Chapter 27

MINERALS AND THE ENVIRONMENT

Case Study: Golden Colorado: Open-pit Mine Becomes a Golf Course

● The city has converted an open pit clay mine into an award winning and profitable golf course, demonstrating that mining sites can be reclaimed.

27.1 THE IMPORTANCE OF MINERALS TO SOCIETY

- Our style of living requires a great diversity of minerals that can be considered to be nonrenewable resources from the geological past. Note that nonrenewable does not mean non-recyclable. Virtually every commodity that is traded depends on a mineral resource for its manufacture. A variety of minerals are also of strategic importance to the United States. Table 27.1 lists many of the products that depend on various minerals. Minerals can be considered to be our nonrenewable heritage from the geological past.

27.2 HOW MINERAL DEPOSITS ARE FORMED

- Minerals are extracted from naturally occurring ore deposits. Ore deposits are areas of unusually high concentrations of the mineral, high enough to profitably extract. Their distribution is entirely due to the history of the biosphere and the geologic cycle. The distribution of some minerals is highly dependent upon biological processes, e.g. deposits of guano, which used to be the source of fertilizer N and nitrate for gunpowder.
- Distribution of Mineral Resources**-** Nine elements account for about 99% of the earth's crust by weight (O, 45%; Si 27%; Al 8%, Fe 6%; Ca 5%; Mg 3%, Na 2%, K 2% and titanium Ti, 1%). The remaining elements are found in trace amounts. The ocean covers about 71% of the earth's surface, and contains only 3.5% of dissolved solids, mostly chlorine.
- Plate Boundaries- Mineral deposits are found at convergent and divergent plate boundaries. Metal sulfides are precipitated at divergent boundaries as hot water carries dissolved metals to the surface. Convergent boundaries mobilize metals in the molten rock, distilling and concentrating some such as mercury (Hg).
- Igneous Processes- Ore deposits may form when magma cools. For example, heavy minerals will tend to sink, while lighter minerals will tend to rise within a column of magma, providing a mechanism for concentrating the minerals. Hot water circulating within the crust, dissolving minerals, then cooling and precipitating the minerals is perhaps the most common mechanism for concentrating ore deposits.
- Sedimentary Processes- Sediments are transported by water and air and tend to sort by size and weight. Sand dunes are examples of this kind of sorting process. In this case the lighter particles have been selectively removed by wind and water, leaving the heavier sand deposits.

- Evaporites- Inland oceans of salt and freshwater can evaporate leaving deposits called evaporates. Marine evaporates are rich sources of bromine, iodine, calcium chloride, sodium chloride, magnesium and in some cases heavy metals such as copper, lead and zinc.
- Non-marine Evaporites (solids rich in sodium, calcium, carbonate, sulfate, borate)
- Brines (high salinity liquids rich in bromine, idodine, calcium, chloride and magnesium.
- Biologicical Processes- Some mineral deposits, including phosphate and iron are formed by biological processes. The ores are associated with sedimentary rocks formed billions of years ago. The formation of some of these deposits would have only occurred at a time when the earth's atmosphere contained much less oxygen.
- Weathering Processes- Weathering, the chemical and mechanical decomposition

A CLOSER LOOK 27.1: Canada's Butchart Gardens: From Eyesore to Eden

The story of the Butchart Gardens on Vancouver Island is a wonderful example of philanthropy, and the vision Jenny Butchart. In the early 1900s a 20 m deep excavation on Vancouver Island was abandoned and then transformed into a garden paradise. Today this garden has become a major tourist attraction The garden was finished in 1921 and is today a major tourist attraction. This is well worth a visit.

of rock, is a process that can concentrate some minerals in the soil, particularly when the minerals are insoluble. An aluminum ore known as bauxite is formed in this manner.

27.3 RESOURCES AND RESERVES

● Mineral **resources** are broadly defined as elements, compounds, minerals or rocks that exist in a form that can be profitably extracted.
● Mineral **reserves** are that portion of the mineral deposit that cannot be economically or legally extracted at the time of the evaluation. Note that today's reserve may be tomorrow's resource as supply declines and prices rise or as legal restrictions are lifted.

27.4 CLASSIFICATION, AVAILABILITY, AND USE OF MINERAL RESOURCES

Availability- Mineral resources can be parsed into several categories:
1) elements for metal production
2) building materials
3) minerals for the chemical industry
4) minerals for agriculture
5) food supplements important for human health (e.g. iodine).

● Minerals cannot be exhausted (there is conservation of mass), so the issue is the cost of maintaining a supply through recycling and mining. Mineral resources are limited, so the option to maintain the supply by mining has a time limit.

● Mineral consumption may take several alternative pathways. See Fig. 27.4 Conservation and recycling can extend the supply.
● U.S. Supply of Mineral Resources- Domestic supplies of many minerals in the U.S. are limited. Like oil, the U.S. relies on imports. The availability of these minerals has an extremely important impact on American industry and in turn, on U.S. defense capabilities. Without just a few critical minerals, such as cobalt, manganese, chromium, and platinum, the defense industry would not be able to function.

27.5 IMACTS OF MINERAL DEVELOPMENT

Impact varies with stage of development, ore quality, mining procedures and local factors such as climate and hydrology.

● Environmental impacts derive from the nature of the extraction process (e.g. surface vs. deep mining), the manner of waste (e.g. tailings) processing, transportation processes (e.g. track damage to sensitive ecosystems), and location (e.g. proximity of the activity to surface and ground water). For example, mine tailings can leach toxins into surface and ground water (acid mine drainage is a classic example). Surface mines or strip mines removes the soil and vegetation, and destroys the ecosystem unless the land is rehabilitated upon the cessation of mining activity.

● Social impacts include problems associated with large scale movements of a workforce specialized on an activity that is often temporary. The closure of a mine, for example, often brings great stress to small towns that depend on a single industry for the economic well-being.

27.6 MINIMIZING ENVIRONMENTAL IMACT OF MINERAL DEVELOPMENT

Minimizing impacts of mineral development requires knowledge of the entire production process (see Fig. 27.7). Minimizing impacts can take several paths:

● Federal, state and local regulation. E.g. Regulation of the mining industry has resulted in the reclamation of about 50% of their abandoned lands.

● On- and off-site treatment of waste. Technologies such as bioremediation, including the use of genetically engineered microbes and artificial wetlands can reduce the waste losses. Losses of wastes that result from erosion can be minimized.

● Adopt best management practices by designing the process so as to reduce the amount of waste produced, reuse materials in the waste stream, and recycle. Economize by locating donor and recipient industries in the same area. For example, when the waste products of one industry are the raw materials in another, both industries and the environment benefit when the industries are located in close proximity. Engineering schools are beginning to develop curricula that focus on ‘green engineering’, which is a based on this new philosophy of designing environmentally benign industrial systems.

27.7 MINERALS AND SUSTAINABILITY

• Balancing consumption with the sustainable development of mineral resources is difficult because mineral *resources* are nonrenewable. The minerals themselves are not destroyed, but they can be rendered unusable. For example, the phosphate fertilizer that is applied to the soil is not destroyed, but is irreversibly lost from further use. New technologies can extend the life of some mineral resources and conservation and recycling can extend the life of mineral resources. The lifetime of a resource (L_T) can be estimated by dividing an estimate of the amount of the resource remaining (R) by its rate

A CLOSER LOOK 28.2: Making a Policy Work: Fishing Resources and Policy Instruments

!The oceans outside national territorial waters are commons, and the fish and other resources in them are common resources. Nations have moved to extend their territorial limits so that they can more effectively manage their fisheries resources. The management options include 1) establishing catch quotas for the entire fishery, allowing anyone to fish until the quota is reached, 2) restrict the number of licenses, but allow each licensed fisherman to catch many fish, 3) tax the catch or the effort (e.g. number of boats, or boat-days), and 4) allocate fishing rights (a quota per fisherman). Economic tools can be used to determine which methods work best.

of consumption (C): $L_T = R/C$. Of course both R and C are likely to vary over time as new deposits are discovered, increasing R, and consumption rises. However, the R/C ratio can tell us which critical resources require our immediate attention. Finally, new technologies can result in substitution of new resources for old, which often occurs when R/C becomes limiting.

CRITICAL THINKING

● Will mining with microbes help the environment?

Web Resources

http://minerals.usgs.gov/ This is the mother lode of information on mineral resources from abrasives to zirconium. Included are links to sustainability, economics, environment, and technology.

http://www.econlib.org/library/Enc/NaturalResources.html This site is an interesting portal for statistics on mineral resource production and reserves, including links to coal, mining, and regulation.