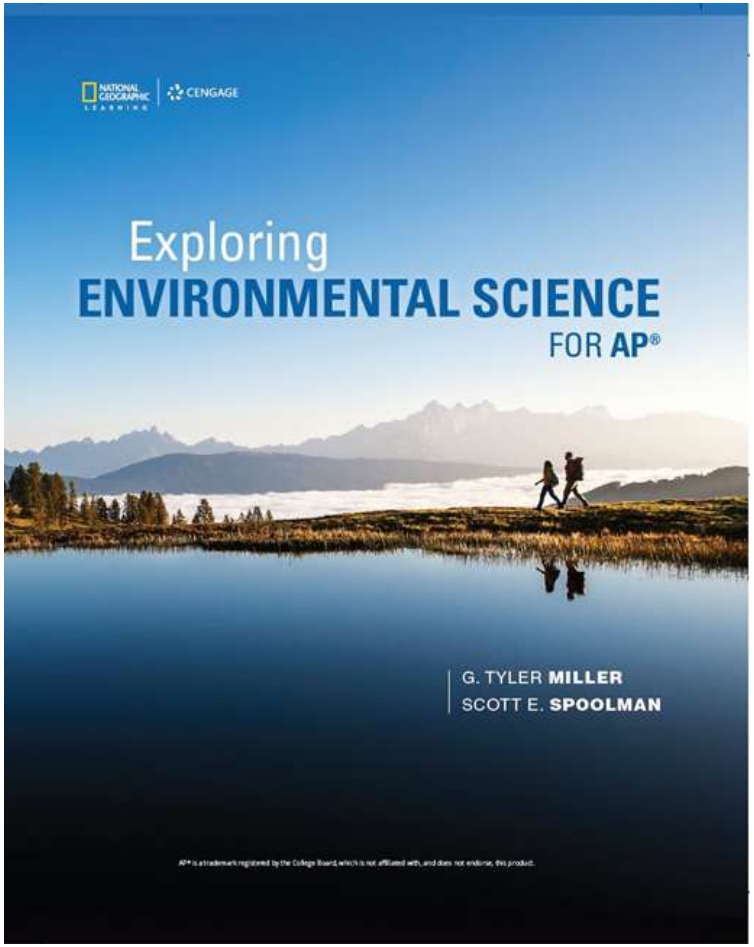
Exploring Environmental Science for AP®

1st Edition



Chapter 11

Geology, Soil, and Mineral Resources

Core Case Study: The Real Cost of Gold

- Harmful effects of gold mining
  - Massive amounts of rock dug to yield small amounts of gold
  - Highly toxic cyanide salts used to extract the gold into settling ponds
    - Toxic to birds and mammals
    - Threaten underground drinking water supplies
  - Romanian gold mine dam collapsed in 2000
    - Contaminated rivers with cyanide and toxic metals

11.1 What Are the Earth's Major Geological Processes/Mineral Resources?

- Dynamic processes within the earth and on its surface produce mineral resources
- Mineral resources are nonrenewable
  - Produced and renewed over millions of years mostly by the earth's rock cycle

The Earth Is a Dynamic Planet (1 of 3)

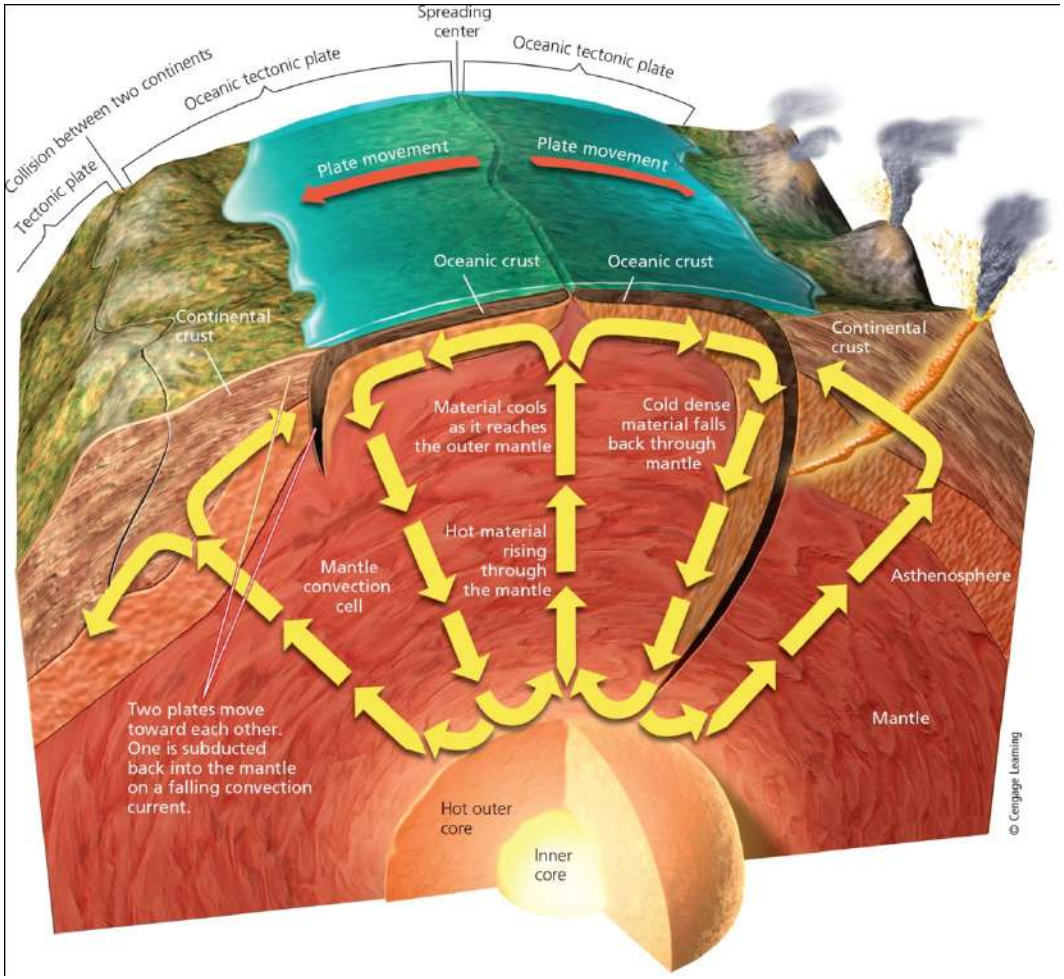
- Geology
  - Study of dynamic processes taking place on the earth's surface and in its interior
- Three major concentric zones of the earth
  - Core
  - Mantle, including the asthenosphere
  - Crust
    - Continental crust
    - Oceanic crust: 71% of crust

The Earth Is a Dynamic Planet (2 of 3)

Era	Period	Time (millions of years ago)	Major Events (approximate time in millions of years ago, in parentheses)
Cenozoic (Age of Mammals)	Quaternary	1.6–present	Likely beginning of new mass extinction (now) Human civilization develops (0.01 to now) Modern humans (*Homo sapiens sapiens*) (0.2) First humans (1.2)
	Tertiary	6.5–1.6	Oldest human ancestors (4.4) Grasses diversify and spread Mammals diversify and spread
Mesozoic (Age of Reptiles)	Cretaceous	146–6.5	Mass extinction (75% of species, including dinosaurs) (66) First primates First flowering plants
	Jurassic	208–146	Mass extinction (75% of species) (200) First birds Dinosaurs diversify and spread
	Triassic	245–208	First dinosaurs First mammals
Paleozoic (Age of Fishes)	Permian	290–245	Mass extinction (90–96% of species) (251) Reptiles diversify and spread
	Pennsylvanian	322–290	First reptiles
	Mississippian	362–322	Coal deposits form
	Devonian	408–362	Mass extinction (70% of species) (375) First land animals (amphibians) Fish diversify and spread First forests
	Silurian	439–408	First land plants and corals
	Ordovician	510–439	Mass extinction (60–70% of species) (450) First fish
	Cambrian	545–510	First shellfish Ozone layer forms Oxygen increases in atmosphere Photosynthetic organisms proliferate
Precambrian	Proterozoic	2,500–545	First animals in sea (jellyfish) First multicellular organisms
	Archean	4,600–2,500	First photosynthesis and oxygen in atmosphere (2,800) First plants in sea (algae) (3,200) Atmospheric water vapor condenses to oceans (3,700) First rocks (3,800) Likely origin of life (first one-celled organisms) (3,800) Earth forms (4,600)

Time scale for major geological and biological changes since the earth formed about 4.6 billion years ago.

The Earth Is a Dynamic Planet (3 of 3)



What Are Minerals and Rocks? (1 of 2)

- Mineral
  - Naturally occurring chemical element or compound that exists as a crystalline solid
- Mineral resource
  - Concentration that we can extract and process into raw materials
  - Nonrenewable
- Rock
  - Solid combination of one or more minerals

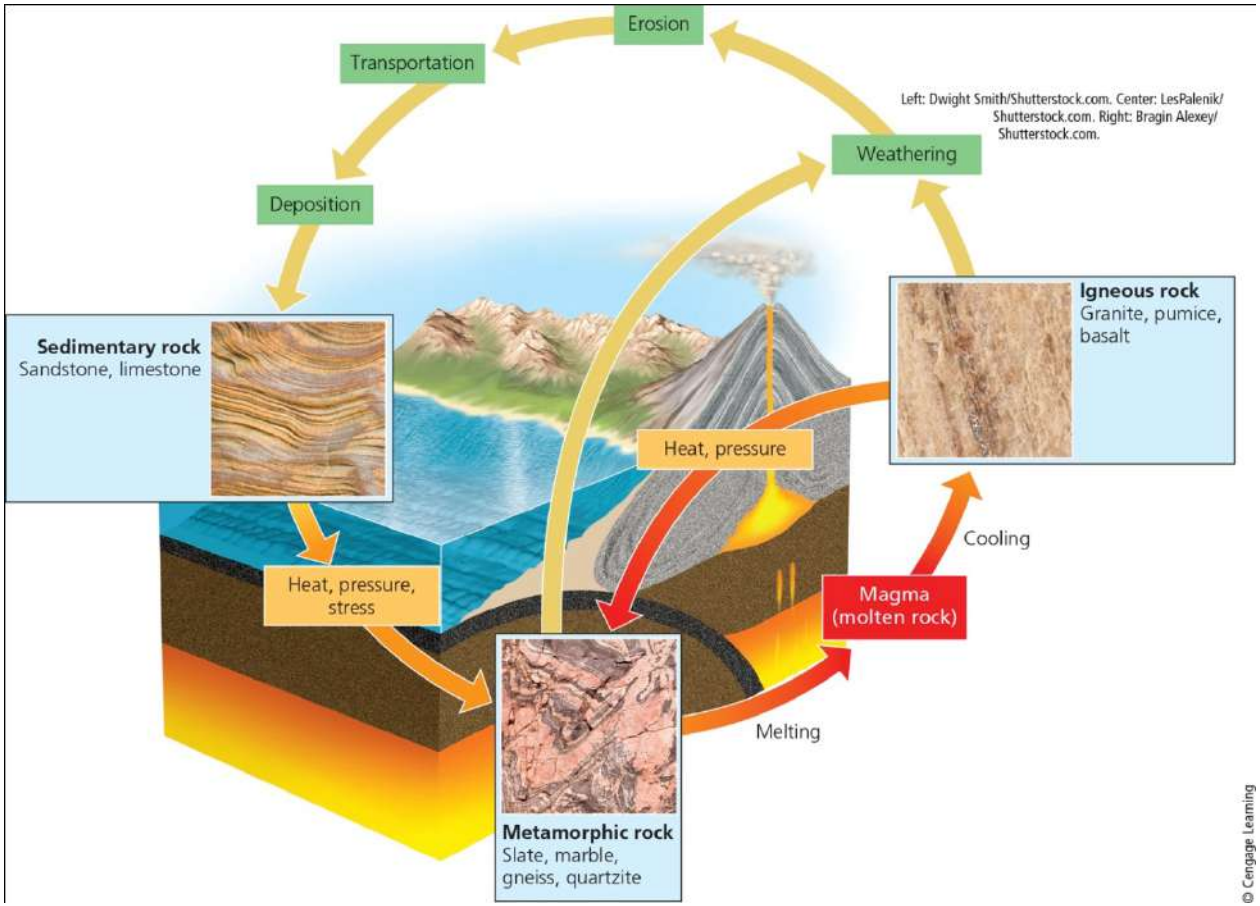
What Are Minerals and Rocks? (2 of 2)

- Sedimentary rock
  - Made of sediments
    - Dead plant and animal remains
    - Tiny particles of weathered and eroded rocks
- Igneous rock
  - Forms under intense heat and pressure
- Metamorphic rock
  - Existing rock subjected to high temperatures, pressures, fluids, or a combination

The Earth's Rocks Are Recycled Slowly (1 of 2)

- Rock cycle
  - Rocks are recycled over millions of years
  - Erosion, melting, and metamorphism
  - Slowest of the earth's cycle processes

The Earth Is a Dynamic Planet (2 of 2)



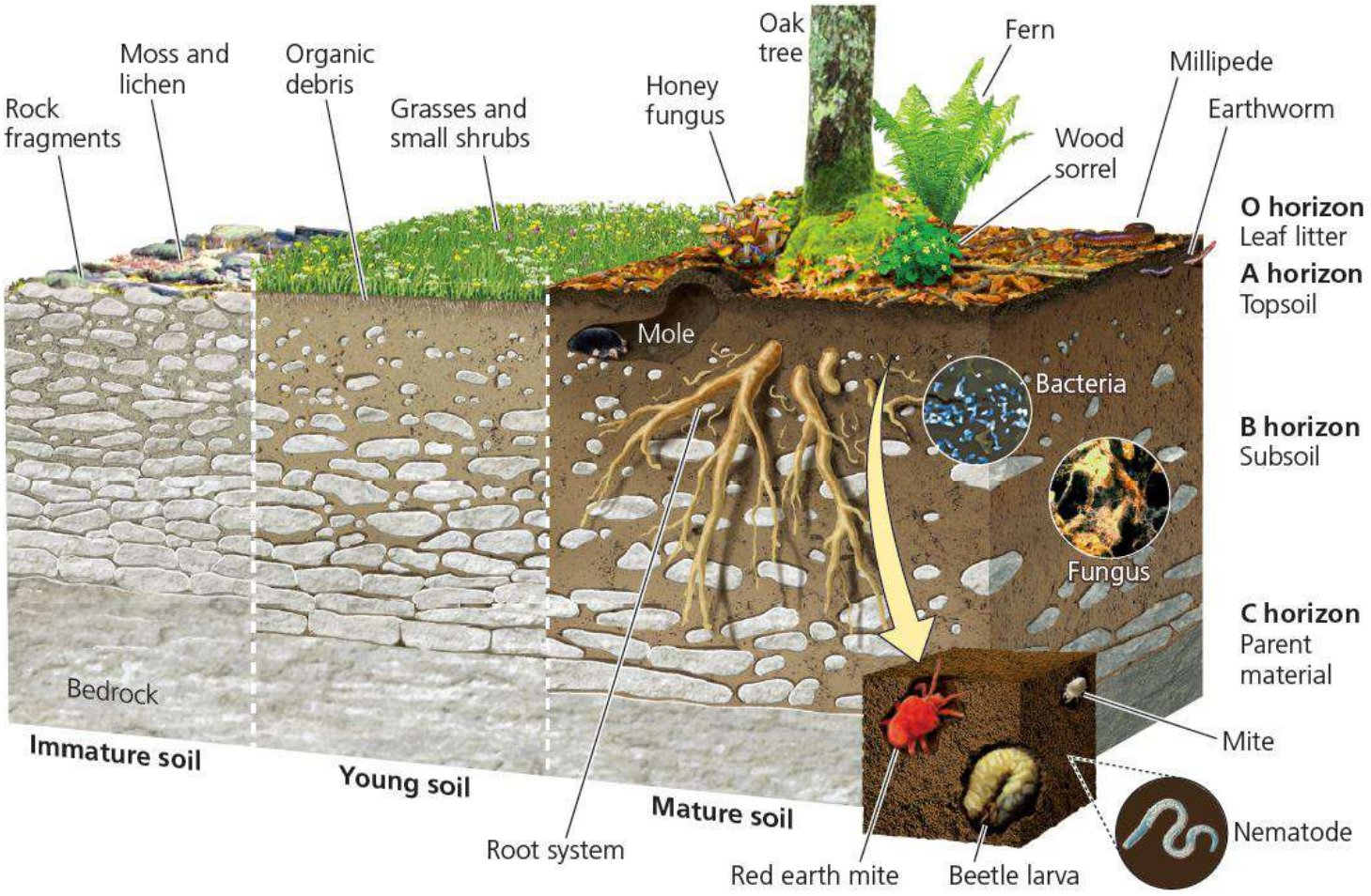
11.2 What Processes Lead to Soil Formations?

- Physical, chemical, and biological processes all contribute to the formation of soil.
- Soil is a renewable resource and a key factor in nutrient cycling

Soil Begins from Bedrock (1 of 2)

- The process of weathering breaks up parent material that is the foundation of soil.
- Lichens secrete acid that breaks down rock, the first step in primary succession
- Humus is formed from dead organic material, releasing nutrients and holding moisture
- Physical, chemical and biological processes form soil

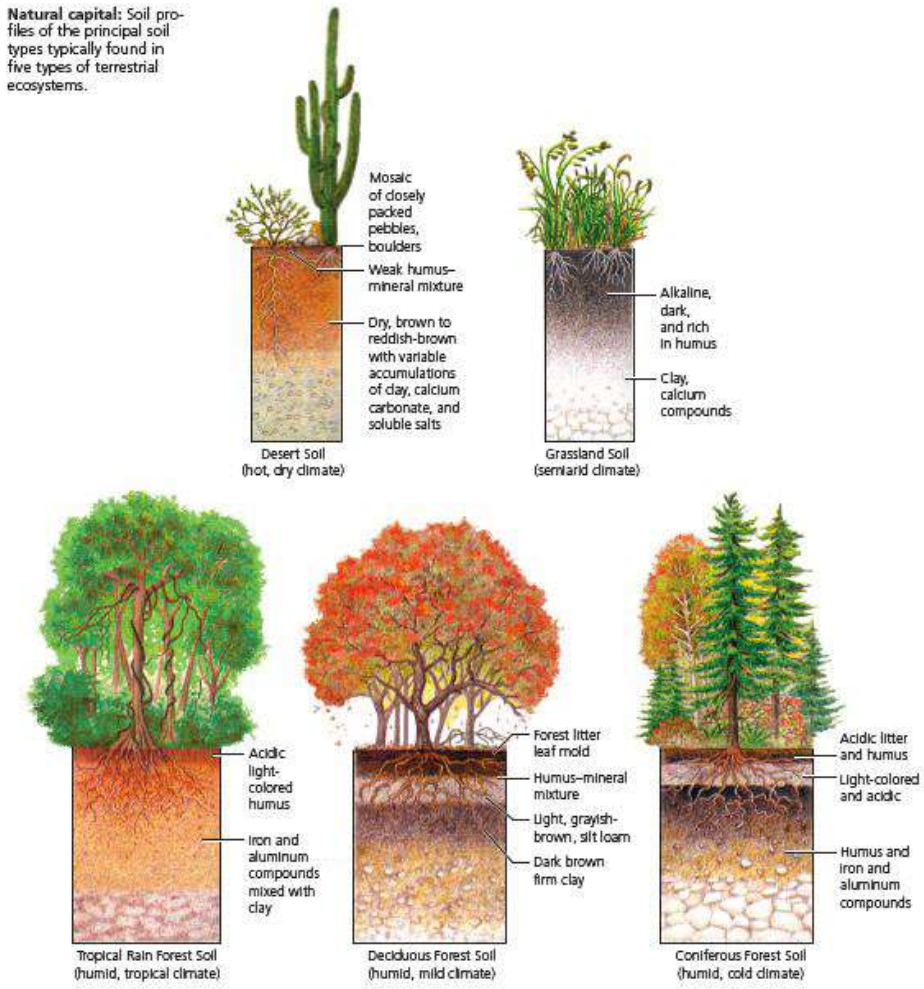
Soil Begins from Bedrock (2 of 2)



Soil is a Renewable Resource (1 of 3)

- Living , organisms rely on soil is essential for agriculture, provides the medium for growing timber, and provides ecological services such as purifying water and degrading wastes
- Mature soils contain horizons
  - O (leaf litter)
  - A (top soil)
  - B (subsoil)
  - C (weathered parent material)

Soil is a Renewable Resource (2 of 3)



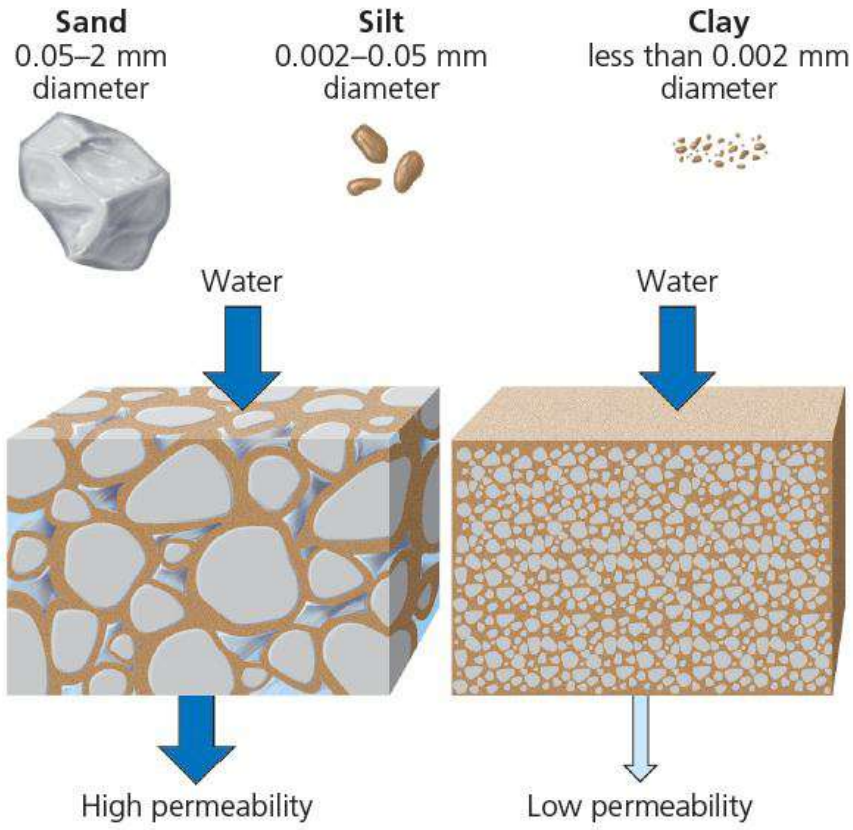
Soil is a Renewable Resource (3 of 3)

- Several factors influence the formation of soil
  - Warm and wet environments form soil faster
  - Tropical rain forest soils have little organic material in soil and are nutrient poor.

The Importance of Soil Nutrients (1 of 2)

- Most nutrients in a and O horizons
- Fertile soil produces high crop yields with this topsoil and bacteria that convert nitrogen into ions that plants can assimilate
- B and C horizons contain most of the soil's inorganic material
- Soil texture determines porosity and permeability

The Importance of Soil Nutrients (2 of 2)



The size, shape, and degree of clumping of soil particles determine the number and volume of spaces for air and water within a soil. Water can flow more easily through soils with more spaces (left) than through soils with fewer spaces (right).

11.3 How Long Might Supplies of Nonrenewable Mineral Resources Last?

- Nonrenewable mineral resources exist in finite amounts
  - Can become economically depleted when it costs more than it is worth to find, extract, and process the remaining deposits
- There are several ways to extend supplies of mineral resources
  - Methods limited by economic and environmental factors

We Depend on a Variety of Nonrenewable Mineral Resources (1 of 2)

- Ore
  - Contains profitable concentration of a mineral
  - May be high-grade or low-grade
- Metallic mineral resources
  - Aluminum
  - Steel: a mixture of iron and other elements
  - Copper
  - Gold
  - Molybdenum

We Depend on a Variety of Nonrenewable Mineral Resources (2 of 2)

- Nonmetallic mineral resources
  - Sand
  - Gravel
  - Limestone
  - Phosphate

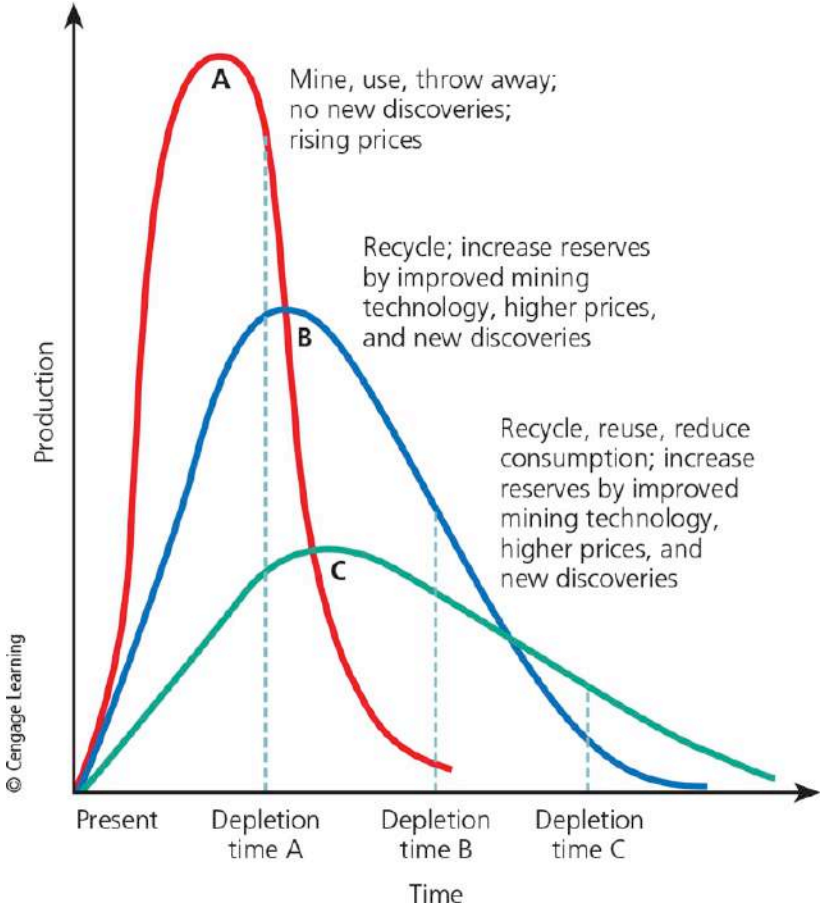
Supplies of Nonrenewable Mineral Resources Can Be Economically Depleted (1 of 3)

- Reserves
  - Identified deposits from which we can extract the mineral profitably at current prices
- Economic depletion
  - Occurs when extraction costs more than remaining deposits are worth
- Depletion time
  - Time to use a certain portion (usually 80%) of reserves at a given rate of use

Supplies of Nonrenewable Mineral Resources Can Be Economically Depleted (2 of 3)

- Options when a resource becomes economically depleted
  - Recycle or reuse existing supplies
  - Waste less
  - Use less
  - Find a substitute
  - Do without

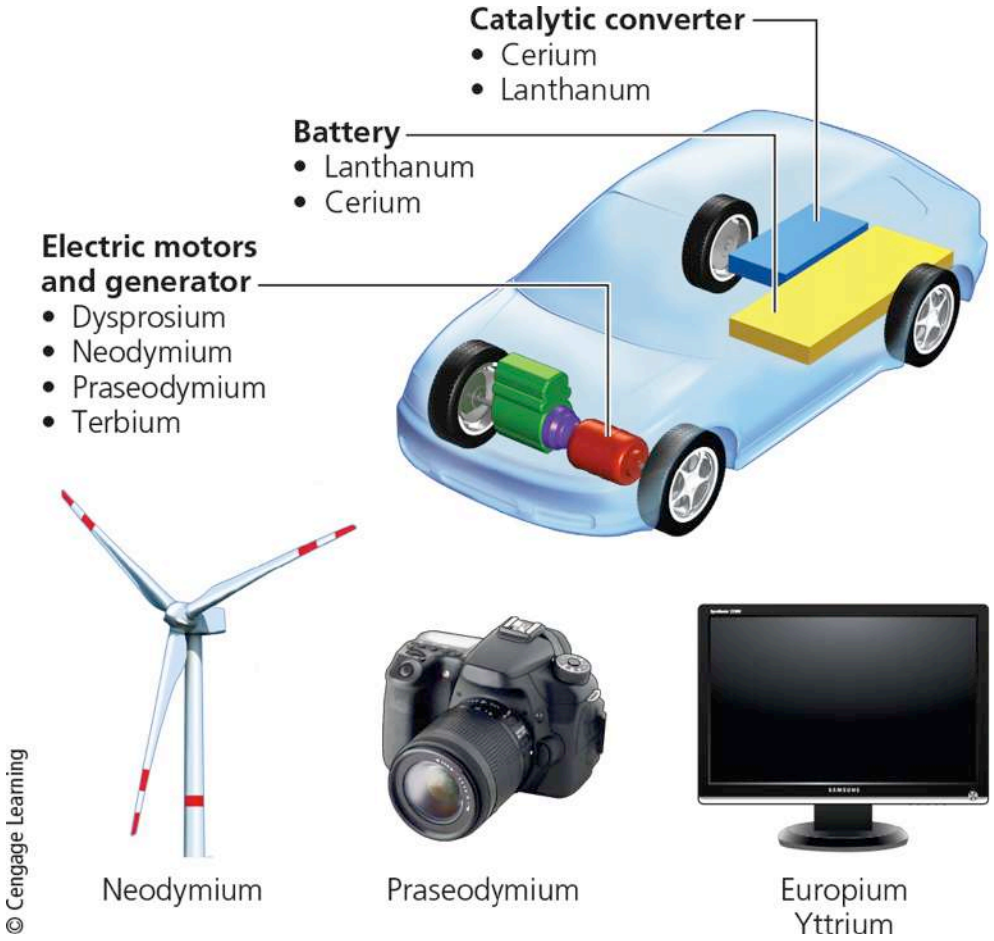
Supplies of Nonrenewable Mineral Resources Can Be Economically Depleted (3 of 3)



Case Study: The Crucial Importance of Rare Earth Metals (1 of 2)

- 17 rare earth metals
  - Important for several widely used technologies
- Products made with rare earth metals
  - LCD flat screens
  - Compact fluorescent and LED light bulbs
  - Solar cells
  - Fiber-optic cables
  - Batteries and motors for electric cars

Case Study: The Crucial Importance of Rare Earth Metals (2 of 2)



Market Prices Affect Supplies of Mineral Resources (1 of 2)

- Higher prices can:
  - Encourage exploration for new deposits
  - Stimulate development of better mining technologies
  - Make it profitable to mine lower-grade ores
  - Promote conservation
  - Promote theft

Market Prices Affect Supplies of Mineral Resources (2 of 2)

- Subsidies, tax breaks, and import tariffs control the supply, demand, and prices of key mineral resources
- U.S. mining companies receive various subsidies

Can We Expand Reserves by Mining Lower-Grade Ores?

- Factors that limit the mining of lower-grade ores
  - Increased cost and energy to mine and process larger volumes of ore
  - Availability of freshwater
  - Environmental impact of land disruption
- Improve mining technology
  - Using microorganisms–biomining
  - Slow process

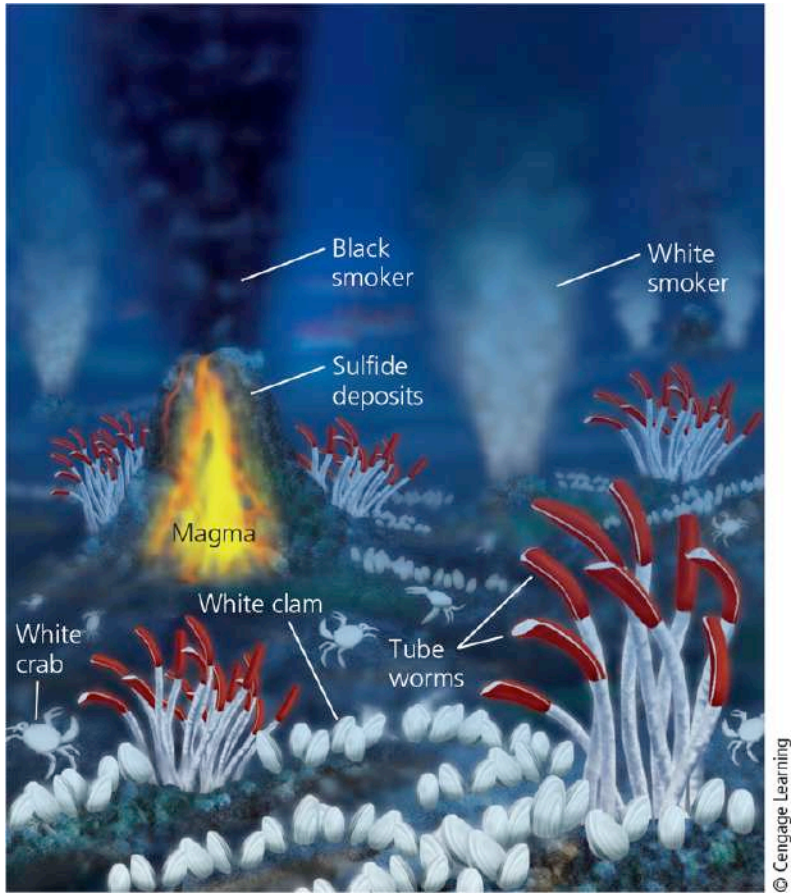
Can We Get More Minerals from the Oceans? (1 of 3)

- Mineral resources dissolved in the ocean
  - Low concentrations
- Deposits of minerals in sediments along the shallow continental shelf and near shorelines

Can We Get More Minerals from the Oceans? (2 of 3)

- Hydrothermal ore deposits
  - Hot water vents in the ocean floor
- Metals from the ocean floor
  - Manganese nodules
- What is the effect of mining on aquatic life?

Case Study: The Crucial Importance of Rare Earth Metals (3 of 3)



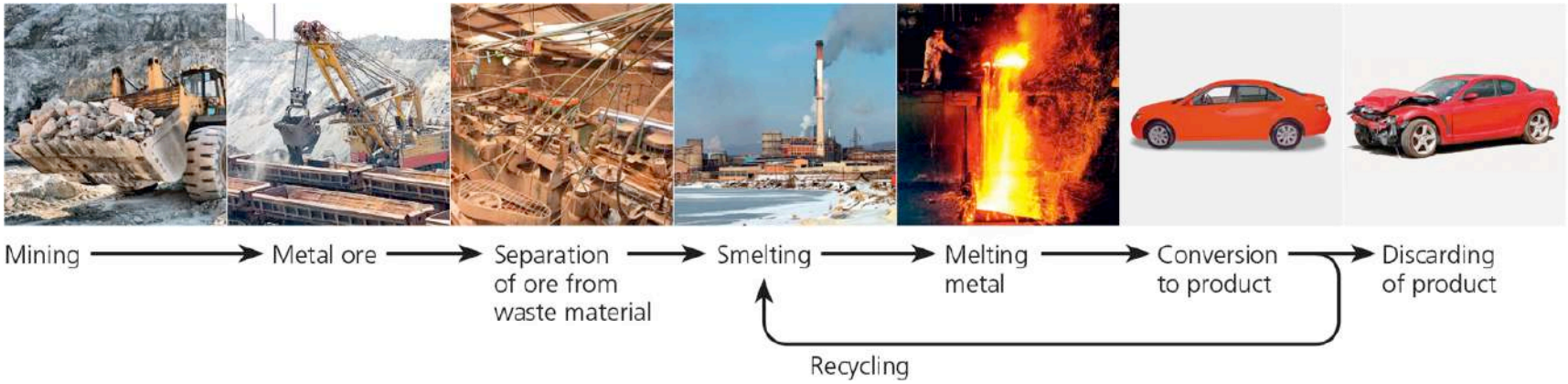
11.4 What Are The Environmental Effects of Using Nonrenewable Mineral Resources?

- Extracting minerals from the earth's crust and converting them into useful products:
  - Disturbs the land
  - Erodes soils
  - Produces large amounts of solid waste
  - Pollutes the air, water, and soil

Extracting Minerals Can Have Harmful Environmental Effects (1 of 8)

- Metal product life cycle
  - Mining, processing, manufacture, and disposal
- Environmental impacts
  - Determined by an ore's grade
    - Percentage of metal content

Extracting Minerals Can Have Harmful Environmental Effects (2 of 8)



Extracting Minerals Can Have Harmful Environmental Effects (3 of 8)

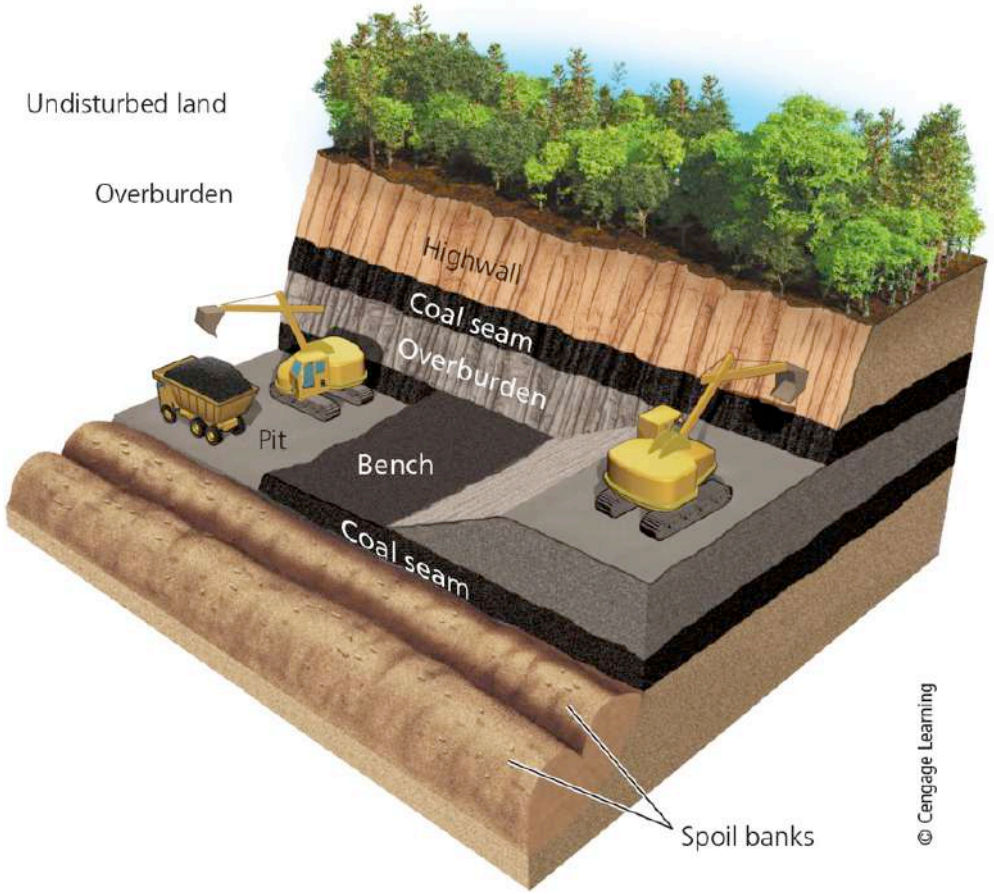
- Surface mining
  - Removes shallow deposits
  - Overburden deposited into spoils
    - Waste material
- Open-pit mining
- Strip mining
  - Area strip mining
  - Contour strip mining

Extracting Minerals Can Have Harmful Environmental Effects (4 of 8)

LianeM/Shutterstock.com

Extracting Minerals Can Have Harmful Environmental Effects (5 of 8)

Extracting Minerals Can Have Harmful Environmental Effects (6 of 8)



Extracting Minerals Can Have Harmful Environmental Effects (7 of 8)

- Mountaintop removal
- Subsurface mining
  - Deep deposits
- Potential problems
  - Subsidence
  - Health hazards for miners
  - Acid mine drainage

Extracting Minerals Can Have Harmful Environmental Effects (8 of 8)

Critical Concept: Life Cycle of a Product

- The life cycle of a product traces the impacts of each step of a product's existence from harvesting or mining the materials to produce it, its use, and how it is discarded, as well as the energy invested at each step.

Critical Concept: External, or Hidden Costs (1 of 2)

- External costs are those costs to the environment or human health not included in the price of the product.

Critical Concept: External, or Hidden Costs (1 of 2)

Internal and External Costs

Internal costs

Reflected in the purchase price of the vehicle

Raw materials

Manufacturing labor

Manufacturing energy consumption

Shipping

Advertising

Other business costs

Profit for the car company

Dealership costs

Profit for the dealership

pixelprof/E+/Getty Images

External costs

Paid for through taxes, increased health costs, loss of ecosystem services

Loss of habitat at metals mining sites

Cleanup of contaminated mine sites

Air pollution from mining, smelting, and manufacturing

Environmental damage from oil spills and cleanup during drilling and transport of crude oil

Increased air pollution, acid rain, and smog from car exhaust and damage to human health and infrastructure

Increased CO_2 emissions from burning fossil fuels

The impacts of climate change

Removing Metals from Ores Has Harmful Environmental Effects (1 of 2)

- Ore extracted by mining
  - Ore mineral
  - Tailings–waste material (gangue)
  - Smelting using heat or chemicals causes:
    - Air pollution
    - Water pollution
- Poverty-stricken miners in less-developed countries have cleared tropical forests
  - Use mercury to separate gold from its ore

Removing Metals from Ores Has Harmful Environmental Effects (2 of 2)

Randy Olson/National Geographic Creative

14.4 How Can We Use Mineral Resources More Sustainability?

- Methods for more sustainable mineral use
  - Try to find substitutes for scarce resources
  - Reduce resource waste
  - Recycle and reuse minerals

Find Substitutes for Scarce Mineral Resources

- Materials revolution
  - Silicon replacing some metals for common uses
- New technologies
  - Nanotechnology and high-strength plastics
  - Graphene and phosphorene
- Substitution doesn't always work
  - Platinum–industrial catalyst

Case Study: Graphene and Phosphorene - New Revolutionary Materials

- Graphene is made from graphite
  - Light, flexible, stretchable, very strong
  - Excellent conductor of electricity
  - Can make stronger and lighter plastics
- Phosphorene is a single layer of black phosphorus molecules
  - More efficient semiconductor than silicon

Use Mineral Resources More Sustainably (1 of 2)

- Recycling and reuse
  - Lower environmental impact than mining and processing metals from ores
  - Extract valuable metals from electronic waste
- Find substitutes without heavy environmental impacts
- Lithium
  - Supplies unevenly distributed worldwide

Use Mineral Resources More Sustainably (2 of 2)

Solutions

Sustainable Use of Nonrenewable Minerals

- Reuse or recycle metal products whenever possible
- Redesign manufacturing processes to use less mineral resources
- Reduce mining subsidies
- Increase subsidies for reuse, recycling, and finding substitutes

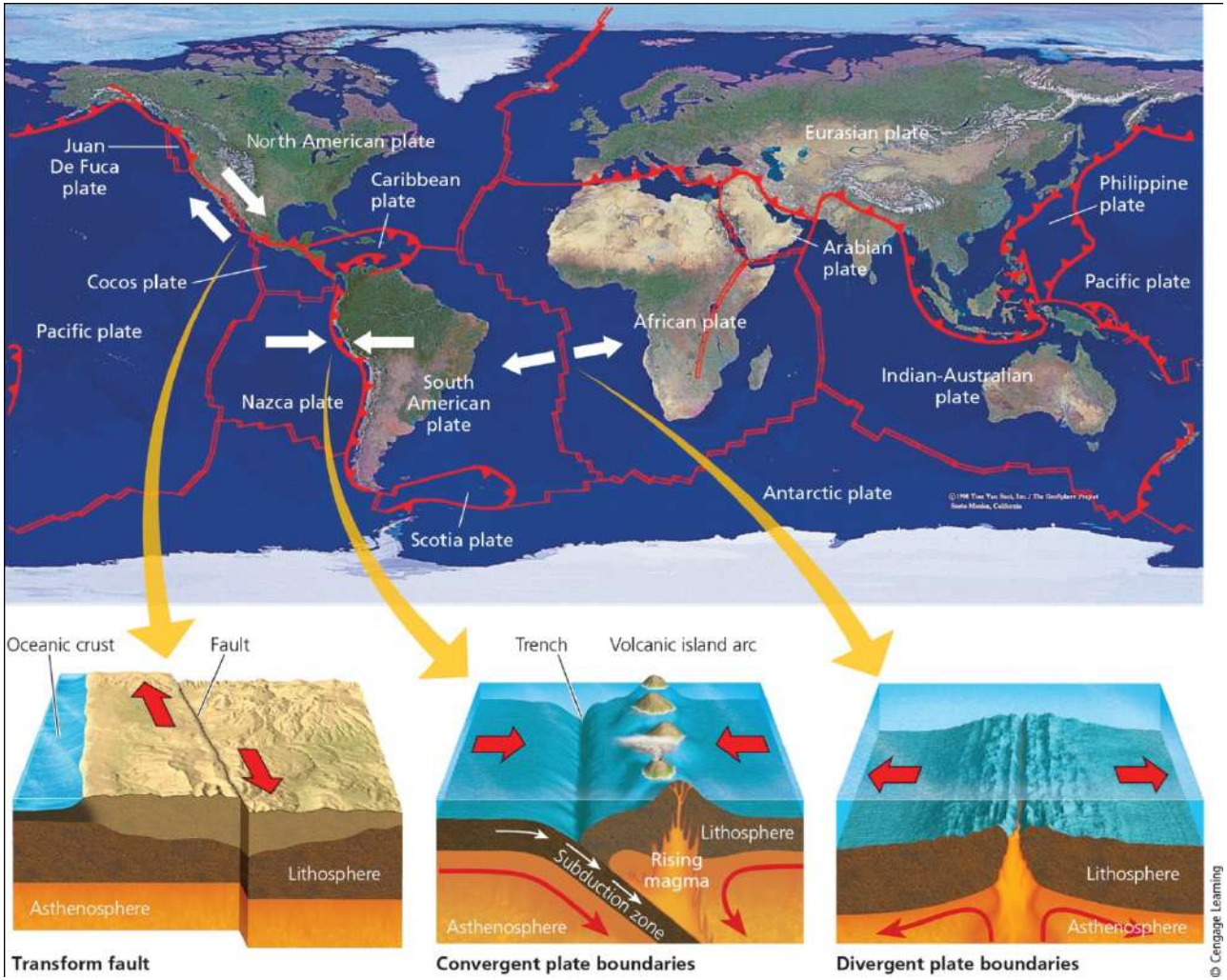
11.6 What Are the Earth's Major Geological Hazards?

- Dynamic processes move matter within the earth and on its surface
  - Cause volcanic eruptions, earthquakes, tsunamis, erosion, and landslides

The Earth Beneath Your Feet Is Moving (1 of 2)

- The earth's crust is broken into tectonic plates
  - "Float" on the asthenosphere
  - Slow movement of continenets is called continental drift
- Much geological activity takes place at plate boundaries
  - Divergent boundary
  - Convergent boundary
  - Transform plate boundary

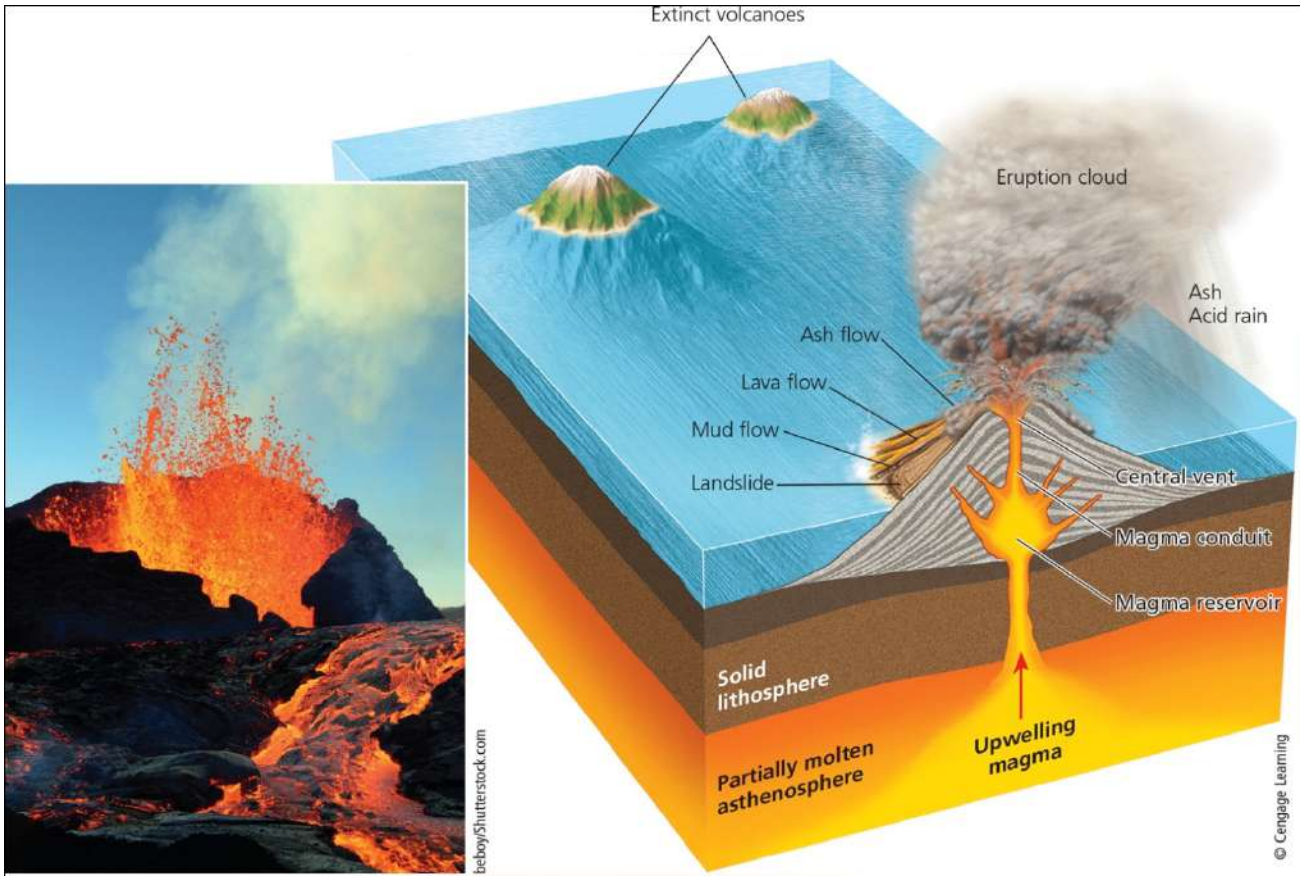
The Earth Beneath Your Feet Is Moving (2 of 2)



Volcanoes Release Molten Rock from the Earth's Interior (1 of 2)

- Volcano
  - Magma rising through the lithosphere reaches the earth's surface through a crack (fissure)
  - Eruption–release of lava, hot ash, and gases into the environment
- Volcanos form majestic mountain ranges and lakes
  - Formed Hawaiian islands
  - Can also cause destruction

Volcanoes Release Molten Rock from the Earth's Interior (2 of 2)



Earthquakes Are Geological Rock-and-Roll Events (1 of 4)

- Earthquake
  - Breakage and shifting of rocks
    - Occurs at a fault
  - Seismic waves
    - Vibrations in the crust
  - Focus–origin of earthquake
  - Magnitude–severity of earthquake
  - Amplitude–size of the seismic waves

Earthquakes Are Geological Rock-and-Roll Events (2 of 4)

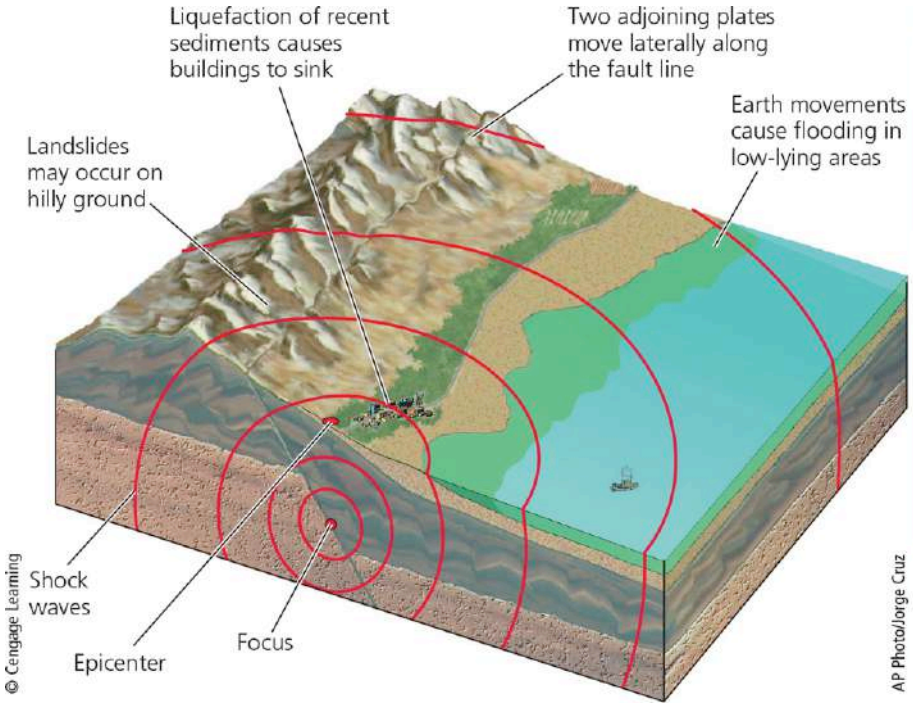
- Richter scale
  - Insignificant: <4.0
  - Minor: 4.0–4.9
  - Damaging: 5.0–5.9
  - Destructive: 6.0–6.9
  - Major: 7.0–7.9
  - Great: >8.0
- Largest recorded: 9.5 in Chile, 1960

Earthquakes Are Geological Rock-and-Roll Events (3 of 4)

© Cengage Learning

Kevin Schafer/Age Fotostock

Earthquakes Are Geological Rock-and-Roll Events (4 of 4)



Earthquakes on the Ocean Floor Can Cause Tsunamis (1 of 3)

- Tsunami
  - Series of huge waves generated when ocean floor suddenly rises or drops
  - Travels several hundred miles per hour
    - Slows down as it approaches coastline
- December 2004–Indian Ocean tsunami
  - Magnitude 9.15 earthquake
  - Over 230,000 people lost their lives
    - No warning system in place

Earthquakes on the Ocean Floor Can Cause Tsunamis (2 of 3)

- 2011–Japan tsunami
  - Killed almost 19,000 people
  - Damaged Fukushima nuclear reactors
- Detection of tsunamis
  - Buoys in open ocean
  - Pressure recorders on the ocean floor

Earthquakes on the Ocean Floor Can Cause Tsunamis (3 of 3)