BCS 312: Land and Environments of the Circumpolar North II

Module 2: Mineral Resources

Developed by
Lawrence K. Duffy
University of Alaska Fairbanks
and
Monique Haakensen
Contango Strategies, Saskatoon, SK

Overview

This module provides an introduction to minerals, metals and ores, and an overview of valuable mineral resources in the circumpolar North. The module examines exploration, extraction and processing methods. Future prospects for mineral resources are discussed, as are environmental concerns and steps taken to lessen their impacts.

Learning Objectives

Upon completion of this module, you should be able to:

1. Identify metals and minerals mined in the circumpolar North, methods of mineral extraction and the location of major mining regions.
2. Describe exploration and extraction methods, and transport and processing steps for mineral resources.
3. Assess current and future prospects for mineral reserve exploration in the circumpolar North.
4. Identify environmental concerns associated with mineral resource extraction and steps taken to lessen these impacts.

Required Readings (including web sites)

Safanov Y.G. 2010. Mineral potential of the Russian Arctic: State and efficient development. Russian Geology and Geophysics 51:112-120.

Dobretsov, N.L., N.P. Pokhilenko. 2010. Mineral resources and development in the Russian Arctic. Russian Geology and Geophysics 51:98-111.

Weihed, P., P. Eilu, R.B. Larsen, H. Stendal, M. Tontti. 2008. Metallic mineral deposits in the Nordic countries. Episodes Journal of International Geoscience 31(1):125-132.

Key Terms and Concepts

- Adit
- Communition (Stage in Ore Processing)
- Concentration (Stage in Ore Processing)
- Decline
- Dewatering (Stage in Ore Processing)
- Element
- Gangue
- Inclined Shaft
- Inorganic
- In-Situ Leach (In-Situ Recovery)
- Metal
- Mineral
- Natural Resource
- Non-Renewable Resource
- Open-pit
- Ore
- Rare Earth Elements
- Renewable Resource
- Sizing (Stage in Ore Processing)
- Solution Mining
- Tailings
- Underground Mining
- Waste Rock

Learning Material

Introduction

The circumpolar North has an abundance of commercially valuable non-renewable mineral and metal resources. More natural resources are needed to supply the world so exploitation of resources has increased. Additional deposits are being sought and becoming more accessible with technological advances and warming of circumpolar areas. Production of these resources can lead to hazardous wastes and unequal distribution of risks and benefits. Key to modern production is a philosophy that looks at people and the planet's ecosystems, not just profits. This module examines mineral resources of the circumpolar North, extraction methods, future prospects and environmental concerns.

2.1 Mineral Resources of the Circumpolar North

Elements, Metals, Minerals and Ores

Rocks, ores, metals and minerals are **natural resources**. A natural resource is anything taken from the physical environment to meet the needs of society. Resources can be either **renewable** or **non-renewable**. Resources such as soil, natural vegetation, fresh water and wildlife are all renewable as they regenerate. Rocks, minerals, oil, natural gas and coal are non-renewable as they are present in the earth in fixed amounts and are not replaced as they are used. Rocks and minerals are quarried and often used in modified form in construction and chemical industries.

The terms **metal**, **mineral** and **ore** are sometimes used interchangeably (but incorrectly) in everyday language and by the media. These terms have distinct meanings critical to our understanding of mining resources in the circumpolar North. An element is a pure chemical compound consisting of a single substance. You may have encountered these in a chemistry class as the “periodic table of elements”. Metals are a subset of elements that have distinctive properties. Metals are chemical elements, good conductors of heat and electricity, and are typically hard, shiny and malleable. A mineral is a naturally occurring mixture of elements with a restricted range of composition. Minerals are **inorganic**, i.e., they are of non-biological origin and do not contain carbon. Therefore, resources such as coal, natural gas and oil are not classified as minerals. Minerals and metals are typically found in **rocks**. A **rock** is an aggregate of minerals and does not have a specific chemical composition. Ore is rock that contains substances (minerals or metals), which can be profitably extracted. Ores are extracted through mining and processed and refined to extract the valuable mineral or element.

Minerals of the Circumpolar North

More than 2,000 distinct minerals have been identified but few are widely distributed over the earth. In the Arctic valuable minerals are found in limited regions where they are concentrated as a result of upheaval and subsidence of crust materials and other rock-forming processes that have occurred over millions of years. Figures 2.1A and 2.1B show locations of mining activities in the circumpolar North and the Barents Sea. Note the difference in the number of mining activities indicated based on the resolution of the maps. Metal ores are unevenly distributed in the earth’s crust so many nations depend on imports for their supplies. Some metals are imported for strategic industrial and defence purposes because no substitutes are available. Within the United States there are few deposits of strategic metal ores, which are essential for modern technologies. All elements have one or two letter abbreviations, e.g., iron (Fe), nickel (Ni) and sulfur (S) are elements and in combination $(Fe,Ni)_9S_8$ form a mineral known as pentlandite, which is mined in northern Russia.

Learning Activity 1

What is an important mineral or metal for the economy in your country or a circumpolar nation of your choice? Has this changed over time? The USGS International Minerals Yearbook could be a good starting point.
http://minerals.usgs.gov/minerals/pubs/country/index.html#pubs

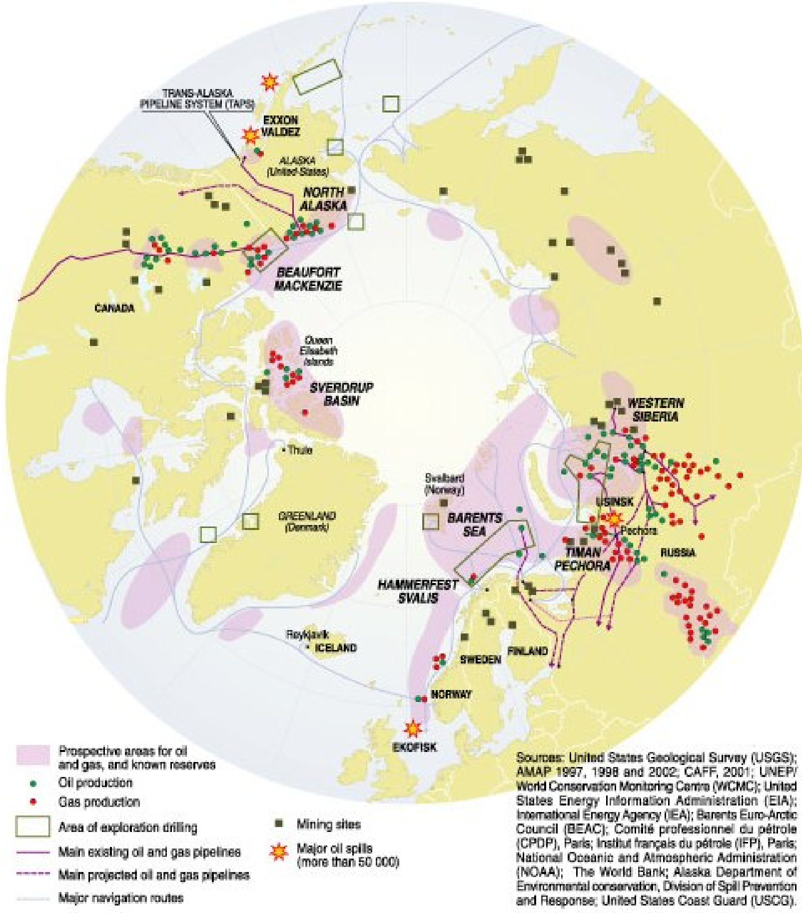

Figure 2.1A.

Figure 2.1. Circumpolar North mining activity locations.

A) A low resolution map indicating sites with high levels of activity in the circumpolar North (Source: http://maps.grida.no/go/graphic/industrial-development-in-the-arctic).

> Learning Highlight 1
>
> “Rare Earth Elements” are a group of 17 elements that are not rare in the earth’s crust but are rare in concentrated mineral deposits. They have increased greatly in value in recent years due to their required use in electronic devices such as cell phones and computers.

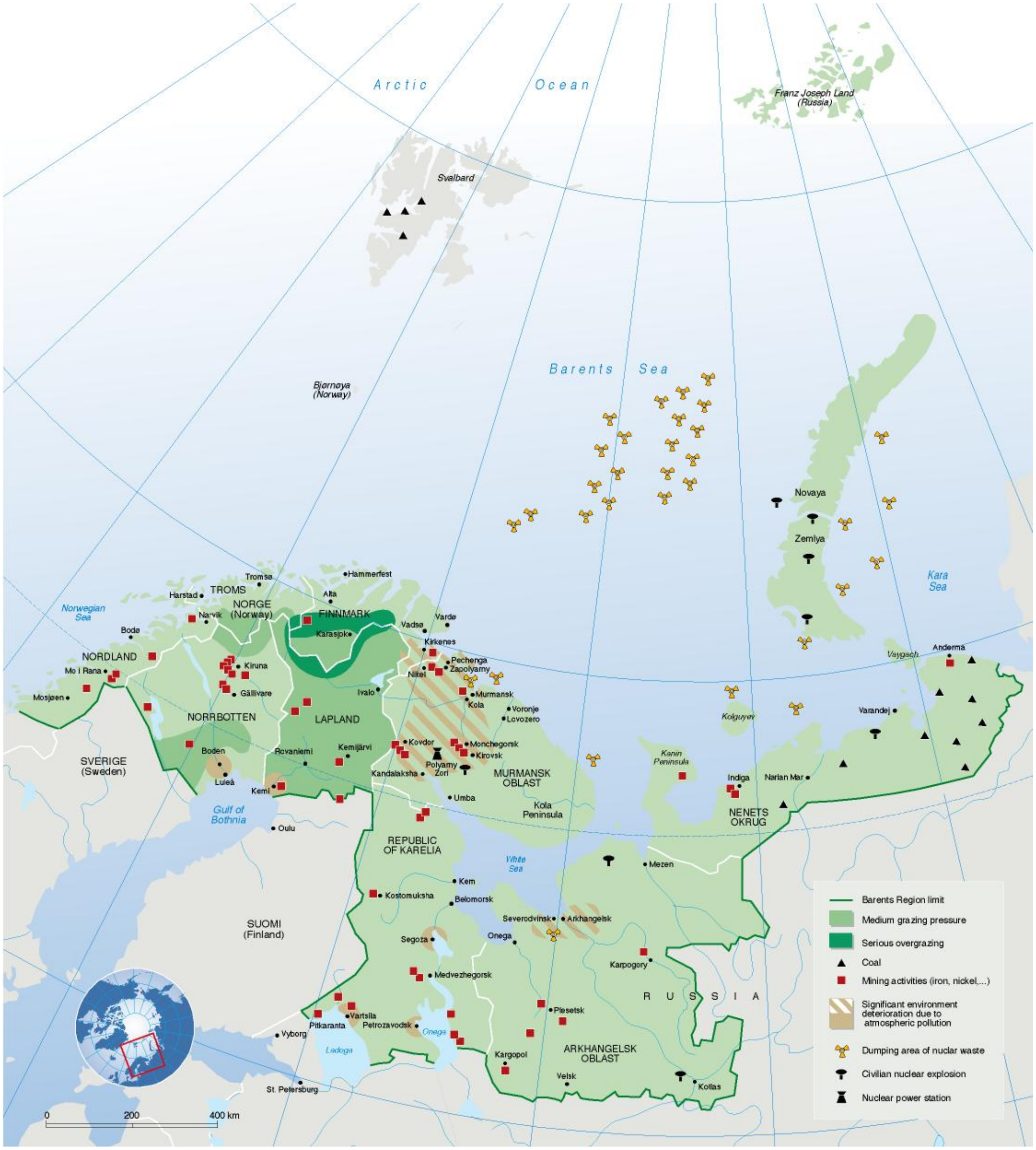

Figure 2.1B.

B) A higher resolution map indicating mining activity in the Barents Sea (Source: http://maps.grida.no/go/graphic/environmental_threats_in_the_barents_region).

Overview of Mineral Resources by Country

A variety of minerals are mined in northern **Canada**, the diversity of which has increased in recent years. Traditionally, mines in northern Canada included copper, gold, lead, nickel, uranium and zinc. The Yukon Territory has a base metal and a small jade mill. Most of the uranium mines in circumpolar regions have been closed. Diamond mining has become an important part of the northern Canadian economy. Recently, Canada's deposits of **rare earth elements** and platinum-group metals (iridium, osmium, palladium, platinum, rhodium and ruthenium) have become more economically important and are expected to increase in value and amounts mined.

Finland contains modest amounts of mineral deposits, which were extensively mined from 1910 through the 1980s when most reserves were depleted. Finnish firms have since purchased interests in mining operations in other countries to maintain employment (US Library of Congress, 2011). Finland produces mainly limestone, gypsum and chalk. Evaluation of less common industrial minerals and rock deposits, such as aluminium silicates (kyanite, andalusite), diamonds, and tantalum-, lithium- and niobium-bearing minerals, and anorthosites are underway (Geological Survey of Finland, 2011).

Historically, **Greenland** has been important to the production of cryolite – a white mineral valuable for soda and enamel production. Lead and zinc formerly played a major role in Greenland's economy; however, these mines were closed in 1990. Greenland's government has been issuing strategies for mineral development. Since 2000, Greenland's mining and exploration licenses and activities have increased exponentially. In 2004, a strategic initiative to enhance gold and diamond exploration was announced. In 2009, the initiative was expanded to include all economically sustainable metals and minerals and areas for which geologically little is known. Greenland is believed to have one of the largest rare earth element deposits in the world, second to China. However, these deposits are in close to proximity to uranium deposits and Greenland currently has a zero-tolerance approach to uranium mining. These policies will need to be changed for rare earth element mining developments to proceed.

The **Icelandic** government held the majority of shares for major mining enterprises except aluminum. Aluminum is Iceland's largest export commodity, followed by ferrosilicon. Iceland is also known for calcite or Iceland Spar. Although this clear mineral is found worldwide, it was first located and described in Iceland and is thought to have played an important role in early navigation.

Minerals and metals from northern **Russia** contribute substantially to the country's economy and Russia is one of the world's leading mineral producers. Russia is also one of the world's leading suppliers of phosphate raw material. The Russian mining industry mines diamonds and uranium. Over the past decade, Russia has become open to western investors and repealed a law that kept production data on platinum-group metals a secret in 2004.

Mining plays an important role for **Sweden**'s economy. Sweden is the biggest iron ore producer in the European Union and a leading producer of copper, zinc, lead, gold and silver. It is expected that production of these and other metals and minerals will continue to increase to meet the needs of importing countries. Plans are underway to increase uranium production as the demand for nuclear power increases.

Learning Activity 2

Research how mining has impacted human exploration and colonization in the circumpolar North? How does this differ by country?

Alaskan Gold Rush

Among the most famous northern mining adventures were the 19th century gold rushes. Beginning with the Klondike Gold Rush in the Yukon Territory in northwestern Canada, a series of gold discoveries had significant consequences for development, especially in Alaska. Within a year of the start of the rush, Skagway, at the foot of the Chilkoot Trail to the Yukon, became the largest city in Alaska with 20,000 inhabitants. In 1898, gold was discovered near Nome, Alaska. The gold rush moved to the Fairbanks area where gold was discovered in 1902. More than 100,000 people came to Alaska as the gold rushes changed everything. For a decade towns flourished, advanced technology was introduced (e.g., heated pavement) and consumption was high. At the time of the First World War, the population of Alaska had stabilized at 65,000, about half of whom were Indigenous peoples.

The success and attraction of the gold rushes was, to a large extent, a result of the type of gold found. Dust and nuggets lent themselves to placer mining, making it possible to find gold mainly by manpower without need for much capital for production. The gold adventure became an integrated part of the northern North American identity. Although many men became very rich, the vast majority never made back their expenses and the value of the gold extracted roughly equaled the overall investment made. The gold rushes founded towns and shipping routes, gave people valuable experience in the North, and established the North as a rich storehouse of mineral wealth. Other kinds of mining followed the gold rushes, especially in Alaska.

Table 1. Minerals and elements of importance to countries of the circumpolar North. (Note: list is not exhaustive or comprehensive.)

Country	Minerals or Elements
Canada	Asbestos, Cobalt, Copper, Diamonds, Gold, Lead, Nickel, Platinum Group of Elements (iridium, osmium, palladium, platinum, rhodium and ruthenium), Silver, Rare Earth Elements, Tungsten, Uranium, Zinc
Finland	Copper, Diamonds, Gold, Lithium, Nickel, Wollastonite, Uranium
Greenland	Aluminum, Copper, Cryolite, Diamonds, Gold, Lead, Molybdenum, Ruby, Silver, Titanium, Tungsten, Zinc
Iceland	Aluminum, Calcite (Icelandic Spar), Ferrosilicon
Russia	Asbestos, Borax, Chromium, Copper, Diamonds, Gold, Lead, Magnesium, Manganese, Nickel, Platinum, Group of Elements (iridium, osmium, palladium, platinum, rhodium, and ruthenium), Potash, Silver, Precious Stones and Gems
Sweden	Copper, Gold, Iron, Lead, Molybdenum, Silver, Uranium, Vanadium, Zinc
United States (Alaska)	Gold, Lead, Silver, Zinc

2.2 Exploration, Extraction and Processing

Exploration

Mining is the discovery, extraction, processing and transportation of mineral resources to the point they can be further processed or used in the production of finished goods. This broad definition includes mining of base metals, such as iron, copper and zinc; precious metals, such as gold, silver and platinum; semi-precious metals, such as molybdenum; industrial minerals, such as graphite, carborundum and silicon; non-metallic minerals, such as sulphur, potash and limestone; quarry stone and gravel; strategic minerals, such as uranium and rare earth elements; and precious and semi-precious stones, such as diamonds, jade and agate. In a broad sense, petroleum (oil and natural gas) recovery falls under the term mining, but this is a large and separate industry.

Mining includes several stages. The first stage is exploration by geologists who determine the potential of an area for mineral resources. Exploration methods include geological, geochemical and geophysical investigation. Areas to be explored are identified by use of geological knowledge and satellite investigation. If an area looks promising, it is assessed for quantity, quality, extent and depth of mineral deposits. Usually this involves drilling into the deposit and removing core samples for analysis.

Extraction

If the results of the first stage indicate sufficient minerals for economic use, the second stage conducts feasibility studies involving economic and engineering evaluations. During this stage, promoters attempt to determine probable costs of constructing a mine. Costs are weighed against the probable value of minerals that could be recovered and decisions are made to carry out or cancel the project. The third stage is construction of the mine and production infrastructure. Costs at this stage are very high and there are no revenues until construction is nearly complete and production begins.

There are three main types of mines: **open-pit** (surface) mines (Figure 2.2), **underground** (subsurface) mines and **solution mines** (also known as **in-situ leach** or **in-situ recovery** mining).

Open-pit mines are the most common mine worldwide and are used when mineral deposits are near the surface and the **overburden** (surface material covering the deposit) is thin or the material of interest is unsuitable for tunneling. Iron, bauxite, copper, diamonds and uranium ores are often surface mined. Open-pit mines are generally considered the simplest type of mine and are typically enlarged until either the mineral resource is exhausted or an increasing ratio of overburden to ore makes mining uneconomical. During mining, water control is required to keep the pit from becoming a lake due to inflow of groundwater. Exhausted mines are sometimes converted to landfills for disposal of solid wastes.

Underground mining refers to various subsurface mining techniques used to excavate minerals such as ore containing copper, gold, iron, lead, nickel, silver, uranium or zinc. Underground mining may also be used to excavate gemstones such as diamonds. Accessing the underground ore can be achieved via a **decline** (ramp), **inclined shaft** or **adit**. Declines can take the form of a spiral tunnel that circles near or around the deposit and are used by trucks to haul ore to the surface. Shafts are vertical excavations sunk beside the ore body. Shaft haulage is more economical than truck haulage at depth so a mine may have a shaft and ramp for use at different depths. Adits are horizontal excavations into the side of a hill or mountain, and are used near ore bodies where there is no need for a ramp or shaft. One of the most important aspects of underground mining is ventilation. Toxic fumes from blasting and diesel equipment can build up underground. Also, at great depths the temperature is hotter so ventilation is required to cool the workplace for miners.

Solution mining also sometimes referred to as in-situ leach or in-situ recovery is a mining process used to recover minerals through boreholes (the generalized term for any narrow shaft bored in the ground either vertically or horizontally) drilled into a deposit in situ. In-situ is a term used to mean “in place” or “in site”. Solution mining leaches or recovers minerals from the deposit without first moving the ore to a processing facility. Solution is pumped into the ore body via a borehole and circulates through porous rock dissolving the ore, which is then extracted through a second borehole. The solution used depends on the type of ore and mineral, but is often acidic. Copper, potash and uranium are examples of minerals often extracted by solution mining.

Figure 2.2. The Diavik Diamond mine in northern Canada is an example of an open pit mine. Photo: J. Bullas.

Transport

Following extraction, ores must be transported to a processing facility for refining and concentration. Sometimes, a processing facility is within proximity of the mine but more often a single centralized processing facility is built to process ores from several mines. This strategy, undertaken for financial reasons, results in the requirement to transport ores. Occasionally, dedicated rail tracks are built to move ore to the processing facility, however, in the circumpolar North this approach can be difficult as tracks can be damaged due to frost heaving in freeze and thaw cycles. Therefore, in the circumpolar North ores are often transported by truck to the processing site. Minerals extracted by solution mining are transported by pipeline as **slurry** (a thick suspension of the ore solids in a liquid). Wet cement is an example of a slurry. In winter months, freezing of the slurry is prevented by salinity or pH (acidity and basicity) combined with heat.

Mineral Processing

Mineral processing separates commercially valuable minerals from ores after minerals have been extracted. In this module, we discuss only general features of mineral processing. In basic terms, mineral processing involves four steps: **communition** – particle size reduction; **sizing** – separation of particle sizes by screening or classification; **concentration** – by taking advantage of physical and surface chemical properties; and **dewatering** – solid and liquid separation. Methods for each step depend on the specific mineral or metal and are further optimized for the ore body, but these steps remain consistent for all mineral and metal processing. Examples of other processes that may be used but are not discussed in this module are hydro-, pyro- and geo-metallurgical processes.

Communition, which is particle size reduction, may be carried out on dry materials or slurries. Crushing and grinding are examples of communition processes. During sizing, particles are separated by size. The simplest sizing process is screening – passing particles through a screen or screens. Many types of industrial scale screens are used in the mining industry. Screens can be static, shake or vibrate. Water may be added to materials to take advantage of classification, a method of sizing that relies on the difference in settling rates of different size particles in water.

Concentration involves increasing the purity of the desired material. Historically, particles were concentrated based on their specific gravity. An example of this process is panning for gold during which heavier gold particles remain in the pan while associated materials wash off. Other ores may be concentrated by flotation, which separates any two particles based on surface chemistry. Flotation requires careful consideration of the chemistry of flotation reagents, the ore body and the compounds to be concentrated. Other methods of concentration include electrostatic separation (using electrical conductivity to separate elements and minerals) and magnetic separation.

Most concentration steps involve the addition of water. After the material has been concentrated, it must be dewatered which separates the liquid phase from the concentrated material. Dewatering enables ore handling and concentrates to be transported easily for further processing. The main processes used in dewatering include screens, sedimentation, filtering and drying. These processes increase in difficulty and cost as particle sizes decrease.

> Learning Highlight 2
>
> Rocks are referred to as “ore” when they contain enough of a mineral or metal to be feasibly mined and processed. The portion of the ore that is not of value is referred to as “gangue”.

Ore processing generates effluents and large amounts of waste called **tailings**. Tailings (also known as slimes, tailings pile, tails, leach residue or slickens) are materials left after separating the valuable fraction from the worthless fraction (**gangue**) of an ore. For example, 99 tons of waste is generated per ton of copper with higher ratios in gold mining. Tailings can be toxic. Tailings, usually produced as slurry, are commonly dumped into ponds formed from existing valleys or depleted open pit mines. Ponds are secured by linings and impoundments, i.e., dams or embankments.

2.3 Prospects for Exploration and Additional Mineral Reserves in the Circumpolar North

Mining companies explore and develop mines for profit. Demand, reflected in prices, drive industry, and prices are the result of supply and demand. The main drivers of demand tend to be population size and age distribution, income and consumption rates, and investment levels. Demand is a function of how much people, business and government spend on products. Most minerals are demanded for their specific industrial or commercial end-use properties. Gem stones are valuable for personal reasons and, like gold, for their intrinsic value.

The mining industry is highly capital intensive. Exploration requires large amounts of risk capital. Construction involves larger capital outlays and, because it generally takes a long time from discovery to production, money must be invested for extended periods before a return on investment is realized. Mineral resources found in isolated northern areas cause construction and transportation costs to increase due to a lack of infrastructure.

Cost and availability of energy are important factors that determine whether a mineral deposit can be developed in a sustainable manner. It is a constant problem to determine the quantity of mineral resources in the earth’s crust. Complete exploration, technological advances and price increases have major effects on estimated exploitable mineral reserves.

The world’s population is growing at an increasing rate and similarily the demand for food and material goods. Therefore, metals and other non-renewable resources are being consumed at increasing rates as developing nations become more industrialized. Industrialized nations currently consume a disproportionate amount of the earth’s mineral reserves. The North American continent has less than 10 percent of the world’s population, but consumes more than 50 percent of the world’s production of aluminum. This same disproportionate usage rate by North America and Europe holds true for many other metals.

Population and societal trends influence the need for material goods, which is reflected in the current increased demand for rare earth elements. **Rare earth elements** are seventeen chemicals in the periodic table, specifically the fifteen lanthanide (atomic numbers 57-71) plus scandium and yttrium. Despite their name they are actually plentiful in the earth’s crust but because of their geochemical properties rare earth elements are not often found in concentrated and economically exploitable forms known as **rare earth minerals.** These elements are all metals and used in many modern devices such as computer memory, DVDs, rechargeable batteries, cell phones, magnets and fluorescent lighting. While rare earth elements historically were of little interest or value, demand during the past twenty years for items that require rare earth metals (e.g., cell phones and computers) has exploded. Deposits of rare earth elements in the circumpolar North include deposits in Russia, Canada and Greenland, which may provide an economic boon to the circumpolar North in the future.

Since most of the earth's surface has been thoroughly explored by geologists, it is unlikely significant new quantities of minerals will be discovered. As technology for exploration and detection of deposits advances, the number of predicted feasible deposits will increase. Also, an increase in value of a mineral or advances in extraction and processing methods can render previously unfeasible ore bodies economically viable for mining. The Arctic Ocean floor has not been fully explored for geological information, and areas where new floor is being formed have been shown to be rich in metal sources. As deep-sea mining technology develops, ocean floor sites may provide a new source of minerals.

2.4 Environmental Concerns and Mitigation

Environmental Concerns

Mining, processing and associated activities contribute to environmental concerns in the circumpolar North. Mining activities can result in direct and/or indirect impacts on the surrounding environment. Direct impacts of mining activity include tailings, effluents, waste rock, emissions from mining vehicles, erosion and diversion of water. Indirect impacts arise from influx of population, i.e., increased infrastructure, which leads to habitat fragmentation and pollution generally associated with cities (e.g., municipal waste).

While mining activities positively contribute to the development of infrastructure in the circumpolar North, this may also lead to habitat fragmentation for native species, especially those with large migratory patterns. Habitat fragmentation is a serious threat to arctic ecosystems as increased resource development and larger human populations lead to construction of roads and pipelines that often impede migration and river systems. Significant freshwater supplies are often drained during construction of ice roads. Land infrastructure represents a fragmentation of natural ecosystems, splitting expanses of land and creating disturbances in the form of traffic and noise pollution. In addition, infrastructure development promotes the building of roads, houses and other facilities.

> Learning Activity 3
>
> How has mining impacted your community or a circumpolar community of your choice? Discuss with others in your community (elders, grandparents) to learn of changes over time or do research (Internet or library). Have these changes been positive, negative or both?

Many metals, such as copper, iron, selenium and zinc are associated with living organisms and essential for development. These so-called trace metals can be harmful if concentrations grow too high. Other metals, such as cadmium, lead and mercury do not play any beneficial role in living organisms and are harmful even in small quantities. Metals are generally more harmful to animals than plants because of their position at the upper end of the food chain. Heavy metals accumulate in bodily fats and can be transported to unborn fetuses. Large carnivores at the top of the food chain are especially in danger. Lichens and submerged plants are the most susceptible to metal poisoning.

Some of the Arctic's biggest sources of pollution occur on the Kola Peninsula in Russia. Metals extracted there, primarily nickel and copper, occur in sulphur compounds and when smelted enormous quantities of sulphur dioxide are released into the environment damaging or destroying nearby vegetation. The area exhibiting vegetation damage has grown steadily since the 1970s and is now 4,000 – 5,000 km^2. In these areas there is massive forest dieback and the lichen flora is greatly depleted. Figure 2.3 shows the relationship between mining activities and polluted areas in Russia.

Figure 2.3 Mining regions and polluted areas in Russia. Source: http://jb-hdnp.org/Sarver/Maps/WC/wc09_minrespollutionm.jpg

In addition to tailings and effluents produced as a byproduct of mineral processing, open-pit and underground mines also generate **waste rock**. This term describes mined rock that did not contain sufficient concentrations of mineral to be ore and was not processed. Waste rock is often piled into heaps and sometimes used as fill in the reclamation process. Environmental concerns associated with waste rock include weathering. These rocks are normally subsurface and can cause the release of potentially harmful compounds into surface and ground water. Although in-situ leaching results in the least surface alteration of the three mining types, it can only be used in specific circumstances dependent upon the ore body, type of mineral to be extracted and consideration of surrounding geochemistry and aquifers. Regardless, solution mining raises environmental concerns about mobilization of potentially hazardous materials into ground water.

Water is a vital raw material and major waste of several mining processes. Poor design of effluents treatment lagoons may cause contaminated water to seep into the ground or run into streams and lakes where minerals, trace and heavy metals can cause serious problems. If the pH level of the effluent is low, negative effects on biota are more severe. This is especially a problem in Nordic countries where waters are naturally weakly buffered and acidic.

Mitigation

Improved accessibility and globalization of information have led to societal demands for more stringent regulatory assessments and guidelines for mining in the circumpolar North. Perceptions of environmental impact or mitigation can also influence stock prices and act as a motivator for environmental stewardship. As scientific data is collected to support observations of effluent impacts on surrounding environments, regulatory guidelines have responded by becoming more stringent. While there has been significant progress in regulation of mining activities in recent years, there is much progress to be made. A struggle in the area of environmental stewardship and mitigation of impacts is the balance between society’s demand for a good (mineral or metal) and society’s desire not to harm the environment to obtain that good.

Mining companies in most countries are required to follow stringent environmental and rehabilitation codes in order to minimize environmental and human health impacts. These codes and regulations commonly require environmental impact assessments, development of environmental management plans, mine closure planning (which must be done prior to the start of mining operations), and environmental monitoring during mining operations and after closure. In some areas, regulation may not be well enforced by governments.

Learning Highlight 3

Mining activities generate pollution and cause environmental concerns. Mining companies, governments and communities must work together to identify solutions and mitigation activities so they can benefit from positive economic impacts of mining activities with reduced environmental effects.

Conclusion

The circumpolar North contains valuable mineral deposits that have played an important historical role in the development of the region. Mining extraction, transportation and processing of diverse minerals share commonalities. Governments and society are imposing regulations and external pressures on mining companies to reduce their impacts on the environment and improve mitigation measures. While there are a number of valid environmental concerns associated with mineral mining and processing activities, global demand and economic value are likely to increase mining activity and minerals mined in the circumpolar North.

Study Questions and Answers

1. Identify two metals, two gemstones and three minerals that have been mined in the circumpolar North.

   Multiple answers are possible, some examples include:
   Metals: Aluminum, Copper, Gold, Nickel, Rare Earth Metals, Silver, Zinc
   Gemstones: Diamonds, Jade
   Minerals: Asbestos, Borax, Calcite, Potash, Rare Earth Minerals

2. Compare and contrast a mineral, metal, ore and rock and explain how they relate to one another.

   Metals are chemical elements that are good conductors of heat and electricity and are typically hard, shiny and malleable. Metals can be found inside minerals, which are naturally occurring solid substances having characteristic chemical compositions, highly ordered atomic structures and specific physical properties. Minerals and metals are found in rocks, which are an aggregate of minerals with no specific chemical composition. If a rock contains sufficient amounts of a metal or mineral to be profitably extracted, it is called an ore.

3. Outline the four basic steps of ore processing and briefly describe each step.

   The four basic steps in ore processing are:
   Communition – particle size reduction,
   Sizing – separation of particle sizes by screening or classification,
   Concentration – by taking advantage of physical and surface chemical properties, and
   Dewatering – solid and liquid separation.

4. Discuss the future prospects for exploration of additional mineral reserves in the circumpolar North, highlighting at least three reasons for potential increased future production.

   It is expected that mineral exploration and mining activities in the circumpolar North will increase in the future. Some reasons include:
   1) increased accessibility due to expanding infrastructure,
   2) improvements in processing methods, and

3) changes in human consumption and needs for minerals, creating a rise in mineral and metal prices and therefore increasing feasibility of mining activities.

5. Describe at least three sources of environmental concern of mining activities, including direct and indirect sources of pollution.

   Multiple answers are possible. An example answer is: Mining activities can result in direct and/or indirect impacts on the surrounding environment. Direct impacts of mining activity include: tailings, effluents, waste rock, emissions from mining vehicles, erosion and diversion of water. Indirect impacts include an influx of population and increased infrastructure leading to habitat fragmentation and pollution generally associated with cities (e.g., municipal waste).

Glossary of Terms

Adit: horizontal excavations in the side of a hill or mountain used for mining.

Communition (stage in ore processing): particle size reduction for ore processing.

Concentration (stage in ore processing): increasing the concentration of the desired material from an ore body and can be achieved by many methods.

Decline: a spiral tunnel that circles near or around an ore deposit and is used by trucks to haul ore to the surface.

Dewatering (stage in ore processing): separation of the liquid from the concentrated material.

Element: a pure chemical substance that cannot be separated into simpler substances and singly or in combination constitute all matter.

Gangue: the worthless fraction of an ore.

Open-pit: an open-surface excavation for the extraction of minerals/ore.

Ore: a naturally occurring solid material (e.g., rock) from which a metal or valuable mineral can be profitably extracted.

Inclined Shaft: vertical excavations sunk beside the ore body.

Inorganic: material consisting of compounds or elements other than those of carbon.

In-Situ Leach (In-Situ Recovery, Solution Mining): a mining process that uses a solution to recover minerals by injecting and recovering the solution through boreholes drilled into a deposit. The three terms are used interchangeably.

Metal: a chemical element that is a good conductor of both heat and electricity and is typically hard, shiny and malleable.

Mineral: a naturally occurring solid chemical substance formed through biogeochemical processes, having characteristic chemical composition, highly ordered atomic structure and specific physical properties.

Natural Resource: anything people can use that comes from nature.

Non-Renewable Resource: a natural resource that does not grow or come back or take a very long time to come back and are formed over long geological periods, e.g., minerals.

Rare Earth Elements: a set of seventeen chemicals in the periodic table, specifically the fifteen lanthanide (atomic numbers 57-71) plus scandium and yttrium.

Renewable Resource: a natural resource that grows again or comes back after we use it.

Rock: an aggregate of minerals with no specific chemical composition.

Sizing (stage in ore processing): the separation of particle sizes by screening or classification.

Solution Mining: *see In-Situ Leach.*

Tailings: tailings (also known as slimes, tailings pile, tails, leach residue or slickens) are materials left over after the process of separating the valuable fraction from the **gangue** of an ore.

Underground Mining: refers to a group of underground mining techniques, including shafts and declines, used to extract minerals or geological materials from the earth.

Waste Rock: rock that was mined but did not contain sufficient concentrations of the mineral of interest to be ore and so was not processed.

References

Geological Survey of Finland, www.gsf.fi July 7, 2011

US Library of Congress, http://countrystudies.us/finland/93.htm July 7, 2011.

Supplementary Resources

The United States Geological Survey (USGS) International Minerals Yearbooks contains information about mineral resources for most countries or by geographic region. http://minerals.usgs.gov/minerals/pubs/country/index.html#pubs