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Chapter 1

Trends and Forces in Mining and Mineral Exploration

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Abstract

The dominant forces that affect the mining industry in today's economy are globalization, entrepreneurship, and unprecedented minerals availability. The current malaise and diminished economic importance of the base and precious metal mining industry in the world economy are the result of ongoing, long-term trends. Shifting market forces within a changed geopolitical landscape have resulted in excess supplies and reduced demands for high-unit-value mineral products and for geologists and engineers in the exploration and mining industries. Although these changes are still evolving, professionals and the mining companies that employ them must realize that these changes are irreversible.

Mining has five dominant characteristics: (1) it is essential to society, (2) it is effective in keeping society supplied with abundant, low-cost mineral products, (3) historically, it has been wealth destructive for investors, (4) it has been subsidized, and (5) it is shaped by social and political forces. What is different now is that instead of being subsidized, the industry is being handicapped by governments and abandoned by investors. The industry has reacted to a marketing problem with an inappropriate strategy of cost reduction and increased production. The increased supply has resulted in decreased prices. Mining companies are earning low or negative rates of return.

Remedies for the larger mining companies and the high-unit-value metals businesses include:

1. Exemplary behavior to regain the trust of the public, governments and investors;
2. Continued consolidation to become sector leaders;
3. Profit through value-added vertical integration and direct marketing to consumers;
4. Development of innovative consumer-based financing mechanisms, especially for exploration ventures.

Individuals and small groups that have been displaced from the mainstream must become entrepreneurs. They must engineer their own survival by shifting careers or by finding, developing, and capitalizing on exploration and production opportunities that are unrecognized by, or are too small for, the major companies.

The mining industry is here to stay. It is too necessary to society to be abandoned; however, the future size and shape of the industry will probably be unrecognizable to most of us. It will be leaner and more opportunistic. It will be characterized by entrepreneurial corporations of all sizes that dominate niches and sectors and that anticipate and profit from the changing needs of society.

Introduction

History never looks like history when you are living through it.
It always looks confusing and messy,
and it always looks uncomfortable.
Garner, 1977

The most reliable way to anticipate the future
is by understanding the present.
Naisbit, 1984

CHANGE IN complex, interrelated systems, economic or biologic, arises from actions and interactions among the entities or organisms comprising them (Jacobs, 2000, p. 174). The result of such change is unpredictable in detail. The mining industry would be well served to recognize that what was believed to be normal in the business for the last 50 years is no longer the norm. Even though the evolving shape and characteristics of the business are unpredictable, science and business depend on using limited factual data to identify patterns and trends to make useful projections. In order to define the trends, we have documented key factors that have shaped the industry's past in an effort to understand the forces acting on it now. We examine the implications of these evolutionary trends for companies and individuals. We hope our perspectives will prove useful in planning how to deal with and capitalize on the changed and changing environment.

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In the context of the meeting, *Global Exploration 2002: Integrated Methods for Discovery*, our purpose is to establish a framework for other papers that will elaborate on some of the themes introduced herein. These themes include industry profitability, the responsibilities of the industry to society, and the expectation that entrepreneurship at all scales will drive the mineral business in the future.

For most people in the mining and exploration business, there is a sense that we are presently in uncharted waters, facing an uncertain future. We perceive that the mining industry feels unappreciated and misunderstood as it becomes increasingly marginalized. Old remedies for dealing with less dramatic situations such as price cyclicity are not appropriate. Large sectors of the metal mining industry are unprofitable, exploration activity is minimal, and large numbers of industry professionals are either unemployed or have left the business for opportunities elsewhere. Two educational organizations, the Minerals Information Institute and the Government, Education and Mining Committee of the Society of Mining Engineers, teach school children that "everything we have and everything we use comes from mining or agricultural resources." Yet, one might ask, if mining is essential to society, why have the fortunes of metal mining been in decline for the past 25 years, and why are the metal mining and exploration businesses distressed today? Will this depression continue? Is the profession of economic geology at a watershed? Is the exploration business finished? What must be done to return to personal and corporate prosperity? Is there any hope for the exploration profession in the new century?

We will attempt to answer these kinds of questions herein. We shall assess the perceived crisis in the context of changes that have affected all of society in the past several decades, and we will propose some solutions.

Historical Perspective

The evolution of civilization is closely related to uses of mineral materials and to advances in mining and materials technology. The earliest archeological evidence of quarrying for flint goes back 300,000 years, and there is evidence that our ancestors first began mining hematite underground about 40,000 years ago (Lacy and Lacy, 1992). The major stages in the development of mankind are named for mined materials, progressing from the Stone Age, through the Bronze and Iron Ages, to our current "Silicon Age." Since prehistoric times, numerous wars have been fought over mineral materials. Many trade routes were established to facilitate commerce in minerals such as chert, gold, salt, tin, and gemstones. Expeditions and discovery voyages led to exchanges of ideas and the spread of civilization. The apices of ancient Greek and more recent British enlightenment were built on their mineral wealth. The European discovery and development of the Americas can be traced to the quest for gold, as can Russia's eastward expansion. Mining fueled the industrial revolution, and the modern industrial age would not have been possible without the discovery and development of large reserves of iron, aluminum, base metals, coal and petroleum, and other mineral commodities.

The role of the mining industry[1] is to find, develop, produce, and keep society supplied with all necessary mineral materials. "Mineral resources have played a dominant role in the political power of nations throughout recorded history, and the current world political situation emphasizes the importance of mineral resources in establishing high standards of living as well as influencing world politics." (Clark, 1983). From our study, we conclude that the mining industry has the following characteristics:

1. Mining is essential to society;
2. Mining has been effective in keeping society abundantly supplied with low-cost mineral products;
3. On average, however, mining has been wealth destructive for investors;
4. Mining has been subsidized by society; and
5. Social and political forces shape the industry.

The modern economic order has its origins in eighteenth century England, where an industrial economy replaced the agrarian economy. In North America, the industrial economy reached its peak between the 1870s and 1970s. Steel, cement, and coal enabled the growth and expansion of the modern world's physical infrastructure. Copper and aluminum became the basis of global electrification. Petroleum made modern medicine and today's chemical, plastics, and transportation industries possible. Specialty metals such as zinc, lead, nickel, chromium, manganese, tungsten, tin, and the platinum group were essential to tools, transportation, and armaments. Agriculture and the "green revolution," based on mined fertilizer materials, enabled the world's population to essentially quadruple between 1900 and 2000. Finally, gold and, to a lesser extent silver, underpinned the world monetary system.

The period from 1900 to 1973 was characterized by worldwide growth in the mining sector. From 1900 to 1929, the United States experienced its most intense period of industrialization as it rose to dominance in the international economy following World War I. A global depression from 1929 to 1939 retarded development in much of the mining industry. European rearmament and the Second World War (1936–1945) caused a worldwide resurgence in mining, especially in North and South America, Australia, and South Africa, all of which escaped the ravages of the war. World War II was followed by a global recession that lasted until the start of the Cold War in the late 1940s.

The modern era of mining has its roots in that part of the Cold War that was bracketed by the start of the Korean War in 1950 and the end of the Vietnam War in 1974. These were the glory years (Fig. 1), as mining and exploration flourished in the Western democracies and in the communist nations because of armament production and the per-

[1]In its most general sense, mining includes metals, nonmetals, and industrial and energy minerals, including liquid and gaseous hydrocarbons. In this paper, hydrocarbons are not considered to be part of the mining industry in any of the statistics or discussions unless specifically mentioned.

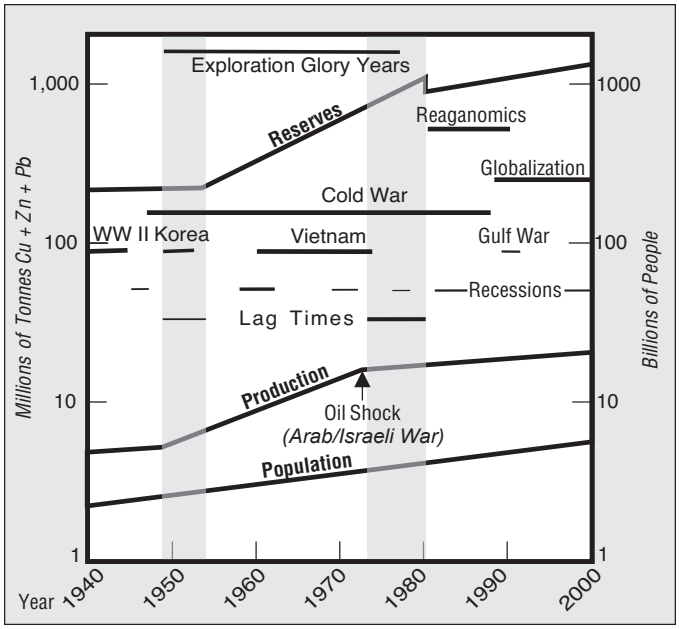

FIG. 1. World events and mining. World production, reserves (as reserve base), and reserve momentum as represented by copper, lead, and zinc. The boom in exploration started in 1950 with the Korean War. Production increased at once, but the reserve base did not increase until about 1954. With the oil shock of 1973, production was cut back, but reserves from exploration success continued to grow for another seven years. The dramatic drop in world reserves in 1981 was due to rationalizing reserves at higher cutoff grades. After the Cold War, the mining industry became globalized. Prior to the Cold War the international reserve base was about 38 years of production, but it has now stabilized at approximately 50 years worth of production (Juhas and Snow, 2000).

ceived need to develop national strategic reserves of all mineral materials.

In the Western alliance, mining and exploration activities were focused in the English-speaking nations—principally Australia, Canada, the United States, and South Africa. Large numbers of scientists and engineers were attracted to mining, economic geology, and the many related employment opportunities. The need to mine lower grade domestic resources led to advances in mining and metal recovery. The exciting challenges of discovery in mature exploration environments caused the blossoming of conceptual exploration and interest in ore deposit genetic models and time-space relationships to guide exploration. The systematic integration of geological, geophysical, and geochemical techniques to find deeply hidden mineral deposits evolved rapidly in this era as well, as did the technology to handle large amounts of data. Exploration success essentially doubled the world's reserves of copper, lead, and zinc on a per capita basis (Fig. 1). Exploration was so successful that iron, bauxite, molybdenum, uranium, lead, tin, and many other commodities became exploration-insensitive. Educational institutions expanded capacity to meet what was perceived as an ever-increasing demand for scientists and engineers. Universities and government agencies focused mapping and research studies on matters of practical importance to the exploration and mining businesses. Government agencies also expanded to serve and regulate the mining industry. Coincidentally, during the Cold War, public opinion became a major arbiter of exploration and mining activity, and environmental considerations became important in resource decisions.

In the Soviet Union and its satellites, mining was an essential and respected endeavor that employed millions of persons in centrally controlled exploration and development "expeditions" and production *combinats*. Their territory was probably better mapped and more thoroughly explored than equivalent terrains in North America. However, endemic secrecy and central control did not allow discoveries to be efficiently exploited. Similar problems in all sectors of the Soviet economy ultimately contributed to its collapse in 1989. Since the end of the Cold War, most of the Eastern European satellite nations have adopted representative democracies and free market economic systems, and have become relatively more prosperous than they were under the Soviet regime. Russia and the independent states formed from the dissolution of the Soviet Union have not committed to Western style economic, legal, and political systems, and their industries and populations are not as prosperous as during the height of the Cold War. China patterned its exploration and extractive industries after the Soviet model, with similar results. China has not changed its political system, but in contrast to the Soviet Union, it has prospered in recent years by allowing an export-driven, market-based economy to operate.

Paradoxically, the nonaligned, generally less developed nations did not significantly participate in this Cold War prosperity because they drifted to socialism. In the 1960s and 1970s, this resulted in a wave of punitive fiscal policies directed at foreign-owned companies, including nationalization of ownership control or outright confiscation of mining operations, especially in Latin America and Africa. Some mines and mineral properties were turned over to existing domestic mining companies, but government corporations run by political appointees operated most. As a consequence, most of these operations became internationally uncompetitive and many mines were ruined. With the end of the Cold War in the late 1980s and early 1990s, most of these nations removed barriers to the entry of foreign mining companies, although many of the better properties, as in Chile, were never returned to their former owners. These less developed nations have become the dominant focus of recent and current international exploration and mining initiatives.

The situation in the metals sector began to deteriorate in 1973, when the Organization of Petroleum Exporting Countries raised crude oil prices severalfold. Inflation and high energy prices—coupled with low demand and low prices—severely hurt the producers of metals and chemical raw materials. Production and exploration for oil surged in the Americas, whereas mine production was immediately cut back. Exploration for and production of most mineral products continued, but at declining rates until the recession of 1982–1986 nearly bankrupted the industry. A rise in

the price of gold caused by political and economic uncertainty in the late 1970s and early 1980s buoyed the metal mining and exploration industry.

After 1986, gold, and to a lesser extent diamonds, became "the only game in town" for the exploration industry, and it continued this way until the mid-1990s. Trouble was already brewing, however, because the price of gold had been declining steadily since 1980. This price decline was due to lessened international turmoil, expanded mine production (the world's gold supply doubled between 1980 and the present), and selling by central banks. Gold prices dropped dramatically in 1997, in part owing to a recession in Southeast Asia, decreased demand, and continued selling by the central banks. The lower gold price and the rush to speculate in the technology sector contributed to a flight of investment capital and the current round of bankruptcies, mergers, and consolidations in the mining industry. Low-cost producers still operate, in the expectation of an upturn in the price of their product, but exploration spending for most types of mineral deposits is at the lowest level since the 1930s (Mining Journal, 2001b). Interest in exploring for gold and diamonds has dominated since the mid-1980s. Since 1998, most grassroots and non-mine-unit gold exploration have been suspended worldwide.

Events, cycles, and inertia

Both external and internal forces control the environment in which the mining industry functions. That environment is comprised of the global economy, society, governments in the developed and developing world, and the mining and exploration businesses themselves.

World events have always influenced exploration and mining (Fig. 1). International conflicts introduce instability and cyclicity to the fortunes of the industry. In times of international tension, domestic mineral sources are emphasized and encouraged. Nations involved in conflicts commonly deem it in their national interest to expand the reserve base (reserves plus indicated resources) of strategic mineral products and to nurture and support a larger domestic mining industry than normal rates of consumption require. When tensions are relieved, this redundant capacity and its enlarged reserve base become a glut on the market until it is absorbed. This can take years, if not decades.

In peacetime in the western world, government policies emphasize open international markets and encourage mineral exports and/or imports. "Developed countries are primarily interested in the lowest prices that guarantee secure sources and a steady supply [of mineral materials]. Developing countries wish to promote mineral development and at the same time to extract a significant rent. Their needs and interests include ensuring the reinvestment of the proceeds from mineral exploitation in other productive activities, gaining greater control over the planning and operation of the industry, increasing value added in the country, and promoting greater employment" (Bosson and Varon, 1977).

A fundamental and seemingly intractable problem faced by the metal mining industry is that the exploration and mining cycle is generally out of phase with political directions, international conflicts, and the ups and downs of the post-industrial economy. Political and modern business cycles are much shorter than the normal mining cycle. The basic exploration-development-production cycle of a modern mine ranges from about 15 years for the smaller operations to 40 or more years for the larger ones, and involves immense amounts of capital. The duration of the discovery process itself is long, and once a mine goes into development, the capital is committed and it is almost impossible to react to changing economic circumstances by changing plans without immediately incurring tremendous losses. As shown in Figure 1, the Korean War emergency resulted in mine production being increased immediately along with a "crash" exploration program, but discoveries did not result in an increased reserve base until five years later. Similarly, mine production was drastically curtailed in 1973 owing to reduced demand; but because of projects already in the pipeline, the rate of increase in the reserve base did not slow for another seven years. The same situation is presently happening with gold. Grassroots exploration was essentially suspended in 1998, but the reserve base (unadjusted for price drops) is still growing and probably will continue to do so until 2004 or 2005, because of mine-unit expansion and work commitments on high-quality prospects.

Mining: Society's loss leader

Base and precious metal mining historically have been wealth destructive for investors. "The best way to end up with a small fortune in the mining business is to start out with a large one." We have all heard and laughed at this remark attributed to Mark Twain, but little did we expect that it might become an aphorism. Various studies (Kruger, 1969; Young, 1970) show that at least since 1521, in North America, real dollar returns to investors in terms of dividends or stock appreciation have not equaled overall outlays for exploration and development. Although individual fortunes have been made and some mining corporations at times have been immensely profitable, rates of return are highly skewed around the average—few companies make money, most do not. This conclusion does not come from our data compilation, but represents the aggregate conclusions of a spectrum of experts who studied the matter. A sample of their opinions follows:

1. 1521 to 1893—"Despite its image as a bonanza frontier, the mining west scarcely broke even. Costs insatiably devoured profits, and the numbers of men and institutions who came away with substantial gain was remarkably small. Most of the mineral strikes were tempting and attracted millions of dollars but returned comparatively few in dividends. Nevertheless, a working mine was doing its share toward western development." (Young, 1970)
2. 1874 to 1920—"If all costs are included—prospectors and subsequent equipment and operation of the more favorable prospects—gold mining is an unprofitable business in any country. Taking the world as a

whole, the gold produced costs more than it sells for. It certainly is no business for amateurs." (Hoover, 1951)

3. 1930s to 1950s—"The total real cost of finding new prospects typically exceeds the total return." (Preston, 1960, referring to the North American exploration and mining experience)

4. 1979 to 1999—"On average the real return on capital of operating mining companies[2] is only 5 percent over the last 20 years." (Humphrys, 1999)

Some will argue that profits and dividends are not the whole story because society has benefited. This is true, but society's gains do not translate into profits for the investor in mining. Others will argue that dividends are not the only place where investors make money. This also is true, but only up to a point. Many investors have made handsome profits in trading the stock of mining companies, but when a company fails, the stock and any wealth it created for shareholders becomes worthless and the entire investment is lost. The last persons in the game of musical chairs are left without seats, holding empty bags. ARCO is still paying out millions of dollars following its "top-dollar" purchase of the now defunct Anaconda Copper Company.

Economists characterize agriculture and mining as "price takers" because each has numerous, highly competitive primary producers that are unable to set prices to guarantee profits. Accordingly, these industries have been subsidized—agriculture more than mining. For this reason we consider the metal mining industry to be society's "loss leader." It is also the reason why society has sustained the mining industry over the centuries with various types of subsidies. There are many ways that nations support and subsidize mining on the one hand or discourage it by withdrawing such support on the other. Subsidies come from government and investors and they may be direct or indirect. The support takes many guises that are not always obvious, but support has been present until recently. As support has been removed, the industry is being forced to operate without subsidies, and indeed, without investment

Venture capitalists and buyers of stocks normally invest knowing the risks and with expectation that high returns in some investments will exceed losses in others. However, when losses become chronic and institutionalized and companies cannot finance new projects and come to depend on the sale of equity, that is a form of subsidy. The billions of dollars invested in the 99 percent of junior mining or exploration companies that have failed over the last 20 years is a direct subsidy from the investing public. Investment in the more than 50 percent of mines that go into production and close before they ever make a profit is a form of subsidy. Society, in the meantime, has benefited from jobs, residual knowledge, data, mineral properties and defined resources, infrastructure development and the multiplier effect of the investments circulating through the economy.

[2]This refers to the top 50 or so major international mining corporations. It does not include the 7,000 or so public and private junior mining and exploration companies worldwide, with a normal three-year life span, that we estimate have come and largely gone in the last 20 years.

Governments subsidize the mining industry directly and indirectly in many ways. Direct subsidies are instituted during national emergencies or when the government is trying to preserve existing businesses or incubate new ones. Price support as buyers of first resort (U.S. uranium program—all production was purchased by the government), or last resort (various nations guaranteed floor prices for gold to generate hard currency for foreign exchange), or as a means to build up stockpiles of strategic mineral materials (U.S. government) are direct subsidies. Direct support also includes grants and such corporate tax breaks as depletion allowances and tax-free holidays. Also included are tax credits to investors and companies to support exploration activities (Canada's "flow through" program of the 1980s, revived in 2001). Exploration and development activities may be conducted by or paid for by government departments (e.g., U.S. base metals programs of the 1940s and 1950s). The United Nations and World Bank also provide similar direct subsidies to underdeveloped countries.

Indirect government subsidies include infrastructure and political support. Although more difficult to quantify, they are no less real and no less important to the fortunes of the mining industry. Infrastructure support includes funding of roads, railroads, and airports. Other support includes provision of secure access to lands and the right to develop them; research programs and transfer of geological, mining, metallurgical, and other technology to the industry; regional geological, geophysical, and geochemical mapping programs; market surveys; mineral and commodity statistics; and various business studies.

Political actions can be positive or negative. Positive political support includes the sales and trade missions that some countries use to promote their national mining industries (Canada and Chile) or to help purchase needed mineral materials (Japan). The military protection that some nations provide to mining and exploration operations is considered positive political support. Examples of negative political actions in support of the mining industry are mainly from the past and include exploitation under apartheid (formerly in South Africa), forced labor (former Soviet Union), stolen technology (former Soviet Union), and union busting (United States in the 1920s). Current examples of negative political forces at work in the mining industry are the mining of "conflict diamonds" to support rebel groups in southwest Africa and the recent United Nations takeover of the base metal and silver mines of Kosovo. The decision of numerous central banks to no longer back their currencies with gold was a move that seriously hurt the gold sector in recent times.

The Current Social, Political, and Economic Context of Metal Mining and Exploration

Over the years, the metal mining industry has experienced numerous cycles in which commodity prices rise and fall, exploration activity waxes and wanes, and jobs are plentiful or scarce. Is the current situation just another down cycle, albeit more severe? We think not. The nature and structure of the world's economy has changed. The atti-

tudes of society and governments have changed. The nature, composition, and attitudes of the metal mining industry have changed.

The current depression in the base and precious metal sector of the mining industry mostly reflects changing external factors, but is partly caused by the industry itself. There are five causes for the diminished role of mining in the economies of the developed world.

1. Our economies have evolved from being industrial- to information- and service-based.
2. The rate of growth in demand for most metals has declined and the prices of nearly all mineral commodities in constant dollars are at historic lows. More than 50 percent of metals used are recycled and other materials have substituted for metals in many applications.
3. Unparalleled exploration successes, more efficient mining methods, innovative recovery techniques, and the decision to expand production have resulted in abundant supplies, if not oversupplies, of most mineral materials.
4. The management of the industry has shifted its focus from strategic vision to reactionary behavior concentrated on short-term considerations.
5. Worldwide, public attitudes and government policies toward domestic resource industries have become neutral or unsupportive since the 1970s.

The environment of mining has changed faster than the mining industry has been able to adjust. There have been numerous corporate and personal casualties. The industry has been slow to recognize and adapt to a new situation and has relied on some unsuccessful strategies to cope with the changes. Nevertheless, the mining industry is not in a terminal phase.

Changes in public and government attitudes

In the past 25 years, there has been a major shift in public concern from issues of security of supply and extractive efficiency of mineral resources to environmental impacts and local social and economic sustainability issues arising from mining and from the use of mineral products, including fuels. The modern trend is to support value-added businesses that seek to add human resources and human capital to exports that are benign to rural and wild ecosystems (J. Jacobs, 2000). Also, there is an impetus to leave more of the fruits of mining as a permanent legacy to local communities. In the developed world, the public takes mineral products for granted and has come to view mining as optional and even objectionable. Some environmental organizations promote efforts to extinguish the mining industry.

Since the early 1970s, governments in the developed world have withdrawn most support from the mining industry and in some cases have become adversarial (Juhas and Snow, 2000). In various countries, national geological and mining bureaus have been eliminated or have changed their missions. Regulations and land withdrawals are increasing worldwide. These are not objectionable in principle, if based on science and concepts of greatest value, but are easily perverted by those who want no mining.

Changes in the economic status of the industry

As societies become more affluent and their economies change to an information and service base, the mining industry diminishes as a factor in their economies (Larson et al., 1986) (Fig. 2). The decreased economic contribution is because of lower per capita mineral consumption and because mineral commodities are relatively inexpensive in postindustrial economies. "Mankind's ingenuity in developing and adroitly applying technology has made concerns of food and material resource availability largely a thing of the past" (Fisher, 2000). In essence, the reduced economic contribution (not importance) of mining and agriculture in modern society is due to the superb efficiency of these sectors.

Bailly (1984) notes, "…in all countries the highest economic efficiency is in the mineral production sector, …a sector which increases in size but decreases in proportion to gross national product (GNP) as a country develops." In the United States, the contribution of the entire metal mining industry to the national income has decreased by an order of magnitude in the past 50 years (Fig. 2). The intensity of use of the basic commodities, defined as the quantity of a material consumed divided by population or by gross domestic product (GDP), has decreased in terms of both measures. For example, relative to GDP, the intensity of use of steel peaked in 1918 and cement in 1926. Relative to per capita consumption, these commodities peaked in 1972 and 1973, respectively. Base metals now contribute an insignificant amount to the GDP (Fig. 3). These changes happen because of more efficient use of materials, recycling, substitution (material and technological), market saturation, and shifting consumer preference. For these reasons, the demand for mineral products at developed country peak levels has not and will not materialize in the developing world. We can foresee no shortages that the industry cannot fill in one exploration-development cycle (5–15 years).

The importance of mining in the global economy should not be confused with its significance to the economy. The economic measure of significance is dollars, not tons and not degree of national dependence. In 2000, the value of raw mineral products in the United States was about $40 billion (0.4 % of GDP), whereas the value of processed materials of mineral origin was $429 billion (4.2 % of GDP) (U.S. Geological Survey, 2001). These percentages of GDP are down from 1980, when raw mineral products composed 1.0 percent and processed materials composed 10 percent. The decline in contribution of mineral raw materials to the U.S. economy parallels the decline in significance of the entire manufacturing sector (Fig. 4). Since 1980, manufacturing has slipped from 23 to 15 percent of GDP. Until the 1980s, finished mineral products contributed about 40 percent to the value of the U.S. manufacturing sector. They contribute 26 percent today, as the value of domestically processed raw mineral products has dropped from 1 to 0.4

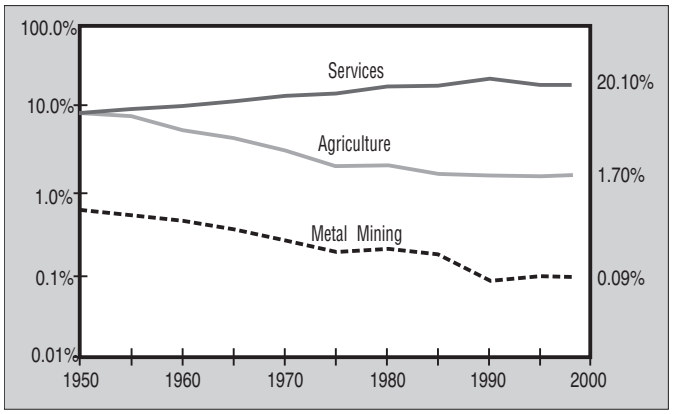

FIG. 2. Contribution to the national income of several sectors of the U.S. economy (U.S. Census Bureau, 1992, 1999, and 2000).

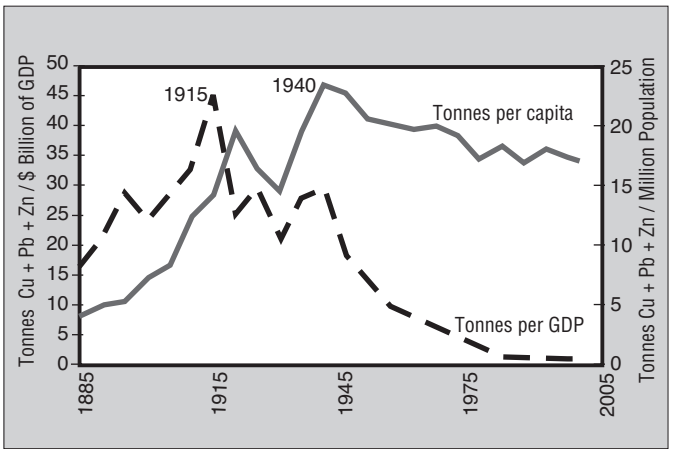

FIG. 3. Intensity of use of base metals in the United States. Whereas per capita consumption has dropped by about 30 percent since 1940, its proportionate value in the economy has diminished by an order of magnitude, translating to a threefold increase in relative productivity (efficiency) since then (U.S. Census Bureau, 1999; Snow and Beaty, 1987; Metal Statistics, 1992 and 1998).

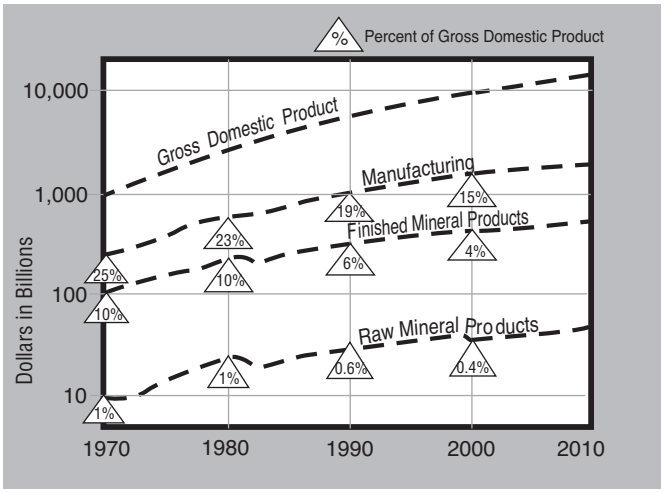

FIG. 4. Contribution of nonenergy minerals to the U.S. economy with trends projected (by the authors) to 2010 (U.S. Census Bureau, 1970–2000; USBM, 1970–1977; USBM, 1978–1995; USGS, 1997–2001). The role of finished mineral products has diminished from 40 to 27 percent of the manufacturing sector in the last 20 years. The value of finished mineral products has consistently been 10 times that of raw mineral products. Gross domestic product and manufacturing sector data are from annual Statistical Abstracts of the United States 1970–2000. Raw and finished mineral product data are from annual USBM and USGS Mineral Commodity Summaries, 1970–2001. The 1970–1976 finished mineral product segment is extrapolated (by the authors) backwards from 1977 using trends for chemicals, primary and finished metals, and glass from GDP data in the annual Statistical Abstracts.

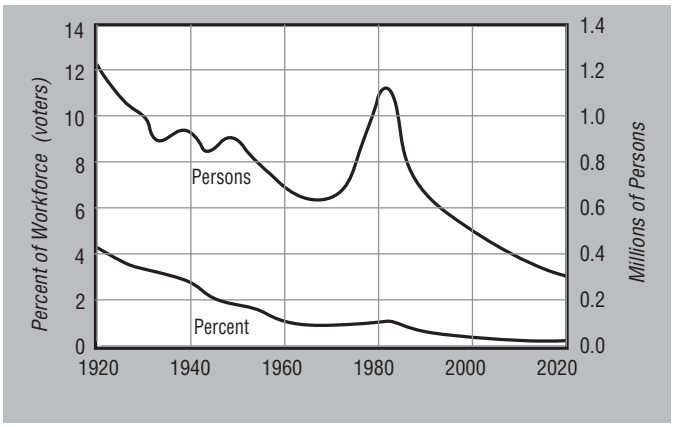

FIG. 5. Mining employment in the United States (E.E. Jacobs, 2000). The anomalous rise in employment culminating in the 1981 peak and its subsequent collapse correspond to the entry and departure of petroleum companies into and from the mining and exploration industries. Current trends are projected to 2020.

percent of the U.S. GDP. The value of domestically produced raw material products to the Canadian economy in 2000 was 4.0 percent.

Figure 5 shows that U.S. mining employment (including finished mineral products to point of first sale) has dropped from 1,200,000 in 1920 to less than 500,000 today, and the trend is still downward. This drop in size of the national mining workforce from about 4.2 to 0.4 percent of the population is one of the reasons the industry has lost influence on public opinion and government officials.

Mining employment is still declining. As we write this article, several major copper mines in Arizona and New Mexico are said to be shutting down because of low metal prices and high energy costs. The same thing is happening to aluminum producers in the United States, Canada, and Brazil. In Canada, Cominco finds it more profitable to close its zinc refinery, give employees holiday pay, and sell the electricity into the North American power grid. Mining professionals are also disappearing. Membership in the Society of Mining Engineers has dropped from 28,000 to 14,000 in the past 15 years, while the number of employed U.S. mining engineers has dropped from about 8,000 to 3,000 in the same time period. Exploration and mine geol-

ogists are in the same boat: U.S. employment dropped from around 3,000 twenty-five years ago to fewer than 1,000 today, and the situation is even worse in other countries. Even in Nevada, the most favorable place in the world to explore according to the Fraser Institute (2001), the number of offices of exploration companies listed in the Reno, Nevada, telephone book has dwindled from 52 in 1991 to 15 in 2001. The number of geologists employed by mining companies active in Nevada has fallen from more than 300 four years ago to fewer than 100 in 2001 (Driesner, 2001).

Growth of influence of the finance sector

Until the early 1980s, the mining business was dominated by large multinational corporations interested in a spectrum of commodity types that tended to even out the cyclicity inherent in individual commodities. Expansion was commonly based on internally generated profits or specific project financing. In the early 1980s, when prices and profits in most commodities, except gold, collapsed, mining companies sought cash infusions from banks, mutual funds, and the stock market. The role of institutions in the finance sector has since evolved from support to mastery. It was a devil's bargain—rather than having to furnish a respectable balance sheet to prospective lenders, mining company management went to the investment market with newly spun-off gold subsidiaries and got cash for capital and operating expenses. The cash was interest free, with no strings attached—or so they thought. In so doing, corporate officers ceded considerable operational and strategic management of their companies to investment firms. By vying with each other for attention in the stock and finance markets, mining companies let those markets determine production rates, acceptable deposit size, and exploration spending. Analysts recommended that corporations divest of peripheral mining and manufacturing interests and concentrate on a core business of mining a single commodity. This worked fine, despite declining profits, until the mid-1990s, when the information technology sector offered better speculation and growth opportunities to investors. Because of mining's poor returns on investments, investors were only too eager to switch, leaving the industry with little cash and obsolete strategies and operations designed to please stock analysts. In essence, mining companies were molded to be valued as investment vehicles rather than as profitable producers of mineral commodities.

Gold, the metal that sustained the mining industry for the past 20 years, has irreversibly diminished as a factor in the global economy. Prior to the 1990s, conventional wisdom dictated that every investment portfolio should contain 10 to 20 percent in gold instruments as a permanent store of value and as a hedge against inflation. In 1980, global gold stocks of 2.4 billion oz were worth $1.4 trillion, or 10 percent of world monetary assets. By 1998, 4.6 billion oz of gold stocks were worth $1.3 trillion and equaled only 1.8 percent of world monetary assets (The Economist, 1999). By unlinking gold from currency, governments inflated the money supply, disappeared as buyers for gold, and become sellers, thus destabilizing the gold mining industry. Gold is no longer money, nor is it perceived as a store of value (Bernstein, 2000) in the developed world.

Structure of the Mining Industry

Mineral commodities

There are 80 mineral commodities of interest to the international mining community exclusive of petroleum and natural gas. The 27 commodities of primary interest to the major mining companies are shown in Figure 6. The problem for producers of the 53 mineral commodities with sales of less than $1 billion is that if a profit of 15 percent return on sales is required, there simply is not enough profit potential from the collective $14 billion in sales of these commodities to share among myriad competitors worldwide.

Many commodities that have sustained the exploration profession now sell at low prices and are in oversupply, with the result that exploration geologists now rely on a small group of commodities for sustenance. These include gold, silver, zinc, copper, nickel, cobalt, platinum group metals, and diamonds. Current sales volumes of these commodities cannot possibly support or justify the current number of economic geologists and related professionals. Moreover, the discovery rate has become so good in recent years that there is hardly a commodity that cannot be taken from shortage to surplus in a single 5- to 15-year exploration-development cycle. Exploration successes coupled with new technology and unhindered global access have made coal, phosphate rock, potash, salt, soda ash, sulfur, and many metals so inexpensive and abundant that they are no longer sensitive to exploration or exploration-oriented research. These metals include aluminum, antimony, arsenic, beryllium, bismuth, cadmium, chromium, columbium, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, tellurium, thallium, tin, tungsten, uranium, and vanadium.

Corporations

The mining industry is highly fragmented and there are thousands of private, public, and state-owned companies, large and small, scattered throughout the world. Most are small and mainly cater to local demand. Data are not available for corporate size or individual sales volumes of state-controlled companies in China and the former Soviet Union. However, taken with data concerning global sales and the contributions of corporations from the Western world, it is certain that fewer than 75 companies control the bulk of the world's mine production of nonfuel minerals. A good idea of the sizes and contributions of Western world companies can be ascertained from the following statistics: 5 companies produce 23 percent, 10 produce more than 30 percent, 20 produce 40 percent, and 50 produce 59 percent of the world's nonfuel minerals (Mining Engineering, 1999). The sector leaders, those who produce 40 percent of the Western world's supply of their product, are shown in Figure 7.

The center of the metal mining industry is now London, where five of the world's largest mining companies are headquartered (Fig. 8). The combined market capitaliza-

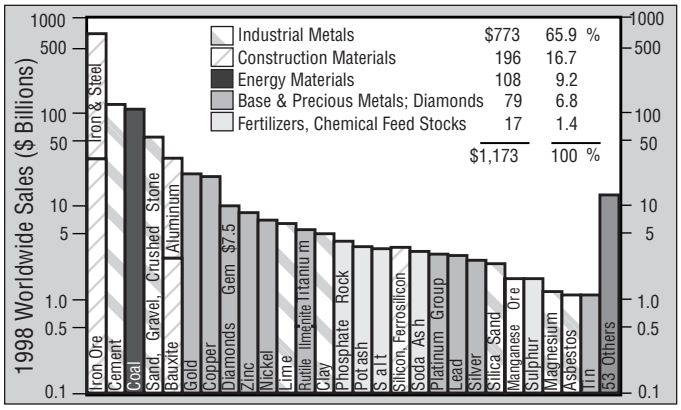

FIG. 6. Structure of the world's mining industry (commodity and value). The mining industry extracts 80 mineral commodities comprising rock materials, specific minerals, and elements. The value of global production is calculated in terms of standard U.S. prices (USGS, 2000). International data are unavailable for some commodities, so a value has been assigned assuming that U.S. figures represent 23 percent of the world's total. The GDP of the global economy in 1998 was about $37,000 billion and that of the United States was $8,511 billion, thus we estimate the United States makes up about 23 percent of the global economy (US. Census Bureau, 1999).

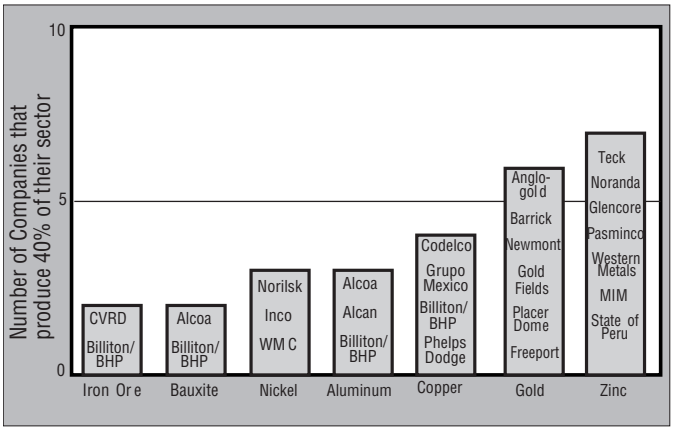

FIG. 7. The number of companies that produce 40 percent of the Western world's production of seven mineral products (Harquail, 2001; Roskills Metals Databook, 2000). These seven were most sought by economic geologists in the last 50 years. Most of the leading companies (> 40 percent of production) of these industry sectors are relatively profitable. Although consolidation in the gold sector has reduced the number of companies that produce 40 percent of the world's gold (33.1 Moz) from 16 to 6 in just one year, the sector is still highly fragmented. The 100 largest primary gold producing companies only produce 45 Moz, or 54 percent of primary production (Mining Journal, 2001d).

tion of the top 3 London-based companies is greater than the combined capitalization of the 15 next largest companies (Mining Journal, 2001c). Pyper (2001) places the boundary between large and mid-sized companies at $8.1 billion. Small companies have market capitalization of less than $2.1 billion. Using this definition, the mining industry has only ten large companies and, of these, four are in aluminum or iron.

The mining industry as a whole is not depressed. An evaluation of the relative health of the businesses in Figure 6 indicates that the troubled sectors (agricultural chemicals and base and precious metal companies) account for only about 7 percent of the overall mining industry. The reasons we are concerned, of course, are that these sectors are the ones that traditionally have been capable of adding significant value by discovery, mining, and beneficiation. Steel, cement, and aluminum companies, as well as many other commodities, once had these attributes, but unprecedented exploration successes over the past 50 years have made these materials so plentiful that these commodities have become insensitive to exploration or more innovative mining and beneficiation techniques. Companies producing aluminum, diamonds, platinum group elements, titanium, and tantalum were making record profits recently. Most other industrial metals, and the construction materials and coal that contribute more than 90 percent of the mining industry's sales, have also been profitable and in most respects are quite healthy.

The role of exploration and geology

To most economic geologists, the mining industry is synonymous with the production of high-unit-value base and precious metals as well as minerals used by the agricultural

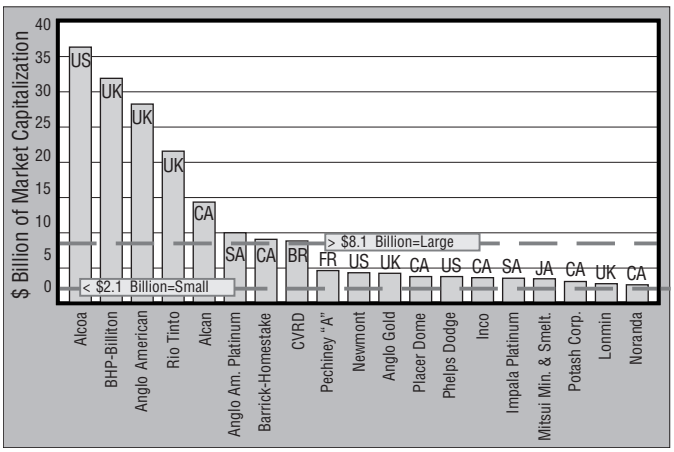

FIG. 8. The largest mining companies, showing size by market capitalization and headquarters location (BR, Brazil; CA, Canada; FR, France; JA, Japan; SA, South Africa; UK, United Kingdom; US, United States) (Mining Journal, 2001c).

and chemical industries. This limited perception of whom and what we are may be one of the root causes of our present situation. Because exploration is an integral part of these sectors of the mining industry, the fortunes of the exploration business are dependent on the fortunes of these sectors.

Major mining companies historically funded and conducted their own exploration, but globalization and reliance on the perceptions of investors have transformed the way they do business. Companies can now seek or acquire mines almost anywhere on Earth because of the opening of favorable areas and the expanded pool of attrac-

tive properties. In spite of attractive exploration plays in many places on the globe, major companies favor acquisition over exploration as it yields results in the short term and may be less costly. Because less science and fewer skilled geologists are required for these activities, the mining companies no longer consider the exploration component important to their prosperity. By the mid-1990s, with falling metals prices, major companies began to cut back on their acquisitions as well. In general, whatever exploration is done by the major companies is concentrated on existing mine units by a small cadre of highly skilled geologists.

In the late 1980s and early 1990s, the major precious and base metal mining companies largely relinquished exploration to the publicly financed junior mining companies and the fortunes of exploration became bound to those of the junior sector. The juniors emphasized grassroots exploration and the major companies served as a steady, receptive market for the larger and economically viable discoveries.

After 1997, when most speculators withdrew their support and with few markets for their properties, the junior mining sector collapsed. In Canada alone, 2,000 of more than 3,000 mining companies disappeared from the various stock exchanges, and the remainder struggled to survive or went into other businesses. The situation is equally bad in Australia, where there remain only 78 exploration companies (Macdonald, 2000) of the some 395 resource companies listed at the end of 1996 (Brook, 1998). In the last three years, we have seen a modest resurgence in interest in copper, zinc, nickel, cobalt, titanium, tantalum, and the platinum group metals. That interest is already waning with the current economic slowdown in the world economy.

The manpower and expenditures spent on metals exploration in the Western world peaked in 1997 at $5.1 billion (current dollars) and has fallen to $2.3 billion in 2000 (Fig. 9). In 1992 constant dollars, exploration spending in 1997 was $4.4 billion and spending in 2000 was $1.9 billion, a 57 percent reduction.

Geologists who were once long-term corporate and government employees are now temporary contractors or consultants. The population of geologists is now viewed as surge capacity to be employed only at peaks of cycles. The remaining corporate geologists are left with large workloads and decreased mentoring. We estimate that more than half of the economic geologists worldwide are underemployed or unemployed. Gold exploration in Australia is down more than 50 percent from 1997, and some 3,000 geologists are out of work. We have no data for the United States and Canada, but anecdotal evidence causes us to estimate that 50 to 70 percent are underemployed. There are dramatic changes elsewhere in the world. In the Soviet Union until 1989, 25,000 self-contained exploration expeditions employed 1 million people. They were still on the books in 1997, but the expeditions are not funded and these people are now out of work. In 2000, the China Geological Survey employed fewer than 10,000 professionals, compared with 400,000 six years earlier.

Although U.S. mine production has been relatively stable, the number of geologists employed by mining companies at the mines has been halved in the past 20 years. Until the mid-1990s, international exploration absorbed most of the surplus of exploration and mine geologists as they trained their host country replacements. Most expatriates have since been discharged and returned home.

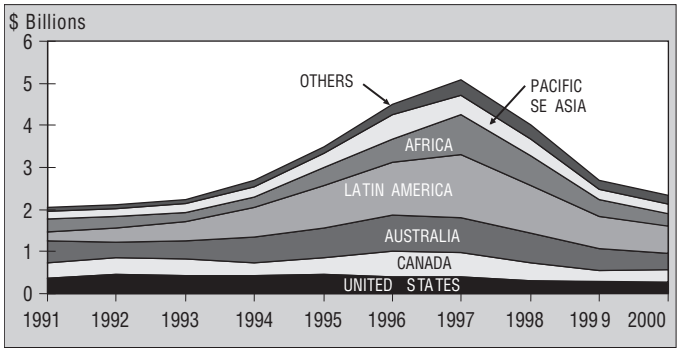

FIG. 9. Worldwide exploration expenditures in current dollars (Juhas and Snow, 2000; Mining Journal, 2001b). Exploration expenditures were at the same levels in 1994 and 1998, although by 1998 the emphasis had shifted from the developed to the developing nations. In 1994 funds were expended on geological work, whereas from 1998 forward, a large part of exploration budgets was spent on acquisitions, resulting in less work for geologists.

The Mining Industry Today

Globalization

The dominant factor affecting mining and exploration is and will continue to be globalization. In the past decade, there has been a dramatic shift of exploration, development, and production to the developing world. This owes to the pull exerted by underexplored countries, where socialism has given way to market-driven economies, and the push of hostility to the industry in the developed world. Globalization is not a new phenomenon. Since the Spanish and Portuguese exploited West Africa and the Americas, there have been three periods of globalization (Juhas and Snow, 2000). Globalization introduces efficiency to the marketplace in many ways. Global competition generally removes overt and hidden subsidies and promotes increased productivity. Consumers tend to buy the cheapest imports. Costly providers of goods and services are forced to reduce prices or go out of business. Hoarding is discouraged and stockpiles are sold off. In the mining business, emphasis is placed on seeking and developing the largest, richest, and most easily developed deposits in the most geologically and politically hospitable terrains. Economies of scale are rewarded and marginal and high-cost producers are forced to shut down. As in the past, new discoveries and production resulting from globalization tend to increase mineral product supplies and reduce commodity prices in real terms.

In the mining business, competition between domestic and foreign corporations has increased everywhere, as has commercial rivalry between nations and trading blocks. There have been shifts in industry control (centers of grav-

ity) as North American corporations and professionals became uncompetitive internationally. Much of the global base and precious metal production has shifted to Chile, Indonesia, Mexico, and Peru. Technology, which may have come at a high price to those who developed it, becomes common currency as it is adopted by industry worldwide. Once transferred, any competitive advantages this technology may have endowed the originators with quickly evaporate. For almost two decades, several of Phelps Dodge's copper mines in the United States were able to compete with larger, higher grade foreign mines because of the company's innovative bulk-mining and heap leach-solvent extraction-electrowinning (SX-EW) technology. Now these U.S. mines are closing as the same advanced technology is employed internationally. In some developing nations, attractive ore bodies can be found cropping out and/or can be easily developed using off-the-shelf technology and equipment. This reduces the need for advanced concepts and the scientific, technological, or exploration skills of professionals from the developed nations.

With globalization, capital is free to chase profits around the world (Kelley, 2001). A by-product of this is that employment shifts from one nation to another as control of certain industries is lost. In the mining business, good jobs have shifted to lower cost nations and are permanently lost to workers, whether laborers or professionals, in the higher cost nations. The shift of exploration and production activities to regions such as Latin America, Africa, and Central Asia is one reason behind the high levels of unemployment among North American-based exploration geologists and mining engineers. This shift has been caused by the pull of cheaper salaries outside North America and Chile[3] as well as the desire of corporations and domestic governments to employ local professionals (Fig.10).

Globalization has also internationalized the environmental, anti-development, and anti-trade movements. Protesters and saboteurs operate globally. The industry has never been under greater scrutiny and must build trust with local communities, government decision makers, and nongovernmental organizations willing to support it (Andrews, 2001). Trust can only be built by good performance, industry-wide condemnation of poor operating practices, and zero tolerance for fraud.

Supply, demand, and prices

An oversupply of many metals has caused low prices and little or no profits for many mining companies. As companies push to decrease unit costs by adding capacity and increasing output, they have made the supply situation worse. Consider copper as a proxy for most metals (Fig. 11). The production of copper has continued to increase in spite of the decline in its price (in constant dollars) to the lowest levels since the 1930s.

Advances in extractive technology, large-scale mining operations, and better equipment have contributed to mineral oversupply. Large modern operations cannot be easily scaled up or down in response to changing market conditions. Consequently, they continue to produce at prodigious rates into declining markets and falling prices. New technology has reduced costs, allowing large, low-grade deposits to be mined, thus adding to the supply. Having revolutionized copper and gold production, hydrometallurgical (autoclave and SX-EW) technology is now being applied to the extraction of nickel and cobalt from laterites and base and precious metals from layered mafic complexes. This may dramatically expand production and reserves of those metals to the detriment of the sulfide-based producers.

The exploration industry has contributed to the oversupply of metals. There is a surfeit of discoveries. Thousands of drilled-off mineral prospects "sit on the shelves" waiting for the right intersection of politics, technology, and economics that will justify making them into viable mining operations. The reserve base of most mineral commodities is about 50 years of supply at current rates of consumption (Fig. 1).

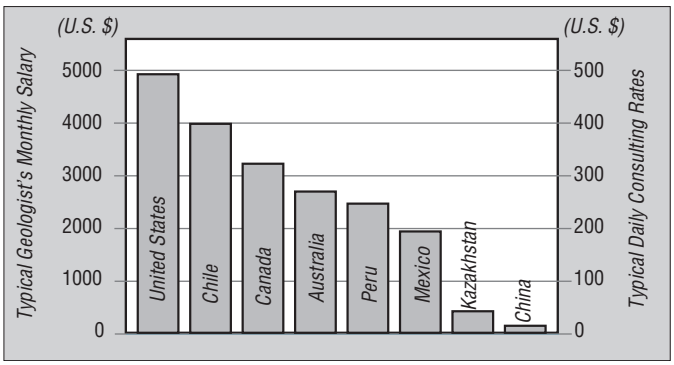

FIG. 10. Comparison of geologists' salaries, showing typical monthly exploration geologists' salaries in various nations.

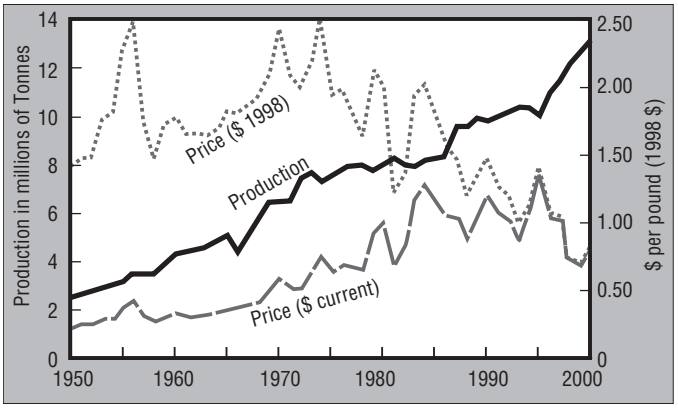

FIG. 11. World copper production and price in current and constant 1998 dollars (Metal Statistics, 1992 and 1998; E&MJ, 2001). The data suggest that as prices fell after 1988, miners aimed at lower unit costs by increasing output from existing mines. Decisions to add new capacity made at the time of a price recovery resulted in a cascade of new metal coming into the market in 1996—an eight-year lag.

[3]In these regions, foreign, as well as domestic, senior managers, in contrast to those at other levels, generally are paid salaries comparable to those in developed nations.

The demand side of the equation is relatively stable. Populations are growing, but in the developed nations, per capita consumption of mineral materials is declining (Fig. 4). The development of mineral deposits in emerging nations has not coincided with increased demand for metals in those nations. The economies of the emerging nations are not growing at predicted rates. These economies are leapfrogging high metal-use technology (e.g., from no phones to cell phones). Finally, demand from the poorest and politically unstable nations is negligible and unlikely to change in the near term.

Prices are the most important factor to the mining industry. There is a close correlation between profit and annual changes in prices (Mining Journal, 2001e). High mineral prices result in corporate prosperity and elevated share prices that keep the investors interested and invested. During the past 50 years, the booms in base metal and gold mining and exploration have coincided with periods when metal prices escalated faster than inflation (Fig.12). The end of the period of intense base metal exploration in the late 1970s was presaged by the negative 1973 copper price inflection (Figs.11, 12). Base metal prices have remained low since the late 1970s and there is little on the horizon to change this. Fortunately for the mining and exploration business in the 1980s and 1990s, the decrease in prices for base metals coincided with a rapid escalation in gold price. At present, gold prices have been driven below $450/oz, the average real price of the last 400 years (Juhas and Snow, 2000).

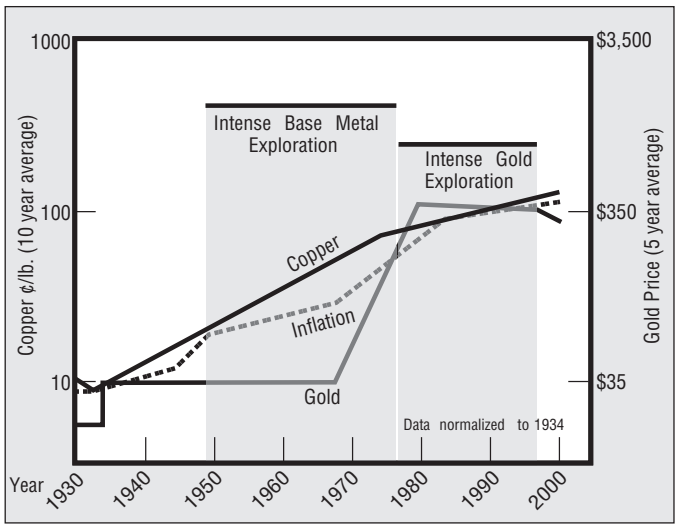

FIG. 12. Prices drive exploration. The period of intense exploration from 1949 to1977 was driven by strong demand for most commodities, especially the base metals and fertilizer minerals, for which prices stayed above the trend of inflation. Interest in gold started about the time of the 1973 negative inflection in copper and by 1982 was the "only game in town." Note how the prices converged relative to inflation in 1934 and 1993, but at an order of magnitude difference. Metal values are normalized to 1934 and prices are in current dollars (Juhas and Snow, 2000).

Ability to attract capital

The mining industry is facing a serious problem—its ability to attract capital. Lenders and investors have fled, and funding is virtually unavailable for exploration, new developments, and mine expansion. As more financial instruments become available, investors have more options globally and are less willing to invest in mining. Investors have lost confidence in the industry because of continual losses and no perceivable prospect of profits. Speculators lost interest because forward selling dampened price movements and reduced stock volatility. In view of mining's poor returns on investment (Fig. 13), it is amazing that it attracts the capital it does. Between 1992 and 1997, the last year for which we have data, the return on equity of North American gold producers was a meager 3.4 percent (Green, 1997). Since 1997, the gold price has fallen 18 percent, accompanied, no doubt, by a further decline in the return on gold equity. These data notwithstanding, the largest companies may be able to attract the capital they require. The small companies with attractive mines will be forced to pay more for capital and those with marginal operations and/or exploration projects will be unable to attract capital at any price (Pyper, 2001).

Consolidation

As with all mature industries, consolidation is reshaping the mining industry. Significant changes have been made in just the last six years, during which time more than $128 billion[4] was spent on mergers and acquisitions (Ericsson, 1999; Mining Journal, 2001a). The following are several justifications that may explain the rush to merge and acquire:

1. The industry has discovered that size matters to the fund managers and investment houses, as they are reluctant to invest in firms with market capitalization of less than $10 billion (Pyper, 2001).
2. Consolidations may be the only way some companies can become profitable as merged companies hopefully will close indifferent assets and look more rationally toward controlling marginal supply. But profits are hard to come by in an industry as fragmented as mining, as even the biggest firms lack the market power to push prices higher.
3. Discovery takes years and fund managers are impatient. Mining companies spent seven times as much on acquisitions in 1998 as they spent on exploration, "… and the gap continued to widen in 1999" (Heffernan, 2000). And because exploration has largely been discontinued, acquisitions and merger are seen as the only way to grow in the short term.
4. Management synergy and reduced overhead costs are also given as rationalization for merging. But because mines are so expensive, headquarters costs are only a tiny fraction of the total.

[4]To put this into perspective, the merger of American Online with Time Warner in 2000 was valued at $182 billion (Hinde, 2000).

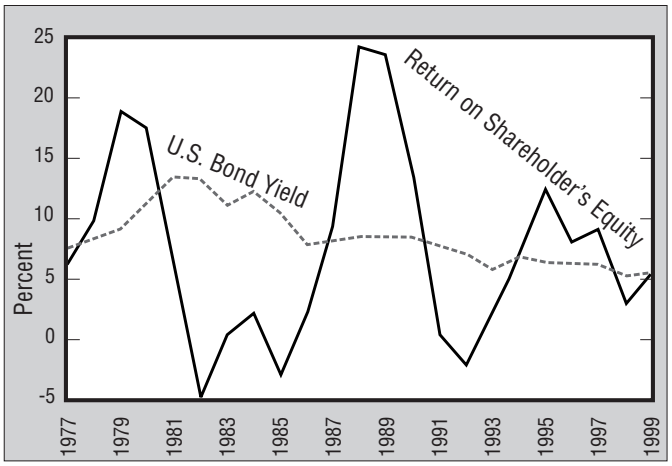

FIG. 13. Returns of base metals versus U.S. bond yields (Mining Journal, 2001e). Over the last decade, the risk-free return on 10-year government bonds averaged about 6.7 percent, whereas the higher risk mining industry, typified by base metals, returned only 5.7 percent.

Pyper (2001) expressed concerns about the rush to merge and consolidate. He observed that most mining companies lack synergies (BHP-Billiton may be an exception). Premiums of 35 percent over market price are usually required and, if paid, put the merged entity at a financial disadvantage from the start. We are aware of no situation in the mining business where a merged entity is more competitive than were its parts before the merger. Nor do we know of a situation where the exploration staffs were not substantially reduced as a result of a merger. Can new, larger corporations deliver more to their shareholders than their predecessors? And are mergers healthy consolidation of a fragmented industry? It is argued that the recent mergers are unlikely to affect the balance between prices and costs enough to ensure the industry's profitability (Mining Journal, 2001e). A final implication is that, as companies become larger, the pool of commodities attractive to them becomes ever smaller. Yet, because the industry is still highly fragmented, we doubt that the recent episode of consolidation has run its course. Industry observers believe that the larger companies will become larger, as in the telecommunications and pharmaceutical sectors.

Management focus

In our view, the mining industry overall has suffered from anachronistic management and a lack of leadership for decades. Policies have become reactive instead of proactive and tactical instead of strategic. Corporate leaders seem not to have recognized the true nature of the industry's travails and have been slow to react in some instances, and in others have employed survival strategies that exacerbate the situation. When corporate officers chose to cater to the investment community, their focus shifted from strategic visions to short-term issues such as approval ratings, stock prices, and their bonuses. This worked satisfactorily until the investors abandoned the mining sector.

Managers of mining companies became preoccupied with share price as analysts and institutional investors, who can affect share prices, considered low cost of production a measure of a company's value. Mining company managers responded by concentrating on increasing productivity (higher output at lower cost), reducing costs by cutting exploration and staff, and by divesting subordinate commodities and businesses. Each company strove to become a lower quartile cost producer in the hope that they would be more competitive. Such strategies only exacerbated the problem as they produced excess supplies and ruinously low prices. Two companies stand in stunning contrast to most of the industry. Barrick Gold and Franco-Nevada Mining Corporation prospered during the 1990s by emphasizing the business of mining, not just production.

Research and technology

One of the problems facing the mining industry is that fundamental research into mineral applications has been dramatically reduced in recent decades. Most mining companies abandoned their research functions years ago, and some governments are doing the same. Research is now being done by universities and to a limited extent by corporate-university cooperatives. But universities are under pressure, as minerals-related teaching and research attract fewer students and as funding drops.

To overcome these problems, industry-university research groups have been formed in some countries, notably Australia and Canada. These groups use university researchers funded by consortia of mining companies. For example, the Australian Minerals Industries Research Association and the Mineral Deposit Research Unit at the University of British Columbia have been successfully doing research that companies want and need.

Entrepreneurship

Entrepreneurs have always populated the mining industry. Many of the well-known North American mining companies of the twentieth century rose to greatness because of intrepid visionaries and persistent iconoclasts promoting the latest technology, or the smartest business plans. Some of the early ones include Anaconda, ASARCO, INCO, Kennecott, Newmont, Texasgulf (Navin, 1978), and Falconbridge. In more recent times, we have seen companies such as Teck, Barrick, and Franco Nevada ascend to prominence from entrepreneurial beginnings.

Entrepreneurs in the mining industry have been experiencing difficult times since 1997, but they are surviving. Some are companies that conserved cash raised before 1997, and others have been able to raise cash based on good business plans. Other individuals and small groups have persisted with specialty operations and markets. All are niche players. A company with an oxidized zinc sulfide ore body in Spain produces and sells pharmaceutical-grade zinc oxide and carbonate. When precious metal prices collapsed, Saint Cloud Mining Company found a new commodity on its doorstep and now dominates the U.S. zeolite market. Other entrepreneurs are establishing new markets through new

applications for zeolites. The recent popularity of stone-slab counter tops has become a profitable industry for several individuals and small mines. Other companies are engaged in customer-based exploration and production programs for specific commodities (platinum and tantalum). We see such examples becoming more commonplace as a new breed of mining entrepreneurs emerges.

Recommendations

As we have examined the base and precious metal mining industry over the past few years, we have two suggestions that may solve some of the industry's problems. Individuals and companies of all sizes should seek attractive niches among the entire list of commodities and vertical range of the industry, both domestic and foreign. All survivors, whether individuals or corporations, must adopt an entrepreneurial mind-set. We expect that many well-managed entrepreneurial mining and exploration companies of all sizes will prosper and offer rewarding careers to the persons involved with them in the not-too-distant future.

Corporations

A shortcoming in our industry recently has been poor management. Leaders of the base and precious metal businesses need to grab the reins and guide the businesses to sustainable profitability. The mining industry's challenge is how to become price seekers instead of price takers. The industry needs to redirect its attention to wealth creation and profits. A good start would be to seek better, creative solutions and capitalize on niche opportunities in mining, value-added vertical integration, and more innovative marketing of mined products (Juhas and Snow, 2001).

Metal miners should market their products in a way that will allow them to differentiate their products and capture more of the profits that now accrue to middlemen and fabricators. Michal (1984) pleaded with the metal-producing industry to add value to its otherwise fungible commodities. He calculated a "99 percent probability that value-added and profitability were related." Where a distinction can be made between raw materials and the finished products first sold (e.g., iron ore/steel, limestone/cement, bauxite/aluminum, and rutile/titanium), the value added through vertical integration is on average more than 1,000 percent (Figs. 4, 6). In the past, some base and precious metals producers sold finished metal into the marketplace. Instead of disposing of their fabrication divisions, perhaps Noranda and Phelps Dodge should have promoted and expanded their upstream, finished product lines. BHP and DeBeers are now profitably selling cut diamonds directly into the retail markets. Corporations should stop viewing themselves as miners and instead see themselves as providers of mineral products.

The industry should direct its energies toward finding new uses or applications for mineral products. The International Nickel and Climax Molybdenum companies took nickel and molybdenum from curiosities into essential modern materials through basic research and effective marketing. The mining industry should promote and support research to employ minerals to solve society's energy, pollution, medical, and transportation problems.

Universities

The mineral industry must develop mechanisms to promote research in economic geology and materials science and encourage the students who have chosen to embark on mineral industry careers. The industry should, at a minimum, return to the practice of offering summer jobs and internships to college students. If the industry wants applications-based research and skilled graduates, it is going to have to do its fair share of funding the research and training the students. This would be more likely to happen if the institutions were to merge the talents of their faculties into fewer, but higher quality "magnet centers" such as the Centre for Global Metallogeny at the University of Western Australia. Professional societies help dozens of students each year with scholarships and research grants. But this is not enough! The industry, worldwide, needs the results of research that solves the practical problems in economic geology and that advance material science. Because the problems and opportunities cross national boundaries, the Society of Economic Geologists, for example, might be an excellent organization, in cooperation with universities, cooperatives, and "magnet centers," to focus corporate donations to the projects that would be most productive for the industry.

Entrepreneurs

Entrepreneurial entities thrive on innovation. Most of innovation is not high technology, but rather incremental improvements in product quality, more flexible management approaches, better marketing concepts, and better service to customers (Drucker, 1985).

Although small companies and individuals may have suffered more from the recent changes than the larger companies, smaller entities may have more opportunities before them. These opportunities can be anywhere between exploration and excavation through final sale of a mineral product. Small companies may find niches too small for the major companies to exploit among the 80 mineral commodities used in today's economy. Small companies that don't need to promote stock sales might find a better chance of success from good deposits in sectors they could dominate among the 53 commodities with less than $1 billion in sales. It is beyond the scope of this paper to identify all the niches and opportunities, but LaPoint and Juhas (2001) identified some of the following main characteristics of niches:

1. They have markets for end products that are not big enough for the major companies.
2. They serve markets that are transportation- and price-sensitive.
3. Customer-based financing can be sought for exploration and production ventures.
4. Niche deposits that are too small for the major companies may present opportunities.

5. They are projects in new territories or districts.
6. They are specialty products differentiated by physical properties, chemical or mineralogical composition, and/or purity.
7. They involve commodities to which value can be added through vertical integration.
8. The product may find an application based on recent research that offers new solutions to problems in the environmental, health, agricultural, industrial, transportation, construction, energy, and lifestyle industries.

The individuals or companies who can take advantage of new opportunities will have some or all of the following characteristics:

1. They will have imagination and creativity and the ability to move quickly.
2. They will be lucky or smart enough to capitalize on the peaks of price cycles.
3. They will be perspicacious enough to recognize and tailor products to new markets.
4. They will be able to draw on other industries to develop hybrid technology.

Conclusions

We conclude that the current dismal state of the metals exploration business and some segments of the mining business are the result of long-term trends and that these trends are evolutionary, not revolutionary. The resultant changes in the business environment are permanent in the sense that there is no going back, but they will continue to evolve. The biological imperative offers three choices to competing entities struggling to survive in a changing environment: they may flee, adapt and evolve, or die. Ecological systems and economies need self-fueling diversity to expand (J. Jacobs, 2000). Environments and organisms are continuously changing, as is the business of mining. One reason base and precious metal mining is in difficult straits is because it has lost its diversity and its ability to fuel itself. It needs to diversify and harness the creativity of its stakeholders, whether individual, corporate, or in universities or government.

We believe the future of the mining industry will reside in those with entrepreneurial mind-sets and visionary and strategic approaches. Aggressive, fast-moving entrepreneurial organizations of all sizes are the ones that will be best able to avoid pitfalls and capitalize on opportunities. Successful corporations will incorporate one or more of the following strategies: (1) become market leaders in a market segment or niche, (2) diversify upstream, and (3) sell upgraded products into wholesale or retail markets. The renaissance of mining will be led by entrepreneurs. The way out is through visionary sector leadership and effective product marketing.

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