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THE DEVELOPMENT OF ENGINEERING AND COST DATA FOR FOREIGN SULFUR PROPERTIES

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FOREWORD

This report was prepared by the Jacobs Engineering Group, Zellars-Williams Division, Lakeland, Florida, under Bureau of Mines Contract number J0225020. The contract was initiated under the Minerals Availability Program. It was administered by the technical direction of the Intermountain Field Operations Office (IFOO) with Mr. Joseph R. Soper, Jr., acting as Technical Project Officer and Mr. Richard J. Fantel, Minerals Availability Field Office (MAFO), acting as Technical Project Coordinator. Mr. A. M. Lechuga was the Contract Administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period October 1982 to February 1984. This report was submitted by the authors in February 1984.

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Mine operators worldwide, whose direct contribution of data greatly added to the value of this study.

This report contains no patentable features. No proprietary information appears herein. Company proprietary information was obtained for this contract. It is included in individual deposit Profile Reports on file at the Minerals Availability Field Office in Denver, Colorado.

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DEVELOPMENT OF ENGINEERING AND COST DATA
FOR FOREIGN SULFUR PROPERTIES

by

Thomas P. Oxford^{1/}

ABSTRACT

This Final Report summarizes the results of work accomplished under Contract No. J0225020. It is presented as a project overview. The number and description of the various technical reports prepared and submitted is outlined. Various property list changes implemented by contract modification are noted. Methods of data acquisition and analysis are described and useful findings of the study are discussed. Difficulties and problems experienced during the project are highlighted.

Iron pyrite, recovered from massive pyrite deposits or as a byproduct of the flotation of complex sulfide ores, is in many local areas an important feedstock for the production of sulfuric acid. Its use has diminished substantially over the past decade due to dramatically increased availability of sulfur recovered from petroleum refining or from the smelting of metal sulfide concentrates. Outside the U.S., but within the Free World, the important Frasch sulfur deposits are in Mexico and Iraq. Deposits amenable to exploitation by the Frasch method are those that can be melted and extracted by injection of hot water and compressed air. Data concerning both Frasch and pyritic sulfur properties are summarized in this report.

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INTRODUCTION

The Minerals Availability Program (MAP) of the Bureau of Mines serves as the base for storing and manipulating data concerning foreign and domestic mineral deposits worldwide. Standard methods have been established for organizing mineral deposit information for storage and retrieval from the MAP files.

For the project, "Development of Engineering and Cost Data for Foreign Sulfur Properties", the Bureau has required the acquisition and submission of data in the areas listed in Table 1. The requirement designations A through J correspond to those given in the foreign sulfur project solicitation of July 1982. Data were to be submitted in the form of Profile Reports for a total of 30 mines/deposits in 12 different countries.

TABLE 1. - Outline of reporting requirements

<u>Requirement</u>	<u>Title</u>
A	Identification
B	Resource description
C	Operation description
D	Infrastructure
E	Post mine/mill processing
F	Manpower requirements
G	Energy requirements
H	Development plan
I	Costs
J	Byproducts evaluation

The Jacobs Engineering Group Inc. was awarded the foreign sulfur project and commenced work in October 1982. All reports were submitted to the Bureau by December 1983. This final report summarizes the work accomplished and describes the methods employed. Only non-proprietary findings are addressed in this report.

PROJECT SUMMARY

The properties that were evaluated are listed in Table 2. Staff members who conducted analyses or who served as site investigators, travelling to the countries of concern, are listed as well. Early in the project, site visits were conducted to all the Mexican Frasch mines. Afterward, trips were made to the Spanish and Italian pyrite-producing districts. Portuguese mine owners were met in Lisbon and on-site in the vicinity of Aljustrel. Travel to Cyprus and Turkey took the investigator to Nicosia and to Etibank offices in Ankara, where detailed data were made available. The site investigator, travelling to Japan, met with officials in Tokyo, then inspected facilities at the Yanahara Mine and Okayama Factory in southern Honshu. Norwegian and Swedish facilities were visited in the summer of 1983.

TABLE 2. Profile reports completed

<u>Country</u>	<u>Deposit</u>	<u>Report Author^{1/}</u>	<u>Site Investigator^{1/}</u>
Portugal	Feitais/Algares Mine	CTS	FSH
	Gaviao/Estacao Deposit.....	CTS	FSH
	Lousal Mine	CTS	FSH
	Moinho/Sao Joao Mine	CTS	FSH
Japan	Okayama Roaster	MAM	TDA
	Tobata Roaster	MAM	TDA
	Tomakomai Roaster	MAM	TDA
	Yanahara Mine	RAH	TDA
Cyprus	Kambia Mine	MAM	DWL
	Mathiatis Mine	MAM	DWL
	Sha Mine	MAM	DWL
Italy	Campiano Mine	RAH	MAM
	Fenice Capanne Mine	MAM	MAM
	Niccioleta Mine	RAH	MAM
Mexico	Coachapa Mine	CTS	PCS
	Jaltipan Mine	SCS	PCS
	Texistepec Mine	SCS	PCS
Spain	Herrerias Mine	MAM	MAM
	La Zarza Mine	MAM	MAM
	Tharsis Mine	MAM	MAM
Norway	Grong Gruber Mine	RAH	PCS
	Sulitjelma Mine	RAH	PCS
Sweden	Boliden Concentrator and Mines	PCS	PCS
	Kristineberg Concentrator and Mines	PCS	PCS
Turkey	Keciborlu Mine	RAH	DWL
	Kure Mine	RAH	DWL
Australia	Brukungu Deposit	TDA	-
Iraq	Mishraq Mine	SCS	-
So. Africa	Pyrite Roasting	BSC	BSC
(Europe)	Pyrite Shipping and Conversion	SKO	-

^{1/}Author/investigator key - Abel (TDA), Br. Sulphur (BSC), Hicks (FSH), Holleman (RAH), Leyshon (DWL), Mendez (MAM), Br. Sulphur/Kouloheris/Oxford (SKO), Staniek (CTS), Stettenbenz (PCS), Stettenbenz/Staniek (SCS)

The following entities were deleted from the original property list through contract modification: (1) Aplike, Lefka "A", Limni, Memi, and Mousoulos Mines, Cyprus; Sain-bel Mine, France; Gavorrano Mine, Italy - all due to mine shutdown attendant to complete or virtual exhaustion of reserves; (2) Hitachi, Kotsu, and Shingu Mines, Japan - due to present inactivity and past low comparative degree of importance; (3) Skorovas and Lokken Mines, Norway - due to removal of pyrite-recovery facilities and limited or exhausted reserves; and (4) Pyhasalmi Mine, Finland - due to prior coverage on a different Bureau contract. In addition, contract modification renamed the Moinho and Feitais Mines, Portugal, to clarify their association with the Sao Joao and Algaes deposits, respectively.

A total of 25 property Profile Reports with 25 Economic Time Diagrams were submitted to the Bureau of Mines. In addition, detailed reports were submitted on pyrites shipping and conversion cost (mainly considering the European sphere), pyrites production and conversion in South Africa, and profiles of three pyrites roasters in Japan.

DATA ACQUISITION AND EVALUATION

A considerable amount of printed matter is available concerning the pyritic and Frasch sulfur trade, industry structure, and individual operations. Several annual review volumes covering industrial minerals provide useful information, but lack detail. The periodical literature often provides data of some detail, but typically the data are very fragmentary.

Thus, a severe limit on the utility of remote or indirect data acquisition exists, particularly in the case of locating data concerning present operating costs. Reliable actual information on costs must come from the owner/operator (though reasonable estimations can be made with an adequate engineering description of the operation). Direct inquiry to operating (or deposit-developing) companies is essential in order to obtain actual cost information. The problem at the outset of the project was to discover the most effective means of making the inquiry.

The likelihood that a detailed and accurate description would be obtained would be enhanced not only by the practice of direct inquiry, but also by face-to-face meetings with mining company representatives, preferably at the site of operations. The advantage of direct access to mine, plant, and files definitely favored a carefully scheduled and controlled travel program. That, in general, was the selected approach. For each mine/deposit, investigators took with them a questionnaire or Deposit Evaluation Form (DEF) to provide the basis for their inquiries and to record the detailed results of their observation.

The use of a comprehensive sulfur questionnaire proved effective in many instances for acquiring detailed and accurate information through direct inquiry and from other sources. The general organization of the form is similar to the organization of the reporting requirements specified in the project contract.

In the early stages of consideration of any given deposit, all available information was assembled and transcribed into the DEF. The site investigator subsequently reviewed the DEF as part of the pre-travel preparation, which also included: indoctrination by project manager and a briefing group, discussion of data gathering techniques, explanation of subject area emphasis, review of all pre-travel correspondence, and briefing by other staff members who had previously completed similar travel.

Trips were scheduled throughout the project in an orderly sequence so as to provide a reasonably constant rate of data input to staff assigned exclusively to report-writing tasks. On return of the site investigator, debriefing was conducted, data were clarified and organized, and the report-writing assignment was made.

Development of each deposit analysis and report was assigned to a single individual assisted by the site investigator, and by other individuals as required, who had completed similar commodity reports. All analyses and reports were submitted to project manager review for technical and editorial control.

Subsequent to report review by the Bureau, report authors were assigned to prepare responses to Bureau comments and to prepare revisions as required. Depending upon the extent of change required, report revision was accomplished with replacement pages or complete resubmission of a final report.

PYRITE USE AND SOURCES

The primary use of pyrites worldwide is as a feedstock for the production of sulfuric acid. Pyrites, obtained in crude form from massive pyrite deposits or as a byproduct of the flotation of complex sulfide ores, are roasted and the offgas SO_2 is collected for the manufacture of H_2SO_4 . Commonly, such facilities are sited in proximity to plants constructed for chemical-fertilizer production, as sulfuric acid is the required agent for digestion of phosphate rock.

Australia

Brunkunga is the only known pyrite deposit of any significance in Australia. It is located 5.6 kilometers north of Nairne in the province of South Australia. Development of the deposit was made possible by a sulfur bounty paid to encourage local production of phosphoric acid. Operations were ceased in 1972 when the bounty was discontinued. Nairne Pyrites Pty. Ltd., the former operating company, is kept in existence because of environmental problems, but most of the company's assets have been sold. There is no current interest in redevelopment of this deposit, but it was included because it is a significant pyrite deposit located in a somewhat remote section of the globe.

Cyprus

At various locations on the fringe of a mountainous region in central Cyprus, called the Troodos Massif, numerous small ore bodies of massive pyrite are present. The Hellenic Mining Co. presently controls a number of these, three of which are currently in operation (renewed operations in the Sha mining area having begun in February 1984).

All three mines are exploited by open-pit, bench-blasting methods. They are located within 10 to 15 kilometers of each other, and ore from each is trucked about 35 kilometers south to a concentrator at Vasilikos. Typical mine production is: Mathiatis, 25-35,000 metric tons per year (mtpy); Kambia, perhaps 75,000 mtpy, but irregular; and Sha, 98,000 mtpy (expected).

At Vasilikos, the ore is upgraded to a nominal 46 percent sulfur by jigging and flotation. The concentrator has the capacity to accept 340,000 mtpy of ore.

Italy

Solmine operates three mines in Tuscany supporting its titanium dioxide facilities on the coast at Scarlino. The oldest of the active works, Niccioletta, is a well-developed mine exploited by sublevel stoping. Past production has been in excess of 600,000 mtpy, but company plans call for output of 300-400,000 mtpy from the present until mineout (estimated to occur in 1995). In 1983, Solmine completed development of the Campiano mine in the Boccheggiano area, in the general vicinity of earlier mining activity known by the same name. Its opening was roughly coincident with closure of the exhausted Gavaranno mine by Solmine. Campiano is expected to produce about 700,000 mtpy ore. The output of both mines is trucked to Scarlino for grinding preparatory to sulfuric-acid production.

Scarlino feed has been augmented by flotation pyrites produced at Solmine's Fenice Capanne Mine. Shut down since 1979, it is scheduled to resume operations by cut-and-fill techniques and to produce copper, lead and zinc concentrates and about 78,000 mtpy pyrites.

Japan

Of the 74 pyrite mines active in Japan in 1966, only the Yanahara mine continues to produce crude pyrites, supplying feedstock for the Dowa roaster at Okayama. The mine is exploited by sublevel stoping and cut-and-fill methods, and sufficient grinding capacity is installed for 840,000-mtpy output, although usual current demand is only 132,000 mtpy.

The Okayama roaster has a capacity of about 300,000 mtpy H₂SO₄ (1100-1200 tpd). In addition to accepting crude pyrite feed from Yanahara, it is supplied with flotation pyrites from the Kosaka mine and from the Hanaoka group of mines.

Two other pyrite-based roasters are active in Japan, both of essentially the same design. Kowa Seiko, a subsidiary of Dowa, developed the process

design and implemented it in its Tobata works at Kitakyushu. The usual sources of the pyrite supply to Tobata are the Kosaka and Hanaoka mines on Honshu. Tomakomai Chemicals bought the Kowa Seiko design for its works on Hokkaido. Pyrites for Tomakomai come from the Shakanai mine on Honsha and from the Toyaha and Ohe mines on Hokkaido. Capacities of the two sulfuric-acid plants are 235,200 and 432,000 mtpy H_2SO_4 , respectively. A primary feature of the Kowa Seiko process is recovery of non-ferrous metals from the pyrite cinder.

Norway

Flotation pyrites are produced at the Sulitjelma mine which, in 1983, was purchased by the Norwegian Government from A/S Sulitjelma Gruber. The mine is located 60 kilometers north of the Arctic Circle, 14 kilometers west of the Swedish border. Extraction is accomplished by drift-and-pillar stoping and the targeted post-1982 production rate is 490,000 mtpy. The mill produces copper, zinc, and pyrite concentrates. All the pyrite is sold abroad.

The Grong Gruber mine, located in North Trondelag, is owned by a consortium including Elkem A/S Sulitjelma Gruber, A/S Sydvaranger and Ardal Og Sunndal Verk A/S. The ore is a complex sulfide, and primary products are copper and zinc concentrates. Pyrites are contained within the waste fraction (zinc-flotation tailings) that are directed for disposal to nearby Lake Huddingsvann. However, this facility is considered the most likely, among several potential pyrite producers, to initiate pyrite recovery. Plans exist for installation of process facilities sufficient to reclaim the pyrites from the estimated 3.8 million mt stored in Huddingsvann.

Portugal

The pyrite belt which runs through the southern part of the Iberian Peninsula is mined in both Portugal and Spain. Portugal's two mines are located at Lousal and Aljustrel. Lousal, operated by Mines et Industries SA, a wholly-owned member of the Belgian company Societe Anonyme Produits et Engrais Chimiques du Portugal (SAPEC), is an open-stope underground mine with a nominal 45,000-mtpy capacity pyrite production rate. Development work is currently being conducted to increase capacity by approximately 57 percent to a projected 70,000 mtpy by 1985. This is expected to be followed by another 57-percent capacity expansion to 110,000 mtpy by 1989.

The cut-and-fill Aljustrel mine is operated through Empresa de Desenvolvimento Mineiro de Alentejo EP with the Luxembourgian firm Sogemindus retaining 6 percent ownership. The concession includes six pyrite ore bodies which, for historical reasons, are grouped into three paired units: Moinho/Sao Joao, Feitais/Algares, and Gaviao/Estacao. The Moinho/Sao Joao unit produced 162,000 mt of pyrite in 1982, while the Feitais/Algares unit produced 55,000 mt. Both units are undergoing expansion development to increase their production capacities to 500,000 mtpy each by 1985. The Gaviao/Estacao unit has not yet been developed for production mining. Both Aljustrel and Lousal mill their production by crushing and screening to minus 8 mm then ship the pyrite by rail to domestic sulfuric-acid plants.

South Africa

Installed capacity for sulfuric-acid production from pyrites in the Witwatersrand Basin region of South Africa between Pretoria and Welkom is about 1.7 million mtpy. Pyrites there are a byproduct of the production of gold and silver concentrates. The sulfuric acid generated from pyrites is, for the most part, consumed by the producers in the process of uranium recovery by leaching. Temporary imbalances in supply and demand of acid are mitigated by the Acid Distribution Committee of the Chamber of Mines of South Africa, which currently deals with some 500,000 mtpy of acid.

Spain

The Spanish portion of the pyrite belt is exploited by three mines located in the Huelva province. The largest of these, with an estimated post-1982 production rate of 600,000 mt of pyrite per year, is the consolidated group of open-pit workings called Filon Norte, operated by Compania Espanola de Minas de Tharsis SA. Tharsis ownership is divided among several shareholders with 52 percent owned by Spanish interests and 22.5 percent owned by SAPEC, the largest single shareholder. Tharsis also operates the underground La Zarza mine using horizontal cut-and-fill stoping methods to produce pyrite at a post-1982 rate of 440,000 mtpy. Extracted ore is milled in primary crushers at both mine sites then shipped by rail to the Tharsis trituration facilities at Corrales for secondary size-reduction to minus 8 mm and distribution to domestic and foreign markets.

The Herrerias mine, owned and operated by the Sundheim family in association with the Banco Urquijo and Banco de Vizcaya, employs room-and-pillar methods to extract approximately 116,000 mt of pyrite annually. Ore is crushed to minus 8 mm at the mine site and distributed to domestic consumers either from Huelva or the company shipping dock on the Guadiana River. Herrerias is expected to deplete its reserve base by 1992.

Sweden

Boliden Minerals operates two concentrators in northern Sweden, inland of Skelleftea, to produce copper, lead, and zinc concentrates and to provide pyritic feedstock for its acid plants far to the south in Helsingborg. The Kristineberg concentrator is fed by several mines, of which only the Kristineberg mine provides ore of suitable composition for pyrite production. Extraction is by cut-and-fill or drift-and-fill methods. The Boliden concentrator is fed by four mines. Two of these, Udden and Langsele, supply ore suitable for pyrite production from zinc tailings. Mining at both sites is by cut-and-fill. Pyrite production of 110,000 mtpy from Kristineberg combined with 280,000 mtpy from the Boliden concentrator is adequate to support operations at Helsingborg.

Turkey

Since 1955 Etibank of Ankara has operated an open-pit mine at Kure in northwest Turkey, linked by aerial cableway to the port of Enibolu. Expansion of the facilities to include an underground mine as well as open-

pit extraction will be conducted with the aim of ultimately producing 105,000 mtpy copper concentrate and 550,000 mtpy pyrite concentrate.

Etibank also operates a sulfur mine at Keciborlu near Isparta. Mining is done by combined underground horizontal cut-and-fill and open-pit methods and the refinery accepts high-grade ore for direct-melt and lower-grade ore for flotation. Overall capacity is 40,000 mtpy at a grade of 99.8 percent sulfur.

FRASCH SULFUR USE AND SOURCES

Outside the U.S. and Poland important "Fraschable" deposits exist in northern Iraq and in the Isthmus of Tehuantepec in southern Mexico. Such deposits are characterized by elemental-sulfur impregnation of limestone strata. The Frasch method involves injection of hot water and compressed air into the deposit to melt the sulfur and permit extraction of the molten sulfur through collector wells.

Depending on the level of organic impurities in the extracted sulfur, the material may be subjected to refining by filtration. Most of the tonnage of refined product is shipped to sulfuric-acid manufacturing facilities in the vicinity of the acid consumer.

Iraq

The largest reserves of free sulfur in the world are contained within the 17 known deposits located in Iraq's Mosul province, but only one of these ore bodies, Mishraq, has been exploited. The Polish-modified Frasch technique, known as hydrodynamic mining, was selected as the exploitation method in 1969 by the State Organization of Minerals, Mishraq's owner-operator (known at the time as National Iraq Mineral Company or NIMCO). After it is extracted, the highly bitumen-impregnated mined sulfur is filtered to yield a product that is 99.8 percent pure. The operation was designed to produce sulfur at a rate of 1 million mined mtpy with its installed water-heating capacity of 7.2 million gallons per day (gpd), but the underlying geological structure proved to be so cavernous that it could only retain enough hot water to produce sulfur at approximately 70 percent of design rate.

Before war broke out between Iraq and Iran in 1979, Mishraq's record high annual production was 650,000 mined mt in 1975, and nearly all production was shipped to the port of Umm Qasr for subsequent export. Since the destruction of the port facilities in 1980, production has been curtailed to 400,000 mtpy with export shipments proceeding through Kuwait or west through Turkey. When the new Al Qaim phosphate-fertilizer complex comes on stream, it is expected to consume virtually all of Mishraq's future production.

Mexico

Mexico's sulfur-rich Saline Basin, located in the southeastern part of the country, is exploited by three Frasch mines: Jaltipan and Coachapa are

operated by Azufrera Panamericana SA and Texistepec is operated by Compania Exploradora del Istmo. Both operating companies are owned by the Mexican government. Jaltipan is the largest operation. It has an installed water-heating capacity of 10.4 million gpd and a production capability of 1 million mined mt of sulfur per year. Texistepec has a water-heating capacity of 6 million gpd and a corresponding sulfur-production capability of 837,000 mined mtpy. Both Jaltipan and Texistepec filter most of their production to remove entrained hydrocarbons to meet shipping specifications. Coachapa came on stream in 1981 with an installed capacity of 4 million gpd and is expected to produce 383,000 mt of sulfur annually when the Salinas salt dome, which it exploits, reaches thermal equilibrium. This same dome was Frasch-mined by Gulf Sulphur Corporation from 1956 to 1969. Due to its low hydrocarbon content, sulfur mined at Coachapa does not require filtering. All three mines ship their final product to the port of Coatzacoalcos, from where it is distributed to domestic and export markets. The currently active Mexican Frasch operations are expected to mine out between 1997 and 2004.

SUMMARY OF SULFUR SOURCES

Characteristics of the sulfur properties evaluated in the present study are listed in Table 3. The properties are grouped as sulfide ores (crude pyrites and flotation pyrites) and native sulfur ores (Frasch mines and the non-Frasch Keciborlu mine). Operational status of each property with respect to sulfur recovery is indicated as active (A), inactive (I), in planning or development stage (D), or merely hypothetical (H). Mine type designations are underground (UG), open-pit (OP), and Frasch (F). Reserve and production entries in the table are expressed as low (L), medium (M), high (H), and very high (VH). The range of values indicated by these designations is as follows:

For sulfide ores -

<u>In-situ demonstrated resources</u>		<u>Ore Production</u>	
<u>10⁶ metric tons</u>	<u>Percent Sulfur</u>	<u>Annual Metric Tons</u>	
L	less than 2	L	less than 100,000
M	2-10	M	100,000 - 250,000
H	10-50	H	250,000 - 500,000
VH	more than 50	VH	more than 500,000
L	less than 21		
M	21-42		
H	42-48		
VH	more than 48		

For native sulfur -

<u>In-situ demonstrated resources</u>		<u>Ore Production</u>	
<u>10⁶ metric tons</u>	<u>Percent Sulfur</u>	<u>Annual Metric Tons</u>	
L	less than 10	L	less than 400,000
M	10-50	M	400,000 - 800,000
H	50-100	H	800,000 - 1,200,000
VH	more than 100	VH	above 1,200,000
M	below 90		
H	90 - 99.8		
VH	above 99.8		

TABLE 3. Sulfur property characteristics^{1/}

Country	Deposit	Status	Mining Method	In-Situ Reserves		Ore Production
				Quantity	Grade	
CRUDE PYRITES						
Portugal	Feitais/Algares Mine	A	UG	H	M	L
	Gaviao/Estacao Deposit	D	UG	H	M	M
	Lousal Mine	A	UG	M	H	L
	Moinho/Sao Joao Mine	A	UG	H	M	M
	Kambia Mine	A	OP	L	M	L
Cyprus	Mathiatis Mine	A	OP	L	M	L
	Sha Mine	A	OP	L	M	L
	Herrerias Mine	A	UG	M	H	M
	La Zarza Mine	A	UG	VH	H	H
Spain	Tharsis Mine	A	OP	VH	H	VH
	Campiano Mine	A	UG	H	M	VH
Italy	Niccioleta Mine	A	UG	M	M	H
	Yanahara Mine	A	UG	M	VH	M
Australia	Brukunga Deposit	H	OP	H	L	H
FLOTATION PYRITES						
Sweden	Boliden Concentrator and Mines	A	UG	M	2/	VH
	Kristineberg Concentrator and Mines	A	UG	M	2/	H
Norway	Grong Gruber Mine	H	UG	H	2/	H
	Sulitjelma Mine	A	UG	H	2/	H
	Fenice Capanne Mine	A	UG	M	2/	H
Turkey	Kure Mine	D	OP	H	2/	H
FRASCH SULFUR						
Mexico	Coachapa Mine	A	F	L	VH	L
	Jaltipan Mine	A	F	M	H	H
	Texistepec Mine	A	F	M	H	H
	Mishraq Mine	A	F	VH	H	M
NATIVE SULFUR						
Turkey	Keciborlu Mine	A	UG	L	M	L

^{1/}See text for key to abbreviations.

^{2/}Not comparable to grade ranges presented for crude pyrites.

REMARKS CONCERNING USE OF REPORTED DATA

In general, the depth of reference data and the reliability of information serving as basis for each deposit analysis are evident from thorough review of the documentation accompanying each Profile Report and Economic Time Diagram. Each report is different in this regard, since the reliability and detail have unquestionably depended on the extent of cooperation extended by deposit owners or operators.

A limited amount of periodic reevaluation will be required to determine status changes that may affect the data base. However, the industry structure worldwide, both with respect to pyrites and Frasch sulfur, is reasonably stable and not expected to undergo major changes in the near term (notwithstanding the potential disruption of the Iran-Iraq conflict).

CONCLUSIONS AND RECOMMENDATIONS

Pyrite production worldwide has been reduced to but a small fraction of its former capacity due to the availability of sulfur recovered from smelter gas and petroleum refining. The change is thought to be essentially complete, however, leading to a stable situation in which, for the most part, pyrites are important only where they are locally available to a sulfuric-acid consumer. The notable exception is the continued supply of Norwegian pyrites to Mediterranean ports; yet it appears that that trade route suffers considerable economic difficulty.

Mexican Frasch producers are well placed to supply U.S. markets (fertilizer production via port of Tampa, Florida, for example), as well as other markets, despite competition from other Gulf of Mexico suppliers. Iraqi exports are expected to decrease, despite projected production increase, as the Al Qaim fertilizer complex in Iraq accepts Mishraq output for domestic use.

In the present study, the availability of flotation pyrites was examined only for a few selected operations, and recovery of sulfur from smelter gas was beyond the scope of work. In order to complete the worldwide picture of mined sulfur availability from mines outside the U.S., other than from centrally-controlled-economy sources, it is suggested that a broad-based evaluation of existing data on complex sulfide ore extraction be conducted. This would permit the estimation of flotation pyrite tonnages and associated sulfur quantities, description of smelting and off-gas conversion practice, and calculation of the cost of sulfuric-acid production from smelter gas.