MINERAL EXPLORATION AND DEVELOPMENT: RISK AND REWARD

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Mineral exploration and development are investigative activities prior to mining. The rewards of successful exploration and development can be large, if a mineral deposit is discovered, evaluated, and developed into a mine. For a mining company, successful exploration and development lead to increased profits. For a local community or nation, successful mineral exploration and development can lead to jobs—often well paying—that otherwise would not exist; to new infrastructure, such as roads and electric power supplies, that are catalysts for broader, regional economic development; and to increased government revenues that, in turn, can be invested in social priorities such as education, health care, and poverty alleviation.

But mineral exploration and development carry with them risks, as well. For local communities and governments, the risks come from the possibility that there will be significant external (or spillover) effects from mining—for example, environmental degradation or strains on local communities and social services when there is an influx of new people into a booming mining town. These spillovers may outweigh the benefits from mining if most jobs go to outsiders, environmental degradation or community disruptions are large, tax revenues accrue to national governments and are not returned sufficiently to local communities, or governments spend mining revenues unwisely.

These social risks associated with mineral exploration and mining are *not* the subject of this paper.

Instead, this paper focuses on the perspectives of private investors in mineral exploration and development. It begins by summarizing the important characteristics of exploration and development, including the various sources of risk. It then discusses the factors that determine the geographic location of private investment in these activities. It closes by describing how exploration and development are financed.

Characteristics of Mineral Exploration and Development

Mineral exploration and development are investments. As such, companies spend money today in the expectation that future revenues will be sufficient to cover all costs including a minimum acceptable profit. Possible investment projects in the mineral sector compete for funds with other investment opportunities, both within and outside the mining sector. The level and location of investment are determined by expected revenues and costs, adjusted for time and risk. The higher the expected revenues or the lower the expected costs, the more attractive an investment opportunity is. When comparing one investment opportunity with another, the longer an investor has to wait to receive revenues or the riskier the investment, the less attractive the investment is.

In the mineral sector, the factors that influence expected revenues, costs, and risks can be grouped into four categories:

- Geologic Factors: Does a mineral resource exist in a region, in what quantities, and of what quality? Geologic risk can be thought of as the likelihood and degree to which actual mineralization (its quantity and quality) differs from what is anticipated at the point a decision is made to undertake exploration or development. For example, what is the likelihood that a mineral deposit exists in a region undergoing initial geologic investigation? Or during mining, what is the likelihood that the grade and quality of ore differs from what was expected at the time the mine was initially developed?

- Technical Factors: Can a known resource be extracted and processed with existing or likely future technologies? Technical risk can be thought of as the likelihood and degree to which actual recovery of a mineral during mining and processing differs from what was anticipated. In other words, are there unanticipated technical problems or complications associated with mining, mineral processing, and extractive metallurgy?

- Environmental, Social, and Political Factors: Can a resource be extracted in ways that are consistent with a nation's preferences and policies for environmental protection? Can it be extracted in ways consistent with preferences and policies of local communities? Risks in this category can be thought of as the likelihood and degree to which actual environmental degradation or impacts on local communities differ from what was expected. Or the likelihood and degree to which public attitudes, public policies, and the overall business environment differ from what was expected at the time of initial investment.

- Economic Factors: Overall, can a mineral resource be extracted at a profit? Economic risk can be thought of as the likelihood and degree to which actual revenues and costs differ from what was anticipated at the time of investment? Economic risk is an overarching type of risk because it incorporates and reflects the three other categories of risk cited above. It incorporates the purely economic risks that actual mineral prices and production costs are different than anticipated at the time of initial investment.

Two important implications of viewing mineral exploration and mine development as investments are (a) the mineral sector competes with other sectors for scarce investment resources, and (b) within the mineral sector, countries compete with one another for investment.

Mineral exploration and development are the first stage in the process of mineral supply. The stages of mineral supply are:

- Mineral exploration and development, in which mineral deposits are identified, evaluated, and prepared for mining. Exploration and development can be subdivided into four substages: (a) grassroots exploration prior to detection of mineralization or identification of a geologic deposit, (b) advanced-stage exploration evaluating a geologic discovery to determine whether it should proceed to development, (c) deposit development, in which full technical and economic assessments are carried out, and a decision is made on whether to proceed to mining, and (d) mine development, in which a mine and all associated facilities and infrastructure are planned, designed, and constructed. Any precise boundaries between these substages of exploration and development are somewhat arbitrary. These substages perhaps most usefully are thought of as a continuum of activities.

A word on the distinction between mineral resources and mineral reserves: Resources are discovered during exploration but not sufficiently well characterized to determine their exact size and quality and whether they can be mined commercially. Reserves are developed (during development, of course); they are known to exist with a high degree of certainty and capable of being extracted and recovered with existing technologies for a profit. Reserves are a subset of mineral resources. Estimates of reserves change over time as a result of exploration, depletion of deposits at existing mines, and changes in technology, public policies influencing mining, and mineral prices and production costs.

In addition, and not part of this paper, mine-site exploration takes place at or in the vicinity of operating mines with the goal of extending the lives of these operations.

- Mining, in which ore and concentrate (or other form of semiprocessed material) are produced. Ore is the rock from which an element ultimately will be extracted. The weight percent (or grade) of the desired element in the rock varies considerably from one mineral to another at operating mines—much less than 1% by weight for gold, more than 60% by weight for some iron-ore mines. Ore usually is transformed into concentrate at the mine site. Concentrate is an upgraded material. For example, copper ore often has a grade of about 1%. Copper concentrate typically contains 20-25% copper by weight.

- Metallurgical processing, in which ore or concentrate is transformed into a saleable product, usually refined metal that is essentially 100% metal by weight.

- Fabrication and manufacturing, in which refined metal or other similar product is transformed into a final product.

From the perspective a mineral deposit, it obviously must be the case that a deposit has to be discovered before it can be mined.

Perhaps just as important is to consider the perspective of a company at a point in time. In its quest for profits, a company can choose to enter the mineral supply chain at any stage of production. A company can emphasize grassroots exploration; should it discover a mineral deposit, it then chooses whether to continue with advanced exploration, take on a partner to jointly undertake further exploration, or sell its rights to further exploration to another company. Alternatively, company can eschew grassroots exploration altogether and enter the supply chain by participating in advanced exploration of a deposit discovered by someone else. Or a company can avoid exploration altogether and develop a known but undeveloped deposit. Or a company can purchase an existing mine from another company, or expand or refurbish an existing operation of its own. Or, finally, a company can choose to invest in technological research and development that creates the possibility of making activities at any stage of production more efficient. How a company allocates its financial resources among these alternative activities depends on its expectations about future revenues, costs, timing of these revenues and costs, and risks. These expectations, in turn, are influenced by how a company evaluates its own strengths and weaknesses. Some companies specialize in grassroots exploration, others in advanced exploration and deposit development, and still others in mining. Many companies have a portfolio of activities at multiple or even all stages of mineral supply.

Table 1 summarizes the characteristics of grassroots exploration, advanced exploration and deposit development. These characteristics inform company decisions about where to enter the mineral supply chain. The typical lead time between grassroots exploration ranges between five and fifteen years. By entering the supply chain at a later point, a company reduces the time it takes to commence mining. Geologic risks are highest during grassroots exploration, lowest during mining. Think of geologic risk here as the probability that a specific exploration or development project leads to an operating mine. It sometimes is said that it takes 500-1,000 grassroots exploration projects to identify 100 targets for advanced exploration, which in turn lead to 10 development projects, 1 of which becomes a profitable mine. The land area involved gets smaller as activities get closer to mining. Costs and economic risks become larger the closer activities get to mining. Grassroots exploration is relatively inexpensive compared to deposit development and mining. Potential profit, however, arguably is higher for any particular grassroots project in the sense that the discovery of a large mineral deposit can literally re-make a mining company and be an essential source of its profitability for years or decades. The later a company enters the supply chain, the less likely it is to fully capture this profitability; when a company buys into a partially explored or developed deposit—or buys an operating mine—it almost certainly will have to share the expected future profitability with the seller, and this sharing of profits will be reflected in the transaction price.

As for political risks facing a company, the balance of negotiating power switches from mining company to government once mining begins. Mineral exploration is “footloose” in the sense that it can move easily and quickly to another location or country if public policies become less favorable. On the other hand, once a company has developed an operating mine, the company cannot easily, quickly, or cheaply redeploy these assets to another location or country.

Mineral exploration and development are information-gathering activities. In this sense, mineral exploration and development represent a variety of activities that collect information necessary to identify mineral deposits and then evaluate whether they should developed into mines.

Table 2 focuses on information gathering in grassroots exploration. The important information-gathering activities are desk studies and reviews of existing information; acquisition of exploration rights for lands identified through desk studies; regional geological, geochemical, and geophysical examinations; and preliminary engagement with local communities. The land area involved is large, ranging typically from several tens to several millions of square kilometers. Costs are relatively low, up to several tens of millions of U.S. dollars. The desired outcome of grassroots exploration is the identification of promising mineralization or even a geologic deposit that will examined more closely and in greater detail in subsequent activities.

Table 3 focuses on advanced exploration, sometimes called detailed target evaluation. Typical information-gathering activities include geological, geochemical, and geophysical studies at much closer scale or greater density than during grassroots exploration; drilling, trenching, and delineation of the mineral deposit; preliminary studies of the amenability of the rock to mineral recovery (extractive metallurgy); collection of environmental and social baseline data; and continued engagement with local communities. The typical land area is smaller than in grassroots exploration, one to several tens of thousands of square kilometers. Typical expenditures are larger, up to several hundreds of millions of U.S. dollars. Possible outcome of advanced exploration are two types of studies. A *scoping study* is an initial, order-of-magnitude evaluation of the deposit's commercial attractiveness. It typically includes a preliminary resource estimate and order-of-magnitude cost estimates. A scoping study may be prepared by only one or a small team of people. *A preliminary feasibility study* is more detailed and includes revised resource estimates, preliminary mine design and engineering (a mining concept), and associated preliminary cost estimates. If a scoping study and, then, a preliminary feasibility study continue to suggest that a mine might be commercially feasible, a deposit moves to the next stage, deposit development.

Table 4 summarizes key characteristics of deposit development. Typical information-gathering activities include detailed (close-spaced) drilling, mine planning, metallurgical testing, continued assessment of the likely environmental consequences of mine development, and continued community engagement. The land necessary becomes smaller, up to about 1,000 square kilometers. Typical expenditures vary, but can exceed US$1 billion. Should a deposit continue to be attractive, a company will begin to apply for the permits and other approvals necessary to proceed with mining. A company will prepare a *feasibility study*, a technical and economic assessment that serves as the basis for making a "go/no go" decision about whether to develop the mine. A feasibility study includes reserve estimates, mine and plant designs, detailed cost estimates, full technical and economic assessments, and details of possible financing arrangements. A so-called "bankable" feasibility study is a type of feasibility study that a company would take to a bank or other entity in its search for financing.

In each stage of exploration and development, there are effects on the natural environment and on local communities. Table 5 summarizes the important environmental and social impacts during grassroots exploration, advanced exploration, and development and mining, as well as their degree of typical severity. In grassroots exploration, effects typically are minimal. The number of people involved is small. Techniques for the most part are noninvasive. For example, airborne geophysical surveys are conducted from the air. Geological mapping involves people walking on the ground and collecting rock samples. In some cases, there may be road building to allow access or clearing of trees to permit collection of rock or soil samples.

During advanced exploration, environmental and social impacts are more significant but typically still moderate compared to those of mining. Road building, vehicle traffic, drilling and trenching, and other activities can affect air, water, land, flora, and fauna. Some of these impacts can be avoided or mitigated at a cost by using helicopters (rather than building new roads) and by remediating drill sites. There may be some impacts on local communities through the presence of non-local exploration geologists and other workers who often reside in an area for one or more years.

It is deposit development and mining that potentially have much more significant environmental and social effects. Construction, mining, mineral processing, disposal of waster rock, and tailings management[1] can have significant effects on the natural environment. Local communities can be significantly affected by an influx of outsiders and other changes that mining brings to a community. An influx of outsiders may strain public infrastructure designed for a smaller population. Outsiders may be culturally different than local residents leading to a clash of lifestyles. Many of the social impacts of a new mine can be minimized or controlled through deliberate planning but some community change is inevitable and permanent.

The Geographic Location of Mineral Exploration and Mine Development
Where mineral exploration and development occur depends on (a) perceptions of geologic potential and (b) the investment climate.

Perceptions of geologic potential. These perceptions are based on at least two factors. First, perceptions reflect geologic knowledge obtained from previous activities, which include previous exploration and mining, as well as non-mining activities such as road building and assessment of geologic hazards. I include in this category the lemming or bandwagon effect that exploration success by one company has on geologic perceptions of others. In a relatively unexplored area, word of mineralized drill core from one company's activities often leads to a flurry of claim staking or purchase of exploration rights in the area by other companies.

Second, geoscientific research and information from public geological-survey organizations often play a critical role in attracting exploration to a relatively unexplored region. Precompetitive research and information can be thought of as examples of what economists call public goods—that is, goods that are likely to be undersupplied from society's perspective by the market acting alone because the benefits or rewards of these

[1] Waste rock is the portion of mined material that is not ore. In surface mining, for example, rock lying above the mineral deposit will have to be stripped and disposed of to gain access to the mineral ore. Tailings are the wastes generated while converting ore into concentrate. Tailings often are transported in liquid slurry to tailings ponds or impoundments in the vicinity of the mine.

activities are difficult for those who fund these activities to fully capture. The benefits of precompetitive research and information usually come far in the future if they come at all. Imitators find it relatively easy to take advantage of research carried out and information gathered by others; some refer to this situation as "free riding" on the efforts of others.

Government can provide a catalyst for mineral exploration in unexplored areas by providing precompetitive (basic) geoscientific information. This information serves as advertising or as a new signal of geologic potential. Using an analogy from chemistry, basic geoscientific information can be thought of as a catalyst that speeds up the rate of chemical reaction. Important types of precompetitive information are geologic maps, regional geophysical surveys, and geochemical analyses of stream sediments (ideally in digital formats, capable of being downloaded from the Internet).

A final word about perceptions of geologic potential: *Exploration of an area can never be done in a once-and-for-all manner*. Different explorers view the same data and information differently. Many deposits have been discovered only after several companies, exploration programs, or drilling campaigns investigated the same area. Moreover, over time, conditions change, altering the attractiveness of the same piece of land. One company may discover promising mineralization but quit an area because economic conditions are not favorable or because extraction techniques do not permit recovery of a certain mineral type. Over time, economic conditions change and technological capabilities improve. Exploration techniques also improve, increasing the chances of detecting subsurface mineralization. Scientific advances in how mineral deposits are formed alter how geoscientists view the prospectivity of an area.

The investment climate. How attractive the investment climate is for private investment in mineral exploration and development depends on (a) general considerations such as macroeconomic and political stability, legal and banking systems, fiscal rules, and (b) policies designed specifically for the mining sector.

These mineral policies include (adapted from Naito, Remy, and Williams 2001):

- <u>The role of the state</u>. Who owns subsurface minerals? Is the state an owner-operator of mines, or a lessor-regulator?
- <u>Access to land and mineral resources</u>. What areas are available or closed to mineral exploration and development? What are the processes and requirements for obtaining the right to explore or mine? Are the processes transparent and predictable?
- <u>Exploration and mining rights and obligations</u>. What are the time lengths for an exploration or mining right? What are the requirements for maintenance and renewal? Is a right transferable and, if so, how? How secure is a right? Are obligations of a right holder clearly defined? Are cancellation criteria and procedures clear? Is the right to proceed from exploration virtually automatic, subject to meeting clear and objective requirements?

- Environmental and social issues. What are the requirements for environmental protection—before mining, during operations, and post-closure? What is the role of local communities and what are their rights?
- Mining taxation. What is the basis for taxation (revenues, profits, etc.)? At what rates? What are allowable costs in determining taxable income? This subject is sufficiently important to warrant a lengthier discussion in the next section of the paper.
- Other commercial considerations. Are there requirements for downstream processing? Are there restrictions on marketing, foreign-exchange transactions, repatriation of profits, and transferability of rights? Are there special considerations for junior exploration companies?

Mining taxation. Much mineral exploration is carried out by junior exploration companies, which typically do not operate mines. These relatively small companies specialize in mineral exploration and aim to sell any partially explored deposits they discover to larger companies that will conduct subsequent activities to determine whether the mineral resources can be developed into reserves and, in turn, a mine. Some governments provide special tax incentives to encourage exploration by junior companies. The best known of these incentives is flow-through shares in Canada. For a junior company with no operating income, the tax deduction for exploration expenses is worthless because it has no operating revenue from which to deduct exploration expenses. Instead the tax deduction for exploration expenses "flows through" to the owners of shares of stock in the company. In some cases, when countries or regions want to provide an especially strong incentive for exploration, equity owners are allowed to deduct more than $1 for every $1 of actual exploration expenses.

More broadly and considering the mining tax system as a whole, both the rate and form of taxation affect the relative attractiveness of different countries or sub-national regions for investment in mineral exploration and development. The effect of tax rates is obvious; the higher the tax rate the lower the attractiveness of a region, other factors remaining the same. The influence of the tax form on the location of investment is more complicated.

Most fiscal systems take one of four forms: (a) units-of-production taxes, in which tax liability is based on the weight or tonnage of produced mineral (for example, dollars per tonne produced), (b) gross-value taxes, in which tax liability is a percentage of revenues (or revenues perhaps slightly adjusted for a few expenses or costs, such as net-smelter-return royalties), (c) net-income or profits taxes, in which tax liability is a percentage of gross value less allowable costs, and (d) upfront bonus payments, in which a company pays money up front to obtain the right to carry out mineral exploration or mine development.

These tax forms influence the attractiveness of investment in two ways:

- The degree to which they tax surpluses and, in turn, distort production and investment decisions. During production, a tax only on the surpluses (or profits) of mining will not influence the profit-maximizing level of output. Such taxes are based on a firm's ability to pay. Unit-of-production and gross-revenue taxes, in contrast, do not distinguish between highly profitable and marginally profitable mine. They will discourage production from marginal mines. Bonus payments made prior to mining, in effect, represent taxes on expected surpluses from mining. A company will bid—at most—an amount representing the present value of expected future net revenues. Another way of looking at bonus payments is that they will have no effect on the profit-maximizing level of output because they are sunk costs.

At the stage of mineral exploration, no tax is completely nondistortionary. As noted earlier, exploration is footloose in that explorers can redirect their activities to regions or countries with more favorable tax regimes.

- How the tax form allocates risks between a company and government. A tax on net income splits financial risks between a company and government. Government does not receive any revenue until there are profits or surpluses to be shared. Gross-value and unit-of-production taxes shift financial risks toward companies. Government receives its revenues "off the top" before profits are determined. In this sense, gross-value taxes represent a cost rather than a sharing of surpluses. Finally, an upfront bonus payment shifts all financial risks to a company. Government receives its revenue before mining begins or even before a company determines whether mining is feasible.

From the perspective of governments, two other considerations are relevant:

- The timing, stability, and predictability of tax revenues. A single, upfront bonus payment obviously comes soonest, is most stable, and most predictable from a government's perspective from among the various tax forms. Comparing the other three forms, gross-value and unit-of-production taxes typically yield earlier, more stable, and more predictable tax streams than net-income taxes—earlier because a mine typically earns small or negative profits early in its life as its developer is ramping up production and repaying capital; more stable because levels of production and gross revenues tend to vary less from one year to the next than profits; and more predictable because government only needs estimates of production and prices to estimate tax revenues, whereas to estimate receipts from net-income taxes a government needs information about accounting costs.

- The ease and cost of implementation. Taxes based on gross revenues typically are easiest and cheapest to implement effectively. The only information needed to calculate tax liabilities are production levels and a market price. Net-income taxes require accounting rules defining, for example, which costs are deductible from gross income before calculating tax liabilities. Net-income taxes are more susceptible to abuse through creative company accounting. Systems based on bonus bids require a different administrative structure, including rules governing bidding procedures and determination of whether a bid is acceptable.

No system of mineral taxation is ideal from both government and company perspectives. Governments often prefer gross-revenue systems because more of the risks are shouldered by companies, tax revenues typically come sooner and are steadier, and this form of taxation is easier to implement and less prone to abuse through creative accounting. However, governments need to realize such tax systems will tend to discourage preproduction investment in mineral exploration than net-income taxes, other factors remaining the same, because mining companies shoulder relatively more risk and the level taxation is not based on ability to pay (profits).

Bonus payments are widely used in the oil and gas sector. In mining, they are almost never used as a basis for awarding rights for exploration, and rarely used for auctioning a partially developed mineral deposit. Occasionally they are used when selling an operating mine.

Public policy, beyond mining taxation, is not the focus of this paper. Nevertheless public policies importantly influence the risks and costs of mineral exploration and mine development. Penney, McCallum, Schultz, and Ball (2007) offer the following as best practices: (a) provision of basic up-to-date geoscientific information, (b) optimal allocation of land, incorporating economic, social, and environmental issues, (c) clear, efficient, and transparent licensing, (d) security of tenure, (e) internationally competitive tax regimes, (f) adequate supply of qualified professionals, (g) appropriate and consistent environmental rules, (g) effective stakeholder engagement, and (h) optimal distribution of benefits.

Financing Mineral Exploration and Mine Development

How mineral exploration and development are financed influences how the financial risks of these activities are allocated. There are three private sources of financing: internal funds, equity, and debt. Internal funds represent earnings retained by a company from its revenues after it pays all its costs and taxes and distributes any dividends to owners. Equity represents funds raised from investors in exchange for which they become partial owners of the company. In both cases, all risks are borne by the owners of the company (those who hold equity). Debt represents funds borrowed from another entity. Lenders (holders of debt) bear the risk that a borrower will be unable to repay a loan. But debt holders bear less risk than holders of equity because loans must be repaid before equity holders receive dividend or other payments. In other words, debt holders bear less risk than equity holders because debt repayment occurs before the sharing of profits to equity owners.

Most mineral exploration, as well as development prior to the decision to build a mine, is financed either through internal funds or equity. Internal funds typically are used by companies with operating mines. Equity is typically used by junior exploration companies with no operating mines. Debt financing for exploration is difficult to obtain because usually there is no asset (collateral) at the time of the loan for the lender to obtain should the borrower be unable to repay the loan.

Mineral exploration is funded with various types of equity financing. Some is raised on organized stock exchanges or markets in the form of initial public offerings (IPOs) or subsequent share issuances. Shares issued through organized stock exchanges are subject to significant reporting standards about, for example, resource and reserve estimates. Such shares also are “liquid” in that owners can sell their equity any time the exchange is open for business, assuming there is a buyer. Significant amounts of equity for mineral exploration, however, are raised “off exchange”—through activities and transactions that are not conducted through organized stock exchanges. Procedures are less standardized, structured, and regulated. Such off-exchange equity typically is less liquid in that a ready buyer usually is more difficulty, costly, and time consuming to find because the equity is not traded on a stock exchange. Examples of off-exchange equity include joint ventures, royalty-based financing, private placements, and venture capital. A joint venture occurs when a mining company funds activities of a junior exploration company, usually advanced exploration of a partially explored deposit, in exchange for partial ownership of the project. Royalty-based financing represents cash in exchange for the right to ongoing royalty payments if and when mining occurs. Private placements are like IPOs except that they are not “public”—they represent shares issued to a small group of individuals or institutions in exchange for cash. Finally, venture capital also is cash in exchange for shares, with the funds provided by institutional investors, such as pension funds, and wealthy investors, who fund entrepreneurial activities and typically plan to get their reward by selling their shares during a later IPO.

Most mine development, activities once a decision has been made to build a mine, is financed with debt. Some debt represents loans to a parent company, known as corporate debt. If mine development is not successful, a lender has recourse to the assets of the parent company in being repaid for the loan. Another form of debt often used in mineral development is project (or nonrecourse) financing—loans to a project rather than the project’s parent company. If mine development is not successful, the lender cannot compel the project’s parent company to repay the loan from other company assets. Project financing is more expensive (involves a higher interest rate) than corporate debt because the lender assumes greater risk (unless a lender views a single project as less risky than the company’s entire portfolio of assets including the project).

Conclusions

Mineral exploration and development are investments. They hold forth the promise of rewards for private companies, governments, and local communities. Yet they involve risks, as well, for all three groups.

This paper provided an overview of mineral exploration and development, including their risks, from the perspective of private investors. It is important that governments, local communities, and other individual and institutional members of society understand the perspectives of private mining companies in developing attitudes toward and public policies for mining. It is just as important that private mining companies understand the perspectives of governments, local communities, and other members of society toward mining—but this is the subject for another paper.

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Table 1. Company Perspectives: Where to Enter the Supply Chain?

	Grassroots Exploration	Advanced Exploration	Deposit Development	Operating Mine
Lead time until mining	Longer → Shorter (5-15 years of continuous activity from start of grassroots exploration)			
Geologic risks	Higher → Lower			
Land area	Larger → Smaller			
Costs and economic risks	Lower → Higher			
Profit potential	Higher → Lower			
Political risks	Lower → Higher (bargaining power switches to government once mining begins; exploration is 'footloose'			

Table 2. Grassroots Exploration

Activities	Desk studies, area selection, land acquisition, regional studies (geology, geochemistry, geophysics), preliminary community engagement
Typical land area	10,000s-1,000,000s of square kilometers
Typical expenditures	Up to 10s (million US$)
Possible outcomes of studies	Target identification for subsequent detailed examination

Table 3. Advanced Exploration

Activities	Detailed target evaluation (geology, geochemistry, geophysics), drilling, trenching, deposit delineation, preliminary metallurgy, collection of environmental and social baseline data, community engagement
Typical land area	1,000s-10,000s of square kilometers
Typical expenditures	Up to 100s (million US$)
Possible outcomes or studies	- Scoping study: resource estimates, order-of-magnitude cost estimates, general idea of what a mine might look like - Preliminary feasibility study: more detailed than scoping study and including revised resource estimates, preliminary mine design and engineering, and preliminary cost estimates

Table 4. Deposit Development

Activities	Detailed drilling, mine planning, metallurgical testing, continued environmental assessment, continued community engagement
Typical land area	Up to 1 (thousand square kilometers)
Typical expenditures	Varies, can be > US$1 billion
Possible outcomes or studies	- Applications for required permits and approvals - Feasibility study: reserve estimates, mine and plant design, detailed engineering and cost estimates, full technical and economic assessment, financing - “Go/no go” decision on mine development

Table 5. Environmental and Social Impacts

Grassroots exploration	- Usually minimal effects from airborne geophysical surveys and regional reconnaissance on the ground
Advanced exploration	- More significant but still moderate effects - Road building, traffic, drilling, trenching, etc., can affect air, flora, fauna, land, water - Most effects can be mitigated at a cost with helicopters, remediation after drilling, and other activities
Deposit development and mining	- More significant effects - Environmental: construction, mining, processing, waste disposal and tailings affect air, flora, fauna, land, water - Social: potential influx of people and significant community change represent challenges - Many effects can be minimized and controlled, but some change is inevitable and permanent