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EXPLORATION FOR NONFERROUS METALLIC MINERALS

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Costs are an important determinant of international competitiveness in mineral production. A mineral producer with relatively low production costs, here defined to include all fixed and variable costs associated with supplying metal to the market, will have an advantage over producers with higher production costs. Over the longer term, costs will be determined largely by advances in technology and by the success of exploration. Both factors tend to reduce costs compared to what costs would be in the absence of technological change or exploration success. Thus, the level and success of exploration today is an important determinant of international competitiveness tomorrow.

In an ideal world of textbook economics, exploration activity would flow smoothly from one geographic area to another over time in response to changes in the economic and technologic factors influencing the potential economic returns from exploration including, for example, expectations about future mineral prices; technologic changes altering expected costs of exploration, development, and production; and advances in geologic knowledge that lead explorationists to search for mineral deposits in areas previously thought unlikely to contain ore mineralization.

In practice, government policies also influence the location of mineral exploration around the world. Some policies, such as those that authorize government collection and dissemination of basic geologic information, stimulate exploration in a country, whereas others, such as restrictions on access to prospective lands, discourage exploration.

This paper examines how government policies influence the incentives facing explorationists. To do so, it reviews worldwide trends in mineral exploration between 1960 and 1990, and then evaluates the role that government policies and activities play in the location of exploration.

EXPLORATION TRENDS

In the three decades since 1960, trends in the level of mineral exploration worldwide have mirrored the general state of the mining industry. The available data on exploration expenditures for metallic minerals (Figures 1-4) reveal two broad similarities among countries and organizations. First, during the 1960s and 1970s expenditures trended upward, while during the 1980s there was a sharp fall. Second, exploration expenditures have been cyclical, particularly in Australia and Canada, less so in the United States and for a group of European mining companies.

Trends in nonferrous metal prices are notably similar to these exploration trends (compare Figure 5 with Figures 1-4), and mineral prices undoubtedly are responsible for the broad similarities worldwide in exploration, for two very different reasons. First, exploration in most organizations is motivated by the prospect of economic gain, and the level of exploration activity reflects expectations, albeit crude and generally unquantified, about potential profits to be made from discovering and developing (or selling) an ore deposit. Of the factors influencing the potential revenues, costs, and risks associated with exploration (and thus profits), mineral prices are the one common factor among nearly all countries. The argument is that expectations about future mineral prices, i.e., those that will determine the profitability of any deposits discovered or evaluated with current exploration expenditures, are strongly influenced by current and recent prices.

The second way in which mineral prices influence the level of exploration activity is through their impact on mining company revenues and in turn the availability of internal funds for exploration. Mining revenues tend to go up and down along with mineral prices over the course of the business cycle, and when prices and revenues are high, companies tend to spend more freely on exploration than when prices and revenues are low.

These aggregate trends in the level of metallic mineral exploration mask important differences in exploration for specific minerals. The 1960s and early 1970s were highlighted by exploration for bauxite, the raw material from which aluminum is produced, and the base metals copper, lead, and zinc. Bauxite exploration actually began on a large scale in the 1950s, as aluminum demand grew rapidly, traditional sources of bauxite were being depleted, and reductions in ocean freight costs permitted explorationists to search outside areas of historical production. Advances in the Bayer process of alumina refining also influenced exploration. Prior to the 1950s, the Bayer process required bauxites (Al_2O_3 + water + impurities) containing greater than 55 percent available alumina (Al_2O_3) and less than 8 percent Fe_2O_3 and 2-3 percent silica. Improvements in the process permitted use of an entire new class of bauxites, known as aluminous laterites, containing as little as 30 percent available alumina and as much as 28 percent Fe_2O_3. The aluminous laterites now account for the majority of bauxite production worldwide. Most of the successful exploration occurred in Australia, Brazil, and western Africa (particularly Guinea). Many if not most of the deposits explored in these areas were not actually discovered in the 1950s and 1960s; rather mineralization had been known to exist for a long time, but prior to growth in aluminum demand, improvements in alumina refining, and reductions in ocean freight costs these mineral occurrences were too remote or low-grade to warrant detailed exploration and possible development. Since the early 1970s, there has been virtually no bauxite exploration, and the little that has occurred has focused on extensions of existing mines or development of known deposits. Bauxite exploration came to a halt because of the abundance of known bauxite reserves and resources relative to expected growth in aluminum demand, the result of successful exploration in the 1950s and 1960s and slower growth in aluminum demand since the early 1970s (see Eggert, 1985).

Exploration for porphyry copper deposits, a particular geologic type of deposit in which copper grading 0.5 - 2.0 weight percent is contained in a granitic igneous rock, was also particularly strong during the 1960s and early 1970s, following significant exploration in the 1950s. More than 20 porphyry copper deposits were discovered in the United States alone, with other deposits discovered around the world in places like Argentina, Canada, Chile, Indonesia, Iran, Panama, and Papua New Guinea. Metal produced from these discoveries -- along with stagnating copper demand and higher capital costs for large low-grade porphyry deposits relative to smaller higher-grade deposits -- contributed to lower copper prices (see Figure 5) and declining exploration for porphyry copper deposits in the late 1970s and 1980s (see Rose and Eggert, 1988).

Exploration for massive sulfide deposits -- generally smaller and higher grade than porphyry copper deposits and typically containing significant amounts of copper, lead, zinc, gold, and silver -- was considerable during the 1960s and early 1970s, but accounted for nearly all base-metal exploration in the late 1970s and 1980s. The primary advantage of massive sulfide deposits over porphyry copper deposits was lower unit capital and energy costs because of their higher grade and smaller size. As metal demand and prices became increasingly difficult to forecast in the middle 1970s, companies re-oriented exploration activities to deposits promising a quicker repayment of capital costs. Also, the often significant precious metal content of massive sulfide deposits provided additional incentives to discover or prove up these deposits during the late 1970s and 1980s when gold prices were high in historical terms relative to most other metal prices.

The search for uranium dominated exploration in the late

1970s. Expenditures on uranium exploration worldwide increased six-fold (in real terms) between 1972 and 1979, stimulated by the first civilian uses of nuclear power in the late 1960s and the expectation of continued and significant growth in nuclear power over the next several decades. The level of uranium exploration paralleled the path of uranium prices (Figure 6). The bottom fell out of uranium exploration in the early 1980s following (a) successful exploration and enormous additions to uranium reserves, particularly in Australia and Canada, and (b) lower projections of capacity growth for nuclear-power plants due to slower-than-expected growth in electricity demand and growing disenchantment in many countries with nuclear power (see Eggert, 1987; Schramm, 1989).

Exploration in the 1980s was dominated by the search for gold. In Australia, Canada, and the United States, gold exploration accounted for significantly more than half of total exploration expenditures for metallic minerals during this period (Figures 2 and 3). Three factors largely explain the boom in gold exploration. The first and most important is the price of gold. Between 1934 and 1968, the price of gold was controlled at $35 per ounce and thus it fell in real (inflation-adjusted) terms. Since then, gold prices have fluctuated freely and have been considerably higher (Figure 5). The impact on exploration was to redefine the meaning of gold ore. What previously was merely subeconomic gold mineralization became an ore deposit, simply because the price of gold rose. Much if not most gold exploration has involved re-examination of areas of historical gold mining or known gold mineralization.

The second factor stimulating gold exploration has been improvements in leaching and carbon-in-pulp recovery techniques, lowering the costs of extracting gold from the low-grade deposits typical of nearly all recent discoveries or re-discoveries. Finally, advances in exploration techniques have improved the ability of explorationists to locate and evaluate gold deposits. For instance, improved geologic models of gold occurrence in sedimentary and volcanic rocks more efficiently guide explorationists to areas with a high probability of containing gold mineralization (a geologic model is a set of physical and chemical attributes of a typical deposit, allowing explorationists in effect to predict where ore should occur). Also, in the field of exploration geochemistry, it is now possible to reliably measure chemical elements associated with gold mineralization in the parts per billion (ppb) range.

The foregoing descriptions of exploration for base metals, uranium, and gold suggest that exploration for particular minerals or geologic-deposit types is episodic. An episode begins with an incentive for increased exploration activity, such as a rise in expected future demand or prices, improvements in the geologic models that guide the early stages of exploration, or advances in the technologies of exploration, mining, and processing that alter the costs of finding or producing a particular mineral or deposit type. Initial discoveries follow, either in areas of known mineralization or mining or in areas previously thought to have little potential for mineralization. In this latter case, initial discoveries may lead to dramatically higher exploration activity as imitators rush in to try to duplicate the success of the discoverer. Eventually, however, further discoveries discourage additional exploration by increasing the stock of reserves and known resources. Falling prices and demand also may bring an episode of exploration to an end.

The discussion to this point has focused on trends in the level of aggregate exploration expenditures and the distribution of these expenditures among particular minerals or geologic deposit types. A third important aspect of exploration trends is the geographic distribution of activity. A sense of how the geographic allocation of expenditures has evolved over time is given by data from a group of European mining companies (Table 1) and groups of Canadian and U.S. companies (Table 2). These data must be used with caution. The composition of the company groups has changed over time, and the groups do not represent all mining companies from Europe, Canada, and the United States. Furthermore, the relative magnitude of exploration in areas other than Europe, Canada, and the United States undoubtedly is understated, perhaps considerably; in Australia and Latin America, for example, domestic private and state-owned companies conduct considerable amounts of exploration that is excluded from Tables 1 and 2. Finally, the data from Canadian and U.S. companies overstate the relative importance of exploration in the home country because in some but not all cases exploration by U.S. subsidiaries of Canadian companies is considered exploration by a U.S. company; the same is true in some cases for Canadian subsidiaries of U.S. companies.

This review of exploration trends focused strictly on the economic and technologic factors influencing the level and distribution of exploration activity. Within a particular country, however, government policies also influence the level of exploration, and the paper turns now to the impact of these policies on exploration.

GOVERNMENT POLICIES AND THE LOCATION OF EXPLORATION

Various types of organizations and people explore for minerals -- lone prospectors, large multinational companies, and smaller domestic companies in the private sector; state-owned companies; government-sponsored geological surveys; and international organizations. The focus here, however, is only on the private sector. This section of the paper identifies the factors that influence an explorationist's choice of where to explore and then examines the effects of government policies and activities on these factors.

Policies Affecting Geologic Potential

The first and most important determinant of where exploration occurs is geologic potential. A government can do nothing to alter a country's mineral endowment. But its policies can contribute significantly to knowledge of this endowment. Government-sponsored geological surveys have an important role to play in providing the basic geologic information on which explorationists base their perceptions of geologic potential. The private sector alone is likely to underinvest in the generation of basic geologic information from the perspective of society as a whole because some of the benefits of new information will not be captured by the private organizations collecting the information. (The benefits of later-stage exploration, however, come largely in the form of economic deposits, and the private sector is likely to invest the socially optimal amount in these activities because it will receive nearly all of the benefits from this investment.)

<u>Policies Affecting the Investment Environment</u>

Geologic potential is a necessary but not sufficient condition for exploration to be carried out in a country. The second necessary condition is a satisfactory investment environment, which obviously is influenced by government policies and activities. The political determinants of a country's investment environment from an explorationist's perspective can be grouped into three categories -- mining laws and related rules and regulations that govern exploration, development, and mining; other rules influencing the mineral sector but designed largely with other purposes in mind, such as environmental and land-use regulations; and political risk.

<u>Mining Law</u>. Mining laws typically contain provisions for (1) ownership of mineral resources, (2) conditions under which exploration, development, and mining occur, and (3) mineral taxation. These laws influence the location of exploration because of their impact on the potential profitability of discovering and developing (or selling) an ore deposit.

Mining law dates back to at least the second century B.C. and the Egyptian civilization. Over the centuries, two traditions of mining law developed. The first is known as regalian law, under which the government owns or at least controls all subsurface mineral resources, regardless of who owns the surface estate. The government typically authorizes exploration, development, and mining through some type of concession, lease, or other arrangement, and usually has significant discretionary authority over whether or not development and mining of a deposit will occur. The government also normally collects a tax on mineral production. Examples of regalian mining law are the French and German mining laws developed in the 19th Century, as well as the Spanish mining ordinances that governed most mineral development in Latin America.

The second tradition of mining law is common law, developed in England. Subsurface mineral rights are not separated from the surface estate (i.e., private ownership of mineral resources is permitted) and the right to extract minerals comes with ownership of the surface.

During the 20th century the regalian tradition and its modern-day extensions have become more influential at the expense of the common-law tradition as governments have become increasingly involved in mineral-development decisions. In the first half of the century, most countries with common-law traditions in mining -- such as England, Canada, and the United States -- incorporated elements of regalian law into their mining law. In the last decade or so, a number of developing countries have extended the regalian traditions of government ownership of mineral resources and discretionary authority over mineral development to include negotiations between mining organizations and the government. These negotiations may cover a wide variety of issues, including work commitments and schedules for exploration, taxation, government equity participation, and training and employment of the local populace (see Mikesell, 1984, and Brown, 1986). The trend has been for host governments to require increasing amounts of geologic information to be turned over to government once exploration has ended and to place stringent work requirements on explorationists to discourage holding of exploration acreage without serious exploration.

Government ownership of mineral resources by itself has not deterred mineral exploration. Rather, growth in the discretionary authority of governments to halt or impede mineral development even after significant exploration has occurred certainly has influenced decisions on where to explore.

Other Policies. One of the important ways in which governments now exercise their discretionary authority over mineral activities is through policies designed largely with other purposes in mind. The most important examples are comprehensive land-use regulations and environmental policies. Of the two, land-use regulations have a greater direct effect on exploration because they often influence the availability of land for exploration. The United States provides a good example, described in the next section. Environmental regulations influence the location of exploration less directly, through their impact on the economic attractiveness of mining and mineral processing in a particular country.

Political Risk. Government policies per se do not influence perceptions of political risk. Rather it is the likelihood of change in policy that is important here. Although political risk is an important consideration when choosing where to explore, it is largely outside outside the scope of this study. The interested reader is referred to a large literature on political risk evaluation and management (see, for example, Ghadar and Moran, 1984; Jodice, 1985; Kobrin, 1979).

ISSUES AND EXAMPLES (To Be Completed)

The study turns now to detailed assessments of specific issues through the use of case studies.

Access to Land for Exploration: the United States, the Mining Law of 1872, and Recent Land-Use Policies

Exploration on U.S. federal lands for metallic minerals, except for uranium, has been governed by the remarkably durable General Mining Law of 1872, which provides for free and open access for claim staking and exploration subject to a minimal amount of annual work and several other requirements. Claim holders can acquire fee title of the surface and subsurface resources if they demonstrate that an economic deposit exists, but ownership is not required for development or mining.

Over the last several decades, exploration and mining have lost much of their dominant-use status on federal lands. Policies originally designed to develop the western part of the country, where more than 90 percent of federal lands lie, have given way to policies aimed at conservation and preservation.

Some observers have argued that the Mining Law of 1872 is at least partly responsible for the restrictiveness of certain conservation and preservation policies, while much of the mining industry refuses to discuss any change in the Mining Law, fearing that this would open up a Pandora's Box of change.

In 1990 the latest of many attempts to reform or replace the Mining Law is receiving serious consideration in Washington. This section of the paper will evaluate the impact of U.S. federal land use policies on access to land for exploration, focusing on the tensions between a mining law designed to promote private development of mineral resources and land-use policies aimed at government retention and management of federal lands.

Does the Form of Taxation Matter? Mining Law Reform in Ghana

In 1986 Ghana significantly revised its mining law, and since then exploration has surged (Mining Journal, February 9, 1990). The changes included a switch from a gross production royalty of 6 percent to a variable royalty ranging from 3 percent to 12 percent based on profitability, and implementation of an additional profits (or resource rent) tax.

This section of the paper will examine the impact of changes in the mining law on exploration in Ghana, and more generally will assess the extent to which the form of taxation influences exploration.

Regional-Development Benefits of Exploration: Were Flow-Through Shares Worth It in Canada?

Between 1983 and 1989, exploration in Canada benefited from a tax provision permitting an equity-financing arrangement known as the flow-through share. Investors purchased shares in a fund that then directed money to individual companies participating in the fund. Shares in the fund were flow through in the sense that the deductibility of exploration expenses flowed through to investors, who were allowed to deduct more than 100 percent of their investment from taxable income. One restriction was that the money had to be spent on exploration in Canada. The Prospectors and Developers Association of Canada estimates that some 40 percent of money spent on metallic mineral exploration in the middle 1980s was raised through flow-through shares.

This section of the paper will examine the impact of flow-through shares on metallic mineral exploration in Canada, focusing on whether regional-development benefits from exploration and any subsequent mineral development are worth the costs of the preferential tax treatment.

FINAL THOUGHTS (To Be Written)

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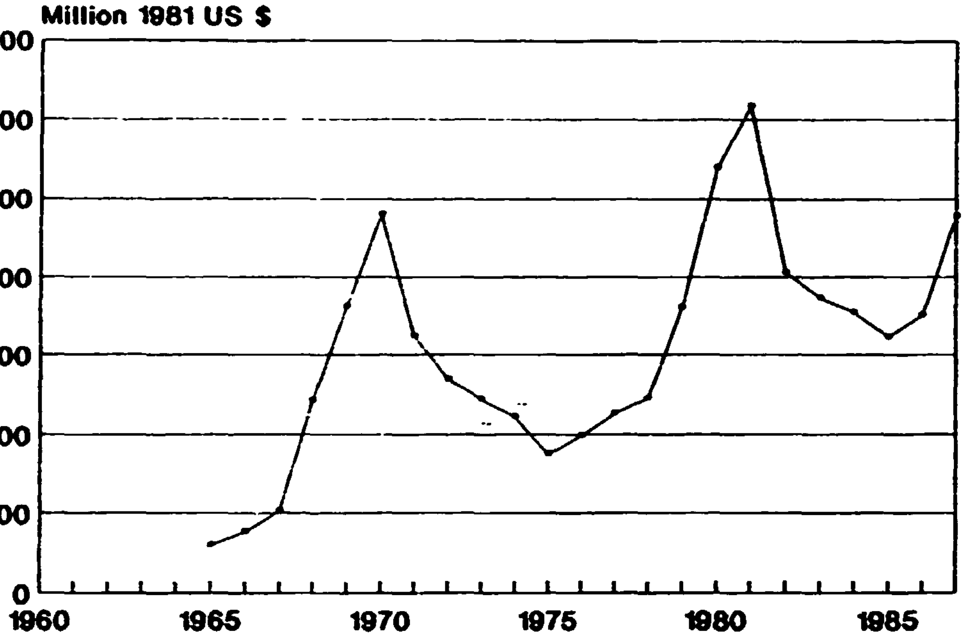
Fig. 1 Exploration Expenditures in Australia, 1965-1987



Source: Australian Bureau of Statistics

Fig. 2 Exploration Expenditures in Canada, 1960-1985

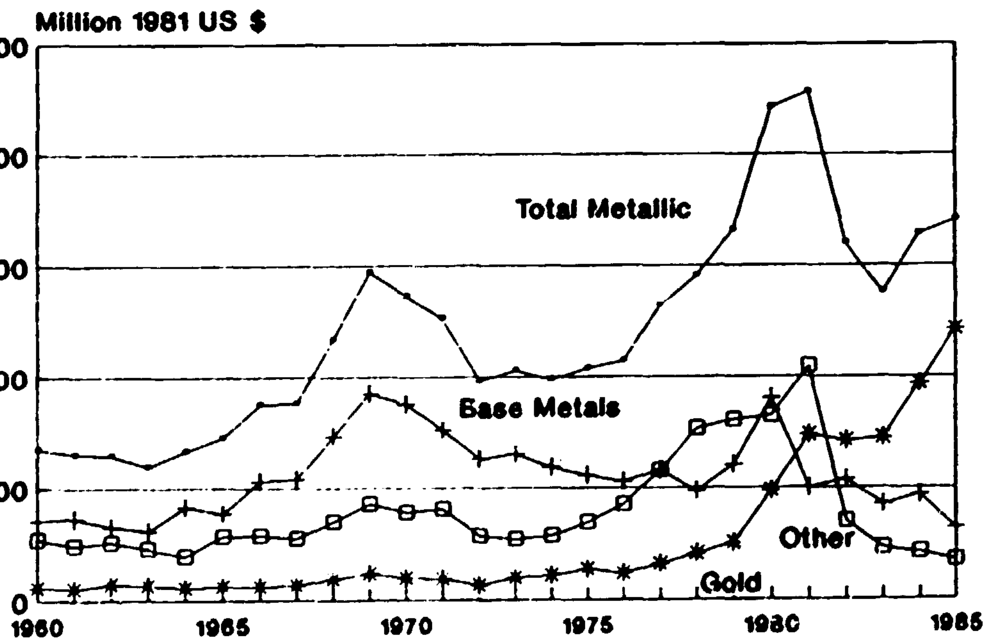


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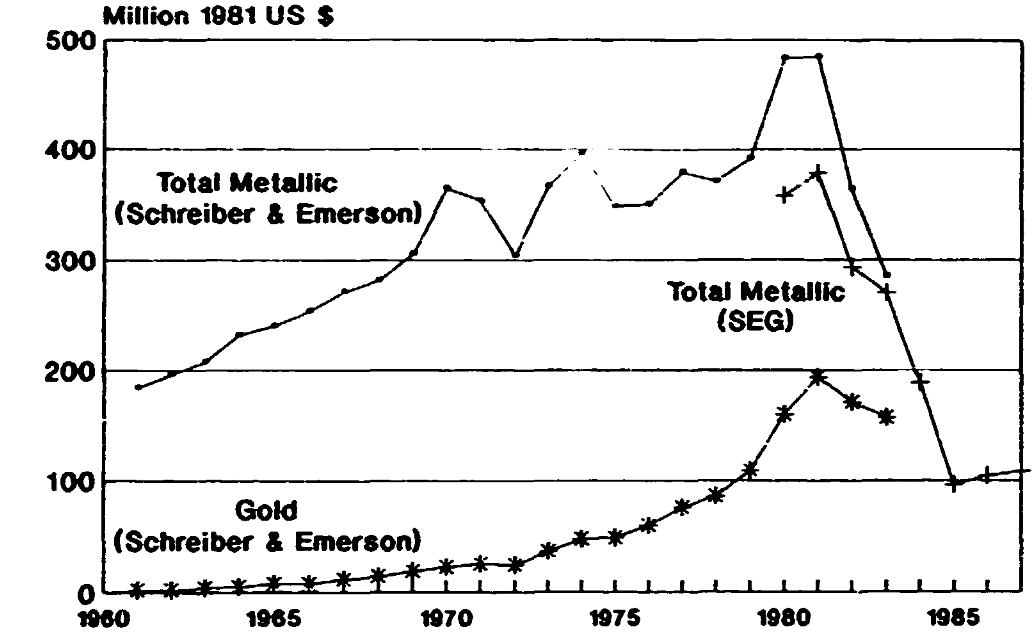
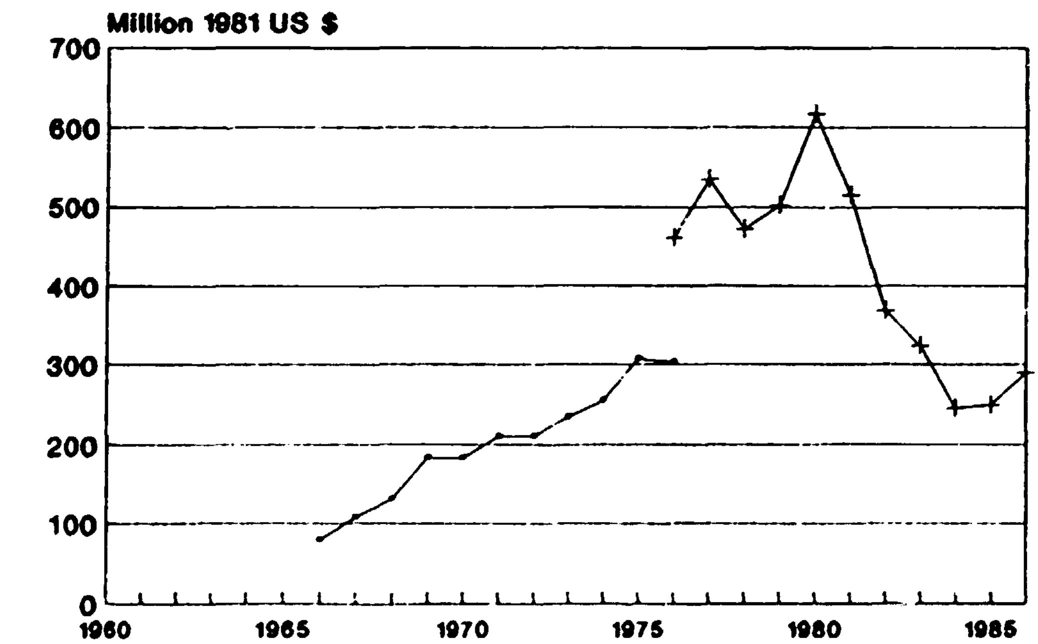
Fig. 3 Exploration in the United States, 1961-1987



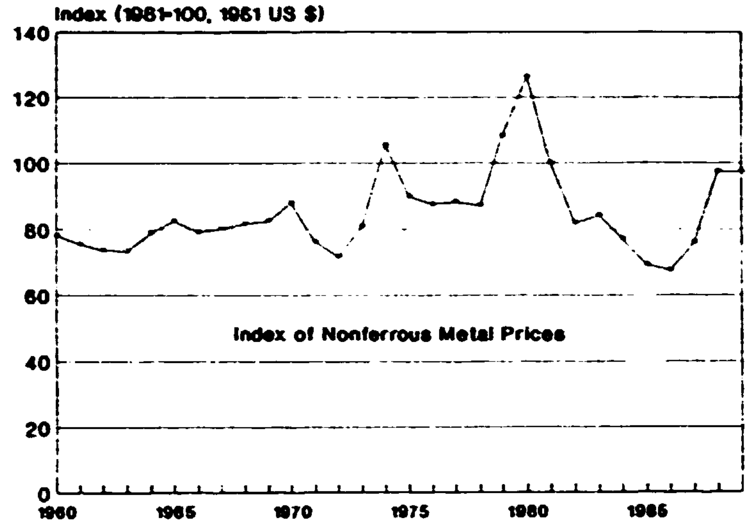
Source: Schreiber & Emerson (1984), SEG

Fig 4 Exploration Expenditures by a Group of European Companies, 1966-86

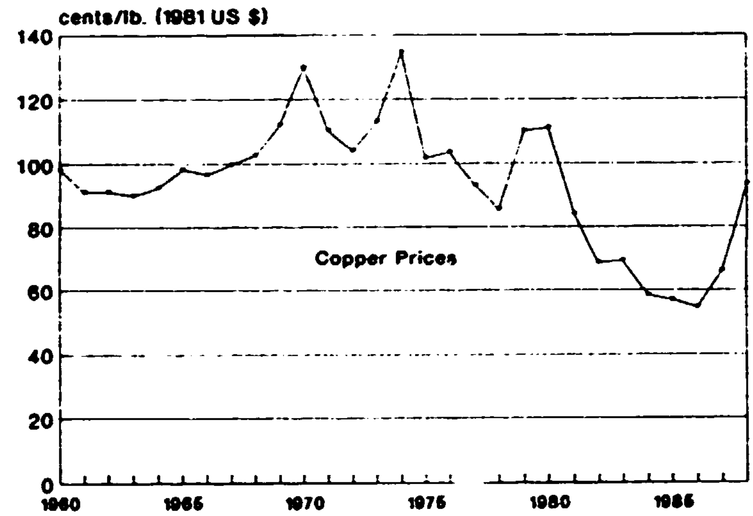


Source:

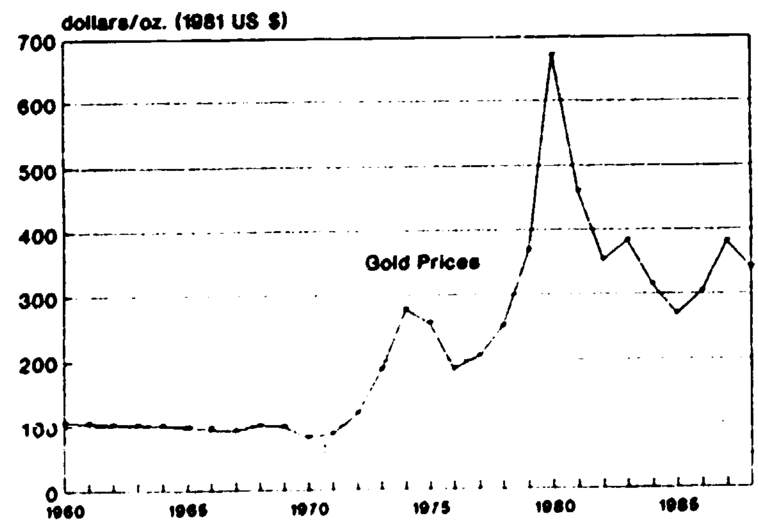
Fig. 5 Metal Prices, 1960-1989



Source: U.S. Dept. of Commerce

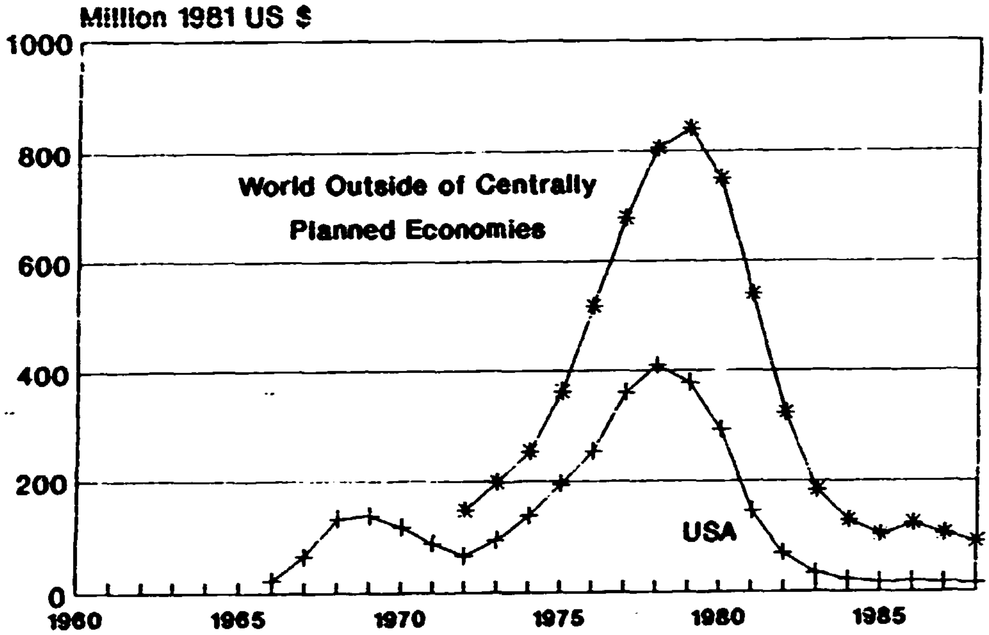


Source: U.S. Bureau of Mines

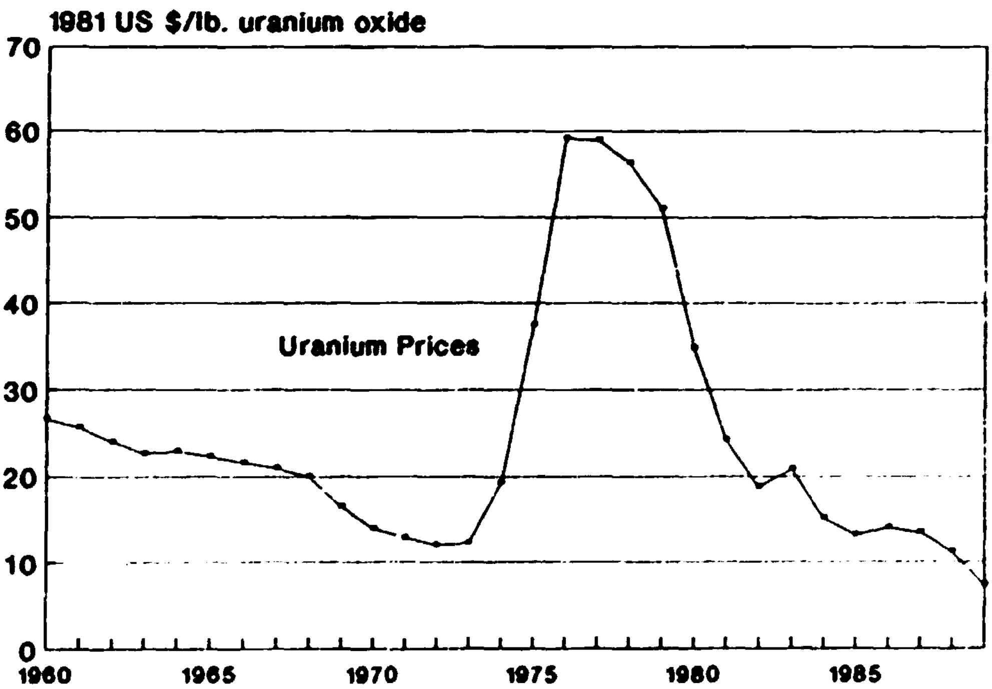


Source: U.S. Bureau of Mines

Fig 6 Uraniuın Prices and Exploration Expenditures, 1960-1989



Sources: US DOE, IAEA/OECD



Source: NUEXCO

TABLE 1. Geographic Distribution of Exploration Expenditures for Uranium and Other Minerals by European Community Companies, 1966-1986 (percent)

		1966	1970	1975	1980	1986
IN DEVELOPED COUNTRIES:						
Africa	Other	4.5	1.6	3.5	2.5	2.0
	Uranium	0.0	6.1	0.0	0.4	0.0
Australia	Other	8.0	18.1	13.2	16.4	13.1
	Uranium	0.1	0.5	1.2	5.3	2.4
North America	Other	8.8	17.3	10.6	11.5	20.9
	Uranium	1.8	2.0	6.9	11.7	8.2
Europe	Other	25.5	15.4	19.4	16.4	14.7
	Uranium	0.0	3.2	10.0	19.2	20.9
Not Allocated	Other	6.9	8.9	9.0	0.1	0.2
	Uranium	0.0	6.0	10.9	0.0	0.0
Subtotal	Other	53.6	61.3	55.9	48.7	50.9
	Uranium	1.9	17.8	28.9	36.5	31.5
IN DEVELOPING COUNTRIES:						
Africa	Other	6.9	1.8	0.1	1.5	2.2
	Uranium	0.0	1.4	0.9	7.4	2.2
Asia	Other	1.3	5.3	2.0	1.4	2.4
	Uranium	0.0	0.0	0.1	0.0	0.0
Latin America	Other	0.0	0.5	4.2	5.3	7.2
	Uranium	0.0	0.0	0.3	0.8	0.0
Oceania	Other	7.3	0.0	0.0	0.1	3.5
	Uranium	0.0	0.0	0.0	0.0	0.0
Not Allocated	Other	29.0	6.2	4.7	0.0	0.0
	Uranium	0.0	5.7	3.0	0.0	0.0
Subtotal	Other	44.5	13.8	10.9	8.4	15.3
	Uranium	0.0	7.1	4.2	8.2	2.2
TOTAL		100.0	100.0	99.8	100.0	100.0

Sources: See notes to Figure 4.

Table 2. Geographic Distribution of Exploration Expenditures by Canadian and U.S. Companies, 1980-1987 (percent)

	Percent of Exploration Expenditures in:			
	U.S.A.	Canada	Other	Total
Canadian Companies				
1980	5	86	9	100
1981	6	84	10	100
1982	5	87	8	100
1983	15	80	5	100
1984	6	90	4	100
1985	10	87	3	100
1986	14	84	2	100
1987	12	83	5	100
U.S. Companies				
1980	62	12	26	100
1981	61	12	27	100
1982	58	11	31	100
1983	66	10	24	100
1984	67	11	22	100
1985	74	6	20	100
1986	7[illegible]	10	11	100
1987	73	8	19	100

Source: Society of Economic Geologists

Note: Included are expenditures for base and precious metals, other metals, uranium, and industrial minerals.