# CHAPTER 1—INDUSTRY OVERVIEW

## MINING LIFE SEQUENCE

## MINERAL EXPLORATION AND MINING

## COMMODITIES

## PARTICIPANTS IN EXPLORATION AND MINING

## FUNDING MINERAL EXPLORATION

The mining industry is vital to our everyday life. The cars we drive, the houses we live in, the appliances and entertainment equipment we use and the health care and medical devices that provide us with a high quality of life rely on the products of the mining industry.

Mining and exploration are a business. As such, they rely on the capital markets to operate. Without the stock market there would be no exploration industry and without the larger financial institutions that support mine development there would be no mining industry.

Mining is a wealth-creation industry. From a seemingly dull and unimportant rock, great wealth and economic activity can be generated. To generate this wealth, a partnership is needed between the financial and business community and the technologists, geologists and engineers that can find and build a mine. Both groups need an understanding of the other for this partnership to work effectively.

This book provides an overview of the technical aspects of the exploration and mining industry for those in the financial and business communities and for anyone interested in learning more about the technical aspects of the industry. It will provide an overview of geology, mineral deposits, exploration techniques, resources and reserves, feasibility studies, mining and processing methods and environmental considerations.

**Facing Page**

A gold pour at the Pogo Mine in Alaska. The molten material will harden into gold doré bars that will be shipped to a refinery for final processing into 99.99% gold (image courtesy of Teck Resources).

This book will help investment advisors, analysts, investor relations personnel, regulators, government employees, investors, accountants, lawyers, students, the service sector, community members and others understand the exploration and mining industry. In particular, the book will help with the development of professional careers, business growth, investment decisions and the informed assessment of exploration and mining projects by communities, governments and the financial sector.

## THE MINING LIFE SEQUENCE

Mineral exploration and mining are part of a dynamic industry sector that includes several key components (FIGURE 1.1). The mining life sequence starts with exploration, moves through mining and ends with the closure and reclamation of a mine site. Each step in the sequence is unique and most mining projects proceed progressively from one step to the next. There is overlap between some of the steps in the sequence. For example, community consultations will normally commence during exploration, and reclamation is typically on going during mining. The mining life sequence includes seven stages.

*Exploration:* The search for and evaluation of deposits of minerals and rocks that may be valuable. A deposit must first be found and defined before it can be mined.

*Consultations, permitting and financial analysis:* The consultation with communities, governments and stakeholders about the social, economic and environmental aspects of a proposed mine, as well as environmental assessment and permitting and detailed engineering and financial analysis.

*Construction:* The development of the mine once permits are secured.

*Mining:* The extraction of ore from the ground.

*Mineral processing:* The crushing, grinding and processing of ore in order to recover the valuable minerals or materials from the rock.

*Smelting and refining:* The treatment of minerals recovered by processing in order to produce the final product such as pure copper (only some ore types require further treatment by smelting).

*Closure and reclamation:* The closure of the mine and reclamation of the land to return it, as much as possible, to its pre-mining state.

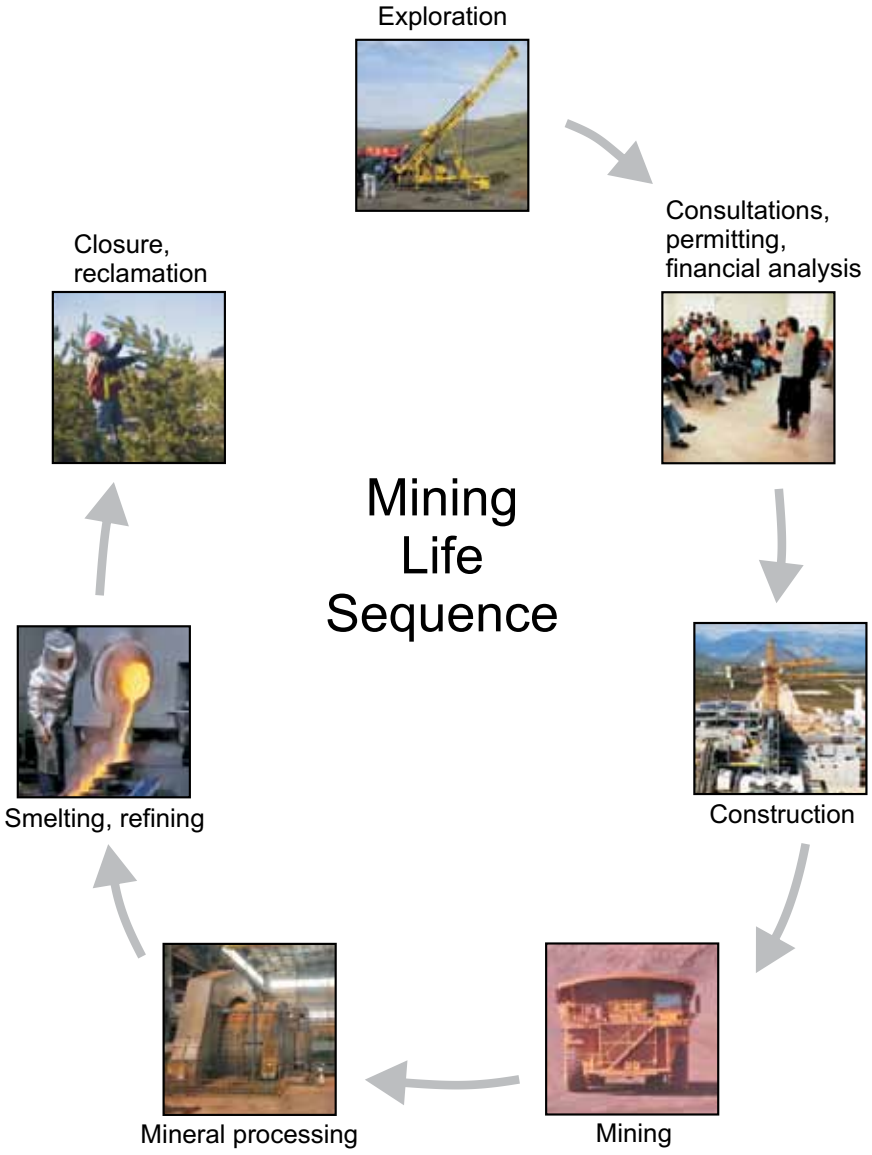



**Figure 1.1** The mining life sequence outlines the stages a mining project passes through from exploration to closure and reclamation.

The time spent and expenditures incurred in each stage of the mining sequence vary considerably (TABLE 1.1). For example, small, relatively simple projects may move from exploration to mine operation within a few years, followed by closure of the mine a decade or so after the start of operation. Whereas, large, complex projects may take upwards of 20 years for exploration, permitting and construction, followed by operation for many decades. Likewise, expenditures for exploration, permitting and construction range

from approximately US$100 million for small projects to more than US$3 billion for large projects.

**Table 1.1 Mining Life Sequence - Time Line and Cost Summary**

| Activity | Time Lines | Cost/Return (US$) |
|---|---|---|
| Exploration | 3–12 years in total to a development decision (exploration often occurs in starts and stops over one or more decades) | $50,000–$20,000,000/year $20–$150+ million to the start of mine construction |
| Permitting and financial analysis | 2–7 years (includes feasibility studies and environmental assessment) | $2–$20 million |
| Construction | 1–4 years | $100 million–$3+ billion |
| Mine operation | 5–100 years | Total mine revenue in the hundreds of millions to billions |
| Closure and reclamation | 2–5 years after mining ends (ongoing monitoring may go on much longer; reclamation usually starts during mining and continues afterward) | $2–$50 million (usually considered part of the mining costs) |

## MINERAL EXPLORATION AND MINING

Although the mining life sequence includes several key components, it is generally divided into two parts: mineral exploration, which is the search for and definition of a mineral deposit; and mining, which includes all other parts of the sequence.

**Mineral Exploration** This is the process of discovery, definition and economic evaluation of mineral deposits. In other words, mineral exploration is about finding a mineral deposit, defining it and determining if it may be economic to mine.

Mineral exploration includes:

- Prospecting (searching for a mineral deposit)
- Geological, geochemical and geophysical surveys (searching and evaluating a deposit on the surface)
- Drilling (evaluating a deposit below the surface)
- Resource estimates (calculating a grade and tonnage)
- Pre-feasibility studies (preliminary mine planning and economic analysis)

**Mining** The process of extracting metallic or non-metallic mineral deposits from the Earth and processing the ore to recover the valuable material. Mining includes:

- Feasibility studies (detailed design, planning and costing)
- Environmental assessment (consultations and permitting)
- Mine development (construction and commissioning)
- Ore extraction (blasting, loading, hauling and dumping)
- Mineral processing (concentrating ore and removing waste material)
- Smelting and refining (recovering final products)
- Closure and reclamation (returning the land to a pre-mining state)

Mineral exploration is the front end of the mining industry. New deposits must be explored for and discovered before new mines can be developed. In the context of other industry sectors, exploration is the "research" part of research and development and mining is the "development" part. This "research" must be ongoing so there is a continual supply of new mines to replace those that close as reserves are depleted.

**Odds of Exploration Success** Exploration is the search for mineral deposits. Mineral deposits, however, are rare and buried beneath the surface of the Earth. Economic mineral deposits are even rarer. Since mineral deposits are rare, finding one is challenging and the odds of success of any exploration program are relatively low.

It has been estimated that the odds of a small mineral showing discovered by a prospector becoming a mine are on the order of 1:1,000,000 or more (recognizing that a prospector may discover many small showings in the course of a field season). Even when a mineral deposit has been defined, the odds of it becoming an operating mine are, at best, 1 in a 1000!

However, when an economic mineral deposit is discovered, the financial and professional rewards for the companies and people involved are significant. To maximize the chances of success, exploration companies and geologists use a wide range of skills and tools in the search for and evaluation of mineral deposits. Nevertheless, there is always an element of *luck*, and more than one deposit has been found by pure chance.

**Importance of Potential** Mineral exploration is all about potential. A newly discovered small mineral showing may have low odds of ever becoming a mine. However, even the smallest showing has potential! Years of work and millions of dollars of expenditures may be required to evaluate the potential of a new mineral showing. And, although the odds of a new mineral showing becoming a mine are low, the odds of this showing being marketable and generating industry and stock market interest are much higher. The potential that a new discovery may become the next big mine can generate an incredible amount of stock market activity.

Evaluating or judging potential is difficult, particularly in the early stages of evaluating a mineral showing. Geologists will use science, experience and intuition, but a mineral showing with high potential to one geologist may have low potential to another. Similarly, one investor may see high potential in an exploration company and its properties while another investor will not.

## Mineral Exploration—Global Perspective

Exploration is carried out by a wide range of companies and individuals and is global in nature. From 2002 to 2013 annual global exploration expenditures were in the range of US$2–22 billion with a low in 2002 and an all time high in 2012 (FIGURE 1.2). Of these expenditures, approximately 20–30% occurred in North America, 20–30% in Latin America, 10–15% in Australia, 15-18% in Africa, and about 15–20% in other parts of the world (FIGURE 1.3). As single countries, Canada and Australia received the highest exploration expenditures followed by the United States.

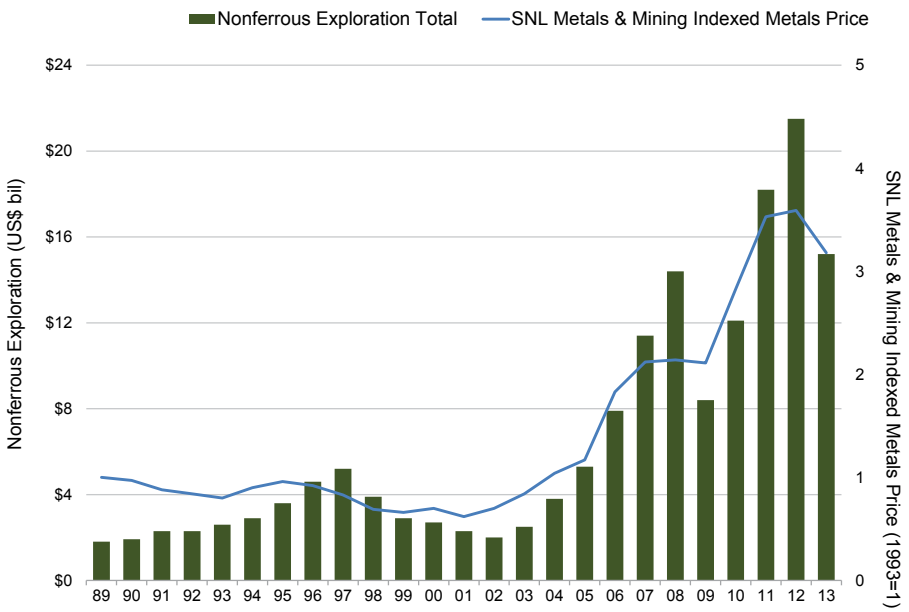



**Figure 1.2** Global exploration expenditures from 1989–2013 in US$ billion (chart copyright SNL Metals & Mining, 2014).

The overall increase in exploration expenditures from 2002 to 2012 (FIGURE 1.2) was accompanied by a substantial increase in the cost of exploration. Everything from drilling to fuel to geoscientists increased by more than the cost of inflation. It has been estimated that from 2004 to mid-2008 overall exploration costs increased by 25–50%! As such, the growth of exploration activity did not increase by as much as the exploration expenditures suggest. The drop in expenditures in 2009 was a result of the global economic crists

and recession that began in 2008. However the drop was short lived with expenditures increasing rapdily through 2012. By 2013 a cyclical slow down in the exploration and mining industry had taken hold with the resultant drop in expenditures as junior companies found it very difficult to raise exploration funds and majors reduced their exploration budgets.

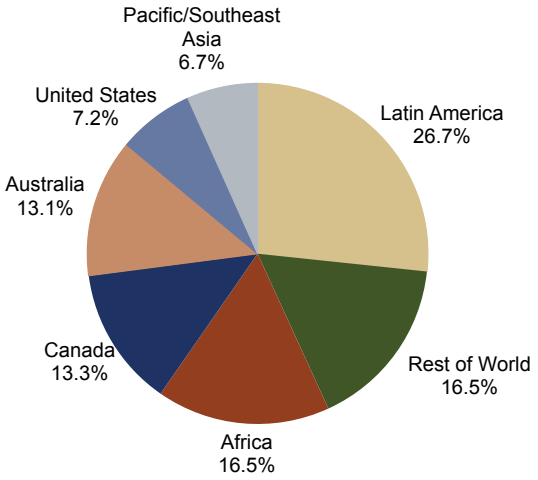



**Figure 1.3** Distribution of global exploration expenditures in 2013. This break down of expenditures by region is representative of the decade preceding 2013, except for Canada which was at 16-19% for most of the past decade (chart copyright SNL Metals & Mining, 2014).

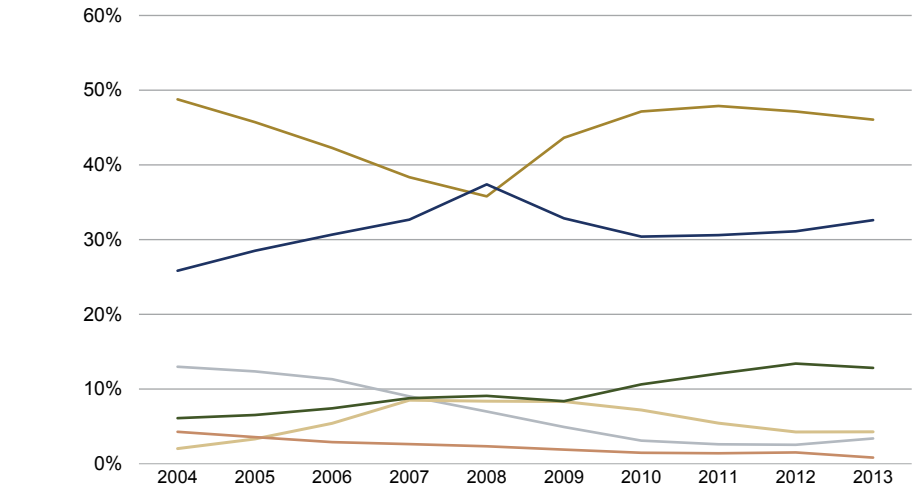
## COMMODITIES

The commodities that are sought after and produced in exploration and mining are diverse and vary with time depending on the prices that commodities command and the demand for these commodities for industrial purposes.

The main groups of commodities are:

- *Precious metals* (gold, silver and platinum group elements or PGE's which include platinum, palladium, osmium, iridium, ruthenium and rhenium)
- *Base metals or non-ferrous metals* (copper, zinc, lead, nickel, tin and aluminium. Copper, zinc and lead are the most common base metals.)
- *Ferrous metals* (iron, molybdenum, chromium, cobalt, manganese and tungsten. Traditionally used to denote those metals that are mined for their alloying properties with iron in the manufacture of steel)
- *Fusionable metals and fuels* (uranium, coal and oil sands)
- *Gems and gemstones* (diamonds, emeralds, rubies, sapphires, etc.)
- *Industrial minerals and rocks* (a wide assortment of minerals and rocks with industrial uses. An industrial mineral is defined as any rock, mineral, or other naturally occurring substance of economic value, exclusive of metallic ore, mineral fuels and gemstones.)

Despite the wide range of mineral commodities, the exploration industry focuses most of its resources on a relatively small number of commodities, specifically gold, copper, zinc, lead, diamonds, uranium and platinum (FIGURE 1.4). The reasons for focusing on these commodities include the demand for these commodities, the difficulty/cost of making new discoveries in these commodities, and, importantly, the ability to raise financing. Investors are generally willing to finance gold exploration projects but may be less enthusiastic to finance a lithium or building stone project.




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gold | 48.8% | 45.7% | 42.3% | 38.4% | 35.8% | 43.6% | 47.2% | 47.9% | 47.2% | 46.1% |
| Base Metals | 25.8% | 28.5% | 30.7% | 32.7% | 37.4% | 32.9% | 30.4% | 30.6% | 31.1% | 32.6% |
| Diamonds | 13.0% | 12.4% | 11.3% | 9.0% | 7.0% | 4.9% | 3.1% | 2.6% | 2.5% | 3.4% |
| Uranium | 2.0% | 3.3% | 5.4% | 8.5% | 8.4% | 8.3% | 7.2% | 5.4% | 4.3% | 4.3% |
| PGM | 4.3% | 3.6% | 2.9% | 2.6% | 2.3% | 1.9% | 1.5% | 1.4% | 1.5% | 0.8% |
| Other | 6.1% | 6.5% | 7.4% | 8.8% | 9.1% | 8.4% | 10.6% | 12.1% | 13.4% | 12.8% |

**Figure 1.4** Global exploration budgets by commodity 2004–2013 (chart copyright SNL Metals & Mining, 2014).

Metal prices can be found at the following sites:

- Gold, silver, platinum and palladium: http://www.kitco.com/market/
- Base metals, nickel, tin and aluminium: http://www.kitcometals.com/ or http://www.metalprices.com/
- Uranium: http://www.uxc.com/
- Molybdenum and other metals: http://www.infomine.com/commodities/

### How are Metal and Mineral Commodity Prices Set?

The prices for metals and other mineral commodities are usually set on the open market or by contract. Metal exchanges in London, such as the London Metal Exchange (LME), and London Bullion Market or in New York (New York Mercantile Exchange) provide a market for the free trade of common metals including gold, silver, platinum, copper, lead, zinc, nickel and alum-

inum. The prices for these commodities are established on a supply/demand basis on an open market, similar to how stock prices are set on exchanges. The prices for most other metals are usually set by contract between producers, suppliers and end users. This includes metals such as titanium, tungsten and uranium. Although the prices are set by contract, a number of organizations track offers, bids and contract prices and publish these regularly. This provides a level of transparency to these metal prices even though they are not traded on an open market. The UX Consulting Company (www.uxc.com), is a good example. UX Consulting independently tracks uranium offers, bids and contracts and uses this to publish a uranium price. Molybdenum and cobalt have traditionally been traded by contract but in early 2010 they were included in the metals traded on the LME and thus prices are now set on an open market.

Coal and potash are examples of non-metal commodities in which the price is established by contract. In addition, since they are bulk commodities, transportation and shipping become an important aspect of the contract price. For example, potash contracts with producers in Saskatchewan, Canada, are usually based on the producer delivering the product to the port of Vancouver (referred to as *free on board* (FOB) Vancouver). Coal prices must also take into account the quality and characteristics of the coal. Every coal deposit differs in aspects such as heat value and degree of impurities. Cleaner coal will command a higher price than coal with a high level of impurities.

The valuing and pricing of diamonds is unique to each diamond or to a small packet of similar sized and quality diamonds from a given mine. In general, the value of a diamond is based on its size, shape, colour and clarity. However, the country of origin of the diamond also influences the price. Diamonds are valued by a number of different groups including the mining company, government agencies (for royalty purposes) and international traders.

## PARTICIPANTS IN EXPLORATION AND MINING

A variety of players are involved in exploration and mining from the individual prospector to large multinational companies. Each has an important role along the road to discovery and mining.

**PROSPECTORS** "An individual engaged in prospecting for valuable mineral deposits, generally working alone or in a small group, and on foot with simple tools or portable detectors." (Bates and Jackson, 1984).

Prospectors often have little or no formal training. What they do have is years of hands-on experience looking at rocks and minerals. Good prospect-

ors know where to look and how to look, and they are tenacious. A prospector's tools are generally limited to those that he/she can carry (hammers and pick axes, hand lens, etc).

Most prospectors operate as individuals using their own financial resources. They will stake ground when they find a showing of interest, and they will try to entice larger companies to option their ground. However, junior exploration companies and mining companies often hire prospectors to work on their exploration projects. Yearly expenditures by an individual prospector are typically in the $1000–$10,000 range.

### Junior Exploration Companies (the "Juniors")

A junior exploration company is defined here as a company that focuses solely on the exploration and discovery of mineral deposits and does not operate a mine. Junior exploration companies play an essential role in the mineral exploration business. Most of the major new discoveries in the past several decades have been made by these companies. Junior exploration companies are also speculative stock investments. As such they also play an important role in the equity markets of places like Canada and Australia.

Some of the characteristics of a junior exploration company are:

- They are publicly listed on a stock exchange (there are a few private exploration companies but most private exploration companies are set up with the intent of listing on a stock exchange).
- They have no operating mines and no revenue.
- They are small, with only a few employees (5–30) and annual expenditures of $250,000 to $5,000,000+. During periods of active exploration there maybe 100 or more employees and expenditures could reach more than $10 million. In many cases, much of the field exploration work is contracted out as required.

The management and operation of a junior is typically a mix of business professionals with financing, accounting and legal backgrounds, and technical professionals with geological or mining backgrounds. Commonly, the most successful junior exploration companies are those that are managed by a mix of business and technical professionals who have the ability to identify opportunities, fund those opportunities and carry out effective exploration programs.

Juniors work on a wide range of exploration properties, but often focus on early stage "grass-roots" properties with good potential to make a discovery.

### Intermediate & Senior Mining Companies (the "Majors")

The majors are those that operate one or more mines. They range from companies with one small mine to large multinationals with many mines. These companies have the largest exploration budgets of any players in the business with annual expenditures ranging from $2–$10 million for small mining companies to $50 million or more for large companies (*e.g.* Barrick Gold had a 2007 exploration budget of $170 million and an exploration staff of over 500). Annual expenditures will, of course, vary depending on market conditions. In the late 1990's and early 2000's exploration budgets of many large gold mining companies were reduced to a few million dollars due to depressed gold prices. In this type of market gold mining companies grow through acquisition, rather than exploration.

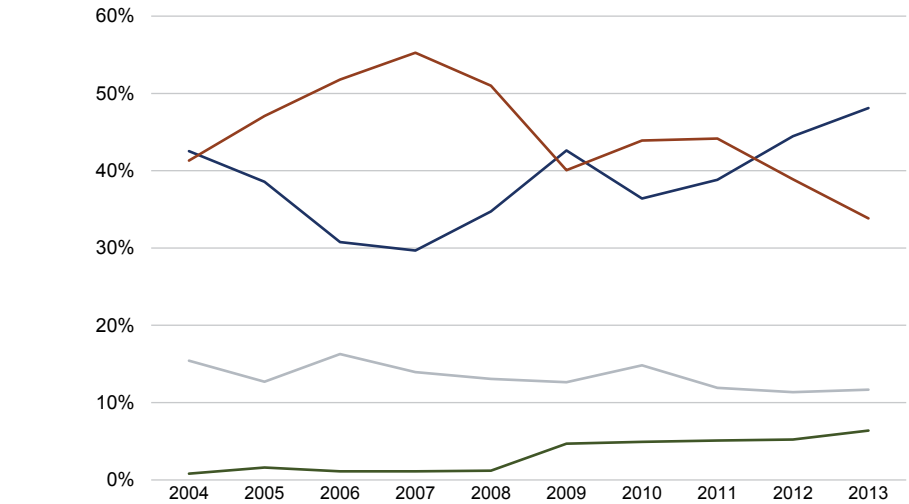
Although intermediate and majors are grouped together here, the Metals Economics Group (www.metalseconomics.com) defines the majors as those companies with annual revenue over $500 million and the financial strength to develop a new mine on their own. Intermediate companies are those with revenue between $50 and $500 million.

The majors are often more selective in their choice of exploration properties. Where a junior company may be happy to discover a relatively small deposit, majors are interested in the "world class" deposits that could be developed into a large mining operation.

Although majors have the largest exploration budgets, they tend to be less successful than juniors at discovering new deposits. Some of the reasons for this include:

- Majors spend a lot of their exploration budgets drilling around deposits that have already been discovered, with the aim of expanding the known deposit.
- Majors become too focused on the search for large deposits and thus miss opportunities.
- Juniors are better risk takers and entrepreneurs. This characteristic often leads to discovery.
- Juniors are lean with little bureaucracy and decisions can be made swiftly.
- Majors buy into deposits or junior companies after the discovery has been made (they leave the high-risk discovery stage to the juniors).

The exploration expenditures by the juniors and majors vary over time. From 2004 to 2013, expenditures by majors ranged from 30–50% of total global exploration and juniors from approximately 35%–55% of global exploration (figure 1.5).




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|
| Majors | 42.5% | 38.6% | 30.8% | 29.7% | 34.7% | 42.6% | 36.4% | 38.8% | 44.5% | 48.1% |
| Intermediates | 15.4% | 12.7% | 16.3% | 13.9% | 13.1% | 12.6% | 14.8% | 11.9% | 11.4% | 11.7% |
| Juniors | 41.3% | 47.1% | 51.8% | 55.3% | 51.0% | 40.1% | 43.9% | 44.2% | 38.9% | 33.8% |
| Gov't/Other | 0.8% | 1.6% | 1.1% | 1.1% | 1.2% | 4.7% | 4.9% | 5.1% | 5.2% | 6.4% |

**Figure 1.5** Global exploration expenditures by company type, 2004–2013. Expenditures by juniors generally surpass those of majors when equity markets are strong for the mining sector and are less than majors during challenging equity markets such as in 2009 and 2012-2013 (chart copyright SNL Metals & Mining, 2014).

## FUNDING MINERAL EXPLORATION

Exploration funding comes from two main sources: (1) equity financing on stock markets (primarily from markets located in Canada, the US, Australia, London and South Africa), and (2) revenue from mining operations.

**Stock Markets** Equity financing on stock markets is one of the most important sources of funding for exploration. Almost all of the money raised by junior exploration companies is on the stock market, and a portion of the exploration dollars spent by major companies also comes from the stock market. In Canada, exploration companies raise money through the Toronto Stock Exchange (TSX and TSX-venture exchanges). In 2007, junior exploration companies were able to raise approximately US$7 billion in equity financing (FIGURE 1.6). At that time, metal prices were strong and the equity markets for speculative junior exploration companies were vibrant. The opposite occurred in 2013 when some metal prices were depressed (in particular gold and silver) and stock market interest in junior exploration companies was limited.

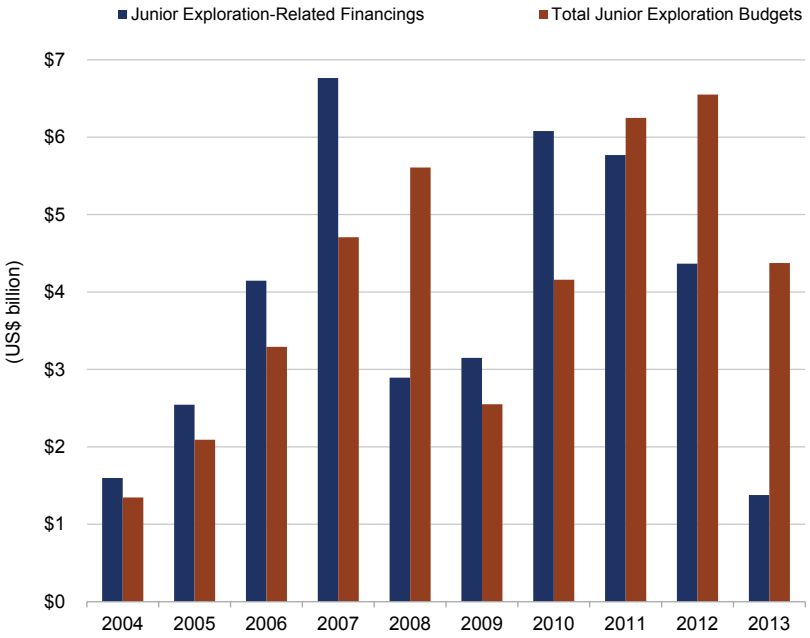



**Figure 1.6** Equity financing and exploration budgets for junior exploration companies between 2004 and 2013. When the stock market and metal prices are strong such as in 2007, juniors are able to raise a significant amount of money for exploration. However when markets for the mining industry and/or metal prices are depressed, such as in 2013, it can be very difficult for juniors to finance exploration (chart copyright SNL Metals & Mining, 2014).

**Mine Revenue** Mine revenue is a dominant source of exploration funds and is the primary way in which major mining companies fund their exploration. Mine revenue is generally directed in one of three ways:

(1) Exploration within and around the mine sites of the company. These dollars are aimed at finding new mineralization to replace the mineralization that has been mined out. Success rates are relatively high in this type of exploration.

(2) Global exploration in areas outside of the company's mine sites. A portion of a company's total revenue or profit for the year from all operations will be directed towards exploration elsewhere in the world.

(3) Funding the exploration work of other companies. Major mining companies are increasingly stretching their exploration dollars by funding the work of other companies, particularly juniors. This usually involves taking an equity stake in the junior company with a right of first refusal on any deposits discovered or by funding exploration work in return for partial ownership of properties developed by the funding.

## REFERENCES

**Bates, Robert L., and Jackson, Julia, A., Editors 1984**. Dictionary of Geological Terms, Third Edition. Prepared by the American Geological Institute. Published by Doubleday, 571p.