Introduction to Environmental Geology, 5e

Chapter 15

Mineral Resources and Environment

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Chapter 15: Overview

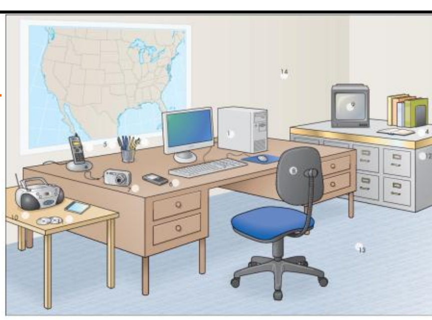
- Understand the relationship between human population and resource utilization
- Understand why minerals are so important to modern society
- Understand the difference between a resource and a reserve
- Know factors that control the availability of mineral resources
- Understand environmental impact of mineral development
- Know the potential benefits of biotechnology
- Understand the economic and environmental role of recycling mineral resources and sustainability

Case History: Mine Transformation

- An award-winning golf course near Golden, Colorado, is now located on land where used to be an open-pit quarry for 100 years
- The mine produced clay from layers between the limestone beds to make bricks
- The bricks were used as a building material for buildings in the Denver area, including the Colorado governor's mansion
- Fossil Trace Golf Club: A unique instance of mine reclamation

Minerals and Human Use

- Backbone of modern societies
- Availability of mineral resources as a measure of the wealth of a society
- Important in people's daily life as well as in overall economy
- Processed materials from minerals accounting for 5 % of the U.S. GDP
- Mineral resources are nonrenewable



1. Computer—Includes gold, silica, nickel, aluminum, zinc, iron, petroleum, products and about thirty other minerals.
2. Pencil—Includes gaphite and clays
3. Telephone—Includes copper, gold, and petroleum products.
4. Books—Includes limestone and clays.
5. Pens—Includes limestone, mica, petroleum products, clays, silica, and talc.
6. Blackberry—Includes gold, nickel, silica, zinc, and petroleum products.
7. Camera—Includes silica, zinc, copper, aluminum, and petroleum products.
8. Chair—Includes aluminum and petroleum products.
9. Television—Includes aluminum, copper, iron, nickel, silica, rare earth, and strontium.
10. Stereo—Includes gold, iron, nickel, beryllium, and petroleum products.
11. Compact Disc—Includes aluminum and petroleum products.
12. Metal Chest—Includes iron and nickel. The brass trim is made of copper and zinc.
13. Carpet—Includes limestone, petroleum products, and selenium.
14. Drywall—Includes gypsum clay, vermiculite, calcium carbonate, and micas.

Mineral Resources and Reserves

- Mineral resources: Usable economic commodity (profitable) extracted from naturally formed material (elements, compounds, minerals, or rocks)
- Reserve: Portion of a resource that is identified and *currently* available to be extracted legally
- Defining factors: Geologic, technological, economic, and legal factors

Types of Mineral Resources

Based on how we use them:

- Materials for metal production and technology
- Construction materials
- Agricultural industry (fertilizers)
- Mineral resources for chemical industry
- Others (gem stones, cosmetics, food, etc.)
- Energy mineral resources

Mineral Resources Problems

- Nonrenewable resources
- Finite amount of mineral resources and growing demands of the resources
- Supply shortage due to the growing global industrialization.
  - More developed countries consuming disproportionate share of mineral resources.
- Erratic distribution and uneven consumption of resources.
  - Highly developed countries use the most of the resources

Responses to Limited Availability

- Use less and make more efficient use of what is available
- Find more sources
- Find a substitute
- Recycle
- Do without

Geology of Mineral Resources

Metallic ore: Useful metallic minerals that can be mined for a profit

- Mining potential depending upon technology, economics, and politics with an emphasis on profitability, technological feasibility, and demands
- Concentration factor: Concentration necessary for profitable mining (e.g., for gold is about 5,000)
  - Variable with types of metals
  - Variable over time

Common Use of Mineral Products

TABLE 15.1 Approximate Concentration Factors of Selected Metals Necessary Before Mining Is Economically Feasible

Metal	Natural Concentration (percentage)	Percentage in Ore	Approximate Concentration Factor
Gold	0.0000004	0.001	2,500
Mercury	0.00001	0.1	10,500
Lead	0.0015	4	2,500
Copper	0.005	0.4 to 0.8	80 to 160
Iron	5	20 to 69	4 to 14
Aluminum	8	35	4

Data from U.S. Geological Survey Professional Paper 820, 1973.

Table 15.1

Geologic Process of Formation

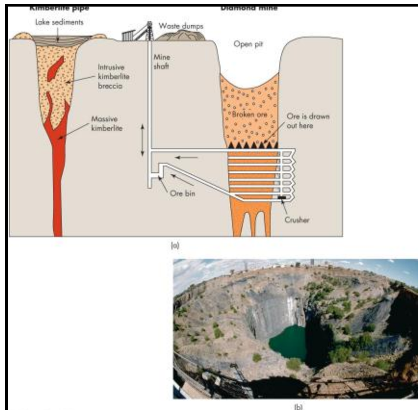
- Igneous
- Metamorphic
- Sedimentary
- Biological
- Weathering

TABLE 15.2 Examples of Different Types of Mineral Resources

Type	Example
Igneous	
Disseminated	Diamonds—South Africa
Crystal settling	Chromite—Stillwater, Montana
Late magmatic	Magnetite—Adirondack Mountains, New York
Pegmatite	Beryl and lithium—Black Hills, South Dakota
Hydrothermal	Copper—Butte, Montana
Metamorphic	
Contact metamorphism	Lead and silver—Leadville, Colorado
Regional metamorphism	Asbestos—Quebec, Canada
Sedimentary	
Evaporite (lake or ocean)	Potassium—Carlsbad, New Mexico
Placer (stream)	Gold—Sierra Nevada foothills, California
Glacial	Sand and gravel—northern Indiana
Deep-ocean	Manganese oxide nodules—central and southern Pacific Ocean
Biological	
	Phosphorus—Florida
Weathering	
Residual soil	Bauxite—Arkansas
Secondary enrichment	Copper—Utah

Modified from Robert J. Foster. 1983. *General Geology*, 4th ed. Columbus, OH: Charles E. Merrill.

15.3



Igneous

Kimberlite-Diamonds

Figure 15.3

Igneous/Metamorphic Hydrothermal-Metals

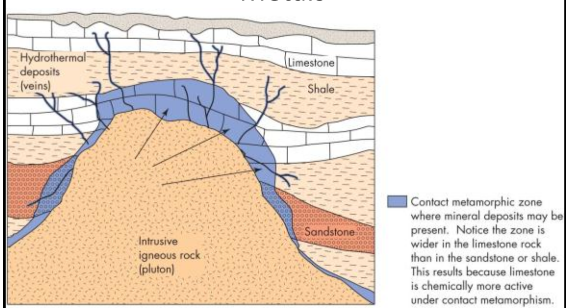
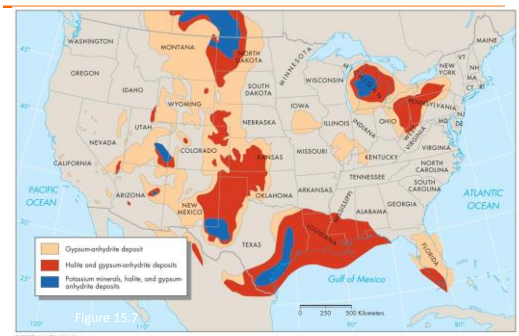


Figure 15.5

Sedimentary Evaporite Deposits



Biologic

Figure 15.10

Weathering Bauxite- Al

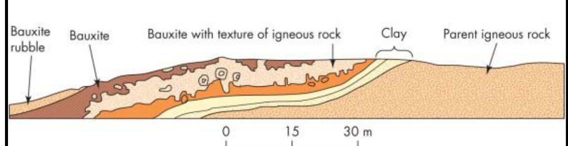


Figure 15.11

Plate Tectonics and Minerals

- Plate tectonic boundaries related to the origins of many ore deposits, Fe, Au, Cu, and Hg, etc.
- Plate tectonic processes (high temp, high pressure, and partial melting) promoting release and enrichment of metals along plate boundaries
- Ore deposits at divergent boundaries is related to the migration (movement) of ocean water
- Ore deposits at convergent boundaries: Related to partial melting of seawater-saturated rocks of the oceanic lithosphere in a subduction zone

Igneous Subduction Zone- Hg

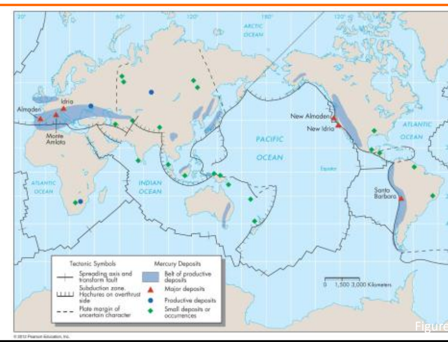


Plate Tectonics and Minerals

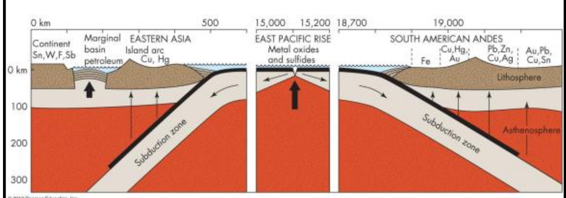


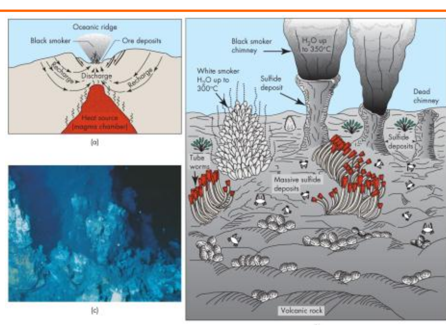
Figure 15.A

Other Minerals from the Sea

Mineral resources on the bottom of the ocean are vast

- Sulfide deposits: sulfide deposits containing zinc, copper, iron, and trace amounts of silver are produced at the black smokers along the oceanic ridges.
- Manganese oxide nodules: cover vast areas of the deep-ocean floor (up to 50 percent in certain area), containing manganese (24 percent) and iron (14 percent), with secondary copper (1 percent), nickel (1 percent), and cobalt (0.25 percent).
- Cobalt-enriched manganese crusts: Present in the mid- and southwest Pacific, on flanks of seamounts, volcanic ridges, and islands

Hydrothermal Vents - Ocean



Mineral Resources and Environmental Impact

Environmental impact:

- From mineral exploration and testing
- From mineral mining
- From mineral resource refining (smelting, leaching, etc.)
- From mining waste disposal and subsequent contamination of environment

Environment Impact

The impact depends upon many factors:

- Mining procedures
- Hydrologic conditions
- Climate factors
- Types of rocks and soils
- Topography

Impact from Exploration and Testing

Mineral exploration and testing:

- Surface mapping, geochemical, geophysical, and remote-sensing data collection
- Test drilling

- Impact
  - Generally minimal impact
  - More planning and care needed for sensitive areas (arid, wetlands, and permafrost areas)

Impact of Mineral Extraction and Processing

General impact from mineral mining:

- Direct impact on land, water, air, and biological environment
- Indirect impact on the environment: Topographic effect, transportation of materials, etc.
- Impact on social environment: Increased demands for housing and services

Figure 15.17

Impact of Mineral Extraction and Processing

Impact from mining operations:

- Land disturbances from access, surface mining
- Waste from mines: 40% of the mining area for waste disposal, mining waste 40% of all solid wastes
- Special mining (e.g., chemical leaching from Au mining)
- Mining acid drainage, during mining and post mining
- Water pollution, such as smelting emissions of SO_2
- Biological environment

Impact of Mineral Extraction and Processing

Impact of Mineral Extraction and Processing

Water pollution:

- Trace elements leaching out into water, such as Cd, Co, Cu, Pb, Mo, Zn
- Flooding of abandoned mine
- Acid mine drainage from tailings
- Acidic and toxic mining wastewater

Impact of Mineral Extraction and Processing

Other pollution:

- Air pollution: Both extraction and processing operations have adverse effects on air quality; smelting has released enormous quantities of pollutants; toxic gases from abandoned mines
- Pollution to overall biological environment: Physical and chemical changes in the land, soil, water, and air associated with mining directly and indirectly affect the biological environment

Minimizing the Impact of Mining

- Knowledge and technology transfer: Developed countries to developing countries
- Environmental regulations: forbid bad mining practices, Clean Air Act, and on- and offsite treatment of wastes
- Land reclamation: About 50 percent of land used in mining industry reclaimed
- Use of new biotechnology in mining: Bio-oxidation, bioleaching, biosorption, genetic engineering
- Practicing the three Rs of waste management

Environmental Degradation

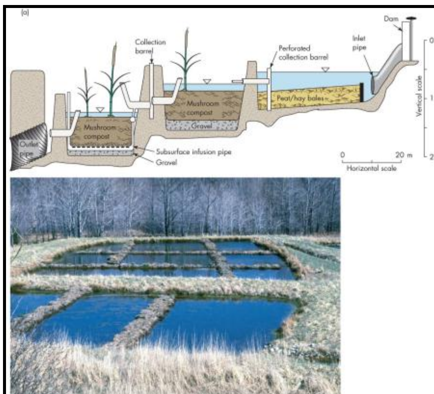


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Figure 15.20

Recycling Mineral Resources

Why recycle? Consider the impact of the wastes:

- Toxic to humans
- Dangerous to natural ecosystem
- Degradation of air, water, and soil
- Use of land for disposal
- Aesthetically undesirable

Recycling Mineral Resources

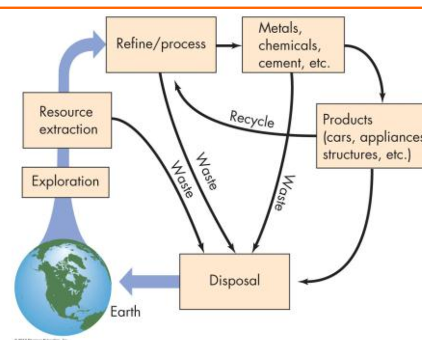

Figure 15.21

Recycling Mineral Resources

- Waste contains recyclable materials
- Saves energy, money, land, raw mineral resources from more mining
- Saves energy and money when recycling instead of refining raw ore materials
- Recycling has been proven to be profitable and workable

Recycling Mineral Resources

- Most-recycled metals: iron and steel, 90 percent by weight. Requires 1/3rd less energy.
- One third as much energy needed to produce steel from recycled scrap as from original ore
- In 2006, the total value of recycled steel in the United States was about $18.5 billion, recycling of iron and steel amounted to approximately 50 percent
- Lead (73 %), aluminum (43 %), copper (32 %), nickel (43 %), and titanium (47 %)

Minerals and Sustainability

- Sustainability: Long term strategy for consuming the resources
- Find an alternative materials for the metal (e.g., glass fiber cable for copper wires)
- Use raw materials more efficiently. The time available for finding a solution to the depletion of a nonrenewable mineral is the R/C ratio, where R is the known reserve and C is the rate of consumption
- More R&D on innovative substitutes or ways to keep the R/C ratio, a solution to the depletion of nonrenewable resources

Critical Thinking

- Considering the fact that mineral resources are nonrenewable, do you believe that technology will eventually help meet the growing demand for mineral resources? If yes, explain.
- Biotechnology shows the potential for cleaner minerals extraction and waste disposal. Will biotechnology bring about any environmental problems?
- What types of environmental impact would there be if we increasingly extract more mineral resources from seafloor?