Geology and Nonrenewable Minerals

Chapter 14

Core Case Study: Environmental Effects of Gold Mining

- Gold producers
  - South Africa
  - Australia
  - United States
  - Canada

- **Cyanide heap leaching**
  - Extremely toxic to birds and mammals
  - 2000: Collapse of a dam retaining a cyanide leach pond
    - Impact on organisms and the environment

Gold Mine with Cyanide Leach Piles and Ponds in South Dakota, U.S.

14-1 What Are the Earth's Major Geological Processes and Hazards?

- ***Concept 14-1A*** *Gigantic plates in the earth's crust move very slowly atop the planet's mantle, and wind and water move the matter from place to place across the earth's surface.*

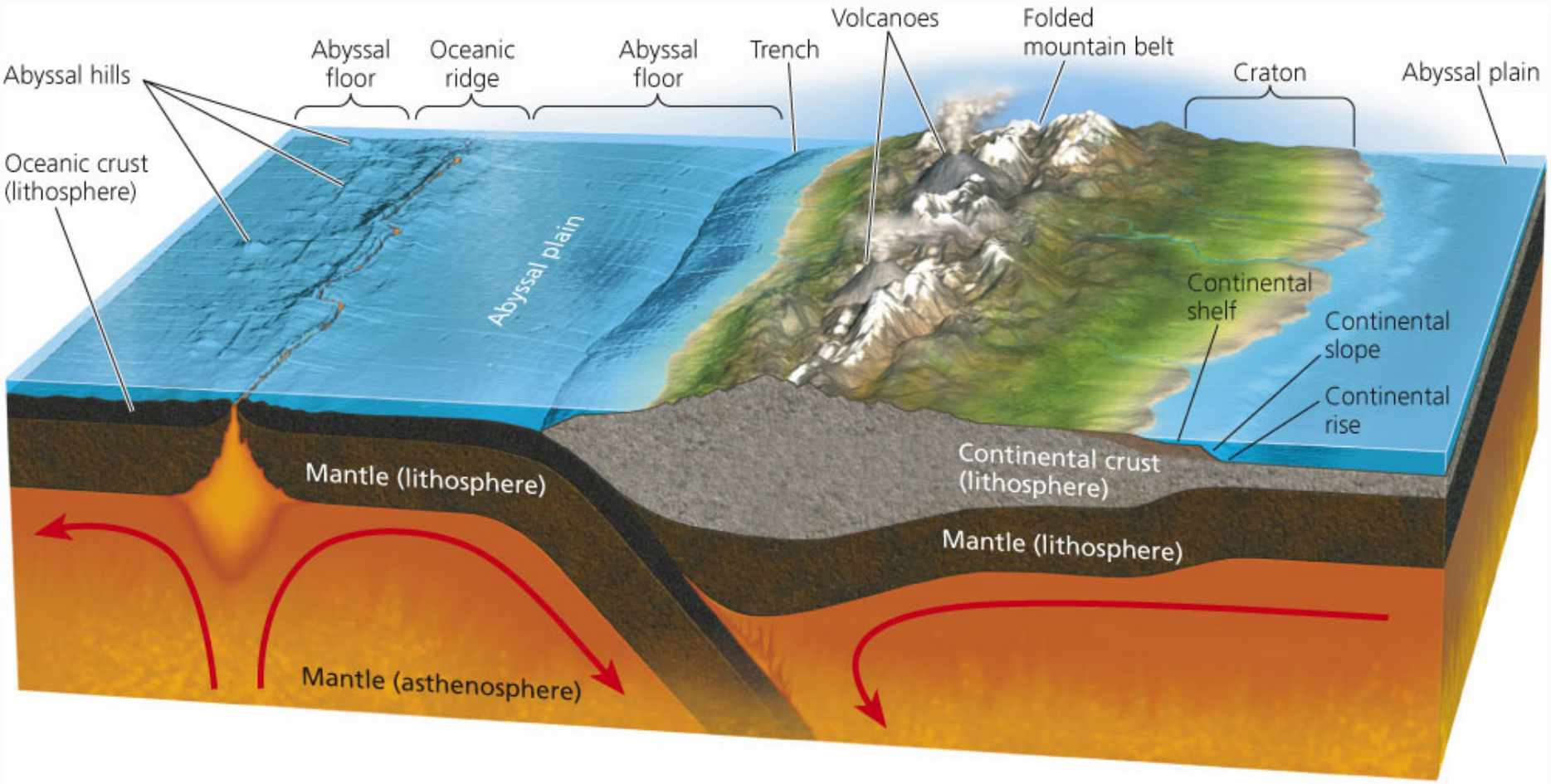
- ***Concept 14-1B*** *Natural geological hazards such as earthquakes, tsunamis, volcanoes, and landslides can cause considerable damage.*

The Earth Is a Dynamic Planet

- What is **geology?**

- Three major concentric zones of the earth
  - **Core**
  - **Mantle**
    - Including the asthenosphere
  - **Crust**
    - **Continental crust**
    - **Oceanic crust:** 71% of crust

Major Features of the Earth's Crust and Upper Mantle



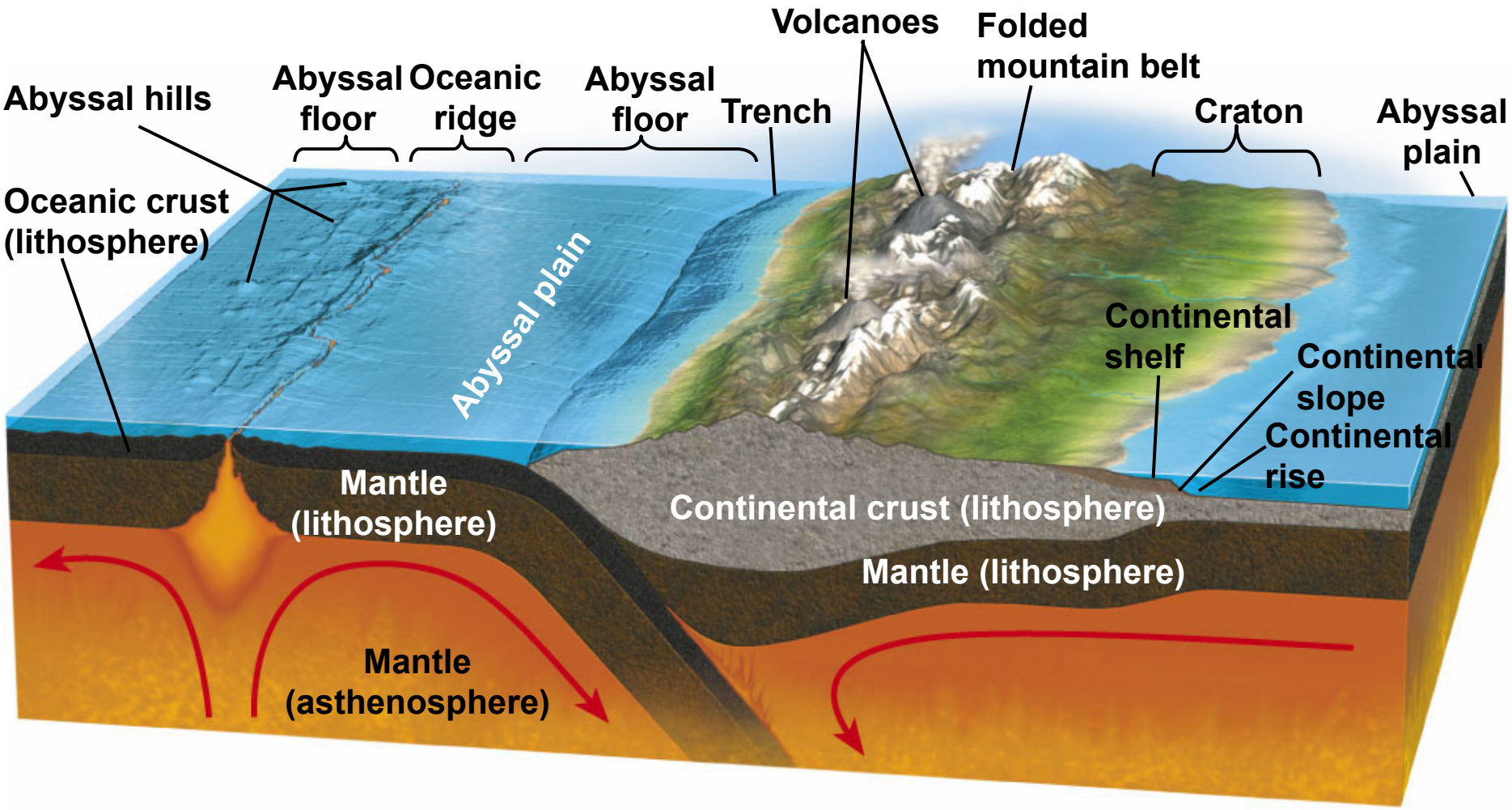


Fig. 14-2, p. 346

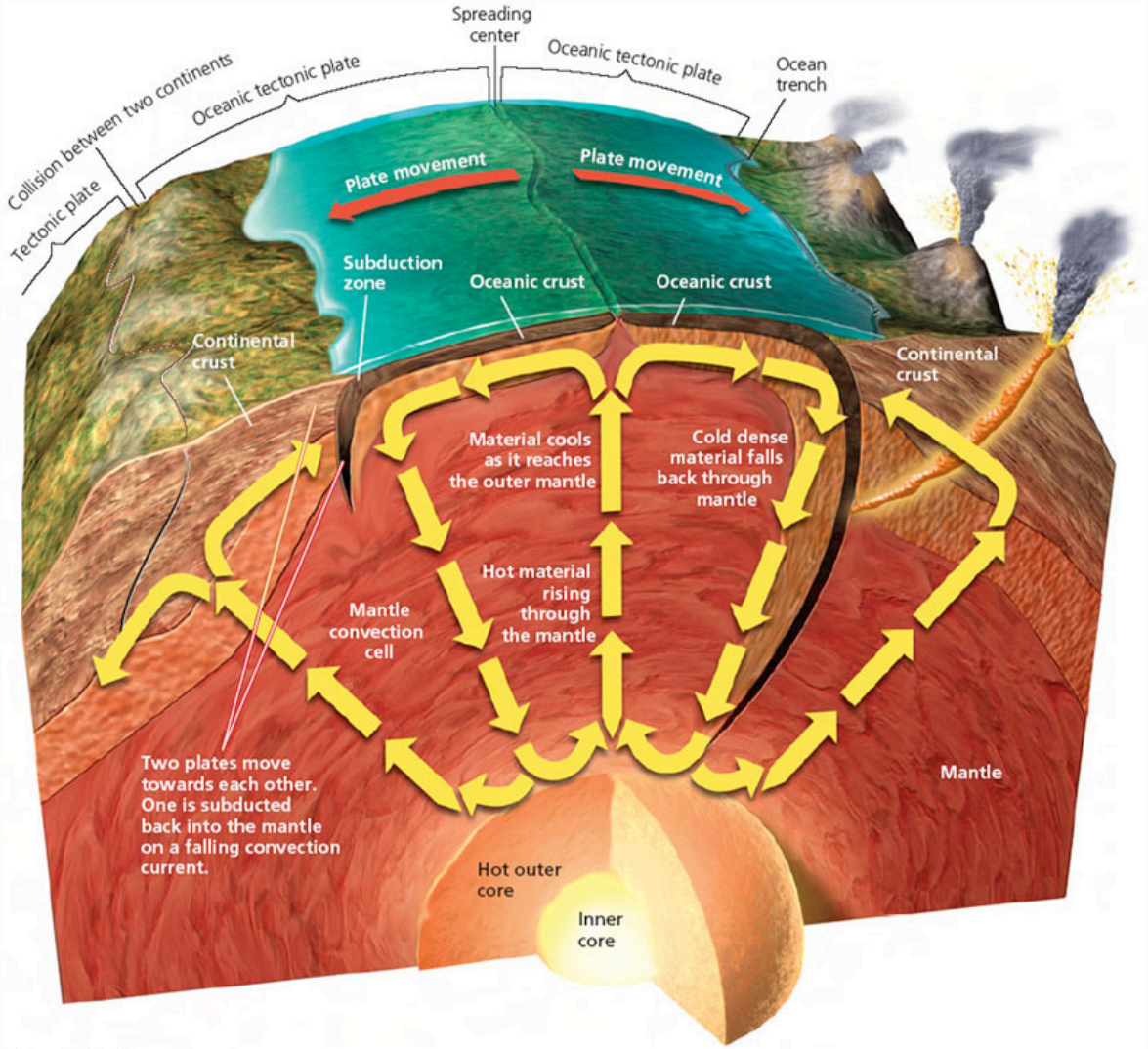
The Earth Beneath Your Feet Is Moving (1)

- **Convection cells**, or **currents**
- **Tectonic Plates**
- **Lithosphere**

The Earth Beneath Your Feet Is Moving (2)

- Three types of boundaries between plates
  - **Divergent plates**
    - **Magma**
    - **Oceanic ridge**
  - **Convergent plates**
    - **Subduction**
    - **Subduction zone**
    - **Trench**
  - **Transform fault; e.g., San Andreas fault**

The Earth's Crust Is Made Up of a Mosaic of Huge Rigid Plates: Tectonic Plates



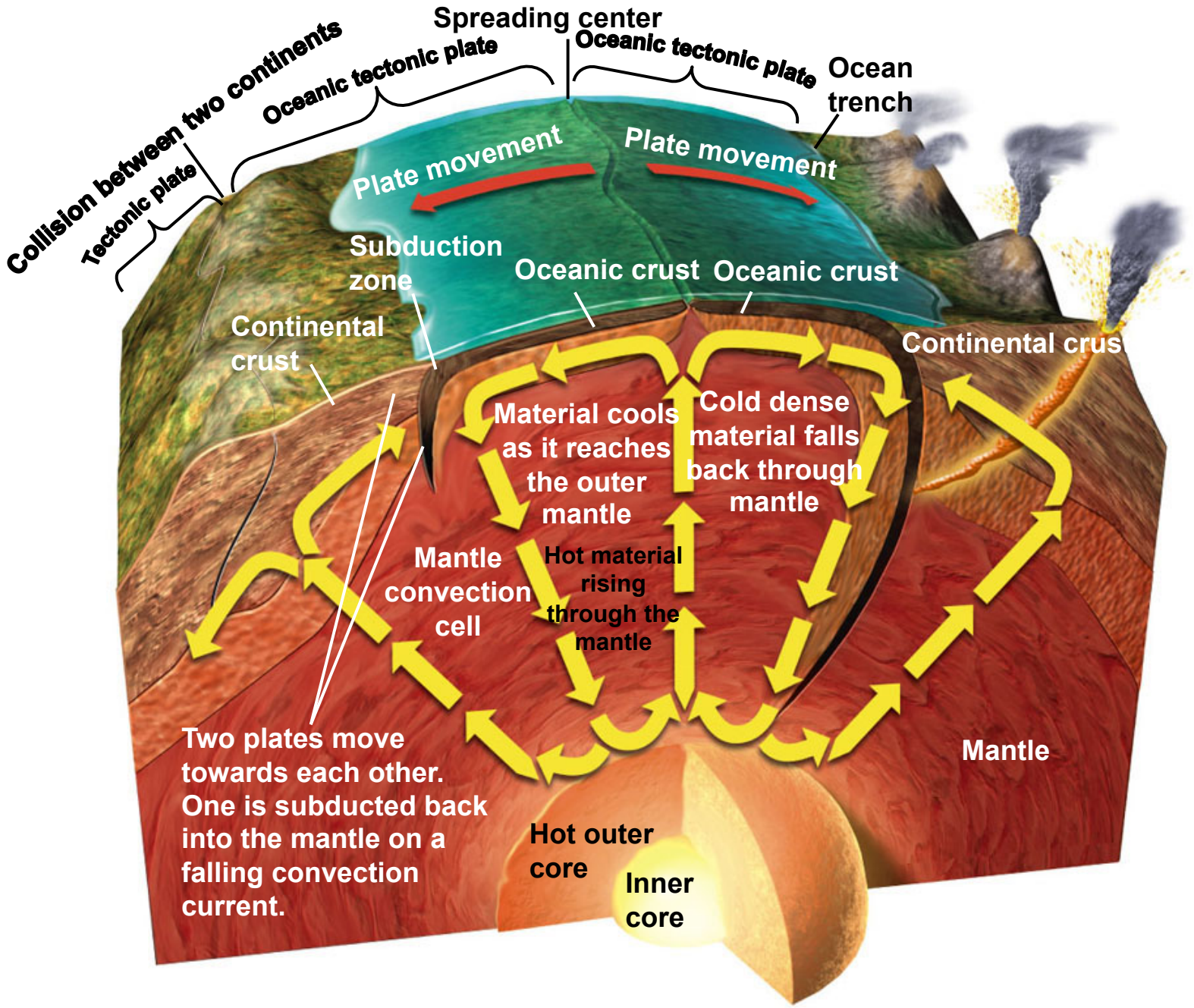
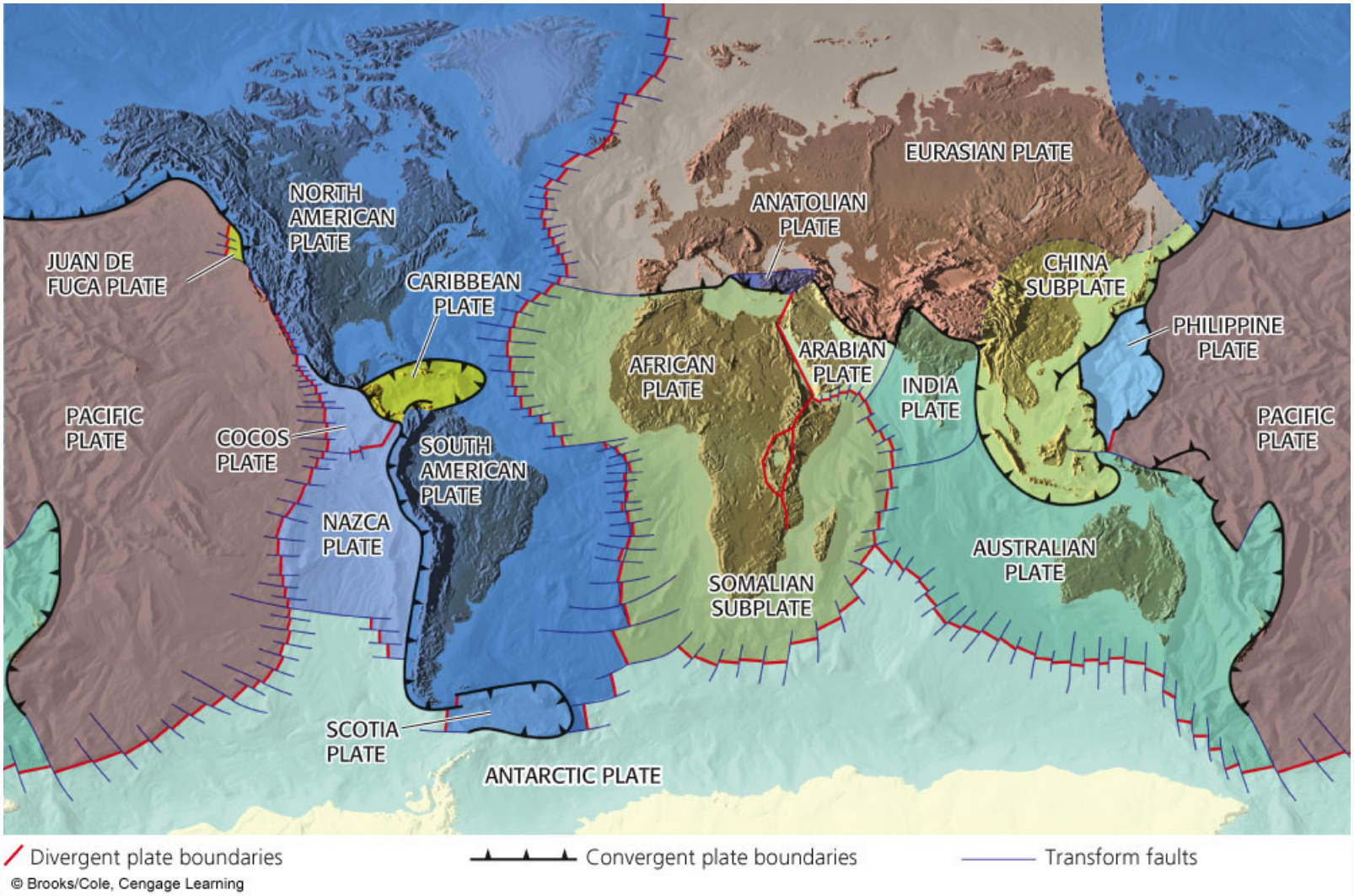
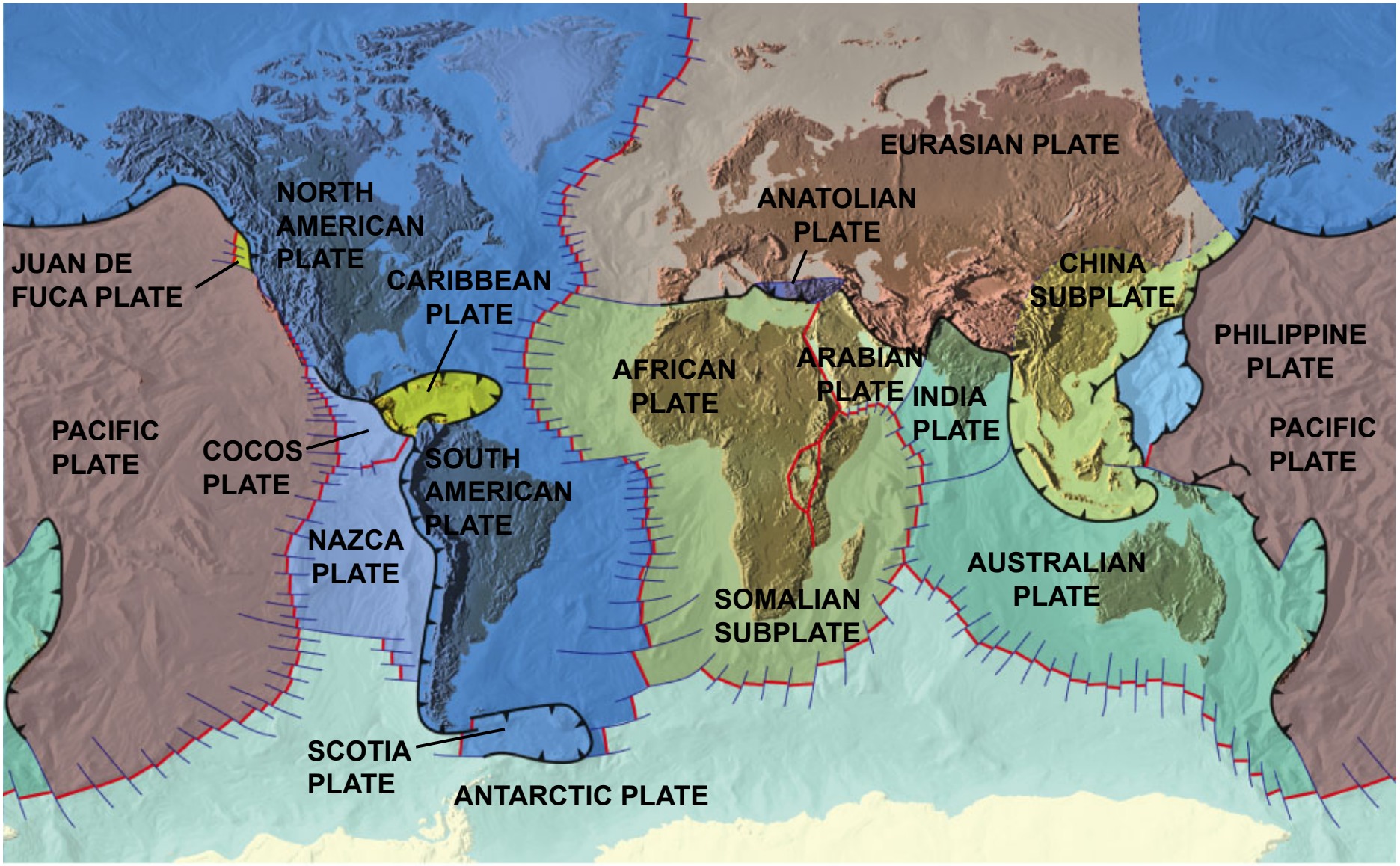


Fig. 14-3, p. 346

The Earth's Major Tectonic Plates



Divergent plate boundaries — Convergent plate boundaries — Transform faults



Divergent plate boundaries

Convergent plate boundaries

Transform faults

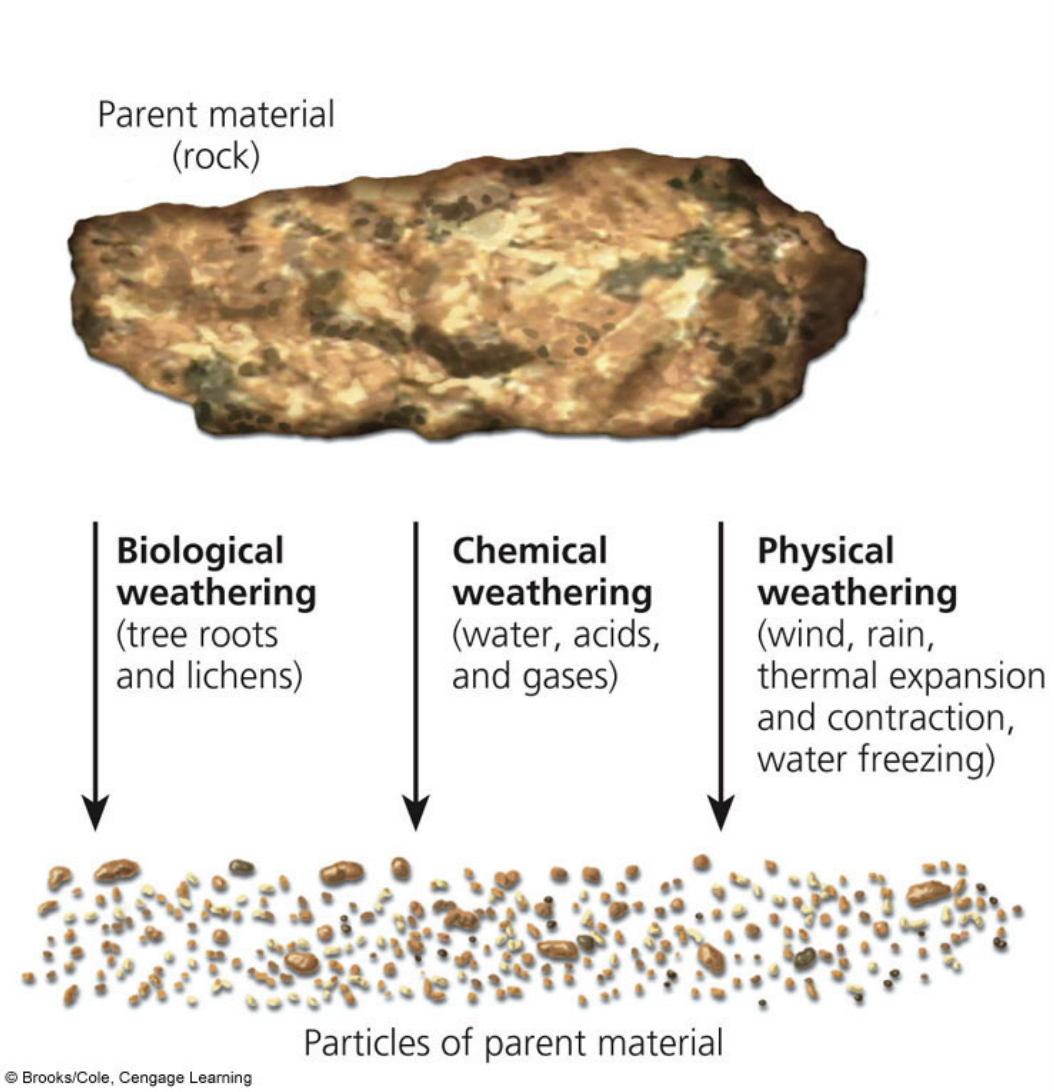
Fig. 14-4, p. 347

The San Andreas Fault as It Crosses Part of the Carrizo Plain in California, U.S.

Some Parts of the Earth's Surface Build Up and Some Wear Down

- **Internal geologic processes**
  - Generally build up the earth's surface
- **External geologic processes**
  - **Weathering**
    - Physical, Chemical, and Biological
  - **Erosion**
    - Wind
    - Flowing water
    - Human activities
    - **Glaciers**

Weathering: Biological, Chemical, and Physical Processes



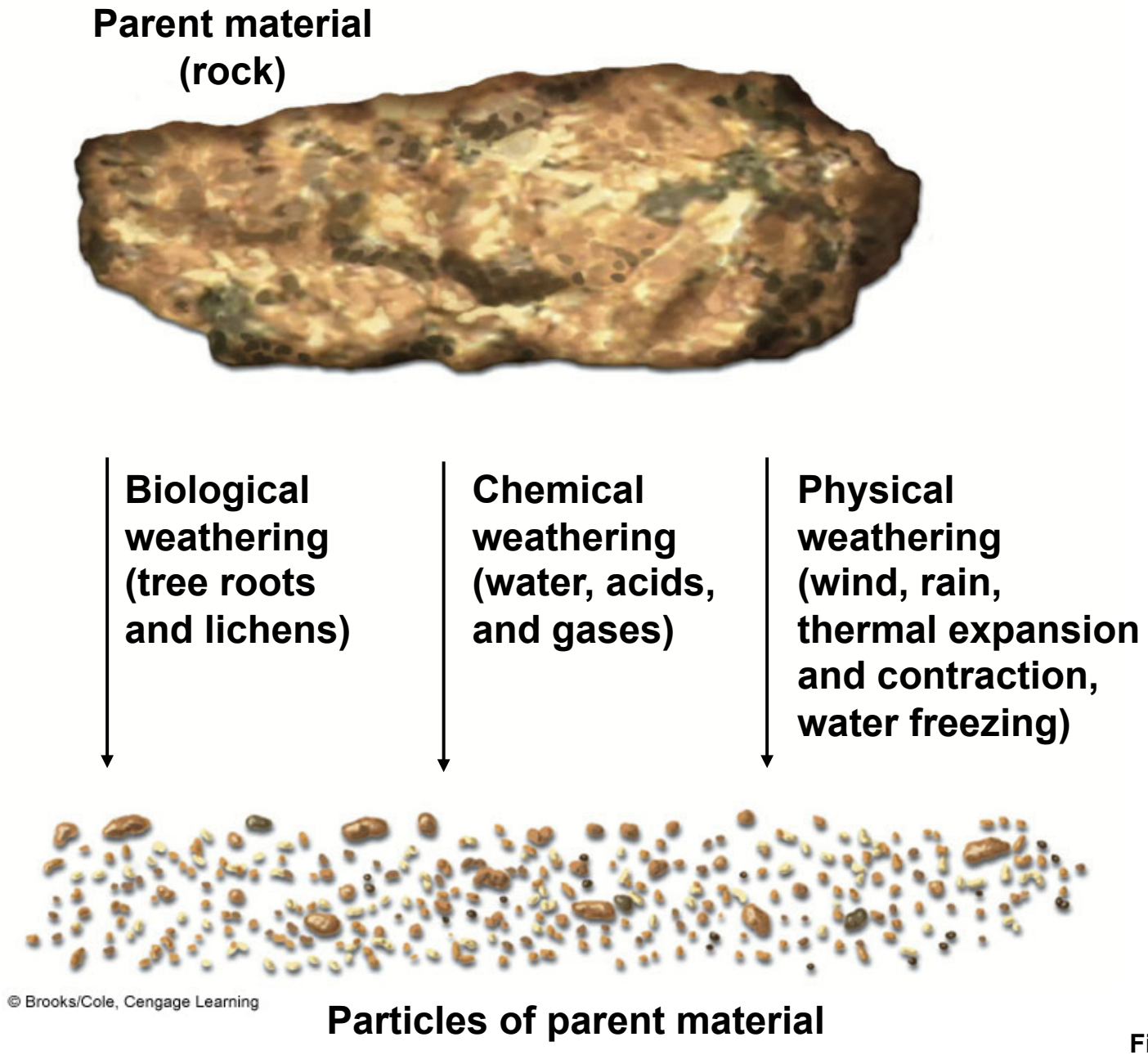
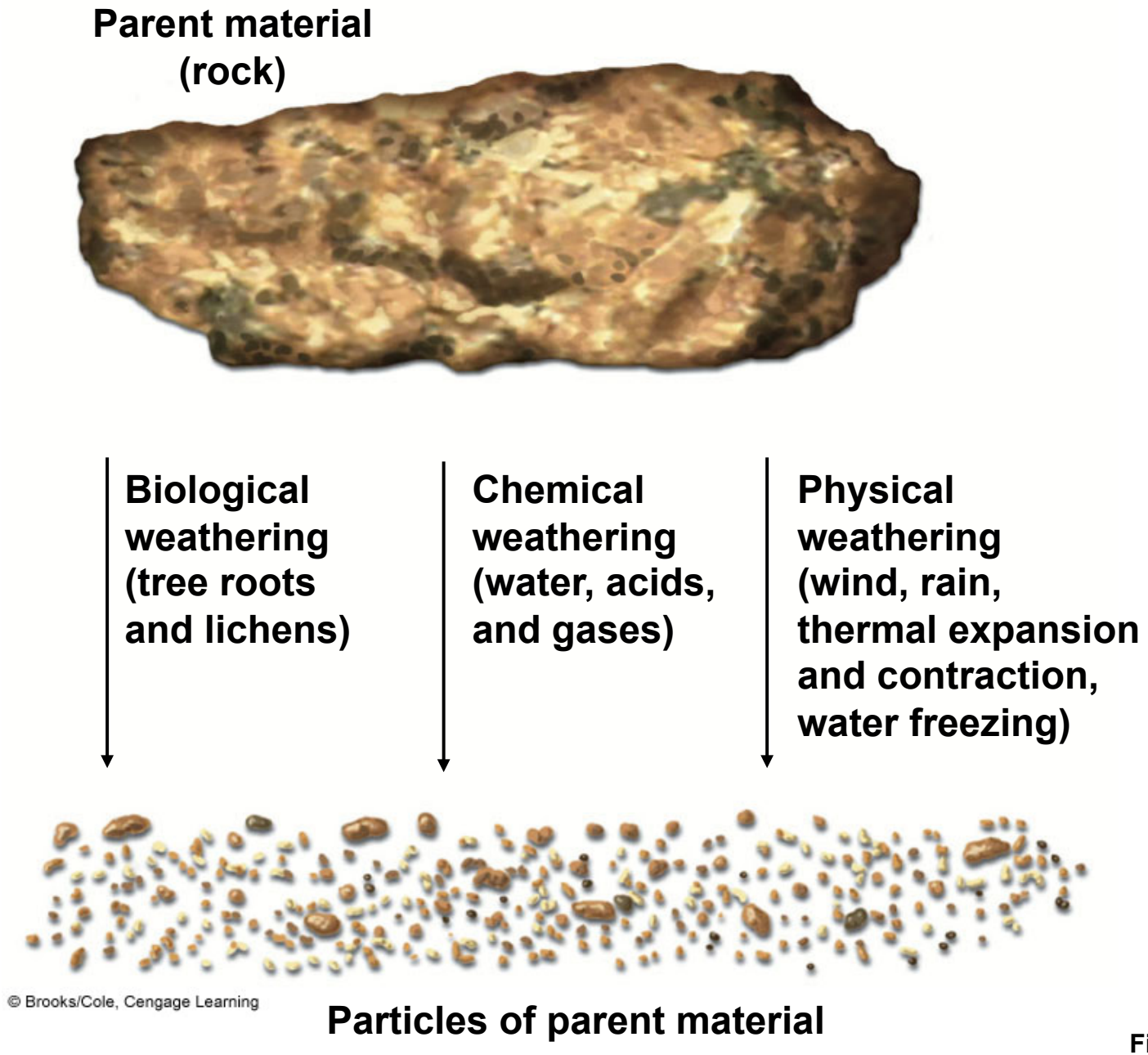


Fig. 14-6, p. 348



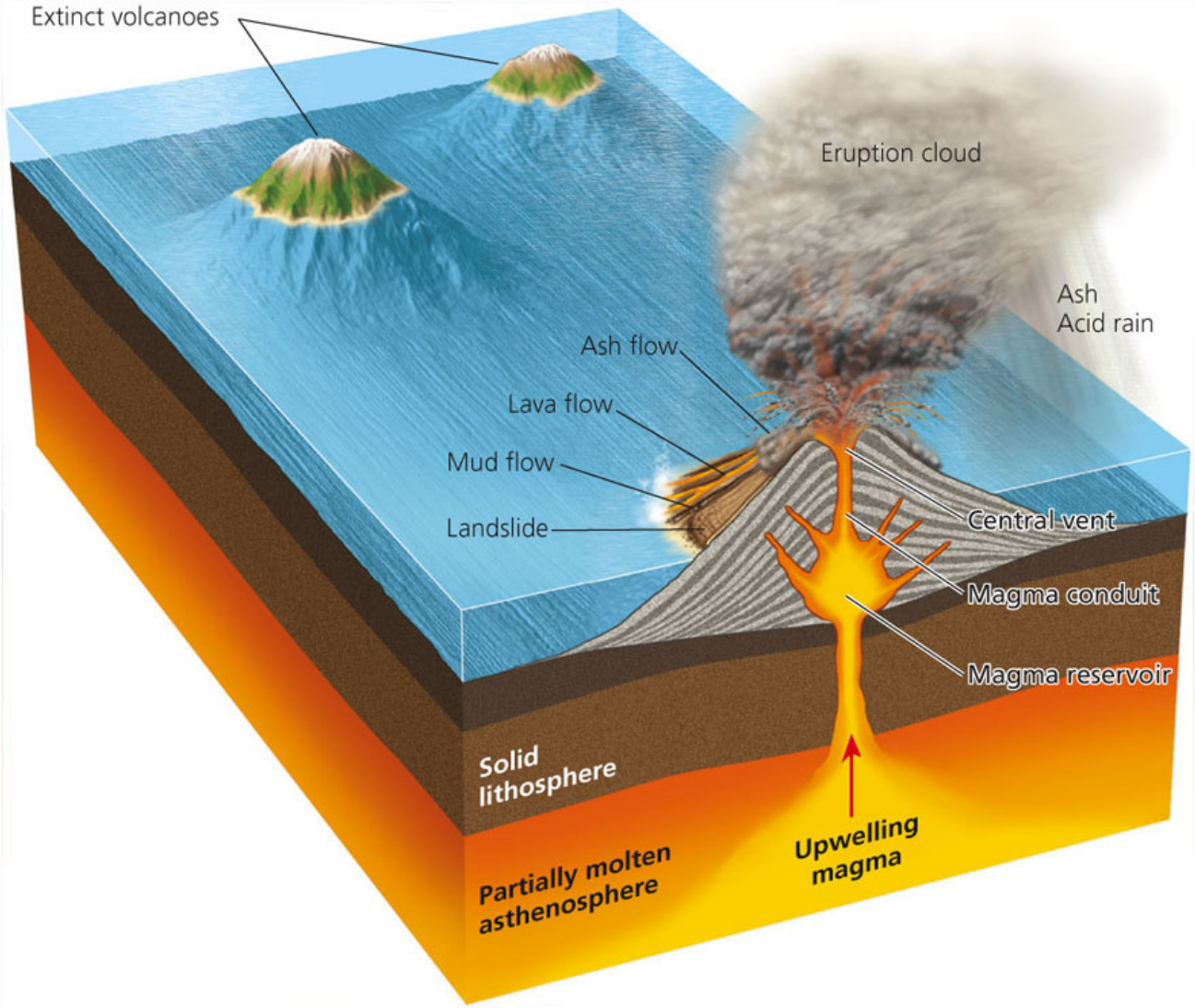
Stepped Art

Fig. 14-6, p. 348

Volcanoes Release Molten Rock from the Earth's Interior

- **Volcano**
  - **Fissure**
  - **Magma**
  - **Lava**
- 1980: Eruption of Mount St. Helens
- 1991: Eruption of Mount Pinatubo
- Benefits of volcanic activity

Creation of a Volcano



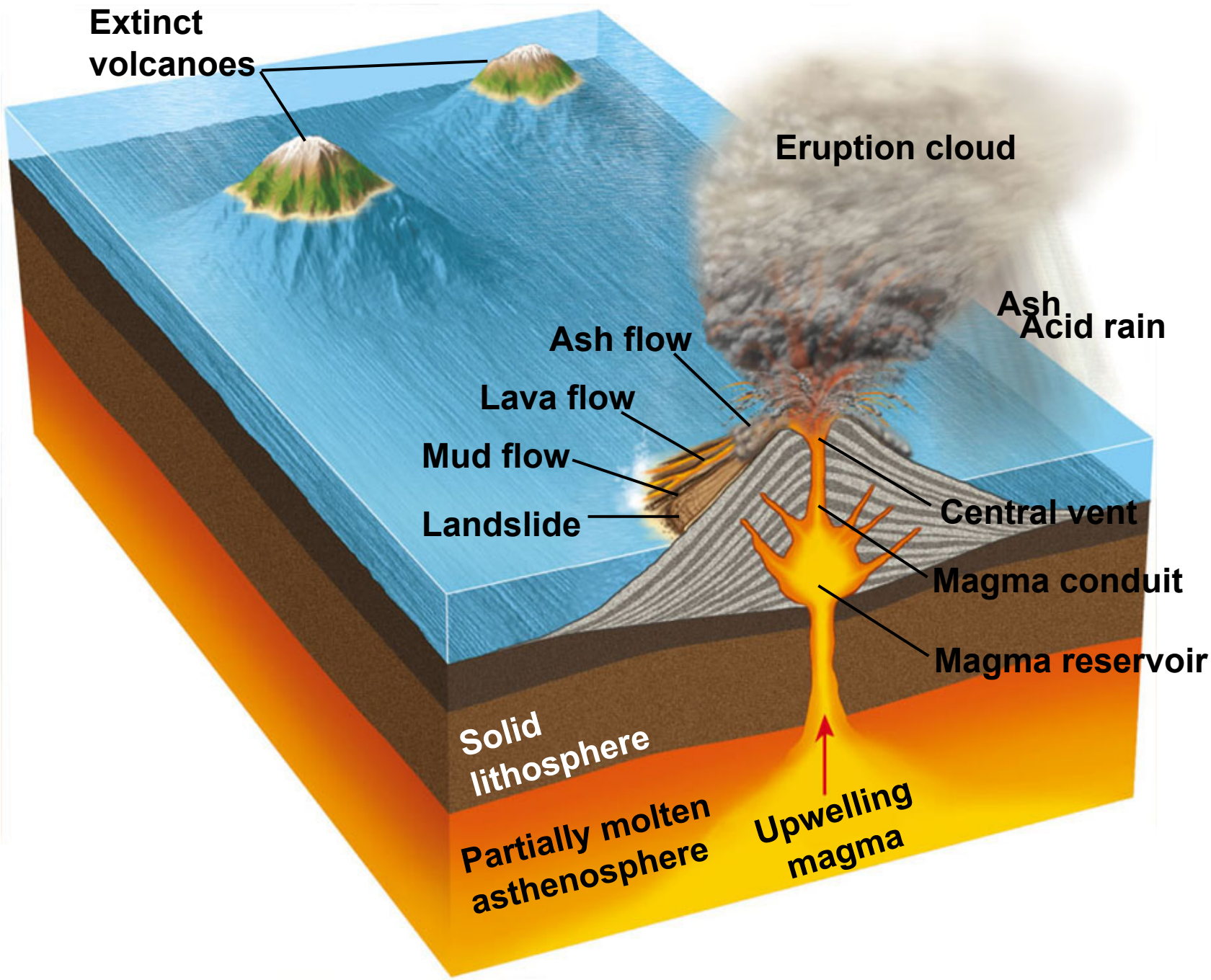


Fig. 14-7, p. 349

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

- Earthquake
  - Seismic waves
  - Focus
  - Epicenter
  - Magnitude
  - Amplitude

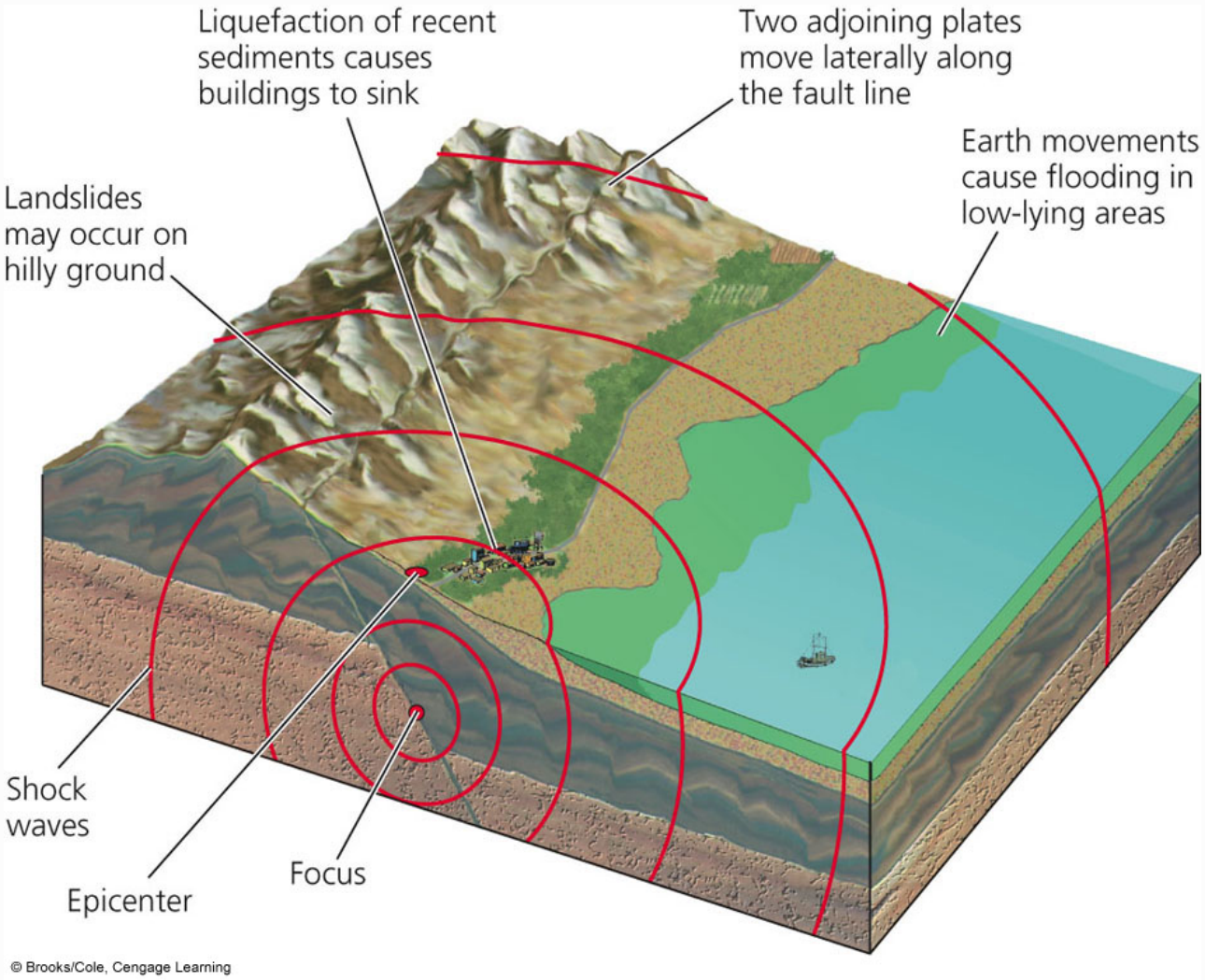
Earthquakes Are Geological Rock-and-Roll Events (2)

- **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

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

- **Foreshocks** and **aftershocks**
- Primary effects of earthquakes

Major Features and Effects of an Earthquake



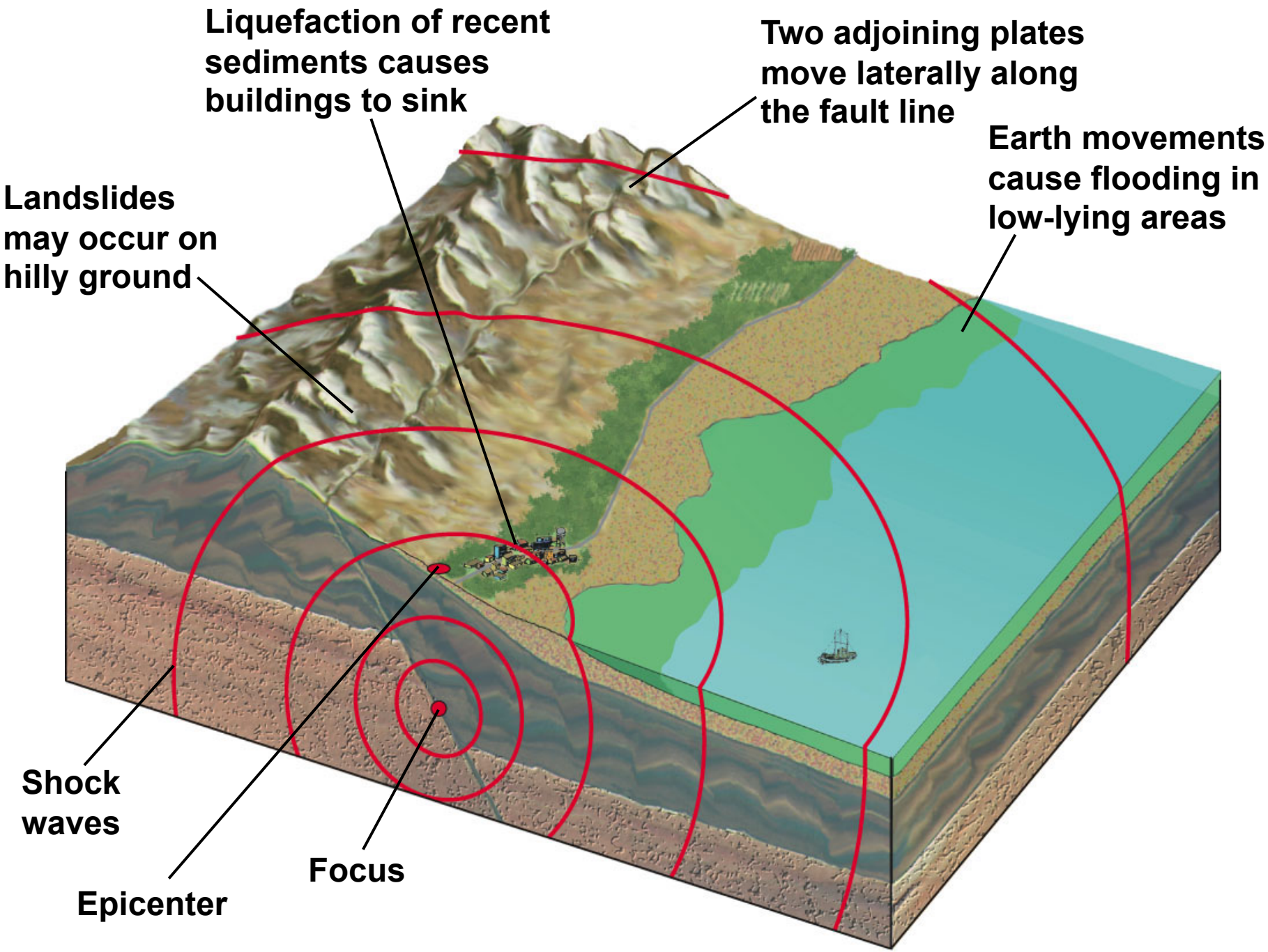
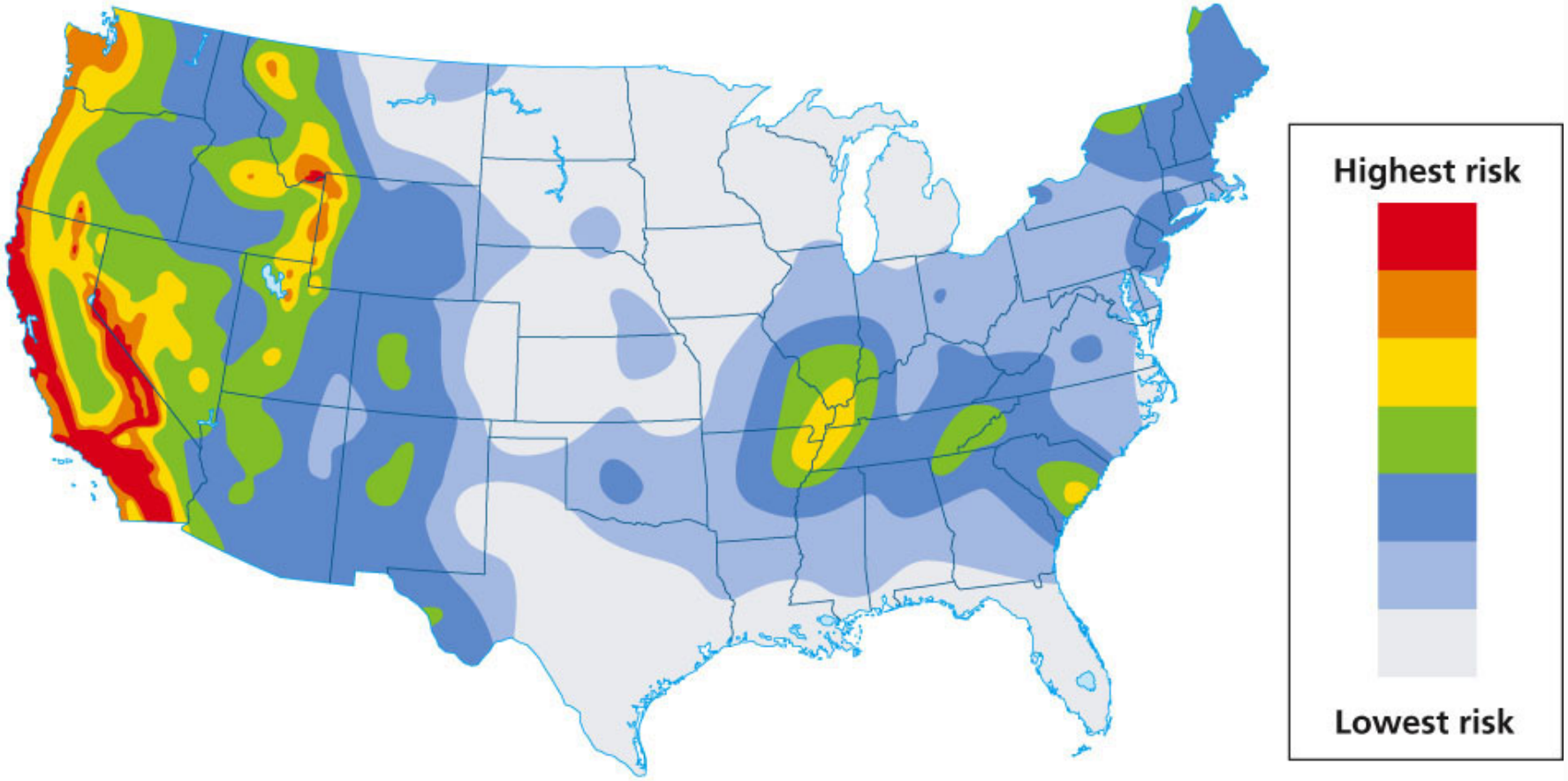


Fig. 14-8, p. 350

Areas of Greatest Earthquake Risk in the United States



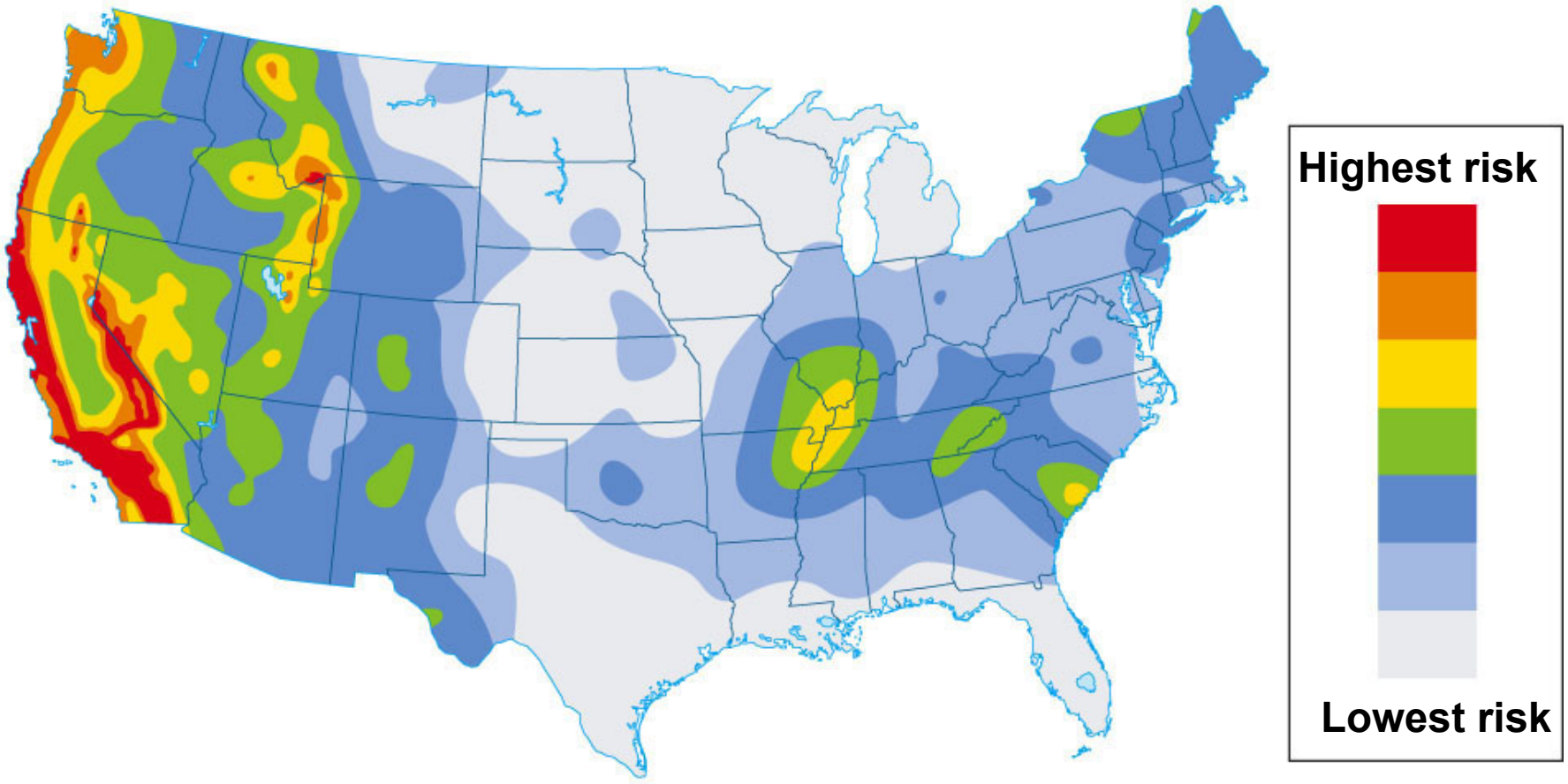
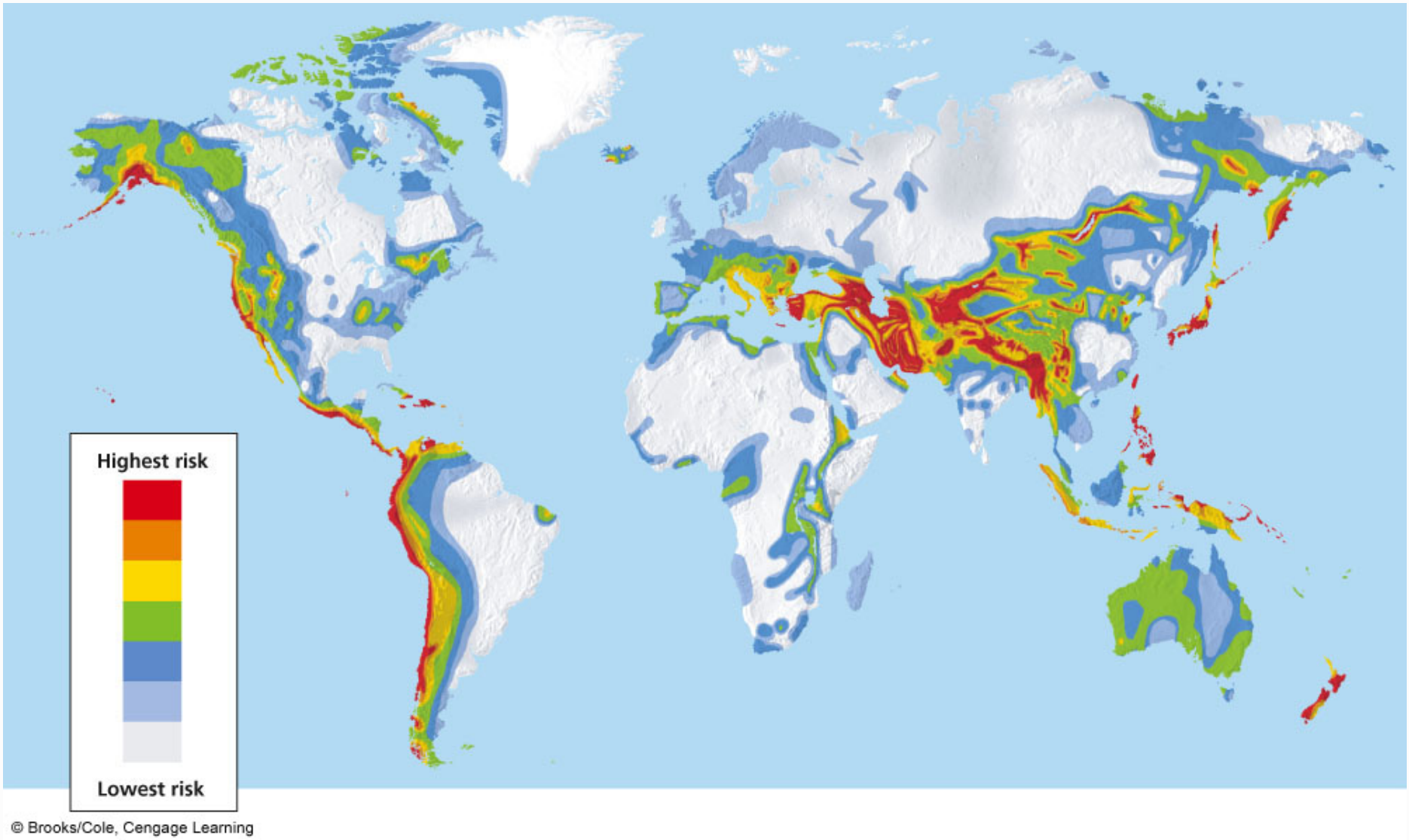


Fig. 14-9, p. 350

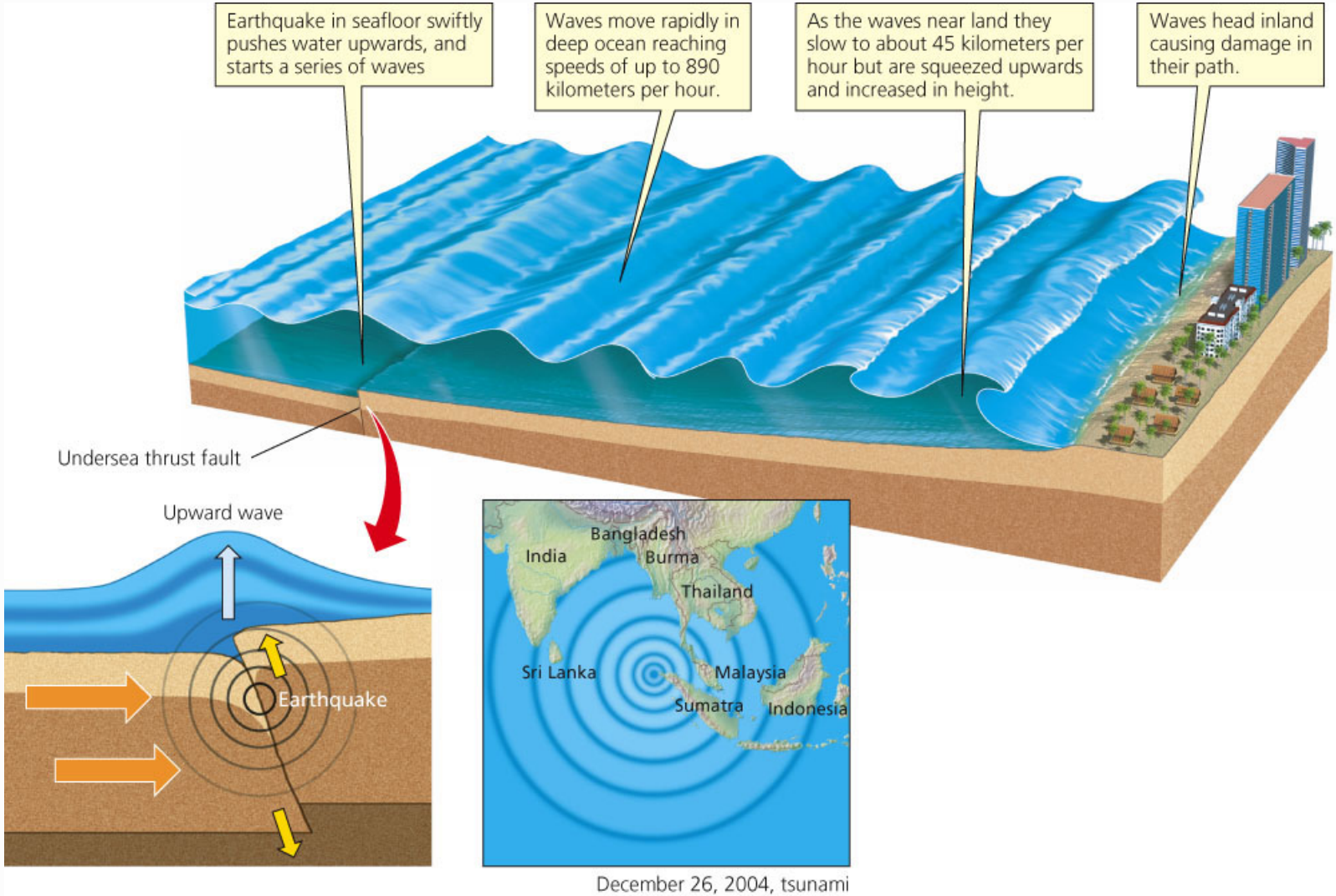
Areas of Greatest Earthquake Risk in the World



Earthquakes on the Ocean Floor Can Cause Huge Waves Called Tsunamis

- **Tsunami, tidal wave**
- Detection of tsunamis
- December 2004: Indian Ocean tsunami
  - Magnitude of 9.15
  - Role of coral reefs and mangrove forests in reducing death toll

Formation of a Tsunami and Map of Affected Area of Dec 2004 Tsunami



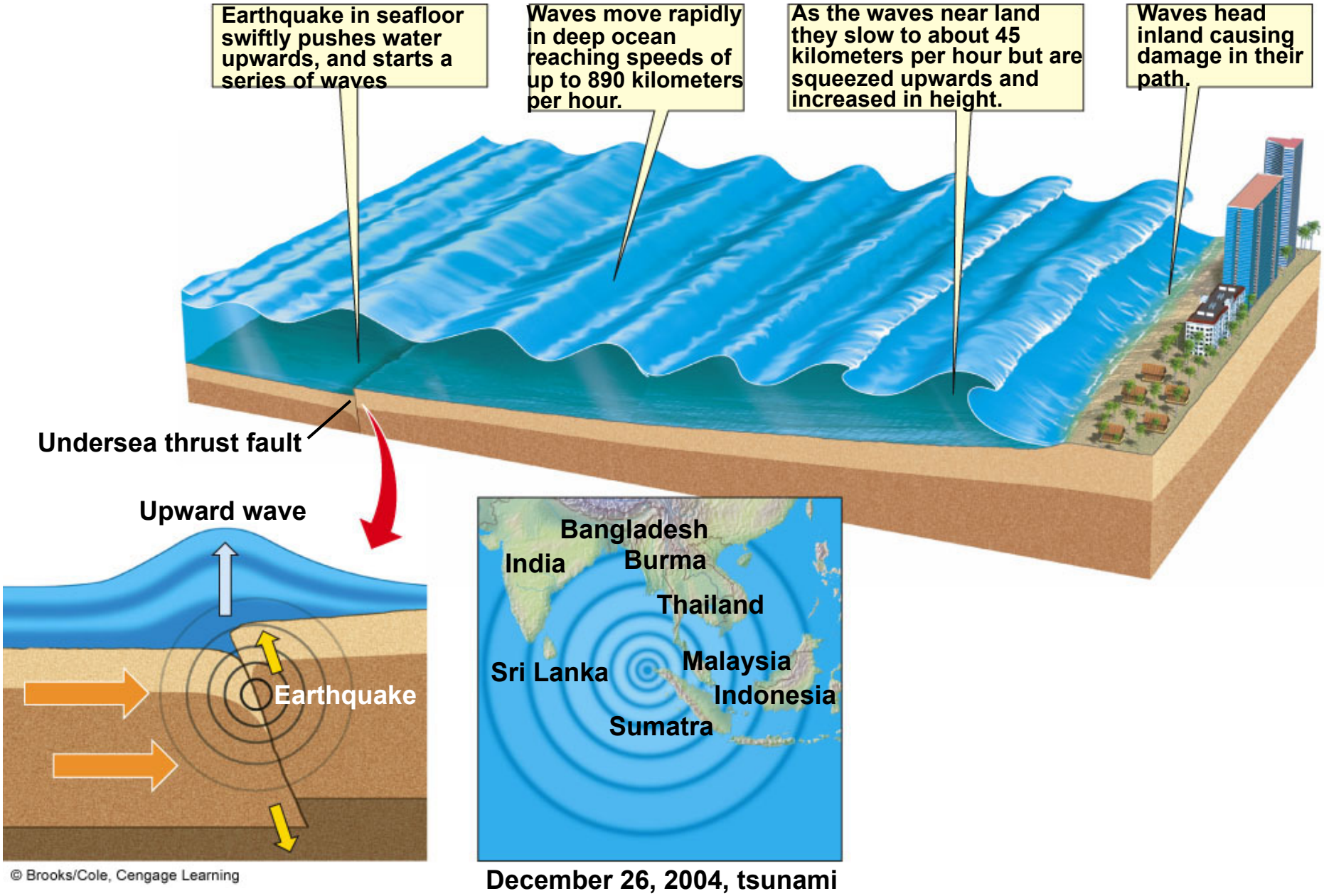


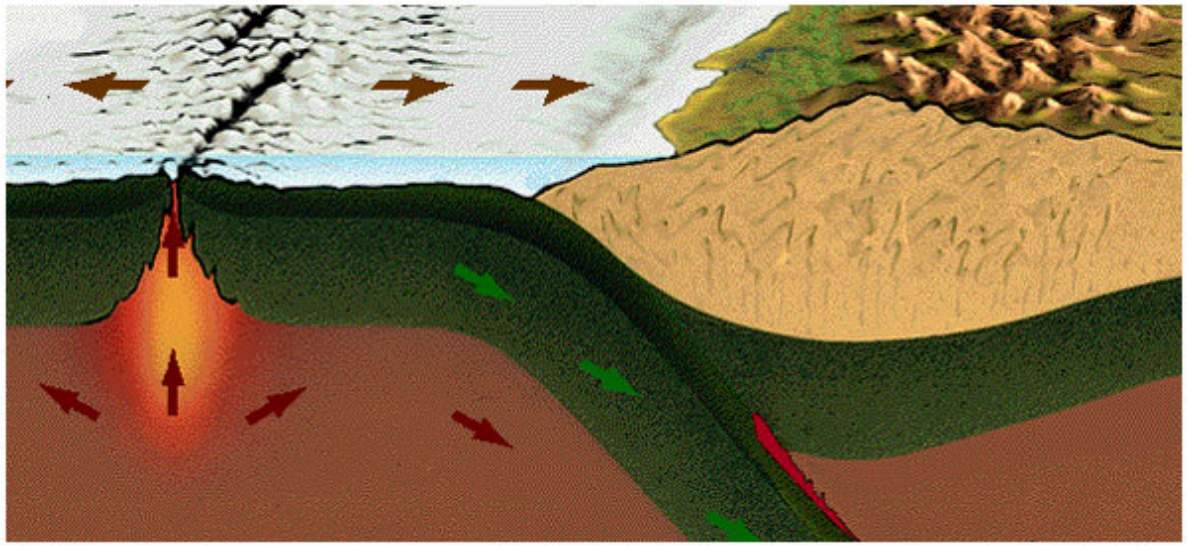
Fig. 14-11, p. 352

Shore near Gleebruk in Indonesia before and after the Tsunami on June 23, 2004

Gravity and Earthquakes Can Cause Landslides

- **Mass wasting**
  - Slow movement
  - Fast movement
    - Rockslides
    - Avalanches
    - Mudslides
- Effect of human activities on such geological events

Active Figure: Geological forces



PLAY

Active Figure: Plate margins

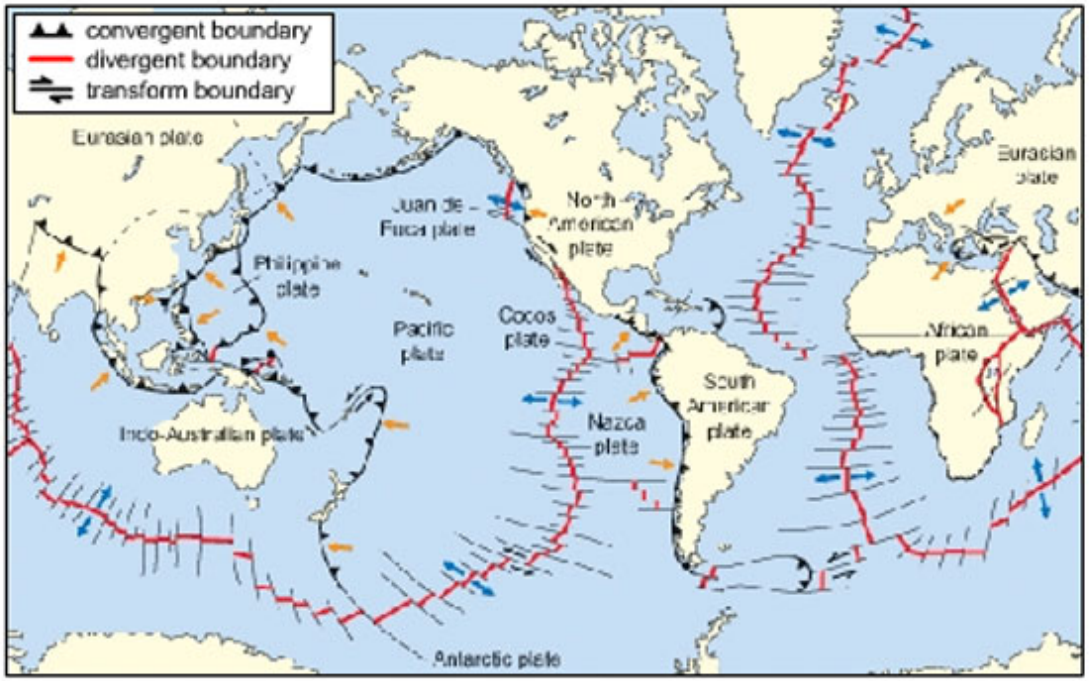


plate boundaries

volcanoes and earthquakes

PLAY

14-2 How Are the Earth's Rocks Recycled?

- ***Concept 14-2*** *The three major types of rocks found in the earth's crust—sedimentary, igneous, and metamorphic—are recycled very slowly by the process of erosion, melting, and metamorphism.*

There Are Three Major Types of Rocks (1)

- Earth's crust
  - Composed of **minerals** and **rocks**
- Three broad classes of rocks, based on formation

1. **Sedimentary**
   - **Sandstone**
   - **Shale**
   - **Dolomite**
   - **Limestone**
   - **Lignite**
   - **Bituminous coal**

There Are Three Major Types of Rocks (2)

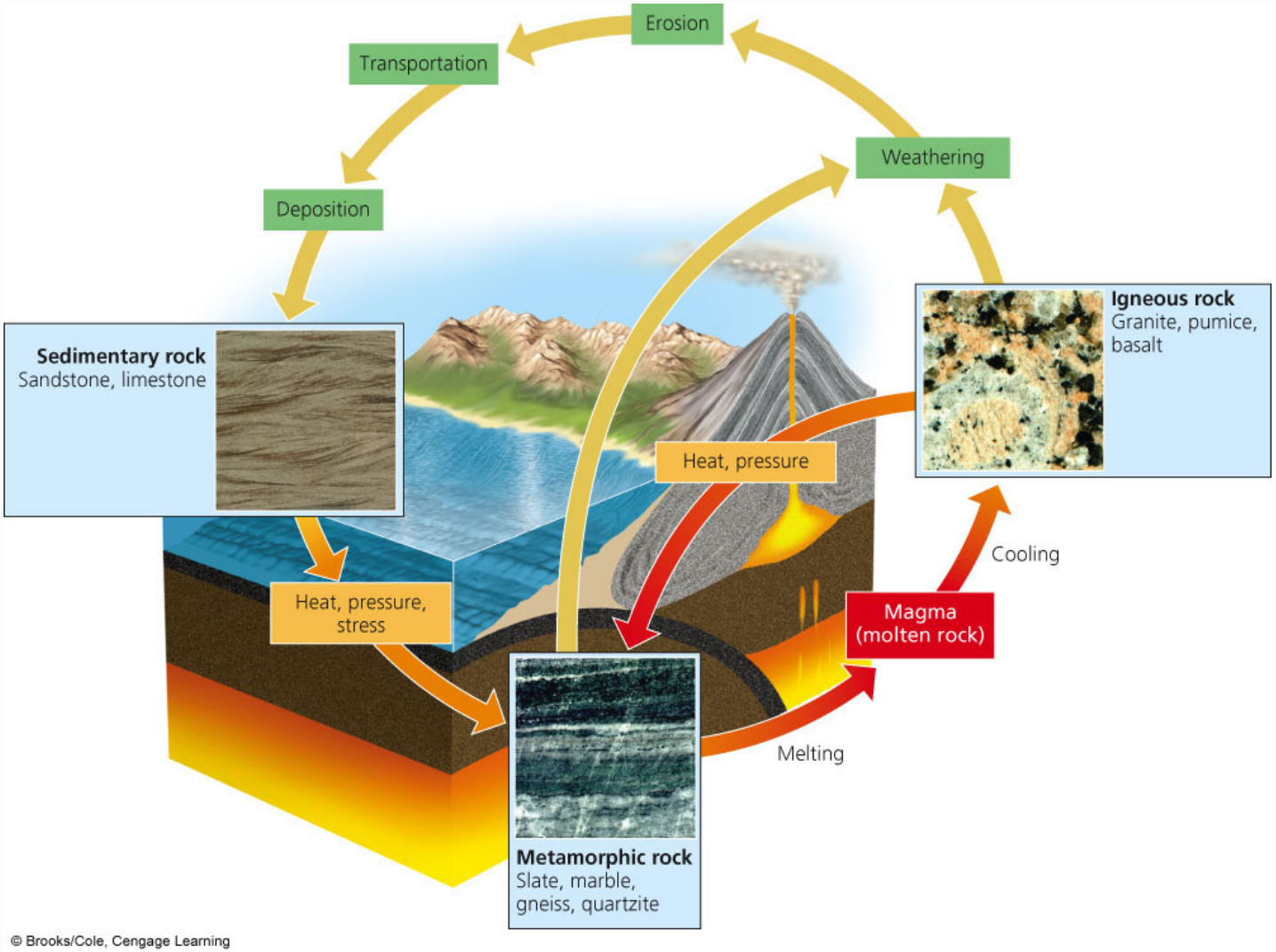
2. Igneous
   - Granite
   - Lava rock

3. Metamorphic
   - Anthracite
   - Slate
   - Marble

The Earth's Rocks Are Recycled Very Slowly

- **Rock cycle**
- Slowest of the earth's cyclic processes

Natural Capital: The Rock Cycle Is the Slowest of the Earth's Cyclic Processes



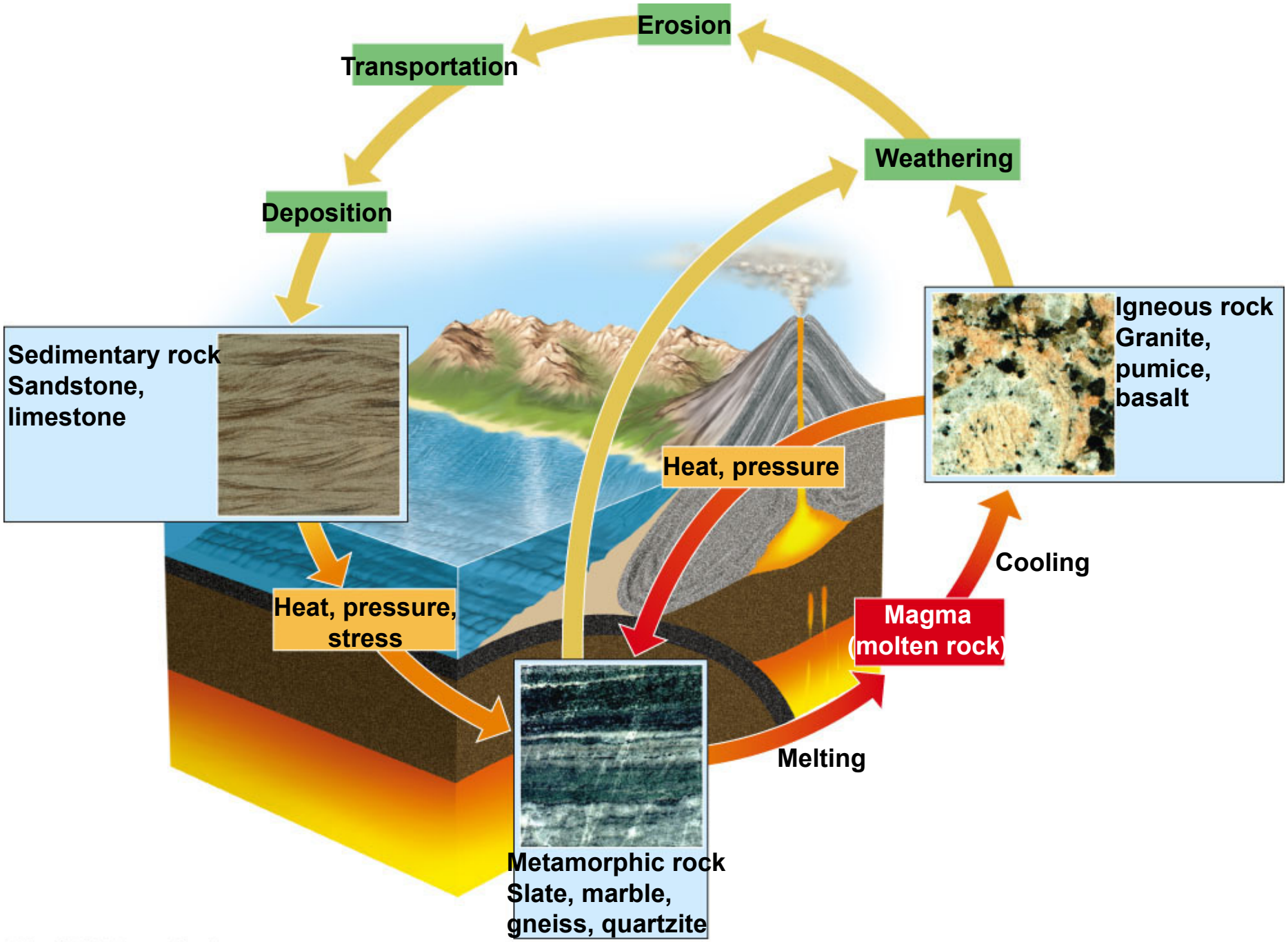


Fig. 14-13, p. 354

14-3 What Are Mineral Resources, and what are their Environmental Effects?

- ***Concept 14-3*A** *Some naturally occurring materials in the earth's crust can be extracted and made into useful products in processes that provide economic benefits and jobs.*

- ***Concept 14-3*B** *Extracting and using mineral resources can disturb the land, erode soils, produce large amounts of solid waste, and pollute the air, water, and soil.*

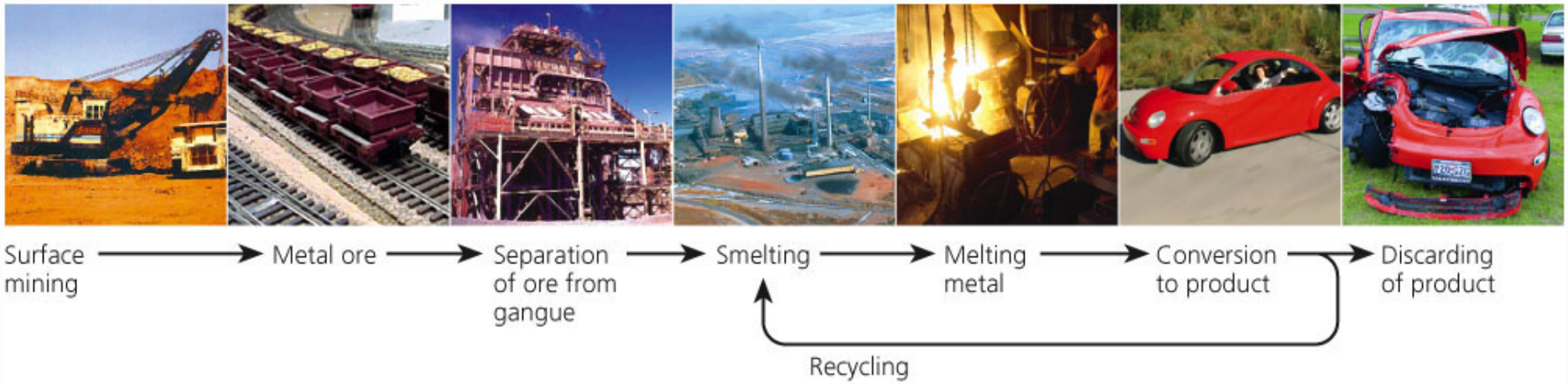
We Use a Variety of Nonrenewable Mineral Resources

- **Mineral resource**
  - Fossil fuels
  - Metallic minerals
  - Nonmetallic minerals
- **Ore**
  - **High-grade ore**
  - **Low-grade ore**
- Importance and examples of nonrenewable metal and nonmetal mineral resources

Mineral Use Has Advantages and Disadvantages

- Advantages of the processes of mining and converting minerals into useful products
- Disadvantages

The Life Cycle of a Metal Resource



Surface mining → Metal ore → Separation of ore from gangue → Smelting → Melting metal → Conversion to product → Discarding of product

Recycling

Fig. 14-14, p. 355

Surface mining → Metal ore → Separation of ore from gangue → Smelting → Melting metal → Conversion to product → Discarding of product

Recycling

Stepped Art

Fig. 14-14, p. 355

Extracting, Processing, Using Nonrenewable Mineral and Energy Resources

NATURAL CAPITAL DEGRADATION

Extracting, Processing, and Using Nonrenewable Mineral and Energy Resources

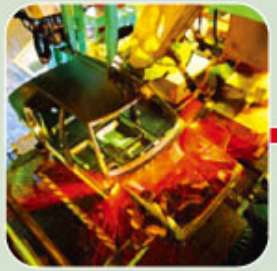
Steps			Environmental Effects
Mining **Exploration, extraction**			**Disturbed land; mining accidents; health hazards; mine waste dumping; oil spills and blowouts; noise; ugliness; heat**
Processing **Transportation, purification, manufacturing**			**Solid wastes; radioactive material; air, water, and soil pollution; noise; safety and health hazards; ugliness; heat**
Use **Transportation or transmission to individual user, eventual use, and discarding**			**Noise; ugliness; thermal water pollution; pollution of air, water, and soil; solid and radioactive wastes; safety and health hazards; heat**

Fig. 14-15, p. 356

There Are Several Ways to Remove Mineral Deposits (1)

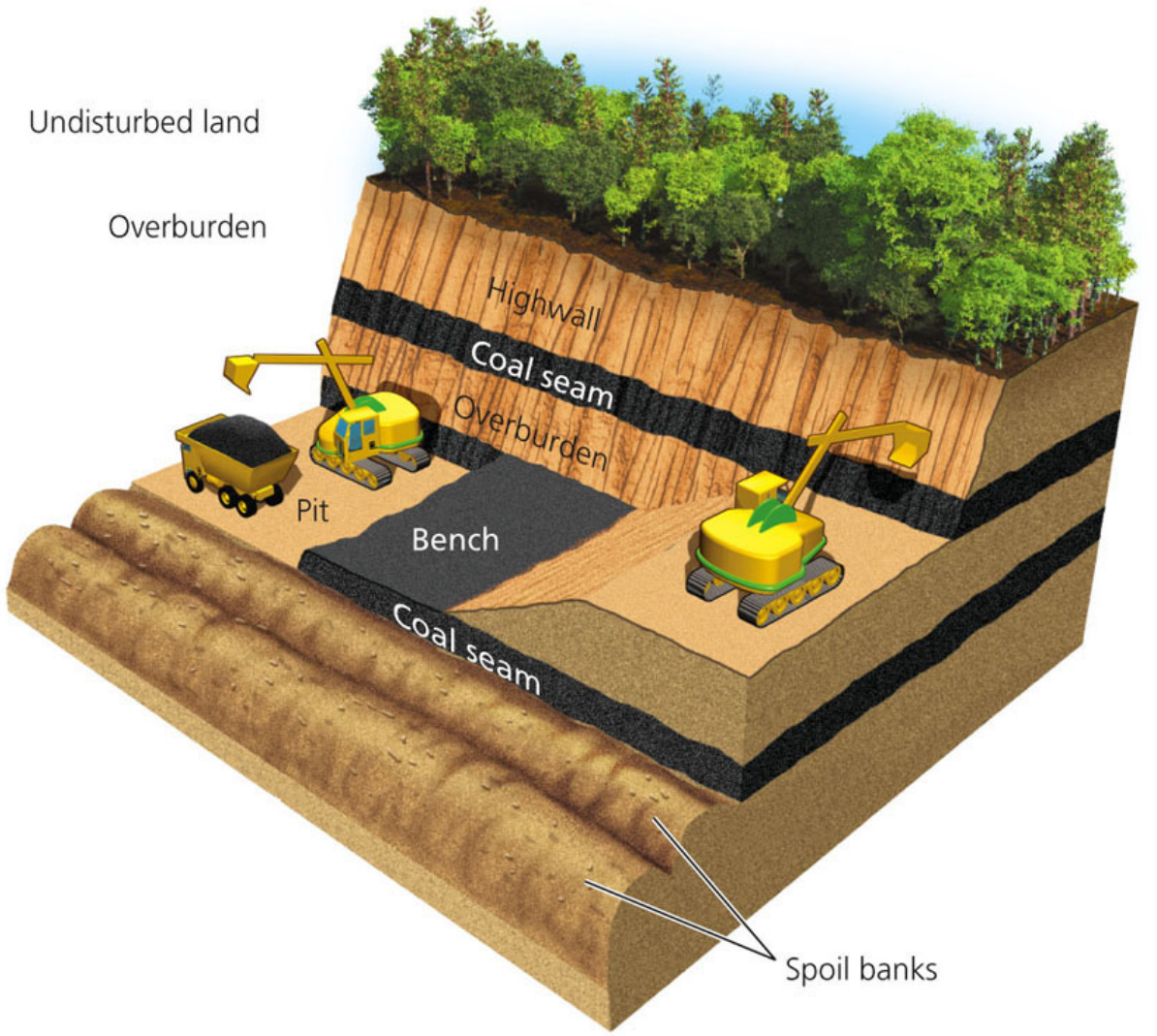
- **Surface mining**
  - Shallow deposits removed
- **Subsurface mining**
  - Deep deposits removed
- Type of surface mining used depends on
  - Resource
  - Local topography

There Are Several Ways to Remove Mineral Deposits (2)

- Types of surface mining
  - **Open-pit mining**
  - **Strip mining**
  - **Contour mining**
  - **Mountaintop removal**

Natural Capital Degradation: Open-Pit Mine in Western Australia

Natural Capital Degradation: Contour Strip Mining Used in Hilly or Mountainous Region



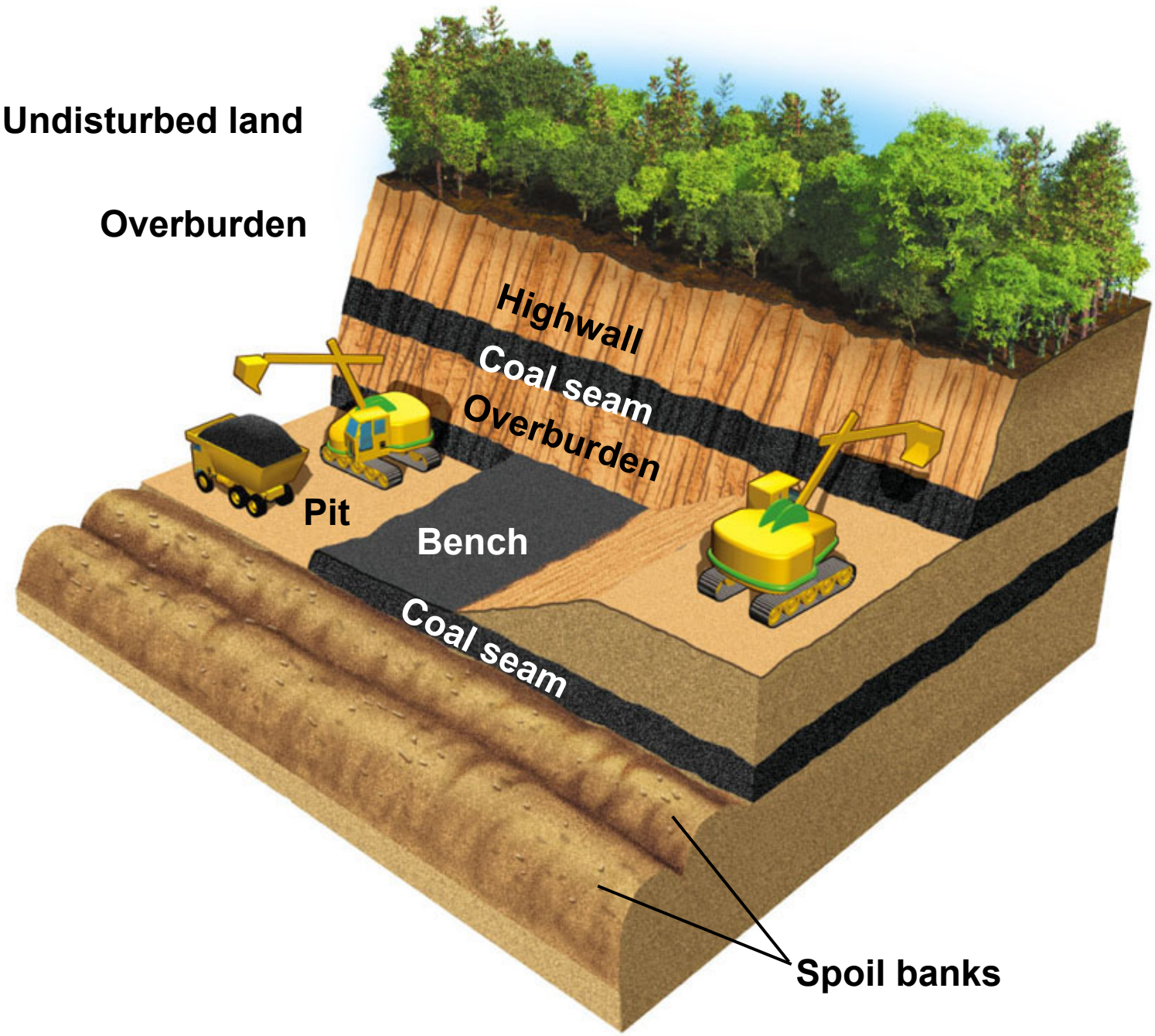


Fig. 14-17, p. 357

Natural Capital Degradation: Mountaintop Coal Mining in West Virginia, U.S.

Mining Has Harmful Environmental Effects (1)

- Scarring and disruption of the land surface
  - E.g., **spoils banks**
- Loss of rivers and streams
- **Subsidence**

Mining Has Harmful Environmental Effects (2)

- Major pollution of water and air
- Effect on aquatic life
- Large amounts of solid waste

Banks of Waste or Spoils Created by Coal Area Strip Mining in Colorado, U.S.

Illegal Gold Mine

Ecological Restoration of a Mining Site in New Jersey, U.S.

Removing Metals from Ores Has Harmful Environmental Effects (1)

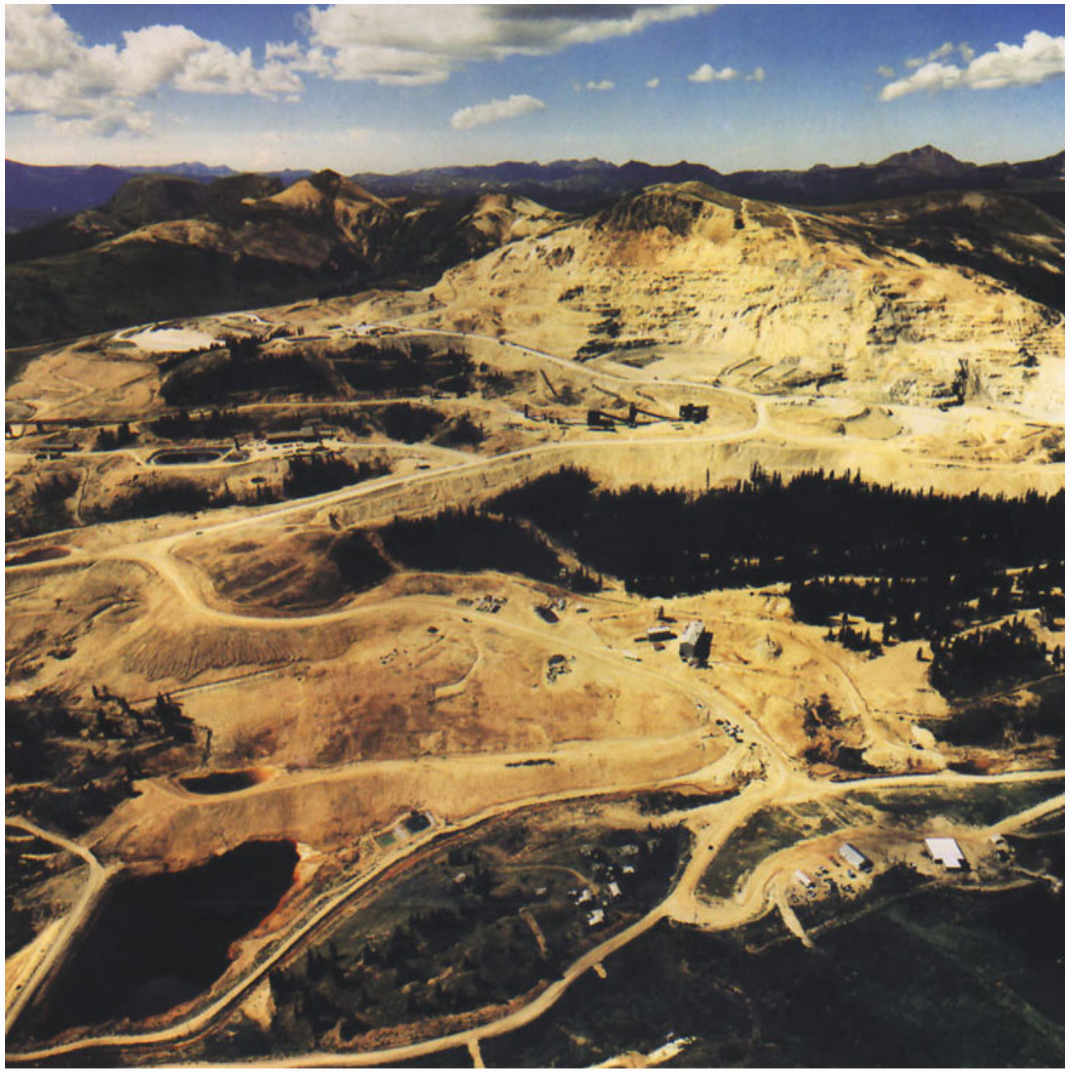
- Ore extracted by mining
  - **Ore mineral**
  - **Gangue**
  - **Smelting**

- Water pollution

Removing Meals from Ores Has Harmful Environmental Effects (2)

- Liquid and solid hazardous wastes produced
- Use of cyanide salt of extract gold from its ore
  - Summitville gold mine: Colorado, U.S.

Natural Capital Degradation: Summitville Gold Mining Site in Colorado, U.S.



14-4 How Long Will Supplies of Nonrenewable Mineral Resources Last?

- ***Concept 14-4A*** *All nonrenewable mineral resources exist in finite amounts, and as we get closer to depleting any mineral resource, the environmental impacts of extracting it generally become more harmful.*

- ***Concept 14-4B*** *An increase in the price of a scarce mineral resource can lead to increased supplies and more efficient use of the mineral, but there are limits to this effect.*

Mineral Resources Are Distributed Unevenly (1)

- Most of the nonrenewable mineral resources supplied by
  - United States
  - Canada
  - Russia
  - South Africa
  - Australia

Mineral Resources Are Distributed Unevenly (2)

- **Strategic metal resources**
  - Manganese (Mn)
  - Cobalt (Co)
  - Chromium (Cr)
  - Platinum (Pt)

Science Focus: The Nanotechnology Revolution

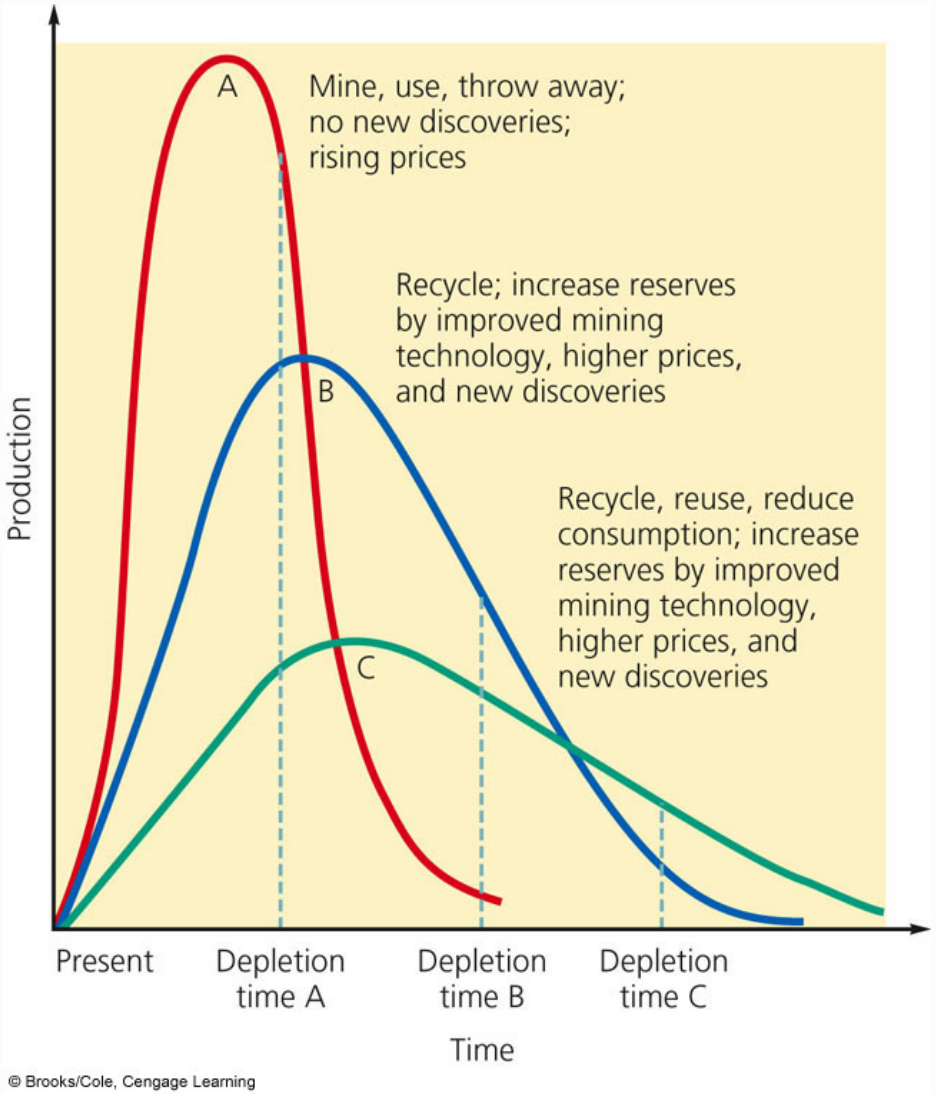
- **Nanotechnology, tiny tech**
- **Nanoparticles**
  - Are they safe?
- Investigate potential ecological, economic, health, and societal risks
- Develop guidelines for their use until more is known about them

Supplies of Nonrenewable Mineral Resources Can Be Economically Depleted

- Future supply depends on
  - Actual or potential supply of the mineral
  - Rate at which it is used

- When it becomes **economically depleted**
  - Recycle or reuse existing supplies
  - Waste less
  - Use less
  - Find a substitute
  - Do without

Natural Capital Depletion: Depletion Curves for a Nonrenewable Resource



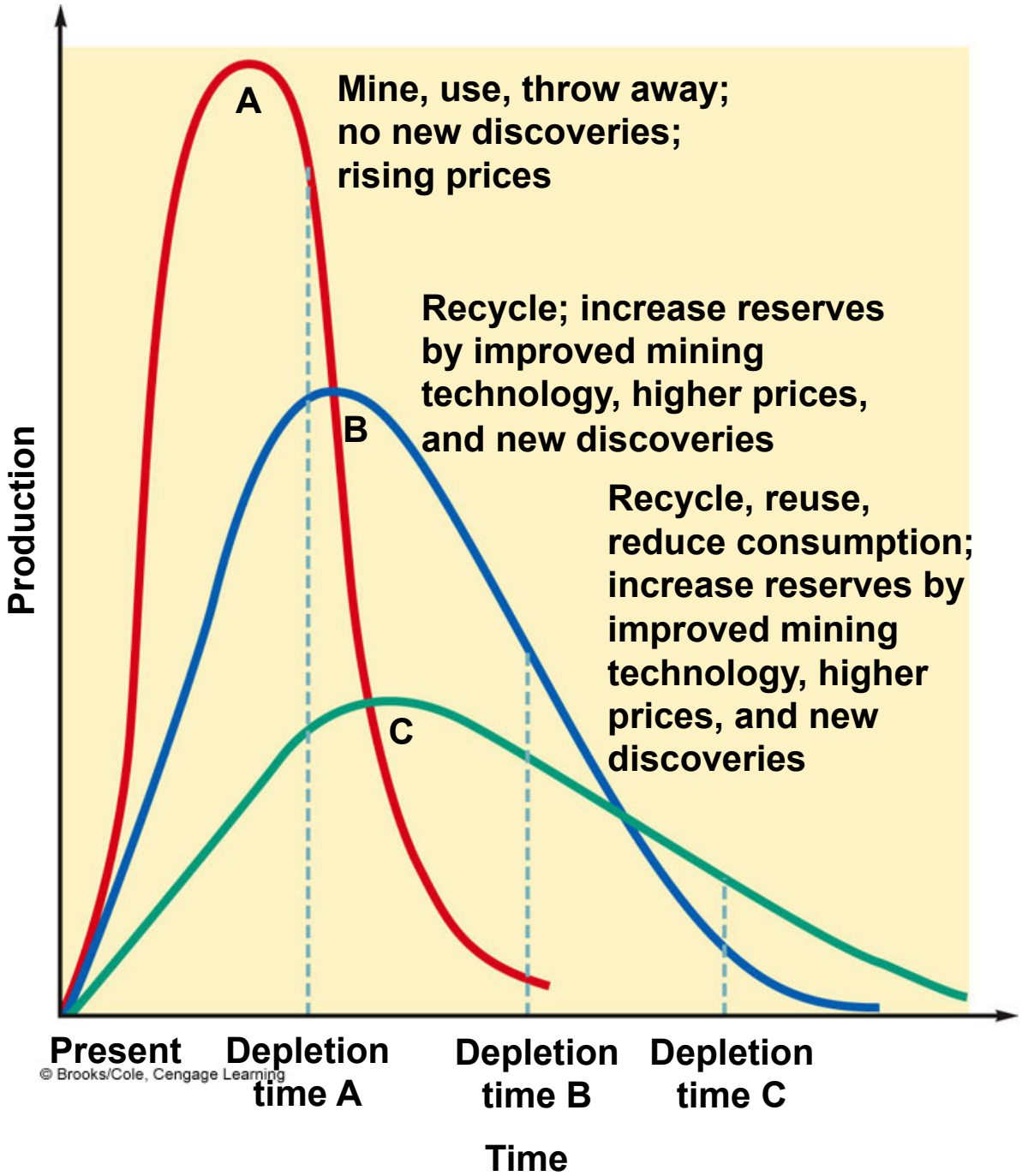


Fig. 14-23, p. 361

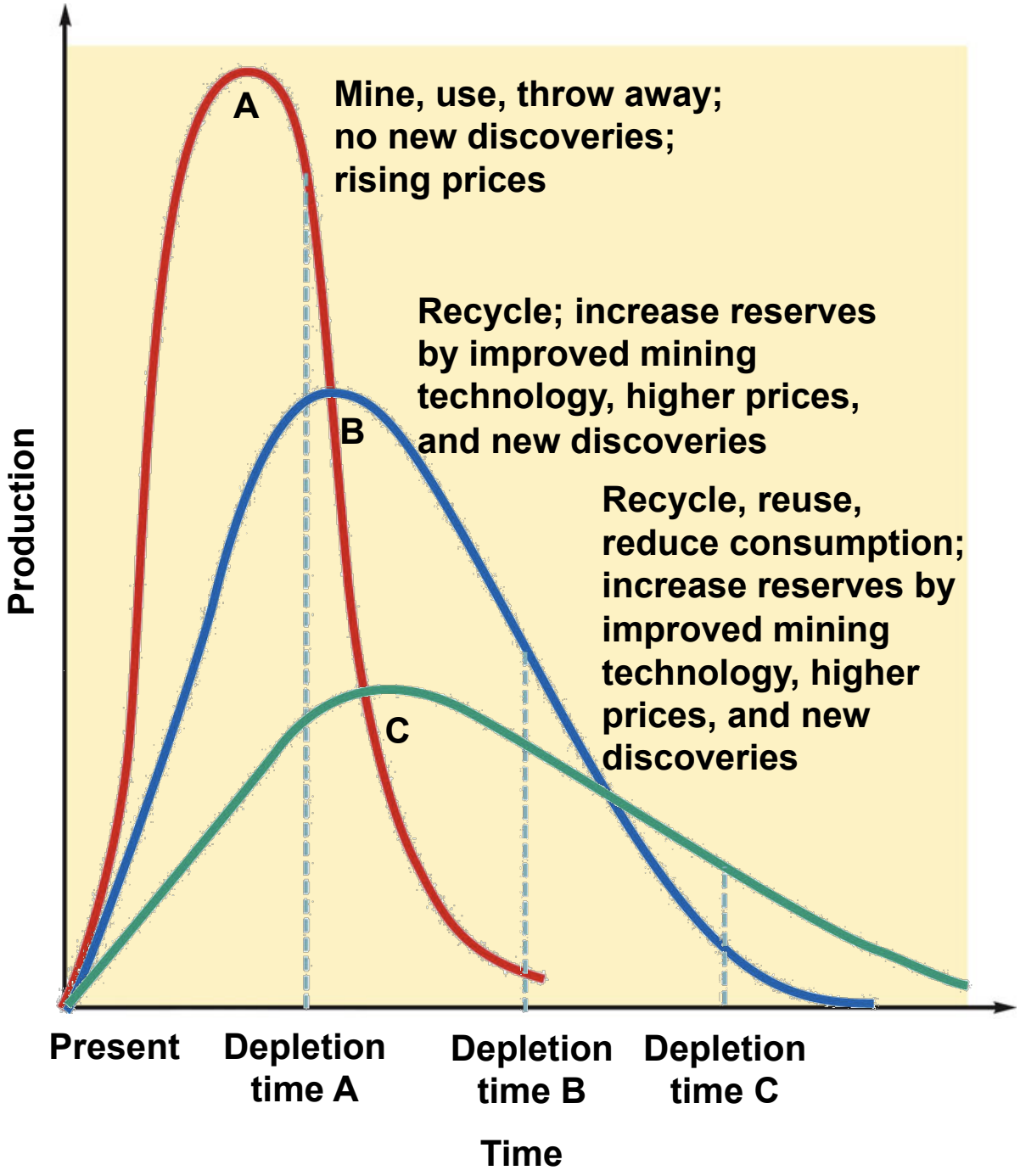


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Fig. 14-23, p. 361

Market Prices Affect Supplies of Nonrenewable Minerals

- Subsidies and tax breaks to mining companies keep mineral prices artificially low
- Does this promote economic growth and national security?
- Scarce investment capital hinders the development of new supplies of mineral resources

Case Study: The U.S. General Mining Law of 1872

- Encouraged mineral exploration and mining of **hard-rock minerals** on U.S. public lands
- Developed to encourage settling the West (1800s)
- Until 1995, land could be bought for 1872 prices
- Companies must pay for clean-up now

Is Mining Lower-Grade Ores the Answer?

- Factors that limit the mining of lower-grade ores
  - Increased cost of mining and processing larger volumes of ore
  - Availability of freshwater
  - Environmental impact

- Improve mining technology
  - Use microorganisms, *in situ*
  - Slow process
  - What about genetic engineering of the microbes?

Can We Extend Supplies by Getting More Minerals from the Ocean? (1)

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

Can We Extend Supplies by Getting More Minerals from the Ocean? (2)

- Hydrothermal ore deposits
- Metals from the ocean floor: **manganese nodules**
  - Effect of mining on aquatic life
  - Environmental impact

14-5 How Can We Use Mineral Resources More Sustainability?

- ***Concept 14-5*** *We can try to find substitutes for scarce resources, reduce resource waste, and recycle and reuse minerals.*

We Can Find Substitutes for Some Scarce Mineral Resources (1)

- Materials revolution
- Nanotechnology
- Silicon
- High-strength plastics
  - Drawbacks?

We Can Find Substitutes for Some Scarce Mineral Resources (2)

- Substitution is not a cure-all
  - Pt: industrial catalyst
  - Cr: essential ingredient of stainless steel

We Can Recycle and Reuse Valuable Metals

- Recycling
  - Lower environmental impact than mining and processing metals from ores
- Reuse

There Are Many Ways to Use Mineral Resources More Sustainability

- How can we decrease our use and waste of mineral resources?

- Pollution and waste prevention programs
  - Pollution Prevention Pays (3P)
  - Cleaner production

Solutions: Sustainable Use of Nonrenewable Minerals

SOLUTIONS

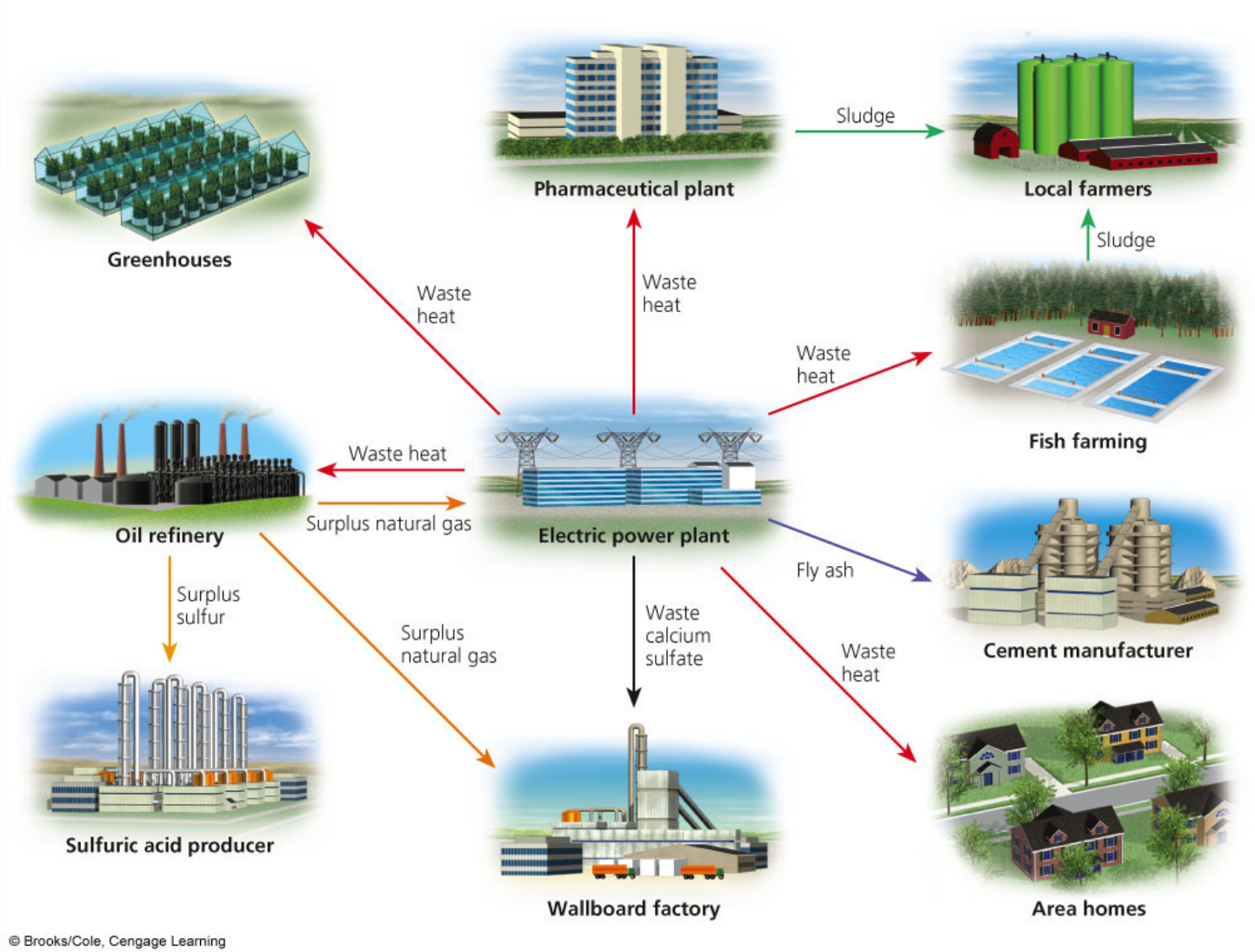
Sustainable Use of Nonrenewable Minerals

- Do not waste mineral resources.
- Recycle and reuse 60–80% of mineral resources.
- Include the harmful environmental costs of mining and processing minerals in the prices of items (full-cost pricing).
- Reduce mining subsidies.
- Increase subsidies for recycling, reuse, and finding substitutes.
- Redesign manufacturing processes to use less mineral resources and to produce less pollution and waste (cleaner production).
- Use mineral resource wastes of one manufacturing process as raw materials for other processes.
- Slow population growth.

Case Study: Industrial Ecosystems: Copying Nature

- Mimic nature: recycle and reuse most minerals and chemicals
- **Resource exchange webs**
- **Ecoindustrial parks**
- Industrial forms of **biomimicry**
  - Benefits

Solutions: An Industrial Ecosystem in Denmark Mimics Natural Food Web



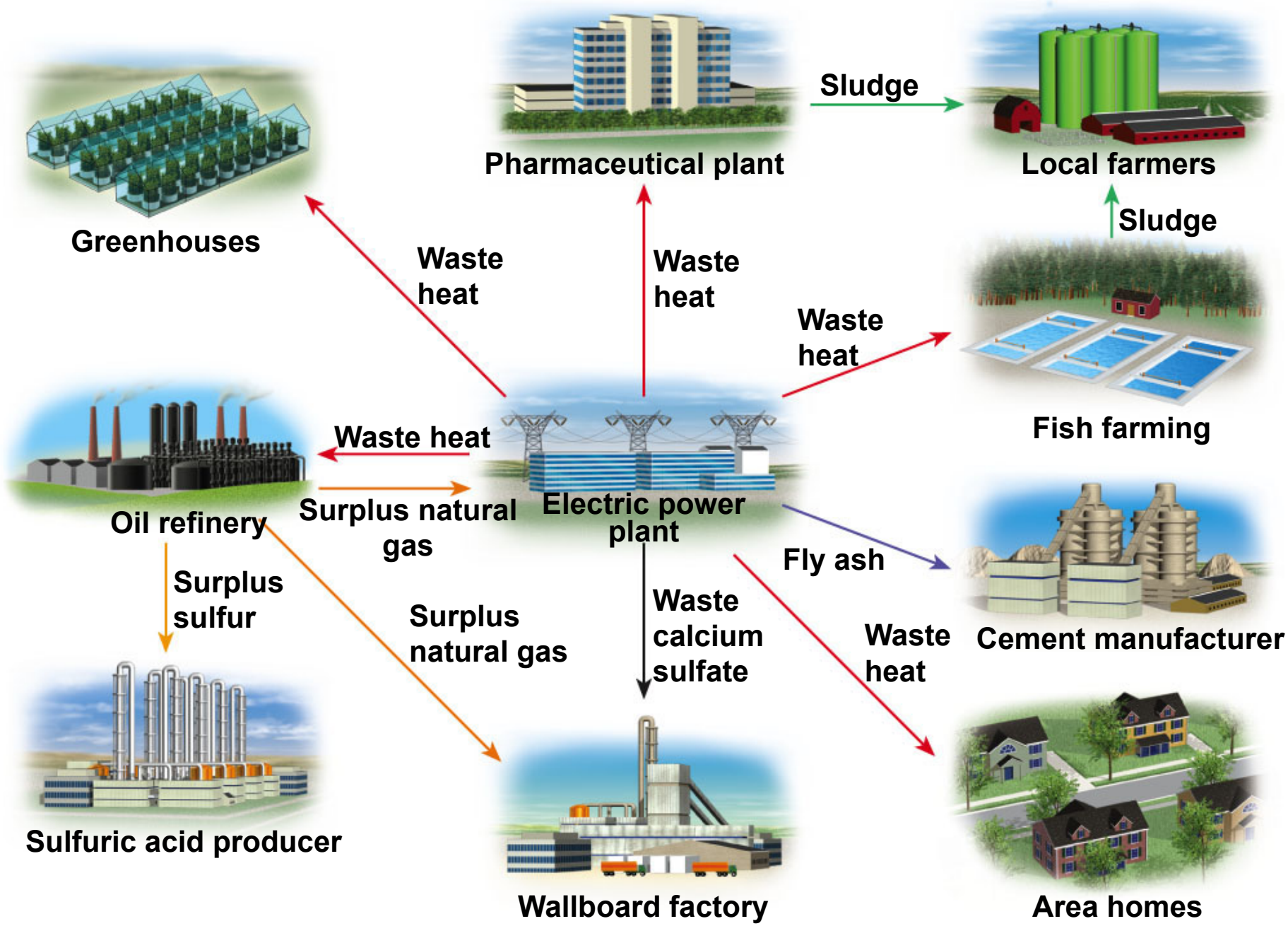


Fig. 14-25, p. 367