable quartz dust sources were identified and evaluated as well as their relative contribution to dust hazards during dry drilling operations. Both personal gravimetric and instantaneous (RAM–1) dust sampling devices were used to estimate the respirable dust levels in the vicinity of the sources. No attempt was made to determine actual source emission strengths. Results indicate that the drill rig has three major dust generating sources during the dry drilling operations: the collector dump, drill shroud leakage and drill stem seal leakage. These sources contributed up to 90% of the total respirable dust and 89% of the total respirable quartz dust generated during drilling.

OP 27–87. The Deserado Mine Monitoring and Control System, by Julie Mitchell, Len Eros, and Robert King. Paper in Proceedings of the Eighth West Virginia University International Mining Electrotechnology Conference, Morgantown, WV, July 30–Aug. 1, 1986. Univ. of WV, 1986, pp. 74–79. The Deserado mine monitoring and control system is a complex system designed to monitor environmental parameters and electrical power, and to operate all types of equipment used in mines, including the entire haulage system. This paper discusses the evaluation of the Deserado monitoring system from the initial design through system installation and operation. It also examines the costs, benefits, and performance of the system.

OP 28–87. Design Guidelines for Improved Water Spray Systems, by S. K. Mukherjee, M. M. Singh, and N. I. Jayaraman. Min. Eng., v. 38, No. 11, Nov. 1986, pp. 1054–1059. In underground mining operations, ventilation and water sprays are the common methods of controlling dust. In recent years, there has been a proliferation of technical literature dealing with water sprays for dust control. However, guidelines for the design of an effective water spray system have not been presented to the mining industry. This paper recommends guidelines for water spray systems to control dust in underground mining operations. These guidelines suggest type, number, location, and orientation of nozzles; the desirable operating water pressure; and an associated filtration system.

OP 29–87. Machine-Mounted Drill and Cutter Dust Control in Mines Extracting Soluble Ores, by Steven J. Page. Trans. Soc. Min. Eng. AIME, v. 276, pp. 1953–1959. Dust from cutter machines and face drills is controlled in most mines by water. However, the large quantities of water used in metal and coal mines for dust control and suppression pose serious

operational problems in water-soluble ores, such as salt, trona, or gypsum. This paper reviews the strategies to suppress and collect dust on cutter machines and face drills where water usage must be restricted to very low flow rates of 3.78 L/min or less.

OP 30–87. Foams for Dust Control, by Steven J. Page and Jon C. Volkwein. Eng. Min. J., v. 187, No. 10, Oct. 1986, pp. 50–52, 54. This paper reexamines the use of foams as a method to control dust in coal mines. In earlier years, high surfactant costs, combined with maintenance and effectiveness problems, had undermined the acceptance of foam as a dust suppression agent. In the last 5 years, however, the effectiveness of foams has improved owing to new treatment methods.

OP 31–87. Relation of Mineralogy to Treatment Methods for Carbonaceous Gold Ores, by B. J. Scheiner. Soc. Min. Eng. AIME preprint 87–96, 1987, 6 pp. The presence of organic materials in gold ores interferes with gold extraction by cyanidation. The carbon contained in the ore has been shown to adsorb gold cyanide complex from solution. Removal of the carbon content by roasting or chemical oxidation prior to cyanidation results in gold extractions of 85 to 95 pct. This paper by the Bureau of Mines, U.S. Department of the Interior, discusses how the mineralogy of the carbonaceous gold ores affects gold recovery by cyanidation. It also discusses the advantages and disadvantages of roasting and chemical treatment to render the ore amenable to cyanidation.

OP 32–87. Factors Affecting Dewatering of Phosphatic Clay Waste Slurries, by B. J. Scheiner and M. M. Ragin. Soc. Min. Eng. AIME preprint 87–47, 1987, 13 pp. This paper describes the Bureau of Mines investigation of the use of polyethylene oxide (PEO) as a flocculant for a variety of mineral wastes. As part of this investigation, the hydrodynamics of the flocculation process were studied. It was determined that to obtain optimum dewatering results, the factors of energy input into the stirrer, polymer concentration, and polymer dosage must be considered. It was found that at a given polymer concentration, there was an optimum stirrer speed and polymer dosage. With excess PEO, the amount of water removed in the trommel decreased, but no evidence for steric stabilization was observed.

OP 33–87. The Bureau of Mines Shock-Prevention Research Program—An Overview, by Michael R. Yenchek. IEEE Trans. Ind. Appl., v. IA–22, No. 5, Sept.–Oct. 1986, pp. 941–945. This paper describes a Bureau of Mines shock-prevention research program to improve general electrical safety in mines by preventing shock and electrocution through investigation of protective devices and equipment design. Results are highlighted and current projects summarized for sensitive ground, fault protection, dead front construction, shielded trailing cables, earth grounding, and overhead powerline safety.

OP 34–87. Sensitive DC Ground Fault Relays for Coal Mines, by Michael R. Yenchek, Fred C. Trutt, Jeffrey L. Kohler, Lloyd A. Morley, and Thomas Novak. Paper in Proceedings of the Eighth West Virginia University International Mining Electrotechnology Conference, Morgantown, WV, July 30–Aug. 1, 1986. Univ. of WV, 1986, pp. 40–45. This paper describes research aimed at virtually eliminating electrocutions on dc utilization circuits and has resulted in an effective circuit protective device, called a sensitive ground fault relay. This relay can detect and act to interrupt small deadly ground currents that can trigger ventricular fibrillation in humans, while ignoring spurious power system signals. Initial relay performance criteria were established to ensure reliability for mine duty as well as effectiveness for shock prevention. Mineworthy prototypes consisting of a saturable transformer current sensor and an electronic relay were constructed and complied with the performance standards in laboratory tests.

OP 35–87. Gas-Phase Production of Titanium Nitride and Carbide Powders, by Donna D. Harbuck, Charles F. Davidson, and Monte B. Shirts. J. Met., Sept. 1986, pp. 47–50. This paper describes an investigation of a procedure to produce fine-sized titanium nitride, carbide, and carbonitride powers. These powders, because of their high hardness and abrasion resistance, can be substituted for tungsten carbide in some cutting tool applications. Titanium nitride and carbide powders can be cemented together with nickel. The investigated approach produces titanium nitride by reducing titanium tetrachloride with magnesium or sodium vapor in a nitrogen atmosphere at temperatures between 750° and 1,050° C (1,382° and 1,922° F.) Titanium carbide and titanium carbonitride can be formed by adding methane to the nitrogen atmosphere. Titanium tetrachloride reduction efficiencies as high as 98% are achieved. X-ray diffraction analyses showed that the powders contain no major impurities. Because the reactions occur in the gas phase, powders finer than 1 μm are produced.

OP 36–87. Analysis and Metallurgy of Manganese Nodules and Crusts, by Benjamin W. Haynes and Michael J. Magyar. Paper in Marine Metals. Advances in Research and Resource Assessment, ed. by P. G. Teleki, M. R. Dobson, J. R. Moore, and U. von Stackelberg (Proc. of the NATO Advanced Research Workshop on Marine Minerals: Resource Assessment Strategies, Gregynog, Wales, June 10–16, 1985). D. Reidel Publ. Co., Dordrecht, Holland, 1987, pp. 235–246. This paper presents an overview of recent research completed on manganese nodules and crusts collected from the Pacific Ocean. Included are elemental and mineralogical compositional analyses, methods of analysis for the minerals and wastes from processing, and process metallurgy. Data are presented for 16 major and minor elements and for the 3 major mineral phases present in nodules and crusts. Methods of analysis for nodules and crusts and their tailings include physical, chemical, mineralogical, and leaching test procedures. Results of processing show varying recoveries of the metals cobalt, copper, manganese, and nickel.

OP 37–87. Dewatering of Red Mud, by G. D. Hood and G. M. Wilemon. Paper in Flocculation in Biotechnology and Separation Systems, ed. by Y. A. Attia. Elsevier Science Publ. B.V., Amsterdam, 1987, pp. 175–185. A solid-liquid separation technique was applied to red mud, the caustic-containing residue generated when alumina is extracted from bauxite by the Bayer process. Red mud obtained from Jamaican bauxite was dewatered in laboratory batch tests and small-scale continuous tests to develop an inexpensive method of washing the mud and recovering the valuable sodium aluminate and caustic. A number of high-molecular-weight polymers were evaluated; a high-anionic powder polymer used in combination with a high-anionic emulsion-type polymer proved to be most effective. In small-scale continuous tests using a baffled tube mixer to aid floc formation and a rotating trommel to dewater the solids, slurries with an initial concentration of 10 pct solids were dewatered to 27 pct solids using 0.17 kg of combined polymer per ton of dry solids. After the trommel treatment, the flocculated red mud was placed in a column fitted with a screen to allow released water to drain; after 15 days, the solids content increased to over 40 pct.

OP 38–87. Longwall Dust Control: An Overview of Progress in Recent Years, by Robert A. Jankowski, Fred N. Kissell, and J. Harrison Daniel. Min. Eng., v. 36, No. 10, Oct. 1986, pp. 953–958. This paper presents an overview of longwall dust control techniques. Factors such as deep cutting, water proportioning, homotropal ventilation, and operating the shearer by remote control are discussed.

OP 39–87. Expert Reasoning Models Applied to Mine Geologic Data, by Roger L. King. Paper in Proceedings of the Eighth West Virginia University International Mining Electrotechnology Conference, Morgantown, WV, July 30–Aug. 1, 1986. Univ. WV, 1986, pp. 69–73. This paper examines

some of the computer programs available to assist decisionmaking in the mining industry, and the potential applications of these programs in such areas as oil field log interpretation and site investigation for ore-grade deposits.

OP 40–87. Wear-Resistant Coatings Applied by Plasma Spraying of Mechanically Alloyed Powders, by J. F. McIlwain and L. A. Neumeier. Prog. Powder Metall., v. 42, 1986, pp. 591–604. This paper describes an investigation by the Bureau of Mines of an iron-based alloy system as a potential replacement for cobalt-based alloys in some thermal-sprayed coating applications to reduce U.S. dependence on imported cobalt.

OP 41–87. Trends in the Quality of Ferrous Scrap as Reflected in Iron Castings: 1981–84, by R. H. Nafziger, A. D. Hartman, R. F. Farrell, and R. D. Burlingame. AFS Trans., v. 94, 1986, pp. 417–426. This paper describes a Bureau of Mines analysis of cast iron samples to determine if the level of tramp elements in charge materials is changing with time. Results have shown that the composition of ferrous scrap materials is changing with respect to a few tramp elements such as B, Co, and Sn over the period 1981–84. Significant regional variations with respect to As, Co, Cr, Cu, Mg, Ni, and P were also noted.

OP 42–87. Water-Powered Scrubber Controls Dust on Continuous Miner, by Steven J. Page and Bobby Hughes. Paper in Proceedings of the Symposium on Control of Respirable Coal Mine Dust, Beckley, WV, Oct. 4–6, 1983, ed. by Joyce A. Barrett, Murray Jacobson, William H. Sutherland, Glenn R. Tinney, and Peter M. Turcic. MSHA, Arlington,VA, 1983, pp. 141–148. This paper describes the testing and evaluation of a water-powered scrubber system on the continuous miner to reduce dust. RAM-1 dust monitors were used with continuous strip chart recorders to measure dust levels during the cutting of coal, both with the scrubber on and off. Dust reductions of up to 78 pct were measured.

OP 43–87. Impurity Effects in Secondary Copper Alloys, by William D. Riley and Harry V. Makar. Conserv. & Recycl., v. 9, No. 4, Jan. 1986, pp. 315–323. As part of the continuing research to develop technology for conserving domestic mineral resources, the Bureau of Mines is investigating scrap identification techniques to improve sorted mixed scrap grade. This paper focuses on various classes of wrought and cast copper alloys produced with recycled scrap. Based on a survey of the literature, principal alloys, such as the brasses and bronzes, are examined with respect to impurity elements and their effects on metallurgical behavior. Effects of various elements, including lead, antimony, iron, chromium, and aluminum are discussed. The metallurgical effects described include hot shortness, fire cracking, and undesirable phase transformations.

OP 44–87. New Wet and Dry Devices for Dust Control at Belt Transfer Points and Mine Face Areas, by Jon P. Sandstedt and Steven Page. Paper in Proceedings of the Symposium on Control of Respirable Coal Mine Dust, Beckley, WV, Oct. 4–6, 1983, ed. by Joyce A. Barrett, Murray Jacobson, William H. Sutherland, Glenn R. Tinney, and Peter M. Turcic. MSHA, Arlington,VA, 1983, pp. 192–212. This paper describes the development of a self-cleaning dry dust collector and a water-powered scrubber and their testing in such varied locations as a trona mine, a silica sand bagging station, and an airlock in a coal mine. Both devices represent improvements over previous wet and dry dust collectors, and are versatile owing to their compact sizes, easy installation, and single utility requirements.

OP 45–87. Applied Flocculation Efficiency: A Comparison of Polyethylene Oxide and Polyacrylamides, by B. J. Scheiner and G. M. Wilemon. Paper in Flocculation in Biotechnology and Separation Systems, ed. by Y. A. Attia. Elsevier Science Publ. B.V., Amsterdam, 1987, pp. 175–185. This paper discusses some advantages and disadvantages of using polyethylene oxide (PEO) polymers and acrylamide-based polymers as flocculants for a wide variety of mineral waste slurries. PEO is shown to be especially effective in wastes that contain a high percentage of clays or claylike materials. Conversely, in the absence of claylike materials, polyacrylamides are superior to PEO. For those wastes that can be flocculated by either PEO or polyacrylamide, PEO generally requires a lower polymer dosage and yields more stable dewatered products. Differences in the behavior of these two flocculants are explained using proposed mechanisms.

OP 46–87. Chemical Processing of Cobalt-Manganese Crusts, by J. P. Allen, L. J. Froisland, and M. B. Shirts. Metall. Soc. AIME tech. pap. A87–15, 1987, 18 pp. This paper describes the screening of several chemical processes for extracting metals from cobalt-manganese crust ores and concentrates. These crusts are a seabed mineral deposit of the Exclusive Economic Zone and represent a significant resource of cobalt, nickel, and manganese. Three processes—sulfuric acid oxidation pressure leaching, aqueous sulfur dioxide leaching, and acid sulfation—have been investigated. The first two methods have been previously tested and proven capable of extracting values from similar land-based or seabed resources. All three methods show promise in treating ocean crust materials and have resulted in metal extractions exceeding 95 pct of each of the metals mentioned above. Also described are the pretreatment methods and leach conditions needed to achieve high metal extractions.

OP 47–87. Design Criteria and Correction Factors for Field Wear Testing, by R. Blickensderfer. Paper in Proceedings of the International Conference on Wear of Materials, Houston, TX, April 5–9, 1987. Am. Soc. Mech. Eng., New York, NY, v. 2, 1987, pp. 877–884. This paper describes some general criteria for wear testing. Laboratory wear tests can be designed to meet the criteria, but test results generally do not accurately predict wear under field conditions. Field wear testing is needed to optimize the final selection of materials for the given application. The concept of wear gradient is introduced. Wear gradients and their variation with time are small and reproducible in laboratory tests but generally are significant and not reproducible under field conditions. Field tests are classified as sequential series, concurrent series, and concurrent group tests. The use of reference specimens for establishing time averaged wear gradients is discussed, and formulas for correcting the test specimen wear for nonuniform tribological conditions over the test area are presented. A field test for abrasive wear of a linear array of specimens in a concurrent group test is described. The corrected wear values of duplicate specimens agreed within 3.4 pct of the mean.

OP 48–87. Methane and Dust Controls for Headgate Cutouts, by A. B. Cecala, J. A. Organiscak, and R. A. Jankowski. Min. and Sci. Technol., v. 4, No. 3, Mar. 1987, pp. 307–313. The headgate cutout is an area of concern for all retreating longwall mining operations. Because of the equipment and activities located in the headgate area, along with the ventilation flow pattern, methane and dust levels recorded at the shearer during the cutout are higher than for any other phase of the longwall mining cycle. This paper presents several different techniques found by the Bureau of Mines over the past few years to successfully lower methane and dust levels during the headgate cutout for retreating longwall sections using antitropal ventilation (headgate to tailgate). Each of these techniques improves the health and safety of longwall workers and is economically feasible.

OP 49–87. Location Strategy for Methane, Air Velocity, and Carbon Monoxide Fixed-Point Mine-Monitoring Transducers, by Anna F. Cohen, Thomas J. Fisher, Richard A. Watson, and Jeffrey L. Kohler. IEEE Trans. Ind. Appl., v.

IA-23, No. 2, Mar.–Apr. 1987, pp. 375–381. The placement of mine-monitoring system sensors, or transducers, requires considerable planning and forethought so that the potential benefits of mine monitoring can be realized. The intended use of the monitored data will often dictate specific locations for sensors, although in many cases technical constraints, imposed by sensor or measured characteristics, will affect the choice of locations. This paper describes some of the factors and considerations that should be examined prior to sensor installation. Some proposed decisionmaking procedures to help the system designer select appropriate locations are given, and a description of forthcoming in-mine experimental programs that will be used to learn more about sensor location procedures and to further evaluate the recommendations are presented.

OP 50–87. Coal Mine Quartz Dust Control, An Overview of Current Regulation and Recent Research Results, by Robert A. Jankowski and George E. Niewiadomski. Paper in Proceedings of the International Symposium on Coal Mining and Safety, Seoul, Republic of Korea, Apr. 22–24, 1987, ed. by Chung-In Lee, Hyo-Taek Chon, and Tai-Yoo Kim. Korean Inst. Miner. and Min. Eng., Seoul, Korea, 1987, pp. 303–313. This paper presents a summary of current U.S. regulations and strategies concerning the reduction of quartz dust in underground coal mines, focusing on the efforts of the Mine Safety and Health Administration and the Bureau of Mines.

OP 51–87. Crack Propagation and Spalling of White Cast Iron Balls Subjected to Repeated Impacts, by G. Laird II, W. K. Collins, and R. Blickensderfer. Paper in Proceedings of the International Conference on Wear of Materials, Houston, TX, Apr. 5–9, 1987. Am. Soc. Mech. Eng., New York, NY, v. 2, 1987, pp. 797–806. This paper describes ongoing research into the mechanisms of spalling in high-chromium white cast irons. These irons are used extensively in mining and mineral processing equipment even though fracturing and spalling from severe contact pressures result in major wear problems. In the laboratory, specimens in the form of 75-mm-diam balls were subjected to repetitive impacts (up to 300,000 in number) to produce cracking and spalling. Three high-chromium white cast iron alloys, each with 10 different heat treatments, were investigated. The interiors of impacted specimens were examined by scanning electron microscopy. The crack patterns were related to residual and Hertzian impact stresses and compared with the work of others on ball bearing spalling. It was found that near the surface the eutectic carbides crack perpendicular to the surface to a tensile stress produced along the perimeter of contact. Farther from the surface, the eutectic carbides crack due to a cyclic Hertzian shear stress that initiates a crack front parallel to the surface of the specimen. It is primarily the merging of the perpendicular and parallel crack fronts that initiates spalling in white cast irons.

OP 52–87. Crude Iodine Production Processes, by Phyllis A. Lyday. Paper in J. Chem. Educ., v. 64, Feb. 1987, pp. 152–153. This paper provides a historical context for the production of iodine beginning with its extraction from seaweed in 1817 and tracing the development of other methods to the present day. Equations for the chemical reactions for these processes are provided.

OP 53–87. Measurement of Erosion-Corrosion Synergism With a Slurry Wear Test Apparatus, by B. W. Madsen. Paper in Proceedings of the International Conference on Wear of Materials, Houston, TX, April 5–9, 1987. Am. Soc. Mech. Eng., New York, NY, v. 2, 1987, pp. 777–786. This paper describes a slurry wear test recently developed by the Bureau of Mines for the measurement of wear rates and electrochemical corrosion rates during slurry wear to establish relationships between erosion and corrosion of metal specimens. Slurries of silica sand and aqueous solutions were continuously fed into the test chamber, where they abraded and corroded the test specimens—a low-alloy steel, a stainless steel, and a wear-resistant low-alloy steel. Three types of tests were conducted to determine the total erosive-corrosive wear rate, the wear rate due to erosion only, and the electrochemical corrosion rate. The total wear rate was determined from the weight losses and densities and reported in units of volume losses per unit of time. The wear rate due to erosion only was determined while cathodically protecting the specimens. The electrochemical corrosion rate was determined by using polarization scans with the test specimen as the working electrode during slurry wear tests. The test parameters included temperature, solids concentration, and impeller speed. The test results showed that the combined effects of erosion and corrosion resulted in total wear rates that were much greater than the additive effects of each process taken alone, thus showing a strong synergism between erosion and corrosion.

OP 54–87. The Diagnosis and Reduction of Mine Roof Failure, by Noel N. Moebs and Raymond M. Stateham. Coal Min., v. 22, No. 2, Feb. 1985, pp. 52–55; v. 22, No. 3, Mar. 1985, pp. 42–48. This paper presents a proposed classification system of the types of mine roof falls in an attempt to prevent and reduce their incidence in coal mines. Rather than classifying roof falls based on specific structural and compositional factors, which tend to be useful only in certain mines, the proposed system separates roof failure into two general categories—geology- and stress-related failures—in an attempt to be useful in a variety of locations. These two categories are further broken down into subtypes, and possible preventive measures are outlined.

OP 55–87. Some Continuous Sections Can Cut More Than 1,000 Tons Per Unit Shift, by Steven J. Page, Jon C. Volkwein, and Fred N. Kissell. Coal Age, v. 92, No. 1, Jan. 1987, pp. 51–55. This paper describes a series of visits to 25 of the most productive continuous mining operations in the United States to ascertain the factors contributing to these high production figures. Some of these factors included positive relations between labor and management, selective hiring practices, specific performance standards, and an emphasis on the health and safety of employees.

OP 56–87. In Situ Mining Geologic Characterization Studies: Experimental Design, Apparatus, and Preliminary Results, by Steven E. Paulson, Linda J. Dahl, and Harland L. Kuhlman. Soc. Min. Eng. AIME preprint 87–139, 1987, 16 pp. This paper details the design and testing of a nonreactive, reusable reaction cell used in in situ leaching. The apparatus developed can be used in constant-pressure or constant-flow experiments and allows for the control of flow rate, pressure, and temperature, thus permitting studies on a wide variety of ore samples. Also included in this paper are the preliminary results from the first series of experiments on an oxide copper ore from the Casa Grande, AZ, area.

OP 57–87. Increasing Profit Through Improved Loss Incident Investigation, by Louis Schaffer and James M. Peay. Paper in Proceedings of TRAM 12 (Training Resources Applied to Mining), University Park, PA, Aug. 11–14, 1985, pp. 2–8. This paper describes a methodology of investigating and reporting loss incidents. In a cooperative arrangement with two mining companies operating a total of five mines, field evaluation of this method was undertaken for a period of nearly 18 months. The major contributing factors in loss incidents included inadequate job definition and training, unnecessary work environment hazards, inadequate task performance supervision, poor tool or equipment design, inadequate protection equipment, tool or equipment failure, and worker stress. Also outlined are the principles of this methodology, the role of the investigator, and the results of the field trials.

OP 58–87. 2p Electron Binding Energies for the Sulfur Atoms in Metal Polysulfides, by S. C. Termes, A. N. Buckley, and R. D. Gillard. Inorg. Chim. Acta, v. 126, 1987, pp. 79–82. Different electron binding energies have been observed for the structurally distinct sulfur atoms in the metal polysulfido

complexes studied. The sulfur atoms nearest to the metal are similar in character to those in mineral sulfides. Sulfur atoms adjacent to those bonded to the metal are appreciably different, with 2p binding energies approximately 1 eV greater, while those one atom more remote from the metal have a 2p binding energy approaching, but still less than, that for bulk elemental sulfur. These binding energies are of relevance to the identification of sulfur species present at the surface of sulfide minerals under flotation conditions.

OP 59–87. Influence of Composition on Abrasive Wear for Several Binary Systems, by J. H. Tylczak and R. Blickensderfer. Paper in Proceedings of the International Conference on Wear of Materials, V. 2, Houston, TX, April 5–9, 1987. Am. Soc. Mech. Eng., New York, NY, 1987, pp. 645–651. This paper describes an investigation into the effects of composition on abrasive wear in four substitutional and two interstitial binary systems. The substitutional systems studied were Hf-Zr, Cu-Ni, Cr-V, and Fe-Ni. Abrasive wear and hardness were measured on arc-melted specimens over the complete range compositions in each substitutional system, and the effects of solidus temperature, lattice strain, and thermal diffusivity on abrasive wear are discussed.

OP 60–87. Recovery of Alumina From Alunite by Acid Sulfation, by M. L. Wouden, L. J. Froisland, and M. B. Shirts. Metall. Soc. AIME tech. pap. A87-22, 1987, 10 pp. This paper describes research in separating and recovering alumina from domestic alunite ($KAl_3(SO_4)_2(OH)_6$) deposits by an acid sulfation process. Development of this process would lessen U.S. dependency on alumina from outside bauxite sources in times of national emergency. In the process, alunite is sulfated by reaction with 200° to 300° C concentrated sulfuric acid. Acid-insoluble aluminum sulfate is water-leached at 95° C and recovered by crystallization upon cooling the solution. Following purification, calcination of the crystals can produce cell-grade alumina. The potassium component of alunite is extracted into the sulfuric acid for eventual recovery in a separate process. This paper describes the effects of reaction variables in the acid sulfation step. Reaction conditions are selected to yield a minimum of 95 pct aluminum and potassium extraction and separation.

OP 61–87. The Use of AC Impedance To Determine the Corrosion Rate of Electrogalvanized Steel, by Marion Datillo. Mater. Perf., v. 25, No. 11, Nov. 1986, pp. 18–22. This paper describes research into the corrosion rate of electrogalvanized (EG) steel using alternating current impedance. Data obtained on EG wire from an industrial pilot test were monitored by impedance measurements and verified by solution analysis. An evaluation of the zinc coatings obtained from an industrial-scale test showed that coatings obtained from a waste-derived electrolyte perform better than normal industrial coatings.

OP 62–87. Bromine, by P. A. Lyday. Min. Eng., v. 39, No. 5, May 1987, pp. 372–373. This paper describes the changes in the bromine industry during 1986. Also discussed are the changes in the domestic and foreign industries, as well as the trade and environmental issues.

OP 63–87. Signature Criteria for Monitoring Abandoned Mine Fires, by A. G. Kim. Paper in Proceedings of the 8th Annual National Abandoned Mine Lands Conference, Billings, MT, August 10–15, 1986. MT Aband. Mine Reclam. Bur., MT Dep. State Lands, Helena, MT, 1987, pp. 8–26. In this laboratory study, gases from mildly heated samples of coal and coal refuse were studied to develop a "signature" for indicating coal sample temperature. Controlled temperature environments were between 100° and 250° C, and the airflow rates over the sample were between 1 and 2 scf/h. A mixture of air and nitrogen was used at temperatures above 200° C to control self-heating of the coal to keep it at the desired temperature. Gas samples were taken periodically and analyzed by gas chromatography.

OP 64–87. Coal Mining Equipment, by T. W. Martin and G. R. Bockosh. Min. Eng., v. 39, No. 5, May 1987, pp. 364–366. This paper describes the recent innovations in coal mining equipment, covering the trend toward longwall mining, the improvements made in bits for continuous miners and shearers, the use of diesel- and battery-powered nontethered haulage systems, the development of a ground fault interrupter to eliminate electrocutions, and the increased use of computer-controlled devices in all aspects of coal mining.

OP 65–87. Barriers to the Prevention of Groundfall Accidents in Underground Coal Mines: The Beliefs of Those Who Work Underground, by Robert H. Peters and William J. Wiehagen. Paper in Proceedings of the Fifth Annual Meeting of the Collegiate Association for Mining Education, Beckley, WV, October 2–3, 1986. MSHA, Beckley, WV, 1987, pp. 98–117. This paper presents the results of a study on attitudes that prevent miners from correcting and avoiding groundfall hazards. Interviews were conducted with 143 miners and 9 coal mine roof and rib inspectors using open-ended and forced-choice questions concerning the inability and/or unwillingness of workers to recognize or correct groundfall hazards.

OP 66–87. Flocculation, by B. J. Scheiner. Min. Eng., v. 39, No. 5, May 1987, pp. 356–357. This paper presents a brief review of the use of flocculation as a recovery process in the mineral industry during 1986.

OP 67–87. Conversion of Phosphogypsum to Sulfur. Part 1—Oxidation of Calcium Sulfate to Calcium Sulfide, by Annie G. Smelley, Margaret M. Ragin, D. R. Brooks, and B. J. Scheiner. Paper in Proceedings of the Third Workshop on By-Products of Phosphate Industries, Tampa, FL, Dec. 5–7, 1985. Univ. Miami, Coral Gables, FL, 1986, pp. 53–65. This paper describes research into the conversion of phosphogypsum to sulfur, focusing on the reduction of phosphogypsum to calcium sulfide, which is later converted to ammonium bisulfide, and from there to sulfur. Baseline experiments determined that phosphogypsum could be reduced to calcium sulfide at 850° to 1,000° C using either coal or carbon monoxide as the reductant. The required temperature was lowered to 750° C using Fe_3O_4 as a catalyst for the reduction reaction. The effects of temperature, catalyst, reaction time, and type of reductant (carbon monoxide and coal) are also discussed.

OP 68–87. Conversion of Phosphogypsum to Sulfur. Part 2—Oxidation of Calcium Sulfide to Sulfur, by Alexander May and John W. Sweeney. Paper in Proceedings of the Third Workshop on By-Products of Phosphate Industries, Tampa, FL, Dec. 5–7, 1985. Univ. Miami, Coral Gables, FL, 1986, pp. 67–78. This paper describes research into the conversion of phosphogypsum to sulfur, focusing on converting calcium sulfide to ammonium bisulfide by reaction of an aqueous slurry with ammonia and carbon dioxide. Calcium carbonate is removed by filtration, and the ammonium bisulfide is oxidized to sulfur using air in the presence of a carbon catalyst. Also included is a discussion of the reaction parameters and their effect upon sulfur yield.

OP 69–87. Sagittal Plane Kinematic Analysis of a Specific Simulated Low-Seam Coal Mining Lifting Task, by Thomas G. Bobick, Robert Shapiro, Christopher Blow, and Sean Gallagher. Paper in Trends in Ergonomics/Human Factors IV, ed. by S. S. Asfour (Proc. of the Annual International Industrial Ergonomics and Safety Conference '87, Miami, FL, June 9-12, 1987). Elsevier Science Publ. B.V. Amsterdam, 1987, pp. 9–16. This paper describes a study of three materials-handling tasks performed by low-seam coal miners while kneeling. One of the tasks simulated was the moving of

50-lb rock dust bags. High-speed cinematographic filming techniques were utilized to obtain front and side views of eight experienced miners performing this task. Standard film analysis techniques were used to obtain kinematic records of leg, trunk, and arm action. The results indicate that trunk extension and rotation are the primary actions used to move these bags while in a kneeling posture.

OP 70–87. Western Thick and Closely Spaced Coal Seams—Geological Factors That Affect Their Development, by D. L. Boreck. Soc. Min. Eng. AIME preprint 87–40, 1987, 7 pp. This paper describes a study of the feasibility of introducing three longwall mining methods—high-face, multislice, and caving—into western coal operations. Geological factors affecting the development of these methods (thickness and three-dimensional configuration of the seam; cleats, joints, and fractures in the coal and roof rock; and coal quality and changes in quality within the seam) are discussed, and the specific applicability of the three proposed longwall mining methods are outlined.

OP 71–87. Significant Dust Exposures From Background Sources, by Andrew B. Cecala and Edward D. Thimons. Pit & Quarry, v. 79, No. 12, June 1987, pp. 46–51. This paper describes a study to identify common background dust sources and show the significant effects that they have on the bag operator's overall dust exposure. Background sources, observed at five different plants over the past 2 years, can expose bag machine operators to more significant dust concentrations than the filling process itself. To keep bag operator exposure within acceptable dust levels established by the Mine Safety and Health Administration, U.S. Department of Labor, the significance of these background sources must be realized, and the sources must be identified and controlled.

OP 72–87. Overburden Analysis Results Compared to Water Quality After Mining, by Patricia M. Erickson. Paper in Innovative Approaches to Mined Land Reclamation, ed. by C. L. Carlson and J. H. Swisher. South. IL Univ. Press, Carbondale, IL, 1987, pp. 307–330. This paper describes the preliminary findings of a study to evaluate 3 overburden analytical techniques for qualitative and quantitative prediction of postmining drainage quality in 30 surface coal mines in the Eastern and Midwestern United States.

OP 73–87. Task Analysis and Laboratory Simulation of Materials Handling in Underground Low-Coal Mines, by Sean Gallagher and Thomas G. Bobick. Paper in Proceedings of the Fifth Annual Meeting of the Collegiate Association for Mining Education, Beckley, WV, October 2–3, 1986. MSHA, Beckley, WV, 1987, pp. 118–142. This paper details a task analysis conducted at three underground low-seam mines to evaluate their supply-handling systems to determine the physiological and psychophysical stresses of lifting in underground low-seam mines. Items were tracked from delivery to the surface storage areas to their final destinations underground. Of particular interest were those tasks that required manual handling of supplies or equipment. Analysis revealed that miners handle materials while on both knees a total of 58.3 pct of the time, 18.5 pct while stooped over, and 16.2 pct while kneeling on one knee. These working postures impose considerable stress on the lumbar spine and may be implicated in the high number of back injuries in underground mines. Videotapes made during this study became the basis for simulating lifting activities in controlled laboratory conditions.

OP 74–87. The Function of Trunk Muscles During Back Strength Exertions in Standing and Kneeling Postures, by Sean Gallagher, William S. Marras, and Thomas G. Bobick. Paper in Trends in Ergonomics/Human Factors IV, ed. by S. S. Asfour (Proc. of the Annual International Industrial Ergonomics and Safety Conference '87, Miami, FL, June 9–12, 1987). Elsevier Science Publ. B.V., Amsterdam, 1987, pp. 27–34. This paper describes a study examining the effects of posture on back strength and electromyography of eight trunk muscles. Each subject performed a series of 12 back strength exertions while standing and kneeling. Mean and maximum integrated electromyography of right and left erectores spinae, latissimus dorsi, external obliques, and rectus abdominis were collected during each test of back strength. The results of this data will be used by the Bureau of Mines to assist in assessing the stresses of working in restricted work postures in underground mines.

OP 75–87. Ground Control Analysis of Multi-Slice Mining for Thick Western Coal Seams, by T. Hackett and H. Park. Soc. Min. Eng. AIME preprint 87–39, 1987, 7 pp. This paper describes a study by the Bureau of Mines into the ground control factors affecting multislice longwall mining under western mining conditions, including field trials at a multislice operation in Colorado.

OP 76–87. Stress Relief To Control Coal Bursts, by K. Y. Haramy, J. P. McDonnell, and L. A. Beckett. Soc. Min. Eng. AIME preprint 87–57, 1987, 12 pp. This report presents a review of the most widely used methods to detect and destress high stress zones along coal faces. Laboratory tests of the drilling yield method for high stress detection were conducted to determine the correlation between the volume of cuttings obtained and the magnitude of the applied stress at various confining pressures. A three-dimensional multiple-seam computer modeling program, MULSIM, was used to evaluate the effectiveness of stress relief methods. Modeling results and guidelines for destressing are presented. Results indicated that dangerously high stress areas can be controlled by either proper planning or destressing. Proper mine planning guidelines and destressing methods such as volley firing, hydraulic fracturing, and auger drilling are discussed.

OP 77–87. Fundamental Studies of Coal Mine Bumps in the Eastern United States, by Anthony T. Iannacchione, Alan A. Campoli, and David C. Oyler. Paper in Rock Mechanics, ed. by I. W. Farmer, J. J. K. Daemen, C. S. Desai, C. E. Glass, and S. P. Neuman (Proc. 28th U.S. Symposium on Rock Mechanics, Tucson, AZ, June 29–July 1, 1987). A. A. Balkema, Accord, MA, 1987, pp. 1063–1072. This paper describes a field study at the Olga Mine in McDowell County, WV, to assess the effects of various mining practices on the control of coal mine bumps. Observations indicated that retreat mining systems that involve sequential extraction along several rows of pillars effectively redirect loads away from the pillar being mined, reducing the occurrence and severity of bumps by spreading the excess stress over a greater number of outby pillars. Other control techniques discussed include the uses of shot firing and auger drilling.

OP 78–87. Laboratory Assessment of Metabolic Demands of Selected Low-Seam Coal Mining Materials-Loading Tasks, by Jay T. Kearney, Sean Gallagher, Robert Shapiro, and Thomas G. Bobick. Paper in Proceedings of the Fifth Annual Meeting of the Collegiate Association for Mining Education, Beckley, WV, October 2–3, 1986. MSHA, Beckley, WV, 1987, pp. 236–260. This paper describes a study to measure the metabolic demands of building a roof support cribbing, moving 50-lb rock dust bags, and building a brattice. Subjects at the University of Kentucky performed these tasks in a low-seam mine simulator while wearing full mining gear except for hard hats, which were replaced by respiratory valve headsets. Continuous readings were recorded before, during, and after the performance of these tasks.

OP 79–87. Control of Acid Mine Drainage: An Overview of Recent Developments, by Robert L. P. Kleinmann and Patricia M. Erickson. Paper in Innovative Approaches to Mined Land Reclamation, ed. by C. L. Carlson and J. H. Swisher. South. IL Univ. Press, Carbondale, IL, 1987, pp. 283–306. This paper describes current techniques used to limit acid production, thereby limiting the amount of acidic drainage

at inactive and abandoned minesites. Control methods discussed include compaction, soil cover and revegetation, plastic coverings, alkaline and phosphate additions, and bacteria inhibition.

OP 80–87. Constructed Wetlands for Treatment of Mine Water—Successes and Failures, by Robert L. P. Kleinmann and Michelle A. Girts. Paper in Proceedings of the 8th Annual National Abandoned Mine Lands Conference, Billings, MT, August 10–15, 1986. MT Aband. Mine Reclam. Bur., MT Dep. State Lands, Helena, MT, 1987, pp. 67–73. This paper describes an inventory of wetlands constructed for acid water treatment. Preliminary results, based on the 20 sites surveyed to date, indicate that the wetlands dominated by emergent species are out-performing the *Sphagnum*-dominated wetlands. In general, iron concentrations as high as 85 mg/L are reduced to less than 3 mg/L after flow through the constructed wetlands. Manganese is also removed, though somewhat less efficiently. The pH at the discharge, if not above 6, can be raised to that level or higher by flow over limestone. Wetland performance appears to increase in the second year after construction as vegetation becomes better established, and if inflow water volume is regulated, constructed wetlands can provide effective treatment of acid mine water at a relatively low cost.

OP 81–87. In Situ Determination of Deformation Modulus and Poisson's Ratio of a Rock Mass With Hydraulic Borehole Pressure Cells, by Paul H. Lu. Paper in Rock Mechanics, ed. by I. W. Farmer, J. J. K. Daemen, C. S. Desai, C. E. Glass, and S. P. Neuman (Proc. 28th U.S. Symposium on Rock Mechanics, Tucson, AZ, June 29–Jul. 1, 1987). A. A. Balkema, Accord, MA, 1987, pp. 273–281. This paper proposes a new method of in situ determination of deformation modulus and Poisson's ratio of a rock mass with hydraulic borehole pressure cells. These two geomechanics constants were determined using a combination of one cylindrical cell and two pre-encapsulated flat cells installed in a single borehole. A variety of states of stress can be generated by induced loading from mining or excavation for long-term tests, and by artificial loading imposed by flatjacks for quick tests. The required instrumentation was simple and inexpensive, and the test procedures were straightforward. The applicability and practicality of the technique was demonstrated by a long-term test conducted in a longwall panel at a coal mine. The investigation revealed the stress dependency of the deformation modulus and the Poisson's ratio of this coal.

OP 82–87. Iodine, by P. A. Lyday. Min. Eng., v. 39, No. 6, June 1987, pp. 415–416. This paper presents a review of changes in the iodine industry during 1986. Also discussed are the changes in the Government stockpile, imports, and the domestic and foreign industries.

OP 83–87. Heat Capacity of $2Al_4C_3 \cdot SiC$ From 447 to 1447 K and Enthalpy of Peritectic Decomposition of Al_4C_3, $2Al_4C_3 \cdot SiC$, and $Al_4C_3 \cdot SiC$, by L. L. Oden and R. P. Beyer. Thermochim. Acta, v. 115, 1987, pp. 11–19. The molar heat capacity of $2Al_4C_3 \cdot SiC$ and the enthalpy of peritectic decomposition of Al_4C_3, $2Al_4C_3 \cdot SiC$, and $Al_4C_3 \cdot SiC$ were measured by the Bureau of Mines to provide fundamental data to assist in the development of a carbothermic reduction process for aluminum. The molar heat capacity of $2Al_4C_3 \cdot SiC$ was measured by differential scanning calorimetry from 447 to 1447 K. The enthalpy of peritectic decomposition was calculated from time-temperature thermal analyses of samples, synthetic sapphire (NBS Standard Reference Material 720), and an empty crucible.

OP 84–87. Factors Influencing the Occurrence of Coal Pillar Bumps at the 9-Right Section of the Olga Mine, by David C. Oyler, Alan A. Campoli, and Frank E. Chase. Paper in Proceedings of the Sixth International Conference on Ground Control in Mining, Morgantown, WV, June 9–11, 1987. WV Univ., 1987, pp. 10–17. This paper discusses the factors that affect the occurrence of coal pillar bumps at the Olga Mine. These factors have been broken down into two categories—in situ, and those that are related to the mining process itself. The in situ factors include those conditions that exist prior to mining, such as variations in lithology and overburden, presence of jointing, the composition and the physical properties of the rock, and the original stress field existing in the coalbed and adjacent strata. The mining-related factors include the mining sequence, changes in stress in the coalbed and adjacent strata during mining, rates of convergence, and the pattern of failure of the coal and adjacent strata. The factors determined to have the greatest effect on bumping were the overburden, the lithology of the roof and floor rock, and the physical properties of the rock.

OP 85–87. Predicting, Controlling, and Diagnosing Production Problems: A Simple Computerized Method, by Robert F. Randolph. Paper in Proceedings of the Fifth Annual Meeting of the Collegiate Association for Mining Education, Beckley, WV, October 2–3, 1986. MSHA, Beckley, WV, 1987, pp. 269–288. This paper presents a new technique for improving coal mine productivity in which a production-function approach was used to model daily coal production at the most fundamental producing unit—the mine crew. The study shows that mine managers already have easy access to information that can help them explain, control, and predict production at the crew level. Computer-derived models were used to assess the relative effects of labor, technology, and environmental factors on the daily reported coal production of 81 mining crews at 7 underground coal mines in eastern coalfields. Almost all of the data came from the daily production foreman reports that are routinely gathered by most mining companies. Production models were derived from the data using a linear regression technique. The models explained a significant proportion of the day-to-day variation in coal production. Also, the input variables were found to significantly affect production in the expected directions. This technique promises to become an inexpensive and useful management tool for detecting and diagnosing production problems, assessing the effectiveness of a change both before and after implementation, and isolating factors that lead to changes in production. Mine managers can readily implement this technique by using their daily crew reports and simple linear modeling software running on any available computer.

OP 86–87. Computerized Assessment of Visual Requirements in Mining Machines, by James P. Rider and Richard L. Unger. Paper in Trends in Ergonomics/Human Factors IV, ed. by S. S. Asfour (Proc. of the Annual International Industrial Ergonomics and Safety Conference '87, Miami, FL, June 9–12, 1987). Elsevier Science Publ. B.V. Amsterdam, 1987, pp. 73–80. This paper describes a computerized technique to assess the visibility from mining machine operator compartments. This research is part of an overall project to make available a computer-based model that could lead to better ergonomic design of mining equipment and a safer mining environment. Visual Attention Locations (VAL's) were developed by identifying the location of important visual features that the operator must be able to see in order to operate the equipment safely and efficiently. VAL's are defined as points in space described in relation to the front-back, up-down, and side-to-side positions on a mining machine. These locations, which may be applied to any type of machine, are defined in the computer software. A design eye point and a focus point are also identified to the program. The user has the option of defining the eye position by either locating a point in space or by defining a point representing the lumbar joint of a 3-D manikin. The focus point is identified by giving the software a visual attention location or by locating an arbitrary point in space. With this, along with field of vision parameters, the user can simulate sitting inside the operator compartment, or looking from a VAL into the compartment. An example of visibility

analysis, using an actual piece of mining equipment, is presented in this paper.

OP 87–87. New Instrumentation for Roof Bolt Load Measurement, by Bernard Steblay. Paper in Proceedings of the Eighth West Virginia University International Mining Electrotechnology Conference, Morgantown, WV, July 30–Aug. 1, 1986. Univ. WV, 1986, pp. 109–113. This paper details research by the Bureau of Mines in electronic means to estimate point-anchored bolt loads. A brief history of the techniques under consideration, and the electronic and mechanical development needed to apply this technology to mine roof bolts, are presented. Also included are the results of laboratory and field tests, current and potential applications of these techniques, their limitations, and the development of a multireflector instrument to avoid the cost and accuracy problems of previous roof bolt load measurement procedures.

OP 88–87. The Application of Computer-Based Training to Annual Refresher Training, by James H. TaVoularis. Paper in Proceedings of the Fifth Annual Meeting of the Collegiate Association for Mining Education, Beckley, WV, October 2–3, 1986. MSHA, Beckley, WV, 1987, pp. 289–308. This paper discusses the design, development, and implementation of a pilot project to deliver annual refresher training to Bureau of Mines personnel using a computer. A history of the Bureau's research into the use of advanced technology to enhance training and how it evolved into the use of computer-based training is outlined, and the hardware configuration and the authoring system used to generate course materials is included. Also discussed is the development of the training objectives and the decisionmaking process used to categorize them for either computer or classroom delivery. The paper concludes with suggestions for the use of computer-based training in the mining community.

OP 89–87. Compressive Strength, Burst Proneness, and Failure Modes of Model Coal Pillars Related to the End Constraint and Geometry, by C. O. Babcock. Paper in Rock Mechanics, ed. by I. W. Farmer, J. J. K. Daemen, C. S. Desai, C. E. Glass, and S. P. Neuman (Proc. 28th U.S. Symposium on Rock Mechanics, Tucson, AZ, June 29–July 1, 1987). A. A. Balkema, Accord, MA, 1987, pp. 173–180. This paper describes tests conducted to determine the relationships between strength, constraint, geometry, and failure mode in coal pillars broken under compression. The model pillars used were 54 mm in diameter with varying diameter-to-length ratios and end conditions, and were composed of coals from Colorado and Utah. The study concluded that the roof-pillar-floor sequence, not the pillar geometry alone, should be an important factor in the design of coal pillars.

OP 90–87. Evaluating Bump Control Techniques Through Convergence Monitoring, by A. A. Campoli. Coal Min., v. 24, No. 7, July 1987, pp. 42–46. This paper describes bump control techniques employed at the Olga Mine in McDowell County, WV. Stress reduction techniques such as shot firing and auger drilling were evaluated using convergence monitoring, and roof and floor extensometer data confirmed that convergence is generally caused by a coal pillar yielding under stress rather than by separations in the roof or the heaving of the floor.

OP 91–87. Underground Observations of Mined-Through Stimulation Treatments of Coalbeds, by William P. Diamond. Q. Rev. Methane Coal Seams Technol., v. 4, No. 4, June 1987, pp. 19–29. This paper describes the effects of hydraulic stimulation treatments using foam, gel and water, kiel and water, and water alone in a total of 22 gas-bearing coalbeds in Pennsylvania, Alabama, West Virginia, Illinois, Virginia, and Utah. Vertical fractures in coalbeds were discernible for most treatments, and sand-propped portions were usually short in lateral extent. Horizontal fractures, present in about one-half of the treatments, were found generally within bedding planes, most commonly on top of the coalbed. For treatments to which fluorescent paint had been added, evidence of stimulation fluid movement could generally be traced beyond the maximum extent of sand-filled fractures. Penetration of strata overlying the coalbeds was observed in nearly one-half of the treatments intercepted, but most of those were interpreted as penetrations into preexisting planes of structural weakness. No roof falls or adverse mining conditions were encountered that could be attributed to the stimulations.

OP 92–87. Acid Mine Drainage From Inactive Eastern Coal Operations, by Patricia M. Erickson, Kenneth J. Ladwig, and Robert L. P. Kleinmann. Environ. Geochem. and Health, v. 7, Mar. 1985, pp. 16–25. This paper describes several field studies intended to determine the location of pyrite oxidation zones and migration pathways of oxidation products at inactive spoil and refuse sites. These studies identify a number of shortcomings in standard reclamation practices and will be used to develop alternative abatement technology.

OP 93–87. Waterjet-Assisted Drag Bit Cutting in Medium Strength Rock: A Fundamental Investigation, by J. E. Geier, M. Hood, and E. D. Thimons. Paper in Rock Mechanics, ed. by I. W. Farmer, J. J. K. Daemen, C. S. Desai, C. E. Glass, and S. P. Neuman (Proc. 28th U.S. Symposium on Rock Mechanics, Tucson, AZ, June 29–July 1, 1987). A. A. Balkema, Accord, MA, 1987, pp. 953–961. This paper presents hypotheses for the mechanism by which water jets reduce the specific energy of cutting for drag bits. Several of these are shown to be inconsistent with published evidence and new observations. The notion of a limiting cutting speed, above which water jets would be incapable of rendering assistance, was shown to be improbable. The hypothesis that seems most plausible is that specific energy reductions are mainly due to the erosion of crushed material from in front of the bit. This hypothesis leads to a prediction that, for a given rock type and jet-bit configuration at a constant depth of cut, the reduction in bit forces should be a function of dW/dx, the jet energy spent per unit length of cut. This dependence upon dW/dx is shown to be consistent with previously reported results.

OP 94–87. Constructed Wetlands for Treatment of Acid Mine Drainage: A Preliminary Review, by Michelle A. Girts and Robert L. P. Kleinmann. Paper in Proceedings of the 1986 National Symposium on Mining, Hydrology, Sedimentology, and Reclamation, Lexington, KY, Dec. 8–11, 1986. Univ. KY, Lexington, KY, 1986, pp. 165–171. This paper is a preliminary review of the use of experimental wetlands as an inexpensive alternative to conventional acid mine water treatment methods. Over 25 wetlands in Pennsylvania, West Virginia, Ohio, and Maryland were inventoried to determine the effect of alternative designs and water conditions on treatment efficiency, maintenance requirements, and construction costs.

OP 95–87. Acid Mine Water Treatment in Wetlands: An Overview of an Emergent Technology, by R. L. P. Kleinmann and M. A. Girts. Paper in Aquatic Plants for Water Treatment and Resource Recovery, ed. by K. R. Reddy and W. H. Smith (Proc. of the Research and Applications of Aquatic Plants for Water Treatment and Resource Recovery Conference, Orlando, FL, July 20–24, 1986). Magnolia Publ. Inc., New York, NY, 1987, pp. 255–261. This paper presents an inventory of 20 constructed wetlands as part of a long-term evaluative study. Preliminary results indicate that the wetlands dominated by emergent species are outperforming the *Sphagnum*-dominated wetlands, and that much of the water treatment is accomplished by other aspects of the wetland, including bacteria, algae, amendments, and other plants.

OP 96–87. Should the Discharge Standards for Manganese Be Reexamined?, by R. L. P. Kleinmann and G. R. Watzlaf. Paper in Proceedings of the 1986 National Symposium on Mining, Hydrology, Sedimentology, and Reclamation, Lexington, KY, Dec. 8–11, 1986. Univ. KY, Lexington, KY, 1986, pp. 173–179. This paper examines arguments for reevaluation of the legal limit for manganese concentration in

effluent mine water. These arguments include new data on the toxicity of manganese, the effects of the high pH of effluent after the required treatment and its detrimental effects on stream biota, and the problem of the manganese-bearing sludge itself.

OP 97–87. A Biological Alternative to Conventional AMD Treatment, by Robert L. P. Kleinmann. Green Lands, Spring 1987, pp. 30–33. This paper describes the use of wetlands as an alternative to chemical treatment of acid mine drainage (AMD), presenting the technique in its historical context and detailing the specific uses of plant varieties such as cattails and the *Sphagnum* species.

OP 98–87. Large-Scale Metals Identification and Sorting Using Instrumented Techniques, by W. D. Riley, R. D. Brown, Jr., and J. M. Larrain. J. Test. and Eval., v. 15, No. 4, July 1987, pp. 239–247. This paper describes methods of identifying scrap metals detailing the instruments involved, the preparation of specimens, sorting procedures, and quality control techniques. Thus far, approximately 250,000 kg of aircraft scrap have been identified and sorted by a combination of conventional and instrumental techniques into 30 categories with better than 95% accuracy at a manual sorting rate averaging 93 kg per worker-hour. Techniques used in this study included fluorescent X-ray spectrography, thermoelectric response, optical spectroscopy, spark testing, magnet testing, and object recognition. The practical application of these techniques in a large-scale test is described.

OP 99–87. Flocculation of Fine Coal Waste—Laboratory and Field Studies, by Bill M. Stewart, Ronald R. Backer, and Richard A. Busch. Paper in Flocculation Sedimentation and Consolidation, ed. by Brij Moudgil and P. Somasundaran (Proc. Engineering Foundation Conference, Sea Island, GA, Jan. 27–Feb. 1, 1985). Eng. Found. NY, New York, NY, 1985, pp. 249–259. This paper evaluates methods of dewatering fine coal refuse slurry using lime and anionic polymer in both manual and automatic flocculant systems. The equipment used in the field tests was relatively inexpensive, and the polymer treatment was shown to be effective both in the laboratory and in the field, its ability to effect immediate separation of water and solids making it an especially useful technique at mines with limited disposal area.

OP 100–87. ICP Analysis of Recycled Superalloy Scrap, by Clarissa W. Whitten. At. Spectrosc., v. 8, No. 3, May–June 1987, pp. 81–83. This paper presents research in the chemical analysis of superalloy scrap and the development of an innovative sequential inductively coupled plasma (ICP) technique. This technique utilizes microwave oven dissolution of the samples, Cu internal standard, and a National Bureau of Standards (NBS) certified standard as a control. Several major and minor components of NBS No. 349 Waspaloy, ranging in value from 58% to 0.01%, were determined to have excellent agreement with certified values.

OP 101–87. Measurement of Mass Transfer Effects in Sulfate Electrogalvanizing Electrolyte, by S. Frederick Chen, J. Sami Cuzmar, Thomas J. O'Keefe, Ernest R. Cole, Vernon R. Miller, and James H. Lindsay. Gen. Motors Res. Publ. GMR-5840, Gen. Motors Res. Lab., Warren, MI, May 4, 1987, 20 pp. This paper describes research into the mass transport properties in a sulfate electrogalvanizing system using a potentiodynamic method and Ag as the tracer ion. The limiting current density, mass transfer coefficient, and diffusion layer thickness of zinc were calculated from the measured limiting current of the tracer. The effects of temperature, zinc concentration, and agitation on the mass transfer rate were evaluated. The effects of hydrodynamic and electrolytic conditions on the structure and properties of the zinc deposits were investigated. These studies showed the structure to be strongly influenced by both types of conditions. Corrosion properties were not significantly influenced by hydrodynamic conditions within the range studied. Sheet drawing properties, more dependent on crystal structure, were influenced by solution flow.

OP 102–87. Coatings on Aluminum To Reduce Incendivity in Methane-Air Mixtures, by T. J. Driscoll. Trans. Soc. Min. Eng. AIME, v. 280, 1987, pp. 1869–1876. This paper describes the effect of coatings on the incendive properties of aluminum alloy 6061–T651 in air-6.4% CH_4. This alloy was studied for collisions between rusted steel and both uncoated and coated projectiles in simulation of the rough handling of equipment in coal mines. The ignition probability using uncoated alloy projectiles increased with increasing relative humidity and appeared to be influenced by atmospheric ozone content. The incendive properties of both the uncoated and coated alloy depended on the type of rust used, but the dependence of the coated alloy was very different from that of the uncoated alloy.

OP 103–87. Soviet Union, by Richard M. Levine. Sec. in Mining Annual Review 1987. Min. J. Ltd., 1987, pp. 458–467. This article presents data based on sources published in the U.S.S.R. concerning the geologic, technologic, and economic influence on the minerals industry in that country. A commodities review is also included.

OP 104–87. An Assessment of the Effects of Longwall Chain Pillar Configuration on Gate Road Stability, by Jeffrey M. Listak and Joseph C. Zelanko. Paper in Rock Mechanics, ed. by I. W. Farmer, J. J. K. Daemen, C. S. Desai, C. E. Glass, and S. P. Neuman (Proc. 28th U.S. Symposium on Rock Mechanics, Tucson, AZ, June 29–July 1, 1987). A. A. Balkema, Accord, MA, 1987, pp. 1083–1093. This paper describes a study to assess the redistribution of mining-induced stress associated with longwall panel extraction. The objective of this study was to assess the performance of various chain pillar configurations on gate road entry stability. Field measurements were collected and analyzed to develop profiles of the stress redistribution occurring in the gate road chain pillars during longwall panel retreat mining. A better understanding of the redistribution of stress will allow for improved gate road design by more accurately defining the loads imposed on chain pillars.

OP 105–87. Application of Computer-Aided Remote Sensing and Potential Hazard Analysis To Improve Mine Design, by D. C. Peters, R. A. Speirer, and T. C. Bettinger. Paper in Underground Mining Methods and Technology, ed. by A. B. Szwilski and M. J. Richards. Elsevier Science Publ. B.V., Amsterdam, 1987, pp. 425–439. This paper describes a hazard analysis of data from field checking both on the surface and underground at the minesite and the corroboration of lineaments as real geologic features in the subsurface by other geological and geophysical data. By crosscomparison in the computer, these data may also indicate the degree and type of hazard that can be associated with the lineaments, and computerized remote sensing analysis can minimize interpreter bias (or dependence on level of experience) and facilitate the lineament analysis, subsequent editing, and data comparison.

OP 106–87. The Effects of Sheltering and Orientation on the Atmospheric Corrosion of Structural Metals, by J. P. Carter, P. J. Linstrom, D. R. Flinn, and S. D. Cramer. Mater. Perform., v. 26, No. 7, July 1987, p. 25–32. This paper describes atmospheric corrosion tests on five alloys and two coated steel products at five sites as part of the National Acid Precipitation Assessment Program. Tests were conducted on samples boldly exposed to the atmosphere, sheltered from the atmosphere, and facing skyward and groundward. Details of the corrosion process related to orientation and sheltering and involving particulates, corrosion film chemistry and morphology, and the dissolution-reprecipitation process were established. The corrosion film on zinc was found to saturate with sulfur at ~7 wt% with increasing ambient sulfur dioxide concentration. Zinc corrosion on the skyward side appeared to be cathodically protected in two-sided bold exposures. Only large particulates were found on the surface of sheltered copper

and zinc, and small particulates dissolved and dispersed into the corrosion film. The dissolution-reprecipitation process occurred primarily during the final stages of drying.

OP 107–87. A Microscopic and Kinetic Study of Coal Particle Devolatilization in a Laser Beam, by Martin Hertzberg and Daniel L. Ng. Paper in Fundamentals of the Physical-Chemistry of Pulverized Coal Combustion, ed. by J. Lahaye and G. Prado (Proc. of the NATO Advanced Research Workshop on Fundamentals of the Physical-Chemistry of Pulverized Coal Combustion, Les Arcs, France, July 28–Aug. 1, 1986). Martinus Nijhoff Publ., Dordrecht, The Netherlands, 1987, pp. 104–125. This paper describes a new experimental method to determine the effect of morphological changes on coal particles when exposed to laser heating. Using direct weight loss measurements for single particles or small arrays of particles, this technique permits devolatilization data to be correlated directly with scanning electron microscopy. For coal particles exposed to the laser flux in an air environment, essentially the same devolatilization process is observed initially; however, when devolatilization is complete, it is followed by a heterogeneous char oxidation process that occurs on a much the reaction mechanism for devolatilization involves the simple, inward progression of a laminar pyrolysis-devolatilization wave from the exposed surface. Simple thermodynamic transport constraints require that the pyrolysis wave velocity be determined by the sum of the absorbing heat flux necessary to raise each element of the solid to its devolatilization temperature (500° to 600° C), plus the flux required to supply the heat of devolatilization. The reaction rate for a particle is then simply controlled by the time required for that devolatilization wave to traverse through it, and that time is predicted to be directly proportional to the particle diameter and inversely proportional to the absorbed flux.

OP 108–87. Investigation of the Important Parameters in a Gas Sparging Technique for Production of Tungsten Carbide, by G. Kazonich, A. E. Raddatz, and T. G. Carnahan. Paper in Proceedings of the Pyrometallurgy '87 Symposium, London, England, Sept. 21–23, 1987. Inst. Min. and Metall., 1987, pp. 1075–1105. This paper describes a bench-scale study to delineate the important parameters in a three-step process to produce commercial quality tungsten carbide (WC) directly from tungsten minerals. In the process, tungsten concentrates of wolframite or wolframite and scheelite were decomposed at 1,050° C in a molten mixture of NaCl and Na_2SiO_3 that forms two immiscible phases. Tungsten, as sodium tungstate, reports to the halide phase and is separated from the gangue constituents, which report to the silicate phase. After decanting to separate the two phases, natural gas was sparged into the molten halide phase at 1,070° C. Submicrometer crystals of tungsten carbide were initially produced. These crystals grow into thin, triangular-shaped plates up to 100 μm on a side or into popcorn-shaped conglomerates. Research was conducted to study sparging chemistry and to determine the effects of operating parameters including time, temperature, and sparging gas composition on the reaction rate, gas utilization efficiency, and WC crystal morphology. This led to a proposed reaction mechanism for the formation of sparged carbide. WC production rates of 60 g/h WC were obtained in a 76-mm reactor by sparging 1,600 g halide melts containing 32 pct Na_2WO_4 with natural gas at flow rates of 3 L/min. WC crystals of 10 μm or smaller were consistently produced at temperatures between 1,060° and 1,070° C. Tungsten recovery from the halide phase was 88 pct after 6 h of sparging. Cleaning techniques employing 6*M* HCl leaches at 65° C for 1 h decreased contaminant concentrations to levels similar to those in commercial tungsten carbide. Sparged tungsten carbide was examined for its suitability for use in sintered carbide products. Physical evaluations of sparged WC ground to an average particle size of 1.5 μm and compacted with 10 pct Co binder into standard 6- by 6- by 22-mm test bars had a density of 14.35 and a Rockwell A hardness of 89.6. This compared favorably with 14.39 and 89.7, respectively, for test bars made from a standard commercial 1.5-μm WC powder. Test bars made from Bureau of Mines WC had no "C" porosity or eta phase.

OP 109–87. Hydrogen Chloride and Hydrogen Bromide Sparging Crystallization of Chloride and Bromide Metal Salts, by E. G. Noble and D. E. Shanks. Paper in Crystallization and Precipitation, ed. by G. L. Strathdee, M. O. Klein, and L. A. Melis (Proc. of the International Symposium, Saskatoon, Saskatchewan, Canada, Oct. 5–7, 1987). Pergamon, Elmsford, NY, 1987, pp. 89–98. This paper describes the effects of hydrogen halide (HCl or HBr) concentration and temperature on the solubility and hydration state of $AlCl_3$, $CaCl_2$, $CoCl_2$, LiCl, $MgCl_2$, $NiCl_2$, KCl, NaCl, $AlBr_3$, $CoBr_2$, $PbBr_2$, $MnBr_2$, KBr, and NaBr. Saturated aqueous solutions of the chloride and bromide salts were sparged with HCl and HBr gas, respectively, until acid saturation was reached. All salts except $CoBr_2$ and $MnBr_2$ were sparged at 20°, 40°, and 60° C; $CoBr_2$ and $MnBr_2$ were sparged only at 20° C. Increased acid concentration caused the salts to crystallize out because of the common ion effect for all investigated halides except $PbBr_2$. $CoBr_2$ and $CoCl_2$ crystallized out and had minimum solubilities at intermediate acid concentrations, and then increased in solubility because of the formation of bromide and chloride complexes at higher acid concentrations. $PbBr_2$ was minimally soluble in water and increased in solubility as HBr concentration increased. The data agree with literature values obtained from long-term equilibrium tests. Hydration states of the salted-out chlorides and bromides were determined by a wet-residue method and depended on temperature and acid concentration.

OP 110–87. A Revealing Look at Roof and Rib Fall Accident Statistics, by Deno M. Pappas. Coal Min., v. 24, No. 9, Sept. 1987, pp. 47–49. This paper describes an investigation of accidents associated with fatal and nonfatal roof-rib falls. Mine Safety and Health Administration accident statistics for U.S. mines during the period 1980–85 were sorted, normalized, and graphed using a computer software program. The statistics indicated that roof and rib accidents have declined 22 pct in the 6-year study period. Moreover, they indicated that there have been increases and/or patterns of roof and rib accidents associated with specific mine characteristics such as mine size, seam height, geographic location, and seasonal variations. Also examined was the worker activity at the time of the roof and/or rib fall accident. The economic effects of roof and rib accidents were emphasized by using a computer program to approximate accident costs. The program estimated that the cost per accident of roof and rib accidents is three times the cost of any other type of underground coal accident.

OP 111–87. Oxidation of Fe-7Cr-12Ni-(0-6)Al-(0-7)Si Alloys, by J. C. Rawers and E. M. Mattlin. Metall. Trans. A., v. 18A, Oct. 1987, pp. 1805–1812. This paper describes oxidation tests performed on a series of Fe-7Cr-12Ni-(0-6)Al-(0-7)Si alloys at temperatures between 800° and 1,000° C. The master alloy, Fe-7Cr-12Ni, had no oxidation resistance at temperatures above 800°C. Aluminum additions to the master alloy produced a protective Al_2O_3 layer over the substrate metal, which prevented rapid oxidation and allowed time for a Cr_2O_3 layer to develop underneath. Silicon addition to the master alloy produced an SiO_2 oxide sublayer at the metal-oxide interface that, when formed, provided an effective barrier to oxidation. A combination of 1.5-pct-Al and 2.0-pct-Si additions provided the best oxidation protection.

OP 112–87. Flocculation of Fine Particles With Polyethylene Oxide: A Proposed Mechanism, by B. J. Scheiner and D. A. Stanley. Trans. Soc. Min. Eng. AIME, v. 280, 1987, pp. 2115–2117. This paper describes a technique for dewatering phosphatic clay waste to recover metals and other minerals by flocculating it with polyethylene oxide (PEO). Results showed that PEO was far superior to polyacrylamide polymers for this type of dewatering, as PEO causes the formation of a stronger bond with the exchange ions, causing the clay to remain stable and resist reslurrying more efficiently than material flocculated with polyacrylamide.

OP 113–87. Improving Dust and Methane Control, by Andrew Cecala, John Organiscak, and Robert Jankowski. Coal Min., v. 24, No. 10, Oct. 1987, pp. 51–52. This paper presents a number of techniques for controlling dust and methane during the headgate cutout of retreating longwall sections that use antitropal ventilation (headgate to tailgate). Some of these techniques are effective for both methane and dust control, while others are effective for only one or the other. The techniques include the gob curtain, the walkway curtain, stage-loader-crusher control, and the wing curtain. Each improves the health and safety of workers and is economically feasible in hardware cost, setup cost, and maintenance.

OP 114–87. Ventilated Drum Controls Longwall Dust and Methane, by Edward F. Divers, Robert A. Jankowski, and Jonathan Kelly. Ch. 10 in Proceedings of the 3rd U.S. Mine Ventilation Symposium, Littleton, CO, Oct. 12–14, 1987, pp. 85–89. This paper presents results for the first underground test of a ventilated drum in a U.S. coal mine. The tests were conducted to evaluate dust control effectiveness in a western

mine and for gas control in a full-scale laboratory facility. The ventilated drum is designed to reduce the amount of dust from cutting by drawing dust-laden air from the cutting zone through 12 water-powered dust capture tubes built into the shell of the shearer drum. High pressure water up to 112.48 kg/cm² (1,600 psig) released from sprays induces maximum airflow of 1.89 m³/sec (4,000 ft³/min) from the face side of the drum and provides cleaning for respirable dust and improved methane dispersion. At the gob side of the drum, a deflector plate attached to the cowl arm turns the spray and a proportion of the cleaned air back into the cutting zone. More than 50 ventilated drums have been installed to date in England, and tests carried out on fixed-height and single-ended ranging drum shearers have shown reductions in respirable dust of 60 to 80 pct as compared with conventional wet cutting. The U.S. test on a double drum shearer showed slightly lower reductions.

OP 115–87. Guidelines for Choosing Face Ventilation Systems, by Edward F. Divers and Jon C. Volkwein. Coal Min., v. 24, No. 10, Oct. 1987, pp. 46–47, 59. This paper discusses the problem of reducing respirable dust and methane in coal mines. Two machine-mounted face ventilation systems are presented that have been shown to successfully address both of these factors whose reduction techniques have usually proven to counteract each other. Included in this discussion are the costs to install and maintain these systems, and the seam conditions under which they work best.

OP 116–87. Altered Layer Formation and Sputtering Yields for 5 keV Ar^+ Bombardment of MoO_3 and WO_3, by T. J. Driscoll, L. D. McCormick, and W. C. Lederer. Surf. Sci., No. 187, Apr. 4, 1987, pp. 539–558. This paper describes a study of the effects on MoO_3 and WO_3 due to ion bombardment using parameters typical of sputter profiling (5 keV Ar^+at approximately 10 μA/cm²) using proton-induced X-ray emission and X-ray photoelectron spectroscopy. During the first 2×10^{15} to 2×10^{16} ions/cm² of sputtering, structurally and chemically altered regions form. The structurally altered regions are due to amorphization. The chemically altered regions consist of both stoichiometric and nonstoichiometric oxides with lower oxygen contents than the original trioxides, as well as trioxide for MoO_3 and elemental W and/or W_3O for WO_3. The thicknesses of the chemically altered regions are comparable to the range of the incident ions for WO_3 and about five times as large as the range for MoO_3. The possibility of distortions in sputter profiles of complex oxide films due to different sputtering yields for component oxides was evident in the measured sputtering yields of 2.1, 2.5, and 3.5 atoms/ion for Ta_2O_5, MoO_3, and WO_3, respectively, for normally incident ions.

OP 117–87. Agglomeration Heap Leaching of Precious Metals, by J. A. Eisele and D. L. Pool. CIM Bull., v. 80, No. 902, June 1987, pp. 31–34. This paper describes a particle agglomeration technique to improve the flow of leaching solution through heaps of low-grade gold-silver ores that contain clays. Bench-scale experiments and industrial practice have shown that the percolation rate of cyanide leaching solution is greatly enhanced by mixing the ore with portland cement as a binder, moistening the mixture, mechanically tumbling it to form agglomerates, and aging it before heap building and leaching. A slight modification of the technique allows its application to tailings containing precious metals, which cannot normally be treated by heap leaching because they are too fine.

OP 118–87. Preliminary Recommendations for Handling and Lifting Materials in Underground Low-Coal Mines, by Sean Gallagher, Thomas G. Bobick, and Richard L. Unger. Paper in Proceedings of the Human Factors Society 31st Annual Meeting, New York, NY, Oct. 12–22, 1987, v. 2, pp. 921–925. This paper addresses the problem of reducing injuries to the lower back resulting from materials handling in underground coal mines. The three main considerations discussed are (1) the research and development of hardware to reduce the number of lifts required, (2) task analysis of the supply-handling systems in use, and (3) the determination of lifting capacity of miners in restricted postures in the mine environment.

OP 119–87. Effects of Lifting in Four Restricted Work Postures, by Sean Gallagher, Richard L. Unger, and E. William Rossi. Paper in Proceedings of the Human Factors Society 31st Annual Meeting, New York, NY, Oct. 12–22, 1987, v. 1, pp. 462–466. This paper describes a study to examine the lifting capacity of low-seam coal miners in four restricted work postures with roof heights of 36, 40, 44, and 48 in; to investigate the associated metabolic costs; and to examine electromyographic data from eight trunk muscles during the lifting procedure. Thirteen underground miners accustomed to handling materials in restricted work postures performed 2 periods of asymmetric lifting in each of 4 postures during the day of testing. The frequency of lifting was 10 lifts per minute. A specially designed lifting box incorporated microswitches in one handle of the box and another in the bottom of the box to examine the trunk muscle function at specific points during the lifting cycle. The data collected will be used by the Bureau of Mines to make recommendations for lifting materials in low-seam coal mines.

OP 120–87. Correction Factors for Vane Anemometer Measurements Taken at Gob Hole Outlets, by Fred Garcia and Joseph Cervik. Ch. 46 in Proceedings of the 3rd U.S. Mine Ventilation Symposium, Littleton, CO, Oct. 12–14, 1987, pp. 301–306. This paper describes the development of method factors to correct vane anemometer measurements used to determine the amount and velocity of gas from gob holes. Factors for 4-, 6-, and 8-in-ID pipe are given, and the effects of wind velocity on the accuracy of measurements are discussed.

OP 121–87. Bureau of Mines Introduces New Hardrock Cutting Concept, by R. L. Schmidt, R. J. Morrell, and D. A. Larson. Skillings' Min. Rev., v. 76, No. 45, Nov. 7, 1987, pp. 4–10. This paper describes an investigation to determine a means to mechanically extract hard rock that would be more efficient and better lend itself to modern remote control methods than the currently favored drill-blast technique. Various existing equipment such as tunnel boring machines, roadheaders, continuous coal miners, raise borers, impactors, saws, ripper cutters, and rotary drills were compared, and it was found that only ripper cutting could fragment hard rock economically enough to compete with drill-blasting.

OP 122–87. Foundation Response to Subsidence Induced Ground Movements: A Case Study, by Jeffrey S. Walker and John C. LaScola. Paper in Proceedings of Longwall USA Conference, Pittsburgh, PA, June 2–4, 1987. Coal Min., Aurora, CO, 1987, pp. 159–171. This paper describes an investigation to determine if mining-induced ground movement is directly transferred to a structure and how that process takes place. A series of four concrete block walls with foundations were constructed and monitored over an active longwall panel as part of a comprehensive subsidence research program. Three of the four walls were located perpendicular to the advance of the longwall face in the zones where maximum inclination, maximum tension, and maximum curvature were predicted. The fourth wall was constructed along the centerline of the panel, parallel to the advance of the longwall face. All of the walls and the surrounding ground surface were instrumented with conventional survey monitoring points and extensometer stations to observe the vertical and horizontal movement. The fourth wall also included continuously recording tiltmeters. The results of this investigation indicate that simple structures respond to subsidence in a similar manner as the ground surface, suggesting that once the transfer mechanism is fully defined through further field and laboratory research, prediction models can be developed or modified to allow accurate estimation of the effect of mining on surface structures.

OP 123–87. Thermal Ignition of Polymethylmethacrylate (PMMA) Particles, by Ronald S. Conti and Isaac A. Zlochower. Paper in Proceedings of the Combined Meetings of the Twentieth Fall Technical Meeting of The Combustion Institute and the National Bureau of Standards Annual Conference on Fire Research, Nov. 2–5, 1987. Natl. Bur. Stand., Gaithersburg, MD, 1987, pp. 37-1–37-4. This paper describes the measurement of the autoignition temperatures and ignition delay time for polymethylmethacrylate

particles as a function of particle size and concentration in the Bureau of Mines 1.2-L furnace. Calculations are presented indicating that the kinetics of the gas phase combustion reactions are rate limiting except for the largest particles studied. For the latter, the delay is due primarily to heat-up time of particles. Measurements on the ignition delay times for preheated and unheated liquid polymethylmethacrylate strongly support the limiting gas phase kinetics model.

OP 124-87. Fire Endurance of Mine Stoppings, by D. Ng and C. P. Lazzara. Paper in Proceedings of the Combined Meetings of the Twentieth Fall Technical Meeting of The Combustion Institute and the National Bureau of Standards Annual Conference on Fire Research, Nov. 2-5, 1987. Natl. Bur. Stand., Gaithersburg, MD, 1987, pp. 100-1—100-4. This paper describes the testing of the fire-enduring qualities of concrete block and galvanized steel stoppings. Both types of stoppings were found to prevent the passage of flame and smoke at 800° C, and although the concrete stopping cracked on the side exposed directly to the fire, the unexposed side showed no damage.

OP 125-87. Fire Tests of Rigid Plastic Ventilation Ducts, by F. Perzak, C. P. Lazzara, and T. A. Kubala. Paper in Proceedings of the Combined Meetings of the Twentieth Fall Technical Meeting of The Combustion Institute and the National Bureau of Standards Annual Conference on Fire Research, Nov. 2-5, 1987. Natl. Bur. Stand., Gaithersburg, MD, 1987, pp. 101-1—101-4. This paper describes a flammability study of plastic ventilation ducts. Six rigid 16-in-diam fiberglass-reinforced-plastic ducts from five manufacturers were examined using laboratory-scale, large-scale, and full-scale fire tests. Ten-foot lengths of the same ducts were also subjected to a large-scale vertical fire test, and 20- to 30-ft lengths were tested in a full-scale in-mine fire test at the Bureau of Mines Lake Lynn Laboratory Mine. The data from the laboratory-scale radiant panel test and oxygen index test indicate that the ducts were fire-resistant. However, five of the six ducts failed the standardized small-scale flammability test (S^3FT) and the vertical fire test, and four of the ducts failed the full-scale in-mine tests with flame propagation rates that ranged from 3 to 10 ft/min. The results indicate the need for improved fire-resistant plastic ducts. The good agreement between the S^3FT results and the vertical and full-scale tests show that the S^3FT provides a good indication of the flammability of fiberglass-reinforced-plastic ducting under realistic fire conditions.

OP 126-87. Patents on In Situ Mining of Metals, by Joseph M. Pugliese and William C. Larson. In Situ, v. 11, Nos. 2-3, June-Sept. 1987, pp. 261-282. This paper contains a listing of U.S. patents granted for inventions for the in situ mining of metals during the period 1910-85. Each patent is coded to indicate the element involved, the year of issue, and the related subject area, and therefore provides an abbreviated subject summary.

OP 127-87. New Approach for Determining Ground Tilt and Strain Due to Subsidence, by Sathit Tandanand and Theodore Triplett. Paper in Proceedings of the 1987 National Symposium on Mining, Hydrology, Sedimentology, and Reclamation, Lexington, KY, Dec. 7-11, 1987. Univ. KY, Lexington, KY, 1987, pp. 217-221. This paper examines the relationships between tilt, ground strain, and curvature in an attempt to develop a technique to simultaneously determine ground tilt and strain due to subsidence without traditional time-consuming topographic surveys.

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OP 1-88. Reducing Bag Operator's Dust Exposure in Mineral Processing Plants, by Andrew Brian Cecala, Jon C. Volkwein, and J. Harrison Daniel. Appl. Ind. Hyg., v. 3, No. 1, Jan. 1988, pp. 23-27. This paper describes the evaluation of five commercially available bag-filling valves to determine their dust reduction capabilities. An extended polyethylene valve was found to be the most effective, resulting in a 62-pct reduction in operator dust exposure as compared to the standard paper valve. A dual bag nozzle system was developed that decreases product loss and significantly lowers the operator's exposure. With this system, one nozzle fills the bag, and the other nozzle exhausts excess air when filling is complete. An improved bag clamp reduces product blowback during filling, thus reducing product accumulation on the outside of the bag. The system reduces operator exposure up to 83 pct and significantly lowers the subsequent exposure of workers stacking the bags onto pallets.

OP 2-88. Modified Fe-Mn-Si-Al Alloys for High Temperature Oxidation, by Je M. Oh. J. Electrochem. Soc., v. 134, No. 12, Dec. 1987, pp. 3209-3210. This paper describes the testing of modified Fe-Mn-Si-Al alloys containing differing proportions of Al and Si. Results showed that alloys with a higher Si content with respect to Al have a number of advantages, including lower oxidation rates, the absence of spalling during thermal cyclings, and a lack of beta-Mn phase formation, making them potential chromium-free substitutes for stainless steel.

OP 3-88. Human Factors Contributing to Groundfall Accidents in Underground Coal Mines: Workers' Views, by Robert H. Peters and William J. Wiehagen. Paper in Proceedings of the Eighteenth Annual Institute on Coal Mining Health, Safety, and Research, Blacksburg, VA, Aug. 26-28, 1987. VA Polytech. Inst. and State Univ., Blacksburg, VA, pp. 137-148. This paper presents findings from a Bureau of Mines study on barriers that may prevent miners from correcting and avoiding groundfall hazards. The barriers identified included (1) the inability to recognize groundfall hazards, (2) the inability to correct groundfall hazards, (3) a lack of motivation to search for groundfall hazards, and (4) a lack of motivation to correct groundfall hazards. Data are presented that summarize the views of miners, section supervisors, and mine inspectors about the contribution of these barriers to groundfall accidents, and what they think should be done to reduce the frequency of injuries sustained by falls of roof and rib. Also included is a summary of miners' responses concerning their recent experiences with groundfall accidents.

OP 4-88. Feasibility of Employee Assistance Programs in the Coal Mining Industry, by Robert F. Randolph and James M. Peay. Paper in Proceedings of the Eighteenth Annual Institute on Coal Mining Health, Safety, and Research, Blacksburg, VA, Aug. 26-28, 1987. VA Polytech. Inst. and State Univ., Blacksburg, VA, pp. 51-60. This paper describes a 6-year investigation to determine the feasibility of utilizing employee assistance programs (EAP's) in the underground coal mining industry. Data were collected at 26 mines from miners, supervisors, and mine superintendents. The types of problems addressed by the EAP's included family, emotional, financial, and legal troubles, as well as the factors of alcohol and drug abuse. These problems were found to impact the on-the-job areas of absenteeism, turnover, grievances, loss of productivity, and accidents both on and off the job. Results indicated that both management and miners favor the use of EAP's, and although the prevalence rate of off-the-job factors that negatively affect critical job behaviors was found to be low, the prevention of even one accident related to these factors could theoretically result in a savings of millions of dollars.

OP 5-88. Inherent Oxidation Protection of Fe-5Cr-15Ni-2Si-4.5Mo, by J. C. Rawers. Oxid. Met., v. 28, Nos. 3-4, Oct. 1987, pp. 183-194. This paper describes an investigation into the oxidation mechanism of Fe-5Cr-15Ni-2Si-4.5Mo alloy to determine the role of Si and Mo in providing oxidation resistance. It was determined that the oxidation protection in the temperature range 750° to 950° C resulted from formation of a continuous oxide sublayer of SiO_2 (or possibly Fe_2SiO_4). Molybdenum formed an intermetallic $Fe_2Mo_{1-x}Si_x$ that eventually diffused out into the grain boundaries and formed a protective barrier to the oxidation process. The mechanism behind the improved oxidation is the formation of an SiO_2 layer at the metal-oxide interface that retards the outward diffusion of Fe. It was also established that the oxidation mechanism was controlled by an activation energy equal to that of Fe^{3+} ions diffusing through SiO_2.

OUTSIDE PUBLICATIONS

OP 6-88. An Abrasive Water Jet Rock Drill, by G. A. Savanick and W. G. Krawza. Paper in Proceedings of the Fourth U.S. Water Jet Conference, Berkeley, CA, Aug. 26-28, 1987. ASME, New York, 1987, pp. 129-132. This paper describes an abrasive water jet drill incorporating a collimator, jet deflectors, and an unpressurized swivel. The drill, which utilizes only commonly used pumps, hoses, fittings, and sandblasting abrasives, can drill hard rock such as 73,000 psi compressive strength quartzite with 10,000 psi water pressure. Holes can be collared at any angle or chambered, and drilling can be done through fractured material such as rubble or loose rock in gob areas of mines. Also, because the water jet drill does not physically make contact with the rock, it can be built of lighter materials than conventional drills.

OP 7-88. Iron Removal and the Complexity of Stainless Steel Pickling Liquors, by J. B. Stephenson, G. L. Horter, and H. H. Dewing. Ch. 28 in Iron Control in Metallurgy, ed. by J. E. Dutrizac and A. J. Monhemius. Ellis Horwood Ltd., Chichester, England, 1986, pp. 571-581. This paper describes research conducted on the recovery and regeneration of spent nitric and hydrofluoric acid pickling liquors. Background information and references to previously published literature are included, and pickling reactions, chemical equilibrium conditions, and iron removal processes are among the topics discussed.

OP 8-88. Evaluating Ventilation Parameters of Three Coal Mine Gobs, by R. J. Timko, F. N. Kissell, and E. D. Thimons. Ch. 75 in Proceedings of the 3rd U.S. Mine Ventilation Symposium, University Park, PA, Oct. 12-14, 1987. Soc. Min. Eng. AIME, Littleton, CO, 1987, pp. 533-543. This paper describes an investigation into the effectiveness of gob ventilation and/or sealing practices using sulfur hexafluoride (SF_6) tracer gas. Practices at three coal mines were examined, each having different problems associated with mined-out areas. The purpose of these ventilation studies was to better understand whether current techniques employed for ventilation or sealing are successful at minimizing the potential for gob fires and explosions. Employment of the SF_6 tracer gas technique resulted in answers to questions raised by the mine operators concerning the effectiveness of their gob ventilation or sealing practices in preventing mine fires.

OP 9-88. Analysis of a Fire in a Colorado Coal Mine—A Case Study, by Robert J. Timko, Robert L. Derick, and Edward D. Thimons. Ch. 63 in Proceedings of the 3rd U.S. Mine Ventilation Symposium, University Park, PA, Oct. 12-14, 1987. Soc. Min. Eng. AIME, Littleton, CO, 1987, pp. 444-452. This paper analyzes the firefighting strategies at a mine in southwestern Colorado in June 1986 and the steps taken to seal the mine when attempts to hold the fire in check failed. The obtaining and analyzing of mine fire gases taken from sampling ports in the seals is described, and the approach used to reenter the mine to assess damage and determine a cause for the fire is detailed.

OP 10-88. Water-Jet-Assisted Roadheaders, by Robert J. Timko, Bradley V. Johnson, and Edward D. Thimons. Ch. 49 in Proceedings of the 1987 Rapid Excavation and Tunneling Conference, New Orleans, LA, June 15-18, 1987. Soc. Min. Eng. AIME, Littleton, CO, 1987, pp. 769-782. This paper describes the evolution of water-jet-assisted roadheaders and the benefits to be gained by their use. Testing has shown that although significant reductions in respirable dust are achieved at water pressures approaching 3,000 psi, there appears to be no effect at pressures above that level. A reduction in bit wear and frictional sparking were also noted, but the optimum water pressures to obtain these benefits have yet to be defined.

OP 11-88. Damage-Resistant Brattice Support Stoppings in Mines With Large Entries, by Robert J. Timko and Edward J. Thimons. Eng. and Min. J., v. 188, No. 5, May 1987, pp. 34-36. This paper describes three damage-resistant brattice (DRB) stoppings built and tested in a Colorado oil shale mine. The results proved the ability of DRB's to economically reduce air leakage and minimize blast damage to stoppings in mines with cross-sectional openings up to 55 ft wide and 30 ft high.

OP 12-88. The Fe-N (Iron-Nitrogen) System, by H. A. Wriedt, N. A. Gokcen, and R. H. Nafziger. Bull. Alloy Phase Diagrams, v. 8, No. 4, 1987, pp. 355-377. This paper contains descriptions of the phases of the Fe-N system. Aspects of its crystal structure and lattice parameters are discussed.

OP 13-88. Leakage Testing of Large Ventilation Control Structures for Room and Pillar Oil Shale Mining, by M. E. Adam, C. E. Brechtel, J. F. T. Agapito, and E. D. Thimons. Ch. 53 in Proceedings of the 3d U.S. Mine Ventilation Symposium, University Park, PA, Oct. 12-14, 1987. Soc. Min. Eng., AIME, Littleton, CO, 1987, pp. 365-370. This paper describes the construction of full-scale stopping and simulated overcast structures in large-opening (30-ft-high by 55-ft-wide) room and pillar excavations in an oil shale mine. The program was undertaken to develop construction techniques and to generate data on structure costs and leakage rates. Leakage rates were measured using both sulfur hexafluoride tracer gas and "brattice window" methods at varying differential pressures. The measurements were conducted before and after a full-scale face blast to characterize the effects of blasting on leakage, and blast air pressures were measured across the stoppings. The operating performance of different combinations of permanent and temporary stoppings was evaluated by developing an operating model for a two-panel oil shale mine. The operating performance for the different stopping combinations was then compared to the system cost to evaluate the overall performance.

OP 14-88. Coal Cutting Noise Control, by William W. Aljoe and Roy C. Bartholomae. Paper in Proceedings—Longwall USA, Pittsburgh, PA, June 2-4, 1987. Coal Mag., Chicago, IL, 1987, pp. 174-184. This paper identifies three basic methods of coal cutting noise control: reduced bit velocity, cutting head structural alteration, and cutting force isolation. These methods take advantage of the dynamic characteristics of the coal cutting force. Laboratory investigations and field demonstrations have proven that all three methods are effective.

OP 15-88. Experimental Studies on Dust Dispersion in Mine Airways, by B. Bhaskar, R. V. Ramani, and Robert A. Jankowski. Trans. Soc. Min. Eng. AIME, v. 39, 1987, pp. 140-151. This paper presents the results of an experimental study on the dispersion and deposition characteristics of fine coal dust in mine airways. Experiments were conducted at various flow velocities using bituminous and simianthracite coal dust which had a large proportion of dust in the respirable size range. Cross-sectional variations in the concentration of dust at various points in the airway were also measured. Instruments used in the experiments included gravimetric samplers and impactors. Concentration measurements were made for both the respirable and total airborne dust. The experimental design, sampler procedures, and results are discussed. The study is aimed at providing a better understanding of the temporal and spatial behavior of dust particles in underground mine airways.

OP 16-88. Depositional Environment of Some Late Devonian and Early Mississippian Coals of the North-Central Appalachian Basin, by David K. Brezinski and Carla A. Kertis. Abstr. With Programs for the NE Sec. Meeting, Geol. Soc. America, v. 19, No. 1, 1987, abstr. 131978. This paper reports that coalbeds are generally thin and discontinuous in Late Devonian and Early Mississippian Pocono Group strata of Pennsylvania and Maryland. Three types of coals, based upon the environment of formation, are recognized. Transgressive coals predominate within the Rockwell Formation in western Maryland and south-central Pennsylvania. These coalbeds are exceedingly thin (1 to 10 cm), often exhibit thin underclays, and are overlain by *Skolithos*- or brachiopod-bearing sandstones. Less frequently, thin regressive coalbeds cap the top of individual transgressive-regressive packages. These coalbeds average 1 to 3 cm in thickness and do not have underclays present. Higher in the section, coals are also present between sandstone bodies of the Burgoon (Purslane) Formation. These coalbeds are typically thicker than those of the Rockwell, but, owing to channel migration in the associated sandstones, are commonly discontinuous. Such coalbeds are swamp deposits which developed lateral to migrating channels.

OP 17-88. Thermodynamic Properties of Potassium Metasilicate (K_2SiO_3), by R. R. Brown and K. O. Bennington. Thermochim. Acta, No. 122, 1987, pp. 289-294. This paper reports that

the standard enthalpy of formation of potassium metasilicate (K_2SiO_3), determined by hydrofluoric acid solution calorimetry, was found to be $\Delta H^{\circ}_{f,298} = -363.866 \pm 0.421$ kcal mol^{-1} (-1522.415 ± 1.762 kJ mol^{-1}). The standard enthalpy of formation from the oxides was found to be $\Delta H^{\circ}_{298} = -64.786 \pm 0.559$ kcal mol^{-1} (-271.065 ± 2.339 kJ mol^{-1}). These experimentally determined data were combined with data from the literature to calculate the Gibbs energies of formation and equilibrium constants of formation over the temperature range of the literature data. The standard enthalpies of formation and Gibbs energies of formation are given as functions of temperature. The standard Gibbs energy of formation is $\Delta G^{\circ}_{f,298.15} = -341.705$ kcal mol^{-1} (-1429.694 kJ mol^{-1}).

OP 18-88. An Explanation of Flocculation Using Lewis Acid-Base Theory, by P. M. Brown, D. A. Stanley, and B. J. Scheiner. Soc. Min. Eng. AIME preprint 88-165, 1988, 5 pp. This paper describes a Bureau of Mines-developed method of dewatering clay slurries based on flocculation by high-molecular-weight polymers and water removal from the formed flocs using a trommel or hydrosieve. The exchange ion on the clays affects their dewaterability. Metal ions in solution and on the exchange sites of smectite clays are known to act as Lewis acids. Recent work has determined that these ions can be titrated with high-molecular-weight polymers. The relative acidity of the exchange ion and the basicity of the polymer determined by the new method give insight into the dewatering mechanism.

OP 19-88. How To Lower Methane Concentrations Around Longwall Shearers, by Andrew B. Cecala and Robert A. Jankowski. Paper in Proceedings—Longwall USA, Pittsburgh, PA, June 2-4, 1987. Coal Mag., Chicago, IL, 1987, pp. 357-362. This paper describes how methane levels around longwall shearers can be reduced by directing more available air along the face and over the shearer body during a laboratory evaluation. To address the entire mining cycle, a combination of two techniques is used to dilute and clear the methane liberated by the shearer during cutting. These techniques are inexpensive, easy to install, and require minimal maintenance.

OP 20-88. Improving Dust and Methane Control, by Andrew B. Cecala, John A. Organiscak, and Robert A. Jankowski. Coal Min., v. 24, No. 10, 1987, pp. 51-52. This paper evaluates a number of techniques for controlling dust and methane during the headgate cutout of retreating longwall sections that use antitropal ventilation (headgate to tailgate). Some of these techniques are effective for both methane and dust control, while others are effective for only one or the other. The techniques include the gob curtain, the walkway curtain, stageloader-crusher control, and the wing curtain. Each improves the health and safety of workers and is economically feasible in hardware cost, setup cost, and maintenance. By combining various of these techniques, mine operators can substantially reduce the dust and methane concentrations at the shearer and ensure the health and safety of longwall workers.

OP 21-88. Methane and Dust Controls for Headgate Cutouts, by Andrew B. Cecala, John A. Organiscak, and Robert A. Jankowski. Min. Sci. and Technol., No. 4, 1987, pp. 307-313. This paper discusses the headgate cutout, an area of concern for all retreating longwall mining operations. Because of the equipment and activities located in the headgate area, along with the ventilation flow pattern, methane and dust levels recorded at the shearer during the cutout are higher than for any other phase of the longwall mining cycle. This report presents several different techniques found by the Bureau of Mines over the past few years to successfully lower methane and dust levels during the headgate cutout for retreating longwall sections using antitropal ventilation (headgate to tailgate). Each of these techniques improves the health and safety of longwall workers and is economically feasible.

OP 22-88. Cut Longwall Ignitions by Lowering Methane Concentrations Around Longwall Shearers, by Andrew B. Cecala, Setler R. Rajan, Robert A. Jankowski, and Fred N. Kissell. Coal Age, v. 91, No. 8, 1986, pp. 66-67. This paper describes Bureau of Mines efforts to prevent methane ignitions at longwall operations by diluting the methane. Use of a walkway curtain during the headgate cutout has been combined with use of a modified shearer clearer system during the rst of the cutting cycle. Together, these two techniques can lower methane concentrations significantly around the shearer for the entire mining cycle at a low cost.

OP 23-88. Maintaining Filters, Bits Can Control Respirable Quartz Dust During Roof Drilling, by Edward F. Divers and Robert A. Jankowski. Coal Age, v. 92, No. 2, 1987, pp. 57-59. This paper describes dust sources and means of controlling the dust devised by the Bureau of Mines.

OP 24-88. Respirable Dust Control in Coal Preparation Plants, by Edward F. Divers and Robert A. Jankowski. Trans. Soc. Min. Eng. AIME, v. 40, 1988, pp. 223-228. This paper reports results of a respirable dust survey of 18 U.S. coal preparation plants. Of these, three were essentially free of dust problems. Respirable dust exposure of workers in the remaining plants depended on the time spent in the dusty areas. In five of the plants surveyed, Bureau tests showed that in some areas worker exposures could exceed Federal dust limits in less than 2 h. Cooperative studies were arranged with coal preparation plants utilizing three different dust control techniques. These included a standard baghouse-type dust collector, two types of scrubbers, and an electrostatic precipitator. Results of these evaluations are presented. Various types of ventilation systems used during summer and winter conditions were also evaluated. Results showed that appropriate ventilation can provide a highly cost effective method for controlling coal preparation plant dust.

OP 25-88. Ventilated Cutting Drum for Longwall Dust Control, by Edward F. Divers and Robert A. Jankowski. Paper in Proceedings—Longwall USA, Pittsburgh, PA, June 2-4, 1987. Coal Mag., Chicago, IL, 1987, pp. 174-184. This paper discusses the ventilated drum, equipped with a full complement of conventional low-pressure drum sprays, which is a safe, reliable, and effective device for reducing respirable dust at and downwind of the machine operators and is especially recommended for use where dust levels at the support setter and tailgate locations must be reduced. The only restrictions to its use are cost and drum diameters.

OP 26-88. Design of Coal Mine Entry Intersections, by K. Hanna and D. P. Conover. Soc. Min. Eng. AIME Preprint 88-39, 1988, 11 pp. This paper describes a method to improve coal mine entry intersection design. The method considers the effect of in situ stresses, local geologic conditions, rock physical properties, and mining sequence. Development of the method is discussed, including the results of field instrumentation studies and numerical modeling investigations. Data required to evaluate the effects of roof span, mining sequence, entry orientation, and bolting patterns on intersection stability are also presented. Ground control studies conducted by the Bureau of Mines in two underground mines in the Illinois Coal Basin have shown that in situ horizontal stresses and roof geology have a critical effect on intersection stability. Methods to reduce the adverse effects of these parameters are emphasized. Typical failure behavior associated with specific geologic and horizontal stress conditions is presented to illustrate proposed control methods to alleviate adverse ground conditions.

OP 27-88. Water Jet Assisted Longwall Shearer: Development and Underground Test, by K. F. Hauer, K. Neinhaus, and E. D. Thimons. Paper in Proceedings—Longwall USA, Pittsburgh, PA, June 2-4, 1987. Coal Mag., Chicago, IL, 1987, pp. 200-212. This paper summarizes water-jet-assisted cutting results obtained in an underground trial at the Auguste Victoria Coal Mine in Marl, West Germany. The system tested consisted of (1) high-pressure water jets to assist in the cutting operation and directed immediately in front of the pick tip, (2) phased high-pressure water only to those picks that are engaged in the coal, (3) reduction of the drum speed and consequently of the pick speed, and (4) pick lacing plan on the drum to optimize cutting. The results of the trial show that the respirable dust is drastically reduced with water pressures around 125 bar (1,812 psi). The grain size distribution of the coal improved, while the pick wear and the temperature of the picks were considerably lowered.

OP 28-88. Longwall Dust Control, An Overview of Progress in Recent Years, by Robert A. Jankowski, J. Harrison Daniel, and Fred N. Kissell. Paper in Proceedings of the 22d International Conference of Safety in Mines Research Institutes, Beijing,

Nov. 2-6, 1987. China Coal Industry Publishing House, Beijing, 1987, pp. 737-748. This paper reviews many effective dust control techniques for longwall mining systems. Experience has shown that several control procedures must be combined to ensure compliance; the procedures employed would depend on the dust source. Compliance records of longwall mining sections have been steadily increasing over the past 5 yr, thanks not only to improved control technology, but also to better understanding of the problem. Application of essential controls on all longwall faces and site-specific optional supplementary controls as needed can improve health protection, compliance, and productivity.

OP 29-88. Water Spray Systems for Reducing the Quartz Dust Exposure of the Continuous Miner Operator, by Robert A. Jankowski, Natesa I. Jayaraman, and Charles A. Babbitt. Ch. 84 in Proceedings of the 3d U.S. Mine Ventilation Symposium, University Park, PA, Oct. 12-14, 1987. Soc. Min. Eng., AIME, Littleton, CO, 1987, pp. 605-611. This paper describes a novel water spray system, consisting of flat fan spray nozzles, mounted across the top of the mining machine, along with high flow, flat fan, and higher pressure hollow cone nozzles mounted under the boom. The anti-rollback underboom spray system minimizes dust rollback while increasing dust knockdown by its unique positioning of spray manifolds and orientation of spray nozzles. Respirable dust suppression characteristics of the system acted in three ways: (1) by wetting the surface of the broken coal material to prevent dust from becoming airborne, (2) by controlling the airflow pattern at and near the face to minimize dust rollback to the operator's control location, and (3) by dust knockdown, i.e., airborne capture, or scrubbing of airborne dust from the air. During underground trials, the anti-rollback underboom spray system reduced dust levels at the operator's position and in the immediate return by 55 and 15 pct, respectively, when compared to a conventional spray system. Quartz dust levels at the operator's position were essentially eliminated, while quartz dust levels in the immediate return were reduced by 57 pct. Applying the concepts of this technique throughout the mining industry should reduce the health hazard associated with excessive exposure to respirable quartz dust, as well as allow coal mine operators to comply with the associated, more stringent, respirable dust standards.

OP 30-88. Longwall Dust Control: An Overview of Progress in Recent Years, by Robert A. Jankowski, Fred N. Kissell, and J. Harrison Daniel. Min. Eng., v. 38, No. 10, 1986, pp. 953-958. This paper indicates that dust exposures on longwall mining operations are, in general, significantly higher than in other mining environments. A variety of dust sources exist on longwall faces, and their contributions to the overall airborne dust level can vary from one face to another. Although in most instances the shearer is the primary dust source, secondary dust sources, in particular coal-transport systems, should not be overlooked. If the shearer is not the major dust source, additional controls on the shearer may not have much effect on dust levels at the operator's position. Although the amount of dust generated is directly related to the amount of coal extraction, no correlation has been found between respirable dust exposure and production. Exposure depends more on dust control techniques used than on the amount of coal produced. Compliance records of longwall mining sections have been steadily increasing over the past 5 yr, thanks not only to improved control technology, but also to better understanding of the problem. Application of essential controls on all longwall faces and site-specific optional supplementary controls as needed can improve health protection.

OP 31-88. Coal Mine Quartz Dust Control, An Overview of Current U.S. Regulations and Recent Research Results, by Robert A. Jankowski and George E. Niewiadomski. Paper in Coal Mining and Safety (Proc. Int. Symp. on Coal Min. and Safety, Seoul, Apr. 22-24, 1987), ed. by Chung-In Lee, Hyo-Taek Chon, and Tai-Yoo Kim. Korean Inst. Miner. and Min. Eng., Seoul, 1987, pp. 303-313. This paper indicates that over 30 pct of underground coal mine operations in the United States have designated occupations and work areas that must comply with more stringent respirable dust standards (below 2.0 mg/m^3) owing to the presence of high levels of quartz in the airborne respirable dust found in the mine atmosphere. The U.S. Department of Labor's Mine Safety and Health Administration has developed and implemented an improved quartz dust enforcement program, providing for more effective monitoring of quartz dust exposure. Its aim is to enhance the health protection of the miners and involve the coal mine operators in the process of setting the dust compliance standard whenever more than 5 pct quartz is found in the miner's work environment. Studies have shown that the primary source of quartz at underground coal mining operations is attributed to the continuous mining machine cutting roof, floor, and rock partings in the seam. To enable U.S. coal mine operators to more effectively control quartz dust levels and thus comply with more stringent dust standards, the U.S. Department of the Interior's Bureau of Mines has conducted research to identify new or improved control measures to reduce the amount of airborne dust created and to reduce dust rollback, and has identified procedures to correct deficiencies inherent in some present roof bolter dust collection systems. The Bureau has also initiated extensive research to control the quartz dust exposure of the continuous mining machine operator and the quartz dust levels downwind of the continuous mining machine, and to identify other promising concepts for reducing quartz dust in underground U.S. coal mining operations. With the progress to date and with the effort currently underway, solutions to these problems should be forthcoming to enable the U.S. coal mining industry to more effectively comply with reduced dust standards without adversely compromising its competitive posture in the domestic and international coal markets.

OP 32-88. Design of a Methane Control Expert System, by Roger L. King. Paper in Proceedings of the International Symposium on Underground Mining Methods and Technology, Nottingham, England, Sept. 8-13, 1986, pp. 11-19. This paper indicates that although the Bureau of Mines has developed sound technical solutions to address the mining industry's excess methane emission problems, a problem still exists in how to transfer this knowledge into all the different mine scenarios exhibiting high methane emissions. An obvious solution in this age of computers is to provide every mine with a computer program capable of analyzing a mine's methane problem and recommending methane control strategies to permit the safe extraction of coal. A knowledge-based expert system was selected as the mechanism by which the transfer of knowledge could best be made. This paper illustrates the expert-level decision making process for applying methane drainage techniques to underground coal mines and how it is being reduced to a comprehensive set of production rules for implementation in a methane control expert system known as METHPRO.

OP 33-88. Expert Reasoning Models Applied to Mine Geologic Data, by Roger L. King. Paper in Proceedings of the 8th West Virginia University International Mining Electrotechnology Conference, Morgantown, WV, July 30-Aug. 1, 1986; WV Univ., 1986, pp. 69-73. Paper in Proceedings of the 3d Conference on the Use of Computers in the Coal Industry, Morgantown, WV, July 28-30, 1986; Balkema, 1986, pp. 65-70. The Bureau of Mines has been involved with gathering and interpreting geologic data for 75 years. This experience has led to a high level of expertise within the Bureau and a desire to make it more accessible to the mining industry. With the recent advances in the field of artificial intelligence over the past few years, it has become more feasible to consider transferring knowledge to computers. Knowledge-based expert systems, the most active branch of artificial intelligence today, are computer programs that seek to combine a knowledge base of domain facts with expert-level decision making to arrive at a plausible solution(s) to a problem. This paper examines some of the expert-level decision-making models or "inexact reasoning" processes to determine their applicability to mine geologic data. The paper describes two models that are available for this task and gives examples of applying these models to mine geologic data.

OP 34-88. Mountain Bump Research at the Bureau of Mines, by Roger L. King and Brian T. Brady. Paper in Proceedings of the 18th Annual Institute on Coal Mining Health, Safety, and Research, Blacksburg, VA, Aug. 25-27, 1987, pp. 159-165. VA Polytechnic Inst. and State Univ., 1987, pp. 159-165. This paper provides an update of the research program at the Bureau of Mines that was specifically mandated to address the needs of the underground coal mining industry in mining coal prone to bumps.

OP 35-88. How To Improve the Accuracy of Coal Mine Dust Sampling, by Fred N. Kissell, Steve K. Ruggieri, and Robert A. Jankowski. AIHA J., v. 47, No. 10, 1986, pp. 602-606. This paper indicates that minimizing error in coal mine dust control mea-

surements involves five basic factors: (1) use of modern equipment, such as flow-regulated pumps or instantaneous monitors, (2) avoiding, if possible, sampling locations with a sharp concentration gradient, (3) ensuring that the airstream being sampled is representative of the source, (4) alternating the baseline and control technology as frequently as possible to minimize dust level changes due to shifts in material cut or productivity, and (5) pinpointing sources to ensure that the dust being measured relates to the control being tested.

OP 36-88. An Analysis of Air Volume-Flowrate Determinations for Mines, by Jeffery L. Kohler and Edward D. Thimons. Min. Sci. and Technol., v. 6, No. 1, 1987, pp. 17-29. The proper control and distribution of ventilation air is a key aspect in the productivity of an underground mining operation and is crucial to the health and safety of mine workers. Accurate measurement of air velocity is an essential component in achieving effective ventilation planning and control. However, the measurement methodology and application is problematic, especially in the use of correction factors. This paper examines the accuracy of these factors as they are affected by measurement location, instrument, and flow characteristics. Definitive recommendations are presented to improve the accuracy of flowrate determinations.

OP 37-88. Development of an Automated Breathing and Metabolic Simulator, by Nicholas Kyriazi. Paper in Proceedings—International Symposium on Rescue Service in the Service of Mines Workmen, Bytom, Poland, Sept. 8-10, 1987. Central Mine Rescue Station, Catovice, Poland, 1987, pp. 400-426. This paper describes the Bureau of Mines efforts to develop breathing and metabolic simulator technology. Breathing simulation has been widely achieved throughout the world and used in the testing of open-circuit breathing apparatus, but satisfactory metabolism simulation has not been achieved. This situation required that the testing of closed-circuit breathing apparatus, with which the Bureau deals exclusively, be done using human test subjects. The goal was a machine that could accurately simulate both the breathing and the metabolic functions of a human being for testing of closed-circuit breathing apparatus. The advantages of using such a machine instead of a human being for testing respiratory protective devices lie in its ability to quantify metabolic input, its repeatability, and the lack of a need to deal with the vagaries of human subjects. This report describes the breathing and metabolic simulators that have been developed and used by the Bureau over the past 15 yr.

OP 38-88. Development of a Low-Profile Breathing Apparatus and a Mine Rescue Team Helmet, by Nicholas Kyriazi. Paper in Proceedings—International Symposium on Rescue Service in the Service of Mines Workmen, Bytom, Poland, Sept. 8-10, 1987. Central Mine Rescue Station, Catovice, Poland, 1987, pp. 389-398. This paper describes the development of two items of mine rescue team equipment, funded by the Bureau of Mines in order to make mine rescue missions safer and more efficient. A 2-h breathing apparatus was developed with the goals of low profile, light weight, positive pressure, cooler breathing air, and low breathing resistance. These goals were achieved through the use of efficient design, proper choice of materials, dual spring-loaded breathing bags, and an integral heat exchanger. The apparatus, the LP-120, has a profile of 10 cm, weighs 10 kg, and contains 240 L O_2. A rescue team helmet was also developed that combines the functions of full head protection, breathing apparatus facepiece, communications, and lighting. This helmet was designed to be used with the LP-120.

OP 39-88. Five-Year Self-Contained Self-Rescuer Field Evaluation: First-Year Results, by Nicholas Kyriazi, John G. Kovac, John P. Shubilla, Wayne H. Duerr, and Jeffrey Kravitz. Paper in Proceedings—International Symposium on Rescue Service in the Service of Mines Workmen, Bytom, Poland, Sept. 8-10, 1987. Central Mine Rescue Station, Catovice, Poland, 1987, pp. 371-388. This paper describes a joint effort by the Bureau of Mines and the Mine Safety and Health Administration to determine how well self-contained self-rescuers (SCSR's), deployed in accordance with Federal Regulations (30 CFR 75.1714), held up in the underground environment. This report presents findings regarding laboratory-tested apparatus from the first year of a 5-yr program as well as other related findings. The SCSR's were tested on human subjects and on a breathing and metabolic simulator. These results indicate that the apparatus, if well-treated, perform as expected except for manufacturing defects or quality control problems, which are identified. However, when the apparatus are carried in and out of the mine every day and stored at the working section, they may suffer abuse that can be extreme. Physical signs of abuse, unless extremely obvious, frequently are not detected by the miners or the mine operators; this poses a danger to a potential user in case of emergency. Recommendations include improved training in inspection procedures.

OP 40-88. Effect of Silver on Oxidative Leaching of an Arsenical Copper Sulfide Concentrate, by K. P. V. Lei and T. G. Carnahan. TMS Tech. Paper A88-4, 1988, 10 pp. This paper describes Bureau of Mines investigation of a silver-catalyzed oxidative procedure for leaching an arsenical copper sulfide concentrate containing 10 pct As and 32 pct Cu. Leaching was conducted in a 2-L autoclave reactor. The effects of catalyst concentration, O_2 pressure, temperature, and H_2SO_4, Cu, As, and Fe concentrations in the leaching solution on extractions of metals from the concentrate were determined. The leaching conditions for extracting 95 pct Cu and As and less than 21 pct Fe were 260 g/L concentrate (22 pct solids), 0.007*M* (1.0 g/L) AgCl, 3.0*M* (294 g/L) H_2SO_4, 100° C, 60 psig O_2, and 6 h. Copper as $CuSO_4 \cdot 5H_2O$ was recovered by crystallization from the pregnant solution. Arsenic as As_2O_3 was recovered by solvent extraction of the copper mother liquor with tributyl phosphate, SO_2 reduction of As^{5+} to As^{3+} in the strip solution, and crystallization of the As^{3+}. Silver catalyst was recovered by brine leaching of the leached residue. A conceptual process was proposed for treating arsenical copper sulfide concentrates.

OP 41-88. Optimizing Face Ventilation and Shearer Water Consumption To Reduce Longwall Dust Levels, by J. J. McClelland, Charles A. Babbitt, and Robert A. Jankowski. Ch. 77 in Proceedings of the 3d U.S. Mine Ventilation Symposium, University Park, PA, Oct. 12-14, 1987. Soc. Min. Eng., AIME, Littleton, CO, 1987, pp. 553-557. This paper describes a study undertaken to develop guidelines to enable mine operators to maximize longwall dust reductions, while optimizing the use of ventilating air and shearer water consumption. A recent investigation by Foster-Miller Incorporated, under a Bureau of Mines contract, quantified the effect of increased face airflow and shearer water supply on face dust concentrations. A 70-pct reduction in respirable dust levels was achieved at the shearer operator's position during tail-to-head cutting by an incremental increase in average face air velocity from 83.8 m/min (275 fpm) to 123.4 m/min (405 fpm), while holding shearer water consumption constant. A 60-pct reduction was achieved through an increase in shearer water pressure and flow from 9.1 kg/cm² (130 psi) at 0.19 m³/min (50 gpm) to 19.7 kg/cm² (280 psi) at 0.28 m³/min (75 gpm), holding airflow constant. The combined effects of increasing both parameters produced an 85-pct reduction. Optimal usage of ventilating air and shearer water consumption can be achieved by defining a "point of diminishing returns" above which further increases no longer reduce dust concentrations proportionately.

OP 42-88. Gas Outbursts Studied at Domal Salt Mines, by Gregory M. Molinda. Geotimes, Jan. 1988, pp. 12-14. This paper describes Bureau of Mines investigations of the nature of methane occurrence and the factors that influence its presence in Louisiana's domal salt mines.

OP 43-88. Software for Metallurgical Calculations (in eight parts), by A. E. Morris and J. B. Stephenson. J. Met., pt. 1, v. 38, No. 10, 1986, pp. 58-59; pt. 2, v. 38, No. 11, 1986, p. 63; pt. 3, v. 38, No. 12, 1986, p. 41; pt. 4, v. 39, No. 1, 1987, p. 49; pt. 5, v. 39, No. 2, 1987 p. 58; pt. 6, v. 39, No. 3, 1987, p. 61; pt. 7, v. 39, No. 5, 1987, p. 53; pt. 8, v. 39, No. 6, 1987, p. 57. This eight-part series examines some of the programs featured at the Computer Software for Metallurgical Calculations Conference, which took place in 1985 at the University of Missouri—Rolla.

OP 44-88. Computer Model for Evaluating the Dust Reduction Potential of Various Mining Practices for a Continuous Miner Section, by J. Drew Potts and Robert A. Jankowski. Int. Mine Computing, v. 2, No. 4, 1987, pp. 19-23; ch. 79 in Proceedings of the 3d U.S. Mine Ventilation Symposium, University Park, PA, Oct. 12-14, 1987, pub. by Soc. Min. Eng., AIME, Littleton, CO, 1987, pp. 564-570. This paper discusses the Alternative Mining Practices (AMP) computer program, which can be an effective hands-on tool in

the effort to reduce respirable dust exposure levels. In a hypothetical case, AMP showed how the mine operator could reduce the respirable dust exposure levels of the roof bolter operator and continuous miner operator by 36 and 42 pct, respectively. Computer models that rely entirely on basic research (not supported by underground experimentation) often raise questions about the validation of results. The dust reduction potentials of the various alternative mining practices, included in AMP, are based on applied research, and have been validated by actual underground and laboratory studies. The dust reduction potentials of the remote control continuous miner, the half-curtain ventilation system, the modified cutting sequence, and the two auxiliary fan-tubing bypass systems were all quantified by underground studies. Procedures were taken to isolate the dust exposure levels of underground workers before and after implementation of these techniques. AMP's comparison between exhausting brattice and exhausting tubing is based on observed "average" leakages, and the linear inverse proportion between air quantity and dust concentrations. The comparison between single-split and double-split ventilation is based on the additive effects of outby operations on the dust exposure levels of inby personnel.

OP 45-88. Reverse Performance Characteristics of Main Fans in an Oil Shale Mine, by V. Rajaram and E. D. Thimons. Trans. AIME, v. 280, 1987, pp. 1850-1853. This paper gives the results of a study conducted to establish main mine fan reverse characteristics under laboratory and field conditions. Laboratory tests were performed using a 2.4-m (96-in) diam vane axial fan to establish the forward and reverse performance characteristics under controlled conditions. Subsequently, a field test was conducted in a Colorado oil shale mine during which two 2-m (79-in) diam fans were reversed. The data obtained indicate that reverse performance characteristics depend on the blade angle and the hub-to-tip ratio. The quantity in the reverse mode ranged from 30 to 65 pct less than in the forward mode, and the static pressure was directly proportional to the square of the quantity.

OP 46-88. Inherent Oxidation Protection of Fe-5Cr-15Ni-2Si-4.5Mo, by J. C. Rawers. Oxidation of Metals, v. 28, No. 3/4, 1987, pp. 183-194. This paper reports results of an investigation of the oxidation mechanism of Fe-5Cr-15Ni-2Si-4.5Mo alloy, undertaken in order to determine the role of Si and Mo in providing oxidation resistance. It was determined that the oxidation protection in the temperature range 750 to 950°C resulted from formation of a continuous oxide sublayer of SiO_2 (or possibly Fe_2SiO_4). Molybdenum formed an intermetallic $Fe_2Mo_{1-x}Si_x$ that eventually diffused out into the grain boundaries and formed a protective barrier to the oxidation process. The mechanism behind the improved oxidation is the formation of a SiO_2 layer at the metal-oxide interface that retards the outward diffusion of Fe. It was also established that the oxidation mechanism was controlled by an activation energy equal to that of Fe^{3+} ions diffusing through SiO_2.

OP 47-88. Calculation of Overburden Stress Using Digital Elevation Model (DEM) Data, by V. R. Shea, T. C. Bettinger, and D. C. Peters. Abstr. in Denver Geotech '87: Computer-Aided Methods in Geology and Engineering, Denver, CO, Oct. 3-6, 1987. CO Sec., Am. Inst. of Professional Geologists, Denver, 1987, p. 326. This abstract discusses computerized methods designed for the calculation of gravitational stress exerted on a lithologic unit by a mass of overlying strata (overburden stress). The method involves the manipulation of two data files containing geographic location coordinates and elevation information for a given study area. The first data file contains Digital Elevation Model (DEM) data, which provide the topographic elevations for the study area. A second data file contains elevation values for the surface of a lithologic unit at depth, generated from information obtained from available maps, field measurements, and drill hole data, or by mathematical simulation of the surface. A gridding program interpolates values between points of known elevation to generate an array of elevations in a grid format matching that of the DEM data. The computer program for stress calculation involves subtraction of the elevation values in the data files to obtain overburden thickness. Stress vectors are calculated from overburden thickness for each grid point on the subsurface unit. The stress calculation options are direct vertical overburden pressure and the determination of stresses based upon a "cone-of-influence" from overlying topography where variations in the nearby terrain are taken into account. These methods of overburden stress calculation were designed for a coal mine property. Stresses due to overburden were analyzed for a coal seam as the lithologic unit at depth. Such an analysis can be used to identify potential ground control problems caused by stress changes or concentrations that might be encountered during mining of the coal seam.

OP 48-88. Measurement and Simulation of Face Ventilation Effectiveness for Large Diesel Powered Equipment, by Edward D. Thimons and Carl E. Brechtel. Ch. 41 in Proceedings of the 3d U.S. Mine Ventilation Symposium, University Park, PA, Oct. 12-14, 1987. Soc. Min. Eng., AIME, Littleton, CO, 1987, pp. 273-278. This paper describes a simulated diesel mucking operation carried out in the Exxon Colony Pilot Mine in Colorado to establish expected levels of diesel pollutants in a dead-ended working heading. This heading was nominally 15.3 m (50 ft) wide by 9.2 m (30 ft) high. Two face ventilation systems were tested using sulfur hexafluoride tracer gas to represent the diesel pollutants. The results of these tests showed that conventional face ventilation systems operating at high flow rates could adequately ventilate diesel equipment in the 447- to 522-kW (600- to 700-hp) range, even in a dead heading 91.4 m (300 ft) in length.

OP 49-88. Water Jet Assisted Longwall Shearer Development and Underground Test, by E. D. Thimons, K. F. Hauer, and K. Neinhaus. Paper in Proceedings of the Fourth U.S. Water Jet Conference, Berkeley, CA, Aug. 26-28, 1987. ASME, New York, 1987, pp. 113-120. This paper summarizes water jet assisted cutting results obtained in an underground trial. The respirable dust was drastically reduced with water pressures around 125 bar (1,812 psi). The grain size distribution of the coal improved, while the pick wear and the temperature of the picks were considerably lowered. A direct reduction of the pick forces and consequently a reduction of the specific cutting energy and of the drum thrust only occurred to a negligible extent, if they can be proved at all. A pressure of up to 200 bar (2,900 psi) seems to be reasonable for the high-pressure water supply system where the required water quantity approximately equals that of a conventional dust suppression system.

OP 50-88. The Development and Assessment of an Innovative SCSR Donning Method, by Charles Vaught and Henry P. Cole. Paper 8.4, Symposium on Safety in Coal Mining, Pretoria, South Africa, Oct. 5-8, 1987. Council for Sci. and Ind. Res., 1987, 13 pp. This paper discusses the development of an innovative self-contained self-rescuer (SCSR) donning method, and assesses the impact of differing instructional strategies used to teach this method. The method is a generic procedure which is applicable to the four SCSR models currently being marketed in the United States. It consolidates the procedural tasks into three critical steps and three secondary steps. The "3 + 3" method has been shown to cut donning times in half, and significantly reduce errors made by trainees. The strategies used to teach this method were a live demonstration, a structured lecture, and a computer-based format. It was found that delivery strategy had a modest initial influence upon how well people did, but that this effect tended to disappear after one initial hands-on experience. It was also noted that a significant amount of skill degradation occurred during the first 3 months following training.

OP 51-88. A Longwall Dust Control Expert System, by Steven D. Wirch, Steven K. Ruggieri, Robert A. Jankowski, and Fred N. Kissell. Paper in Proceedings—Longwall USA, Pittsburgh, PA, June 2-4, 1987. Coal Mag., Chicago, IL, 1987, pp. 88-96. This paper describes an expert system that provides longwall operators with site-specific advice on the application of dust control techniques. The system is a PC-based computer program that analyzes and diagnoses dust control problems and recommends corrective measures to reduce dust levels.

OP 52-88. Partitioning of Chalcopyrite by Sulfidation, by M. J. Adam and L. A. Neumeier. Paper in Process Mineralogy VII: Applications to Mineral Beneficiation Technology and Mineral Exploration, With Special Emphasis on Disseminated Carbonaceous Gold Ores, ed. by A. H. Vassiliou, D. M. Hausen, and D. J. T. Carbon (proceedings of a symposium held during the Metall. Soc. Annu. Meeting, Denver, CO, Feb. 23-27, 1987). The Metall. Soc., 1987, pp. 511-523. This paper discusses Bureau of Mines investigations of the feasibility of partitioning complex sulfide minerals to

simpler sulfide phases by sulfidation reactions. Such partitioning can afford opportunity to improve selective extraction of mineral constituents of value. This report describes research involving sulfidation partitioning of byproduct chalcopyrite concentrates from Missouri lead ore processing, and a Utah chalcopyrite concentrate from Cu ore processing. Small chalcopyrite samples were sulfidized with elemental S in glass capsules sealed after evacuating and backfilling with He, by heating for 1 to 24 h at specific temperatures in the range of 250° to 500° C, extending from below to above the boiling point of S (~445° C). Above the boiling point of S, the overall reaction with adequate S (13.9 wt pct) is $5CuFeS_2 + 4S^0_v \rightarrow Cu_5FeS_6 + 4FeS_2$. The reaction below the boiling point of S, with adequate S (17.4 wt pct), results in partitioning to the simple Cu sulfide, covellite, according to the reaction $CuFeS_2 + S^0_v \rightarrow CuS + FeS_2$. The covellite forms as a crust on particulate pyrite cores. Larger amounts of concentrate were sulfidized to the covellite-pyrite product in a tube furnace reactor.

OP 53-88. Ore Microscopy in Support of Applied Beneficiation Research To Recover Cobalt From Missouri Lead Ores, by W. L. Cornell and W. K. O'Connor. Paper in Process Mineralogy VII: Applications to Mineral Beneficiation Technology and Mineral Exploration, With Special Emphasis on Disseminated Carbonaceous Gold Ores, ed. by A. H. Vassiliou, D. M. Hausen, and D. J. T. Carbon (proceedings of a symposium held during the Metall. Soc. Annu. Meeting, Denver, CO, Feb. 23-27, 1987). The Metall Soc., 1987, pp. 603-615. This paper discusses the use of ore microscopy in support of both bench- and large-scale continuous beneficiation testing programs. Reflected-light microscopy and Vickers hardness measurements were utilized to help identify problems relating to mineral identification, mineral association, mineral liberation, mineral distribution in product streams, and froth entrainment. Specimens studied were size fractions of concentrates and tailings resulting from Bureau of Mines research to recover a siegenite-enriched product by beneficiating chalcopyrite concentrates. Other specimens were size fractions of bulk sulfide concentrates recovered during the enhanced amine scavenging of final tailings by froth flotation. The findings from studies directly affected flowsheet development.

OP 54-88. Using Image Analysis To Determine Liberation Sizes in a Bulk Sulfide Concentrate From Missouri Lead Ore Tailings, by W. L. Cornell and W. K. O'Connor. Paper in Process Mineralogy VII: Applications to Mineral Beneficiation Technology and Mineral Exploration, With Special Emphasis on Disseminated Carbonaceous Gold Ores, ed. by A. H. Vassiliou, D. M. Hausen, and D. J. T. Carbon (proceedings of a symposium held during the Metall. Soc. Annu. Meeting, Denver, CO, Feb. 23-27, 1987). The Metall. Soc., 1987, pp. 461-474. This paper discusses studies conducted to determine grinding parameters for optimum liberation of sulfide values from bulk sulfide concentrate produced from Missouri Pb ore concentrator tailings; optical microscopy was used coupled with image analysis. The major sulfide phases present in the ground mineral particulates are marcasite, pyrite, sphalerite, galena, chalcopyrite, siegenite, and bravoite. Results showed that the base metal minerals were liberated by grinding to 74 μm (200 mesh), but the siegenite and bravoite required grinding to 20 μm or less to achieve liberation. Both the experimental method and results are presented.

OP 55-88. Recovery of Nickel-Cobalt Alloy From Superalloy Scrap, by J. H. Holman, S. A. Molloy, and L. A. Neumeier. Paper in Process Mineralogy VII: Applications to Mineral Beneficiation Technology and Mineral Exploration, With Special Emphasis on Disseminated Carbonaceous Gold Ores, ed. by A. H. Vassiliou, D. M. Hausen, and D. J. T. Carbon (proceedings of a symposium held during the Metall. Soc. Annu. Meeting, Denver, CO, Feb. 23-27, 1987). The Metall. Soc., 1987, pp. 347-360. This paper describes Bureau of Mines investigations of recovery of Ni, Co, Cr, and other metals from mixed contaminated superalloy scrap. The scrap is melt-refined and cast into anodes for electrodeposition of recyclable Ni-Co alloy. Melt oxidation using roasted superalloy grinding sludge as oxygen source can divert the Cr to the slag but with excessive Ni-Co loss. Melt oxidation-carburization or direct melt carburization retains ~95 pct of the Ni-Co in the anode alloy. With direct carburization, ~90 pct or more of the Cr and other refractory metals report to the anode alloy, largely as carbide phases insoluble in electrolysis. Electrorefining data relate parameters such as controlled cathode potential, Fe and Cr impurities, pH, and compartmented cell use to current efficiency and Ni-Co deposit quality. Recovery of ~90 pct of the Ni-Co in the scrap can be achieved. Preliminary experiments to recover Cr, W, and other metals from the anode sludge and other byproducts are discussed.

OP 56-88. The Standard Formation Data for $KAlO_2$, by K. O. Bennington and G. E. Daut. Thermochim. Acta, v. 124, 1988, pp. 241-245. This paper reports that the standard enthalpy of formation of $KAlO_2$ was determined by hydrofluoric acid solution calorimetry to be $\Delta H^o_{f,298.15} = -272.60 \pm 1.43$ kcal mol^{-1}. This value, combined with the previously determined low-temperature heat capacity and high-temperature enthalpy functions, provides the Gibbs energies and equilibrium constants of formation over the temperature range of the measurements. The standard Gibbs energy was determined as $\Delta G^o_{f,298.15} = -257.45$ kcal mol^{-1}.

OP 57-88. Experimental Studies on Dust Dispersion in Mine Airways, by R. Bhaskar, R. V. Ramani, and R. A. Jankowski. Min. Eng., v. 40, No. 3, 1988, pp. 191-195. This paper presents the results of an experimental study on the spatial distribution of airborne dusts, deposition of dust in the airway, as well as the effect of airflow velocity and particle density on dust behavior in mine airways under controlled conditions. Considerable deposition of dust near the source was indicated. Pronounced effects due to velocity were observed in ambient dust concentration and deposition along the mine airway, both in the respirable and the total size ranges. Cross-sectional concentration measurements indicate an increase in concentration from the roof to the floor. The average cross-sectional concentration is about 75% of the concentration in the center of the airway.

OP 58-88. Design Criteria and Correction Factors for Field Wear Testing, by R. Blickensderfer. Wear, v. 122, 1988, pp. 165-182. This paper describes some general criteria for wear testing. Laboratory wear tests can be designed to meet the criteria but test results generally do not accurately predict wear under field conditions. Field wear testing is needed to optimize the final selection of materials for the given application. The concept of wear gradient is introduced. Wear gradients, with respect to time and location, are small and reproducible in laboratory tests but generally are significant and fluctuate under field conditions. Field tests are classified as sequential series, concurrent series, and concurrent group tests. The use of reference specimens for establishing time-averaged wear gradients is discussed and formulae for correcting the test specimen wear for non-uniform tribo-conditions over the test area are presented. A field test for abrasive wear of a linear array of specimens is described. The corrected wear values of duplicate specimens agree within 5% of the mean.

OP 59-88. Method Factors for Anemometer Measurement at Pipe Outlets, by F. Garcia and J. Cervik. Paper in Proceedings—Longwall USA, Pittsburgh, PA, June 2-4, 1987. Coal Mag., Chicago, IL, 1987, pp. 125-134. This paper discusses vertical gob holes routinely used to control methane in gobs. In most cases, vane anemometers are used to measure the velocity of gas flowing from the gob holes and subsequently to calculate the volume flow of gas. Generally, the anemometer is centered on the end of the pipe during the measurement. If the cross section of the anemometer is appreciably larger than one-sixth of the pipe diameter, then erroneous velocity readings occur, owing to the blocking effect of the instrument.

OP 60-88. Flammability Limit Measurements for Dusts and Gases: Ignition Energy Requirements and Pressure Dependences, by Martin Hertzberg, Kenneth L. Cashdollar, and Isaac A. Zlochower. Paper in Proceedings of the Twenty-first Symposium (International) on Combustion. Combustion Inst., Pittsburgh, PA, 1986, pp. 303-313. This paper presents data on the flammability limits of Pittsburgh Seam bituminous coal dust, polyethylene powder, and methane in air at pressures in the range of 0.5 to 3 bar. Explosibility test chambers of 20 and 120 L were used, and ignitability limitations were overcome with efficient pyrotechnic ig-

nitors with nominal energies of 500 to 5,000 J. The propagation criterion used was based on the maximum explosion pressure and the size-normalized maximum rate of pressure rise. The latter is a dynamic criterion that tends to minimize "overdriving" effects as the 20-L data are taken to their asymptotic limits at high ignition energies. The measured lean limits in air at atmospheric pressure are 90 g/m³ for the coal dust, 35 g/m³ for polyethylene, and 4.9 vol pct for methane. The rich limit for methane is 18–19 vol pct, whereas the dusts have no rich limits out to concentrations as high as 4,000 g/m³. A linear, lean-limit pressure dependence was measured for the dusts which was essentially the same as the pressure dependence measured for methane when all are expressed in comparable units: namely, mass concentration of fuel per unit volume of air. This observation further confirms a lean limit dust flame propagation mechanism that is controlled by the gas-phase reaction rate. The limit concentrations are then determined by the dust loading required to generate a lean limit concentration of pyrolysis products in the volatiles-air mixture, and the dust behaves as an equivalent "homogeneous," premixed gas, regardless of the initial pressure.

OP 61-88. Volatility Model for Coal Dust Flame Propagation and Extinguishment, by Martin Hertzberg, Isaac A. Zlochower, and Kenneth L. Cashdollar. Paper in Proceeding of the Twenty-first Symposium (International) on Combustion. Combustion Inst., Pittsburgh, PA, 1986, pp. 325–333. This paper presents a theoretical analysis for the propagation and extinguishment of coal dust flames and of dust and gas flames containing inhibitor powders. The analysis is based on the established mechanisms for homogeneous flame propagation and the well known concept of a constant limit flame temperature for a given class of homogeneous fuels. The analysis is expanded to phase-heterogeneous systems such as coal dust by means of a volatility model. The analysis includes the singly heterogeneous system of a solid fuel dust in air; the singly heterogeneous solid inhibitor dust in a homogeneous fuel-air flame; and the doubly heterogeneous system consisting of a solid fuel and inhibitor dust mixture in air. The data for measured explosion pressures, flammability limits, and extinguishant requirements for heterogeneous systems are shown to be consistent with the established mechanisms and processes for homogeneous flame propagation provided that one adds an additional process: the heating and devolatilization of the solid fuel or inhibitor. The limitations on the rates of devolatilization of the solid particles become rate controlling at high burning velocities, at high dust loadings, and for large particle sizes. Devolatilization rates are controlled by the intrinsic devolatilization rate constant for the solid fuel or inhibitor and the effective heating flux of the approaching flame front. The effective yield of volatiles is a function of those factors, the decomposition chemistry, and the time available for devolatilization. The fraction of the total volatiles that can be generated in the time available is the β-factor, and it determines the effective yield of fuel or inhibitor that participates in the flame propagation process. The data for explosion pressures, flammability limits, and extinguishant requirements are readily understood in terms of those β-factors.

OP 62-88. The Interaction Between Electrogalvanized Zinc Deposit Structure and the Forming Properties of Sheet Steel, by James H. Lindsay, Robert F. Paluch, Harmon D. Nine, Vernon R. Miller, and Thomas J. O'Keefe. General Motors Research Laboratories, Warren, MI, Res. Publ. GMR-6194, Mar. 1, 1988, 32 pp. This paper describes the use of electrogalvanized steel to enhance the corrosion resistance of automobile body panels in the forming of sheet steel. The zinc coating structure and morphology, as influenced by electrolytic and hydrodynamic conditions during electrodeposition, can influence the drawing character of electrogalvanized sheet. Sheet steel samples plated with zinc deposits exhibiting 1) strong basal (0001) plane and 2) strong pyramidal plane ($10\bar{1}X$) orientation were prepared. Sheet metal forming properties, including cup deformation and drawbead performance, were related to deposit morphology and structure. The results were compared to those for commercial electrogalvanized product.

OP 63-88. Development of Low Chromium Substitute Alloys for High Temperature Applications, by Je M. Oh. J. Electrochem. Soc., v. 135, No. 3, 1988, pp. 749–755. This paper describes the oxidation of a base-line Fe-8Cr-16Ni (weight percent) composition, compared to that of alloys with small additions of Al, Si, Mo, and Mn. Oxidation was done in air over the temperature range of 600°-1000°C for up to 1000h. Alloys that contained Al and Si showed excellent oxidation resistance because of the formation of a layer containing Si at the scale-metal interface. Small additions of Al seemed to form oxide nuclei during a transient oxidation period, aided the formation of a layer containing Si and/or a chromium oxide, and provided better oxide adherence. Molybdenum and manganese additions stabilized a fully austenitic microstructure at room temperature. The oxidation behavior of these alloys was compared to that of 304 stainless steel and some commercial superalloys. Reaction kinetics, oxide morphologies, and oxidation mechanisms of the substitute alloys are described.

OP 64-88. Relation of Mineralogy to Treatment Methods for Carbonaceous Gold Ores, by B. J. Scheiner. Paper in Process Mineralogy VII: Applications to Mineral Beneficiation Technology and Mineral Exploration, With Special Emphasis on Disseminated Carbonaceous Gold Ores, ed. by A. H. Vassiliou, D. M. Hausen, and D. J. T. Carbon (proceedings of a symposium held during the Metall. Soc. Annu. Meeting, Denver, CO, Feb. 23–27, 1987). The Metall. Soc., 1987, pp. 3–12. This paper discusses the presence of organic materials in gold ores, which interferes with gold extraction by cyanidation. The carbon contained in the ore has been shown to adsorb gold cyanide complex from solution. Removal of the carbon content by roasting or chemical oxidation prior to cyanidation results in gold extractions of 85 to 95%. This paper discusses how the mineralogy of the carbonaceous gold ores affects gold recovery by cyanidation. It also discusses the advantages and disadvantages of roasting and chemical treatment to render the ore amenable to cyanidation.

OP 65-88. Safe Practices for Use of the Sheathed Charge in Underground Coal Mines, by Harry C. Verakis, Richard J. Mainiero, and John J. Mulhern. Paper in Proceedings of the 13th Conference on Explosives and Blasting Technique, Miami, FL, Feb. 1–6, 1987. Soc. Explosives Eng., Montville, OH, 1987, pp. 115–130. This paper describes applications in coal mines where it would be advantageous from a safety standpoint to fire unconfined shots. However, the firing of mudcaps or other unconfined explosive charges in underground coal mines is not permitted because of the explosion hazards associated with methane gas and coal dust. Present safety regulations in Title 30, Code of Federal Regulations prohibit such practices. Recently, MSHA proposed revised coal mine regulations for the approval and use of sheathed explosives for public comment. Preceding the proposed regulations, the Bureau of Mines developed a prototype sheathed explosive charge and demonstrated in numerous tests that it would not ignite atmospheres of methane and coal dust. Subseqent to the development work, some studies were conducted by MSHA and the Bureau of Mines in an operating coal mine to demonstrate the performance and safe use of the sheathed charge. The development work and experimental studies are presented with respect to safe, practical coal mine applications.

OP 66-88. Foundation Response to Subsidence Induced Ground Movements: A Case Study, by Jeffrey S. Walker and John C. LaScola. Paper in Proceedings, 1987 National Symposium on Mining, Hydrology, Sedimentology, and Reclamation, Lexington, KY, Dec. 7–11, 1987. Univ. KY, Lexington, KY, 1987, pp. 235–241. This paper describes the Bureau of Mines efforts to determine if mining-induced ground movement is directly transferred to a structure, and how that process takes place. A series of four concrete block walls with foundations were constructed and monitored over an active longwall panel as part of a comprehensive subsidence research program. Three of the four walls were located perpendicular to the advance of the longwall face, in the zones where maximum inclination, maximum tension, and maximum curvature were predicted. The fourth wall was constructed along the centerline of the panel, parallel to the advance of the longwall face. All of the walls and the surrounding ground surface were instrumented with conventional survey monitoring points and extensometer stations to observe the vertical and horizontal movements. The fourth wall also included continuously recording tiltmeters. The results of this investigation indicate that simple structures respond to subsidence in a similar manner as the ground surface, suggesting that once the transfer mechanism is fully defined through further field and laboratory research, prediction models can be developed or modified to allow accurate estimation of the effect of mining on surface structures.

OUTSIDE PUBLICATIONS

OP 67-88. Microwave Heating Characteristics of Selected Minerals and Compounds, by J. W. Walkiewicz, G. Kazonich, and S. L. McGill. Miner. & Metall. Process., v. 5, No. 1, 1988, pp. 39–42. This paper describes naturally occurring minerals and reagent-grade compounds which were tested to determine their receptivity to microwave heating. The maximum temperature achieved for the samples and the time required to reach temperature are reported. A description of the microwave oven and a thermocouple technique that accurately measures and continuously records the temperature of samples during irradiation are reported. Extractive applications using the generated microwave data were investigated. Stress fracturing at mineral grain boundaries in a gangue matrix was shown. This should significantly affect grinding energy requirements and liberation properties. A method to produce a magnetic phase on pyrite surfaces, a method of using microwave heating to retort cinnabar concentrate, and a roast-leaching microwave treatment of chalcopyrite ore are described.

OP 68-88. The Desensitization and Malfunction of Coal-Mine Explosives, by Michael S. Wieland. Paper in Proceedings of the 13th Conference on Explosives and Blasting Technique, Miami, FL, Feb. 1-6, 1987. Soc. Explosives Eng., Montville, OH, 1987, pp. 97–114. This paper indicates that underground coal-mine explosives can be substantially degraded by the underground stress waves from the explosion of neighboring borehole charges. This cross-borehole interaction generally yields the worst receptor charge performance when the borehole separations are too close. For explosives which recover, the receptor degradation is worst when the delay until firing is small. Except for a poor quality muck pile or unreacted cartridge fragments, degraded charge malfunctions of this type are difficult to detect in coal-mine delay blasting. A simulator which reproduces the underground wave/receptor charge interaction and special underwater donor/receptor tests were utilized to study this transient desensitization problem. Test results revealed reductions in receptor energy output, delayed transitions into detonation, inferior reaction rates, or sympathetic reaction responses from the impaction. Tests on detonators showed reduced tip-strengh, abnormal functioning times, or sympathetic firing as a result of transient impaction. The cross-borehole desensitization and sympathetic reaction response problems warrant concern because they are logical mechanisms for raising the risk of hazardous mining conditions, including blown-out shots, flyrock, charge deflagration, and methane/coal dust ignitions.

OP 69-88. A Pin-On-Drum Abrasive Wear Test and Comparison With Other Pin Tests, by Robert Blickensderfer and George Laird. Paper in Proceedings of the ASM's International Materials Week '87 Conference, Cincinnati, OH, Oct. 10–15, 1987. ASM International, Metal Park, OH, 1987, pp. 71–83. This paper describes Bureau of Mines efforts to combat the wear of mining and mineral processing equipment. Investigations into existing pin abrasive wear testing machines resulted in the construction of the Bureau's own pin-on-drum wear testing apparatus, incorporating the best features of the previous designs. Comparisons of pin diameters, loads, and other factors are made between the Bureau of Mines' pin-on-drum test and other pin abrasion tests. The effects of variations in abrasiveness over the drum were essentially eliminated by making corrections based on the wear of a standard pin traveling a parallel path. Reproducibility of wear values on homogeneous alloys was generally within ±0.5 pct. Statistical analyses and test procedures are given for heterogeneous alloys. Design parameters for future pin abrasion tests are recommended.

OP 70-88. Computer Simulation of Face Ventilation To Dilute High Methane Concentrations Developed by Blasting Oil Shale, by C. E. Brechtel and E. D. Thimons. Paper in Computer Applications in the Mineral Industry, ed. by Kostas Fytas, Jean-Luc Collins, and Raj K. Singhal (Proc. First Canadian Conf. on Computer Applications in the Miner. Ind., Quebec, Mar. 7–9, 1988). A. A. Balkema, 1988, pp. 605–612. This paper describes a one-dimensional finite element model used to simulate turbulent mass transfer in face ventilation of oil shale mines. The computer model was applied to study dilution of methane released by rubblizing oil shale during face blasting. A methane release function was back analyzed from field measurements and the finite-element model was calibrated using tracer gas characterization of full-scale face ventilation systems.

OP 71-88. Characterization of Chain Pillar Stability in a Deep Western Coal Mine - Case Study, by M. J. DeMarco, J. R. Koehler, and P. H. Lu. Soc. Min. Eng. AIME preprint 88–76, 1988, 12 pp. This paper describes a Bureau of Mines investigation of longwall chain pillar and entry design in two- and three-entry gateroad systems at a deep underground coal mine located in central Utah. To evaluate their respective stability characteristics, four chain pillars and two longwall panels within the two separate entry systems were instrumented with hydraulic borehole pressure cells to continuously monitor vertical and horizontal pillar and panel stresses through adjacent panel retreat. In addition, supplemental entry closure information was obtained from sites located in the vicinity of the instrumented pillars. The findings presented in this report demonstrate the practicality of evaluating mine pillar stability using in situ methods and support three significant conclusions regarding ground control aspects of the investigated two-entry system: (1) Total areal entry loading was considerably less for the two-entry system, as opposed to the three-entry system, (2) a smaller percentage of opened ground in the two-entry system contributed to a marked reduction in roof falls, and (3) lower areal loading in the two-entry system suggests improved ground conditions when mining the underlying seam.

OP 72-88. Electromagnetic Energy Applications in Lunar Resource Mining and Construction, by David P. Lindroth and Egons R. Podnieks. Paper in Proceedings of the Eighteenth Lunar and Planetary Science Conference, Houston, TX, Mar. 16–20, 1987. Cambridge Univ. Press (New York), 1988, pp. 365–373. This paper reports the investigation of past work during the Apollo Program and current efforts to determine extraterrestrial mining technology requirements leading to the exploration of various methods applicable to lunar or planetary resource mining and processing. The use of electromagnetic energy sources is explored and demonstrated using laboratory methods to establish a proof of concept for application to lunar mining, construction, and resource extraction. Experimental results of using laser, microwave, and solar energy to fragment or melt terrestrial basalt under atmospheric and vacuum conditions are presented. Successful thermal stress fragmentation of dense igneous rock was demonstrated by all three electromagnetic energy sources. The results show that a vacuum environment has no adverse effects of fragmentation by induced thermal stresses. The vacuum environment has a positive effect for rock disintegration by melting, cutting, or penetration applications due to release of volatiles that assist in melt ejection. Consolidation and melting of basaltic fines are also demonstrated by these methods.

OP 73-88. Coal Research and Development, by J. N. Murphy. Min. Eng., v. 40, No. 5, May 1988, pp. 359–360. This paper discusses the technology and human factors that dominated coal research and development in 1987. In technology, the use of computers continues to grow as management tools with commercially available and custom software.

OP 74-88. Melting of Nitride Seeded Ti-6Al-4V Alloy Ingots, by J. I. Paige and T. K. Redden. J. Met., v. 40, No. 3, Mar. 1988, pp. 26–28. This paper describes and evaluates alpha-stabilized defects in titanium ingots, a subject of continuing interest to both titanium producers and aircraft engine manufacturers. Alpha defects are interstitially stabilized regions of substantially higher hardness than the surrounding normal material. They arise from a high local concentration of nitrogen with or without oxygen which increases the beta transus temperature and produces a hard, brittle region rich in the alpha phase. These defects are sometimes called high interstitial defects (HIDs) or low density inclusions (LDIs). The term LDI arose from the observation that these defects are usually associated with a void or voids in the microstructure; the alpha-rich phase itself, however, is not of low density. Over the years, these defects have acted as fracture sources or crack initiation sites in fan or compressor disk failures in the products of several jet engine manufacturers. To diminish the occurrence of these failures, several previous studies have focused on understanding of the formation and elimination of type 1 hard alpha defects. As part of a cooperative program with the General Electric Company, research at the Bureau of Mines has been undertaken which: evaluates the bureau's induction slag melting (ISM) process as a method of causing dissolution of hard alpha defects versus commercial consumable electrode vacuum are melting (CVAR); compares the rate of dissolution of hard alpha defects in a single melt (ISM vs. CVAR); determines the detectability, by ultrasonic inspection, of hard alpha defects; and characterizes the defects found using metallographic techniques. Production of the test plates was carried out at the Bureau of Mines

Albany Research Center in Oregon, and plate evaluation was performed at the General Electric Company's Aircraft Engine Business Group in Cincinnati, Ohio.

OP 75–88. Flocculation, by B. J. Scheiner. Min. Eng., v. 40, No. 5, May 1988, p. 345. Publications in the field of flocculation as applied to mineral processing for the year 1987 are reviewed. During 1987, the flocculation process was studied in great detail and a better understanding of the mechanism for this process is beginning to emerge. Such understanding should lead to increased efficiency within the mineral industry.

OP 76–88. Methods of Evaluating Explosive Reactivity of Explosive-Contaminated Solid Waste Substances, by T. S. Bajpayee and Richard J. Mainiero. Paper in Proceedings of the Fourth Mini-Symposium on Explosives and Blasting Research, Anaheim, CA, Feb. 4–5, 1988. Soc. Expl. Eng., 1988, pp. 137–145. This paper describes procedures and criteria developed by the Bureau of Mines for evaluating explosive reactivity of explosive-contaminated solid waste substances generated by U.S. Army Ammunition Plants. These substances are produced as explosive-contaminated sludge from waste water treatment plants, residues from the burning of munitions and explosives on open ground, and residues from deactivation furnaces. The characterization of explosive reactivity is a prerequisite for disposal of such waste materials, which may be contaminated with primary explosives, propellants, or pyrotechnic materials. The Bureau has proposed two tests for this purpose. These tests were developed to evaluate the explosive reactivity as defined in Title 40, Code of Federal Regulations, Part 261.23(a)(6) and (7). These are Bureau of Mines Gap and Bureau of Mines Internal Ignition tests, which determine the sensitivity to shock and thermal stimuli, respectively. This paper also includes gap and internal ignition reference data for typical blasting agents, high explosives, propellants, and marginally reactive substances. These reference data were used to establish test criteria. The Bureau has evaluated over 400 samples of contaminated soil, sludge, and burning residues using these two test methods.

OP 77–88. Retrofit Noise Control Modifications for an Underground Mine Haulage Vehicle, by Thomas B. Bobick. Paper in Trends in Ergonomics/Human Factors V, ed. by F. Aghazadeh (Proc. Int. Found. for Ind. Ergonomics Safety Conf., New Orleans, LA, June 8–10, 1988). Elsevier, 1988, pp. 541–548. This Bureau of Mines paper addresses noise exposure problems posed by diesel-powered haulage vehicles used in underground mining. Full-shift dosimeter surveys indicated that load-haul-dump (LHD) vehicle operators had noise exposures that ranged from 160 to 470 pct of the allowable. Retrofit treatments were installed on a typical LHD machine during two 3-day work periods. Three acoustical instrumentation systems indicated that the noise level at the operator's location was reduced by 4.5 to 5.2 dBA. These reductions will increase the permitted time of vehicle operation by 87 to 106 pct. The total cost for the abatement materials amounted to $325. This project indicated that low-cost modifications can be effective in reducing the noise generated by diesel-powered LHD vehicles.

OP 78–88. Pilot Subject Evaluation of Whole-Body Vibration From an Underground Mine Haulage Vehicle, by Thomas G. Bobick, Sean Gallagher, and Richard L. Unger. Paper in Trends in Ergonomics/Human Factors V, ed. by F. Aghazadeh (Proc. Int. Found. for Ind. Ergonomics Safety Conf., New Orleans, LA, June 8–10, 1988). Elsevier, 1988, pp. 521–528. This paper describes an in-house test facility developed by the Bureau of Mines to evaluate the effects of whole-body vibration levels experienced by underground mobile equipment operators. Vibration data were collected from a coal haulage vehicle via a uniaxial accelerometer attached to the machine frame. The data were analyzed and processed so a computer-controlled vibration platform could duplicate the vibration signals. Six men (36.0 yr of age ± 6.9 SD) participated in a pilot study to evaluate the effects of shock and whole-body vibration on heart rate (HR), blood pressure (BP), back extensor strength, stature, manual dexterity, and subjective discomfort. The subjects were exposed to vibration for 30-min periods while seated in a typical operator's seat (with the backrest angle at 90° or 130°) that was plain steel or treated with 2 in of foam padding. To control for diurnal variations in stature, HR, and BP, each subject repeated the same protocol on a separate day, but without the vibration. Results indicated that vibration significantly increased the HR, systolic BP, mean BP,and overall subjective discomfort rating ($p < 0.05$). Also, the number of times subjects reported discomfort increased significantly during vibration ($p < 0.05$) and when seated in the steel seat ($p < 0.005$). The seat back angle had no significant effect on any of the dependent measures.

OP 79–88. Batteries Recharge Future US Cadmium Industry, by V. A. Cammarota and P. A. Plunkert. Paper in Cadmium 86 (Proc. 5th Int. Cadmium Conf., San Francisco, CA, Feb. 4–6, 1986). Cadmium Council, Inc., 1988, pp. 27–32. This Bureau of Mines paper projects that growth in demand for cadmium in the United States based on 1983 apparent consumption data will be 1.7 pct per year. The forecast expansion of the nickel-cadmium battery industry is expected to be the driving market force in the growth of domestic cadmium demand. Barring any National Defense Stockpile disposals, the United States is expected to become increasingly dependent on imported cadmium material to meet this projected growth in demand. However, the world estimated reserves of cadmium and the announced expansion in zinc processing capacities in those countries that export to the United States should be adequate to meet the projected domestic demand.

OP 80–88. Substantial Time Savings Achieved Through Computer Dust Analysis, by Andrew B. Cecala, John J. McClelland, and Robert A. Jankowski. Appl. Ind. Hyg., v. 3, No. 7, July 1988, pp. 203–206. This paper describes a computer analysis system used presently by the Bureau of Mines to analyze quickly and accurately large volumes of information obtained from real-time dust monitors during research studies. It substantially reduces the time necessary to perform various data analysis calculations and manipulations, including graphics. It also provides raw data files that can be transferred to other software packages for other required manipulations. A major benefit of the computer analysis system is the availability of information at the end of each test day. On-site analysis makes it possible to modify a study during the field evaluation process. The system does not alter the data collection process, other than requiring a small data logger instrument to be connected to each dust monitor. In some cases, the system has reduced manpower requirements during the data gathering phase. The system reduces the analysis time required by previous methods while improving many aspects of the data evaluation process. Although the paper deals solely with the use of the data analysis system with instantaneous dust monitoring equipment, it can be used with other monitoring equipment. The system has much flexibility and thus can be used in many different applications.

OP 81–88. Environmental Effects in the Atmospheric Corrosion of Zinc, by Stephen Cramer, J. P. Carter, P. J. Linstrom, and D. R. Flinn. ASTM, Spec. Tech. Publ. 965, 1988, pp. 229–247. This paper describes a field program conducted by the Bureau of Mines to measure the corrosion damage on commonly used structural metals and the incremental effects of acidic deposition and other environmental variables. Corrosion damage, air quality, rain chemistry, and meteorology are being continuously measured at five sites in the Eastern and Midwest United States for periods up to 84 months. Corrosion damage on zinc for periods up to 36 months was determined from weight-loss measurements and analysis of corrosion film chemistry and of precipitation runoff chemistry. The results suggest the long-term zinc corrosion film consists of a stable inner layer sensitive to atmospheric sulfur dioxide (SO_2) concentrations and a nonprotective outer layer. A synergistic reaction involving SO_2 and nitrogen dioxide (NO_2) may occur. Dry deposition of SO_2 and NO_x on the corrosion film is substantial. Zinc losses from the corrosion film are proportional to hydrogen ion loading. Covariance between many air quality and rain chemistry variables may be low enough to avoid, to a considerable degree, problems in developing linear regression models of corrosion damage.

OP 82–88. Application of Refraction Tomography To Map the Extent of Blast-Induced Fracturing , by Calvin L. Cumerlato, Virgil J. Stachura, and Daryl R. Tweeton. Paper in Key Questions in Rock Mechanics: Proceedings of the 29th U.S. Symposium, Univ. MN, Minneapolis, MN, June 13–15, 1988. Balkema, 1988, pp. 691–693. This paper describes high-resolution refraction surveys conducted by the Bureau of Mines at a limestone quarry both before and after standard production blasts where variations in the blast design were made. The data collected were processed using a tomographic inversion algorithm to produce maps (tomograms) of the seismic velocity field of a shallow refracting layer in the rock left standing. Overlapping of surveys, velocity measurements from shotholes (preblast), and measurements of predominant joint sets were used to verify results. Resulting tomograms show sublinear low-velocity zones whose orientations correspond to those of measured joint sets. Low-velocity zones near

pitwalls are interpreted as the extent of intense fracturing caused by blasting. These results demonstrate that refraction tomography can be a powerful and economical tool for locating predominant jointing and areas of preexisting or blast-induced fracturing, an important aid to operators during premine planning and blast designing.

OP 83–88. Repeatability of Static and Isokinetic Maximum Voluntary Back Strength Exertions, by Sean Gallagher. Paper in Trends in Ergonomics/Human Factors V, ed. by F. Aghazadeh (Proc. Int. Found. for Ind. Ergonomics Safety Conf., New Orleans, LA, June 8–10, 1988). Elsevier, 1988, pp. 779–785. This Bureau of Mines paper describes tests in which 12 subjects (mean age 36 ± 8 *SD*) performed static and dynamic back strength exertions in standing and kneeling postures using an isokinetic dynamometer. A test-retest criterion was employed that required two maximum voluntary contractions (MVC's) to be within 10 pct of one another for each of 12 experimental conditions. The higher of these two values was accepted as the true maximum exertion. Data were analyzed to determine (1) the number of trials required to satisfy the test-retest criterion and (2) at which trial the MVC occurred for each experimental condition. An analysis of variance with repeated measurements demonstrated that dynamic back strength measurements required significantly more trials to satisfy the test-retest criterion ($F_{1,11} = 5.837$, $p < 0.05$) than did the static exertions. The posture assumed (standing or kneeling) had no effect on the number of exertions required ($F_{1,11} = 0.258$, $p = 0.622$). Analysis of the static exertions indicated that back angle (i.e., trunk flexion of 22.5°, 45.0°, or 67.5°) had no effect on the number of repetitions required ($F_{2,22} = 1.082$, $p = 0.356$). Speed of contraction (i.e., 30°/s, 60°/s, or 90°/s) was a significant factor in number of trials required in the isokinetic tests ($F_{2,22} = 6.073$, $p < 0.01$); the 90°/s condition required significantly more trials than the two slower dynamic speeds. The average trial upon which the true maximum was observed was lower for static (2.39 trials) tests than dynamic (2.82 trials) tests; however, this difference was not significant ($F_{1,11} = 4.199$, $p = 0.065$). The results of this study indicate that fast isokinetic contractions are not as easily repeatable as slower isokinetic or static contractions. This may be due to the effects of rapid acceleration and perhaps an increased potential for a variable jerking motion during the strength measurement. The results of this study indicate that the use of a test-retest criterion may provide better estimates of both isometric and isokinetic strength.

OP 84–88. Effects of Posture on the Metabolic Expenditure Required To Lift a 50-Pound Box, by Sean Gallagher and Thomas G. Bobick. Paper in Trends in Ergonomics/Human Factors V, ed. by F. Aghazadeh (Proc. Int. Found. for Ind. Ergonomics Safety Conf., New Orleans, LA, June 8–19, 1988). Elsevier, 1988, pp. 927–934. This Bureau of Mines paper describes tests in which 11 healthy, underground coal miners (36 yr of age ± 8 *SD*) participated in an experiment examining the metabolic cost of lifting a 50-lb box asymmetrically in stooped and kneeling postures. Lifting periods were 10 minutes in duration and the frequency was 10 lifts/min. Dependent measures included heart rate, oxygen consumption, ventilation volume, respiratory exchange ratio, and integrated electromyography (EMG) of eight trunk muscles. Results of an analysis of variance with repeated measures showed that heart rate ($p < 0.05$), oxygen consumption ($p < 0.001$), ventilation volume ($p < 0.001$), and respiratory exchange ratio ($p < 0.05$) were all significantly elevated in the kneeling posture as opposed to stooped. A multivariate analysis of variance indicated that the maximum integrated EMG of the trunk muscles was significantly different between the two postures ($p < 0.05$); univariate F-tests demonstrated that the right and left erectores spinae were the muscles accounting for the significant multivariate effects, being substantially higher in the kneeling posture ($p < 0.01$). These results indicate that workers may be more susceptible to muscular fatigue when handling materials in the kneeling posture and that increased erectores spinae activity may cause higher compressive loads to be experienced by the spine when lifting in the kneeling posture. Results of this study suggest that decreasing the weight of loads handled in underground mines would be advisable, especially when lifting in the kneeling position.

OP 85–88 Improving Health, Safety, and Productivity Through the Use of Machine-Mounted Scrubbers, by Natesa I. Jayaraman, Robert Jankowski, and David Stritzel. Proc. IL Min. Inst., v. 95, No. 1, 1987, pp. 62–75. This Bureau of Mines paper identifies guidelines for the optimum use of scrubbers on continuous mining machines. The guidelines are for maximum dust control with respect to quartz dust exposure of miner operators and shuttle car operators, while maintaining an output of more than 1,000 tons per unit shift. The optimum use of a continuous miner would be to mine coal for a 40- to 45-foot advance before place changing. The use of radio remote control can help achieve greater advance between lifts by locating the operator in fresh air during part of the mining cycle. The operator is also kept away from newly exposed roof which is not supported. A study by the Bureau of Mines indicates that a high output was achieved from a 50-in seam with a scrubber-mounted continuous miner and remote control. Research results in the use of a scrubber system with exhaust face ventilation are discussed. Bureau studies also indicate that a water-powered scrubber system can reduce the dust exposure of the miner operator without the noise and complexity of a fan-powered system. Results of laboratory and underground evaluation indicate the feasibility of such a system. Finally, attention has to be paid to good installation and maintenance of beltlines for increased productivity.

OP 86–88. Computer-Based Remote Control of a Highwall Mining System, by August J. Kwitowski, William H. Lewis, William D. Mayercheck, and Michael C. Leigh. Paper in 21st Century Higher Production Coal Mining Systems Symposium, Wollongong, New South Wales, Apr. 5–8, 1988, ed. by E. Y. Baafi. Australasian Inst. Min. and Metall., Illawrra Branch, 1988, pp. 232–241. This Bureau of Mines paper describes a new highwall mining system (HMS) for coal extraction in unreclaimed and active contour strip mines. This prototype system is comprised of a computer-based remote control system to monitor and remotely control a thin-seam continuous miner (TSCM) and a 76-m-long multiple-unit continuous haulage (MUCH) conveying system, plus other manually operated support equipment located on the highwall bench. The TSCM and MUCH coal haulage system are both controlled remotely by a single operator in a protective enclosure at an ergonomically designed workstation located on the highwall bench. Two other personnel work on the bench to operate other support equipment. Full-scale mockup fabrications were employed in the design of the unique remote control operator workstation. The HMS should allow the safe and economical exploitation of increased coal reserves where they outcrop in hilly regions of the United States. It should also be competitive with conventional auger mining and other coal extraction techniques, with a productivity goal at a highwall site of 20 mt/man-h.

OP 87–88 Conditions Affecting the Formation of Chlorinated Carbon During Carbochlorination, by A. Landsberg, R. D. Wilson, and W. Burns. Metall. Trans. B, v. 19B, June 1988, pp. 477–482. This Bureau of Mines paper describes an extensive study of the relationship between various metal oxide carbochlorination reactions and carbon compound byproducts. Experiments in which oxides of titanium, zirconium, and aluminum with graphite, charcoal, metallurgical coke, and petroleum coke were chlorinated at 600° to 1,000° C produced 136 identified and quantified carbon byproduct compounds. The 20 most abundant of these compounds were correlated with reactants and reaction conditions. Experimental results support a proposed carbochlorination reaction with an initial chlorine-carbon step, followed by a reaction between the resulting chlorine-carbon products and the metal oxide.

OP 88–88. Bromine, by P. A. Lyday. Min. Eng. 1987 Annu. Rev., v. 40, No. 6, June 1988, pp. 416–417. This Bureau of Mines paper reviews changes in the bromine industry during 1987, including domestic and foreign production and environmental and trade issues.

OP 89–88. Iodine, by P. A. Lyday. Min. Eng. 1987 Annu. Rev., v. 40, No. 6, June 1988, p. 425. This Bureau of Mines paper reviews changes in the iodine industry in 1987, including changes in the Government stockpile, imports, and domestic and foreign producers.

OP 90–88. Adaptive Learning Networks Applied to Coal Interface Detection and Resin Roof Bolt Bonding Integrity, by Gary L. Mowrey. Paper in Proceedings of the Third International Conference on Innovative Mining Systems, Univ. MO—Rolla, Nov. 2–4, 1987. Univ. MO—Rolla, 1987, pp. 160–174. This Bureau of Mines paper discusses two important basic problems facing the mining industry today: (1) how to reliably detect the coal-roof and/or coal-floor interface (hereafter referred to as coal interface), such that an automated mining machine can remain in the coal seam, and (2) how to correctly assess the bonding integrity of a resin roof bolt, since there is currently no reliable way to test this type of bolt after installation. The Bureau of Mines is currently pursuing two possible approaches to the coal interface detection (CID) problem by monitoring mining machine signals (1) via accelerometers mounted directly on the mining machine itself (machine

vibration) and (2) via accelerometers affixed to the roof, coal, and floor a distance from the mining machine (in-seam seismic). In either case, very complex signals are generated depending upon the type of material being cut and the type of mining machine being used. The Bureau is investigating the effectiveness and utilization of computer-based analysis and discrimination techniques to CID decision-making based on these signals. Both machine vibrational and in-seam seismic data are stored on a multichannel analog tape recorder and later digitized and analyzed using sophisticated signal processing, feature extraction, and adaptive learning network (ALN) computer programs. It is this advanced data analysis that distinguishes this approach from those of prior researchers. The ALN program is initially trained using a database of features extracted from known signals measured under conditions of interest (e.g., cutting coal, starting to cut roof, starting to cut floor, etc.). Afterwards it uses this database to determine whether new unknown signals (generated by the mining operation) belong to one or more defined "classes" or conditions. Assuming that the ALN system correctly classifies these signals, such a system could have the potential for controlling a mining machine cutting drum, such that it always stays in the coal, via a suitable feedback loop. Another area where the Bureau is utilizing ALN systems is in evaluating the bonding integrity of resin roof bolts by ultrasonic and seismic impact techniques. Laboratory and underground field data associated with "well bonded" and "poorly bonded" resin bolts are being analyzed using a hardware-based ALN discriminator which has signal processing and feature extraction capabilities. This paper describes how the adaptive learning network concept is being applied to help solve the coal interface detection problem and the resin roof bolt bonding integrity problem.

OP 91–88. Guidelines Set for Controlling Dust on Auger Sections, by J. Drew Potts. Nat. Independent Coal Leader, v. 22, No. 11, June 1988, pp. 14–15. This paper describes Bureau of Mines tests conducted to identify factors that distinguish clean auger mining operations from dirty ones. Results revealed that ventilation is the most important element of auger mining dust control.

OP 92–88. Computer Control of a Continuous Mining Machine, by John J. Sammarco and William H. H. Schiffbauer. Paper in Proceedings of the Third International Conference on Innovative Mining Systems, Univ. MO—Rolla, Nov. 2–4, 1987. Univ. MO—Rolla, 1987, pp. 175–181. This paper describes a research base, composed of a specially instrumented Joy 16 CM mining machine and a Bureau of Mines integrated computer system, developed for performing a variety of autonomous mining machine experiments. Initial tests with this base have been completed and have proven that accurate control of the machine, in both free space and a simulated coal seam, can be accomplished with open- and closed-loop software algorithms. The computer, the software, the control mode, and the test results are described.

OP 93–88. Dust Control on Longwall Shearers Using Water-Jet-Assisted Cutters, by C. D. Taylor, P. D. Kovscek, and E. D. Thimons. Paper in Respirable Dust in the Mineral Industries: Health Effects, Characterization, and Control (Proc. Int. Symp. on Respirable Dust in the Miner. Ind., University Park, PA, Oct. 14–16, 1986). Pennsylvania State Univ., 1988, pp. 343–348. This paper describes how the Bureau of Mines equipped a longwall shearer with a water-jet-assisted cutting system and measured dust levels during the cutting of a simulated coal block. The block was cut dry at a conventional water spray pressure of 190 psi, and with water-jet-assisted cutting pressures ranging from 1,000 to 6,000 psi. At water pressures of 3,000 psi and higher, dust concentrations were reduced by as much as 85 pct via water-jet-assisted cutting in comparison with conventional water sprays. This reduction was achieved without any increase in the water flow rate.

OP 94–88. Measurement and Simulation of Face Ventilation Effectiveness for Large Diesel Powered Equipment, by Edward D. Thimons and Carl E. Brechtel. Paper in Proceedings of Fourth International Mine Ventilation Congress, Brisbane, Australia, July 3–6, 1988. Australian Inst. Min. and Metall., 1988, pp. 611–616. In the work described in this Bureau of Mines paper, a simulated diesel mucking operation was carried out in the Exxon Colony Pilot Mine in Colorado to establish expected levels of diesel pollutants in dead-ended working headings. This heading was nominally 15.3 m (50 ft) wide by 9.2 m (30 ft) high. Two face ventilation systems were tested using sulfur hexafluoride tracer gas to represent the diesel pollutants. The results of these tests showed that conventional face ventilation systems operating at high flow rates could adequately ventilate diesel equipment in the 447- to 522-kW (600- to 700-hp) range, even in a dead heading 91.4 m (300 ft) long.

OP 95–88. Analysis of a Fire in a Colorado Coal Mine—A Case Study, by Robert J. Timko, Robert L. Derick, and Edward D. Thimons. Paper in Proceedings of Fourth International Mine Ventilation Congress, Brisbane, Australia, July 3–6, 1988. Australian Inst. Min. and Metall., 1988, pp. 345–353. In early June 1986, a fire of unknown origin erupted in one of several main entries of a coal mine located in southwestern Colorado. The fire was aggressively fought with high-expansion foam. As a result of several strategic decisions, the fire appeared to be held in check. Unfortunately, sufficient quantities of foam were unavailable and as soon as the foam was depleted, control of the fire was lost. To prevent further damage and the possibility of an explosion, all entries to the mine were sealed. This Bureau of Mines paper recounts activities from the discovery of the fire to the initial reentry of the sealed mine including location of the fire, the decisions made to best combat it, and the steps taken to rapidly and securely seal the mine when this became necessary. The mine operator requested the Bureau's assistance in obtaining and analyzing mine fire gases taken from sampling ports placed through the mine seals. This report describes how samples were taken and what gases were analyzed. In addition, this work describes the initial exploration of the sealed mine by personnel using oxygen breathing apparatus.

OP 96–88. Evaluating Ventilation Parameters of Three Coal Mine Gobs, by R. J. Timko, F. N. Kissell, and E. D. Thimons. Paper in Proceedings of Fourth International Mine Ventilation Congress, Brisbane, Australia, July 3–6, 1988. Australian Inst. Min. and Metall., 1988, pp. 55–63. This paper describes how the Bureau of Mines used sulfur hexafluoride (SF_6) tracer gas to evaluate the effectiveness of gob ventilation and/or sealing practices at three coal mines, each having different problems associated with their mined-out areas. The purpose of these ventilation studies was to better understand whether current techniques employed for ventilation or sealing are successful at minimizing the potential for gob fires and explosions. The work performed at each mine is discussed: One is a longwall operation that uses ventilation to carry off hazardous gases, and two are room-and-pillar operations, each with far different concerns, that seal off the gobs to isolate them from the main mine ventilation. In all cases, employment of the Bureau's SF_6 tracer gas technique resulted in answers to questions raised by the mine operators concerning the effectiveness of their gob ventilation or sealing practices in preventing mine fires.

OP 97–88. Cross Borehole Stress Wave Measurements in Underground Coal, by Michael S Wieland. Paper in Proceedings of the Fourth Mini-Symposium on Explosives and Blasting Research, Anaheim, CA, Feb. 4–5, 1988. Soc. Expl. Eng., 1988, pp. 16–32. This Bureau of Mines paper addresses the problem of stress waves generated during delay blasting in underground and surface mines. These waves not only fracture the surrounding coal, rock, or other strata, but also impact delayed charges remaining in neighboring boreholes. This crossing wave interaction is a ubiquitous fundamental damage mechanism, ultimately responsible for numerous occurrences of misfires and flyrock. The hazards and waste from wave-induced malfunctions are just the recognized tip of the iceberg. Undetected marginal performance of damaged delay detonators and desensitized charges poses a tremendous unresolved problem, resulting in the reduction of mining profits and the certain retention of unwanted risks.

Until recently the magnitude of wave interactions in underground coal mines remained rational guesswork, hard to directly confirm close to the charge explosion. Utilizing instrumented boreholes with submerged gauges in different fluids, synchronized gauge traces of stress waves through coal were recorded at close range. The gauges were 25 to 125 cm from a single borehole charge, thereby reproducing both typical and worst case mining conditions in underground coal. Wave propagation to the surrounding gauges occurred prior to any significant coal motion. Over 140 gauge records provided the dominant waveform characteristics: magnitude, specific impulse, and relative energy flux. Regression techniques yielded damping constants and scaling relations for the waveform characteristics as a function of propagation distance. The recorded waveforms determine the wave strength at surrounding boreholes, and this ultimately correlates to detonator and charge degradation criteria. Results of this type determine whether or not a particular detonator or explosive is rugged enough for the conditions utilized in mining underground coal, rock, or other strata.

OUTSIDE PUBLICATIONS

OP 98-88. Reducing Manual Materials Handling in Underground Coal Mining With Mechanical-Assist Devices, by Thomas G. Bobick, Richard L. Unger, and Ernest J. Conway. Paper in Proceedings of the Human Factors Society 31st Annual Meeting, New York, Oct. 19-23, 1987. Human Factors Society, Santa Monica, CA, 1987, pp. 457-461. Historically, manual handling of materials has consistently accounted for over 25 pct of all industrial accidents. In underground coal mining, the situation is worse. Materials-handling accidents routinely account for 30 to 35 pct of all lost-time injuries. This paper describes research sponsored by the Bureau of Mines, and conducted by Essex/Canyon Research, Inc., to develop and evaluate several mechanical-assist devices to reduce the manual effort and the corresponding risk of injury from handling supplies and equipment in underground coal mines. The prototype devices were supplied to cooperating coal mining companies for evaluation. On-site visits, task analyses, and interviews were used to evaluate the devices. Three of them performed exceptionally well and have shown promise for reducing the amount of manual lifting and handling required underground.

OP 99-88. An Explanation of Flocculation Using Lewis Acid-Base Theory, by P. M. Brown, D. A. Stanley, and B. J. Scheiner. Soc. Min. Eng. AIME preprint 88-165, 1988, 5 pp. This paper describes a method developed by the Bureau of Mines for dewatering clay slurries, based on flocculation by high-molecular-weight polymers and water removal from the formed flocs using a trommel or hydrosieve. The exchange ion on the clays affects their dewaterability. Metal ions in solution and on the exchange sites of smectite clays are known to act as Lewis acids. Recent work has determined that these ions can be titrated with high-molecular-weight polymers. The relative acidity of the exchange ion and the basicity of the polymer determined by the new method give insight into the dewatering mechanism.

OP 100-88. Ceramic Research at the U. S. Bureau of Mines, by Hendrik Heystek. Ceramic Bull., v. 67, 1988, pp. 1345-1348. This paper discusses ceramic research at the Bureau of Mines from 1911 to the present. Emphasis has gradually changed over the years: from evaluating properties and processing of natural raw materials, important to the structural clay and refractory industries, to the present-day studies of synthetic raw materials for advanced ceramic composites; and from research to improve the performance of or finding substitutes for refractories requiring imported raw materials to development of advanced ceramic composites with high fracture toughness and temperature properties that could replace metals requiring critical chrome, cobalt, or manganese. Research efforts now include studies of green-body and sintered microstructures, intergranular bond phases, and processing of high-purity raw materials, all directed at producing wear- and corrosion-resistant advanced ceramic materials.

OP 101-88. The Influence of Stream Valleys on Coal Mine Ground Control, by John L. Hill III. Paper in Proceedings, 7th International Conference on Ground Control in Mining, Morgantown, WV, Aug. 3-5, 1988. WV Univ., 1988, pp. 247-258. Over 50 mines of the Appalachian and Illinois Basins are presently experiencing poor ground conditions believed to be caused by overlying stream valleys. This paper describes research being conducted by the Bureau of Mines into the causes of this problem with the aim of developing a predictive method for determining the safe limits of mining beneath stream valleys. In addition, the factors that control instability in these regions will be analyzed to provide design guidelines for adjusting support requirements.

OP 102-88. Improved Bubble-Particle Collision Rates With Fine-Bubble Flotation, by C. E. Jordan. Soc. Min. Eng. AIME preprint 88-172, 1988, 6 pp. This paper describes research conducted by the Bureau of Mines to determine the effect of fine bubbles on the flotation of fine-sized particles (minus 20-μm size). Turbulent flow collision models for fine particles and fine bubbles were reviewed. Velocity distributions within the flotation cell along with measured bubble and particle size distributions were considered in the models to predict the flotation response. The models were corroborated with laboratory fine-bubble flotation tests to verify the expected increase in flotation efficiency.

OP 103-88. Effect of Ventilation on Conveyor Belt Fires, by Charles P. Lazzara and Frank J. Perzak. Paper in Proceedings, Symposium on Safety in Coal Mining, Pretoria, Republic of South Africa, Oct. 5-8, 1987, 15 pp. CSIR Distributor of Publications S. 420, Pretoria, 1987. This paper describes full-scale fire tests of conveyor belts conducted by the Bureau of Mines to determine the effect of airflows of 1.5 and 4.1 m/s on fire development and propagation. The tests were performed in an aboveground fire gallery approximately 27 m long. Rubber and polyvinyl chloride (PVC) belt samples 9.1 m long were placed on the top rollers of a belt conveyor frame and instrumented with thermocouples to measure flame spread rates. Additional sensors monitored air temperatures and major combustion products. The ignition source was a liquid fuel tray fire located just below the upstream edge of the belt sample. Three different styrene butadiene rubber belts ignited and completely burned at both airflow rates. The flame spread rates, downstream gas temperatures, and CO and CO_2 concentrations for each belt were less at the 4.1-m/s than at the 1.5-m/s airflow. Two PVC belts burned at the lower airflow with rapid flame spread rates, but at the higher airflow the same belts did not propagate flame, and damage was limited to the ignition region. A PVC belt and a chloroprene rubber belt did not burn at either airflow. The overall results indicate that for these test conditions, the higher airflow reduced the hazards of propagating conveyor belt fires.

OP 104-88. Field Evaluation of Yield Pillar Systems at a Kentucky Longwall Headgate, by Christopher Mark and Timothy M. Barton. Paper in Proceedings, 7th International Conference on Ground Control in Mining, Morgantown, WV, Aug. 3-5, 1988. WV Univ., 1988, pp. 1-9. This paper describes research conducted by the Bureau of Mines to assess the effectiveness of different chain pillar designs in maintaining gate entry stability. The study described in this paper was performed in a 1,200-ft-long, experimental headgate section which contained three pillar designs: a three-entry, yield-abutment pillar system, a four-entry, yield-yield-abutment pillar system, and a five-entry, all-yield pillar system. As the longwall mined by the experimental section, Bureau engineers monitored entry convergence, roof sag, and changes in roof quality. The results of the study indicate that the all-yield system performed at least as well as, and probably better than, the two abutment pillar systems.

OP 105-88. Yielding Coal Pillars—Field Measurements and Analysis of Design Methods, by Christopher Mark, Jeffrey M. Listak, and Z. T. Bieniawski. Paper in Key Questions in Rock Mechanics: Proceedings of the 29th U.S. Symposium on Rock Mechanics, Minneapolis, MN, June 13-15, 1988. Balkema, Rotterdam, 1988, pp. 261-270. Yielding pillars are gaining increasing acceptance as a technique for improving ground control in coal mines. The field studies described in this paper provide insights into the failure mechanics of yielding pillars that may prove helpful in improving yielding pillar design. Analysis includes the derivation of expressions for the stress distribution within a yielding pillar implied by several well-known empirical pillar design formulas. The field studies were conducted in three narrow longwall pillars at two mines. The pillars were instrumented with vibrating-wire stress meters, and in one case with a sonic extensometer. As the longwall faces passed the pillars, measurements were made of vertical stress changes, changes in confining stress, and horizontal pillar deformation. The measurements, in particular the vertical stress profile measured in one pillar as it yielded, are compared with the predictions of several pillar strength models. The models include the analytical one developed by Wilson as well as those derived from the empirical pillar strength formulas. The paper concludes that the stress gradients derived from the empirical formulas provide good fits to the measurements, and that the analytical models used for yield pillar design would benefit from more reliable determinations of in situ material properties.

OP 106-88. Lineaments: A Predictive Tool for Bad Roof, by Noel N. Moebs and Gary P. Sames. Coal, v. 25, Mar. 1988, pp. 94-96. This paper describes Bureau of Mines investigations of five LANDSAT lineaments in the coal mining region of southwestern Pennsylvania to determine their geologic character, relation to subsurface conditions, and the means of discriminating one from another. The investigation included earth resistivity and very low frequency electromagnetic traverses, soil moisture sampling, and a correlation with coal mine roof conditions. The lineaments could not be detected by the methods used, suggesting that they might be a

surface phenomenon unrelated to subsurface geologic structures or roof stability in coal mine workings beneath.

OP 107-88. Aerostatic Support System for Underground Coal Mines, by R. J. Morrell and R. L. Schmidt. Paper in Proceedings, 7th International Conference on Ground Control in Mining, Morgantown, WV, Aug. 3-5, 1988. WV Univ., 1988, pp. 259-270. This paper describes a ground support system developed by the Bureau of Mines for use with an underground coal auger. The system consists of inflatable airbags that are inserted in the holes as they are drilled, and then gradually deflated to provide controlled roof caving. Laboratory and field tests of the system show it to be technically feasible.

OP 108-88. MINIRAM Performance in the Coal Mining Environment, by John A. Organiscak, Kenneth L. Williams, and Thomas Ozanich. Paper in Respirable Dust in the Mineral Industries: Health Effects, Characterization and Control, ed. by Robert L. Frantz and Raja V. Ramani (Proc. Int. Symp. on Respirable Dust in the Mineral Industries, University Park, PA, Oct. 14-16, 1986). PA State Univ., University Park, PA, 1988, pp. 41-50. This paper describes an underground performance evaluation conducted by the Bureau of Mines on the MINIRAM. This new compact light-scattering instrument measures relative instantaneous respirable dust concentrations by passively allowing environmental air to flow through an open-ended sensing chamber. A personal sampler adapter (utilizing a 10-mm nylone cyclone) that fits over the sensing chamber, in combination with a personal dust pump, also can be used to actively measure relative instantaneous dust concentrations and collect a gravimetric sample. Tests to compare the MINIRAM (passively and actively) with the RAM-1 and the personal gravimetric sampler were conducted at two continuous miner sections and one longwall section. Active sampling results indicate that the seal (foam padding) on the MINIRAM personal sampler adapter may not be adequate in all cases and might eventually deteriorate, making the MINIRAM's instantaneous and gravimetric measurements significantly higher than those of the RAM-1 and the personal sampler. When a good seal exists between the MINIRAM's sensing chamber and personal sampler adapter, the instantaneous and gravimetric measurements correspond well with those of the RAM-1 and personal sampler. Passive sampling with the MINIRAM yields values that are higher, although well correlated with the values obtained by active sampling using the personal sampler adapter. The higher values are probably due to water droplets and/or larger dust particles entering the sensing chamber during passive sampling.

OP 109-88. Miner Absenteeism: Consequences, Causes and Control, by Robert H. Peters. Paper in TRAM XIV: Training Resources Applied to Mining, Proceedings of a Conference Held at the Pennsylvania State University, University Park, PA, Aug. 16-19, 1987. PA State Univ., 1987, pp. 27-36. This paper indicates that high absenteeism among underground miners seriously hampers productivity and is a threat to miner safety. Using the findings from absenteeism research and what is known about the coal mining industry, a conceptual model of the factors that produce absenteeism among coal miners was generated. This model posits that variations between miners' attendance rates are due to variations in perceived ability and level of motivation to attend, and identifies several important determinants of their motivation and perceived ability to attend work. Several specific strategies for controlling miner absenteeism are identified and discussed. These strategies are designed to decrease absenteeism by (1) improving hiring procedures, (2) removing obstacles that make miners unable to attend work, and (3) increasing miner motivation to attend work.

OP 110-88. Computer Model for Evaluating the Dust Reduction Potential of Various Mining Practices for a Continuous Miner Section, by J. D. Potts and R. A. Jankowski. Paper in Proceedings of 3d Mine Ventilation Symposium, University Park, PA, Oct. 14, 1987. Soc. Min. Eng. AIME, 1987, pp. 564-569; also published in Int. Mine Computing, v. 2, July-Aug. 1987, pp. 19-23. By implementing various mining practices, mine operators can reduce the respirable dust exposure levels of the roof bolter and the continuous miner operators. This paper describes a computer program, developed by the Bureau of Mines and entitled AMP (Alternative Mining Practices), that gives a quantitative comparison of these reductions. The alternative mining practices and their corresponding reductions in dust exposure levels, evaluated by the program, include a remote control continuous miner, a half-curtain ventilation system, two auxiliary fan-tubing bypass ventilation systems, a modified cutting sequence, a comparison between single-split and double-split ventilation networks, and a comparison between exhausting brattice and exhausting tubing. Descriptions of each of the above mentioned mining practices are included in the report. AMP is a compiled basic program that has been designed to run on computers with a DOS version 2.0 or later operating system. It includes high-resolution graphics (640 × 200 dot positions) designed to run with video boards that are functionally compatible with the IBM Monochrome/Printer Adapter. Graphic screens are selected from menus and can be bypassed if the computer is not equipped to handle high-resolution mode. Their primary function is to show proper implementation of the mining practices evaluated by the program. This package requires a minimum of 256K bytes of RAM.

OP 111-88. Recovery of Sulfur From Phosphogypsum: Conversion of Calcium Sulfide to Sulfur, by D. A. Rice, A. May, O. C. Carter, Jr., and R. G. Swanton. Soc. Min. Eng. AIME preprint 88-33, 1988, 9 pp. As part of a cooperative effort between the U.S. Bureau of Mines and the Florida Institute of Phosphate Research, with input from the phosphate industry, the conversion of phosphogypsum to sulfur is being investigated. The proposed process incorporates a thermal reduction of phosphogypsum to calcium sulfide (CaS) and a hydrometallurgical treatment to convert calcium sulfide to ammonium bisulfide (NH_4SH), which is then oxidized using a catalyst to produce elemental sulfur. The paper summarizes the results of continuing laboratory studies using an activated carbon catalyst which was loaded with sulfur through oxidation of ammonium bisulfide solution. The extraction of the sulfur that forms in situ on the catalyst is a key area in the development of the sulfur recovery process. Two approaches for removing the sulfur are being investigated: (1) thermal treatment to volatilize sulfur and (2) leaching the sulfur using liquid anhydrous ammonia. The research has shown that it is technically feasible to recover over 90 pct of the sulfur from the carbon by either volatilization or ammonia leaching. Locked-cycle testing has demonstrated that the carbon has the potential to be recycled after ammonia leaching.

OP 112-88. Lightning Warning for Blasting Operations, by Lon D. Santis. J. Expl. Eng., v. 6, May-June 1988, pp. 24-38. If lightning strikes an explosive or blasting circuit, detonation is very probable regardless of the precautions taken. Even a near miss will probably cause a detonation. Many studies have shown that a lightning strike can initiate electric blasting caps several miles away. Only a direct strike will initiate nonelectric initiation systems. When explosives prematurely detonate, the chances of death or serious injury are very high. Since 1962, premature initiations caused by lightning killed at least 10 miners and injured 17; 31 incidents were reported. More incidents have occurred but, quite often, when no one was hurt, the incident went unreported. U.S. Bureau of Mines accident studies report that lightning was responsible for 16 out of 80 premature initiations of explosives from 1978 to 1985, more than any other single cause. This paper reviews the lightning warning systems available to the mining industry.

OP 113-88. Dust Control With Clean Air From an Overhead Air Supply Island (OASIS), by Jon C. Volkwein, Mark R. Engle, and Thomas D. Raether. Appl. Ind. Hygiene, v. 3, Aug. 1988, pp. 236-239. The objective of the work reported in this paper was to test the dust control effectiveness of an Overhead Air Supplied Island (OASIS). This device provides an envelope of clean air for dust protection for individual work stations in environments where other engineering controls are not practical or available. A fan-powered filtration unit and a unique air distribution system provide 6,000 ft^3/min of clean air over the operator. RAM-1 light-scattering dust monitors were used to measure dust concentrations as the unit was turned on and off at a bagging machine operator's work station at two industrial silica plants. Dust concentration reductions at the operator's breathing zone were 98 and 82 pct, and dust concentrations never exceeded 0.06 mg/m^3 during operation of the OASIS. The OASIS has potential applications in many industrial areas where dust exposures are excessive. It is a simple, self-contained unit which can reduce worker exposure to dust at a work station. In addition to the health benefits of the OASIS, worker comfort is improved in the clean and heated airstream. Maintenance of the unit is minimal. Another significant advantage of this approach to opera-

tor protection is that the unit is not part of the process, and thus production is unaffected.

OP 114-88. Coal Mine Safety Research in the Bureau of Mines, by Lewis V. Wade and James J. Olson. Paper in Proceedings, Symposium on Safety in Coal Mining, Pretoria, Republic of South Africa, Oct. 5-8, 1987, 22 pp. CSIR Distributor of Publications S. 420, Pretoria, 1987. This paper reviews various aspects of accident and fatality statistics in U.S. coal mines over the past 20 yr. Significant improvement has been achieved in making mines safer. Accident rates in the U.S. mining industry are now comparable with those encountered in other major industries. Although improvement has been made in reducing the frequency of mine accidents, coal mining remains one of the most hazardous occupations in terms of severity. Mine accidents are more likely to result in death or serious injury. The U.S. Bureau of Mines uses analyses of accident data for several purposes. For example, detailed information on the accidents is studied to establish causes, while overall trends in coal mining accidents and fatalities are used to structure research programs to improve mine safety. The overall goal of the Bureau's Safety and Health Program is to provide the U.S. mining industry with the technologies necessary to reduce or eliminate mine hazards. The Bureau's current Safety and Health Research Program is also reviewed.

OP 115-88. Aluminum Chloride Leaching and Hydrolytic Disproportionation To Produce Alumina From Kaolin, by G. L. Dan and J. A. Eisele. Paper in Light Metals 1988, ed. by Larry G. Boxall (Proc. Tech. Sess., TMS Light Metals Committee, 117th TMS Annu. Meeting, Phoenix, AZ, Jan. 25-28, 1988). Metallurgical Society, Inc., 1988, pp. 825-832. In the work described in this paper, the Bureau of Mines extracted aluminum from calcined kaolin with aluminum chloride solution or substoichiometric amounts of hydrochloric acid. The leaching method produced solutions containing basic aluminum chloride salts, which require less energy for decomposition to alumina than the aluminum chloride hexahydrate (ACH) produced in the Bureau of Mines clay-HCl process. Hydrolytic disproportionation at elevated temperature and pressure of the basic aluminum chloride solution produced hydrated aluminum oxide with very low chloride content and an aluminum chloride solution for recycle to leaching. Simulated two-stage counter-current leaching and the hydrolytic disproportionation of the resulting basic aluminum chloride solution were integrated. Buildup of silica and iron in solution and coprecipitation during disproportionation prevented recovery of a cell-grade alumina product; and aluminum recovery, under the conditions tested, was not adequate to achieve complete aluminum chloride leachant regeneration.

OP 116-88. Newly Developed Technology Permits Soft Solder Fabrication of Aluminum, by W. L. Falke, L. A. Neumeier, and K. W. Mlynarski. Navy Civil Eng., v. 28, No. 1, Summer 1988, pp. 19-21. This paper describes a technology developed by the Bureau of Mines that permits the soft-solder fabrication and repair of aluminum and aluminum alloy substrates and assemblies. The process involves electrodeposition of a thin Ni-Cu alloy coating on the zincated aluminum substrate. This coating induces standard Sn-Pb solders to wet and spread when using standard fluxes. Solder joints so formed are relatively corrosion resistant and equivalent in strength to joints formed on copper or brass using the same solders and fluxes. The Ni-Cu alloy (30 to 70 pct Ni) coating is electrodeposited from buffered acetate electrolyte by electrolytic cell (more suitable for initial fabrication) or by brush-coating (more appropriate for repairs). The method has also been used to soft-solder aluminum and aluminum alloys to copper and brass. In general, the process appears applicable for any reactive substrate that will accept an adherent Ni-Cu-alloy coating. A variety of potential uses for fabrication and repair of items such as heat exchangers, electrical components, and energy conversion systems are envisioned for the soldering process.

OP 117-88. An Assessment of Coal Mine Escapeway Reliability Using Fault Tree Analysis, by Gerrit V. R. Goodman. Min. Sci. and Technol., v. 7, No. 2, July 1988, pp. 205-215. The issue of miner safety in case of an underground mine fire has been extensively examined by both government and industry. These efforts have intensified in recent years following a number of fatal fires at underground coal mines. As a result, there is an increasing interest in the reliability of coal mine escapeways during a mine fire. This paper discusses the use of fault tree analysis for evaluating escapeway reliability. A fault tree is developed using standard logic formulations. It is later evaluated using commercially available software. The computer model uses Boolean reduction to obtain the minimal cut sets and minimal path sets of the tree. A brief analysis is also conducted to determine the occurrence probability of the TOP event. This study shows that fault tree analysis is a viable means of analyzing escapeway reliability. The cut and path sets reveal those event sequences leading to fatalities. Such information is useful in safety training and accident prevention. The probability of the TOP event shows the frequency of occurrence for fatalities in an underground mine fire. The usefulness of this value, however, is limited by the accuracy of the data for the initiating events. For mining events, the data are difficult to estimate precisely.

OP 118-88. Longwall Shearers Reverse Drum Rotation and Show Production and Health Benefits, by Robert A. Jankowski and Jonathan S. Kelley. Coal, v. 25, No. 9, Sept. 1988, pp. 72-76. This paper describes recent evaluations by the Bureau of Mines comparing conventional (roof-to-floor) rotation to reverse (floor-to-roof) rotation on longwall shearer faces. The results showed improvements in product size and tram speed, and reductions in respirable dust generation and gas liberation.

OP 119-88. Complete Geomechanical Characterization of Rock Mass With Hydraulic Borehole Pressure Cells, by Paul H. Lu. Paper in Key Questions in Rock Mechanics (Proc. 9th U.S. Symp. on Rock Mechanics, Minneapolis, MN, June 13-14, 1988). Balkema, 1988, pp. 725-728. The Bureau of Mines has been actively engaged since the 1950's in developing practical techniques to determine geomechanical factors for use in realistic design of underground structures such as mines, tunnels, and large rock caverns. These factors include the deformation modulus, Poisson's ratio, existing in situ stresses, and the in situ strength of a rock mass. A reliable method to determine realistic in situ values for these important design parameters has remained a major issue in rock mechanics for many decades. During the past few years the Bureau has been experimenting with an innovative and practical technique to determine the in situ values of the above four parameters, simultaneously utilizing a combination of three borehole pressure cells installed in one hole. This paper provides a brief description of the theoretical approach.

OP 120-88. Ferrochromium From Domestic Lateritic Chromites, by R. H. Nafziger. J. Met., v. 40, No. 9, Sept. 1988, pp. 34-37. This Bureau of Mines paper indicates that a high-carbon ferrochromium can be smelted satisfactorily from a chromite concentrate derived from domestic laterite residues in a small electric arc furnace, provided suitable flux additions are made and the phosphorus and sulfur levels can be decreased during the subsequent steelmaking process. From 78 to 97 pct of the chromium can be recovered in a ferroalloy containing 54 or higher wt pct chromium, depending on the amount of carbon used. Approximately 120 pct of the stoichiometric carbon requirement should be added to produce acceptable results. This can be divided equally between wood chips and a reductant such as metallurgical-grade coke. Chromium recovery and final slag basicity were decreased when less carbon was used. In general, techniques for smelting lateritic chromites parallel those for the production of high-carbon ferrochromium from off-grade chromites. On the basis of this research, an agglomeration procedure may not be required for this material as long as submerged arc conditions are maintained. Dusting and handling losses were comparable to those experienced in commercial chromite smelting operations that use coarser ores and concentrates.

OP 121-88. Superalloy Recycling 1976-1986, by John F. Papp. Paper in Superalloys 1988, ed. by S. Reichman, D. N. Duhl, G. Maurer, S. Antolovich, and C. Lund (Proc. 6th Int. Symp. on Superalloys, Champion, PA, Sept. 18-22, 1988). Metallurgical Society, 1988, pp. 367-376, This paper indicates that about 55 million lb of clean and contaminated superalloy scrap were processed in 1986; about 92 pt (50 million lb) went to domestic buyers, and 8 pct (4.3 million lb) was exported. About 93 pct (4.0 million lb) of the exported material was refinery-destined grindings and 7 pct (0.3 million lb) was vacuum-melting-grade superalloy scrap. Of the 55 million lb of superalloy scrap processed in 1986, about 70 pct (38.5 million lb) was recycled into the same superalloy, 20 pct (11 million lb) was downgraded, and 10 pct (5.5 million lb) was sold to refineries. The average

element content of superalloy scrap processed in 1986 was about 44 pct Ni, 16 pct Cr, 5 pct Co, 2 pct Cb, less than 1 pct each of Mn and Ta, and nil for Re. The remaining 30 pct was primarily Al, Fe, Mo, Ti, W, and other minor constituents. The major changes in the superalloy recycling industry since 1976 were the introduction of premelted superalloy scrap as a material supply source and increased use of closed-loop recycling agreements among forger-scrap processor-alloy producer-engine manufacturer groups. Since 1976 Inconel 718 has become the predominantly produced superalloy.

OP 122-88. On-Board Navigation for a Continuous Mining Machine, by J. J. Sammarco. Paper in Mining Automation, ed. by J.-M. Robert and J. B. Edwards (Proc. 3d Canadian Symp. on Min. Automation, Montreal, Sept. 14-16, 1988). Canadian Centre for Automation and Robotics in Mining, Montreal, 1988, pp. 159-163. The Bureau of Mines is seeking to increase safety and efficiency in U.S. coal mines. A multifaceted project is utilizing robotics and automation technologies to develop equipment and techniques for improving mine safety and productivity. One area of research is the technology for automation of a continuous mining machine. The realization of an autonomous mining machine requires development of many subsystems for machine intelligence, navigation-positioning, and computer control. This paper focuses on the Bureau's work on one subsystem for a navigation-positioning system. This subsystem is responsible for determining machine heading. An onboard heading system for a mining machine is under development. This multisensor system determines machine heading, pitch, and roll. A directional gyroscope provides heading (yaw), fluxgate sensors provide a compass heading, and gravity-referenced clinometers give machine tilt and roll information. The onboard system utilizes a dedicated microcontroller networked to an external system of computers. Tramming commands, supplied to the network from external computers, are executed by the onboard system. Sensor feedback is employed for closed-loop control of tramming. Further detail is given concerning the operating limitations and error sources of the gyroscope, fluxgate sensors, and clinometers. Actual test results with the mining machine are used to exhibit the various sensor shortcomings. Methods under investigation to limit and circumvent these sensor problems are also discussed.

OP 123-88. U.S. Bureau of Mines Coal Mining Automation Research, by George H. Schnakenberg, Jr. Paper in Mining Automation, ed. by J.-M. Robert and J. B. Edwards (Proc. 3d Canadian Symp. on Min. Automation, Montreal, Sept. 14-16, 1988). Canadian Centre for Automation and Robotics in Mining, Montreal, 1988, pp. 145-157. The automation (robotization) of coal mining activities at the face offers improvements in worker safety and productivity. The evolutionary introduction of autonomous, intelligent robotic machines to perform the most hazardous tasks may become a reality within the next 5 yr. The U.S. Bureau of Mines Robotics and Automation research program described in this paper is aggressively pursuing the development of the enabling technology necessary to achieve this goal. This program consists of both core and applications research, each focused on the fundamental issues of robotic technology. In the short term, the research is directed specifically to the robotization of present-day underground equipment and is being performed in a manner that can make incremental improvements in safety and productivity. The long-term goal is the development of intelligent autonomous mining systems. The research program includes a review of robotic machine and autonomous vehicle technologies and of the current mining technology that provides a base for developing innovative mining methods; research in navigation and guidance technology emphasizing control of a continuous mining machine; research on sensing technology of the coal-rock interface for horizon control, and rib thickness control in highwall mining; the development of computer systems and hierarchical architectures for real-time control; and the development of expert systems for machine system fault diagnostics and preventive maintenance.

OP 124-88. HCl Process for the Production of Alumina From Clay, by D. E. Shanks and J. A. Eisele. Paper in Chemeca '88: Australia's Bicentennial International Conference for the Process Industries (Preprints of Papers, v. 1 of 2, Sydney, Aug. 28-31, 1988). Institution of Engineers, Australia, 1988, pp. 316-322. This paper describes in-depth studies conducted by the Bureau of Mines on the recovery of alumina from kaolinitic clay in order to provide technology for alumina production from domestic raw materials. The hyrochloric acid (HCl) process consists of the following steps: (1) clay calcination at 750° C, (2) clay leaching with 26-pct HCl, (3) removal of iron from pregnant liquor by solvent extraction, (4) crystallization of aluminum chloride hexahydrate from pregnant liquor by HCl gas injection, and (5) calcination of aluminum chloride hexahydrate to Al_2O_3 with HCl recovery. All unit operations except 5 were run on a semicontinuous basis in a pilot plant. Research also investigated process alternatives, such as leaching of uncalcined clay, changes in leaching acid concentration and stoichiometry, elimination of solvent extraction for iron removal, and formation of aluminum oxychloride instead of aluminum chloride hexahydrate as an intermediate product.

OP 125-88. Autonomous Face Navigation of a Continuous Mining Machine, by Donna L. Anderson. Paper in Conference Record of the 1988 IEEE Industry Applications Society Annual Meeting, Part II. IEEE, 1988, pp. 1255-1259. The tasks of autonomous face navigation for a continuous mining machine and the navigational information necessary to perform these tasks are discussed. The proposed solution is presented, in this Bureau of Mines paper, including the employment of a mobile control structure to serve as a reference in the face area, of laser-based optical scanning units and retroreflective targets to determine the machine's position relative to the reference, and of a gyroscope to maintain a short-term knowledge of heading of the machine. An algorithm for fusion of the laser system's data is outlined. Future work on the navigational control software is discussed. The current status of the project is stated.

OP 126-88. Rare-Earth Oxide Availability in Market Economy Countries, by T. F. Anstett, J. B. Hedrick, and W. D. Jackson. Natural Resources Forum, v. 12, No. 1, 1988, pp. 19-30. This paper presents a review by the Bureau of Mines on the 1985 status of the rare earths industry in the market economy countries (MEC). Demonstrated resources for the 38 evaluated MEC properties are estimated at 3.3 million metric tons of recoverable rare-earth oxides. About 75 pct of the total is contained in producing properties, and 21 pct is contained in undeveloped properties; the remaining 4 pct is contained in past producers. Total MEC production in 1985 was estimated at 30,500 mt. Assuming demand does not increase sharply, producing properties can continue to meet overall rare earths demand through at least the end of this century.

OP 127-88. Nickel Production—1987 and 1988, by Donald I. Bleiwas. Metall. Soc. AIME, TMS Tech. Paper A88-22, 1988, pp. 1-10. This Bureau of Mines paper estimates world nickel production in 1987 at 763,000 mt, of which 517,000 mt originated from market economy countries. Mine production in 1988 will be dependent on much the same factors as in previous years—demand, energy prices, currency exchange, Soviet nickel sales from both domestic and Cuban sources, and the price of nickel.

OP 128-88. The Availability of U.S Frasch Sulfur, by D. A. Buckingham. Ind. Miner., No. 244, Jan. 1988, pp. 39-47. This Bureau of Mines study evaluates the availability of elemental sulfur produced by the Frasch process. Secondary sulfur sources, not included in the analysis, are recovered elemental sulfur, a by-product from the desulfurisation of sour gas and petroleum, and sulfuric acid from the conversion of sulfur dioxide contained in smelter-refinery offgases. Recovery of sulfur from these sources is nondiscretionary and cannot be readily adjusted to sulfur supply and demand since their production is based on market requirements for sulfur-free and low-sulfur products, and on the removal of sulfur and its compounds from solid, liquid, and gaseous waste effluents for protection of the environment. In this report nine elemental sulfur Frasch operations are evaluated, four in Louisiana and five in Texas. Four of these operations are currently producing; five others are shut down.

OP 129-88. The Relative Safety Factors Obtained by Using Various Materials as Spark Electrodes in Methane-Air Atmospheres, by James C. Cawley and J. Shawn Peterson. Paper in Conference Record of the 1988 IEEE Industry Applications Society Annual Meeting, Part II. IEEE, 1988, pp. 1283-1287. Previous research by the Bureau of Mines determined the probability of spark ignition versus current in methane-air atmospheres with a high degree of statistical confidence. However, all of these measurements

were obtained using tungsten and cadmium electrodes as specified in Underwriters Laboratories Standard UL 913, a national intrinsic safety standard. In the realistic mining environments, spark ignitions rarely occur between tungsten and cadmium components. Information defining the spark ignition probability of other more common materials is of far more value. The Bureau's Pittsburgh Research Center is currently engaged in research to estimate the spark ignition probabilities associated with more commonly used materials such as copper, cold-rolled and stainless steel, brass, tin, aluminum, and lead in a standard breakflash apparatus. By comparing the currents which give the same probability of spark ignition, the relative safety factor associated with each material can be more precisely estimated. The work and findings to date are summarized in this paper.

OP 130-88. The Worldwide Availability of Phosphate Rock, by R. J. Fantel, G. R. Peterson, and W. F. Stowasser. Natural Resources Forum, v. 9, No. 1, 1985, pp. 5–24. The Bureau of Mines has investigated the resource potential of 201 phosphate mines and deposits in 28 market economy countries and 17 mines and deposits in the U.S.S.R. and China. The 201 mines and deposits contain an estimated 34.2 billion mt of recoverable phosphate rock (at the demonstrated resource level), with Morocco and Western Sahara accounting for 61 pct (21 billion mt) and with the United States accounting for 19 pct (6.4 billion mt). The 17 mines and deposits evaluated in the U.S.S.R. and China contain approximately 1.5 billion mt of potentially recoverable phosphate rock. Potential annual capacity from low-cost, high-grade producing mines in the United States is estimated to decline significantly during the latter half of the next decade, and the U. S. phosphate fertilizer industry will have to obtain phosphate rock by developing new, higher cost, lower grade mines or import phosphate rock to satisfy anticipated demand in the next century. Of the world's new production capacity that is likely to be developed over the next decade, slightly over one-third could be produced at an estimated 1981 cost of $40/mt or less, and about two-thirds would cost in the $40 to $50 per mt range (including a 15-pct rate of return). In comparison, most of the competing phosphate rock from producing mines in Morocco could be produced for less than $40/mt.

OP 131-88. The Availability of Phosphate Rock From the Southeastern United States, by R. J. Fantel and R. D. Rosenkranz. Soc. Min. Eng. AIME Preprint 83-87, 1983, 11 pp. The Bureau of Mines performed engineering and economic analyses on 130 domestic phosphate mines and deposits, all containing demonstrated resources, of which 73 are in the Southeastern States of Florida and North Carolina, to determine the domestic availability of phosphate rock. Of the total domestic resources studied (6.4 billion tons of recoverable rock), over 60 pct is found in these two States. At an estimated cost of $30 per ton, in January 1981 dollars, approximately 1 billion tons of rock is potentially recoverable from southeastern deposits, increasing to 3 billion tons at $45. In addition, there is nearly 6 billion tons of recoverable rock at the inferred level (some presently unminable) in Florida and Georgia.

OP 132-88. Numerical Prediction of Cobalt Sorption in a Continuous Ion-Exchange Column, by K. S. Gritton. Ch. in The Mathematical Modelling of Materials Processing Operations, ed. by J. Szekely, L. B. Hales, H. Henein, N. Jarrett, K. Rajamani, and I. Samarsekera. Metall. Soc. AIME, 1987, pp. 329–346. The Bureau of Mines investigated the feasibility of numerically modeling the sorption of cobalt, a vulnerable, strategic, and critical metal, from spent copper leach solutions in a multiple-compartment ion-exchange (MCIX) column. Equilibrium resin loadings, cobalt-sorption kinetics, and resin-fluidization characteristics were determined in simple laboratory tests, and a numerical model was developed to predict cobalt extraction and the MCIX-column resin inventory based upon the test results. The model was implemented on a microcomputer to approximate the solution to the set of differential equations which govern model performance. Results compared very well to data from 12 pilot-scale MCIX-column experiments. The average difference between predicted and actual cobalt extractions was 3.2 pct, while the maximum difference was 9.3 pct. The actual and predicted resin inventories differed by an average of 5.8 pct, and the maximum difference was 12.0 pct.

OP 133-88. Beneficiation of Cobalt-Rich Manganese Crust, by W. C. Hirt, D. G. Foot, Jr., and M. B. Shirts. Marine Min., v. 7, 1988, pp. 165–180. Bureau of Mines research is developing beneficiation technology for processing manganese crust to produce a concentrate containing the valuable metals (Mn, Co, and Ni) and a tailings product containing the gangue. Beneficiation studies on cobalt-rich Mn crust from the Hawaiian Islands and Johnston Atoll Exclusive Economic Zone (EEZ) have shown that magnetic separation and conventional and column froth flotation are promising techniques. Column flotation produces metallurgical results similar to those from conventional flotation but requires fewer processing stages. The best flotation collectors are mixtures of neutral oils (diesel fuel, kerosene) with fatty acids and minor amounts of sulfonate. Flotation in sea water of minus 28-mesh cobalt-rich manganese crust (with substrate) assaying 6.2 pct Mn, 0.20 pct Co, and 0.13 pct Ni, with a mixture of 2 kg/ton sulfonate, and 5 kg/ton each of diesel fuel and distilled oleic acid, or 7.5 kg/ton each of diesel fuel and Unitol CTF tall oil, has produced concentrates containing more than 15 pct Mn with 91.2- to 94.2-pct recovery. The concentrate also contained approximately 0.57 pct Co and 0.32 pct Ni with 93 pct Co recovery and more than 85 pct Ni recovery. The paramagnetic Mn-, Co-, and Ni-containing minerals can be separated from the nonmagnetic gangue by high-intensity magnetic separation. Magnetic separation testing of minus 35- plus 100-mesh (425- by 150-μm) material, assaying 6.6 pct Mn, 0.24 pct Co, and 0.13 pct Ni, produced a concentrate assaying 15.6 pct Mn, 0.6 pct Co, and 0.26 pct Ni, which contained 82.8 pct of the Mn, 88.3 pct of the Co, and 72.1 pct of the Ni.

OP 134-88. Ultrafine Ceramic Powders Produced by Turbomilling, by Jesse L. Hoyer. Am. Ceram. Soc. Bull., v. 67, No. 10, Oct. 1988, pp. 1163–1668. The Bureau of Mines turbomill was originally developed for grinding filler-grade clays into paper-coating-grade material. Particle size reduction achieved by turbomilling was much greater than when using jar mills, colloid mills, or ultrasonics. The operating variables found to influence kaolin comminution efficiency were type, size and shape of grinding media, the ratio of medium weight to clay weight, clay pulp density, degree of pulp dispersion, and the angular arrangement of the rotor and stator bars. The Bureau also investigated milling of other industrial minerals, including natural and synthetic mica, pyrophyllite, talc, marble, barite, sericite, and anthracite. The Bureau also investigated the use of the turbomill as a technique for the production of submicrometer ceramic powders including barium ferrite, calcite, dolomite, fluorspar, silica, and zirconia. Autogeneous turbomilling in which the milling medium and the material to be milled are of similar composition was used to produce high-purity, ultrafine powders. Additional studies included turbomilling of nonoxide ceramic materials. Use of polymer construction for parts of the mill aided in elimination of metal contaminants in the final milled product. The effects of dispersants, temperature, pH, presence of different gases, and milling time for α-SiC were investigated. Optimum milling efficiency was obtained at 50° C in a slurry of pH 9.5 using a sodium lignosulfonate as the dispersant. Eighty percent of a minus 100- plus 200-mesh α-SiC was ground to less than 1 μm in 4 h. Similar results were observed for Si_3N_4 and TiB_2.

OP 135-88. Recovery of Cobalt From Spent Copper Leach Solution Using Continuous Ion Exchange, by T. H. Jeffers, K. S. Gritton, P. G. Bennett, and D. C. Seidel. Nuclear and Chem. Waste Management, v. 8, June 1988, pp. 37–44. Significant amounts of cobalt are present in readily accessible spent copper leach solutions. The Bureau of Mines investigated the feasibility of extracting cobalt from one of these solutions in a multiple-compartment ion-exchange (MCIX) column. The effects of aqueous flow rate, resin flow rate, column height, and compartment height on cobalt extraction were determined. Cobalt extractions of 92 pct or higher were achieved at solution flow rates of up to 5.5 gpm/ft^2 (13.4 m^3/h·m^2) of column cross-sectional area and an aqueous-to-resin flow ratio of 40:1. Overall cobalt extraction increased as the column height increased, but cobalt extraction per unit of height was more efficient in 2.4- and 3.7-m columns than in a 5.5-m column. Solvent extraction procedures were utilized to purify and concentrate the MCIX column eluates and produce a cobalt sulfate solution containing 70 to 80 g/L Co. Metallic cathodes, containing over 99 pct Co, were electrowon from this solution. Nickel, zinc, and copper byproducts were also recovered during processing of the ion-exchange eluates. Estimated total capital cost for a commercial-scale plant processing 10,000 gpm (2,270 m^3/h) of a spent leach solution containing 26 mg/L Co was $23.1 million (U.S.). With credits for zinc, nickel, and copper byproducts, the estimated net operating cost was $5.10/lb ($11.24/kg) of cobalt.

OUTSIDE PUBLICATIONS

OP 136-88. An Overview of Selected Surface and Underground Mining Systems R&D Sponsored by the US Bureau of Mines, by William D. Mayercheck. Paper in Mine Planning and Equipment Selection, ed. by Raj K. Singhal (Proc. Int. Symp. on Mine Planning and Equipment Selection, Calgary, Nov. 3–4, 1988). Balkema, 1988, pp. 199–205. For overall economic viability, the United States must have a dependable source of competitively priced minerals. To ensure this supply, the Bureau of Mines has been conducting research to investigate, test, and evaluate a variety of new mining system approaches. A systems approach is important in devising, evaluating, and testing for proof-of-concept, new and innovative methodologies to advance the technology base in both surface and underground mines. This paper summarizes the status of selected projects at the Bureau's Pittsburgh Research Center that are directed toward new extraction and transport system techniques in the surface or underground mining of coal, sand and gravel, and metal and nonmetal ores.

OP 137-88. Adaptive Signal Discrimination as Applied to Coal Interface Detection, by Gary L. Mowrey. Paper in Conference Record of the 1988 IEEE Industry Applications Society Meeting, Part II. IEEE, 1988, pp. 1277–1282. The Bureau of Mines is becoming increasingly involved in the areas of automation and robotics for the U.S. mining industry to increase both mining productivity and safety. Both robotization of existing mining equipment and future integrated robotic and/or automated mining systems are being investigated. One of the primary concerns associated with automated underground coal mining is the development of an appropriate coal-rock interface detection (CID) sensing system to determine when a mining machine is mining coal or starting to mine adjacent strata (e.g., roof or floor). Several promising CID techniques are currently being investigated by the Bureau, including strata-machine vibration, natural gamma radiation, X-ray fluorescence, ground-probing radar, and thermography. This paper describes two CID methods associated with vibrations generated by mining machines and how adaptive signal discrimination (ASD) technology is being used to process these signals. In these CID methods, strata (roof, coal seam, floor) or mining machine vibrations are monitored for complex signals generated, which vary according to the type of geologic material being cut and the type of mining machine being used. These signals are then analyzed using sophisticated state-of-the-art ASD technology. It is this advanced signal analysis that distinguishes this approach from those of prior research. The ASD system is initially "trained" using a database of features extracted from known signals measured under conditions of interest (e.g., "cutting coal," "starting to cut roof," etc.). Subsequently, it uses this database to determine if new, unknown signals belong to a given condition. Assuming that the ASD system classifies these signals correctly, such a system could have the potential for controlling a mining machine so that it always remains in the coal seam.

OP 138-88. A New Approach to Coal Interface Detection: The In-Seam Seismic Technique, by Gary L. Mowrey. IEEE Trans. on Ind. Applications, v. 24, No. 4, July–Aug. 1988, pp. 660–665. Over the years, numerous researchers have attempted to develop a method for detecting the interface between coal, roof, and floor during the mining operation. The complex nature of the geological interface has proven to be a formidable problem for any type of coal interface detection system. A novel approach to detecting coal-roof and coal-floor interfaces during mining operations, currently being pursued by the Bureau of Mines, is based on a seismic acquisition method integrated with various signal-processing techniques. Seismic transducers (accelerometers) are affixed to the roof, coal, and floor at a distance from the mining machine. Unique seismic signals are generated during mining, depending upon which stratum is being cut. A discriminator extracts and stores mathematical parameters characteristic of the signals in the form of an adaptive learning network (ALN). The system is initially "trained" to recognize three cases by intentionally cutting some sample roof, coal, and floor. The computer uses this ALN to tell where new unknown signals associated with the mining process are originating. Via a feedback loop, the computer has potential for keeping the machine in the coal seam. Described are the in-seam seismic concept, the experimental setup, the data analysis methods being used, and some preliminary findings.

OP 139-88. Development of an In Situ Probe for Monitoring Redox Conditions, by C. R. Neuharth, C. S. O'Dell, and G. W. Walker. Ch. in The Mathematical Modelling of Materials Processing Operations, ed. by J. Szekely, L. B. Hales, H. Henein, N. Jarrett, K. Rajamani, and I. Samarsekera. Metall. Soc. AIME, 1987, pp. 247–262. A number of sulfide mineral-thiol collector interactions have been identified as electrochemical or electron transfer processes. Laboratory studies have confirmed that these interactions can be controlled by variation of the mineral potential, using either a directly applied potential or redox-controlling reagents to induce or depress flotation. Control of the mineral potential in the laboratory has proved to be a very precise means of achieving flotation. If similar results can be achieved on a commercial scale, more efficient recovery of domestic critical and strategic minerals might be possible. To develop an understanding of the relationship between redox potential and recovery in commercial flotation plants, a portable system for in situ monitoring of the pulp conditions in sulfide flotation circuits has been developed. The multichannel capability of this data acquisition system provides for the simultaneous monitoring of redox potentials on a variety of metal and mineral electrodes. The system also provides for the monitoring of such parameters as pH, dissolved oxygen content, and soluble ion concentration. The results of probe tests at two commercial processing plants will be discussed in terms of the differences in mineral and metal electrode potentials under similar conditions; the effects of reagent, pH, and dissolved oxygen on these potentials; and the viability of using potential as a commercial flotation control parameter.

OP 140-88. Lineament Analysis for Hazard Assessment in Advance of Coal Mining, by Douglas C. Peters, Robert A. Speirer, and Valois R. Shea. Paper in Proceedings of the Sixth Thematic Conference on Remote Sensing for Exploration Geology, Houston, TX, May 16–19, 1988. Environ. Res. Inst. of Michigan, v. 1, 1988, pp. 253–264. Lineament analysis, a common remote sensing tool for petroleum and mineral exploration, can be used for coal mine properties to assess potential ground control hazards by estimating the relative degrees of risk that may be associated with geologic structures that cause the lineaments. This assessment can be applied to unmined properties to provide a preliminary analysis for mine feasibility planning or to active mines to evaluate potential hazards in as-yet-undeveloped reserves. Studies using lineament analysis, in-mine observation of lineament locations and ground control problems, and ancillary data (additional geologic and geophysical data sets) have been carried out in central Utah and northern Alabama. Surface lineaments have been found to match with fractures, fracture zones, paleochannels, and zones of ground control problems at the mine level. Using a zone of 250-ft radius around the lineaments as projected onto the mine map, approximately 80 pct of the known ground control problems in the two Utah study mines matched with these zones and are at least partially controlled by the presence of lineament-controlling geologic structure. Likewise, a correlation of 92 pct was found between the number of roof falls and their proximity to lineaments in the Alabama study mine.

OP 141-88. Environmental Considerations for Lunar Base Engineering, by Egons R. Podnieks. Paper in Proceedings—Engineering and Construction, and Operations in Space, Albuquerque, NM, Aug. 29–31, 1988. Aerospace Div., ASCE, 1988, pp. 55–66. Currently a large number of conceptual designs are being offered for the lunar base involving various types of structural materials and equipment for construction or resource recovery. In these endeavors, the effects of the lunar environment are frequently overlooked, and the proof-of-concept tests are conducted in Earth atmosphere. The importance of considering lunar environmental aspects must be stressed in planning the lunar base and in developing methods for construction, mining, extraction, and utilization of lunar resources. The general findings in this paper are based on the experience of Apollo astronauts and on Bureau of Mines research results.

OP 142-88. The Evolving Role of Task-Group Leaders: A Field Study, by Robert F. Randolph. Paper in Proceedings of the Human Factors Society—32nd Annual Meeting. Human Factors Soc., 1988, pp. 760–764. Leaders of task-oriented production groups play an important role in their groups' functioning and performance. That role also evolves as groups mature and learn to work together more smoothly. The present study uses a functional analysis of the evolving role of supervisors of underground coal mining crews to evaluate the impact of supervisors' characteristics and behaviors on their crews' efficiency and safety, and makes recommendations for improving supervisory selection and training. Data were

gathered from a sample of 138 supervisors at 13 underground coal mines. Detailed structured observations of the supervisors indicated that most of their time was spent attending to hardware and paperwork, while comparatively little time was spent on person to person "leadership." The findings point out that while group needs changed over time, the supervisors' behaviors typically did not keep pace and probably restricted group performance.

OP 143-88. Economic Reconnaissance of Selected Placer Deposits of the U.S. Exclusive Economic Zone, by Joseph L. Ritchey. Marine Min., v. 7, No. 3, 1988, pp. 219-231. The Bureau of Mines performed an "economic reconnaissance" of mineral resources on the Outer Continental Shelf in response to proposals by the Department of the Interior's Minerals Management Service to offer offshore mineral leases. Three marine placer areas were investigated in detail because of their perceived near-term potential for containing economically viable deposits: (1) gold-bearing placers near Nome, Alaska; (2) chromite-rich black sands offshore southern Oregon; and (3) titanium-bearing sands on the Atlantic Shelf off Virginia and Georgia. Available resources information was used to construct deposit models that allowed evaluation of engineering parameters and costs associated with potential mining and processing operations. Economic sensitivity analyses were performed on selected parameters to establish threshold conditions of economic viability. Estimated conditions for viable operations are distinctly different for the three resource areas. A dredging operation off Nome, Alaska, is expected to be profitable at present gold prices. Mining operations offshore southern Oregon could be viable for deposits of at least 50 million short tons (Mst) that contain recoverable grades of 6.3 pct Cr_2O_3, 1.0 pct TiO_2 (in ilmenite), 0.2 pct rutile, 0.7 pct ZrO_2, and 0.005 tr oz/st gold. Similarly, a mining operation on the Atlantic Shelf could be economically viable if large deposits are discovered that contain concentrations of heavy minerals about twice those of onshore deposits presently mined in Florida. A potentially economic grade would be 4.2 pct total recoverable oxides consisting of 3.6 pct TiO_2 in ilmenite, rutile, and leucoxene, 0.4 pct ZrO_2, and 0.2 pct total rare earth oxides in monazite.

OP 144-88. Geology and Geochemistry of Carbonate-Hosted Lead-Zinc Deposits of the Kootenay Arc (82F/East Half), by Andrew E. Sabin. Paper 1988-1 in Geological Fieldwork. British Columbia Ministry of Energy, Mines and Petroleum Resources, 1988, pp. 531-534. Carbonate-hosted, lead-zinc deposits of the Kootenay Arc have been grouped as either transgressive or concordant types, based on field characteristics. Lead isotope analyses suggest that each ore deposit type contains a unique grouping of lead ratios that do not adequately conform to the Bluebell or Shale lead growth curves. Detailed ore and gangue mineral petrology, lithogeochemistry, ore geochemistry, lead isotopy, and field evidence will be gathered and then used to qualitatively and quantitatively compare and contrast among these carbonate-hosted deposits.

OP 145-88. Tin Availability—Market Economy Countries: A Minerals Availability Appraisal, by Andrew E. Sabin. Tin International Special Issue: The Market for Tin (Proc. 1st Int. Tin Symp.). 1985, pp. 79-103. The Bureau of Mines determined costs associated with the production of tin from 18 market economy countries (MEC's). The resource and relative economic positions of 146 tin deposits or regions were evaluated. The demonstrated resource of recoverable tin metal within the countries evaluated is estimated to be 2.8 million mt. Over 73 pct of this total is recoverable from three Southeast Asian countries, Malaysia, Thailand, and Indonesia; all are members of the International Tin Council (ITC). In recent years, Brazil, a nonmember of the ITC, has become a major low-cost, high-volume supplier of tin and has tin resources that could allow it to maintain, or perhaps increase, current production levels. Given the 1984 tin market price of US$5.69/lb in January 1984 dollars, over 60 pct of demonstrated tin resources are economically recoverable.

OP 146-88. Tin Availability, ed. by Andrew E. Sabin. Tin International, v. 59, No. 1, Jan. 1986, pp. 11-15. Engineering, geologic, and economic data were gathered for most producing and developing tin deposits in market economy countries. Economic time diagrams were constructed for each deposit or mining district. Ten- and 15-pct discounted cash flow rate of return analyses incorporating in-house tax data, cost indices, and currency exchange rates were performed on each deposit or district. Operating and production costs, in 1984 U.S. dollars, together with current and projected production schedules over the deposits' lives, were reported for 146 deposits and districts. Malaysia, Thailand, Indonesia, and Brazil are the world's major tin-producing countries. Most tin is produced by surface gravel pump or dredging methods; these methods require minor capital investments and are relatively low-cost operations that exploit large volumes of low-grade tin ore. At a spot market price of $5.69/lb refined tin, the majority of the world's tin production, reported in production costs exclusive of transportation to New York, was operating at a minor to negative cash flow.

OP 147-88. Tin Availability in Market Economy Countries, by A. E. Sabin, D. I. Bleiwas, and G. R. Peterson. Natural Resources Forum, v. 10, No. 3, Aug. 1986, pp. 267-280. The Bureau of Mines determined costs associated with the production of tin from 18 market economy countries (MEC's). The resource and relative economic positions of 146 tin deposits were evaluated. Demonstrated resources of recoverable tin metal are estimated to be 2.8 million mt. Over 70 pct of this material is recoverable from three Southeast Asian countries—Malaysia, Thailand, and Indonesia; all are members of the International Tin Agreement (ITA). In the last 5 yr, Brazil has become a major, low-cost tin producer. In light of its large resources, Brazil has become a dominant MEC tin producer and one of the world's few tin producers that can prosper during a protracted period of low tin prices.

OP 148-88. Mining Machine Orientation Using Inertial, Magnetic, and Gravitational Sensors, by John J. Sammarco. Paper in Conference Record of the 1988 IEEE Industry Applications Society Annual Meeting, Part II. IEEE, 1988, pp. 1260-1262. The Bureau of Mines is developing methods and devices that show promise in improving mine safety and increasing productivity. One such area of research is autonomous operation of a mining machine. With autonomous operation workers would be relieved of dangerous tasks, and exposure to hazardous areas would be reduced. Productivity gains could be realized by optimizing machine operation through computer control. Autonomous operation requires integration of many subsystems in the areas of navigation-positioning, computer control, and data acquisition. Our stage of research is solving the navigation and positioning tasks. A combination of devices will be used. A directional gyroscope provides heading (yaw), flux-gate sensors provide a compass heading, and gravity-referenced clinometers give machine tilt and roll information. Methods to reduce the operating limitations of these sensors are developed through an understanding of the sensors and their application to room-and-pillar mining operations. This paper discusses results obtained using a Joy 16CM continuous mining machine at the Bureau of Mines Pittsburgh Research Center. Future areas of work are also discussed.

OP 149-88. Lightning Warning Systems Pay Off! by Lon D. Santis. J. Expl. Eng., v. 6, No. 3, Sept.-Oct. 1988, p. 32. This paper briefly reviews lightning-caused premature initiations of explosives in U.S. mines and shows how lightning warning devices can significantly reduce the chances of experiencing these undesirable events.

OP 150-88. A Generalized Network With Material Routing for Mineral Supply Analysis, by D. J. Shields, R. Glover, and F. Glover. Paper in APCOM 87: Proceedings of the Twentieth International Symposium on the Application of Computers and Mathematics in the Mineral Industries. S. Afr. Inst. Min. and Miner., v. 3, 1987, pp. 303-309. The Bureau of Mines has developed a microcomputer-based mineral modelling system that enhances the analytical capabilities of the agency. It draws upon the extensive data base previously developed for the Bureau's Availability studies. The model is first formulated as a generalized network flow optimization problem, the optimal flows from which are fed into a transportation algorithm. The goal of the modelling system is first to fulfill prespecified demand at the minimum opportunity cost, and second to identify feasible, optimal trade patterns. The system facilitates the analysis of policy issues on a real-time basis and supports the Bureau's mission to assess mineral resources.

OP 151-88. A Network Flow Model of Mineral Supply, by D. J. Shields and R. J. Hurdelbrink. Paper in 19th APCOM Symposium: Proceedings of the Nineteenth International Symposium on the Application of Computers and Operations Research in

the Mineral Industry. Soc. Min. Eng. AIME, 1986, pp. 775–783. This paper describes a dynamic short-run mineral supply model that incorporates secondary processing, transportation, mineral market structure, and direct mining and milling costs. The method employed is network flow programming. Empirical tests utilizing domestic phosphate industry data have been conducted by the Bureau of Mines. In the model, nodes represent physical locations such as a mine or port. Arcs represent either a process, such as mining, or movement, such as rail or barge transport. Each arc is described by lower or minimum allowable flow bounds, upper or maximum possible flow bounds, and variable cost. Mines and previous period inventories represent potential supply. The model is optimized via a cost minimizing algorithm, which attempts to fulfill stated total demand at the minimum possible system cost given the arc constraints. An optimal solution of the model will predict production patterns by mineral property for each prespecified level of demand. A mineral property is defined as a separate accounting entity such as a mine. The results of serial optimizations are used to construct the short-run supply curve. Dynamic policy analysis can be conducted by altering the arc constraints.

OP 152–88. Foreign Investment Increasing in U.S. Minerals Industry, by Louis J. Sousa, Elizabeth H. Yaremchuk, and Annette P. Graham. Min. Eng., v. 40, No. 8, Aug. 1988, pp. 795–799. Responding to Congressional inquiries regarding the purchase of a number of major domestic mining and metals companies by foreign firms, the Bureau of Mines examined trends in foreign direct investment in the U.S. mining and mineral processing industries. This paper analyzes the extent of foreign investment in several major mineral commodity industries, and identifies the countries of origin of foreign investment in U.S. mineral assets. The study also describes several reasons for the growth of foreign investment, in U.S. minerals and discusses some potential implications of this activity.

OP 153–88. The Outlook for the United States Phosphate Rock Industry and Its Place in the World, by William F. Stowasser and Richard J. Fantel. Soc. Min. Eng. AIME Preprint 85–116, 1985, 11 pp. The United States has traditionally been the world's largest producer and net exporter of phosphate rock and related fertilizer products with the exception of rock exports from Morocco. In recent years, however, U.S. producers have faced increasing competition from operations in foreign countries, leaving the future position of the U.S. phosphate industry as a leader in the world markets somewhat less certain. This paper reviews the U.S. phosphate rock industry in relation to its known demonstrated reserves, its historical and present production and export levels, and its future mining potential. The paper includes an analysis of the availability of phosphate rock in the United States represented by cost-tonnage relationships.

OP 154–88. Supercritical Fluid Extraction Apparatus for the Mineral Processing Laboratory, by W. K. Tolley, P. B. Altringer, S. R. Crane, and D. C. Seidel. Paper in Proceedings of the Reinhardt Schumann International Symposium on Innovative Technology and Reactor Design in Extraction Metallurgy. Metall. Soc. AIME, 1986, pp. 885–889. Supercritical fluids are being investigated extensively as solvents to selectively extract valuable components from complex matrices. Practical systems usually operate at temperatures of ambient to a few hundred degrees Celsius and pressures of 70 atm or more. Common supercritical fluids are inert, cheap, and nontoxic. Laboratory apparatus for research on the extraction of minerals and related materials with supercritical solvents can be difficult to assemble and operate smoothly. The Bureau of Mines has successfully operated a 100-mL, flow-through, supercritical extraction autoclave capable of processing both liquid and solid samples at pressures and temperatures to 400 atm and 250° C. Data are presented to indicate areas where supercritical fluid extraction could benefit the metals industry.

OP 155–88. Stripping Organics From Metal and Mineral Surfaces Using Supercritical Fluids, by W. K. Tolley, P. B. Altringer, and D. C. Seidel. Separation Sci. and Technol., v. 22, Nos. 2–3, 1987, pp. 1087–1101. Superalloy grinding swarf was treated with supercritical CO_2 alone, and with various modifiers. Experiments were conducted in a downflow batch mode at pressures of 0 to 5,000 psig, temperatures of 20° to 250° C, and times of 15 to 240 min using up to 25 g of solvent per gram of swarf. Organic dissolution increased with pressure almost linearly to 5,000 psig. Temperature affected dissolution slightly at lower pressure, but not significantly at higher pressure. Certain alcohols used as modifiers dramatically improved organic dissolution. The solvent, modifier, organics, and solids were easily recovered as separate products.

OP 156–88. Scrubbers Versus Sprayfans for Face Ventilation—A Comparison, by John C. Volkwein and Edward F. Divers. Min. Eng., Sept. 1988, pp. 898–900. Adequate ventilation of coal mine working faces is the most important technique for controlling respirable dust and methane. Choosing the right technique presents some tough questions. Bureau of Mines research has shown that to control respirable dust, dust must be contained near the face, keeping rollback (turbulence) to a minimum. For methane, the most effective approach has been to use a blowing brattice, or tubing, and to create turbulence and disperse the face methane, allowing it to pass over the machine and into the return. It is immediately apparent that the two approaches may counteract one another, thus complicating the decision as to which system may be best for a given situation. At present, Bureau research has developed two successful machine-mounted face ventilation systems to meet these different needs and allow deeper cutting. The fan-powered dust scrubber is designed to control dust primarily associated with blowing face ventilation systems. The sprayfan controls methane on exhaust-ventilated sections.

OP 157–88. Mechanical Performance of Thermally Aged Trailing-Cable Insulation, by Michael R. Yenchek and Peter G. Kovalchik. Paper in Conference Record of the 1988 IEEE Industry Applications Society Annual Meeting, Part II. IEEE, 1988, pp. 1231–1236. As part of an overall effort relating cable life and current load, the Bureau of Mines conducted research to determine the effects of elevated temperatures on the mechanical performance of coal mine trailing cable insulation. Insulation samples from six low-voltage, unshielded, portable power cables were thermally aged in air ovens. The specimens were exposed to constant temperatures ranging from 230° to 290° F for periods up to 10 months. At regular intervals over the test terms, samples were extracted and subjected to mechanical tests in accordance with Insulated Cable Engineers Association Standard S–68–516. These tests included tensile strength, elongation at rupture, hot creep elongation, and set. Characteristic variations over time were plotted for each aging temperature. Arrhenius (useful life) graphs showed that 80 pct retention of tensile strength and 50 pct retention of elongation were equally critical determinants of thermal degradation. Extrapolation to 90° C yielded useful lives ranging from 4.4 to 7.5 yr for the cables evaluated. The findings support the tentative contention that, in service underground, cables fail mechanically long before they deteriorate thermally.

OP 158–88. Recovering Valuable Metals From Cobalt-Manganese Crusts, by J. P. Allen. Paper in Proceedings, Pacific Congress on Marine Science and Technology Honolulu, HI, May 16–20, 1988. Pacific Congr. Marine Sci. and Technol., Honolulu, 1988, pp. MRM3/39–41. This Bureau of Mines paper reviews several chemical processes for extracting metals from cobalt-rich manganese crust ores and concentrates. These crusts represent a significant seabed mineral deposit of the Pacific Exclusive Economic Zone and an important resource of cobalt, nickel, and perhaps manganese. Three hydrometallurgical extraction processes—sulfuric acid oxidation pressure leaching, aqueous sulfur dioxide leaching, and hydrogen peroxide leaching—have been investigated. The first two methods have been previously tested and proved capable of extracting valuable metals from similar land-based or seabed resources. All three methods show promise in treating ocean crust materials and have resulted in metal extractions exceeding 95 pct.

OP 159–88. Chemical Processing of Cobalt-Manganese Crusts, by J. P. Allen, L. J. Froisland, and M. B. Shirts. TMS-AIME Tech. Paper A87-15, 1987, 18 pp. The U.S. Bureau of Mines is screening several chemical processes for extracting metals from cobalt-manganese crust ores and concentrates. These crusts are a seabed mineral deposit of the Exclusive Economic Zone and represent a significant resource of cobalt, nickel, and manganese. Three processes—sulfuric acid oxidation pressure leaching, aqueous sulfur dioxide leaching, and acid sulfation—have been investigated. The first two methods have been previously tested and proven capable of extracting values from similar land-based or seabed resources. All three methods show promise in treating ocean crust materials and have resulted in metal extractions exceeding 95 pct of each of the metals

mentioned above. This paper describes the pretreatment methods and leach conditions needed to achieve high metal extractions.

OP 160-88. Effect of Fluids on the Performance of Acoustical Materials, by J. A. Berks and E. R. Spencer. Paper in Noise-Con 88 (Proc. 1988 Nat. Conf. on Noise Control Eng., West Lafayette, IN, June 20-22, 1988). Purdue Univ., 1988, pp. 267-272. In a recently completed Bureau of Mines study, the effect of oil and water on the absorption coefficient of 16 different acoustically absorptive materials was investigated. The most common materials such as fiberglass, mineral wool, and urethane foams were found to suffer a substantial degradation in performance at mid-to-high frequencies. However, anomalous behavior was observed in the high-density fibrous materials when exposed to oil; in contrast to an expected reduction in the absorption coefficient, a significant improvement at low frequencies was measured. This paper describes work undertaken to further investigate this unexplained effect, as well as the effects of other physical agents.

OP 161-88. A Biomechanical Analysis of Manual Materials Handling Tasks in Restricted Working Postures, by Sean Gallagher and Richard L. Unger. Paper in Proceedings of the Human Factors Society 32nd Annual Meeting. Human Factors Soc., 1988, pp. 670-674. The U.S. Bureau of Mines has developed a biomechanical modeling system to examine the stresses on the lumbar spine when lifting in stooped and kneeling work postures utilized by low-seam underground coal miners. This system allows Bureau researchers to digitize two videotaped views (frontal and sagittal) of underground miners performing various lifting tasks under laboratory conditions. These points are then translated into a three-dimensional coordinate system, and a link man (developed from known anthropometry of the subject) is fitted to the 3-D coordinates. The centers of mass for the various links are calculated according to the body type (rotund, muscular, thin, or median) of the subject. Compression results were estimated using a linear programming internal-external load model. The location of the L_3 vertebral body center was calculated based upon anthropometric data and morphometric studies of the lumbar spine. Results of the compression and shear force analyses for restricted lifting postures are presented and discussed.

OP 162-88. Effect of Solution Composition on Redox Potentials of Platinum and Sulfide Mineral Electrodes, by J. E. Gebhardt and K. B. Shedd. Paper in Electrochemistry in Mineral and Metal Processing II, ed. by P. E. Richardson and R. Woods. Electrochem. Soc., v. 88-21, 1988, pp. 84-100. As part of a Bureau of Mines investigation of the feasibility of using electrochemical potential as a control parameter in sulfide mineral flotation, the effects of copper and iron species on the response of the electrochemical potentials were examined for platinum (Pt), chalcopyrite ($CuFeS_2$), chalcocite (Cu_2S), and pyrite (FeS_2) electrodes. Electrode potentials were measured in copper (II) and iron (II) sulfate solutions under nitrogen, oxygen, and open-to-air conditions. In general, the potentials agreed with thermodynamic values. In the absence of oxygen, electrode potentials were pH independent in the acidic pH range but were dependent on metal ion concentration. In the alkaline pH range, electrode potentials varied with pH as a result of passivation of the electrode surface due to the formation of oxides and hydroxides. The Pt and mineral electrode potentials, with the exception of Cu_2S in copper (II) sulfate solution, were sensitive to the presence of oxygen. Redox potential values measured in a copper-molybdenum rougher flotation circuit of an operating plant are presented. Electrode potentials measured in the plant for FeS_2 and $CuFeS_2$ follow the equilibrium for FeS_2 and hydrous Fe (III) oxide in the pH range 10 to 12.

OP 163-88. Corrosion Rate Determination in Industrial Ore Grinding Environments, by A. E. Isaacson, P. J. McDonough, and J. H. Maysilles. Paper 240 in Corrosion 88, Nat. Assoc. Corrosion Eng., 1988, 23 pp.; paper in Process Mineralogy VII, Metall. Soc. AIME, 1988, pp. 441-459. Bureau of Mines researchers developed and tested equipment to measure corrosion rates on a commercial-scale mill as an aid in predicting the effect of corrosion on minerals and how this effect relates to downstream processing. Bench-scale experiments were designed for duplicating ore grinding conditions closely enough that realistic rate determinations can be made in laboratory tests. Rates measured in a laboratory system compared favorably with those measured in the field. Cast steel was found to have corrosion rates in a copper mill and laboratory test cell of 22 and 21 mpy, respectively. Corrosion was found to account for less than 5 pct of the total grinding media wear in the operations studied.

OP 164-88. Human Factors Contributing to Groundfall Accidents in Underground Coal Mines: Workers' Views, by Robert H. Peters and William J. Wiehagen. Paper in Proceedings of International Conference on Ergonomics, Occupational Safety and Health and Health and the Environment, Beijing, Oct. 24-28, 1988. Chinese Society of Metals, 1988, pp. 242-253. Also available in Min. Sci. and Technol., v. 7, Nov. 1988, pp. 285-294. This paper presents findings from a Bureau of Mines study on barriers that may prevent miners from correcting and avoiding groundfall hazards. Such barriers stem from four basic types of problems: (1) inability to recognize groundfall hazards, (2) inability to correct groundfall hazards, (3) lack of motivation to search for groundfall hazards, and (4) lack of motivation to correct groundfall hazards. Data are presented that summarize the views of miners and mine inspectors about the contribution of these barriers to groundfall accidents and what they think should be done to reduce the frequency of injuries caused by falls of roof and rib. The paper also includes a summary of miners' responses concerning their recent experiences with groundfall accidents.

OP 165-88. Evaluation of Additives To Inhibit the Spontaneous Combustion of Coal, by Alex C. Smith and Yael Miron. Paper in Chemical and Physical Processes in Combustion. Combustion Inst., 1988, pp. 40-1 to 40-4. The effectiveness of several additives to inhibit the self-heating of coal was evaluated in the Bureau of Mines adiabatic heating oven. Aqueous solutions were applied to a bituminous coal with a high spontaneous combustion potential, and the minimum self-heating temperatures (SHT's) of the dried coal-additive mixtures were determined. The relative effectiveness of the additives was determined by the observed changes in the minimum SHT's of the mixtures compared to the untreated coal and a coal-water blank. The relative effectiveness of the additives within a group of coal-additive mixtures with the same minimum SHT was determined by the time required for the sample temperature to reach 150° C. Sodium nitrate, sodium chloride, and calcium carbonate were found to be the most effective inhibitors, followed by ammonium dihydrogen phosphate, calcium chloride, ammonium chloride, sodium acetate, and potassium chloride. Two additives, sodium formate and sodium phosphate, promoted the self-heating process. Differential scanning calorimetry experiments on the coal-additive mixtures showed that reactions occurred between the coal and some of the additives, but these reactions did not influence the self-heating process.

OP 166-88. The Changing World of Metals, by Louis J. Sousa. Advanced Materials and Processes, v. 134, No. 3, Sept. 1988, pp. 27-30. This article discusses structural changes that have occurred on both the supply and demand sides of the major metal markets. It also addresses the recent strategies that the major U.S. metal producers have employed in order to adjust to these long-term trends.

OP 167-88. Noise Reducing Technologies for Newly Designed Percussion Drills, by Roy C. Bartholomae and Robert R. Stein. Paper in Noise-Con 88 (Proc. 1988 Nat. Conf. on Noise Control Eng., West Lafayette, IN, June 20-22, 1988). Purdue Univ., 1988, pp. 123-128. The culmination of a long-term Bureau of Mines research effort into hand-held pneumatic percussion drill noise controls has resulted in the commercial availability of a reduced-noise hand-held pneumatic drill that is as quiet as similar classes of hydraulic drills. This technology can also be used to redesign other classes of pneumatic percussion drills and should result in similar noise reductions of up to 15 dBA. It is important to note that this reduced-noise drill has similar drilling rates to existing drills. Also similar classes of hand-held percussion drills weigh about 50 pct more than this new design, which has a fiberglass feedleg. This weight reduction has the potential to greatly increase production owing to reduced times to set the drill up to drill each hole. At the same time the reduced weight has the potential to reduce the incidence of back injuries.

OP 168-88. Nickel Production—1987 and 1988, by Donald I. Bleiwas. Paper in Extractive Metallurgy of Nickel

and Cobalt, ed. by G. P. Taylor and C. A Landolt. Metall. Soc., 1988, pp. 3–12. World primary nickel production in 1987 is projected by the Bureau of Mines to be 770,000 mt, slightly higher than that in 1986. Market economy country (MEC) production in 1987 is projected to be about 524,000 mt, an increase of almost 5 pct over 1986 production. Production cutbacks and closures at Japanese ferronickel plants in 1987 resulted primarily from the strong yen and higher energy prices. Cutbacks also caused reductions in ore production from Indonesia, New Caledonia, and the Philippines. Technical problems affected production, to varying degrees, in Botswana, Indonesia, and Yugoslavia. World primary nickel production for 1988 is projected to be 787,000 mt, of which 536,000 mt will be produced in MEC's. Increased production is projected from Botswana, Canada, Cuba, and possibly Greece and Yugoslavia, while slight production decreases are projected for Indonesia, New Caledonia, the Philippines, and Zimbabwe. South African nickel production in 1988 could be severely curtailed by social strife. In the early 1990's Brazil and China could be major economic competitors to Western nickel producers.

OP 169-88. Primary Cobalt Production, by William S. Kirk and Donald I. Bleiwas. Paper in Extractive Metallurgy of Nickel and Cobalt, ed. by G. P. Taylor and C. A. Landolt. Metall. Soc., 1988, pp. 13–19. World cobalt production in 1987 was estimated by the Bureau of Mines to be about 26,600 mt, of which market economy country (MEC) production was estimated to be about 22,000 mt. Zaire and Zambia produce about 80 pct of the primary cobalt produced among MEC's. Production cutbacks, declining cobalt grades, and mining curtailments in Finland and Zambia in 1987 resulted in lower production than that of 1986. The trend is expected to continue through 1988. Cobalt production from Canadian ores and from Botswana is expected to increase significantly in 1988 as a result of increased nickel production. MEC production in 1988 is estimated to be 22,100 mt, only slightly higher than that of 1987. There are currently no primary cobalt mines. Virtually all cobalt is recovered as a byproduct of copper and/or nickel mining. Zaire, which produces cobalt as a byproduct of copper, is the world's largest cobalt producer, with over 50 pct of total estimated world cobalt production and nearly 65 pct of MEC production. Zambia follows with about 14 pct and 17 pct, respectively. Zambia's cobalt production also results from copper production.

OP 170-88. Competition Among Producers in the World Copper Market, by K. E. Porter and Paul R. Thomas. Eng. and Min. J., v. 189, No. 11, Nov. 1988, pp. 38–44. Numerous factors have influenced the competitive position of producers in the world copper industry in recent years. The oversupply of copper and low metal prices have caused producers throughout the world to institute rationalization and cost reduction measures in an attempt to improve their competitive position and profitability. Many operations made changes in their mine plans. Stripping ratios were lowered, pit slopes were increased, mill feed grades were raised, manpower requirements were reduced and wage rates cut, new smelting and refining charges were negotiated downward, and technological improvements were implemented. Some high-cost operations were unable to compete in the world market and were forced to close down. These factors resulted in copper production-cost reductions in many countries, some significant. Other factors beyond the control of mine operators also influenced production costs. In some countries, inflation, exchange rates, Government policy, and byproduct prices offset many cost-reduction measures. This resulted in a reordering of the competitive position of the major copper-producing countries in the years 1981 to 1986. Zaire and Zambia, for example, improved their competitive positions, while the United States and Canada, despite implementing some of the same cost-reduction measures as other countries, saw little or no improvement in their positions. To assess the results of cost-cutting steps implemented by domestic producers as well as the long-term viability of the U.S. copper industry, it is necessary to view these efforts in an international context, measured against the relative success of similar cost-cutting efforts undertaken by other producers and the effects of inflation, currency devaluations, and market trends.

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OP 1-89. Training Miners To Recognize Roof and Rib Hazards Using 3-D Slides, by Edward A. Barrett and William J. Wiehagen. Paper in TRAM XIV: Training Resources Applied to Mining (Proc. Conf. PA State Univ., University Park, PA, Aug. 16–19, 1987). Nat. Mine Health and Safety Academy, 1987, pp. 122–130. Ground control accident reports frequently have concluded that injuries and fatalities occurred because roof or rib hazards were not detected by the worker. One component, therefore, in the prevention of such accidents could be the ability of miners to recognize the visual cues that are associated with the geologic or mining-induced irregularities that precede roof and rib falls. Even though knowledge of hazardous ground conditions may be extensive due to years of experience, the miner may not be competent in recognizing the warning signs of imminent danger. The competent miner, as a minimum, should be able to perceive, recognize, and correct potentially dangerous roof and rib conditions. The visual skills needed for recognition of ground hazards may be taught in the classroom if training aids are available that can realistically simulate actual mine conditions. Stereoscopic (3–D) slides are that type of training aid, a high-fidelity medium for representing roof and rib hazards, and, as such, provide an excellent proxy for instructing miners about dangerous ground conditions. To this end, practical and inexpensive 3–D photographic equipment and procedures have been advanced by the Bureau of Mines to the level that mine companies can develop, in-house, customized, stereo slide ground control training materials.

OP 2-89. Pilot Subject Evaluation of Whole-Body Vibration From an Underground Mine Haulage Vehicle, by Thomas G. Bobick, Sean Gallagher, and Richard L. Unger. Paper in Preprints of International Conference on Ergonomics, Occupational Safety and Health and the Environment (Beijing, Oct. 24–28, 1988). Chinese Soc. Met., v. 1, 1988, pp. 182–194. The Bureau of Mines has developed an in-house test facility to evaluate some of the effects of whole-body vibration levels experienced by underground mobile equipment operators. Vibration data were collected from a coal haulage vehicle via a uniaxial accelerometer (vertical direction) attached to the machine frame under the operator's seat. The data were analyzed and processed so a computer-controlled vibration platform could approximate the vibration signals. Six men (36.0 yr of age $\pm$ 6.9 SD) participated in a pilot study to evaluate the effects of shock and whole-body vibration on heart rate (HR), blood pressure (BP), back extensor strength, stature, manual dexterity, and subjective discomfort. The subjects were exposed to vibration for 30-min periods while seated in a typical operator's seat (with the backrest angle at 90° or 130°) that was plain steel or modified with 2 in of foam padding. To control for diurnal variations in stature, HR, and BP, each subject repeated the same order of tests on a separate day, but without the vibration. Results indicated that vibration significantly increased the HR, systolic BP, mean BP, and the overall subjective discomfort rating ($p < 0.05$). Also, the number of times subjects reported discomfort increased significantly during vibration ($p < 0.05$) and when seated in the steel seat ($p < 0.005$). The seat back angle had no significant effect on any of the dependent measures.

OP 3-89. Computer Simulation of Face Ventilation To Dilute High Methane Concentrations Developed by Blasting Oil Shale, by C. E. Brechtel and E. D. Thimons. Paper in Computer Applications in the Mineral Industry, ed. by K. Fytas, J.-L. Collins, and R. K. Singhal (Proc. 1st Can. Conf. on Computer Applications in the Miner. Ind., Quebec, Canada, Mar. 7–9, 1988). Balkema, 1988, pp. 605–612. In this Bureau of Mines study, a one-dimensional finite element model was used to simulate turbulent mass transfer in face ventilation of oil shale mines. The computer model was applied to study dilution of methane released by rubblizing oil shale during face blasting. A methane release function was back-analyzed from field measurements, and the finite-element model was calibrated using tracer gas characterization of full-scale face ventilation systems.

OP 4-89. Sulfur Enrichment at Sulfide Mineral Surfaces, by A. N. Buckley and G. W. Walker. Paper in XVI International Mineral Processing Congress, ed. by E. Forssberg. Elsevier, 1988, pp. 589–599. Recent electrochemical and X-ray photoelectron spec-

troscopic (XPS) investigations of sulfur enrichment at sulfide mineral surfaces have been reviewed. The nature of the hydrophobic species acquired in the absence of conventional collectors by some sulfides under oxidizing conditions or when treated with hydrosulfide in the presence of oxygen has been discussed. It is concluded that the sulfur-rich surfaces resulting from metal loss in the former case, and sulfur deposition in the latter, are not significantly different in principle. A distribution of sulfur environments is possible, from sulfidic to bulk-elemental in character, depending on the proximity to metal atoms. For low sulfur enrichment, the surface is best regarded as a metal-deficient sulfide. A moderately high level of metal deficiency may result in restructuring to form a polysulfide.

OP 5-89. Spark Ignition Probability Estimates for Resistor and Inductor Circuits in Methane-Air Atmospheres, by James C. Cawley. IEEE Trans. on Ind. Applications, v. 24, No. 5, Sept.-Oct. 1988, pp. 878–883. Safety factors are employed by the engineering profession to ensure that a margin of safety exists between engineering test conditions and the conditions of actual or anticipated use. The safety factor presently used by the Mine Safety and Health Administration (MSHA) to assess the safety of electronic circuits for use in methane-air atmospheres is a factor of 1.5 on energy at the point of test plus two worst-case faults. A precise knowledge of the degree of safety over and above the conditions of actual use obtained by using the 1.5 factor, however, is not easily determined. The Bureau of Mines is engaged in intrinsic safety research that will ultimately relate the conditions of test and actual use by estimating the simple ignition probability, p_i, versus current for circuits in an 8.3 pct methane-air atmosphere. The experimental design minimizes the probability of not observing an ignition that should occur during a series of tests. For resistive circuits in 8.3 pct methane-air mixtures, no ignitions were observed below 2,000 mA at 20 V dc, 350 mA at 30 V dc, 150 mA at 40 V dc, and 175 mA at 50 V dc. The simple probability of ignition corresponding to these currents is estimated to be, respectively, 1.0×10^{-6}, 1.7×10^{-7}, 3.0×10^{-7}, and 1.0×10^{-5}. Results for inductive circuits show that ignition was not obtained below 35 mA for 600 mH, 90 mA for 100 mH, 230 mA for 10 mH, and 700 mA for 1 mH, corresponding to an estimated probability of ignition of 3.8×10^{-6}, 4.0×10^{-6}, 2.0×10^{-6}, and 3.3×10^{-7}, respectively. The ignition mechanism seems to break down below this point, implying that a threshold value exists, below which spark ignition does not occur.

OP 6-89. Respirable Dust Control in Coal Preparation, by E. F. Divers and R. A. Jankowski. Min. Eng., v. 40, No. 12, Dec. 1988, pp. 1111–1114. In response to a request from the Mine Safety and Health Administration, the Bureau of Mines completed a respirable dust survey of 18 U.S. coal preparation plants. Of these, three were essentially free of dust problems. Respirable dust exposure of workers in the remaining plants depended on the time spent in the dusty areas. In five of the plants surveyed, Bureau tests showed that in some areas worker exposures could exceed Federal dust limits in less than 2 h. Cooperative studies were arranged with coal preparation plants using three different dust control techniques. These included a standard baghouse-type dust collector, two types of scrubbers, and an electrostatic precipitator. Results of these evaluations are presented. Various types of ventilation systems used during summer and winter conditions were also evaluated. Results showed that appropriate ventilation can provide a highly cost-effective method for controlling coal preparation plant dust.

OP 7-89. Gold Metallurgy—A Historical Perspective, by J. A. Eisele. Can. Metall. Q., v. 27, No. 4, 1988, pp. 287–291. This Bureau of Mines paper reviews the extractive metallurgy of gold, starting with the introduction of cyanide leaching in 1887. Cyanidation procedures involving the loading and stripping of gold from activated carbon are described. Recent developments including treatment of refractory ores, biological processes, and alternative leachants are summarized.

OP 8-89. Electrochemical Effects on Rock Drilling, by W. H. Engelmann, P. J. Watson, P. A. Tuzinski, J. E. Pahlman, and S. E. Khalafalla. J. Electrochem. Soc., v. 135, No. 4, Apr. 1988, pp. 1043–1044. A strong correlation was found between drilling performance and the zeta potential at the rock-solution interface. Maximized drilling performance occurred where the ionic concentration produced a zero point of charge (ZPC). At the rock ZPC, the zeta potential is also zero. A model based on correlations between the electrical double layer profiled in the rock interfacial layer and Lippmann's electrocapillarity curve is proposed to account for the observed phenomena. At the ZPC concentration, the rock interfacial tension is maximized; drilling enhancement is also maximized, possibly because the rock is weaker in tension than in compression. Surface tension reducers are efficient in chemical crack propagation. Taking drilling as an activated cracking with catastrophic growth of microcracks into more destructive ones, it is possible that the interfacial tension, or surface energy, must first reach a critical tension before fragmentation occurs, with an overall lowering of the interfacial tension. This distinction between the kinetic process of drilling and the thermodynamic transition of crack formation explains why an increase in interfacial tension can facilitate drilling by lowering the energy barrier for rock fragmentation.

OP 9-89. Preliminary Recommendations for Handling and Lifting Materials in Underground Low-Coal Mines, by Sean Gallagher, Thomas G. Bobick, and Richard L. Unger. Paper in Preprints of International Conference on Ergonomics, Occupational Safety and Health and the Environment (Beijing, Oct. 24–28, 1988). Chinese Soc. Met., v. 1, 1988, pp. 464–471. The Bureau of Mines has developed preliminary guidelines for handling materials in low-seam coal mines in an effort to reduce the incidence and cost of low-back pain in these mines. Three main approaches to reducing back injuries are discussed: (1) examining the supply-handling systems currently in use at low-seam coal mines through task analysis, (2) research and development of task-specific materials-handling hardware that would reduce the number of manual lifts in underground coal mines, and (3) examining the lifting capacity of low-seam coal miners in the restricted postures that must be used in underground mines. Results of the task analysis indicated that the predominant posture used to handle materials underground was kneeling on two knees (58.3 pct of materials-handling tasks documented on videotape), followed by stooped (18.5 pct), kneeling on one knee (16.2 pct), and other (7.0 pct). Mechanical-assist devices developed by the Bureau include a rail-timber handling car that effectively eliminates the need for manual lifting of heavy wooden crossbeams or sections of steel rail for roof support, and a heavy component lift-transport to assist with such jobs as installing drive motors on shuttle cars or replacing wheels on underground vehicles. Experimental studies upon which lifting recommendations are established include biomechanical studies of lifting in the kneeling posture, studies examining the metabolic cost of performing various underground materials handling tasks, and psychophysical studies used to establish maximum acceptable weights of lift (MAWL) in both kneeling and stooped postures. Significant findings include that the kneeling MAWL is lower than MAWL in the stooped posture ($p < 0.05$), while heart rate is higher during kneeling tests ($p < 0.01$). Preliminary acceptable weights of lift based on psychophysical testing are 43.5 lb in the kneeling posture and 54.0 lb in the stooped posture for materials that are handled in a repetitive manner. Additional research findings and recommendations are presented and discussed.

OP 10-89. Lifting in Stooped and Kneeling Postures: Effects on Lifting Capacity, Metabolic Costs, and Electromyography of Eight Trunk Muscles, by Sean Gallagher, William S. Marras, and Thomas G. Bobick. Int. J. Ind. Ergonomics, v. 3, No. 1, Nov. 1988, pp. 65–76. Twelve healthy, experienced underground coal miners performed lifting-capacity tests in stooped and kneeling postures using a modified psychophysical procedure. Subjects adjusted weight in a lifting box to the maximum they could handle without undue fatigue in an asymmetric lifting task. Lifting periods were 20 min in duration, and the frequency was 10 lifts/min. Tests were performed under a 48-in roof that restricted the subject's posture. Psychophysical, physiological, and biomechanical dependent measures included the maximum acceptable weight of lift (MAWL), heart rate (HR), rate of oxygen consumption ($\dot{V}O_2$), ventilation volume rate, respiratory exchange ratio, and integrated electromyography (EMG) of eight trunk muscles. Results indicated that MAWL was significantly lower when kneeling than when stooped ($p < 0.05$). Furthermore, metabolic demands were greater in terms of HR ($p < 0.005$) and VO_2 ($p < 0.05$) when kneeling. Left and right erectores spinae muscles exhibited increased EMG activity in the kneeling posture ($p < 0.001$). It was concluded that psychophysical lifting capacity is decreased, while the metabolic stress and internal load on the spine are increased, in the kneeling posture. Results of this Bureau of Mines study indicate that it may be advisable to reduce the weight of materials that are handled repetitively in the kneeling posture.

OP 11-89. A Biomechanical Analysis of Manual Materials Handling Tasks in Restricted Working Postures, by Sean

Gallagher, Richard L. Unger, and Thomas G. Bobick. Paper in Preprints of International Conference on Ergonomics, Occupational Safety and Health and the Environment (Beijing, Oct. 24-28, 1988). Chinese Soc. Met., v. 2, 1988, pp. 1150-1156. The Bureau of Mines has developed a biomechanical modeling system to examine the stresses on the lumbar spine when lifting in stooped and kneeling postures utilized by low-seam underground coal miners. This system allowed Bureau researchers to digitize two videotaped views (frontal and sagittal) of underground miners performing various lifting tasks under laboratory conditions. These points were then translated into a three-dimensional coordinate system, and a link man (developed from known anthropometry of the subject) was fitted to the 3-D coordinates. The centers of mass for the various links were calculated according to the body type (rotund, muscular, thin, or median) of the subject. This model employed the linear programming internal-external load model developed by Schultz, *et al.* The location of the L_5 vertebral body center was calculated based upon anthropometric data and morphometric studies of the lumbar spine. Results of the compression and shear force analyses for restricted lifting postures are presented and discussed.

OP 12-89. Ergonomically Designed Operator Workstation for a Computer-Aided, Remotely Controlled Mining System, by August J. Kwitowski, William H. Lewis, and William D. Mayercheck. Paper in Preprints of International Conference on Ergonomics, Occupational Safety and Health and the Environment (Beijing, Oct. 24-28, 1988). Chinese Soc. Met., v. 1, 1988, pp. 362-373. The Bureau of Mines, in conjunction with a U.S. cooperator, is jointly developing new technology to economically mine a greater percentage of coal reserves in highwall outcrop settings. This new mining system features a computer-based remote control subsystem for distant, out-of-the-line-of-sight control of a thin-seam continuous miner and coal haulage units. A single operator, situated within a protective enclosure on a highwall bench at an ergonomically designed workstation, controls all the coal extraction and haulage equipment that penetrate into the coal seam deep within the hillside. This workstation consists of a special task chair, two control modules, two color video monitors, an array of displays, and a control computer. Details of this operator workstation, a summary of the overall highwall mining system, and current test status are discussed.

OP 13-89. Fast-Response, Wet-Bulb Thermocouple, by Nicholas Kyriazi. J. Int. Soc. for Respiratory Protection, v. 6, No. 3, July-Aug. 1988, pp. 12-14. The Bureau of Mines has developed a fast-response, wet-bulb thermocouple that is able to respond on a breath-by-breath basis to the changing inhalation and exhalation wet-bulb-temperatures of a human subject while wearing a closed-circuit breathing apparatus. Bureau research has shown that wet-bulb temperature, taking into account both dry-bulb temperature and humidity, is the heat-load stressor of importance to human subjects; therefore, the ability to measure this variable is considered important. Prior to this development, the ability to measure breath-by-breath wet-bulb temperature had not been achieved.

OP 14-89. Assessment of Illumination for Tasks Performed by Operators of Mobile Surface Coal Mining Equipment, by Alan G. Mayton. Paper in Preprints of International Conference on Ergonomics, Occupational Safety and Health and the Environment (Beijing, Oct. 24-28, 1988). Chinese Soc. Met., v. 1, 1988, pp. 499-511. This paper presents a portion of the results of an extensive Bureau of Mines study to assess the task illumination needs on mobile surface mining machinery. The intent of the research was to study these needs and the visibility requirements of machinery operators in performing visual tasks. Investigations were performed at 22 surface mining operations, coal and metal-nonmetal, within several mining regions of the United States. Visibility and illumination measurements were taken for 159 visual tasks on 57 surface mining machines, including draglines, shovels, blasthole drills, bulldozers, loaders, haul trucks, graders, scrapers, and several service-type vehicles. This paper addresses only the results of investigations at surface coal mines; Bureau of Mines IC 9153 presents the overall results and recommendations of the entire study. Tables are presented that compare computed levels of luminance and illuminance for workers in the 25- and 50-yr age groups and that show that illumination, and consequently task visibility, could be improved. The paper also makes recommendations for improvements in illumination and/or task visibility.

OP 15-89. Issues and Needs of the U.S. Metal Mining Industry, by James J. Olson and John C. Nigro. Paper in Proceedings of the 62nd Annual Meeting of the Minnesota Section AIME and 50th Annual Mining Symposium (Duluth, MN, Jan. 18-19, 1989). Center for Professional Development, Continuing Education and Extension, Duluth Center, Univ. MN, 1989, pp. 1.1-1.56. Over the past 15 yr, the domestic metal mining industry has been subjected to severe stress from a variety of sources. In the 1970's, double-digit inflation created an atmosphere of uncontrolled expansion. Government attempted to temper this growth with price controls, and interest rates soared. Sharply rising energy costs, worldwide recessions in 1975 and 1982, increased Government regulation, increased foreign competition, and the acquisition of major mining companies by large international oil interests and foreign companies also impacted the metal mining industry. Clearly the basic structure of the domestic mining industry was being altered. Early in 1987, the Mining Research Directorate of the Bureau of Mines undertook an evaluation of the state of the industry to help in structuring its research programs to better respond to industry needs. The goal was to target the research on technological improvements needed to help U.S. producers regain and hold a competitive position in the world market. At the time this study was initiated, the future looked bleak for most of the industry. In the intervening 2 yr significant improvement has occurred owing to such factors as massive restructuring and plant closures, changes in tax structures, the weakened dollar, and adoption of new, more productive technology. This paper briefly reviews the key issues still confronting the metal mining industry in 1989. Characteristic trends for key commodities are documented to show the general nature of the changes that have occurred, and the needs of the producers are identified and analyzed as potential areas for research. Special emphasis is given to the problems facing the iron ore mining industry, and a brief review is provided on some of the Bureau research aimed at resolving these problems.

OP 16-89. 4,000 Ton-Per-Shift Longwalls: How Do They Do It? by J. A. Organiscak, S. J. Page, and R. A. Jankowski. Coal, Dec. 1988, pp. 31-33. Longwall mining accounted for nearly 21 pct of U.S. underground coal production in 1987. Although national longwall production normally averages about 1,900 tons-per-shift (tps), some U.S. longwall sections consistently produce more than 4,000 tps. To identify the factors responsible for this high level of production, the Bureau of Mines surveyed eight of the highest producing longwall sections in the United States. Earlier, the Bureau had examined continuous miner sections to seek out causes for high production levels. It was discovered that labor-management relations were the key factor for the continuous miner sections, especially in high coal. The Bureau wondered if this was also true for exceptionally productive longwalls. Results indicate that it was not. In longwalls, new equipment and technology are the key factors in achieving greater production.

OP 17-89. Computerized Assessment of the Illumination and Visual Requirements of Underground Mining Machines, by James P. Rider. Paper in Preprints of International Conference on Ergonomics, Occupational Safety and Health and the Environment (Beijing, Oct. 24-28, 1988). Chinese Soc. Met., v. 1, 1988, pp. 490-498. The Bureau of Mines is researching a computerized technique to assess the illumination and visibility requirements of underground mining machines. This research is part of an overall project to make available a computer-based model that could lead to better ergonomic design of mining equipment and a safer mining environment. Federal underground coal mine regulations require that designated surfaces within the miner's normal field of vision be illuminated to 0.06 ft-lambert while self-propelled mining equipment is being operated in the working place. The program simulates mine illumination systems and allows the user to quickly analyze proposed lighting configurations without resorting to building physical mockups and manually taking light readings. Through a task analysis, visual attention locations (VAL's) were developed by identifying the location of important visual features that the operator must be able to see in order to operate the equipment safely and efficiently. The location of the VAL's can be specified by their position in three planes: fore-aft, lateral or side to side, and vertical or up-down. A view from the operator's station is drawn, taking into account the field of vision at the eye, and the user then notes which VAL's can or cannot be seen and what modifications may be needed in the machine design.

OP 18-89. TiO_2 and Rare Earth Metals Recovery From Perovskite Using Acid Sulfation, by R. G. Sandberg, A. E. Petersen, and C. F. Davidson. Paper in Proceedings of the First International

Conference on the Metallurgy and Materials Science of Tungsten, Titanium, Rare Earth, and Antimony (Changsha, China, Nov. 6–11, 1988). Int. Academic Publishers, v. 1, 1988, pp. 244–249. Perovskite deposits in the United States represent a significant but unused titanium, columbium and rare earth metals resource. An acid sulfation process was developed by the Bureau of Mines that extracts up to 97 pct of the titanium and columbium and up to 90 pct of the rare earth byproducts from perovskite concentrates. A flowsheet describing the titanium recovery process is discussed. Cost evaluation results indicate that processing perovskite concentrates by acid sulfation can be an economically viable means of producing TiO_2.

OP 19–89. Supported Liquid Membrane Separation of Aluminum From Copper Leaching Liquors, by L. E. Schultze, S. P. Sandoval, J. A. Eisele, and T. G. Carnahan. Separation Sci. and Technol., v. 23, No. 12–13, 1988, pp. 1683–1693. The Bureau of Mines investigated the separation of aluminum from copper dump leaching liquors using a supported liquid membrane. Aluminum was selectively transported through porous polypropylene impregnated with di (2-ethylhexyl) phosphoric acid in an aliphatic diluent. The effects of variables, such as solution composition, temperature, and extractant concentrations, were measured using a three-level fractional factorial experimental design. Experimental results were used to derive equations for predicting transport rates for aluminum, iron, and copper. The major variables influencing aluminum transport were solution temperature, feed solution pH, aluminum concentration in the feed solution, and extractant concentration. Copper and iron transport rates were almost zero when aluminum transport rates were high. Measured aluminum transport rates under the best conditions of 55° C, pH 3.0, 16 g/L Al^{3+}, and 65 pct extractant solution confirmed the predicted value of 210 $\mu g/(cm^2 \cdot h)$. Transport rates for iron and copper were less than 5 $\mu g/(cm^2 \cdot h)$ under these conditions.

OP 20–89. Treatability Tests for Thermal Treatment and Chromium Recovery From Tannery Sludge, by Joseph J. Sczurko, L. C. George, Steven E. Paulson, and Marina P. Meier. Paper in Superfund '88: Proceedings of the 9th National Conference of the Hazardous Materials Control Research Institute (Washington, DC, Nov. 28–30, 1988). Hazardous Materials Control Research Institute, 1988, pp. 413–418. Bench-scale pyrolysis and incineration tests were performed on sludge from the Saco Tannery Waste Pits Superfund Site to assess the waste's nature when subjected to thermal treatment. Chemical analysis indicates the raw sludge contains chromium concentrations in excess of 10,000 mg/kg and a variety of organic constituents including dichlorobenzenes, xylenes, and phenols. The diverse mix of contaminants and significant levels of chromium in the 100,000 cu yd of sludge at the site supported treatability tests to assess the feasibility of chromium recovery. An extensive treatability study program conducted by the Bureau of Mines evaluated the technical aspects of applying metallurgical processes for sludge treatment and chromium recovery. Thermal treatment residues were subjected to leaching tests to analyze leachability and to help conceptualize a chromium recovery process. Waste characterization studies were also performed to provide information regarding waste structure and chromium phases. The research program is particularly important because of SARA's emphasis on utilizing alternative treatment technologies and resource recovery methods to remediate hazardous waste sites.

OP 21–89. Evaluation of Water-Jet-Assisted Cutting on Longwall Shearers, by E. D. Thimons, P. D. Kovscek, K. Neinhaus, and C. D. Taylor. Paper in Proceedings, Eighth International Conference on Coal Research (Tokyo, Oct. 16–20, 1988). International Committee on Coal Research, 1988, pp. 92–107. About 20 pct of U.S. underground coal production comes from longwall mining, and indications are that the number of longwall operations will increase significantly over the next 10 yr. For this reason the Bureau of Mines has undertaken an extensive laboratory and underground evaluation of the benefits to be derived from the application of water-jet-assisted cutting on longwall shearers. Water-jet-assisted cutting involves the interaction of a high-pressure water jet and a mechanical cutting bit with the water jet directed just in front of the bit tip. Possible benefits from water-jet-assisted cutting are improved cutting, reduced respirable dust, reduced product fines, improved bit life, and reduced frictional sparking. Full-scale laboratory tests were run at the Pittsburgh Research Center of the Bureau of Mines, where a simulated coal block was cut with a water-jet-assisted shearer. An underground evaluation of a water-jet-assisted shearer was conducted at the Auguste Victoria Coal Mine in Marl, West Germany, under a Bureau of Mines contract with Eickhoff Corp. Results obtained in the laboratory testing were similar to those obtained during underground testing. Both test programs showed that use of high-pressure water did little to reduce the shearer motor energy required to maintain a given cutting rate. However, several other major benefits were achieved with the use of water-jet-assisted cutting. At a pressure of 1,800 psi (12 MPa), respirable dust was reduced about 80 pct compared to the conventional water spray system operating at 340 psi (2.3 MPa). Operating at the higher pressures required for water-jet assist also resulted in an increase in the average size of coal cut, which translates into a decrease in product fines. Finally, while no controlled measurement of bit wear as a function of water pressure was made, mine personnel reported that the shearer bits lasted longer when water-jet-assisted cutting was being used. These findings show that use of water-jet-assisted cutting on longwall shearers can be beneficial in terms of both productivity and health and safety.

OP 22–89. Teaching Miners Proficiency With an Innovative Self-Contained Self-Rescuer Donning Method, by Charles Vaught and Henry P. Cole. Paper in TRAM XIV: Training Resources Applied to Mining (Proc. Conf. PA State Univ., University Park, PA, Aug. 16–19, 1987). Nat. Mine Health and Safety Academy, 1987, pp. 82–94. The purpose of this paper is to discuss the development of an innovative self-contained self-rescuer (SCSR) donning method, and to assess the impact of differing instructional strategies used to teach this method. The method is a generic procedure that is applicable to the four SCSR models currently being marketed in the United States. It consolidates the procedural tasks into three critical steps and three secondary steps. The "3 + 3" method has been shown to cut donning times in half and to significantly reduce errors made by trainees. The strategies used to teach this method were a live demonstration, a structured lecture, and a computer-based format. It was found that delivery strategy makes little difference as long as the content is presented thoroughly and systematically and followed up with hands-on experience. The question of how often, and at what level, miners should be retrained has not yet been answered.

OP 23–89. DOE/USBM Will Study Water-Jet Assist for Mechanized Mining of Oil Shale, by Joseph E. Virgona and Edward D. Thimons. Eng. and Min. J., v. 189, No. 9, Sept. 1988, pp. 70–71. The physical characteristics of oil shale make conventional mechanical mining methods using continuous roadheader or drum-type equipment impractical. Large amounts of machine vibration, high pick wear rates, and excessive dust generation make these methods less efficient and more costly than traditional drill-and-blast methods. Blasting, despite its advantages, also has limitations. Total resource recovery is reduced, and working conditions are less favorable. An improved, continuous, mechanized production method would increase efficiency, decrease costs, and make oil shale more competitive with other energy sources. The U.S. Department of Energy and the Bureau of Mines believe a technology currently under development would solve these problems. Called water-jet-assisted cutting, this method will be investigated in a 24-month, three-phase program.

OP 24–89. The Use of Simple Interatomic Potentials To Investigate the Relationship Between Abrasive Wear and Other Mechanical and/or Physical Properties, by M. C. Y. Lee, J. H. Tylczak, and N. H. Macmillan. Paper in Wear Resistance of Metals and Alloys, ed. by G. R. Kingsbury (Proc. of Conf. held in Conjunction with 1988 World Mater. Congr., Chicago, IL, Sept. 24–30, 1988). ASM, 1988, pp. 1–11. In wear research, as in other areas of scientific endeavor, discoveries of empirical correlations between particular properties or combinations of properties continue to be reported. Usually they extend only to a limited group of more-or-less similar materials. Ultimately, of course, all such correlations must be explicable, in principle if not in practice, in terms of a proper quantum mechanical treatment of the relationship between each of the properties involved and interatomic cohesion. In the absence of such understanding, the value of such correlations depends primarily on how widely they extend. The present paper reports a Bureau of Mines investigation into the problem of relating abrasive wear to other mechanical and/or physical properties. It begins by demonstrating that the correlation between abrasive wear and enthalpy of vaporization reported for pure metals cannot always be extended to binary alloys in which the two components exhibit complete mutual solid solubility. It then proposes a plausible, if simplistic, dislocation-based model of abrasive wear and demonstrates that this model does

not lead to any simple relationship between abrasive wear and enthalpy of vaporization, even when interatomic cohesion is characterized by very simple models.

OP 25-89. Mining Mountaintop Coal Reserves, by Richard B. Farrar and William D. Mayercheck. Paper in Proceedings: 1988 Symposium on Mining, Hydrology, Sedimentology, and Reclamation (Lexington, KY, Dec. 5-9, 1988). Univ. KY, 1988, pp. 41-46. The Bureau of Mines is conducting research aimed at providing technology for a low-cost, high-recovery, environmentally acceptable mining system to recover the vast thin-seam coal reserves existing in the mountainous areas of the Appalachian region. Approximately 1 trillion st of U.S. coal resources are located in seams 14 to 28 in thick; however, less than 5 pct of U.S. coal production comes from these resources. Approximately 40 pct of the minable coal reserves in Appalachia exist in 28- to 42-in-thick seams. These thin coal seams represent a huge energy resource left largely untapped, owing mainly to unavailable technology for commercial exploitation. In past decades, only a very small part of these reserves were exploited, with mining conducted along the contour of the mountain ridge, where the coal seam cropped out and was easy to reach. This type of contour strip mining removed only a small fraction of the total coal reserve on the mining property and scarred the landscape with highwalls for future generations. A variety of conceptual approaches are outlined and discussed to mine the mountaintop coal reserves with near-total recovery, at low cost with minimal environmental impact to the surrounding area. A successful approach in mining these thin-seam reserves will lower the overall cost of coal produced in the United States, and create a more competitive price for U.S. coal in international markets.

OP 26-89. The Prediction of Microstructure in Low-Chromium Substitutes for Stainless Steels, by Max L. Glenn. J. Mater. Eng., v. 10, No. 3, 1988, pp. 181-191. Previous Bureau of Mines research has shown that additions of Si and Al can partially replace the Cr in stainless steels for use in oxidation-resistant applications. Because an austenitic microstructure is desired for optimum mechanical properties, a series of Fe-(4 to 12)Cr-(8 to 18)Ni-(0 to 8)Si-(0 to 6)Al-1Mn-0.05C alloys were metallographically examined to determine the compositions that stabilized this austenitic microstructure and inhibited the formation of ferrite or martensite. A series of Fe-1Mn-0.05C-Si-Al metastable phase diagrams for various Cr and Ni contents were drawn to provide better predictions of alloy microstructure than does the Schaeffler diagram. At the 8- to 10-pct Cr level, an austenitic region is formed only when Ni is at least 14 pct. An equation was developed to correlate the austenite and/or ferrite content to Cr- and Ni-equivalent relationships. A second equation was developed to predict the transformation of austenite to martensite. These relationships can be used to predict alloy microstructure for Fe-base alloys containing 4 to 12 pct Cr.

OP 27-89. Physical and Chemical Properties of Potential Tailings From Manganese-Nodule Processing, by Benjamin W. Haynes, Gary W. Kramer, David C. Barron, and Stephen L. Law. Ch. 11 in Oceanic Processes in Marine Pollution, Volume 4: Scientific Monitoring Strategies for Ocean Waste Disposal, ed. by Donald W. Hood, Amy Schoener, and P. Kilho Park. Krieger, Malabar, FL, 1989, pp. 113-125. In cooperation with several Federal agencies, the Bureau of Mines is conducting research to obtain a first-order physical and chemical characterization of tailings from each of five industry-feasible, first-generation nodule-processing schemes. The results of this research will provide Federal and State agencies, as well as industrial interests, with information that will assist in commercial waste-management plans for the disposal of tailings from manganese-nodule processing. This chapter presents results of the characterization from three of the five processes as performed in the laboratory. The laboratory-generated tailings were characterized by chemical, physical, and mineralogical methods. Three leachate tests were conducted on the tailings: the U.S. Environmental Protection Agency's extraction procedure toxicity test, the American Society for Testing and Materials shake extraction test, and the U.S. Army Corps of Engineers seawater elutriate test. Test results for these first three processes indicate that the wastes are not hazardous as judged by existing regulatory definitions. Predicted tailing compositions for the remaining two processes indicate minimal environmental hazard.

OP 28-89. Investigation of the Important Parameters in a Gas Sparging Technique for Production of Tungsten Carbide, by G. Kazonich, A. E. Raddatz, and T. G. Carnahan. Metal Powder Rep., v. 43, No. 12, Dec. 1988, pp. 800-810. The Bureau of Mines conducted a study to delineate the important parameters in a three-step process to produce commercial-quality tungsten carbide (WC) directly from tungsten minerals. In the process, tungsten concentrates of wolframite or wolframite and scheelite are decomposed at 1,050°C in a molten mixture of NaCl and Na_2SiO_3 that forms two immiscible phases. Tungsten, as sodium tungstate, reports to the halide phase and is separated from the gangue constituents, which report to the silicate phase. After decanting to separate the two phases, natural gas is sparged into the molten halide phase at 1,070°C. Submicrometer crystals of tungsten carbide are initially produced. These crystals grow into thin, triangular-shaped plates up to 100 μm on a side or into popcorn-shaped conglomerates.

OP 29-89. Selective Electrowinning of Mercury From Gold Cyanide Solutions, by S. A. N. Sheya, J. H. Maysilles, and R. G. Sandberg. TMS Tech. Paper A89-21, 1989, 17 pp. Many gold-bearing ores in the Western United States also contain small amounts of mercury. The presence of mercury creates potential pollution and health hazards during several steps in gold processing. An investigation was undertaken by the Bureau of Mines to develop techniques for removing mercury from cyanide mill solutions by selective electrowinning in order to reduce the potential hazards. Sixty-five percent of the mercury was selectively electrowon from synthetic solution at applied potentials of 1.00 to 1.50 V when using a mercury-coated platinum or copper plate cathode. Increasing the active surface area by using mercury-coated copper wool resulted in up to 96 pct of the mercury being electrowon from mill carbon strip solutions that contained 1.9 to 20 ppm Hg, 20 to 345 ppm Au, and 0.35 to 39.5 ppm Ag. About 98 pct of the silver was electrowon with the mercury onto the mercury cathode. Gold extraction ranged between 0 and 20 pct. Results of the investigation showed that choice of cathode material was critical to the success of the process. Selectivity was not achieved using uncoated steel wool cathodes.

OP 30-89. Evaluation of the Phase Contrast Microscopy Method for the Detection of Fibrous and Other Elongated Mineral Particulates by Comparison With a STEM Technique, by J. G. Snyder, R. L. Virta, and J. M. Segreti. Am. Ind. Hyg. Assoc. J., v. 48, No. 5, May 1987, pp. 471-477. The USPHS/NIOSH Membrane Filter Method is used to monitor for asbestos in occupational and mining atmospheres, and employs the phase-contrast optical microscope (PCM) that under optimum conditions has a resolution of approximately 0.25 μm. While amphibole cleavage fragments are usually visible by PCM, asbestos fibers (such as amosite and chrysotile) have finer widths that may render them invisible by PCM. In this Bureau of Mines study, personal air-monitoring filters containing chrysotile, amosite, and amphibole cleavage fragments from various sources have been analyzed by PCM in accordance with the USPHS/NIOSH Method and scanning transmission electron microscopy (STEM) to assess the effectiveness of the PCM technique. Each STEM specimen was prepared using a direct-transfer technique to ensure that particle size distribution and concentration were not altered. STEM results for chrysotile samples are highly variable, with 9 to 81 pct of regulatory particles having widths smaller than 0.25 μm—the resolution of the optical microscope. Amosite samples have 27 to 38 pct of regulatory particles with widths below microscope resolution, indicating that routine particle counts by PCM on these samples would underestimate true fiber content by approximately one-third. All amphibole cleavage fragment samples had regulatory particles that would be observed by PCM. Multiplication factors have been suggested for application to routine counts by PCM to more accurately assess true particle content for mineral particulates on personal air-monitoring filters.

OP 31-89. Comparison of Cost Structures at Selected U.S. and Colombian Coal Mines, by Joseph J. Yancik and Sam J. Fraser. Nat. Resour. Forum, v. 12, No. 2, 1988, pp. 129-136. This Bureau of Mines paper summarizes a study designed to measure the differences in production costs at certain U.S. and Colombian coal mines and to identify those factors, including mine health, safety, and environmental requirements, that account for the difference. Meaningful cost-structure comparisons required that mines with similar geology, techniques, and sizes be evaluated in each country. Standard engineering estimating techniques were used to develop costs at three roughly matched pairs of mines, one from each country. Tax and labor cost differences were found to be more important factors than regulatory differences in the cost advantage of the Colombian mines in each set.

OUTSIDE PUBLICATIONS

OP 32-89. Voice Technology in Mining—A Miner's Spoken Word Is as Powerful as His Action, by Dean H. Ambrose. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26–29, 1988. WV Univ., 1988, pp. 84–88. U.S. Bureau of Mines research currently has a major program directed toward robotics and automation of mining systems to increase mining productivity and safety. One area that the Bureau is investigating under this program is the use of voice technology as a means to interface to computers on intelligent mining systems. Voice technology can allow communication to computers on mine machinery, and its use does not require the operators or mechanics to direct their eyes from their work. Voice technology, which uses the spoken word as an input-output medium to computer systems, has already been implemented with success in the manufacturing environment. Such technology would interface to robotic and other intelligent mining systems to provide information about various aspects of the mining operation or conditions, or to control mining systems. Bureau research in this area is investigating the functionality, ease of implementation, and feasibility of using voice recognition and voice synthesis as a user interface to intelligent mining systems. Commercially available voice technology devices are described and Bureau applications are discussed in this paper.

OP 33-89. Position and Heading Determination of a Continuous Mining Machine Using an Angular Position Sensing System, by Donna L. Anderson. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26–29, 1988. WV Univ., 1988, pp. 229–235. A system to determine the position and heading of a continuous mining machine during the maneuvers required at the face area of a mine is described. The system incorporates commercially available angular position sensors with a computer interface developed and tested at the U.S. Bureau of Mines. The sensors employed are laser-based scanning devices that report the angular location of retroreflective targets within their 90° field of view. The targets are mounted on the continuous mining machine; the laser scanners are mounted on an external reference structure. The computer interface consists of a single-board computer-controller programmed to gather and process the angular position information, and to calculate the machine's position and heading relative to the reference structure. A sensor fusion algorithm will be incorporated into the computer interface programming to increase the accuracy and reliability of the system. As an introduction, the role of the position and heading determination system is illustrated in a brief description of the overall autonomous navigation scheme.

OP 34-89. A Knowledge-Based Electrical Diagnostic System for Mining Machine Maintenance, by Bruce E. Berzonsky. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26–29, 1988. WV Univ., 1988, pp. 89–94. Studies indicate that a significant portion of all mining machine failures are associated with electrical system problems. As more highly automated machines are developed, the complexity of a machine's electrical control system can be expected to increase considerably, requiring a greater degree of skill and experience on the part of mine maintenance personnel. Knowledge-based expert diagnostic systems can provide a powerful method of improving equipment maintenance by quickly diagnosing control circuit malfunctions and recommending appropriate repair procedures. To investigate the applicability of expert systems in the area of control circuit diagnostics, the U.S. Bureau of Mines has developed a knowledge-based system to diagnose component malfunctions in the electrical control circuit of a continuous mining machine. The system leads the user through the appropriate procedures required to quickly identify the faulty control circuit component. Graphical displays are incorporated within the system to assist the user in locating the various components and test points. Once the faulty component has been isolated, the system is capable of accessing a database which can provide mine personnel with information concerning specific component part numbers and the availability and location of spare parts. This paper discusses the expert system development tool used to build the system, the structure and development of the knowledge base, and the software used to implement the graphical displays and equipment database.

OP 35-89. The Probability of Spark Ignition in Intrinsically Safe Circuits, by J. C. Cawley. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26–29, 1988. WV Univ., 1988, pp. 125–127. The U.S. Bureau of Mines has completed research to empirically estimate the probability of spark ignition in resistor, inductor, and capacitor circuits in 8.3 pct methane-air mixtures. Tabular and graphical data are presented for currents and voltages that correspond to probabilities of spark ignition from 10^{-3} to 10^{-7}. Data are presented in the format used in Underwriter's Laboratories Standard UL 913, to provide a quick, graphical reference. Statistics are presented that indicate that for spark ignition probabilities between 10^{-5} and 10^{-7}, depending upon component and test parameter values, the ability to cause spark ignition by electrical means ceases.

OP 36-89. A Personal Miner's Carbon Monoxide Alarm, by Joseph E. Chilton and Clarence R. Carpenter. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26–29, 1988. WV Univ., 1988, pp. 70–78. Underground miners may be exposed to hazardous quantities of toxic gases such as carbon monoxide (CO) generated from mine fires or explosions. Every underground miner is required to carry a filter self-rescuer (FSR) that when operated will remove CO from the miner's breathing air. In addition every underground miner must maintain near his or her work site a self-contained self-rescuer (SCSR) that, when activated, will supply breathing oxygen. In many situations, a miner does not know when to don either self-rescuer, since he does not know there is a fire in the mine. Usually he does not carry instrumentation necessary for the detection of the toxic, colorless, and odorless fire product CO. If each miner carried a personal CO alarm that would respond to preset concentrations of CO, the miner would then be alerted to don his FSR or SCSR and exit the mine. A prototype personal miner's CO alarm called PEMCOAL has been developed by the U.S. Bureau of Mines. The PEMCOAL unit is small enough to be carried on a miner's belt, has a flash lamp visual alarm, requires no calibration for use, and uses a chemical sensor that changes color by reaction with trace quantities of CO. The chemical sensor was tested at concentrations of CO from 10 ppm to 1,000 ppm, at temperatures from 5° C to 40° C, and with several potential mine gas interferents. The response times of the PEMCOAL unit are sufficiently quick to warn a miner before he is exposed to hazardous quantities of CO.

OP 37-89. Synthetic Doppler Radar for Coal Interface Detection, by Robert L. Chufo. Paper in Proceedings of the Ninth WVU International Mining Eletrotechnology Conference, Morgantown, WV, July 26–29, 1988. WV Univ., 1988, pp. 65–69. To provide a safer work environment and efficient minerals extraction, the U.S. Bureau of Mines is investigating the application of automation and robotics for mining. The capabilities of robotic mining systems cannot be used unless an improved coal interface detector is developed. Previous research has investigated various radar sensor systems using video pulse, pulse doppler, and frequency modulated-containers wave radar technology. However, these systems have had limited resolution and have required advanced knowledge of the coal dielectric constant. New research by the Bureau has shown that the resolution limits of previous systems may be overcome by a modified synthetic doppler radar system using several fixed antennas. The system fully utilizes the information contained in both the amplitude and phase of the reflected signal through digital signal processing techniques, and uses a new antenna concept that provides increased information from the geometric advantage created by several small antennas. This paper describes the synthetic doppler radar technique and shows how the system can be applied to coal interface detection to resolve both the coal dielectric constant and the coal thickness. The research to date has been investigating and comparing computer correlation algorithms with several modeling theories and test data gathered using a network analyzer and simple dipole transmitting and receiving antennas.

OP 38-39. Evaluation of a Machine Vibrational Coal Interface Detector, by Richard P. Cislo and Michael J. Pazuchanics. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26–29, 1988. WV Univ., 1988, pp. 51–58. Before remote or autonomous mining machines can improve upon the performance of current man-machine systems in terms of mineral recovery, safety, and productivity, suitable environmental sensors must first be developed. The U.S. Bureau of Mines is addressing one facet of the problem relative to keeping an extraction machine within the coal seam through its coal interface sensor research. This paper reports on the performance evaluation of a coal interface detector developed by the General Electric Co. that uses the vibrational response of the machine to

distinguish between cutting coal and rock. The evaluation was performed under contract by Wyle Laboratories through an extensive field and data collection effort that spanned four mines, four different longwall shearing machines, and three different coal seams. Results of the study indicated that the General Electric detector was not effective in identifying the material being cut.

OP 39-89. Thermal Autoignition Temperatures for Hydrogen-Air and Methane-Air Mixtures, by Ronald S. Conti and Martin Hertzberg. J. Fire Sci., v. 6, No. 5, Sept.-Oct. 1988, pp. 348-355. The autoignition temperature and ignition delay times for hydrogen-air mixtures and methane-air mixtures as a function of concentration were measured in the U.S. Bureau of Mines 1.2-L ignitability furnace. The data show that the minimum autoignition temperature (MAIT) values obtained for hydrogen-air and methane-air mixtures are in excellent agreement with previously reported AIT values of other researchers. There is also good agreement in the gas concentrations at which the MAIT's occurred.

OP 40-89. Application of Refraction Tomography To Map the Extent of Blast-Induced Fracturing, by Calvin L. Cumerlato, Virgil J. Stachura, and Daryl R. Tweeton. Paper in Key Questions in Rock Mechanics: Proceedings of the 29th U.S. Symposium, ed. by P. A. Cundall, R. L. Sterling, and A. M. Starfield (Minneapolis, MN, June 13-15, 1988). Balkema, 1988, pp. 691-698. The U.S. Bureau of Mines has conducted high-resolution refraction surveys at a limestone quarry both before and after standard production blasts where variations in the blast design were made. The data collected were processed using a tomographic inversion algorithm to produce maps (tomograms) of the seismic velocity field of a shallow refracting layer in the rock left standing. Overlapping of surveys, velocity measurements from shotholes (preblast), and measurements of predominant joint sets were used to verify results. Resulting tomograms show sublinear low-velocity zones whose orientations correspond to those of measured joint sets. Low-velocity zones near pitwalls are interpreted as the extent of intense fracturing caused by blasting. These results demonstrate that refraction tomography can be a powerful and economical tool for locating predominant jointing and areas of preexisting or blast-induced fracturing—an important aid to operators during premine planning and blast designing.

OP 41-89. Blasting Accidents in Mining, by Dennis V. D'Andrea, Larry R. Fletcher, and Michael A. Peltier. Paper in Proceedings of the Thirteenth Conference on Explosives and Blasting Technique, Miami, FL, Feb. 1-6, 1987. Soc. Expl. Eng., 1987, pp. 291-305. Accident data obtained from the Mine Safety and Health Administration (MSHA) were analyzed by the U.S. Bureau of Mines to determine the most frequent causes of blasting accidents in U.S. mining and to examine trends in blasting accidents. This accident analysis is an update of a similar blasting accident study conducted by the Bureau and published in 1983. The analysis shows that there has been a recent reduction in mine blasting accidents: The annual average number of non-fatal injuries has decreased from 107 for 1978-81 to 46 for 1982-85. The annual average number of fatal injuries was reduced from 11.3 to 5.0 during that time. The largest decrease in blasting accidents occurred in underground mining, where both coal and metal-nonmetal showed declines. There was also a slight decline in accidents in surface mining. In terms of severity rate (average number of lost work days per injury), blasting accidents remain one of the most serious types of accidents in mining. Failure of the blast area security system is the most common cause of blasting accidents. Emphasis should be placed on clearing and guarding of blast areas and on having miners retreat to safe locations during production blasting. Other common causes include premature blasts, excessive flyrock, fumes, and misfires. Trends in blasting accident causes are discussed in this report.

OP 42-89. The Application of Coal Interface Detection Techniques for Robotized Mining Machines, by Harry Dobroski, Jr. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26-29, 1988. WV Univ., 1988, pp. 223-228. One major objective of U.S. Bureau of Mines research is to increase and improve mining efficiency by investigating the feasibility of a robotized mining system. Such a system holds great promise for increased productivity necessary to achieve advantages in the world coal markets. However, for a robotized system to be effective, it must be able to immediately identify the interface between coal and adjacent strata, no matter how complex the interface may be, or how similar the coal may be to the adjacent strata. Extensive research in coal interface detection (CID) techniques has already been done, but little of this research has been applied. With the exception of natural gamma devices, the various CID techniques have not even been applied to longwalls, which operate in a well-defined structured manner in the best geologies available. Continuous mining methods represent even greater challenges. The operating methods and geologic conditions of current continuous mining sections are different from those found in the longwall sections. A different approach is required. This paper addresses the CID problem as it applies to robotized mining machines. A brief review of prior CID research is given. Comparisons are made between longwall CID and continuous miner CID. In-mine data and information are presented concerning the geologic nature of the interface and the fundamental parameters of the materials that comprise it. It is the identification of these fundamental parameters that holds the key to a general CID solution. Some possible schemes for a robotized mining machine are presented.

OP 43-89 Communications and Telemetry for Rescue and Recovery Operations, by Harry Dobroski, Jr., and J. Emery Chilton. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26-29, 1988. WV Univ., 1988, pp. 101-104. Future underground coal mines will be difficult places for rescue and recovery teams. Such mines will be deeper, gassier, and inherently less stable, and will be located in thinner seams. Such mines will be far greater challenges for successful escape, rescue, and recovery. Rescue and recovery teams will need better equipment and techniques. U.S. Bureau of Mines research is focusing on these problems. Several communication and monitoring systems have been developed. First, a radio communication system has been developed that uses the lifeline as a long antenna for voice communications anywhere along the line and for short distances away from it. This gives the team communications flexibility not possible with sound-powered phones. Lighter, longer lines can be used that need not be recovered. Second, a small portable environmental monitor-telemetry system that uses the lifeline in much the same way has been developed for monitoring the interior of sealed mines. Postdisaster environments often contain high concentrations of toxic or explosive gases in oxygen-reduced atmospheres where conventional sensors do not perform accurately. A novel solution to this problem is presented. Finally a communication interconnect for the outside management and monitoring of in-mine rescue and recovery operations is also presented.

OP 44-89. Optimization of Gallium and Germanium Extraction From Hydrometallurgical Zinc Residues, by D. D. Harbuck, J. W. Morrison, and C. F. Davidson. Paper in Light Metals 1989, ed. by Paul G. Campbell. Miner. Met., and Mater. Soc., 1988, pp. 983-989. The U.S. Bureau of Mines studied the extraction of gallium and germanium from hydrometallurgical zinc processing residues. Statistically designed experiments showed that the most significant variables were H_2SO_4 concentration for gallium extraction and pulp-solids density for germanium extraction. Leaching the residue with 2,000 lb H_2SO_4/st residue for 4.5 h at 80°C using 20 pct pulp solids extracted 95 pct of the gallium. Optimum germanium extraction of 73 pct was obtained using the same conditions but decreasing pulp solids to 5 pct. X-ray diffraction analysis and SEM techniques showed that the insoluble germanium was present in the residue as a SiO_2-GeO_2 solid solution. Additional leaching of the residue with 500 lb HF/st residue for 2 h at 80°C using 10 pct pulp solids extracted 93 pct of the remaining germanium. Combined germanium extraction from sulfuric and hydrofluoric acid leaching was 98 pct.

OP 45-89. Application of Adaptive Learning Networks for the Detection of Failing Power System Components, by Gerald T. Homce. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26-29, 1988. WV Univ., 1988, pp. 210-222. A system capable of monitoring mine electrical power systems and detecting component failure in early stages could significantly improve power system safety and availability. Such monitoring would require a method of evaluating electrical features, calculated from terminal values, for indications of component deterioration. Research conducted by the U.S. Bureau of Mines is examining the use of mathematical models to aid in this evaluation, by creating polynomial networks or adaptive learning networks that can indicate deteriorated conditions in cable-connected motor systems. This process uses laboratory "train-

ing" data to select the electrical features most significant for accurately modeling cable-motor system conditions, and forms mathematical expressions relating these features to the presence and severity of deterioration. Adaptive learning networks developed thus far are capable of correctly identifying deterioration levels to within 1 pct of motor full-load current.

OP 46-89. Determining Corrosion Rates in Industrial Ore Grinding Environments, by A. E. Isaacson, P. J. McDonough, and J. H. Maysilles. Soc. Min. Eng. AIME preprint 89-2, 1989, 16 pp. Researchers at the U.S. Bureau of Mines developed and tested equipment to measure corrosion rates on a commercial-scale mill. Bench-scale experiments were also designed for duplicating ore grinding conditions closely enough that realistic rate determinations can be made in laboratory tests. Rates measured in a laboratory system compared favorably with those measured in the field. Cast steel was found to have corrosion rates in a copper mill and laboratory test cell of 22 and 21 mpy, respectively. Corrosion was found to account for less than 5 pct of the total grinding media wear in the operations studied.

OP 47-89. Copper Mineral Reactions in Supercritical and Subcritical Water, by A. E. Isaacson and D. C. Seidel. Soc. Min. Eng. AIME preprint 89-125, 1989, 7 pp. The U.S. Bureau of Mines is studying the effect of supercritical water, at 400°C and 3,500 psi, and of subcritical water at lower temperatures and pressures, on mixtures of minerals and metals to determine the possible applications of water at high temperature and pressure for processing these materials. This research was conducted using a flowthrough bench-scale system. Copper-bearing minerals studied were chalcocite, chalcopyrite, covellite, and cuprite. In general, mixtures of copper minerals and pyrite reacted to form bornite. Intermediate phases formed were chalcopyrite and digenite. Similar reactions occurred between pyrite and metallic copper. A mixture of chalcopyrite and pyrite was inert in supercritical water. The reaction between cuprite and metallic zinc yielded metallic copper. The cuprite was reduced by hydrogen generated by the reaction between metallic zinc and water. None of the reactions occurred exclusively in supercritical water, but also occurred in water at high temperature and pressure below the critical point. Experimental results did show that a dual-reaction process, consisting of solid-state diffusion and fluid transport, was occurring.

OP 48-89. Evaluation of a Turbulent Flow Model for Fine Bubble and Fine Particle Flotation, by C. E. Jordan and D. R. Spears. Soc. Min. Eng. AIME preprint 89-172, 1989, 12 pp. The U.S. Bureau of Mines conducted research to measure the improvement provided by fine bubbles on the flotation of fine-sized particles (minus 20-μm size) in an effort to improve flotation efficiency in our domestic minerals industry. The turbulent velocity distributions of the fluid within the flotation cell were measured as a function of time and position and used to increase the precision of a fine-particle, turbulent flotation model. For the mineral system investigated, improved flotation response was obtained under laboratory conditions by using small bubbles and intense agitation. These results matched the model's predicted response.

OP 49-89. Stemming Ejection and Burden Movements of Small Borehole Blasts, by John W. Kopp. Paper in Second International Symposium on Rock Fragmentation by Blasting, Keystone, CO, Aug. 23-26, 1987. Soc. Exp. Mech., 1987, pp. 224-230. The types and amounts of stemming material that are desirable in underground metal and nonmetal mine blasting to improve fragmentation while containing the hot gases are largely unknown. U.S. Bureau of Mines researchers examined the effectiveness of differing lengths of stemming by measuring stemming ejection times as related to burden movement. Test blasts at two surface limestone quarries were evaluated using high-speed photography. Cooling of explosive gases was calculated assuming adiabatic expansion as the gas worked its way into the fractured burden region. For the conditions of these tests, a stemming length of at least 26 charge diameters was found to prevent premature stemming ejection. In tests with stemming lengths of 16 charge diameters, the stemming was effective, but there was early venting of hot gases through fractures in the rock.

OP 50-89. Computer-Based Monitoring and Remote Control of a New Highwall Mining System, by August J. Kwitowski, William H. Lewis, William D. Mayercheck, and Michael C. Leigh. Paper in Proceedings of the Ninth WVU Mining Electrotechnology Conference, Morgantown, WV, July 26-29, 1988. WV Univ., 1988, pp. 37-43. The U.S. Bureau of Mines and a cooperator have developed a new highwall mining system (HMS) for coal extraction in unreclaimed and active contour strip mines. The system is comprised of a computer-based, remotely controlled thin-seam continuous miner, a multiple-unit continuous haulage system, and other support equipment located on the highwall bench. The mining process is controlled remotely by a single operator from a protected, ergonomically designed workstation. The HMS offers safe, economical mining of unreclaimed coal resources. It has the potential to be competitive with other highwall coal extraction techniques, with a productivity goal of 22 tons/man-h. Surface tests of the miner and haulage systems were completed at the Bureau test facility in Pittsburgh, PA. Specific results from these tests are included. Field production trials of the HMS are being conducted at a West Virginia highwall site.

OP 51-89. A Biohydrometallurgical Approach to Selenium Removal, by D. M. Larsen, K. R. Gardner, and P. B. Altringer. Paper in Proceedings of the Symposium on Water Resources Related to Mining and Energy—Preparing for the Future, ed. by Richard F. Sworsky. Am. Water Resour. Assoc., 1987, pp. 419-426. The U.S. Bureau of Mines is conducting research on the removal of heavy metal ions from residual waters. This research has included exploratory batch and small-scale continuous laboratory studies on the biohydrometallurgical removal of selenium from agricultural drainage waters. Tests were conducted on alkaline drainage waters obtained from the Kesterson National Wildlife Refuge, San Joaquin Valley, CA. The water contained 280 to 3,800 ppb selenium present as SeO_4^{2-}. Using indigenous bacteria, the selenium was reduced from selenate, Se(VI), to selenite, Se(IV), and then precipitated in elemental form from solution. Selenium removal ranged from 87 to 96 pct, regardless of the initial selenium concentration; in one system, the selenium level was reduced from 3,800 ppb to less than 150 ppb in about 1 h. The technique was effective when the bacteria were added directly to the water, or when the water was pumped through a substrate that had been previously inoculated with bacteria.

OP 52-89. Biologically Assisted Control of Selenium in Process Waste Waters, by D. M. Larsen, K. R. Gardner, and P. B. Altringer. Ch. 22 in Biotechnology in Minerals and Metals Processing. Soc. Min. Eng. AIME, 1989, pp. 177-185. The U.S. Bureau of Mines is conducting batch and small-scale continuous laboratory studies on the biologically assisted removal of selenium from process waste waters. Mixed cultures of gram-negative bacteria isolated from several brackish water marshes are capable of reducing selenate [Se(VI)] to selenite [Se(IV)] and precipitating an amorphous elemental selenium product. Selenium extractions ranged from 80 to 96 pct regardless of the initial selenium concentration. The conditions for rapid bacterial growth and reactor design for optimal selenium removal have been investigated. The mechanisms of bacterial reduction and the rate of selenium removal for scaleup to larger systems are discussed.

OP 53-89. New Approach To Protect Operators of Thin-Seam Shuttle Cars, by A. G. Mayton, J. R. Bartels, and W. D. Mayercheck. Soc. Min. Eng. AIME Preprint 89-96, 1989, 8 pp. U.S. Bureau of Mines research has addressed improved operator protection for thin-seam shuttle cars. Because of working height restrictions in thin-seam mines ($\leq$1.22 m or 48 in), MSHA regulations require that canopy protection on shuttle cars be provided only in mines 1.07 m (42 in) and greater; however, variances are given to mines 1.22 m (48 in) and below. This paper reviews past Bureau efforts to develop protective structures for thin-seam shuttle car operators. The paper also discusses recent research leading to a novel method of protecting shuttle car operators, in mines as low as 1.02 m (40 in), through the use of a cross-car, end-mounted operator compartment.

OP 54-89. Hot-Surface Ignition Temperatures of Dust Layers, by Yael Miron and Charles P. Lazzara. Fire and Mater., v. 12, No. 3, Sept. 1988, pp. 115-126. The U.S. Bureau of Mines determined minimum dust layer ignition temperatures on a hot surface for several dusts, using a test procedure recommended by the National Academy of Sciences. The dusts included coal, three oil shales, lycopodium spores, corn starch, grain, and brass powder. For a few of the dusts the effects of particle size and layer thickness on the minimum ignition temperatures were examined. Test results were repeatable and reliable for the fuels, the lycopodium, and the brass

powder. The minimum hot-surface ignition temperatures of 12.7-mm-thick layers of these dusts ranged from 160°C for brass to 290°C for 20-gal ton^{-1} oil shale. Flaming combustion was observed only with the brass powder. The minimum ignition temperatures decreased with thicker layers and with smaller particle sizes. Some difficulties were encountered with the corn starch and grain dusts. During heating, the starch charred and expanded; the grain dust swelled and distorted. The test was found acceptable for the purpose of determining the minimum layer ignition temperature of a variety of dusts. To prevent fire hazards due to smoldering or flaming dust layers, the temperatures of surfaces on which combustible dusts accumulate should be lower than the minimum hot-surface ignition temperatures of the dusts.

OP 55-89. Diagnostic Maintenance Expert System for the Hydraulic Sub-System of a Continuous Miner, by Julie Mitchell. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26-29, 1988. WV Univ., 1988, pp. 95-100. The U.S. Bureau of Mines is conducting research on the application of expert systems technology to mining equipment diagnostics, to increase mining productivity and efficiency. Specifically, an expert system is being developed for diagnostic maintenance of the hydraulic system of a continuous coal mining machine. Through the use of such a system, lengthy and costly delays due to equipment failure and repair can be significantly reduced. This type of equipment diagnostic system may be applied to the electrical and mechanical systems as well as other mining machinery. This paper discusses the functional requirements of the expert system, the approach to the problem, the application domain, a description of how the present system works, its software design and sensor interface, and the future plans for the continued development of this and other expert systems in mining.

OP 56-89. Applying Adaptive Signal Discrimination Systems to Mining Problems, by Gary L. Mowrey. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26-29, 1988. WV Univ., 1988, pp. 59-64. Two important mining research issues are (1) how to detect a coal-noncoal interface such that an automated mining machine can track the coal seam and (2) how to assess the bonding integrity of resin roof bolts. The U.S. Bureau of Mines is applying a new approach to solving both problems by utilizing adaptive signal discrimination (ASD) systems to extract features and classify complex signals. The Bureau is investigating the coal interface problem by using accelerometers mounted on the mining machine and/or strata to monitor mining machine vibration signals. An ASD system is trained on a database of known signals (e.g., "cutting coal" and "starting to cut roof") and then can be used to objectively determine the type of formation being cut. The feasibility of utilizing ASD-type systems to assist in the evaluation of the bonding integrity of resin roof bolts via analysis of ultrasonic and seismic signals is also being investigated.

OP 57-89. Recovery of Critical Metals From Hardface Alloy Grinding Waste by a Chloride-Based Hydrometallurgical Process, by L. D. Redden and D. C. Seidel. Miner., Met., and Mater. Soc., TMS Tech. Paper A89-11, 1989, 20 pp. As part of the U.S. Bureau of Mines program to reduce the U.S. reliance on foreign suppliers of critical metals, research has been conducted to develop technology for the recovery of critical metals from hardface alloy grinding waste, a form of superalloy scrap. This report describes a hydrometallurgical process for the recovery of values such as cobalt, chromium, manganese, nickel, and tungsten. The process involved deoiling the grinding waste followed by chloride-based dissolution of the deoiled material. A high-grade calcium tungstate product was recovered from the resultant leach residue. Iron, cobalt, manganese, and nickel chlorides were sequentially recovered from the leach liquor by solvent extraction. Market-grade cobalt chloride, manganese chloride, and nickel chloride products can be produced directly from the strip liquors. The final raffinate was a relatively pure chromic chloride solution that compares favorably with commercial solutions.

OP 58-89. A Computer Program To Predict the Probability of Overlap or Crowding of Adjacent-Period Millisecond-Delayed Initiators, by Stephen A. Rholl and Mark S. Stagg. Paper in Proceedings of 4th Mini-Symposium on Explosives and Blasting Research, Anaheim, CA, Feb. 4-5, 1988. Soc. Explosive Eng., 1988, pp. 91-105. The firing times of millisecond-delayed initiators are random variables that exhibit varying degrees of scatter. This scatter can cause crowding and overlap of adjacent delay periods, which results in adverse effects on safety, fragmentation, and blasting vibrations. The U.S. Bureau of Mines developed a computer program to calculate the probability that initiators from any two adjacent periods would fire out of sequence or that crowding might occur. The program assumes that the firing times are normally distributed and that the mean and standard deviation can be adequately estimated by sampling the initiator population. Results of the program are given using delay-time statistics that are typical of commercially available initiators. The effect of more precise initiators on the probability of overlap or crowding is presented. The results allow blasters to determine the initiator accuracy needed to ensure that overlaps or crowding do not occur for a given probability. The implications of improved-accuracy initiators as they pertain to fragmentation are discussed. The initiator accuracy required to maintain 1 ms/ft of burden separation while shooting at 2 or 4 ms/ft is shown.

OP 59-89. A Computerized Continuous Mining Machine for Autonomous Mining Research, by John J. Sammarco and William H. Schiffbauer. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26-29, 1988. WV Univ., 1988, pp. 22-28. The U.S. Bureau of Mines has developed a testbed for performing autonomous mining machine experiments. A continuous mining machine has been modified with a computer system and instrumented with various sensors to monitor machine movements and conditions. The computer hardware is based on a Multibus I system and utilizes a modified iRM x 86 operating system. Various application software programs have been developed by the Bureau for monitoring and controlling the continuous mining machine. At this time tests have been completed for computer control of the mining machine's appendages. Open-loop tests were conducted to characterize the motion of each appendage. From these data, closed-loop control algorithms were formulated. Machine tests in free space and in the cutting of a simulated block of coal verified the closed-loop control algorithms. The closed-loop control algorithm is discussed in detail, as are other factors that must be considered from a control standpoint.

OP 60-89. Modern Management and Loss Control, by Louis Schaffer and James M. Peay. Paper in Proceedings of the Nineteenth Annual Institute on Coal Mining Health, Safety and Research, Blacksburg, VA, Aug. 23-25, 1988. Dep. Min. and Miner. Eng., VA Polytechnic Inst. and State Univ., 1988, pp. 81-90. Worker injuries and illnesses, and many other kinds of losses, are not dealt with effectively by many mining operations. As a result, these operations realize substantially less profit than would be attainable if efficient management techniques were used consistently. This U.S. Bureau of Mines paper addresses various aspects of this situation.

OP 61-89. Increasing Dewatering Efficiency Through Optimization of the Flocculation Sequence, by Bernard J. Scheiner. Fluid/Particle Separation J., v. 1, No. 1, Sept. 1988, pp. 53-55. The optimization of the flocculation sequence for mineral slurries has been studied by the U.S. Bureau of Mines. This paper discusses the importance of flocculation in obtaining optimum results from the solid-liquid separation unit operation common to most mineral processing schemes. Emphasis on how the flocculation step affects dewatering performance of screens and belt presses is discussed. Flocculation of phosphatic clay waste, effluents from placer gold mines, and coal-clay waste are discussed in terms of dewatering efficiency.

OP 62-89. The Use of Rheology To Explain the Flocculation of Calcium Montmorillonite, by B. J. Scheiner and D. A. Stanley. Soc. Min. Eng. AIME Preprint 89-141, 1989, 7 pp. The U.S. Bureau of Mines has investigated the use of rheology to provide insight into the mechanism of flocculation. A technique developed by Tattersall has been modified and used to explain the flocculation of calcium montmorillonite with polyethylene oxide. The results indicated that there are two type of bond systems operating during the flocculation sequence. Also, flocculation results are highly dependent on the shear rate and the amount of polymer added.

OP 63-89. Vented Explosion-Proof Enclosure Research, by Lawrence W. Scott. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26-29, 1988. WV Univ., 1988, pp. 79-83. The performance of Retimet as a flame arrester on explosion-proof electrical enclosures was investigated by the U.S. Bureau of Mines. Four grades of Retimet, a stainless steel foam, were evaluated: 45 NC-13,

45 NC-7, 80 NC-13, and 80 NC-7. Explosive mixtures were prepared by a dynamic flow system. A series of 30 tests were conducted on each grade of Retimet in a 9.7 pct methane-air mixture. Ignition was by a low-voltage arc. Each grade of Retimet successfully arrested the flame front in all methane-air tests. To establish a safety factor, a series of 30 tests were conducted in various mixtures of methane, hydrogen, and air on all four grades. A safety factor was defined as $S.F. = V_2/V_1$, where V_2 is the flame front velocity in methane-hydrogen-air and V_1 is the flame front velocity in methane-air. The maximum hydrogen concentration of methane-hydrogen-air in which each grade of Retimet could safely function was then determined to be 10% H_2–6.33% CH_4 for grade 45 NC-7, 15% H_2–4.75% CH_4 for grade 45 NC-13, 20% H_2–3.17% CH_4 for grade 80 NC-7, and 25% H_2–1.58% CH_4 for grade 80 NC-13.

OP 64-89. Elastic Wave Velocity and Attenuation as Used To Define Phases of Loading and Failure in Coal, by V. R. Shea and D. R. Hanson. Int. J. Rock Mech. Min. Sci. and Geomech. Abstr., v. 25, No. 6, 1988, pp. 431–437. This U.S. Bureau of Mines paper discusses a procedure used to investigate the behaviour of elastic wave velocity and attenuation as an indicator for changes in load and structural integrity of coal samples. By measuring the changes in compressional (P)- and shear (S)-wave attenuation and velocity under uniaxial and triaxial testing conditions, their effectiveness for distinguishing changes in applied load and structural failure of the sample can be observed. The velocity and attenuation values were used in further calculations such as ratios of P-wave to S-wave attenuation and velocity values, dynamic elastic constants, normalized velocities, and attenuation coefficients to reveal any trends that may exist upon loading and failure. The behaviour of both P-wave and S-wave attenuation and velocity considered together define distinct and consistent phases of load change and failure under uniaxial and triaxial testing conditions. The S-wave attenuation and velocity are more sensitive than those of the P-wave to changes in axial load and the initial development of microfractures within the sample preceding structural failure. The attenuation and velocity ratio curves and the dynamic elastic constant curves are not very sensitive to changes in load, but are responsive to structural failure of the coal sample. The attenuation coefficient and normalized velocity curves revealed the same trends observable in the original velocity and attenuation curves.

OP 65-89. Blast Initiation Delay and Vibration Frequency: A Surface Coal Mine Case History, by David E. Siskind. Paper in Proceedings of Second International Symposium on Rock Fragmentation by Blasting, Keystone, CO, Aug. 23–26, 1987. Soc. Exp. Mech., 1987, pp. 80–87. Vibration wave amplitudes and frequency from surface mine blasting are important influences on the response and potential cracking of nearby structures. The U.S. Bureau of Mines studied blasting vibrations in a midwestern coal mine that occasionally produces 4-Hz surface waves in its production blasting and has had numerous complaints from neighbors. The mine and nearby town are underlain by abandoned underground coal mines at depths of 30 to 110 m (100 to 360 ft) below the surface. Blast vibration measurements at the site and analysis of mine and regulatory agency records indicated that the propagating medium was primarily responsible for the vibration wave characteristics, including low frequencies, long durations, and lower-than-normal attenuations of amplitude with distance. The observed low-frequency waves were consistent with predictive theoretical models of surface wave generation using the depths to the old mines. Blast designs also contributed to the vibrations problem. The complex multidelayed blasts generated vibration amplitudes up to three times those of same-weight-per-delay single charges. Because of these low-frequency, long-period waves, the widely adopted 8-ms minimum charge separation criterion may not apply at this site. Knowing how and when initiation timing can influence vibration character would provide the industry with a valuable tool for controlling and reducing vibrations.

OP 66-89. Low-Frequency Vibrations From Surface Mine Blasting Over Abandoned Underground Mines, by David E. Siskind. Paper in Proceeding of the 6th International Congress on Rock Mechanics, Montreal, Canada, Aug. 30–Sept. 3, 1987. Balkema, 1987, pp. 731–734. Blasting for surface mining is a source of potentially damaging ground vibrations. Of particular concern are sites with low-frequency surface waves, those below 5 Hz. These vibrations can produce excessive structural response and strains in nearby buildings. A U.S. Bureau of Mines study of one such site found the ground acting as the propagating medium primarily responsible for generating and sustaining these low-frequency waves. The observed waves were consistent with predictive models based on layer thicknesses equal to the depths to abandoned underground mines known to exist in the area. A thick zone of low-velocity glacial till also exists between the blasts and the affected homes. Because some influence was also found from the initiation delay timing, blast designs based on specific timing patterns could be used to reduce the generated vibrations at such sites.

OP 67-89. Structural Response and Cosmetic Cracking in Residences From Surface Mine Blasting, by David E. Siskind and Mark S. Stagg. Paper in Proceedings of the 59th Shock and Vibration Symposium, Albuquerque, NM, Oct. 18–20, 1988. Sandia Nat. Labs., Sandia Rep. SAND88-2473C.UC–13, v. 1, Oct. 1988, pp. 319–334. The U.S. Bureau of Mines studied the problems of blasting-vibration-induced structural response and cracking of low-rise residential structures in a series of research projects between 1976 and 1983. This paper summarizes the published Bureau findings and presents them from the point of view of the cracking and failure of the construction materials used for homes. The damage data suggest that, for plaster and wallboard attached to the superstructure, an increase in the rate of cracking is not likely to result from blasts generating vibrations of less than 0.5 in/s. Data on cracks in masonry walls suggest that blast-induced vibration levels of up to 3.0 in/s may be a threshold for local block-length cracks. However, additional data are needed to quantify vibration level effects necessary to generate stair-stepped cracks in masonry walls, which indicate loss of shear load capacity.

OP 68-89. Influence of Blast Delay Time on Rock Fragmentation: One-Tenth Scale Tests, by Mark S. Stagg. Int. J. Surface Min., v. 1, 1987, pp. 215–222. The U.S. Bureau of Mines is studying blast delay timing influences on rock fragmentation in a series of tests that started in 3-ft concrete blocks and includes reduced-scale and full-scale bench blasts. This paper reports on the reduced-scale tests. In a 45-in-high dolomite bench, 18 single-row blasts were fired with 15-in burdens. Spacings were 21 and 30 in. Delay intervals ranged from 0 to 45 ms, equivalent to 0 to 36 ms/ft of burden. Each shot was instrumented for strain and pressure for both in situ dynamics and interactions between blastholes. All fragmented rock was screened. The finest fragmentation occurred at blasthole delay intervals of 1 to 17 ms/ft of burden. In this range, stress-wave-induced strains interacted with longer lasting gas-pressure strains from earlier holes. Coarse fragmentation resulted from short delays (< 1 ms/ft), where breakage approached presplit conditions with a major fracture between blastholes and large blocks in the burden region. Coarse fragmentation also resulted from long delays (> 17 ms/ft), with explosive charges acting independently. The broad acceptable range provides blast design tools useful for a variety of purposes, including optimum muckpile displacement and vibration control.

OP 69-89. Effects of Accurate Delays on Fragmentation for Single-Row Blasting in a 6.7-m (22-ft) Bench, by Mark S. Stagg and Stephen A. Rholl. Paper in Proceedings of Second International Symposium on Rock Fragmentation by Blasting, Keystone, CO, Aug. 23–26, 1987. Soc. Exp. Mech., 1987, pp. 210–223. The recently introduced improved-accuracy pyrotechnic caps have the potential for enabling blasters to design blasts with precision timing to tailor fragmentation to specific rock and site requirements. The Bureau of Mines conducted an experiment where six single-row blasts were shot in a 6.7-m (22-ft) bench of horizontally bedded limestone to study the effects of precise delays on fragmentation. Precise delays ranging from 2 to 48 ms between holes, equivalent to 1.1 to 26 ms/m (0.33 to 8.0 ms/ft) of burden, were achieved using a sequential blasting machine with seismic caps. The shots were instrumented with dynamic pressure gauges and six-component strain gauges and filmed with high-speed cameras. Fiber optics were used to confirm firing times and measure detonation velocities. The blasted rock was sized using grizzlies and vibrating shakers. All the broken material from four shots and about one-third and one-half of the material from the remaining two shots was screened. Analysis of the first four shots established that sampling 25 to 34 pct of the material adequately predicted the total shot fragmentation size distribution. The fragmentation data were best described by two distribution functions. The finer sizes are best fit by a power curve, while the coarse material is best fit by a normal distribution. The different distribution functions suggest that there are two distinct fragmenta-

tion processes. Most of the finer material was apparently produced by a process in the region around the blastholes, while the coarse material came from the region between blastholes and near the free face. The delay of 1.1 ms/m (0.33 ms/ft) of burden produced more coarse and less fine material than the shots with delays of 3.3 to 26 ms/m (1 to 8 ms/ft). Statistical analysis of the coarse size data showed that the shots with delays longer than 3.3 ms/m (1 ms/ft) could be combined. However, the data for the 1.1-ms/s (0.33-ms/ft) shot could not be combined with the longer delay interval blasts. The 1.1-ms/m (0.33-ms/ft) shot produced a size increase of 15 pct for the coarse material. The difference in the distribution curves for the finer sizes was not statistically significant. The effects of preexisting fractures are discussed. Results are compared to those of recent Bureau tests at a reduced scale in a massive dolomite where at least a 40-pct increase in the average size resulted from the delay of 1.1 ms/m (0.33 ms/ft) compared to delays of 3.3 to 26 ms/m (1 to 8 ms/ft). Strain and pressure data suggest the improvement in fragmentation results from an interaction of blasthole stress wave fracture mechanisms with the previously detonated blastholes' late failure processes. The effect is predicted to last for delays as long as 56 ms/m (17 ms/ft) of burden. While cutoffs prevented the use of these long delays in the highly jointed material, reduced-scale tests in a massive rock found that optimum fragmentation occurred from ~1 to 17 ms/ft. A statistical method for estimating the cap accuracy necessary to maintain a given delay interval such as 3.3 ms/m (1 ms/ft) was developed.

OP 70–89. Influence of Blast Delay Time on Rock Fragmentation in a 22-ft Bench, by Mark S. Stagg and Stephen A. Rholl. Paper in Proceedings of the Fourteenth Conference on Explosives and Blasting Technique, Anaheim, CA, Feb. 1–5, 1988. Soc. Explosive Eng., 1988, pp. 318–333. The U.S. Bureau of Mines is studying blast delay timing influences on rock fragmentation in a series of tests that started in 3-ft concrete blocks, progressed to 45-in-bench reduced-scale tests in massive dolomite, and has now included 22-ft-bench full-scale tests in a thin-to-thick horizontally bedded dolomite. This paper discusses the full-scale test results and how they compared to the concrete block and reduced-scale studies. Six full-scale single-row blasts were shot at a 6-ft burden at delays of 2 to 48 ms, equivalent to 0.33 to 8.0 ms/ft of burden. All the blasted rock was screened from the first four shots. It was also established that sampling about 30 pct of the material adequately predicted the total distribution. Optimum fragmentation occurred in shots delayed from 1 to 8 ms/ft of burden. The shot delayed at 0.33 ms/ft increased the 80-pct-passing size by 15 pct during the full-scale tests in the highly bedded rock, compared to a 40-pct increase for the same delay ratios in the reduced-scale tests in the massive dolomite. Each full-scale shot was filmed with high-speed cameras and instrumented with strain and pressure gauges. At optimum delays the arrival of gas-pressure-driven radial fractures interacted with stress waves emanating from the next hole, causing an increase in both strain level and duration.

OP 71–89. Polymer Configuration and Its Importance During the Flocculation Sequence, by D. A. Stanley, B. J. Scheiner, and P. M. Brown. Soc. Min. Eng. AIME Preprint 89–165, 1989, 5 pp. The U.S. Bureau of Mines has developed an equation that describes the dewatering of clay slurries with polyethylene oxide. This dewatering equation is $A^n = kC + b$ where n, k, and b are empirical constants and C is the concentration of polymer solution used for dewatering. The minimum amount of polymer required for dewatering, A, is determined by titration of the clay slurry with a polymer solution. In this report, the dewatering equation is applied to data obtained for a polyacrylamide dewatering sequence. Fundamental similarities between the dewatering properties of clays and the viscosity of polymer solutions were observed. These similarities were explained by correlating an equation describing polymer configuration in solution with the dewatering equation. This correlation showed that amount of polymer required for dewatering and polymer solution viscosity are both consequences of the frictional interaction of entangled polymer coils.

OP 72–89. An Overview of the Bureau of Mines Automation and Robotics Program, by Jeffrey H. Welsh. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26–29, 1988. WV Univ., 1988, pp. 15–21. The U.S. Bureau of Mines is approaching the problems of productivity and accidents in the U.S. coal mining industry through the application of artificial intelligence and robotics to mining systems. This technology can increase the productivity of mining systems through a reduction of downtime and through more efficient operation of mining equipment. Safety should increase since workers are removed from hazardous areas or tasks, thereby reducing the number of accidents. The near-term goal is to develop technology that can be implemented as an autonomous continuous mining machine. This requires research on navigation systems, coal-rock interface detectors, machine condition monitoring, and intelligent machine control. The Bureau's program on Automation and Robotics is presented, and plans for the future are discussed.

OP 73–89. Extraction of Phosphate Values From Phosphatic Clay Wastes: An Acid-Alcohol Technique, by G. M. Wilemon and B. J. Scheiner. Ch. 25 in Challenges in Mineral Processing, ed. by K. V. S. Sastry and M. C. Fuerstenau. Soc. Min. Eng. AIME, 1989, pp. 421–436. The U.S. Bureau of Mines conducted investigations on extracting phosphate values from fine-particle wastes generated during the mining and beneficiation of phosphate ore by leaching dried wastes using an H_2SO_4-methanol mixture. Although phosphatic clay waste contains up to a third of the phosphate originally present in the ore, recovery of these values represents a significant challenge due to the fine grain size of the material, the particles averaging less than 1 μm in diameter. Waste samples obtained from two Florida producers yielded phosphate extractions of 71 and 84 pct, respectively, when leached under ambient conditions and at a stoichiometric acid ratio of 1.4:1. Elevated temperatures did not improve the amount of phosphate extracted. Undesirable Al_2O_3, Fe_2O_3, and MgO impurities were largely rejected; higher grade wastes gave acids that met established industry impurity standards, and lower grade samples yielded acids that marginally fell short of the standard. Separation of the crude acids from the insoluble residues was accomplished via vacuum filtration through either filter paper or commercial filter cloths. Both filtration rates and solids retention were improved by the addition of 0.5 lb/ton of polyvinyl acetate (PVAc) or polyethylene oxide (PEO) to the methanol-acid slurries. These results show potential for substantially increasing the reserves of an important domestic resource.

OP 74–89. Leaching of Phosphate Values From Phosphate Wastes Using H_2SO_4-Methanol Mixtures, by G. M. Wilemon, R. G. Swanton, J. G. Davis, and B. J. Scheiner. Miner., Met., and Mater. Soc. Paper A89–4, 1989, 17 pp. The U.S. Bureau of Mines conducted investigations on extracting phosphate from fine-particle wastes that are generated during the mining and beneficiation of phosphate rock. These wastes may contain up to one-third of the phosphate originally present in the untreated ore. Samples of the dried wastes were leached using sulfuric acid and methanol mixtures. The phosphate extractions in these experiments ranged from 60 to 85 pct when leached under ambient conditions and at stoichiometric ratios ranging from 1.2:1 to 1.4:1. Undesirable Al_2O_3, Fe_2O_3, and MgO impurities were largely rejected. Higher grade ores produced acids that met established industrial impurity standards. The presence of up to 24 pct water in the waste did not depress the extraction of phosphorus from the waste or adversely affect the impurity content of the acid product. Methanol was recovered via vacuum distillation and used in subsequent tests. No significant difference was observed between the tests using recycled methanol and those using fresh methanol. Crude acid products were separated from insoluble residues via vacuum filtration using either filter paper or commercial filter cloths. Filtration times and fines retention were improved by the addition of 0.5 lb/ton of polyvinyl acetate (PVAc) or polyethylene oxide (PEO) to the methanol-acid slurries. These results show potential for substantially increasing the reserves of an important domestic resource.

OP 75–89. Thermal Characteristics of Energized Coal Mine Trailing Cables, by Michael R. Yenchek and Peter G. Kovalchik. Paper in Proceedings of the Ninth WVU International Mining Electrotechnology Conference, Morgantown, WV, July 26–29, 1988. WV Univ., 1988, pp. 178–185. The U.S. Bureau of Mines conducted research to determine the relationship between current load and temperature rises in coal mine trailing cables. Six low-voltage, unshielded, portable power cables were continuously and intermittently loaded with direct current of various magnitudes. Temperature rises within and on the cables were measured with thermocouples, and the data were recorded with a computer. Thermal time constants were calculated and fixed the periods of the duty cycle tests. Relationships between average temperature at the conductor-insulation interface and current load were established.

The steady state and intermittent currents that produce a 90°C average conductor-insulation temperature were then determined by mathematical modeling. Comparisons to Insulated Cable Engineers Association steady state ratings revealed that 10 to 25 pct more current is required to reach rated insulation temperature. Examination of the maximum intermittent temperatures attained showed that autoignition of coal dust and burns to personnel handling the cable would not be concerns if the temperature at the conductor-insulation interface averaged 90°C.

OP 76-89. Distribution of Platinum-Group Elements in an Ultramafic Complex Near Rainbow Mountain, East-Central Alaska Range, by James C. Barker. Paper in Process Mineralogy VII: Applications to Mineral Beneficiation Technology and Mineral Exploration, With Special Emphasis on Disseminated Carbonaceous Gold Ores, ed. by A. H. Vassiliou, D. M. Hausen, and D. J. T. Carson (Proc. Symp. on Process Mineral. held during Metall. Soc. Annu. Meeting, Denver, CO, Feb. 23–27, 1987). Metall. Soc., 1988, pp. 197–220. According to this U.S. Bureau of Mines study, near Rainbow Mountain in the east-central Alaska Range an ultramafic complex forms a sill-like intrusion composed of dismembered bodies exposed along the south side of the Denali Fault and Broxson Gulch Thrust. The complex comprises dunite and peridotite with lesser gabbro, which together exhibit poorly defined, steeply dipping compositional layering. The complex hosts four types of copper-nickel occurrences which have characteristic platinum-group elements (PGE), gold, and cobalt distributions. Three of the occurrence types are considered to have formed as a result of primary mineral segregations that developed during intrusion of the complex. The fourth type of copper-nickel occurrence formed as a result of postmagmatic hydrothermal fluids at intrusive contacts. Scanning electron microscope examination indicates that PGE occur as micrometer-size telluride and arsenide minerals.

OP 77-89. Coal Resources Within the Yukon Drainage, Interior Alaska, by James C. Barker and Kathleen Goff. Paper in Focus on Alaska's Coal '86, ed. by P. D. Rao (Proc. of Conf. held at Anchorage, AK, Oct. 27–30, 1986). Univ. AK–Fairbanks, Miner. Ind. Res. Lab., MIRL Rep. 72, 1987, pp. 336–349. According to this U.S. Bureau of Mines study, although some basins may contain adequate tonnage reserves, the potential for large-scale commercial development of the Yukon drainage coals is limited by a lack of transportation infrastructure and distance to market. They could, however, meet local energy needs. Even the relative small size and structural complexity of some of the coal occurrences in the Rampart and Eagle troughs need not be prohibitive to small-scale, local use as has occurred in the past. Those occurrences that are close to villages and proximal to a navigable river are especially worthy of evaluation as alternative energy resources for local heating use. Those that may occur within reasonable transport distance of other types of potential industrial developments (e.g., hardrock mines) constitute a viable energy option.

OP 78-89. Lithophile Metal, REE-Y-Nb Deposits on Southern Prince of Wales Island, Alaska, by James C. Barker and Cheryl L. Mardock. Paper in Process Mineralogy VII: Applications to Mineral Beneficiation Technology and Mineral Exploration, With Special Emphasis on Disseminated Carbonaceous Gold Ores, ed. by A. H. Vassiliou, D. M. Hausen, and D. J. T. Carson (Proc. Symp. on Process Mineral. held during Metall. Soc. Annu. Meeting, Denver, CO, Feb. 23–27, 1987). Metall. Soc., 1988, pp. 139–157. Recent U.S. Bureau of Mines investigations of a 55-km-long trend of intrusive complexes on southern Prince of Wales Island have identified significant resources of Nb, Y, REE, U, Zr, and a host of potential byproduct metals. The northwesterly trend comprises multiphased sodic alkaline and peralkaline diorite, monzonite, syenite, and riebeckite granite. There are at least three significant deposit types recognized, two of which contain most of the lithophile metals: (1) pegmatite dikes and/or vein dikes that zone laterally from the intrusions and (2) concentrically zoned pegmatites. A third, epigenetic replacement-type mineralization contains much of the U resource. Other deposit types with minor or unknown resource potential include diatremes, carbonatite, and placers. This report summarizes the deposit evaluations, characterizes the mineralization, and estimates the resources. To date a total of 40.7 million tons of mineralized material is estimated as indicated or inferred. Most of the Y_2O_3 plus REO is at a grade exceeding 0.5 pct, and half of the Nb_2O_5 exceeds 0.125 pct. Tonnage estimates would likely be substantially increased with additional exploration. Mineralogy is generally fine-grained and complex, and consists of more than a dozen principal REE–Y–Nb–U–Th–Zr phases, the sum of which may compose up to half of the rock. Approximately half of the REE–Y content comprises the heavy yttrium subgroup, which is uncommon compared to deposits elsewhere. Although the Alaskan deposits are likely subeconomic at today's metal prices and consumption levels, recent technological advances suggest future demand may increase.

OP 79-89. Diesel Particulate Matter Emission Control, by Kirby J. Baumgard and Winthrop E. Watts, Jr. Paper in Technical Papers: Diesel Use Seminar (Lexington, KY, June 7, 1988; Reno, NV, June 9, 1988). Am. Min. Congr., 1988, pp. 48–61. Diesel particulate matter (DPM) is a normal byproduct of diesel fuel combustion. It is composed mainly of submicrometer, insoluble, carbonaceous soot agglomerates, and adsorbed or condensed soluble organic compounds. DPM is almost entirely respirable in size; therefore, it is regulated under the respirable coal mine dust standard. Tests conducted by the U.S. Bureau of Mines have shown that an engine in good mechanical condition can emit up to 300 mg/scm of DPM, and those in need of maintenance can emit much higher concentrations. To ensure that DPM is not a major contributor to the respirable dust in mines, emissions should be reduced to the lowest possible levels. An industrial hygiene strategy aimed at reducing DPM levels in mines should include a combination of work practice modifications, emission controls, and regular monitoring of DPM levels. Work practices that should be emphasized include engine and fuel selection, engine maintenance, operator habits, and ventilation. Emission controls such as fuel additives, catalytic converters, water scrubbers, and diesel particulate filters should be considered. In some cases the use of emission controls may decrease the levels of some contaminants, while at the same time increasing the levels of others; thus they must be carefully evaluated before being selected for in-mine use. The objective of this report is to present information on the work practices and diesel exhaust controls that can be used to reduce DPM emissions now and in the future. A brief discussion of state-of-the-art DPM monitoring methods is also included.

OP 80-89. Tungsten Carbide Production From Ore Concentrates by Molten Salt-Natural Gas Sparging Treatment, by T. G. Carnahan, G. Kazonich, and A. E. Raddatz. Paper in Proceedings of First International Conference of the Metallurgy and Materials of Tungsten, Titanium, Rare Earths, and Antimony (Changsha, China, Nov. 5–8, 1988). Int. Acad. Publ., Beijing, 1988, v. 2, pp. 626–633. The U.S. Bureau of Mines conducted a bench-scale study to delineate the important parameters in a three-step process to produce commercial-quality tungsten carbide (WC) directly from tungsten minerals. In the process, tungsten concentrates of wolframite or wolframite and scheelite are decomposed at 1,050° C in a molten mixture of NaCl and Na_2SiO_3 that forms two immiscible phases. Tungsten, as sodium tungstate, reports to the halide phase and is separated from the gangue constituents, which report to the silicate phase. After decanting to separate the two phases, natural gas is sparged into the molten halide phase at 1,070° C. Submicrometer crystals of WC are initially produced. These crystals grow into thin, triangular-shaped plates up to 100 μm on a side or into popcorn-shaped conglomerates. Sparged WC was examined for its suitability for use in sintered carbide products. In physical evaluations, sparged WC ground to an average particle size of 1.52 μm and compacted with 10 pct Co binder into standard 6- by 6- by 22-mm test bars had a density of 14.35 and a Rockwell A hardness of 89.6. This compared favorably with 14.39 and 89.7, respectively, for test bars made from a standard commercial 1.52-μm WC powder. Test bars made from Bureau of Mines WC had no "C" porosity or eta phase.

OP 81-89. Molten-Salt Electrolysis of Neodymium From a Chloride Electrolyte, by M. F. Chambers and J. E. Murphy. Paper in Rare Earths: Extraction, Preparation, and Applications, ed. by R. G. Bautista and M. M. Wong (Proc. Symp. on Rare Earths held at TMS Annu. Meeting, Las Vegas, NV, Feb. 27–Mar. 2, 1989). Miner., Met., and Mater. Soc., 1988, pp. 369–376. Neodymium metal was electrowon by the U.S. Bureau of Mines from a molten-chloride electrolyte at 650° C using a molten-metal cathode. A 50 mol pct $NdCl_3$–50 mol pct KCl mixture served as the electrolyte. Binary metal alloys of Mg with Zn and Mg with Cd were used as molten cathodes. Under the best conditions, current efficiencies were 90 pct with an Mg–Zn cathode and 80 pct with an Mg–Cd cathode. Vacuum distillation was performed at 1,100° C for 30 min under a vacuum of 10^{-3} torr to separate the cathode metals from the neodymium. Neodymium metal of 99.9 + pct purity was recovered from the Mg–Cd alloy cathode. Almost 2 pct Zn remained in the neodymium recovered from the Mg–Zn alloy.

OP 82-89. Impact of a Ceramic Trap and Manganese Fuel Additive on the Biological Activity and Chemical Composition of Exhaust Particles From Diesel Engines Used in Underground Mines, by William M. Draper, Heidi Hartmann, David B. Kittelson, Winthrop F. Watts, Jr., and Kirby J. Baumgard. SAE Tech. Paper Series 871621, 1987, 18 pp. This U.S. Bureau of Mines study examines the effect of a ceramic particle trap and a manganese fuel additive on the mutagenic activity and chemical composition of diesel exhaust particulate matter from a heavy-duty mining engine. Particles were collected by dilution tunnel sampling from a four-cylinder, Caterpillar 3304, naturally aspirated, indirect-injection engine operated at six steady-state conditions. Depending on engine load and speed, the ceramic particle trap reduced the following emissions: particulate matter, 80 to 94 pct; soluble organic fraction (SOF), 83 to 95 pct; 1-nitropyrene, 94 to 96 pct; and SOF mutagenicity, 72 pct (cycle-weighted average). When the Mn fuel additive was used without a ceramic particle trap, the total cycle mutagenic activity emitted increased seven-fold, in part due to elevated emissions of 1-nitropyrene. When used with the trap at the recommended concentration the Mn additive lowers the trap regeneration temperature by 65°C, SOF removal efficiency from 86 to 62 pct, and removal efficiency for mutagenic substances from 72 to 43 pct.

OP 83-89. Comparative Leaching of Gold and Silver Ores With Cyanide and Thiourea Solution, by J. A. Eisele. Paper in Precious Metals '89, ed. by M. C. Jha and S. D. Hill (Proc. Int. Symp. Held at TMS Annu. Meeting, Las Vegas, NV, Feb. 27-Mar. 2, 1989). Miner., Mat., and Mater. Soc., 1988, pp. 253-259. There is currently much interest in how extraction of gold and silver from ores with acidic thiourea solution compares with extraction using alkaline cyanide solution. Agitation leaching tests were performed by the U.S. Bureau of Mines on 14 precious metal ores using sodium cyanide (NaCN) and thiourea [$(NH_2)_2CS$] as extractants. The objective was to compare the results of the two extractants. NaCN was used at a concentration of 2 g/L with and without H_2O_2 as an oxidant. $(NH_2)_2CS$ was used at concentrations of 2 and 20 g/L, and the solution potential was controlled at 390 to 420 mV standard hydrogen electrode (Eh) with $Fe_2(SO_4)_3$. With both reagents at 2 g/L extractant levels, NaCN extracted more gold and silver than $(NH_2)_2CS$ from all of the ores. At 20 g/L $(NH_2)_2CS$ compared with 2 g/L NaCN, $(NH_2)_2CS$ extracted more gold than NaCN from two ores, the same amount from one ore, and more silver from one ore. NaCN extracted more gold than $(NH_2)_2CS$ from 10 ores and more silver from 4 ores.

OP 84-89. Placer Platinum-Group Metal Potential in Alaska, by Jeffrey Y. Foley. Paper in Proceedings of the Tenth Alaskan Placer Mining Conference, Fairbanks, AK, Mar. 24, 1988, pp. 76-80. According to this U.S. Bureau of Mines study, platinum-group metals (PGM) are reported in dredge, sluice box, and pan concentrates and in placer gold bullion from more than 40 sites in Alaska. These include onshore, coastal, and offshore sites. Best known among these are the Salmon River placers, where the Goodnews Bay Mining Co. and other operators produced about 650,000 troy ounces of PGM and about 10,000 troy ounces of gold. The offshore potential at Goodnews Bay and nearby Red Mountain, where PGM mineral grains and submarine source rock have been identified, is yet undefined. Offshore targets at Lituya Bay and Kodiak Island, where PGM have been identified in beach sand concentrates, are unexplored. More typically, PGM occur in trace to minor amounts in certain onshore placer gold concentrates, but statistics on the amount of PGM recovered in this manner are generally unpublished. Such occurrences range from common reports of "small amounts of platinum in placer gold concentrates" to the relatively exceptional situation at Miller Gulch in the Chistochina placer gold district, where recovered precious metals have included 1 to 2 pct PGM since mining began in 1900. In addition to the possibly large offshore resources at Goodnews Bay and elsewhere along the extensive Alaska coast, significant unrecognized placer PGM resources that contain little gold and, therefore, have not been prospected as thoroughly as existing placer gold districts might exist in onshore areas that are proximal to mafic and ultramafic bedrock sources. Foremost among PGM placer targets are areas marginal to, or underlain by, "concentrically" zoned Alaskan-type ultramafic complexes like those that are the source rocks for productive PGM placers at Goodnews Bay, Alaska, and in the U.S.S.R. and British Columbia.

OP 85-89. Platinum-Group Elements in the Tonsina Ultramafic Complex, Southern Alaska, by J. Y. Foley, C. L. Mardock and D. C. Dahlin. Paper in Process Mineralogy VII: Applications to Mineral Beneficiation Technology and Mineral Exploration, With Special Emphasis on Disseminated Carbonaceous Gold Ores, ed. by A. H. Vassiliou, D. M. Hausen, and D. J. T. Carson (Proc. Symp. on Process Mineral. held during Metall. Soc. Annu. Meeting, Denver, CO, Feb. 23-27, 1987). Metall. Soc., 1988, pp. 165-195. According to this U.S. Bureau of Mines study, platinum-group elements (PGE) are preferentially associated with chromian spinels, including high-iron chromite, magnesian-chromian hercynite, and chromian magnetite in clinopyroxene-rich upper stratigraphic portions of the Tonsina ultramafic complex in southern Alaska. Ratios of Pt:Pt + Pd are proportional to chromium content in the associated chromian spinels. The maximum PGE content of geochemical rock samples from Dust Mountain is greater than 20,000 ppb (>0.6 oz/ton) with minor gold values. The maximum PGE content of tabled chromite concentrates is 3,430 ppb (0.1 oz/ton) at Dust Mountain, 1,029 ppb (0.03 oz/ton) at Sheep Hill, and 1,749 ppb (0.051 oz/ton) at Bernard Mountain. High-iron chromite at Dust Mountain yields tabled chromite concentrates with Cr:Fe ratios between 0.5 and 1.2. Lower PGE contents are found in more chromium-rich chromitites from Sheep Hill and Bernard Mountain that yield concentrates with Cr:Fe ratios between 1.0 and 2.8. Platinum-group minerals include amalgams, arsenides, PGE alloys, and sulfides. These minerals are between 3 and 40 μm in size and are concentrated along grain boundaries and fractures of metasomatically and hydrothermally altered chromian spinel grains.

OP 86-89. The As (Arsenic) System, by N.A. Gokcen. Bull. Alloy Phase Diagrams, v. 10, No. 1, 1989, pp. 11-22. This paper presents data on the arsenic system, including the equilibrium diagram, metastable phases, and thermodynamics and an extensive bibliography.

OP 87-89. Behavior of a Coal Pillar Prone To Burst in the Southern Appalachian Basin of the United States, by Anthony Iannacchione. Paper in Pre-Printed Papers, Second International Symposium of Rockbursts and Seismicity in Mines, Minneapolis, MN, June 8-10, 1988. Univ. MN, 1988, pp. 427-439. One of the more pressing engineering problems for deep longwall mines in the Southern Appalachian Basin is to design longwall systems that will eliminate catastrophic coal pillar failure from the working environment. The purpose of this U.S. Bureau of Mines study is to quantify the behavior of a particular size abutment pillar prone to burst or bump (local terminology). Because the 24.4-m (80-ft) square abutment study pillar is within the pillar size commonly used in this region, understanding the behavior of this pillar should aid in future efforts to design optimum mining strategies. This research has attempted to construct the stress and convergence profiles of the pillar in order to evaluate the ultimate strength, pillar deformation modulus, visco-elastic deformation, and violent failure characteristics during longwall mining. This information reflects the overriding influence of the local geologic characteristics on bursts, provides the field measurements needed to verify concurrent modelling studies, and suggests some basic mechanisms associated with the coal pillar bursts discussed in this paper.

OP 88-89. The Occurrence and Characterization of Geological Anomalies and Cutter Roof Failure: Their Effect on Gateroad Stability, by Anthony T. Iannacchione, John T. Popp, and Jodi A. Rulli. Ch. 24 in Second International Conference on Stability in Underground Mining, ed. by A. B. Szwilski and C. O. Brawner (Lexington, KY, Aug. 6-8, 1984). Soc. Min. Eng. AIME, 1984, pp. 428-445. According to this U.S. Bureau of Mines study, anomalous geological features in the coal and surrounding strata of a mine in northern West Virginia have fractured and deformed an inherently weak roof rock prior to mining. Horizontal stresses, as much as six times greater than overburden-related horizontal stresses, have induced cutter roof failure. This failure was distinguishable from rock deformation associated with geological anomalies because it was induced by mining. The characterization of these features has allowed for the prediction of zones of unstable roof rock and the determination of failure trends on gateroad stability. Geological anomalies included clastic dikes and a narrow zone of sandstone roof. Clastic dikes, representing intrusions of shale and claystone, were invariably accompanied by local roof rock instability and often formed the boundaries of roof falls. Shale was the dominant roof lithology except where a small sandstone occurred in the northwest portion of the longwall mining area. The sandstone occurs in two phases: a sandstone-filled channel, 5 m thick and 60 m wide, that eroded and

replaced the shale roof and the upper part of the coalbed, and a sheet sandstone unit that was crossbedded to interbedded with the underlying shale. Horizontal stresses are naturally relieved through the initiation of cutter roof failure. This failure may extend from a few meters to several tens of meters horizontally, and from a few centimeters to several meters vertically. Orientations of entries and crosscuts have a greater influence on the direction and total length of cutter roof failure at the rib-roof intersection than do the principal directions of the in situ horizontal stresses. Seventy-four percent of the cutter roof failures occurred along the rib-roof intersection. Orientations of cutter roof failure away from the rib-roof intersection were clustered in the north-south direction and may have been influenced by the horizontal stress field.

OP 89-89. Geological Association of Coalbed Gas and Natural Gas From the Hartshorne Formation in Haskell and LeFlore Counties, Oklahoma, by Anthony T. Iannacchione and Donald G. Puglio. Paper in Ninth International Congress of Carboniferous Stratigraphy and Geology: Compte Rendu, Volume 4: Economic Geology: Coal, Oil, and Gas (Washington and Champaign-Urbana, IL, May 17-26, 1979). Southern IL Univ. Press, 1985, pp. 739-752. According to this U.S. Bureau of Mines study, the Hartshorne Formation of the Arkoma Basin contains a complex association of gas reservoirs and possible source rocks. Geological and geochemical data suggest possible solutions to problems concerning the generation, migration, and retention of gases within the formation. The close association of the Hartshorne Coalbeds and Sandstones complicates an understanding of the origin and subsequent migration of the gas. Possible source rocks are the Hartshorne Coalbed, the marine Atoka Shales below, and the carbonaceous McAlester Shales above the Hartshorne Formation. The Hartshorne Coalbeds in Haskell and LeFlore Counties, OK, contain an estimated 1.1 to 1.5 Tcf of gas. In the same area, the Hartshorne Sandstones produce natural gas from the Quinton, Poteau-Gilmore, and Camaron Gasfields. These small gasfields are producing from combination traps (structural and stratigraphic). Gas samples were collected from nine producing wells in the three gasfields, from several gas drainage holes in the Hartshorne Coalbeds, and from two Hartshorne coal cores. The δC^{13} value of the methane, ranging from -34 to -44 per mil, and the amount of ethane, propane, and butane are thought to depend on the rank of the coal associated with each gasfield. Coalbed gas sampled from a mine near the Quinton Field contained more methane and less ethane, propane, and butane than natural gas from the Quinton Field. This may be due to the high sorption properties of coal. The heavier hydrocarbon gases remain adsorbed on the surface of the coalbed micropore structures, with higher proportions of methane released into coalbed macropore structures. Data collected so far indicate that the gas from the Poteau-Gilmore and Camaron Fields is derived, at least partially, from associated coalbeds, while the gas from the Quinton Field may have another origin.

OP 90-89. A Study of the Subsidence of Sloping Terrain due to Undermining, by Paul W. Jeran and Vladimir Adamek. Paper in Proceedings, 1988 Symposium on Mining, Hydrology, Sedimentology, and Reclamation, Lexington, KY, Dec. 5-9, 1988. Univ. KY, 1988, pp. 35-39. Subsidence over a series of longwall panels undermining sloping terrain in southwestern Pennsylvania was monitored to verify the U.S. Bureau of Mines Subsidence Prediction Model for the Northern Appalachian Coal Region. Comparison of the field data to model output shows close agreement. Vertical movements over each panel ceased with the mining of the adjacent panel. Horizontal movements were significantly affected by topographic slope. The distribution of horizontal strains over each panel was similar with a zone of compression occurring over the center of each panel flanked by zones of tension toward the rib. The magnitudes of the tensions were affected by the slope. The strains developed at the completion of each panel were not significantly altered by the mining of subsequent panels. (Note.—A similar paper was presented under the title "Subsidence due to Undermining of Sloping Terrain: A Case Study" at the Fifth International (FIG) Symposium on Deformation Measurements and 5th Canadian Symposium on Mining Surveying and Rock Deformation Measurements, Fredericton, NB, Canada, June 6-9, 1988, and published in the Proceedings.)

OP 91-89. Evaluation of Water-Jet-Assist Mechanical Cutting of Oil Shale, by W. J. Kogelmann, J. E. Virgona, E. D. Thimons, and A. L. Weakly. Paper in Proceedings of the Third Annual Oil Shale, Tar Sand, and Mild Gasification Contractors Review Meeting, ed. by T. C. Bartke (Morgantown, WV, July 19-21, 1988). U.S. DOE, DOE/METC-88/6098, 1988, pp. 306-321. The U.S. Department of Energy's Grand Junction Projects Office has entered into a $1.5 million Cooperative Agreement with Alpine Equipment Corp./Astro International Corp. of State College, PA, for the evaluation of water-jet-assisted mechanical cutting of oil shale under actual mining conditions. The 24-month, three-phase Technology Development Project began in February 1988, and the project costs will be equally shared between Alpine and the DOE. Alpine Equipment Corp. has designed and will assemble and field test a commercial-sized, water-jet-assisted, mechanized mining machine. Field testing of the machine will be conducted at Exxon's Colony Pilot Mine located in the Piceance Basin of Western Colorado. Additional support will be provided by the oil shale companies through the Colorado Mining Association and the U.S. Bureau of Mines Pittsburgh Research Center. The physical characteristics of oil shale (a dolomitic limestone containing kerogen) make conventional mechanized production mining methods impractical. Excessive machine vibration, high pick wear rates, and excessive dust generation make current mechanical production excavation methods less efficient and more costly than the traditional drill-and-blast methods. However, conventional drill-and-blast methods have limitations imposed by excessive rock damage and regulatory considerations. Improved mechanical production excavation technologies could make oil shale more competitive with other energy sources. The evaluation under actual mining conditions will provide field data that can be utilized by the private sector to develop and commercialize water-jet-assisted mechanized mining equipment for use in oil shale. The successful application of high-pressure water-jet technology in conjunction with mechanical mining could favorably impact the mining of oil shale by reducing capital and operating costs, improving safety, and increasing the extraction ratio of oil shale mined. Water-jet-assisted roadheader field tests on coal have shown that high-pressure water jets cool the cutting head, remove already mined rock from the cutting surface, and reduce dust production. This in turn results in increased cutter life and reduced ventilation costs.

OP 92-89. Longwall Mining Subsidence Surveying: An Engineering Technology Comparison, by John C. LaScola and Michael A. Trevits. Paper in Proceedings of 5th International (FIG) Symposium on Deformation Measurements and 5th Canadian Symposium on Mining Surveying and Rock Deformation Measurements, ed. by A. Chzanowski and W. Wells (Fredericton, NB, Canada, June 6-9, 1988). Univ. NB, 1988, pp. 298-307. This U.S. Bureau of Mines investigation evaluates and compares conventional and high-technology geodetic surveying systems using a survey grid installed over stable ground with physical characteristics typical of current longwall mine subsidence study sites. The positions of 145 monuments along the grid were measured during a 1-month period by electronic distance meter-theodolite-levels (EDM-theodolite), an automatic recording infrared laser tachymeter, a satellite-based global positioning system, aerial photography (photogrammetry), and a prototype inertial surveyor. Statistical analysis indicates that the average three-dimensional displacements from the base (EDM-theodolite) for both the tachymeter and photogrammetry were within 0.25 ft (0.076 m).

OP 93-89. Longwall Pillar Design—Some Recent Developments, by C. Mark. Soc. Min. Eng. AIME preprint 89-103, 1989, 9 pp. Effective ground control in the gate entries, particularly in the tailgate travelways, is essential for safe longwall mining. Longwall pillars maintain gate entry stability and carry abutment loads. To answer the need for effective longwall pillar design, an empirical method called Analysis of Longwall Pillar Stability (ALPS) was proposed several years ago. Some recent research at the U.S. Bureau of Mines has focused on the refinement and verification of the ALPS method. ALPS was originally developed from field studies in which multiple stressmeters were installed in longwall pillars and monitored during mining. Several new field studies have now been incorporated into the ALPS data base. The field measurements have been used to verify formulas for predicting abutment strength and pillar loads, and to develop an expression for the distribution of the abutment load. Since its development, the ALPS method has been applied to nearly 100 mining case histories from longwalls located throughout the Eastern United States. Back-analysis of "stability factors" for these case histories indicates that ALPS is applicable to a wide variety of mining situations. In its present form ALPS is most useful for preliminary longwall pillar design, and for optimizing pillar size based on site-specific experience. A computer program is being prepared that will make ALPS even more accessible to mine planners. Future Bureau research will

incorporate ALPS into a complete gate entry design package, which will address entry support and roof and floor rock properties as well as pillar design.

OP 94-89. Sulphur Polymer Cement for Chemically Resistant Concrete, by W. C. McBee, Harold Weber, and Frank E. Ward. Const. and Building Mater., v. 2, No. 4, Dec. 1988, pp. 220-224. Composite materials based on sulfur polymer cement and mineral aggregate have been developed by the U.S. Bureau of Mines as part of a program to utilize abundant material resources. Goals are to develop durable, chemically resistant construction materials with lowered costs. Chemical degradation of portland cement concrete is a serious problem due to acid and salt attack.

OP 95-89. Characterization of the Transient Response of a Diesel Exhaust-Gas Measurement System, by B. T. McClure. SAE Tech. Paper Series 881320, 1988, 10 pp. The U.S. Bureau of Mines conducts research to reduce exposure of miners to exhaust emissions of diesel-powered mining equipment. Conventional sampling and instrumentation techniques used to measure emissions over a research duty cycle distort the signal generated by time variation of the concentration of gases in the exhaust. Delays up to 30 s, effective integration times up to 2.9 s, and dispersions up to 1.4 s are observed. This paper reports numerical techniques that make it possible to infer the actual variation of concentration in the exhaust on a time scale of about 1 s. These techniques are used to evaluate the product of concentration and flow to yield accurate total gaseous emission during a test.

OP 96-89. A Knowledge-Based System for Hydraulic Maintenance of a Continuous Miner, by Julie Mitchell. Ch. 90 in Proceedings of 21st International Symposium on Application of Computers and Operations Research in the Mineral Industry, ed. by A. Weiss. Soc. Min. Eng. AIME, 1989, pp. 993-1002. The U.S. Bureau of Mines is conducting research on the application of expert systems technology to mining equipment diagnostics and predictive maintenance, to increase mining productivity and efficiency. One of the greatest hindrances to mining productivity is the breakdown of equipment, causing lengthy and costly delays. A diagnostic maintenance expert system (DIMES) is being developed for the hydraulic system of a continuous coal mining machine. Through the use of such a system, the frequency of equipment failures and repair time should be significantly reduced. This paper describes the application domain, the functional requirements, and the problem approach for DIMES, the design and implementation of the knowledge-based system, the sensor work involved with the project, and the future plans for the continued development of this and other expert systems.

OP 97-89. Bureau of Mines Ripper Miner, by R. J. Morrell, D. A. Larson, and R. L. Schmidt. Soc. Min. Eng. AIME preprint 89-132, 1989, 16 pp. The U.S. Bureau of Mines has developed a hardrock cutting concept and incorporated it into an extraction system called the ripper miner. This concept uses a single, wide bit that attacks the rock at a shallow angle and slow speed. Research has demonstrated that the system is capable of excavation rates exceeding those possible with conventional drill-blast and can effectively cut rock too hard for conventional roadheaders or continuous mining machines. It has the additional advantages of low bit wear and dust generation. This highly flexible concept is applicable to both mining and driving development openings and can cut any material from coal to hard rock. A single ripper miner can perform the functions of a continuous mining machine, a roadheader excavator, and a tunnel boring machine. This paper presents the history of the development of the ripper miner from the initial laboratory tests through the construction and testing of the full-scale, laboratory prototype. It includes a comparison of the ripper miner to systems currently used from the standpoint of energy efficiencies and operating costs.

OP 98-89. Recovery of Precious Metals From Cyanide Solutions Using Ion-Exchange Resins, by G. R. Palmer, W. L. Staker, and R. G. Sandberg. Paper in Process Mineralogy VIII: Applications of Mineralogy to Mineral Beneficiation Technology, Metallurgy, and Mineral Exploration and Evaluation, With Emphasis on Precious Metal Ores, ed. by D. J. T. Carson and A. H. Vassiliou (Proc. Symp. on Process Mineral. held during Miner., Met., and Mater. Soc. Annu. Meeting, Phoenix, AZ, Jan. 25-28, 1988). Miner., Met., and Mater. Soc., 1988, pp. 81-91. The U.S. Bureau of Mines investigated the use of ion-exchange technology for the recovery of precious metals from cyanide leach and spent electrolytic solutions. This research included adsorption of gold and silver on both weak- and strong-base anion-exchange resins. The effects of nickel, mercury, and iron on precious metal loading of strong-base resins were also determined. Owing to the nonselectivity of strong-base resins, selective elution also was investigated. Both commercially available and experimental weak-base anion-exchange resins were tested. None of the commercial weak-base resins tested were suitable for a caustic-cyanide system owing to their low recovery of precious metals at pH 10 or above; however, three experimental resins have possible application. Continuous tests conducted with mill cyanide solution in a multicompartmented ion-exchange column using strong-base anion-exchange resins adsorbed nearly 100 pct of the precious metals as well as the iron and nickel. During the elution of this loaded resin the iron was first removed with NaCl plus NaOH; then nickel with dilute H_2SO_4 or HCl; finally gold and silver with thiourea in dilute HCl.

OP 99-89. Structural Deformation of the Allegheny Group of Coalbeds in the Appalachian Plateau of Central Pennsylvania, by Donald G. Puglio and Anthony T. Iannacchione. Paper in Ninth International Congress of Carboniferous Stratigraphy and Geology; Compte Rendu, Volume 4: Economic Geology; Coal, Oil, and Gas (Washington and Champaign-Urbana, IL, May 17-26, 1979). Southern IL Press, 1985, pp. 731-736. According to this U.S. Bureau of Mines study, large- and small-scale structural anomalies have had both positive and negative effects upon the minability of the Freeport and Kittanning Coals. Several small-scale thrust and normal faults have been encountered underground and are associated with poor roof conditions, high methane and water flow rates into mine workings, and displacements not conducive to safe and economic extraction. A large-scale strike-fault zone had both a positive and negative effect upon the minability of the Upper Freeport Coal. The steep dip of coal-bearing strata associated with the strike fault complicated strip mining, but there were more reserves than expected. Nearly vertical dips on a coalbed west of the Allegheny Front in Pennsylvania were observed in a strip mine near Bolivar, Westmoreland County. The mine is working the Upper Freeport Coal on the downthrown side of a northeast-southwest-trending strike-fault zone, traced for roughly 3 miles (4.8 km) along the eastern flank of the Chestnut Ridge anticline. Coal-bearing strata dip between 12° and 85° southeast on the downthrown side of the fault; on the upthrown side, rock strata are essentially flat-lying. Local structural adjustment to the large-scale faulting resulted in at least three thrust faults in members of the Upper Freeport Coal. Seven thrust faults, similar in character to those observed in the strip mine, were encountered in three underground mines (two in the Upper Freeport and one in the Lower Freeport Coals) located west of the Chestnut Ridge anticline in Indiana and Armstrong Counties. Underground, the thrust faults are associated with poor roof and inordinately high water and methane gas flow into mine workings. Thrust faults in both surface and underground mines are characterized by (1) small displacement, (2) strikes roughly parallel to the local rock strata strike, (3) dips between 20° and 45°, and (4) a 1- to 3-inch-thick mylonite or fault gouge zone along the fault plane. A series of normal faults occurs in sections of an underground mine working the Lower Kittanning Coal on the eastern flank of the Laurel Hill anticline in Cambria County. Even though unstable roof is not associated with these normal faults, the displacement caused by faulting severely hampered the mining of a longwall panel. Certain characteristics of one or more of these faults suggest a synsedimentary origin: (1) strike and dip vary with each fault, (2) in one instance, reverse drag occurs along the fault plane, and (3) one fault flattens out directly into the bedding plane above the coalbed.

OP 100-89. Increasing Dewatering Efficiency Through Optimization of the Flocculation Sequence, by Bernard J. Scheiner. Paper in Proceedings of the International Technical Conference on Filtration and Separation, Ocean City, MD, Mar. 21-24, 1988. Am. Filtration Soc., 1988, pp. 371-378. The optimization of the flocculation sequence for mineral slurries has been studied by the U.S. Bureau of Mines. This paper discusses the importance of flocculation in obtaining optimum results from the solid-liquid separation unit operation common to most mineral processing schemes. Emphasis is placed on how the flocculation step affects dewatering performance of screens and belt presses. Flocculation of phosphatic clay waste, effluents from placer gold mines, and coal-clay waste is discussed in terms of dewatering efficiency.

OP 101-89. A Microcomputer Network for Autonomous Mining Research, by William H. Schiffbauer. Ch. 85 in Pro-

ceedings of 21st International Symposium on Application of Computers and Operations Research in the Mineral Industry, ed. by A. Weiss. Soc. Min. Eng. AIME, 1989, pp. 928–935. Research is being conducted toward making underground mining equipment autonomous. This will facilitate improvements in safety by relieving workers of dangerous tasks and will increase production by providing more accurate control with less downtime. A U.S. Bureau of Mines-developed microcomputer network has enhanced this research by permitting a group of diverse computers to interact with a mining machine as well as with each other over a common data link. The network is composed of specially integrated off-the-shelf hardware and industry-standard operating system and programming languages. Using the network, researchers can conduct various experiments with the mining machine using a diverse group of intelligent sensors, computers, and microcontrollers. Descriptions of the mining machine, the mining machine control computer, control algorithms, the microcomputer network architecture, and communication protocols are discussed.

OP 102–89. Disintegration of Frozen Granular Materials Using High Pressure Water Jets, by Frank J. Skudrzyk, James C. Barker, and Vijayan Sugumaran. Paper in Cold Regions Engineering—Proceedings of the Fifth International Conference, ed. by R. L. Michalowski. Am. Soc. Civil Eng., 1989, pp. 320–334. Increasing geotechnical activities in subarctic and arctic regions, such as major opencast coal mining, pipeline construction, and alluvial underground mining, call for improved techniques of frozen granular ground disintegration and better control of the breakage processes. Out of many comminution methods available, high-pressure water jetting may be preferred for disintegration of frozen granular materials. The U.S. Bureau of Mines conducted high-pressure water jet cutting experiments on frozen, gold-bearing, granular materials. The objective was to evaluate performance and efficiency in terms of required specific energy for disintegration. The tests were conducted underground during the winters of 1984 and 1985, at the U.S. Corps of Engineers experimental permafrost tunnel near Fox, AK. Testing pressures from 6.9 to 51.8 MPa (1,000 to 7,500 psi) and flow rates ranging from 0.2 to 3.2 L/s (3.2 to 50 gpm) were used. All testing was performed under actual in situ conditions in a section of frozen auriferous gravel and underlying bedrock. Specific energies needed to cut frozen gravels, the overlying silt, and the partially decomposed bedrock were determined. Furthermore, large holes were drilled in frozen bedrock and gravel to assess the effectiveness of high-pressure water jets in large-volume fragmentation of frozen materials. Artificial frozen samples of known composition were also tested to determine the influence of composition and standoff distance on specific energies. Based on observations and experimental results, the ranges of pressure and standoff distances are determined for optimum cutting of frozen materials. Equipment selection and operation at various temperatures are discussed.

OP 103–89. Computer-Aided Analysis of Mining Crewstations, by Roger Unger and James Rider. Paper in MinTech '89: The Annual Review of International Mining Technology and Development, ed. by T. L. Carr. Sterling Pub. Ltd., London, 1989, pp. 187–189. The design of underground mining machinery has generally stressed the technical and engineering aspects related to the machine's functions over the needs of its human operators. This has resulted in machines that strain the capabilities of their operators and contribute to the high accident rate during the operation of mobile underground coal equipment. In 1984, there were 1,822 injuries to miners while operating or riding in underground mobile equipment. This amounts to 17 pct of all injuries that occurred in underground coal mining during that year. A study conducted by the Mine Safety and Health Administration found that 36 pct of the fatalities involving underground coal mobile equipment were related to improperly designed operator compartments. Operators must often lean outside the confines of the compartment in order to steer the equipment, increasing the likelihood of striking the rib or roof. Controls are often unlabelled and placed where they are difficult to reach and cannot be distinguished from one another. In panic situations, the wrong control may be activated, which can lead to accidents. To address these and other related problems, the U.S. Bureau of Mines is developing a computer-based model to aid in the analysis of the human engineering aspects of mining equipment design. The model, known as CAP (Crewstation Analysis Programs), is intended for use by original equipment manufacturers and mining companies for the initial design work on new machines, and to evaluate proposed modifications to existing machines. This article outlines the overall structure of CAP and briefly describes the visibility and illumination analysis sections.

OP 104–89. Foundation Response to Subsidence Induced Ground Movements: A Case Study, by Jeffrey S. Walker and John C. LaScola. Paper in Proceedings of 5th International (FIG) Symposium on Deformation Measurements and 5th Canadian Symposium on Mining Surveying and Rock Deformation Measurements, ed. by A. Chzanowski and W. Wells (Fredericton, NB, Canada, June 6–9, 1988). Univ. NB, 1988, pp. 563–572. The purpose of this U.S. Bureau of Mines effort was to determine if mining-induced ground movement is directly transferred to a structure, and how that process takes place. A series of four concrete block walls with foundations were constructed and monitored over an active longwall panel as part of a comprehensive subsidence research program. Three of the four walls were located perpendicular to the advance of the longwall face, in the zones where maximum inclination, maximum tension, and maximum curvature were predicted. The fourth wall was constructed along the centerline of the panel, parallel to the advance of the longwall face. All of the walls and the surrounding ground surface were instrumented with conventional survey monitoring points and extensometer stations to observe the vertical and horizontal movements. The fourth wall also included continuously recording tiltmeters. The results of this investigation indicate that simple structures respond to subsidence in a similar manner as the ground surface, suggesting that once the transfer mechanism is fully defined through further field and laboratory research, prediction models can be developed or modified to allow accurate estimation of the effect of mining on surface structures.

OP 105–89. Enhanced Drilling Performance With Polymer Solutions at Zero Surface Charge Conditions, by P. J. Watson, J. E. Pahlman, P. A. Tuzinski, and W. H. Engelmann. Paper in Drilling Symposium 1989, ed. by J. C. Rowley (Houston, TX, Jan. 22–25, 1989). ASME, 1988, pp. 43–48. In an overall program to increase minerals extraction efficiency, the U.S. Bureau of Mines has investigated the use of chemical additives to enhance drilling performance. Laboratory drilling results have demonstrated increased penetration with simultaneous extension of bit life using various concentrations of chemical additive solutions that produce a zero surface charge (ZSC) on the rock. This enhanced ZSC-controlled drilling performance was demonstrated for Sioux Quartzite, Westerly Granite, Minnesota taconite, and Tennessee marble using a variety of chemical additives at their respective ZSC concentrations in several waters of varying purity. Penetration improvements with ZSC concentration solutions ranged from 84 pct to over 600 pct, while bit life improvements ranged from 77 to over 400 pct for the additives tested. The best additive for enhanced ZSC-controlled drilling performance was a high-molecular-weight nonionic polymer, since it sustained the highest enhanced drilling performance over a continuous range of concentrations. These results may have applicability to other processes related to mining and petroleum engineering.

OP 106–89. Reducing Workers' Dust Exposure During Bag Stacking in Enclosed Vehicles, by Andrew B. Cecala, Anthony Covelli, and Edward D. Thimons. Am. Ind. Hygiene Assoc. J., v. 50, No. 2, Feb. 1989, pp. 99–104. The U.S. Bureau of Mines has evaluated cost-effective systems to ventilate enclosed vehicles being loaded directly with bagged product material at mineral processing plants. This evaluation included both forms of transportation: railcars and trailer trucks. The goal of this research was to lower the dust exposure of workers stacking bags in these enclosed vehicles; these workers usually have the highest dust exposures in the entire processing plant. The problem occurs because there is no mechanical ventilation inside these vehicles. As the vehicle is being loaded, dust concentrations increase to substantial levels because released dust has no means of exiting the vehicle or of being diluted with fresh air. In cases where the dust is hazardous, as with silica sand, this may present a serious health hazard. This research project was a two-step effort. The first step was a qualitative laboratory evaluation performed in a railcar to compare different types of ventilation systems (blowing, exhaust, and push-pull systems) using a methane (CH_4) tracer gas technique. An exhaust system located over the snake conveyor was the most effective system at reducing gas levels in and around the bag stacker's work area. The second step then involved a field evaluation at a silica sand processing plant to determine the system's effectiveness in the actual work environment. Three different versions were evaluated in an attempt to optimize the exhaust ventilation system's effectiveness. The most effective

version involved exhausting 54.5 m³/min (2,000 ft³/min) through a fiberglass tube located 1.1 m past the end of the slinger at a 2.0-m height so as not to interfere with the bag stacker's job function. A small exhaust tube drawing approximately 8.8 m³/min (300 ft³/min) at the snake conveyor-slinger transfer point captured the dust generated at this location. Dust reductions in and around the bag stacker ranged between 65 and 95 pct when loading both 22.7-kg (50-lb) and 45.4-kg (100-lb) bags of ground silica sand into railcars and trailer trucks with this system.

OP 107-89. Gainsharing: A Technique To Improve Management-Employee Relations and Mine Productivity, by A. B. Cecala, S. J. Liebowitz, and W. D. Presutti. Min. Sci. and Technol., v. 8, 1989, pp. 215–225. This U.S. Bureau of Mines article discusses a potentially cost-effective means of increasing mine production through improved management-employee relations. This article specifically examines one particular technique—gainsharing. This involves two fundamental elements. The first is a working committee of personnel from the workforce and management whose primary purpose is to evaluate suggestions from employees on ways of improving the work or production process. An additional and equally important objective is to develop a trusting relationship between the employees and management through this two-way communication network. The second element of the gainsharing technique is a bonus plan in which employees are paid a bonus based on the amount of production increase over a base level for a prescribed time period. The key to a successful gainsharing plan, or to any other human factor management program or technique, is to establish a trusting and open relationship between employees and management. This technique must be "a way of life" for management and not just an attempt to increase productivity. The gainsharing plan is an excellent initial technique for developing this trusting relationship because it develops a communication network which shows employees that they have an input into the company's success, and that management is willing to listen and reward them as a group for their ideas and efforts.

OP 108-89. An Assessment of Coal Mine Escapeway Reliability Using Fault Tree Analysis, by Gerrit V. R. Goodman. Min. Sci. and Technol., v. 7, 1989, pp. 205–215. The issue of miner safety in case of an underground mine fire has been extensively examined by both Government and industry. These efforts have intensified in recent years following a number of fatal fires at underground coal mines. As a result, there is an increasing interest in the reliability of coal mine escapeways during a mine fire. This U.S. Bureau of Mines paper discusses the use of fault tree analysis for evaluating escapeway reliability. A fault tree is developed using standard logic formulations. It is later evaluated using commercially available software. The computer model uses Boolean reduction to obtain the minimal cut sets and minimal path sets of the tree. A brief analysis is also conducted to determine the occurrence probability of the TOP event. This study shows that fault tree analysis is a viable means of analyzing escapeway reliability. The cut and path sets reveal those event sequences leading to fatalities. Such information is useful in safety training and accident prevention. The probability of the TOP event shows the frequency of occurrence for fatalities in an underground mine fire. The usefulness of this value, however, is limited by the accuracy of the data for the initiating events. For mining events, the data are difficult to estimate precisely.

OP 109-89. Atomization of Water Sprays for Quartz Dust Control, by Natesa I. Jayaraman and Robert A. Jankowski. Appl. Ind. Hyg., v. 3, No. 12, Dec. 1988, pp. 327–331. The use of water spray systems for respirable dust control on continuous mining machines has been a traditional and relatively effective approach. However, with the implementation of more stringent dust standards due to quartz, the efficacy of these systems has been questioned. In response, the U.S. Bureau of Mines has undertaken a study to determine the relationship between spray pressure, total respirable dust control, and specific quartz dust control. Laboratory and full-scale model studies have been completed in an effort to evaluate the effectiveness of low-pressure, high-pressure, and combination water spray systems. Results of these tests indicate that high-pressure atomized sprays will improve reduction of all respirable dusts, especially dust in the 3.0-μm size range and below. These are also the size ranges that have been shown to contain the most significant amounts of airborne respirable quartz dust. Improved control techniques, such as those presented in this article, may be required in mine sections where more stringent dust standards are in effect.

OP 110-89. Microwave Drying of Fine Coal, by David P. Lindroth. Mine and Quarry, v. 18, No. 3, March 1989, p. 37. Worldwide, an increasing number of coal preparation plants are drying fine coals and gaining a variety of benefits. Transport costs can be reduced; heat loss during the burning process can be reduced; freezing problems may be avoided. Microwave technology has been one of the potential methods studied by the U.S. Bureau of Mines as part of a research program into drying fine coal. Efficiency for all tests was 77 pct, which compares very favorably with conventional drying techniques, particularly since less energy was needed to dry the coal. Since water tends to readily absorb microwave energy and coal does not, microwave energy selectively focuses on the moisture content in the coal, drying it far more efficiently than conventional drying processes. Results showed that water absorbs microwave energy significantly, but coal does not. Secondly, microwave energy heats only the water, unlike existing drying methods, which heat both water and coal. Finally, the method was found to be energy efficient and minimized the generation of fugitive dust.

OP 111-89. Sulfur Polymer Concrete for Special-Purpose Applications, by William C. McBee, Harold H. Weber, and William T. Dohner. Paper in Structural Materials, ed. by James F. Orofino (Proc. Sess. Related to Structural Materials at Structures Congr '89, San Francisco, CA, May 1–5, 1989). Am. Soc. Civil Eng., 1989, pp. 31–43. Special-purpose sulfur concrete construction materials, based on sulfur polymer cement (SPC) and mineral aggregate, have been developed by the U.S. Bureau of Mines as part of a program to utilize domestic mineral resources. Program goals are to develop durable, chemically resistant construction materials to increase productivity in the chemical, fertilizer, and metallurgical industries by lowering maintenance costs for labor, energy, equipment, and material. This paper describes the research related to development of SPC, the sulfur polymer concrete (SC), and the industrial testing, together with the development of commercial-scale equipment and a brief overview of some recent special-purpose applications. Thermoplastic SPC is produced commercially by reacting cyclic olefinic hydrocarbon chemical modifiers with elemental sulfur at 300° F (149° C) in a sealed chemical reactor. The molten SPC is mixed with mineral aggregates, producing a high-strength concrete product with an average compressive strength of 7,000 psi (48 MPa) upon cooling. Because of its thermoplastic nature, the mechanical strength properties of SC are achieved rapidly upon solidification, with 80 pct of the ultimate strength achieved after a few hours. SC's have been developed that are essentially impervious to moisture permeation and are extremely resistant to most mineral acid and salt solutions. The materials have been evaluated in over 50 industrial process environments in a cooperative testing program with the Sulphur Institute and industry. The use of SC for resisting salt corrosion in marine environments and its rapid-setting, high-strength characteristics for use in the transportation industry are being demonstrated and evaluated. Commercial-scale equipment has been developed and utilized for large-scale construction applications. State-of-the-art production and construction techniques are described. Currently, SC materials are showing superior performance characteristics, compared to portland cement concrete in general industrial applications and are demonstrating versatility for use in many other special-purpose construction applications.

OP 112-89. Hot-Surface Ignition Temperatures of Dust Layers, by Yael Miron and Charles P. Lazzara. Fire and Mater., v. 12, No. 3, Sept. 1988, pp. 115–126. Minimum dust layer ignition temperatures on a hot surface were determined for several dusts by the U.S. Bureau of Mines, using a test procedure recommended by the National Academy of Sciences. The dusts included coal, three oil shales, lycopodium spores, corn starch, grain, and brass powder. For a few of the dusts, the effects of particle size and layer thickness on the minimum ignition temperatures were examined. Test results were repeatable and reliable for the fuels, the lycopodium spores, and the brass powder. The minimum hot-surface ignition temperatures of 12.7-mm-thick layers of these dusts ranged from 160°C for brass to 290°C for 20-gal ton^{-1} oil shale. Flaming combustion was observed only with the brass powder. The minimum ignition temperatures decreased with thicker layers and with smaller particle sizes. Some difficulties were encountered with the corn starch and grain dusts. During heating, the starch charred and expanded; the grain dust swelled and distorted. The test was found acceptable for determining the minimum layer ignition temperature of a variety of dusts. To prevent fire hazards due to smoldering or flaming dust layers, the temperatures of surfaces on which combustible dusts

accumulate should be lower than the minimum hot-surface ignition temperatures of the dusts.

OP 113-89. Marine Placer Deposits, by Mark S. Robinson and James C. Barker. Paper in Proceedings of the Tenth Annual Conference on Alaskan Placer Mining, ed. by James A. Madonna. Alaskan Prospectors Publ., Fairbanks, AK, 1988, pp. 34–37. Marine placer deposits can be divided into three categories, including modern beaches, ancient beaches (either onshore or offshore), and submarine deposits. Alaska has 54 pct of the coast line and 74 pct of the continental shelf of the United States and contains known marine placers of all three major categories. Recent U.S. Bureau of Mines studies indicate that this area contains enormous potential for new discoveries of industrial minerals, in addition to precious metal marine placers.

OP 114-89. Water-Jet-Assist Improves Shearer Performance, by Charles D. Taylor and Edward D. Thimons. Eng. and Min. J., v. 190, No. 4, Apr. 1989, pp. 37–39, 53. This U.S. Bureau of Mines study indicates that there are major advantages in using water-jet-assisted cutting for dust control. Maximum benefit is achieved at pressures between 2,000 and 3,000 lb/in^2 with no increase in normal water flowrate. Use of water-jet-assisted cutting increases bit life by keeping the bit tip cooler. Improving bit life reduces the number of times new bits must be installed, and this is particularly important during cutting in very hard and abrasive rocks.

OP 115-89. Clay Veins: Their Physical Characteristics. Prediction, and Support, by Frank E. Chase. Paper in Proceedings, Fourth Conference on Ground Control in Mining, July 22–24, 1985. WV Univ., 1985, pp. 212–219. Clay veins, also referred to as clay or clastic dikes, have been responsible for numerous underground injuries and fatalities. These hazardous structures are also responsible for increased production costs during all phases of mining. For these reasons, the U.S. Bureau of Mines has investigated the physical characteristics of and roof instability problems associated with clay veins in order to make support and other mining recommendations. In addition, the occurrence and origins of clay veins were examined to determine whether or not the structures could be projected into unmined portions of the coalbed. This investigation included portions of the Arkoma, Illinois, Northern Appalachian, Southern Appalachian, and Warrior Coal Basins. Virtually all clay veins observed or documented occurred in the Illinois and Northern Appalachian Basins. Observed clay veins ranged from 1 in to 16 ft in cross section and were found under shale, siltstone, sandstone, and limestone roof rock. Individual clay veins were predominantly composed of claystone; however, limestone, siltstone, and sandstone infilled clay veins do occur. Clay vein formation has been associated with the infilling of fissures which result from compressive, tensile, or shear ground failures. These gaping fissures were propagated by compactional processes and/or tectonic stresses active during and subsequent to coalification. Associated fault, fracture, and slickenside planes commonly parallel clay veins and disrupt the lateral continuity of the immediate and, sometimes, main roof. When clay veins parallel or subparallel the direction of face advance, the roof is segmented into cantilever beams, causing unstable conditions. Therefore, the strata on either side of the clay vein must be bolted and strapped together to form a beam.

OP 116-89. Chromite, by John F. Papp. Am. Ceram. Soc. Bull., v. 68, No. 5, May 1989, pp. 1037-1038. Chromite is the only source of chromium for metal alloys and chemicals and is also used in refractories and foundry sand. Chromite is accompanied by various amounts of silicate gangue minerals and is generally beneficiated. Compositions vary widely, from 28 to 56 pct Cr_2O_3, with the important Cr:Fe ratio varying from 1.5 to 4.1. Silica content ranges from 0.8 to 14 pct. High-silica chromites are acceptable for some uses if the chromite is a hard lump type and the rest of the chemistry, e.g., Cr_2O_3 content and Cr:Fe ratio, is favorable. Alumina, magnesia, and iron oxide are other components. The United States has no commercial chromite deposits; it has been 100 pct import dependent for many years. This U.S. Bureau of Mines article reviews chromium output, use, etc., in 1987–88.

OP 117-89. A Summary of U.S. Bureau of Mines Research on Stillwater Complex Platinum-Palladium Ore, by E. G. Baglin. Paper in Precious and Rare Metal Technologies, ed. by A. E. Torma and I. H. Gundiler (Proc. Symp. on Precious and Rare Metals, Albuquerque, NM, Apr. 6–8, 1988). Elsevier, 1989, pp. 395–411. The U.S. Bureau of Mines investigated methods for beneficiating and recovering platinum-group metals from ores from the Stillwater Complex in Montana, the only primary resource of platinum-group metals in the United States. A 100-lb/h flotation pilot plant recovered more than 91 pct of the PGM from the ore. Oxidative leaching of roasted flotation concentrate to selectively extract precious metal values was investigated. Several leaching schemes were developed for selectively extracting the base metals and recovering the PGM from matte prepared by smelting the flotation concentrate. Mining of the Stillwater Complex was inaugurated in March 1987. A flotation concentration mill is in operation onsite, but the concentrates are currently shipped overseas for refining. The Bureau of Mines research provides alternative techniques for processing the concentrates and recovering the values should domestic recovery become desirable for economic or strategic reasons.

OP 118-89. Spalling of High-Chromium White Cast Iron Balls Subjected to Repetitive Impact, by R. Blickensderfer, J. H. Tylczak, and G. Laird II. Wear of Metals, v. 1, 1989, pp. 175–183. This U.S. Bureau of Mines study indicates that retained austenite in the matrix of high-Cr white cast irons tends to increase the spalling rate resulting from repeated impacts. The as-cast condition results in the most retained austenite and the highest spalling rate. As the retained austenite is reduced to about 10 vol pct, the spalling rate decreases. Below 10 vol pct austenite the spalling rate depends upon some other factors, probably residual stress, martensite strength, and ferrite formation. Heat treatments can be used to greatly reduce the spalling rate, although many heat treatments resulted in an increase in pin wear over that of the as-cast condition. Retained austenite content of about 20 pct or more is desired for low pin wear. As the carbide volume fraction increases from 20 to 40 vol pct by adjusting the carbon and chromium contents, the possibility of achieving low pin wear and low spalling rate by heat treatment improves, but the tendency for catastrophic failure greatly increases. A desirable heat treatment is austenitizing at about 1,000° C for 4 h followed by air cooling, with or without a subcritical treatment at 495° to 525° C for 12 h, depending upon the desired combination of wear and spalling resistance. Heat treatments should be adjusted for section thicknesses other than the 75 mm used here. When selecting a high-Cr white cast iron, the metallurgist must choose an appropriate composition and heat treatment to provide a combination of abrasion resistance and spalling life that will best satisfy a particular impact-abrasion wear condition, with due consideration for the price of chromium and the cost of heat treatment.

OP 119-89. Control of Liquid Level Via Learning Classifier System, by C. L. Karr, D. L. Meredith, and D. A. Stanley. Paper in SPIE Vol. 1095—Applications of Artificial Intelligence VII. Soc. Photo-Optical Instr. Eng., 1989, pp. 78–85. A learning classifier system (LCS) that learns rules for controlling a mathematical model of the liquid level in a vessel has been developed by the U.S. Bureau of Mines. LCS's resemble familiar production rule-based systems that incorporate a human expert's knowledge. However, in classifier systems the production rules are represented by strings of characters rather than in linguistic terms. This paper presents two specific examples in which an LCS produces a rule set for controlling liquid level whose performance is comparable to the performance of a human expert's rule set. In the first example, the LCS learns a rule that has been deleted from an author-supplied data base of effective rules. In the second example, the LCS learns rules to supplement a set of rules provided by the authors which included one rule detrimental to controlling liquid level. The LCS-generated rule set obtains a higher level of control over the liquid level system.

OP 120-89. A Comparison of the Wear of Polymers and Metal Alloys in Laboratory and Field Slurries, by B. W. Madsen. Wear of Metals, v. 2, 1989, pp. 741–752. A portable slurry wear apparatus developed by the U.S. Bureau of Mines was used to study slurry erosion in the laboratory and at a gold ore processing plant. It was shown that it is easier to transport the portable wear apparatus to field locations rather than ship slurries to the laboratory. The wear cell of the apparatus was identical to a earlier laboratory model. It used an impeller running at tip speeds < 22 m/s to drive a continuous flow of fresh slurry past 16 specimens. Laboratory experiments run in an aqueous slurry of silica sand showed ultra-high-molecular-weight polyethylene (UHMWPE) to wear less than any metal alloy or other polymers evaluated at 8 or 12 m/s, and at 16 m/s several polymers wore less than two steels. However, in

gold ore slurries from an industrial float cell and rod mill, high-chromium white cast irons wore less than UHMWPE at 8 and 12 m/s; and in the rod-mill slurry at 16 m/s the polymers wore no better than the steels. The same trends were observed previously in an industrial slurry containing a lead-zinc sulfide ore. In all cases the wear rate varied roughly as the fourth power of the impeller tip velocity. When particle shape was held constant, the wear rate always increased with particle size. The effect of particle shape was more complex: angular particles were more detrimental to polymers, and rounded ones were more detrimental to alloys. Pitting corrosion also removed material from the alloys. For high-chromium white cast irons, corrosion and erosion varied with microstructure.

OP 121-89. Partitioning of Pendlandite by Sulfidation, by M. J. Adam and L. A. Neumeier. Paper in Process Mineralogy VIII: Applications of Mineralogy to Mineral Beneficiation Technology, Metallurgy, and Mineral Exploration and Evaluation, With Emphasis on Precious Metal Ores, ed. by D.J.T. Carson and A.H. Vassiliou (Proc. Symp. on Process Mineral. held during Miner., Met., and Mater. Soc. Annu. Meeting, Phoenix, AZ, Jan. 25-28, 1988). Miner., Met., and Mater. Soc., 1988, pp. 309-322. As part of its research programs, the U.S. Bureau of Mines is investigating the partitioning of complex sulfide minerals to simpler sulfide phases by sulfidation reactions. Partitioning in this manner can afford opportunity to improve selective extraction of mineral constituents of value. This report describes research involving the sulfidation partitioning of the mineral pentlandite, which is an important source of Ni in primary production. For the laboratory studies, the pentlandite was synthesized in nominally equiatomic proportions of Ni and Fe. Elemental Ni, Fe, and S powders were blended, compacted, and sealed under reduced He pressure in vitreous silica tubes. The tubes were heated under controlled conditions at 500 °C for 24 h. The product was verified by X-ray diffraction and chemical analysis to consist essentially of $(Ni,Fe)_9S_8$. Small samples of the $(Ni,Fe)_9S_8$ were encapsulated with sulfur in silica tubes at reduced He pressures and heated for 1 to 24 h at specific temperatures between 400 and 600 °C, both below and above the boiling point of sulfur (~445 °C). Reaction rate increased with temperature. Within this temperature range, partitioning to individual Ni and Fe disulfides proceeded to essential completion according to the reaction

$$2(Fe,Ni)_9S_8 + 20S^0_{(g)} \rightarrow 9FeS_2 + 9NiS_2.$$

The substitutional solubility of Fe in the NiS_2 phase and Ni in the FeS_2 increases with temperature. Scanning electron microscope evaluation indicated a tendency for the NiS_2 phase to form as a crust on particle surfaces. Selected thermodynamic relationships are discussed.

OP 122-89. Geological Setting and Deposit-Type Classification of REE in Alaska, by James C. Barker. Paper in Process Metallurgy 5: Precious and Rare Metal Technologies, ed. by A. E. Torma and I. H. Gundler (Proc. Symp. on Precious and Rare Metals, Albuquerque, NM, Apr. 6-8, 1988). Elsevier, 1989, pp. 415-434. Deposits of rare-earth elements (REE) in Alaska can be classified into several groups according to their geologic environment and mineralogical composition, according to this U.S. Bureau of Mines paper. Weathering of silica-rich, late-stage hydrous phases of granitic intrusions produced monazite-xenotime-allanite placers usually associated with tin and tungsten minerals. Additionally, REE in silica-rich intrusions concentrate in greisens, rhyolite porphyry, and radioactive veins. Lithophile element concentrations in some peralkaline complexes and silica-poor intrusions are derived from deeper crustal melts and generally contain higher levels of yttrium subgroup REE. Significant REE resources in polymineralic pegmatite dikes, zoned pegmatites, and epigenetic deposits are associated with peralkaline-alkaline complexes and characterized by multiple REE-Cb-U-Th mineral phases. About half of the total REE in Alaskan deposits occur in the heavy yttrium subgroup. In contrast to the crustal-related deposits, mantle-derived intrusions, particularly carbonatite and diatreme-breccia pipes, contain the light, cerium subgroup, phosphate and carbonate REE minerals and show a pronounced lack of the yttrium subgroup. The geology and mineral resource potential in much of Alaska is poorly known, particularly as it relates to the occurrence of lithophile elements. However, several definable trends of granites and subalkaline to alkaline and peralkaline rocks provide regional exploration opportunities.

OP 123-89. Tips on Controlling Cutter Roof Failure, by Eric R. Bauer. Coal Magazine, v. 26, No. 5, May 1989, pp. 80, 80A, 80D. Cutter roof failure is a ground control problem that exposes miners to the danger of falling roof rock and frequently results in massive roof failures, causing delays in production, increased mining costs, and loss of recoverable reserves. It occurs most often in the Northern Appalachian Coalfields, but it also occurs in each of the major coal basins where underground mining is practiced. Cutter roof is unpredictable, creating widely variable problems. The uniqueness of this problem has limited the techniques available for its treatment. Trial and error has proven unsatisfactory in many cases, as the causes often differ from mine to mine; thus the selection of the optimum control technique has proven to be a difficult task. This U.S. Bureau of Mines article presents information on the causes of cutter roof failure and the effective control techniques.

OP 124-89. Productivity and Equipment Removal Enhancement Using Predriven Longwall Recovery Rooms, by Eric R. Bauer and Jeffrey M. Listak. Paper in Proceedings, 1989 Multinational Conference on Mine Planning and Design, ed. by G. T. Lineberry and Kot F. Unrug (Lexington, KY, May 23-26, 1989). Univ. KY, 1989, pp. 119-124. The U.S. Bureau of Mines, in cooperation with a southwestern Pennsylvania coal mining company, recently assessed the feasibility of using predriven recovery rooms (open entry recovery) when longwall mining to increase the productivity of the coal extraction process. Four recovery entries, one 200 ft long and three 600 ft long, were supplementally supported with bolts, channels, and wire mesh, and either fly ash-cement piers, fiber cribs, or cement-sand piers, then mined into by the longwall face. The recovery entries showed little deterioration as the supports provided adequate resistance to the front abutment loading. As compared to conventional recovery methods, recovery rooms allowed for panel extraction to be completed an average 12.5 days faster and reduced face equipment move time by 30 pct. The productivity increase accompanying recovery rooms was greater than the 2 to 4 times increased support costs. Recovery rooms provided over 22 additional production days and the opportunity to mine nearly 85,000 short tons of coal per year per panel mined.

OP 125-89. Effects of Random Whole-Body Vibration on Back Strength and Back Endurance, by Thomas G. Bobick, Sean Gallagher, and Richard L. Unger. Paper in Advances in Industrial Ergonomics and Safety I, ed. by Anil Mital (Proc. Annu. Int. Ind. Ergonomics and Safety Conf., Cincinnati, OH, June 5-9, 1989). Taylor & Francis, 1989, pp. 537-544. Whole-body vibration (WBV) has been implicated as a cause of low-back pain in the industrial workforce. The U.S. Bureau of Mines conducted two studies to determine whether random, low-intensity WBV had an effect on maximum back extensor strength and on back endurance. In the first, maximum back strength was measured before and after 30-min periods of vibration while seated in four different seats. In the second, back endurance was measured before and after 30-min periods of vibration while positioned in eight different seating postures. Results from the two studies indicated that back muscle function is not compromised by WBV at the intensity and duration studied.

OP 126-89. Ore Leaching in Underground Stopes, by D. L. Boreck, W. W. Lutzens, and R. A. Speirer. Paper in Proceedings 1989 Multinational Conference on Mine Planning and Design, ed. by G. T. Lineberry and Kot F. Unrug (Lexington, KY, May 23-26, 1989). Univ. KY, 1989, pp. 143-153. Research is currently being conducted by the U.S. Bureau of Mines on determining the feasibility of incorporating in situ stope leaching into active underground metal and nonmetal mines. This modified in situ technique proposes to recover metals from ore by creating underground rubblized stopes, leaching the stopes underground for metal recovery, and collecting and processing the metal-bearing solution. Stope leaching incorporates stope design and fragmentation techniques for developing optimum sized rock particles, chemical lixiviants for metal extraction from the broken rock, and solution control techniques to prevent loss of metal-bearing solution. Increased temperatures and pressures can theoretically be applied for metal recovery enhancement. Stope preparation requires removing as much as 25 pct of the ore to create a void space for subsequent swell during the fragmentation process. Fragmentation can be achieved either by blasting or by allowing the ore to cave naturally. If high-grade ore has already been removed, broken low-grade ore, extracted from elsewhere in the mine, may also be dumped into the stope. Management of the leach solution is an important part of stope design. Escaping solutions result in loss of the target metal and possible contamination of the ground water. Solution management can be broken down into three major elements: (1) detection of solution loss, (2) solution control during active leaching, and (3) stope closure.

Detection of solution loss entails the use of all means currently available to detect and monitor solution migration. Solution control includes procedures designed to effectively shut off solution loss from the stope. Closure includes the steps necessary to halt chemical interactions in the stope and render the leached stope to an inactive status.

OP 127-89. A Comparison of Methane Flow Patterns on Advancing and Retreating Longwalls, by Andrew B. Cecala, Balesh W. Konda, and George W. Klinowski. Ch. 59 in Proceedings of 4th U.S. Mine Ventilation Symposium, Berkeley, CA, June 5–7, 1989. Soc. Min., Metall., and Exploration, Wilton, CO, 1989, pp. 484–490. Methane ignitions continue to be a major concern to the longwall mining industry. In spite of numerous advances in technology over the past decade, there has not been a measurable reduction in the number of longwall face ignitions. These ignitions will continue to be a problem as deeper and gassier seams are mined, as production rates are increased through numerous improvements in longwall mining equipment, and as the output of the workforce increases due to improved management-labor relations. It is necessary to know methane liberations, emissions, and flow patterns in order to effectively deal with it and to design control technology to reduce the occurrence of longwall face ignitions. A cooperative research project between the U.S. Bureau of Mines and the Canada Centre for Mineral and Energy Technology (CANMET) has been established to address longwall methane problems. The initial direction of this work was to look at methane flow patterns during the entire longwall mining process, and more specifically to examine and compare methane levels and flow patterns for advance and retreat methods of longwall mining. Both advance and retreat longwall mining is practiced in the Sydney Coalfields in Nova Scotia. In 1986, a study was performed on advancing longwall panels at the Lingan Colliery, and a similar study was recently completed at the Phalen Colliery on a retreating panel. Methane monitors were placed at various locations along the face, intake, return, and bleeder airways. Handheld methane monitors were also used upstream and downstream of the shearer mining machine. This setup allowed a determination of methane sources on the longwall panels, including liberation from cutting with the shearer mining machine, emissions from the coal seam along the face, emissions from the gob area, and methane already in the intake air. The results from both studies are reported, and the differences between the two longwall mining methods are compared.

OP 128-89. Controlled Recirculation of Section Air in a Trona Mine, by Andrew B. Cecala, Robert J. Timko, and Christopher J. Pritchard. Ch. 32 in Proceedings of 4th U.S. Mine Ventilation Symposium, Berkeley, CA, June 5–7, 1989. Soc. Min., Metall., and Exploration, Wilton, CO, 1989, pp. 253–259. As mine ventilation systems become more complex, it is increasingly difficult to supply fresh air to the working face. A high percentage of the fresh air entering a mine never reaches the working face because it short-circuits through stoppings and doors, exiting the mine without being utilized. When ventilation limits are reached, the only option presently available to most US. mines is to sink a new shaft—an extremely expensive undertaking that many companies cannot afford. Reusing or recirculating a percentage of ventilating airflow may make it possible for some mines to remain operational while maintaining a safe environment for workers. The U.S. Bureau of Mines performed such a study at a trona mine in Granger, WY. A vane axial fan was used to recirculate approximately 9.4 m^3/s (20,000 cfm), 25 pct of the total ventilating airflow, back to the working face area of a three-entry continuous miner section. This study involved two evaluations: the first when the face was 305 m (1,000 ft) from the recirculation fan, the second when the face was 610 m (2,000 ft) from the fan. The evaluation consisted of monitoring the mine atmosphere for respirable dust, methane (CH_4), carbon monoxide (CO), and nitric oxide (NO) at various locations in the intake and return entries. Several shifts were monitored, with and without the recirculation system in operation. With the recirculation system in operation, there was an increase in measured respirable dust concentrations in the intake along with a slight increase in the mine temperature (1.67 °C). There were also some minor changes in CO and NO levels in the intake entry, but this seemed to depend more on the proximity of the instruments to the turn-around point for the diesel haulage vehicles than on whether the recirculation system was or was not in use.

OP 129-89. Recommendations for Handling Materials in Low-Seam Coal Mines, by Sean Gallagher. Appl. Ind. Hygiene J., June 1989, pp F8–F12. It is estimated that approximately 25 pct of all injuries in the mining industry involve trauma to the back and that the cost of back injuries in coal mining alone approaches $20 million a year. However, the tremendous cost of these injuries is overshadowed by the human disability and suffering experienced not only by the affected miners but also by their families. Unfortunately, the underground coal mining environment presents some uncommon barriers to preventing back injuries. The restricted roof height of many low-seam coal mines (mines with seams ≤ 48 in) forces workers to adopt exceptionally stressful working postures during manual lifting activities, generally stooped or kneeling, which produce a considerable strain on the lower back. This may help to account for the high incidence of low-back pain in coal miners. The use of certain types of mechanical-assist devices is also made more difficult by the confined workspace of low-seam mines. In addition, poor illumination and slippery footing compound the problems associated with underground materials handling. The traditional approach to reducing the risk of back injuries has been to train miners to cope with the existing conditions. Unfortunately, the effectiveness of this method has been relatively limited, and new approaches are needed. This U.S. Bureau of Mines article briefly describes methods that can be used to *redesign* hazardous materials-handling tasks to reduce the threat of injury to workers. The redesign strategies outlined here may be broadly applicable to many industrial hygiene settings.

OP 130/131-89. Static and Dynamic Back Strength of Underground Coal Miners, by Sean Gallagher. Paper in Advances in Industrial Ergonomics and Safety I, ed. by Anil Mital (Proc. Annu. Int. Ind. Ergonomics and Safety Conf., Cincinnati, OH, June 5–9, 1989). Taylor & Francis, 1989, pp. 531–536. Twenty-two underground coal miners performed back strength exertions using an isokinetic dynamometer. Static exertions were performed in two postures (standing or kneeling) and three angles of trunk flexion. Dynamic tests were performed in the same postures and at three isokinetic velocities. Results of the static back strength ANOVA indicated that posture and angle of trunk flexion both significantly affected peak torque ($p < 0.001$). Posture and velocity also affected dynamic torque production ($p < 0.001$). Results of this U.S. Bureau of Mines study indicate that back strength is significantly reduced when a kneeling posture is used.

OP 132-89. The Kinetics of Leaching Rock Ilmenite With Hydrofluoric Acid, by Dennis A. Hansen and Davis E. Traut. J. Met., May 1989, pp. 34–36. As part of a U.S. Bureau of Mines program to develop a more continuous titanium metal process that exploits domestic resources, a study was made of the kinetics of hydrofluoric acid (HF) leaching of New York rock ilmenite. The effects of leach temperature, HF concentration, and particle size on leach rate were investigated. The data fit a shrinking core model with the rate controlled by the chemical reaction step. The rate of reaction is related to temperature by the Arrhenius relationship, with the activation energy being 52.6 kJ/mol for titanium and 48.4 kJ/mol for iron. The rate is linearly dependent on the HF concentration and inversely proportional to the average starting diameter of the particle. Generalized rate expressions were developed for titanium and iron. Using 19.33M HF at 45 °C, 99 pct of the titanium and 100 pct of the iron in New York rock ilmenite were leached in 40 min.

OP 133-89. Poor Longwall Productivity and Claystone Roof Rock: A Need for Geotechnical Analysis, by A. T. Iannacchione. Paper in Proceedings, 1989 Multinational Conference on Mine Planning and Design, ed. by G. T. Lineberry and Kot F. Unrug (Lexington, KY, May 23–26, 1989). Univ. KY, 1989, pp. 21–26. Longwall failures can occur when shield supports are used in inappropriate strata conditions. This U.S. Bureau of Mines paper is a case study of one such failure. Shield rotation resulted in poor longwall production rates in a mine with fractured claystone roof rock. The fractured claystone, with abundant fossilized root casts, was further weakened by its tendency to swell upon contact with mine air at the longwall face. The immediate claystone roof rock crushed between an overlying massive, cantilevering main roof rock and the stiff shields. The loss of confinement in this low tensile and shear strength roof rock was aggravated by the use of four-leg shield

supports. These factors have combined to cause the claystone roof rock to disintegrate into small blocks. These blocks then became dislodged and fell onto the conveyor. This action created an irregular roof surface for the shields to pressurize against, causing them to rotate out of position. Straightening rotated shields caused extensive production delays. Solutions to the problem consist of utilizing shield designs that best support this type of rock or avoidance of these areas by longwall mining techniques. Advanced planning to utilize these solutions could be accomplished with progressive geotechnical techniques prior to the selection of equipment and the start of mining. The matching of appropriate mining systems with specific strata conditions can minimize the unanticipated instability problems and greatly diminish the potential for future longwall failures.

OP 134-89. Computer-Based Tele-Operation of a New Highwall Mining System, by August J. Kwitowski, William H. Lewis, and William D. Mayercheck. Paper in Proceedings, 1989 IEEE International Conference on Robotics and Automation, Scottsdale, AZ, May 14-19, 1989. IEEE, v. 3, 1989, pp. 1478-1483. The U.S. Bureau of Mines, in conjunction with a cooperator, has developed new technology to economically mine a greater percentage of coal reserves in highwall outcrop settings. This new mining system features a computer-based tele-operating subsystem for distant, non-line-of-sight control of a thin-seam continuous miner and coal haulage units. A single operator, situated at an ergonomically designed workstation within a protective enclosure on a highwall bench, controls all the coal extraction and haulage equipment that penetrate the coal seam deep within the hillside. This workstation consists of a special chair, two control modules, two color video monitors, an array of displays, and a control computer. Details of this operator workstation, a summary of the overall highwall mining system, and current test status are discussed.

OP 135-89. Ventilation for New Highwall Mining System, by Alan G. Mayton and Jon C. Volkwein. Ch. 27 in Proceedings of 4th U.S. Mine Ventilation Symposium, Berkeley, CA, June 5-7, 1989. Soc. Min., Metall., and Exploration, Wilton, CO, 1989, pp. 209-216. The U.S. Bureau of Mines, in cooperation with an American firm, has been contributing toward the creation of a new highwall mining system for extracting coal in active, unreclaimed contour strip mines in the United States. The prototype system features the computer-based, remote control, video operation of a thin-seam continuous miner. Haulage is accomplished remotely also with a 76-m (250-ft) long multiple-unit continuous haulage conveyor system on rubber-tired vehicles. One aspect of this multifaceted effort has been to design a ventilation system for removing dust generated at the face during the extraction process. The remote mining system eliminates the need for personnel in the mined workings. Ventilation is required to remove visible dust from the area inby two video cameras. These cameras are located approximately 6 m (20 ft) from the face, one on either side of a modified Jeffrey 102HP continuous miner. Removing the dust from this area provides the remote operator with constant visual monitoring of coal extraction at the face and thus ensures the effective operation of the mining system. A ventilation system was designed for use in a mine opening with a maximum cross-sectional area of roughly 4 sq m (44 sq ft), excluding the mining machinery. This paper describes the ventilation system and discusses how it was developed in view of the constraints imposed by the mining equipment, mining conditions, and extraction process.

OP 136-89. The Effects of Power Level on the Microwave Heating of Selected Chemicals and Minerals, by S. L. McGill, J. W. Walkiewicz, and G. A. Smyres. Paper in Microwave Processing of Materials, ed. by Willard H. Sutton, Merton H. Brooks, and Irving J. Chabinsky (Materials Research Soc. Symp. Proc., v. 124). Mater. Res. Soc., 1988, pp. 247-252. The effect of power level on the microwave heating characteristics of a variety of reagent-grade chemicals and minerals has been determined in a U.S. Bureau of Mines study. Heating rates of the powdered samples are presented for incident power ranging from 500 to 2,000 W at 2.45 GHz. The apparatus consisted of a WR 975 waveguide-applicator mounted to WR 284 waveguide sections and connected to a 3-kW power source. Tests were conducted in an alumina crucible enclosed in a fused-quartz beaker that was fitted with a Teflon lid to allow for a controlled inert atmosphere and thermocouple insertion. In general, heating rates increased as input power increased. Exceptions to this were some very high-lossy (microwave receptive) and very low-lossy materials that showed negligible changes with increased power. Microwave data collected should provide insight as to possible chemical and mineral processing applications and should assist in predictions of processing parameters.

OP 137-89. Mine Design and Ground Control, by Noel N. Moebs. World Min. Equipment, v. 9, No. 1, Jan. 1985, pp. 10-13. There are a number of reasons for mine roof failure. The cause of some roof falls is obscure and attributed to poorly understood stress concentrations surrounding the mine openings; these falls occur most commonly when mine entries are located beneath stream valleys and topographic relief is 60 m or more. Some falls result from poor roof-bolting techniques or improper installation of bolts. However, most roof falls associated with the geologic hazards referred to in this U.S. Bureau of Mines paper occur because unusual geologic structures are not reognized or anticipated and adequate support is not provided. Identification of structures will require either the services of a geologist with underground experience or the training of miners (especially mining machine and roof-bolting machine operators) and their supervisors. Through regular examination of mine roof structures and conditions and the recording of this information systematically on the operating maps, and through some trial and error, it should become possible to determine the trends of hazardous structures so that mine entry projections can be revised or potentially troublesome zones anticipated, roof support practices upgraded, and roof falls reduced. The task will not be easy because of the complex character of many geologic features, but in consideration of both the high priority of accident prevention and the immense financial investment at stake in developing a mine, the attempt to identify and properly support roof structures should become an integral part of every underground operation. The application of geologic methods to other mines and quarry operations should provide similar opportunities to improve ground control practices and reduce the inherent safety hazards.

OP 138-89. Appalachian Roof Instability, by Noel N. Moebs and Eric R. Bauer, Coal, v. 26, No. 3, Mar. 1989, pp. 43-45. For decades mine operators in the northern and central Appalachian coal region have struggled to control roof failures occurring in coal seams lying beneath stream valleys. At times the roof in this zone is virtually unsupportable and results in complete collapse. This type of roof failure, known as the *notch effect* because of the notch it forms in the topography, was once attributed to jointing in the overlying strata. Because streams often form in areas of weakness in the earth's surface, faults or fractures were thought to be probable causes of this roof problem. Stream valleys in the Appalachian region, however, appear to form at random with little, if any, influence from the underlying bedrock. Their dendritic drainage pattern presumably formed during the normal erosion of relatively weak flat-lying sediments and not from underlying structure. Coal seam continuity beneath the stream valleys further demonstrates the absence of major structural faults. Very small thrust fault structures of Quaternary age, which developed as the valleys formed, probably occur beneath most valley floors, however. Also, stress relief joints occur in valley walls and are well-documented. These, too, postdate erosional valley formation and may cause severe roof fall problems, especially in the drift mines of eastern Kentucky, where they are known as *hillseams*.

OP 139-89. The Diagnosis and Reduction of Mine Roof Failure, by Noel N. Moebs and Raymond M. Stateham. Coal Min., pt. 1, Feb. 1985, pp. 52-55; pt. 2, Mar. 1985, pp. 42-48. Coal mine roof falls can be categorized according to character, trend, or pattern of occurrence. These U.S. Bureau of Mines articles propose two principal categories—geology-related and stress-related failure—and a number of subcategories. Then, by reflecting the probable cause of failure, each subcategory can suggest an appropriate technique for reducing the incidence of failure. Depending on local conditions, these control techniques may include supplementary support, destressing, or reduction of mine air humidity.

OP 140-89. Dewatering, by B. J. Scheiner. Min. Eng., 1988 Annu. Rev., May 1989, pp. 342-343. Technical articles that were published during 1988 regarding dewatering of minerals and waste slurries from mineral operations were reviewed by the U.S. Bureau of Mines. Papers from major conferences such as the Engineering Foundation Symposium on Flocculation and Dewatering, American Filtration Society's Annual Meeting, and the Annual AIME Meeting were included in the review.

OP 141-89. Elements of an Effective Instrumentation and Monitoring Program: A Case Study for Mine Support Design, by Stephen C. Tadolini and Dennis R. Dolinar. Paper in Proceedings, 1989 Multinational Conference on Mine Planning and Design, ed. by G. T. Lineberry and Kot F. Unrug (Lexington, KY, May 23-26, 1989). Univ. KY, 1989, pp. 47-50. An underground mine design instrumentation program must address certain critical elements to be safe, effective, and useful. The recommended elements are (1) well-defined staff roles and responsibilities, (2) adequately trained staff, (3) good reasons for installing instruments, (4) well-installed instruments with proven historical performance records, (5) established data base, (6) established procedures for taking readings and maintaining instruments, (7) quick and effective transmittal, processing, and review of data, (8) formal review and documentation procedures, (9) good communication and team work, and (10) lack of complacency. The omission of any of these critical elements may result in a design program that has the potential for being dangerous, costly, and time consuming by failing to provide the required information. An investigation conducted by the U.S. Bureau of Mines Denver Research Center, in an underground coal mine, illustrates the necessity for including these critical elements in an instrumentation and monitoring program. The Bureau's investigation demonstrated that such a program will provide results that permit an accurate analysis of the underground strata behavior as it relates to the mine design program. Instrumentation and monitoring included in the Bureau study were differential sag stations, pressure pads, and ultrasonically monitored roof bolts. This paper illustrates some critical elements in an instrumentation and monitoring plan through a description of the Bureau's underground instrumentation, data acquisition, and data analysis, and the resulting support and design recommendations.

OP 142-89. Determining the Integrity of Escapeways During a Simulated Fire in an Underground Mine, by Robert J. Timko and R. Lincoln Derick. Ch. 7 in Proceedings of 4th U.S. Mine Ventilation Symposium, Berkeley, CA, June 5-7, 1989. Soc. Min., Metall., and Exploration, Wilton, CO, 1989, pp. 48-56. The U.S. Bureau of Mines evaluated the integrity of escapeways in a three-entry underground coal mine. A center conveyor belt entry (secondary escapeway) was flanked by an intake (primary escapeway) and a return entry. Diesel equipment was used throughout the mine for material and personnel haulage. A carbon monoxide monitoring system, tied to a data recording computer on the surface, was deployed throughout the belt entry and at selected sites in the intake and return entries. Previously, the company had a fire of unknown origin in another mine, which prompted an interest in the performance of their escapeways. An initial, qualitative evaluation was performed by burning approximately 14 kg of coal at the mouth of the intake entry. The first test was followed by a similar burn at the mouth of the belt entry. These initial trials showed a high quantity of leakage between entries. In several followup evaluations, simulated fires, using a tracer gas, were set in the intake and belt entries. Tracer gas concentrations were obtained in all entries at four different underground locations. The results of these tests showed that permanent stoppings could not guarantee isolated, contaminant-free escapeways.

OP 143-89. Impact of Shuttle Car Movements on Face Ventilation, by John C. Volkwein, Edward D. Thimons, and Natesa Jayaraman. Ch. 24 in Proceedings of 4th U.S. Mine Ventilation Symposium, Berkeley, CA, June 5-7, 1989. Soc. Min., Metall., and Exploration, Wilton, CO, 1989, pp. 190-194. The U.S. Bureau of Mines has studied the impact of shuttle car movement on face ventilation. Real-time measurements of air velocity, methane gas, and respirable dust were recorded and compared with a time study of face shuttle car movement. Work was conducted in a blowing face ventilation section where a scrubber-equipped mining machine operated. Air velocities decreased by an average of 35 pct as the shuttle car entered the face, restricting air flow, and increased by an average of 35 pct as the shuttle car pulled away from the face, drawing with it additional air. Return air methane levels follow the face air flow volumes, decreasing as air volume increases. The surge of air created as the shuttle car leaves the face helps to dilute methane. Respirable dust levels, however, increased as the air flow increased and decreased the scrubber capture efficiency.

OP 144-89. Impact of Water Sprays on Scrubber Ventilation Effectiveness, by John C. Volkwein and Travis S. Wellman. Ch. 25 in Proceedings of 4th U.S. Mine Ventilation Symposium, Berkeley, CA, June 5-7, 1989. Soc. Min., Metall., and Exploration, Wilton, CO, 1989, pp. 195-201. The U.S. Bureau of Mines conducted a study to assess the impact of a directional water spray system on a unique single-inlet dust scrubber on a low-profile mining machine. Tests were conducted in a full-scale model mine using a Joy 12 CM 10-AA continuous mining machine. Tracer gas was introduced at the face, and concentrations of the tracer gas were monitored at the face and in the return. Various parameters included mining position, depth of cut, brattice setback, and combinations of scrubber, directional sprays, or symmetrical sprays. Results indicated that either directional or symmetrical water spray configuration improved the ventilation effectiveness of the scrubber by a factor of 2 to 3. Average face ventilation effectiveness (FVE) values for all testing of the scrubber and directional sprays were 0.95, versus 0.37 for a standard 6-m (20-ft) blowing curtain without sprays. No FVE values were less than the standard 6-m (20-ft) blowing results.

OP 145-89. Improved Grindability of Iron Ores Using Microwave Energy, by J. W. Walkiewicz, S. L. McGill, and L. A. Mover. Paper in Microwave Processing of Materials, ed. by Willard H. Sutton, Merton H. Brooks, and Irving J. Chabinsky (Materials Research Soc. Symp. Proc., v. 124). Mater. Res. Soc., 1988, pp. 297-302. The U.S. Bureau of Mines has conducted studies to utilize rapid microwave heating to stress-fracture ore samples. Iron ores containing hematite, magnetite, and geothite were subjected to microwave energy in batch operations at 3 kW and heated to average temperatures between 840 and 940 °C. Scanning electron microscope photomicrographs verified fracturing along grain boundaries and throughout the gangue matrix. Standard Bond grindability tests showed that microwave heating reduced the work index of iron ores by 9.9 to 23.7 pct. Preliminary studies using a continuous feed belt in a microwave applicator indicated that samples heat more uniformly and with better temperature control than in batch operations.

OP 146-89. Marine Placer Development and Opportunities in Alaska, by J. C. Barker, M. S. Robinson, and T. K. Bundtzen. Paper in Proceedings of the 21st Annual Offshore Technology Conference, Houston, TX, May 1-4, 1989. Offshore Technology Conf., Houston, TX, 1989, pp. 551-558. Alaska, with about 74 pct of the U.S. continental shelf, is largely unexplored for placers in its vast shallow marine waters. According to this U.S. Bureau of Mines paper, there are numerous occurrences of marine minerals, including gold, platinum, and cassiterite. Offshore dredging has recently begun in the Nome area. State and Federal agencies are preparing additional acreage for leasing.

OP 147-89. Roll Cladding in a Vacuum, by Robert Blickensderfer. Advanced Mater. and Processes, Met. Prog., v. 133, No. 4, Apr. 1988, pp. 47-50. With the application of new materials, the vacuum-rolling technique first demonstrated in the U.S.S.R. now has been further extended in the United States, and the technology and operating parameters for vacuum roll bonding of many bimetals have been established. The technology is difficult, but the potential for commercialization probably exists. This U.S. Bureau of Mines paper indicates that with larger scale, continuous vacuum-cladding equipment, the process may be a profitable, as well as prudent, approach to the use of critical and scarce metals.

OP 148-89. A Pin-on-Drum Abrasive Wear Test and Comparison With Other Pin Tests, by R. Blickensderfer and G. Laird II. J. Testing and Eval., v. 16, No. 6, Nov. 1988, pp. 516-526. The U.S. Bureau of Mines, in its ongoing effort to combat the wear of mining and mineral processing equipment, has used several types of laboratory wear tests. Investigations into existing pin abrasive wear testing machines resulted in the construction of the Bureau's own pin-on-drum wear testing apparatus, incorporating the best features of the previous designs. Comparisons of pin diameters, loads, and other factors are made between the Bureau of Mines' pin-on-drum test and other pin abrasion tests. The effects of variations in abrasiveness over the drum were essentially eliminated by making corrections based on the wear of a standard pin traveling a parallel path. Reproducibility of wear values on homogeneous alloys was generally within ± 0.5 pct. Statistical analyses and test procedures are given for heterogeneous alloys. Design parameters for future pin abrasion tests are recommended.

OP 149-89. Evaluation of Commercial U.S. Grinding Balls by Laboratory Impact and Abrasion Tests, by R. Blickens-

derfer and J. H. Tylczak. Miner. and Metall. Processing, May 1989, pp. 60–66. Impact and abrasion properties of various commercial grinding balls were evaluated and compared by the U.S. Bureau of Mines. Laboratory tests were conducted on balls obtained from eight major U.S. manufacturers. The balls included forged steel, cast steel, and alloyed white cast iron and were subjected to repeated impacts until they broke or until 300,000 impacts were exceeded. Pin abrasion tests also were conducted. The results showed wide differences in impact lives, ranging from a few thousand to over 500,000 impacts. The life of inferior commercial balls was increased five to six times by a laboratory tempering heat treatment. For balls that did not break, the major impact wear mode was spalling and ranged from an average rate of 0.28 to 4.46 mg per impact. The softest balls (steel) had excellent impact resistance but low abrasion resistance. The abrasion resistance of the steel balls generally increased with hardness. The alloyed white cast irons had about twice the abrasion resistance of the steel balls. Users should become aware of the wide variations among commercial balls, and ball manufacturers should be aware that their product can be improved.

OP 150–89. New Dual Bag Nozzle System, by Andrew B. Cecala and Edward D. Thimons. Ceram. Eng. and Sci. Proc., v. 10, Jan.–Feb. 1989, pp. 36–41. A new dual bag nozzle system has been designed, tested, and shown to effectively reduce workers' exposure to the dust associated with the bag filling process at mineral processing plants. This U.S. Bureau of Mines system is composed of a nozzle within a nozzle. The inner nozzle is used to fill the bag with product. The outer nozzle exhausts excess air from the bag after filling is completed. This depressurizes the bag and reduces product loss through the bag valve during ejection from the fill station and during the conveying process. An improved bag clamp also reduces product blowback during bag filling. Dust reductions of 80 to 90 pct have been achieved for both the bag operator and the workers loading the bags onto pallets. There has also been a 90-pct reduction in product blowback during bag filling, which can account for tremendous product savings.

OP 151–89. Methods To Determine Pillar Stress Distribution and Its Effect on Stability, by David P. Conover, Khamis Y. Haramy, and Kanaan Hanna. Paper in Rock Mechanics as a Guide for Efficient Utilization of Natural Resources, ed. by A. W. Khair (Proc. 30th U.S. Symp. on Rock Mech., Morgantown, WV, June 18–23, 1989). Balkema, 1989, pp. 419–424. The effects of stress distribution on pillar stability were evaluated through rock mechanics studies conducted in three underground room-and-pillar coal mines. Results of the three field instrumentation programs are presented to illustrate the use of borehole pressure cells to determine vertical stress distribution in coal pillars at various stages of mine development. Vertical stresses and stress changes are determined using methods developed at the U.S. Bureau of Mines. Measured stress distributions are compared against theoretical distributions, and possible explanations for observed behavior are discussed. Results indicate that stresses and stress changes calculated from pressure cell data are inconsistent with theoretical values; however, the data are useful for qualitative evaluation of trends over time. Calculated values are found to be sensitive to coal properties and initial setting pressures of the cells.

OP 152–89. Development of a Prototype Hard Rock Excavating Machine, by H. J. Handewith, W. D. Coski, and E. D. Thimons. Paper in Proceedings, 1989 Rapid Excavation and Tunneling Conference, ed. by Robert A. Pond and Patrick B. Kenny (Los Angeles, CA, June 11–14, 1989). SME-AIME, 1989, pp. 769–787. This paper describes the development and testing of the RAMEX excavation system. Incorporating a synergy of low-velocity, high-energy impact and kerf cutting, this machine offers a competitive alternative to drilling and blasting in hard rock. It is a boom mining machine that incorporates the features of a lightweight roadheader, and it can mine nearly any shape opening in hard rock. The RAMEX Tunneler has been developed to satisfy industry demands for a nonexplosive, flexible, continuous, and rapid underground rock excavation system. It will produce minimum ground vibration in the urban environment and allow the flexibility necessary for thin-seam mining conditions. It will also reduce initial ground support costs and has a minimum impact on rock integrity. Developed by RAMEX Systems with cooperative research provided by the U.S. Bureau of Mines, this system could produce the next step in the continuing evolution of mechanical mining systems.

OP 153–89. Improved Design and Support Techniques for Coal Mine Entry Intersections, by K. Hanna and D. Conover. Paper B15 in Proceedings of the 8th International Strata Control Conference, Dusseldorf, May 22–24, 1989. Steinkohlenndergbauverein, Postfach 130140, D-4300, Essen 13, Federal Republic of Germany, 1989, 20 pp. This U.S. Bureau of Mines paper describes the development of improved design and ground support techniques for coal mine entry intersections to reduce the severity of ground control problems associated with high horizontal stresses and variable geological conditions. Through field investigations and numerical modeling studies, four major parameters that influence the failure behavior of entry intersections were identified: in situ stresses, geological discontinuities, intersection geometry, and diagonal roof span. Three primary design criteria are emphasized: prompt installation of support, control of failure progression, and minimization of diagonal roof span. Conceptual and proven implementations are also discussed.

OP 154–89. Integrity Factor Approach To Assess the Stability of Room-and-Pillar Mines, by Kanaan Hanna, David Conover, and Paul H. Lu. Paper in Proceedings of the 7th International Conference on Ground Control in Mining, Morgantown, WV, Aug. 3–5, 1988. WV Univ., 1988, pp. 20–29. The integrity factor approach was developed by the U.S. Bureau of Mines to assess the stability of mine pillars and has been applied primarily to longwall chain pillars. Recently, this approach was applied to a room-and-pillar mine in the Illinois Coal Basin. A special configuration of hydraulic borehole pressure cells was installed in a pillar to determine the in situ strength-and-stress relationship of the coal pillar and to verify the applicability of the integrity factor approach. Results indicate that the integrity factor approach is applicable to the assessment of pillar stability and may be a realistic and effective approach for room-and-pillar mine design.

OP 155–89. Comparative Study of Western U.S. Longwall Panel Entry System, by Khamis Y. Haramy and Richard O. Kneisley. Paper in Rock Mechanics as a Guide for Efficient Utilization of Natural Resources, ed. by A. W. Khair (Proc. 30th U.S. Symp. on Rock Mech., Morgantown, WV, June 18–23, 1989). Balkema, 1989, pp. 125–132. This paper summarizes ground control studies of longwall panel entry systems in two Western U.S. coal mines. Presented are comparisons of in situ pressure change measurements and assessments of chain pillar and entry behavior under a wide range of cover. Results indicate that no one entry system design is universally applicable, and that site-specific factors need to be considered for panel entry design. Relationships between overburden depth, face advance, and magnitude and location of the forward abutment are discussed for western operations. In addition, analysis indicates that use of yield pillars may reduce or eliminate some stress-related problems that plague longwall panel entry design.

OP 156–89. Numerical Simulation of Coal Pillar Loading With the Aid of a Strain-Softening Finite Difference Model, by A. T. Iannacchione. Paper in Rock Mechanics as a Guide for Efficient Utilization of Natural Resources, ed. by A. W. Khair (Proc. 30th U.S. Symp. on Rock Mech., Morgantown, WV, June 18–23, 1989). Balkema, 1989, pp. 775–782. Numerical simulation of coal pillar loading has traditionally been a difficult task owing to the unique and highly variable properties of coal and the inability of numerical procedures to duplicate these properties. This U.S. Bureau of Mines simulation was based upon material properties developed from laboratory tests of coal cubes and examined against coal pillar strength data developed from actual underground measurements. The coal cube measurements indicated the coal followed a nonlinear Mohr-Coulomb failure criterion. The in situ measurements showed that a pillar yield zone developed similar to Wilson's hypothesis; at high confinements, the pillar core seemed to follow a pseudo-ductile behavior. The strain-softening material model, based on a linear Mohr-Coulomb failure criterion, simulated coal cube and pillar behavior at moderate load conditions. However, at high loads the models were inaccurate, owing to an inadequate failure mechanism and/or to changes in the pillar constraints at the coalbed interface.

OP 157–89. An Applications Approach to Barrier Pillar Design for Improved Resource Recovery, by John R. Koehler, Steven D. Jones, and Matthew J. DeMarco. Paper in Rock Mechanics as a Guide for Efficient Utilization of Natural Resources, ed. by A. W. Khair (Proc. 30th U.S. Symp. on Rock Mech., Morgantown, WV, June 18–23, 1989). Balkema, 1989, pp. 403–410. Available barrier pillar design methods do not adequately account for overburden caving charac-

teristics, the timing and magnitude of associated load transfers, the occurrence of unusual geologic features, or the effects of multiple-panel, multiple-seam mining. To address this problem, the U.S. Bureau of Mines, in cooperation with Cyprus Plateau Mining Corp., conducted a barrier pillar study in a multiple-seam mine setting. Insufficient barrier width resulted in excessive load transfer to an adjacent underlying section. Consequent entry and pillar deterioration resulted in the section being prematurely abandoned. This paper proposes an approach based on in situ measurements, which includes mine-specific loading conditions in the barrier design process.

OP 158-89. Bromine, by Phyllis A. Lyday. Min. Eng., v. 41, No. 6, June 1989, p. 403. This paper reviews bromine in 1988.

OP 159-89. Iodine, by Phyllis A. Lyday. Min. Eng., v. 41, No. 6, June 1989, p. 410. This paper reviews iodine in 1988.

OP 160-89. Guidelines for Developing Microwave Dissolution Methods for Geological and Metallurgical Samples, by S. A. Matthes. Ch. 3 in Introduction to Microwave Sample Preparation. Am. Chem. Soc., 1988, pp. 33-51. Guidelines for developing microwave dissolution methods for geological and metallurgical samples are being investigated at the U.S. Bureau of Mines. By varying sample size, acid mixture, vessel type (open or closed), microwave power, and digestion times, procedures have been developed to successfully dissolve metals and minerals. A general scheme of microwave digestion and fusion methods is presented, as well as specific techniques for the dissolution of phosphate rock, ores, solder, superalloys, and other geological and metallurgical samples. Development of specific methods involves the selection of parameters that best exploit the chemistry of the sample matrix and the dissolution-enhancing effects of microwave radiation.

OP 161-89. Coal Research and Development, by John N. Murphy. Min. Eng., May 1989, pp. 336-338. This paper reviews recent trends in coal technology, with emphasis on computer applications.

OP 162-89. Trends in Iron Casting Compositions as Related to Ferrous Scrap Quality and Other Variables, 1981-1986: A Synopsis, by R. H. Nafziger, A. D. Hartman, and R. F. Farrell. AFS Trans., v. 96, 1988, pp. 237-248. Foundrymen have expressed concern regarding the quality of scrap used to prepare iron castings owing to the growth of alloy steel production and its influence on tramp element levels when recycled. Reliable and current information is unavailable on the amount of tramp elements contained in iron castings made over a period of time. Accordingly, the U.S. Bureau of Mines, in cooperation with the American Foundrymen's Society, analyzed cast iron samples from participating foundries throughout the United States on a quarterly basis to ascertain possible trends. Each sample was analyzed for 28 elements to determine if changes had occurred as a function of several input variables from January 1981 through September 1986. Results show that iron casting compositions had changed with respect to a few tramp elements such as As, B, Co, and Sn over the 5-3/4-year period. Changes in charge compositions probably are responsible. A few significant regional variations also were observed with respect to Al, As, Co, Cr, Cu, and Mn.

OP 163-89. A Simplex Method-Based Algorithm for Source Location of Microseismic Events Associated With Underground Mining, by Jennifer Riefenberg. Paper in Rock Mechanics as a Guide for Efficient Utilization of Natural Resources, ed. by A. W. Khair (Proc. 30th U.S. Symp. on Rock Mechanics, Morgantown, WV, June 18-23, 1989). Balkema, 1989, pp. 655-662. In recent years, information obtained through the monitoring of microseismic events has gained acceptance in the mining industry as a indicator of potential rockburst conditions. One of the most important tasks in microseismic monitoring is the determination of the source location of microseismic events. It is with these spatial source location coordinates that zones of increasing rock stress may be delineated. This paper presents a fresh approach, based on the Simplex Method algorithm, for determining the source location of microseismic events. Presently the location algorithm being utilized by the U.S. Bureau of Mines is an iterative least squares method. A well-documented disadvantage of a least squares method is that the solutions may be weighted in favor of the most erroneous data. This paper compares the two procedures and demonstrates the advantage of the Simplex Method-based approach.

OP 164-89. Molten Streams of Ti Alloys by a Single-Melt System, by Gregory J. Slavens. J. Met., Mar. 1988, pp. 23-25. The U.S. Bureau of Mines has developed a single-melt system to purify pressed-alloy-sponge electrodes and produce molten titanium alloy streams. Melting was done in a vacuum arc furnace under an inert gas atmosphere using a single, funnel-shaped, water-cooled copper anode. Melt parameters were varied to increase the superheat and produce a stream of molten titanium alloy metal that could ultimately be fed to rotary atomizing equipment. Increasing the power to the arc from 36 to 150 kW produced a molten stream of titanium alloy metal, while a constant flow of helium gas removed volatile impurities. Both the chlorine and magnesium concentrations in the product were below 25 ppm, and aluminum and vanadium homogeneity matched that of commercial titanium alloy powder.

OP 165-89. Processing and Superconducting Properties of $GdBa_2Cu_3O_{7-z}$, by Chinnarong Asavaroengchai, Robert M. Metzger, David A. Robinson, Anny Morrobel-Sosa, Joseph S. Thrasher, Chester Alexander, Jr., Donald A. Stanley, and M. Abbott Maginnis. Ch. 26 in High-Temperature Superconducting Materials: Preparations, Properties, and Processing, ed. by W. E. Hatfield and J. H. Miller, Jr., Dekker, 1988, pp. 327-333. So far, two families of crystal structures exhibit superconductivity. The first family, with T_c around 40-50 K, is typified by $La_{2-x}Ba_xCuO_{4-z}$, which has *nominal* Cu oxidization number CON = $2+x-2z$; the second family has T_c = 90-100 K and is typified by $YBa_2Cu_3O_{7-z}$, with CON = $2.333-0.666z$. In both families, there are planar, or almost planar ("dimpled"), arrays of Cu and O atoms of stoichiometry CuO_2, surmounted by apical O atoms, yielding a square-pyramidal (i.e., distorted octahedral) coordination about Cu; these are the "2-D planes," possibly responsible for T_c around 40 K. In the $YBa_2Cu_8O_{7-z}$ structure, there is also a ribbon motif of square-planar Cu and O atoms of stoichiometry CuO_3; this "1-D ribbon" may be responsible for T_c around 90 K. The present authors first achieved superconductivity in a rapid-quenched green-black composite $Gd_3Ba_5Cu_8O_z$, with T_c = 62 K (onset at 71 K), and have also found superconductivity in single-phase $YBa_2Cu_3O_{7-z}$, with T_c = 90 K (onset at 96 K). The present paper reports on the synthesis, powder X-ray diffraction, and conductivity of $GdBa_2Cu_3O_z$, in which T_c = 100 K (onset at 108 K).

OP 166-89. An Expert System for Mica Beneficiation, by J. H. Marchal, D. J. Kleikamp, G. V. Sullivan, and R. W. Wilkerson. Paper in Proceedings of the Artificial Intelligence in Minerals and Materials Technology Conference, Tuscaloosa, AL, Oct. 20-21, 1987. Univ. AL, Coll. Eng., 1987, pp. 142-148. In the fall of 1985, the U.S. Bureau of Mines and the University of Missouri-Rolla began a research project to develop an expert system consultant for applications in research and development of mica beneficiation. This consultant would be used both as an aid in the design of mica beneficiation plants and as a tutorial tool. The system could also serve as a model for research in a larger area of mineral beneficiation. The expert system consultant would provide the following recommendations for an ore body: usability of the nonmica minerals present in the ore, feasible end uses for the mica, concentration treatments for the mica, equipment configurations, parameter settings for concentration treatment circuits, and fine tuning the treatment circuits. To date, a prototype consultant has been developed that provides the first three of these recommendations. This paper describes the prototype system and discusses its continuing development.

OP 167-89. Water-Jet-Assisted Mechanized Oil Shale Mining Technology Development, by Wilhelm J. Kogelmann, Edward D. Thimons, Joseph E. Virgona, and L. Alan Weakly. Paper in Proceedings: 1988 Eastern Oil Shale Symposium, Lexington, KY, Nov. 30-Dec. 2, 1988. Inst. Min. and Miner. Res., Univ. KY, 1988, pp. 225-236. The U.S. Department of Energy's Grand Junction Projects Office is participating in a $1.5 million cooperative agreement with Alpine Equipment Corp./Astro International Corp. (Alpine) of State College, PA, to evaluate the water-jet-assisted (WJA) mechanical cutting of oil shale under actual mining conditions. The cost of the 24-month, three-phase technology development project, started in February 1988, is shared equally between Alpine and the Department of Energy. Alpine has designed, is assembling, and will field-test a commercial-sized WJA mechanized mining machine. Field testing of the machine will be conducted at the Exxon Company, USA, Colony Pilot Oil Shale Mine located in the Piceance Basin of western Colorado. Additional support will be provided by the U.S. Bureau of Mines Pittsburgh Research Center and oil shale companies, through the Colorado Mining Association. The physical charac-

teristics of oil shale (a dolomitic limestone containing kerogen) make conventional mechanized production mining methods impractical by causing excessive machine vibration, high bit-wear rates, and excessive dust generation. Current mechanical excavation methods for oil shale are less efficient and more costly than the traditional drill-and-blast methods. However, conventional drill-and-blast methods have limitations imposed by excessive rock damage and regulatory considerations. By improving mechanical excavation technologies, oil shale could be more competitive with other energy sources. The WJA cutting technology currently being developed is expected to be applicable to oil shale deposits in the Eastern and Western United States. An evaluation under actual mining conditions will provide field data that can be utilized by the private sector to develop and commercialize WJA mechanized mining equipment to mine oil shale. The successful application of high-pressure water-jet technology in conjunction with mechanical mining could favorably impact the mining of oil shale by reducing capital and operating costs, improving safety, and increasing the extraction ratio of oil shale mined. The WJA roadheader field tests on coal have shown that high-pressure water jets increase cutter life and reduce ventilation costs by cooling the cutting head, removing already mined rock from the cutting surface, and reducing dust production.

OP 168-89. The Interaction Between Electrogalvanized Zinc Deposit Structure and the Forming Properties of Sheet Steel, by J. H. Lindsay, R. F. Paluch, H. D. Nine, V. R. Miller, and T. J. O'Keefe. Plating and Surface Finishing, v. 76, No. 3, Mar. 1989, pp. 62–69. The use of electrogalvanized steel to enhance the corrosion resistance of automobile body panels affects the forming of sheet steel. The zinc structure and morphology, influenced by electrolytic and hydrodynamic conditions during deposition, alters the drawing character of the sheet. Steel plated with zinc deposits exhibiting strong basal (0001) plane and strong pyramid plane (101X) orientation were prepared. In this U.S. Bureau of Mines study, forming properties were related to deposit morphology and structure and compared to those for commercial products.

OP 169-89. Lineaments and Mines: Defining Subsurface Structure and Potential Ground Control Hazards With Remote Sensing, by D. C. Peters, R. A. Speirer, V. R. Shea, and P. E. Wilson. Paper in Abstracts Volume 2, 28th International Geological Congress, Washington, DC, July 9–19, 1989, p. 2–598. In an effort to more fully understand and predict areas of underground coal mines that have a potential for ground control problems (such as roof falls and water inflows), the U.S. Bureau of Mines has been researching the use of lineaments derived from remotely sensed data (such as Landsat images and aerial photography). Lineaments have long been used as indicators of fractures and other geologic structure, even where outcrops are rare and the structures that may control the lineaments are obscured or difficult to define using standard geologic field methods or drilling.

OP 170-89. Chloride-Oxygen Leaching of Sulphide, Oxide and Scrap Metal Feeds, by G. A. Smyres. Paper in Extraction Metallurgy '89. Inst. Min. and Metall., 1989, pp. 839–860. The U.S. Bureau of Mines has investigated methods for the hydrometallurgical treatment of copper, lead, zinc, nickel, cobalt, mercury, gold, silver, and other metals from a number of sources. Extraction procedures were demonstrated with simple and complex sulfide concentrates, scrap metals, smelter waste products, and metal oxides. The procedures developed include leaching with Cl_2-O_2, HCl-O_2, $FeCl_2$-O_2, $CaCl_2$-O_2, and H_2SO_4-$CaCl_2$-O_2 at 95° to 120° C and 30 to 50 psig. Air can be used as the O_2 source, and the importance of the reactor design is stressed. The treatment procedure used depends on the material being leached, and the methods of subsequent metal recovery determine whether Cl_2, HCl, $FeCl_2$, or $CaCl_2$ are available for recycle to the reactor. Metal recoveries are typically 95 to 99 pct, and elements rejected to the leaching residue as insoluble constituents are Al, As, Cr, Fe, S, Sb, and Si. Methods for controlling the solubility of certain metals in the chloride-oxygen leaching system are also discussed. Descriptions of leaching procedures and extraction results are given.

OP 171-89. Moisture Application for Dust Control, by Jon C. Volkwein, Andrew B. Cecala, and Edward D. Thimons. Appl. Ind. Hyg., v. 4, No. 8, Aug. 1989, pp. 198–200. The U.S. Bureau of Mines and several member companies of the National Industrial Sand Association have been working in many areas to reduce personal exposure to respirable dust. Areas investigated have included ventilation, improved hardware design, improved housekeeping practices, and addition of moisture to products. This article reviews information to date on various methods of using moisture to reduce respirable dust concentrations in mineral processing plants. Individual studies present an inconclusive case for additional work in this area. Together, however, these studies indicate a good potential for the development of an economical and practical plantwide dust control technique. Naturally, these techniques may only be applicable for certain mineral products. Methods used in the individual studies to evaluate dust reductions included observation, gravimetric filter analysis, and instantaneous light-scattering methods. Various methods of moisture addition included the use of foams, steam, and water sprays. Reductions achieved were dependent on the method of moisture addition and ranged up to 90+ pct. In general, foam and steam were nearly twice as effective in reducing dust as plain water sprays. This was attributed to increased surface area of the medium. The other significant finding was the need for thorough mixing of the product with the water. Methods other than reintroducing moisture to a dried product material would be preferred, yet are untried. Technical and material handling problems of producing a product material with a specific moisture content may be significant. Further effort is needed to control the amount of moisture in the product and to reduce costs.

OP 172-89. Blasting Agents for Use in Flammable Atmospheres, by Eric S. Weiss, Michael J. Sapko, and Richard W. Watson. Paper in Proceedings of the Fifteenth Conference on Explosives and Blasting Technique, New Orleans, LA, Feb. 5–10, 1989. Soc. Expl. Eng., 1989, pp. 329–338. As part of U.S. Bureau of Mines research into the hazards associated with the mining and processing of oil shale, experimental mine tests have been conducted to evaluate preferred combinations of explosives and inerting materials to prevent ignition of oil shale dust and mixtures of oil shale dust and methane. The relative incendivity of several blasting agents was evaluated in the Bureau's Bruceton Experimental Mine (BEM). The minimum charge weights resulting in the ignition of predispersed oil shale dust clouds were measured for each of the explosives. Several stemming materials were evaluated in the BEM for their effectiveness in preventing the ignition of near-stoichiometric methane-air mixtures. Results are encouraging and indicate that there is merit in pursuing explosive composition as a means of reducing ignition probability of oil shale and sulfide dust clouds generated during normal blasting operations. The proper selection of explosives and stemming materials should significantly reduce the probability of secondary dust explosions in oil shale and sulfide ore mining.

OP 173-89. Preparation of Submicron Titanium Nitride Powder by Vapor-Phase Reactors, by G. W. Elger, D. E. Traut, G. J. Slavens, and S. J. Gerdemann. Metall. Trans. B, v. 20B, Aug. 1989, pp. 493–497. The U.S. Bureau of Mines continued research on the preparation of titanium nitride powder for potential use as a substitute for imported tungsten used in metal cutting tools and wear-resistant applications. Major emphasis was directed toward improving the purity of the powder produced by vapor-phase reaction of titanium tetrachloride with magnesium in the presence of nitrogen or anhydrous ammonia at 1,000°C. Modifications were made in powder collection, handling, and purification procedures that significantly reduced the oxygen content of the product from >5 wt pct to <1 wt pct. Powder samples contained oxygen contents as low as 0.23 wt pct and exhibited a median particle size of 0.28 μm.

OP 174-89. The Dynamics of Multi-Phase Flow in Collimated Jets, by A. L. Miller, R. W. Kugel, and G. A. Savanick. Paper in Proceedings of the 5th American Water Jet Conference, August 29–31, 1989, Toronto, Canada, ed. by M. M. Vijay and G. A. Savanick. National Research Council of Canada and U.S. Water Jet Technology Association, 1989, pp. 179–189. The dynamics and thermal characteristics of a small-diameter, high-speed waterjet expanding into a larger diameter open-ended pipe were studied by the U.S. Bureau of Mines. The void created as the jet expands into the larger pipe are filled by vaporization or by entrainment of backflowing air from the pipe exit. The resulting mixture exits the larger pipe as a well-dispersed multiphase fluid. Observation of the vaporization-dispersion phenomena through glass pipes indicated three distinct flow regions: (1) jet breakup, (2) collimation, and (3) backflow. Mass-flow distribution measurements in region 2 suggest a system of well-dispersed droplets. Pressure and temperature measurements in the first two regions are consistent with vaporization equilibrium values and show little variation. A computer simulation of evaporation rate

was used to verify that vaporization equilibrium is reached in a fraction of the residence time of the fluid in the pipe. Surface conductivity measurements indicate the absence of a water film on the inner pipe walls up to region 3, where a significant increase in surface conductivity occurs. The boundary between regions 2 and 3 is marked by a considerable discontinuity in pressure and temperature. These observations will be used to develop a model to determine flow losses and momentum transfer in the multiphase flow.

OP 175–89. Management and Mine Safety, by Robert H. Peters. Eng. and Min. J., v. 190, No. 6, Aug. 1989, pp. 22M–22S. Researchers have come up with a lengthy list of factors associated with miners, mine management, and company policy that appear to have an impact on coal-mine safety. This article calls attention to a relatively small set of factors that have been found to be important in accounting for these various differences in mine safety. Four factors emerged as being consistent predictors of underground coal mine safety performance: (1) the extent to which underground employees perceive that upper management is concerned about their welfare, (2) the extent to which management actively involves the work force in identifying safety problems and defining solutions, (3) the favorability of management-labor relations, and (4) the rate of employee absenteeism.

OP 176–89. Uranium In Situ Mining Research by the United States Bureau of Mines—A Review, by J. M. Pugliese and W. C. Larson. Paper in In Situ Leaching of Uranium: Technical, Environmental and Economic Aspects (Proc. of a Tech. Committee Meeting, Int. Atomic Energy Agency, Vienna, Nov. 3–6, 1987). International Atomic Energy Agency, Vienna, 1989, pp. 37–62. The Bureau of Mines initiated its in situ mining research program in 1974 to advance in situ mining as a viable alternative to conventional open pit and underground mining methods. At first, research work was conducted in two principal areas—fluid flow modeling and geochemical modeling to represent leaching reactions in the ore body. Subsequently, the work effort evolved into a multiphase in situ mining research program designed to find a more economical way of mining while minimizing negative impacts on the environment. This paper discusses aspects of the Bureau's laboratory and field research accomplishments on the following topics: (1) permeability of uranium-bearing sandstone, (2) environment and restoration of ground water, (3) fluid flow and geochemical modeling, (4) environmentally attractive leach solutions, (5) well construction and completion, and (6) cost and sensitivity analysis for uranium in situ mining.

OP 177–89. A Miner's Personal Carbon Monoxide Alarm, by Joseph E. Chilton and Clarence R. Carpenter. IEEE Trans. on Ind. Applications, v. 25, No. 3, May-June 1989, pp. 503–508. Underground miners may be exposed to hazardous quantities of toxic gases such as carbon monoxide (CO) generated from mine fires or explosions. Every underground miner is required to carry a filter self-rescuer (FSR) that, when operated, will remove CO from the miner's breathing air. In addition, all underground miners must have near their work site self-contained self-rescuers (SCSR) that, when activated, will supply breathing oxygen. In many situations with fires, miners do not know when to don either self-rescuer, since they have not been informed of a fire in a different mine location. Usually miners do not carry the gas instrumentation necessary for the detection of the toxic, colorless, and odorless fire product CO. If each miner carried a personal CO alarm that responds to life-threatening concentrations of CO, the miners would then be alerted to don either the FSR or SCSR and exit the mine. For this purpose, a miner's personal CO alarm prototype called PEMCOAL has been developed by the U.S. Bureau of Mines. The PEMCOAL unit is small enough to be carried on a miner's belt, has a flashlamp visual alarm, requires no calibration for use, and uses a disk sensor that changes color by reaction with CO. PEMCOAL was tested at concentrations of CO to 1,000 ppm, at temperatures from 5 to 40°C, and with several potential mine gas interferents. The PEMCOAL alarm times are sufficiently fast to warn miners before they are exposed to hazardous quantities of CO.

OP 178–89. A Portable Slurry Wear Test for the Field, by B.W. Madsen. Trans. ASME, J. Fluids Eng., v. 111, Sept. 1989, pp. 324–330. A new portable slurry wear test apparatus developed by the U.S. Bureau of Mines makes it possible to gather materials wear and corrosion data at a mineral processing site. The portable wear cell is identical in design to a laboratory cell reported previously. It allows simultaneous evaluation of 16 specimens in a continuous flow of fresh slurry. Data obtained from selected metals and polymers showed high-chronium white cast irons to perform particularly well in tests with an aqueous lead-zinc sulfide ore slurry. However, ultra-high-molecular-weight polyethylene that exhibited superior wear resistance in comparable laboratory tests with an aqueous slurry of silica sand did not perform as well in field tests. Such results show how misleading it can be to use laboratory data to predict relative rates of wear in industrial slurries, even under nominally identical flow conditions. Field testing is therefore needed. In situ electrochemical corrosion measurements on a low-alloy steel showed that the field and laboratory slurries were similarly corrosive.

OP 179–89. Sulfur Polymer Cement for the Production of Chemically Resistant Sulfur Concrete, by W. C. McBee, H. Weber, and F. E. Ward. Paper SP 116–12 in Polymers in Concrete: Advances and Applications (Proc. 1988 ACI Annu. Conv.). Am. Concrete Inst., 1989, pp. 193–203. Composite materials based on sulfur polymer cement (SPC) and mineral aggregate have been developed by the U.S. Bureau of Mines as part of a program to utilize abundant mineral resources. Program goals are to develop durable, chemically resistant construction materials to increase productivity in the chemical, fertilizer, and metallurgical industries by lowering maintenance costs for labor, energy, equipment, and material. This paper describes the research related to development of SPC, the sulfur concrete, and the industrial testing, together with commercial-scale equipment development and large-scale construction practices.

OP 180–89. In Situ Mining: Research by U.S. Bureau of Mines May Lead To Innovative and Low-Cost Copper Mining Methods, by Daniel J. Millenacker. Eng. and Min. J., v. 190, No. 9, Sept. 1989, pp. 56–58. The U.S. Bureau of Mines is conducting research on technology that will allow mining companies to develop methods of extraction that will keep them competitive on world mineral markets into the 21st century. One research effort is the Advanced Mining Systems program. A major focus of the Bureau's research of advanced mining systems is the development of in situ leach mining methods. An important part of this research will be an in situ copper mining field test near Casa Grande, AZ. To support the field test, the Bureau is conducting a comprehensive in-house research program.

OP 181–89. In Situ Copper Leach Mining—An Alternate Mining Method, by Daniel J. Millenacker and Jon K. Ahlness. Paper in Proceedings, 1989 Multinational Conference on Mine Planning and Design, Lexington, KY, May 23–26, 1989. Univ. KY, 1989, pp. 181–187. The U.S. Bureau of Mines is evaluating in situ leach mining as a method for extracting copper from previously unmined copper oxide deposits. In situ leach mining involves the in-place leaching of metal values from an ore zone using fluid injection and recovery wells completed from the surface or from underground workings. This mining method differs dramatically from conventional mining in that metal recovery does not require extraction and handling of ore, or corresponding disposal of large quantities of rock and processing waste. This may result in a lower unit cost of production since labor and energy requirements are reduced. A draft manual has been developed by the Bureau that will allow a user to economically evaluate the potential for any copper oxide deposit to be in-situ-leach-mined, and also prepare design specifications for a commercial-scale operation. A field research project is being conducted to verify the draft manual. This paper will discuss the key components of the draft manual and field verification program.

OP 182–89. Roof Outbursting at a Canadian Bedded Salt Mine, by Steven J. Schatzel and Mark S. Dunsbier. Ch. 60 in Proceedings of 4th U.S. Mine Ventilation Symposium, Berkeley, CA, June 5–7, 1989. Soc. Min., Metall., and Exploration, Wilton, CO, 1989, pp. 491–499. Large roof outbursts began occurring in November 1986 at Domtar's Sifto Salt Mine in Goderich, Ontario, Canada, working the bedded Salina A-2 Salt unit. The outbursts, measuring about 13 to 20 m in diameter, released high concentrations of methane from cavities that extended into carbonate roof units. Spontaneous ignitions of methane gas during an outburst seriously burned a mine technician. The Canadian Ministry of Labour contacted the U.S. Bureau of Mines for technical assistance to aid in mine management's efforts in alleviating the problem. Initial gas content determinations of salt samples from the outbursts by acoustic test methodology revealed no methane enrichment. In-mine core drilling and subsequent methane content testing indicates the main source of methane in overlying roof units. Drilling the roof units demonstrated the potential of draining

methane from areas showing signs of impending outbursting and alleviating the danger. Three mechanisms are considered the most likely means by which methane was introduced to the mine environment. These are (1) hydrocarbon gases released from brines, (2) gas transport along horizontal bedding planes or gas accumulations in bedding separations, and (3) mining-induced fracturing. The abundance of higher hydrocarbons in gas yielded by nonevaporate rock samples from the Goderich mine may be indicative of a former association with liquid petroleum.

OP 183–89. Mineral Industries of China—1988, by E. Chin. Paper in Mining Annual Review 1989, ed. by M. West (reprint). Min. J. Ltd., London, 1989, 6 pp. This paper presents data on the mineral industries of China in 1988.

OP 184–89. Entry Stabilization Utilizing Rib Bolting Procedures, by Dennis R. Dolinar and Stephen C. Tadolini. Paper in Longwall U.S.A. (Proc. Int. Exhibition and Conf., Pittsburgh, PA, June 19–22, 1989). Industrial Presentations, Inc., Aurora, CO, 1989, pp. 135–147. The danger to men, equipment, and pillar structure created by the spalling of a coal rib can be minimized by installing rib bolts. To assure that a configured support system will maintain a coal rib, the U.S. Bureau of Mines developed a rib bolt system based on a nonpreventable failure concept. A statistical equation quantitatively relates the amount of rib retained to the bolt spacing and the width of the spalled material. Laboratory test results show that the equation accurately predicts the amount of material retained while the results also confirm the validity of the support concept. The examination of rib bolting at a coal mine experiencing rib sloughage provides evidence that the effectiveness of the support can be related to the failure pattern of the spalled material. An analysis of roof and roof support reaction to rib sloughage at the mine indicated that the rib sloughage had little effect on roof stability. Although supporting ribs might not affect roof stability, laboratory test results indicate that the material retained by the support can sustain a load up to 20 pct of the material's intact compressive strength.

OP 185–89. Isometric Pushing, Pulling, and Lifting Strengths in Three Postures, by Sean Gallagher. Paper in Proceedings of the Human Factors Society 33rd Annual Meeting (Denver, CO, Oct. 16–20, 1989). Human Factors Society, Denver, CO, v. 1, 1989, pp. 634–640. Nine underground coal miners (mean age = 36.9 yr ± 6.3 *SD*; height = 174.5 cm ± 7.4 *SD*; weight = 87.8 kg ± 12.5 *SD*) participated in a U.S. Bureau of Mines study examining the effects of posture on isometric strength. Five tests of static strength (maximum push, maximum pull, maximum lift with elbows flexed at 90°, maximum lift with lifting handle 45.7 cm [18 inches] above floor, and maximum push up with handle at eye height) were performed in three postures: standing, kneeling on one knee, and kneeling on two knees. Results indicated that neither test of lifting strength was affected by posture ($p > 0.05$). However, maximum pulling strength was significantly greater when kneeling on one knee ($p < 0.001$) than when standing or kneeling on both knees. Also, maximum pushing strength was greater when kneeling on both knees than when standing ($p < 0.05$). The test of maximum push up was not affected by posture ($p > 0.05$), and the forces generated in the three postures for this test were highly correlated ($r = 0.94$). Results of these strength tests may be useful when recommending appropriate postures to assume when performing specific underground materials-handling tasks.

OP 186–89. Water-Jet-Assisted Mechanized Oil Shale Mining Factory Test, by Wilhelm J. Kogelmann, Edward D. Thimons, Joseph E. Virgona, and L. Alan Weakly. Paper in 22nd Oil Shale Symposium Proceedings, ed. by James H. Gary. CO Sch. Mines Press, Golden, CO, 1989, pp. 56–77. The U.S. Department of Energy's Grand Junction Projects Office is participating in a $1.5 million cooperative agreement with Alpine Equipment Corp./Astro International Corp. (Alpine) of State College, PA, to evaluate the water-jet-assisted (WJA) mechanical cutting of oil shale under actual mining conditions. The cost of the 24-month, three-phase technology development project, started in February 1988, is shared equally between Alpine and the Department of Energy. Alpine has designed a commercial-sized WJA mechanized mining machine for testing in 1989. Factory testing will comprise not only startup and QA/QC testing but also state-of-the-art and innovative tool screening tests on oil shale boulders. Field testing of the machine will be conducted at the Exxon Co., USA, Colony Pilot Oil Shale Mine located in the Piceance Basin of western Colorado. Additional support will be provided by the U.S. Bureau of Mines Pittsburgh Research Center and oil shale companies, through the Colorado Mining Association. The physical characteristics of oil shale (a dolomitic limestone containing kerogen) make conventional mechanized production mining methods impractical by causing excessive machine vibration, high bit-wear rates, and excessive dust generation. Current mechanical excavation methods for oil shale are less efficient and more costly than the traditional drill-and-blast methods. However, conventional drill-and-blast methods have limitations imposed by excessive rock damage and regulatory considerations. By improving mechanical excavation technologies, oil shale could be more competitive with other energy sources. An evaluation under actual mining conditions will provide field data that can be utilized by the private sector to develop and commercialize WJA mechanized mining equipment to mine oil shale. The successful application of high-pressure water-jet technology in conjunction with mechanical mining could favorably impact the mining of oil shale by reducing capital and operating costs, improving safety, and increasing the extraction ratio of oil shale mined. The WJA roadheader field tests on coal have shown that high-pressure water jets increase cutter life and reduce ventilation costs by cooling the cutting head, removing already mined rock from the cutting surface, and reducing dust production.

OP 187–89. Application of Numerical Modeling Techniques for Gateroad Design in Bump Prone Mines, by N. P. Kripakov and L. E. Rockwell. Paper in Longwall U.S.A. (Proc. Int. Exhibition and Conf., Pittsburgh, PA, June 19–22, 1989). Industrial Presentations, Inc., Aurora, CO, 1989, pp. 88–89. Coal mine bumps continue to cause serious accidents involving loss of life and extensive damage to mining properties. Bumps are characterized as releases of energy associated with unstable yielding that occurs with progressive mining. Unstable release of energy occurs when the coal and rock are not able to absorb the excess energy released by the surrounding rock mass during the yielding process. The U.S. Bureau of Mines, as part of its coal mine bump research program, is developing computational procedures utilizing accepted principles and methods to aid mine operators in eliminating and reducing the occurrence of bumps. This paper presents recent work aimed at demonstrating how numerical modeling techniques can be useful in distinguishing between the merits of using one mine configuration over another to minimize coal bump potential. Some basic theory and potential failure mechanisms are discussed in a mining context. Key elements required for future development are identified. These developments will allow numerical model analysis to be a useful tool for distinguishing between stable, nonviolent pillar yielding versus an unstable, violent pillar collapse.

OP 188–89. Mineral Industries of the U.S.S.R.—1988, by Richard M. Levine. Paper in Mining Annual Review 1989, ed. by M. West (reprint). Min. J. Ltd., London, 1989, 12 pp. This paper presents data on the mineral industries of the U.S.S.R. in 1988.

OP 189–89. Dielectric Properties of Selected Minerals at 1 to 22 GHz, by S. O. Nelson, D. P. Lindroth, and R. L. Blake. Geophysics, v. 54, No. 10, Oct. 1989, pp. 1344–1349. Metallurgical mineral separation makes use of the large differences in dielectric properties of individual minerals. Microwave heating for thermal rock fragmentation uses differences in the complex electrical properties of rock due to inhomogeneities in composition, structure, and texture. Knowledge of the relative complex permittivity is required to determine the differential absorption of microwave energy in an aggregate of minerals (rock). Electrical properties are also essential in modeling electromagnetic wave propagation and interaction in layered earth models (gas and oil exploration), remote sensing of ore deposits, and detection of pollutants in groundwater. In this U.S. Bureau of Mines research measurements at 24° C at frequencies from 1 to 22 GHz of the complex relative permittivities of dry pulverized samples of 10 minerals, 6 silicates and 4 metal oxides, showed that the permittivities of 1 mineral from each class, pyroxene (salite) and goethite, were practically independent of frequency. The other metal oxides, hematite, ilmenite, and manganese oxide (hollandite), had high permittivities that decreased significantly with increasing frequency. The dielectric loss factor of manganese oxide (hollandite) revealed a dielectric relaxation in the 1- to 22-GHz range with losses peaking between 2.45 and 11.7 GHz. The other silicates, amphibole (richterite), chlorite (clinochlore), feldspar (lab-

radorite), and muscovite and phlogopite micas, had lower permittivities that showed moderate reductions with increasing frequency. Their loss factors showed relatively little frequency dependence, but moderate reductions with increasing frequency were evident for amphibole (richterite), feldspar (labradorite), and pyroxene (salite).

OP 190-89. Bonus Plans in the Coal Industry: How Are They Affecting Employee Motivation, Safety and Productivity? by Robert H. Peters. Paper in Longwall U.S.A. (Proc. Int. Exhibition and Conf., Pittsburgh, PA, June 19-22, 1989). Industrial Presentations, Inc., Aurora, CO, 1989, pp. 150-155. Bonus plans have been amazingly successful in some organizations, and it is encouraging to note that some of these successes have been in coal mines. However, a recent U.S. Bureau of Mines-sponsored study by Dr. Paul Goodman found that several bonus plans at underground coal mines are simply *not* working very well. Some important lessons about the design of bonus plans for coal mines can be learned from studying these plans and seeing how they differ from their more successful counterparts. This paper discusses some of the common mistakes made in designing bonus plans for coal mines.

OP 191-89. Reducing Coal Miner Absenteeism, by R. H. Peters and M. R. Clingan. Min. Sci. and Technol. J., v. 9, 1989, pp. 227-236. High absenteeism at coal mines can seriously affect safety and hamper productivity. Several effective strategies for achieving high attendance which mine operators may not have considered are presented, and a method is proposed for implementing programs for minimizing absenteeism among coal miners. The best strategies for improving attendance will vary according to the needs and circumstances of the particular mine; however, the process for establishing such a program is relatively invariant. A four-stage process is recommended: evaluate data from prior attendance records, communicate attendance goals and policy, develop and implement an attendance promotion program, and recycle.

OP 192-89. Recovery of Sulfur From Phosphogypsum: Conversion of Calcium Sulfide to Sulfur, by D. A. Rice, A. May, O. C. Carter, Jr., and R. G. Swanton. Paper in Transactions Volume 284, Soc. Min. Eng., 1988, pp. 1848-1854. As part of a cooperative effort between the U.S. Bureau of Mines and the Florida Institute of Phosphate Research, with input from the phosphate industry, the conversion of phosphogypsum to sulfur is being investigated. The proposed process incorporates a thermal reduction of phosphogypsum to calcium sulfide (CaS) and a hydrometallurgical treatment to convert calcium sulfide to ammonium bisulfide (NH_4SH), which is then oxidized using a catalyst to produce elemental sulfur. The paper summarizes the results of continuing laboratory studies using an activated carbon catalyst which was loaded with sulfur through oxidation of ammonium bisulfide solution. The extraction of the sulfur that forms in situ on the catalyst is a key area in the development of the sulfur recovery process. Two approaches for removing the sulfur are being investigated: (1) thermal treatment to volatilize sulfur and (2) leaching the sulfur using liquid anhydrous ammonia. The research has shown that it is technically feasible to recover over 90 pct of the sulfur from the carbon by either volatilization or ammonia leaching. Locked-cycle testing has demonstrated that the carbon has the potential to be recycled after ammonia leaching.

OP 193-89. The Effect of Particle Size on the Dewatering of Coal-Clay Waste, by Bernard J. Scheiner. Paper in Proceedings of the Annual Technical Conference on Filtration and Separation (Pittsburgh, PA, Mar. 27-29, 1989). Am. Filtration Soc., 1989, pp. 347-350. In field tests, the Bureau of Mines has investigated the use of polyethylene oxide (PEO) to dewater coal-clay waste using a variety of dewatering devices such as a static screen, a static screen followed by a trommel screen, and a static screen followed by either a horizontal vacuum belt filter or a filter press. During these field tests, the particle size distribution of the material treated varied, leading to different results in terms of dosage requirements and percent solids produced on the dewatering device.

OP 194-89. Factors Affecting Dewatering of Phosphatic Clay Waste Slurries, by B. J. Scheiner and M. M. Ragin. Paper in Transactions Volume 284, Soc. Min. Eng., 1988, pp. 1801-1806. The U.S. Bureau of Mines has been investigating the use of polyethylene oxide (PEO) as a flocculant for a variety of mineral wastes. As part of this investigation, the hydrodynamics of the flocculation process were studied. It was determined that to obtain optimum dewatering results, the factors of energy input into the stirrer, polymer concentration, and polymer dosage must be considered. It was found that at a given polymer concentration, there were an optimum stirrer speed and polymer dosage. With excess PEO, the amount of water removed in the trommel decreased, but no evidence for steric stabilization was observed.

OP 195-89. Recovery of PGM From Virgin Automotive Catalysts by Cyanide Leaching, by G. B. Atkinson, D. P. Desmond, R. J. Kuczynski, and L. A. Walters. Paper in Platinum Group Metals and the Quality of Life: Proceedings of a Seminar of the International Precious Metals Institute, Las Vegas, Nevada, ed. by A. Austin, C. M. Barnard, and G. E. Haslam. Int. Precious Met. Inst., 1989, pp. 109-115. The U.S. Bureau of Mines investigated leaching virgin automotive catalytic convertor biscuits with cyanide solution for recovery of platinum-group metals to establish baseline leaching parameters for expansion of the technology to leaching used catalysts. Two types of monoliths were tested: an oxidation type with 500 ppm Pd and 1,000 ppm Pt, and a three-way type with 2,000 ppm Pt and 200 ppm Rh. Monoliths were crushed to minus 12, plus 30 mesh. Preleaching treatment of the biscuits was necessary for high recovery. This involved oxidation and reduction. Best results were obtained with air for 1 h at 550° C followed by H_2 reduction for 1 h at 550° C. Twenty-gram samples were leached in stirred beakers with 100 mL of solution for 1 h at 80° C. Five percent NaCN-1 pct proprietary promoter dissolved 99 pct of the Pd and 98 pct of the Pt in the oxidation catalyst. This reaction consumed 20 lb NaCN per ton of catalyst. Five percent NaCN-1 pct promoter dissolved 98 pct Pt and 98 pct Rh from the three-way catalyst and consumed 150 lb NaCN per ton of catalyst.

OP 196-89. Evaluation of New Control Technology for Diesel Engines Used in Underground Coal Mines, by Kirby J. Baumgard and Johnny L. Coffey. Paper in Proceedings of American Mining Congress (Pittsburgh, PA, June 20-21, 1989). Am. Min. Congr., Washington, DC, 1989, pp. 173-186. Permissible diesel-powered equipment operating in underground coal mines must meet temperature requirements and must not emit flames or sparks into the mine atmosphere. The most common device used to meet exhaust control requirements is the water scrubber. Water scrubbers cool the exhaust and remove approximately 30 pct of the diesel particulate matter (DPM), but they are large, require frequent maintenance, and consume large quantities of water. The U.S. Bureau of Mines evaluated a new emission control device designed to meet the safety requirements and control DPM emissions. The dry exhaust conditioning system (DS) cools the exhaust using a fin and tube heat exchanger and removes DPM with a ceramic diesel particle filter (DPF), which is placed downstream of the DS. The objectives of the research were to determine the effect the DS-DPF has on particle emissions, engine performance, and cooling efficiency. Additional objectives were to evaluate an off-board cleaning system and to determine if the DS-DPF is ready for in-mine tests. Laboratory tests indicated that the DS alone removed about 42 pct of the DPM, the DPF alone removed about 91 pct, and when the systems were combined over 97 pct of the DPM was removed. During transient tests, the DS maintained exhaust temperatures below the 150° C limit; however, when the engine was operated at rated speed and full load, the temperatures exceeded this limit. This was due to DPM being deposited on the cooling fins, lowering the heat transfer capability. To rectify this problem, the manufacturer has built a second unit that is larger, has a slightly different internal configuration, and incorporates a special water injection cleaning system. The complete package is currently being evaluated at the Mine Safety and Health Administration's Approval and Certification Center, where the system must pass all the necessary safety tests before it can be used in underground gassy mines.

OP 197-89. Diesel Particulate Matter Emission Control, by Kirby J. Baumgard and Winthrop E. Watts, Jr. Paper in Joint AMC/BoM Diesel Use Seminar 1988 (Lexington, KY, and Reno, NV, June 7-9, 1988). Am. Min. Congr., Washington, DC, 1988, pp. 48-60. Diesel particulate matter (DPM) is a normal byproduct of diesel fuel combustion. It is composed mainly of submicrometer, insoluble, carbonaceous soot agglomerates and adsorbed or condensed soluble organic compounds. Because DPM is almost entirely respirable in size, it is regulated under the respirable coal mine dust

standard. Tests conducted by the U.S. Bureau of Mines have shown that an engine in good mechanical condition can emit up to 300 mg/scm of DPM, and those in need of maintenance can emit much higher concentrations. To ensure that DPM is not a major contributor to the respirable dust in mines, emissions should be reduced to the lowest possible levels. An industrial hygiene strategy aimed at reducing DPM levels in mines should include a combination of work practice modifications, emission controls, and regular monitoring of DPM levels. Work practices that should be emphasized include engine and fuel selection, engine maintenance, operator habits, and ventilation. Emission controls such as fuel additives, catalytic converters, water scrubbers, and diesel particulate filters should be considered. In some cases the use of emission controls may decrease the levels of some contaminants, while at the same time increasing the levels of others; thus they must be carefully evaluated before being selected for in-mine use. The objective of this report is to present information on the work practices and diesel exhaust controls that can be used to reduce DPM emissions now and in the future. A brief discussion of state-of-the-art DPM monitoring methods is also included.

OP 198-89. Measurement of Normal Incidence Absorption Coefficient Using Sound Intensity, by J. A. Burks and E. R. Spencer. Paper in Inter-Noise 89 (Newport Beach, CA, Dec. 4-6, 1989). Inst. Noise Control Eng., Poughkeepsie, NY, pp. 1077-1080. The accepted laboratory procedure for measuring the normal incidence absorption coefficient of materials depends on a determination of the standing wave pattern in an enclosed tube. This method has been relied on by the U.S. Bureau of Mines in its efforts to characterize the performance of acoustical materials that have been subjected to physical agents typically found in mining environments. However, the standing wave method is not ideally suited for this kind of measurement since the physical condition of a test sample saturated with either oil or water can change rapidly with time. Thus, with the standing wave method it is simply not possible to obtain absorption data for all frequencies at the same point in time. Due to the continuing research interest in the long-term performance of acoustical materials used in mining noise control, sound intensity has been investigated as an alternative approach to measuring the absorption coefficient. In general, it is concluded that the sound intensity technique promises a more convenient and efficient method for the measurement of normal incidence absorption coefficient. This will provide a tremendous advantage in those situations where it is critical to measure at all frequencies simultaneously.

OP 199-89. Comparison of Predicted and Measured Diesel Exhaust Emission Levels During Transient Operation, by Timothy J. Callahan, Thomas W. Ryan III, Sherrill F. Martin, and Robert W. Waytulonis. SAE Tech. Paper Series 872140, 1987, 8 pp. This U.S. Bureau of Mines paper verifies a technique for mapping the exhaust emission levels of a diesel engine during transient operation. Particulate matter, oxides of nitrogen, hydrocarbons, and carbon monoxide emissions were sampled for discrete segments of various transient cycles. Each cycle consisted of four distinct segments. The discrete segments are described by average engine conditions, rate of change variables, and segment length. Regression analysis was used to develop equations relating the emission levels during each segment to the engine parameters. The regression equations were then used to obtain estimates of composite emission levels of several complex transient cycles that were subsequently tested. These cycles included the Environmental Protection Agency (EPA) heavy-duty transient cycle and two simulated heavy-duty cycles developed for underground mine vehicles. Comparison of the predicted and measured cycle emissions are made for the EPA heavy-duty cycle and the simulated mine cycles. Good agreement was obtained between the predicted and measured emission levels.

OP 200-89. Source Apportionment Analysis Applied to Mine Dust Aerosols: Coal Dust and Diesel Emissions Aerosol Measurement, by Bruce K. Cantrell. Ch. 69 in Proceedings of 3rd U.S. Mine Ventilation Symposium (University Park, PA, Oct. 12-14, 1987), ed. by J. M. Mutmansky. Soc. Min. Eng. AIME, 1987, pp. 495-501. As part of a continuing study of diesel exhaust aerosol characteristics, the U.S. Bureau of Mines has applied chemical mass balance (CMB) model source apportionment analysis to evaluate a size-selective sampling method for determining the separate diesel exhaust and coal dust aerosol concentrations in a diesel-equipped coal mine. Size-selective sampling was used under the premise that diesel exhaust aerosol dominates the submicrometer aerosol size range, while most of the mineral dust aerosol is greater than 1 μm. A microorifice, uniform deposit impactor (MOUDI) was used as the size-selective sampling method. Concurrent samples of mine aerosol were collected using a dichotomous, respirable aerosol sampler. This sampler separated the fine and coarse size portions of its sample at 0.7 μm. Trace element concentrations for in-mine aerosol sources and the dichotomous samples used by the CMB model were measured using instrumental neutron activation analysis. The CMB analysis, applied to both the fine and coarse fractions of the respirable mine aerosol, yielded the mass concentration contributed to each by diesel exhaust and mineral dust aerosol sources. The MOUDI size distribution data were analyzed using nonlinear regression to parameterize the fine and coarse fractions of the sampled aerosol and to estimate the contributions to each fraction from both coal dust and diesel aerosol sources. For the diesel mine visited, analysis of the MOUDI samples yielded a value for the fraction of the fine aerosol attributable to coal dust of 15 ± 7 pct fine fraction coal from analysis of the MOUDI samples versus 25 ± 4 pct from the CMB analysis. The remainder of the fine aerosol in the mine was diesel exhaust aerosol. CMB analysis confirms the original premise for such sampling. After correcting for the presence of coal dust in the fine aerosol fraction, analysis of the MOUDI size distributions yielded estimates of respirable mineral and diesel exhaust aerosol concentrations that were accurate to within 10 pct of values determined by the CMB apportionment.

OP 201-89. Mineral Dust and Diesel Exhaust Aerosol Measurements in Underground Mines, by B. K. Cantrell and K. L. Rubow. Abstract in Proceedings of American Industrial Hygiene Association, 1988, p. 85. Two source apportionment techniques have been applied to U.S. Bureau of Mines measurements of mineral dust and diesel exhaust aerosol concentrations in diesel-equipped underground coal, metal, and nonmetal mines. The first technique, using results of size-selective sampling, is based on modeling aerosol size and the premise that the diesel exhaust portion of the aerosol is predominately submicrometer and the mineral dust portion is mostly greater than 1 μm in size. The second technique, chemical mass balance (CMB) modeling, was used to referee the analysis of diesel exhaust and mineral dust aerosol concentrations in the diesel-equipped mines from the size-selective sampling results. Aerosol size distributions, used in the size modeling technique, were obtained with a microorifice uniform deposit impactor (MOUDI). Concurrent samples of respirable mine aerosol for trace element analysis used in the CMB modeling were obtained with a dichotomous sampler. This sampler separates respirable aerosol into fine and coarse size fractions at an aerodynamic diameter of 0.7 μm. Trace element concentrations for in-mine aerosol sources and the dichotomous samples were measured using instrumental neutron activation analysis. The MOUDI size distribution data were modeled using nonlinear regression to obtain parameters describing the fine and coarse fractions of the sampled aerosol and to estimate the contributions to each from both mineral dust and diesel exhaust aerosol sources. For the coal mines visited, this analysis yielded an average value for the fraction of the fine aerosol attributable to mineral dust of 1 pct. Analysis of data for the metal and nonmetal mines yielded an average of 3 pct for this fraction. CMB analysis of the coal mine samples confirms the original premise for using aerosol size to separate diesel exhaust and mineral dust aerosol during sampling. After correcting for the presence of mineral dust in the fine aerosol fraction, analysis of the corresponding MOUDI size distributions yielded estimates of respirable mineral and diesel exhaust aerosol concentrations that were within 10 pct of values determined by the CMB apportionment. Less than 5 pct of the coal mine diesel aerosol was found in the coarse size fraction. In the metal and nonmetal mine aerosol, although less than 5 pct of the fine fraction was mineral dust, as much as 20 pct of the diesel aerosol was found in the coarse fraction, requiring a correction of the fine fraction sample for the missing mass. For more accurate measurement of the diesel exhaust aerosol concentration in metal and nonmetal mines, a carbon-specific analytical technique is required.

OP 202-89. Laboratory Study of Rock Dust Inerting Requirements: Effects of Coal Volatility, Particle Size, and Methane Addition, by K. L. Cashdollar and M. Hertzberg. Paper in Proceedings of the 23rd International Conference of Safety in Mines Research Institutes, Washington, DC, Sept. 11-15, 1989, comp. by E. T. Wallace and T. H. Koslosky. BuMines OFR 27-89, 1989, pp. 965-974; NTIS PB 89-225262/AS. The U.S. Bureau of Mines has conducted a systematic study of the rock dust inerting requirements for various coals, using a 20-L laboratory test chamber. Particle sizes of the coals ranged from very fine pulverized dusts to coarse (minus 20-

mesh) dusts. The data show that, with respect to the rock dust inerting requirement, the particle size of the coals has as much effect as the standard volatility. In testing various $CaCO_3$ rock dusts against a bituminous coal dust, the finer sized rock dusts were more effective. The laboratory rock dust inerting data also showed reasonable agreement with full-scale mine data. Laboratory data on the effect of added methane gas also showed good agreement with mine data.

OP 203-89. Potential Productivity and Safety Advantages for the Mining Industry Through Gainsharing, by Andrew B. Cecala. Paper in Proceedings of Longwall USA. Am. Min. Congr., Washington, DC, 1989, pp. 157-162. If you were told of a gainsharing technique that has been adopted by a number of industries and might increase your production by 20 pct using your current equipment and work force, would you be interested? Gainsharing is an organizational development technique that has substantially increased the safety performance and profitability of many operations, while establishing a social contract of trust and commitment between management and the workforce. Gainsharing has two fundamental elements that contribute to this relationship. The first is a working committee of employees and management whose purpose is to evaluate suggestions from employees on ways to improve the work process; this committee also functions as a two-way communication network between management and employees. Second is a bonus plan paid to employees based on the amount of increased output over a predetermined time period; in some cases, this bonus payment also includes expense savings and safety considerations. The intent of this U.S. Bureau of Mines article is to suggest the potential applicability of gainsharing to the mining industry.

OP 204-89. Impact of a Ceramic Trap and Manganese Fuel Additive on the Biological Activity and Chemical Composition of Exhaust Particles From Diesel Engines Used in Underground Mines, by William M. Draper, Heidi Hartmann, David B. Kittelson, Winthrop F. Watts, Jr., and Kirby J. Baumgard. SAE Tech. Paper Series 871621, 1987, 18 pp. This U.S Bureau of Mines study examines the effect of a ceramic particle trap and a manganese fuel additive on the mutagenic activity and chemical composition of diesel exhaust particulate matter from a heavy-duty mining engine. Particles were collected by dilution tunnel sampling from a four-cylinder, Caterpillar 3304, naturally aspirated, indirect-injection engine operated at six steady-state conditions. Depending on engine load and speed, the ceramic particle trap reduced the following emissions: particulate matter, 80 to 94 pct; soluble organic fraction (SOF), 83 to 95 pct; 1-nitropyrene, 94 to 96 pct; and SOF mutagenicity, 72 pct (cycle-weighted average). When the manganese fuel additive was used without a ceramic particle trap, the total cycle mutagenic activity emitted increased sevenfold, in part due to elevated emissions of 1-nitropyrene. When used with the trap at the recommended concentration, the manganese additive lowers the trap regeneration temperature by 65° C, SOF removal efficiency from 86 to 62 pct, and removal efficiency for mutagenic substances from 72 to 43 pct.

OP 205-89. Impact of a Barium Fuel Additive on the Mutagenicity and Polycyclic Aromatic Hydrocarbon Content of Diesel Exhaust Particulate Emissions, by William M. Draper, Jane Phillips, and H. William Zeller. SAE Tech. Paper Series 881651, 1988, 19 pp. This U.S. Bureau of Mines study examines the effects of a barium-based fuel additive on the polycyclic aromatic hydrocarbon (PAH) content and Ames test mutagenic activity of exhaust particulate matter from a diesel engine commonly used in underground mining equipment. The additive, sold for smoke suppression as Lubrizol 565 and containing 20 to 25 pct barium, was tested at three concentrations in the fuel: 0.75, 1.5, and 3.0 g/L. A Deutz F6L 912W six-cylinder, air-cooled, naturally aspirated, indirect-injection engine was operated on a programmed, light-duty cycle, and particulate matter was collected by dilution tunnel sampling using Teflon-coated, glass-fiber filters. At the manufacturer's recommended level of the additive in the fuel, 3.0 g/L, particulate emissions were elevated ~30 pct for either intake condition (both with $p < 0.01$). The barium-based fuel additive also produced statistically significant increases ($p < 0.05$ or 0.01) in both exhaust mutagenicity (i.e., 160 pct, standard engine air intake condition with 1.5 g/L) and exhaust PAH concentration (i.e., 60 pct, restricted intake with 0.75 g/L, and 79 pct, restricted intake with 1.5 g/L). These results suggest that the barium additive should not be used for smoke suppression under light-duty operation. Additional studies are needed to evaluate the additive's effects in heavy-duty work cycles.

OP 206-89. A Safety Risk Evaluation of Vigilance Tasks in the U.S. Surface Mining Industry, by Stephen D. Hudock and James C. Duchon. Paper in Proceedings of the Human Factors Society 32nd Annual Meeting (Anaheim, CA, Oct. 24-28, 1988). Human Factors Soc., Santa Monica, CA, 1988, pp. 990-994. Due to the labor-intensive nature of mining, the health, safety, and performance of miners is critical to the success of the industry. The U.S. Bureau of Mines has conducted research on accident risk associated with performance of vigilance tasks in surface mining occupations. Over one-third of all surface mining occupations were judged to require extreme to high levels of vigilance for proper task performance. Through accident data analysis of all reported mining accidents available on the Mine Safety and Health Administration accident data base for the year 1986, it was determined that the occupational accident severity level for those employed in high-vigilance surface mining jobs was about twice that for low-vigilance surface mining occupations, based on actual days lost and statutory days charged. This difference in accident severity level was analyzed with respect to the nature of the task activity involved. It was shown that accident severity is higher for employees in high-vigilance groups, even for activities that only require low vigilance to perform. These findings support the conclusion that vigilance demands in mining represent a distinct safety risk which may persist for different types of tasks and activities.

OP 207-89. Sonic Flotation of Phosphate Ores, by C. E. Jordan and B. J. Scheiner. Paper in Advances in Coal and Mineral Processing Using Flotation: Proceedings of an Engineering Foundation Conference, Palm Coast, FL, Dec. 3-8 1989, ed. by S. Chander and R. R. Klimpel. Soc. Min., Metall., and Exploration, Littleton, CO, 1989, pp. 147-153. The U.S. Bureau of Mines has developed a continuous ultrasonic flotation cell for the recovery of Florida phosphate ore. Within a small mixing chamber near the bottom of the flotation cell, an ultrasonic probe agitates an injected mixture of air, water, and phosphate ore and breaks the air into fine bubbles. Phosphate particles are preferentially attached to these fine bubbles and floated in the main chamber of the flotation cell. Over 94 pct of the phosphate was recovered, resulting in a 30 pct P_2O_5 concentrate. The ultrasonic energy consumption was less than 7 kW•h/mt of phosphate ore.

OP 208-89. Overview of Highwall Mining Systems, by August J. Kwitowski, William D. Mayercheck, and Alan G. Mayton. Paper in Coal Mining Technology, Ergonomics and Policy 1989: Session Papers From the American Mining Congress Coal Convention, Pittsburgh, PA, June 19-21, 1989. Am. Min. Congr., Washington, DC, 1989, pp. 25-40. The significant number of highwall mining systems (HMS) that either have appeared or are in the process of being developed shows the need for this type of mining system. Because all of the described systems require a minimum of operating personnel, with none permitted in the mined workings, very productive and safe operation is anticipated. Excluding the augering equipment, the new breed of HMS share these common attributes: High coal recovery ratios on the order of 60 to 85 pct, with the U.S. Bureau of Mines mountain top conceptual system having the potential for nearly complete extraction; deep highwall penetration because (1) there are no power losses associated with increased extraction depth for the cutting (all systems) and haulage (most systems) functions and (2) most systems can be guided vertically and laterally to stay in the coal seam and maintain barrier ribs for roof control; extended flexibility in selecting mining strategies; the expanded recovery of coal reserves that were once considered not minable.

OP 209-89. Conveyor Belt Flammability Tests: Comparison of Large-Scale Gallery and Laboratory-Scale Results, by C. P. Lazzara and F. J. Perzak. Paper in Proceedings of the 23rd International Conference of Safety in Mines Research Institutes, Washington, DC, Sept. 11-15, 1989, comp. by E. T. Wallace and T. H. Koslosky. BuMines OFR 27-89, 1989, pp. 138-148; NTIS PB 89-225262/AS. The U.S. Bureau of Mines conducted flammability tests of synthetic rubber and polyvinyl chloride conveyor belts in a large-scale fire gallery and a laboratory-scale ventilated tunnel. The gallery was 27 m long, 3.8 m wide, and 2.5 m high with a 7.5-m-square cross-sectional area. For the gallery tests, 9.1-m lengths of belting were placed on the top rollers of a conveyor frame, and thermocouples were installed to measure flame spread rates. The airflow was 1.52 m/s, and the ignition source was a liquid fuel tray fire. The laboratory-scale tests were conducted in a 1.8-m-long by 0.46-m-square insulated tunnel

at an airflow of 1.02 m/s. A 1.52-m-long by 0.23-m-wide belt sample, fastened to a metal rack, was used; the igniter was a 12-jet gas torch applied to the upstream end. A belt was judged to have passed the gallery test if a portion of the sample was undamaged. The same criterion was also applied to the laboratory-scale tunnel test. Of 17 belts examined, 1 belt that underwent surface charring in the gallery test and failed, passed the tunnel test; another belt that passed the gallery test failed the tunnel test. The results for the remaining 15 belts were in complete agreement.

OP 210-89. Relationships Between Smoke and Carbon Monoxide and Their Implication Toward Improved Mine Fire Detection, by C. D. Litton. Paper in Proceedings of the 23rd International Conference of Safety in Mines Research Institutes, Washington, DC, Sept. 11-15, 1989, comp. by E. T. Wallace and T. H. Koslosky. BuMines OFR 27-89, 1989, pp. 77-82; NTIS PB 89-225262/AS. The U.S. Bureau of Mines conducted tests to determine the relative levels of carbon monoxide (CO) and smoke produced from smoldering and flaming mine combustibles, including wood, coal, and conveyor belting. The data indicated that smoldering combustibles generate a very low level of CO compared to the level of smoke produced. Even though during flaming, the level of CO relative to that of smoke increases, it is found that a "typical" alarm level for smoke is comparable to a CO level of about 6 ppm. For smoldering, the equivalent CO level is about 2 ppm. The implications of these findings in regard to early warning mine fire detection are discussed. The overall results clearly indicate that developing mine fires can be detected earlier using smoke sensors rather than CO sensors.

OP 211-89. A Comparison of the Wear of Polymers and Metal Alloys in Laboratory and Field Slurries, by B. W. Madsen. Wear, v. 134, 1989, pp. 59-79. A portable slurry wear apparatus, developed by the U.S. Bureau of Mines, was used to study slurry erosion in the laboratory and in situ at a gold ore processing plant. The wear cell of the apparatus was identical with an earlier laboratory model. It used an impeller running at tip speeds of less than 22 m s^{-1} to drive a continuous flow of fresh slurry past 16 specimens. Laboratory experiments run in an aqueous slurry of silica sand showed that ultrahigh molecular weight polyethylene (UHMWPE) wore less than any metal alloy or other polymers evaluated at 8 or 12 m s^{-1}; at 16 m s^{-1} several polymers wore less than two steels. However, in gold ore slurries from an industrial float cell and rod mill, high-chromium white cast irons wore less than UHMWPE at 8 and 12 m s^{-1}, and in the rod mill slurry at 16 m s^{-1} the polymers wore no better than the steels. The same trends were observed previously in an industrial slurry containing a lead-zinc sulfide ore. In all cases the wear rate varied roughly as the fourth power of the impeller tip velocity. When particle shape was held constant, the wear rate always increased with particle size. The effect of particle shape was more complex: angular particles were more detrimental to polymers and rounded ones were more detrimental to alloys. Pitting corrosion also removed material from the alloys. For high-chromium white cast irons, corrosion and erosion varied with microstructure.

OP 212-89. Novel Design for a Thin Seam Shuttle Car Featuring an Ergonomic Operator Compartment, by A. G. Mayton, J. R. Bartels, and W. D. Mayercheck. Min. Eng., v. 41, No. 11, Nov. 1989, pp. 1132-1134. Since 1982, the U.S. Bureau of Mines has investigated improvements in protection for operators of thin-seam shuttle cars. Owing to working height restrictions in thin-seam mines ($\leq$1.22 m or 48 in), Federal mine regulations require that canopy protection on shuttle cars be provided only in mines $\geq$1.07 m (42 in). However, court-obtained variances are granted to mines $\leq$1.22 m (48 in). This paper presents ongoing research to design and evaluate a uniquely positioned, ergonomic compartment for a shuttle car that provides the operator with full canopy protection in working heights of 1.02 m (40 in).

OP 213-89. Engineering Data Evaluation Using a GIS, by Douglas C. Peters and Valois R. Shea-Albin. Paper in Proceedings of Denver GeoTech '89: Geoscientific Information Systems Applied to Exploration and Research (Denver, CO, Sept. 23-26, 1989). GeoTech, Inc., Denver, CO, 1989, pp. 64-68. Geographic information systems (GIS's) have gained wider use and acceptance in the geosciences over the past several years and now are being used in engineering fields as well. To demonstrate some of the capabilities of GIS's for engineering data manipulation and presentation, this paper discusses an application at the U.S. Bureau of Mines of a GIS called "ARC/INFO" to merging engineering data with geological and geographical data to evaluate vertical stress conditions in mines. ARC/INFO consists of a cartographic (locational) information system and a linked relational database containing nonlocational information.

OP 214-89. Linear Cutting Concept Improves Health and Safety for Miners, by Wallace W. Roepke and Kelly C. Strebig. SAE Tech. Paper Series 890978, 1989, 6 pp. Research results by the U.S. Bureau of Mines are presented for a major area of effort addressing a long-term solution to problems associated with health and safety aspects of rotary drum mining machines. Proof-of-concept testing for the Bureau's constant depth linear cutting concept is described. The concept uses a triangular drum, mounted on an eccentric arm, cutting to a free face at low rpm. Preliminary comparative test results, for synthetic coal, between the linear cutting concept and a standard rotary drum, show the linear cutting concept reduces entrained respirable dust by more than 95 pct, reduces -1/4-in-mesh product by more than 50 pct, and reduces horsepower by approximately 70 pct. These results are used to calculate the power requirements for a new, all-diesel mining system to improve miner health and safety and productivity while reducing costs.

OP 215-89. Review Paper: Prevention and Suppression of Coal Mine Explosions, by M. J. Sapko, N. B. Greninger, and R. W. Watson. Paper in Proceedings of the 23rd International Conference of Safety in Mines Research Institutes, Washington, DC, Sept. 11-15, 1989, comp. by E. T. Wallace and T. H. Koslosky. BuMines OFR 27-89, 1989, pp. 791-806; NTIS PB 89-225262/AS. There has been a notable decline in the frequency and severity of mine explosions since the turn of the century. Among the major safety measures responsible for this decline are the use of rock dusting, development of permissible explosives and electrical equipment, improved ventilation, and improved methods for detecting hazardous conditions. While these advances in mine safety are noteworthy, an examination of recent statistics indicates that the problem of mine explosion prevention is not completely solved. There is also growing concern over the number of frictional methane ignitions that occur annually; the frequency of methane ignitions has not as yet seriously impacted fatal accident statistics, but their potential for disastrous consequences is well known. This U.S. Bureau of Mines paper reviews recent research aimed at explosion prevention. Particular emphasis is given to the present practice of rock dusting and the implications of recent experimental evidence on the overall effectiveness of rock dust standards. Developments in supplemental explosion protection including devices for monitoring the explosibility of mine dust and passive and triggered explosion barriers are also discussed. The paper concludes with a section on frictional face ignitions and methods for their control.

OP 216-89. Hydrodynamic Effects in Flotation of Ores, by B. J. Scheiner and C. E. Jordan. Paper in Advances in Coal and Mineral Processing Using Flotation: Proceedings of an Engineering Foundation Conference, Palm Springs, FL, Dec. 3-8, 1989, ed. by S. Chander and R. R. Klimpel. Soc. Min., Metall., and Exploration, Littleton, CO, 1989, pp. 219-224. The U.S. Bureau of Mines conducted research on the flotation hydrodynamics of fine-particle flotation to improve the flotation efficiency in our domestic minerals industry. The turbulent fluid velocity profile was measured in various flotation cells at different levels of dissipation energy. The importance of dissipation energy and bubble size within the flotation cells for the flotation response of a chalcopyrite ore was evaluated. Both increased turbulent fluid flow and fine-size bubbles improved the flotation rate of fine-size chalcopyrite particles.

OP 217-89. The Effect of Turbulence on the Flotation Rate of Galena When Using Fine Bubbles, by D. R. Spears and C. E. Jordan. Paper in Advances in Coal and Mineral Processing Using Flotation: Proceedings of an Engineering Foundation Conference, Palm Springs, FL, Dec. 3-8, 1989, ed. by S. Chander and R. R. Klimpel. Soc. Min., Metall., and Exploration, Littleton, CO, 1989, pp 77-84. The U.S. Bureau of Mines examined the influence of turbulence on the fine-bubble flotation of fine-sized (minus 40-mm) galena in order to improve flotation efficiency. Fine bubble flotation was carried out in a spinning-disk flotation cell and was compared to results obtained from flotation in a conventional cell at equivalent agitation levels. An automated electrochemical technique was used to monitor the turbulent velocity distributions of the fluid within the cell as a function of time and position. The velocity profiles were used to increase the precision of the fine particle, turbulent flotation

model. While improved flotation response was obtained with intense agitation, the effect of bubble size was small. These results matched the model's predicted response for fine-particle flotation.

OP 218-89. Comparison of Sound Power Measurement Techniques for Mining Drills: Sound Intensity vs ISO 3741, by Robert R. Stein and Roy C. Bartholomae. Paper in Inter-Noise 89 (Newport Beach, CA, Dec. 4-6, 1989). Inst. Noise Control Eng., Poughkeepsie, NY, pp. 1021-1024. Percussion drills used in mining and quarrying operations pose one of the greatest dangers to the hearing of the people employed in those industries. Drilling holes in rock for blasting or ground support purposes is an energy-intensive process that requires a rugged and powerful machine that is inherently noisy. This paper describes a U.S. Bureau of Mines research program to investigate the noise-generating mechanisms of rock drills as part of its overall noise research effort.

OP 219-89. The Bureau of Mines' Hydrogen Powered Mine Vehicle, by Kelly C. Strebig and Robert W. Waytulonis. SAE Tech. Paper Series 871678, 1987, 12 pp. This paper summarizes U.S. Bureau of Mines research to develop a low-emission underground mining vehicle. This vehicle required the development of an ultra-low-emission hydrogen engine and a rechargeable metal hydride fuel system. This work was part of the Bureau's research program on alternative power sources. The 75-kW engine can propel a 5,700-kg articulated four-wheel-drive vehicle for 4 h under a moderate duty cycle (30-pct load factor) while consuming about 8 kg of hydrogen evolved from the 1,200-kg hydride system. The engine and fuel storage system could have other industrial applications in cases that require a low-pollution power source. Possible applications include warehouse forklifts, factory trucks and forklifts, mobile equipment used in tunnel driving, and buses in congested urban areas.

OP 220-89. Hydrogen Fueled Engine for Utility Mine Vehicle, by Kelly C. Strebig and Robert Waytulonis. Diesel Prog. Mag., v. 54, No. 4, Apr. 1988, pp. 18-21. This paper is based on the research reported in OP 219-89.

OP 221-89. Bureau of Mines Diesel Research Highlights, by Robert W. Waytulonis. Paper in Proceedings of Fourth International Mine Ventilation Congress (Brisbane, Australia, July 3-6, 1988). Australasian Inst. Min. and Metall., Melbourne, 1988, pp. 627-633. The goal of the U.S. Bureau of Mines diesel engine research program is to reduce exhaust emissions and minimize the risk of fires and explosions caused by the use of diesel-powered equipment in underground mines. Significant results of research conducted during the last 5 years are briefly described, with references to published reports on specific topics. Topics covered here include brief discussions of a newly completed diesel research laboratory, the effects of a fuel additive on diesel exhaust particulate matter, the effect of diesel engine maintenance on emissions, a diesel particulate filter for equipment used in underground metal, nonmetal, and coal mines, and the prototype hydrogen-powered mine vehicle. These research accomplishments could favorably affect the mining industry by reducing the health and safety hazards associated with the use of diesel-powered equipment in underground mines.

OP 222-89. Diesel Particulate Filters for Underground Mine Equipment, by Robert W. Waytulonis. Paper in Proceedings of AMC MINExpo International '88 (Chicago, IL, Apr. 24-28, 1988). Am. Min. Congr., Washington, DC, 1988, pp. 89-98. Diesel-powered equipment is widely used in underground metal and nonmetal mines (M/NM), and its use is increasing in underground coal mines. However, there is concern over problems that may be associated with the inhalation of diesel exhaust, especially diesel particulate matter (DPM), or soot. To minimize DPM exposure, the U.S. Bureau of Mines conducted laboratory tests of a ceramic diesel particulate filter (DPF) and demonstrated that up to 90 pct of the DPM can be removed from the exhaust. Currently, the DPF cannot be used safely in designated areas of gassy mines where explosive mixtures of gas or dust might be present. In response to this problem, a dry-type safety system was coupled with the DPF to form an integrated control system. The dry system replaces the conventional diesel exhaust-gas water scrubber to ensure safe performance of the DPF in mine areas where permissible equipment is required. A cooperative research project with several segments of the mining industry is underway to evaluate the integrated control system. The goals of the project are to determine the performance and durability both in the laboratory and underground, and to determine whether this integrated system will meet the needs of the mining industry. This report briefly overviews the safety and health issues associated with operating diesels underground, describes DPF technology and its applications in underground coal and M/NM mines, and describes an ongoing cooperative research project to evaluate the integrated dry system and DPF for coal mines.

OP 223-89. Status of Developments in Diesel Engine Control Technology, by Robert W. Waytulonis and Kenneth L. Bickel. Paper in Proceedings of American Mining Congress (Denver, CO, Sept. 25-28, 1988). Am. Min. Congr., Washington, DC, 1988, pp. 123-136. The goal of the U.S. Bureau of Mines diesel engine research program is to reduce exhaust emissions and minimize the risk of fires or explosions from diesel-powered equipment used in underground mines. Diesels are prevalent in underground metal and nonmetal mines, and their use is increasing in underground coal mines. There is concern over the occupational health problems that may be associated with inhaling diesel exhaust, especially particulate matter or soot. To minimize exposure to diesel particulate matter and to the safety hazards that diesels present in gassy mines, the Bureau is conducting research to improve emission and fire and explosion control technology. This report briefly describes the status of research on a barium fuel additive, exhaust-gas water scrubbers, a filter to reduce particulate emissions, and a dry-type safety system to control fire and explosion hazards on diesel engines used in gassy mines. References to the published reports completely describing these developments are also given.

OP 224-89. New Control Technology for Diesel Engines Used in Underground Coal Mines, by Robert W. Waytulonis and George J. Dvorznak. Ch. 42 in Proceedings of 3rd U.S. Mine Ventilation Symposium (University Park, PA, Oct. 12-14, 1987), ed. by J. M. Mutmansky. Soc. Min. Eng. AIME, 1987, pp. 279-285. The U.S. Bureau of Mines is conducting a research project in cooperation with the Mine Safety and Health Administration (MSHA). Mining companies and equipment manufacturers are also participating through the Colorado Mining Association. The objectives of this cooperative research project are to determine the practicality of coupling a dry exhaust conditioning system (dry system) and diesel particulate filter (DPF) to make an integrated control system, and to determine the effectiveness and durability of the integrated system in an underground coal mine. Diesel-powered mining machines must be equipped with control devices to reduce surface and exhaust temperatures to safe levels and prevent flames and sparks from being emitted to the mine atmosphere. Diesel exhaust-gas water scrubbers have been successfully used for many years, but they have several disadvantages; they are large, consume large quantities of water, and require frequent maintenance to remain functional. Additionally, diesel exhaust is a source of noxious gases and particulate matter. Particulate emissions are composed primarily of small carbon particles with adsorbed hydrocarbons and they are almost entirely respirable in size. Even an engine in good mechanical condition can emit up to 400 mg/cu m of respirable particulate matter. A dry system for control of diesel fire and explosion hazards, coupled to a DPF, promises to be a complete control system for diesel engines. The dry system cools the exhaust and suppresses sparks and flame with a heat exchanger and flame and spark traps. The conditioner is smaller, consumes no water, and requires less maintenance than a comparable water scrubber. The DPF uses a ceramic substrate as a wall-flow filter and is very efficient at collecting exhaust particles. Average particulate mass collection efficiency is 90 pct. This report describes a cooperative research project to combine the dry system with the DPF, conduct performance tests on the integrated system at Bureau and MSHA laboratory facilities, and conduct field tests of the system on a production machine in an underground coal mine.

OP 225-89. A Safe Way To Clean Diesel Exhaust, by Robert W. Waytulonis and William S. Wagener. Coal Min., v. 24, No. 8, Aug. 1987, pp. 40-42. Diesel-powered equipment is being used increasingly in underground coal mines as operators discover its versatility. But its safe operation requires that the exhaust gases and particles be diluted to safe levels. Also, since many diesels operate in potentially gassy air, special engine controls must keep temperatures down. Good maintenance and work practices are required to minimize these dangers. To simplify this task, two promising exhaust control technologies are currently being evaluated by the U.S. Bureau of Mines, at its Twin Cities Research Center in Minneapolis, MN, as well as in an actual underground coal mine. This project is being undertaken by the Bureau in cooperation with the

Colorado Mining Association (CMA) and the coal industry. Participation in the project is being coordinated by the CMA, and a steering committee of participants is being formed. The integrated control system combines a diesel particulate filter with a dry exhaust conditioning system. Each of these control devices has been developed to minimize a specific industrial health or safety problem. The diesel particulate filter has been shown to reduce tailpipe particulate emissions by 90 pct, while the dry exhaust conditioning system is designed to eliminate flames and sparks in the exhaust while reducing surface and exhaust temperatures to below regulated levels. The dry exhaust conditioner has the added benefit of eliminating the need for the hard-to-maintain and costly water scrubbers that are currently in use. By combining these devices on a single diesel vehicle, it is hoped that these two major problems associated with diesels will be minimized.

OP 226-89. Recent Results of Dust Explosion Studies at the Lake Lynn Experimental Mine, by E. S. Weiss, N. B. Greninger, and M. J. Sapko. Paper in Proceedings of the 23rd International Conference of Safety in Mines Research Institutes, Washington, DC, Sept. 11-15, 1989, comp. by E. T. Wallace and T. H. Koslosky. BuMines OFR 27-89, 1989, pp. 791-806; NTIS PB 89-225262/AS. The U.S. Bureau of Mines, as part of its continuing research program for evaluating coal dust explosion hazards, has recently completed a series of tests in the Lake Lynn experimental mine (LLEM) to study the effect of entry size on the flammability limits of pure coal and of coal dust-rock dust mixtures. Data will be presented that compare measurements from explosions of mixtures of coal dust, methane, and rock dust. There are significant differences in dust explosion propagation characteristics between the LLEM and the smaller entry Bruceton experimental mine (BEM). The larger entry (LLEM) results indicate a larger rock dust percentage is required to prevent flame propagation than in the BEM. Lower flammable limits of coarse and fine Pittsburgh seam coal dusts were obtained in the LLEM. A lower volatile mine-size coal required about 40 pct total incombustible content (TIC) to prevent propagation in previous BEM experiments, whereas recent tests with a similar volatile (18 pct) Pocahontas seam mine-size coal required 60 pct TIC in the larger entry of the LLEM to prevent flame propagation. As one means of preventing these coal dust explosions, 80-L water tub barrier units were tested in the larger entry of the LLEM. The relative efficiencies of roof-mounted and rib-stacked barriers were determined for suppressing fully developed coal dust explosions in a single entry. Barrier sets were evaluated at various locations (40 to 160 m from the face) and configurations in the entry. Units were suspended near the roof and triply stacked at the ribs. Stacked barrier units, which are portable, simple to install, and inexpensive to erect, provided protection against coal dust explosions in the LLEM. In wide mine entries, they pose less of an impedance problem for men and equipment than do roof-mounted barriers. For some mines having high dust deposition rates, stacked barriers would offer additional protection beyond that afforded by generalized rock dusting.

INDEX OF BUREAU OF MINES PUBLICATIONS

ABBREVIATIONS

B	Bulletin	MP	Mineral Perspective
CP	Computer Product	MY	Minerals Yearbook*
HB	Handbook	OFR	Open File Report
IC	Information Circular	OP	Outside Publication
MI	Mineral Issues	P	Patent
MIR	Mineral Institutes Report	RI	Report of Investigation
MLA	Mineral Land Assessment Report	SP	Special Publication

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