Chapter 14

Geology and Nonrenewable Mineral Resources


Tunnel under bygging
Foto: Bjørn Nilsen

Civilization exists by geological consent, subject to change without notice.

- Will Durant

Core Case Study: The Real Cost of Gold

Gold producers

- China
- South Africa
- Australia
- United States
- Canada

Cyanide heap leaching

- Extremely toxic to birds and mammals
- Spills contaminate drinking water and kill birds and fish

Video: Amazon Gold

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

Concept 14-1 *Dynamic processes move matter within the earth and on its surface, and can cause volcanic eruptions, earthquakes, tsunamis, erosion, and landslides.*

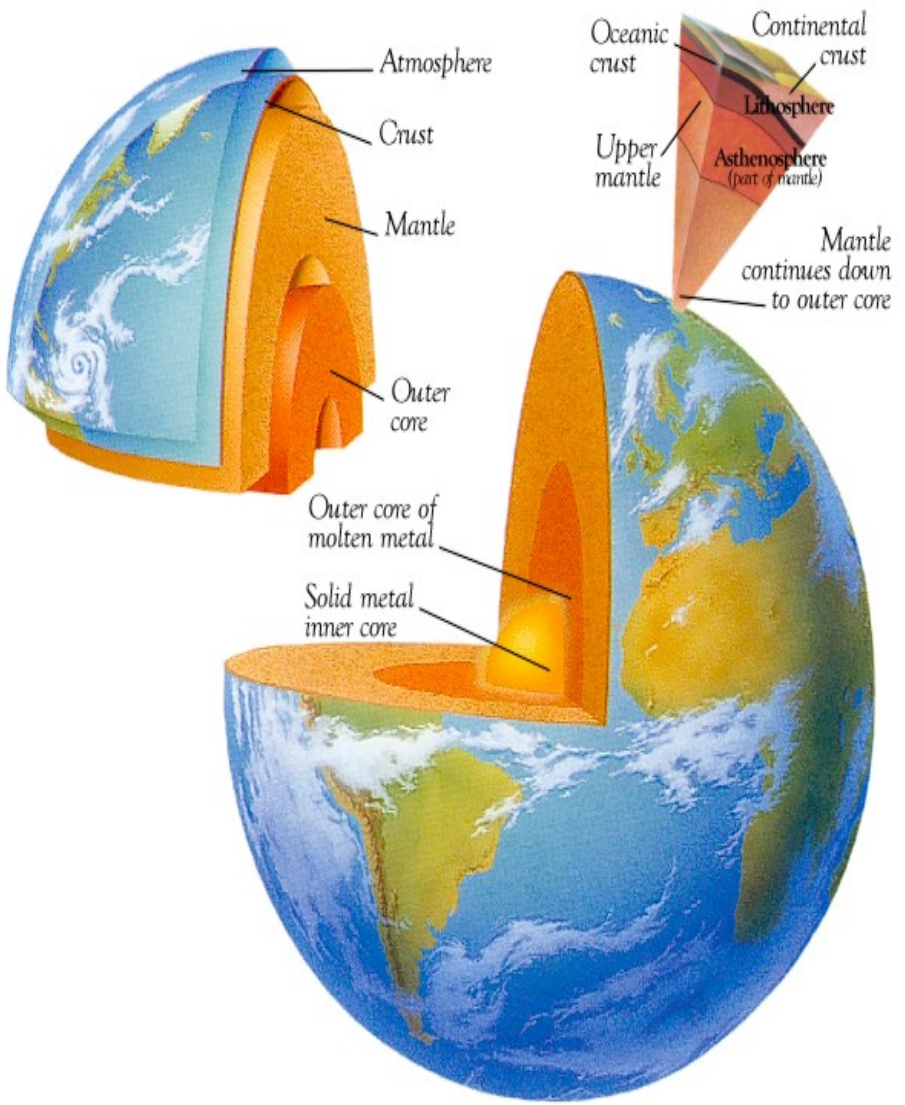
The Earth Is a Dynamic Planet

What is **geology?**

- Dynamic processes taking place on earth's surface and in earth's interior

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

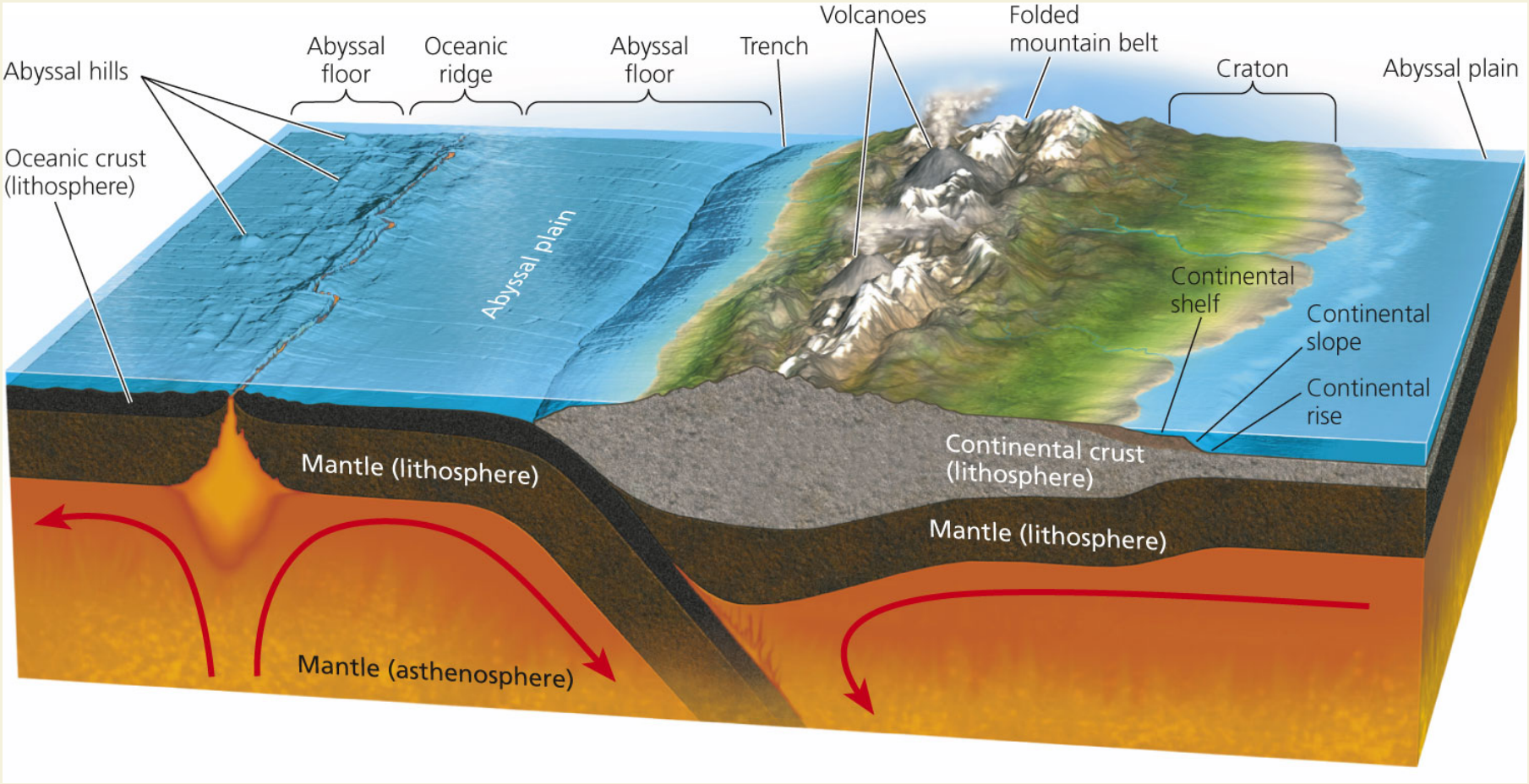
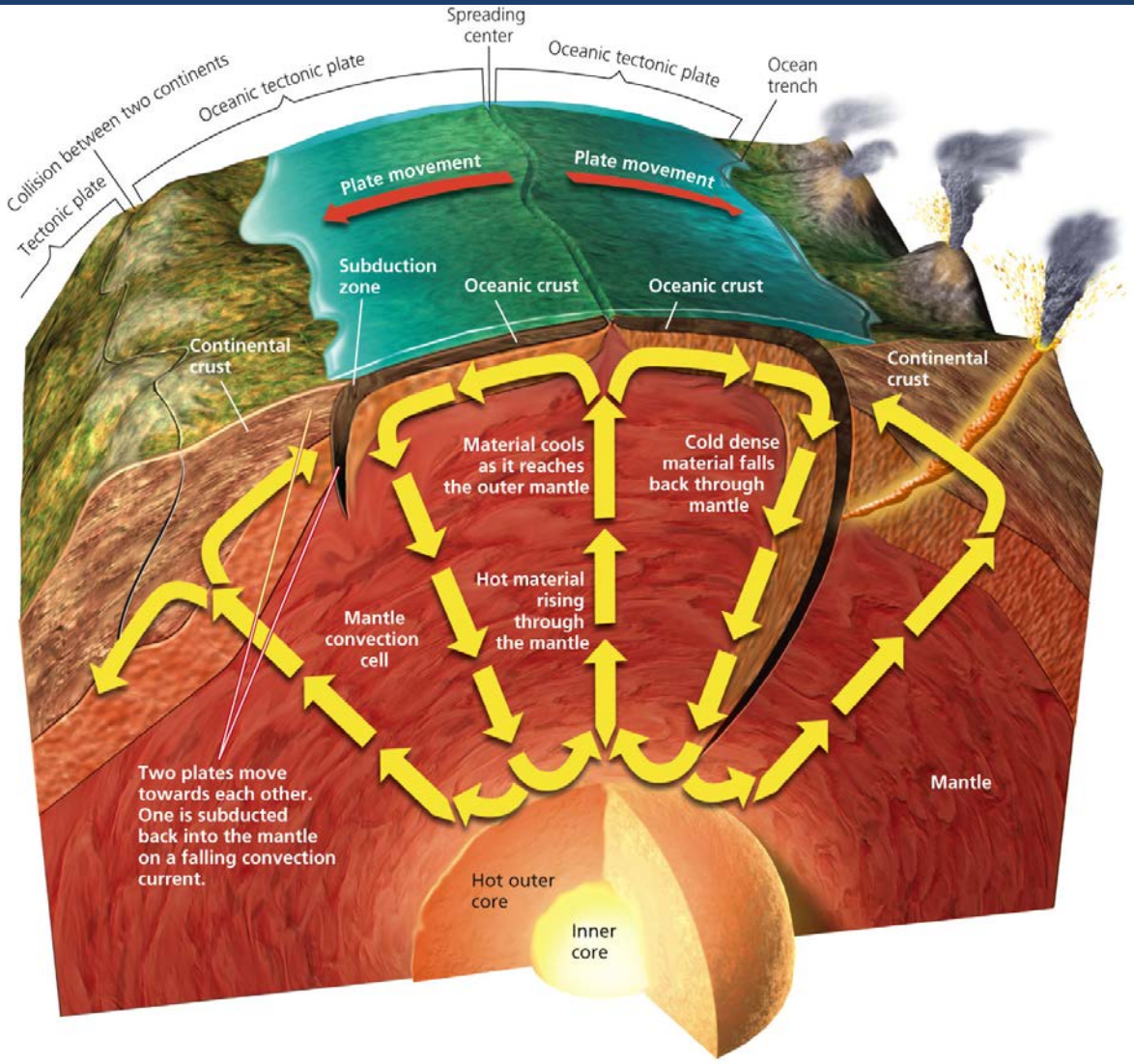


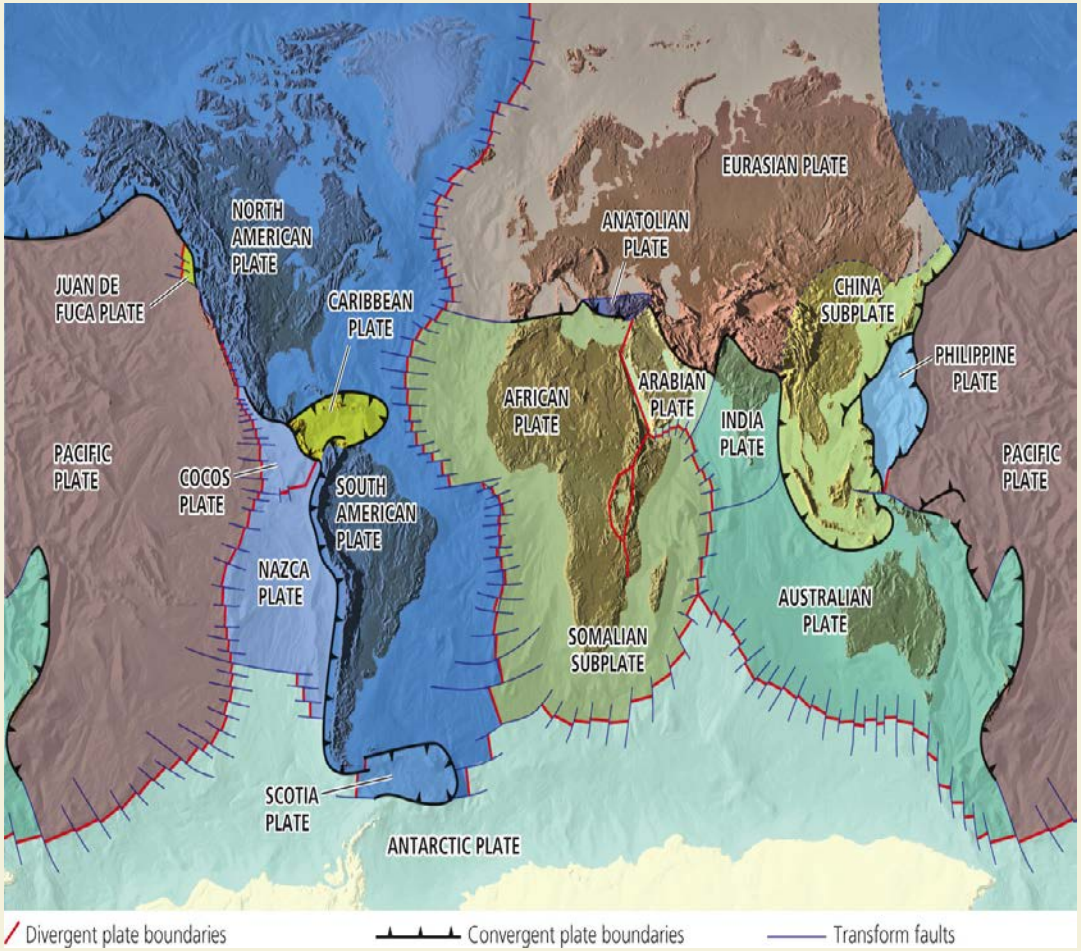
Fig. 14-2, p. 348

The Earth Beneath Your Feet Is Moving

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



Tectonic Plates
Types of Boundaries



Divergent boundaries

- Magma
- Oceanic ridge

Convergent boundaries

- Subduction zone
- Trench

Transform boundaries:

- San Andreas fault

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

Fig. 14-5, p. 350

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

Erosion

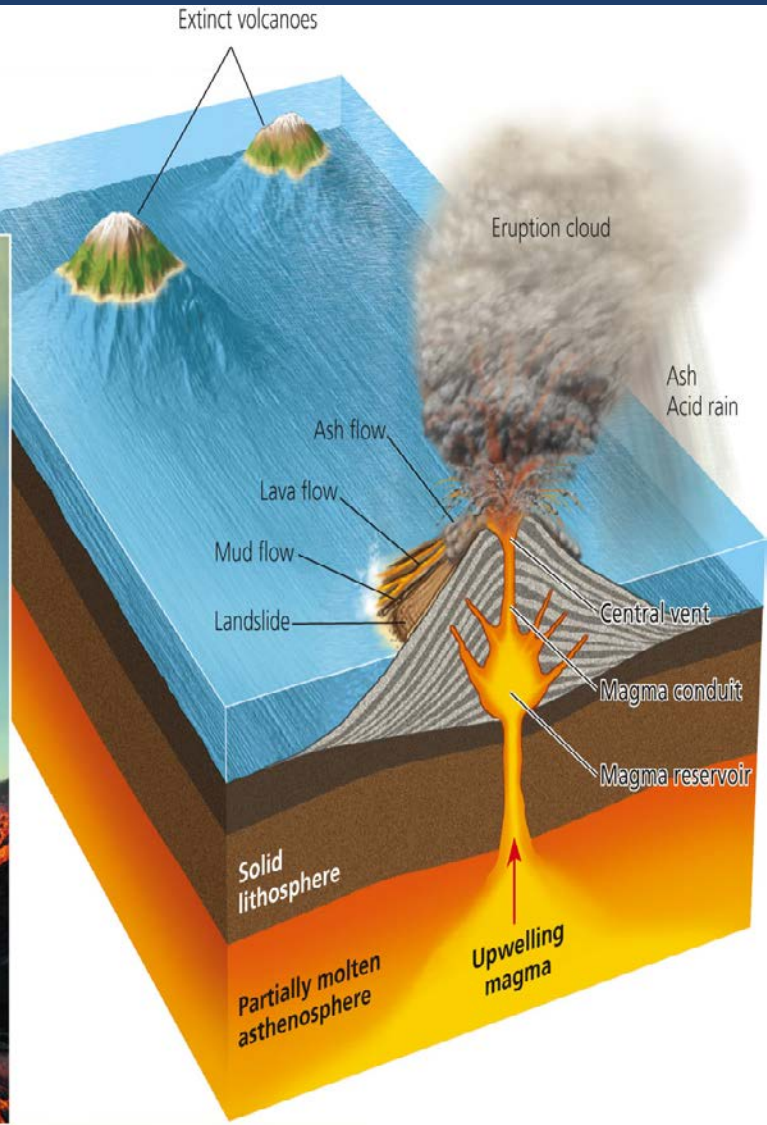
Volcanoes Release Molten Rock from the Earth's Interior

Volcano

- Fissure
- Magma
- Lava

- 1991: Eruption of Mount Pinatubo

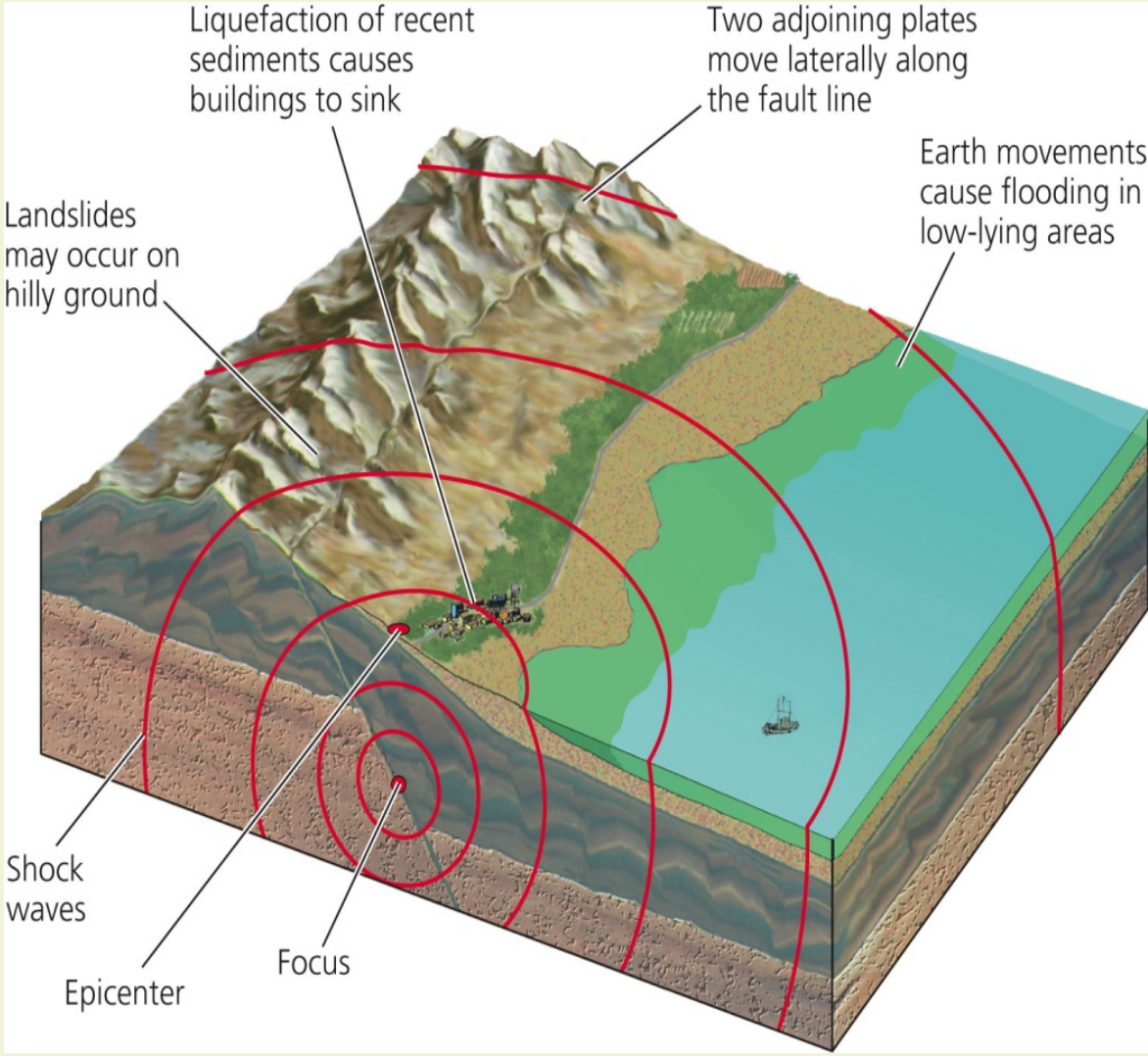
- Benefits of volcanic activity



Earthquakes
Geological Rock-and-Roll Events

Earthquake

- Seismic waves
- Focus
- Epicenter
- Magnitude
- Amplitude



Effects of Earthquakes

- 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 earthquake: 9.5 in Chile in 1960

Earthquake Risk in the United States

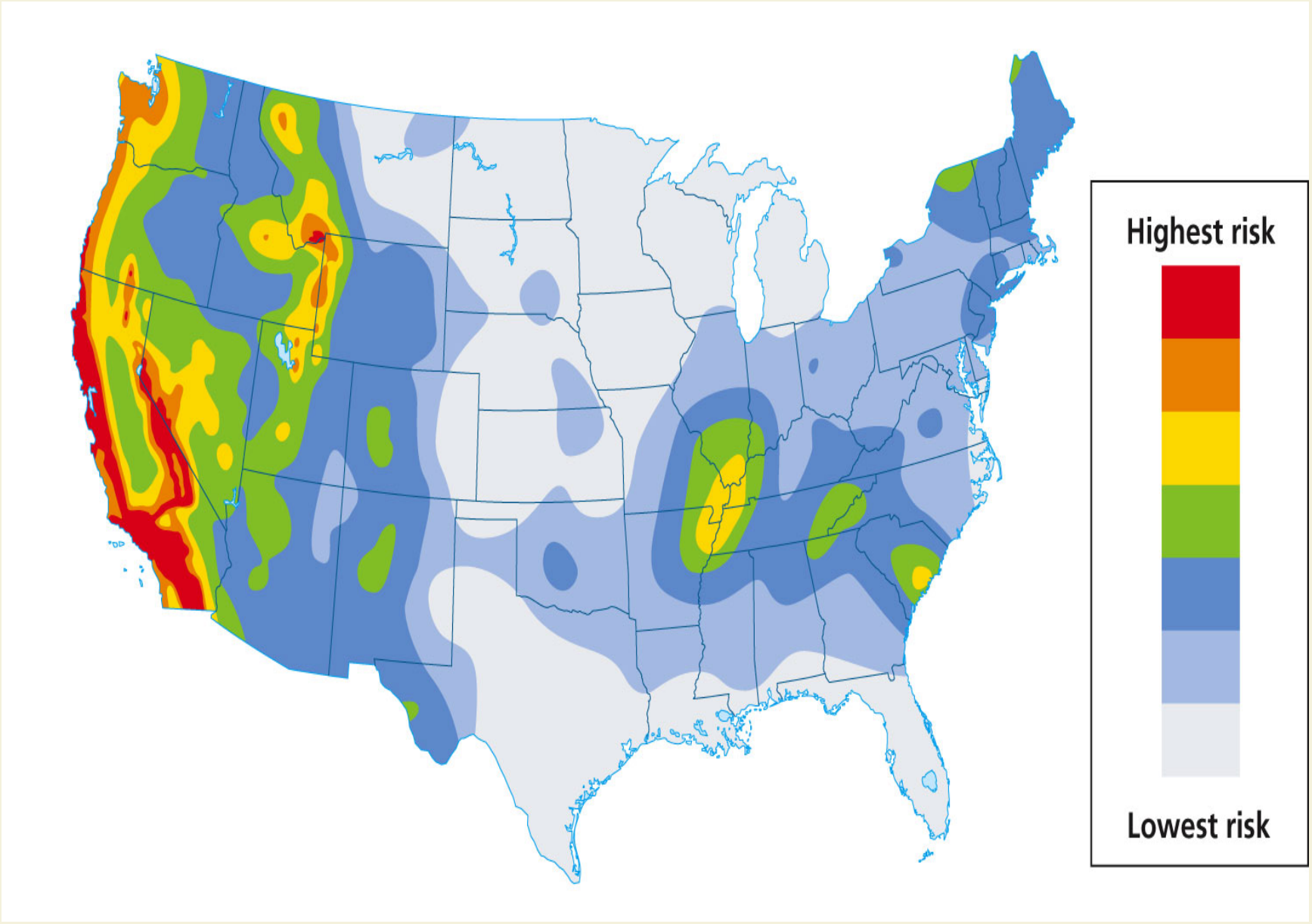


Figure 16, Supplement 8

World Earthquake Risk

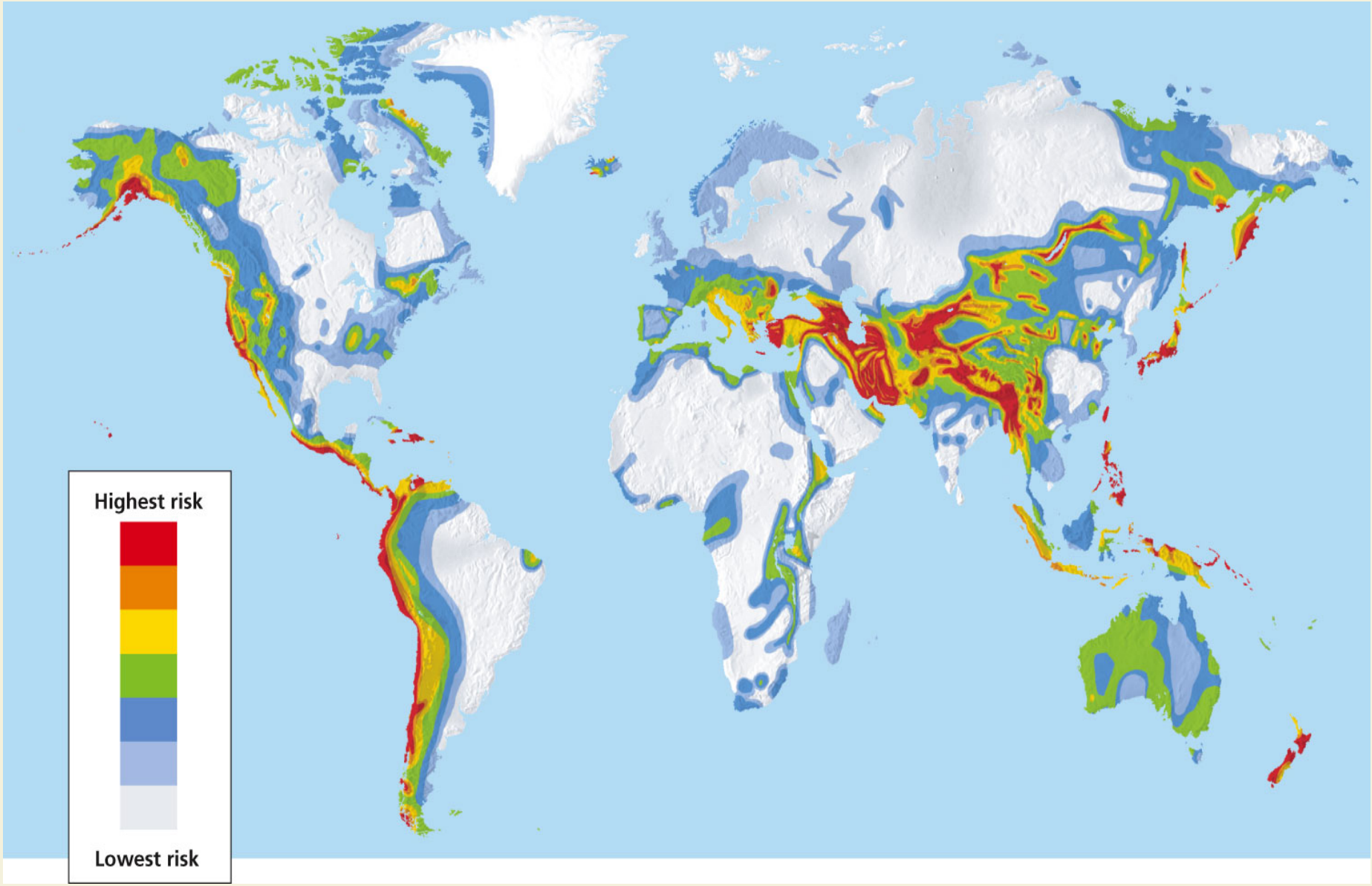


Figure 17, Supplement 8

Earthquakes on the Ocean Floor Can Cause Huge Waves Called Tsunamis

- **Tsunami**, tidal wave
  - Travels several hundred miles per hour
- Detection of tsunamis
  - Buoys in open ocean
- December 2004: Indian Ocean tsunami
  - Magnitude 9.15 and 31-meter waves at shore
  - Role of coral reefs and mangrove forests in reducing death toll

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

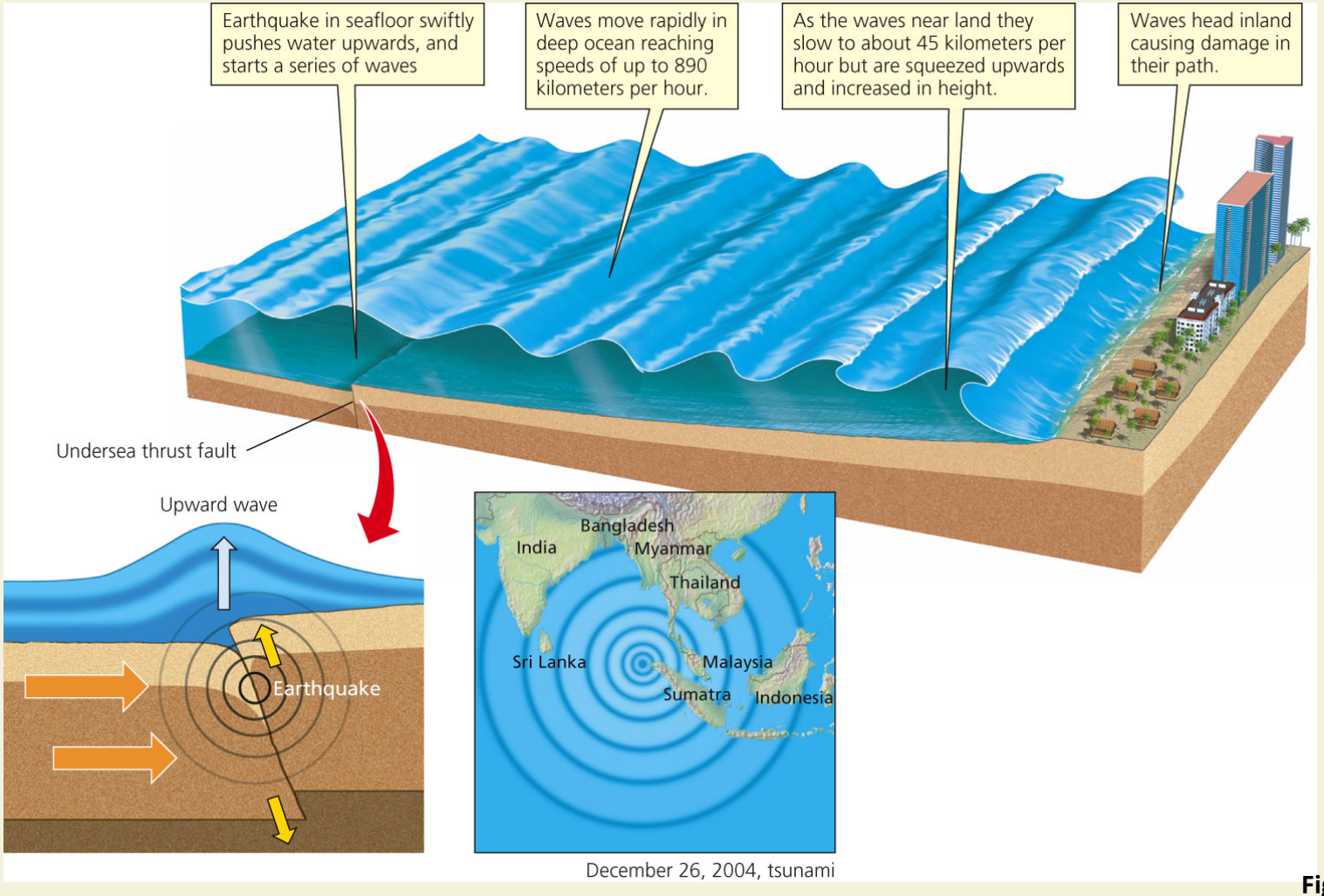


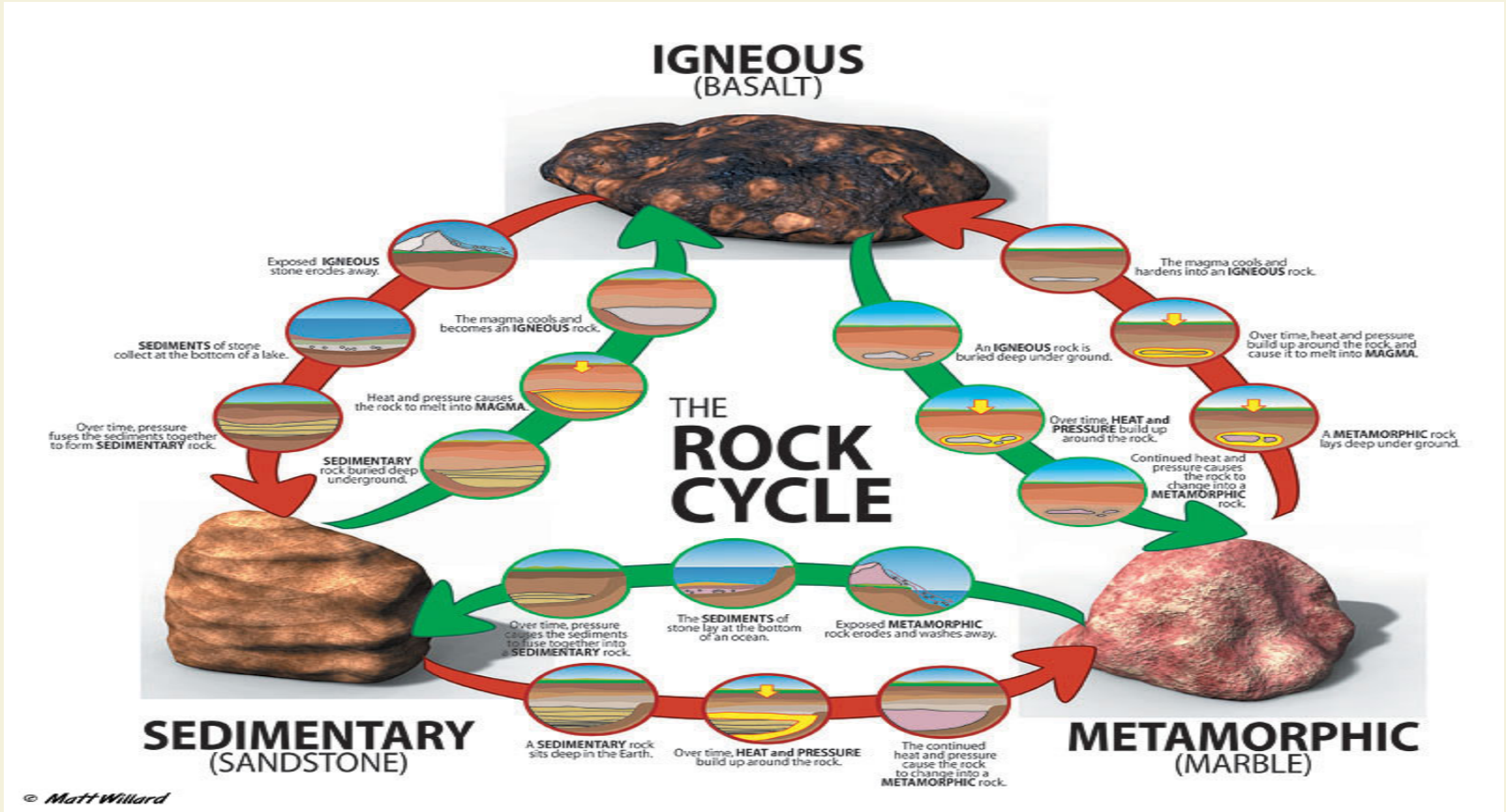
Fig. 14-8, p. 352

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

Fig. 14-9, p. 353

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)

- **Minerals**
  - Element or inorganic compound in earth's crust
  - Usually a crystalline solid
  - Regular and repeating arrangement of atoms

- **Rock**
  - Combination of one or more minerals

There Are Three Major Types of Rocks (2)

1. **Sedimentary**
   - Sediments from eroded rocks or plant/animal remains
     - Transported by water, wind, gravity
     - Deposited in layers and compacted
   - Sandstone
   - Shale
   - Dolomite
   - Limestone
   - Lignite
   - Bituminous coal

There Are Three Major Types of Rocks (3)

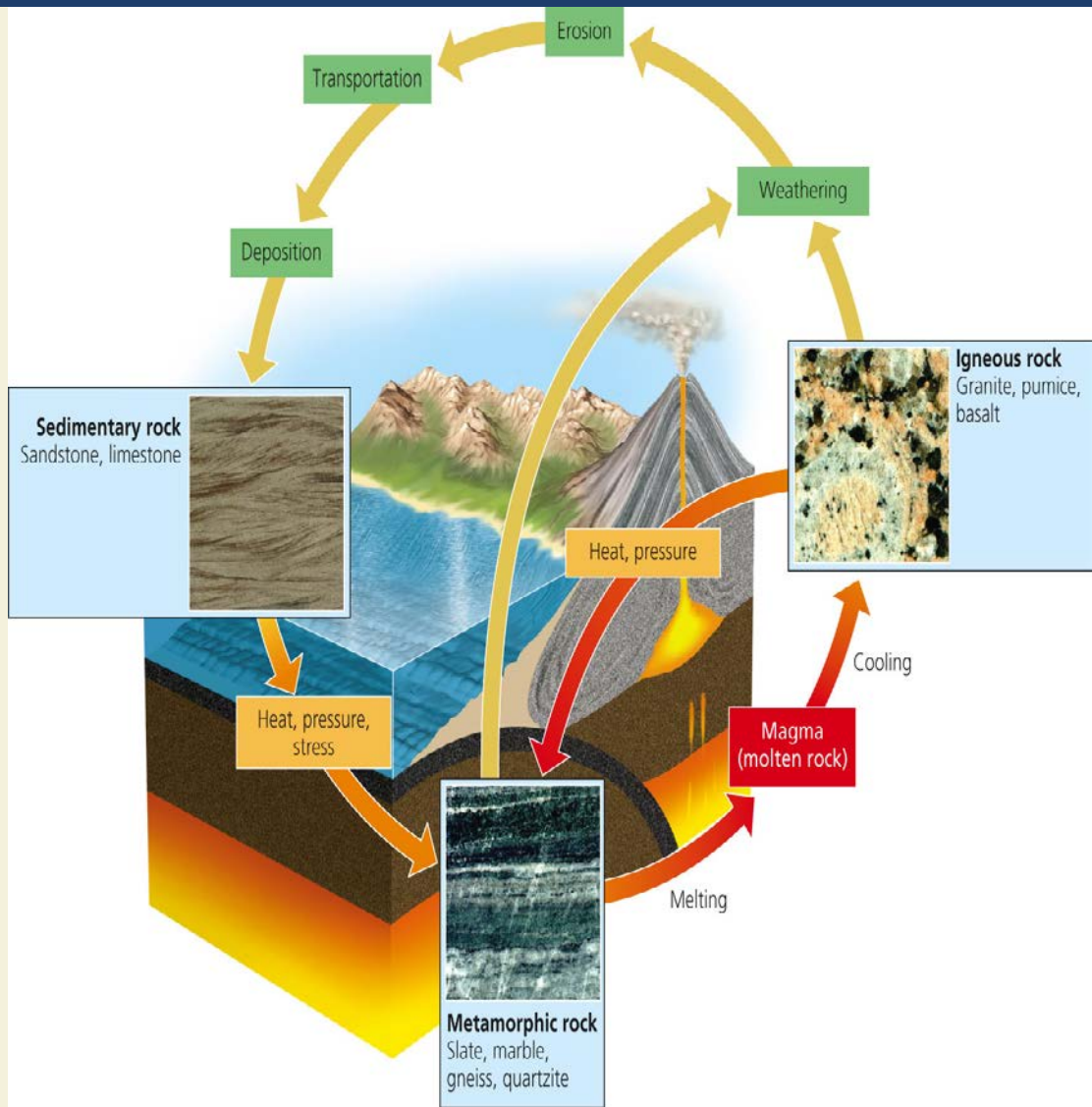
2. **Igneous**
   - Forms below or at earth's surface from magma
   - Granite
   - Lava rocks

3. **Metamorphic**
   - Preexisting rock subjected to high pressures, high temperatures, and/or chemically active fluids
   - Anthracite
   - Slate
   - Marble

The Earth's Rocks Are Recycled Very Slowly

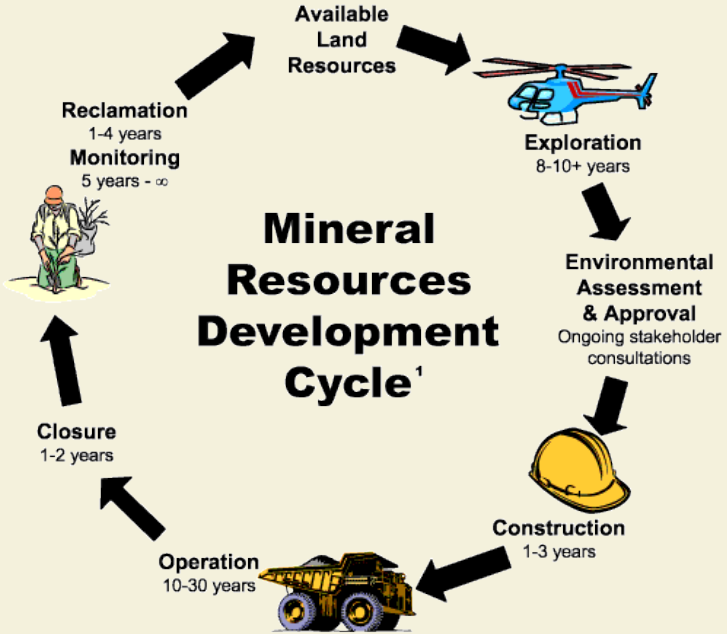
Rock cycle

- Slowest of the earth's cyclic processes



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

Concept 14-3 *We can make some minerals in the earth's crust into useful products, but extracting and using these 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 (1)

- **Mineral resource**
  - Can be extracted from earth's crust and processed into raw materials and products at an affordable cost
  - Metallic minerals (aluminum, gold)
  - Nonmetallic minerals (sand, limestone)

- **Ore**
  - Contains profitable concentration of a mineral
  - **High-grade ore** (large concentration)
  - **Low-grade ore** (smaller concentration)

We Use a Variety of Nonrenewable Mineral Resources (2)

Metallic mineral resources

- Aluminum
- Iron for steel
- Copper

Nonmetallic mineral resources

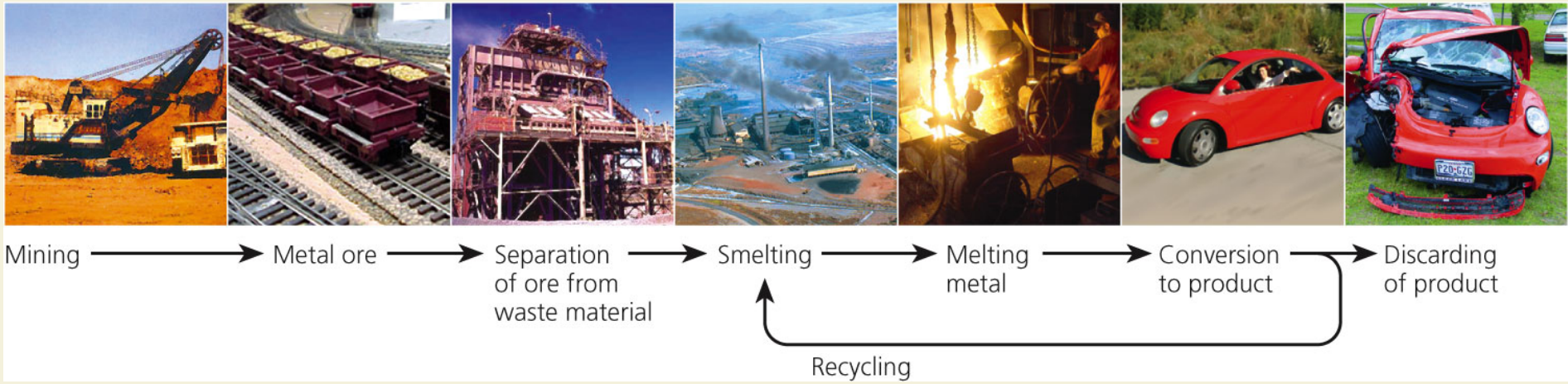
- Sand, gravel, limestone

- **Reserves**: estimated supply of a mineral resource

Some Environmental Impacts of Mineral Use

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

- Disadvantages - Each metal resource that we use has a *life cycle*. Each step in this process uses large amounts of energy and water, and produces some pollution and waste.



The Life Cycle of a Metal Resource

Extracting, Processing, Using Nonrenewable Mineral and Energy Resources

Natural Capital Degradation

Extracting, Processing, and Using Nonrenewable Mineral and Energy Resources

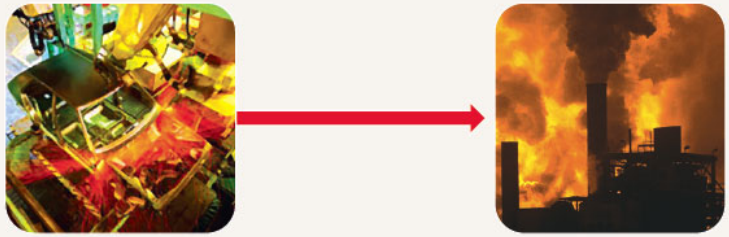
Steps		Environmental Effects
Mining Exploration, extraction		Disturbed land; mining accidents; health hazards; mine waste dumping; oil spills and blowouts; noise; ugliness; heat
Processing Transportation, purification, manufacturing		Solid wastes; radioactive material; air, water, and soil pollution; 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. 14-12, p. 356

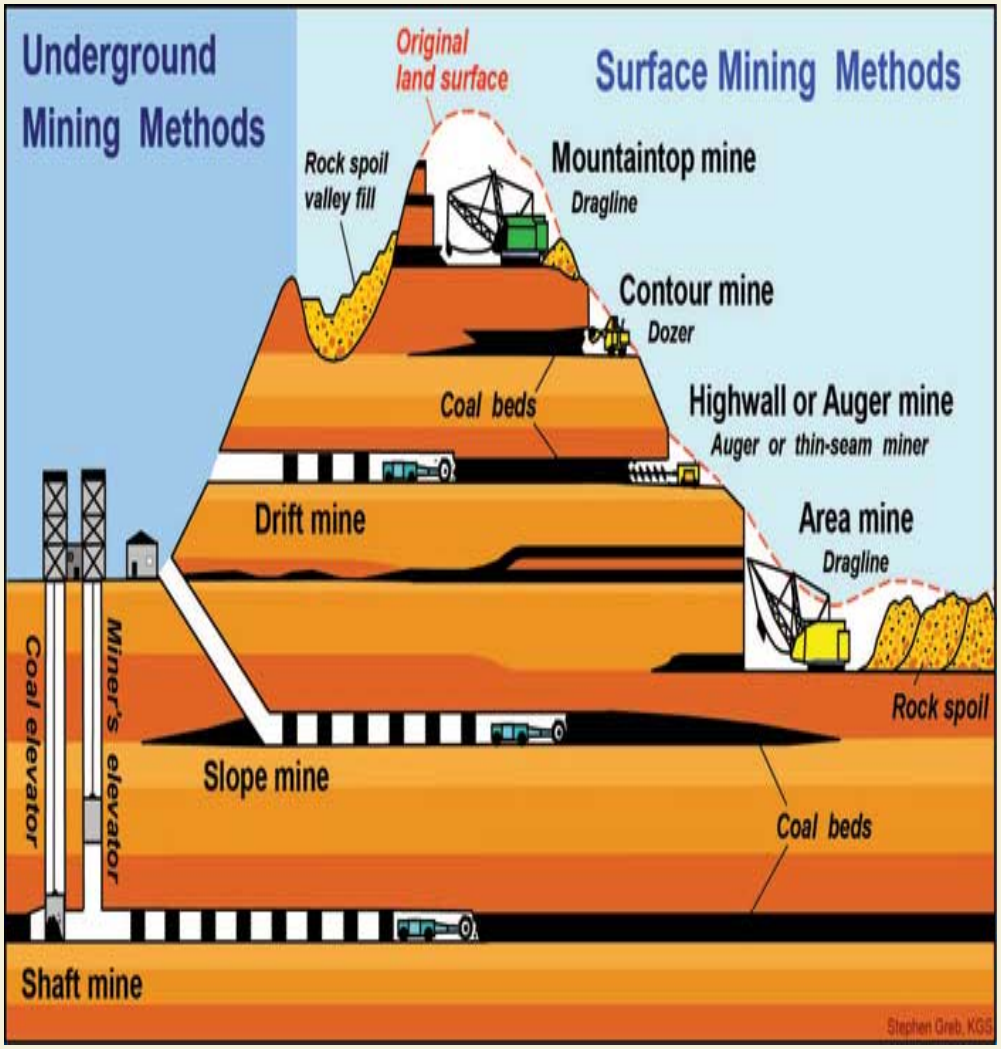
There Are Several Ways to Remove Mineral Deposits (1)

Surface mining

- Shallow deposits removed
- **Overburden** removed first
- **Spoils**: waste material

Subsurface mining

- Deep deposits removed



There Are Several Ways to Remove Mineral Deposits (2)

Type of surface mining used depends on

- Resource
- Local topography

Types of surface mining

- **Open-pit mining**
- **Strip mining**
- **Contour strip mining**
- **Mountaintop removal**

Natural Capital Degradation: Open-Pit Mine in Arizona

Fig. 14-13, p. 357

Area Strip Mining in Wyoming

Fig. 14-14, p. 357

Natural Capital Degradation: Contour Strip Mining

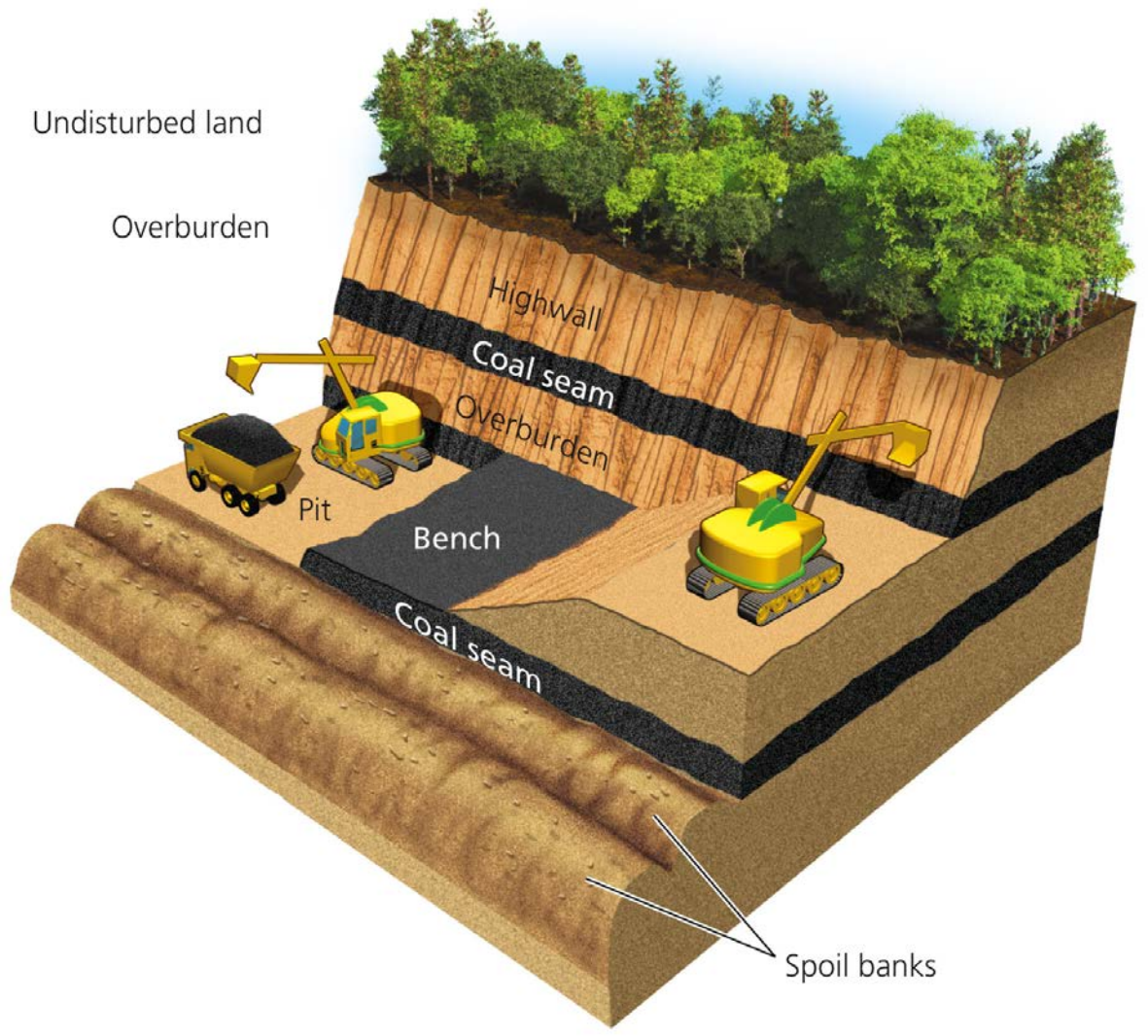


Fig. 14-15, p. 358

Mining Has Harmful Environmental Effects

Scarring and disruption of the land surface

- E.g., spoils banks (no topsoil, chemical weathering & wind/water erosion)

Mountain top removal for coal

- Loss of rivers and streams
- Air pollution (coal dust)
- Groundwater disruption (release arsenic & mercury)

Biodiversity decreased

- Clearing of forests, pollution from mining wastes

Spoils Banks in Germany from Area Strip Mining

Fig. 14-16, p. 358

Mining Has Harmful Environmental Effects

- Subsurface mining (less common, produces less waste)
  - ➢ Subsidence
    - collapse of land above mines
  - ➢ Acid mine drainage
    - rainwater seeps through mine or spoil pile and carries sulfuric acid (from bacteria acting on iron sulfide)
- Major pollution of water and air
- Effect on aquatic life
- Large amounts of solid waste (3/4 of all U.S. solid waste)

Mountaintop Coal Mining in West Virginia

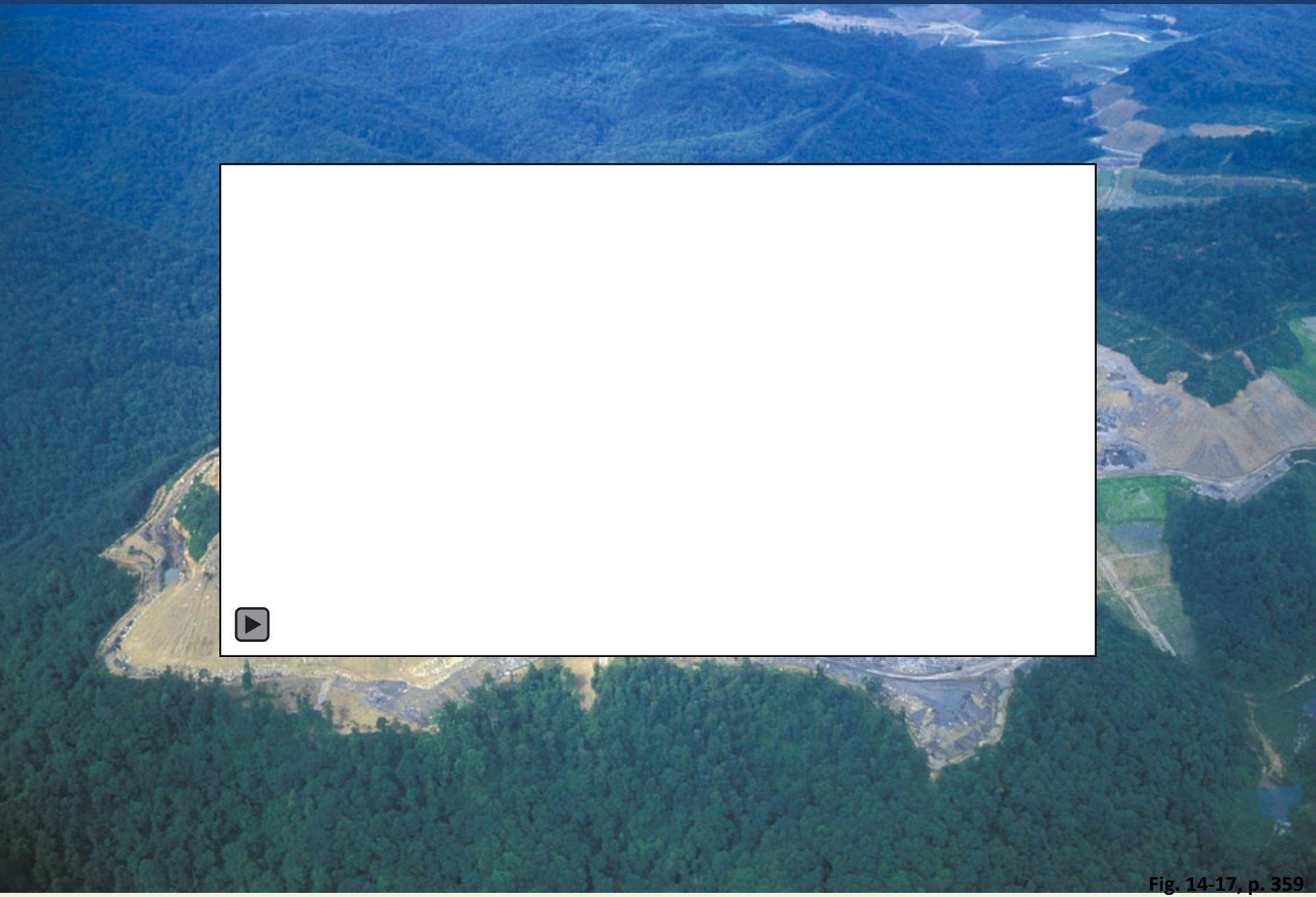


Fig. 14-17, p. 359

Ecological Restoration of a Mining Site in Indonesia

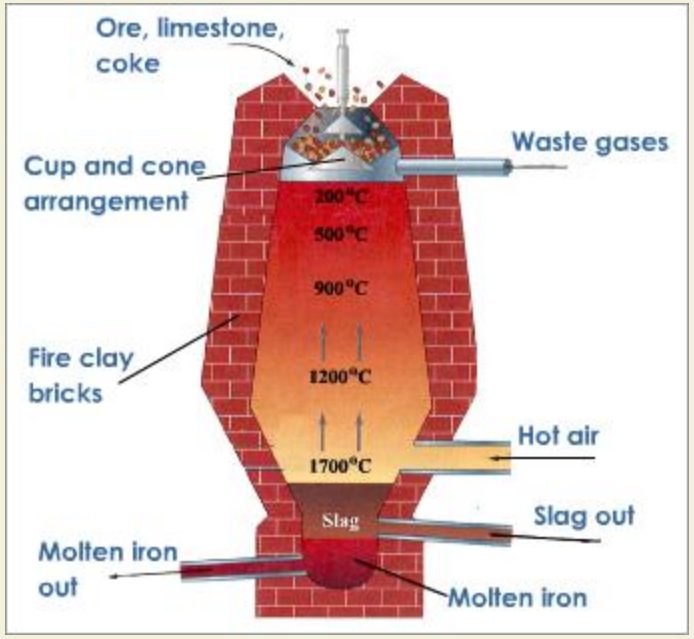
Fig. 14-18, p. 360

Removing Metals from Ores Has Harmful Environmental Effects (1)

- Ore extracted by mining
  - Ore mineral
  - Gangue = waste material
  - **Smelting** using heat or chemicals

- Air pollution
  - sulfur dioxide
  - suspended toxic particles

- Water pollution



Removing Metals 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.

Individuals Matter: Maria Gunnoe

- West Virginia environmental activist
- Won $150,000 Goldman Environmental Prize for efforts against mountaintop coal mining
- Her home
  - Flooded 7 times
  - Coal sludge in yard
  - Well contaminated

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.*

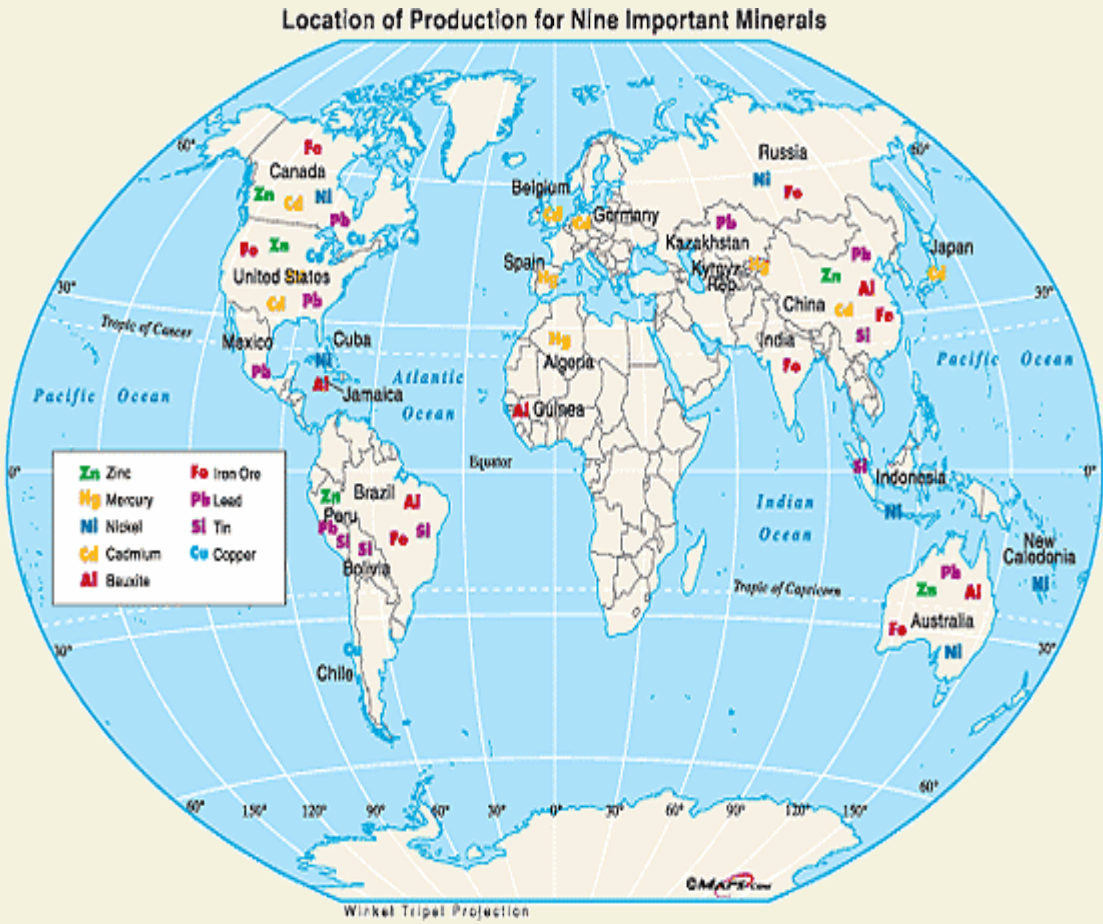
Concept 14-4B *Raising the price of a scarce mineral resource can lead to an increase in its supply, but there are environmental limits to this effect.*

Mineral Resources Are Distributed Unevenly

Most of the nonrenewable mineral resources supplied by

- United States
- Canada
- Russia
- South Africa
- Australia

- Sharp rise in per capita use in the U.S.



Strategic Metal Resources
Essential for Country's Economy & Military Strength

- Manganese (Mn)
- Cobalt (Co)
- Chromium (Cr)
- Platinum (Pt)

Supplies of Nonrenewable Mineral Resources Can Be Economically Depleted

When it becomes economically depleted

- Recycle or reuse existing supplies
- Waste less
- Use less
- Find a substitute
- Do without

- **Depletion time**: time to use a certain portion of reserves

Natural Capital Depletion: Depletion Curves for a Nonrenewable Resource

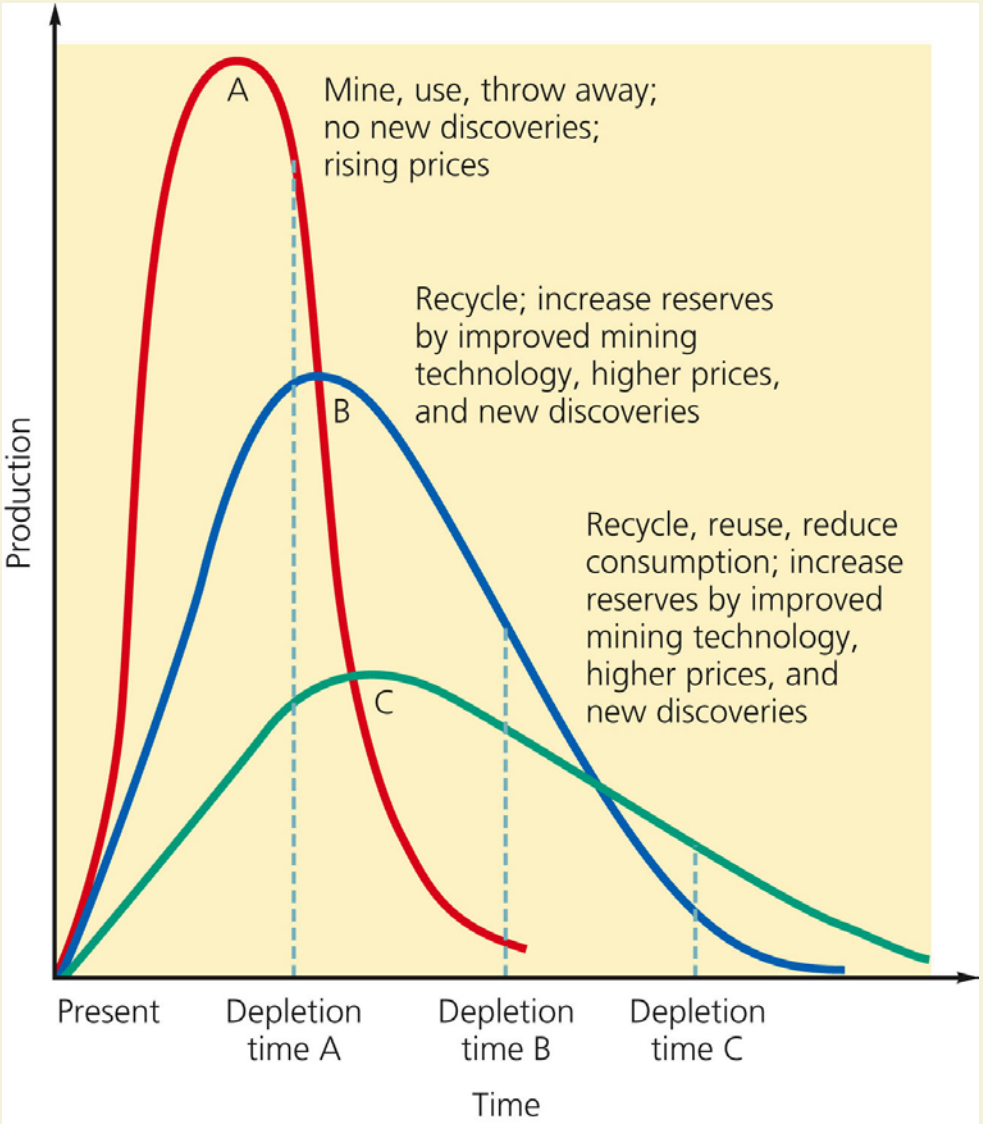


Fig. 14-19, p. 361

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 now pay for clean-up

Colorado Gold Mine Must Be Cleaned up by the EPA

Fig. 14-20, p. 363

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)

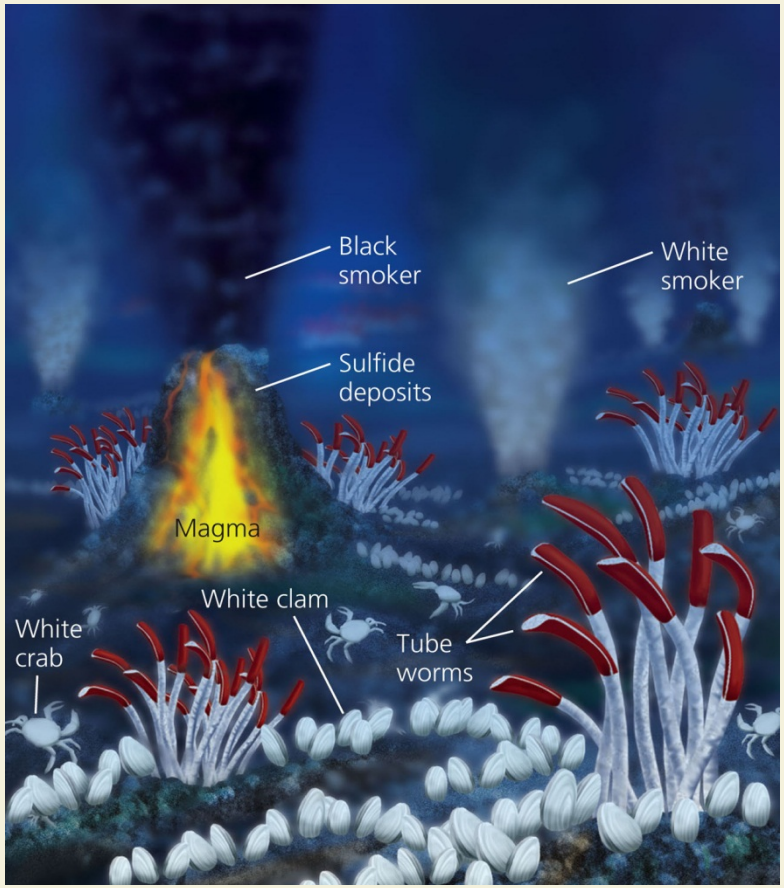
- Mineral resources dissolved in the ocean -- low concentrations

- 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?

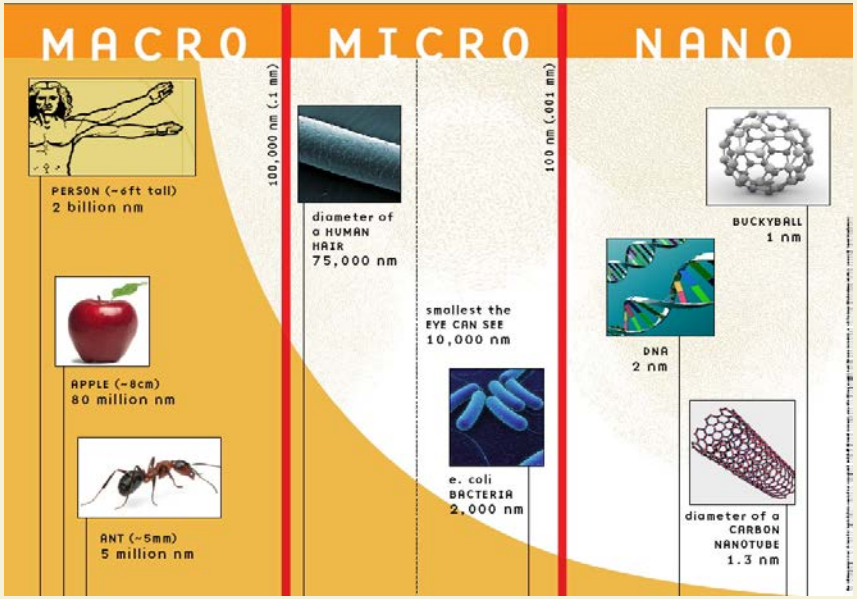
Concept 14-5 *We can try to find substitutes for scarce resources, reduce resource waste, and recycle and reuse minerals.*

We Can Find Substitutes for Some Scarce Mineral Resources

- Materials revolution
  - Ceramics
  - High-strength plastics
- Nanotechnology
- Substitution is not a cure-all
  - Pt: industrial catalyst
  - Cr: essential ingredient of stainless steel

Science Focus: The Nanotechnology Revolution

- Nanotechnology, tiny tech
  - Uses
- Nanoparticles
  - Are they safe?



- Investigate potential ecological, economic, health, and societal risks
  - Develop guidelines for their use until more is known about them

We Can Recycle and Reuse Valuable Metals

Recycling and Reusing

- Lower environmental impact than mining and processing metals from ores

We Can Use Mineral Resources More Sustainability

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.
- 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.

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

Case Study: Pollution Prevention Pays

- Begun in 1975 by 3M company, a very large manufacturing company
- Redesigned equipment and processes
- Fewer hazardous chemicals
- Recycled or sold toxic chemical outputs
- Began making nonpolluting products
- Company saved $1.2 billion
- Sparked cleaner production movement

Three Big Ideas

1. Dynamic forces that move matter within the earth and on its surface recycle the earth's rocks, form deposits of mineral resources, and cause volcanic eruptions, earthquakes, and tsunamis.

2. The available supply of a mineral resource depends on how much of it is in the earth's crust, how fast we use it, mining technology, market prices, and the harmful environmental effects of removing and using it.

3. We can use mineral resources more sustainably by trying to find substitutes for scarce resources, reducing resource waste, and reusing and recycling nonrenewable minerals.