



Chapter 12

Lecture Outline



Learning Outcomes

After studying this chapter, you should be able to answer the following questions:

- What are tectonic plates and how does their movement shape our world?
- Where and why do volcanoes and earthquakes occur?
- What are some of the environmental and social costs of mining and oil- and gas-drilling?
- How can we reduce our consumption of geologic resources?
- Explain why floods and mass wasting are problems.

*When we heal the earth, we heal
ourselves.*

–David Orr

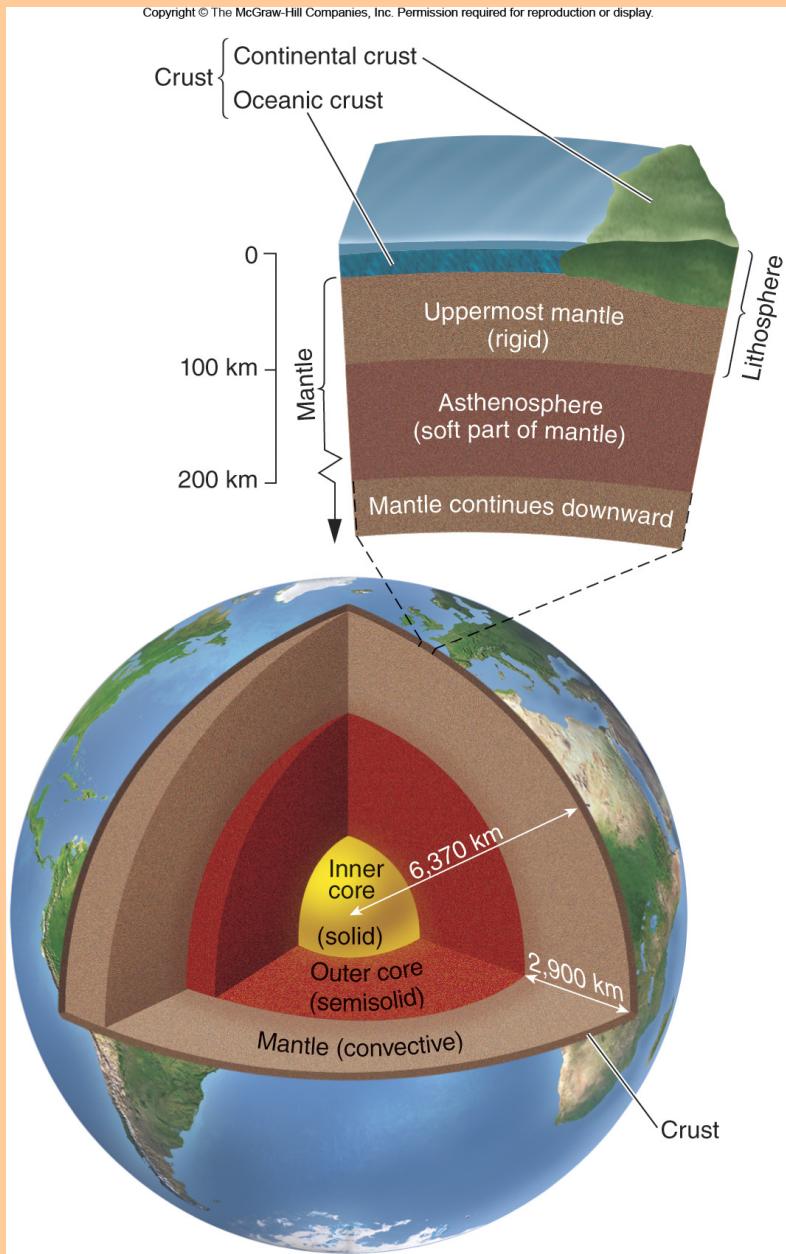
CASE STUDY:

Mountaintop Removal Mining



12.1 Earth Processes Shape Our Resources

- Many people are exposed to geologic hazards of one type or another, but all of us benefit from the earth's geological resources.
- Right now you are probably wearing several geologic products:
 - Plastics of many types are made from petroleum.
 - Iron, copper, and aluminum mines produced electrical wiring that brings you power.
 - Rare Earth metals are essential in your cell phone, your MP3 player, and your computer.
- All of us also share responsibility for the environmental problems that result from mining, drilling and processing materials.



Earth is a Dynamic Planet

- The **core** is composed of a dense, intensely hot mass of metal—mostly iron.
- **Mantle** surrounds the molten outer core, and is a hot, pliable layer of rock.
- **Crust** is the outermost cool, lightweight, brittle layer of the Earth.

TABLE 12.2 | Primary Uses of Some Major Metals

METAL	USE
Aluminum	Packaging foods and beverages (38%), transportation, electronics
Chromium	High-strength steel alloys
Copper	Building construction, electric and electronic industries
Iron	Heavy machinery, steel production
Lead	Leaded gasoline, car batteries, paints, ammunition
Manganese	High-strength, heat-resistant steel alloys
Nickel	Chemical industry, steel alloys
Platinum group	Automobile catalytic converters, electronics, medical uses
Gold	Medical, aerospace, electronic uses; accumulation as monetary standard
Silver	Photography, electronics, jewelry

Tectonic Processes Reshape Continents and Cause Earthquakes

- The Earth's crust is divided into a mosaic of huge blocks called **tectonic plates**.
- These plates slide slowly across the Earth's surface like wind-driven ice sheets on water.
- **Magma** (molten rock) forced up through the cracks forms new oceanic crust that piles up underwater in **mid-ocean ridges**.
- Earthquakes, such as the ones that struck Japan in 2011, are caused by jerking as plates grind past each other.

Map of Earth's Tectonic Plates

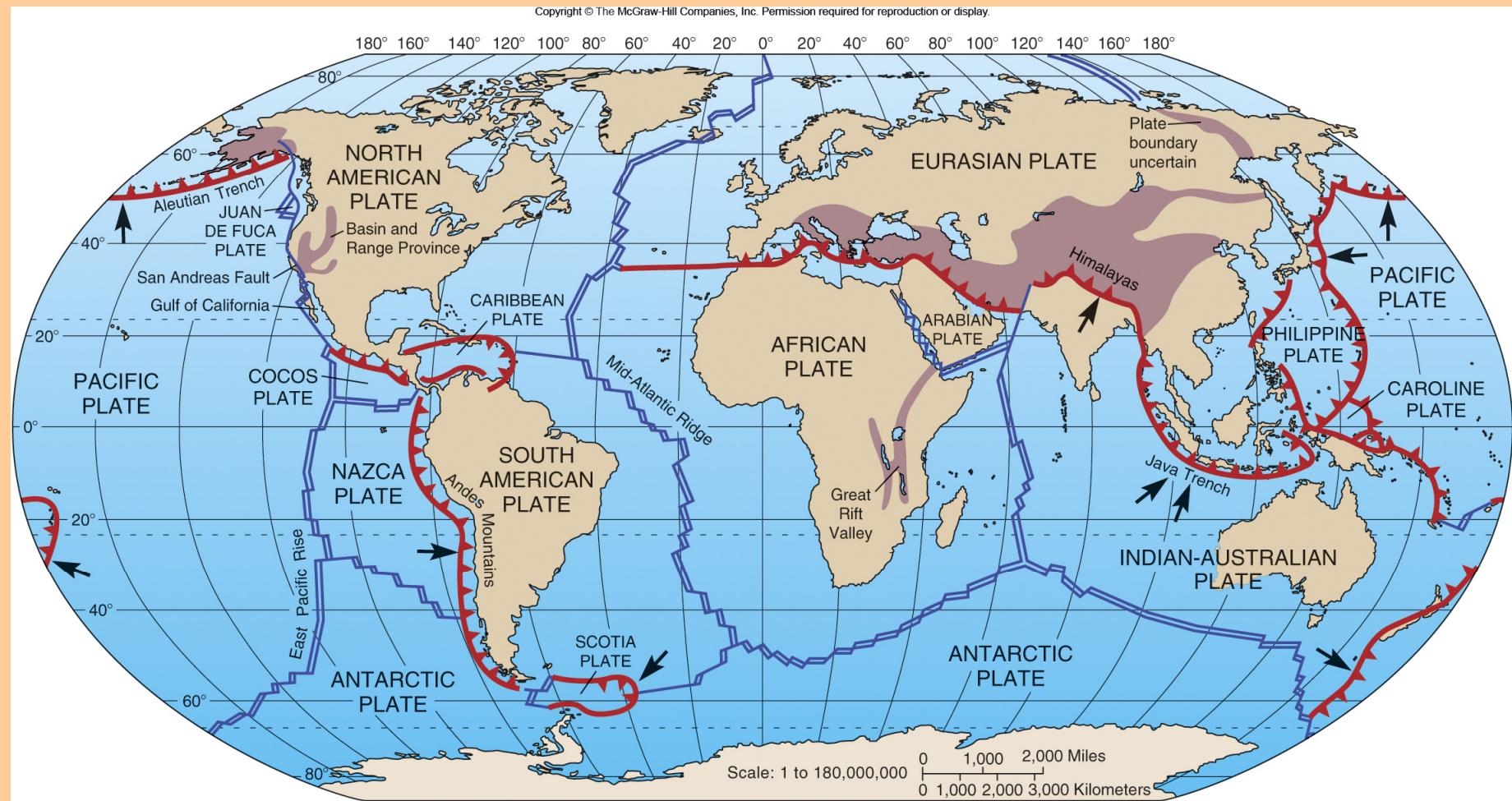
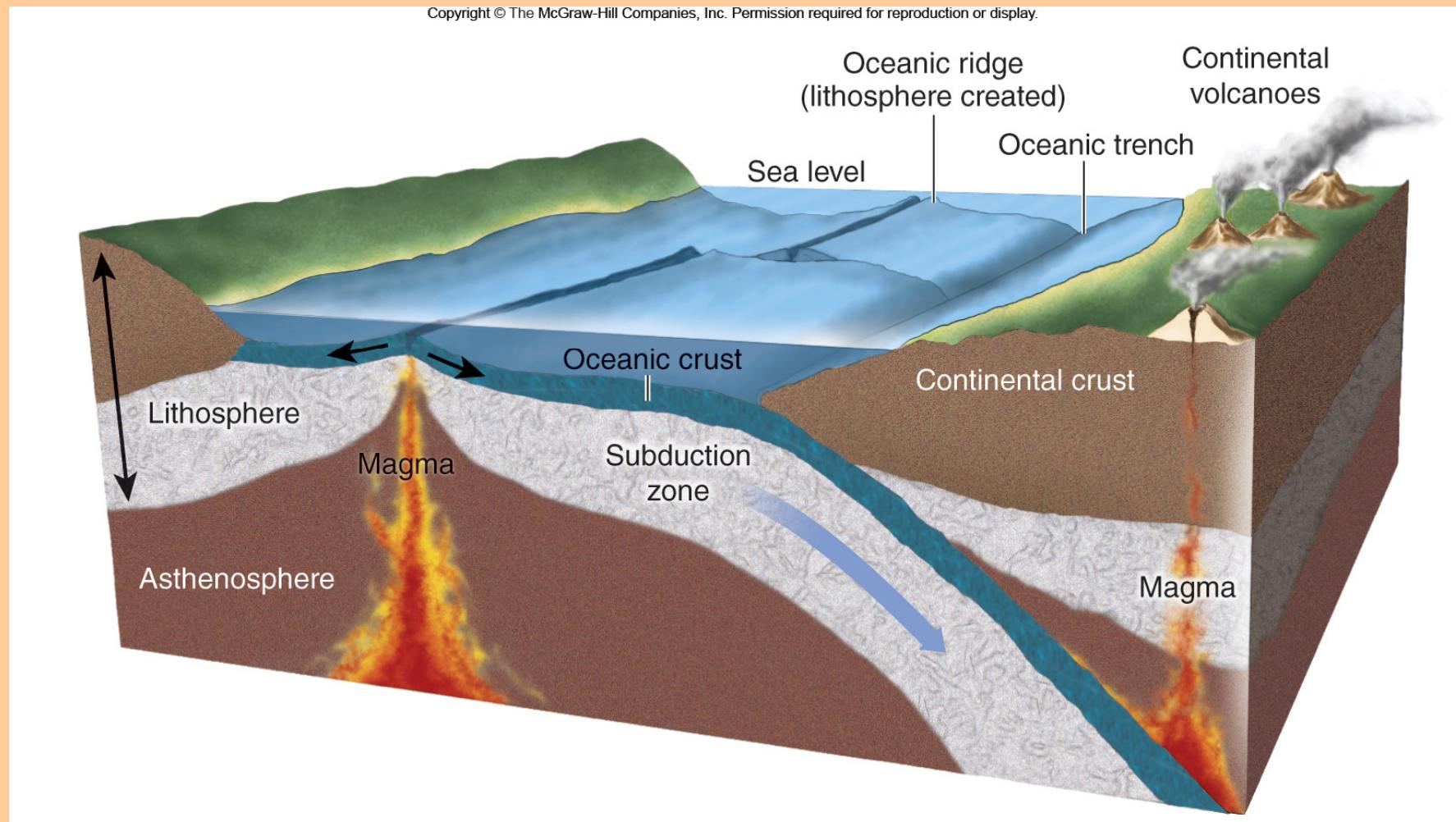
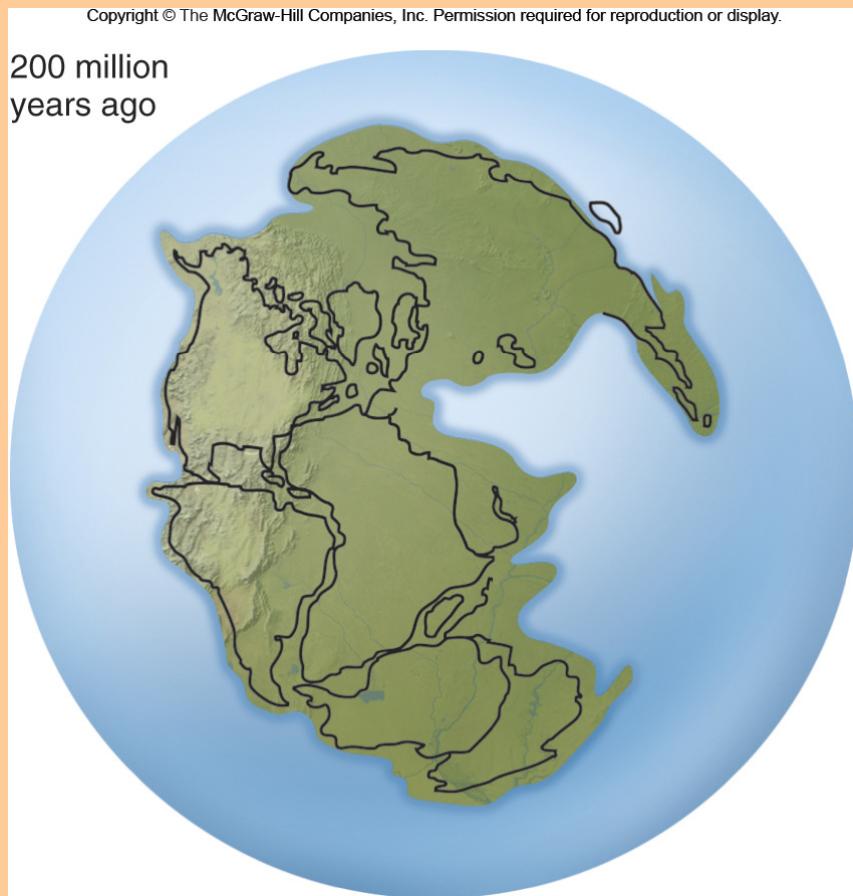


Plate Tectonic Movement: Subduction



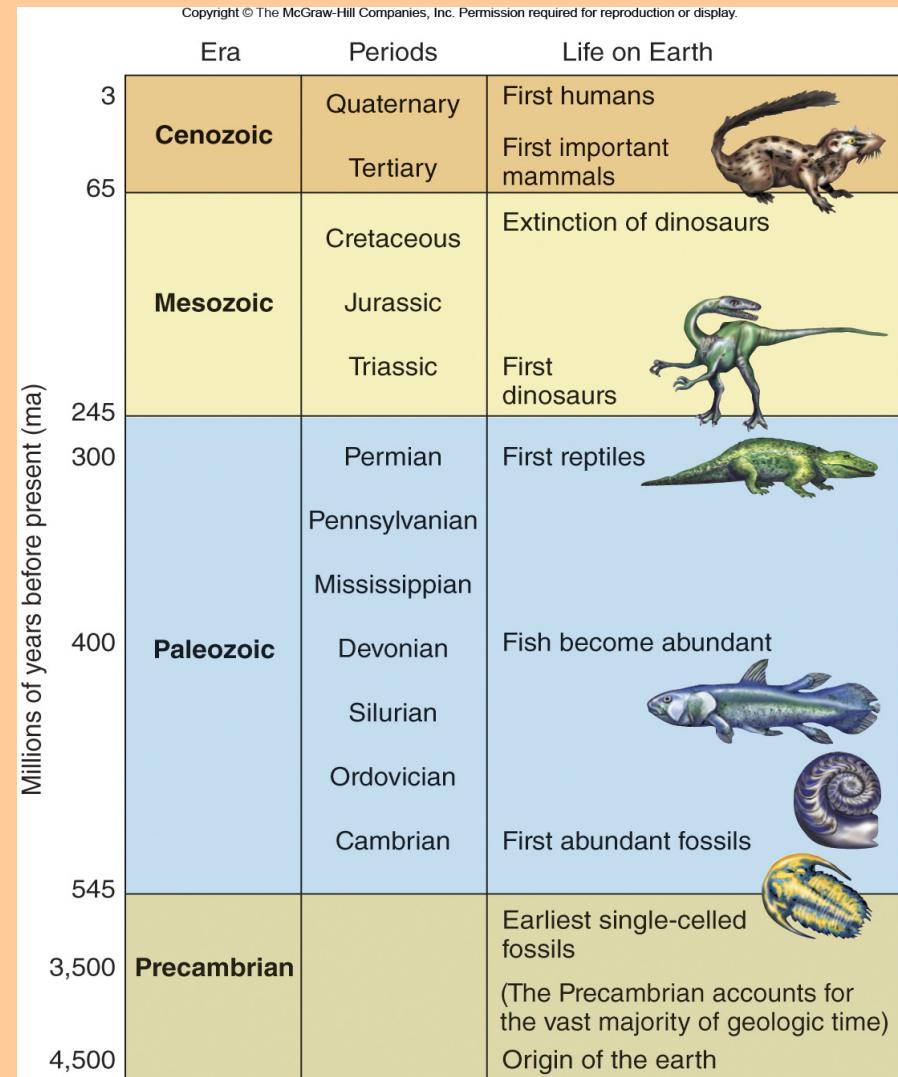
Pangea—an Ancient Supercontinent—Existed 200 Million Years Ago



- Geologists suggest that several times in the Earth's history, most or all of the continents have gathered to form supercontinents.
- These have ruptured and re-formed over hundreds of millions of years.

Periods and Eras in Geological Time

The redistribution of continents has profound effects on the Earth's climate and may help explain the periodic mass extinctions of organisms marking the divisions between many major geologic periods.



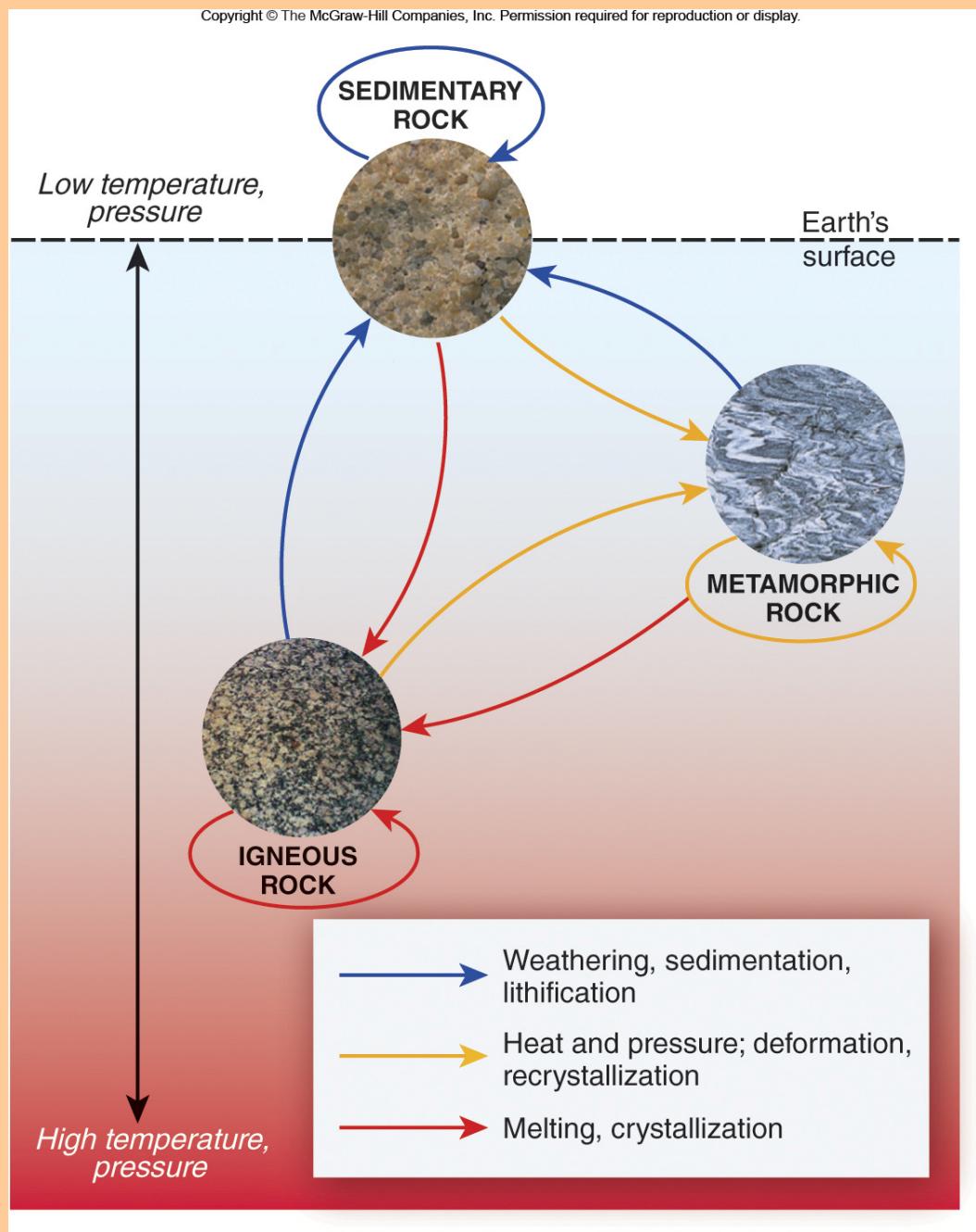
12.2 Minerals and Rocks

- A **mineral** is a naturally occurring, inorganic solid with a specific chemical composition and a specific internal crystal structure.
- **Metals** (such as iron, copper, aluminum, or gold) come from mineral ores, but once purified, metals are no longer crystalline and thus are not minerals.
- A **rock** is a solid, cohesive aggregate of one or more minerals.

The Rock Cycle Creates and Recycles Rocks

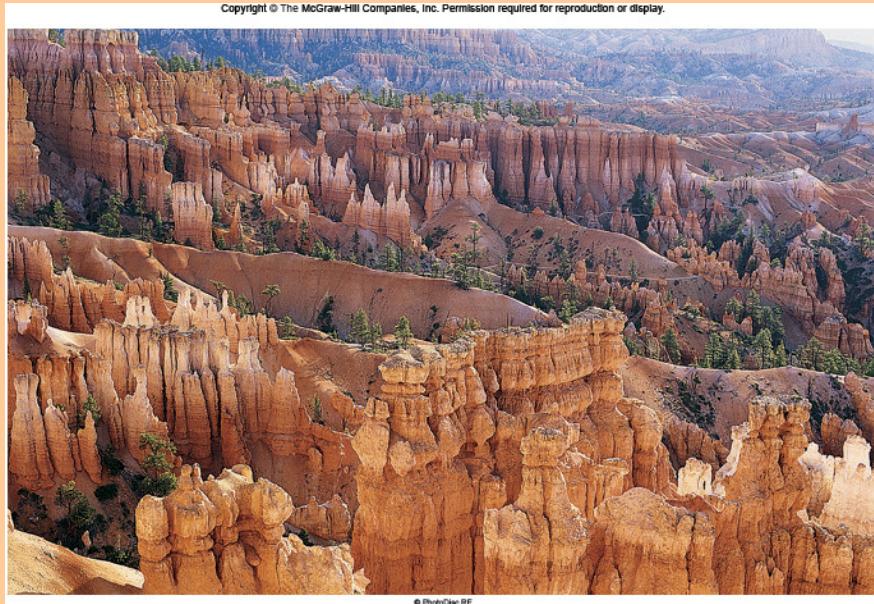
- Rocks are part of a relentless cycle of formation and destruction called the **rock cycle**.
- There are three major rock classifications: igneous, metamorphic, and sedimentary.
 - **Igneous rocks** are solidified from hot, molten magma or lava.
 - **Metamorphic rocks** form from the melting, contorting, and recrystallizing of other rocks.
 - **Sedimentary rocks** are formed when loose grains of other rocks are consolidated by time and pressure.

The Rock Cycle



Sedimentary Rock Experiences

Erosion



- Particles of rock loosened by wind, water, ice, and other weathering forces are carried by wind or water until they come to rest again in a new place.
- The deposition of these materials is called **sedimentation** and erosion can further carve these rocks.

Weathering

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Courtesy of David McGahey

12.3 Economic Geology and Mineralogy

- The Earth is unusually rich in mineral variety. Mineralogists have identified some 4,400 different mineral species; far more, we believe, than any of our neighboring planets.
- Economic mineralogy is the study of resources that are valuable for manufacturing and trade.
- Most economic minerals are metal ores, minerals with unusually high concentrations of metals.
- The mining, processing, and distribution of these materials have broad implications for both our culture and our environment.

Metals are Essential to our Economy



- Metals are useful and valuable because they are strong, malleable, and can be reshaped for many purposes.
- Their availability and use have influenced economic and political power for individuals and nations.

World Industrial Consumption of Metals

- The metals consumed in greatest quantity by world industry include iron (740 million metric tons annually), aluminum (40million metric tons), manganese (22.4 million metric tons), copper and chromium (8 million metric tons each), and nickel (0.7 million metric tons).
- Russia, China, Canada, the United States, and Australia, for example, are especially rich in metal resources. South Africa is unusually rich in diamonds, gold, and other valuable minerals.

Nonmetal Mineral Resources Include Gravel, Clay, Glass, and Salts

- Nonmetal minerals include:
 - *Sand and gravel* production for road and building construction comprise by far the greatest volume and dollar value of all nonmetal mineral resources.
 - *High-purity silica sand* is our source of glass.
 - *Limestone* is mined and quarried for concrete, crushed for road rock.
 - *Halite*, or *rock salt*, is used for water softening and ice melting on winter roads in northern areas or refined for use as table salt.
 - *Gypsum (calcium sulfate)* now makes our plaster wallboard.

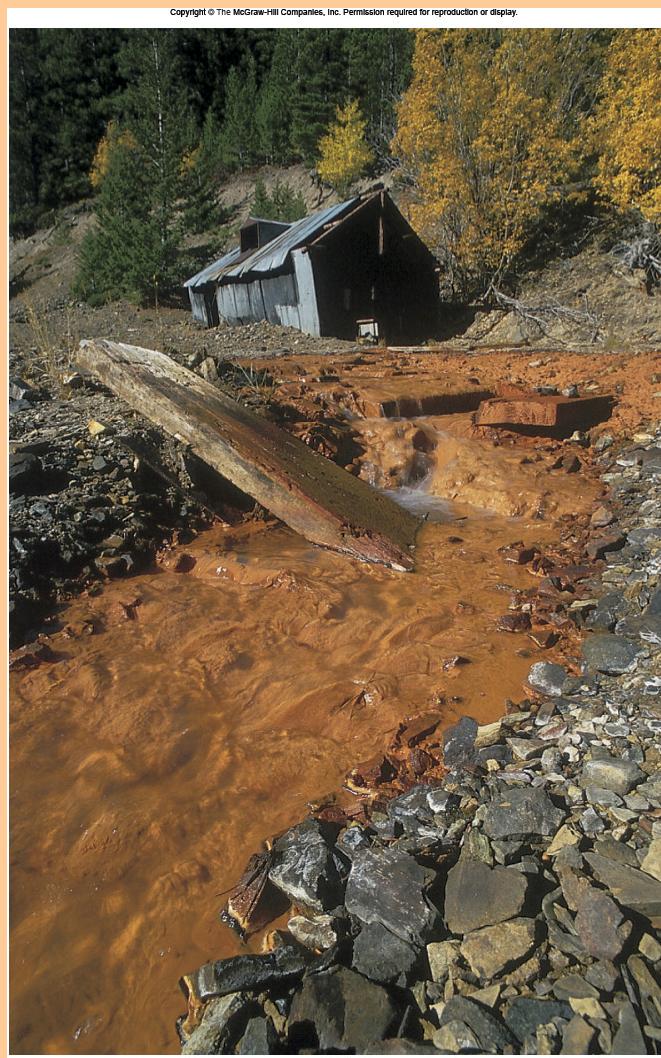
Currently, the Earth Provides Almost All of Our Fuel

- Currently, society functions largely on energy produced from geologic deposits of oil, coal, and natural gas.
- These fuels are created over millions of years as extreme heat and pressure transformed the remains of ancient organisms. Although they are organic rather than mineral, they can be considered part of economic mineralogy and are important geologic resources.
- Nuclear energy, which runs on uranium (a radioactive mineral), provides about 20% of our electricity.

12.4 Environmental Effects of Resource Extraction

- The most obvious effect of mining and well drilling is often the disturbance or removal of the land surface. Farther-reaching effects, though, include air and water pollution.
- The EPA lists more than 100 toxic air pollutants released from U.S. mines and wells every year.
- Sediment runoff and acidic mine runoff has damaged or destroyed aquatic ecosystems in many places.
- After use in ore processing, much of the rinse water contains arsenic, heavy metals, and other contaminants and is unsuitable for any other use.

Acid and Metal-Laced Pollutants Leaching from an Abandoned Mine



Mining and Drilling can Degrade Water Quality

- There are many techniques for extracting geologic materials. The most common methods are open-pit mining, strip-mining, and underground mining.
- An ancient method of acquiring gold is **placer mining**, in which pure nuggets are washed from stream sediments. This method chokes stream ecosystems with sediment.
- With underground mining, water seeps into mine shafts and can dissolve toxic minerals and then seep into groundwater or enter streams and lakes.

Methane Extraction

- A current controversy in the United States involves extraction of methane gas from coal deposits that are too deep or too dispersed for mining.
- Because the gas doesn't migrate easily through tight shales, it often takes many closely spaced wells to extract this methane.
- Perhaps even worse is the effect on water supplies.

Methane Extraction Well in a Shale-bed

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Courtesy Mike Williams, Ohio Department of Natural Resources
Division of Mineral Resources Management

Hydraulic Fracturing Can Contaminate Water Also

- A current controversy in the United States involves extraction of methane gas from coal deposits that are too deep or too disperse for mining.
- To boost well output, mining companies rely on **hydraulic fracturing**. A mixture of water, sand, and toxic chemicals is pumped into the ground at extremely high pressure to crack sediments and release the gas.
- This often disrupts aquifers, however, and contaminates wells.

Surface Mining Destroys Landscapes

- Open-pit mines are used to extract massive beds of metal ores and other minerals.
- A chief environmental challenge of open-pit mining is that groundwater accumulates in the pit.
- In metal mines, a toxic soup results.
- No one yet knows how to detoxify these lakes which endanger wildlife and nearby watersheds.

Strip Mining

- Half the coal used in the United States comes from strip mines.
- The entire land surface covering a coal bed can be stripped away to cheaply and quickly expose the coal. The overburden, or surface material, is placed back into the mine, but with no topsoil, re-vegetation occurs very slowly.
- The 1977 Federal Surface Mining Control and Reclamation Act (SMCRA) requires better restoration of strip-mined lands, but restoration is expensive.

Strip Mining

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Surface Mines Revegetate Slowly

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Processing Contaminates

Air, Water, and Soil

- Metals are extracted from ores by heating or by using chemical solvents. Both processes release large quantities of toxic materials that can be even more environmentally hazardous than mining.
- **Smelting**— roasting ore to release metals—is a major source of air pollution.
- Chemical extraction is used to dissolve or mobilize pulverized ore but it uses and pollutes a great deal of water. Chemicals used include toxins like cyanide.

12.5 Conserving Geologic Resources

- Conservation offers great potential for extending our supplies of economic minerals and reducing the effects of mining and processing.
- The advantages of conservation are significant: less waste to dispose of, less land lost to mining, and less consumption of money, energy, and water resources.

Recycling Saves Energy as Well as Materials

- Some waste products are already being exploited, especially for scarce or valuable metals.
- Recycling waste aluminum, such as beverage cans, consumes 1/20 of the energy of extracting new aluminum.
- Today, nearly 2/3 of all aluminum beverage cans in the United States are recycled, up from only 15 percent 20 years ago.
- Other commonly recycled metals are gold, silver, copper, lead, iron, and steel.

Metals Can be Mined From Old Cars



New Materials Can Replace Mined Resources

- Mineral and metal consumption can be reduced by new materials or new technologies developed to replace traditional uses.
- The introduction of plastic pipe has decreased our consumption of copper, lead, and steel pipes. In the same way, the development of fiber-optic technology and satellite communication reduces the need for copper telephone wires.

12.6 Geologic Hazards

- Earthquakes, volcanoes, floods, and landslides are normal Earth processes that have made our Earth what it is today.
- However, when they affect human populations, their consequences can be among the worst and most feared disasters that befall us.

Earthquakes are Frequent and Deadly Hazards

- **Earthquakes** are sudden movements in the Earth's crust that occur along faults (planes of weakness), where one rock mass slides past another one.
- **Tsunamis** are giant sea swells that can move at speeds in excess of 1,000 kph (600 mph). About 25,000 people were killed and four nuclear reactors were destroyed by the 2011 Japanese tsunami.
- In 2004 an earthquake and tsunami off the coast of Indonesia, for example, killed over 230,000 people!

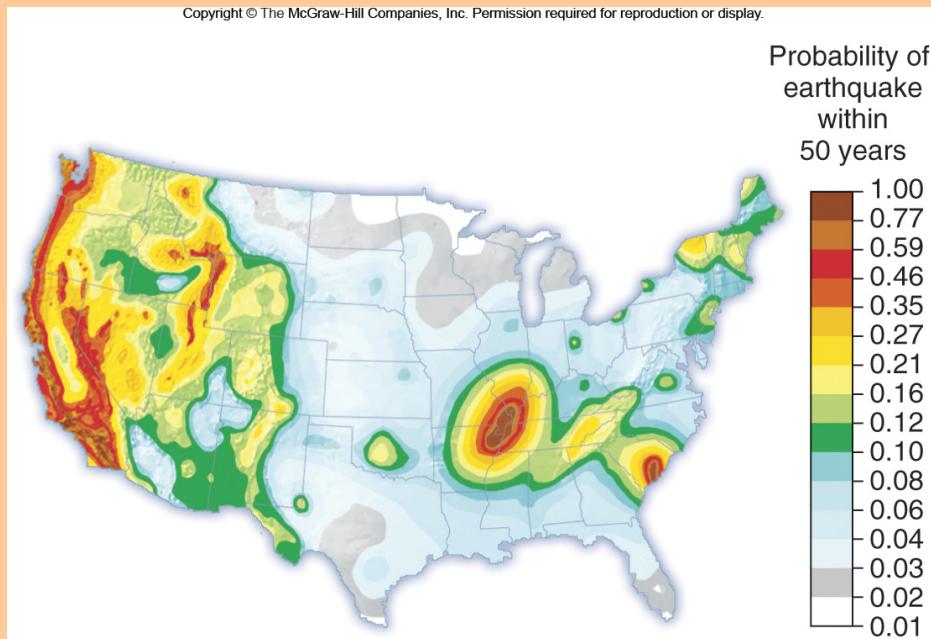
2011 Japanese Earthquake & Tsunami

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Where Do Earthquakes Occur?



- Earthquakes frequently occur along the edges of tectonic plates, but earthquakes sometimes also occur in the centers of continents.
- The largest earthquake in North America was a magnitude 8.8 quake that struck New Madrid, Missouri, in 1812.

Volcanoes Eject Deadly Gases and Ash



Volcanoes and undersea magma vents are the sources of most of the Earth's crust.

Volcanic Activity at Mt. Ranier

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Floods are Part of a River's Land-Shaping Processes



- Like earthquakes and volcanoes, **floods** are normal events that cause damage when people get in the way.
- As rivers carve and shape the landscape, they build broad **floodplains**, level expanses that are periodically inundated.

Flood control

- After the 1927 floods the U.S. Army Corps of Engineers was ordered to control the Mississippi River.
- They built the world's longest system of levees and flood walls, but every levee simply transfers the problem downstream.
- In recent years, however, this elaborate system helped turn large floods into major disasters.
- Some now believe that floodplains should only be used for wildlife habitat, parks, and recreation areas.



Mass Wasting Includes Slides and Slumps

- **Landslides** are sudden collapses of hillsides. In the United States alone, landslides and related mass wasting cause over \$1 billion in property damage every year.

Erosion Destroys Fields and Undermines Buildings

- Beach erosion occurs on all sandy shorelines because the motion of the waves is constantly redistributing sand and other sediments.
- Normally, fragile vegetation holds the shifting sand in place on a barrier island, but breaching dunes with roads can destabilize barrier islands. Storms then wash away beaches or even whole islands.
- Erosion from Hurricane Katrina in 2005 caused \$100 billion in property damage along the Gulf coast of the United States.

Beach Erosion on Dauphin Island After Hurricane Katrina

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Photo courtesy of the U.S. Geological Survey

Conclusion

- Geologic hazards, including earthquakes, volcanic eruptions, tsunamis, floods, and landslides represent major threats.
- Devastating events have altered human history many times in the past, sending geopolitical, economic, genetic, and even artistic repercussions around the planet.
- Earth resources, including oil, gas, and coal, are the foundation of our economy.
- Many materials can be recycled, saving money, energy, and environmental quality.