



Chapter 15 Geology and Nonrenewable Mineral Resources



“It’s A Small World After All”

Outline

Geologic Processes

- A. The earth is made up of a core, mantle, and crust and is constantly changing as a result of processes taking place on and below its surface. Geology is the study of dynamic processes occurring on the earth’s surface and in its interior.
 1. The crust is soil and rock that floats on a mantle of partly melted and solid rock.
 2. The core is intensely hot. It has a solid inner part surrounded by a liquid core of molten or semisolid material.
 3. The mantle is a thick, solid zone. It is mostly solid rock, but an area called the asthenosphere is very hot, partly melted rock about the consistency of soft plastic.
 4. The crust is thin and is divided into the continental crust and the oceanic crust.
- B. Huge volumes of heated and molten rock moving around the earth’s interior form massive solid tectonic plates that move extremely slowly across the earth’s surface.
 1. About 12 or so rigid tectonic plates move across the surface of the mantle very slowly. These thick plates compose the lithosphere.
 2. There are three types of boundaries for lithospheric plates. The boundaries are divergent plate boundaries, where plates move apart in opposite directions, convergent plate boundaries, where plates are pushed together by internal forces and one plate rides up over the other. A trench generally occurs at the subduction zone. The third type of boundary is a transform fault and occurs where plates slide/grind past one another.
 3. The movement of these plates produces mountains on land and trenches on the ocean floor.
 4. Earthquakes and volcanic action are violent and disruptive actions of the earth. Volcanoes and earthquakes are likely to be found at the plate boundaries.
 5. The plate tectonic theory also helps to explain certain patterns of biological evolution occurred.
- C. Some processes wear down the earth’s surface by moving topsoil and pieces of rock from one place to another, while other processes build up soil on the earth’s surface. Weathering is the physical, chemical, and biological processes that break down rocks and minerals into smaller pieces.

Minerals, rocks, and the rock cycle

- A. The earth’s crust consists of solid inorganic elements and compounds called minerals and rocks that can sometimes be used as resources.
 1. The crust is the source of the nonrenewable resources we use as well as the source of soil.
 2. A mineral is an element or inorganic compound that is solid with a regular internal crystalline structure.
 3. A mineral resource is a concentration of naturally occurring material in or on the earth’s crust that can be extracted and processed into useful materials at an affordable cost.
 4. Examples of mineral resources are fossil fuels (coal, oil, and natural gas), metallic minerals (such as aluminum, iron, and copper), and nonmetallic minerals (such as sand, gravel, and limestone). As they take so long to produce, these components of the earth’s natural capital are classified as nonrenewable mineral resources.
 5. Mineral resources can be classified into four major categories:
 - a. Identified resources with a known location, quantity, and quality
 - b. Reserves are identified resources that can be extracted profitably at current prices
 - c. Undiscovered reserves are potential supplies of a mineral resource assumed to exist
 - d. Other resources are undiscovered resources and identified resources not classified as reserves.
 6. Future developments in nanotechnology may have potential benefits and drawbacks to the environment and the economy.
- B. Deposits of nonrenewable mineral resources in the earth’s crust vary in their abundance and distribution.
 1. Iron and aluminum are fairly abundant whereas manganese, chromium, cobalt, and platinum are fairly scarce.
 2. Massive exports can deplete a countries supply of nonrenewable minerals.

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3. Three countries (the United States, Canada, and Russia) with only 8% of the world’s population consume about 75% of the world’s most widely used metals.
 4. Japan has virtually no metal resources and has to rely on resource imports.
 5. The United States currently depends on imports of 50% or more of 24 of its 42 most important nonrenewable mineral resources.
 6. Experts are concerned about the availability of four strategic metal resources (manganese, cobalt, chromium, and platinum) that are essential for the country’s economic and military strength.
- C. A very slow chemical cycle recycles three types of rock found in the earth’s crust. The earth’s crust contains igneous, sedimentary, and metamorphic rocks that are recycled by the rock cycle.
1. Rock is a solid combination of one or more minerals.
 2. An ore is a rock that contains a large enough concentration of a particular mineral (often a metal) that the rock can be mined and processed to extract the desired mineral.
 3. Igneous rock is formed below or on the earth’s surface when molten rock wells up and hardens. They form the bulk of the earth’s crust.
 4. Sedimentary rock is formed from small, eroded pieces of rock that are carried to downhill sites. Layers accumulate over time and an increase of weight and pressure plus dissolved minerals bind the sediment particles together to form sedimentary rock.
 5. Metamorphic rock is produced from preexisting rock that is subjected to high temperatures, high pressures, chemically active fluids, or some combination of these.
 6. The rock cycle is the interaction of physical and chemical processes that change rock from one type to another. It is the slowest of the earth’s cyclic processes.

Environmental Effects of Using Mineral Resources

- A. The extraction, processing, and use of mineral sources have a large environmental impact. The greatest danger from mineral extraction may be environmental damage from the processes used to get to the end product.
1. Higher grade ores are more easily extracted.
 2. Greater environmental damage comes with extraction of lower grade ores in higher energy costs and greater environmental damage to the land.
- B. Minerals are removed through a variety of methods that vary widely in their costs, safety factors, and levels of environmental harm. Shallow deposits are removed by surface mining, and deep deposits are removed by subsurface mining.
1. In surface mining, the overburden of rock and soil is removed and discarded as spoils. This mining method extracts about 90% of nonfuel mineral and rock deposits and 60% of the coal used in the U.S.
 2. Surface mining is done by one of several methods:
 - a. open-pit mines are large holes dug to remove ores
 - b. strip mining is useful and economical for extracting mineral deposits that lie close to the earth’s surface; area strip mining is used where land is relatively flat
 - c. contour strip mining is used on hilly or mountainous land where a series of terraces are cut into the hill
 - d. mountaintop removal uses explosives, and huge machinery to remove the top of a mountain for the coal seams beneath it. This method causes considerable environmental damage.
 3. The Surface Mining Control and Reclamation Act of 1977 (in the U.S.) requires mining companies to restore most surface-mined land.
 4. Reclamation efforts are only partially successful.
 5. Subsurface mining removes coal and various metal ores too deep for surface mining.
 6. Subsurface mining disturbs less than 1/10 as much land as surface mining with less waste, but is more dangerous and expensive.
- C. Mining scars the land and produces large amounts of solid waste and air and water pollution.
1. The land is left scarred and the surface is disrupted. Cleanup may cost in the billions.
 2. Subsidence from underground mining causes sewer, gas and water systems to break.
 3. Mining wastes contain toxins and acid drainage carries to streams and groundwater.
 4. Toxic chemicals can also be emitted to the atmosphere.
- D. After waste material is removed from metal ores they are smelted or treated with chemicals to

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extract the desired metal.

1. Ore has two components: the ore mineral and the waste material called gangue.
2. Removing the gangue from ores produces large piles of solid waste called tailings.
3. Ore is separated from gangue, smelted to obtain the metal, made into products that are used and discarded or recycled.
4. There can be enormous amounts of air and water pollution from these processes.
5. Cyanide is used to separate about 85% of the world’s gold ore in a process called cyanide heap extraction. Cyanide is extremely toxic.

Supplies of Mineral Resources

- A. The future supply of a resource depends on its affordable supply and how rapidly that supply is used. A nonrenewable resource generally becomes economically depleted rather than totally depleted. There are five choices at that point: recycle or reuse existing supplies, waste less, use less, find a substitute, or do without.
 1. Depletion time for a resource depends on how long it takes to use up a certain proportion (usually 80%) at a given rate of use.
 2. Depletion time is extended by recycling, reusing and reducing consumption of a given resource.
 3. New discoveries of a resource extend the depletion time also.
 4. The demand for mineral resources is increasing at a rapid rate with increased consumption.
 5. No one knows whether we will run out of a mineral resource.
- B. A rising price for a scarce mineral resource can increase supplies and encourage more efficient use.
 1. Economics determines what part of a known mineral supply is extracted and used.
 2. Some economists feel that price effect may no longer apply since industry and government often control the supply, demand, and prices of minerals so that a truly competitive market does not exist.
 3. Governments subsidize development of domestic mineral resources. In the U.S. mining companies get depletion allowances of 5-22% of their gross income. They are also allowed to deduct much of the cost of finding and developing mineral deposits.
 4. Rather than receiving billions in government subsidies, critics feel that taxing extraction of nonfuel mineral resources would create incentives for more efficient resource use, reduce waste and pollution, and encourage recycling and reuse of these resources.
- C. New technologies can increase the mining of low-grade ores at affordable prices, but harmful environmental effects can limit this approach.
 1. In 1900, the average copper ore mined in the U.S. was about 5% copper by weight; today that ratio is 0.5%.
 2. One limiting factor in mining low-grade ore is the increased cost of mining; another is the availability of freshwater that is needed to mine and process some minerals; a third is the environmental impacts of increased land disruption, waste material, and pollution produced during mining and processing.
 3. One way to improve mining is to use microorganisms for in situ mining. However, the process is slow and biological mining may only be feasible with low-grade ores for which conventional techniques are too expensive.
- D. Most minerals in seawater and on the deep ocean floor cost too much to extract, and there are squabbles over who owns them.
 1. Rich hydrothermal deposits of gold, silver, zinc, and copper are found as sulfide deposits in the deep-ocean floor and around hydrothermal vents.
 2. Another potential source from the ocean floor is potato-size manganese nodules that cover about 25-50% of the Pacific Ocean floor.
 3. High costs of extraction of both the nodules and hydrothermal ore deposits are prohibitive.

Using Mineral Resources More Sustainably

- A. Scientists and engineers are developing new types of materials that can serve as substitutes for many metals. This is known as the materials revolution.
 1. Development of silicon and ceramics may replace the need for as much metal.

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2. Ceramics have many advantages over conventional metals (harder, stronger, lighter, last longer) and do not corrode.
3. Automobiles and planes are being made of plastics and composite materials since they cost less to make, are lower maintenance and can be molded to any shape.
4. Use of plastics has drawbacks; they require the use of oil and other fossil fuels.
5. Nanotechnology is the use of science and engineering at the atomic and molecular level to build materials with specific properties.
 - a. Buckyballs are soccer-ball shaped forms of carbon that have been engineered.
 - b. Nanotechnology is a new area that could provide many things in the near future.
 - c. One concern about nanotechnology is that smaller particles tend to be more reactive and potentially more toxic due to large surface area compared to mass.
 - d. They can pass through the natural defenses of the body.
 - e. Analysts say we need to carefully investigate its potential harmful aspects and then develop guidelines and regulations to control and guide this new technology.
- B. Recycling valuable and scarce metals saves money and has a lower environmental impact than mining and extracting them from their ores.
- C. We can use mineral resources more sustainably by reducing their use and waste and by finding substitutes with fewer harmful environmental effects.
- D. Growing signs point to an ecoindustrial revolution taking place over the next fifty years.
 1. The goal is to make industrial manufacturing processes cleaner and more sustainable by redesigning them to mimic how nature deals with wastes.
 2. One way is to mimic nature by recycling and reusing most minerals and chemicals instead of disposing of them. Another is to have industries interact through resource exchange webs.
 3. Figure 15-19 shows the industrial ecosystem in Kalundborg, Denmark.
 4. These industrial forms of biomimicry provide many economic benefits for business and the environment.
 5. In 1975, the 3M company began a Pollution Prevention pays (3P) program. Other companies are also adopting similar pollution and prevention programs.

Summary

1. Major geological processes that occur within the earth are known as internal processes, and they build up the surface of the earth. Geological processes that occur on the surface of the earth include erosion and weathering.
2. Tectonic plates have rearranged the earth’s continents and ocean basins over millions of years like pieces of a gigantic jigsaw puzzle. The plates have three types of boundaries. Natural hazards such as earthquakes and volcanoes are likely to be found at plate boundaries.
3. Rocks are large, natural, continuous parts of the earth’s crust. There are three major types of rocks: igneous, sedimentary, and metamorphic. Rocks are affected by changes of physical and chemical conditions that change them over time from one type to another through the rock cycle.
4. Mineral resource extraction methods include surface and subsurface mining. Surface mining types are open-pit, strip, contour strip mining, and mountain removal.
5. Mineral resources that can be reused and recycled have a longer depletion time compared to those that cannot be reused or recycled and there is no increase in reserves discovered.
6. Scientists are developing new types of materials as substitutes for many metals. Mineral conservation and more sustainable manufacturing processes are helping to decrease our use and waste of such resources. An ecoindustrial revolution is underway in some parts of the world.

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Objectives

1. Briefly describe the layers of the earth's interior. Describe the internal and external earth processes responsible for forming earth's landscape. Be sure to distinguish three different tectonic plate boundaries and the geologic features often found at each. Explain how this knowledge is significant for understanding mineral deposits and evolution.
2. Distinguish between internal and external geologic processes. Discuss how these processes affect human activities and natural ecosystems.
3. List and define three broad classes of rock. Briefly describe the rock cycle and indicate interrelationships among these classes.
4. Describe how earthquakes are caused. Describe how tsunamis are formed. Describe the role of volcanoes in the rock recycling process.
5. List three types of mineral resources, and give one example of each. Clarify the relationship between identified resources and reserves.
6. Distinguish between subsurface and surface mining. Briefly describe the environmental impacts of mining.
7. Draw a hypothetical depletion curve. Project how this curve would be affected by the following changes in assumptions: (a) recycling of the resource is increased, (b) discoveries of new deposits of the resource are made, (c) prices rise sharply, (d) a substitute for the resource is found.
8. Describe the economics of nonrenewable minerals. Explain the limitations of mining lower-grade ores. Discuss the option of getting more minerals from the ocean.
9. Describe how mineral resources can be used more sustainably. Summarize the nanotechnology revolution and its implications.

Key Terms (**Terms are listed in the same font style as they appear in the text.**)

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| <p><i>Acid mine drainage</i> (p. 347) area strip mining (p. 345) <i>asthenosphere</i> (p. 336) <i>biological weathering</i> (p. 340) <i>biomimicry</i> (p. 352) <i>biomining</i> (p. 349) <i>brownfields</i> (p. 352) <i>buckyballs</i> (p. 335) <i>chemical weathering</i> (p. 340) <i>continental crust</i> (p. 336) <i>continental glaciers</i> (p. 340) contour strip mining (p. 345) <i>fossil fuels</i> (p. 341) <i>frost wedging</i> (p. 340) <i>gangue</i> (p. 347) geology (p. 336) <i>glaciers</i> (p. 340) high-grade ore (p. 342) <i>highwall</i> (p. 345) igneous rock (p. 342) lithosphere (p. 336)</p> | <p><i>convection cells</i> (p. 337) convergent plate boundary (p. 338) core (p. 336) crust (p. 336) <i>currents</i> (p. 337) <i>cyanide heap extraction</i> (p. 347) depletion time (p. 348) divergent plate boundary (p. 339) <i>earthquakes</i> (p. 339) <i>economically depleted</i> (p. 348) <i>erosion</i> (p. 340) <i>external processes</i> (p. 340) open-pit mining (p. 345) ore (p. 342) <i>ore mineral</i> (p. 347) overburden (p. 345) <i>physical (mechanical) weathering</i> (p. 340) <i>resource exchange webs</i> (p. 352) rock (p. 342) rock cycle (p. 343) sedimentary rock (p. 343)</p> |
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| <p>low-grade ore (p. 342) <i>magma</i> (p. 337) <i>manganese nodules</i> (p. 350) mantle (p. 336) <i>mass wasting</i> (p. 340) <i>materials revolution</i> (p. 350) <i>metallic minerals</i> (p. 341) metamorphic rock (p. 343) mineral (p. 341) mineral resource (p. 341) <i>molecular economy</i> (p. 335) mountaintop removal (p. 345) <i>nanotechnology</i> (p. 335) <i>nanotubes</i> (p. 335) <i>nonmetallic minerals</i> (p. 341) <i>nonrenewable resources</i> (p. 341) <i>oceanic crust</i> (p. 336) <i>oceanic ridges</i> (p. 339)</p> | <p>smelting (p. 347) <i>spoil banks</i> (p. 345) spoils (p. 345) <i>strategic metal resources</i> (p. 342) strip mining (p. 345) <i>subduction</i> (p. 339) <i>subduction zone</i> (p. 339) <i>subsidence</i> (p. 347) subsurface mining (p. 345) surface mining (p. 345) <i>Surface Mining Control and Reclamation Act</i> (p. 346) <i>tailings</i> (p. 347) tectonic plates (p. 336) transform fault (p. 339) <i>trench</i> (p. 339) <i>tsunamis</i> (p. 339) <i>volcanoes</i> (p. 339) weathering (p. 340)</p> |
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