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Special Publication

WORLD GOLD
A MINERALS AVAILABILITY APPRAISAL

U.S. DEPARTMENT OF THE INTERIOR
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U.S. BUREAU OF MINES

PREFACE

This Special Publication summarizes a number of in-depth studies of the major gold mining regions of the world. Gold resources and reserves and production costs are estimated and compared for the major producers and developing regions and countries. All data and analysis results are presented in U.S. dollars to facilitate the comparisons. Dramatic changes in resource development and mining and processing technologies that have occurred in the gold industry since the early 1980's are documented. Future growth areas such as the former Soviet Union, the Asia-Pacific region, and Latin America are reviewed. Finally, this publication identifies factors that may influence the future of worldwide gold supply and any impacts on the economy of the United States.

The studies supporting this Report were undertaken for a variety of reasons. The U.S. Bureau of Mines Organic Act (30 U.S.C. 3) directs it "to conduct inquiries and scientific and technologic investigations ... with a view to ... increasing ... economic development and conserving resources through the prevention of waste in the mining, quarrying, metallurgical, and other mineral industries; to inquire into the economic conditions affecting these industries" Further, the Mining and Minerals Policy Act of 1970 (30 U.S.C. 21(a)) directs the implementation of a policy "to foster and encourage mineral resources, reserves, and reclamation of metals and minerals to help assure satisfaction of industrial, security, and environmental needs...." The National Materials and Minerals Policy, Research, and Development Act of 1980 (30 U.S.C. 1601-05) declares it is a national policy to promote an adequate and stable supply of materials necessary for national security, economic well-being and industrial production by, among other things, "establish[ing] a long-range assessment capability concerning materials demands, supply and needs, ..."

The last Bureau review of worldwide gold availability was based on 1981-83 data (Information Circular 9070). Since that time gold production in the United States has increased six-fold. Gold production represents a major component of the capacity and revenue increase in the domestic "hard-rock" minerals industry since that time. The technological changes that fueled this were also being applied world-wide. While the Republic of South Africa maintained its production levels, its share of the world market has been reduced by nearly half since 1983. Other countries, including the United States, have become significant players. Such changes have made the previous study inadequate for understanding producing, developing, and explored deposits and production facilities associated with the current gold industry.

Gold is at the center of emerging minerals issues, making it clear that current gold familiarity is critical. A significant amount of new U.S. gold production capacity is from Federal land. Further, gold is the dominant material produced from Federal land, at least by value. When the decision to proceed with this study was made, it was clear that reform of the Mining Law of 1872 was on the horizon. It was also obvious that the policy debate around mining law reform would require accurate, independent assessments of the domestic and international industry.

A study such as this one has unique limitations. The first of these limitations is associated with the Bureau's Organic Act. The Bureau is not allowed to "issue any report as to the valuation or the management of any mine or other private mineral property..." (30 U.S.C. 6). While this report provides an assessment of world gold supply, supported by individual assessments of major worldwide producers, the Bureau does not place any sort of value on gold as a commodity or on any individual company or mineral deposit. Details on individual companies or mineral deposits are available in company annual reports and other material filed with the Securities and Exchange Commission. That information can be accessed on the INTERNET.

Another limitation of the study results from the volatility of gold prices. Most of the analyses in this report were done when gold was in the \$330 - \$370 per troy ounce range. In the fall of 1994, just before this report was published, the price was approaching \$400. Such significant fluctuations in the price of gold can affect the reserves at individual deposits, at least theoretically. While mine design may have a more practical impact, shifts in the price of gold may change the economics of deposits, with the possibility that material once thought to be economic becomes uneconomic and vice versa. The reader is cautioned to consider gold price volatility as this report is used. In all cases where the analysis assumed a price for a commodity, it is clearly stated.

This study evaluates gold deposits throughout the world. It is important for the reader to remember that resource and reserve classification systems for the various countries involved are different. The same terms, such as reserve or reserve base, can have different meanings in these different classification systems. To the maximum extent possible, resource and reserve data are expressed in this report using terminology from the McKelvey classification scheme developed by the U.S. Bureau of Mines and the U.S. Geological Survey. When it was necessary to report resource and reserve information in different terms, these instances are clearly identified.

Finally, any report has limitations related to the cutoff date for its analysis. Data in this report are current through 1992.

A series of Open File Reports giving more detail on the gold industries of each region is planned. These reports will provide more detailed background information on the geologic, economic, and political factors underlying the resource and cost estimates summarized in this report.

This Special Publication is one of a series of reports that analyze the availability of minerals from domestic and foreign sources. Questions about the Minerals Availability program, this Special Publication, or reports on other minerals should be addressed to Chief, Minerals Availability Field Office, Post Office Box 25404, Denver, CO 80225.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm-g	centimeter-gram	mt	metric ton ¹
g	gram	M tr oz	million troy ounce
g/mt	gram per metric ton	mtpd	metric ton per day
k	thousand	mtpy	metric ton per year
kg	kilogram	pct	percent
km	kilometer	pct/yr	percent per year
km ²	square kilometer	R	RSA rand
kmt	thousand metric ton	tr oz	troy ounce ²
kmtpy	thousand metric ton per year	tr oz/yr	troy ounce per year
kW·h	kilowatt hour	\$	U.S. dollar
lb	pound	\$/tr oz	U.S. dollar per troy ounce
m	meter	\$/mt	U.S. dollar per metric ton
m ³	cubic meter	wt pct	weight percent
M	million	wtd avg	weighted average
Mmt	million metric ton	yr	year
Mmtpy	million metric ton per year		

¹One metric ton of gold = 32,150.75 troy ounces of gold = 1,000,000 grams.

²One troy ounce of gold = 31.103473 grams of gold.



EXECUTIVE SUMMARY

THE WORLD GOLD INDUSTRY - AN INTRODUCTION

More gold is being produced now than ever before in recorded history. All over the world huge quantities of ore are being mined and processed, thanks to historically high prices for gold and the use of processing techniques demonstrated as cost efficient in the last 20 years. Over the past 10-15 years prices for many other metals have been depressed, and gold has accounted for a significant proportion of worldwide exploration and development expenditures⁽¹⁾.

The revenues generated from gold mining are providing greater return on investment, more jobs, and more tax revenues to national governments than ever before. Emerging nations are using the gold industry as a springboard for development; developed nations are continuing to fuel their economies with gold industry revenues; and China and countries of the former Soviet Union are using the gold industry to generate foreign exchange, modernize their mining industries, and take the first tentative steps toward private sector participation in their economies.

There is competition between countries to attract foreign investment in exploration and the production facilities that normally follow. The form of that competition is anything that makes investment in a particular country a good business decision: land access, land tenure, tax structure, royalties, local employment conditions, foreign participation through ownerships and quality of resources and reserves.

The purpose of this study is to discuss changes in the world gold industry that have occurred since an earlier Bureau study describing the status of the industry as of the 1982-84 period⁽²⁾. Since that time there have been large scale applications of new technologies, significant changes to the cost

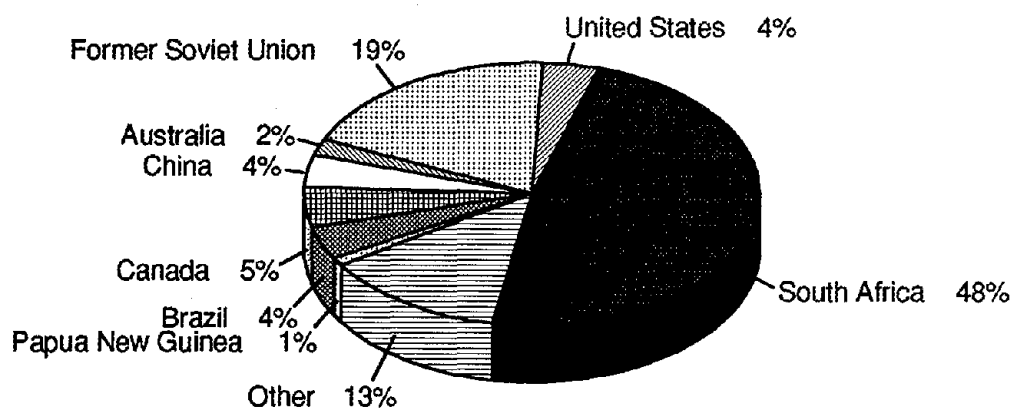
structure, and many adjustments to the legal, environmental, and social framework within which gold mining companies operate. These changes, along with large scale restructuring of ownership and vastly differing rates of growth in gold production for individual countries, make this new assessment of gold valuable for understanding the current situation and prospects for the future.

The United States is now the world's second largest gold producer, with mine output 2-3 times larger than at any time prior to the mid-1980's (see figure E-1, table E-1 and U.S. chapter). More than 200 mining operations produced over 331 mt (10.6 M tr oz) of gold in 1993, generated more than \$3.7 billion in revenues (one-third of the value of all U.S. metals mined), and provided nearly 15,000 direct mining and milling jobs spread over more than half the States in the Union⁽⁴⁾. Production in 1993 was dominated by Nevada and California, with much of the remainder from other Western States, Alaska and South Carolina (see figure E-2).

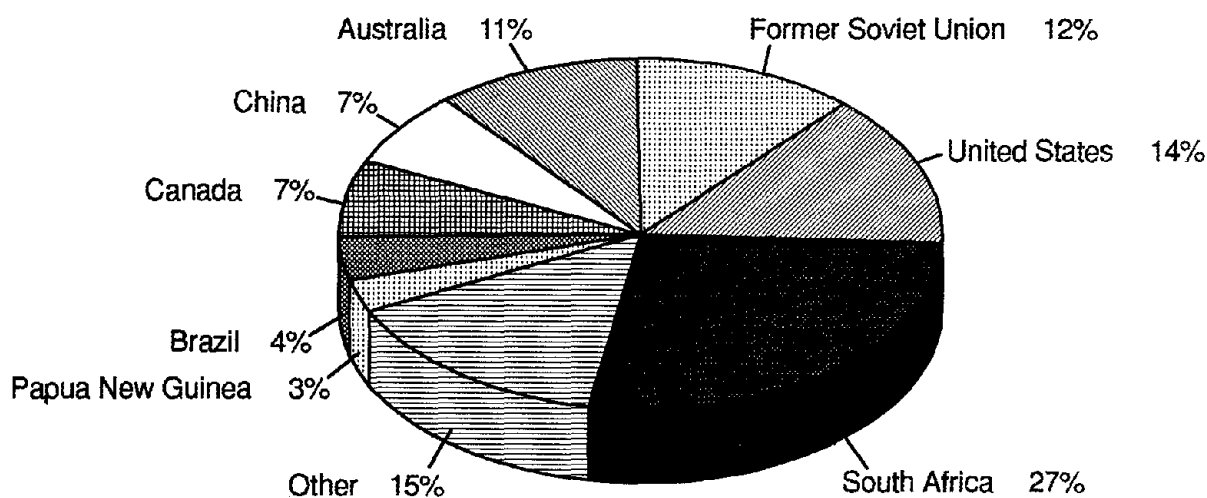
According to information gathered for the analysis described in the U.S. chapter, about one-quarter of U.S. gold production comes from two large open pit mines on the Carlin Trend in Nevada. One-third comes from heap and dump leaching operations that are treating low-grade, surface-mined ore by inexpensive but capital intensive methods. Another third comes from mostly surface mines treating a more complex but higher grade ore requiring grinding and/or a variety of other treatment processes. The remainder of the mined gold comes from two sources: (1) byproduct gold, and (2) a host of small operations.

¹Italic numbers in parentheses refer to items in the references list at the end of the report.

x



1983 = 1,405 mt (45 M tr oz)



1993 = 2,330 mt (75 M tr oz)

Figure E-1.--World gold production by country, 1983 and 1993.

Sources: Lucas (3, p. 433), Lucas (4).

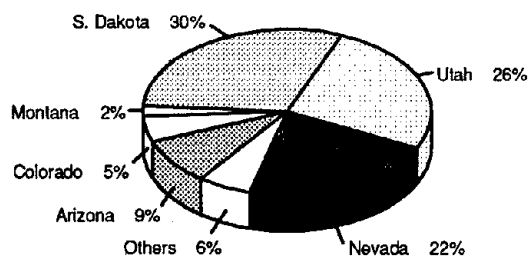
Table E-1.--U.S. historical gold production

Year	Production ¹		Pct of world total
	(mt)	(k tr oz)	
1831-1840	5	152	NA
1841-1850	161	5,171	NA
1851-1860	829	26,655	NA
1861-1870	714	22,942	NA
1871-1880	595	19,129	NA
1881-1890	492	15,808	NA
1891-1900	772	24,834	NA
1901-1910	1,318	42,371	23.2
1911-1920	1,222	39,301	19.5
1921-1930	699	22,480	12.6
1931-1940	1,076	34,858	12.4
1941-1950	672	21,609	7.2
1951-1960	565	18,179	4.9
1961-1970	499	16,047	3.6
1971-1980	353	11,355	2.8
1980	30	970	2.5
1981	43	1,379	3.3
1982	46	1,466	3.4
1983	62	2,003	4.5
1984	65	2,085	4.5
1985	75	2,427	4.9
1986	116	3,739	7.2
1987	154	4,947	9.3
1988	201	6,460	10.9
1989	266	8,543	13.2
1990	294	9,458	13.5
1991	294	9,454	13.4
1992	330	10,617	14.4
1993	331	10,642	14.2

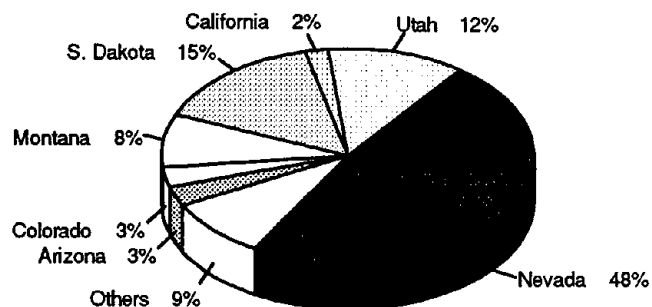
NA Not available.

¹Quantities are mine production of recoverable gold.

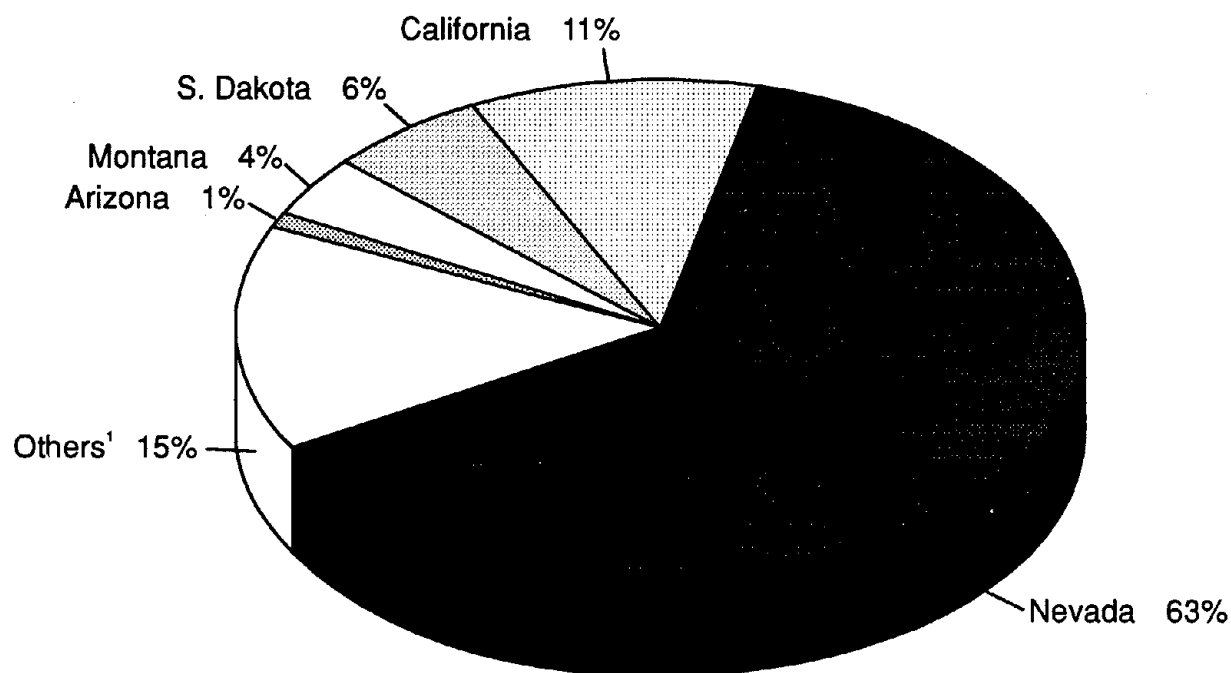
Sources: Lucas (4), St. Clair (5).



1973 = 37 mt (1.2 M tr oz)



1983 = 62 mt (2.0 M tr oz)



1993 = 331 mt (10.6 M tr oz)

Figure E-2.--U.S. mine production of gold by State.

¹ Includes Colorado & Utah values, which were withheld to avoid disclosing company proprietary data.
Sources: Lucas (4), Lucas (6, p. 423), West & Buttermann (7, p. 608)

Analysis shows that almost all of the U.S. ore bodies being exploited, with the exception of two large mines on the Carlin Trend and the byproduct operations, have demonstrated resources sufficient for less than 10 years of production at current levels. Many have only a few years of production assured, and all will need to extend the known boundaries of their ore bodies, or close.

Many gold industry observers have noted another possibility: that exploration and mining companies may take their dollars and explore areas in other parts of the world, especially Latin America (8).

This report summarizes a number of in-depth studies of the major gold mining regions of the world. More detailed reports on each of these regional gold industries are planned to be available as Open File Reports in the near future. Each of these more detailed Open File Reports is referenced within the chapter which summarizes the important findings. The country and regional chapters in this document highlight information important for both government policy makers and persons active in or interested in the industry. The chapters describe the gold industries extant in the large producing countries or regions, and include analyses of trends over the past decade, reserves, production methods and capacities, and costs at the most significant operations accounting for the preponderance of production. Each country chapter also discusses the legal context for mining, including such topics as taxes, royalties, land and mineral ownership, land access, and environmental conditions and constraints.

TRENDS IN THE WORLD GOLD INDUSTRY

World mine production of gold in 1993 was 2,330 mt (74.9 M troy oz), the highest level ever achieved(4). The Republic of South Africa continued to be the largest single

producer, as has been the case for nearly the past century. Record levels of gold production came from the United States and Australia, and production at somewhat declining levels continued from Canada, China, and former Soviet Union countries (Russia and Uzbekistan being the most notable)(4). Significant amounts (near 1 M tr oz) of gold were produced in a number of developing nations as well (e.g., Brazil, Chile, Colombia, Ghana, Indonesia, and Papua New Guinea)(4).

This growth in world production has been fueled in part by a 15-20 year period of historically high constant dollar prices for gold (see table E-2). At these prices it has been profitable to find and develop a large number of medium and large-size primary lode gold deposits, many with relatively low yet economic gold grades. Many of these deposits are mined by surface methods, and much of the gold is recovered with inexpensive heap leaching or tank leaching processes. The amount of gold produced by small miners continues at near or above the levels existing prior to the boom period, but the rest of the industry has grown into a worldwide giant.

Growth in world production in response to the recent high prices for gold is not a new phenomenon. Historical periods of peak production have been matched by periods of relatively high gold prices. For example, the constant (1987) dollar gold price has been above \$300/tr oz only two previous periods in this century. The first peak was around 1900, in the middle of a boom that saw average annual world gold production double each decade from 1890 to 1910. World mine output went from under 200 mt (nearly 6 million tr oz) in 1890, to over 300 mtpy (10 million tr oz) in the decade through 1900, and then to an average over 600 mtpy (20 million tr oz) for the next decade (9). The second peak for prices was during the depression years, from 1934 to 1940. Production had dropped off from

Table E-2.--World gold price, 1861-1993

Year	Price ¹	
	(\$/tr oz)	(1987 \$/tr oz)
1861-1870	23	NA
1871-1880	19	238
1881-1890	² 19	² 273
1891-1900	³ 19	³ 324
1901-1910	19	286
1911-1920	⁴ 19	⁴ 218
1921-1930	21	165
1931-1940	30	281
1941-1950	34	224
1951-1960	35	149
1961-1970	36	122
1971-1980	191	327
1980	612	839
1981	460	575
1982	376	444
1983	424	479
1984	361	393
1985	318	337
1986	368	379
1987	448	448
1988	438	425
1989	383	356
1990	385	344
1991	363	309
1992	345	285
1993	361	291

NA Not available.

¹Prices are average annual world market gold prices for 22 karat standard gold 1861-1914; thereafter for 24 karat fine gold. Prices for 1968-present are average annual U.S. market gold price. Constant dollar prices for 1991-93 are calculated using the GDP deflator from the 1994 Economic Report of the President.

²Values are averages for 1881-85 period; other data not available.

³Values are 1900 averages only; other data not available.

⁴Values are averages for 1911-14, 1919-20; other data not available.

Sources: St. Clair (5), Lucas (10, 11).

1910 to 1930, but production levels picked up strongly to about 900 mtpy (nearly 30 million tr oz/yr) throughout the 1931-40 decade. Every extended period of high prices has been coincident with a period of high production.

Gold production trends examined in this publication have several common themes. One significant tendency has been for exploration dollars all over the world to target medium and large-sized ore bodies, many of them near surface and low grade, that can be mined and processed by relatively inexpensive methods. This trend has been modified in the 1990's with increased mining of underground deposits and increased processing of refractory gold ores. Even the Republic of South Africa, which continues to obtain the bulk of its output from underground mines in the Witwatersrand Basin, is processing large quantities of low-grade surface reclamation material from old rock dumps and tailings dams.

Several of the developed regions and many of the developing gold-producing countries examined in this report view mineral development as an engine for new or continued economic growth. Some of them already depend on mining for a large share of Gross Domestic Product (GDP), tax revenues, or export earnings (see figure E-3). Mining is seen as one of the few areas that will attract large foreign investment. Mining is also viewed as a tool for building infrastructure, opening up remote geographic areas for further development, and building a skilled labor force. In some cases, development of a mining industry is the only major tool available for bringing economically emerging countries into the modern free market economy.

TRENDS IN INDIVIDUAL COUNTRY GOLD INDUSTRIES

Each of the countries and regions examined in this study has a unique set of geologic, climatic,

social, and political conditions that influence gold production and mining in general. Some producing countries, including the United States and Australia, currently have industries that are radically different from 10-15 years ago. A few countries, such as South Africa, have industries that have not changed much since the Bureau's previous evaluation, while other nations like China, Papua New Guinea, Indonesia, and certain Latin American countries seem poised to become even bigger players in the world gold market.

As discussed later in the report, one country, the Republic of South Africa, has been the major producer of gold for almost 100 years. Over that entire span, production has come almost exclusively from the Witwatersrand Basin. Since 1970, South Africa has experienced a decline in the ore grades being treated and, consequently, a corresponding gradual reduction in gold production. However, their reserves remain enormous and seemingly guarantee at least 30 years of production at current levels under present economic conditions.

The rest of the world is the setting for radical changes in the gold industry which are discussed in more detail in the individual country chapters. These include higher output levels, restructuring of ownership and mine sizes, broad application of new and old recovery technologies, and relatively short-lived primary ore bodies accounting for a big percentage of the increased production capacity. Here is where South Africa stands strong. They have assured production from well known ore bodies while the rest of the world must continue to spend large amounts on exploration and development to maintain current production levels. As long as prices remain as high or higher than the levels of the past decade, the incentives are in place for mining companies to continue exploration and development spending.

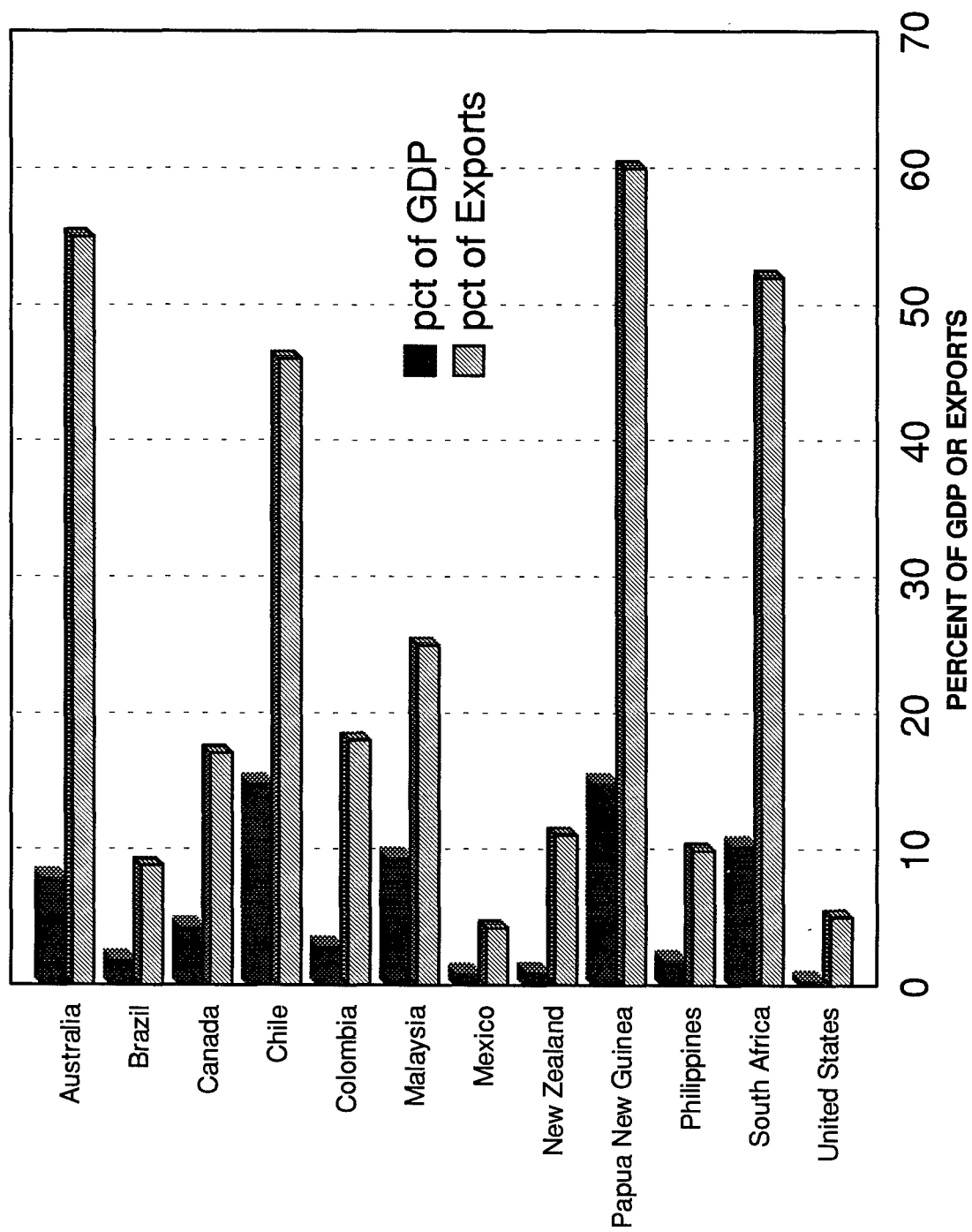


Figure E-3.--Mineral industry importance, selected countries, 1992.

Source: USBM (12).

Where this money will be spent is in question, however. Various countries are considering new laws, regulations, environmental controls, royalties, etc., to attract or repel those dollars, and/or to insure that mining exploration and development expenditures are not made at the expense of higher priority goals like environmental integrity (13).

A recent survey of Australia's leading resource companies (14) demonstrates how complex the risk consideration in mining investment decisions can be. Although geologic prospectivity and the identification of economically viable ore bodies are of paramount concern, a host of other considerations also come into play.

The survey results (shown in figure E-4) suggest that the recent trend toward increased mining investment in Latin American countries is based on more than their geologic attractiveness. Chile, the country with the lowest perceived risk, is viewed as having minimal investment risk in all categories. Argentina is viewed as only slightly more risky. China, Russia, and Papua New Guinea, at the bottom of the rankings, are all seen with high sovereign risk, infrastructure problems, a potential for civil unrest, difficulties with land access, and an imposing amount of red tape. The United States was seen with the maximum "green tape" risk because of the plethora of environmental constraints on mining activity; however, survey respondents accorded that factor only a mid-level weighting, and the overall U.S. investment climate was ranked as the third most attractive.

Mining and mineral processing sectors generally cannot respond quickly to radical changes in market conditions. If exploration has been neglected, it may take years to identify new ore bodies; if research has been neglected it may take years to develop lower cost methods of processing known ore bodies; if development has been neglected, it may take years to get

permits, do environmental impact statements, and build the mining and processing plants required for significant expansion of output. With much of the international mining industry dominated by transnational corporations, funds are targeted to those minerals with the brightest prospects (15). Gold received attention and dollars during the 1980's and early 1990's because it is the metal market where the best return can be made. If prices fall, those dollars will flow to other commodity markets and locations that show better potential for profit.

The remainder of this executive summary is a brief country-by-country discussion of highlights from the chapters that follow. Trends in production, resource discoveries, technological developments, current competitive position, and outlook for the future are only touched on here. More information will be contained in the planned series of Open File Reports which are referenced in the regional chapters to follow.

United States Gold

The U.S. gold industry is characterized by unparalleled growth, concentration of mining ownership, larger operations, lower grade ores, more complex ores being treated for a higher percent of production, and a two-tier structure for total costs of production.

At over 331 mt (10.6 M tr oz) in 1993, the United States is producing more than double its annual amount in any previous boom period. Production has been above 4 million oz (124 mt) in only two periods prior to the late 1980's: 1909-16 and 1937-41. Neither the California gold rush nor the Alaskan gold rush was big enough to push U.S. production anywhere near that level.

The U.S. gold mining industry chapter to follow gives a detailed look at the resources and costs for 33 of the largest gold producing properties and 8 of the large

Question number	1	2	3	4	5	6	7	8	9	10	Weighted totals
Question heading	Sovereign risk	Land access	Green tape	Land claims	Red tape	Social risk	Infrastructure	Civil unrest	Natural disasters	Labor relations	
Investment risk weighting (0 being unimportant to 5 being most important.)											
No.	5	3	4	4	3	3	4	1	2	2	
Country risk levels:											
	0-No risk			to			5-Maximum risk				
1 Chile	2	1	2	1	1	1	2	2	2	1	9.8
2 Argentina	2	2	2	2	2	2	3	2	1	2	13.6
3 United States	1	3	3	2	3	3	1	0	1	2	13.8
4 Indonesia	2	2	2	2	2	2	3	2	2.5	2	13.9
5 Mexico	2	2	3	2	2	2	3	2	2	2	14.4
6 Canada	2	2	4	5	5	5	1	0	1	2.5	14.4
7 Vietnam	2	2	2	1	2.5	2	4	2	1	2	14.8
8 Australia	2	3	3	3	2.5	3	1	0.5	1	3	14.8
9 South Africa	3	2	2	2	2	2	2.5	4	1	3	15.3
10 Zimbabwe	4	2	2	2	2	2	4	3	1	2	17
11 Philippines	3	2	3	3	2	2	4	3	3	2	17.2
12 Brazil	3	2.5	3	3	3	2	3	3	2	2	18.2
13 China	4	4	2	1	4	2	4	3.5	2	2	19.2
14 Russia	4	3	1	2	4	2	5	3.5	2	3	20.4
15 Papua New Guinea	4	2.5	3	5	3	3	4	4	3	2	23

Figure E-4.--Survey of Australian resource companies regarding mining investment risk, by country.

Source: Roberts (14, p. 8)

nonproducing properties. The 33 producing operations represent over 70 pct of reported 1992 production. Based on analyzed recoverable reserves as of January 1992, these producing properties have an average of about 11 more years of production available at current production levels. (The average is less than 10 years when the Carlin Trend operations are not considered.) The analyzed non-producing properties also have about an 11 year life, but would only provide 20 pct of the production capability of the analyzed producers.

Production costs for a significant number of U.S. gold producers are relatively high. Two large operations on the Carlin Trend in Nevada have been profitable in recent years at prevailing prices, as have properties accounting for about one-half of remaining production capacity. However, the profitability of all analyzed producers is very sensitive to the market price for gold.

A large percentage of all analyzed output comes from surface operations. A significant part of this output is heap leached, low-grade ore. The recoverable amount of gold is estimated at slightly more than 80 pct of the gold contained in the ore, reflecting the low recovery rates associated with the heap leaching process. The average feed and recoverable grades for all U.S. deposits evaluated are under 2 g/mt.

With increased processing of lower grade ores, the U.S. gold industry is generating more waste. Assume an average yield grade of 1.5 g/mt. The amount of ore required to recover 1 tr oz of gold is more than 20 mt (31.1035 g/tr oz divided by 1.5 g/mt). The weighted-average ratio of waste rock moved to ore moved is 2.7/1.0 for the analyzed producing surface mines in the United States. Assuming that 90 pct of the 332 mt (10.7 M tr oz) of gold produced in 1993 came from surface-mined material, there would be about 190

million mt of tailings from the ore, and another 510 million mt of waste rock. This 700 million mt of waste would cover an area the size of Denver's new International Airport (53 square miles) to a depth of 2-3 meters. With the U.S. average grade and production levels, the United States needs to mine and process at least twice the amount of ore that South Africa does to produce slightly more than one-half of South Africa's gold output.

The U.S. gold industry seems to be slowly reverting to underground operations. For example, the two major Carlin Trend operations are developing underground mining operations. Although this will decrease the amount of waste being generated, it will also mean, in most cases, higher costs of production than at the near-surface oxide deposits that are being depleted. The reduction in waste comes because no overburden removal is needed and higher grade ores will be mined. This trend could mean lower production levels as well, because underground reserves equivalent to the contained gold in surface reserves have not yet been identified.

Changes in the legal environment under which U.S. gold producers operate is currently under consideration in the U.S. Congress. The gold industry could be impacted by the changes proposed to the General Mining Law of 1872. Because of the short-lived nature of many ore bodies and the need to replace depleting reserves through exploration, companies are vulnerable to land-use restraints. Considering the two-tier nature of costs at current operations, profitability levels are sensitive to major increases in mining fees, increases in delays due to permitting procedures, major increases in royalties, and other administrative cost items.

South African Gold

The South African gold industry is mainly characterized by the Witwatersrand Basin Reef gold

xx

deposits; the largest, richest concentration of gold bearing ore known to exist in the world. It is home to a small number of very large operations on a series of underground reefs that have been mined for more than 100 years. Earlier, because of high grades and low-cost labor, mining was inexpensive, and so South Africa accounted for as much as 76 pct of western world mine production in 1965-70. Since the freeing of the gold price in the early 1970's, cut-off grade levels have declined and remuneration levels for the black miners have risen. Mining has also grown more expensive as mines have gone deeper and costs of nonlabor inputs such as electricity and haulage have risen sharply.

The South African mining industry accounts for a significant percentage of that country's GDP, employment, and foreign trade. The government has historically been supportive of the mining industry, including a policy of considering effects on mining industry competitiveness when making currency exchange rate adjustments. Only a constant devaluation of the country's currency during the 1980's and the 1990's has kept the South African gold industry competitive on a cost basis. There is some concern that the newly elected government may try to effect changes in the taxation system, particularly for the gold mines. Under the current tax system, revenues are highly variable. There are no state or national royalties, and nearly all capital expenditures can be deducted in the year incurred, allowing certain marginal mines to have a 0-pct tax rate.

South Africa is well-explored and the chances for significant new discoveries appear minimal. However, a compilation of gold contained in prospective mining lease areas not evaluated in this study totals 159 M tr oz, nearly as large as the entire U.S. reserve base. There is much less exploration in South Africa than in other parts of the world, and when new mines are developed to replace

depleted ones, they are generally adjacent ore bodies of a similar character to the ones being replaced.

Another factor is the huge amount of tailings and other surface waste material from past mining operations, both of which represent resources from which gold can be recovered. Compared with total South African production, the amount is small, only 4-5 pct of their total. That is still 1 M tr oz/yr, a level that would rank near the top ten producing countries of the world.

Most of South Africa's mines are by necessity labor intensive. The thin gold-bearing seams are not conducive to extensive use of low-cost highly mechanized mining methods. Compared to other major world producers, they also use a disproportionate amount of electricity. This is because of the ventilation and refrigeration requirements associated with very deep underground mining. Because South Africa leans toward energy independence and generates a high proportion of electricity by using a coal gasification technology, electricity costs have escalated. Also, during the recent period of high gold prices and high profits, labor unions in South Africa have been able to bargain effectively for higher wages. As current mines go deeper and costs continue to rise, the profitability of many of the mines will be dependent on higher gold prices or a continued cheaper currency vis-a-vis the U.S. dollar.

Canadian Gold

Canada is the world's fifth largest gold-producing country. In 1980, Canada was the world's number three producer. Since then, output has increased threefold and its share of the world market nearly doubled, but many of the world's producers (outside of South Africa) have grown even faster.

Most of Canada's production comes from large underground mines in Ontario and Quebec. These

deposits are relatively expensive to mine, but the ore bodies are generally high grade. Canada's average cost of production for all evaluated properties is well below the current world price for gold.

Replacement of reserves has kept pace with the expanding level of production, and expected mine life currently is about 9 years. One incentive for the aggressive exploration program in the 1980's was a "flow-through shares" provision in the Federal and provincial tax codes that allowed these expenditures as deductions for personal income tax purposes. Shareholders deducted the cost of current exploration efforts at rates between 133 pct and 167 pct of actual expenditures. The flow-through share program was at best a mixed blessing. A high level of deposit discoveries was made during the 1980's but at a higher discovery cost per ounce than in other producing regions. The average value of these discoveries was lower than the historical average. In 1989, this provision was scaled back to allow only actual expenditures as deductions. As a result, exploration efforts have decreased.

The climate in Canada has a major effect on the industry. The conditions for oxidizing near-surface ore bodies through weathering over long time periods do not exist in cold, northern areas like most of Canada. This forces the Canadian gold industry to find and treat more complex ores than many of its major competitors. The cold also reduces the season for outdoor operations, making heap leaching a nonviable option for treating the low-grade ore bodies that do exist near the surface.

The only nonproducers in Canada evaluated in this study, with the exception of one operation temporarily shut down, are four large gold-copper ore bodies in British Columbia. These are all projected as surface operations and average 23 years of mine life at planned capacity levels. At current gold and copper prices, such operations are estimated to be capable of earning a

reasonable profit. However, as with many polymetallic deposits, a sharp drop in the price of either metal could jeopardize the economics of their development.

Australian Gold

Australia is the world's third largest producer of gold. Like the United States, its gold industry mushroomed over the last decade. Output grew from 18 mt to 247 mt between 1981 and 1993.

Growth during the 1980's resulted from mining soft, near-surface oxidized ores with cheap, quickly assembled plants that are mobile. Because these plants are prefabricated and assembled on-site, this type of processing plant requires only 3 to 6 months to construct and commission. Nearly 75 pct of this gold comes from operations in one State--Western Australia. Most of the operations in Western Australia are surface mines. The ores are medium to high grade, but there appears to be a recent trend toward more refractory ores with complex chemistry, which can be relatively expensive to process.

There has been a considerable change over the past decade in the type of ore body from which gold is recovered. Polymetallic deposits accounted for nearly one-third of gold output in 1981, but in 1992 these deposits contributed less than 2 pct of mined gold. Although the amount of gold produced from polymetallic deposits did not change much over that period, the amount of gold coming from primary gold deposits skyrocketed.

Over the past decade the concentration of production capacity in larger mines increased. In 1981, 38 pct of output came from operations producing less than 25,000 tr oz/yr, and there was only one operation with an annual output over 100,000 tr oz. By 1992, nearly two-thirds of all output came from 25-30 operations with production capacity higher than 100,000 tr oz/yr; consequently, the output from small operations is now a very small part of the total.

Most of Australia's gold production outside of Western Australia comes from a small number of large operations. Two very large operations in Queensland have adequate reserves for 10 years of production at current levels. Many operations outside Western Australia are in remote locations, and utilize a fly-in, fly-out workforce or require construction of a company town.

Exploration efforts in Australia have been very successful in the last 10 years. Economic demonstrated reserves, for example, have gone from 332 mt of contained gold in 1980, to 2,466 mt in 1992. All of the increase in reserves has been in primary gold deposits. Reserves at polymetallic deposits have declined. Along with the increase in reserves came an increase in expected mine life. Typical expected mine life (measured as reserves/production ratio) in the mid-1980's was only 5 to 6 years. Now it is 8 to 10 years.

Only 12 pct of Australia's gold production currently comes from underground operations. However, many of the surface operations are nearing the economic limits for open pit mining, and there are plans at many of these mines to develop underground portions of the deposits. Several properties expected to be developed in the near future are underground properties as well. These changes could cause the proportion of output coming from underground operations to double over the next few years.

The government retains ownership of mineral rights in Australia. It has been generally supportive of the mining industry, offering land access and rights to mine when companies show due diligence in exploring and developing properties. Recently, there has been uncertainty regarding mineral rights in lands claimed by aboriginal peoples. These disputed regions cover more than one-quarter of Australia's land area, and until the situation has been settled,

exploration and development dollars will likely flow to unencumbered lands.

Latin American Gold

Latin America has more or less tripled gold production over the last decade, and has enormous potential for even higher levels of gold output in the future. There have been many political and economic changes over this period, including a pronounced move toward capitalism and free market economies. With the sole exception of Brazil, every South American country with a potential for expansion of its domestic gold production has recently changed its laws regarding taxation and mine ownership to encourage more private sector mining investment and development. Expectations are that Brazil may, in the near future, liberalize laws to encourage foreign investment (16).

Along with these changes have come improved standards of living for a large number of mining industry employees, and increasing amounts of tax revenues for national and local governments. The mining industry accounts for a significant share of GDP and foreign trade in almost all Latin American countries. Also, the development of environmental laws and rules for land access and land tenure has tended to be a cooperative exercise in these countries, with codes being developed in conjunction with the industries being regulated.

With a few exceptions, gold mining operations in Latin America are small or medium sized, and most grass roots exploration dollars come from junior (i.e., small) exploration/mining companies. Larger mining companies tend to explore in the immediate vicinity of known producing areas.

Two large areas in Latin America have the greatest promise for expanded production: the Guiana Shield (which straddles northern Brazil, French Guiana, Suriname,

Guyana, and Venezuela) and the Andes mountains area (which runs along the western edge of the continent, passing through Colombia, Ecuador, Peru, Bolivia, Argentina, and Chile). These areas currently receive most of the exploration dollars and, if developed, will most likely be home to large primary gold operations with expected long producing lives. The operations would be both underground and open pit, and the open pit ores will likely be heap leached because of the generally low grades. There is also potential for discovery and development of large copper-gold ore bodies.

Asia-Pacific Region Gold

The Asia-Pacific region may be one of the emerging giants in world gold. Production currently comes in significant amounts only from Papua New Guinea (PNG) and Indonesia, primarily because most of the nations in this region are relatively unexplored. However, there is great promise because of the favorable geology of the area. As with the Latin American countries, the lack of exploration up to now is partly due to rugged terrain, lack of infrastructure, mining legislation not supportive of foreign investments, and the relatively recent advent of apparent political and economic stability.

Since there is still a large risk factor involved in investment in many of these countries, current exploration efforts have targeted only the largest and richest ore bodies. Each of the countries discussed later in this report has unique characteristics that can make potential investors both interested and cautious. Even New Zealand, a modern economy by most standards, is relatively unexplored in many regions. PNG and Indonesia already have two huge copper-gold ore bodies developed. Gold mine operations in the region are mining primarily epithermal gold deposits (some very large) and the geology is favorable for additional epithermal gold discoveries. Two large primary gold deposits are in

production, and a third large deposit is in the early stages of development (see chapter 7). However, recent concern about lawlessness in remote areas of PNG has served to deter some investment.

There is also uncertainty concerning land ownership rules and security of tenure in many of the Asia-Pacific countries. The large, rich ore bodies targeted by exploration efforts may provide a very short payback period for investment, thereby minimizing a company's risk that rules may change after mining and processing investments have been made.

One positive development in recent years is Indonesia's Contract of Work (COW) agreement. This is an explicit statement of the rights and responsibilities of investors, land owners and the government, and is a model for countries throughout the region.

Many developing nations share common characteristics and needs that must be considered. Many of them lack a trained workforce, yet require a high percentage of workers to be locals. Some areas cannot guarantee the safety of employees, and the mining companies are asked to provide police forces. Most of the countries are badly in need of basic infrastructure and many expect the mining companies to provide it.

Mining is viewed by many of these countries as an opportunity to enter the modern world society. It would bring foreign exchange needed for development in other sectors as well as modern technology which may stimulate other industries to modernize. Finally, it would provide employment and education for the populace, and a level of social stability that is difficult to attain any other way.

China and Countries of the Former Soviet Union

As of 1993, China, Russia, and Uzbekistan are the world's fourth,

sixth, and eighth largest gold producers, respectively. China's rank reflects a near doubling of annual gold output in the last 5 years, from 53-90 mt throughout the 1980's to its current output of about 160 mt. The total for all countries of the former Soviet Union represents a small decline from the 260-290 mtpy of gold produced during most of the 1980's. Information for these countries is not available in the same detail as for market economy countries. Only in the past few years have foreign companies been invited to participate in the exploration and development of mineral deposits. Even now, access to large land areas is limited, and foreigners may participate but are not allowed ownership positions.

Both China and the countries of the former Soviet Union are thought to have sufficient gold reserves to sustain current levels of production or even to surpass them. No comprehensive resource estimates are available for China, but the USBM estimates resources in the former Soviet Union are larger than for the United States (chapter 8).

China and the former Soviet Union depend on foreign sales of gold to generate currency for foreign credit obligations and internal development programs. They also depend on foreign involvement for the technology and equipment needed to develop some of the known large deposits with complex ores. Because the large equipment and advanced technology needed to develop large ore bodies are not produced within the country, China derives a large part of its output from small and medium sized mines.

Most gold production in China comes from underground operations. All production is sold to a refinery owned by the Peoples Bank of China, which markets the gold. The recent move to pay a price more closely tied to the world market price is intended to provide an incentive for expanded output.

Russian gold production comes mainly (90 pct) from very large alluvial placer deposits. Many of these are mined by groups of independent gold miners, or "artels," working under contract to larger enterprises. Gold in Uzbekistan is derived mostly from lode deposits; the largest operation is a surface mine moving 17 million mt of ore annually. Gold in Kazakhstan comes as byproduct production from copper and lead/zinc deposits. The former Soviet Union shows great potential for new gold from permafrost areas and from huge waste areas at old mining operations.

OUTLOOK FOR THE WORLD GOLD INDUSTRY

The detailed mine-specific data that are central to the analyses contained in this report provide information for speculating about what is to come, and some of the potential pitfalls each of the gold-producing countries face. Table E-3 gives an abbreviated set of data and evaluation results for all regions covered in this report. The table provides an estimate of total production from each of these regions for 1992 and 1983. The amount of production capacity evaluated is shown, along with average life-of-mine grades and the estimated life-of-mine costs for mining and processing.

All dollar values in the table and elsewhere in this report are expressed in U.S. dollars. The values for 1983 are taken from an earlier USBM availability study of the world gold industry (2). The weighted average costs from that earlier study have been updated to 1992 dollars using a GDP deflator to facilitate comparisons with the current study.

The costs shown in table E-3 show a sharp decline between 1983 and 1992, as measured in constant (1992) dollars. Among the factors which account for this change are the application of new processing technologies, cost-cutting measures

Table E-3.-- Summary findings of gold availability studies

Country	1992					1983								
	Total estimated production (mt gold)	Evaluated production capacity (mt gold)	Wtd avg feed grade ¹ (g/mt)	Evaluated reserves (contained gold, mt)	Wtd avg costs ² (1992\$/tr oz)		Total estimated production (mt gold)	Evaluated production capacity (mt gold)	Wtd avg feed grade ¹ (g/mt)	Evaluated reserves (contained gold, mt)	Wtd avg costs ² (1992\$/tr oz)			
					Operating cost	Total cost					Operating costs	Total cost		
Major producers:														
United States	330	224	1.9	3,100	230	281	368	62	49	³ 2.2	1,200	360	471	527
South Africa, Republic of	614	653	6.1	22,900	243	290	313	680	741	⁴ 7.4	23,600	328	379	402
Canada	161	116	8.3	1,100	208	248	288	74	65	⁵ 9.9	1,300	270	367	466
Australia	243	196	2.5	2,500	⁶ 238	⁶ 310		31	14	⁷ 6.1	200	317	427	466
Total or wtd avg ⁸	1,348	1,189	4.9	29,500	232	289		847	869	7.3	26,300	326	384	415
Other countries														
Brazil	86	33		544		263	373	50						
Chile	34	15		299		243	371	18						
Brazil and Chile surface mines					193									
Brazil and Chile, underground mines					239									
China	140							59						
Former Soviet Union (FSU)	251							268						
New Zealand ⁹	11				215									
Papua New Guinea/Indonesia	109				155	214		18						
Others	319							129						
Subtotal	950							542						
World total	2,298							1,389						

¹These grades represent average life-of-mine feed grades for the evaluated primary gold operations. Conversion factors: 32,150.7 tr oz = 1 mt and 1 tr oz = 31.103 g.

²Values in 1992 dollars based on U.S. GDP deflator (\$1.00 in 1984 = \$1.33 in 1992). 1984 dollars from Thomas and Boyle are in parenthesis.

³The grade of U.S. primary gold producers in 1983 is for 15 of the 16 largest producers in that year, accounting for well over 70 pct of U.S. output.

⁴The grade of RSA primary gold producers is for 35 underground mines, accounting for well over 90 pct of RSA output.

⁵The grade of Canadian primary gold producers is for the 14 largest producers, accounting for about 50 pct of the total output.

⁶Actual cash costs and total costs are for the year ending 6/30/92, and reflect taxes based on realized profits. Life-of-mine estimated costs would be somewhat lower.

⁷The grade of Australian primary gold producers is for the seven largest producers, accounting for about 40 pct of total output.

⁸Totals may not add due to independent rounding.

Source: Thomas and Boyle (2), Lucas (4, 10), USBM engineering and cost model estimates.

taken by many of the producers, and development of new lower-cost open pit operations in the United States and Australia.

For the four major market economy producers, the amount of production capacity evaluated is equal to almost 90 pct of the reported production. The costs reported in this study are reflective of the cost structure of the industry as a whole. Likewise, the average feed grades reflect the current situation in the world gold industry. That is, the average feed grades for primary gold operations are going down, but the low-costs of new technologies, especially open-pit mining and heap-leach processing, have enabled mining companies to lower average costs over the past decade.

The levels of evaluated reserves shown in table E-3 emphasize a major problem of the world gold industry -- the need to find and develop new ore bodies. Only South Africa has long-term, assured production from known deposits. The rest of the world does not enjoy the same geologic assurance.

In general, the majority of production comes from large ore bodies that have only been developed in the last 10 years. Many of them have been known for a long time. Many are near-surface, low-grade, oxide ore bodies that are being processed by heap leaching. These ore bodies could not have been economically exploited 20 years ago.

The average life-of-mine cost values shown in table E-3 illustrate this situation. For the United States and Australia, where many of these near-surface, low-grade oxide deposits are located, the average cash operating costs are low. However, taxes, high exploration costs, and higher capital expenditures result in higher total costs for countries with short-lived gold mines. South Africa, which mines well-known underground deposits, has marginally higher cash operating costs but relatively low life-of-mine total costs.

Because of the relatively short-lived ore bodies outside South Africa, exploration expenditures will be required on a continuing basis into the foreseeable future. Exploration always involves time and risk; even with the development of sophisticated, high-technology exploration techniques, luck is involved in whether or not new reserves will be found and where they will be located. When they are found, they may be in areas where development is restricted, that require high expenditures for infrastructure development, or entail protracted negotiations to protect environmental values or native peoples' rights.

Gold mining is increasingly being done by major companies. The gold mining industry is finding more complex ore body types (e.g., refractory ores) that can be processed most efficiently in large operations where high capital expenditures are needed. Also, with the international movement toward protecting environmental values, companies are more often required to prove they have the financial resources to clean up potential disturbances to land and water from mining and processing operations. This may involve posting substantial up-front bonds or providing some other guarantees of financial solvency and accepting the often long-term liability risks associated with gold mining operations.

The U.S. competitive position in the future is unclear. Many of the countries discussed in this volume are offering exploration or development incentives to mining companies specifically intended to lure financial capital. Many industry sources suggest that the shift away from North America and into Latin America and the Asia-Pacific region has already begun (17).

Technologies suited to the type of ore bodies fueling the dramatic growth in U.S. gold output are applicable to similar ore bodies in other parts of the world. For example, large disseminated gold ore bodies are now economic to mine

and treat. Developments on the Carlin Trend have demonstrated the economies-of-scale advantages of the mining and processing technologies needed to make them profitable.

One of the greatest uncertainties facing the world's gold producers is market price. About one-third of the evaluated mining and processing facilities around the world are working on narrow profit margins, despite a number of cost reduction measures taken in many countries that are outlined in the chapters to follow. Their continued operation depends on continuation of current price levels, based on availability analysis shown in the chapters.

Most of the nonproducers evaluated also depend on market price at least as high as the current level to justify the large investments required to complete development. One hedge taken by many of the mining companies in the United States and Australia is the use of forward sales contracts, which guarantee a fixed price and a fixed profit margin. This has proven to be a boon to many operations in the last few years as prices have gradually declined. On the other hand, when the gold price rises these operations do not share in the extra revenues and profits obtained with the higher price levels.

LEGAL, FISCAL, AND ENVIRONMENTAL CONDITIONS FOR MINING

In every major gold-producing country in the world, except the United States, mineral rights are owned by the government. Governments can develop the deposits themselves or grant concessions to private companies for exploration and mining. In many of these countries, concessions contain such items as requirements for local employment, local participation in ownership and management, fees for the rights to explore or mine the land, and payments based on revenues or profit levels (see individual country chapters).

In the past, there have been large parts of the world where private companies could not obtain mining concessions, or where they could do so only in a minority ownership role. Recently, however, many of these countries and some of the newly developed nations have changed the rules for granting mining concessions in an effort to attract foreign investment. The minerals industry, especially mining operations financed with foreign capital, is now seen as a positive economic force promoting growth, employment, and advances in the standard of living (18).

One of the broad catchwords that describes recent events in mining in many countries is "privatization." That is, mining operations originally developed and operated by government-owned enterprises are now being sold to private companies (19). The motivations are plentiful. There is a strong perception that private investors can operate the properties more efficiently and generate more revenue, and that a fair return from mineral resource extraction is still possible. Another important consideration for emerging countries is that private investors are likely to bring up-to-date technology with them, provide training for a private workforce, and accelerate entry into the modern free market economy.

Each of the country and region chapters to follow discusses the legal framework under which mining investments are made. The attractiveness of an investment can depend as much on these conditions as on the characteristics of the ore body considered for development. Similarly, without strong assurance that a right to mine will be forthcoming there is no incentive to explore for new deposits.

The financial parameters of a mining concession or a lease can also influence an investment decision. Tax rates, royalty rates, ownership limitations, etc. can all turn an otherwise promising investment into a risky venture or a money-losing proposition. The

following country and regional chapters will show an enormous change in attitude by many of the countries that were formerly closed to private ownership and investment. The more assured land tenure positions should be a strong incentive for mining investment.

The political stability and civil conditions of some of the countries are also discussed. In some regions of the world, such as in the Asia-Pacific region, companies must provide their own security forces or provide basic infrastructure to the local population. Countries such as Russia and other countries of the former Soviet Union are undergoing significant changes in leadership and business practices and many are still working out the conditions under which their natural resources will be exploited.

The environmental and climatic conditions and constraints in each country are also discussed in the chapters and are an important area of concern to mining. Often these conditions will dictate the feasible methods for developing a deposit. Canada's cold climate almost precludes using heap leaching. Countries in rainy tropical climates are limited in the use of heap leaching because excess precipitation dilutes the cyanide solutions being sprayed on uncovered piles of crushed ore, and the containment of these fluids becomes problematic or costly.

CHAPTER 1

METHODOLOGY OVERVIEW

INTRODUCTION

The country and regional chapters in this study are based on a detailed availability analysis of the world gold industry. The individual country studies that are summarized provide a level of detail sufficient to understand current conditions influencing production in each of these regions, and to anticipate directions in which the industry is headed. More extensive data and analysis will be available in the planned series of Open File Reports for each of the major producing countries and regions covered in the following chapters.

The Minerals Availability methodology is to examine a mineral industry at the mine-site level. The first step is to identify the sizes and types of reserves available at major mining operations. These data answer questions like "How long can a country sustain current levels of production?" The technologies and overall costs of production are also estimated for each of these operations, answering questions like "Will production continue at current levels if the gold price falls?" and "Which countries have the potential to expand under different economic conditions?"

This level of detail also suggests which regions are likely to take advantage of recent processing technology developments. The U.S. industry has been able to utilize pretreatment processes for refractory gold ores, and other regions of the world are utilizing these techniques as well. Sometimes even small improvements to existing processes can pay big dividends. Australia benefitted from improvements in surface mine pit wall design, for example, and

the development of moveable treatment plants that can be constructed in only 3-6 months has made it economic to mine small ore bodies in remote locations (see Australian chapter). In gold mining, improvements like these spread quickly to other regions of the world able to employ them.

The comprehensive financial analysis of each deposit also accounts for inflation, exchange rate variations, and taxation systems. This allows assessment of the likely impact of actions governments might take to encourage or discourage investment in the mining industry.

Not all operations are looked at in this detail. The first cut is to only look at operations that account for a significant percentage of output or are expected to in the future. A second cut is to include enough operations of different types to be able to make general statements that apply to the industry as a whole. The Minerals Availability approach also includes examination of the legal, political, environmental and economic conditions in each important gold producing country to see how those conditions may affect the industry.

The main focus of this report is on existing mining and processing operations, and on additional operations with well-explored reserves and well defined plans for development of those ore bodies. Because the gold industry is characterized by relatively short life operations, there is a significant amount of attention paid to exploration activity as well. Much of the information in this report was obtained through

site visits and other direct contacts with mining companies and/or operations in each of the countries analyzed.

RESERVE AND RESOURCE ASSESSMENT

Determining the character, size and placement of the ore body to be mined are essential to the success of mineral operations. The character of the ore will determine what types of processing techniques can be used to extract the gold from the ore, and whether this can be done economically. The size, placement and structural characteristics of the ore body will dictate which mining techniques can be profitably employed. Ore of a given grade and mineralogy may be very profitable to mine and process if an operator can utilize open pit methods, yet be worthless if a company needs to go deep underground to extract it.

Each of the chapters to follow gives a detailed picture of the resource position for that country or region. It will report an overall level of resources and assess its adequacy for continued support of current or expanded production levels. The resource estimates will also be presented for different categories of ore types, each of which has different economic considerations.

One common division into gold resource types is (1) alluvial (or placer) ores, (2) lode (or primary) deposits, and (3) polymetallic (i.e., by- and co-product) ore bodies. Thanks to recent advances in processing technologies, tailings and other waste material from previous mining operations are another source material for gold production.

Most of the world's mined gold is produced from primary lode gold deposits. This dominance has become more pronounced in the last 10-20 years as high gold prices have encouraged large exploration expenditures focused on finding this type of deposit.

Lode deposits can be further subdivided into oxide or refractory ores. Oxidized deposits are generally near the surface and natural weathering processes have altered the rock in ways that enable leaching agents to contact the contained gold. Often ores with a grade below 1.0 g/mt can be profitably mined if using surface-mining methods and heap leaching treatment methods.

In refractory ores the gold particles are intimately associated with sulfide and other minerals and may require expensive pretreatment processes to separate the gold from the gangue materials and to allow easy contact with the leaching agents. If the grade of the ore body is high enough to justify the investment, these ores can be economically mined and processed. Heap leach bio-oxidation can make even low grade refractory ores economic to mine.

The alluvial deposits have been the easiest to find because they are generally near the surface. They are also the easiest to process because they contain free gold. Much of the work of separating the gold from host rock has been accomplished by weathering.

In some countries, such as Russia, this type of ore body accounts for most of gold production (20). However, in a well-explored country like the United States most of these deposits were found long ago, brought into production, and depleted.

The polymetallic deposits yield gold as a byproduct of mining for some other mineral, generally copper or silver. Usually this type of mine generates most of its revenue from the principal metal mined, and the amount of gold produced is unlikely to change in response to rising or falling gold prices. In the past, periods of depressed prices for the primary metal (such as copper) often meant lower gold output from this source even if the gold price was high.

Waste rock dumps and tailings dams at prior mining operations have become another source for gold. These low-grade resources used to be considered waste, but are now economic to process with heap leaching and processing techniques developed in the past 10-20 years. In South Africa, for example, 4-5 pct of output (about 1 M tr oz/yr) comes from treatment of this type of material (see South African chapter).

The tonnage and grade estimates made for the availability analyses are for demonstrated resources (see figure 1). This is the portion of known ore bodies which is well defined and possible to exploit given current technology. Estimates for the United States are based on a resource classification scheme developed jointly by the U.S. Bureau of Mines and the U.S. Geological Survey. The principle is to categorize mineralized material on the basis of both increasing geological assurance and increasing economic feasibility. Estimates for Canada and Australia are based on a similar classification scheme; differences will be explained in the planned Open File Reports for those countries.

Reserves are generally reported in terms of the contained gold in minable ore bodies. In many cases this is supplemented with information on the total size of the ore body, the average grade of contained gold, the amount of dilution or waste rock which must be mined, and the recoverable portion of the contained gold. If available, this information is further subdivided into ore bodies of different types such as placer, lode, or polymetallic.

COST ESTIMATING PROCEDURES

An estimate of the cost of producing refined gold from each of the operations is a standard output from a Minerals Availability assessment. This is accomplished by first establishing a detailed flowsheet for each operation, including operating and technical parameters such as recovery rates

for the mining and processing, and then estimating the cost of accomplishing each facet of that flow. For undeveloped properties, this entails choosing a mining plan and processing technologies appropriate to the size and type of the ore body.

Each operation is associated with a specific production capacity. For final economic analysis results, the capacity value is in terms of annual refined gold output. However, the actual capacity constraints are in terms of the material processed at each stage. The level of gold output will depend on the grade of ore being mined and the recoveries at each stage. Separate cost estimates are made for the processes that occur at each stage of an operation and for the specific form of material processed in that stage.

Cost data are collected directly from site visits whenever possible. Most of the chapter authors were able to visit and collect information at many of the evaluated mines and processing operations in the countries or regions they describe. If company data are made available, the Bureau evaluators may adjust the data based on their observations made during the site visit. When appropriate, evaluators have used other sources to verify values obtained from outside sources, or to make estimates when no other data are available.

Cost items estimated include a variety of operating cost and capital expenditure categories, administrative overhead, and even infrastructure, when it is necessary to the operation of the property. Mine and mill operating cost estimates for the purpose of availability analyses are long-run averages and specific mine plans are taken into account in evaluations. All operations are treated as separate corporate entities, and all expenditures are assumed to come from 100 pct equity funding, unless information is available to the contrary. It is

Cumulative production	IDENTIFIED RESOURCES		
	Demonstrated		Inferred
	Measured	Indicated	
ECONOMIC	Reserves		Inferred reserves
MARGINALLY ECONOMIC	Marginal reserves		Inferred marginal reserves
SUB-ECONOMIC	Demonstrated subeconomic resources		Inferred subeconomic resources

Figure 1.--McKelvey reserves/resources classification scheme.

further assumed that all facilities operate at the full analyzed capacity production level.

Operating costs include charges for materials, utilities, direct and maintenance labor, payroll overhead, technical and clerical staff, administrative costs, facilities maintenance and supplies, and research. Either actual or estimated capital expenditures are included for exploration, acquisition, mine development, mine plant and equipment, beneficiation plant and equipment, infrastructure, working capital and all necessary reinvestment in the operations. Capital expenditures for mining and processing facilities include the costs of mobile and stationary equipment, construction and engineering. Infrastructure includes the cost of access and mine facilities, water facilities, power supply, and personnel accommodations. Working capital is a revolving cash fund required for such operating expenses as labor, supplies, taxes, and insurance. For these studies, working capital was generally estimated as 2 to 3 months of operating costs or actuals were used. Other costs included in the analysis are charges such as Federal, State and local taxes, royalties, insurance, depreciation and amortization, deferred expenses, depletion allowance, and return on investment. Corporate overhead or home office charges that could not be tied directly back to a specific operation were not included.

AVAILABILITY ANALYSIS PROCEDURES AND RESULTS

The objective of the availability analysis is to categorize the amounts of gold available from each gold-producing region or country according to the cost of production. This allows an analyst to estimate the competitive position of each major supply source relative to others in the market. Policy options and risk factors can be evaluated in terms of how they affect competitive

positions, and whether they provide the incentives to continue production at current levels, or to expand or contract.

All of the regions discussed in this volume have a strong focus on the level of total operating costs at current producing properties. In some cases availability of gold is presented in terms of these operating cost levels. In most cases, availability results reflect needed capital costs, royalties and tax payments, thus allowing the competitive positions of nonproducers to be compared to producing operations.

For a full availability analysis, the cost data for all aspects of each operation and the parameters of the flowsheet are entered into a financial evaluation program (the Bureau's MINSIM/SAM cash flow model) to determine an average overall cost of production. That is, the evaluation program solves for a price of gold at which investment in the property would obtain a prespecified target rate of return. This rate of return is referred to as the discounted cash flow rate of return, or DCFROR.

The taxes, royalty rates, and other fees which apply in each country are automatically applied to each property when the evaluation program is run. Similarly, the evaluation program contains a database of internal inflation factors and a time series of currency exchange rates so that all evaluations are performed in U.S. dollars for a specific time period. Cost values reported in this volume are mostly in constant (1991 or 1992) U.S. dollars.

Separate financial evaluations are made for each operation at different target rates of return, generally at 0-, 10-, and 15-pct DCFROR's. For a 0-pct DCFROR, referred to as "breakeven", the solved-for price of gold allows an operation to recover all costs including capital expenditures, but no positive rate of return is achieved. Alternatively, the solved-for price of gold which

would allow a 10- or 15-pct DCFROR was considered a reasonable target rate of return to induce potential investors to develop a gold property.

The results of the availability analyses for each country are presented in a variety of tables and graphics accompanying each country and region report. Each of these forms shows an amount of gold "available" to the market at different levels of cost. The most common presentation is in the form of an availability curve. This shows a cumulative tonnage, ordered from lowest cost source to highest cost source. By superimposing the market price for gold onto this graph, the relative profitability of operations is shown, suggesting how operating rates might change as conditions in the market change.

The availability curves are not supply curves in the conventional sense. They do not reflect all the concerns and conditions which determine a producer's "short-term" response to changing market conditions. For example, some gold mining operations have the flexibility to respond to price changes with an adjustment to the grade of material being mined, mining higher grade material in periods of low price, and vice versa. Another adjustment might be to do more waste rock stripping at surface mines in periods of high prices, so that the mine can avoid costly stripping during periods of low prices. Another short-term response to falling prices may actually produce a rise in gold output as some deposits, mainly underground operations, are high-graded.

The choices made at specific mining operations are also influenced by another unique characteristic of the mining industry: an operation only continues until the ore body is exhausted. At that point a company must find a new ore body and make the large, up front investments to begin a new operation. For gold, the size of ore bodies is generally small in relation to production

capacity. Often the expected life of a mine will be less than 10 years, sometimes as little as 3 or 4. The incentive is to completely mine out an ore body rather than abandon it when the price falls temporarily to a level that might have deterred investment had it been anticipated.

In the longer term, output from the industry will be affected by the relationship between cost and price. Development expenditures will not be made unless an owner expects a profit. Exploration dollars will not flow to the gold sector unless there is a reasonable expectation that profitable ore bodies can be found. And always there is the competition between different regions of the world which may have more prospective areas to explore, or may offer more attractive financial incentives for investment.

TECHNOLOGIES FOR MINING AND PROCESSING GOLD

Mining is inherently risky and uncertain. No two ore bodies are the same; they all require a unique approach. Mining and processing techniques are individually tailored to match the spatial configuration and the chemistry of the material being mined and processed.

Basic technologies for mining and processing gold have been known and practiced for thousands of years. The technologies employed first were appropriate to the earliest sources for gold: alluvial deposits in stream beds containing high values of free gold. These were mined by labor-intensive gravity methods, aided by crushing to mechanically free the gold from enclosing rock. Gravity concentration is still the preferred method for these deposits, but the number of appropriate ore bodies is relatively small.

Surface mining operations begin with the removal of soil (which is stockpiled for reclamation

purposes) and waste rock to expose the ore body. Ore and associated waste are separately drilled and blasted. The stripping ratio (ratio of waste rock material to ore) is a significant economic factor which affects both capital and operating costs.

For smaller operations, ore and waste are loaded into haul trucks by front-end loaders. Larger operations utilize hydraulic excavators and shovels. The waste material is hauled to dump areas while the ore is hauled to stockpiles or directly to the processing facility.

When compared to surface mines, underground mines are generally much smaller in physical size and capacity and do not generally have the same level of benefit of economies of scale. For this and other reasons such as safety considerations, underground operations incur proportionately greater capital and operating costs when compared to surface operations on a per ton of ore basis.

Important technical factors to consider in analysis of underground mining economics are (1) depth of mining, (2) width/height of workings, (3) competency of host rock and occurrence of mineralization, (4) access methods, and (5) haulage considerations. The underground mining methods chosen depend on these factors. Some mining methods are conducive to large capacity operations (e.g., room & pillar) and some require much smaller, more labor-intensive operations (e.g., cut & fill).

The evolution of technology for recovering gold has paralleled the evolution in types of ore bodies available for mining and processing. Mercury was discovered long ago to have an affinity for gold, amalgamating the gold from concentrated material obtained by mechanical methods. However, the decreasing availability of placer deposits and the deleterious health effects from mercury led to its replacement by other methods of separating gold. Various flotation methods have been used to separate gold from sulfidic ores, sometimes

in conjunction with an oxidative pretreatment phase to break down some of the complex chemical forms in which gold is found. Smelter/refinery operations can also be utilized to recover gold when it is in concentrated forms, or if ore high in silica is added as smelter flux.

In 1886 cyanide was discovered to have an ability to form a precious metal complex with gold and was utilized in leaching gold from the most common host rock known at that time, the reefs of the Witwatersrand Basin in South Africa. Ores in New Zealand were being cyanide leached about the same time (22). Cyanide leaching in tanks is currently the most common form of processing primary lode gold ores. Cyanide leaching of heaps and dumps is one of the more recent developments. In the last 15-20 years heap leaching has developed into the low-cost method for obtaining gold from low-grade oxidized ore, and now accounts for about a third of U.S. production.

The treatment methods available to the U.S. gold industry are very diverse. Figures 2 and 3 graphically summarize the variety of approaches available. For categorization purposes, the simplest split is into (1) material treated using dump/heap leaching and (2) material that is subjected to grinding (milling ore).

In regular heap leaching, the mined material is subjected to crushing before placement on the leach pads. The added cost of crushing and, sometimes, agglomeration of the ore makes regular heap leaching more expensive, on an ore treated basis, than run-of-mine (ROM) or dump leaching.

Likewise, ore that is milled (i.e., ground) is more expensive, on an ore treated basis, than either ROM/dump or regular heap leaching because of the need for additional size reduction. The additional size reduction for "milling ores" is usually necessary because of the nature of the gold occurrence in the ore.

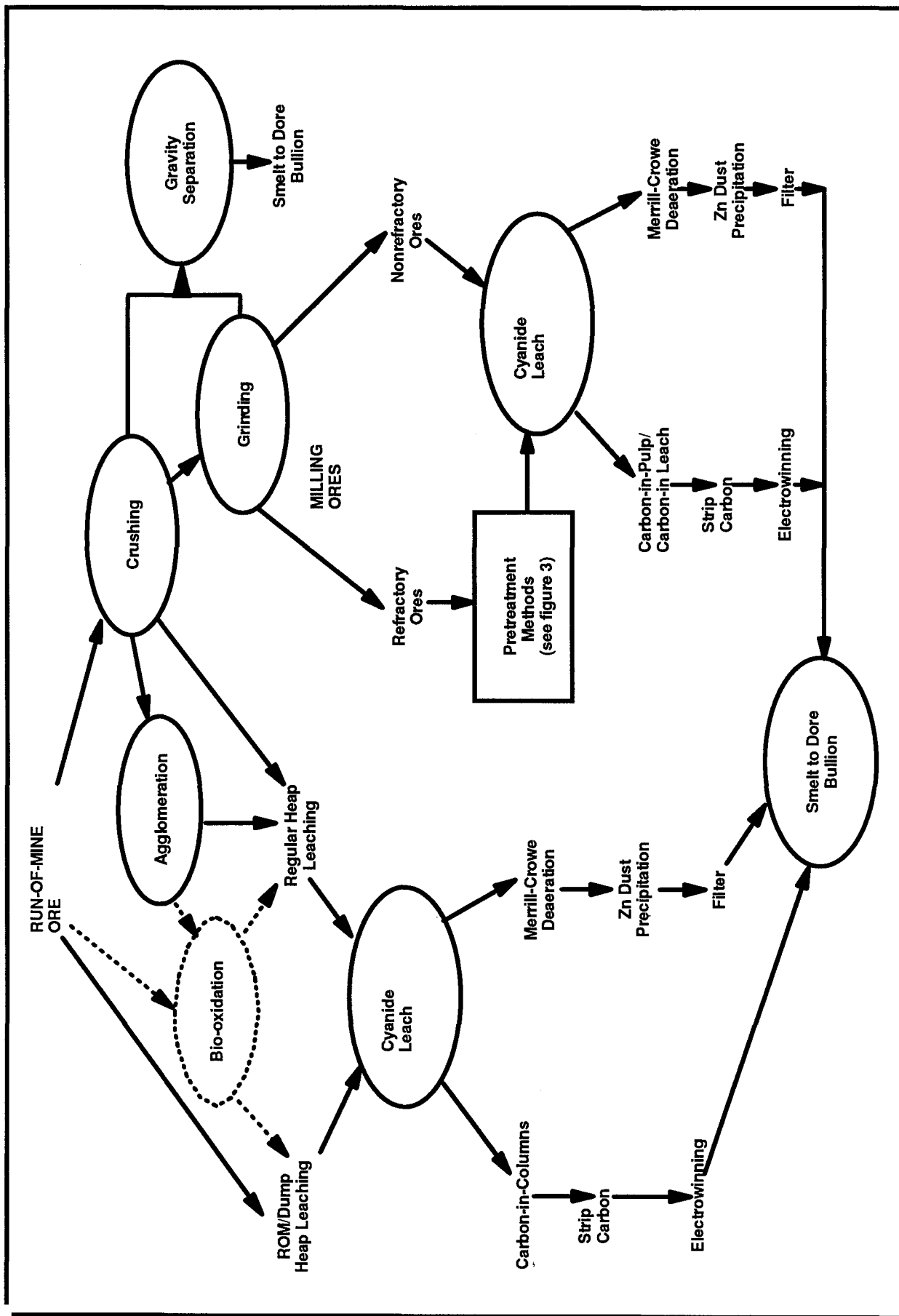


Figure 2.--Processing technologies for gold ore.

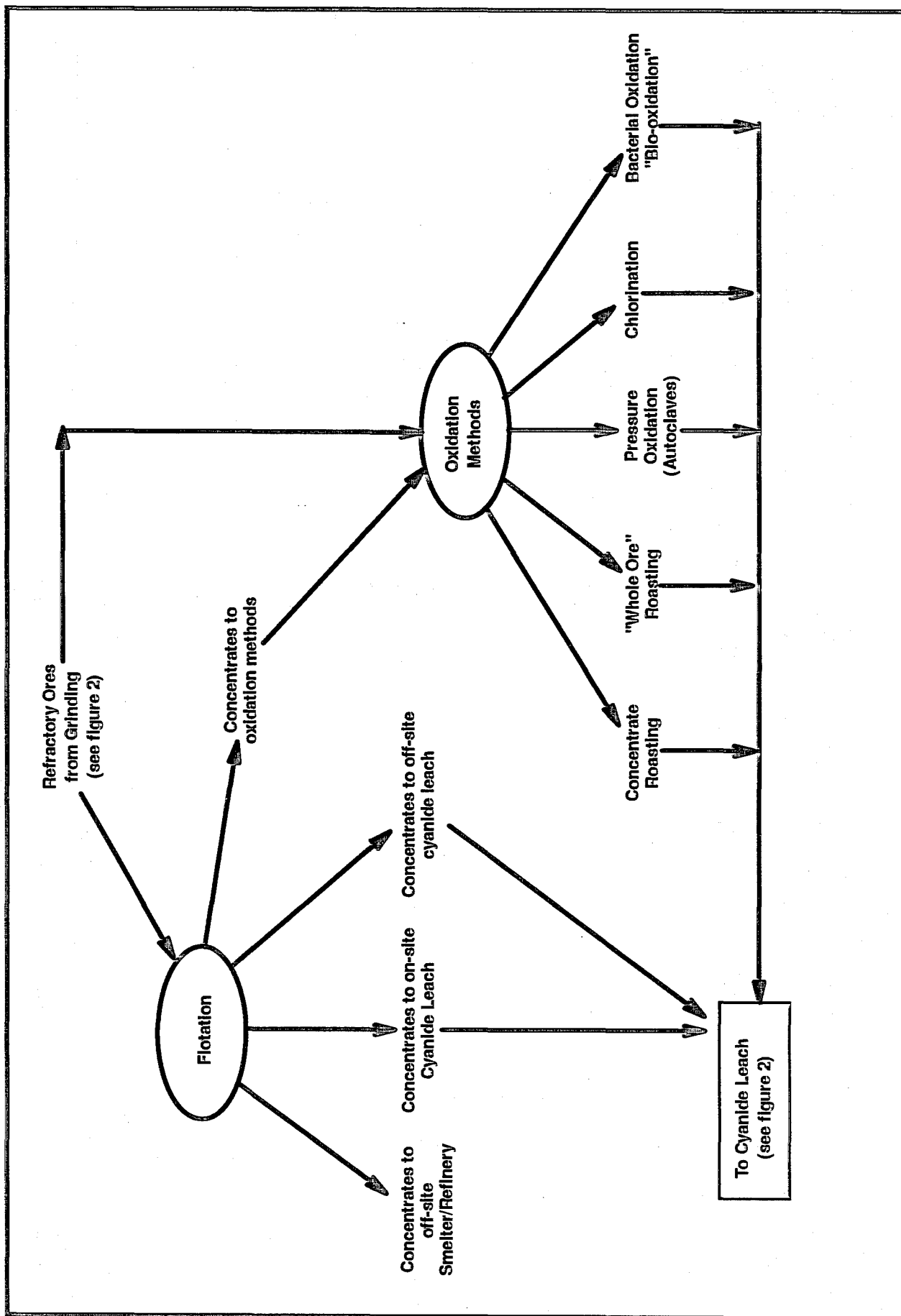


Figure 3.--Pretreatment processes for sulfide ores.

In the milling ore category the principal differentiation is between refractory ores and non-refractory ores. Refractory ores, by definition, are "difficult to treat". In gold treatment, this generally means that cyanide leaching, by itself, of the milled ore will only give recoveries of 80 pct or less. Usually, this is due to the gold particles being silica encapsulated or closely associated with sulfitic or carbonaceous materials.

As shown in figure 3, there are now a variety of ways to treat refractory ores. The primary methods used in the United States are whole ore roasting or pressure oxidation. Bio-oxidation, particularly bio-heap leaching, is gaining some acceptance. The sulfides can be concentrated by flotation methods, resulting in a gold-containing concentrate of much smaller volume or whole ore processing may be used. The concentrate can undergo oxidative pretreatment and be cyanide leached or be sent to an off-site smelter/refinery for further gold extraction. Application of oxidative pretreatment methods releases the gold particles from the gangue minerals for further extraction by cyanide leaching, at much improved recoveries.

There are two additional points to emphasize with respect to the processing of gold bearing ores. First, processing costs are major cost items for most mines. Second, each additional processing step adds costs and therefore higher grades are necessary to make the ore types requiring additional processing steps economic to produce.

CHAPTER 2

UNITED STATES GOLD AVAILABILITY

by Edward H. Boyle, Jr.¹

This chapter analyzes the availability of gold from the world's second largest producing nation in 1991 and 1992, the United States of America. In 1992, U.S. gold mining operations produced over 330 mt of gold or 15 pct of total world output. More than 90 pct of this came from primary lode gold mines.

Total production costs to obtain a 15-pct DCFROR from extracting proven and probable reserves as of Jan. 1992 are estimated to average \$368/tr oz for 33 major producing properties that accounted for 70.2 pct of total 1992 U.S. gold production and \$618/tr oz for 8 nonproducing properties.

The 33 producers contain 3,104 mt (99.8 M tr oz) of gold in reserves; the 8 nonproducers contain 555.9 mt (17.9 M tr oz) of gold in reserves. The overall recovery rate for all 41 properties is estimated to be 82 pct.

The study found (1) there is a two-tier aspect to the relative profitability levels of the U.S. gold mining industry, and (2) 37.3 pct of the total of 3,001 mt (96.5 M tr oz) of recoverable gold in all 41 properties is contained in only two producers. Small shifts in gold price levels may have large impact on profitability, measured by rate of return.

INTRODUCTION

The purpose of the study is two-fold. First, it will explore the development of the United States gold industry from the fifth largest gold producing country in 1982, behind the Republic of South

Africa, the former Soviet Union, the People's Republic of China, and Canada (23) to its present position as second largest (behind only South Africa) (4). Second, the technical, reserve, and cost position of the industry as of the early 1990's will be described and the potential gold availability and total cost structure, as of the study date, will be assessed. An expanded discussion of this analysis will be contained in a planned Open File Report on gold availability from the United States of America.

All 41 properties analyzed in this study--33 in production and 8 not in production as of Jan. 1992--are listed in table 1. The producers accounted for 231.1 mt (7.43 M tr oz) of production in 1992, representing about 70 pct of total U.S. production and more than 75 pct of production from primary lode gold mines in that year. Only six analyzed producers--Newmont Mining Corp.'s Carlin Trend operations, the venerable Homestake mine in South Dakota, the Zortman/Landusky operations in Montana, and the Round Mountain, Jerritt Canyon, and Pinson/Preble mines in Nevada--were in production in 1981 and have produced throughout the 1982-92 period. The other 27 are all new producers since 1981.

Figure 4 illustrates U.S. production for the period 1982-92. It shows dramatic increases in all categories. On a percentage basis, total production increased 625 pct, production from primary gold mines increased 778 pct, and production from the 33 producers included in the availability analysis increased

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Table 1.—Status, major ownership, mining and treatment types, and first year of production during the 1982-92 period;
U.S. gold properties analyzed in the availability study

Status/state	Property name	Largest ownership position (As of the study date)	Mining Types ¹	Treatment Types ²	Year of first production 1982-1992 ³
Producers:					
California	Castle Mountain	Viceroy Resources Corp.	S	HL	1992
	Hayden Hill	AMAX Gold Inc.	S	HL	1992
	McLaughlin	Homestake Mining Co.	S	MR(AC)	1985
	Mesquite	Santa Fe Pacific Corp.	S	HL	1986
	Royal Mountain King	FMC Gold Co.	S	MR(F)	1989
Colorado	San Luis	Battle Mountain Gold Co.	S	M	1991
Montana	Beal Mountain	Pegasus Gold Inc.	S	HL	1988
	Golden Sunlight	Placer Dome Inc.	S	M	1983
	Zortman/Landusky	Pegasus Gold Inc.	S	HL	Pr
Nevada	Bald Mountain	Placer Dome Inc.	S	HL	1983
	Bullfrog	Lac Minerals Ltd.	S/U	M	1989
	Chimney Creek	Santa Fe Pacific Corp.	S	HL/M	1987
	Florida Canyon	Pegasus Gold Inc.	S	HL	1986
	Getchell	First Mississippi Corp.	S	HL/MR(AC)	1985
	Gold Bar	Atlas Corp.	S	M	1987
	Goldstrike (Carlin)	American Barrick Resources Corp.	S	HL/M/MR(AC)	1982
	Hollister	Newmont Mining Corp.	S	HL	1990
	Jerritt Canyon	Independence Mining Co. Inc.	S	HL/MR(C/WOR)	Pr
	Marigold	Rayrock Yellowknife Resources Inc.	S	HL/M	1989
	McCoy/Cove	Echo Bay Mines Ltd.	S	HL/M/MR(F)	1986
	Newmont (Carlin)	Newmont Mining Corp.	S	HL/M/MR(WOR)	Pr
	Pinson/Preble/Kraemer Hill	Rayrock Yellowknife Resources Inc.	S	HL/M	Pr
	Rabbit Creek	Santa Fe Pacific Corp.	S	HL/M	1990
	Rawhide/Denton	Kennecott Corp.	S	HL	1990
	Round Mountain	Echo Bay Mines Ltd.	S	HL	Pr
	Sleeper	AMAX Gold Inc.	S	HL/M	1986
	Ridgeway	Kennecott Corp.	S	M	1988
	Annie Creek/Foley Ridge	Wharf Resources Ltd.	S	HL	1983
	Homestake (Lead)	Homestake Mining Co.	S/U	M	Pr
Utah	Barney's Canyon	Kennecott Corp.	S	HL	1989
	Mercur	American Barrick Resources Corp.	S	DL/M/MR(AC)	1983
Washington	Cannon	Asamera Minerals Inc.	U	MR(F)	1985
	Kettle River	Echo Bay Mines Ltd.	S/U	M	1990
Nonproducers:					
Alaska	Alaska-Juneau	Echo Bay Mines Ltd.	U	M	NAP
	Fort Knox	AMAX Gold Inc.	S	M	NAP
	Kensington	Echo Bay Mines Ltd.	U	MR(F)	NAP
California	Pine Tree	Northwest Gold Corp.	S	MR(F)	NAP
Idaho	Atlanta Project	Atlanta Gold Corp.	S	HL	NAP
Montana	New World Project	Crown Butte Resources Ltd.	U	MR(F)	NAP
Oregon	Grassy Mountain	Newmont Mining Corp.	S	HL/M	NAP
Washington	Crown Jewel	Crown Resources Corp.	S	M	NAP

NAP Not applicable.

Pr First year of production was prior to 1982.

¹S = surface mining, U = underground mining, S/U = combination of surface and underground mining.

²HL = heap leaching, DL = dump leaching, M = nonrefractory ore milling, MR = refractory ore milling (AC = Autoclaves, F = flotation, WOR = whole ore roasting, and C = chlorination).

Source: Compiled from various available public documents such as mining industry periodicals and company annual reports.

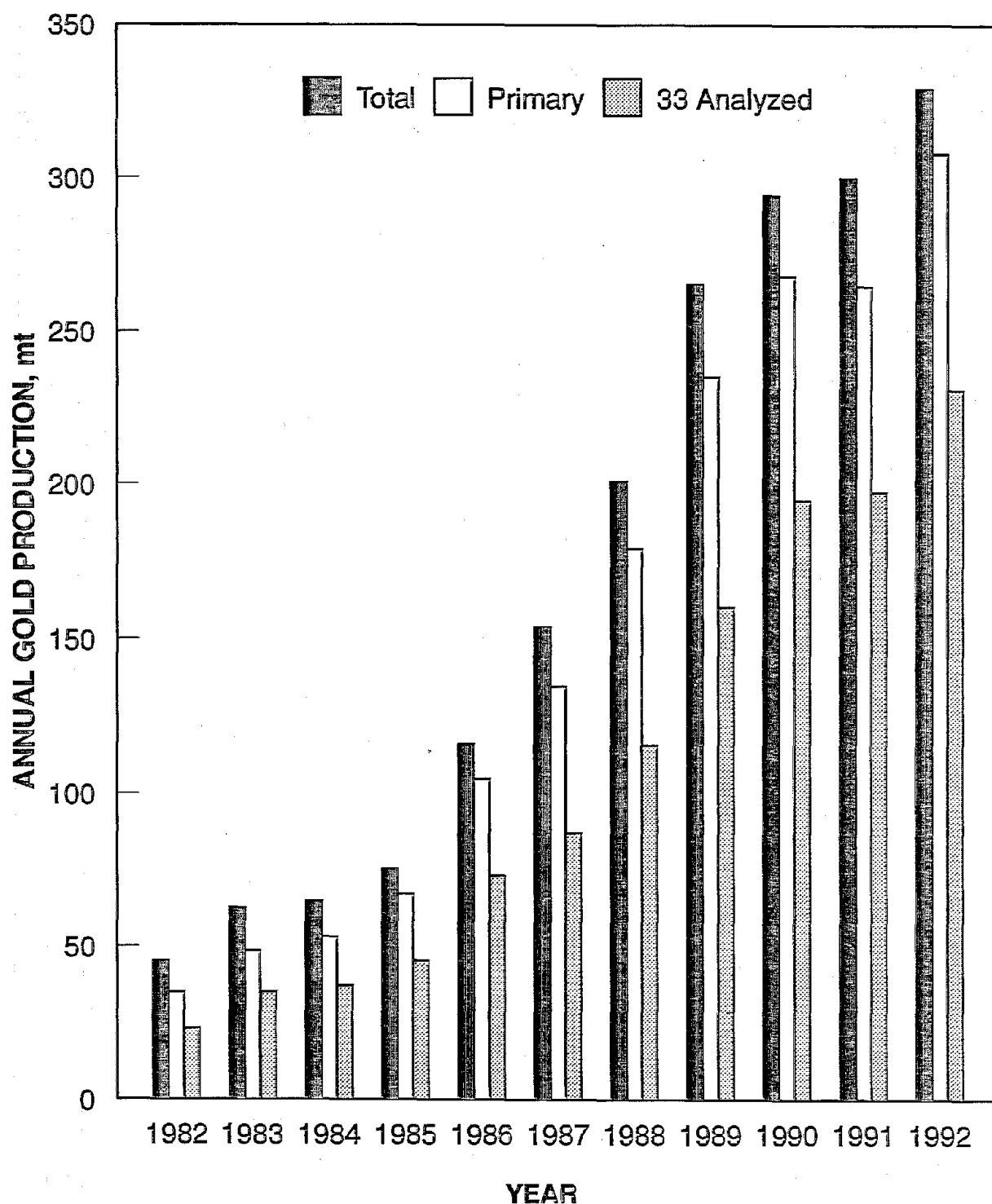


Figure 4.--Annual gold production in the United States, 1982-92; total, primary, and 33 producers analyzed for the availability study.

Source: Lucas (24), and various public documents such as journal articles and company annual reports.

895 pct. The major contribution to increased production from primary gold mines over this period has been from operations beginning production after 1981. The 8 nonproducers listed represent a sampling of the larger nonproducing properties that were at the most advanced stage of exploration, study, and permitting as of 1991. A compilation and short discussion of 28 other nonproducing properties as of 1994 will be included in the planned Open File Report.

In 1979, U.S. production hit the lowest level since 1848. In that same year, world market gold prices surged to unheard of levels, peaking in the low \$800/tr oz range in January 1980. The price increase, along with technical developments such as heap leaching and gold extraction with carbon methods and financial developments combined to cause the surge in U.S. production during the 1980's and early 1990's.

Comparing 1981 to 1991, U.S. Bureau of Mines statistics reveal a trend toward fewer producers, bigger deposits, and larger, more efficient mines (25). The ratio of reserves to production (r/p) for the primary gold mines--a measure of relative longevity of reserves--declined. Also, the amount of contained gold in reserves at all types of operations grew from nearly 2,200 mt to about 4,800 mt between 1981 and 1989, but has stagnated since then.

One of the most important trends is shown graphically in figure 5. It illustrates that the average, overall ore head grade² at primary gold mines in the U.S. from 1981 through 1991 has declined significantly.

GEOLOGY

Primary gold deposits in the United States occur in a multitude of geologic settings, making classification and general discussion very difficult. In a simple scheme, they can be classified into three separate

types: (1) placer deposits, (2) lode deposits, and (3) disseminated lode deposits.

There are no placer operations included in this updated availability report. This reflects their relative insignificance in the present U.S. gold mining industry outside of the State of Alaska. Placer deposits are generally small and utilize the simplest of mining and processing techniques to free the gold. The combined production from all placer mining operations is presently 1.5 pct of total U.S. gold output(4).

In lode (hardrock) deposits, the gold particles occur in quartz veins or in enclosing country rock. Vein deposits usually extend downward, at some angle, to considerable depth; sometimes thousands of meters. Because of this, the majority of lode deposits are mined using underground mining methods. Additionally, the gold particle occurrences are not always free, many times being intimately associated with grains of other minerals, such as sulfides. The processing of lode ores is much more expensive than placer ores because of the need to separate the gold particles from the enclosing gangue rocks and minerals.

Disseminated deposits were identified as a deposit type in the 1960's, although geologically similar deposits were known long before then. They are included by the Bureau in the lode production category; however, their distinctive and important nature deserves a separate discussion.

The Carlin Trend deposits of Nevada were the first major example of this deposit type. Typically, these hardrock deposits are characterized by very fine-grained gold particles (0.00001 to 0.01 mm) disseminated throughout calcareous host rocks, although variants

²The ore head grade is the grade of the material fed to treatment processes such as heap leaching or milling.

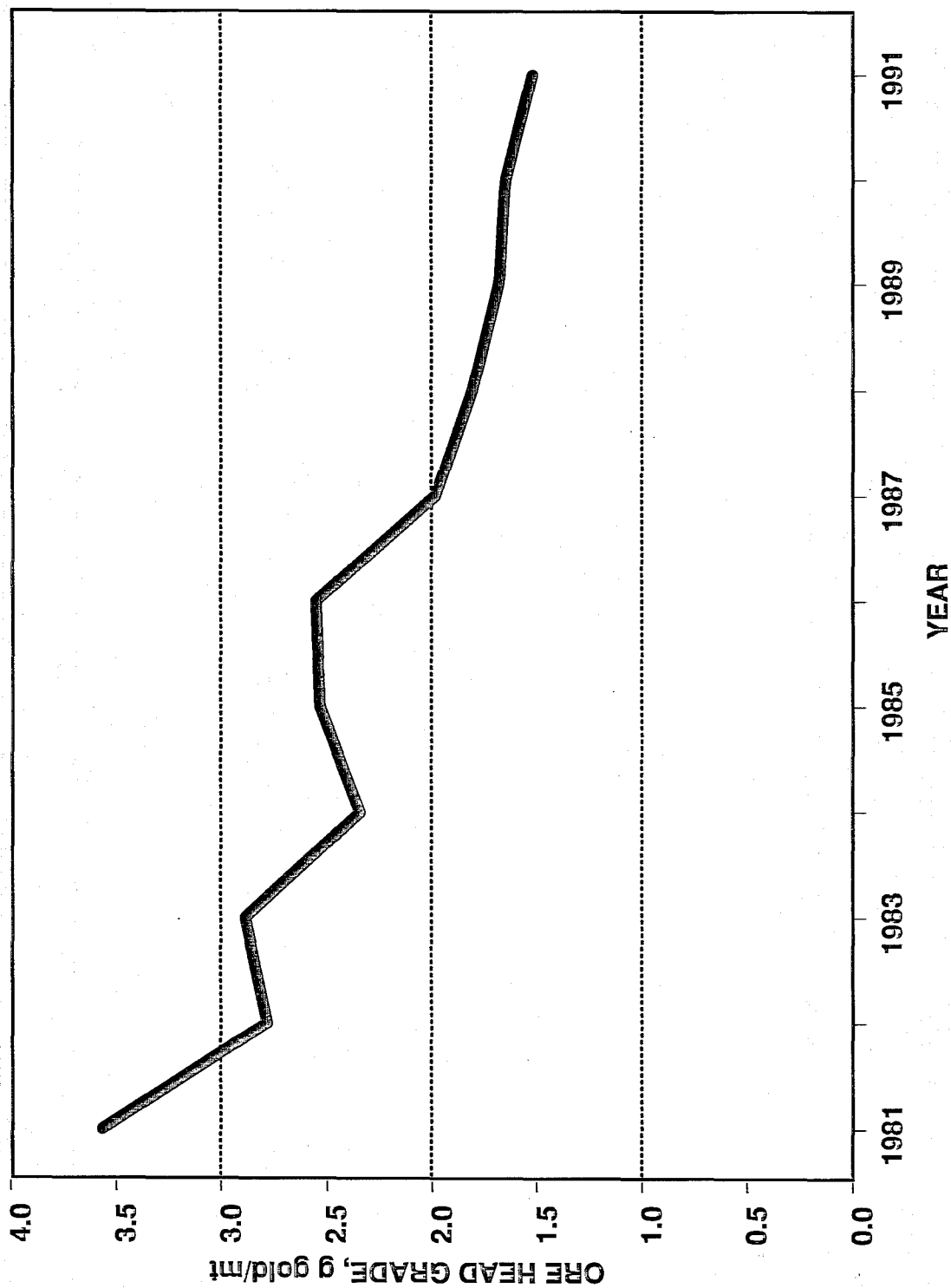


Figure 5.--Average ore head grade, 1981-91; U.S. primary gold mines.¹

¹ Average ore head grade is for all primary U.S. producing mines. Average U.S. grade shown in Table E-3 includes only the 33 largest primary producers. Weighting factors for average grades are based on annual gold production.

Source: Slater and Ward (25).

(stockworks, veins, breccias) and different host rocks (mainly volcanic) are known. Most disseminated gold deposits have a high gold-to-silver ratio and are associated with arsenic, mercury, carbonaceous material, silica, and intrusive rocks. Most of the disseminated deposits have been found in the southwestern United States, primarily in Nevada, Utah, and southern California. They constitute the vast majority of present production in Nevada.

Because of the generally low grade and relatively recent nature of their exploitation, nearly all production from disseminated deposits is by open pit methods. However, zones at depth within several of the deposits are of high enough grade that underground mining methods will eventually be employed after the surface minable ores are depleted.

RESERVES AND RESOURCES

When discussing gold reserves and resources, it is critical to distinguish between the contained gold amount, which is the gold content prior to mining and treatment, and the recoverable gold amount, which takes into account expected mining and beneficiation losses in producing a marketable doré bullion product. This is because a significant portion of U.S. reserves will be processed using heap or dump leaching and about 6 pct of production comes as byproduct gold from copper operations. For both these sources, gold recoveries generally range from 60 to 70 pct. To address these distinctions, separate discussions of contained and recoverable values are given in this section.

TOTAL RESERVES

According to the Bureau's Mineral Commodity Summaries (MCS) 1993 (26), U.S. gold reserve for the year 1992 contained 4,770 mt (153.4 M tr oz) within a reserve base containing 5,050 mt (162.4 M tr oz). This is more than twice

the estimate in the MCS 1982 (27), which lists the U.S. reserve base as 2,177 mt (70 M tr oz).

At present, there is no published estimate of total recoverable gold. To accomplish this, every mine and deposit included in the compilation should have an estimate made of the extraction technologies to be used and the expected recoveries from application of those technologies. A rough estimate can be made by applying a recovery factor of 76.2 pct. This was the average recovery rate for 1991 as determined by Slater and Ward (25). Use of this factor gives an estimated value for total recoverable gold in the U.S. reserve base as of 1992 of 3,848 mt (123.7 M tr oz).

RESERVES ANALYZED IN THE AVAILABILITY STUDY

The base Jan. 1992 analyzed reserve values mainly are from the American Mines Handbook 1993(28) which compiles company reported information from annual reports and 8K and 10K forms. Other sources were the actual corporate reports and property evaluation data from studies by Bureau employees. The 41 properties analyzed contain an

³Reserves are defined in the MCS as "...that part of the reserve base which could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative."

⁴The reserve base is defined in the MCS as "...that part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated".

estimated 3,660 mt (117.7 M tr oz) of gold in their Jan. 1992 proven plus probable reserves, which is more than 75 pct of the total U.S. reserve estimate given in MCS 1993. Based on actual or proposed mining and treatment technologies, an estimated 3,001 mt (96.5 M tr oz) of gold will be recoverable from all 41 properties (table 2).

Contained and Recoverable Gold in Producing Properties

The 33 producing properties contain approximately 3,104 mt (99.8 M tr oz) of gold in a total of 1.68 billion mt of ore grading 1.86 g gold/mt in proven and probable reserves as of Jan. 1992. Ore for milling⁵ has a relatively higher grade and comprises 66.1 pct of total contained gold. Ore for dump/heap leaching, grading 0.90 g gold/mt, accounts for the remaining 33.9 pct of total contained gold.

The weighted average recovery factor for the milling ore was 87.9 pct resulting in a yield (recoverable) grade for the U.S. milling ore of 3.55 g gold/mt ore. The weighted average recovery factor for the dump/heap leach ore was 67.4 pct resulting in a yield (recoverable) grade for the U.S. dump/heap leach ore of 0.61 g gold/mt ore. Milling ore contains 71.8 pct of the recoverable gold and dump/heap leaching ore contains 28.2⁶ pct of the total recoverable gold.

The overall treatment recovery for all 33 producers was 81 pct, and the overall yield (recoverable) grade for all the reserve tonnage in the 33 producers is 1.51 g gold/mt.

Contained and Recoverable Gold in Nonproducing Properties

The 8 nonproducing properties contain approximately 556 mt (17.9 M tr oz) in a total of 328 million mt of ore grading 1.70 g gold/mt in proven and probable reserves as of

Jan. 1992. The vast majority of this tonnage (304 million mt grading 1.66 g gold/mt) is proposed for milling and contains 90.9 pct of the gold; only 23 million mt grading 2.19 g gold/mt is proposed for dump/heap leaching and contains 9.1 pct of the gold.

Milling ore contains 93.1 pct of the total recoverable amount; only 6.9 pct of the total recoverable gold is from dump/heap leaching ores.

The weighted average recovery factor for the dump/heap leach ore is 65.9 pct resulting in a yield (recoverable) grade for the nonproducing heap leach material of 1.44 g gold/mt ore. The weighted average recovery factor for the milling ore is 90 pct resulting in a yield (recoverable) grade of 1.49 g gold/mt ore.

The overall treatment recovery for all 8 nonproducers is a high 87.8 pct reflecting the large percentage of ore that is proposed for milling. The overall yield grade for all the reserves contained in these 8 nonproducing properties is 1.49 g gold/mt, which is nearly identical to the yield grade for the 33 producers. More detailed breakdowns and discussions of treatment aspects will be provided in later sections.

MINING AND TREATMENT

Three types of mining operations are represented in this availability analysis: entirely surface mining operations (29 of

⁵See Chapter 1 for definition of milling ore and heap leaching ore.

⁶This value--28.2 pct of the total recoverable gold in producing properties contained in heap leaching ore--compares with the following percentages of total U.S. gold production represented by heap leaching: 1981-19.2 pct, 1982-26.7 pct, 1991-33.0 pct, 1992-35.0 pct (23, 29).

Table 2.--Contained and recoverable U.S. gold analyzed in the study
disaggregated by operational status and milling method
(metric tons)

Milling method	Producing properties (33)		Nonproducing properties (8)		Total all properties (41)	
	Contained gold	Recoverable gold	Contained gold	Recoverable gold	Contained gold	Recoverable gold
Milling ore . .	2,051	1,803 (58.0 M tr oz)	505	454 (14.6 M tr oz)	2,556	2,257 (72.6 M tr oz)
Dump/leach ore	1,053	710 (22.8 M tr oz)	51	34 (1.1 M tr oz)	1,104	744 (23.9 M tr oz)
Totals . .	3,104	2,513 (80.8 M tr oz)	556	488 (15.7 M tr oz)	3,660	3,001 (96.5 M tr oz)

Source: Compiled from various published documents, company annual reports, and USBM engineering estimates.

the gold producers and 5 of the nonproducers), entirely underground mining operations (only 1 of the producers and 3 of the nonproducers), and combination surface/underground mining operations (3 of the producers).

Table 3 shows the breakdown of the total reserves analyzed in the availability study in terms of surface minable and underground minable tonnages and grades. Nearly 93 pct of the total reserve tonnage is surface minable while about 7 pct of the tonnage is underground minable. In contrast, the underground minable tonnage contains more than 13 pct of the total gold, reflecting the higher grade of ore required to make underground mining economic. Seven percent of the producers' contained gold and 49 pct of the nonproducers' contained gold is in underground minable reserves.

SURFACE MINING

The surface mining operating cost estimates for producers in this study reflect a range of waste to ore ratios from 0.4 to 15.1 mt waste per mt ore. Weighted on the basis of annual ore output, the overall average is 2.7 mt waste per mt ore.

Operating cost estimates for the nonproducers in this study are based on a narrower range of waste to ore ratios of from 0.9 to 11.0 mt waste per mt ore. Weighted on the basis of annual ore output, the overall average for nonproducers is 2.5 mt waste per mt ore.

All current producers have mines located in close proximity to treatment facilities. However, as the search for replacement reserves continues, new deposits will be found at greater distances from existing treatment facilities and the ore transport cost is likely to become more important.

Surface Capacities

Table 4 summarizes the various annual capacities for ore and ore

plus waste that are represented in this availability analysis. On average, producing surface gold mining operations in the U.S. are moving extraordinary amounts of material in an attempt to obtain the best economies of scale. In this regard, they have been assisted in the 1970's and 1980's by a noticeable improvement in the size and quality of available equipment from the manufacturers. For the nonproducers, the range of material moved is narrower than for producing operations and the average amount of material moved is smaller.

Surface Operating Costs

Table 4 also summarizes ranges and weighted averages for the various mine operating costs. On a per mt of material moved basis, operating costs estimates for the nonproducers are higher than those estimated for the producers. This is most likely due to smaller sized operations (an average of 13,180,000 mtpy versus 21,480,000 mtpy moved). However, because of a smaller overall average waste/ore ratio (2.56/1 versus 2.71/1), the difference in operating costs between nonproducers and producers on a cost per mt ore basis is not as great.

UNDERGROUND MINING

Four of the producing properties analyzed in this study utilize underground mining. Most employ more than one mining method. Among the methods used are:

- End-slicing
- Room-and-pillar and panel-and-pillar
- Shrinkage stoping
- Vertical crater retreat (VCR)
- Mechanized, overhand, and open cut-and-fill.

Three of the nonproducing properties are proposed to use

Table 3.—Surface and underground mineable reserve breakdown;
U.S. reserves analyzed in availability study

Status	Mining type	Tonnage (kmt)	Pct mineable ore	Wtd avg grade (g gold/mt)	Pct contained Au	Grade range ¹ (g gold/mt)
Producers:						
	Surface mineable	1,638,000	98	1.76	93	0.49-4.86
	Underground mineable	36,000	2	6.02	7	4.96-9.74
	Total mineable	1,674,000	100	1.86	100	0.49-9.74
Nonproducers:						
	Surface mineable	216,000	66	1.30	51	0.82-6.38
	Underground mineable	112,000	34	2.44	49	1.75-6.96
	Total mineable	328,000	100	1.70	100	0.82-6.96

¹Compiled on a property-by-property basis.

Source: Compiled from various published documents, company annual reports, and USBM analysis.

Table 4.—Summary of annual capacities and operating cost estimates,
by mining type and status; U.S. availability study

Mining type/status	Material category	Annual capacity ¹ (kmtpy material)		Operating cost estimates ¹ (Avg 1991 \$/mt material)	
		Range	Average	Range	Wtd avg ²
Surface mining:					
Producers	Ore	130 - 52,500	5,760	1.21 - 31.40	3.80
	Ore plus waste	1,090 - 183,750	21,480	0.68 - 2.20	1.02
Nonproducers	Ore	990 - 11,790	3,740	2.28 - 11.64	4.01
	Ore plus waste	5,250 - 22,400	13,180	0.97 - 1.31	1.14
Underground operations:					
Producers	Ore	300 - 1,940	820	14.63 - 35.38	30.33
Nonproducers	Ore	500 - 7,350	3,050	9.06 - 23.88	11.25

¹Compiled on a property-by-property basis.

²Weighted on basis of annual ore capacity.

Source: Various published documents, company annual reports, and USBM estimates

underground mining methods for 100 pct of the analyzed reserves. Two of the three will use long-hole stoping methods and the third will be a traditional cut-and-fill operation.

Underground Capacities

Table 4 also summarizes the various annual ore capacities for underground operations. The underground ore capacities proposed for the nonproducers are much larger than for the producers. These relatively high values for the nonproducers are heavily influenced by a very large (7.35 M mtpy) proposed underground operation in Alaska.

Underground Operating Costs

The estimated weighted average underground mine operating cost for nonproducers is about one third the level estimated for the producers. This is not unexpected since two of the three nonproducers are planning to use relatively high-tonnage, long-hole open stoping methods. These relatively high annual capacity levels will result in significant economies of scale.

TREATMENT

The mix of treatment schemes for the 33 producers is quite balanced; 12 are entirely heap leach operations, 10 are entirely milling ore operations, and 11 are combination heap leach/milling ore operations. In contrast, the nonproducers in this study are heavily oriented toward proposed milling of their ore reserves; six are proposed to be entirely milling ore operations, one will be a heap leaching operation, and another will be a combination heap leach/milling ore operation.

Table 5 shows the tonnages, grades, and recoveries for the different treatment methods at all operations analyzed. The weighted average feed grade for refractory milling ore of the producers, at 5.61 g gold/mt, is nearly double the weighted average grade for the

nonrefractory milling ore of the producers.

Of particular note in the table is the very low grade of the proposed milling ore for the nonproducers. The overall milling ore grade for the nonproducers is less than half that for the producers (1.66 vs. 4.05 g gold/mt). The overall total is heavily influenced by one large proposed operation that will mill ore grading only 0.82 g gold/mt. However, even if this proposed operation is excluded from the calculation, the weighted average for the milling ore of the nonproducers only increases to 2.57 g gold/mt, still 36.5 pct below that of the producers.

Recoveries

The weighted average recoveries for the producing properties are 67.4 pct for heap leaching and 87.9 for milling ore. For the nonproducers, the projected values are similar at 65.9 pct for heap leaching and 90 pct for milling ore. However, the overall recovery for the producers--at 80.9 pct--is much lower than for the nonproducers which is 87.8 pct. This simply reflects the much larger percentage of heap leach ore represented in the producers' analyzed reserves.

Capacities

Table 6 summarizes the annual treatment capacity levels and operating cost estimates for different treatment methods at all analyzed operations. On average, producing heap leaching operations are 2-3 times larger than milling operations but they are treating a much lower grade of ore. The milling operations currently treating refractory or nonrefractory ores have capacities that are of a similar size, on average, and there is a much narrower range of capacities than for heap leaching operations.

As of the early 1990's, if all 8 nonproducers came on-stream at

Table 5.—Treatment methods and recoveries for analyzed U.S. reserves

Status	Treatment method	Reserve tonnage (kmt)	Wtd avg grade (g gold/mt)	Grade range (g gold/mt)	Pct recovery	
					Range	Wtd avg
Producers:						
	Heap leaching	1,166,000	0.90	0.49-2.25	20-85	67.4
	Milling:					
	Nonrefractory	290,000	2.88	0.97-5.44	75-96	85.5
	Refractory	217,000	5.61	1.85-9.74	72-93	89.6
	Subtotal	507,000	4.05	0.97-9.74	72-96	87.9
	Grand total ..	1,673,000	1.85	0.49-9.74	20-96	80.9
Nonproducers:						
	Heap leaching	23,000	2.19	1.85-2.46	59-70	65.9
	Milling:					
	Nonrefractory	263,000	1.35	0.82-6.38	87-94	89.1
	Refractory	42,000	3.62	1.80-6.96	90-92	91.3
	Subtotal	305,000	1.66	0.82-6.96	87-92	90.0
	Grand total ...	328,000	1.70	0.82-6.96	59-92	87.8

Source: Compiled on a property-by-property basis from various published documents, company annual reports, and USBM analysis.

Table 6.—Summary of annual ore treatment capacities and operating cost estimates, by treatment method; U.S. availability study

Status	Treatment method	Annual treatment capacity		Operating cost estimates	
		Range (kmtpy ore)	Average (kmtpy ore)	Range (Avg 1991 \$/mt ore)	Wtd avg ¹ (Avg 1991 \$/mt ore)
Producers:					
	Heap leaching	320 - 40,000	6,520	1.12 - 6.72	2.81
	Milling:				
	Nonrefractory	500 - 4,900	2,380	3.63 - 18.13	9.61
	Refractory	450 - 9,300	2,270	9.37 - 22.28	15.79
	Subtotal, milling	450 - 9,300	2,560	3.63 - 22.28	12.25
	Grand total	320 - 40,000	6,170	1.12 - 22.28	5.67
Nonproducers:					
	Heap leaching	1,250 - 1,450	1,350	3.94 - 4.33	4.11
	Milling:				
	Nonrefractory	640 - 11,790	5,190	2.95 - 12.27	4.00
	Refractory	500 - 2,600	1,470	5.86 - 15.60	9.26
	Subtotal, milling	500 - 11,790	3,600	2.95 - 15.60	4.72
	Grand total	500 - 11,790	3,480	2.95 - 15.60	4.68

¹Weighted on basis of analyzed Jan. 1992 proven plus probable reserves.
Source: Compiled from various published documents, company annual reports and USBM analysis.

the same time, they would represent a total of 2.7 million mtpy of heap leaching ore capacity and 25.2 million mtpy of milling ore capacity. The grand total of 27.9 million mtpy of treatment capacity from these 8 nonproducers would be only 13.7 pct of the total treatment capacity of 204 million mtpy available from the 33 analyzed producers.

Operating Costs

The treatment operating cost ranges and weighted averages shown in table 6 were compiled on a property-by-property basis. Separate estimates were made for that portion of ore treated by each of the different methods represented in the study. The difference in the weighted averages for heap leach operations between the producers and nonproducers is likely due to economies of scale.

The nonrefractory milling ore operating costs for the producers range from \$3.63 to \$18.13/mt ore with a weighted average of \$9.61. The estimated costs for treating nonrefractory milling ore at the nonproducers show a much narrower range, from \$2.95 to \$12.27/mt ore, and at \$4.00/mt ore, a weighted average operating cost less than half of the producers'.

The weighted average cost for nonproducers' refractory ore treatment is also much lower than for producers. The main reason for the more expensive treatment of the refractory ores by producers is due to onsite oxidation steps employed such as chlorination, whole ore roasting, and pressure oxidation.

The number of operations utilizing each of these treatment methods is shown in table 7. None of the refractory ore processing for the three applicable nonproducers involves onsite oxidation stages.

Transport and Refining of Doré Bullion

The final onsite product forms in this analysis are as either gold/silver doré bullions (32

producers and 5 nonproducers) or as gold/silver/sulfides concentrates (1 of the producers and 3 of the nonproducers). In both forms, the gold and silver must be further separated and refined into marketable forms of very high purity (99.7 - 99.9 pct) metals. The analysis of total costs takes into consideration the additional costs of transporting onsite treatment products to offsite smelting/refining facilities and the costs of separating and upgrading to the final high-purity gold and silver products.

In this study, transport and refining of gold and silver in doré bullion was addressed using the following cost values:

Transport	\$1.50 per tr oz contained gold
Refining gold	\$4.50 per tr oz contained gold
Refining silver	\$0.20 per tr oz contained silver

Capital Costs

Two major producing operations in the Carlin Trend area of Nevada account for \$2.1 billion (49.3 pct) of the \$4.3 billion in total capital expenditures applicable as of the Jan. 1992 study date for all 33 of the producers. This high percentage of capital expenditures is not unusual in that these two Carlin Trend operations also contain 44.6 pct (1,118 mt, or 35.9 M tr oz) of the total recoverable gold analyzed for the 33 producers. What is unusual is the level of dominance of the industry by only two operations operating in the same geological trend.

ECONOMIC ANALYSIS AND RESULTS

The economic analysis results for the producing and nonproducing operations have not been combined. This is due to significant differences in cost structure and in the timing of investments that have material effects on the economic analysis results. Each group will be discussed separately.

PRODUCERS

This section presents results of economic analysis of the 2,513

Table 7.—Refractory ore treatment methods in use or proposed
for the U.S. availability study, by property

Status	Refractory ore treatment method(s)	Property
Producers:		
	Flotation, concentrates sent to smelter/refinery	Cannon
	Flotation, concentrates to on-site cyanide leach	McCoy/Cove, Royal Mountain King
	"Whole ore" roasting	Newmont (Carlin)
	"Whole ore" roasting/chlorination	Jerritt Canyon
	Pressure oxidation (autoclaves)	Mercur, Goldstrike (Carlin), McLaughlin, Getchell
Nonproducers:		
	Flotation, concentrates sent to smelter/refinery	New World
	Flotation, concentrates to on-site cyanide leach	Kensington
	Flotation, concentrates to off-site cyanide leach	Pine Tree

Source: Compiled from various published documents, company annual reports, and USBM analysis.

mt (80.78 million tr oz) of recoverable gold contained in the 33 primary gold operations in production as of the Jan. 1992 study date and included in the analysis.

Total Availability Curves

Figure 6 contains total cost curves for 0-, 10-, and 15-pct discounted cash flow rates of return. As shown, nearly all (98.2 pct) of the recoverable gold can provide breakeven economics (a 0-pct DCFROR) at \$400/tr oz. At \$344/tr oz, the average Handy and Harman market gold price for all of 1992 (30), 83.5 pct of production capacity is achieving a breakeven cost level or making a positive rate of return. However, only about half of the total recoverable gold can earn as much as 10-pct DCFROR at average 1992 prices. A gold price higher than \$400/tr oz would be needed for a significant number of producers to earn 15-pct DCFROR's.

Total Cost Composition

Table 8 provides a tabulated, item-by-item breakdown of the weighted average total cost results for the 3 DCFROR scenarios. There are several major points highlighted by this table. The first is that transport and refining of doré bullion or transport, smelting, and refining of concentrates represents an insignificant percentage (1.8-2.4 pct) of the net total cost results. This is important to note because a proponent of one version of the proposed royalty on production from Federal lands uses as an example a case where "...further processing has costs equal to fifteen percent of the commodity value, the impact of the royalty would only be on the equivalent of 85 pct of the commodity price of the refined product." (31, p. 16) In the text this statement does not identify that the 15 pct value is based only on copper smelting, refining, transport costs and prices. As these results show, use of a 15 pct value is not representative of the

situation for primary gold mining operations which accounted for 80.9 pct of the estimated value of hardrock mineral production from Federal lands in 1990 (32, p. 35).

A second point is that private and State royalties also represent an insignificant percentage (2.1-2.5 pct) of the net total cost results. On an individual property basis, 17 of the 33 had applicable private or State royalties. Separate analysis of the results for these 17 properties shows royalty costs ranging from 0.7 to 9.3 pct of the net total cost results. Overall, the current level of royalty payments by the U.S. gold industry to private individuals and States averages less than 4 pct of net smelter return.

Table 8 also shows that all taxes (local, State, and Federal) are a small part of total cost, ranging from \$10.63/tr oz in the 0-pct DCFROR (breakeven) scenario, to \$34.30/tr oz for the 15-pct DCFROR requirement. Respective percentages are 3.8 pct and 9.3 pct of the net total cost results. Local property taxes are most important at the breakeven level. This is because they are based on assessed value of the physical facilities at the mines. Not surprisingly, Federal taxes become the largest taxation factor in the 10- and 15-pct DCFROR (profitable) situations.

The results also show the large impact that capital expenditures and the related return on capital requirements add to the overall total cost structure of the U.S. gold mining industry. These two categories account for between 18.8 pct (\$52.84/tr oz in the 0-pct DCFROR scenario), to 30.8 pct (\$113.57/tr oz for the 15-pct DCFROR requirement) of net total cost.

For further analysis of the U.S. industry's cost structure, the results of table 8 were split into three groups (table 9). One group was comprised of two major operations on the Carlin Trend in

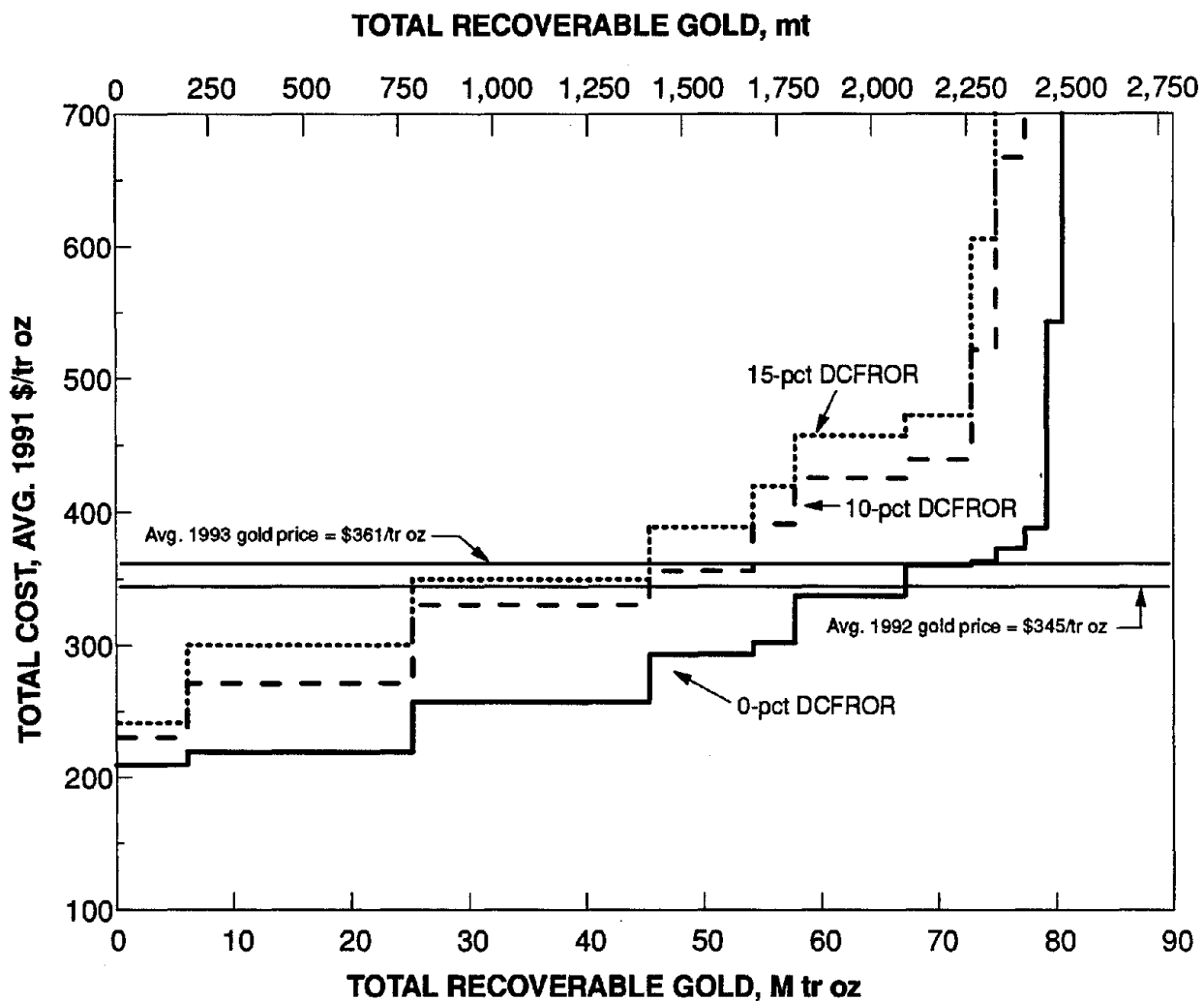


Figure 6. -- Potential gold availability from 33 U.S. producing gold properties.

Source: USBM estimates.

Table 8.--Weighted average DCFROR total cost¹ results, 33 analyzed U.S. producers

Cost item	Wtd avg DCFROR total cost (avg 1991 \$/tr oz recoverable gold)		
	0-pct	10-pct	15-pct
Mining	96.43	96.43	96.43
Treatment	113.76	113.76	113.76
Smelt/refine/transport	6.58	6.58	6.58
Capital expenditures	52.84	52.84	52.84
Private and State royalties	5.87	8.22	9.22
Property (local) taxes	6.10	8.21	9.46
Severance (State) taxes	1.15	2.08	2.63
Income (State) taxes	0.13	0.55	0.81
Income (Federal) taxes	3.25	15.48	21.40
Return on capital	0.00	40.62	60.73
Gross total	285.11	344.77	373.88
(Byproduct credits)	(5.58)	(5.58)	(5.58)
Net total	280.53	339.19	368.30

¹Total cost results of this study do not include overall corporate general and administration costs. Based on corporate data, Dobra and Thomas (33, table 4) have estimated these costs to average \$26/tr oz in 1992, prorated over total corporate gold production.

Source: USEM estimates.

Table 9.—Weighted average DCFROR total cost results; two major Carlin Trend operations, other U.S. low-cost, and other U.S. high-cost operations

Category	Cost item	Wtd avg DCFROR total cost (avg 1991 \$/tr oz recoverable gold)		
		0-pct	10-pct	15-pct
Two major Carlin Trend operations:				
	Mining	59.65	59.65	59.65
	Treatment	96.76	96.76	96.76
	Smelt/refine/transport . .	6.10	6.10	6.10
	Capital expenditures . .	57.86	57.86	57.86
	Private and State royalties	6.79	11.03	12.73
	Property (local) taxes . .	5.04	7.57	9.07
	Severance (State) taxes .	1.01	2.28	3.03
	Income (State) taxes . .	0.00	0.00	0.00
	Income (Federal) taxes .	2.08	18.56	25.73
	Return on capital	0.00	49.67	73.44
	Gross total	235.29	309.48	344.37
	(Byproduct credits) . . .	(0.17)	(0.17)	(0.17)
	Net total	235.12	309.31	344.20
Other low-cost producers: (15 properties)				
	Mining	131.99	131.99	131.99
	Treatment	105.40	105.40	105.40
	Smelt/refine/transport . .	6.81	6.81	6.81
	Capital expenditures . .	29.31	29.31	29.31
	Private and State royalties	4.24	4.78	5.05
	Property (local) taxes . .	3.46	4.45	5.01
	Severance (State) taxes .	1.67	2.19	2.49
	Income (State) taxes . .	0.31	0.84	1.12
	Income (Federal) taxes .	2.70	8.39	11.10
	Return on capital	0.00	20.25	30.85
	Gross total	285.89	314.41	329.13
	(Byproduct credits) . . .	(2.48)	(2.48)	(2.48)
	Net total	283.41	311.93	326.65
Other high-cost producers: (16 properties)				
	Mining	117.17	117.17	117.17
	Treatment	160.29	160.29	160.29
	Smelt/refine/transport . .	7.19	7.19	7.19
	Capital expenditures . .	77.86	77.86	77.86
	Private and State royalties	6.44	7.72	8.41
	Property (local) taxes . .	12.15	15.09	16.87
	Severance (State) taxes .	0.64	1.51	2.07
	Income (State) taxes . .	0.10	1.24	1.99
	Income (Federal) taxes .	6.40	19.87	28.10
	Return on capital	0.00	52.86	79.79
	Gross total	388.24	460.80	499.74
	(Byproduct credits) . . .	(21.03)	(21.03)	(21.03)
	Net total	367.21	439.77	478.71

Source: USBM estimates.

Nevada. The other two groups, a high-cost group and a low-cost group, were formed from the remaining 31 properties. This split was made because of the fact that these two Carlin Trend operations account for 44.6 pct of the total recoverable gold in the 33 producers.

With this split, it became apparent that there is a distinct "two-tier" nature to the total cost structure of the U.S. gold industry. The weighted average total cost results shown in table 9 highlight the difference in relative economics between the low-cost and high-cost groups once the Carlin Trend operations have been separated out.

It is important to investigate this "two-tier" aspect further since many of the proposed Federal royalty calculations under consideration do not consider the relative ability of all producers to pay additional monies. In the gold price climate of the early 1990's, some U.S. producers are making good returns on investment and others are not getting any.

Examination of the data for these two groups of properties reveals a number of operational, geological, and economic reasons for the differences in treatment costs and capital expenditures. The main reason lies in the fact that the low-cost group uses heap leaching quite extensively (87.6 pct of the analyzed ore reserves is treated using heap leaching), while the high-cost group uses milling extensively (46.1 pct of the analyzed ore reserves is treated by milling the ore). Also, the milling ore for the low-cost group is high-grade (weighted average of 5.07 g gold/mt) while the milling ore for the high-cost group is very low grade (weighted average of only 2.4 g gold/mt). The heap leach ore grade for both the low- and high-cost groups are similar at 0.95 and 1.00 g gold/mt, respectively.

Other differences of some economic importance are (1) only two of the low cost group mill

refractory ore while five in the high-cost group do so, (2) none of the high cost group were producing prior to 1982, and (3) only four operations in the low-cost group began production after 1988 while 7 of the 16 operations in the high-cost group did so. All other factors being equal, these differences would cause higher treatment and capital costs. However, the main reasons are the amount of milling ore and the striking difference in grades of the milling ore.

As documented in IC 9070 (2), heap leaching is much less capital intensive than constructing all the plant and equipment necessary for milling ore. Also, the grinding and more complex processes involved in treating milling ores add appreciably to overall treatment costs on an ore basis. An important lesson from these results is the major role that ore grades play in overall economics and treatment schemes. If milling of an ore will cost an average of about 4.4 times more than heap leaching (table 6), then the differences in ore grade and recoveries between the two ores must be similar in relative value to obtain a similar rate of return. This analysis also points out the important implications of the overall decline in U.S. feed and recovery grades documented by Slater and Ward (25). Not all ores can, or should, be heap leached. If the trend continues toward lower grades and more milling of ores, then the cost structure of the U.S. industry may also trend toward the high-cost producer results of this study.

Annual Availability Curves

Figure 7 presents annual gold production curves for the 33 producing operations included in the analysis. Projected annual gold output levels at full, analyzed capacity are shown from 1992 (the first full year of the study's timeframe) through 2012. Annual curves are shown for each of four total cost ranges based on the

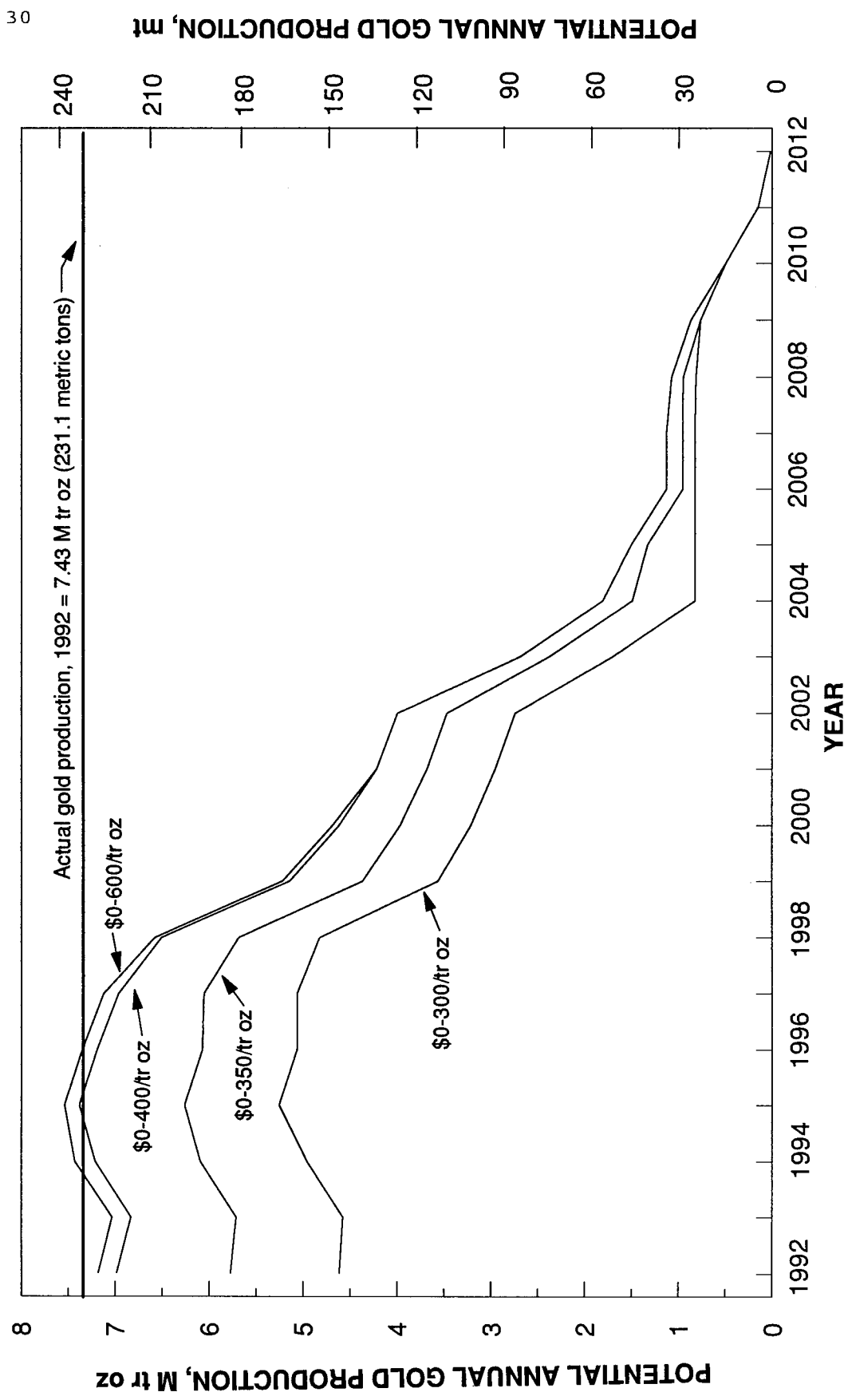


Figure 7. -- Potential annual gold production at various 0-pct DCFROR total cost levels, 33 U.S. producing gold properties.

Source: USBM estimates.

0-pct DCFROR economic analysis results. That is, production from all operations able to return a 0-pct DCFROR at \$300/tr oz is shown on the lowest curve on the graphic, and so on.

For comparison purposes, a line has been superimposed on figure 7 showing the actual 1992 level of gold production--231.1 mt (7.43 million tr oz)--from these 33 operations. It is important to note that these annual curve results represent a *static* analysis in that there is no assumed replacement of the analyzed Jan. 1992 proven plus probable reserves with potential new reserves.

Figure 7 shows drastic declines in annual output over a 10-yr period from 1995 through 2004 at all prices. There are significant questions regarding the industry's ability to find and put into production enough replacement ore reserves to mitigate the decline shown. This decline is in sharp contrast to results which will be shown in the next chapter for the world's number one producer, the Republic of South Africa. The vast majority of U.S. gold operations must constantly replace depleting reserves, whereas most South African operations have up to 30 years of assured production from proved and probable reserves.

One reason for this situation is that the U.S. industry is much larger than in the early 1980's. In addition, feed and recovery grades have declined, tonnages treated have increased greatly, and reserve/production ratios have declined significantly during the 1980's (25).

NONPRODUCERS

The eight analyzed nonproducing properties do not represent comprehensive coverage of all the known U.S. nonproducers as of 1994. This set of properties is also unique in that none are located in the State of Nevada. However, as of Jan. 1992 these eight were the furthest along in terms of reserves

delineation and the steps necessary to put them into production. Questions to be answered in this section are whether there is sufficient potential among the nonproducers to mitigate the possible drastic decline in output by the years 2004-05 from the 33 analyzed producers, and what gold prices are required?

Total Availability Curves

Figure 8 presents the total availability curves for the nonproducing U.S. gold properties at 0-, 10-, and 15-pct DCFROR's. Results show that the vast majority of this recoverable gold in nonproducers needs \$400-\$500/tr oz gold to provide reasonable levels of return on the required capital investments. Average total costs are obviously much higher than for the analyzed producing operations.

Total Cost Composition

Table 10 provides a tabulated, item-by-item breakdown of the weighted average total cost results for the three DCFROR scenarios performed. There are several points to be made from this table, especially in comparison to the total cost composition results for the producers. The first is that, in contrast to the producers, mining costs are actually higher than treatment costs. This is despite the fact that the vast majority of the ore for these nonproducers will have to be milled. The reason for this is that a much larger percentage of nonproducing ore reserves will have to be mined using underground methods versus less expensive surface methods which dominate current production.

Transport and refining costs of doré bullion or transport, smelting, and refining of concentrates are basically insignificant, much like for the producers. Likewise, private and state royalties represent a small percentage of total costs, approximately 4 pct of the net total cost for all rates of return.

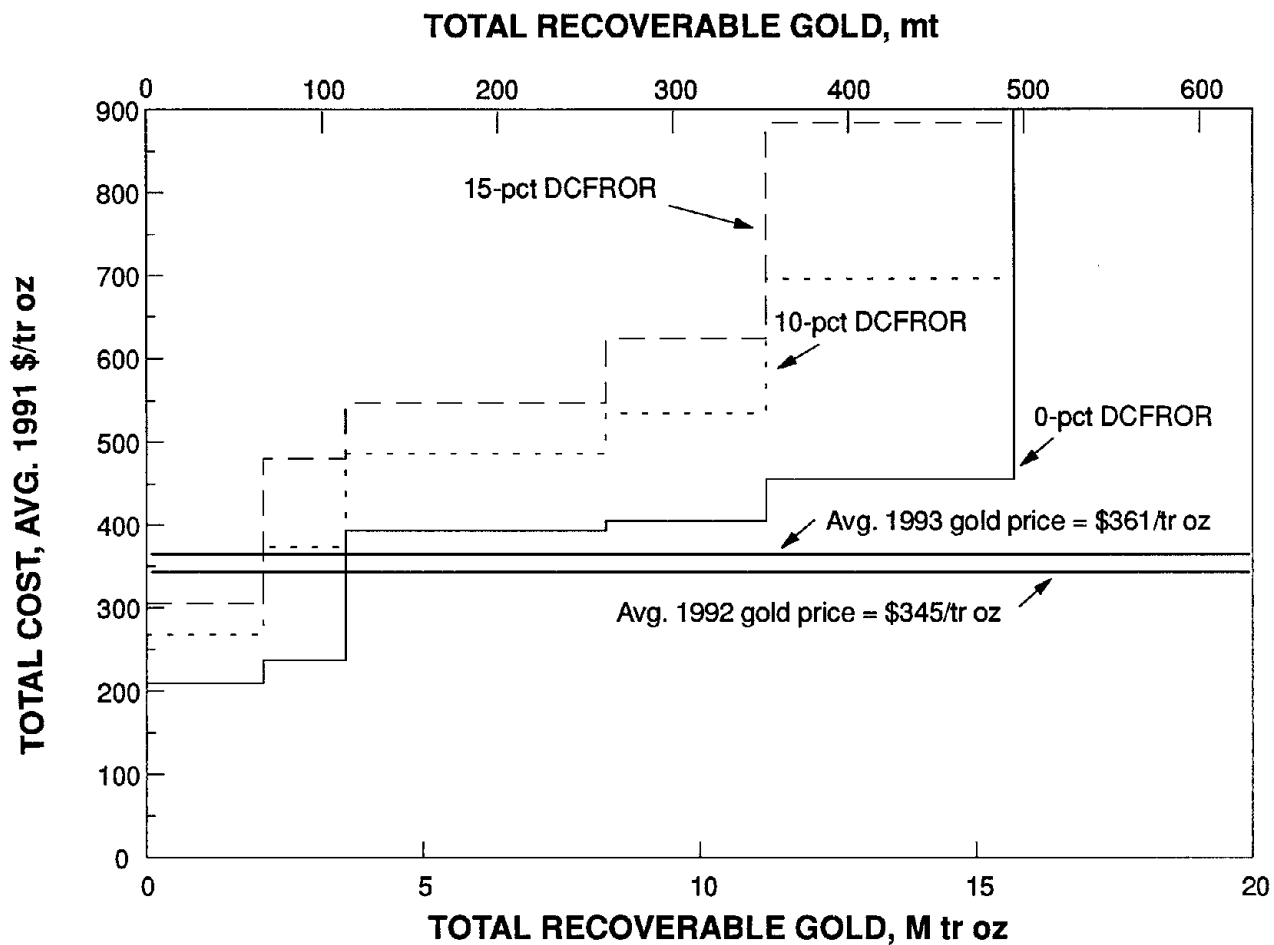


Figure 8. -- Potential gold availability from 8 U.S. nonproducing properties.

Source: USBM estimates.

Table 10.—Weighted average DCFROR total cost results, 8 analyzed U.S. nonproducing properties

Cost item	Wtd avg DCFROR total cost (avg 1991 \$/tr oz recoverable gold)		
	0-pct	10-pct	15-pct
Mining	126.78	126.78	126.78
Treatment	105.20	105.20	105.20
Smelt/refine/transport	8.94	8.94	8.94
Capital expenditures	87.30	87.30	87.30
Private and State royalties	14.34	19.65	23.59
Property (local) taxes	19.01	19.86	20.45
Severance (State) taxes	17.14	30.39	40.28
Income (State) taxes	2.96	9.84	15.74
Income (Federal) taxes	1.63	27.50	49.24
Return on capital	0.00	89.42	151.05
Gross total	383.30	524.88	628.57
(Byproduct credits)	(10.37)	(10.37)	(10.37)
Net total	372.93	514.51	618.20

Source: USEM estimates.

Taxation results (both the levels and the percentages) are much higher for nonproducers than is the case for the U.S. producers. There are several reasons for this, including the higher comparative level of capital expenditures, the need for a higher breakeven price to determine taxes upon, and the fact that several high tax rate States, particularly Alaska, are heavily represented in the nonproducing properties analyzed.

Even more than with the producers, the results show the large impact that capital expenditures and the related return on capital investment add to the overall total cost structure of the U.S. gold mining industry. In table 10, Federal and State income taxes, plus capital expenditures and the required return on capital investment add up to \$91.89/tr oz in the 0-pct DCFROR results, \$214.06/tr oz in the 10-pct DCFROR results, and \$303.33/tr oz in the 15-pct DCFROR results. These "add-ons" account for 24.6 pct of the net total cost at a 0-pct DCFROR, 41.6 pct at a 10-pct DCFROR, and 49.1 pct for the 15-pct DCFROR requirement. These costs are different from production cost items that are typically paid in cash (mining, treatment, smelting-refining-transport, private royalties, and property taxes) and commonly reported in the literature as "cash costs". However, they can be a very substantial part of the overall total cost structure and are particularly important for judging profitability levels.

Annual Availability Curves

Figure 9 presents annual gold production curves for the 8 nonproducing properties based on the 0-pct DCFROR economic analysis results. The annual curves represent a static analysis in that there is no assumed replacement of the analyzed Jan. 1992 proven plus probable reserves with potential new reserves.

Annual curves for nonproducers include evaluator assumptions about (1) when all necessary permits will

be received, (2) when and if development decisions will be made, and (3) the time required for development and construction of mine, treatment, and infrastructure facilities. The assumptions made here about time required are likely optimistic. Many of these properties have been in the study/permitting stages for years and still have not obtained all permits. Also, whether or not a development decision is made depends upon anticipated gold market conditions, and the necessary market price for profitability at some properties is at the high end of the range seen over the last 15 years.

Assuming all these properties come into production at about the same time, a maximum of 44.2 mt (1.42 M tr oz) of annual output could be provided and a maximum price of \$500/tr oz would be required. Even if this occurred, a decline begins after only 6 years at the maximum production level, falling to only 3 mt (0.1 M tr oz) after 16 years.

As was the case in the producers' annual curve, this decline occurs no matter what price range is chosen, indicating that these nonproducers have little more in the way of reserve longevity than the producers. These annual curves indicate that the analyzed nonproducers have very limited ability to mitigate the potential decline in production from the analyzed producers.

ISSUES AFFECTING THE U.S. GOLD INDUSTRY

The tremendous increase in U.S. gold production during the 1980's caused a series of environmental and governmental issues to be brought into public discussion and debate. Much of the public concern is due to the fact that the majority of the increased production has come from development of very large, very visible open pit mines, and from the use of cyanide in open areas due to heap leaching.

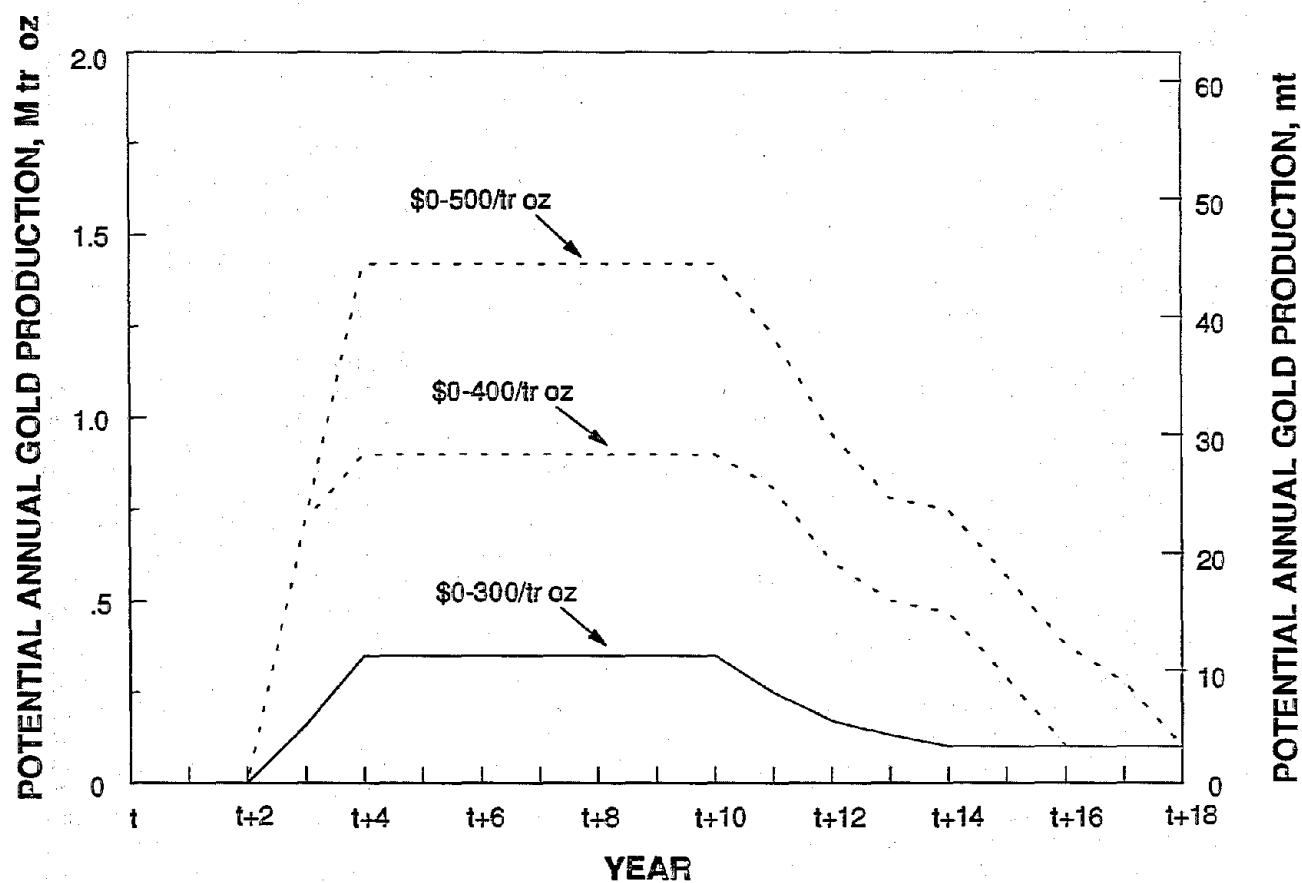


Figure 9. -- Potential annual gold production at various 0-pct DCFROR total cost levels, 8 U.S. nonproducing gold properties.

Source: USBM estimates.

One problem has been that some heap leaching operations developed in the early- to mid-1980's caused unforeseen problems in terms of "bird-kills" and leakage from ill-designed operations. The bird-kill problem was largely caused by inattention to the attraction of migrating birds to uncovered collection ponds. In response to this public reaction, actions by the operators have limited the number of bird-kills dramatically and this no longer appears to be a major concern.

Most environmental concern has involved potential contamination of water sources. The most notorious example of this is the Summitville, CO, heap leaching operation. The issues concerning this particular operation are many and complex and are beyond the scope of this report. In retrospect, the development, production, and closure and subsequent closure problems at Summitville should be considered as a very unusual case, albeit one holding many important lessons for all involved in the gold industry.

The Summitville heap leaching operation was constructed in an area of very high precipitation (in the form of snow) and of very cold temperatures. Worse conditions for attempting a heap leaching operation can hardly be found. This situation, plus having marginal economics, a long history of past mining, and geologic conditions that are very favorable for acidic water runoff conditions, suggest that prudent operators would never have developed this operation.

Another criticism of the U.S. gold industry has been the charge of an excessive amount of foreign ownership. Dobra and Thomas deal with this subject at some length (33, pp. 25-27). They found that, weighted by all stock ownership including minority shareholders holders, 41.9 pct of 1991 U.S. gold production was held by foreign interests; weighted by controlling shareholder interest, 24 pct of the 1991 U.S. gold production was

controlled by foreign shareholders. In both cases, Canadian and United Kingdom interests represented the vast majority of foreign shareholders. Comparable percentages of in-situ gold reserve control were 45.8 pct foreign control, weighted by stock ownership, and 33.9 pct foreign control, weighted by controlling interest. Again, the foreign interests were predominately Canadian and British.

As of the 1990's, investment flows are worldwide and occur as part of strategic decisions made on a worldwide basis. An example is Homestake Mining Company, a U.S. corporation, which obtained a controlling interest in one of the lowest-cost Canadian gold mining companies (34).

Since 1987, Congress has been debating the reform of the Mining Law of 1872. During 1993, two separate bills dealing with the mining law revision had been passed by the respective Houses of Congress. Conference committee efforts to reconcile the significant differences were not successful during 1994.

During the debate several major issues surfaced including (1) the type and size of royalties, (2) approaches to reclamation and environmental issues, and (3) patenting provisions. Table 11 summarizes the debate involved with these issues. Other issues include the possible impact on jobs and economic activity, the size of claims, the fees associated with holding a claim, the security of land title (the right to mine), exploration permits, citizen initiated lawsuits, and land access confusion due to the "suitability to mine" review process.

A 1993 Department of Interior study of Federal royalty options and impacts was based on the set of evaluations summarized in this chapter (32). That royalty study relied on the fact that gold makes up 80 pct of hardrock mineral revenues from Federal land and that this sample of 33 U.S. producers

Table 11.--Summary of major U.S. mining law revision issues

Issue	Mining Law of 1872	Range of the debate
Royalties on Federal lands	None	Debate involves two issues: (1) the basis for determining the royalty base, that is, what costs are subtracted before the royalty calculation is made, and (2) the royalty percentage itself.
Reclamation and environmental issues	No standards set. Covered by other laws such as NEPA and FLPMA.	A significant part of the debate involves whether the mining law should have reclamation and environmental provisions, or whether other State and Federal laws should prevail. Provisions suggested in proposed legislation include suitability of Federal lands for mining and the use of collected royalties for the reclamation of abandoned mines on Federal lands.
Patents	Allows for the transfer of surface and mineral rights to claim holders after the claim holder has proven the existence of a "valuable mineral deposit".	Debate regarding this issue centers around the private acquisition of Federal land at below fair market value. Options include ending minerals only patenting or requiring payment of fair market value.

Source: Compiled from various available public documents.

accounts for about three-quarters of domestic production. It made rough estimates of the unpatented Federal land shares at these 33 producers as of 1992. At 12 operations no patented Federal land was involved. At nine operations 100 pct of the land holding was Federal unpatented land. The others had Federal unpatented land shares ranging from 2 to 95 pct.

Applying these percentages to reported production, that study estimated that about 42 pct (132 mt) of U.S. gold production would come from unpatented Federal lands. Using the early 1993 price for gold (\$330 per tr oz) and extrapolating from the 33 gold producers covered here, it estimated that from \$48 million to \$133 million would be collected annually under an 8 pct royalty based on net smelter return and from \$1 to \$2 million under a 2 pct royalty based on mine-mouth net income. The range for each of these calculations reflects the uncertainty over how many properties already in the patenting process would be completed by the time royalty collections start.

The offsetting consideration of the proposed royalty is the ability (or inability) of all operators to pay additional royalties. This concern is most clearly seen with the marginal producers. As shown earlier in table 9 of this report, there is a two-tier aspect to the industry's cost structure and the weighted average breakeven net total cost for the 16 operations in the high cost tier is \$367.21/tr oz. At a gold price of \$367/tr oz, this high cost tier of operations pays about \$6.50/tr oz in private royalties. For those operations producing from unpatented Federal land, an additional \$28.80/tr oz would be owed under an 8 pct royalty based on net smelter return, or an additional \$ 0.50/tr oz under a 2 pct royalty based on mine-mouth net income. These 16 operations account for a little over one-fifth of the production from the Federal unpatented lands of all 33 operations.

ENVIRONMENTAL COSTS AND PERMITTING DELAYS

Capital and operating cost expenditures for environmental protection and reclamation are generally accepted by the mining industry as part of the cost of doing business. Unfortunately, costs that are specifically environmental and regulatory related are usually not reported comprehensively or consistently by the companies. Similarly, the cost aspects of this study related to environmental and regulatory requirements can not be addressed specifically. Where possible, they have been included in the overall operating and capital cost estimates of the study. In Dobra and Thomas an estimate of minimum environmental compliance cost for a typical surface mine in Nevada is cited (35). The results were an increase to capital costs of 9 pct and to operating costs of 5 pct for a total cost increase of \$20/tr oz. Another recent study by Sherman estimates the direct costs for permitting lode mines in Alaska at an average of 4 pct of the total project cost. Compliance costs, including indirect costs such as roads to bypass sensitive habitat, are estimated at twice that of direct permitting costs.

A possibly more important issue to the U.S. gold industry involves delays in the regulatory and permitting procedure that occur between defining a potential operation in a feasibility study and receiving all the numerous state, county, and local permits required to begin production. The U.S. gold mining industry is capital intensive, particularly during the deposit evaluation and startup phases, and regulatory delays, permitting delays, and court challenges detract from the overall financial attractiveness of a mining investment. If these regulatory compliance and

⁷OFR 35-90. Permitting and Environmental Constraints by Gary E. Sherman.

permitting delays are significant, they can completely destroy the viability of a project, particularly those that are already marginal by virtue of tonnage, grade, or other factors (36).

The regulatory/permitting procedure is constructed such that projects undergo a high degree of local scrutiny and debate. This can cause major changes to the original operating plan. One of the nonproducing properties included in this analysis reflects this. The county where the mine would be located would not allow the use of a fluid bed roaster or the use of cyanide but would allow the use of bulk sulphide flotation. The company changed its plan to producing concentrates onsite and transporting the concentrates to a neighboring State for subsequent roasting and leaching.

Based on data, circa 1992, from three of the eight analyzed nonproducers, 2 to 3 years would elapse from the time the permitting process was begun until the final EIS statement was expected to be issued. This does not appear to be an unreasonable length of time to assess the overall impact of a large proposed operation.

LAND WITHDRAWAL AND RESTRICTIONS

Withdrawal of land from mineral entry is perhaps the most important of the issues discussed at length in this section. Federal lands becoming less attractive for mining due to a possible royalty and other new regulatory requirements, increasing environmental and regulatory costs, and delays in permitting are important issues. However, even with the most liberal of environmental regulations, expeditious permitting, and no substantive changes in the Mining Law, the number of mining operations will probably decrease. This will decrease will occur because of the depletion of current deposits and as Federal lands are increasingly withdrawn from mineral entry.

This study has not examined the availability of privately-held lands for mineral exploration and development in much detail. These lands could be significant in Alaska, where Native peoples control approximately 20 pct of the land available for mineral exploration and are favorably disposed toward mining. Alaska's Native corporations see mineral development of their lands as a significant factor in providing for the future well-being of their shareholders and all Native peoples (37).

The U.S. Bureau of Mines has studied 3.5 million km² of lands in Alaska and the Western States as a part of the Inventory of Land Use Restraints Program (38). Within this area the Federal government holds 2.1 million km² (60 pct) of the mineral estate. About 1.2 million km² (55 pct) of this Federal estate is severely restricted to mineral development by location, 162,000 km² (8 pct) is restricted, and only 798,000 km² (37 pct) is available for mineral entry.

According to Hyndman and others (38), "The Federal Government holds about 59 pct of the known mineral areas in the States studied, one-third of which are available. This one-third represents only one-fifth of the identified mineral areas which means that only 20 pct of all identified mineral areas are subject to location and are available, without added restrictions, to mineral exploration and development. An additional 4 pct is available with some restrictions. It is evident that the mineral hunting grounds and their contributions of mineral resources from Federal lands will decrease as additional lands are restricted or withdrawn from mineral entry."

As already shown, the replacement of depleting reserves in a context of declining grade

⁸Personal communication with the Mariposa County (CA) Planning Commission, March 1989.

trends is probably the most critical issue in maintaining the long-term viability of the U.S. gold industry. It is possible that the trends of these issues just discussed are already having an impact. There does appear to be a trend of U.S. gold mining companies moving offshore to countries that are more friendly to companies developing their natural resources (8). How much this trend reflects a combination of all the issues -- changes to the Mining Law of 1872, increasing regulatory and environmental costs, permitting delays, or the lack of available land to explore on -- cannot be documented in this study.

RESULTS AND CONCLUSIONS

The following summarizes the results of this availability analysis of gold in the United States of America:

Producers:

- Contained gold in the Jan. 1992 proven and probable reserves of the 33 operations totals 3,104 mt (99.8 M tr oz), 2,513 mt (80.78 M tr oz) of which is recoverable after mining, treatment, smelting and refining. The total tonnage available for feed to treatment is 1.674 billion mt at 1.86 g gold/mt.
- A very high percentage (93 pct) of the contained gold is in surface minable reserves. Of the total recoverable gold amount, 71.8 pct is from ores requiring milling and 28.2 pct is from dump/heap leaching ores. The overall recoverable gold (yield) grade after treatment is 1.51 g gold/mt.
- Two large operations in the Carlin Trend of Nevada contain 44.6 pct of the total recoverable gold and account for 49.3 pct of the total capital expenditures in the economic analysis.
- The analyses show that, in the \$344 to \$400/tr oz gold price

range, overall profitability of the industry is very sensitive to the target rate-of-return. At \$344-\$400/tr oz, 83.5 to 98.2 pct of the recoverable gold can provide breakeven economics (a 0-pct DCFROR). Similar percentages for a 10-pct DCFROR are 49.1-87.8 pct and only 33.0-77.0 pct can provide a 5-pct DCFROR. The sensitivity is due to the short-lived nature of the reserves and the basic tax systems the gold mines operate under.

- Analysis of the weighted average total cost composition of three groupings shows a two-tier (low- and high-cost) structure to the industry. The high-cost tier consists of 16 operations where a high percentage of the reserve tonnage is milled, rather than heap leached. They are also characterized by relatively low grades of this milling ore.
- The annual curve results emphasize the short-lived nature of the U.S. gold industry's reserve situation. The curve shows a drastic decline of 75.6 pct in annual output from 1995 through 2004. If reserve replacement efforts falter, this size of decline will be very hard to mitigate.

Nonproducers:

- Contained gold is in the Jan. 1992 proven and probable reserves of the 8 analyzed nonproducing properties totals 556 mt (17.9 M tr oz), 487.7 mt (15.7 M tr oz) of which is recoverable after mining, treatment, smelting, and refining. The total tonnage available for feed to treatment is 327.6 M mt ore grading 1.70 g gold/mt.
- Just over half of contained gold is in surface minable reserves. A very high percentage (93.1 pct) of the total recoverable gold will come from ores requiring milling and only 6.9 pct will be from heap leaching

ores. Overall recoverable gold grade after treatment is 1.49 g gold/mt, nearly the same as for the producers.

- Two large proposed operations in Alaska contain 53.5 pct of the total recoverable gold and account for 57.1 pct of the total capital expenditures in the economic analysis.
- Price determination analysis shows that, in the \$344 to \$400/tr oz gold price range, the overall cost structure of the industry is higher and even more sensitive to rate-of-return targets than the producers. At \$344-400/tr oz, only 22.9 to 71.3 pct of the recoverable gold can provide breakeven economics (a 0-pct DCFROR). Similar percentages for a 10-pct DCFROR are 13.4-22.9 pct and only 13.4 pct can provide a 15-pct DCFROR at both \$344 and \$400/tr oz. Most of these properties need \$400-500/tr oz gold prices to provide reasonable rates of return on investment. As with the producers, the sensitivity is due to the short-lived nature of the reserves and the basic tax systems the gold mines operate under.
- Analysis of the weighted average total cost composition of these nonproducing properties shows that, vis-a-vis the producers, nearly all cost items are higher. This is due to higher amounts of underground ore reserves and a larger percentage of ore that must be milled, resulting in higher overall capital and operating costs. Also, as a group, these nonproducers reflect somewhat higher State tax systems than the analyzed producers.
- The annual curve results for the reserves of the nonproducers are nearly as short-lived as of the producers which further emphasizes the short-lived nature of the U.S. gold industry's reserve situation. Only at high gold prices (\$400-500/tr oz) are high levels of

annual output achieved. Even if all were developed at the same time, as shown in the curve, a steep decline in production would begin after 8-9 years.

The U.S. gold mining industry is at a critical juncture. From being the fifth largest producing country in 1982 it has moved up to second. The increase has been affected almost completely through development of high-tonnage surface mines and utilization of heap leaching for low-grade ores.

The combination of the much higher level of production, the trend towards larger reserve tonnages with lower grades, and the short-lived nature of the reserves means that reserve replacement becomes critical to maintenance of production levels. Yet reserve replacement may require ever larger tonnages of lower grade reserves. At the same time, some public policies have the potential to make reserve replacement more difficult. All of these represent reasons why the direction of future production, as shown in this study's annual curves, is likely to be a decline following the 1998-2002 period.

This study's compilation of differences in surface/underground reserves and heap leaching/milling ore breakdowns between the producing operations and the nonproducing properties may provide a glimpse of the future composition of the U.S. gold industry. With the combination of bioleaching (not addressed or included in any aspect of this study) and heap leaching technologies, production from heap leaching will not disappear. However, the grades and characteristics of the typical material being heap leached probably will change, particularly to more refractory material.

The industry is competitive but it also is in a tenuous reserve and resource position. Some improvement in this situation could be provided by future technological developments and higher gold prices but the industry is up against some very powerful trends.

CHAPTER 3

SOUTH AFRICAN GOLD AVAILABILITY

By Edward H. Boyle, Jr.¹

This chapter analyzes the availability of gold from the world's largest producing nation, the Republic of South Africa. The report provides an analysis of trends in costs, material treated, gold yield grades, and production for the period 1981-92. Estimates were determined for life-of-mine reserves as of the Jan. 1992 study date for 33 major producing operations accounting for 93 pct of total South African production. Estimates of the costs to mine and treat these available reserves are presented and discussed.

The present mining leases of the analyzed operations are estimated to contain 23,297 mt (749 M tr oz) of gold. This amount is 4.6 times higher than the 1992 reserve base for the world's second largest producer, the United States. Total recoverable gold is 22,305 mt (717.2 M tr oz).

About 78.5 pct (17,509 mt, or 563 M tr oz) of the total recoverable gold can provide a 15 pct discounted cash flow rate of return (DCFROR) at \$390/tr oz. There is a low cost core of 10,139 mt (326 M tr oz) that is very profitable with 15 pct DCFROR's attainable at a price of \$300/tr oz or less. Given a constant 1991 U.S. dollar gold price of \$400/tr oz, no major decline in output from these 33 producers would occur until about the year 2010.

INTRODUCTION

This analysis of the reserve and cost position of the Republic of South Africa (RSA) gold industry is an update of a similar evaluation done for U.S. Bureau of Mines IC 9070 entitled "Gold Availability - World", published in 1986(2). An

expanded presentation of the results of this analysis will be contained in a planned Open File Report examining the gold industry and gold availability from the Republic of South Africa.

All cost and reserve estimates presented in this report as of Jan. 1992. A variety of information sources were utilized in this study. The most important sources of detailed data for the specific property evaluations and analyses were the annual reports of the individual operating companies, and quarterly and annual reports published by the Chamber of Mines of South Africa. A variety of published and unpublished reports have also been utilized in the study.

The purpose of this chapter is twofold. First, it will explore the 1982-91 trends in the South African gold industry. Second, it will assess long term potential gold availability from the largest gold-producing nation in the world and its impact upon possible U.S. policies towards the industry.

The South African gold industry can be grouped into six categories: (1) the major, active mining lease areas in the Witwatersrand Basin that comprise the 33 operations included in this availability analysis; (2) the minor active mining lease areas in the Witwatersrand Basin; (3) the prospective mining lease areas in the Witwatersrand Basin; (4) the "reprocessing"² operations which

²In the remainder of this chapter, the term "treatment" is used as a synonym for all gold ore processing activities.

¹Minerals specialist, Minerals Availability Field Office, U.S. Bureau of Mines, Denver, CO.

only process material from old rock dumps and tailings dams; (5) the mines outside of the Witwatersrand Basin; and (6) byproduct gold production from antimony, copper, lead-zinc and platinum group metals production.

Figure 10 shows total South African gold production for the years 1982-91 and the share of production represented by the 33 major producing operations included in the availability analysis. Total South African reported production declined 9.5 pct or 63.4 mt (2.04 M tr oz) during that period. Reported production from the 33 analyzed operations shows a larger decline of 13.3 pct. As a result, the percentage of total South African production represented by the 33 analyzed operations has declined from 96.7 pct in 1982 to 92.9 pct in 1991. Names and ownership by mining finance group for these 33 producing operations are listed in table 12.

HISTORICAL PERSPECTIVE

Since the peak of production in 1970, South Africa's output has continually declined. This is mainly due to the "freeing" of the world gold price in the early 1970's, which resulted in higher gold prices during the 1970's and 1980's. As a result, lower grade underground material and dump and tailings dam material from prior production became economic to extract and treat. The ability to utilize lower grade material has extended the lives of the mines but, because so few new mines have been added (Deelkraal, Elandsrand, and Unisel/Jurgenshof in the late 1970's, Beatrix, H.J. Joel, and Oryx/Beisa in the 1980's), the lowering of the overall yield grade³ has caused a decline in total South African gold production.

By 1980, production had fallen to 672.9 mt (21.6 M tr oz), derived from the treatment of 93.3 Mmt of ore (39). This level of gold production was down almost 30 pct from the average annual production

level over the entire 1965-1974 period (39). Gold production stayed relatively constant from 1981 through 1985, ranging from 656 to 680 mt (21.1 to 21.9 M tr oz)(39). However, the total tonnage of ore treated continued to increase, reaching 114.1 Mmt in 1985 and a maximum of 119.5 Mmt in 1988(39). The years 1988 through 1991 saw a decrease in total gold production (from 638 to 601 mt). This trend of larger amounts of ore treated with lower gold production reflects the larger amounts of lower grade material, such as surface dump and dam material and lower grade underground material, being treated by the 33 producing operations analyzed in this study. In the remainder of the report the low-grade material in dumps and dams on the surface will be referred to as "reclamation material".

The 9.5 pct decrease in total South African gold production from 1982 through 1991 (see figure 10) occurred while total world mine production was increasing from 1,328 mt (42.7 M tr oz) in 1982(24) to 2,110 mt (67.8 M tr oz) in 1991(26), a dramatic increase of 58.8 pct. Further, South Africa's 1991 production of 601 mt (19.3 M tr oz) was the lowest since 1958 when total production was only 549.2 mt (17.7 M tr oz)(39).

In this chapter, tonnage and grade trends should be considered in the context of both the rand and dollar gold price trends for 1981-91 shown in figure 11.

Since costs at the mines are incurred in the local currency, the gold price trends in terms of rands (both actual and deflated) are

³The overall yield grade for Chamber of Mines members declined from 12.5 g gold/mt for 1970 to 7.2 g gold/mt for the year 1980, a decrease of 42.4 pct; however, the ore tonnage treated only increased by 16.6 pct from 1970 to 1980(39). As a result, total gold production fell by 32.7 pct over this time period.

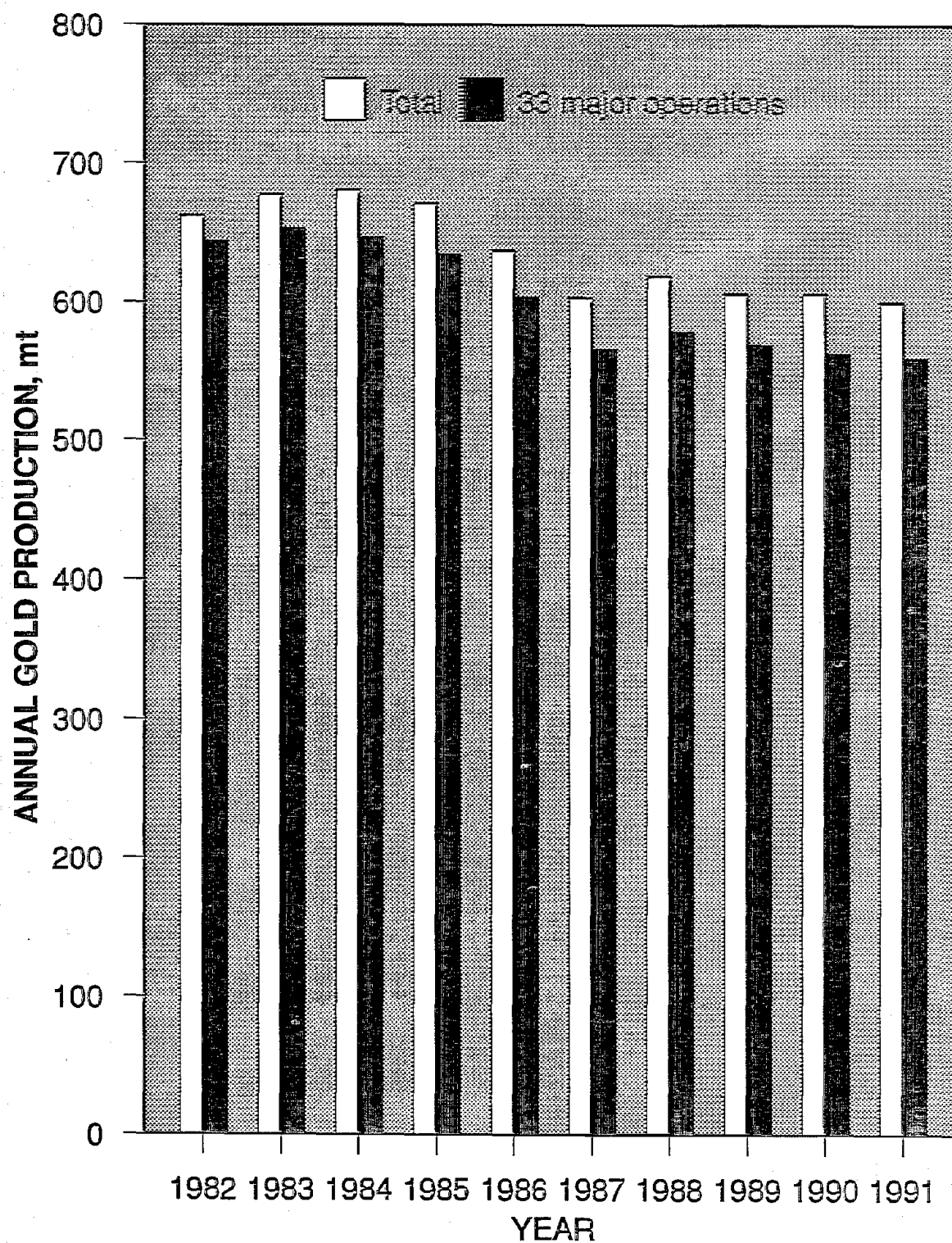


Figure 10.--South African gold production, 1982-91; total and the 33 producing operations included in analysis.

Source: Various South African Chamber of Mines Publications and company annual reports

Table 12.—Evaluated producing South African gold mining operations

Owner	Operation name
Anglo American	Elandsrand Free Gold North Free Gold South Vaal Reefs/Moab Western Deep Levels
Anglovaal	Hartebeestfontein Lorraine
Gengold	Beatrix Bracken Buffelsfontein Grootvlei Kinross Leslie Marievale Oryx/Beisa St. Helena Stilfontein Unisel/Jurgenshof/Tarka West Rand Consolidated Winkelhaak
Gold Fields	Deelkraal Doornfontein Driefontein Consolidated Kloof/Leeudoorn Libanon Venterspost
JCI	H.J. Joel Randfontein Estates Western Areas
Randgold	Blyvooruitzicht Durban Roodepoort Deep East Rand Prop. Mines Harmony

Source: Compiled from various Chamber of Mines of South Africa annual reports.

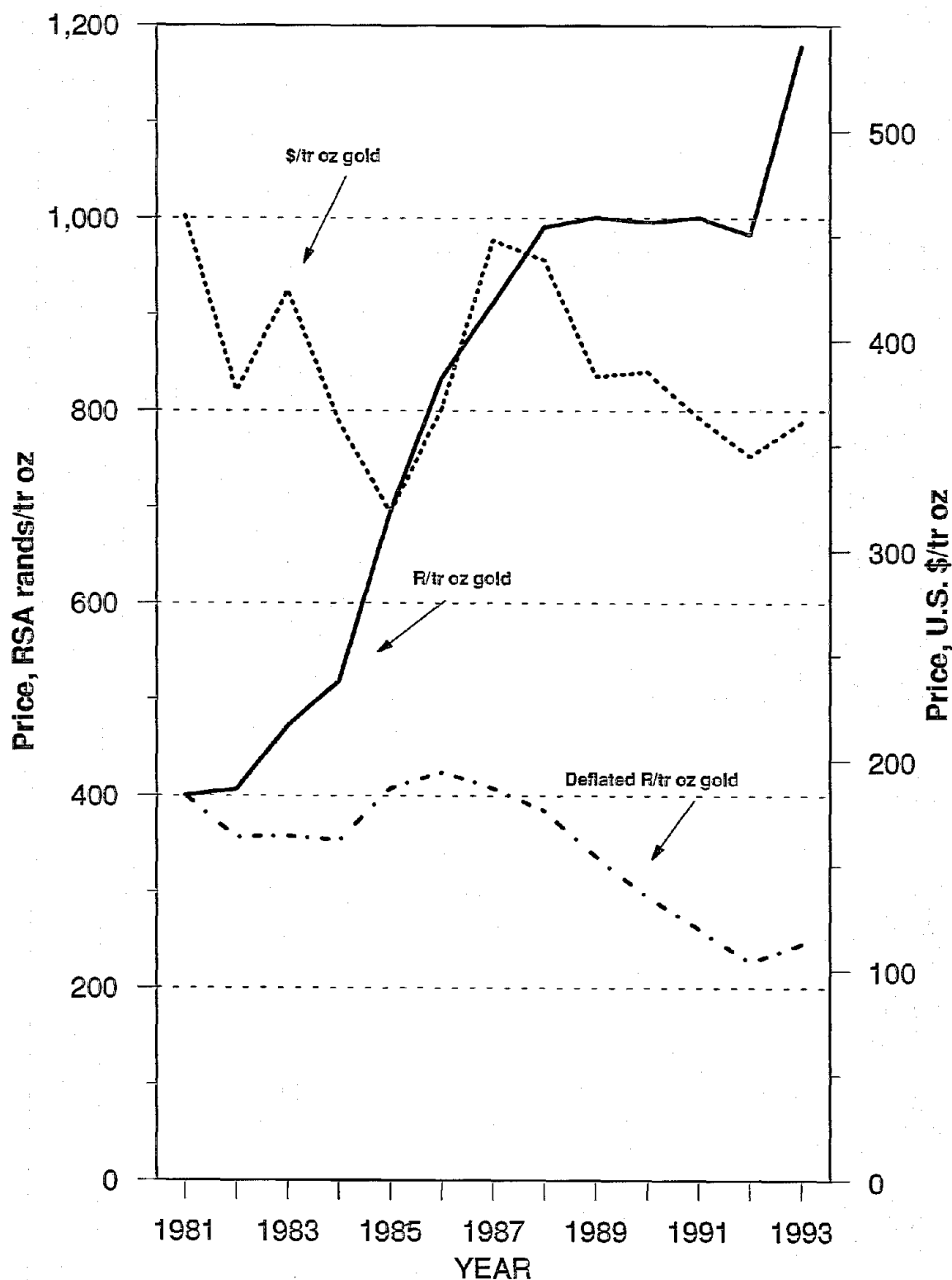


Figure 11.--Price of gold, 1981-91; U.S. dollars, RSA rands, and deflated RSA rands per troy ounce gold.

Source: Lucas (24), and IMF (40, pp.636-639).

particularly important to understand the operational responses of the South African gold industry.

Compilation of data from company annual reports and various Chamber of Mines publications show that from 1982 through 1989 the total tonnage treated by the 33 analyzed producers increased by 19.5 pct (from 95.3 Mmt to 113.9 Mmt) while the overall gold yield (recovered) grade decreased 26.3 pct to 4.98 g/mt.

Over this same time frame the nominal rand gold price increased 144 pct, from R409/tr oz in 1982 to R1,001/tr oz in 1989. Simply multiplying gold production in 1982 and 1989 by the rand gold prices for those years results in a 116 pct increase in overall revenues to the 33 operations from 1982 through 1989. The record rand gold prices in 1988 and 1989 and the high deflated rand gold price throughout the 1980's allowed the mines to feed very low grade material to their mills in those years, thereby extending the life of these mines.

Conversely, the years 1990 through 1993 show a reversal of the 1982-89 yield grade and tonnage treated trends. At 105.5 Mmt, the tonnage treated in 1993 was 7.3 pct less than in 1989 and the 1993 yield grade of 5.44 g gold/mt is 9.2 pct higher than in 1989 (39). This happened during a period when the nominal rand gold price stayed fairly constant, even rising sharply again in 1993. The U.S. dollar gold price declined 9.5 pct from \$383/tr oz in 1989 to \$345/tr oz in 1992 and then rose again to \$361/tr oz in 1993. The deflated (real) rand gold price (see figure 11) has continued to decline since 1986, falling to R227/tr oz for the year 1992 and then rose slightly in 1993 to R246/tr oz.

It is important to note that in 1982 the 95.3 Mmt of material treated by the 33 operations was nearly all reef material from underground mining. By 1990, the 113.3 Mmt of total material treated was comprised of 97.1 Mmt (85.7

pct) of underground reef material and 16.2 Mmt (14.3 pct) of reclamation material. This reclamation material comprises ore stockpiles, old waste rock dumps, and sand and slime material in tailings dams. It requires only surface mining methods with no drilling and blasting, providing an easily accessible source of additional mill feed material. Nearly all of the additional ore treatment capacity installed since 1982 at these 33 operations was being used to treat this low-grade, rock dump and tailings material as of 1990.

The substitution of easily handled, previously mined or treated surface dump and dam material for more expensive underground reef material during times of high rand gold prices makes sense as a strategy to prolong the overall life of an operation. However, the availability of this reclamation material is limited (compared to the underground reef material) and, in terms of total cost to produce a troy ounce of gold, is not necessarily more economical than mining and treating the higher grade underground reef material.

The reclamation material in dumps and dams will continue to play a role in the South African gold industry, providing flexibility and adding to the overall life of the operations. In that context, it is noted that the maximum annual treatment level for all 33 operations in this availability study is 119.9 Mmtpy which is comprised of 101.4 Mmtpy (84.6 pct) of underground reef material and 18.5 Mmtpy (15.4 pct) of reclamation material.

Another change in the South African industry since the early 1980's is in costs of production.

⁴The deflated rand price of gold is based on the annual average rand/U.S. dollar exchange rate to get a nominal rand gold price, and uses the South African GDP deflator to account for internal inflation since 1981.

According to numbers compiled by Consolidated Gold Fields, South Africa had the lowest total cost of production in 1983--\$209/tr oz before depreciation and \$263/tr oz after depreciation-- of five major producing countries (Australia, Canada, the Philippines, South Africa, and the United States) (41). By 1991, Gold Fields Mineral Services Ltd., the successor to Consolidated Gold Fields, ranked South Africa highest in terms of "cash costs" (\$294/tr oz) and second in terms of "total costs" (\$325/tr oz) of seven major producing countries (Australia, Brazil, Canada, the Philippines, Papua New Guinea, South Africa, and the United States) (42).

GEOLOGY

All current gold production from primary gold deposits in South Africa is from Witwatersrand Basin deposits or from deposits in the Barberton area of the eastern Transvaal. As of 1987, some 99 pct of the gold being produced in South Africa was from mines and treatment plants situated on the Witwatersrand Triad (43).

In Witwatersrand Basin gold deposits the gold particles occur in hard, abrasive conglomerate beds referred to as reefs. The reefs generally have a tabular shape, with long extensions along strike and down dip. Because of channeling during original deposition, the grades of gold and the thickness of the reefs vary from area to area on the same mining lease and from lease to lease. Thus, development results (sampling grades and widths) vary, and estimation of reserve or resource potential must adjust these development results to an expected or assumed mining width (thickness). Grade variability is important and will be addressed in the reserves and availability sections of this report.

There are numerous gold-bearing reefs within the Witwatersrand basin. Nearly all of the productive reefs are contained

within the "Witwatersrand Triad" which refers to the Dominion Reef Group, the Witwatersrand Supergroup, and the Ventersdorp Supergroup.

Nearly all reefs, even within groups, occur separately (i.e., at different depths) in cross-section, requiring separate development and stoping. At some operations (and potential mining lease areas) the reefs "coalesce" to allow some bulk mining activities; however, these occurrences are limited.

There are variations in the degree of dip; some are very flat (10-15 degrees) and some are steep (30-40 degrees). Faults (regional and local) and dike intrusions are common and their likely presence affects estimates of potential reserves and resources available from a given mining lease.

RESERVES

In South Africa, the Chamber of Mines, the mining finance houses, and individual operating companies provide detailed information on proved reserves on an annual and quarterly basis. However, a typical Witwatersrand gold mining operation will also make regular assessments of four different categories of available tonnages and grades: proved reserves, probable reserves, possible reserves and life-of-mine reserves (44). Only the proved reserve is published regularly in typical shareholder literature. The life-of-mine category is an estimate of the total tonnage of ore in the mine, both payable and unpayable, and represents the summation of the other three categories. This estimate forms the basis of all detailed long-term forecasts (more than 5 years into the future), which are required periodically for determination of development plans at producing operations and for undeveloped, potential mining lease areas.

Because of the nature of Witwatersrand Basin gold deposits, the life-of-mine reserves can be

considered as equivalent to the demonstrated resource category of the U.S. resource classification system. These life-of-mine estimates for each of the 33 producers are based on lease boundaries as of the study date. Information on additional prospective mining lease areas' resources and methods used to estimate the reserve tonnages and grades will be available in the planned Open File Report.

The tonnages and grades of all reclamation material available to each analyzed operation were estimated. These estimates were based on (1) typical amounts of reclamation material being treated by individual operations during the 1990-91 period, (2) longevity that was assumed to be the same as the life-of-mine estimate for that operation's underground reef tonnage, and (3) yield grades reported for past years.

CONTAINED GOLD

Table 13 summarizes the evaluated demonstrated (life-of-mine) reserves, as of January 1992, for all 33 producing operations included in the analysis. The material available for treatment is 3.83 billion mt of ore grading 6.09 g gold/mt. The overwhelming majority (22,895 mt, or 98.5 pct) of the contained gold is in the underground reef material. South Africa's production for 1992, at about 614 mt (19.7 million tr oz) (4), is only 1.87 times the U.S. level, yet this study's estimate of South Africa's demonstrated reserve is at least 4.5 times larger. In effect, the United States is depleting its gold reserves at a much higher rate than South Africa, making medium- to long-term reserve replacement in the United States a very important issue to the world's gold industry.

RECOVERABLE GOLD

Estimated treatment recoveries in this study ranged from 90.5 to 98.0 pct. In general, the operations with lower estimated

recoveries are treating more low-grade rock dump and slimes dam material and somewhat lower grade underground reef material.

Based on results from the economic evaluations, treatment of the 3.83 billion mt of material would result in recovering 22,305 mt (717.2 M tr oz) of gold. This represents an overall recovery of 95.8 pct.

The average yield value of 5.79 g gold/mt estimated for this study is near the middle of the range (4.98 to 6.76 g gold/mt) of actual reported results for 1982 through 1993 at these 33 operations. Reported yield grades for 1993 have increased dramatically from the lows of 1989 and 1990 as the rand (and U.S.dollar) price of gold has fallen.

Future prices of gold, how the South African operations respond to those prices, and the results of future development and extraction in the undeveloped areas of the mining leases will eventually reveal the true yield grade of the underground material. The higher the price of gold, in both rand and U.S. dollar terms, the better chance there is that this entire estimated life-of-mine reserve will be extracted.

MINING AND TREATMENT

TECHNICAL ASPECTS

Mining

Because of the depths of mining (1,500 to 4,000 m, or about 1 to 2.5 miles) and large tonnages, the gold mines of the Witwatersrand Basin are capital intensive, requiring large sums of money both to bring into production and to keep in production. The vast majority of the conglomeritic reef occurrences are thin (1 to 2.5 m), resulting in low-backed stoping areas which can't accommodate large sized equipment. Because of the large amounts of material moved,

Table 13.—Recoverable demonstrated reserves in South Africa as of January 1992, by mining finance group

Owner/operation	Underground material		Reclamation material		Total material	
	Tonnage (kmt)	Grade (g gold/mt)	Tonnage (kmt)	Grade (g gold/mt)	Tonnage (kmt)	Grade (g gold/mt)
Anglo American:						
Elandsrand	73,580	8.61	NAP	NAP	73,580	8.61
Free Gold North	271,170	5.74	19,500	0.60	290,670	5.40
Free Gold South	351,340	5.53	120,000	0.74	471,340	4.31
Vaal Reefs/Moab	284,000	9.16	49,330	0.56	333,330	7.89
Western Deep Levels	141,400	10.50	81,900	0.46	223,300	6.79
Subtotal	1,121,490	7.33	270,730	0.61	1,392,220	6.02
Anglovaal:						
Hartebeestfontein	61,250	9.10	35,330	1.51	96,580	6.32
Lorraine	17,620	5.68	8,960	0.83	26,580	4.04
Subtotal	78,870	8.34	44,290	1.37	123,160	5.83
Gengold:						
Beatrix	53,190	5.77	NAP	NAP	53,190	5.77
Bracken	2,240	3.60	NAP	NAP	2,240	3.60
Buffelsfontein	42,640	7.00	NAP	NAP	42,640	7.00
Grootvlei	5,890	5.77	190	0.90	6,080	5.61
Kinross	53,590	6.96	NAP	NAP	53,590	6.96
Leslie	28,670	4.20	6,050	0.50	34,720	3.60
Marievale	450	4.00	240	1.00	690	2.95
Oryx/Belsa	44,000	7.50	NAP	NAP	44,000	7.50
St. Helena	42,700	5.97	NAP	NAP	42,700	5.97
Stillfontein	51,600	4.12	6,000	0.93	57,600	3.79
Unisel/Jurgenshof/Tarka ¹	33,540	6.31	NAP	NAP	33,540	6.31
West Rand Consolidated	3,820	5.60	5,280	0.56	9,100	2.67
Winkelhaak	46,060	5.86	NAP	NAP	46,060	5.86
Subtotal	408,390	5.98	17,760	0.67	426,150	5.77
Gold Fields:						
Deelkraal	63,740	7.10	NAP	NAP	63,740	7.10
Doornfontein	65,350	5.43	11,880	0.80	77,230	4.72
Dreifontein Consolidated	291,080	11.31	122,640	0.43	413,720	8.09
Kloof/Leeudoorn	190,500	14.40	NAP	NAP	190,500	14.40
Libanon	81,740	5.53	NAP	NAP	81,740	5.53
Venterspost	58,100	3.79	NAP	NAP	58,100	3.79
Subtotal	750,510	10.02	134,520	0.46	885,030	8.57
JCI:						
H.J.Joel	31,530	5.63	NAP	NAP	31,530	5.63
Randfontein Estates	199,040	4.52	44,160	0.60	243,200	3.81
Western Areas	230,400	5.41	NAP	NAP	230,400	5.41
Subtotal	460,970	5.04	44,160	0.60	505,130	4.65
Randgold:						
Blyvooruitzicht	9,700	5.50	4,400	0.92	14,100	4.07
Durban Roodepoort Deep	72,750	4.16	36,430	0.45	109,230	2.92
East Rand Prop. Mines	172,880	4.95	61,700	0.80	234,580	3.86
Harmony	135,570	3.89	NAP	NAP	135,570	3.89
Subtotal	390,900	4.45	102,580	0.68	493,480	3.67
Total or wtd avg	3,211,130	7.13	614,040	0.65	3,825,170	6.09

NAP Not applicable.

¹Tonnage and grade shown in table are for Unisel and Jurgenshof farms only.

Source: Estimates by the author using data from various public sources, including Chamber of Mines publications and company annual reports.

the spread-out nature of the mining areas, and the narrow stoping widths the Witwatersrand Basin gold mines are very labor intensive.

These same characteristics result in a potentially dangerous working environment involving rockbursts, seismic activity, and high ambient temperatures. Because of these aspects, the South African gold mining industry puts great emphasis on all aspects of safety, including research and training. In this study's estimates, the maximum annual ore treated from underground mining would require about 419,000 skilled, unskilled, and semi-skilled employees for underground operations and for surface support operations directly related to underground mining. It is assumed that this level of staffing would be sufficient to handle the estimated 21.5 Mmtpy of waste⁵ to be hoisted with the 100 Mmtpy of underground ore.

According to published Chamber of Mines reports and various company annual reports, on an operation-by-operation basis the underground mining productivities for the estimates of this study range from a low of 153 mt ore/year/employee at the Kloof/Leeudoorn operation to 556 mt ore/year/employee at the H.J. Joel operation, which was designed as a fully "trackless" operation⁽⁴⁵⁾. The weighted average for all analyzed operations is 242 mt ore/year/employee. Compared to the prior study, underground mining productivity is indicated to have improved over the 1982-91 period by approximately 20 pct.

On a reef-by-reef basis, stoping widths ranged from 1 to 4 m. On an operation-by-operation basis, the average stope width was about 1.5m.

A large majority (27) of the 33 operations use conventional development and stoping methods for extraction of all of the life-of-mine reserve. The other six operations were analyzed as using "trackless" development and/or stoping for extraction of from six to 100 pct of the evaluated tonnage.

For South African gold operations, "trackless" basically means utilizing large, rubber-tired equipment such as articulated drilling machines, rock bolting machines, and, particularly, trucks and LHD's for haulage of ore and waste from development and stoping areas to main passes.

The development of trackless approaches for use in the more common, "thin-reef" operations has been the object of much research and experimentation during the 1980's and early 1990's. As of the present, it appears that few stoping areas will likely ever be made totally trackless as the stoping panels are too low in height and attitudes generally too steep. However, development, which constitutes nearly 50 pct of the extraction effort, is being made totally trackless at nearly all of the newer operations⁶.

⁵Waste amounts to be hoisted are based on the levels being handled as of the 1990-91 period as reported in various operating company annual reports. In this analytical structure, 8 of the 33 operations had no waste material hoisted and the other 25 had waste percentages ranging from 4.5 to 26.5 pct of the total material hoisted. On an overall basis, the 21.5 Mmt of waste cited in the text would represent about 17.5 pct of the total material needing to be hoisted to the surface. Vertical hoisting distances, on a shaft-by-shaft basis, were estimated to range from 600-4,000 m. The average vertical hoisting distance for all 33 operations was about 2,100 m.

⁶At the H.J. Joel operation, development is totally trackless. At the No.2 shaft of the Oryx/Beisa operation, development will be totally trackless. At Vaal Reefs, the new No. 10 shaft will have a high degree of trackless development and the No. 11 shaft (the Moab area) will likely have all the development as trackless.

Four specific advantages have been discussed about trackless mining (45). They include:

- Lower working costs, mainly due to the drastic cut in required labor and greatly reduced footwall development.
- A reduction in capital expenditure, estimated at 11 pct.
- A large improvement in productivity as a result of the reduced labor force.
- Much safer operations.

Treatment

Ores of the Witwatersrand Basin are pebble conglomerates containing sulfur (as pyrite) and uranium as well as the gold/silver particles. Because the gold is not intimately associated with the pyrite, the Witwatersrand basin ores are all "free milling", requiring no pretreatment (flotation and/or oxidation of sulfides) prior to cyanidation to achieve acceptable recoveries.

At certain operations producing uranium for sale as a separate product, flotation of a pyrite concentrate is done to produce sulfuric acid (H_2SO_4) which is then used for U_3O_8 leaching. The number of operations producing pyrite/sulfuric acid and/or uranium concentrate is very dependent upon the uranium market and the number decreased significantly during the 1982-91 period.

CAPACITIES

Of the 33 producing operations included in the analysis, 16 are underground mining operations. The remaining 17 are a mix of underground mining of reef material and surface mining of reclamation material.

For this availability analysis, it was necessary to estimate a long-term average level of ore treatment capacity. For producers, this capacity estimate is based on actual, in-place facilities as of

the study date and any planned, or known, expansions. Decisions (for this study) as to what long-term average capacity levels to choose were difficult. This was because during the early 1990's the South African industry has been adjusting ore treatment levels, mostly downwards, in reaction to the stagnant to declining world gold prices since 1988.

Table 14 lists the actual maximum reported value for annual ore treated during the 1982-91 period for each of the operations considered. Included for comparison purposes is the assumed maximum annual ore treated value for each operation in the long-term availability analysis (beyond the study date of Jan. 1992) and the percentage difference between the two treatment levels.

Twenty-three of the 33 operations have assumed maximum treatment capacities in the study that are either close to or higher than the maximum ore treatment level achieved in the 1982-91 period. The assumption is made that these operations will not contract with the declining price of gold, or that the price of gold will not continue its steady decline of the early 1990's and that the majority of the necessary

OPERATING COSTS

METHODOLOGY

The South African gold mining industry has been in a "rationalization" mode since 1989 and one of the major thrusts of this rationalization program has been directed towards labor costs and productivity. As a result, the

⁷Footwall development in trackless operations is about one-third that required for conventional layouts. According to early experiments at Vaal Reefs, once all development is in place for a trackless section it is good for about 300-m strike length of stoping compared to 90-m which is typical for the conventional layouts.

Table 14.—Summary capacity data, evaluated South African operations

Owner	Operation	Actual maximum annual ore treated, 1982-91 (kmt)	Maximum annual ore treated in analysis ¹ (kmt)	Pct difference ²
Anglo American	Elandsrand	2,276	2,300	+ 1.1
	Free Gold North	10,890	11,220	+ 3.0
	Free Gold South	15,593	15,720	+ 0.8
	Vaal Reefs/Moab	11,335	11,640	+ 2.7
	Western Deep Levels	6,623	7,040	+ 6.3
	Subtotal	46,717	47,920	+ 2.6
Anglovaal	Hartebeestfontein	4,848	4,730	- 2.4
	Loraine	1,610	1,600	- 0.6
	Subtotal	6,458	6,330	- 2.0
Gengold	Beatrix	2,156	2,160	+ 0.2
	Bracken	1,001	640	-36.2
	Buffelsfontein	3,479	2,580	-25.9
	Grootvlei	2,001	610	-69.6
	Kinross	2,241	2,000	-10.8
	Leslie	1,411	1,090	-22.8
	Marievale	480	230	-51.9
	Oryx/Beisa	1,060	1,200	+13.2
	St. Helena	2,390	2,100	-12.1
	Stilfontein	1,988	2,000	+ 0.6
	Unisel/Jurgenshof/Tarka	1,380	1,160	-15.9
	West Rand Consolidated	2,230	910	-59.2
	Winkelhaak	2,430	1,900	-21.8
	Subtotal	24,247	18,580	-23.4
Gold Fields	Deelkraal	1,642	1,620	- 1.3
	Doornfontein	1,560	1,560	0.0
	Driefontein Consolidated	8,075	8,100	+ 0.3
	Kloof/Leeudoorn	2,745	4,050	+47.4
	Libanon	1,740	1,740	0.0
	Venterspost	1,652	1,600	- 3.2
	Subtotal	17,414	18,670	+ 7.2
JCI	H.J. Joel	1,012	1,080	+ 6.7
	Randfontein Estates	9,144	8,800	- 3.8
	Western Areas	3,921	2,850	-27.3
	Subtotal	14,077	12,730	- 9.6
Randgold	Blyvooruitzicht	2,401	2,350	- 2.1
	Durban Roodepoort Deep	2,447	2,280	- 7.0
	East Rand Prop. Mines	3,238	3,800	+17.4
	Harmony	9,571	7,200	-24.8
	Subtotal	17,657	15,630	-11.5
Grand total		126,570	119,860	- 5.3

¹Maximum annual amount of ore assumed to be treated during remaining life-of-mine, as estimated for this availability study.

²Difference, availability study maximum treatment capacity from actual maximum treated during 1982-91 period.

period 1989-91 has seen a decline in employment levels. This decline is reflected in estimates of the number of laborers required in the gold industry.

Estimated annual remuneration levels used in this study for the various employment categories and skills are summarized in table 15. Wage rates are set by agreement between the National Union of Mine Workers (NUM) and the Chamber of Mines. The 1991 agreement represented a major departure from past agreements. It featured modest basic wage increases of only 4-9 pct (compared to mid-teens percentage increases typical of the 1970's and the 1980's), and included a new type of bonus tied to the price of gold.

The acceptance by the NUM of "below inflation level" wage increases in this agreement was important. It can be considered as acceptance that, given a stagnant to declining gold price, improving the profitability of the South African gold mining industry and, in the process, preserving NUM jobs will be achieved by restraining the rise in labor costs. However, at the start of negotiations for the 1992 agreement the NUM had supposedly already ruled against another profit and productivity linked wage deal (46).

Estimates for the costs of materials, supplies, and equipment are based on estimates from the previous study, which utilized the Bureau's Cost Estimating System (CES)(47) supplemented by updates to the system and personal site visits. This system provides an annual cost for each of the individual categories (e.g., stopping, hoisting, and ventilation in underground mining costs and crushing and grinding in treatment costs) comprising overall production costs. After technical adjustments addressing changes from the prior study, the Bureau's Cost Indexation System (internal to the Bureau's economic evaluation program) was used to update these cost estimates to a common, Jan. 1992 U.S. dollar base for this report. The CES was not used to

estimate labor costs because of significant differences in the productivities typical of South African gold mining operations compared to conventional world underground operations. In the United States and Canada the ratio of skilled to unskilled mining wage rates is typically less than 2:1 (47), rather than the 4:1 ratio shown in table 15.

In April 1994, the Republic of South Africa held its first universal-franchise election. This election allowed black citizens to vote for the first time and to elect an interim government of national unity. Until recently, black workers held unskilled and semi-skilled positions primarily, while white workers held skilled positions almost exclusively. As shown in table 15 there is a great disparity between unskilled and semiskilled workers' remuneration levels and the remuneration level for skilled workers. Therefore, it should be expected that a government elected by, and comprised mostly of, black citizens should be expected to address some of these differences in job availability and pay. The only question is the form in which the differences will be addressed.

Whether the new government can influence changes in wage remuneration is not clear. Absent any control over world gold prices, only improvements in labor productivity would allow major adjustment of the average wage and benefit remuneration system and the labor structure. Internal inflation has been, and still is, a major threat to the profitability of the South African gold industry. Black employees constitute about 90 pct of the total employment in the gold mines. Thus, major (above the normal inflation rate) wage and benefit increases for blacks would exacerbate these inflationary pressures.

Figures 12 and 13 illustrate how much internal South African inflation occurred from 1981-91. Individual cost indexes are shown (figure 12) as well as the impact

Table 15.--Total annual remuneration values used in South African operating cost estimates,
by mining finance group¹
(U.S. \$/yr)

Category	Ownership group					
	Anglo American	Anglovaal	Gengold ²	Gold Fields	JCI	Randgold
Skilled	16,700	16,700	16,700	16,700	16,700	16,700
Un-,semi- skilled;						
Surface	4,200	3,800	3,760	3,800	4,230	4,040
Underground	5,230	4,580	4,560	4,580	5,250	4,920

¹Converted from rand values using average exchange rate of .363 \$/R.

²Average of two different sets of remuneration scales; one being the normal scale and the other for the "marginal" operations.

Source: Compiled from various Chamber of Mines documents, company annual reports, and USBM estimates.

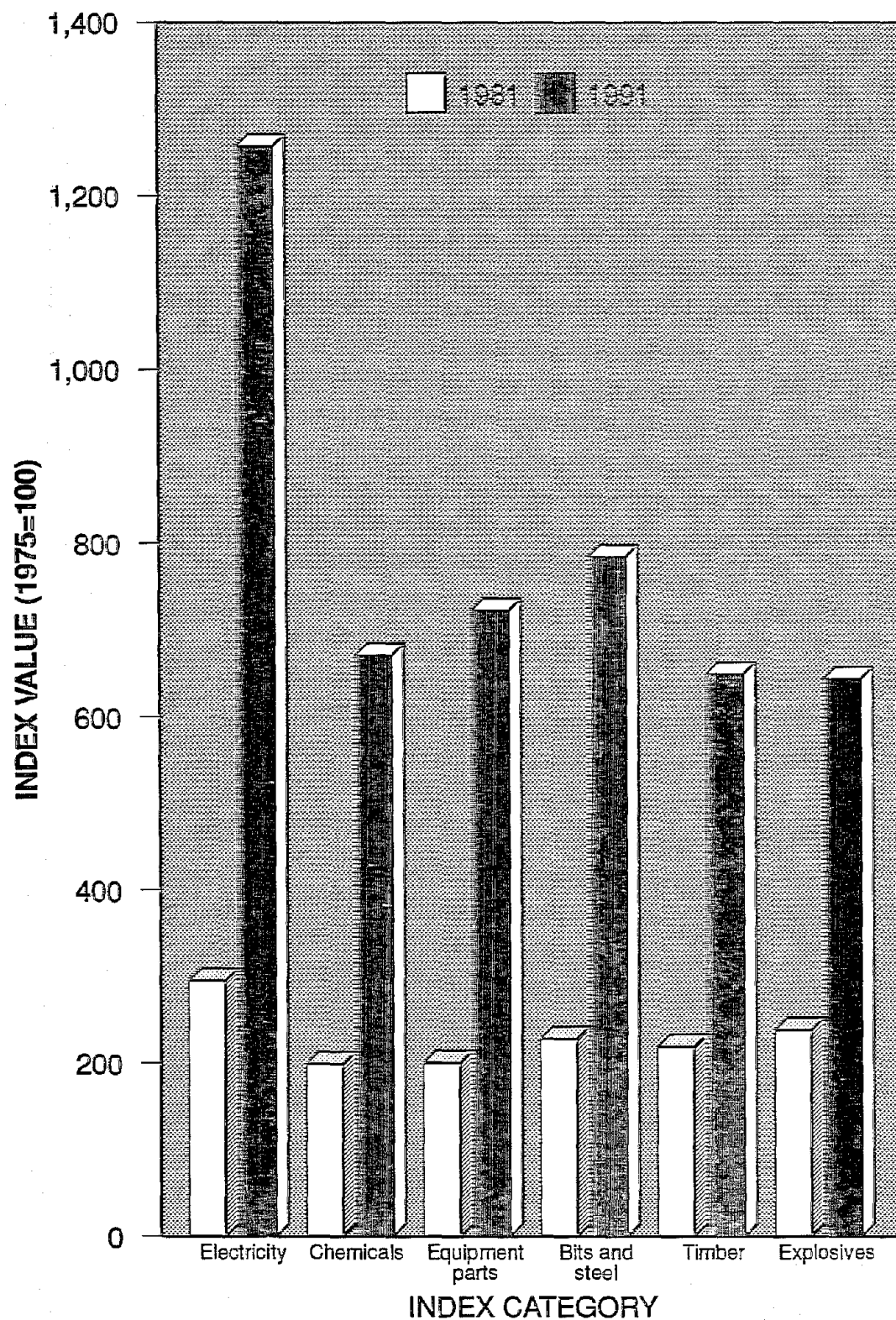


Figure 12.--Selected non-labor cost indices, 1981 and 1991, measured in RSA rands.

Source: Sullivan, et al (48), updated by USBM using published documents.

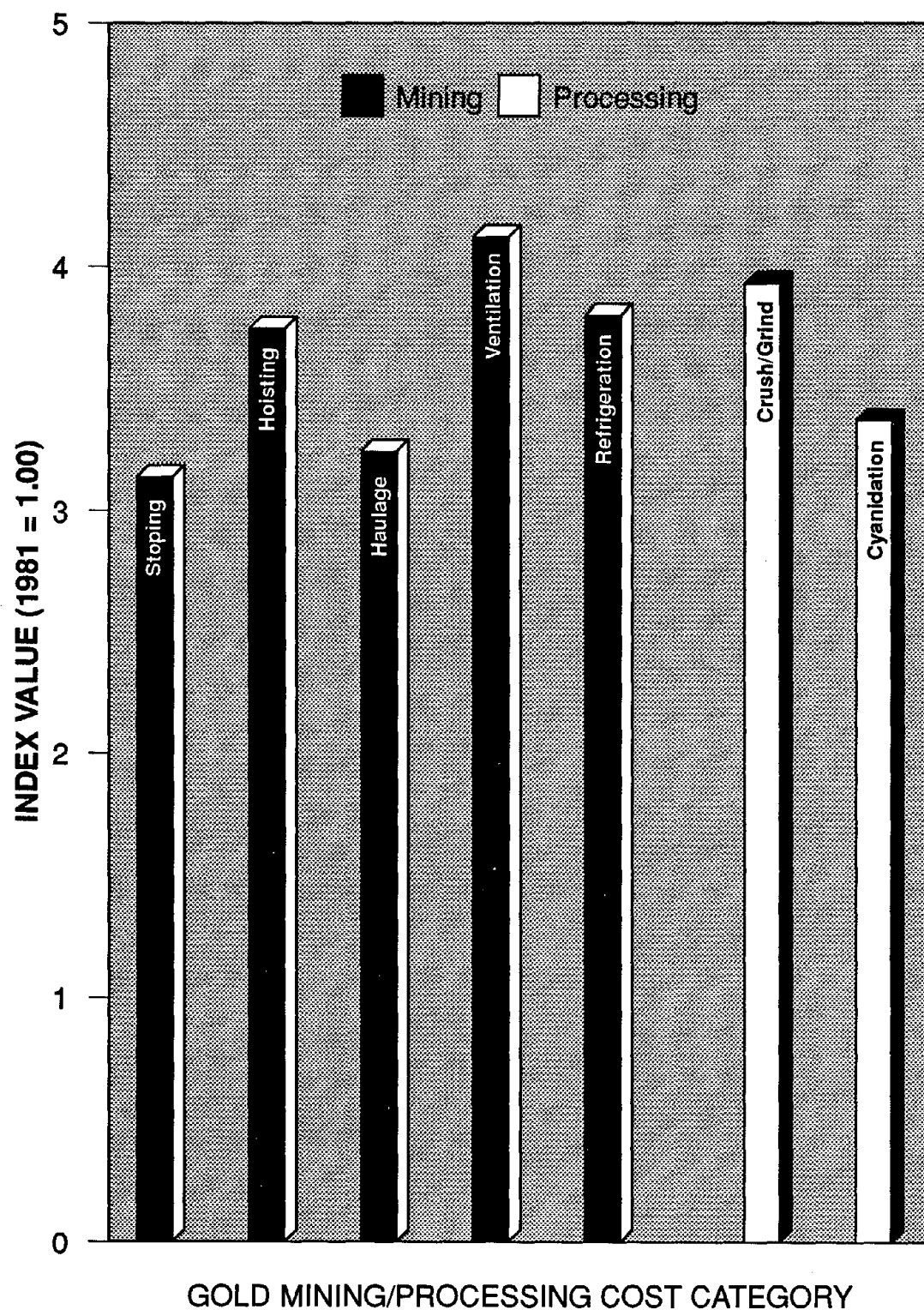


Figure 13.--Escalation factors for selected gold mining and treatment activities, 1981 and 1991, measured in RSA rands.

Source: Author's estimates, based on index data described in (48).

of this inflation on the most significant individual mining and treatment activities comprising the South African industry (figure 13). These cost indexes, as well as country exchange rates have been maintained for the past 15 years by the Minerals Availability Field Office, in Denver, CO for approximately 100 countries. A description of the methodology underlying these indexes can be found in U.S. Bureau of Mines Bulletin 692 (21).

All of the doré bullion produced in South Africa is refined at the Rand Refinery in Germiston, about 15 km south of Johannesburg. The refinery was completely refurbished during the 1980's and it is now estimated to be capable of refining about 809 mt (26 M tr oz) of gold/yr. The refinery is owned and operated by The Rand Refinery Ltd. Corp. This cooperative service company was established for the benefit of the South African gold mining industry. It processes doré bullion on behalf of members of the Chamber of Mines who are credited for 99.2 pct of the gold in their doré bullion(49).

MINING AND TREATMENT OPERATING COSTS

Table 16 summarizes the operating cost estimates made for this study. Labor percentages are included because of their importance to the South African gold industry's cost structure.

Mining

For all analyzed operations, the mining cost estimates range from \$20.07 to \$63.25/mt ore treated with a weighted average of \$40.23/mt. Using a yield grade of 5.79 g gold/mt, the \$40.23/mt value is equivalent to about \$216/tr oz of recovered gold.

Treatment

For all operations, the treatment cost estimates range from \$3.56 to \$11.85/mt ore treated; the weighted average is \$5.85/mt. Using a yield grade of 5.79 g

gold/mt, the \$5.85/mt ore value is equivalent to about \$31/tr oz of recovered gold.

Mining Plus Treatment

For all analyzed operations, the mining plus treatment cost estimates ranged from \$25.07 to \$69.99/mt ore treated with a weighted average of \$46.08/mt. Using the weighted average yield grade of 5.79 g gold/mt, the \$46.08/mt equates to about \$247/tr oz of recovered gold. Overall, labor costs account for 49.0 pct of the mining plus treatment cost estimate of \$46.08/mt ore treated for all 120 Mmtpy of annual ore capacity.

CAPITAL COSTS

In this study, the total capital investment estimated to be required for extraction of the demonstrated reserves at all operations was about \$37 billion (Jan. 1992 dollars). Ranging from \$0.42 billion to \$4.78 billion per operation, the average was \$1.12 billion per operation. The total capital investment requirement for all operations is equivalent to \$52/tr oz of recoverable gold.

ECONOMIC ANALYSES AND RESULTS

TAXATION STRUCTURE IN ANALYSIS

The tax structure of South African gold operations includes the State's Share of Profits (SSP) tax and a national tax rate on mining. The rates for both taxes are determined using formulas based on revenues minus all operating and capital expenditures⁸. The formulas

⁸In practice, most capital expenditures at South African gold mines can be deducted in this formula. The remainder is subject to a small pct of depreciation over 5 and 10 years. This depreciable amount is not considered large enough to impact the tax structure used in this study or the economic analysis results.

Table 16.--Summary of annual ore treatment levels and operating cost estimates for South African gold availability study, by mining type

Category	Total annual treatment capacity (kmtpy)	Operating cost estimate values			
		Operating cost estimates		Labor pct	
		Range ¹ (Jan.1992 \$ per mt ore treated)	Wtd. avg. ² (Jan.1992 \$ per mt ore treated)	Range ¹	Wtd. avg. ²
Mining:					
Combination:					
Underground	65,180	30.62 - 63.97	48.57	37.5 - 62.6	52.8
Reclamation	18,500	0.44 - 7.55	3.94	16.4 - 40.0	31.5
Subtotal wtd avg	83,680	20.07 - 57.57	38.61	16.4 - 62.6	52.3
Underground only:					
Underground	36,170	31.69 - 63.25	43.97	39.0 - 56.2	49.5
Subtotal wtd avg	36,170	31.69 - 63.25	43.97	39.0 - 56.2	49.5
Summary:					
Underground	101,350	30.62 - 63.97	46.92	37.5 - 62.6	51.7
Reclamation	18,500	0.44 - 7.55	3.94	16.4 - 40.0	31.5
Total wtd avg	119,850	20.07 - 63.25	40.23	16.4 - 62.6	51.4
Treatment:					
Combination	83,680	3.93 - 10.17	5.63	13.2 - 42.0	32.0
Underground only	36,170	3.56 - 11.85	6.37	16.4 - 49.3	33.1
Total wtd avg	119,850	3.56 - 11.85	5.85	13.2 - 49.3	32.5
Mining plus treatment:					
Combination	83,680	25.07 - 63.44	44.24	36.3 - 53.1	49.7
Underground only	36,170	40.02 - 69.99	50.14	35.4 - 56.7	47.4
Total wtd avg	119,850	25.07 - 69.99	46.08	35.4 - 56.7	49.0

¹Ranges compiled on a property-by-property basis.²Weighted average based on annual ore treatment capacity, property-by-property.

Source: Author's estimates.

for these two taxes are different and the mining tax includes the SSP tax as a deduction along with the operating and capital expenditures.

The combined total effective tax rates used in this analysis for each operation are listed in table 17. In the economic evaluation system, the rates shown are applied to total taxable income, defined as total revenues minus total operating and capital costs. In the methodology of the study, a tax rate of 0-pct means that the calculation of the estimated revenue at \$362/tr oz (the 1991 average gold price) minus long term operating and capital expenditures was negative.

Eleven of the operations have no (0 pct) effective tax rate while 14 have fairly high rates ranging from 45.1 to 56.7 pct. The remaining 8 operations have rates ranging from 12.4 to 39.4 pct. In effect, the study's tax structure mimics the actual South African tax structure in that the worst operations from an economic standpoint have a much lower effective tax rate than those operations having the best economics.

The tax structure of this study is based on gold prices typical of the early 1990's, i.e., in the \$300-\$400/tr oz range. Because the South African taxation system is dependent on revenue levels, which vary greatly based on gold price, overall tax rates used in this study would be different at significantly higher or lower gold market prices. In particular, those operations which have a zero percent taxation level in this study would likely be paying taxes in a higher gold price range of \$400-\$500/tr oz.

ECONOMIC EVALUATION

For this study, discounted cash flow rate of return (DCFROR) runs were made to determine the price of gold required for each operation to obtain a specified rate of return on its investments. Evaluations were conducted at 0-, 10- and 15-pct DCFROR's. Byproduct revenues from the sale of silver (all

operations), sulfur as sulfuric acid (two operations) and uranium as U_3O_8 (five operations) were calculated using average 1991 prices of \$4.04/tr oz for silver, \$48.00/mt for sulfuric acid, and \$4.00/kg for U_3O_8 . On an overall weighted average basis, the amount of byproduct revenue in the economic evaluation of this study is minimal, amounting to a credit of only \$3.23/tr oz gold.

No royalties were included for any of the analyzed operations because there are no applicable governmental royalties. All DCFROR runs assume 100 pct equity and full analyzed capacity production over the life of the mine.

TOTAL AVAILABILITY CURVES

Figure 14 presents the availability curves showing the total cost results from economic evaluation of the 33 producing operations. The figure shows that all of the 22,305 mt (717.2 M tr/oz) estimated as recoverable from the 33 operations can be produced at total costs at or below \$561/tr oz for a 0-pct DCFROR and \$570/tr oz for a 15-pct DCFROR.

A total of 17,509 mt (563 M tr/oz) needs prices up to \$390 tr/oz to provide a 15-pct DCFROR. Only 10,139 mt (326 M tr/oz) of gold are estimated as recoverable at total costs of less than \$300/tr oz at a 15-pct DCFROR, representing 45.5 pct of the total recoverable gold. This amount is contained in 8 of the 33 producing operations and represents the most profitable "core" of the South African gold industry.

ANNUAL AVAILABILITY CURVES

Figure 15 presents the potential annual gold production curves for the combined output of the 33 producing operations included in the analysis. The vast majority of the annual output can be produced at a total cost under \$400/tr oz for a 0-pct DCFROR.

Given the necessary prices by the marketplace, a drastic decline in output does not occur until the

Table 17.--Effective tax rates, evaluated producing South African gold mining operations

Owner	Operation name	Effective tax rate in analysis ¹ (pct)
Anglo American	Elandsrand	51.4
	Free Gold North	19.1
	Free Gold South	33.4
	Vaal Reefs/Moab	55.5
	Western Deep Levels	47.2
Anglovaal	Hartebeestfontein	55.3
Gengold	Loraine	0.0
	Beatrix	49.8
	Bracken	0.0
	Buffelsfontein	39.4
	Grootvlei	0.0
	Kinross	55.2
	Leslie	0.0
	Marievale	48.3
	Oryx/Beisa	50.3
	St. Helena	33.3
	Stilfontein	0.0
	Unisel/Jurgenshof/Tarka	52.6
	West Rand Consolidated	0.0
	Winkelhaak	0.0
Gold Fields	Deelkraal	52.1
	Doomfontein	0.0
	Driefontein Consolidated	56.7
	Kloof/Leeudoorn	56.3
	Libanon	34.3
	Venterspost	0.0
JCI	H.J. Joel	47.1
	Randfontein Estates	30.5
	Western Areas	45.1
Randgold	Blyvooruitzicht	18.1
	Durban Roodepoort Deep	12.4
	East Rand Prop. Mines	0.0
	Harmony	0.0

¹Effective total Federal and State rate applied in the study to the net of revenues minus operating and capital expenditures, according to the following formulas:

$$\text{SSP Tax Rate} = 15 - (120 \div X)$$

where

$$X = [(\text{revenues} - (\text{operating} + \text{capital costs})) \div \text{revenues}] \times 100$$

$$\text{Mining Tax Rate} = 58 - (290 \div Y)$$

where

$$Y = [(\text{revenues} - (\text{operating} + \text{capital costs} + \text{SSP tax})) \div \text{revenues}] \times 100$$

To determine a combined, long-term, effective tax rate for each operation, each operation's total revenue was calculated based on a gold price of \$362/tr oz (the 1991 average). Total operating and capital cost were subtracted, the SSP tax rate was calculated, and the amount of the SSP tax was determined. The National Tax Rate was determined in a similar fashion. The two tax rates were combined to give the single value shown in the table for use in the economic evaluation program.

Source: Compiled from published articles from the R.S.A. Chamber of Mines.

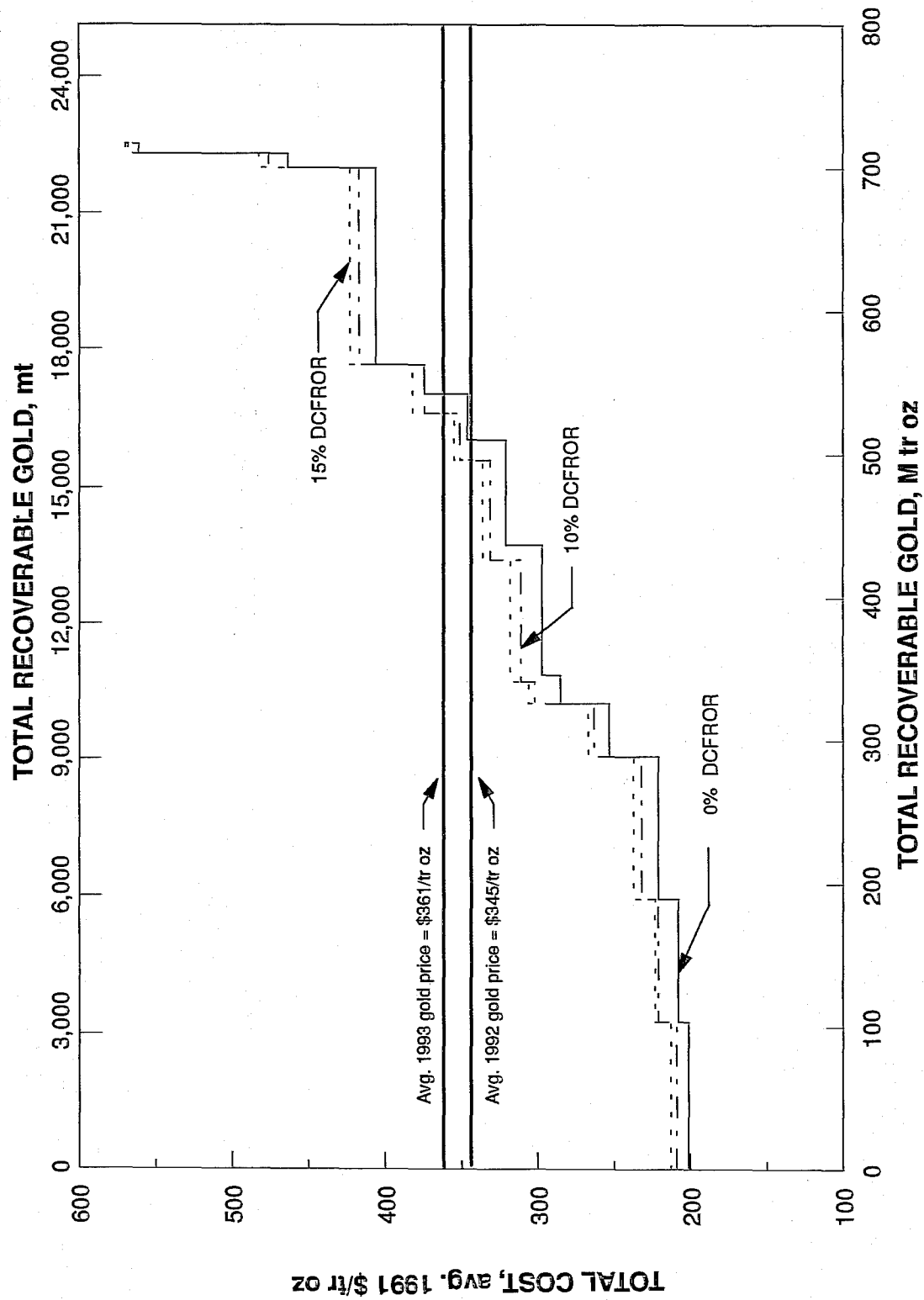


Figure 14. -- Potential gold available from 33 major South African producing operations.

Source: USBM estimates.

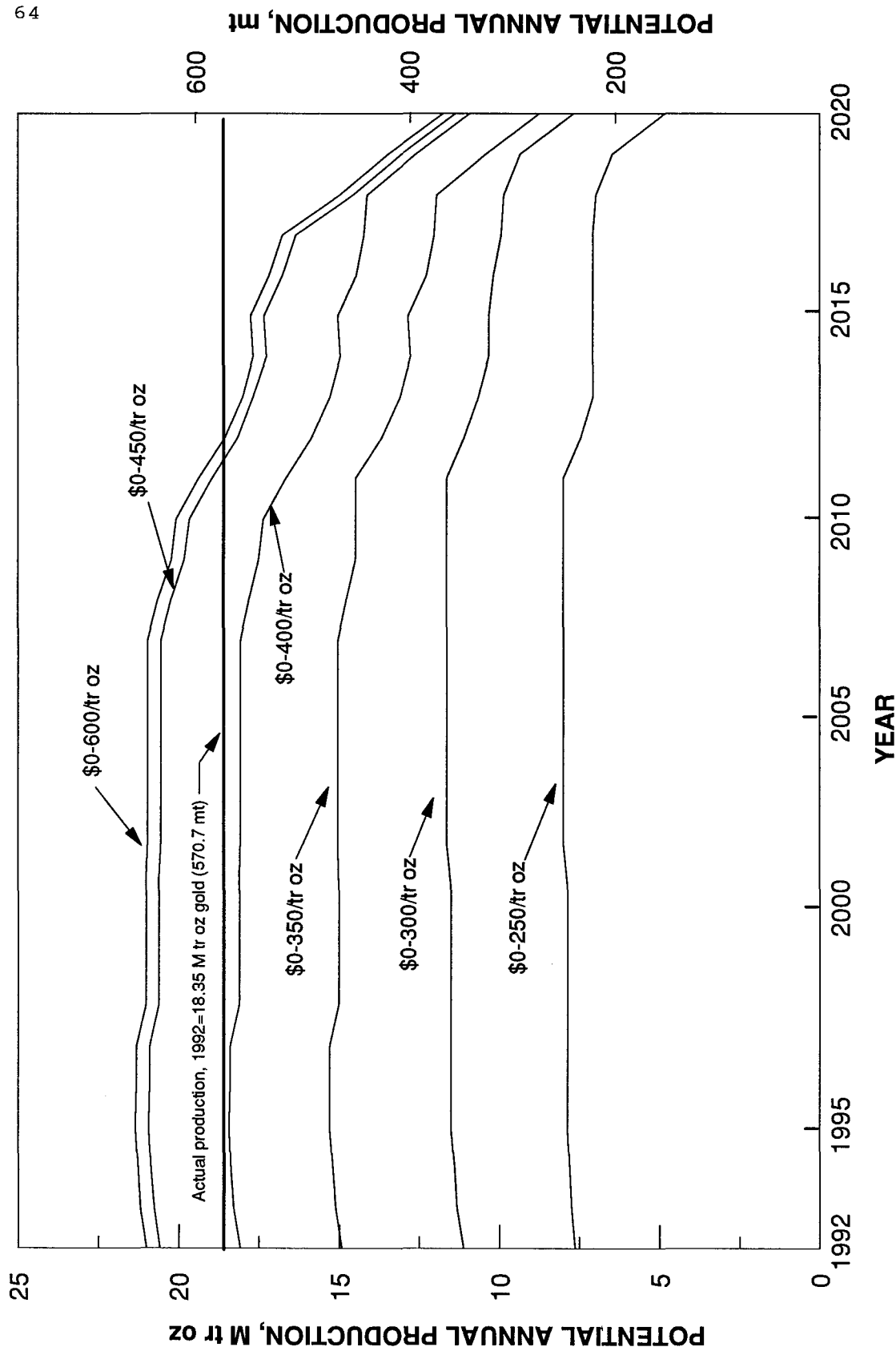


Figure 15.--Potential South African annual gold production at various 0-pct DCFROR total cost levels.

Source: USBM estimates.

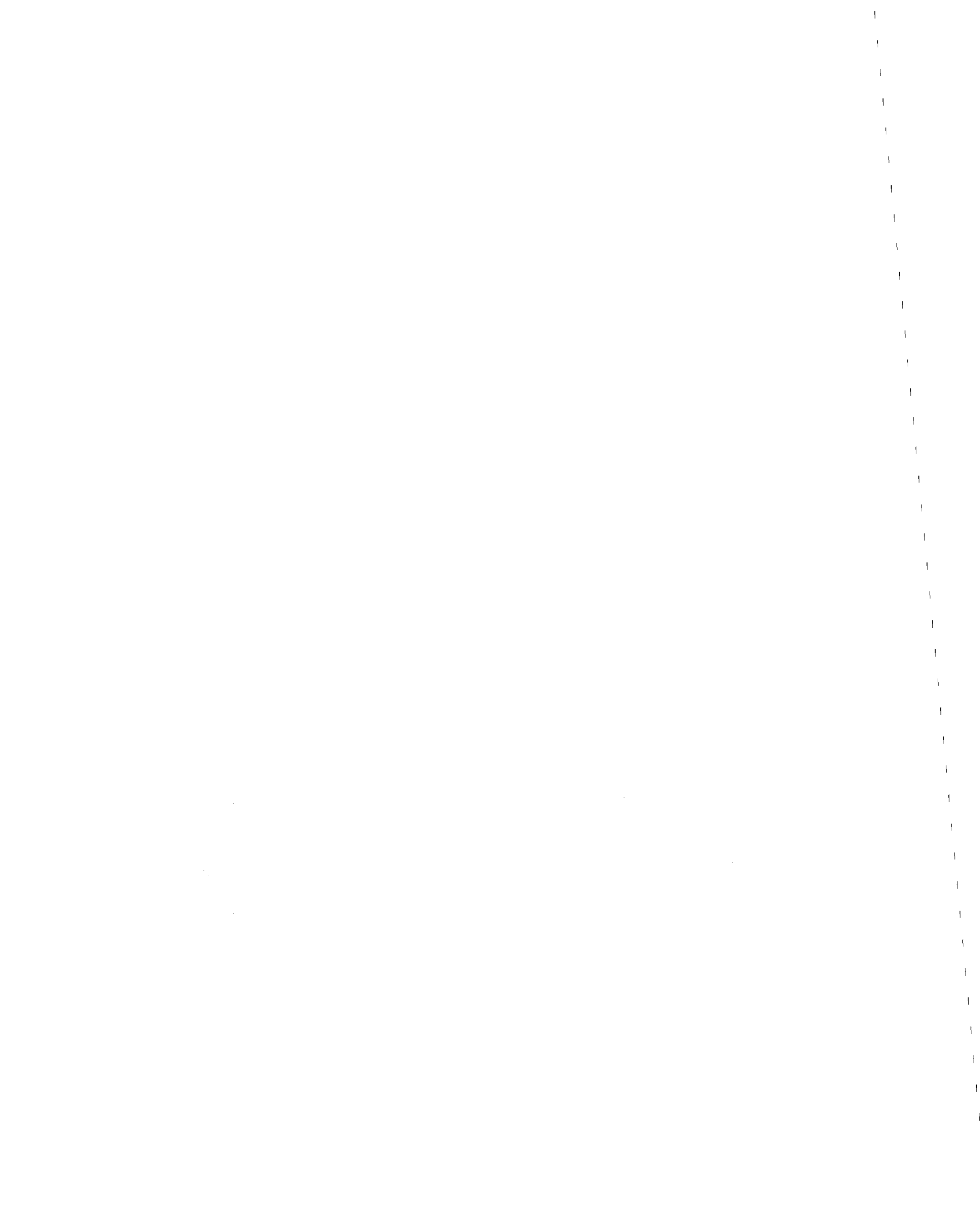
year 2017. The major declines shown at the end of these annual curves reflect reserve exhaustion at the defined mining leases (as estimated for this study). These annual curves represent a static analysis, assuming no replacement of depleted reserves with potential new reserves from areas beyond the existing, defined mining leases. The curves also do not include possible new reserves available from future development of the prospective mining lease areas not included in this availability study.

It has been suggested from several sources that South Africa's gold production could fall from the current 613.9 mt (19.7 M tr oz) to 470 mt (15.1 M tr oz) without a rescue by a gold price surge(50). The annual availability curve results are consistent with that suggestion for, as shown, the annual amount available at costs below the \$350/tr oz level is about 470 mt.

RESULTS AND CONCLUSIONS

The following summarizes the results and conclusions of this study of gold availability from the Republic of South Africa:

- The 33 major South African gold producers can profitably produce about 560 mt (18 M tr/oz) per yr through the year 2007, given a constant average 1991 U.S. dollar gold price of \$400/tr oz. A very rapid decline in output would not begin until the year 2017. Regardless of the cost of production, the curves show annual production from the 33 operations declining to 364 mt (11.7 M tr/oz) by the year 2020. The results shown in these curves assume no replacement to reserves by development beyond the boundaries of the analyzed mining lease areas.
- In local currency measures, the country has experienced high rates of annual inflation over the 1982-91 period. Internally, the deleterious effect of this inflation on the mines' cost structure has been mitigated mainly by devaluation of the rand vis-a-vis the U.S. dollar. Declining U.S. dollar gold prices beginning in 1988 and continuing through the early 1990's has put great pressure on the industry to control increases in costs of labor, materials, and other supplies.
- A total of 23,297 mt (749 M tr oz) of gold is contained on the present mining lease areas of the 33 analyzed operations. This amount is 4.6 times larger than the 1992 reserve base of the world's 2nd largest producing country, the United States. Gold contained in underground reef material totals 22,895 mt (736.2 M tr oz), or 98.3 pct of the total. Total recoverable gold is 22,305 mt (717.2 M tr oz)
- Economic evaluation results show that about 69 pct (15,426 mt, or 496 M tr/oz) of the available gold can provide a 15-pct DCFROR at a gold price of \$345/tr oz, which is nearly equal to the average gold price for all of 1992. At \$390 tr/oz, 17,509 mt, (563 M tr/oz) can provide a 15-pct DCFROR.



CHAPTER 4

CANADIAN GOLD AVAILABILITY

By Kenneth E. Porter¹ and David A. Buckingham¹

This chapter presents a study on the gold industry of Canada. Historical trends are depicted for production, commodity price, exploration expenditures, flow through shares, employment and reserves/resources. Technical aspects that characterize the Canadian gold mining industry are also discussed along with many of the factors affecting production costs.

Economic evaluation results are compiled and presented for 27 primary gold (25 producing) and 4 gold-copper properties, showing the 1993 cash operating cost structure. Capital costs are tabulated by region and presented by investment category.

Evaluation results are shown for the 25 primary gold producers evaluated for this study at 0-pct and 15-pct DCFROR. The weighted average cash operating cost and total production cost are shown by region. All results are reported in U.S. dollars to facilitate comparisons with other sections of this report.

Also included are the total availability curve and annual production curves at varying gold prices over the period 1993 through 2000. Analysis is presented for the gold-copper properties evaluated showing the sensitivity of the production cost at 0-pct DCFROR to changes in byproduct prices. A complete discussion of the availability of gold from Canada will be contained in a planned Open File Report on the gold industry of Canada.

INTRODUCTION

A three-fold increase in economic minable reserves and production from 1980-91 was brought about by a combination of high gold prices in the early 1980's and low commodity prices for silver and many of the base and ferrous metals produced in Canada. According to the U.S. Bureau of Mines, Canada's market share of world gold production doubled from 4.2 pct in 1980, when it was the world's third largest producer, to 8.3 pct in 1991, then declined to 7.1 pct in 1992, when Canada ranked fifth in world gold production (4). Output from the United States and Australia grew much faster than it did in Canada. Application of heap leach technology in the United States and bulk mining methods at a large number of properties in Australia and the United States made possible the economic recovery of gold from low-grade and large-tonnage oxidized deposits. Canada does not have a similar mineral endowment. The northern climate makes the recovery of gold from heap leach piles difficult, if not impossible, during the winter when the leaching solution would freeze. Another factor is that the gold deposit type most commonly mined in Canada is in vein or shear zone structures that require more costly underground mining methods (with lower productivity) for extraction of ore.

Thirty-one properties were selected for inclusion in the Canadian gold industry analysis based on production or potential

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production and significant remaining reserves. Twenty-five primary gold operations were producing in 1992 (representing 73.5 pct of 1992 gold production); one is on temporary shutdown status, and one property is currently being explored and evaluated for permitting and development. The remaining four are co-product gold-copper deposits in British Columbia in various stages of exploration and evaluation leading to potential development. Table 18 provides a list of properties selected for evaluation and figure 16 shows the locations of these properties. The geographical distribution of the selected properties provides a good representation of the major centers of gold production and exploration activity in Canada. Technologies represented cover the full spectrum of Canadian gold recovery methods currently employed.

HISTORICAL PERSPECTIVE

GOLD PRODUCTION

Gold production from mining operations in Canada more than tripled from 50.6 mt (1.63 M tr oz) in 1980 to a peak of approximately 175.3 mt (5.64 M tr oz) in 1991, declining in 1992 to 159.9 mt (5.14 M tr oz) (46). In 1991 three mines in the Hemlo district, Ontario, contributed over 23 pct of total Canadian gold production.

From 1981-93, the average annual gold price fluctuated between \$317 and \$460 per tr oz (24). At the same time the prices for other commodities, such as copper, iron, lead, nickel, silver and zinc, which are also important to Canada's mining industry, were depressed. Gold was the commodity of choice for many exploration and mining companies in Canada. Additionally, expansions at existing mines and start up at numerous smaller operations had their positive impact on production. Declining gold production since 1991 primarily resulted from mine closures due to exhaustion of reserves and reduced

replacement capacity from new mines and expansion at existing mines. The peak in gold production in 1991 is also an indication of the "maturing" of some mines, such as in the Hemlo district, where declining ore grades are being processed following initial treatment of higher grade ores.

Canadian gold production by source for the period 1980-92 as reported by Natural Resources Canada, is shown in table 19 (52). Primary gold deposits provided the greatest proportion throughout the period, increasing from 63 pct to 88 pct of the total. Though production of gold has remained relatively constant from base metal ores, the proportion of gold production from this source has declined from nearly 33 pct to below 10 pct.

EXPLORATION EXPENDITURES

As stated by Natural Resources Canada, the lack of new gold production capacity has been a matter of major concern in recent years in Canada. Between 1983 and 1990, there were a number of incentives for exploration in Canada's tax code. The combination of the tax benefits of flow-through shares, improved Mining Exploration Depletion Allowance (MEDA), the Canadian Exploration Incentive Program (CEIP), and favorable gold prices led to a significant increase in exploration activity in Canada during this period (53).

The flow-through shares provisions allowed shareholders to deduct the Canadian Exploration Expense (CEE) on their personal income tax filings at the rate of 100 pct plus, from 1983 through mid 1988; an additional 33-1/3 pct could be deducted as an earned depletion allowance. These changes in the tax laws were enacted in an effort to promote minerals exploration in Canada and reverse the declining reserves trend. According to Natural Resources Canada, the provisions in the flow-through tax laws benefitted junior companies more than the established

Table 18.—Canadian gold properties evaluated in study

Province	Map number ¹	Ownership	Mine type ²	Status ³	First year of production	Ore capacity (kmtpy)	1992 gold production (kg)
Primary Gold							
British Columbia:							
1.	Eskay Creek	Prime Resources Group Inc./Stikine Resources Ltd	U	E	1996*	126	NAP
2.	Golden Bear	Homestake Mining Co.	S	P	1990	133	1,800
3.	Nickel Plate	Homestake Mining Co.	S	P	1987	1,154	2,600
4.	Snip	Cominco Ltd./Prime Resources Group Inc.	U	P	1991	165	4,800
Subtotal						1,578	9,200
Newfoundland:							
5.	Hope Brook	Royal Oak Mines Inc.	U	P	1987	1,100	1,600
Subtotal						1,100	1,600
Northwest Territory:							
6.	Colomac	Royal Oak Mines Inc.	S	T	1990	2,800	NAP
7.	Con	Miramar Mining Corp.	U	P	1938	345	3,800
8.	Giant	Royal Oak Mines Ltd.	U	P	1948	345	3,000
9.	Lupin	Echo Bay Mines Ltd.	U	P	1982	642	6,700
Subtotal						4,132	13,500
Ontario:							
10.	Arthur W. White	Dickenson Mines Ltd.	U	P	1948	260	2,300
11.	Campbell	Placer Dome Inc.	U	P	1949	460	9,300
12.	David Bell	Homestake Mining Co./Teck Corp.	U	P	1985	470	6,500
13.	Detour Lake	Placer Dome Inc.	U	P	1983	862	4,000
14.	Dome	Placer Dome Inc.	U	P	1912	1,225	5,400
15.	Golden Giant	Hemlo Gold Mines Inc./Teck Corp./Homestake Mining Co.	U	P	1985	1,200	14,000
16.	Golden Patricia	Lac Minerals Ltd.	U	P	1988	115	2,500
17.	Holt-McDermott	American Barrick Resources Corp.	C	P	1988	430	1,400
18.	Macassa	Lac Minerals Ltd.	U	P	1933	154	2,400
19.	Williams	Homestake Mining Co./Teck Corp.	U	P	1985	2,200	15,500
Subtotal						7,376	63,500
Quebec:							
20.	Bousquet #1	Lac Minerals Ltd.	U	P	1979	327	1,900
21.	Bousquet #2	Lac Minerals Ltd.	U	P	1990	635	4,600
22.	Casa Berardi	TVX Gold Inc./Golden Knight Resources Inc.	U	P	1988	527	2,500
23.	Donald J. LaRonde	Agnico-Eagle Mines Ltd.	U	P	1988	650	4,200
24.	Doyon	Lac Minerals Ltd./Cambior Inc.	U	P	1981	1,180	7,800
25.	Kiena	Placer Dome Inc.	U	P	1981	500	2,500
26.	Sigma	Placer Dome Inc.	C	P	1937	460	2,600
27.	Silidor	Hemlo Gold Mines Inc./Cambior Inc.	U	P	1990	440	2,300
Subtotal						4,719	28,500
Total						18,905	116,000
Gold-Copper							
British Columbia:							
28.	Fish Lake	Taseko Mines Ltd.	S	E	1998*	20,000	NAP
29.	Kemess South	El Condor Resources Ltd./St. Phillips Resources Inc.	S	E	1997*	14,600	NAP
30.	Mount Milligan	Placer Dome Inc.	S	E	1998*	22,700	NAP
31.	Mount Polley	Imperial Metals Corp.	S	E	1996*	5,000	NAP
Total						62,300	NAP

NAP Not applicable.

*Estimated.

¹Numbers refer to property locations on figure 16.²U = Underground; S = Surface; C = Combined surface and underground.³E = Explored; P = Producing; T = Temporary shutdown.

NOTE: Totals may not add due to independent rounding.

Source: Compiled from various available public documents, including Energy, Mines and Resources Canada Yearbooks and Company annual reports.

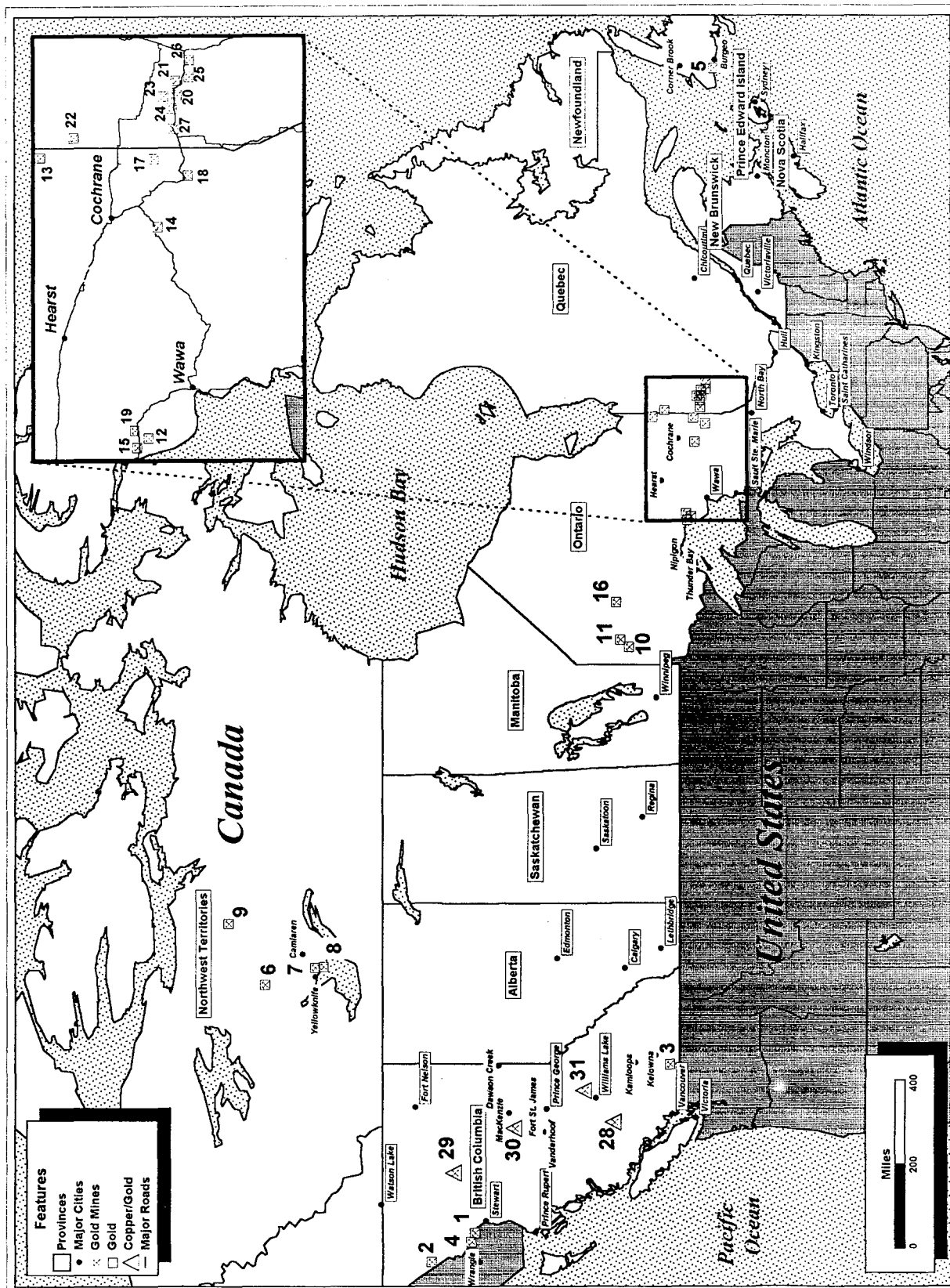


Figure 16.--Property location map of Canada.

Source: USBM data, numbers refer to properties in table 18, map prepared by Geoquest (51).

Table 19.-Canadian gold production by source, 1980-92

Year	Primary gold ores		Placer		Base metal ores		Total
	(kg)	(pct)	(kg)	(pct)	(kg)	(pct)	
1980	31,929	63.1	2,060	4.0	16,632	32.9	50,620
1981	35,877	69.0	1,633	3.1	14,525	27.9	52,034
1982	47,866	74.0	2,476	3.8	14,393	22.2	64,735
1983	55,522	75.5	3,235	4.4	14,756	20.1	73,512
1984	62,554	75.0	3,393	4.1	17,499	20.9	83,446
1985	67,241	76.8	3,464	4.0	16,857	19.2	87,562
1986	83,197	80.9	2,802	2.7	16,900	16.4	102,899
1987	94,723	81.8	4,009	3.5	17,086	14.8	115,818
1988	112,404	83.4	4,879	3.6	17,530	13.0	134,813
1989	138,211	86.6	5,354	3.4	15,930	10.0	159,494
1990	147,355	88.0	3,993	2.4	16,025	9.6	167,373
1991	153,859	87.8	3,834	2.2	17,589	10.0	175,282
1992	141,472	88.5	3,469	2.2	14,917	9.3	159,858

* Revised.

NOTE: Totals may not add due to independent rounding.

Source: Natural Resources Canada (52).

senior companies, by providing access to exploration financing for high risk ventures that otherwise would not have been available (54). The effectiveness of flow-through shares in the finding of new reserves is mixed (55). On the one hand, discoveries were made during the 1980's, primarily gold vein type. On the other hand, the average value of these discoveries was lower than the historical average.

The Mining Sector of the Department of Natural Resources Canada has studied this aspect of the Canadian exploration efforts (56). Their preliminary results and comments are summarized here. The gross value and number of discoveries was compared to the exploration expenditures for the period 1946-90 in 3-year period increments. In looking at the decade of the 1980's, the 1988-90 3-year period had the highest combined gross value of metals discovered, and highest value of metal discovered per dollar spent on exploration, relative to the periods 1985-87 and 1982-84.

The number of deposits discovered per 3-year period during the latter half of the 1980's was at a record high. However, the average size of the deposits discovered, measured by the value (corrected for inflation) of contained metals was much smaller in the period 1982-87 than it had been in previous periods. The much smaller average size of discoveries may be related to the nature of the exploration targets selected by companies. If junior mining companies were to continue to be able to raise funds by selling flow-through shares, it was important that they obtain, in short order, positive exploration results to show current or prospective investors. As a result, most exploration programs in Canada during the flow-through share period, 1983-90, were not concentrated on longer-term grassroots exploration programs of

the type that tend to yield major new discoveries.

As of July 1, 1988, the earned depletion allowance available under CEE was reduced to 16-2/3 pct and on July 1, 1989 the allowance was discontinued. Although the CEE's can still be deducted 100 pct on a flow-through basis, the elimination of the earned depletion allowance makes this form of financing less attractive.

The impact of flow-through financing for funding Canadian exploration projects is evident in figure 17, which shows exploration expenditures in Canada from 1983 to 1992. The curve for funds raised from flow-through shares, as reported by the Natural Resources Canada, shows a similar trend to the total exploration and gold exploration expenditure charts. Exploration activity in Canada decreased after 1988, especially for gold. This relates not only to the elimination of MEDA, but also to the market losses suffered by the majority of flow-through share investors after 1987, to the declining price of gold after 1987, and to the changes that took place in 1987 in the taxation rules on income and capital gains.

The apparent lag time between exploration and discovery of new deposits, and the development of new production capacity would indicate the reduction in exploration activity since 1988 will have significant impact on future gold reserves and production.

EMPLOYMENT

Total employment in the Canadian non-fuel minerals industry experienced significant cutbacks, approximately 40 pct, over the 1980-92 period (57, 58).

²Private communication from Gilles Couturier, Canadian gold specialist, Natural Resources Canada, 1994.

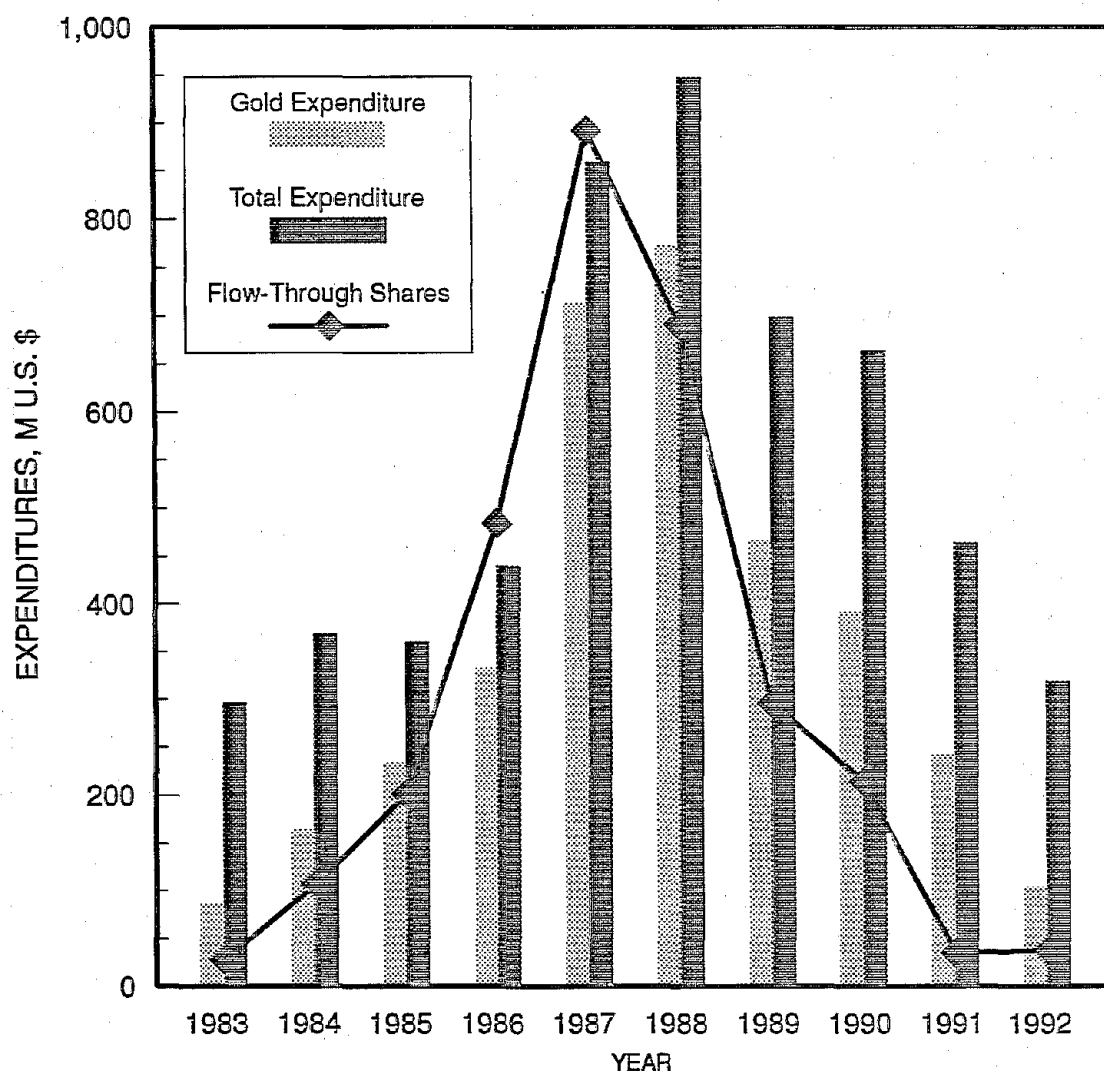


Figure 17.--Exploration expenditures in Canada, 1983-92.

Note: Data reported in Canadian dollars converted to U.S. dollar equivalent using annual average exchange rate from International Financial Statistics Yearbook 1994.

Source: Natural Resources Canada (56).

There was a 44 pct decline in employment in the nickel-copper-zinc sector, and a decline of over 70 pct in the non-metals segment. Gold was the only mining segment that saw an overall increase in employment, approximately 70 pct. Much of the observed decline in metal mining employment resulted from increases in productivity, spurred by low commodity prices.

GEOLOGY

The majority of Canadian gold deposits evaluated in this study occur in the Canadian Shield in the Archean greenstone belts of Superior (geologic) Province in Ontario and Quebec and Slave (geologic) Province³ in the Northwest Territories. Other deposits include Hope Brook in the Paleozoic Appalachian Orogen and several deposits of Mesozoic age in the accreted island arch terrains of British Columbia. The copper-gold deposits that are potential sources of by-product gold occur in the Quesnel Trough of British Columbia (59).

The Canadian Shield is Precambrian rock which covers approximately half of Canada. It is subdivided into structural provinces and subprovinces on the basis of age, internal fold trends and structural lineaments. Of the seven Provinces identified by Patrick, two are important to the discussion presented here. The Superior structural Province is host to the majority of the historical gold mining activity in Canada and has accounted for more than 80 pct of total Canadian gold production through 1981. Since 1981, this province has increased in importance for gold production as a result of development of three mines on the Hemlo deposit (David Bell, Golden Giant, Williams) and other deposits in the Hemlo district. The Abitibi-Wawa Belt, which forms a subprovince of the Superior Province and traverses some 700 km of Quebec and Ontario, is the site of most of the gold mining and exploration activity in this structural Province.

Much of the gold mineralization associated with the major regional structural zones such as the Larder-Cadillac and Destor-Porcupine faults are subsidiary zones. The most significant annual production, however, comes from the Hemlo deposit which is isolated from other deposits and not related to a regionally significant structural feature. In the Slave Province, most gold production comes from shear zones in the Kam Group volcanic at Yellowknife and from folded iron formation at Contwoyto Lake. Both structural provinces are made up of discontinuous linear greenstone belts which contain high proportions of volcanic rocks and which alternate with belts dominated by sedimentary, granitic or gneissic rocks.

RESERVES AND RESOURCES

RESERVE CLASSIFICATION

The Canadian system for mineral resource classification (60) is almost identical to the scheme developed in the United States between the U.S. Geological Survey and the U.S. Bureau of Mines (61). For the purpose of this analysis the two systems will be considered interchangeable and the U.S. nomenclature will be used. Demonstrated reserves are the sum of measured and indicated reserves. Identified reserves or resources are the sum of demonstrated and inferred (possible) material.

CANADIAN GOLD RESERVES

Canadian gold reserves, as reported by Natural Resources Canada, are defined as the metal contained in proven and probable (i.e., demonstrated) minable ore in operating mines and deposits

³The following description of the regional geology of the Canadian Shield has been extracted from an article by Dr. D.J. Patrick (59).

committed for production (table 20). There is no allowance made for losses in milling, smelting and refining. In addition, reserves include metal in mines where production has been suspended temporarily and "geological reserves" for some mines that do not report minable ore.

Gold reserves increased over 250 pct from 1980 to the peak year of 1989. In 1990, total reported reserves declined until in 1992 the level was 25 pct less than in 1989, indicating virtually no replacement of reserves over this period. The greatest contribution to new reserves came from Ontario, where a 550 pct increase was achieved from 1980 to 1989. The major source was the newly discovered Hemlo gold camp where three new mines, David Bell, Golden Giant and Williams came on stream in 1985.

Current reserves (1,446 mt in 1992) are sufficient for over 9 years of production at 1992 production rates. The official USBM estimate for Canadian reserves is almost identical at 1,400 (26). By far the largest portion of the Canadian gold reserve base is contained in primary gold ores. Base metal deposits are the next most important source.

CANADIAN GOLD RESOURCES

Table 21 shows the demonstrated gold resource base, defined with the same level of geological assurance as the reserves, but also containing marginal and submarginal economic deposits that do not fit the reserve definition. This table is an independent compilation by the author of information taken from publicly available literature and from personal contacts within the industry. The resource base also contains in-situ material while reserves are defined as minable. At the demonstrated level, 2,881 mt (92.6 M tr oz) of gold have been defined in over 170 deposits specifically reported in the literature. This is double the previously mentioned reserves, but still not a complete accounting. The official USBM estimate for

Canada's reserve base (which has a comparable definition) is slightly higher at 3,300 mt (26).

At the identified level, which includes the demonstrated resource, a total of 4,713 mt (146.6 M tr oz) have been estimated. An additional 70 exploration projects, as well as inferred resources at properties with an established demonstrated resource are responsible for the additional 1,832 mt (57 M tr oz) of gold reported here. This, by no means, represents the total inventory of Canadian gold resources, but is presented here as an indicator of the magnitude of the potential resource for gold mining in the future.

RESOURCES ANALYZED IN STUDY

Thirty-one gold operations and deposits were evaluated for their reserves and resources. Location of the principle gold properties evaluated is shown in figure 16, and more detailed maps will be available in the planned Open File Report. Table 22 shows the demonstrated and identified resource for 25 producing, one temporary shutdown property (Colomac) and one exploration project (Eskay Creek), which constitute the primary Canadian gold operations evaluated for this study. These properties account for 74 pct of the Jan. 1, 1993 Canadian gold reserves reported by Natural Resources Canada (see table 20), and 43 pct of the demonstrated resource base estimate compiled by the author (see table 21).

The remaining four evaluated properties are gold-copper porphyry exploration projects that contribute an additional 23 pct to the demonstrated resource base, bumping representation up to 66 pct. Resources for the Eskay Creek project, the four gold-copper exploration projects, and a portion of Placer Dome's resource listed as measured and indicated do not qualify for reserve status but do fall into the demonstrated resource category. Using a somewhat more

Table 20.—Canadian gold reserves¹ by region, 1980-92
(Kg contained gold)

Year	Ontario	Quebec	British Columbia	Northern ² territories	Atlantic ³ provinces	Prairie ⁴ provinces	Total
1980	155,973	140,344	139,043	47,110	26,636	31,387	540,493
1981	298,081	149,099	170,792	83,100	30,503	38,315	769,890
1982	303,105	212,328	186,552	81,196	19,249	39,786	842,216
1983	326,444	204,822	194,582	89,251	15,706	37,837	868,642
1984	652,343	226,178	136,443	87,211	15,359	42,240	1,159,773
1985	725,437	241,822	146,581	76,592	14,940	35,138	1,240,510
1986	845,389	215,468	131,307	70,005	1,555	43,089	1,306,813
1987	881,898	229,387	162,528	64,561	115,222	42,761	1,496,357
1988	997,747	297,355	167,419	103,966	100,417	59,748	1,726,652
1989	1,016,919	372,660	171,684	182,090	114,224	56,618	1,914,195
1990	951,000	352,000	124,000	165,000	111,000	44,000	1,747,000
1991	812,000	343,000	117,000	131,000	98,000	47,000	1,548,000
1992	766,000	342,000	103,000	119,000	73,000	43,000	1,446,000

¹Gold contained in demonstrated (proven and probable) mineable ore in operating mines and deposits committed for production as of January 1, 1992. No allowance is made for losses in milling, smelting, and refining. Includes gold in mines where production has been suspended temporarily. Excludes gold in placer deposits.

²Northwest and Yukon Territories.

³Newfoundland, New Brunswick, and Nova Scotia.

⁴Manitoba and Saskatchewan; Alberta does not have any reported reserves.

NOTE: Totals may not add due to independent rounding.

Source: Natural Resources Canada (52, 57).

Table 21.—Canadian gold resources by source

Category	Demonstrated resource			Identified resource		
	Quantity (kmt)	Grade (g/mt)	Gold ¹ (mt)	Quantity (kmt)	Grade (g/mt)	Gold ¹ (mt)
Primary gold	304,441	6.54	1,992	548,390	6.17	3,386
Gold-copper	1,439,770	0.47	674	2,092,000	0.42	888
Gold tailings	152,225	0.58	88	152,225	0.58	88
Total gold bulk mining	78,200	1.63	127	316,180	1.11	351
Grand total ¹ or wtd avg	1,974,636	1.46	2,881	3,109,095	1.52	4,713

¹Contained.

NOTE: Totals may not add due to independent rounding.

Source: Compiled from various available public documents, including Natural Resources Canada Yearbooks and company annual reports.

Table 22.— Gold resource for evaluated Canadian properties¹
(January 1, 1993)

Province	Demonstrated resource			Identified resource			Ore	Demon-	Ident-	Reference*
Property name	Quantity	Grade	Gold ²	Quantity	Grade	Gold ²	capacity	strated	ified	
	(kmt)	(g/mt)	(mt)	(kmt)	(g/mt)	(mt)	(kmtpy)	mine	mine	
								life	life	
Primary Gold										
British Columbia:										
Eskay Creek	1,089	65.10	70.9	5,888	18.35	108.0	126	8.6	46.7	62-63
Golden Bear	197	17.70	3.5	197	17.70	3.5	133	1.5	1.5	64
Nickel Plate	5,358	2.61	14.0	5,358	2.61	14.0	1,154	4.6	4.6	64
Snip	641	28.49	18.3	641	28.49	18.3	165	3.9	3.9	64
Subtotal or wtd avg .	7,285	14.65	106.7	12,084	11.90	143.8	1,578	4.6	7.7	—
Newfoundland:										
Hope Brook	7,489	3.57	26.7	10,207	3.63	37.1	1,100	6.8	9.3	65
Subtotal or wtd avg .	7,489	3.57	26.7	10,207	3.63	37.1	1,100	6.8	9.3	—
Northwest Territory:										
Colomac	12,562	1.89	23.7	17,852	1.89	33.7	2,800	4.5	6.4	66
Con	3,215	10.60	34.1	4,674	9.60	44.9	345	9.3	13.5	67
Giant	2,559	10.94	28.0	8,122	8.54	69.4	345	7.4	23.5	65
Lupin	3,439	10.08	24.7	6,104	9.59	58.5	642	5.4	9.5	68
Subtotal or wtd avg .	21,775	5.07	110.5	36,752	5.62	206.5	4,132	5.3	8.9	—
Ontario:										
Arthur W. White	2,800	11.00	30.8	3,700	11.00	40.7	260	10.8	14.2	69-70
Campbell ⁴	5,717	16.70	95.5	5,717	16.70	95.5	460	12.4	12.4	71
David Bell	6,319	11.01	69.6	6,319	11.01	69.6	470	13.4	13.4	64
Detour Lake ⁴	5,959	5.42	32.3	5,959	5.42	32.3	862	6.9	6.9	71
Dome ⁴	26,987	3.83	103.4	26,987	3.83	103.4	1,225	22.0	22.0	71
Golden Giant	13,122	11.47	150.5	13,122	11.47	150.5	1,200	10.5	10.9	72
Golden Patricia	327	21.90	7.2	666	18.40	12.3	115	2.8	5.8	73
Holt-McDermott	1,261	6.21	7.8	2,270	5.88	13.3	430	2.9	5.3	74
Macassa	1,151	18.50	21.3	1,236	18.40	22.7	154	7.5	8.0	73
Williams	31,888	5.97	190.4	31,888	5.97	190.4	2,200	14.5	14.5	75
Subtotal or wtd avg .	95,531	7.42	708.8	97,884	7.47	730.7	7,376	13.0	13.3	—
Quebec:										
Bousquet #1	2,356	5.80	13.7	3,933	6.20	24.4	327	7.2	12.0	73
Bousquet #2	3,959	8.20	32.5	8,205	6.50	53.3	635	6.2	12.9	73
Casa Berardi	8,263	8.20	67.8	10,567	7.50	79.3	527	15.7	20.1	76-77
Donald J. LaRonde ..	5,543	6.50	36.0	5,543	6.50	36.0	650	8.5	8.5	78
Doyon	10,206	6.20	63.3	11,759	6.50	76.4	1,180	8.6	10.0	73
Kiena ⁴	6,676	4.92	32.8	6,676	4.92	32.8	500	13.4	13.4	71
Sigma ⁴	3,037	4.99	15.2	3,037	4.99	15.2	460	6.6	6.6	71
Silidor	2,588	5.35	13.8	2,588	5.35	13.8	440	5.9	5.9	72
Subtotal or wtd avg .	42,626	6.45	275.1	52,306	6.33	331.2	4,719	9.0	11.1	—
Total or wtd avg ..	174,706	7.03	1,227.8	209,213	6.93	1,449.3	18,905	9.2	11.1	—
Gold-Copper										
British Columbia:										
Fish Lake	871,000	0.43	375	1,279,000	0.42	537	20,000	43.6	64.0	79
Kerness South	222,000	0.62	138	222,000	0.62	138	14,600	15.2	15.2	80
Mount Milligan	298,000	0.45	134	298,000	0.45	134	22,700	13.1	13.1	71
Mount Polley	48,770	0.56	27	293,000	0.27	79	5,000	9.8	58.6	82-83
Total or wtd avg .	1,439,770	0.47	674	2,092,000	0.42	888	62,300	23.1	33.6	—

¹These are not official U.S. Bureau of Mines estimates. Data are from company annual reports and other public documents.

²Contained in mineable resource.

³Reference numbers refer to sources listed at the end of this report.

⁴Contains about 160 mt in-situ resource for which mineable quantity has not been estimated by company and is not considered reserves.

NOTE: Totals may not add due to independent rounding.

Source: Compiled from company annual reports and other available public documents (62-83).

restrictive definition, the Bureau's MCS 1993 reports total reserves of 1,780 mt (26).

MINING AND PROCESSING

Canadian mining and processing technology for gold is largely dependant on ore deposit type and ore characteristics. Climate also influences the selection of extraction and recovery methods due to the severe winter weather encountered in many of the northern deposit locations. Table 23 shows annual ore capacity, ore description, and mining and processing methods currently in use or proposed to be used for the 31 evaluated properties.

MINING

The typical Canadian gold ore deposit type is associated with vein or shear zone structures that provided channels for mineralizing fluids to migrate to favorable sites of deposition. The relatively narrow, steeply dipping, tabular shaped mineralized bodies formed in this environment generally require underground mining methods to extract the ore. Where ore mineralization is disseminated over a wide zone or individual veins are closely spaced enough, large capacity, bulk mining methods are used to reduce mining costs.

Average ore production per operation in 1992 was 670,000 mt ore grading 8.3 g/mt gold for production of nearly 4.7 mt (150,000 tr oz) gold. The relatively high average gold grade tends to offset the higher cost of underground mining. Less than 10 pct of production in 1992 was from surface operations.

PROCESSING

Class of ore, as referred to in table 23, is the distinction between refractory and non-refractory (free milling) ore. As discussed earlier in the methodology overview, free milling

is a term used to define ore that only requires crushing and grinding to liberate the gold for direct treatment with a cyanide solution to dissolve the gold. Refractory ore requires some form of pretreatment prior to cyanide leaching to improve the availability of gold to leaching solutions, or it may be subjected to a flotation process, followed by smelting and refining. Whole ore roasting, roasting of flotation concentrates, or pressure oxidations using an autoclave are common pretreatment methods employed in Canada. Only about 6 pct of the 1992 primary gold process capacity analyzed is refractory.

Average gold feed grade ranged between 7 g/mt and 9 g/mt and average recovery was about 93 pct. The four gold-copper porphyry operations proposed for production by 1998 will average 13 Mmtpy ore grading 0.42 grams gold per mt, and 0.24 pct copper.

CASH OPERATING COSTS

Cash operating costs are a useful means of comparing operations on a consistent basis. Cash operating cost in this analysis includes all costs for mining, processing, site overhead (administrative expenditures) and downstream smelting, refining and transportation necessary to produce a refined gold product. The costs of mining, the largest portion of the on-site cost, account for an average of 61.2 pct of the direct site cash operating cost as shown in table 24. The relatively small scale of gold operation in Canada, averaging 670,000 mtpy ore, is a contributing factor to high average costs.

Processing costs account for 25.5 pct with general and administrative (overhead) making up the remaining 13.3 pct. Total cash cost decreased dramatically from 1991-93 because of improvements in productivity implemented by the companies in an effort to remain competitive in a declining price market.

Table 23.—Mining and processing methods used at evaluated Canadian gold operations
(Including annual ore capacity and ore description)

Province/territory Property name	Ore Capacity (kmtpy)	Ore description		Mining ¹ method	Processing method		
		Type ²	Class ²		Pretreat ³	Extraction ³	Recovery ³
British Columbia:							
Eskay Creek	126	ST	R	C&F	POx	G,CN	MC
Fish Lake	20,000	P	R	OP	--	F	S&R
Golden Bear	133	V	R	OP	R	CN	CIP,EW
Kemess South	14,600	P	R	OP	--	F	S&R
Mount Milligan	22,700	P	R	OP	--	F	S&R
Mount Polley	5,000	P	R	OP	--	F	S&R
Nickel Plate	1,154	SK	F	OP	--	CN	MC
Snip	165	V,SZ	F	C&F,SH	--	G,F	S&R
Newfoundland:							
Hope Brook	1,100	V	F	BH	--	CN	CIP,EW
Northwest Territories:							
Colomac	2,800	D	F,R	OP	--	G,CN	CIP,EW
Con	345	V	F	C&F	POx	CN	MC
Giant	345	V	R	C&F	R	F,CN	MC
Lupin	642	SB	F	SL,LH,F	--	CN	MC
Ontario:							
Arthur W. White	260	V	F,R	C&F	--	CN	MC
Campbell	460	V	F,R	C&F,LH	POx	G,F,CN	CIP,EW
David Bell	470	D,V	F	LH,F	--	CN	CIP,EW
Detour Lake	862	V	F	C&F,LH,SH	--	CN	CIP,EW
Dome	1,225	V	F	LH,C&F,C	--	G,CN	CIP,EW
Golden Giant	1,200	D	F	LH,F	--	CN	CIP,EW
Golden Patricia	115	SB	F	SH	--	G,CN	MC
Holt-McDermott	430	D	F	OS	--	CN	CIP,EW
Macassa	154	V	F	C&F	--	CN	CIP,EW
Williams	2,200	D,B	F	BH,F	--	CN	CIP,EW
Quebec:							
Bousquet #1	327	V,D	F	OS,F	--	CN	MC
Bousquet #2	635	M	F	OS,F	--	G,F,CN	MC
Casa Berardi	527	V,D	F	C&F,LH	--	CN	CIL,EW
Donald J. LaRonde ...	650	M	F	SL,LH,OS	--	F,CN	CIP,EW
Doyon	1,180	D,V	F,R	C&F,SH,BH	--	CN	CIP,EW
Kiena	500	B	F	LH,C&F	--	CN	CIP,EW
Sigma	460	V,SZ	F	C&F,R&P,SH,LH	--	G,CN	MC
Slidder	440	V	F	LH,SH	--	F,CN	CIP,EW

¹ST = Stockwork; P = Porphyry; V = Vein; SK = Skarn; SZ = Shear zone; D = Disseminated; SB = Stratabound; B = Breccia; M = Massive.

²R = Refractory; F = Free milling.

³C&F = Cut and fill; OP = Open pit; SH = Shrinkage; BH = Blast hole; SL = Sublevel; LH = Long hole; F = Fill; C = Caving; OS = Open stope; R&P = Room and pillar.

⁴POx = Pressure oxidation; R = Roasting.

⁵G = Gravity; CN = Agitation cyanide leach; F = Flotation.

⁶MC = Merrill Crowe; S&R = Smelting and refining; EW = Electrowinning; CIP = Carbon-in-pulp; CIL = Carbon-in-leach.

NOTE—Dash indicates no pretreatment.

Source: Compiled from various available public documents, including Natural Resources Canada Yearbooks and company annual reports.

Table 24.--Average cash operating costs by region for evaluated producing Canadian gold operations, 1991-93¹

Property name	Production		Direct site cash operating costs ²								
	Ore	Gold ³	Mining		Processing		General and administrative		Total cash cost		
			(k tr oz)	(mt)	(\$/mt ore) (\$/tr oz)	(\$/mt ore) (\$/tr oz)	(\$/mt ore) (\$/tr oz)	(\$/mt ore) (\$/tr oz)			
										(kmt)	(k tr oz)
1991											
British Columbia	1,388	257	8.0	25.70	138.60	17.60	94.80	7.40	40.10	50.70	273.40
Northwest Territory	2,532	516	16.1	32.80	160.80	16.60	81.50	9.90	48.50	59.30	290.80
Ontario	7,305	2,062	64.1	35.00	124.00	13.60	48.10	7.20	25.30	55.70	197.50
Quebec	4,402	962	29.9	33.60	153.90	13.30	60.80	6.20	28.30	53.10	243.00
Total or wtd avg	15,629	3,798	118.1	33.50	138.00	14.30	58.50	7.40	30.40	55.20	227.40
1992											
British Columbia	1,532	297	9.2	23.30	109.10	16.90	79.20	7.40	34.40	47.60	222.70
Northwest Territory	1,387	431	13.4	28.90	169.80	11.30	66.30	7.90	46.50	48.10	282.60
Ontario	7,517	2,040	63.5	34.10	122.20	13.20	47.10	6.70	24.00	54.00	193.30
Quebec	4,260	915	28.5	31.00	148.90	12.20	58.50	5.60	27.10	48.70	234.00
Total or wtd avg	14,697	3,683	114.6	32.80	133.40	13.50	55.00	7.00	28.50	53.30	216.80
1993											
British Columbia	1,293	290	9.0	20.00	95.90	14.50	69.40	6.10	29.30	40.60	194.60
Northwest Territory	1,342	418	13.0	27.90	168.70	10.90	65.70	7.60	45.70	46.30	280.10
Ontario	7,616	2,053	68.8	32.80	116.90	12.70	45.00	6.60	23.60	52.10	185.50
Quebec	4,428	922	28.7	28.90	136.60	11.30	53.40	5.20	24.80	45.40	214.80
Total or wtd avg	14,679	3,683	114.6	30.40	126.50	12.50	52.00	6.60	27.50	49.50	206.00

¹Does not include Hope Brook to avoid disclosing individual property cost estimates.²Does not include off site smelting, refining or transportation. All costs are constant 1992 U.S. \$.³Recovered metal.

NOTE: Totals may not add due to independent rounding.

Source: USBM estimates.

MINING

British Columbia's average cost was low throughout the 1991-93 period due to the influence of the Nickel Plate open pit operation. By region, the spread in average cost is nearly \$13.00 per mt of ore treated for the 3 years shown in table 24, but is less than \$6.00 if British Columbia and its open pit mining is excluded. Cash costs in terms of \$/tr oz show a much wider variance. The cost per tr oz was lowest in Ontario in 1991, indicative of the higher average feed grade, but British Columbia took over the low cost position when the high grade Snip operation reached and exceeded full capacity in 1992.

PROCESSING

Process costs are greatly influenced by the necessity for milling the ore prior to treatment. Crushing and grinding are high power usage unit processes used prior to leaching to liberate the free gold from highly silicious ore and gangue material. Leaching is accomplished in vats or tanks instead of the less expensive heap leach methods employed in much of the gold industry in the United States and Australia. The higher cost for processing in British Columbia is primarily due to flotation at Snip to recover a concentrate and roasting required at Golden Bear.

GENERAL AND ADMINISTRATIVE

Costs to cover general camp operation, mine-site administrative duties and support (e.g., engineering and geology departments and warehousing) are higher for some of the more remote projects. In recent years, the trend in camp operation has been to use the fly-in, fly-out schedule for rotating employees in and out of the mine site. This practice has the advantage of improving morale by allowing workers time with families in less remote and isolated environments and the company does not have to provide for a large

permanent camp site. The Snip mine in British Columbia and Lupin in Northwest Territories are examples of this type of schedule.

The last several years have seen a slow reduction of operating costs in response to fluctuations in gold price and declining ore grades at many of the operations. This trend has been projected out to 1996 in constant 1992 dollars based on a continuation of recent successful efforts and the best available data. Figure 18 shows the projected weighted average on-site cash operating costs for 1991 through 1996 and shows mining, processing and G&A costs for the producing operations evaluated for the study. All on-site cost categories are affected by these cost cutting efforts. Over the 1991-93 period an estimated 10 pct reduction in direct cash operating cost has been achieved. An additional 12 pct reduction is anticipated over the 1994-96 period.

TRANSPORTATION, SMELTING AND REFINING

Transportation, smelting and refining cost estimates are \$1.50/tr oz for transporting gold bullion, and approximately \$4.50/tr oz for smelting and refining. Higher costs are encountered at operations where copper is recovered as a byproduct to cover the downstream transportation, smelting and refining of the copper.

CAPITAL COSTS

Total undepreciated capital costs (table 25) estimated for the 27 primary gold operations over the last 15 years and any additional reinvestment considered necessary over the remaining life of the operations were estimated at approximately \$1.5 billion (\$44/tr oz). Average total capital cost per primary gold operation is approximately \$56 million. This is distributed heavily towards development with 41 pct of the total capital expenditure. The

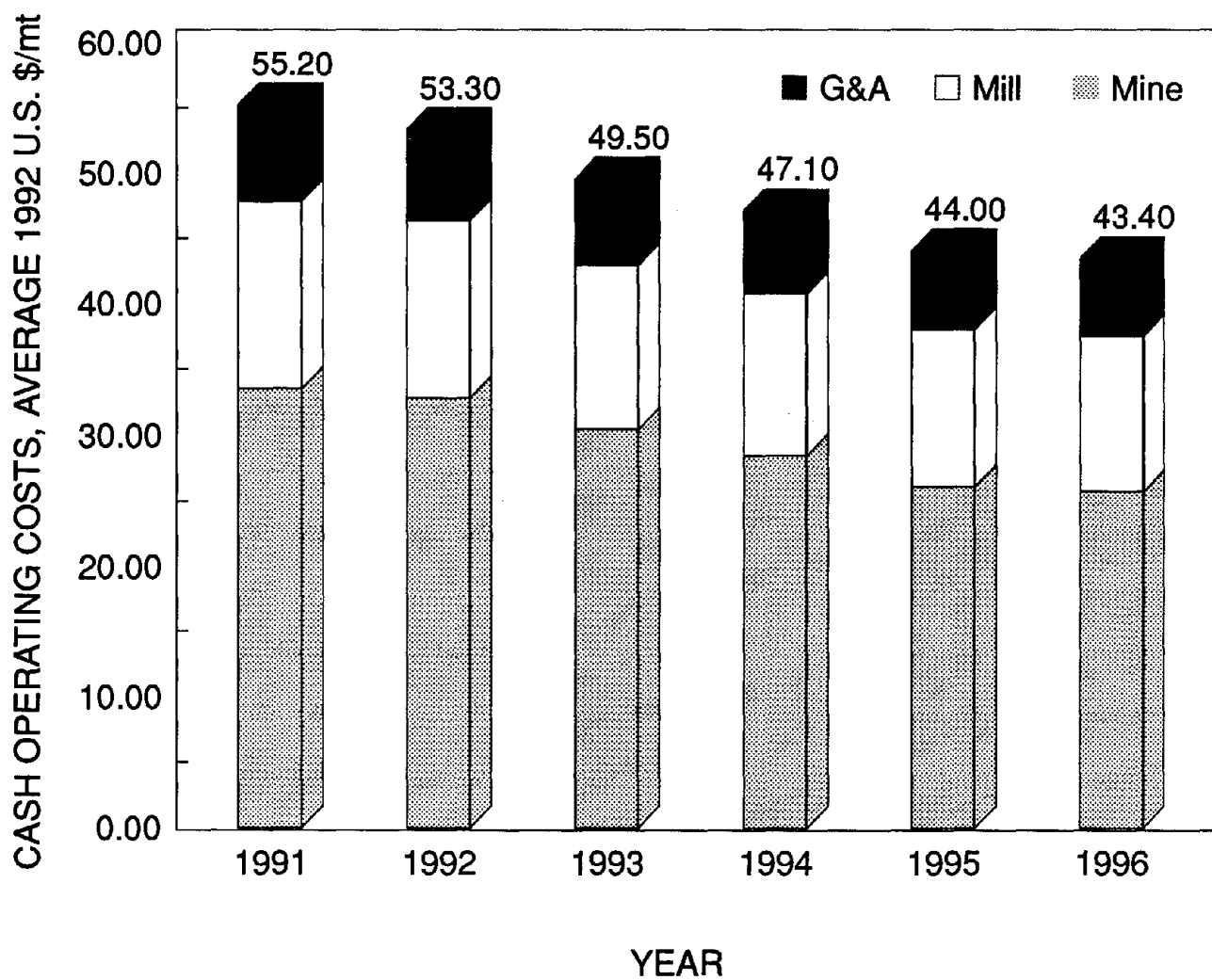


Figure 18.--Canadian on-site cash operating cost projection, 1991-96.

Source: USBM estimates.

Table 25.--Total capital cost by category and region in Canada¹
(M U.S. \$)

Province	Recoverable gold (tr oz)	Exploration	Land acquisition	Development	Mine plant and equipment	Mill plant and equipment	Infrastructure	Working capital	Total capital expenditures
Primary Gold:									
British Columbia ²	984,949	44.8	0	26.5	3.9	1.3	0	9.6	86.1
Northwest Territories	3,543,872	3.2	53.4	83.3	38.7	20.2	0	28.1	226.8
Ontario	19,631,490	74.8	35.2	283.5	35.8	10.2	0	66.7	486.2
Quebec	7,598,200	43.6	20.5	176.9	55.4	25.5	0.6	36.4	358.9
Other	2,821,984	43.9	0	76.7	13.0	134.6	64.7	20.1	353.7
Total	34,580,495	210.2	109.0	627.9	146.7	191.8	65.3	160.9	1,511.8
Gold-Copper:									
British Columbia	11,910,305	29.4	6.0	45.4	422.4	413.5	203.5	54.2	1,174.4
Grand total	46,490,800	239.6	115.0	673.2	569.0	605.4	268.8	215.1	2,686.2

¹Capital cost prior to January 1993 are in actual year's dollars. Capital cost after January 1993 are in constant 1993 dollars.

²Excludes the Eskay Creek operation.

NOTE: Totals may not add due to independent rounding.

Source: Compiled from various available public documents including Natural Resources Canada publications and company annual reports.

higher cost of underground development more than offsets the higher grades encountered. Exploration follows at 14 pct of total capital costs. Exploration for underground vein deposits requires more extensive drilling and sampling to define. The high development cost is the result of a significant number of recent underground developments and capacity expansions.

The gold-copper properties, on the other hand, are all undeveloped projects. The average total capital cost for these 4 large scale proposed projects is nearly \$294 million per operation, over five times the average for the analyzed primary gold operations. Infrastructure expenditures, which are insignificant for the developed properties play an important role due to the lack of existing infrastructure in the areas in British Columbia.

The three major cost categories for gold-copper deposit development in order of decreasing importance are mine plant and equipment, mill plant and equipment, and infrastructure. They represent 36.0 pct, 35.2 pct, and 17.3 pct respectively. The four gold-copper projects evaluated are all proposed open pit mining operations with flotation for recovery of a copper-gold concentrate. The scale of these operations is approximately 20 times the average size of the primary gold operations. The low grade of the ore was the major contributor to the nearly \$100/ tr oz total capital charge.

ECONOMIC ANALYSIS AND RESULTS

To determine the potential availability and supply of gold from operations in Canada, geologic and operating data were collected, and total production costs were determined for all of the Canadian deposits analyzed. Costs are presented on a U.S. dollar per ounce recoverable gold basis over the life of the operation. The total recoverable gold amount is based on resources reported in table 22, which uses a more

restrictive definition than the reserve base definition underlying the much higher quantity of gold reported in the 1995 MCS (26).

PRIMARY GOLD PRODUCERS-1993

Figure 19 shows the comparison between cash operating cost and total production cost at 0-pct and 15-pct DCFROR for the 25 operations that were producing in 1993. Six operations could not cover their total production costs at a breakeven (0-pct DCFROR) level of earning at the 1993 average gold price. Ten operations were not able to achieve a 15-pct DCFROR at the 1993 price.

LIFE-OF-MINE PRODUCTION

Figure 20 shows the total potential gold available from all 31 evaluated Canadian gold and gold-copper properties. These values are the recoverable portion of the demonstrated resource reported in table 22. Just over 70 pct of this gold can be recovered and earn at least a 0-pct DCFROR at an average gold price between \$350 and \$400/tr oz. The long term, life-of-mine cost analysis results for all gold properties are presented in table 26. Mining costs make up the largest portion (58.9 pct) of the \$225/tr oz average total cash operating costs for primary gold properties. Processing costs averaged 24.6 pct of the total cash operating costs. On-site overhead costs, at 12.9 pct, and smelting, refining and transportation costs, at 3.6 pct. account for the remainder.

The average cash operating costs for gold-copper projects are also shown in table 26 with an average cost nearly 130 pct higher than that for primary gold operations. However, average direct cash operating cost is only part of the Canadian gold mining industry cost structure. Table 26 shows the net operating cost, or cash operating cost with byproduct credits deducted. For the most part, byproduct credits have very little impact on the average net operating costs for the primary gold operations, while byproduct

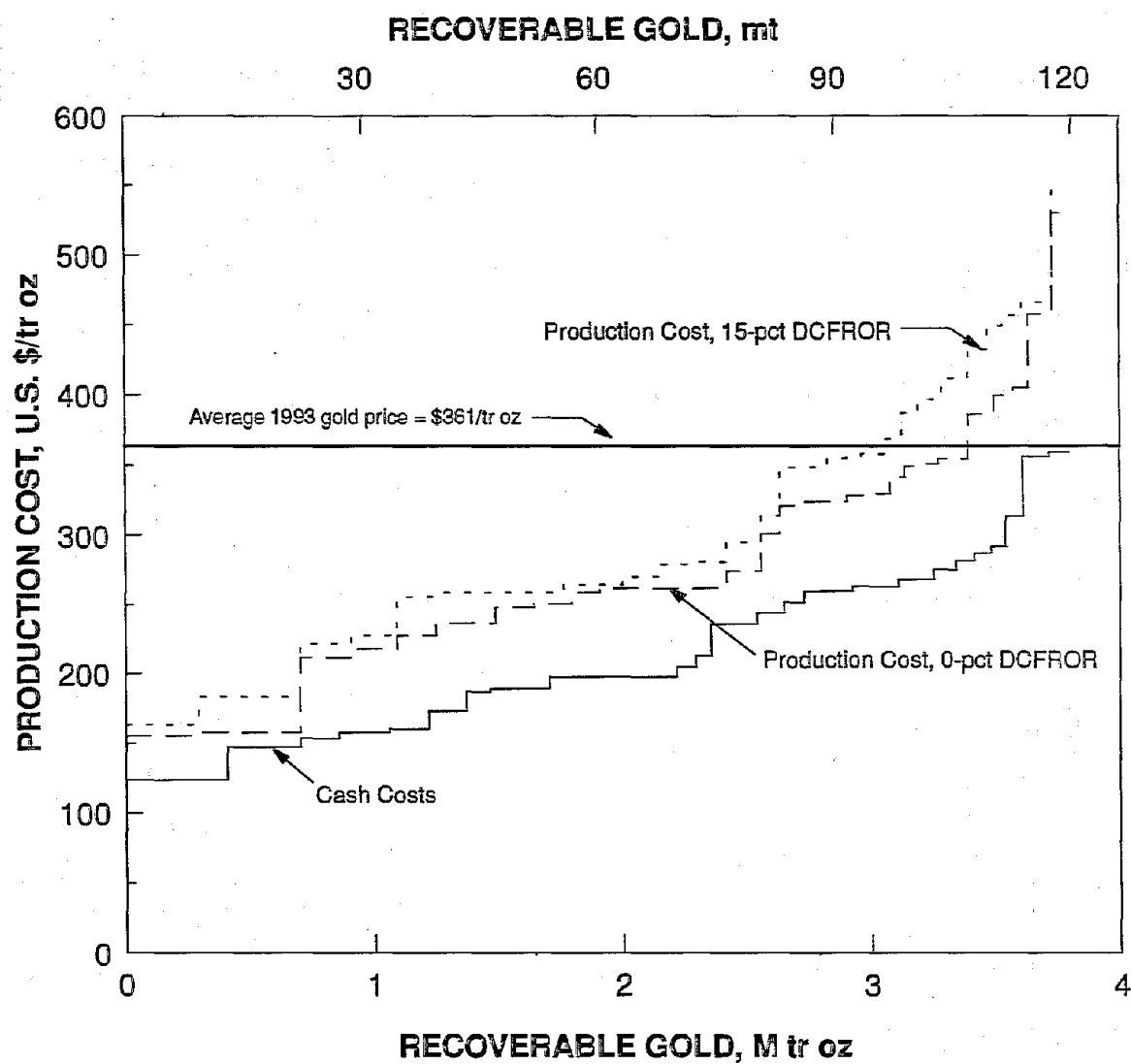


Figure 19.--Canadian gold production costs, 1993.

Source: USBM estimates.

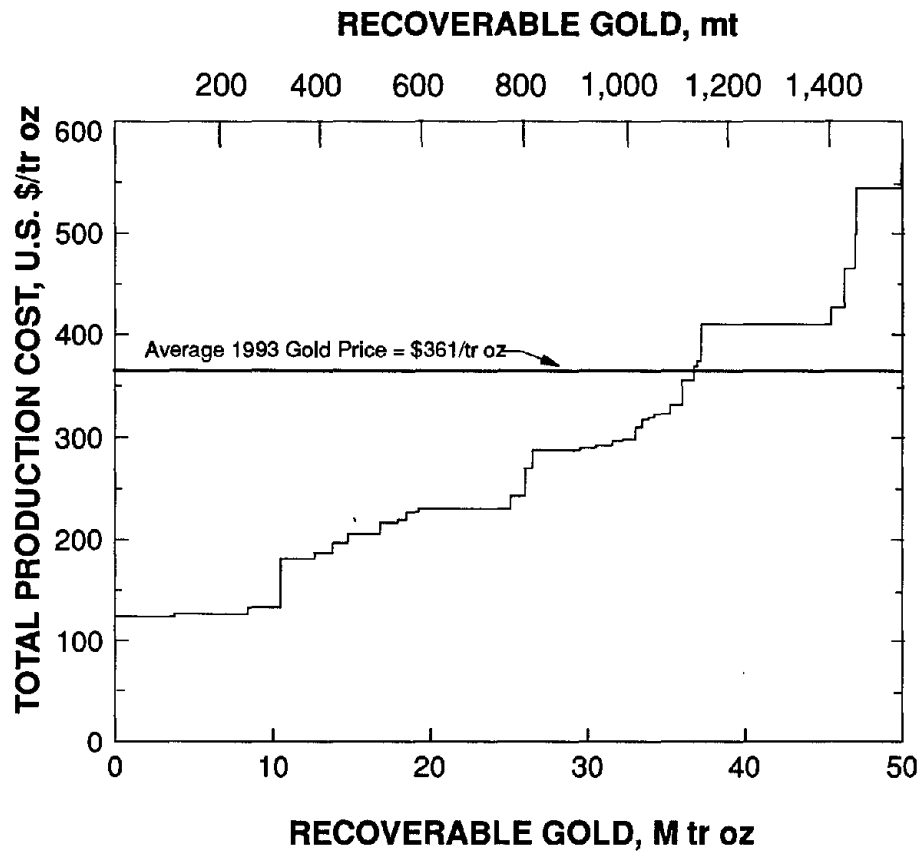


Figure 20.--Total potential gold available from evaluated Canadian gold properties, 0-pct DCFROR.

Source: USBM estimates.

Table 26.--Total weighted average gold production cost for 0-pct and 15-pct DCFROR by region in Canada¹
(U.S. \$/tr oz recoverable gold)

Type deposit Province/territory ¹	0-pct DCFROR ²					15-pct DCFROR ²		
	Cash operating cost	(Less) byproduct credits	Net operating cost	Capital recovery	Taxes ³ and royalties ⁴	Total ⁵ production cost	Additional ⁶ taxes ³ and royalties ⁴	Return on investment ⁷
Primary gold:								
British Columbia	236.20	0.50	235.70	71.30	8.60	315.60	3.30	15.70
Northwest Territories	298.90	0.70	298.20	36.90	13.00	348.00	16.70	40.40
Ontario	206.50	0.50	206.00	18.50	4.40	228.90	2.30	11.80
Quebec	249.40	15.50	233.90	38.90	3.30	276.10	4.50	26.50
Total or wtd avg ⁸	225.60	16.80	208.80	33.30	6.30	248.40	10.20	29.40
Gold-copper:								
British Columbia	517.10	360.00	157.10	100.90	16.90	274.90	77.70	172.30
Grand total or wtd avg ⁸	300.30	104.70	195.60	50.60	9.00	255.20	27.50	66.00
								348.70

¹Evaluated over the life of the operations.

²Discounted cash flow rate of return.

³Includes property, Provincial and Federal taxes.

⁴Includes revenue based provincial mineral royalties.

⁵Includes all site specific costs and excludes corporate overhead charges.

⁶Additional taxes and royalties is the difference in estimated taxes and royalties at 0-pct and 15-pct DCFROR.

⁷The amount required to earn a specified rate of return on the invested capital.

⁸Eskay Creek in British Columbia and Hope Brook in Newfoundland are included in total recovered gold with a combined 2,821,984 oz recoverable gold and are included in cost weighted averages. Eskay Creek is excluded from the British Columbia primary gold analysis to avoid disguising the results for the three properties represented due to the unusual deposit and operational characteristics of Eskay Creek. Hope Brook is included here to avoid disclosing cost estimates for a single operation.

NOTE: Totals may not add due to independent rounding.

Source: USBM estimates.

credits at the gold-copper properties are extremely significant. The average net operating cost for gold-copper properties analyzed is about 25 pct lower than for primary gold properties.

The total production cost is estimated at 0-pct DCFROR by adding capital recovery, taxes, and royalties to the net operating cost. Taxes are the sum of property taxes and provincial and Federal income taxes at the 0-pct DCFROR level. Royalties are the sum of the provincial revenue-based mineral royalties and vary by province as to the rate and base against which the rate is applied. Total production costs are also estimated at 15-pct DCFROR by including taxes and royalties that are in addition to those estimated at the 0-pct level along with the required return on investment necessary to earn a 15-pct DCFROR on all investments for primary gold properties. These additional payments add about \$40/tr oz above the production cost estimate for a 0-pct DCFROR, and are almost \$80/tr oz above the net cash operating cost estimate.

ANNUAL GOLD PRODUCTION

Figure 21 shows the potential annual gold production availability curves from 1993 to the year 2000 at various gold price levels. Each curve represents production from those deposits able to earn at least a 0-pct DCFROR at those prices. Production levels at the properties studied are expected to remain at close to 1993 capacity until 1998 at which time there is an anticipated decline in production. This occurs as a result of mine closures due to exhaustion of reserves. Declining gold production after 1998 could be offset if the gold-copper porphyry deposits are developed in this time frame, or if the numerous smaller operations and exploration projects not accounted for are developed.

GOLD-COPPER PROPERTIES

An analysis was performed on the four gold-copper properties

proposed for development to determine the cost sensitivity to changes in commodity prices. First, the required price of gold to achieve a 0-pct DCFROR was determined for each property using the January, 1993, copper price of \$1.04/lb copper. Then, a copper price of \$0.85/lb was substituted for the byproduct copper price and a new financial evaluation was performed. Table 27 shows the comparison at the two copper prices. Decreasing the copper price in the analysis from \$1.04/lb to \$0.85/lb resulted in an increase of \$64.80/tr oz in the necessary price for gold to maintain a 0-pct DCFROR, from \$274.90/tr oz to \$339.70/tr oz.

The gold-copper properties were then analyzed as copper operations with gold as the byproduct. The gold price was allowed to vary while the required copper price to achieve a 0-pct DCFROR was determined. Gold prices used were \$300, \$350, and \$400/tr oz. Table 28 shows the results of the analysis. Every \$50/tr oz increase made to the gold price resulted in a corresponding \$0.13 to \$0.14/lb decrease in the necessary price of copper to attain a 0-pct DCFROR. It appears that a prolonged period of depressed price for either copper or gold could prevent these operations from developing.

CONCLUSIONS

The Canadian gold industry has had nearly a decade of explosive growth and expansion, prompted in part by the high gold prices achieved in the early 1980's and low commodity prices for other metals produced in Canada. From 1980, gold production tripled to a peak level of over 175 mt (5.6 M tr oz) in 1991 and Canada's world market share doubled to 8.3 pct. Employment in the gold industry more than doubled at a time when all other metal mining segments in Canada were declining. However, gold production has declined since 1991.

Exploration expenditures attained an all time high in 1988 with gold accounting for over 80

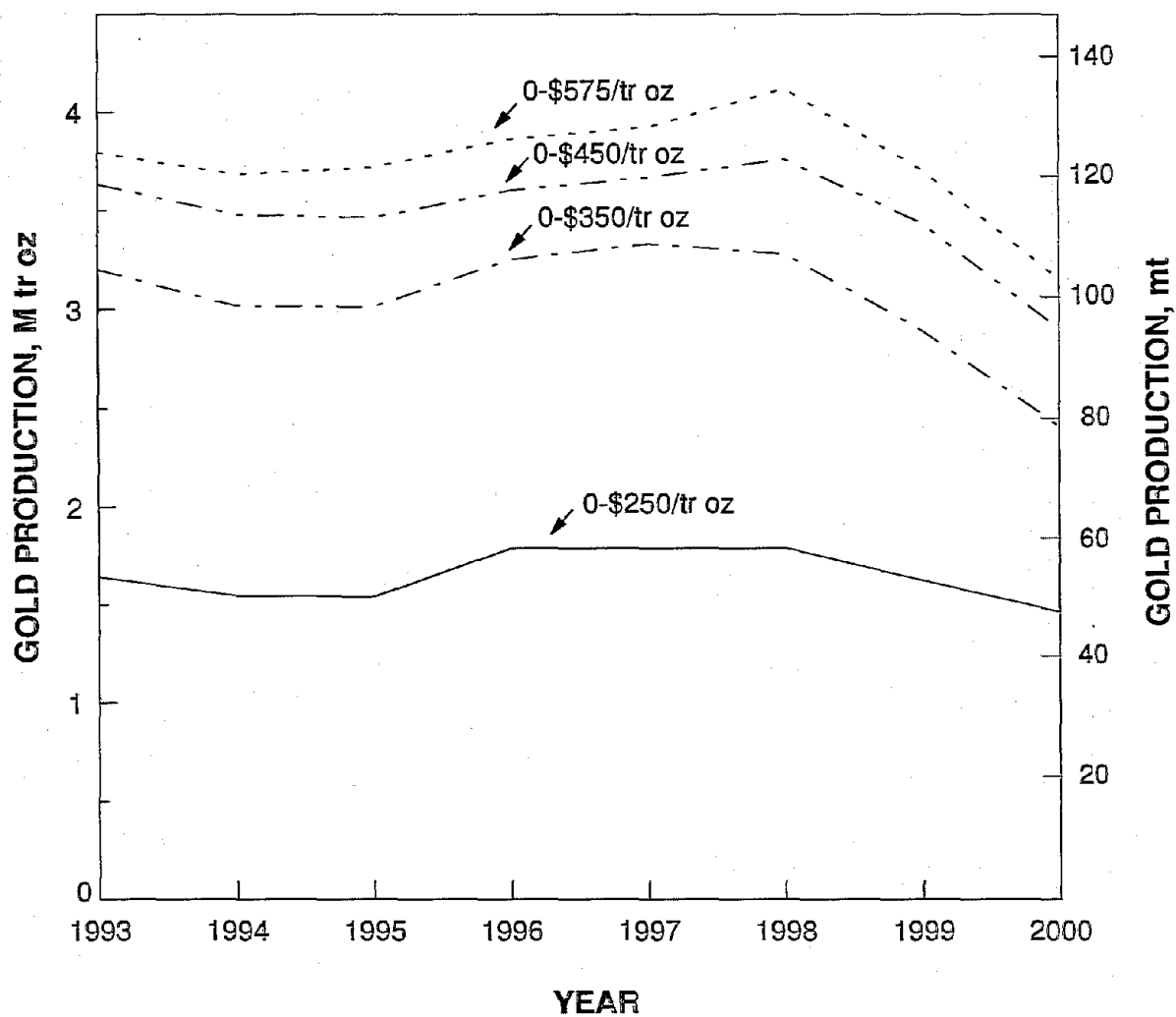


Figure 21.--Potential annual Canadian gold production, 1993-2000

Source: USBM estimates.

Table 27.--Canadian gold production cost sensitivity to changes in copper price¹
(U.S. \$/tr oz gold at 0-pct DCFROR)

Cost category	Production cost	
	at \$0.85/lb copper ²	at \$1.04/lb copper ²
Cash operating cost	517.10	517.10
Royalties	2.20	2.20
Taxes	14.70	14.70
Total operating cost	534.00	534.00
Byproduct credits	<295.20>	<360.00>
Net operating cost	238.80	174.00
Capital cost	100.90	100.90
Net production cost	339.70	274.90

¹Includes only the four gold-copper properties evaluated in British Columbia.

²Copper price used in byproduct credit calculations.

Source: USBM estimates.

Table 28.--Canadian copper production cost sensitivity to changes in gold price¹
(U.S. \$/lb copper at 0-pct DCFROR)

Cost category	Production cost		
	at \$300/tr oz ²	at \$350/tr oz ²	at \$400/tr oz ²
Mining	0.42	0.42	0.42
Processing	0.46	0.46	0.46
Overhead	0.14	0.14	0.14
Smelting, refining, transportation	0.41	0.41	0.41
Cash operating cost	1.43	1.43	1.43
Royalties	0.01	0.01	0.01
Taxes	0.04	0.04	0.04
Total operating cost	1.48	1.48	1.48
Byproduct credits	<0.83>	<0.97>	<1.11>
Net operating cost	0.64	0.51	0.37
Capital cost	0.28	0.28	0.28
Net production cost	0.92	0.79	0.65

¹Includes only the four gold-copper properties evaluated in British Columbia.

²Gold price used in byproduct credit calculations.

Source: USBM estimates.

pct. Between 1983 and 1990, the combination of flow-through shares, improved Mining Exploration Depletion Allowance (MEDA), the Canadian Exploration Incentive Program (CEIP), and favorable gold prices led to an increase in exploration activity throughout Canada. Flow-through shares provided a significant portion of the financing for this Canadian exploration activity. Exploration activity in Canada decreased after 1988, especially for gold. This relates not only to the elimination of MEDA, but also to the market losses suffered by the majority of flow-through share investors after 1987, to the declining price of gold after 1987, and to the changes in the taxation rules on income and capital gains that took place in 1987. Gold reserves discovered during this time period followed a similar trend that peaked in 1989, a year after the peak in exploration expenditures. Gold production's peak in 1991 reflects the time lag between the discovery and development of reserves. Although flow-through shares proceeds provided a large portion of the funding for exploration, the efficiency of the exploration dollar in the 1980's was at an all time low. This means that even though the number of discoveries was high, the value or size of the deposits was small.

Large-tonnage surface operations in British Columbia that use flotation to recover a gold-copper concentrate may contribute significantly to future gold and copper production in Canada. The longer life associated with a gold-copper surface operation (23 years versus 9 years average life of a typical underground gold vein deposit) provides greater stability in the workforce and local economy. Currently, more than 90 pct of the ore mined in Canada is by high cost underground mining methods. Nearly all of the gold ore currently being processed in Canada requires milling of one form or another. Some gold is recovered by gravity methods, but the predominate extraction and recovery method is agitation leach, followed by carbon-in-pulp and electrowinning to produce doré bullion for further

refining. The Merrill-Crowe process is used extensively where the recovery of silver is important.

Over the life of the evaluated properties, the higher cost of underground mining and milling of the ore is offset by the higher ore grades and recoveries. The result is a \$226/tr oz total average cash cost for the 27 primary gold properties. Capital costs add another \$33/tr oz to the total cash cost (excluding undepreciated capital changes). Byproduct credits play a minor role in the economics, providing approximately \$17/tr oz additional revenues. Incremental taxes and royalties and a return on investment to earn a 15-pct DCFROR add another \$46/tr oz, bringing the market price necessary to cover all costs and earn a 15-pct DCFROR to \$288/oz, well below the \$361/oz average gold price for 1993.

The Canadian gold industry, with its low cost structure, is competitive on the world market at current gold prices. The continued efforts to cut costs and improve efficiencies will help strengthen an already strong position. The potential for development of large low-grade gold-copper resources should help slow the recent declining reserve and production trends, but exploration efforts to prove up existing resources and the discovery of new resources will be required if these trends are to be totally reversed.

CHAPTER 5

AUSTRALIAN GOLD AVAILABILITY

by C. Linda Slater¹ and R. Grey Christiansen²

There are several significant trends that characterize Australia's gold industry. Gold production is increasingly being sourced from a few larger companies, many open pit gold operations are transitioning to underground mines, there is increased processing of refractory ores, and the resource base continues to grow as replenishment of reserves through exploration continues to exceed production. Financial gains made from the widespread use of forward selling have provided stability to the industry and capital for continued high levels of exploration and development. Cost efficiency has contributed to recent high production levels.

INTRODUCTION

The factors and trends that impact near-term gold supply are addressed in this report on the resources and production potential of Australia. The resource analysis includes data provided by the Australian Bureau of Resource Sciences from over 300 gold properties. The analysis of production potential includes operating cost estimates for 23 operations in Western Australia and 15 operations in four other gold-producing States in eastern Australia. The basis for this analysis of the cost structure of the Australian gold mining industry is data obtained through site visits to Australian gold operations and proprietary data provided by Australian gold mining companies. The cost data were further used to generate regression cost models for gold mining and

processing costs in Australia. The costs derived from the regression models and actual site costs were then used to develop a curve showing estimated cash operating costs versus cumulative production for the Australian gold industry. As in all chapters of this summary report, cost values are reported in U.S. dollars. More detailed information on all aspects of the Australian gold industry will be available in a planned Open File Report covering the Australian gold availability and mining investment climate.

OVERVIEW OF THE AUSTRALIAN GOLD MINING INDUSTRY

The world gold industry underwent significant expansion throughout the 1980's resulting in structural changes to the industry, changes in ownership and new sources of gold resources and production capacity. These changes have not been uniform in major gold producing regions, and Australia's gold industry has undergone more transformation than many of the other producing regions.

Australia's production of 240 mt (7.7 M tr oz) of gold in 1992 makes it the world's third largest gold producer following South Africa and the United States(10). Gold production rose dramatically in Australia during the 1980's, reflecting cost reducing technological advances in recovery techniques made early in the decade, higher gold prices and the high level of exploration expenditures committed by the industry. Other factors

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contributing to the maintenance of Australian gold production levels are the high level of gold ore reserves, and the financial gains made by Australian companies from the development of gold forward sales portfolios.

Australian mines maintained gold production in 1992 at near record levels despite the reintroduction of corporate taxation on gold profits in January, 1991 (84). Australian gold production has the potential to increase significantly over the next 10 years. A number of smaller Australian mines which commenced operations in the mid-1980's are reaching the end of their economic lives and these closures could contribute to a slight near-term production decline (85). However, production should resume expansion when a substantial number of the open pit operations develop the deeper underground reserves and several large new discoveries commence production (86). Significant new mines which are slated to reach production during the next few years include Kanowna, Cadia, Plutonic, Telfer Mariners, Bronzewing, and Northparkes (88). This represents new annual production capacity of over a half million ounces.

Gold is mined in all the Australian States and the Northern Territory³. The locations of major mines in Australia's States and Territory are shown in the figure 22 (89). Approximately 75 pct of Australia's gold production comes from Western Australia (87). Figure 23 illustrates the production derived from each of Australia's States and Territory.

Smaller companies are producing a decreasing share of Australia's gold output. As recently as 1987, companies with less than 100,000 ounces (3.1 mt) of annual production accounted for 64 pct of total Australian gold production (90). In 1992, based on ABARE production data, such companies accounted for only 40 pct of total production. Currently, a few large mines provide a significant portion

of Australia's total gold production. Table 29 shows the relative importance of these mines.

GEOLOGY

Most of the western and central part of the Australian continent consists of basement rocks of Precambrian age. Younger Paleozoic rocks form a discontinuous belt several hundred kilometers wide extending from north Queensland to Tasmania. Mesozoic platform sediments form a broad zone between the Paleozoic and Precambrian rocks extending from the Gulf of Carpentaria to central New South Wales and southern South Australia. Mesozoic age basaltic rocks form a residual capping over extensive areas of Paleozoic rocks in eastern Australia (91-93).

The major ore deposits of Australia are associated with crustal lineaments which are observed as tracks or belts of attenuation or disturbance in the overall geologic or tectonic pattern. The lineaments reveal a structural ore signature which is found to be common to a great many ore deposits at both local and regional scales. There is a marked concentration of major gold and base metal deposits within the younger granite-greenstone belts in the Archean tectonic superprovince of Western Australia. The Archaean deposits of the Yilgarn and Pilbara Cratons in Western Australia are the most numerous and account for most of the 75 pct of current gold production in Australia (94, 95).

EXPLORATION

Gold exploration expenditure in Australia remains high. The 1991-92 gold exploration expenditure as reported by the Australian Bureau of Agricultural and Resource Economics was about \$220 million, slightly above the 1990-91 level.

³Personal communication, Andrew Browne, North Mining Company, Denver, Colorado.

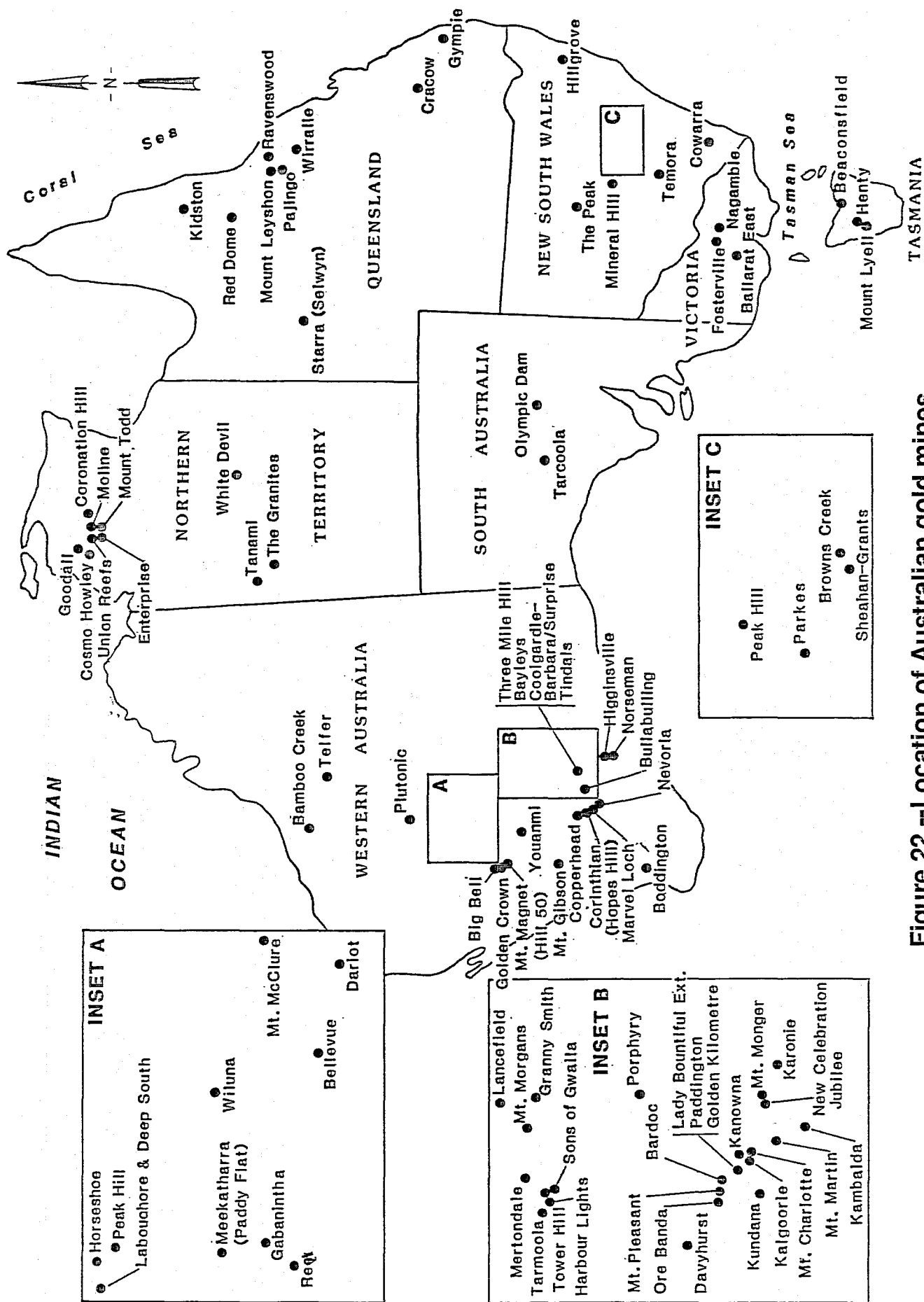
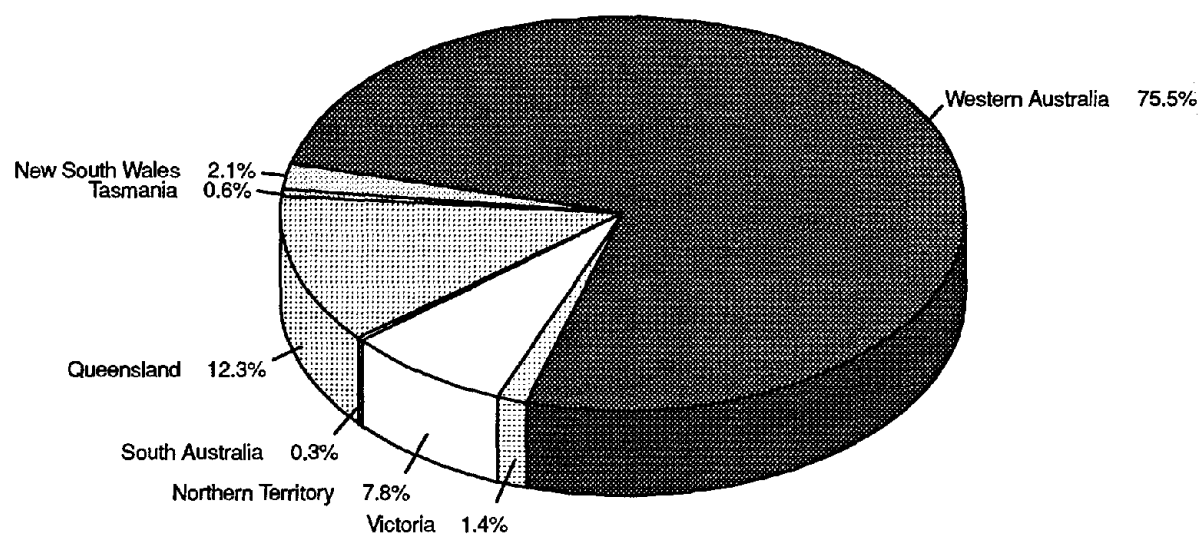


Figure 22.--Location of Australian gold mines.

Source: Clark and Cook (89), modified by author based on publicly available information.



Total = 240 mt

Figure 23.--Australian gold production share, by State, 1992.

Source: ABARE (87).

Table 29.--Australia's largest producing gold mines in 1992

Mine	Owner	Output		Pct of total Australian gold production, 1992
		(mt)	(tr oz) ¹	
Super Pit	KCGM	14.8	474,825	6.2
Boddington	Reynolds/Billiton	11.6	371,603	4.8
Telfer	Newcrest	11.4	366,401	4.8
Mt. Magnet	WMC	7.7	248,812	3.2
Mt. Leyshon	Poseidon Gold ..	6.7	216,028	2.8
St. Ives	WMC	6.5	208,320	2.7
Kidston	Placer Gold	5.5	177,064	2.3
Granny Smith	Placer Pacific . . .	5.4	174,211	2.3
Hedges	Alcoa	5.4	172,945	2.2
Plutonic	Plutonic Res. . . .	5.2	166,032	2.2
Big Bell	Poseidon Gold ..	4.9	156,700	2.0
New Celebration	Newcrest	4.4	142,799	1.9
Mt. Charlotte	KCGM	4.2	135,822	1.8
Cosmo Howley	KCGM	3.9	126,161	1.6
The Granites	Poseidon Gold ..	3.7	120,156	1.6
Subtotal		101.3	3,258,000	42.4
Total 1992 Australian gold production .		240.0	7,713,154	100.0

¹Production data is for the fiscal year 1992 (ending June 30, 1992).

Source: Personal communication from John Cairns of ABARE, Canberra, Australia.

While this level is considerably below the peak expenditure years of 1987-88 and 1988-89 (87), it is still high by historical standards.

The level of exploration activity has been affected by a number of issues. The Mabo and other native rights land use issues around title sovereignty have resulted in diversion of some exploration funds abroad (96). The discovery of new ore bodies in known mineral belts and many grass roots discoveries were aided by the development of geochemical and geophysical exploration methods adapted to the deeply weathered terrain characteristic of most of Australia⁴.

A large portion of Australian gold exploration expenditures are focused around presently operating gold mines. These areas are highly prospective for reserve expansion and adjacent new discoveries. An example of this is the discovery of the Sailfish deposit adjacent to the Norseman operations (97).

Western Australia continues to absorb the preponderance of gold exploration expenditures (98). There is still much prospective ground which has not been evaluated in Australia and exploration there continues to generate multiple prospects and new discoveries.

RESERVES/RESOURCES

The Australian Bureau of Resource Sciences' Division of Resource Assessment uses the category of economic demonstrated gold resource for official reporting of its in-situ gold ore resources. Whether the resource is near surface, oxidized, or is a reasonably sized resource adjacent to an existing operation are supplemental factors considered for inclusion of resources besides the proven and probable reserves into this category. Other criteria related to processing, geology of the deposit and the status of the parent company (99) can affect whether a deposit is classified as an economic demonstrated resource. These categories are non-standard

as compared to other large gold producing regions.

GOLD RESOURCES

The Australian gold industry's overall resource base has continued to expand every year over the past decade, and for 1992 stands at an economic demonstrated resource base of 2,466 mt of contained gold. Australia ranks fifth, behind South Africa, the former Soviet Union, the United States and Canada with 6 pct of the world's economic demonstrated resources (100). Western Australia has 60 pct of the economic demonstrated resources. The 1992 paramarginal demonstrated resources are reported by the Australian Bureau of Resource Sciences⁴ as 680 mt, and submarginal demonstrated resources are 91 mt. Undifferentiated inferred resources for 1992 were 1,469 mt. Table 30 shows Australian gold resources, excluding inferred resources, for the period 1980 to 1992.

Economic demonstrated resources increased seven-fold from 1980-92. Changes in the average grade and deposit types over this period can be understood by categorizing the ore resources, grades and gold content by deposit type as provided by the Bureau of Resource Sciences for the years 1981, 1985 and 1992 in table 31. Over this period, most of the growth in Australian gold resources has been in the higher grade primary gold deposits. The category of economic demonstrated resources is similar to the reserve definition used for official USBM statistics. Australia's estimated reserves are reported by Lucas (10) at 2,500 mt.

Total Australian gold resources in 1981 including inferred resources but excluding Olympic Dam, were 498.4 Mmt at a grade of 1.14 g/mt for total contained gold of 569 mt. Total Australian gold resources in 1992 including inferred resources and excluding Olympic Dam were 1,682 Mmt of ore

⁴Personal communications, Staff, Division of Exploration Geoscience, CSIRO, Australia.

Table 30.--Australian demonstrated gold resources¹
(mt of contained gold)

Year	Demonstrated resources		
	Economic	Subeconomic	
		Paramarginal	Submarginal
1980	332	73	14
1981	282	176	14
1982	343	444	53
1983	394	653	0
1984	728	158	73
1985	959	119	122
1986	1,026	253	122
1987	1,274	182	157
1988	1,378	329	85
1989	1,486	773	464
1990	2,129	588	126
1991	2,145	618	84
1992	2,466	680	91

¹Includes Olympic Dam, excludes inferred resources.

Source: Australian Bureau of Resource Sciences. Resource categories are defined in (99).

Table 31.--Australian gold ore resources¹, grade, and contained gold

	1981			1985			1992		
	Mmt	g/mt	kg gold	Mmt	g/mt	kg gold	Mmt	g/mt	kg gold
Tailings	40.0	1.10	44,000	40.8	1.09	44,400	83.4	0.78	67,900
Alluvial	6.0	0.28	1,700	9.2	0.45	4,200	74.9	0.36	26,700
Primary	102.0	3.28	334,100	264.0	3.27	864,500	1,212.8	2.47	2,990,700
Polymetallic ¹	350.4	0.54	189,700	154.9	1.64	254,800	310.4	1.22	379,300
Total ...	498.4	1.14	569,400	468.9	2.49	1,167,900	1,681.5	2.06	3,464,700

¹Excludes Olympic Dam, includes inferred extensions.

Source: Australian Bureau of Resource Sciences. Resource categories are defined in (99).

with an average grade of 2.06 g/mt for a total of 3,465 mt contained gold. Olympic Dam is a very large copper-gold-silver-uranium deposit which produces gold as a byproduct. Even though the average gold grade is quite low, this property accounts for a significant portion of Australia's gold production and gold resources. It was excluded from the figures because of the impact its resource size has on the average grade of Australian gold resources. The resource data described in this section was provided by Australia's Bureau of Resource Sciences.

Prior to the gold price increase of 1980-81, the only gold being recovered was from very high grade deposits or polymetallic deposits. At about the same time as the gold price increased, developments in cyanide leaching carbon absorption technology made mining lower-grade deposits more economical. Based on the data in table 31, the grade of resources from primary gold deposits has declined by 25 pct from 1981 to 1992 but is still much higher than the grade of gold contained in polymetallic deposits.

GOLD ORE RESERVES

Australia's 1992 proven and probable contained gold reserves total 1,100 mt, based on analysis of data on 300 properties provided by the Australian Bureau of Resource Sciences⁵.

Australia's 20 largest producers in 1992 accounted for more than 50 pct of Australia's proven and probable gold ore reserves. The percentage of proven and probable reserves as distributed between Australia's States/Territory is shown below:

<u>State</u>	<u>Pct</u>
Western Australia.....	71.7
Queensland.....	13.1
New South Wales.....	5.6
Tasmania.....	4.5
Northern Territory....	2.0
South Australia.....	1.6
Victoria.....	1.5

Approximately 45 pct of Australia's 1992 proven and probable reserves is from deposits which are or will be mined by open pit methods. Another 34 pct is related to operations which are either currently both open pit and underground operations or will have an underground operation in the near future. Exclusively underground operations account for 15 pct of the proven and probable reserves. The remaining 3 pct is contained in tailings.

A growing proportion of new reserves will likely be from expansions of the reserve base of known deposits, as companies seek to better demonstrate the potential of their mines to sources of capital and they seek to reduce risk in their exploration programs (101).

PRODUCTION

PRODUCTION HISTORY

Australian gold production rose dramatically since 1980, paralleling similar trends in the United States and Canada. Australian gold production increased from 18.4 mt (0.6 M tr oz) of gold in 1981 to about 240 mt (7.7 M tr oz) of gold in 1992, as shown in figure 24 (87). Australia is now the third largest among world gold producers behind only South Africa and the United States. This growth since 1980 was fueled by the development of new lower cost technology and the open pit mining of shallow oxide gold deposits by numerous small operators. In addition, the industry operated during the 1980's in a period of low sovereign risk and favorable tax regimes. Gold loans and the widespread use of gold futures contracts also boosted the industry output significantly.

⁵Under the Australasian Code for Reporting, reserves are a subset of resources modified by economic, mining, metallurgical, marketing, legal, environmental, social and governmental factors (99).

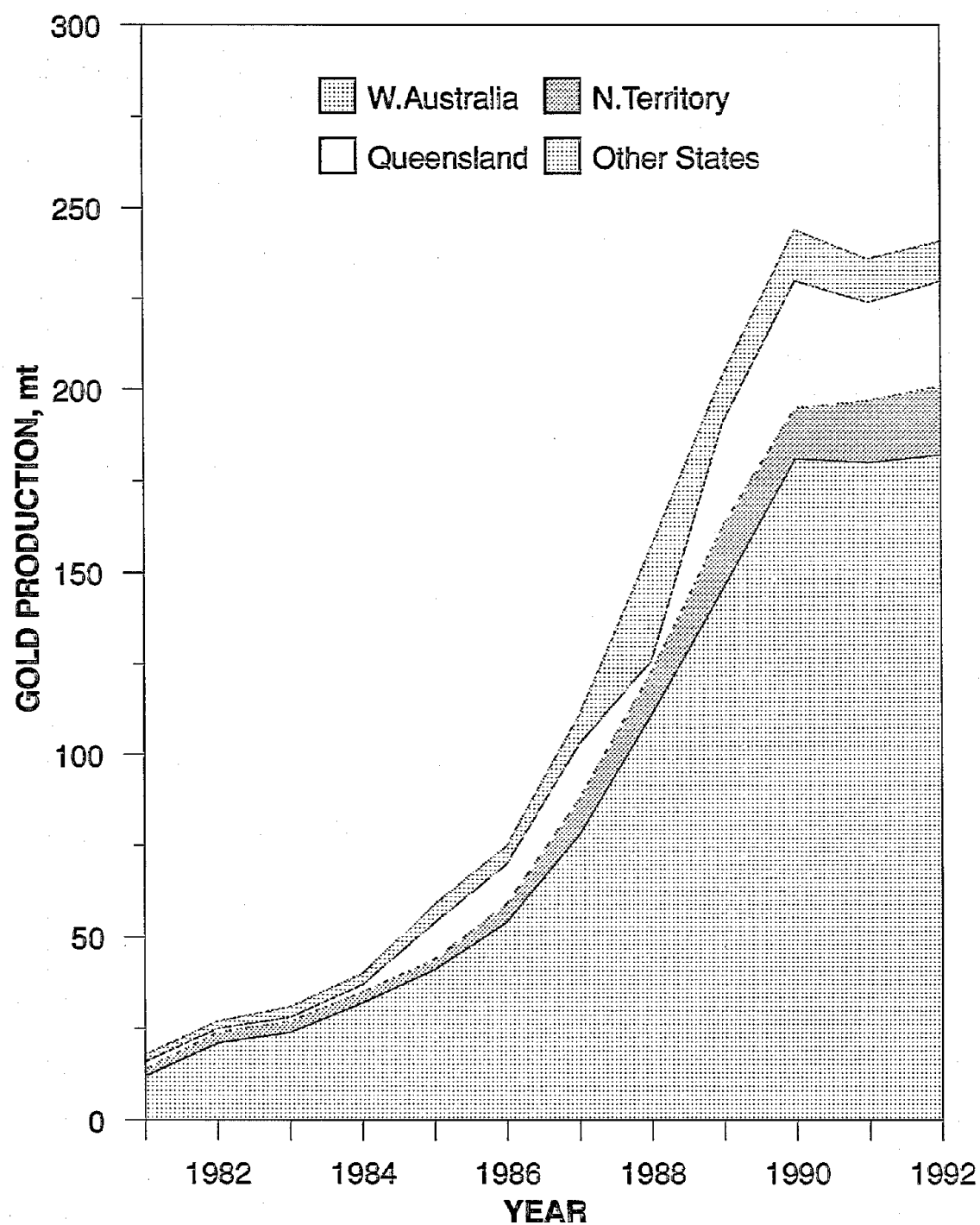


Figure 24.--Australian gold production by State and total, 1981-92.

Source: ABARE (87).

The general trend is for larger, new operations to replace the smaller ones which are reaching the end of their mine lives. This is expected to lead to a production upswing as the larger deposits occupy an increasing share of production (85). Over the next 2-3 years, three or four large new deposits could add a total of 20 mt of gold per year to Australian gold production.

The Australian gold mining industry is in a period of consolidation consisting of a concentration of production among the larger operators. There has been both rationalization and expansion for the purpose of economies of scale. The quality of deposits is improving and there is a trend towards longer mine lives. In the mid-1980's the average mine life was 5-6 years (90). Many gold mine lives have now been expanded to 11 or 12 years because exploration has been so successful. Australian gold producers have benefitted from the continued weakness of the Australian dollar, which maintained profit margins for gold mining companies despite fluctuations in international bullion prices.

AUSTRALIAN GOLD PRODUCERS

There were 31 gold mines in Australia in 1992 with production greater than 100,000 tr oz (3.1 mt) based on ABARE production figures. Figure 25 shows the distribution of production according to size of operation. This distribution is in sharp contrast to 1981 when there were only three gold mines with annual production greater than 75,000 troy ounces (2.3 mt)⁶: Telfer, Mt Charlotte, and Norseman.

Seventy-five percent of the mines producing more than 100,000 tr oz/yr (3.1 mt) in 1992 are located in Western Australia, with more than half of this gold production derived from the Eastern Goldfields. This is a big increase from 1981, when 51 pct of production was derived from Western

Australia. Significant production in 1992 also comes from Queensland (16 pct) and the Northern Territory (8 pct) (85). None of the other States had large operations until 1993. The Peak mine in New South Wales began producing at a rate of 100,000 tr oz/yr (3.1 mt) in 1993. A small increase may occur in 1994 as Kanowna (located in Western Australia) reaches full capacity and Mt. Todd in Queensland begins production. Figure 24 shows the distribution of Australian gold production for the years 1981-92 (87) by State. The percentage gold production, by resource type, for the periods 1981 and 1992 is shown in table 32. The obvious major shift in production by resource type is from polymetallic to primary gold deposits.

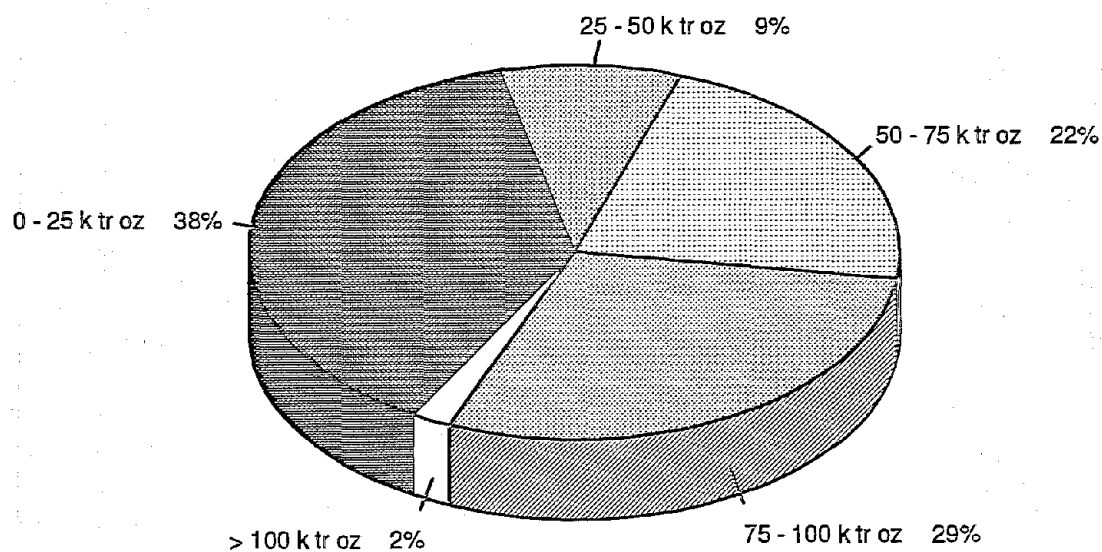
UNDERGROUND PRODUCTION

An increasing number of mines are developing underground reserves and an increasing proportion of Australian production will be sourced from these operations (88). Currently, underground mining accounts for only 12 pct of Australia's total gold mine production (100). With the change to underground mining at many small deposits, together with the start up of underground production at Wiluna, Boddington, Kanowna, Yilgarn Star, and others, this proportion is set to double over the next 5 years.

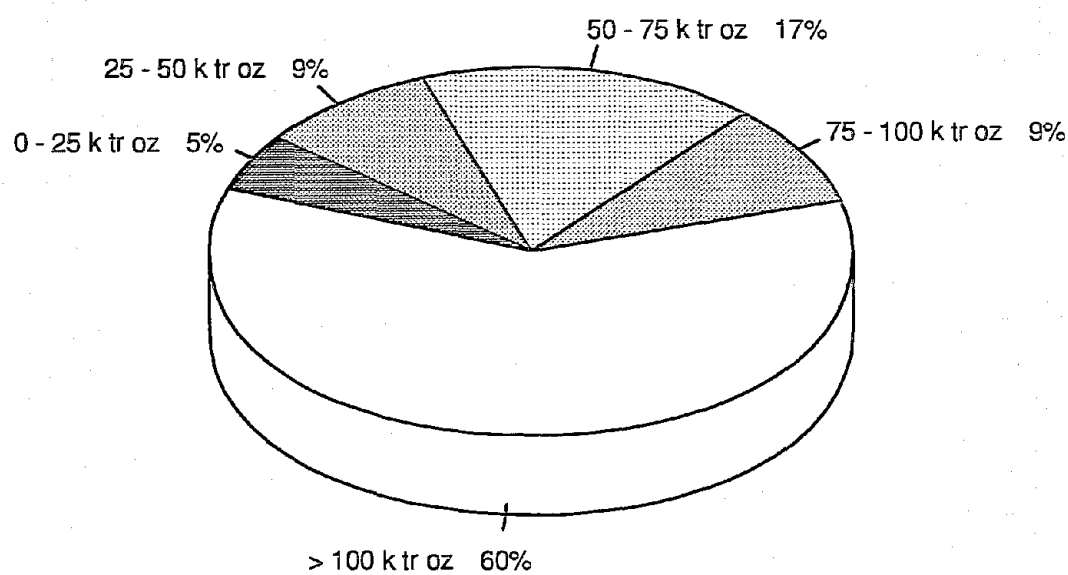
GOLD ORE MINING IN AUSTRALIA

The Australian gold mining industry is robust on price and competitiveness but has been short on mine life longevity. This situation is improving with new discoveries having larger resources and many of the present operations discovering additional reserves within the vicinity of the mine either through fresh discoveries or

⁶Data provided by Michael Huleatt, Bureau of Resource Sciences, Canberra, Australia.



1981



1992

Figure 25.--Distribution of gold production by mine size.

Source: Various published documents, information obtained from ABARE, and other data gathered during author's visits to Australia.

Table 32.--Australian gold production
by deposit type

Deposit type	Pct of production	
	1981	1992
Alluvial	0	0.1
Polymetallic	31.6	1.5
Primary	68.0	97.4
Tailings	0.4	1.0

Source: Personal communications with
M. Huleatt, Bureau of Resource Services
and data developed by the USBM.

by incorporating lower grade resources into the reserve base through greater economies of scale.

GENERAL PRACTICES IN AUSTRALIAN GOLD MINING

Gold mining in Australia is showing the signs of a maturing industry. Open pit mining is deeper and ore is increasingly brought in from satellite operations to provide feed for the plant. Stripping ratios for Australian gold operations can reach a level of 20:1 as with the Yilgarn Star mine. It is not uncommon to find stripping ratios of 10:1 to 13:1 at Australian gold operations. Mine economics on a recoverable gold basis are a function of depth, stripping ratios, and grade. The grade of Australian gold deposits often increases with depth as primary and transitional ore is encountered. The grade increase can offset increased stripping cost.

Contract mining has become more competitive as the ownership of mining equipment became an attractive alternative following the re-imposition of the gold income tax in 1991. Mining contractors have become more efficient in response to a more competitive environment and a reduction in interest costs in Australia.

With a greater proportion of production costs now occurring in the mining of a deposit, larger equipment is being utilized in the mines. However, cost reductions are not always reflective of just economies of scale, but also are reflective of operator expertise and cost-cutting measures. A matter which greatly improves cost competitiveness of Australian underground gold mines is the change from a 5 day, 7.5 hour per day work week in underground operations to a 7 day continuous roster (102). Another cost cutting measure has been an increasing emphasis on the geotechnical design of pit walls, with substantial improvement in pit wall stability techniques. These have enabled pit

walls to become steeper with a resultant reduction in the waste to ore ratio and stripping costs (103).

AUSTRALIAN GOLD MINING COST STRUCTURE

The cost analysis of the Australian gold mining industry is based on information collected during site visits to 24 gold mining operations in Australia as well as additional project cost data provided by Australian gold companies on another 14 gold operations. The distribution, by State, for data obtained on site visits to Australian gold mining operations is as follows:

<u>State</u>	<u>Operations visited</u>
Western Australia....	10
Victoria.....	2
New South Wales.....	4
Queensland.....	4
Northern Territory...	3
South Australia.....	1
Total.....	24

The production costs were compiled for three primary categories: mining, processing, and administration and general. The range of values for these cost categories are presented in the sections below. The ranges represent typical operations for which data were collected and do not include those operations where anomalous operational variables impacted the operating costs. Open pit mining costs in Australia ranged from \$4.84 to \$15.27 per mt of ore milled, representing a capacity range of 0.3 M mt/yr to 11.75 M mt/yr, as shown in table 33. Open pit mining costs calculated as a percentage of production costs ranged from 36-63 pct of total costs for all of the Australian gold operations analyzed. The range of mining costs for open pit operations was broader for Western Australia than for the rest of Australia. Open pit mining costs in the Northern Territory and the States of Victoria, New South Wales and Queensland varied between 36-49 pct

Table 33.--Australian gold mining, processing, and site overhead costs

Type	Capacity (Mmt/yr)	Cost (U.S. \$/mt ore)	
		Range	Wtd avg
Mining:			
Open pit	0.3 - 11.75	4.84 - 15.27	5.10
Underground	0.13 - 1.50	12.03 - 31.95	13.62
Processing:			
CIL/CIP	0.50 - 11.75	5.11 - 14.20	5.48
Site overhead:			
Administrative and general	0.13 - 11.75	0.78 - 6.06	0.87

Source: USBM cost model estimates, and data gathered during personal site visits.

of production costs and the median value was 42 pct.

Underground mining costs ranged from \$12.03 to \$31.95/mt milled. Underground mining costs for all of Australia as a percentage of total production costs ranged from 50-66 pct. Most of the underground data in the range presented are for operations which used bulk mining techniques or a combination of bulk mining and selective mining methods.

Underground mining costs, similarly to open pit mining costs, ranged more widely in Western Australia than for the rest of the country. Detailed mining and processing cost data are shown in table 34.

Drilling and blasting costs for oxidized ore ranges from 13 pct to 29 pct of Australian gold mining costs; the median value was 27 pct. Actual values ranged from \$0.23/mt milled to \$0.53/mt milled for very large operations with high economies of scale; and, from \$1.30/mt milled to \$3.77/mt of ore for smaller to intermediate size operations, with most of those being in the \$2-3/mt milled range.

Load and haul gold mining costs for an average operation varied from 32 pct to 49 pct of mining costs; the median value was 47 pct. Grade control related costs made up 5 pct to 10 pct of total mining cost for the operations analyzed. Actual cost ranges were from \$0.50/mt to \$1.13/mt milled.

Contract mining of gold deposits is much more widely used in Australia than in the United States. The advantage which exists under contract mining involves the wide range of equipment sizes and types available from a contractor. Underground mines do not normally use contract mining except for a few specialized functions. Contract mining costs vary by State or territory throughout Australia. The lowest contract costs are found in Western Australia.

GOLD ORE TREATMENT

GENERAL PRACTICES

The use of plant leaching is more prevalent in Australia than heap leaching. The Australian gold mining industry has achieved marked reductions in plant processing costs. These have come about as a result of improvements in plant technology and the introduction of more efficient comminution systems.

The Australian gold mining industry has directed a great amount of effort toward developing more efficient comminution systems. The largest component of processing cost is for consumables/grinding media, which can be up to 33-50 pct of the processing cost. The present trend is to greater use of the semi-autogenous grinding (SAG) mill circuit, regardless of the ore type⁸.

Carbon-in-leach (CIL) plants have gained favor over carbon-in-pulp (CIP) plants in recent years, particularly for larger operations. The large number of tanks and space needed in these operations can be better managed through exclusive use of CIL tanks. A combination of the two types of plants is often found. Australian operations commonly add a little cyanide to the ore in the SAG or ball mill stage to improve the leaching kinetics.

COST STRUCTURE

Cash cost of processing was analyzed for the same operations and capacity ranges for which mining costs were reported in tables 33 and 34. The processing

⁷Personal communication, Bruce Fraser, Australian Mineral Industries Research Association Ltd., Melbourne, Australia.

⁸Personal communication, Gary Johnson, Dominion Mining Ltd., West Perth, Australia.

Table 34.--Detailed gold mining and processing cost ranges in Australia

Mining costs category	Capacity (Mmt/yr)	Cost range (U.S. \$/mt)
Mining Cost:		
Drilling and blasting		
Large capacity	7.5 - 11.75	0.23 - 0.53
Small capacity	0.5 - 4.00	1.30 - 3.77
Loading and hauling	0.5 - 11.75	0.79 - 5.52
Grade control	0.5 - 11.75	0.50 - 1.13
Processing costs:		
Crushing and grinding	0.5 - 11.75	1.55 - 4.84
CIP\CIL	0.5 - 11.75	1.07 - 4.40
Gold room	0.5 - 11.75	0.21 - 1.07
Tailings disposal	0.5 - 11.75	0.06 - 0.38

Source: USBM cost model estimates, and data gathered during personal site visits.

costs for gold mines ranged from 27-53 pct of total production costs (\$5.11/mt milled to \$14.20/mt milled) for operations using CIL/CIP plants with the majority of processing costs falling mid-range at near 40 pct of production costs.

The processing cost range of 27-43 pct (\$5.11/mt milled to \$8.52/mt milled) for Western Australia is narrower than for the rest of Australia. The Western Australian range can be extended to over 47 pct of production if operations which float roast ore are included. Bio-oxidation processing costs lie on the high side of the above reported range.

The reasons for the generally lower processing costs in Western Australia are several. Much of the ore mined in Western Australia is soft, clayey, oxidized ore from shallow open pit minable deposits. This material does not incur high comminution costs and leaches easily. With a few exceptions, the Western Australian ores currently being mined are strictly gold/silver ores with few problems associated with high cyanide consumption from carbon or copper in the ore. Most of it is oxide ore, although a few operations are processing sulfidic ores. Only two of the Western Australian operations included in the cost analysis were processing metallurgically refractory ore.

Crushing and grinding costs comprised 26-41 pct of gold processing costs for the operations reviewed. The actual cost range was from \$1.55/mt milled to \$4.84/mt milled, with most of Western Australian operations falling in the low end of the range.

The plant CIP/CIL cost range was varied from 14-33 pct with more than 80 pct of the values in the 20-30 pct of total processing costs range. Actual costs varied from \$1.07/mt milled to \$4.40/mt milled. The higher cost end was not common and usually represented a situation where copper consumption of cyanide resulted in higher costs.

The gold room category of processing costs includes desorption, elution, and electrowinning. These costs do not comprise a large portion of the processing costs, commonly ranging from 2-4 pct with a few operations in the 5-6 pct range. Actual costs ranged from \$0.21/mt milled to \$1.07/mt milled.

Tailings disposal cost usually ranged from 1-3 pct of processing costs with a maximum of 6 pct. Average costs ranged from \$0.06/mt milled to \$0.38/mt milled.

Power costs in Australia vary significantly, anywhere from approximately \$0.07/kW·h in New South Wales and the Queensland grid to approximately \$0.12/kW·h in the Northern Territory. In some cases power costs are subsidized or the mine is given a special rate such as in New South Wales where the regular grid cost without subsidization is \$0.091/kW·h.

The administrative and general cost component of production costs ranged from 5-17 pct for Western Australia with the median being 7-8 pct. The range for the remainder of the operations reviewed outside of Western Australia is 6-15 pct with a median value of 8 pct.

MINE COST ESTIMATION

Production costs collected from company sources and from site visits were used in an analysis of the entire Australian gold industry cash production cost. Cost estimates were made for 30-40 additional operations using a regression analysis model. Costs collected for the individual operations described earlier formed a statistical basis for estimating costs for additional operations.

Statistical testing of the regression equation was performed for validity. It should be emphasized that these regression equations are for "average"

⁹Provided by the South Australia Department of Mines and Energy.

operations and do not include data from mines incurring abnormal circumstances. Detail on these regression curves will be in the planned Open File Report. Table 35 gives the regression equations.

CASH COST VERSUS CUMULATIVE GOLD PRODUCTION

Figure 26 is a cash cost curve for all Australian gold producers for which costs were collected or estimated. These properties account for approximately 80 pct of Australia's production for the fiscal year 1992. Production omitted is from the smaller gold producers. This curve accounts for over 192 mt (6.2 M tr oz) of gold produced in Australia annually. Capital depreciation and amortization, return on and of capital, and taxes are not included in this analysis. Examination of the curve shows a cash cost range of \$75/tr oz to \$363/tr oz of gold. Table 36 shows the ounces of production by ranges of cash operating cost.

Of total gold production, about 26 pct of the operations fell below the \$200/tr oz range, 64 pct in the \$200/tr oz to \$300/tr oz range with most of the remaining production capacity, approximately 10 pct, having cash costs above \$300/tr oz.

Almost all of these operations were able to cover cash costs at the average 1992 gold price (\$345). However, a number of the properties had only a small margin to apply toward capital expenditures and taxes. A further consideration for many of these operations is the benefits they receive from forward selling. That is, much of the gold being produced in Australia has already been sold at agreed on prices higher than the current market price. The industry's success in using forward sales helped to generate additional revenues which the companies used on the ambitious exploration programs described earlier.

CAPITAL COST OF PLANTS IN AUSTRALIA

Gold processing plants can be constructed and commissioned very quickly in Australia, normally within 3 to 6 months. The capital cost of the plants is lower than in the United States by about 15 pct¹⁰. They are pre-fabricated and assembled on site. The plants are highly portable and can easily be moved to a new location. Because of these efficiencies and other considerations, plant processing is preferred over heap leaching. Generally, the cut-off ore grade between heap leaching and plant processing in Australia is 2 g/mt. The economics of CIP/CIL leaching versus heap leaching is much better in terms of recovery and the payback period when feed grade is above that cut-off level.

A regression equation has been developed to model plant capital cost in Australia. This model is designed only for CIL or CIP plants at gold operations in Australia. The cost equation is valid for ore capacities of 50,000-800,000 mt/yr. Capital costs ranged from \$4.5 million to \$14.5 million. The plant capital cost equation is $y=14,990(X)^{.48}$.

CONCLUSIONS

Australia, the world's third largest gold producer, has experienced dramatic growth in its gold output since the 1980's. In 1992, and again in 1993, production reached historically high levels. Technological advances, relatively high gold prices, emphasis on cost efficiency, and widespread forward selling are key factors in the industry's growth.

¹⁰Personal communication, Bruce Fraser, Australian Mineral Industries Research Association Ltd., Melbourne, Australia.

Table 35.--Regression curve data for gold mining and processing cost estimations in Australia

Location	Mining or milling method (number of properties)	Capacities (kmtpy)	Estimated operating cost (\$/mt ore)	Feed grades (g/mt)	Mill recovery (pct)	Regression equations ^{1,2,3}
Western Australia	Open Pit Mining (15)	400 - 6,150	6.41 - 14.14	NAP	NAP	$Y = 837(X)^{-0.280}$
Rest of Australia	Open Pit Mining (7)	295 - 4,146	5.27 - 14.10	NAP	NAP	$Y = 2,159(X)^{-0.372}$
All of Australia	Underground Mining (4)	125 - 1,500	11.43 - 32.06	NAP	NAP	$Y = 5,885(X)^{-0.415}$
Western Australia	CIP Processing (6)	756 - 2,900	5.03 - 8.26	1.77 - 3.32	85.89 - 95.00	$Y = 1,703(X)^{-0.363}$
Rest of Australia	CIP Processing (5)	55 - 4,150	6.26 - 28.77	1.68 - 15.55	76.60 - 97.00	$Y = 1,903(X)^{-0.353}$
Western Australia	CIL Processing (6)	200 - 2,828	6.43 - 14.22	1.66 - 15.00	87.50 - 96.00	$Y = 780(X)^{-0.360}$
Rest of Australia	CIL Processing (4)	450 - 1,567	6.98 - 11.86	2.03 - 9.10	81.50 - 95.80	$Y = 4,227(X)^{-0.425}$
Western Australia	CIP & CIL Processing (12)	200 - 2,900	5.67 - 13.70	1.66 - 15.00	85.89 - 97.00	$Y = 1,083(X)^{-0.330}$
Rest of Australia	CIP & CIL Processing (11)	55 - 4,146	5.72 - 23.74	1.68 - 15.55	76.60 - 97.00	$Y = 1,213(X)^{-0.329}$

NAP Not available.

¹All regressions were developed using Australian currency and converted to U.S. dollars at the average 1992 rate of exchange (.71 A\$ = 1 U.S. dollar).

²X is the independent variable representing metric tons per year of ore mined or processed.

³Y is the dependent variable representing the cost per metric ton of ore mined or processed.

Source: USBM estimates, and data gathered during personal site visits.

Table 36.--Australian gold production capacity broken down by cash cost and pct, 1992

State	Production by cash operating cost range (k tr oz)				Output		
	\$0-\$100	\$100-\$200	\$200-\$300	\$300-\$400	mt	k tr oz	pct
New South Wales	--	--	160.5	30.8	5.95	191.4	3.1
Northern Territory	0.5	360.6	227.6	135.3	22.52	724.0	11.7
Queensland	--	156.5	493.9	--	20.23	650.5	10.5
Tasmania	--	100.0	--	--	3.11	100.0	1.6
Victoria	--	49.2	65.4	--	3.56	114.6	1.8
Western Australia	--	933.4	2,805.9	675.7	137.32	4,415.0	71.3
Total	0.5	1,599.8	3,753.3	841.9	192.70	6,195.4	100.0

¹Equivalent to 80 pct of total Australian gold production.

NOTE.--Dash indicates no production.

Source: USBM estimates, and data gathered during personal site visits.

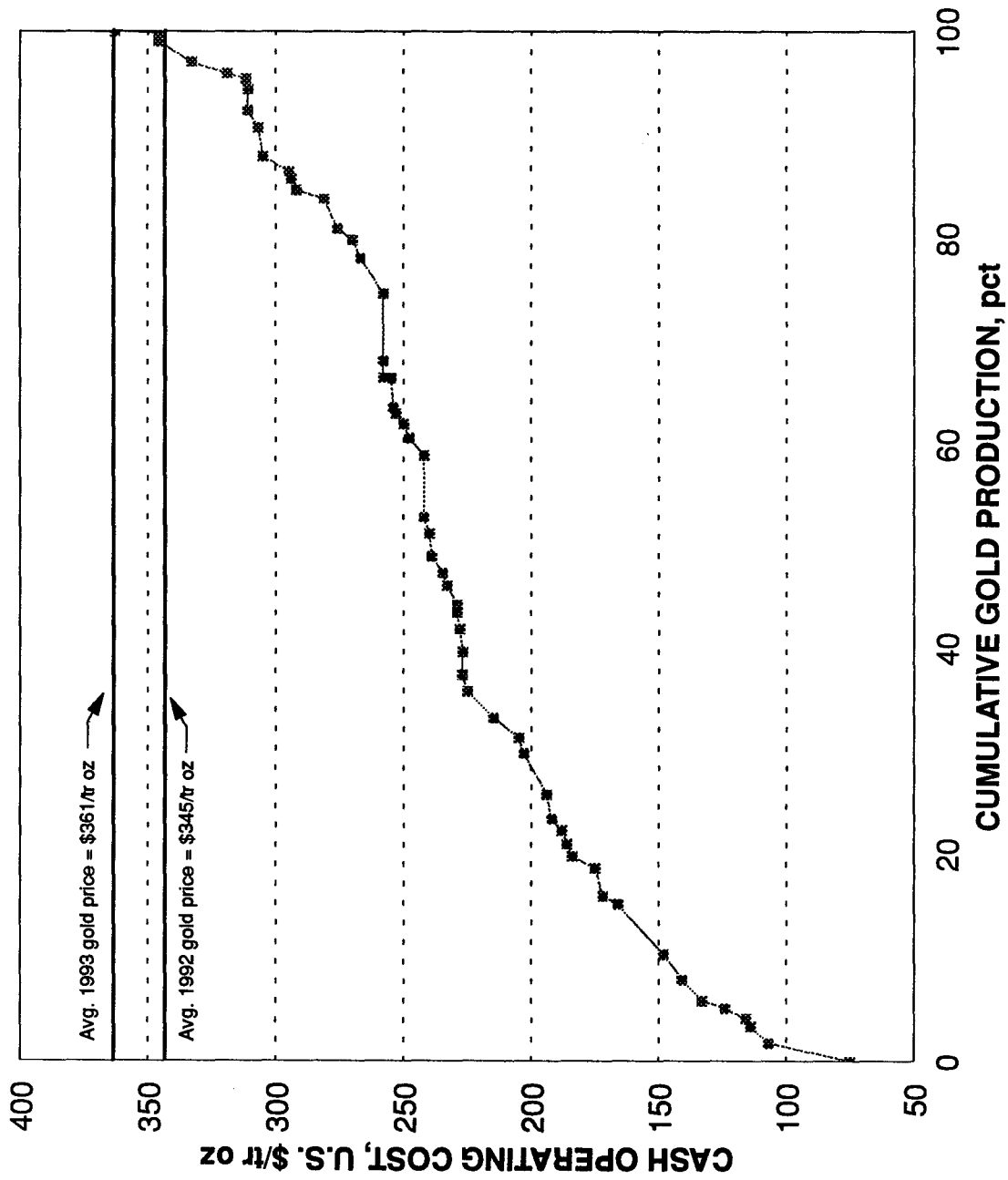


Figure 26.—Cash cost vs cumulative gold production, Australia 1992.

Source: USBM estimates.

Primary gold mines account for the preponderance (over 97 pct) of Australia's gold production. Geographically, Western Australia leads the industry with 75 pct of national gold production.

Exploration activities and expenditures by Australia's gold industry remain high, resulting in the discovery of a growing number of important deposits. The level of economically recoverable gold reserves has been maintained despite high rates of extraction.

The general trend in the industry is toward concentration of gold production among Australia's larger operators. Successful exploration of new reserves adjacent to existing operations and the quality of the new deposits has resulted in longer mine lives.

Open-pit mining, which represents the bulk of all mining operations, is becoming deeper as the industry matures; many operations are in transition to underground mining. Larger equipment and more sophisticated geotechnical engineering are required; as a result, the proportion of production costs assigned to mining the ore has increased.

Because a great amount of research and effort has been directed toward developing more efficient ore treatment systems, the industry has achieved a marked reduction in plant processing costs. Innovative plant modifications have been created to deal with the wide variety of ore types processed by Australian operators.

CHAPTER 6

LATIN AMERICA GOLD AVAILABILITY WITH EMPHASIS ON BRAZIL AND CHILE

by Gary R. Peterson¹

Since the late 1980's, Latin American countries have attempted to open up their economies to foreign investment and freer trade. These countries now encourage privatization of state-owned enterprises and recruitment of foreign investment. At the same time, uncertainty has been created in the United States by the debate over proposed reforms of the General Mining Law of 1872. These conditions have resulted in a fourfold increase since 1990 in spending for both exploration and acquisitions in Latin America. This report estimates the potential availability of gold from 14 representative mines and deposits in Brazil and Chile by performing detailed geologic, engineering, and cost evaluations, including discounted cash flow rate of return (DCFROR) for each of the operations. In addition, a general overview of the gold industries of the other Latin American countries is presented, with discussions of current projects, mining laws, and taxation systems. This analysis will be presented in much more detail in a planned Open File Report on the gold availability and mining investment climate of Latin America, emphasizing Brazil, Chile, and Mexico.

The economic analysis of operations in Brazil and Chile provide mixed results, particularly for several Chilean properties in the Maricunga region. The gold potential of Brazil continues to be delayed by economic and political turmoil in that country. Much success in Latin America over the past several years has occurred in

countries which had previously been inhospitable to foreign investment, especially in the mining sector. The development of Korri Kollo in Bolivia, Omai in Guyana, Yanacocha in Peru, and the Kilometer 88 and El Callao regions of Venezuela have stimulated intense exploration activities in those countries.

INTRODUCTION

The foreign investment climate in Latin America has become more favorable over the past several years because of changes to the mining laws of many countries. Chile was the first country to revise its legislation concerning foreign private investment. Following Chile's success in reforming its economy over the past decade, the leaders of Mexico, Argentina, and other Latin American countries have made tremendous strides in promoting foreign investments and overhauling their national economies. At the "Investing in the Americas" Conference held in Miami in March, 1993, representatives from virtually every country in Latin America touted their respective nations as attractive locations for foreign investment in their mining industries. Countries that had previously been closed to foreign investment, technology and management have encouraged massive privatization of state-owned enterprises and recruitment of foreign investment.

Most Latin American countries have rewritten their mining laws since 1990 to reflect this new

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attitude. The changes in the foreign investment climate in Latin American are reflected in recent expenditures for exploration and acquisition. Doppler & Associates estimated 1993 exploration expenditures in Latin America at \$300+ million and acquisition expenditures at \$405 million (104). Expenditures for both exploration and acquisition were approximately four times the amount spent in 1990.

Latin American gold production increased by 91 pct between 1982 and 1992, from 110 mt (3.5 M tr oz) to 206 mt (6.74 M tr oz). However, Latin America's share of world gold production only increased from 10.6 pct to 11.4 pct, as world output increased nearly as dramatically (3, 4).

The respective shares of Latin American gold production in 1992 by the major producing countries are illustrated in figure 27. Brazil, with about 37 pct of total Latin American gold production, and Chile, with 17 pct, remain the largest gold producers in Latin America.

THE CHILEAN GOLD INDUSTRY

HISTORICAL PERSPECTIVE

Prior to 1980, Chile was a minor gold producer with total annual production of less than 3.5 mt (113 k tr oz) (23). Most of this was a byproduct of copper production (105). In 1979, copper producers accounted for 70 pct of total Chilean gold production. This situation changed beginning in 1980 with the initial production at St. Joe's El Indio mine near the Argentine border in the Andes mountains.

Following the development of El Indio, gold exploration in Chile was greatly enhanced by an airborne survey run during 1980-81. The survey, conducted by Bernstein y Thompson Ltd., encompassed the entire high Andes region from southern Peru to Tierra del Fuego and was financed by Anglo-American

and Cominco (106). The main objective of this airborne survey was to identify color anomalies indicative of sulfide oxidation. The color anomalies identified were followed up by helicopter-supported ground surveys and geochemical prospecting. This program led to the discovery of many of the ore bodies in the Salar de Maricunga area, including Marte, Lobo, Valy, Escondido, Soledad, and Refugio (106). This exploration program also led to the discovery of the Pimentón, Amos and Novicio prospects east of San Felipe in central Chile. During this period, discoveries were also made at La Coipa by Gold Fields Mining Corp., and at El Hueso by Codelco.

All of the ore bodies in the Maricunga district are hydrothermal, epigenetic deposits related to Tertiary volcanism. The potential for discovering other significant gold properties in this region is favorable.

PRODUCTION

Currently, the production of gold in Chile comes from three main sources: (1) primary gold mines with both large and small producers; (2) as a byproduct from the copper mining sector, which is comprised of both privately-owned and state-owned mines; and (3) other mines with primary products such as lead, zinc, and silver. As mentioned previously, the proportion of gold production as a byproduct has decreased significantly.

Chilean gold production in 1992 amounted to 34.5 mt (1.1 M tr oz). Gold mines accounted for 73.4 pct of total production and byproduct gold from copper mines and others accounted for 26.6 pct (105, 107, 108). In 1992 Chile ranked ninth among the world's gold producers.

The list of all gold properties evaluated for this report is presented in table 37, and a detailed description of each property will be presented in the planned Open File Report.

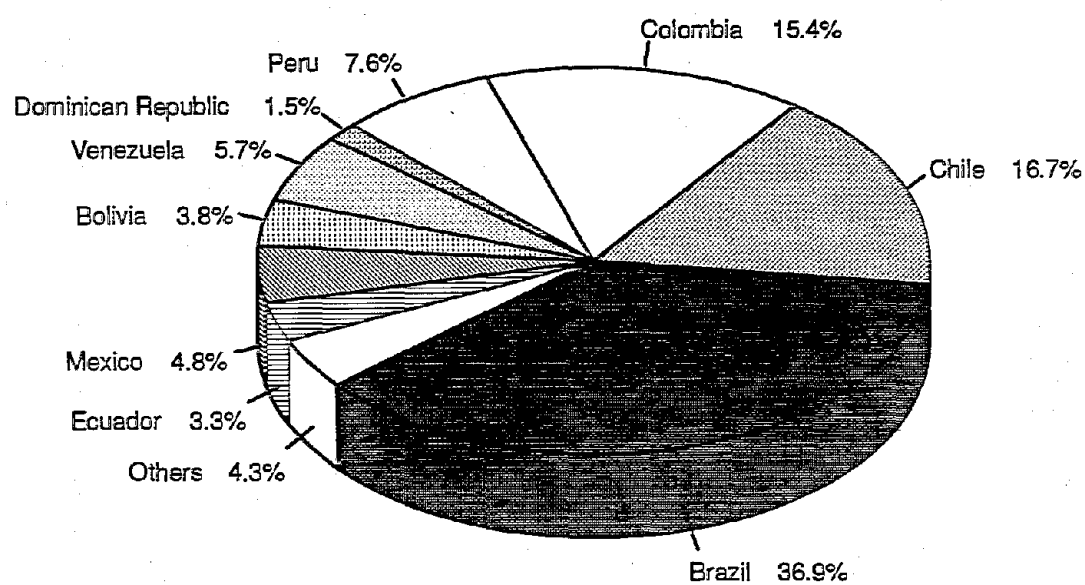


Figure 27.--Country shares of Latin American gold production in 1992.

Table 37.—Gold properties included in the Latin American study

Property name	Ownership	Current ¹ status	Mining ² method	Recovery ³ method	First year of production	Average annual recoverable ⁴ gold	
						(k tr oz)	(mt)
Brazil							
Crixás	TVX Gold/Mineração Morro Velho	P	C&F	CIL, MC	1990	124	3.9
Fazenda Brasileiro	CVRD	P	C	G, CIP	1984	167	5.2
Igarapé Bahia	CVRD	P	OP	CIP	1991	265	8.2
Jacobina	Mineração Morro Velho	P	SL	G, CIL, MC	1983	73	2.3
Morro do Ouro	RTZ Mineração/Autram	P	OP	F, G, CIL, CIP	1987	165	5.1
Morro Velho	Mineração Morro Velho	P	OS, C&F	F, Rst., CIP	1834	198	6.2
Novo Astro	TVX Gold	P	SL	G, Cl, MC	1989	62	1.9
São Bento	AMIRA/Gencor	P	C&F, SH	G, F, P Ox, CIL	1986	117	3.6
Chile							
Andacollo Gold	Dayton Developments Corp.	E	OP	HL, CIP	1995	112	3.5
El Indio/Tambo	LAC Minerals	P	OP/C&F	HL, F, Rst., CIP	1980	197	6.1
Guanaco	AMAX Gold	P	OP	HL, CL, MC	1988	105	3.2
La Colpa	TVX Gold/Placer Dome	P	OP	CL, MC	1989	174	5.4
Refugio	Berna Gold/AMAX Gold	D	OP	HL, CIP	1995	208	6.5
San Cristobal	Niugini Mining Limited	P	OP	HL, CIP	1990	76	2.4

¹Current status: P, producing; D, developing; E, explored.²Mining method: OP, open pit; C, Caving methods; C&F, cut and fill; OS, open stope; Sh, shrinkage; SL, sublevel stoping.³Recovery method: CIL, carbon in leach; CIP, carbon in pulp; F, flotation; G, gravity; HL, heap leach; MC, Merrill-Crowe; P Ox, pressure oxidation; Rst, roasting; CL, agitation cyanide leach.⁴Estimated average annual production over remaining mine life.

Source: Compiled from available public documents such as company annual reports, and data gathered during author's site visits.

A map showing the location of gold properties in South America is shown in figure 28. Significant Chilean gold properties that were not included in the analysis include Homestake's El Hueso mine, the Marte mine and the Lobo deposit, which were owned by Cominco Resources and Anglo American, and the Fachinal property in southern Chile, owned by Coeur d'Alene Mines Corporation.

El Hueso was not included in the analysis because production was not expected to continue beyond 1994 due to exhaustion of reserves. However, Homestake is allowed to extend the lease area at El Hueso in order to allow the company to explore the Aguade la Falda deposit. The Marte Mine represented the first major setback in the development of the modern Chilean gold industry (107). Marte began production in the third quarter of 1989, and shut down in September 1991, due to problems in the crushing circuit and poor recoveries. The Lobo property is similar to Marte and has yet to be developed. Cominco Resources sold its 50 pct share of the Lobo deposit to the Teck Corporation in 1993. Fachinal was not included in the analysis because it was still in the exploration stage and not enough data were available to perform meaningful economic analysis on the project.

ISSUES AFFECTING THE CHILEAN GOLD INDUSTRY

Much of the following section was extracted from the Industrial Outlook Report for Chile, published by the U.S. Embassy, Santiago (109). Chile's foreign investment statute, as embodied in Decree Law 600, reflects four main principles:

- non-discriminatory treatment of foreign investors;
- free access to markets and economic sectors (subject to a limited number of strategic reservations, of which restrictions on activities by or with Corporacion Del Cobre

(CODELCO) are most relevant to the mining sector);

- the requirement of clear and transparent rules on taxes and repatriation of earnings and capital;
- simple registration procedures.

Mining Title

Chile's 1980 constitution follows the Spanish tradition that "the state has absolute, exclusive, inalienable and irrevocable dominion" of all mineral deposits. The constitution allows the state to grant concessions to exploit these deposits. However, in contrast to several Latin American countries, where disputes are handled administratively, the courts in Chile have the responsibility to settle all disputes about the expiration or abolition of titles.

Environmental Legislation

Chile lacks a comprehensive environmental law. However, there are over 2,000 separate pieces of legislation affecting the environment, many of which have an impact upon mining. The National Environmental Commission, an inter-ministerial body, sets overall policy. Various administrative decrees govern solid, liquid, and air pollution. A decree limiting sulfur dioxide emissions and establishing monitoring requirements came into effect in 1992. In particular, the CODELCO and Enami copper smelters will be required to make extensive new investments to fully comply with this decree. There is no formal requirement that full-scale environmental impact statements accompany new mining investments; however, such statements are prepared for most new projects.

The Government of Chile is expected to submit comprehensive new environmental legislation to Congress in the near future. Even under the current patchwork of

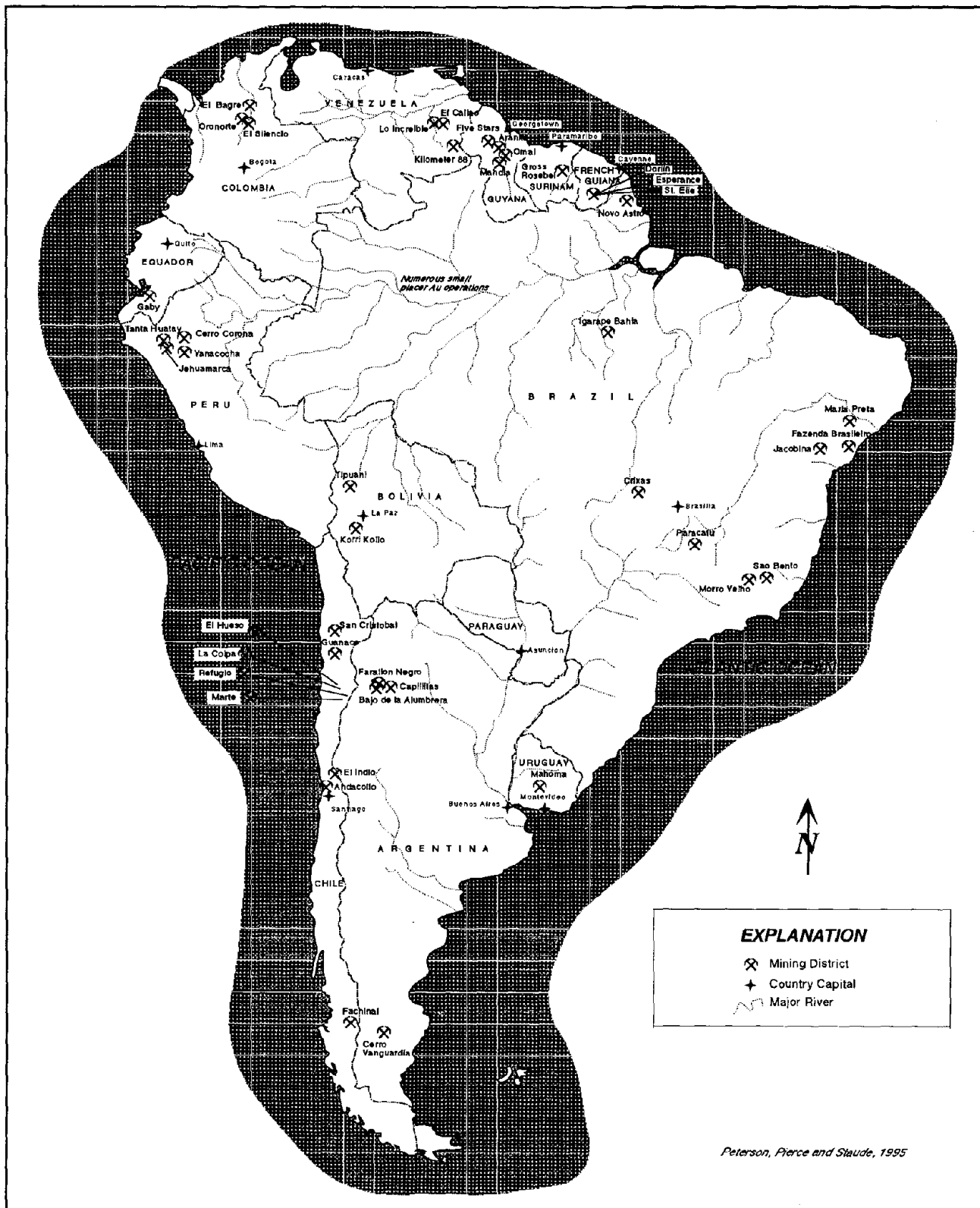


Figure 28.—Selected gold mines and advanced projects in South America.

Source: USBM data, map prepared by USGS.

environmental decrees, environmental groups have occasionally been able to use the court system to challenge the activities of mining companies which may pollute the air, ground, or water.

Taxation

Taxes are levied by the Republic of Chile through the Internal Revenue Service in compliance with the tax law and regulations. The main body of tax legislation is the Law 824 "Ley de Impuesto a la Renta", which was promulgated in 1974. The tax law applies to all residents in the country, and to non-residents deriving rents from business in Chile.

Chile maintains an 11 pct tariff on imported goods (reduced in 1991 from 15 pct). Tariffs are waived, however, on imports of capital goods for export industries. Thus, mining equipment usually enters the country duty-free. Another crucial element in Chile's recent success in attracting minerals investment is the absence of any royalties or severance taxes. Chile relies entirely upon corporate and individual income taxes to generate revenue from privately held mines (109).

THE BRAZILIAN GOLD INDUSTRY

HISTORICAL PERSPECTIVE

Brazil is the largest gold producer in Latin America with 1992 production of 76 mt (2.44 M tr oz) (110). It has the largest known reserves and perhaps the greatest potential for significant new discoveries. However, Brazil has not been able to attract much foreign investor interest to its gold industry because of ongoing political and economic problems. This situation may change. Brazil continues to debate how to amend its Constitution in order to attract foreign investment in mining.

The Brazilian operations evaluated were shown in table 37.

Figure 29 shows the locations of major Brazilian gold operations.

The Informal "Garimpeiro" Sector

Although in decline since the late 1980's, the informal gold mining sector accounted for a majority of gold production over the past 20 years. The gold rush of the 1980's involved an army of small miners (garimpeiros) as well as the major mining houses. Increases in the gold price, poverty in the northeast of Brazil, and headlines about gold strikes lured hundreds of thousands of garimpeiros to the Amazon region. At the peak of garimpeiro activity in 1988-89, an estimated 400,000 people were working in these types of garimpo operations (111). The peak year for production from these operations was 1988, when an estimated 90 mt of gold were produced from garimpo operations.

The most important garimpo areas were located in the Amazon region and comprise (1) the Tapajós-Parauari area in the States of Pará and Amazonas which has been mined since the 1950's over a 150,000 square km² area, (2) Alta Floresta in the State of Mato Grosso, (3) Cumaru in Pará State, and (4) Serra Pelada in Pará State. Other major garimpo areas include the Peixoto de Azevêdo in Mato Grosso, Xingu-Araguaia in the States of Pará and Goiás, Rio Madeira in Rondônia, Cuiabá-Poconé in Mato Grosso, Gurupi in Maranhão, Tepequém in Roraima, Mara-Rosa-Crixás-Pilar in Goiás, Cassiporé-Lourenço in Amapá, and Aripuanã-Gavião in Amazonas (110). Serra Pelada, the most famous of the garimpo operations, produced an estimated 50 mt (1.6 M tr oz) of gold during the 1980's. Peak production was in 1985 with 12.9 mt (0.4 M tr oz) of gold produced by about 40,000 workers (110).

Production

Garimpo operations became largely uneconomic by 1990 as Brazil's gold price was realigned to international levels and as the

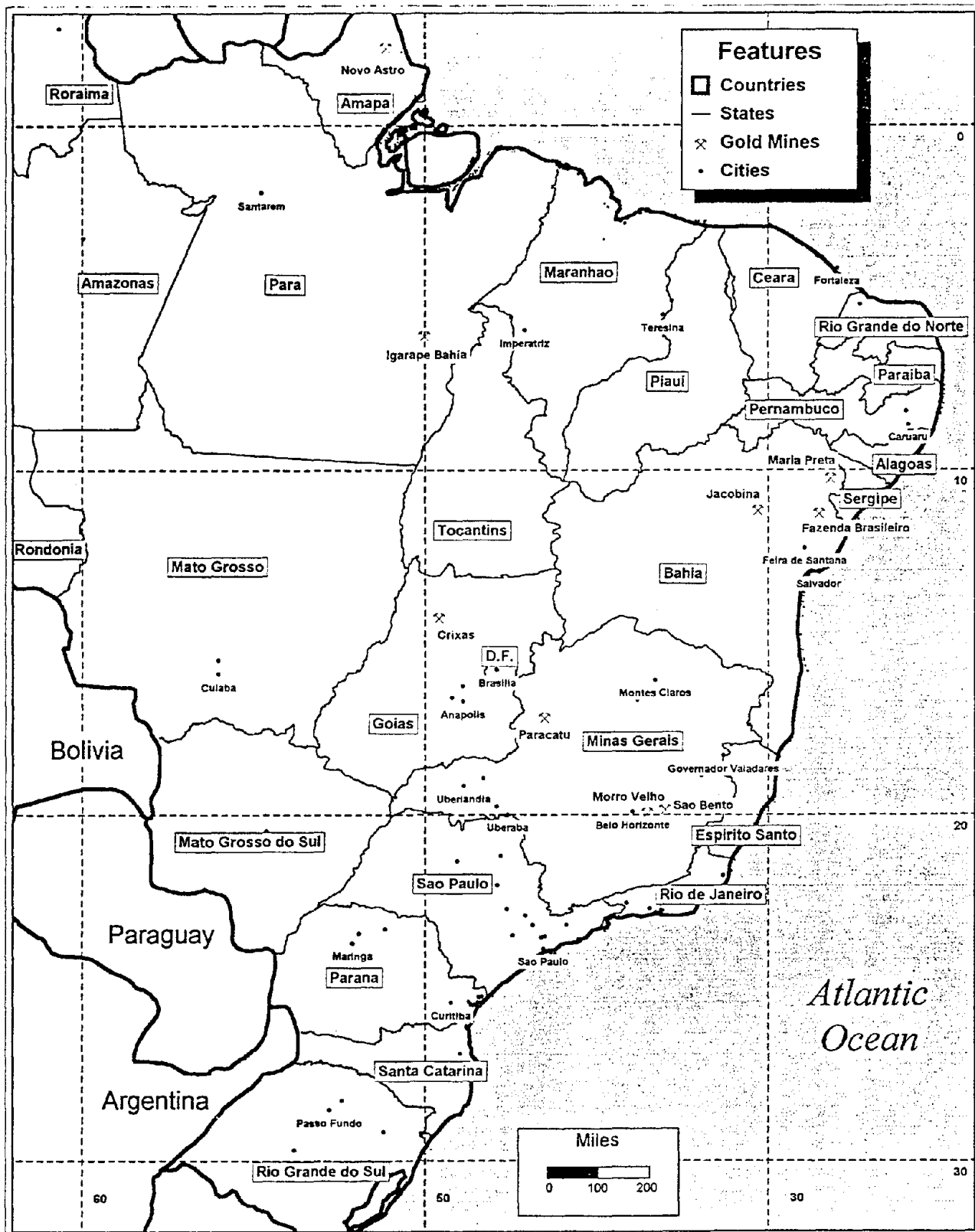


Figure 29.--Map of selected gold mines and advanced projects in Brazil.

Source: USBM data, map prepared by Geoquest (51).

accessible surface deposits began to be exhausted. Gold production from the informal mining sector was estimated at 37 mt (1.2 M tr oz) in 1992, which was less than production from the formal mining sector for the first time since 1972. Of the garimpos remaining in operation, most are located in Mato Grosso State, which produced about two-thirds of estimated garimpeiro production in 1992. Total Brazilian gold production from 1972-92 is shown in figure 30 (111-113). The figure also shows the major influence that garimpo production has had on total Brazilian gold production trends during this time.

Garimpeiros have posed a dilemma for the Government of Brazil. Brazil's 1988 Constitution essentially favored garimpeiros at the expense of formal, particularly foreign, operators. Severe environmental and sociological problems were caused by the movement of thousands of garimpeiros into the remote Amazon interior. Despite the banning of mining in certain localities and the outlawing of mercury amalgamation to recover gold, dislocation of indigenous populations, deforestation, and pollution of the river systems had reached crisis proportions (114).

The Government of Brazil now prefers that the formal mining sector develop new mines and remediate much of the damage caused by garimpeiros, but large new investments, especially from foreign mining companies, will not occur until the government amends its taxation of corporations and amends the foreign investment provisions of the 1988 Constitution.

ISSUES AFFECTING THE BRAZILIAN GOLD INDUSTRY

Brazilian Mining Code

The 1988 Constitution imposed rules governing foreign mining investment that are the opposite of investment codes in Chile and, more recently, in most other South

American countries. The Constitution established a legal distinction between Brazilian companies and international companies, allowing only the former to apply for mineral exploration or exploitation concessions. Under the 1988 Constitution, Brazilian companies (or national companies) are those in which the majority stockholders are Brazilians and management control is exerted by Brazilians or foreigners with permanent residence in Brazil. Majority foreign ownership or management control disqualifies that company from applying for exploration or exploitation concessions.

Under the current mining code, Brazilian mineral production, distribution, trade, and utilization are controlled by the State through the granting of concessions, licenses, or monopolies. Concessions are granted by the Ministry of Mines and Energy through federal decrees. Licenses are granted under applicable municipal regulations through an authorization Ministry of Finance. Monopolies are the exclusive right granted to the federal government through enabling legislation.

Control and supervision is the responsibility of the Ministry of Mines and Energy through the Mines and Metallurgical Office, which consists of three agencies: the Superior Mining Council (the coordinating agency); the Executive Group of the Mining Industry (manager of development and incentive measures); and the Departamento Nacional De Produção Mineral (DNPM), which is in charge of planning, coordination, and execution of geological studies and surveys (115). DNPM controls prospecting authorization and mining concessions for all minerals. Details relating to the Brazilian mining code and taxation structures will be available in the planned Open File Report.

Taxation

The high tax burden on the mining industry in Brazil has been

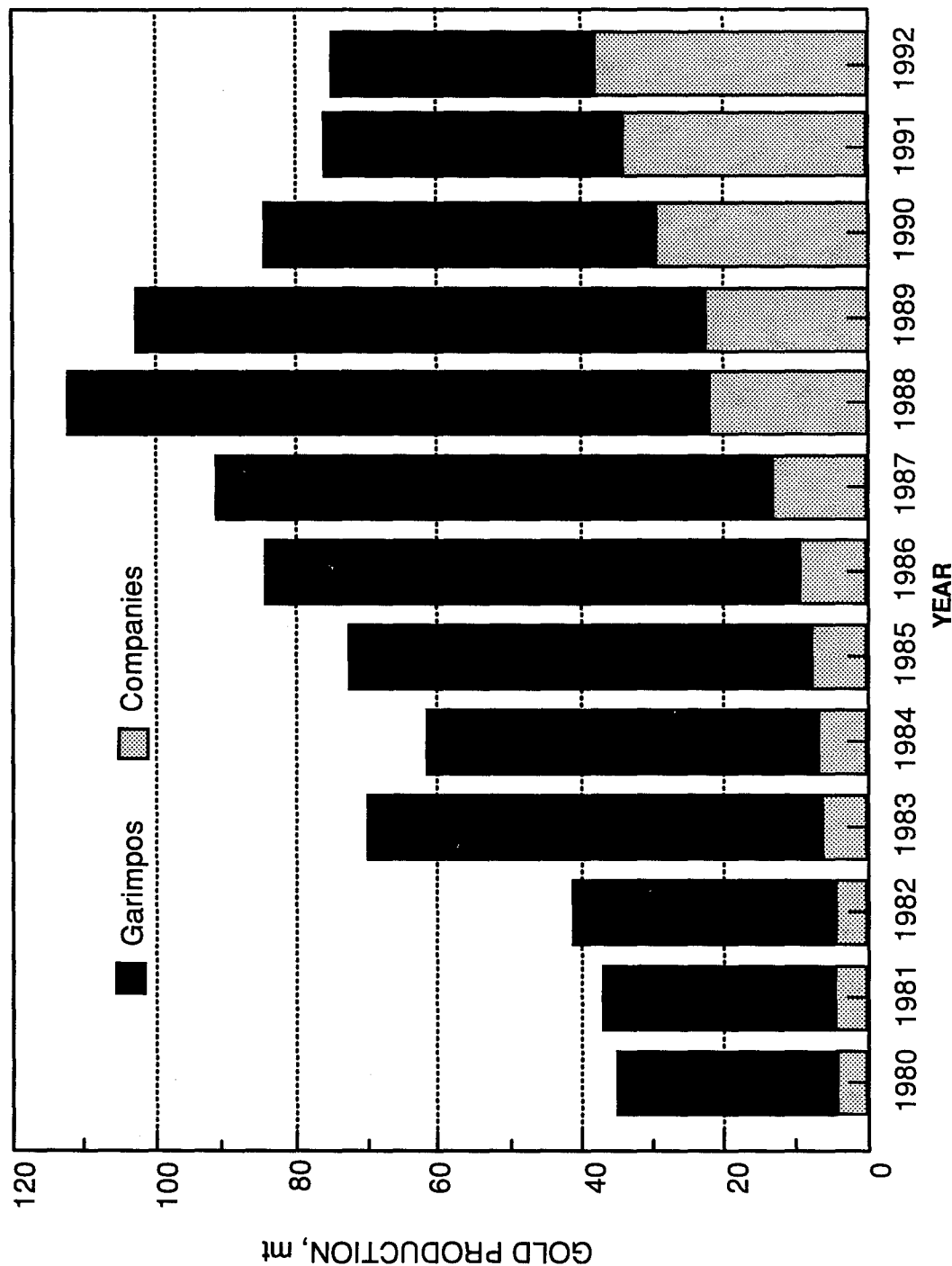


Figure 30.--Gold production in Brazil by mining companies and garimpos, 1980-92.

Source: Perfil Analítico Do Ouro (112) and Chapters in Sumário Mineral for years 1988-92 (113).

a major disincentive for investment. Mining taxation in Brazil is multi-tiered; tax payments may be revenue-based levies, social contribution taxes, income taxes, or liquid profits taxes (116).

GOLD AVAILABILITY OF CHILE AND BRAZIL

METHODOLOGY AND COST EVALUATION

To determine the potential availability and supply of gold from operations in Brazil and Chile, geologic and operating data were collected and analyzed for each of the 6 Chilean and 8 Brazilian mines and deposits evaluated. Most of the data used in the economic analysis of the 14 properties in Brazil and Chile were collected during site visits by the author for both countries.

Mining, recovery plant (treatment), and G&A (general and administrative) operating costs were estimated, on a per metric ton of ore basis, for the surface and underground mines in Brazil and Chile, as well as for the developing operations at their proposed design capacity. A comparison of the operating cost estimates for the seven surface and seven underground properties are shown graphically in figure 31 and in table 38.

The open pit properties, 4 of which are heap leach operations, have operating costs per metric ton of ore that are much lower than the high-cost underground mines. The estimated mining operating costs for underground operations are an order of magnitude higher than for surface operations, on a per ton of ore basis. Estimated treatment plant operating costs for the seven surface mines are also much lower than for the underground ore reflecting the low cost of heap leaching and the high cost of treating refractory ores. General and administrative costs are much higher for the underground operations, reflecting the higher staffing requirements, higher

warehouse inventories, and additional surface facilities required for personnel.

The operating cost differential shown between surface and underground mines narrows considerably when measured on a per ounce recoverable gold basis. The estimated weighted-average operating cost for the evaluated surface operations was \$192.80/tr oz, the range was very wide, from \$116/tr oz up to double that amount. For the underground operations, the estimated weighted-average operating cost was \$238.78/tr oz recoverable gold and the range was higher but similar in that the highest operation was double the level of the low cost operation. Two of the underground operations and 3 of the surface operations evaluated have estimated total cash operating costs under \$200/tr oz. Since the mines in Brazil and Chile are so different, it is difficult from the data in this study to make many direct comparisons for unit operating costs. In general, Brazil has an advantage in labor costs, which average about 40 pct less than in Chile, and lower power costs. Chile has lower taxes and lower import duties, which make capital equipment purchases and repair parts significantly less expensive in Chile. The cost of other major consumables such as diesel, sodium cyanide, steel, explosives, and other items are similar in both countries.

TOTAL PRODUCTION COSTS AND AVAILABILITY

As of January 1992, 12 of the evaluated mines were in production and 2 (Andacollo and Refugio in Chile) were awaiting financing and further feasibility studies. Total refined gold potentially available from the 14 evaluated mines and deposits is illustrated in figure 32 where total production costs in January 1992 dollars were estimated at both a 0-pct and a 15-pct DCFROR. A total of 843 mt (27.1 M tr oz) of gold is potentially recoverable from the evaluated properties. The 8 evaluated Brazilian properties contain 544 mt

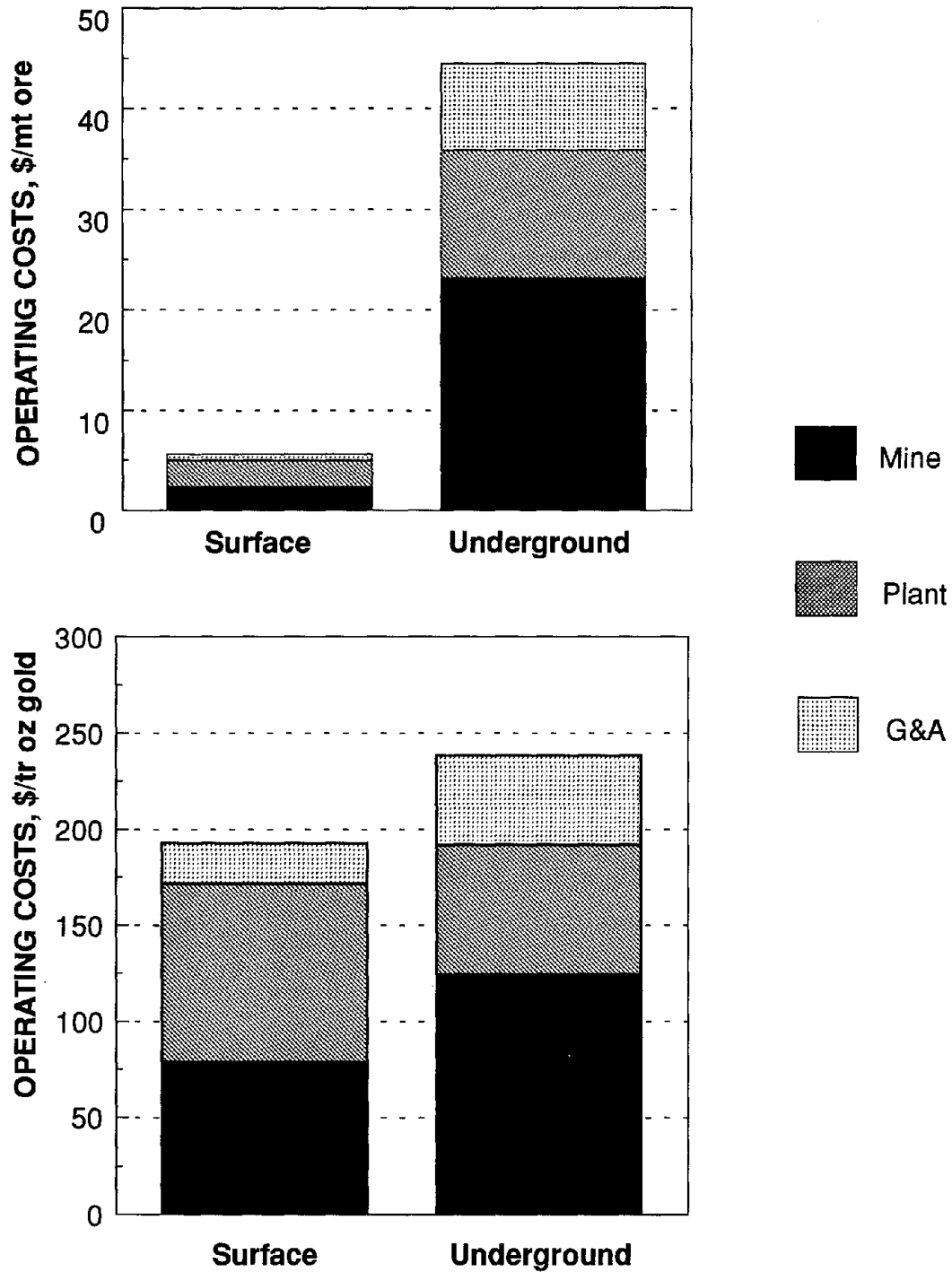


Figure 31.--Operating costs for surface and underground gold mines in Brazil and Chile.

Source: USBM estimates.

Table 38.--Estimated operating costs at evaluated operations in Brazil and Chile
(\$/mt--except where indicated)

	Surface		Underground	
	Range	Wtd avg	Range	Wtd avg
Mining costs	1.30 - 6.95	2.27	13.08 - 61.21	23.16
Treatment costs	2.04 - 5.10	2.68	8.17 - 25.25	12.63
G & A	0.29 - 1.99	0.61	3.75 - 13.67	8.73
Total operating costs	3.70 - 14.04	5.57	25.00 - 90.21	44.52
Total operating cost (\$/tr oz)	116.54 - 238.65	192.80	169.39 - 325.08	238.78

NOTE.--Excludes the underground mine at El Indio.

Source: USBM estimates.

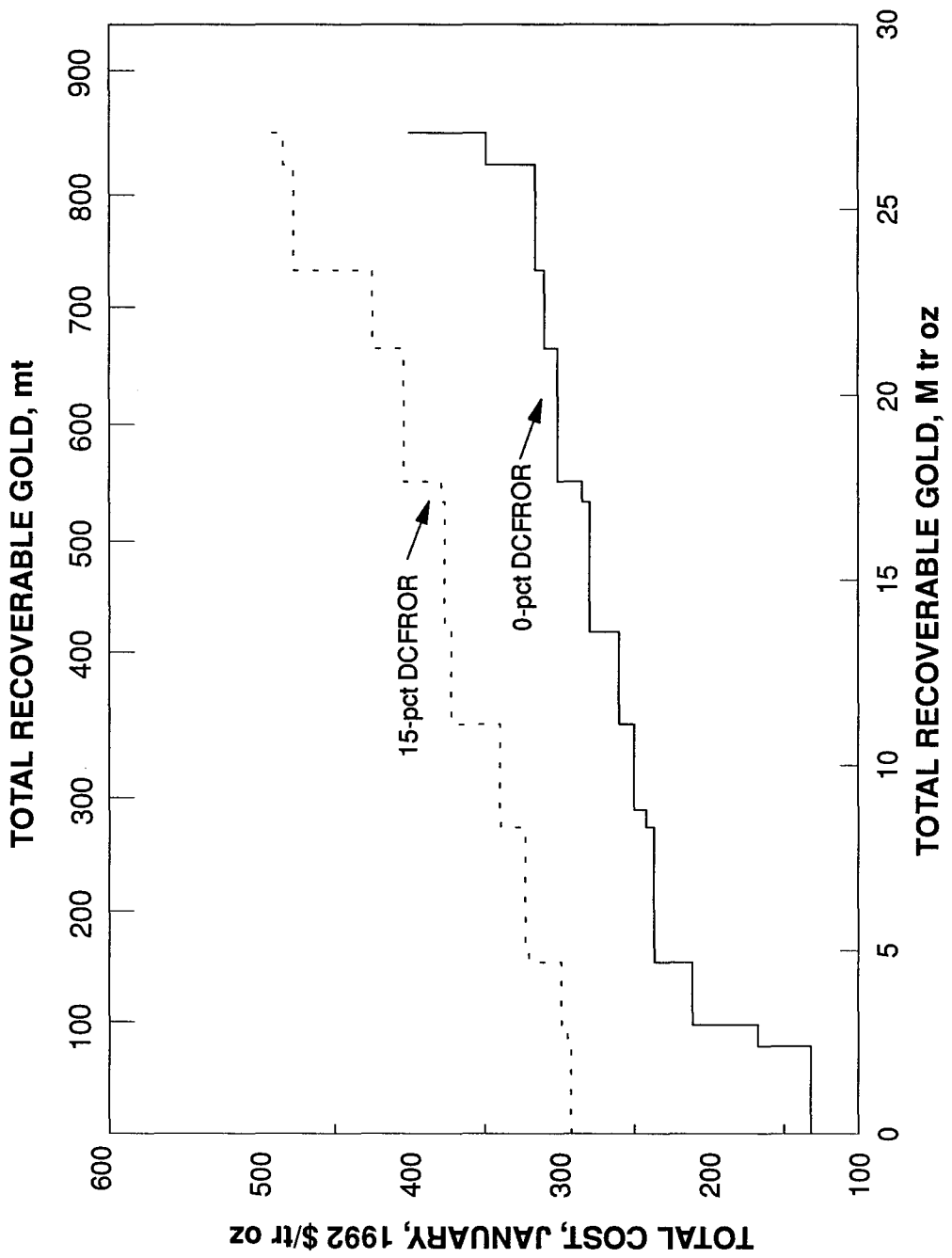


Figure 32. - Potential gold available from 14 evaluated operations in Brazil and Chile.

Source: USBM estimates.

(17.5 M tr oz) of recoverable gold and the 6 evaluated properties in Chile contain almost 300 mt (9.6 M tr oz) of recoverable gold.

At a 0-pct DCFROR, the Chilean properties had a weighted-average total cost of \$242.94/tr oz ranging from \$131.97 to \$300.98/tr oz. The Brazilian producers were slightly higher, with an estimated weighted-average total cost of \$263.48/tr oz, ranging from \$166.96 to \$348.80/tr oz recoverable gold. All evaluated properties were able to achieve at least breakeven economics (0-pct DCFROR) at the average 1993 price for gold of \$360.91/tr oz.

ANNUAL GOLD PRODUCTION POTENTIAL THROUGH 2000

Of the 14 properties evaluated, 10 will still be producing beyond the year 2000, based on the analysis of 1992 demonstrated resource estimates. Figure 33 and table 39 present estimates of long-run breakeven (0-pct DCFROR) annual gold availability from 1992 through 2000, for the 14 mines and deposits. By 1995, annual primary gold output from these operations is expected to increase to 68 mt (2.2 M tr oz), and then decrease gradually to 51 mt (1.7 M tr oz) in the year 2000.

The only mines with relatively shortlived surface minable ore bodies are Guanaco, Andacollo, and San Cristobal. Additional exploration, however, may provide sufficient reserves for these properties to continue production. The other open pit mines, such as La Coipa, Igarape Bahia, and Morro do Ouro are large, relatively new mines and have demonstrated sufficient resources for production past 2000. Refugio is a large deposit which will also have a producing life that extends well past 2000 once production commences in 1995.

The underground mines in Brazil all have sufficient reserves for production to extend into the next century, with the exception of Novo Astro, a small high-grade deposit.

THE GOLD INDUSTRIES OF OTHER LATIN AMERICAN COUNTRIES

ARGENTINA

Although Argentina is the second largest country in South America after Brazil, it is a relatively minor producer of minerals. It is discussed here because of its considerable future potential. Over the past 30 years, mining production, including hydrocarbons, has varied from 0.24 pct to 0.44 pct of total Gross Domestic Product (GDP). In 1992, mining activities, excluding hydrocarbons, accounted for an estimated 0.3 pct of the country's GDP of about \$153 billion.

Gold production in Argentina amounted to 1.3 mt (42 k tr oz) in 1990, most of which was from the government-owned Mina Farallón Negro in Catamarca Province (117). However, with the recent changes in the mining investment code and the tax code, Argentina appears poised to become a larger player in the gold and copper sectors.

The Andean orogenic belt in South America runs all along the western border of Argentina. There are producing porphyry copper deposits with byproduct gold along this belt all the way from Colombia in the north to Chile in the south. Chilean porphyry copper deposits lie in a narrow belt of the Andean orogen, to the east of the coastal Jurassic and Cretaceous batholiths and to the west of Chile's border with Argentina. Some of the Chilean operations are only a few kilometers from the Argentine border.

The newly approved Mining Investment Law includes a number of fiscal incentives for mining investors (118). The law includes fiscal stability, tax exemptions, exemption from import duties levied on capital goods and spare parts, provincial royalty ceilings, and accelerated depreciation rates. Further details will be available in the planned Open File Report.

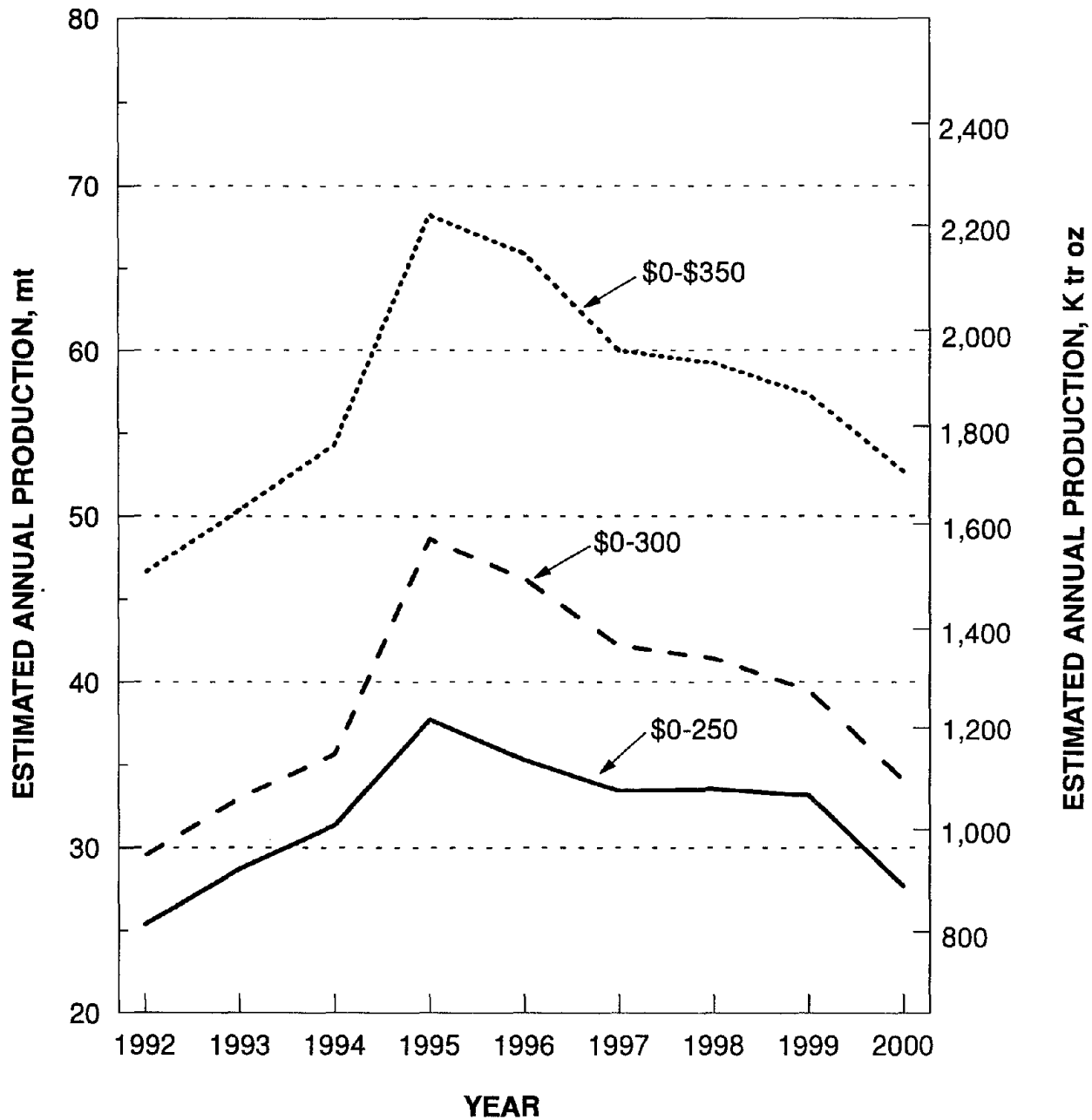


Figure 33.--Potential annual gold production from the 14 evaluated gold operations in Brazil and Chile at various prices (0 pct DCFROR).

Source: USBM estimates.

Table 39.—Potential annual production estimates for 14 major gold properties
in Brazil and Chile

Year	Number of producing operations	Total potential annual production ¹		Production from Brazil		Production from Chile	
		(mt)	(k tr oz)	(mt)	(k tr oz)	(mt)	(k tr oz)
1992	12	47	1,497	31	1,004	15	493
1993	12	50	1,619	33	1,050	18	569
1994	13	54	1,745	35	1,136	19	609
1995	14	68	2,194	39	1,249	29	945
1996	14	66	2,118	39	1,261	27	857
1997	13	60	1,929	37	1,190	23	739
1998	13	59	1,904	37	1,189	22	715
1999	11	57	1,843	37	1,189	20	654
2000	10	53	1,693	35	1,116	18	577

¹Totals may not add because of independent rounding.

Source: U.S. Bureau of Mines availability analysis estimates. Assumes two operations currently under development begin production in 1995.

Mining companies in Argentina are subject to a 30 pct corporate profits tax. In addition, a value added tax (VAT) of 18 pct is assessable on the sales value at the time of sale for most goods and services as well as imports (119). Exporters enjoy a tax credit for the VAT billed to their suppliers, which may be offset against other taxes, transferred to third parties, or reimbursed by the government.

BOLIVIA

Bolivia has not been known as a significant gold producing country. Official gold production in Bolivia was 4.69 mt (151 k tr oz) in 1992. A large but unknown volume of gold continued to be smuggled by gold miners and illegal traders to neighboring countries (120).

All mineral resources, regardless of the origin or nature of the ore deposits, are under the dominion of the state. The government has exclusive power to grant concessions to private concerns to prospect for, explore, mine, beneficiate, and smelt mineral substances. A new mining code enacted in April 1991 allows limited additional rights to foreign companies including equal treatment with local investors under the law (121). Details on exploration activity, the Korri Kollo deposit and the mining regime will be available in the planned Open File Report.

COLOMBIA

Annual gold production in Colombia has been fluctuating between 1.0 and 1.4 M tr oz during the period 1985-92. Reported gold production in 1992 amounted to 32.1 mt (1.033 M tr oz), an 8 pct decrease from production of 34.8 mt (1.12 M tr oz) in 1991 (122).

Over 90 pct of total precious metals production in Colombia is generated by small and medium mining enterprises. Some 48 pct of Colombian gold production was from the Antioquia Department in the central cordillera, and 29 pct was from alluvial deposits in the

Caribbean Departments of Bolívar and Córdoba. In Latin America, Colombia has historically ranked second in gold production after Brazil, but dropped to third place behind Chile in 1989. Colombia currently ranks eighth in western world gold production.

The Government of Colombia estimates that only about 20 pct of the country's gold mineralization has been technically explored and the potential for new discoveries is high (123). However, even though the Government has created an attractive environment for investment from the economic and legislative perspective, Colombia's reputation for violence and drug problems has deterred many mining companies from prospecting in that country. Mining law and tax code will be covered in the planned Open File Report.

COSTA RICA

Costa Rica is currently a minor gold producer with reported production in 1992 of only 550 kg (17.7 k tr oz) (124). This number is generally regarded as significantly understated since informal production from placers located on the Osa Peninsula is rarely reported. Gold production in Costa Rica was primarily in the gold belt of the Tilaran Cordillera in the northwest Abangares District. Alluvial gold potential is very widespread in the Osa Peninsula occurring in gravels in most of the major rivers draining the Peninsula that have the Nicoya Complex exposed in their catchments.

The principal legislation governing mining was Law No. 6797 of October 4, 1982. Under the law, the State has inalienable and absolute domain over all mineral resources found in the national territory and seabed. In exercising its power, the State may, directly or through its administrative dependents, exploit the nation's mineral resources. Details for exploration activities Mineral Code and tax information for Costa Rica will be available in the planned Open File Report.

GUYANA

Mine production of gold in Guyana was estimated to be 4.5 mt (145 k tr oz) in 1992 (125). Most gold mined during early 1992 involved small-scale river dredging operations. The gold situation in Guyana changed dramatically in May 1992 with the opening of the Omai project, owned by Cambior Inc. (65 pct), Golden Star Resources (30 pct), and the Government of Guyana (5 pct). The potential exists to more than double gold output because of this single operation. An overview of the gold industry of Guyana including mining law and taxation will be provided in the planned Open File Report.

MEXICO

Historical Perspective

Mexico is not a major gold producing country, with most gold production occurring as a byproduct or co-product from ores that are mined primarily for their silver or base-metal content. Historically, gold has been mined from the gossans or supergene oxide zones which overlie sulfide deposits and from which it was mined as the rich bonanza deposits of the past.

Mine production of gold has ranged between 6.1 and 10.1 mt (196 to 326 k tr oz) since 1980. Mine production of gold decreased in 1992 to 9.9 mt (318 k tr oz), a small decline from the 10.1 mt (326 k tr oz) in 1991 (126). Relative shares of Mexican gold production, by State, are reported in table 40 (127). Also shown are the shares of silver production since many of the deposits produce both metals.

Guanajuato continued to be the leading producing State, contributing about 30 pct of the national volume of production from a single mine. Sonora is the second largest source for gold (25 pct), followed by Durango (19 pct), Sinaloa (6 pct), Chihuahua (5 pct), and Zacatecas (4 pct). The most important development for Mexican gold in 1991-93 was the increased interest by both Mexican and

foreign mining companies in exploring for gold in Sonora, Baja California, Chihuahua, Durango, and Sinaloa.

Under the 1917 Mexican Constitution, minerals are considered to be part of the patrimony of the nation. The Government awards concessions for the exploration and exploitation of nonfuel minerals. In most cases, foreign participation in the nonfuel mineral sector was limited. In 1990, a new regulation was issued by the Secretaría de Energía, Minas e Industria Paraestatal (SEMIP), which among other things, allowed more flexibility in foreign ownership.

Mexico's new Mining Law, which became effective in September 1992, allows the private sector to play a much larger role in the mining industry as the Government of Mexico continues to privatize State-owned companies, decontrol its mining reserves, and encourage domestic investment and foreign participation in the mining industry. The beneficial aspects of the 1992 Mining Law, combined with the reduction of corporate income tax to 35 pct in 1989 and the elimination of the mineral production tax in 1991, have led to an increase in large mining projects being launched with the participation of domestic and international private capital. During 1990 and 1991, it is estimated that almost \$1 billion was invested in the Mexican mining sector, twice the level of investment in 1989 (126).

Foreign investment in Mexican mining companies is now allowed up to 100 pct without any further requirements except that of registration of the company at the National Registry of Foreign Investments. However, the law requiring that total personnel must be 90 pct Mexican nationals remains in effect.

Environmental Policies

Environmental awareness and regulation in Mexico has matured dramatically over the past decade.

Table 40.—Mexican production of gold and silver by State and municipality, 1991-92

State	1991				1992			
	Gold		Silver		Gold		Silver	
	(k tr oz)	(kg)	(k tr oz)	(kg)	(k tr oz)	(kg)	(k tr oz)	(kg)
Chihuahua	16	490	8,993	279,720	17	524	9,126	283,858
Durango	46	1,418	8,256	256,801	59	1,844	9,972	310,150
Guanajuato	127	3,962	5,228	162,624	95	2,949	4,784	148,794
Hidalgo	14	443	3,557	110,620	11	356	3,580	111,349
Nayarit	5	148	488	15,172	7	209	600	18,669
San Luis Potosi	10	298	3,964	123,288	6	187	2,667	82,953
Sinaloa	26	809	2,538	78,932	19	590	1,720	53,502
Sonora	52	1,609	4,405	137,018	81	2,519	4,330	134,680
Zacatecas	16	502	28,422	884,019	13	416	26,406	821,335
All others ¹	11	331	7,507	233,487	6	193	4,086	127,101
Grand total	326	10,142	73,611	2,289,562	318	9,891	67,441	2,097,665

¹Includes: Aguascalientes, Coahuila, Guerrero, Jalisco, Mexico, Michoacan, Morelos, Nuevo Leon, Queretaro and Tamaulipas.

Source: Camara Minera De Mexico (127).

The gap between environmental regulation in the United States and Mexico is rapidly narrowing, to the extent that it is no longer necessarily less burdensome to operate in Mexico from a regulatory perspective (128). There are 2 government entities which are charged with the preservation of Mexico's environment: SEDESOL (Ministry of Social Development) and SARH (Ministry of Agriculture and Water Resources). Specific standards pertaining to the mining industry are still being developed, however.

Mineral Taxation

The taxable income of corporations is assessed at a rate of 35 pct. There are no federal surtaxes or State taxes, and there are no mining taxes. The mining production tax of 4.2 pct of ore value for gold and silver production was repealed in 1991 (126).

A minimum tax is imposed to supplement the federal income tax payable by corporations. The tax is 2 pct of the value of the taxpayer's assets. The tax is only payable if and to the extent of the amount by which it exceeds the taxpayer's regular income tax liability. There is also a surface tax on exploration and exploitation concessions (119).

Finally, every business concern with employees is required to distribute a portion of annual profits among all employees. The amount distributable to the employees amounts to 10 pct of taxable income and is not deductible for corporate income tax purposes (119).

PANAMA

Reported gold production in Panama is negligible, with 1992 production of only 250 kg (8 k tr oz) plus an unquantifiable amount from placer deposits in the Darien Province. However, the geology of Panama is similar to neighboring countries, and there is a potential for increased output in the future. The Santa Rosa mine of Greenstone

Resources of Canada is currently being developed and is expected to produce 1,900 kg of gold per year once production begins (129).

The mining laws of Panama were modified in February 1988 in order to bring the code in line with other competing countries in the region and to stimulate foreign and local investment within the mining industry. As with all other Latin American countries, ownership of mineral deposits of all kinds existing in Panama, including the islands, territorial waters, undersea bed, subsea, and its continental shelf are the property of the State. The State may grant rights through prospecting permits or concessions. Mining regulations and concessions are administered by the Mineral Resources Department, a division of the Ministry of Commerce and Industry. Information on these topics will be available in the planned Open File Report.

PERU

Gold has become the third most important mineral commodity produced in Peru, after copper and zinc. Reported exports of gold hit a record 19.6 mt (630 k tr oz) in 1992, a 57 pct increase over 1991. Although domestic production did increase, much of the export increase was the result of the March 1991 domestic sales liberalization decree from the Government of Peru. As a result, most of the production that used to be smuggled out of Peru is now legally exported.

Peru's Ministry of Energy and Mines (MEM) reported production of 10.01 mt of gold in 1992. In addition, an estimated 4.35 mt was produced by registered companies not filing statistical reports with MEM, plus an estimated 10.4 mt from the informal mining sector (artisanal miners), for an estimated 1992 total of 24.79 mt (797 k tr oz) of gold (130). This amount represents an increase of 4.3 pct over estimated total gold production in 1991.

Peru has 2 main regions where gold is produced from veins; Pataz

in the north, covering some 130 km along the right bank of the Marañón River, and a much larger area in the southern Andes between the cities of Ica and Arequipa. Placer gold is produced in Madré de Dios Department and in areas bordering Cusco and Puno Departments, and there is artisanal gold recovery in rivers throughout the jungle region. Some 43,200 "informal" miners are estimated to be digging for gold in the above areas, producing about 10.4 mt (334 k tr oz) of gold per year. An important quantity of gold is also contained in many of the concentrates produced by polymetallic mines.

The largest lode producers in 1992 were Poderosa, Retamas, Calpa, and Horizonte. Orcopampa fell back to fifth place in gold production from being the largest gold producer in 1991.

The most important gold news emanating from Peru is the development by Newmont Mining Corporation of the Yanacocha project in northern Peru. The development of the Yanacocha district will significantly increase Peru's gold output beginning in 1994.

As part of President Fujimori's economic reform program, the Government has initiated a program of selling off its stake in State-run companies. The largest privatization offerings are the mineral projects of Minero Peru. These include the Cerro Verde copper mine and concentrator, the Cajamarquilla zinc refinery, the Ilo copper refinery, and the San Antonio de Poto gold mine and plant (130).

Several decree laws issued in late 1992 introduced improvements to the 1991 General Mining Law, which should help attract investment and provide some relief to the mining industry. Changes were made in the area of concessions; reducing housing expenses and various fees levied on mining companies, as well as permitting U.S. dollar-based accounting practices under certain conditions.

VENEZUELA

Historically, Venezuela has not been a major producer of gold, although it has shown the most rapid rate of growth in Latin American output since the early 1980's. Estimated production increased from less than 2.0 mt (64 k tr oz) per year in the early 1980's to 20 mt (643 k tr oz) in 1988, declining to an estimated 13.2 mt (424 k tr oz) in 1991. Production statistics may be somewhat imprecise due to production from the informal mining sector (131).

The largest and most important deposits of primary gold in Venezuela are associated with the extensive vein and lode systems in Bolívar State, and the extensive alluvial plains and eluviums related to the drainage of the Caroni, Cuyuni, and Paragua rivers. Venezuela's primary gold-bearing zone covers an area of more than 50,000 square kilometers, extending from Guasipati to La Escalera in Bolívar State. In general, the gold-bearing zone of Bolívar State has four districts where the greatest gold production is concentrated as well as where the exploration interests of domestic and international mining companies are.

A modern day gold rush is beginning to emerge from the area known as the "Kilometre 88 mining district" in Bolívar State, in southeastern Venezuela in the Las Claritas-Las Cristinas zone. The area forms the northern portion of the Guiana Shield, a pre-Cambrian greenstone belt with similarities to the gold producing regions of West Africa and Canada.

Venezuela's current Mining Law, governing everything connected with exploration, evaluation, and extraction of raw materials throughout the country, was published on December 28, 1944. A new Mining Law is presently being discussed in Congress to encourage more mining investment. The present Mining Law specifies that all metallic minerals, coal, and

industrial minerals belong to the Venezuelan state. On August 13, 1991, the Venezuelan government implemented a significant tax reform which lowered the marginal tax rate for mining companies from 60 pct to 30 pct. An investment tax credit was also instituted which allows a tax reduction of 10 pct of the amount of new investments made during the 5 years following implementation of the tax law. Repatriation of all earnings and capital is permitted and import duties on mining equipment have been removed.

CONCLUSIONS

The flow of exploration dollars moving from North America to Latin America is a recent phenomenon and it is premature to estimate what gold production in Latin America will be a decade from now. However, with a few exceptions, the geologic and cost data underlying this study suggest that the development of many world class mines in parts of Latin America remains an elusive goal.

Part of the problem throughout Latin America is a lack of infrastructure, and rough terrain, jungles, etc., have limited the proportion of land area that has been explored. In Chile, the enthusiasm stemming from the tremendous success of La Coipa (which is a world class mine for both gold and silver) has been dampened by the failure of the Marte and Lobo deposits to be developed into profitable mines. Other mines in the Maricunga region have been marginally profitable, or in the case of El Hueso, consistently unprofitable. The obvious gold potential of Brazil continues to be delayed by economic and political turmoil in that country. Hopefully, constitutional changes proposed in Brazil for sometime in the near future will attract foreign exploration dollars.

Much of the exploration success in Latin America over the past several years has occurred in countries which heretofore have

been inhospitable to foreign investment, especially in the mining sector. The development of Kori Kollo in Bolivia, Omai in Guyana, Yanacocha in Peru, and the Kilometer 88 and El Callao regions of Venezuela have stimulated intense exploration activities in those countries. It seemed inconceivable a decade ago that countries such as Bolivia, Guyana, Peru, and Venezuela would be the hot spots for North American gold exploration companies in the 1990's.

Exploration results for gold in Mexico have been relatively disappointing. The two largest gold deposits now being explored, La Herradura and Mulatos, are not recent discoveries. Other gold properties in northwestern Mexico currently being explored and/or developed are small by world industry standards. The potential for large gold deposits in Mexico is probably greater in the south-central part of the country than in the northwest. The gold production potential in Central America is promising, especially considering the lack of previous exploration efforts.

Latin America may soon become a much larger player in the world gold industry as new deposits are developed, especially from the Guiana Shield, Peru, and (eventually) Brazil. Whether additional production from Latin America can counteract much of the expected decline in gold production from South Africa and North America remains to be seen.

CHAPTER 7

ASIA-PACIFIC GOLD AVAILABILITY

By C. Linda Slater¹ and Dick C. Bornemann²

This chapter investigates the potential availability of gold from the Asia-Pacific region, an emerging gold producing region. The most significant gold producing countries in this region are Papua New Guinea, Indonesia, the Philippines, Fiji, Japan, New Zealand and Malaysia. Regions having recently generated new interest and opened themselves for exploration are Vietnam, Thailand, and Laos.

The region is currently of major interest to gold mining companies and the recipient of large gold exploration expenditures. It has the potential for a significant increase in gold production. Many of the new discoveries being made in this region have been large deposits with long lives and low production costs. The geologic environment is favorable for additional discoveries. Production in 1993 from the Asia-Pacific region is estimated at about 157 mt and is projected, based on project development press releases, to increase to 227 mt by the year 2000 (132).

Political stability, infrastructure development, attractive mining legislation, and geological prospectivity are key factors impacting gold availability from these countries.

INTRODUCTION

The Asia-Pacific region is important as a potential major contributor to future gold

production. As a measure of geologic prospectivity, \$124 million (1/3 that of Latin America) was spent on mineral exploration in the Asia-Pacific region in 1993 (18). This chapter examines gold availability from two perspectives: (1) the mining and investment climate in the region, and (2) the geological prospectivity of the region. A more complete discussion of these topics and of the analyses presented in this chapter will be contained in a planned Open File Report on Asia-Pacific gold availability and mining investment climate.

This area has become important as a gold producing region because of several factors: an attractive investment climate, fair taxation policies and the development of sound mining law. These factors are crucial to the area's mineral development and gold availability throughout the Asia-Pacific region. Papua New Guinea (PNG) through its Mining Development Agreement (MDA) and Indonesia through the Contract of Work (COW) have set the standard for mining investment legislation in the region. Mining legislation is just beginning to be developed in many of the other Asia-Pacific countries (133).

The Asia-Pacific region is subdivided into two groups of countries for this report, the Pacific Basin and the Indochina region, which show distinct differences in the level of development of their mining laws and respective gold industries.

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The main body of this chapter focuses on the Pacific Basin, with particular emphasis on PNG and Indonesia. Gold availability projections are made for the current major producing operations as well as for future potential. The gold production potential of the Indochina region is also discussed later in this chapter.

ASIA-PACIFIC REGIONAL OVERVIEW

The Asia-Pacific region is defined in this chapter as those countries which form the rim of the Pacific Basin, and the Indochina countries. Included in this grouping are: New Zealand, PNG, Indonesia, Malaysia, the Philippines, Japan, Fiji, Thailand, Vietnam, Cambodia (also called Kampuchea), Burma (also called Myanmar), Thailand, and Laos. Locations of these countries are shown in figure 34.

Political and economic risk and local infrastructure vary widely among these nations. Many of the Asia-Pacific countries have reviewed their mining legislation and revised it to encourage mining exploration and investment.

Table 41 shows the gold production for 1992 and projected future potential from the Pacific Basin countries (132). PNG, Indonesia and the Philippines have the highest levels of production. The Philippine output has been declining since 1987 (29). High taxation and nationalist policies are said to have deterred mining companies from investing in the Philippines: however, a new Mining Act and lowering of the gross royalty rate from 5 pct to 2 pct are under consideration and these may change the mining companies perspective (134). Higher sovereign risk factors and safety issues are impacting investment in PNG.

PACIFIC BASIN COUNTRIES

The countries reviewed in this region include: PNG, Indonesia, the Philippines, New Zealand, Japan, Fiji, and Malaysia. The location of many of the major gold mines,

projects and prospects in this region are highlighted in figure 35. Summaries on the history of mining for these areas will be available in the planned Open File Report.

PAPUA NEW GUINEA

Papua New Guinea lies in the southwest Pacific Ocean about 160 km northeast of Cape York Peninsula in Queensland, Australia. It includes the eastern half of the island of New Guinea, the Bismark Archipelago, of which New Britain, New Ireland and Manus are the largest islands, Bougainville and Buka Islands in the Western Solomons, and the Trobriand, Woodlark, D'Entrecasteaux, and Louisiade Island groups to the east of the New Guinea mainland. The eastern half of the island of New Guinea constitutes the bulk of the country's 451,710 km² landmass and is surrounded by a handful of large islands and hundreds of islands of smaller area. PNG contains four distinct geographical regions: Papua (southern portion of New Guinea), Momase (northern portion of New Guinea), the Highlands (central portion of New Guinea), and the islands (136).

PNG's economic growth and development is tied directly to the minerals and energy sector. Mining of mineral deposits accounts for about 60 pct of export earnings (137). It is anticipated that this percentage will remain very high because of new gold deposits expected to commence production in the near term.

PNG has been very successful in attracting mineral investment on terms and conditions generally favorable to the country and commensurate with their perceived geological promise. PNG has attracted approximately \$1 billion in mineral investment in the past 5 years (137). Future prospects are less certain following the introduction of harsher conditions in the latest draft agreements, including the possibility of the government taking a larger ownership position in future projects (138).

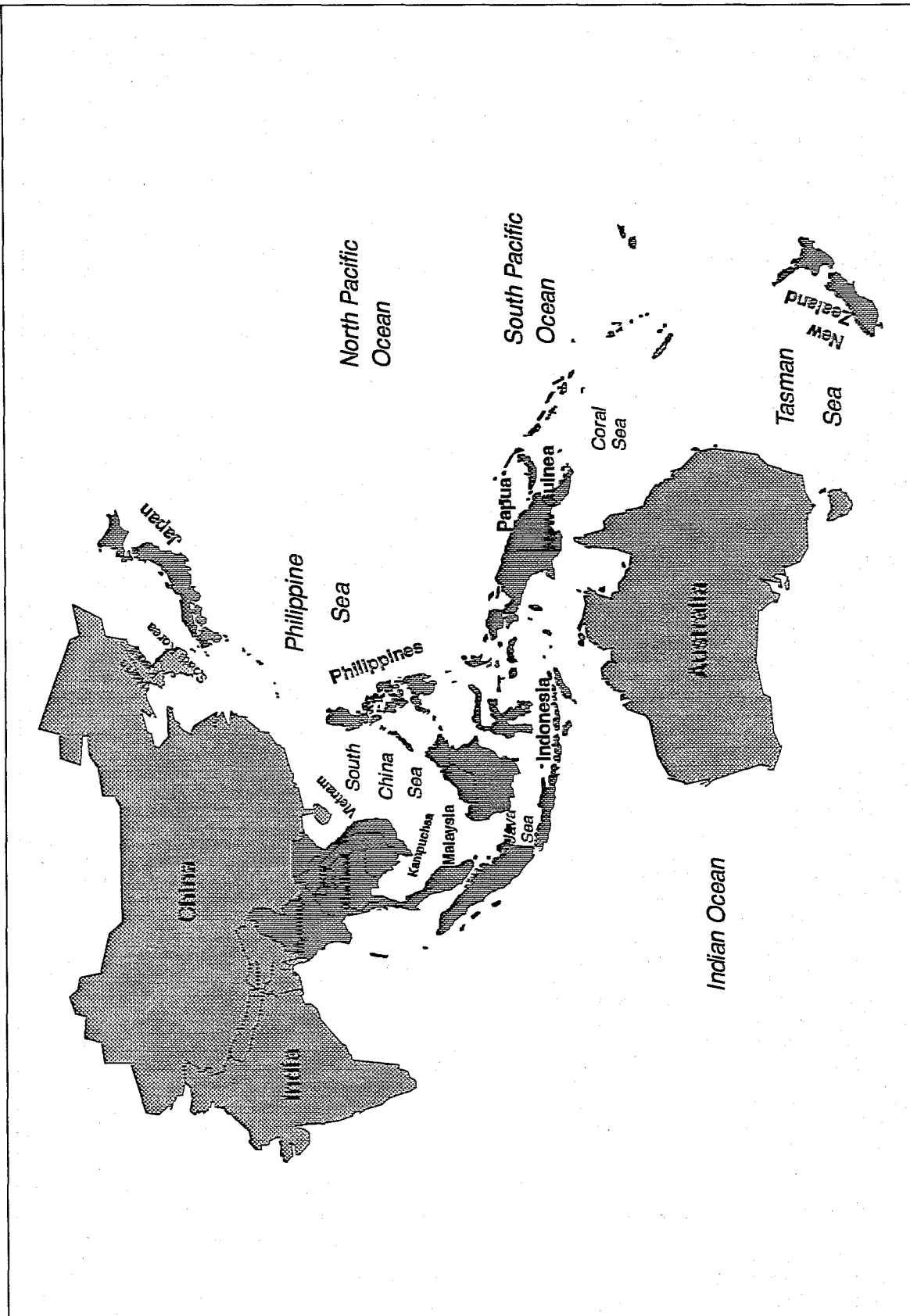


Figure 34.--Asia-Pacific regional map.

Source: map prepared by USBM.

Table 41.--Projected gold production for Australia and selected Asia-Pacific countries.

Country	1992		1995		2000	
	(mt)	(M tr oz)	(mt)	(M tr oz)	(mt)	(M tr oz)
Australia	240	7.7	250	8.0	260	8.4
Papua New Guinea	71	2.3	80	2.6	100	3.2
Indonesia	40	1.3	50	1.6	60	1.9
Philippines	27	0.9	30	1.0	30	1.0
New Zealand	10	0.3	10	0.3	10	0.3
Malaysia	4	0.1	6	0.2	8	0.3
Fiji	3	0.1	4	0.1	4	0.1

Source: Based on Tyrwhitt (132), and other available public literature, such as company annual reports.

All aspects of mining are tightly regulated by the government through detailed Mining Development Agreements (MDA). The planned Open File Report will give detailed information on mining agreements in PNG.

The Mining Journal reported recently that the rating of the investment climate has been downgraded in PNG (139). This is related to the government's proposal to arbitrarily increase its holdings in Porgera from 10 pct to 30 pct and to increase its interest in Lihir (a developing gold property), as well as Prime Minister Wingti's non-sympathetic comments towards mining companies (139). Pre-election comments in 1994 by Foreign Minister Michael Somare about renegotiating all resource development agreements have also created much concern (139).

All rights of landowners are respected at all stages of exploration and they are included in the final negotiations stage for any project through a forum process. Through the "Development Forum" the operators set out to ensure that everyone who had claim to land which could be affected by the mine development is consulted as a part of the mine feasibility studies. The result is a role model in community relations involving PNG's National Government, the provincial Government and local landholders. Individual land compensation payments, a 30 pct share of royalties, special grants and other development initiatives ensure that the local people received direct benefits from the project (140). Table 42 is a summary of PNG's and other Asia-Pacific countries' pertinent tax provisions.

INDONESIA

Indonesia is located between the mainland of Southeast Asia and Australia (see figure 34). It covers a land area of over 1.8 million km², and has an area extent of 5,500 km in the east/west direction, and 1,600 km from north to south. The archipelago consists of five major islands and 30

groups of smaller islands totalling approximately 13,500. The five major islands are Sumatra, Java, Kalimantan (a major part of Borneo), Sulawesi, grouped as the Greater Sunda Islands, and Irian Jaya, the western part of New Guinea. The Lesser Sunda, or Noesatenggara Islands, are a chain of islands east of Java which runs from Bali through Timor (141).

Mineral production is an important part of the Indonesian economy. Much of Indonesia's mineral production is for export. Although oil and gas are still the major revenue generators from the mineral sector to the Indonesian economy, the importance of metallic minerals, particularly that of precious metals, is increasing. Since the change of government in 1966, the administration has adopted a new and more stabilizing economic policy. These laws promote development of the country's mineral resources, not only as a source of income and employment, but also to open up new and, in many cases, remote areas. The new laws allow foreign companies to conduct mining operations. In 1992, Indonesia's 40 mt of gold production ranked ninth among major gold producing countries. Its gold production is expected to approach that of PNG in the next decade.

All minerals found within the mining jurisdiction of Indonesia are controlled by the State. According to the Indonesian Development Digest (142), foreign companies actively engaged in exploration and mining in Indonesia consider Indonesia to be a stable country which welcomes investors, although they consider government bureaucracy to be frustrating.

The company or contractor is not subject to royalties, taxes, and levies other than stated in the Contract of Work (COW). Rates and methods of computation are defined and described in the COW. The tax liabilities and payments to the government will be described in detail in the planned Open File Report. Table 42 summarizes the Indonesian taxes and how they compare to other Pacific Basin country tax regimes.

Table 42.--Summary of major Pacific Basin country tax provisions

	Papua New Guinea	Australia	Indonesia	Malaysia	New Zealand
Corporate tax rate	35 pct	33 pct	35 pct	35 pct	33 pct (resident) 38 pct (nonresident).
Dividends withholding tax	17 pct	15 pct on unfranked income	20 pct	0-15 pct depends on treaty	20 pct if no tax treaty.
Excess profit tax	35 pct	None	None	None	None.
Maximum marginal tax rate	64.9 pct	33 pct	48 pct	48 pct	43.5 pct.
Royalties ¹	1.25 pct	0-5 pct	1-3 pct-.5 pct	2.5-5 pct	2-5 pct.
Other taxes	3 pct Provincial sales tax	Some State taxes	None	5 pct development tax	None.
Customs duty	14.62 pct	15 pct some items exempt	Mining exempt	0-15 pct VAT ² refundable on exports	12.5 pct GST ³ refundable on exports.
State equity	Up to 30 pct	None	None	None	None.
Local ownership	None	None	51 pct after 15 years	None	None.
Ring fencing	Yes	None	For each contract of work	None	Partial, 66 pct of expense from other projects.

¹Calculated as a percent of gross revenue.²VAT Abbreviation for value added tax.³GST Abbreviation for goods services tax.

Source: Anderson (137), and various public documents from the PNG Chamber of Mines.

PHILIPPINES

The Philippines is an archipelago located at the western rim of the Pacific Ocean. This archipelago is made up of more than 7,100 islands, the largest of which are: Luzon, Mindanao, Panay, Negros, Palawan, Samar, Leyte, Bohol Cebu, Mindoro, and Masbate. The Philippines has a total land area of nearly 300,000 km², and a coastline that measures 36,289 km in length. Terrain is mostly mountains with coastal lowlands. The climate is considered tropical marine. Agriculture is the largest economic sector in the country. However, the mining industry contributes a large portion of national revenue, approximately 2.0 pct of gross domestic product (GDP) in recent years (143).

The Philippine government is aware of the mining industry's contribution to the national economy. The government is striving to improve the business climate to attract overseas investors and further develop the country's mineral wealth (143).

Threats to political stability and fighting between guerilla and government troops in the countryside make the risk factor high in the Philippines. Also, traditional communal land ownership complicates the government's right to award prospecting and mining rights. This is an unsettling and complex issue in the Philippines (143).

One question dominating foreign investment decisions in Philippine mineral resource development is the 60:40 rule, which is constitutionally mandated. In essence, the rule states that exploration and development of mineral resources is restricted to interests in which 60 pct of the equity capital is owned by Philippine citizens. Foreign ownership of mineral resource ventures is limited to 40 pct, even if the foreign company supplies 100 pct of the capital investment to get the project started (143).

Since 1988, a joint effort by the Philippine government, the mining industry, academia, professional associations, and the United Nations has resulted in a new mining code to establish new regulations for mineral development. If the new code becomes law, it will provide tax and monetary incentives to attract new investments to mineral development projects. It will also clarify and streamline processes involved in obtaining licenses and permits, and clarify definitions of claim areas. Established mining ventures will be liable to taxation (143). The planned Open File Report will summarize Philippine tax codes.

NEW ZEALAND

New Zealand is located in the South Pacific Ocean approximately 1,600 kilometers east of Australia. The two main islands, North Island and South Island, separated by the narrow Cook Strait, give the country an area of 268,670 km².

The communications and transportation infrastructure of New Zealand is well developed and infrastructure for current mineral industry operations is regarded as adequate (144). However, exploration in New Zealand, on average, is more costly than in many Pacific Rim countries because many of the exploration and mining targets are in rugged terrain and lacking infrastructure backup. An advantage of operating in New Zealand is its cheap electric power cost (NZ \$.03/kW·h) (145).

According to the New Zealand Mining Magazine, New Zealand's mineral policy, until recently, had been dominated by strong environmental and anti-development factions within the country. In light of high unemployment and a sluggish economy, the new National Government party has instituted more balanced policies towards development and the environment. The mining investment climate in New Zealand has significantly improved with passage of the Resource Management Act (RMA), which explicitly recognizes an

interrelationship between conservation and development, and provides a statutory framework for the re-integration of mining into the mainstream economy. The RMA focuses on the effects of an activity on the environment rather than on the industry. All activities and industries must be treated equally and comply with environmental rules set by regional councils who are responsible for integrated management of natural and physical resources (146).

An additional factor which has improved the investment climate in New Zealand is the Employment Contracts Act which has produced more flexible work practices. Deregulation of transport, and energy reforms, are also occurring. The New Zealand tax regime will be detailed in the planned Open File Report, and a summary is provided in table 42. New Zealand has no government equity requirements.

JAPAN

Japan consists of four principal islands (Hokkaido, Honshu, Shikoku and Kyushu) and a number of smaller islands. The nation covers a land area of 374,744 km², approximately the size of California. The country is mountainous, with typical heights rising to about 2,700 meters, with Mt. Fuji standing out at 3,776 meters. Japan's climate varies widely in different localities due to the geographical spread over 22° of latitude. Japan has one of the most modern and complete infrastructures for its mining and mineral processing industries (147).

The Japanese tax structure related to mining will be discussed in the planned Open File Report. There are no royalties, but mining companies are subject to income taxation. Japanese mineral rights are separate from surface land rights. Since the owner of the land does not own the subsurface minerals, holders of mineral rights must negotiate with the land owner. The most common practice is for the mineral rights' holder to purchase

the surface land rights as well. One may apply for the mineral rights without owning the land. The mining law refers to a consultation with the local people when the surface is held separately. According to a U.S. Embassy source³, Japanese mining law does not provide strong protection for the original landowners as in the case of aboriginal land rights protection in Australia.

FIJI

Fiji lies in the South Pacific approximately 2,100 km due north of New Zealand. About 330 islands, of which approximately one-third are inhabited, make up a land mass of 18,270 km². The largest islands are Viti Levu and Vanua Levu. Fiji has a tropical climate without undue extremes of temperature and humidity (148).

Fiji is the most developed of the small Southwest Pacific island nations and has an extensive infrastructure. There are 2 international airports and 3 shipping ports. There is an extensive local shipping network to the smaller outlying islands. Fiji has approximately 3,300 km of roads, one-third of which are all-weather roads (148).

There are a number of tax provisions affecting potential minerals project developers in Fiji. These include royalties, corporate income tax, personal tax and dividend tax. All information pertaining to the tax rates, deductions, etc., will be offered in the planned Open File Report.

The Director of Finance may stipulate that the income of any mining company may be exempt from tax or taxed at a reduced rate. There are also provisions for carrying forward losses and there is a 5 year tax relief for new businesses. The country has no

³Personal communication, Michael McNaul, Regional Resource Officer, U.S. Embassy, Jakarta, Indonesia.

policy of reserving the right to take up equity in a project; however the government may take up equity in certain projects (149).

MALAYSIA

The federation of Malaysia, located in Southeast Asia, is composed of 2 regions, West Malaysia, and East Malaysia, separated by 644 km of the South China Sea. The land area of 328,550 km² is slightly larger than that of the State of New Mexico. West Malaysia occupies most of the Malay Peninsula south of latitude 6° 40' North. Topographically, it is dominated by parallel jungle-covered mountain ranges in the interior, extending southward from Thailand. Bordering the mountainous core are the coastal lowlands (150).

East Malaysia, consisting of the territories of Sarawak and Sabah (formerly North Borneo), occupies most of the northwestern coastal part of the island of Borneo. Both these territories share common boundaries with the Indonesian province of Kalimantan. Surrounded by Sarawak is the Sultanate of Brunei, still under British protection but politically separate from Malaysia. The topography of East Malaysia consists of coastal plains with a mountainous backbone forming the divide with Kalimantan. These mountains are higher and closer to the coast in Sabah than they are in Sarawak.

Compared to most developing countries, Malaysia is advanced in its commercial and financial systems, and the management, professional, and administrative skills of its population. Real economic growth rate in the 1987-92 period averaged 8-9 pct. Agriculture, forestry, and mining constitute the most important sectors of the Malaysian economy. About 25 pct of Malaysia's total export earnings come from mining. The most important mineral resources of the country include tin, bauxite, iron ore, coal, gold and kaolin (151).

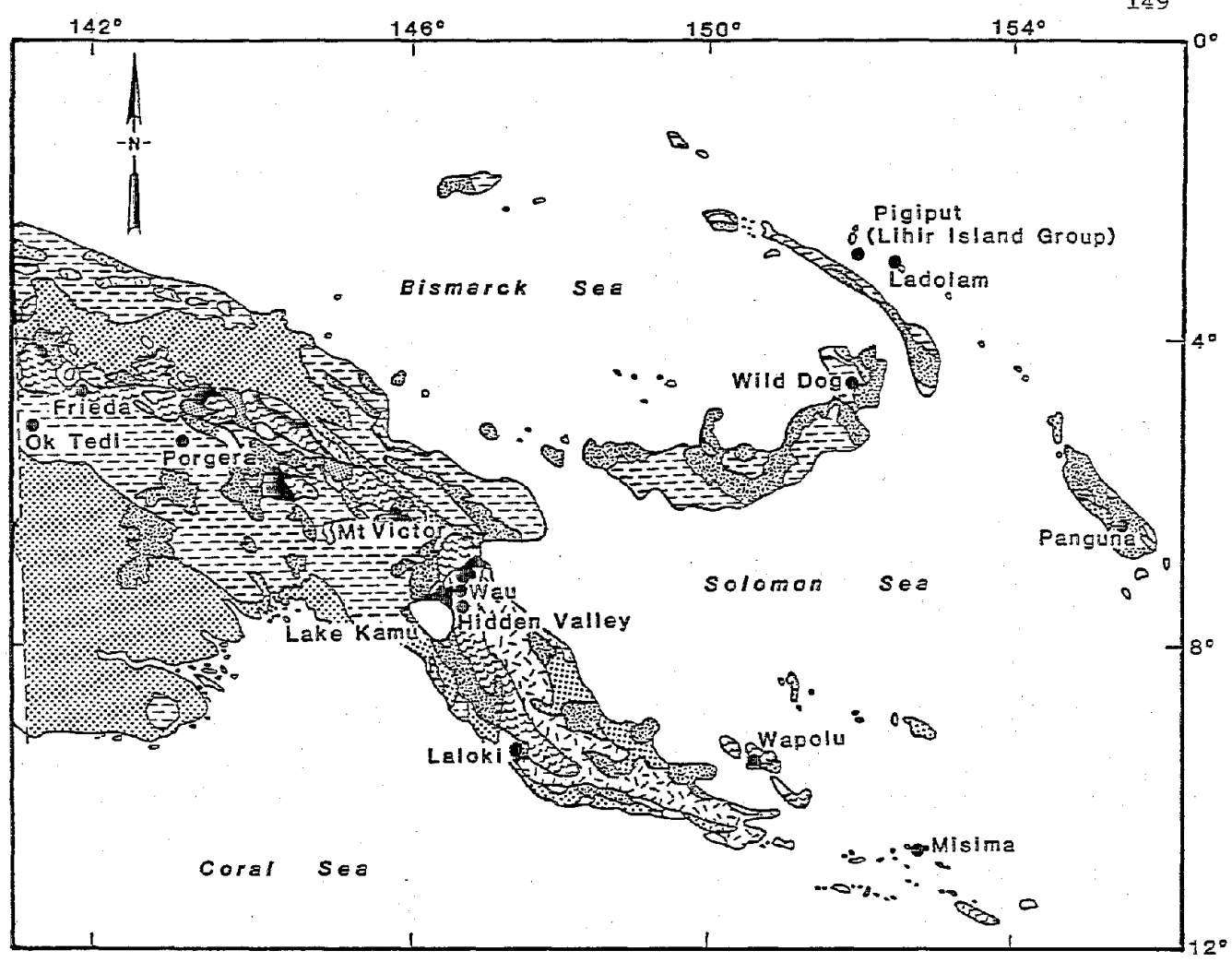
To attract and encourage foreign investment in the Malaysian minerals industry, substantial incentives are allowed to foreign investors under the Free Trade Zone Act of 1972, and the 1986 Promotion of Investment Act. Nevertheless, there is still a lack of diversification in the Malaysian mineral industry with respect to foreign investment, participation, and expertise. Recognizing these shortcomings and realizing that improvement is needed in this sector, the government started in 1989 with the assistance of the United Nations on a 2-year Mineral Development Policy and Planning Project. The objective of this project is to create an investment environment that attracts the needed foreign interest and capital (152, 153). The Malaysian tax regime is portrayed in summary in table 42. Detail for this tax regime as with other Pacific Rim countries will be contained in the planned Open File Report.

GEOLOGY AND EXPLORATION POTENTIAL

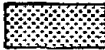
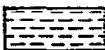
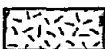
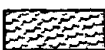
PAPUA NEW GUINEA

Figure 36 is a map of PNG showing the main geological features. Table 43 is a listing of the environments favorable for gold deposits and the major PNG gold deposits (154). Geological prospectivity in PNG is very high. Active exploration prospects in PNG include Hidden Valley, Woodlark Island, Frieda River Joint Venture, Ramu River, Laloki, Tolukuma, Nena, and other reconnaissance stage prospects (154).

According to a paper by G. Anderson given in 1993, mineral and exploration budgets have contributed greatly to growth of the PNG economy over the last 20 years, especially in the 1980's (137). A fall off in exploration expenditures in 1993 can be partially attributed to the resource policy as evidenced by the PNG government's recent decision to arbitrarily increase its equity



EXPLANATION

-  Surficial deposits—coarse and fine clastic sediments, coronas
-  Sedimentary environment
-  Calc-alkaline volcanics
-  Calc-alkaline hypabyssal intrusions
-  Oceanic crust and surficial sediments
-  Metamorphic rocks—various protoliths
-  Granitic intrusions

● Mineral deposits

Figure 36.—Generalized geology of Papua New Guinea with locations of major deposits.

Source: Lum, et al (149).

Table 43.--Papua New Guinea geologic environments favorable for gold deposits

Geological environment	Deposit type	Known deposits
Oceanic crust and mantle		
Oceanic sediments	Besshi massive sulfide	Laloki.
Calc-alkaline hypabyssal intrusion and volcanic rocks		
Porphyry intrusions	Porphyry Cu-Mo-Au Porphyry Cu-Au	Yandera. Panguna.
Porphyry intrusions into carbonates	Cu skarn, gold cap	Ok Tedi.
Distal environment to intrusions and volcanic centers	Adularia Au-Ag Alunite Cu-As-Au Au Hot Springs	Edie Creek. Nena. Wafi. Iamalele.
Alkaline intrusions and volcanic rocks	Lihir Au Epithermal veins Au-Ag-Te veins	Ladolam. Pigiput. Wild Dog.
Surficial deposits	Placer Au-PGE	Bulolo.

Source: Rogerson and McKee (154) .

interest in current PNG gold operations and near-development projects, (2) a deteriorating law and order situation, and (3) decreased investor's perception of security of tenure (137).

In conclusion, PNG is highly prospective for major mineral discoveries and remains one of the least explored regions of the world. It is also one of the most expensive and logistically difficult places to prospect. Because of the high risk associated with exploring and investing in mining, the country is trying to balance this with a stable political and fiscal environment which insures an adequate return to the investor.

INDONESIA

Indonesia has taken over from PNG as the most favored exploration location. There are two major types of gold exploration targets in Indonesia, epithermal and porphyry.

Much more recent gold exploration is concentrated on epithermal deposits. Because of the rugged terrain and thick cover, much of the grass-roots exploration in Indonesia is with helicopter support involving stream-sediment and pan-concentrate sampling, BLEG processing of sediments from all major catchments, photogeologic and remote-sensing imagery study, and airborne magnetics/radiometrics (155). Figure 37 shows the location of major gold activity in Indonesia.

PHILIPPINES

The Philippines is considered one of the most highly mineralized countries in the world, and probably has the highest concentration of epithermal deposits recognized in Southeast Asia. Additionally, 40 porphyry deposits have been discovered, many containing precious metals (132). Prospective areas for gold mineralization are shown in figure 38. Not all of these discoveries

have been brought into production. As late as the mid-1970's, only about 61 pct of the total land area had been explored; of this only 5 pct had been surveyed, and the remaining 56 pct had been covered only by wide range reconnaissance work (143).

NEW ZEALAND

There are at least four distinct types of lode gold mineralization occurrences in New Zealand (shown in figure 39) (156). Lode gold production from the tertiary volcanic province of the Coromandel Peninsula is the most important.

The greatest potential in New Zealand for gold occurrence is in areas of granitic, ultramafic and ancient carbonate rocks (South Island) and young but extinct volcanic zones (North Island) (156). New Zealand has some excellent epithermal gold targets on the Coromandel Peninsula of the North Island, which are receiving intense exploration activity, many untested targets in the thermal regions of the same areas, and many old gold mining areas of the South Island left untested in modern times.

There is still good potential for additional alluvial gold deposit discoveries in New Zealand. However, strong environmental constraints impact the attractiveness of this deposit type (156).

JAPAN

The Japanese islands are situated at the border of continental and Oceanic crust. They face deep trenches on the oceanic side with the continental side being surrounded by marginal seas. The islands form a part of the Circum-Pacific Volcanic and Seismic Belts. The Ryuku arc is distinct from the more familiar green tuff regions (which are composed predominantly of submarine volcanic), and host the well known Kuroko deposits (158).

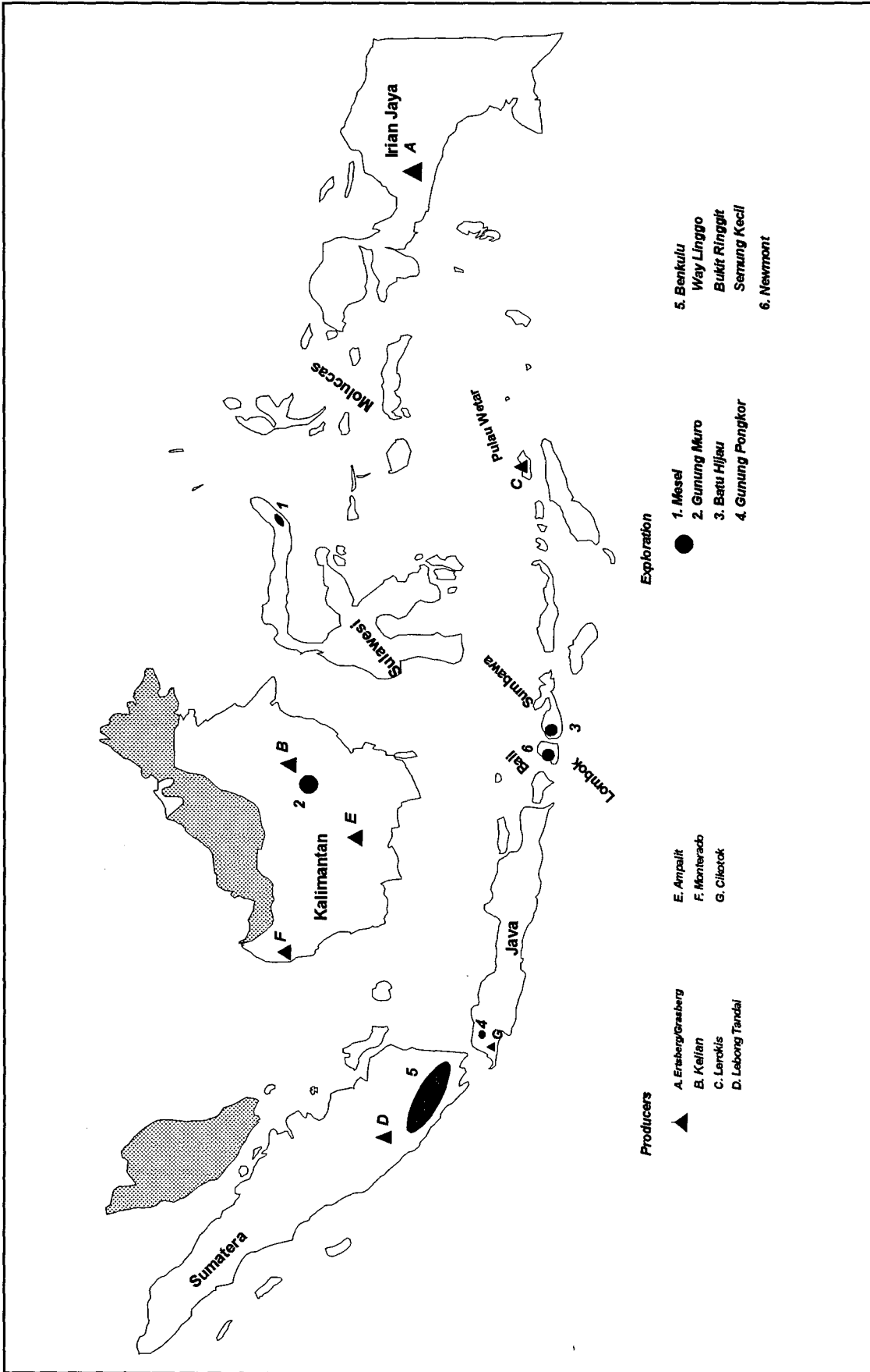


Figure 37.--Republic of Indonesia - gold activities.

Source: Map prepared by USBM using data from Tyrwhitt (132).

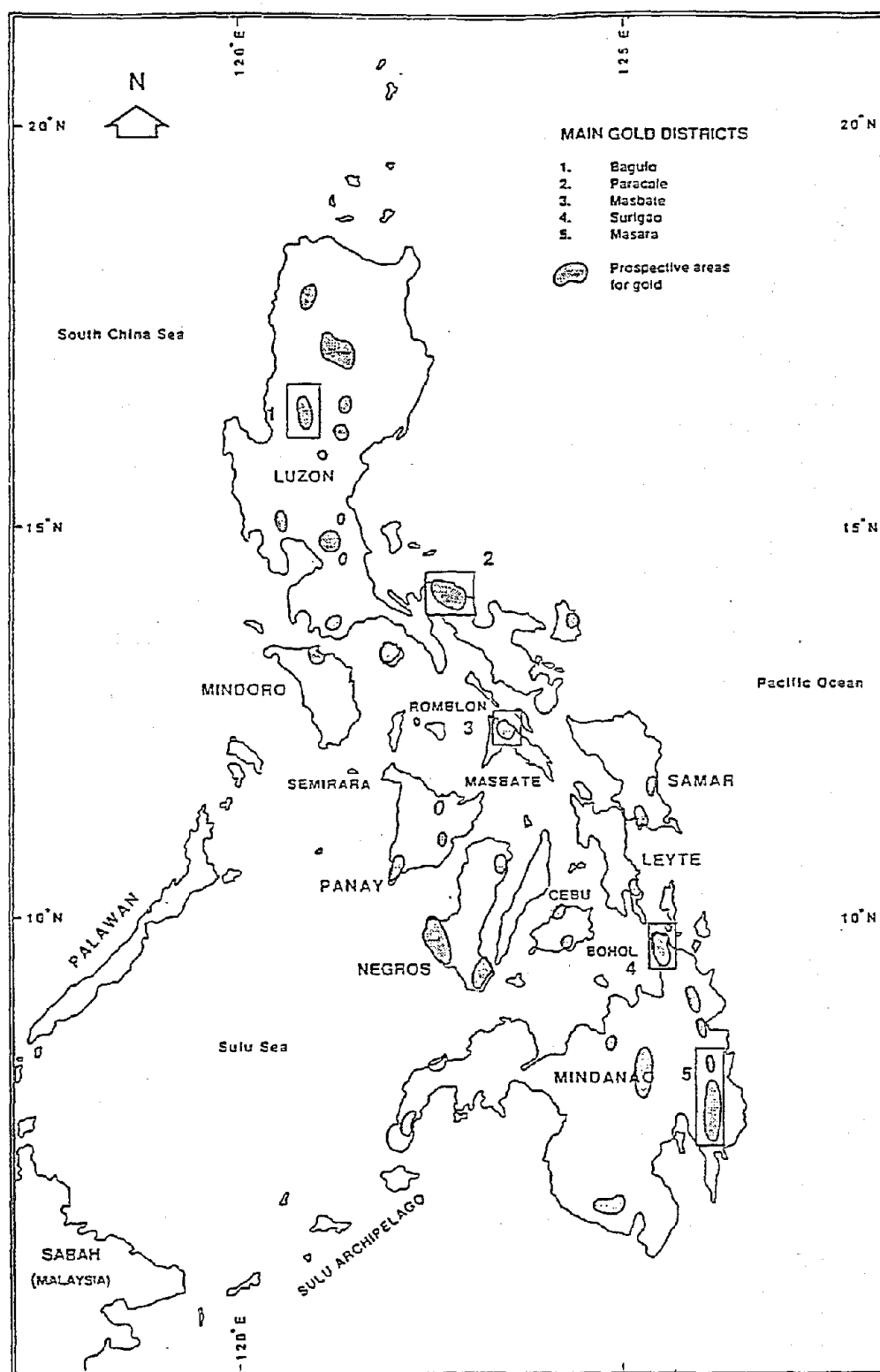


Figure 38.--Philippines locations of prospective areas for gold mineralization.

Source: UNDP (143).

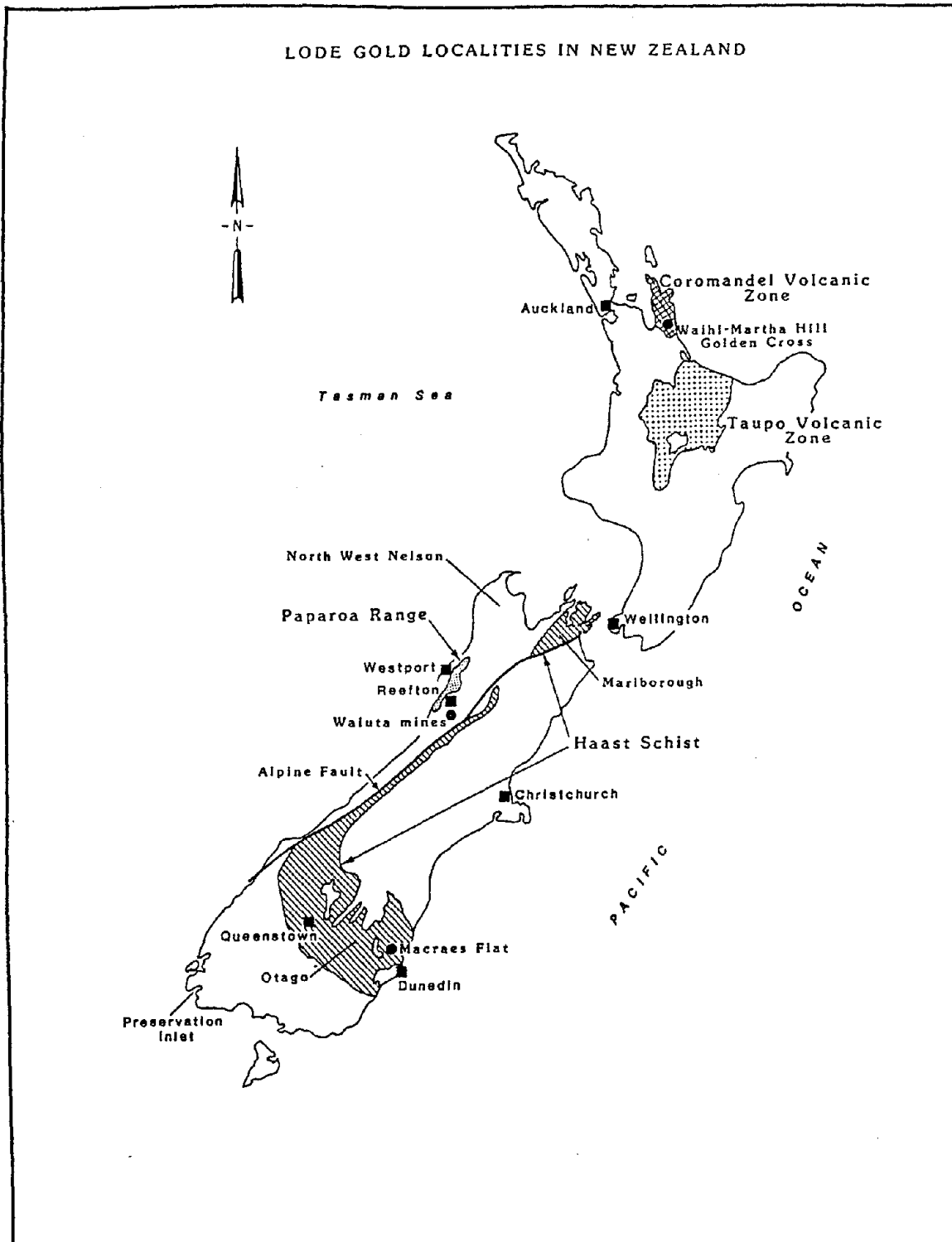


Figure 39.--Lode gold occurrences in New Zealand.

Source: Douch (157).

A number of deposits occur within the Ryuku arc of southwestern Kyushu Island. The locations are shown in figure 40. Other areas within Japan where gold occurrences are concentrated include the Izu Peninsula and Northern Hokkaido.

In Japanese nomenclature, two types of gold occurrences are recognized⁴. These are:

1. Kushikino type (low sulfur/adularia-sericite alteration)
2. Nansatsu type (high sulfur/acid sulfate alteration).

A domestic partner is almost essential to be able to conduct effective exploration in Japan. Most recent gold exploration activity in Japan has been in northeast and southwest sections of Hokkaido, parts of Honshu, and Kyushu. A list of major exploration projects and detail of the Otoge, Rubeshibe, and Buho projects will be available in the planned Open File Report.

FIJI

The Fiji platform is comprised of the two large islands of Viti Levu and Vanua Levu, 2 strings of small islands making up the Mamanuca and Yasawa groups to the west, and several volcanic islands to the south and east (149). The generalized geology of Fiji is shown in figure 41.

Gold has been produced in Fiji since the 1930's from the Emperor mine at Vatukoula and other minor workings (149). The potential for additional discovery of ore at the Emperor mine is good and is focused in the immediate mine area. Other exploration projects will be explained in more detail in the planned Open File Report. These projects are; Nasomo, Ciraniu, Namosi/Waisoi and other reconnaissance stage projects.

MALAYSIA

Within West Malaysia, the States of Pahang and Kelantan are currently considered good targets

for gold exploration. Whereas, in the past, many alluvial deposits have supported gold mining in this region, many of the current target areas have great potential for hard rock gold mining. Of particular interest is the Selinsing mine area located in central Pahang north of Raub and west of Kuala Lipis (160). Figure 42 shows gold activities in West Malaysia.

In East Malaysia, governmental restrictions, particularly with respect to foreign investments, have kept the search for gold at a low level. Recent modification of the investment policy, however, is expected to renew the interest of foreign companies in mineral exploration and development in Sarawak and Sabah (161). Figure 43 shows the location of East Malaysian gold activities.

ORE RESERVES/PRODUCTION

PAPUA NEW GUINEA

The reported 1993 proven and probable ore reserves for the three major primary gold operations and one byproduct gold operation are listed below. These reserves are taken from annual reports of BHP Minerals Holdings Pty., Ltd., Niugini Mining Ltd., and Placer (P.N.G.) Pty. Ltd.

Project	Mnt of ore	Grade (g/mt)	Mine life
Misima	39.0	1.18	10
Porgera	46.7	5.81	18
Lihir	264.0	3.10	31
Ok Tedi	431.0	0.67	20

According to these annual reports, the three primary gold operations all have excellent potential for extension of the ore reserves through exploration. The Lihir deposit (also called Ladolam) was awaiting approval of a mine development proposal in late 1994, and represents a significant percentage of PNG's expansion

⁴This discussion of Japan is based on personal communications with R.F. Horsnail and J. Hedenquist, Geological Survey of Japan, Mineral Resources Dept.

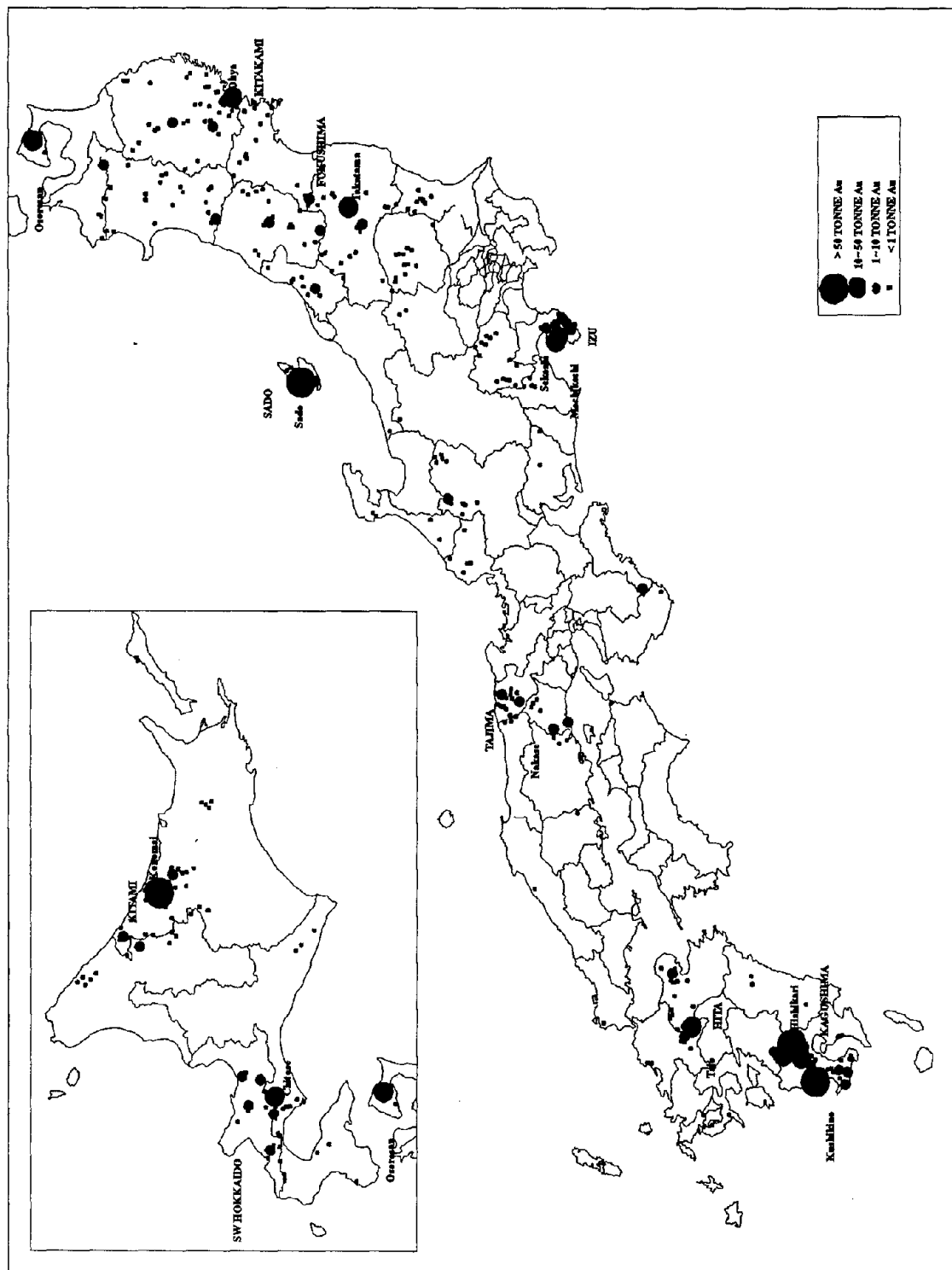
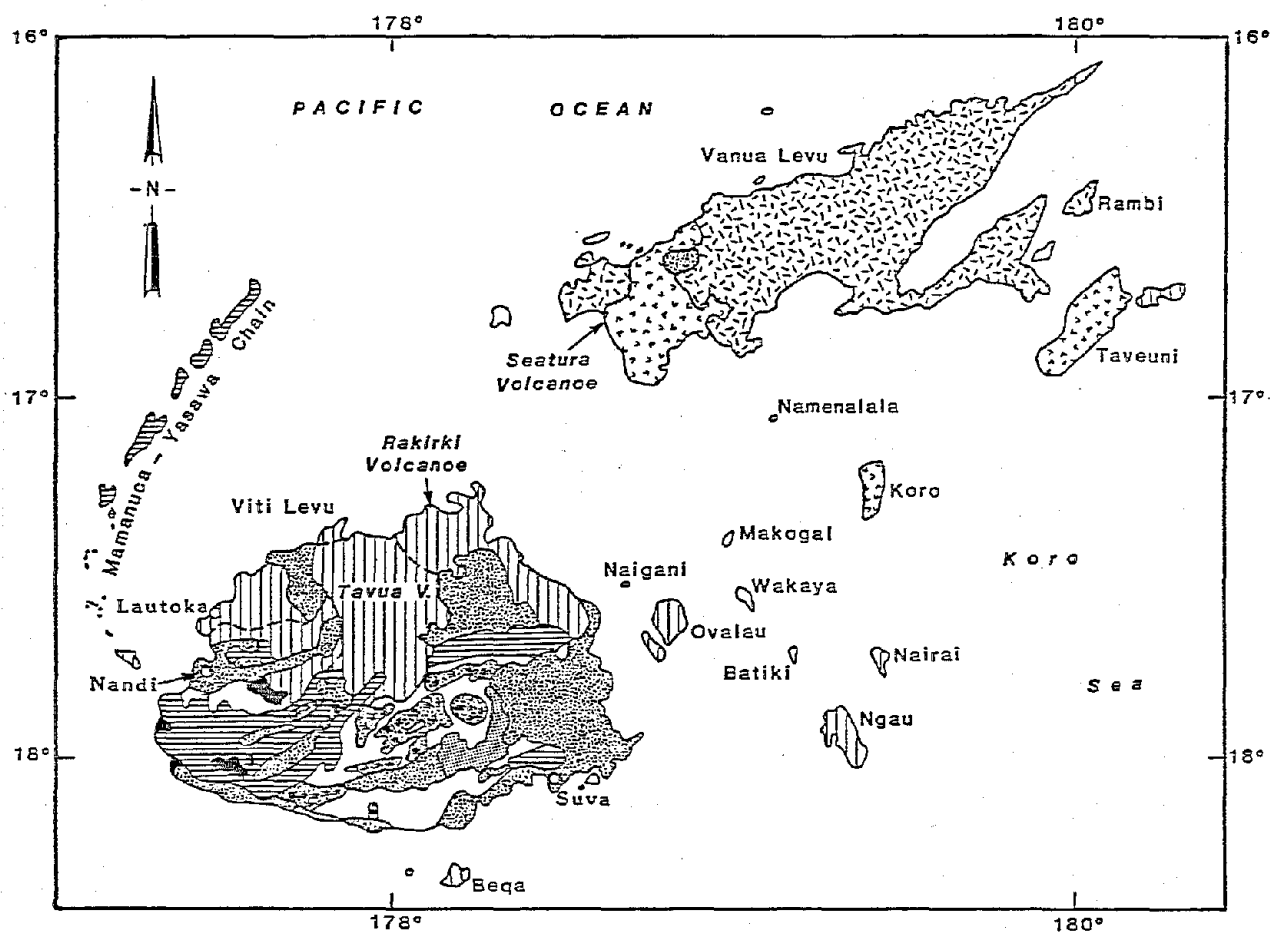


Figure 40.--Location of gold and silver deposits in Japan.

Source: Kamatani and Kanazawa, (159).



EXPLANATION

- | | |
|--|--|
| | U. Miocene-Holocene sedimentary rocks |
| | U. Oligocene-U. Miocene Upper Wainimaisa |
| | Pliocene shoshonitic or calcalkaline basaltic volcanoes |
| | Miocene-Holocene alkalic basalts (1. Mio. on Viti Levu, Pilo. on Vanua Levu, Pilo.-pleist. on Koro, Pleiest.-Holo. on Taveuni) |
| | U. Miocene-L. Pliocene Macuadrovo super group (Vanua Levu) |
| | U. Miocene calcalkaline rocks |
| | Miocen stocks |
| | Oligocene Yavuna stock |
| | } Colo Plutonic suite (Tholeiitic) |
| | City or town |

Figure 41.--Generalized geology of Fiji (after Rodda in Kroenke, 1984).

Source: Lum, et al (149).

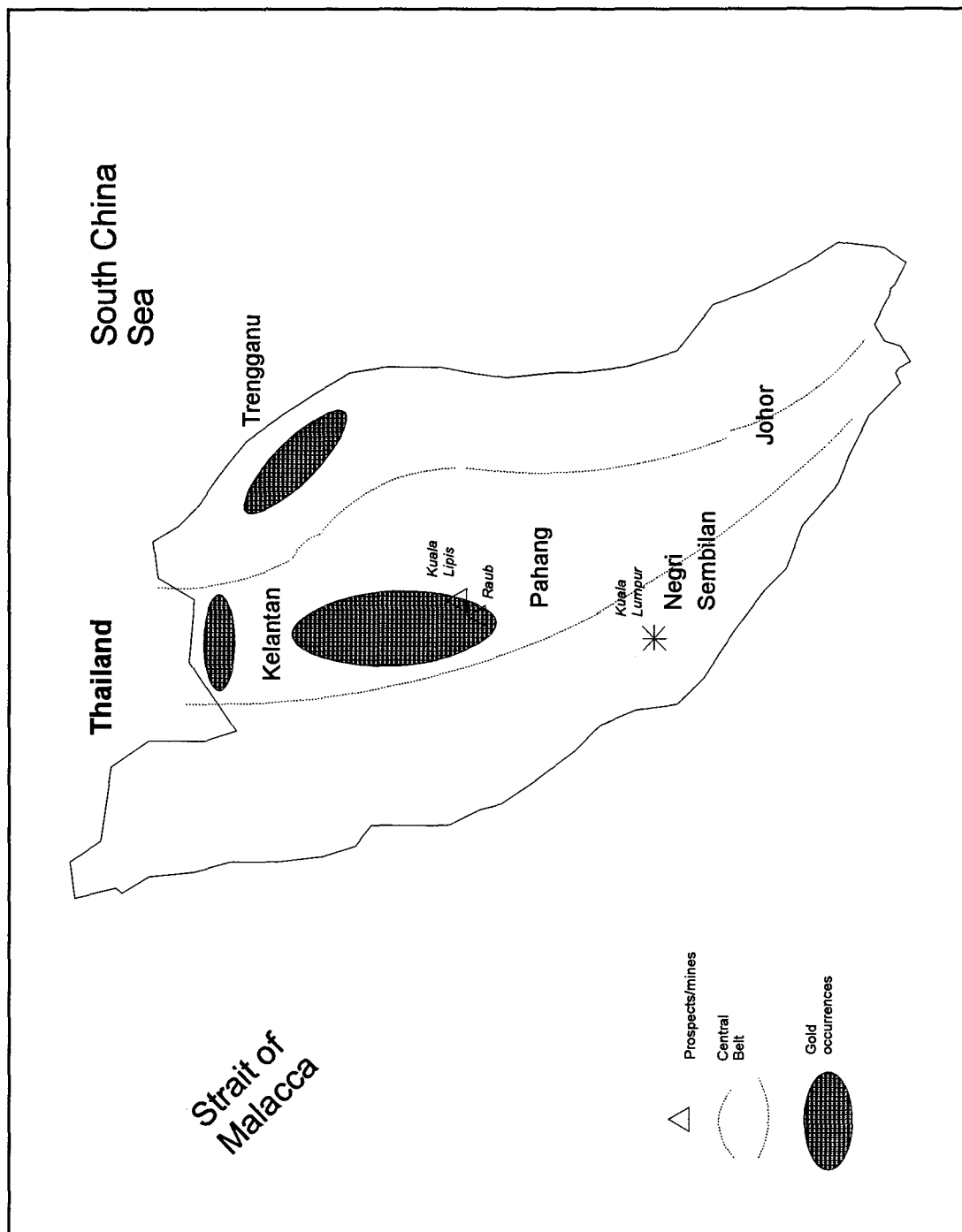


Figure 42.--West Malaysia - gold activities.

Source: Map prepared by USBM using data from Richardson (160).

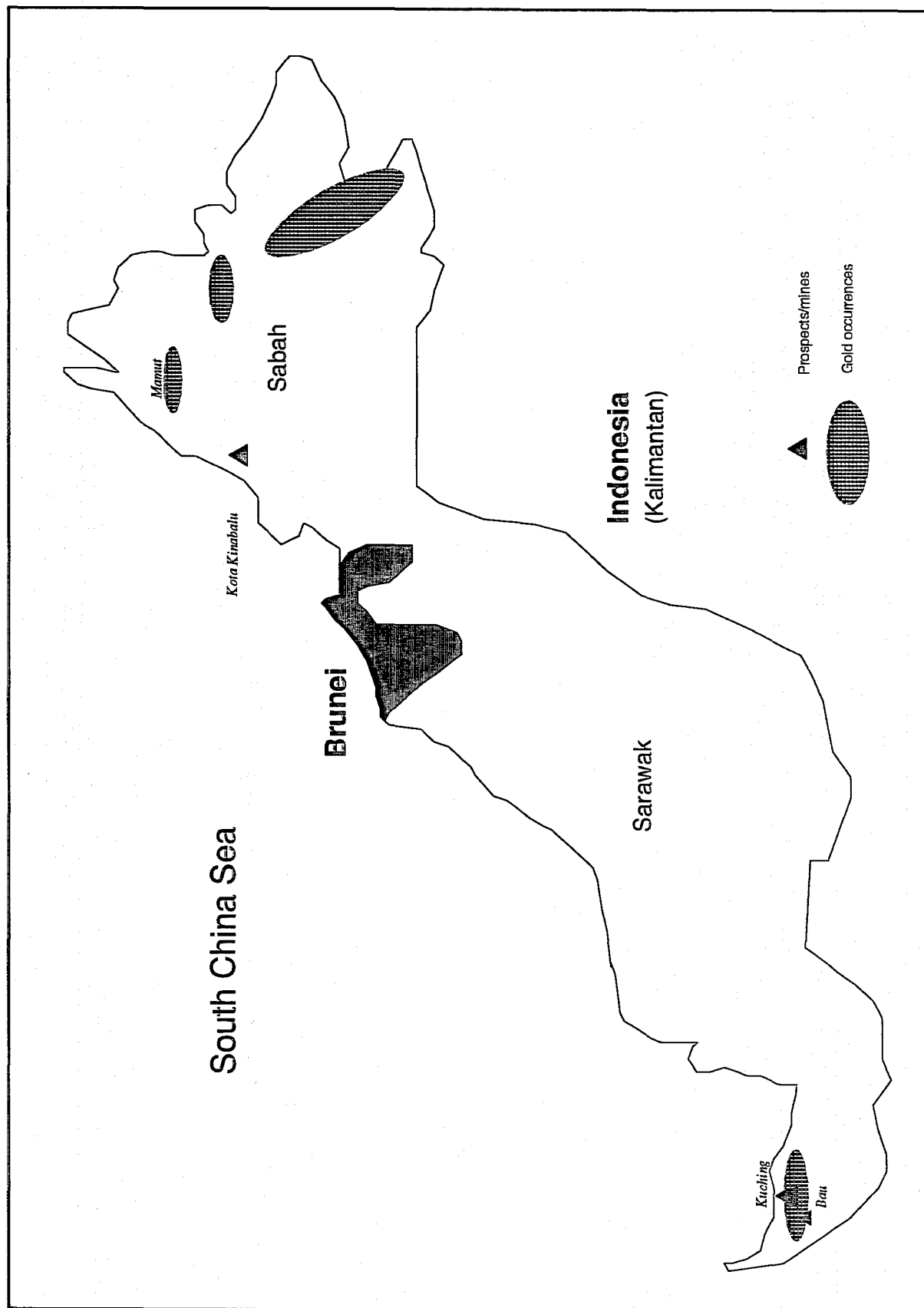


Figure 43.--East Malaysia - gold activities.

Source: Map prepared by USBM using data from Crisp (153).

potential. In addition, many similar types of geologic environment are yet unexplored in PNG leaving the potential for more discoveries of similar size.

PNG gold production was at a record level in 1992 with production of 71.2 mt (2.2 M tr oz) (162).

INDONESIA

The 1992 gold production for Indonesia is shown in table 44. Indonesia is ranked third in the Pacific Basin region. The largest gold producer in Indonesia is Freeport's copper-gold deposit, the Ertsberg/Grasberg operation, in Irian Jaya. Total proven and probable ore reserves are reported as 1,074 Mmt at an average grade of 1.31 pct copper, 1.47 g/mt gold, and 4.04 g/mt silver (163).

The second largest gold producer in Indonesia is CRA's Kelian open pit gold mine in east Kalimantan. The Kelian deposit was discovered in 1976 and is located 50 km from the Mahakaim River and 450 km from the coast of eastern Kalimantan. The mine presently the largest epithermal gold deposit in Indonesia, is operated by P.T. Kelian Equatorial Mining (KEM). The 1993 annual report for CRA gives a geologic resource estimated at 99 Mmt at a gold grade of 1.7 g/mt, and a minable reserve of 53 Mmt at almost 2 g/mt of gold (164). There are several smaller domestic producers.

PHILIPPINES

According to Mining Journal magazine, Philippine gold resources as of January 1993 were estimated at 800 mt (25 M tr oz) of gold at the identified level and 1,500 mt (48 M tr oz) of gold at the hypothetical level (143). In both cases this is about 1.0 pct of the world's gold reserve/resource.

Average gold production was about 37 mt per year throughout the 1980's. Production steadily increased through the early 1980's,

reaching its peak in 1986 at about 40 mt of gold. Production started to decline thereafter, and has been declining ever since with production in 1992 of less than 24 mt of gold (29), and production in 1993 at an estimated 16 mt (4).

Philippine gold production has been dominated by four companies: Benguet Corp, Atlas, Philex, and Lepanto (see table 45). In 1991 they officially accounted for nearly 15 mt or about 86 pct of all large scale gold mines production. Gold production in 1992 for these companies had dropped to about 12 mt and their estimated gold production in 1993 was 9 mt (0.3 M tr oz) (165). This decline came about because of lower commodity prices. Benguet began a phased shutdown of all its underground operation in mid-1992, which was completed by the first quarter of 1993. Atlas and Lepanto also announced workforce cut-backs and layoffs. Lepanto and Philex have suspended development of new gold mining projects (165). There is a thriving small-scale mining sector in the Philippines (143).

NEW ZEALAND

Ore reserves for New Zealand's three largest primary gold producing operations and for one producing placer operation are listed in table 46. This data is taken from company annual reports. All of the deposits are said to have good potential for expansion.

New Zealand's gold output nearly doubled in 1992 to the highest level since 1915. Hardrock mining dominated production, with Martha Hill, Macraes Flat and Golden Cross contributing 78 pct of production. Alluvial operations on the west coast of South Island and in Otago produced the remainder (166).

JAPAN

Gold production in Japan was traditionally a byproduct of base metal mines but is now dominated by Sumitomo's high grade Hishikari

Table 44.--Gold production in Indonesia, 1992

Operation	(mt)	(k tr oz)	Type of deposit
1. Ertzberg/Grasberg	20.6	662	Porphyry.
2. Kelian	15.1	485	Primary.
3. Lerokis	1.8	58	Primary.
4. Lebong Tandai	0.6	19	Primary.
5. Smaller producers (includes Ampalit and Monterado)	0.8	26	Alluvial.
6. Small scale mining (mostly by locals)	4.8	154	Alluvial and eluvial.
Total	43.7	1,405	

Source: Tyrwhitt (132).

Table 45.--Gold production from principal Philippine producers

Mine	Owner	1992		1993	
		(mt)	(k tr oz)	(mt)	(k tr oz)
Dizon	Benguet Corp ...	3.1	101.0	3.3	107.0
Antamok	Benguet Corp. ..	2.7	88.4	NA	NA
Cebu	Atlas	1.4	45.0	1.4	44.5
Santo Tomas II	Philex	3.1	100.3	2.4	76.9
Lepanto	Lepanto	1.4	46.4	1.6	52.9
Total		11.8	381.0	8.7	281.3

NA Not available.

Source: Mining Magazine (165), and other available public documents.

Table 46.--New Zealand ore reserves, selected deposits, 1993
(proven and probable)

Deposit name	Ore tonnage (Mmt)	Gold grade (g/mt)
Martha Hill	5.1	3.1
Macraes	21.5	1.6
Gold Cross	2.3	2.8
West Coast/Rimu	9.1	0.2

Source: Compiled from company annual reports and other public documents.

gold mine, where production is increasing to 7 mt (225 k tr oz) per year.

All primary gold operations in Japan are high grade by world standards. Since cyanide treatment processes are not used, these high grades are necessary to support the higher production costs. Sumitomo has made a recent discovery near the Hishikari mine, but total Japanese gold output is expected to continue at an annual level of 7 to 10 mt/yr (167).

FIJI

The Emperor gold mine is the only producing gold operation in Fiji. It is located on the northern part of the island of Viti Levu, and has been in production for 55 years (149). It has published ore reserves equivalent to another 8 years of production at the current production level near 4.0 mt/yr of gold. Total ore reserves as of June 1992 were 2.6 Mmt at 6.3 g/mt of gold (168). Total reserves and resources amounted to 4.2 Mmt at 7.0 g/mt. Resources at the Emperor mine are expected to double from 8 years upon reappraisal of resources using a lower cut-off grade because mining efficiency has improved (169).

MALAYSIA

Malaysia is the sixth largest gold producer in the Asia-Pacific region. Currently most of the gold production (62 pct in 1992) is recovered as a by-product from the porphyry copper deposit at Mamut in Sabah (132). The remainder is from small scale mining in Sarawak, Terengganu, Kelantan and Pahang. Malaysian gold production is expected to double in the next decade. New discoveries and developments of epithermal and porphyry type deposits together with rehabilitation and re-examination of old mines are expected to be the major contributors to the production increase with East Malaysia having the leading gold producers (170).

EVALUATION RESULTS

COST DATA

Labor rates are generally lower in the Pacific Basin; however, this does not appear to have had a significant impact on production costs in PNG, partly because this savings is offset by training costs for an unskilled workforce. The labor cost component is lower in Indonesia but also includes a significant training cost. Operations are required to employ nationals (approximately 85 pct of staffing at these operations); hence the need for training⁶.

Another important factor which can significantly impact mining costs in PNG and Indonesia is compensation costs for land purchase and resettlement of nationals from land affected by the mining operations. In several cases this expenditure is so large that site overhead costs account for more than 50 pct of gold production costs⁷.

The major difference in the cost structure of operations located in the Pacific Basin is capital costs for infrastructure. For example, access to Porgera in the interior highlands of PNG took 2 years and millions of dollars just to get the equipment in to build the mine. This is in contrast to Australia, where mines are remote but it is not difficult to bring equipment and materials into a location. It is rare in the Pacific Basin to have an operation such as Misima (an island), where

⁵Personal communication, J. Hedenquist, Geological Survey of Japan, Mineral Resources Dept.

⁶Personal communication, John Eldham, Newmont, Indonesia, Juningan - Jakarta, Indonesia.

⁷Personal communication, Ian Williams, Placer Pacific Ltd., Sydney, Australia.

it is very inexpensive to bring in materials and supplies by boat. Except for access problems and infrastructure, capital costs in the Pacific Basin are much the same as elsewhere; however, construction labor rates are much lower.

Table 47 gives the range of cash cost on a per metric ton of ore basis for evaluated deposits in PNG, Indonesia and New Zealand. Detailed costs were not available for the Japanese, Fijian, and Malaysian operations. The cost data is taken from company annual reports and press releases. The estimated cash operating costs/tr oz are shown in table 48.

The large Indonesian and PNG epithermal deposits have costs ranging from around \$126/tr oz to \$179/tr oz, for 1993. The low-grade bulk tonnage operations such as Misima PNG, are currently operating at near the upper end of this cost range. Misima, with an average gold grade of 1.6 g/mt, is not a typical mine for PNG.

The Japanese gold deposits are refractory and are either milled to produce a concentrate, usually with base metals, or used as smelter flux. The underground operations are high cost which is offset by the higher grade of many of the Japanese deposits. Open pit mining costs in Japan would also be very high, if permitted, due to environmental concerns.

Japanese use of cyanide in the production of gold has declined since 1970. The cessation of its use reflects the decline of mining in Japan,⁶ not regulatory restrictions. Most gold ore is high silica and is reserved for smelter flux in the course of smelting copper. Total production costs range from \$259 - \$389/tr oz of gold. Normally a Japanese gold operation will be profitable if the gold content of the ore is in the range of 20-30 g/mt, the minimum grade for an underground vein target in Japan. The Hishikari gold mine is an exceptionally high grade operation (average production grade of 50.5 g/mt) and is reported to have a cash cost of \$30/oz (159).

Production from the epithermal style New Zealand gold operations is higher cost than PNG and Indonesian operations and ranges from \$165/tr oz - \$265/tr oz. The Emperor operations at Vatukuola and Tavua Basin, the only operating gold mines in Fiji, are primarily underground mines and have been fairly high cost operations at around \$360/tr oz. It is refractory ore and requires roasting prior to processing.

ANNUAL GOLD AVAILABILITY

Availability curves were generated for the combined region of Indonesia and PNG for 3 operating gold mines (Misima, Porgera, and Kelian) and 4 projects expected to be in production within the next 5 years. All of these operations are epithermal gold deposits. Two of the current producers are open pit operations and the third is a combination open pit/underground operation. This aggregation approach was taken because of similarities between the 2 countries in infrastructure, deposit types, and the existence of well-developed mining legislation. These 2 countries are also believed to be those with the highest potential for future increases in gold production and of greatest interest to explorers in the Pacific basin region. New Zealand has similar epithermal deposits; but, they appear to be much smaller and the cost structure of New Zealand is not analogous to PNG's and Indonesia's. The cost data used in the availability analyses below was either taken from company annual reports or confidential data provided by the companies concerned.

Base Case Annual Gold Production

Gold price determinations were performed for the 3 primary gold

⁶Personal communication, H. Hirano, Geological Survey of Japan, Mineral Resources Department.

⁹Personal communication, Michael McNaull, Regional Resource Officer, U.S. Embassy, Jakarta, Indonesia.

Table 47.--Consolidated cash production costs in Papua New Guinea, Indonesia, and New Zealand

Cost category	Cost range (1993 \$/mt ore)	Pct of cash production cost
Mining:		
Open Pit	1.40 - 12.10	15.4 - 47.3
Underground	32.00	57.3
Processing:		
Leaching w/autoclaving or roasting	7.00 - 17.00	27.9 - 48.0
Leaching	3.90 - 5.70	33.6 - 38.0
Site Overhead	1.30 - 7.10	9.5 - 38.1
Including resettlement cost ¹	25.60	NA

NA Not available.

¹One operation had high land purchase and resettlement cost.

Source: Company annual reports and other available public documents.

Table 48.--Production costs for Pacific Basin deposits

Cost definition	Cost range (1993 \$/tr oz)
Cash costs, selected countries:	
Indonesia	126 - 165
PNG	150 - 179
New Zealand	165 - 265
Fiji	360
Total costs ¹ , Indonesia and PNG:	
0-pct DCFROR	88 - 313
15-pct DCFROR	168 - 403

¹Expansion case scenario.

Source: Company annual reports and other available public documents.

operations now in full production in PNG and Indonesia. Figure 44 shows the projected annual gold availability for a 0-pct DCFROR.

Annual gold production at a cost of less than \$250/tr oz peaks in year 3 at 36.4 mt (1.17 M tr oz) of gold. At less than \$300/tr oz, it peaks in year 3 at 48.9 mt (1.57 M tr oz) of gold produced. At costs up to \$350/tr oz, maximum gold production over the life of the operations peaks in year 4 at 61.0 mt/yr (1.96 M tr oz) of gold; in this year 60% of the gold is produced at a cost less than \$250/tr oz. All of the production for the 0-pct DCFROR scenario can be achieved at a cost of less than \$350/tr oz. The evaluated properties have total average life-of-mine production costs which fall below the average 1993 price of gold (\$361/tr oz). Production, as illustrated in figure 44, drops off steeply after only a few years of production to approximately 15.6 mt (500 k tr oz) of gold after the tenth year of production. Only one of these operations has a mine life extending beyond 15 years.

When these same properties are evaluated at a 15-pct DCFROR, maximum gold production is achieved at a cost of less than \$450/tr oz over the life of the operation. However, approximately 80 pct of the gold production in the earlier high production years is secured at a cost less than \$400/tr oz and approximately 60 pct of gold production at a cost of less than \$300/tr oz.

These cost estimates demonstrate the low cost nature of production associated with this region's epithermal gold deposits which make them so attractive to explorers. These production cost curves do not include by-product gold production.

Expansion Case Annual Gold Production

The expansion case includes four gold projects, in addition to the 3

base case mines, which could begin production within the next 3 years. One of these gold projects is located in PNG and the remaining 3 are located in Indonesia.

The average mine life for the additional properties is 8 to 10 years except for the Lihir gold project which has a 34 year projected life at full production levels. The additional 4 projects will be open pit mined. Ore at 2 of the undeveloped projects will require roasting; all the 4 undeveloped projects are designed to recover the gold through CIP or CIL leaching.

Peak gold production in the expansion case scenario, 69.9 mt/yr (2.25 M tr oz/yr) of gold, is reached in the tenth year, when all 7 properties are operating. This production declines gradually until it reaches a plateau of 6.85 mt (220 k tr oz) in approximately the twenty-fifth year. Maximum production, as shown in figure 45, is achieved at a total production cost of less than \$350/tr oz of gold for a 0-pct DCFROR. The average annual production costs for all 7 projects fall below the average 1993 price of gold (\$361/tr oz).

One high-grade property is expected to produce at a total production cost of less than \$100/tr oz of gold at a 0-pct DCFROR, and a second property is expected to have total costs less than \$150/tr oz of gold. During the highest production years, over 70 pct of the gold is produced at a cost of less than \$250/tr oz.

A gold price of slightly over \$400/tr oz is required to cover total annual production costs for all 7 properties at a 15-pct DCFROR. Over one-half of annual gold production at a 15-pct DCFROR can still be secured at a cost of less than \$350/tr oz of gold in the prime production years. The lowest cost project can produce gold at a cost under \$200/tr oz for the 15-pct DCFROR scenario.

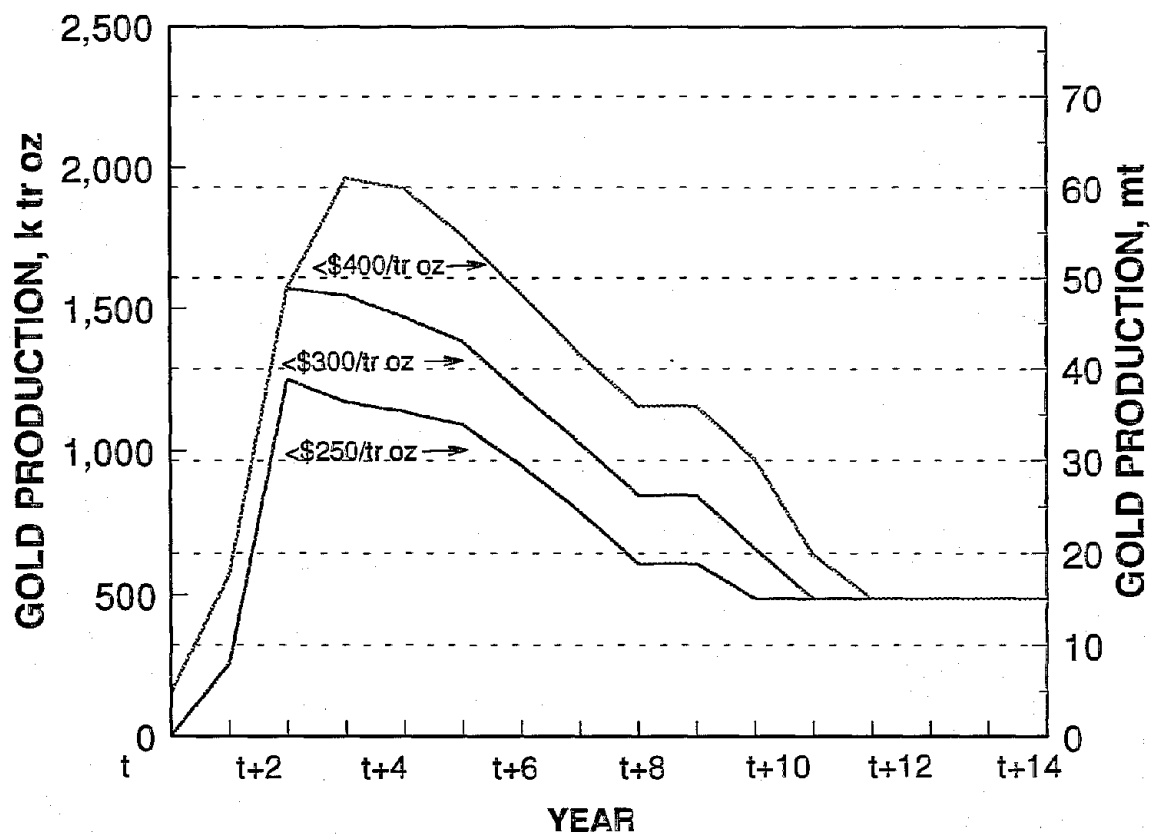


Figure 44.--Potential annual gold production at a 0-pct DCFROR and various gold cost levels, Asia-Pacific region, base case.

Source: USBM estimates.

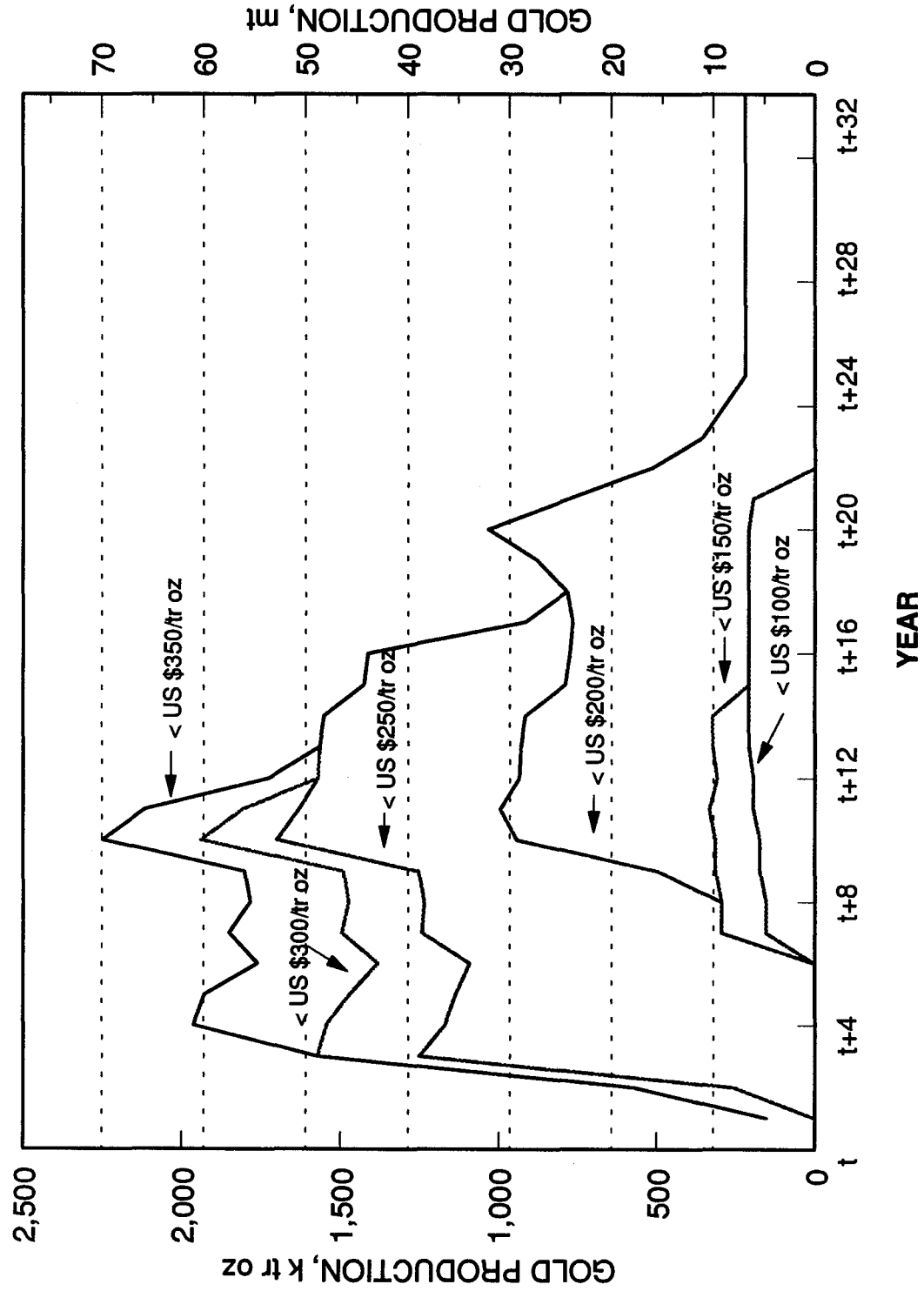


Figure 45.--Potential annual gold production at a 0-pct DCFROR and various gold cost levels, Asia-Pacific region, expansion case.

Source: USBM estimates.

TOTAL GOLD AVAILABILITY

Base Case

The total gold availability curve shows the total recoverable gold, over the life of the operations, available from the three PNG and Indonesian operations currently producing gold. As shown in figure 46, at a 0-pct DCFROR almost 335 mt (10.8 M tr oz) of gold is available at a cost of less than \$250/tr oz. Approximately 426 mt (13.7 M tr oz) of gold is available at less than \$300/tr oz of gold and 520 mt (16.7 M tr oz) of gold is available at less than \$350/tr oz of gold.

Expansion Case

The expansion case represents the total gold available from the 3 producing operations and 4 undeveloped gold properties in PNG and Indonesia over the life of mines. A total of 1,031 mt (33.2 M tr oz) of gold is available from these properties. As shown in figure 47, at a 0-pct DCFROR 32.5 pct (335 mt) of the gold is available at a cost less than \$100/tr oz. Over 50 pct (516 mt) of total production is procured at a cost less than \$200/tr oz and 88 pct (907 mt) of the gold produced from these 7 properties is estimated to be available at a total cost of less than \$250/tr oz.

There is by-product gold production from the OK Tedi mine in PNG and from the Grasberg/Ertsberg mine in Indonesia, which are producing at annual rates of 10.9 mt (350 k tr oz) and 46.7 mt (1.5 M tr oz) of gold, respectively. The Ok Tedi mine is projected to have possibly 20 years of remaining life and the Grasberg/Ertsberg mine has a projected life of slightly greater than 26 years at current levels of production. The total by-product recoverable gold from Ok Tedi and Grasberg/Ertsberg is greater than what is available from the evaluated primary gold operations at 218 mt (7 M tr oz) and 1,232 mt (39.6 M tr oz) respectively.

FUTURE POTENTIAL

Papua New Guinea has strong potential for expansion of its annual gold production. The earliest production increases are likely to come from the Laloki and Tokuluma deposits. Mining permits have been applied for and feasibility studies initiated at both operations (171). According to South-East Asia Mining Letter, Laloki will have a fairly short life, probably not more than 4 years (172).

The Lihir gold project was scheduled to come on-line at full production as early as 1996 or 1997. Output levels as much as 25 mt/yr (815 k tr oz) through the year 2008 are possible with a gradual decline to 6.2 mt/yr (200 k tr oz) by the year 2032 (173). There are also known deposits in other parts of PNG, including a high grade gold zone above the main body of a copper mineralization on the Frieda River gold joint venture (174).

Indonesia also has the potential for large (up to 20 mt/yr) low-cost annual gold production in the next decade with at least 3 properties capable of producing 4-5 mt/yr likely to be developed. According to Newmont Indonesia Company personnel, the Mesel deposit is scheduled for production start-up by the end of 1995 (175). The Mt. Muro project is also scheduled to come on-line at the end of 1995 (176). The Gunung Pongkor project, held by the state owned mining company of P.T. Aneka Tambang, is projected to be in production in 1995 (177). Newmont Gold also has a copper-gold porphyry project, still in the preliminary feasibility stage, which may contribute 3.1 mt (100 k tr oz) per year or more by the end of the decade¹⁰.

New Zealand annual production could expand by approximately 4.7 mt (150 k tr oz) by 1996. This increase could come from the

¹⁰Personal communication, John Eldham, Newmont, Indonesia, Juningan - Jakarta, Indonesia.

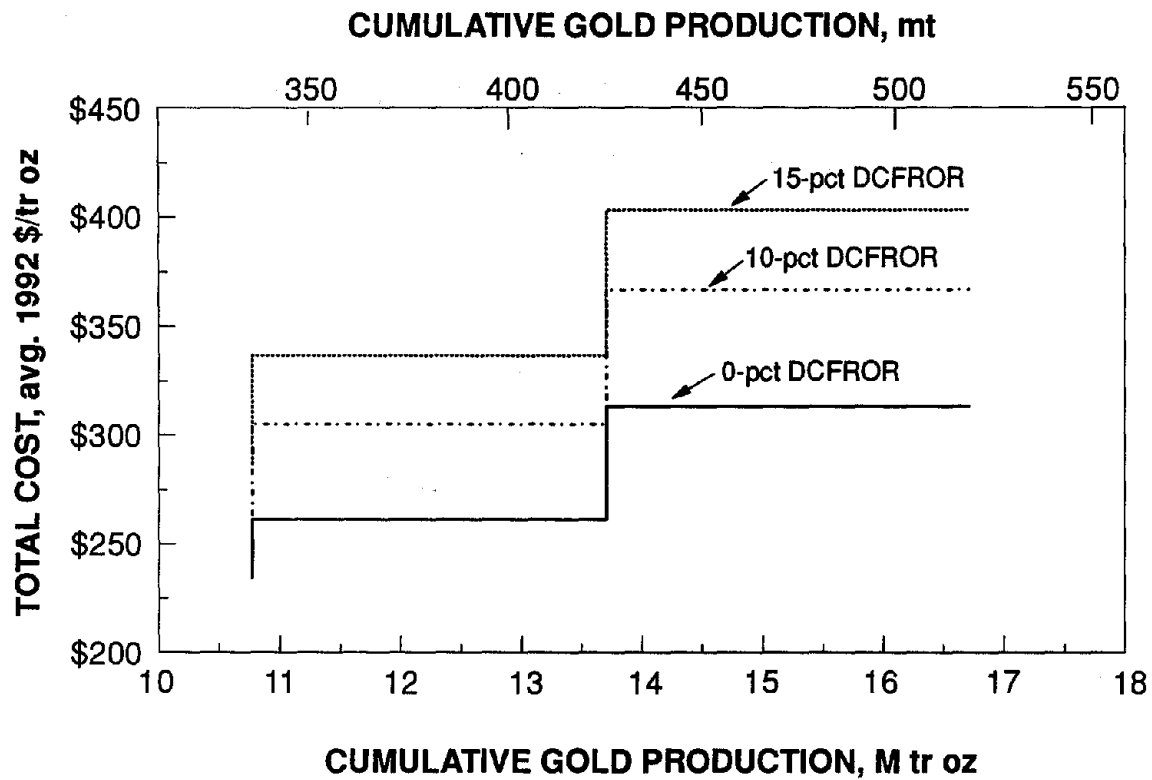


Figure 46.--Base Case: Potential gold availability for PNG and Indonesian gold properties.

Source: USBM estimates.

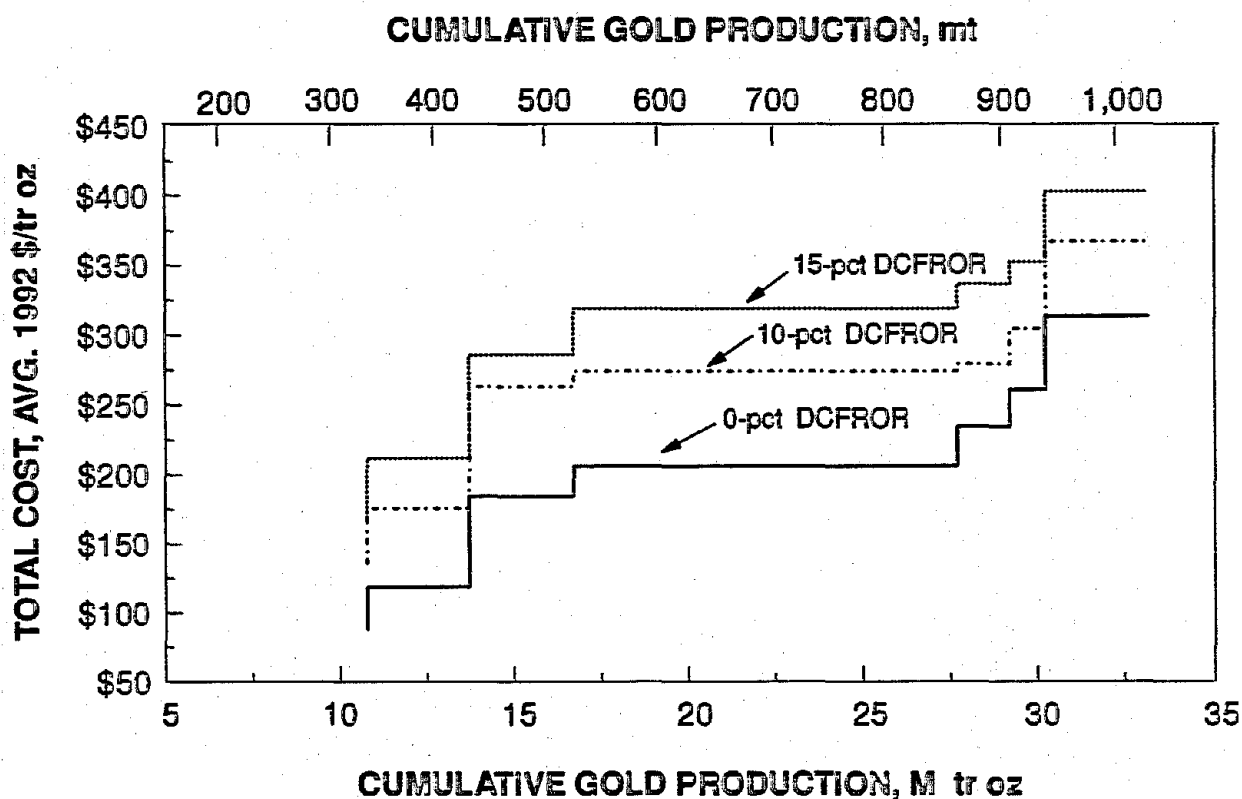


Figure 47.—Expansion Case: Potential gold availability for PNG and Indonesian gold properties.

Source: USBM estimates.

Macraes expansion, start-up of the Globe-Progress operation, and some additional small scale alluvial gold mining (178).

Philippine production is also expected to increase. The capital intensive Far Southeast Gold Resources copper-gold porphyry project is scheduled to start up in 1995 at an annual production rate of 70 mt (250 k tr oz) of gold and 30,000 mt of copper (179). The Didipio project could contribute 7.8 mt (250 k tr oz) per year (180).

Another prospect in the Pacific Basin area is the Namosi project in Fiji, which may be a very large Bougainville style copper-gold deposit. This deposit could add 6.2 mt (150 k tr oz) per year of gold beginning in 1999 (181). Sumitomo is developing a new discovery near the Hishikari mine in Japan but no estimated production figures have been published (167). There are several other smaller projects which may be developed in the Pacific Basin region. Gold production increases for the region are projected to continue, and will likely fall in the lower quartile of world gold mine production cost (182).

INDOCHINA OVERVIEW

Economic development has become the primary objective of the Indochina nations. One way to stimulate long term economic growth is to encourage development of mineral resources. The first step toward opening up to foreign investment in mineral resources is the development of mining legislation and fiscal regimes that provide a clear and direct framework for foreign companies to operate under. This is precisely the stage of development the Indochina countries have entered, the development of competitive mining legislation. It is presently difficult for companies to explore these regions due to poor infrastructure development and lack of comprehensive geological assessments of the mineral

potential of the region. Many of the Indochina countries are receiving help in assessing their mineral potential through funding by international agencies of geochemical and geophysical surveys as well as mapping programs (183). Previous gold mining production in the Indochina region has been low with no major gold operations. Potential throughout the region is variable, although Vietnam, Laos, Thailand, and Burma have generated significant speculative interest. Vietnam may have greater potential for iron ore and copper-gold deposits than for primary gold deposits since its known primary gold deposits are low grade. To date, Laos has probably the highest potential and most successful gold exploration. Availability of gold from this region will be dictated by the development of competitive mining legislation and fiscal policies which will permit a more comprehensive assessment of the region's mineral potential (184).

Mineral production in the Indochina area is below geologic potential (185). No consistent mineral and energy resource assessment program has been undertaken for any nation in the Indochina area and only Thailand has completed an airborne geophysical survey. This relative lack of mineral development is related to 4 factors:

- lack of infrastructure development;
- economies that are largely agricultural;
- government opposition to private investment in the mineral's sector; and
- relatively low levels of technical expertise and technology.

Table 49 provides a description of the transportation infrastructure development in the Indochina area. Official development aid may facilitate mining development in the Indochina area. This is for both the

Table 49.—Status of transport infrastructure in the Indochina area

Country	Railways	Roads	Waterways	Ports
Burma	Fair condition. Hub at Rangoon. Moderate network. Recent improvements.	Used moderately. Highway near Rangoon in good condition, others deteriorating quickly. Moderate network.	Used extensively. Difficult to facilitate regional trade.	Main port: Rangoon. Usage over capacity. Poorly laid out. Equipment outdated and deteriorating.
Cambodia	Poor condition. Limited network. Under-utilized due to condition.	Used moderately. Highway in poor condition. Secondary roads poor. Limited network.	Used moderately. Could be used for regional trade. Dredging needed. Not used to full potential.	Main port: Kampongson. Lacks modern equipment. Usage under capacity, but still very inefficient.
Laos	No railways.	Used extensively. Highways in fair condition. Secondary roads impassable. Very limited network.	Used moderately. Could be used for regional trade. Dredging needed. Not used to full potential.	No ports; landlocked.
Thailand	Fair condition. Hub at Bangkok. Moderate network. Limited recent improvements.	Used extensively. Highways in good condition, some secondary roads adequate. Extensive network.	Used moderately. Facilitates regional trade. Dredging needed. Not used to full potential.	Main port: Bangkok. Usage over capacity, with delays, congestion. New port planned to augment Bangkok.
Vietnam	Very poor condition. Connects north with south. Severely under-utilized due to condition.	Low utilization. Highways in poor condition, secondary roads unusable. Limited network.	Used extensively. Could facilitate regional trade. Dredging needed.	Main ports: Ho Chi Minh City and Haiphong. Ho Chi Minh: modern, good equipment, usage over capacity, expansion very difficult. Haiphong: lacks modern equipment, poorly laid out, due to be replaced if finances permit.

Source: Clark, et al (195).

construction of infrastructure and technical assistance for mineral exploration and development. An Asian Development Bank 5 year technical assistance grant included a provision for geological consultants to rank mineral resources and potential sites for exploration and development (183). Lack of an adequate transportation network represents a significant bottleneck for economic development.

INDOCHINA COUNTRY DISCUSSIONS

General country discussions and mining investment/operating environment information are provided in this section for all countries in Indochina. Additional detail will be available in the planned Open File Report. These countries include: Vietnam, Thailand, Laos, Cambodia, and Burma. Table 50 gives summary information on the geologic, economic and political conditions in the Indochina countries.

Vietnam

Vietnam does not have a unified mining code. The Australian government and the UN Development Program signed a deal to help the Vietnamese draft one. The new law was expected to be passed by the National Assembly by mid-1994. It will supplement the 1989 Ordinance on Mineral Resources, and the 1993 Land Law approved by the National Assembly. New entrants into Vietnam should first contact the embassy (184).

All minerals, wherever found, belong to the people of Vietnam and are managed by the government. As regulated by law in Vietnam, the land within a boundary of the province is under the control and management of the People's Committee of that province. The People's Committee only allocates the land in respect to the contract area after the joint venture or foreign party pays compensation to the land users or residents living in the contract area (184).

Foreign investors may be permitted to conduct geological

exploration by themselves or in cooperation with the local mining company. There are two state owned companies under the direct control of the Ministry of Heavy Industry, the Vietnam Precious and Rare Mineral Corporation (VMC), and the Mineral Development Corporation (MIDECO). These companies are responsible for management of existing mines, or development of mineral deposits in Vietnam and doing business with foreign investors. Foreign investors may enter into contracts with either VMC or MIDECO or a local mining company. Investors are subject to a variety of taxes in Vietnam. Exploration rights are gained through fees linked to the acreage being explored. During the mining phase, investors are required to pay royalties, income tax and a profit remittance tax. The highest income tax rate applies to larger companies producing goods for export. Foreign firms may receive a tax holiday of up to 4 years and the tax may be reduced by up to 50 pct for 4 years after receiving the first profit (186).

Thailand

The Department of Mineral Resources under the Ministry of Industry is responsible for the administration, promotion and development of the mineral industry in the country. In Thailand, minerals belong to the state and no one can explore for minerals or undertake mining unless a prospecting license or mining lease is first obtained (187).

A foreign owned or controlled business must obtain an Alien Business License if it wishes to engage in mining or exploration. As a general rule, foreign corporations are not granted concessions in their own right and therefore usually operate through subsidiaries incorporated in Thailand. Applicants for exploration licenses must pay fees for issuance of the license, and surface rental fees in advance for the area granted (187).

A mining lease is required in order to exploit any ore deposit

Table 50.--Summary comparison of the countries in the Indochina area

Country	Geologic gold potential	Minerals policy	Physical infrastructure	Economic stage	Country risk	Foreign investment provisions	Political structure
Vietnam	Medium - high; gold deposits are low grade	In preparation . . .	Fair	Low-income .	Moderate	Exists	Centrally planned.
Thailand	Medium - high . .	Well-developed .	Good	Middle income	Low	Exists	Constitutional monarchy.
Laos	Medium	Being drafted . . .	Poor	Low income .	Moderate	Exists	Centrally planned.
Kampuchea .	Low	None	Poor	Low income .	High	None	Centrally planned.
Myanmar . . .	Medium high . . .	None	Fair	Low income .	Moderately high . .	Exists	Centrally planned.

Source: Clark, et al (185).

found. Before a lease is granted, it is necessary to obtain the consent of the owner or possessor of the land in which the deposit has been found. It is also necessary to obtain an environmental impact study from an approved company or organization. The applicant must pay a fee for the lease and surface rental fees for use of the land yearly in advance. A leaseholder may not sublease or transfer the mining operation without the approval of the Minister. A lease is valid for a period not exceeding 25 years (187).

Mineral revenues are collected by the government through the Royalty Rates Act. Royalties are not considered to be a tax but a compensation due to the government for minerals deemed to belong to the state. The rates range between 2 pct and 20 pct (187).

A company involved in mining is liable to pay corporate income tax under the Revenue Code. Generally companies pay a flat rate of 30 pct of net profits.

In October 1991, Thailand passed a value added tax which is levied at each stage of the production and distribution chain but with full tax credit. The initial standard rate applied by the government is 7 pct. Dividend payments to overseas shareholders are generally subject to a withholding tax of 10 pct (188).

Laos

The draft mining code in Laos envisions specific taxes and levies for the mining sector. The new fiscal regime is clearer and easier to understand. The tax burden appears to be competitive by international standards. The draft mining legislation was prepared by the World Bank and the Asian Development Bank and is expected to be passed soon. This should make it more attractive to small and medium size investors who prefer working with an established mining code. The code specifies the

rights and obligations of parties to a mining venture as well as the general administrative and regulatory powers of the government (189).

In summary Laos has:

- good mineral potential;
- attractive incentives and a competitive fiscal regime for the mining sector under the new mining code;
- increasing readiness on the government's part to reform and restructure the political, administrative, and economic structures;
- a new 'open door' policy towards foreign investors. Exploration and mining agreements signed in Laos to date contain basic provisions reiterating the ownership of mineral resources by the Laotian nation and the conditions for development of these resources through agreements between the State, represented by the relevant ministerial department and the investor.

The majority of agreements concluded have been joint ventures. The government reserves the right to participate in mining operations and activities and can do so on a carry through basis of up to 5 pct of total equity of the investment. Alternatively the government may participate in a cost sharing venture where its participation could reach up to 35 pct (190).

SUMMARY AND CONCLUSIONS

World-wide political and economic changes are impacting regional minerals industries in a number of ways. Recent slow growth rates in the global economy can be linked to reduced prices and, in some cases, reduced demand for mineral commodities. While the price of gold has recently experienced a moderate rebound, major mining companies continue to explore with reduced budgets. The

reduction in budgets is accompanied by an associated reassessment of the risks and potential of exploration areas throughout the world and the re-targeting of budgets on those countries perceived as having the lowest risk and the greatest potential.

Countries in the Asia-Pacific area which have been most severely impacted by these global economic changes are PNG and the Philippines. A higher level of country risk, adverse changes in mining legislation, and high taxation and/or royalties have resulted in reduced levels of mineral exploration and mining investment in those countries and production declines between 1992 and 1993. PNG is no longer the "hot spot" and must vie with other prospective gold producing regions to attract exploration expenditures.

The key factors most impacting the availability of gold from the Asia-Pacific region are:

- high geological potential,
- adequacy of infrastructure,
- remoteness of many exploration targets,
- legislative climate,
- limited availability of skilled labor, and
- political stability.

Table 51 provides a comparison of the most important foreign investment factors in the Pacific Basin countries.

The Asia-Pacific region is highly prospective geologically. The most attractive and desirable type of exploration targets in this region are epithermal gold deposits. These deposits are generally higher grade and tend to have, relative to other regions, longer mine lives. Examples of this type of discovery are Forgera and Lihir in PNG and Misel and Kelian in Indonesia. New Zealand's Coromandel Peninsula is still

largely unexplored but considered prospective for epithermal targets.

Copper-gold porphyry deposits are also a target of much exploration activity. These deposits tend to be very large, as in the case of Ok Tedi and Grasberg/Ertsberg, with mine lives often exceeding that of epithermal deposits. However, only a couple have been found over a period of exploration spanning decades. Low-grade bulk-tonnage disseminated deposits such as Misima can be attractive if they are easily accessible. However, Misima does not appear to be typical for the region.

The cost of exploring and developing operations in the Pacific Basin countries is relatively high. The lack of adequate infrastructure and rugged terrain makes many of the Pacific Basin countries expensive to explore. Exploration costs reflect the logistical difficulties inherent in remote, mountainous and thickly vegetated terrain that prevails in the Pacific Basin. This results in a very high cost of work since there is no way that the ground can be evaluated rapidly and cheaply in these regions. Sometimes these higher infrastructure costs can be offset by factors such as favorable power costs as in New Zealand.

Indonesia is a difficult country to explore. Elevations near the Grasberg operation are 15,000-16,000 ft. Similarly, steep rugged terrain is characteristic of the interior highlands of PNG. Excessive rainfall is just one of the climatic conditions which can affect operating in this region. Sometimes torrential downpours can make it too difficult to mine, and flotation and leaching units must be covered. Also, the region is located in a high seismic zone.

Mining legislation can have a big impact on investment in a country. PNG has the Mining Development Agreement which protects foreign investors against expropriation and guarantees rights to remit earnings, capital, and certain expenses in foreign

Table 51.--Summary comparison of the Pacific Basin countries

Country	Production growth	Exploration potential	Country risk	Legislative effects	Infrastructure cost	Economic growth	Taxes
Papua New Guinea . .	Growth anticipated from known projects.	High.	High.	Well-developed mining law.	High cost, poor infrastructure.	Very strong.	High tax.
Indonesia	Growth expected from exploration success.	High, poorly explored.	Attractive country for mining investment.	Mining law has set pattern for other Pac-Rim countries.	High cost, poor infrastructure.	Very strong.	Moderate, competitive.
New Zealand	Expect moderate expansion.	Medium.	Low.	Fairer, more balanced development legislation.	Low except in rugged terrain.	Moving out of stagnant growth period.	Moderately high.
Philippines	Stagnant.	Good potential.	High.	Problematic with equity ownership requirement; may be revised.	High cost in remote areas.	Moderate.	High taxes and royalties.
Malaysia	Growth expected if government reforms occur.	Good potential, particularly in East Malaysia.	Moderate.	Under review and being modernized.	Well developed in West Malaysia; expect higher cost in East Malaysia.	Strong.	Moderately high.
Fiji	Growth possible if Placer develops Namosi.	Medium.	Somewhat turbulent.	Formulated to encourage development.	Most well developed of the Southwest Pacific Island nations.	Dependent on a few major commodities.	Moderate.

Source: Clark (133).

exchange. PNG is one of the few countries which has an excess profits tax on a project return over 20 pct.

The Indonesian government recognized the desirability of foreign investment to accelerate development of natural resources some decades ago and has evolved a number of practical, flexible, and effective approaches, such as the Contracts of Work (COW) and Production Sharing Agreements, in order to attract such investment.

The Indonesian COW's are being copied in Malaysia, Thailand and other countries in the Indochina region. Laos also has a type of agreement similar to the Indonesian COW. The Indonesian government went through a period of making the terms of the COW's less and less attractive until foreign investment in minerals exploration began to decline strongly. Still, the terms of the current generation COW are attractive enough that it compares very favorably with the investment incentives of neighboring countries.

This contrasts with the Philippines where a requirement for immediate local equity of 60 pct is a major obstacle to foreign investment. Taxes and royalties in the Philippines are also higher than for other countries in the region. Though new legislation is currently being drafted, this has had a negative impact on mineral investment.

In terms of country risk, the investors must be confident that the rules will not change significantly. Detrimental ad hoc policy changes, that are imposed after project agreements have been signed, are a disincentive to further investment and do not promote an image of consistency in governmental policy and commitment.

Examples of this in PNG are the changes in migration policy and changes to aviation policy in contravention of existing agreements, and the land tenure disputes such as the recent Mt.

Kare incident regarding landowner identification and land negotiations associated with resource development.

One of the positives of operating in the Asia-Pacific region is the availability of an inexpensive work force, especially when compared to the high cost of using expatriate employees. The employment situation is favorable partially due to high unemployment levels and lack of alternative, well paying jobs.

Once in operation, the labor component of production costs is lower than for other regions, averaging around 23 pct of total production cost. However, a lack of a trained workforce and high training costs are major considerations when operating in the Asia-Pacific region. Most countries in the region have requirements related to the use of nationals, somewhere in the range of 60 to 85 nationals per expatriate employee. Normally, there are also requirements to show that nationals are being given training for advancement into higher level positions.

The problem of artisanal miners squatting on near-surface deposits of high-unit-value commodities such as gold occurs in both PNG and Indonesia. It is less of a problem than in the Philippines where firearms are far more readily available.

Law and order is an important criteria for consideration of mineral investment in the emerging regions. Situations where the company must basically act as its own police force in outlying areas, such as is occurring in countries such as the Philippines and some parts of PNG and Indonesia, are viewed as high risk. This has affected the exploration investment levels in these countries with some major multinationals refusing to send their staff into these countries.

Social issues are an important aspect also. In isolated rural

areas of some emerging countries, the company is cast in the role of a surrogate government. This situation places the company under great pressure to provide basic infrastructure which intensifies markedly as the project progresses towards development. In recent years, these kinds of demands have intensified and are arising earlier in the project life.

CHAPTER 8

GOLD IN CHINA AND THE FORMER SOVIET UNION

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GOLD IN CHINA

Two major characteristics of the Chinese gold industry are the predominance of local mining operations and the lack of direct marketing procedures and/or capabilities. According to the U.S. Bureau of Mines, the 1993 gold production was 160 mt, nearly 7 pct of world production (fourth largest in the world) (4). This continues the major expansion over the last four years from production levels of 55-90 mt that prevailed throughout the 1980's.

The Ministry of Metallurgical Industry (MMI) controls the larger gold mining operations. Other gold operations can be controlled by any of three levels of Gold Bureaus: State (National), Provincial, and regional. In 1988, the State Council reorganized the gold sector. Exploration and production management are now separated from the government and were organized into several levels of state-operated gold companies under the China National Gold Corporation (CNGC) (191). The National Gold Administration Bureau (NGAB) is under the joint management of MMI and the State Council's Special Gold Task Force Group, and is responsible for marketing, research, and development activities.

There are 15 provincial gold Bureaus in China, coinciding with

each of the major gold producing provinces. Administratively, the gold Bureau is under each provincial government, but it is also functionally under the direction of the NGAB. These 15 Bureaus are divided into 2 groups. Group I consists of eight provinces and autonomous regions: Heinan, Hunan, Jilin, Nei Mongol, Shandong, Xizang (Tibet), Xinjiang and Yunnan. Each gold Bureau in Group I is under the total control of the provincial government. Group II is made up of 7 provinces: Guangxi, Hebei, Heilongjiang, Henan, Liaoning, Shaanxi, and Sichuan. Gold Bureaus in Group II form a separate NGAB production center within the provincial government.

There are approximately 460 known significant gold operations in China; 88 pct of them are under local government control and have daily capacities of less than 200 mtpd of ore (192). Eight provinces produce over three-quarters of China's gold. The Shandong province accounts for a full 25 percent (193). Table 52 lists the most significant of China's large deposits.

According to the Chinese gold deposit classification scheme, small capacity mines range between 100-250 mtpd of ore and are usually managed by local government groups. Medium capacity mines range from

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Table 52.--Deposits of significance in China with at least 5 Mmt of ore in resources or a daily capacity of greater than 500 mtpd

Province	Property name	Type of operation	Status
Guizhou	Lannigou Gold Mine	Underground	Dev. deposit.
Hebei	Jinchanggu Gold Mine	..do.	Producer.
Heilongjiang	Wulaga/Tuanjiegou Gold Mine	Surface	..Do.
Henan	Qingling Gold Mine	Underground	..Do.
Do.	Wenyu Gold Mine	..do.	..Do.
Hunan	Xiangxi Gold Mine	..do.	..Do.
Jilin	Jiapigou Gold Operations	..do.	..Do.
Do.	Xiaoxinancha	Surface/Underground	..Do.
Liaoning	Wulong Gold Mine	Underground	..Do.
Shandong	Changshang Gold Mine	Surface	..Do.
Do.	Hexi Gold Mine	Underground	..Do.
Do.	Jiaojia Gold Mines	..do.	..Do.
Do.	Laizhou Gold Operations-6	..do.	..Do.
Do.	Lingnan Gold Mine	..do.	..Do.
Do.	Longkou City Gold Operations-4	..do.	..Do.
Do.	Luoshan Gold Mine	..do.	..Do.
Do.	Muping County Gold Operations-8	Surface/Underground	..Do.
Do.	Rushan County Gold Operations-8	..do.	..Do.
Do.	Sanshandao Gold Mine	Underground	..Do.
Do.	Xincheng Gold Mine	..do.	..Do.
Do.	Zhaoyan Gold Mine	..do.	..Do.
Do.	Zhaoyuan County Operations-17	Surface/Underground	..Do.
Sichuan	Baishui Gold Mine	Surface	..Do.
Do.	Zhangla Gold Mine	..do.	..Do.

Source: Cui (192), Tien (193), and other various available public documents.

250-500 mtpd of ore, and are usually managed by the province. Large capacity mines range from 500-1,500 mtpd of ore and are managed directly by CNGC. All gold bullion produced in China is sold to the People's Bank of China, at a price set by the Bank based on world prices, for refining and marketing.

The majority of gold deposits mined by underground methods are hydrothermal quartz vein type. Various stoping mining methods are employed depending on the geology of the ore body. Refractory ores and ores with high arsenic present recovery problems. Although technology exists to handle these problems, the relative high costs make it prohibitive at the present time. The limited involvement of foreign mining companies in China's gold industry means there is limited access to foreign capital and technology for processing these more complex ores.

Prior to 1993, each gold operation had a quota to fulfill, and the assigned tonnage was sold to the Bank at a price lower than the world market price. If the production exceeded the quota, the surplus gold would get a higher price according to a set formula. China plans to improve production by expanding existing operations and improving the efficiency of management.

According to the USBM country specialist, China also plans expansion of its nonferrous metals industry in the next several years. It is expected that national laws would be changed to allow foreign investors in the exploration and development of China's minerals. Under the current regulations, gold information is considered a state secret. The Chinese government does not reveal geological reserves of gold nor statistical data on gold production. However, this may change if certain gold deposits need high technology and funds for development (191).

Based on a variety of information sources, there are potential gold resources in several regions of China, but advanced

exploration technology is necessary for delineating these resources (table 52 for partial listing). Many of the deposits will require large investments for development, and most of the mining and processing equipment for large scale operations will have to be imported. The Chinese gold industry is seeking foreign investment by means of joint venture to explore and develop. The huge bureaucracy that still exists may make this difficult.

GOLD IN THE FORMER SOVIET UNION

The gold industry has long been an important factor in the overall economic structure of the former Soviet Republics and has become even more critical with the breakup of the Soviet Union. The Soviet government gave priority to gold production in order to meet foreign credit obligations.

Historical production numbers were not made available by the former Soviet government, but estimates made by Bureau specialists show only a small increase between 1980 (when 265 mt of gold were produced) and 1989 (the peak production year at about 304 mt). A somewhat reduced level of gold production (260-300 mt) has been estimated for all years since 1990 (24).

Many gold mines are operating in the Former Soviet Union (FSU). Table 53 gives a partial listing of the most significant large deposits identified in the Bureau's Minerals Availability data base. Gold is recovered from lode and placer deposits as well as a byproduct of base metal mining. Russia is reported to produce about half of total gold output from the former Soviet Republics, with Uzbekistan at about a third, Kazakhstan at 11 pct and Kyrgyzstan at 2 pct of the total (196).

Russian production comes mainly (90 pct) from alluvial placer deposits in the Magadan (Northeastern Russia), Yakut-Sakha (Siberia), and Amur (Southeastern Russia) regions. More than half of

Table 53.--Deposits of significance in the FSU with at least 30 mt of contained gold in reported resources

Republic	Property name	Type of operation	Commodities	Status
Armenia	Zod	Surface/underground	Au	NA.
Kazakstan	Akbakay	NA	Au	Producer.
Do.	Bakyrchik	Surface/underground	Au-Ag	..Do.
Do.	Leninogorsk	Surface	Au-Ag	..Do.
Kyrgyzstan	Dzheruy	NA	Au	Developing.
Do.	Kumtor	NA	Au	..Do.
Do.	Makmal	Surface	Au	Producer.
Russia	Adycha River	NA	Au	..Do.
Do.	Allakh-Yun	NA	Au	..Do.
Do.	Dambuly	NA	Au	..Do.
Do.	Dukat	Surface/underground	Au-Ag	..Do.
Do.	East Kolyma Placer	Placer	Au-Sn	..Do.
Do.	Mailsky	NA	Au-As-Sb-Ag	Developing.
Do.	Nezhdanino	NA	Sn-W-Au-Ag-Zn	Producer.
Do.	Oktyabrskysy Group	NA	Ag-Au	..Do.
Do.	Olimpiadninsky	NA	Au	..Do.
Do.	Peschanka	NA	Cu-Au-Ag	Exp. Pros.
Do.	Pyrkakai	NA	Au	Developing.
Do.	Rogovik	NA	Ag-Au	Exp. Pros.
Do.	Susman Placer Deps.	Placer	Au	Producer.
Do.	Ukokan Copper Field	Prospect	Cu-Au-Ag	..Do.
Do.	Unnamed Placer Reg.	Placer	Au	..Do.
Uzbekistan	Charmitan	Underground	Au	..Do.
Do.	Dalnee Deposit	Surface	Cu-Au-Mo-Ag	..Do.
Do.	Kalmakir Mine	..do.	Cu-Mo-Au-Ag	..Do.
Do.	Muruntau	..do.	Au	..Do.

NA Not available.

Source: Borodaevskaya and Rozhkov (194), Nokleberg (195), Interfax (196), and other available public documents.

Uzbekistan's gold production comes from lode deposits, with less than 1 pct from placers. The largest operation in Uzbekistan is the Muruntau primary surface gold mine, which treats over 17 million mt of ore per year (196). Most of Kazakhstan's gold production comes as a byproduct of copper and lead/zinc mining.

There appears to be great potential for growth of the gold industry of the FSU. Many new placer and lode deposits are being proposed for development while at the same time new mining techniques are being investigated to recover the gold from permafrost areas without damaging the environment. Huge waste areas from old mining operations have also shown much potential as a source of significant gold amounts.

Placer mining in the Russian Far East is similar to that in Alaska, but on a much larger scale (197). Many Russian gold operations are huge. At least 400 million m³ of frozen overburden and ore are moved annually in Magadan (197). Much of the former Soviet Union is affected by harsh weather conditions, resulting in a 4-5 month mining season for many gold producing regions. Overburden is removed in the winter months using drilling, blasting and scraping, then the gold-containing gravel is transported to sluice or washing installations. Ore often remains frozen, and must be allowed to thaw on the surface before being treated. Underground placer mining is used when the overburden is thick and the ore bed is at least 1.3 meters thick (198). Underground placer operations can continue year-round since equipment is protected from the harsh weather.

Mechanized mining methods are employed where practical; however, gold mining is performed by comparatively lightly mechanized "artels" in more rugged or inaccessible areas. Artels are much like the Garimpeiros of Brazil. They are groups of individual gold miners working

under contract to larger enterprises. They work independently to prospect and recover gold values from designated placer deposits. Because their pay is tied directly to gold produced, artels typically have higher productivity rates. It is estimated that artels account for over half of Russia's total gold output (198).

Much like the emerging economies of Latin America and Southeast Asia, revenues from the export of natural resources provide major sources of foreign exchange. Traditionally, the FSU has exported gold by selling to Swiss banks affiliated with the Zurich gold market. The breakup of the Soviet Union and the need for hard currency has forced the Republics to turn to Western sources for gold sales, investment and equipment. Gold is now sold directly to a number of foreign sources for hard currency.

There are several problems which face the FSU in maintaining as well as attempting to expand the gold industry. They are:

- Decentralization and the issue of control of the gold resources; the breakup into independent states has caused serious problems for some of the Republics that were not well endowed (199).
- Production losses have been sustained with the breakup because of the uncertainty of wages and payments to the workers, causing strikes, etc.
- Lack of capital, deteriorating equipment, maintenance facilities with inadequate supplies of fuel, power sources and consumables are par for the course.
- Environmental problems include (20):
 - arsenic contamination and disposal,
 - cyanide waste disposal,

- sulphur dioxide emissions from metallurgical plants,
- tailings disposal, and
- water contamination from large scale dredge operations.

Future production of gold in the FSU depends upon the domestic gold industry's ability to produce under conditions more oriented towards the Western economic system, as well as their ability to import raw materials (20). The FSU gold industry is also dependent upon the availability of capital and a reliable transport network. The industry will and must undergo further restructuring.

Each Republic has expressed its own goals for the industry, and has its own approach for maintaining output levels. Russia recently offered tenders to foreign investors on significant gold properties and revised laws on foreign investment. Uzbekistan developed plans for new property development and to build a new refinery. Additional increases in production should come from the introduction of Western cyanide leaching technology to process the vast waste dumps. Kazakhstan announced similar mine development plans to quadruple gold production by 1997. Other Republics have also given priority to developing gold deposits within their territories. If the FSU is successful in acquiring just a portion of the capital it needs for mine development, it is likely that a world class gold industry will remain intact and possibly produce even larger quantities of gold.

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