Modern Metallic Mining – An Overview

Introduction

Mining and beneficiation (ore processing) of metallic minerals are human activities dating back thousands of years. Metallic mineral exploration and mining are necessary to find metals that enable our culture to grow and prosper Increased focus on responsible practices, reclamation, and sustainability have led to significant improvements in the environmental, social, and economic impacts of mining operations around the world.

Mining operations inherently impact the local environment, if only from varying amounts of surface disturbance. While improvements have been made in recent years, there is no such thing as a 'perfect' mine – one that truly has zero impacts, whether favorable or unfavorable. A goal of modern responsible mining today is to reasonably predict and manage such impacts, and to provide an overall net benefit for having done so. Many award-winning mines are recognized for their achievements in maximizing favorable impacts, and minimizing unfavorable impacts.

Since the 1980s, all industries in the United States (including the minerals industry) have been required to comply with new, stringent state and federal laws and regulations designed to protect the environment. These legal requirements are the results of a profound cultural shift that has resulted from unfavorable environmental impacts caused during less-regulated times. Industries have adapted to these new requirements by use of new technologies and management methods, designing for facility closure and reclamation, environmental monitoring to ensure "early warning" of potential impacts, contingency plans to mitigate unplanned impacts, and financial assurance to ensure that public monies are not needed for environmental protection. Additionally, corporations now accept that their track record of cleaning up environmental impacts from older operations, preventing unfavorable impacts from new and expanded operations, and promptly mitigating unplanned impacts are essential elements of doing business in America today.

Exploration

Metallic mineral exploration is the search for naturally occurring, potentially valuable concentrations of metals within the earth. It involves the use of science, technology, and financial risk management to identify and delineate the extent and concentration of a mineral occurrence.

Exploration today is conducted by highly skilled geologists, geochemists, and geophysicists who utilize new technologies to find subsurface mineral occurrences. Metallic mineral exploration typically includes geologic mapping, geophysical surveys, drilling and sampling, geochemical analyses, and geologic modeling. Despite the increased chance of success in mineral exploration today, very few exploration projects progress to a mining phase. Most simply do not "pan out" as more information is obtained about the site geology and the economics of mineral extraction and processing becomes unfavorable.

Environmental protection is necessary during exploration activities, as called for by permits, regulations, and company policies. Special measures are taken to protect surface and ground water, soils, sensitive vegetation, and cultural resources. Surface disturbance is generally reclaimed to allow for future beneficial land uses.

Development

Metallic mineral exploration may lead to a development phase if the preliminary economic factors look favorable. Development will determine the economic, environmental, and social benefits of a proposed mining operation. Development consists of additional testing, computer modeling, economic modeling, and an extensive permitting process. The purpose is to design a mining operation that results in overall favorable economic, social, and environmental aspects and impacts.

A development phase is commonly several years in length, often requiring 5 to 10 years or more to complete. Typically, development consists of additional drilling and sampling, metallurgical testing, mine and beneficiation designs, economic feasibility study, and permitting.

Permitting is an extensive process that involves disclosure and review of a proposed mine plan. Numerous permits and approvals are necessary to start, operate, and reclaim modern exploration and mining operations. Many local, state, and federal agencies are responsible for administering the laws and regulations that protect the environment, and human health and safety. Exploration and mining must adhere to all of these, and several more that are specifically designed for this industry. Public input is an important part of today's permitting process.

Once permits and approvals are obtained, often with stipulated changes to the mine plans, the company will decide whether or not, and when, to proceed with the proposed mining and beneficiation.

Mining and Beneficiation

Mining is the extraction of naturally occurring, mineral bearing ore from bedrock or surface sediments. Ore is the term applied to mineralized rock that is economically feasible to mine; in other words, it has enough mineral content to pay for the mining and processing costs. There are three primary types of metallic mineral mining:

- *Hardrock Mining* – mechanical fracturing and excavation of bedrock-hosted mineral deposits (such as most metallic and non-metallic minerals)
- *Placer Mining* – mechanical excavation of sand- and gravel-hosted minerals (such as gold nuggets)
- *Solution Mining* – subsurface dissolving of soluble minerals from bedrock, and extraction by pumping wells (such as salts, sulfur, and sometimes metals) using water, steam, or chemical reagents

Hardrock mines are of two types, depending on the depth and geometry of a mineral deposit:

- Underground Mine – subsurface excavation to remove ore and minimal amounts of non-ore rocks. Generally, these types of mines have minimal surface disturbance consisting of a shaft building, tunnel entrance, support buildings, and small rock stockpiles. Excavation is created by engineered blasting (to induce fractures in bedrock), loading, and hauling (via wheeled vehicles, conveyor belts, hoists and drop chutes). The geometry of workings may consist of tunnels, shafts, and rooms (referred to as stopes). Ore is brought to the surface for on- or off-site beneficiation.
- Surface Mine – surface excavation to remove ore and non-ore rocks. These types of mines are also called open pits and quarries (when referring to non-metallic minerals). Surface mines generally yield more surface disturbance than underground mines, although some surface mines are small in size. For the safety of workers, surface mined walls are benched (stair-stepped) up and far away from the ore to provide better

stability and catch benches for loose rocks. The mine excavation is created by engineered blasting, loading of broken rock, and hauling (via wheeled vehicles or conveyor belts). Ore is beneficiated on- or off-site.

Lower concentration and non-mineralized rock mined to liberate the ore are managed on site, either in engineered stockpile facilities at the surface, or sometimes as backfill in the mine workings (if no future mining is anticipated).

Beneficiation is the physical and sometimes chemical liberating of metals from ore that has been mined. Depending on the quality of the ore, beneficiation may be completed on- or off-site. As technology improves, more and more methods become available to remove the desired metallic minerals or metals from the ore. Methods are selected based on the mineral/metal types of ore, size of mineral particles, whether or not the minerals are encapsulated (encased) in less desirable minerals (such as quartz), the overall mining rate, and more. Typical beneficiation methods are conducted inside a mill and consist of several technologies such as:

- Crushing – mechanical fracturing of large rocks, using powerful jaw, cone, or gyratory crushing machines.
- Grinding – further size reduction of coarsely crushed rock by ball mill or other pulverizing methods.
- Magnetic Separation – separation of magnetic minerals from the milled rock using electromagnets. In certain iron mines, this is the primary method of beneficiating the ore.
- Gravity Separation – separation of heavier minerals from lighter ones, using gravity. Milled rock may be passed over a sluice box or washed through a centrifugal cyclone separator with water.
- Flotation – separation of selected minerals from the milled rock by adhering small air bubbles to enable them to float in a wet slurry. Reagents such as soaps and alcohols are used to selectively wet certain minerals, enabling air bubbles that preferentially attach to them. The floated minerals are dried using filter presses.
- Leaching – separation of selected minerals and metals from the milled ore using various chemical reagents. The dissolved minerals are then precipitated chemically, onto carbon, or electroplated out of solution.

Concentrates of metals or metallic minerals are usually shipped to an off-site location for further refining and marketing. Process water is filtered, treated and reused in the beneficiation process. Excess process water is treated to standards set by state and federal agencies, and is discharged to nearby surface water or groundwater. Often the water treatment standards are such that the discharged water is cleaner than the receiving water body.

Reclamation and future land use planning have become an integral part of modern mining operations. Completing as much reclamation as practical during mining operations minimizes the total surface disturbance at any one time, achieves post-mining land use goals sooner, and is often more cost effective.

Reclamation and Post Mining Land Use

Reclamation is the restoration of a mining site for future beneficial use. Post mining land uses may include pre-mining uses, or new and different ones as long as they provide an overall benefit to the area. Reclamation can be conducted during (concurrent) or after mining operations have ceased. State regulations require that all mining operations be reclaimed, and financial assurance is one available mechanism to ensure it is completed.

In most states, a comprehensive reclamation plan is now required as part of the application for a new mining permit.

This means that approval for a mine will include review and approval of its reclamation plan. Reclamation is an integral part of designing a modern mine.

All reclamation plans must start with a vision and commitment for a particular post-mining land use(s). Examples of post-mining land use includes:

- Wildlife Habitat and Fisheries
- Wetland and Sensitive Plant Habitat
- Hunting and Fishing
- Tourism and Recreation (mining history, wildlife viewing, hiking, etc.)
- Real Estate for Residential Homes and Cabins
- Commercial Property
- Future Mineral Resource Development

Choosing one or more of these options will determine the vision and methods for reclamation to achieve those goals. The project's operator works with governments and local residents to determine the most appropriate future land use. This helps ensure an acceptable plan is prepared. It also identifies important socioeconomic aspects such as property tax revenue changes, future jobs, affects on surrounding residents, and more.

Mining reclamation addresses the following facilities, depending on the mining operation and the proposed post-mining land use:

- Structures - all structures constructed to operate the mine and beneficiation processes, such as buildings, utilities, and internal roadways, would be removed. Often this material is reused at another industrial site or is recycled.
- Process Materials – all process solutions, solid wastes, and associated piping and tanks would be treated and/or removed from the site
- Mine Workings – underground mines may be sealed, surface mines may be backfilled, flooded, and/or bermed and fenced
- Rock Stockpiles – recontouring would be performed and revegetating would be accomplished with a mixture of perennial plants. For rocks that may impact water resources, specially engineered liner or cap systems are constructed as a preventative measure
- Tailings Storage – if a beneficiation method were used on site that created a tailings storage area (residual sand/silt rock particles after metallic minerals have been removed), capping and/or revegetating much like that for rock stockpiles would be employed
- Fencing and signage – as appropriate, given the future land use

Recontouring is accomplished by using conventional grading equipment (bulldozers, earthmovers, road graders, etc). Each reclamation plan will prescribe the outer sideslope angles to be achieved for rock stockpiles and other large features. These sideslope angles are designed to achieve both structural stability and aesthetic goals.

Revegetation is accomplished by conventional farming or aerial seeding equipment. Seed mixtures are selected to initiate and sustain soil development and perennial vegetation, with minimal maintenance. Some reclamation sites require placing topsoil, organic growth media, prior to reseeding. Others require initial and periodic organic and inorganic fertilizer applications until soil and vegetation become self-sustaining. Reclamation success is measured over many years with vegetation test plots, rock and soil stability testing, and more. When necessary, further reclamation is implemented based on monitoring results.

These modern mining practices have evolved over the past hundred years. By taking future land use into consideration, many highly successful reclamation projects have been completed in recent years.

Environmental Protection

Environmental protection is an integral part of today's metallic mining industry. From exploration, through development, mining, and post-mining reclamation and land use, environmental protection is now both regulatory- and publicly-required.

Not only is environmental protection required, mining companies now recognize that protection is far more cost-effective than clean up. To prevent pollution or unplanned impact is a far better management method than allowing it, which only results in paying more in future clean up costs and corporate reputation.

Numerous local, state, and federal agencies administer laws and regulations that protect the environment. Exploration and mining must adhere to all of these, and several more that are specifically designed for this industry. Many permits and approvals are necessary to start, operate, and reclaim modern exploration and mining operations. Public input is an important part of today's permitting process.

Environmental protection consists of:

- Baseline Studies – measuring and documenting pre-mining conditions at the site and in the surrounding area. This provides a "snapshot" of natural conditions and pre-existing human impacts by which future impacts can be compared
- Prevention – designing and implementing measures to prevent unplanned and unwanted impacts to environmental resources
- Training – education of employees and contractors about environmental protection
- Regulatory Compliance – operating within the environmental protection limits set forth by laws, regulations, permits, and approvals
- Monitoring – routine inspections and measurement of the affects on environmental resources
- Contingency Plans – plans, equipment, and human/financial resources to manage a spill or unplanned impact to the environment
- Mitigation – the clean up or remediation of an unplanned environmental impact, as necessary

Environmental impact prevention is the cornerstone of modern exploration and mining operations. To prevent is to protect from unplanned and unwanted impacts to various resources. Each resource in our environment can be protected in different ways such as:

- Surface and Ground Water
    - Primary containment of fuels and process solutions (tanks, lined ponds and impoundments, properly maintained pipes and valves)
    - Secondary containment (lined catchments, double-walled piping, etc.)
    - Liners of clay or thick-mil plastics beneath leachable materials

- Capping, neutralizing, or submerging (for example: beneath groundwater) of sulfide rock materials (if it would produce runoff or leachate elevated in dissolved metals and acidity – so called "Acid Rock Drainage")
- Erosion and sediment runoff control through revegetation, silt fencing, sediment collection basins, and storm water runoff management
- Bacterial disinfection of exploration drilling water using chlorine solution
- Water conservation by reuse of settled or filtered water
- Temporary capping (locking) of exploration drill holes
- Final sealing of completed exploration drill holes from bottom to top using cement
- Water treatment prior to discharge

- Soil and Sediment
  - Storm water management
  - Sedimentation basins (including "sumps")
  - Silt fencing
  - Reclamation

- Wildlife and Fisheries
  - Fencing
  - Netting of open process solutions
  - Habitat replacement / enhancement
  - Containment of chemicals

- Vegetation and Sensitive Plants
  - Fencing
  - Avoidance
  - Habitat replacement / enhancement
  - Containment of chemicals
  - Reclamation

- Air Quality
  - Fugitive dust control (for example: watering of roads)
  - Wet drilling methods
  - Vehicle / equipment maintenance
  - Engineered blasting
  - Air emission controls

- Noise and Visual
  - Barriers and screens (for example: trees and shrubs)
  - Equipment selection and operation
  - Concurrent reclamation
  - Engineered blasting
  - Operational controls
  - Traffic controls
  - Land buffer

- Cultural Resources
    - Identification
    - Avoidance to protect
    - Mitigation, if necessary

Environmental protection is best achieved through these protection measures. However, since unplanned and unwanted impacts might occur, monitoring programs are designed to detect them, and comprehensive contingency plans will enable prompt mitigation and cleanup so as to minimize adverse affects. Today's environmental management at industrial facilities rely on technically sound project designs, operating practices, monitoring, and contingency plans.

For More Information
To learn more about modern metallic mining, we recommend these sources:

Mine Life-Cycle Center, University of Nevada, Reno
(http://www.unr.edu/mines/mlc/index.html)

This organization and website focus on key environmental and life-cycle issues facing mining in the U.S. and elsewhere.

Natural Resources Canada
(http://www.nrcan-rncan.gc.ca/inter/index_e.html)
This federal agency site contains information about mining, environmental, and sustainability issues in Canada.

Australian Center for Mining Environmental Research (ACMER)
(http://www.acmer.com.au/)

The ACMER website and organization is led by Australian mining industry, government, and other stakeholder representatives. It is designed to provide the scientific and technological support to enable the minerals industry to enhance its environmental performance from exploration to active mine management and closure.

Minerals Information Institute
(http://www.mii.org/)

This non-profit institute provides mining, mineral use, and reclamation information to teachers, students, and the general public. The website contains many examples of successful reclamation of mining sites throughout the world.

Mining Environ Handbook: Effects of Mining on the Environment and American Mining Controls on Mining
(Edited by Jerrold J. Marcus, published by Imperial College Press, 1994.)

This comprehensive handbook is a compilation of technical, regulatory, and policy issues facing mining in the United States, and from diverse points of view. Individual chapters were prepared by a wide range of professionals representing state and federal agencies, mining companies, consulting firms, and non-governmental organizations.