

The Dynamic Earth

CHAPTER 3

- 1 The Geosphere
- 2 The Atmosphere
- 3 The Hydrosphere and Biosphere



READING WARM-UP

Before you read this chapter, take a few minutes to answer the following questions in your **EcoLog**.

1. What is one way in which air, rock, and water can affect living things?
2. What are three conditions that allow life on Earth to survive?

Landmasses are moving slowly across our planet's surface. The atmosphere is a swirling mix of gases and vapor. Our planet, which may appear placid from space, is not stable and unchanging.

SECTION 1

The Geosphere

Molten rock from Earth's interior flows over the surface of the planet, and violent eruptions blow the tops off of volcanoes. Hurricanes batter beaches and change coastlines. Earthquakes shake the ground and topple buildings and freeway overpasses. None of this activity is caused by people. Instead, it is the result of the dynamic state of planet Earth. What are the conditions that allow us to survive on a constantly changing planet?

The Earth as a System

The Earth is an integrated system that consists of rock, air, water, and living things that all interact with each other. Scientists divide this system into four parts. As shown in **Figure 1**, the four parts are the geosphere (rock), the atmosphere (air), the hydrosphere (water), and the biosphere (living things).

The solid part of the Earth that consists of all rock, and the soils and sediments on Earth's surface, is the **geosphere**. Most of the geosphere is located in Earth's interior. At the equator, the average distance through the center of the Earth to the other side is 12,756 km. The atmosphere is the mixture of gases that makes up the air we breathe. Nearly all of these gases are found in the first 30 km above the Earth's surface. The hydrosphere makes up all of the water on or near the Earth's surface. Much of this water is in the oceans, which cover nearly three-quarters of the globe. Water is also found in the atmosphere, on land, and in the soil. The biosphere is made up of parts of the geosphere, the atmosphere, and the hydrosphere. The biosphere is the part of the Earth where life exists. It is a thin layer at Earth's surface that extends from about 9 km above the Earth's surface down to the bottom of the ocean.

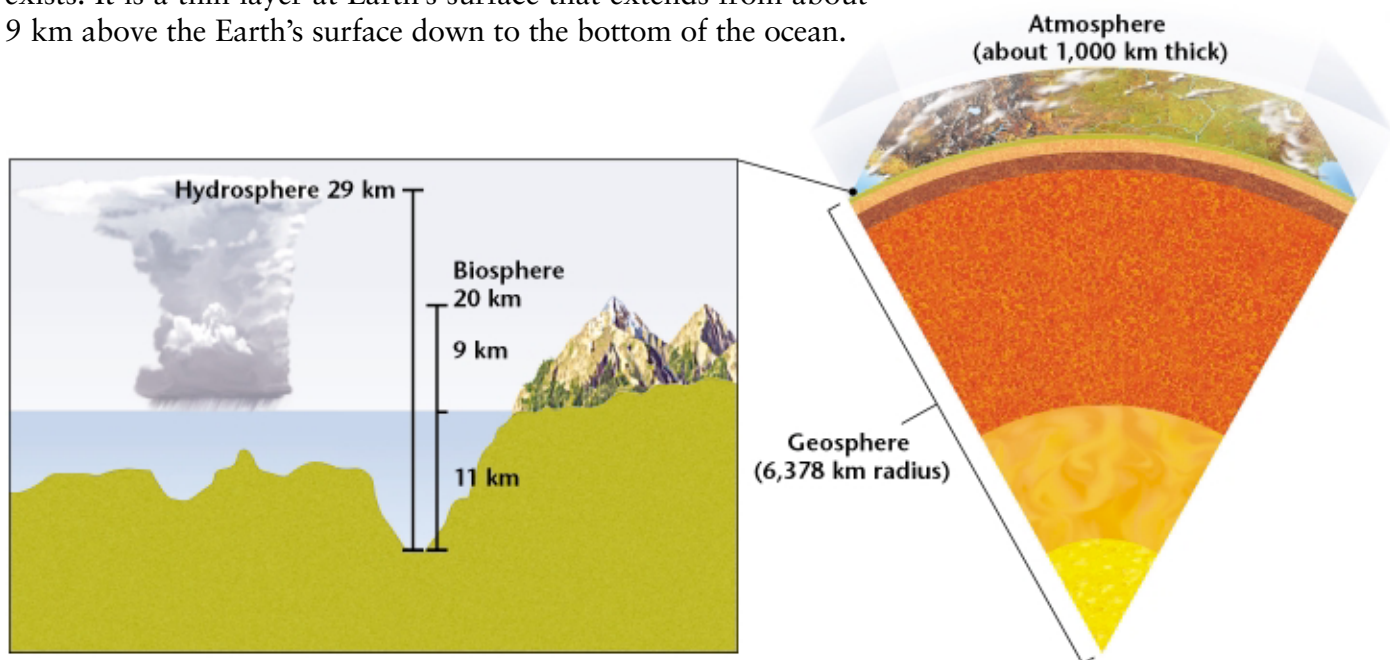
Objectives

- ▶ Describe the composition and structure of the Earth.
- ▶ Describe the Earth's tectonic plates.
- ▶ Explain the main cause of earthquakes and their effects.
- ▶ Identify the relationship between volcanic eruptions and climate change.
- ▶ Describe how wind and water alter the Earth's surface.

Key Terms

geosphere
crust
mantle
core
lithosphere
asthenosphere
tectonic plate
erosion

Figure 1 ▶ The Earth is an integrated system that consists of the geosphere, the atmosphere, the hydrosphere, and the biosphere (inset).



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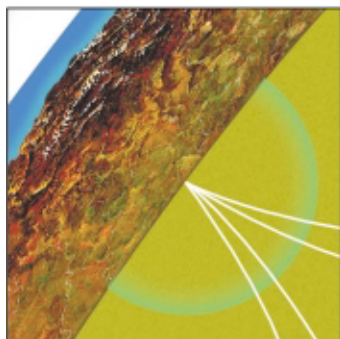
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Discovering Earth's Interior

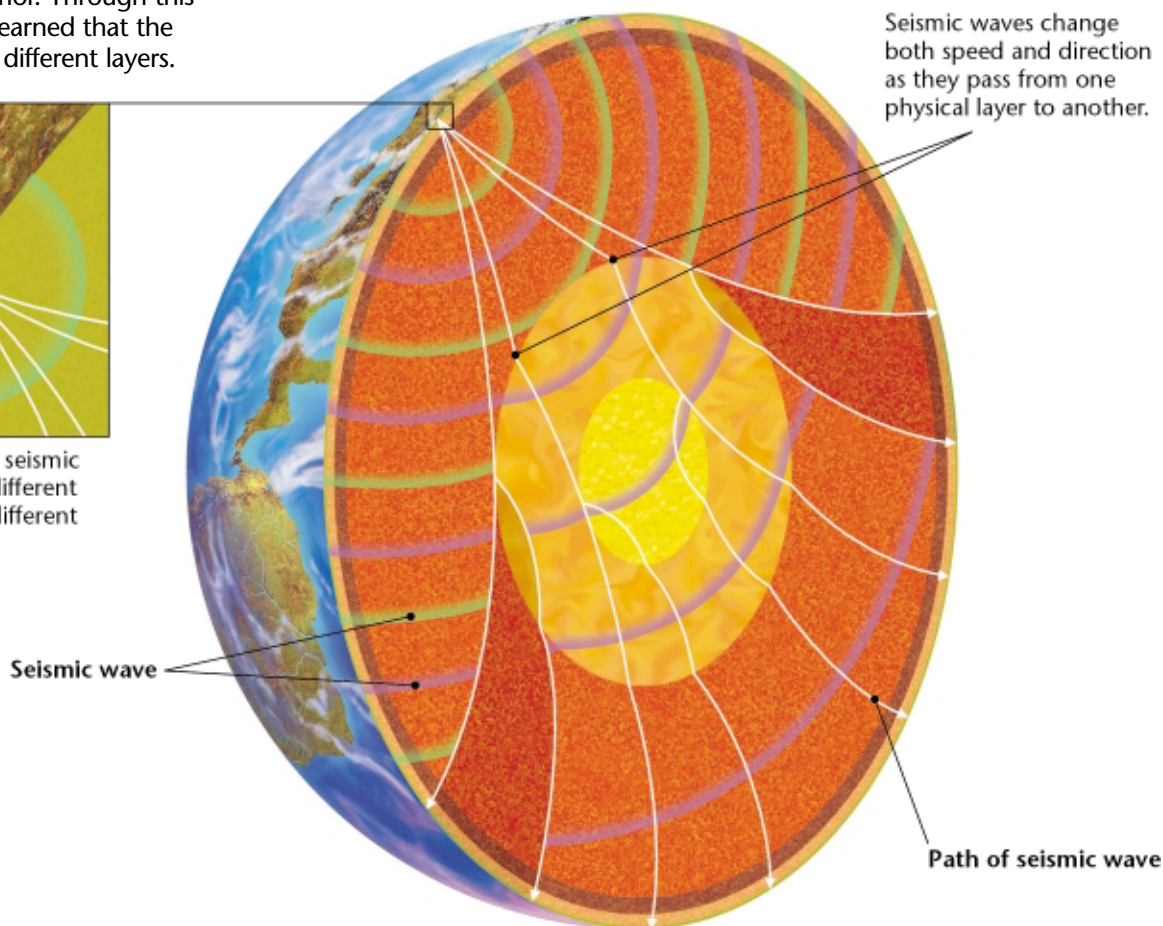
Studying the Earth beneath our feet is not easy. The deepest well that has been drilled into Earth's interior is only about 12 km deep and gives us no direct information about conditions farther beneath the surface. An alternative method must be used to study the interior of the Earth. Scientists can use *seismic waves* to learn about Earth's interior. Seismic waves are the same waves that travel through Earth's interior during an earthquake. If you have ever tapped a melon to see if it is ripe, you know how this process works. The energy of your tap travels through the melon, and the state of the melon's interior affects the sound you detect. A seismic wave is also altered by the nature of the material through which it travels. As shown in **Figure 2**, seismologists measure changes in the speed and direction of seismic waves that penetrate the interior of the planet. In this way seismologists have learned that the Earth is made up of different layers and have inferred what substances make up each layer.

The Composition of the Earth Scientists divide the Earth into three layers—the crust, the mantle, and the core—based on the composition of each layer. These layers are made up of progressively denser materials toward the center of the Earth. **Figure 3** shows a cross section of the Earth. Earth's thin outer layer, the **crust**, is made almost entirely of light elements. It makes up less than 1 percent of the planet's mass. The crust is Earth's thinnest

Figure 2 ▶ Seismologists have measured changes in the speed and direction of seismic waves that travel through Earth's interior. Through this process, they have learned that the Earth is made up of different layers.



Earthquakes produce seismic waves that travel at different speeds through the different layers of the Earth.



layer. It is 5 km to 8 km thick beneath the oceans and is 20 km to 70 km thick beneath the continents. The **mantle**, which is the layer beneath the crust, makes up 64 percent of the mass of the Earth. The mantle is approximately 2,900 km thick and is made of rocks of medium density. Earth's innermost layer is the **core**. The core is composed of the densest elements. It has a radius of approximately 3,400 km.

The Structure of the Earth The Earth can be divided into five layers based on the physical properties of each layer. Earth's outer layer is the **lithosphere**. It is a cool, rigid layer that is 15 km to 300 km thick that includes the crust and uppermost part of the mantle. It is divided into huge pieces called *tectonic plates*. The **asthenosphere** is the layer beneath the lithosphere. The asthenosphere is a plastic, solid layer of the mantle made of rock that flows very slowly and allows tectonic plates to move on top of it. Beneath the asthenosphere is the mesosphere, the lower part of the mantle.

The Earth's outer core is a dense liquid layer. At the center of the Earth is the dense, solid inner core, which is made up mostly of the metals iron and nickel. The temperature of the inner core is estimated to be between 4,000°C to 5,000°C. Even though the inner core is so hot, it is solid because it is under enormous pressure. Earth's outer and inner core together make up about one-third of Earth's mass.



Geofact

Pangaea Two hundred and forty-five million years ago almost all the land on Earth was joined into one supercontinent known as *Pangaea*, which is Greek for "all earth." Pangaea was surrounded by a world ocean called *Panthalassa*, which means "all sea." By the time the dinosaurs became extinct 65 million years ago, Pangaea had separated into all the present continents with positions close to the present positions.

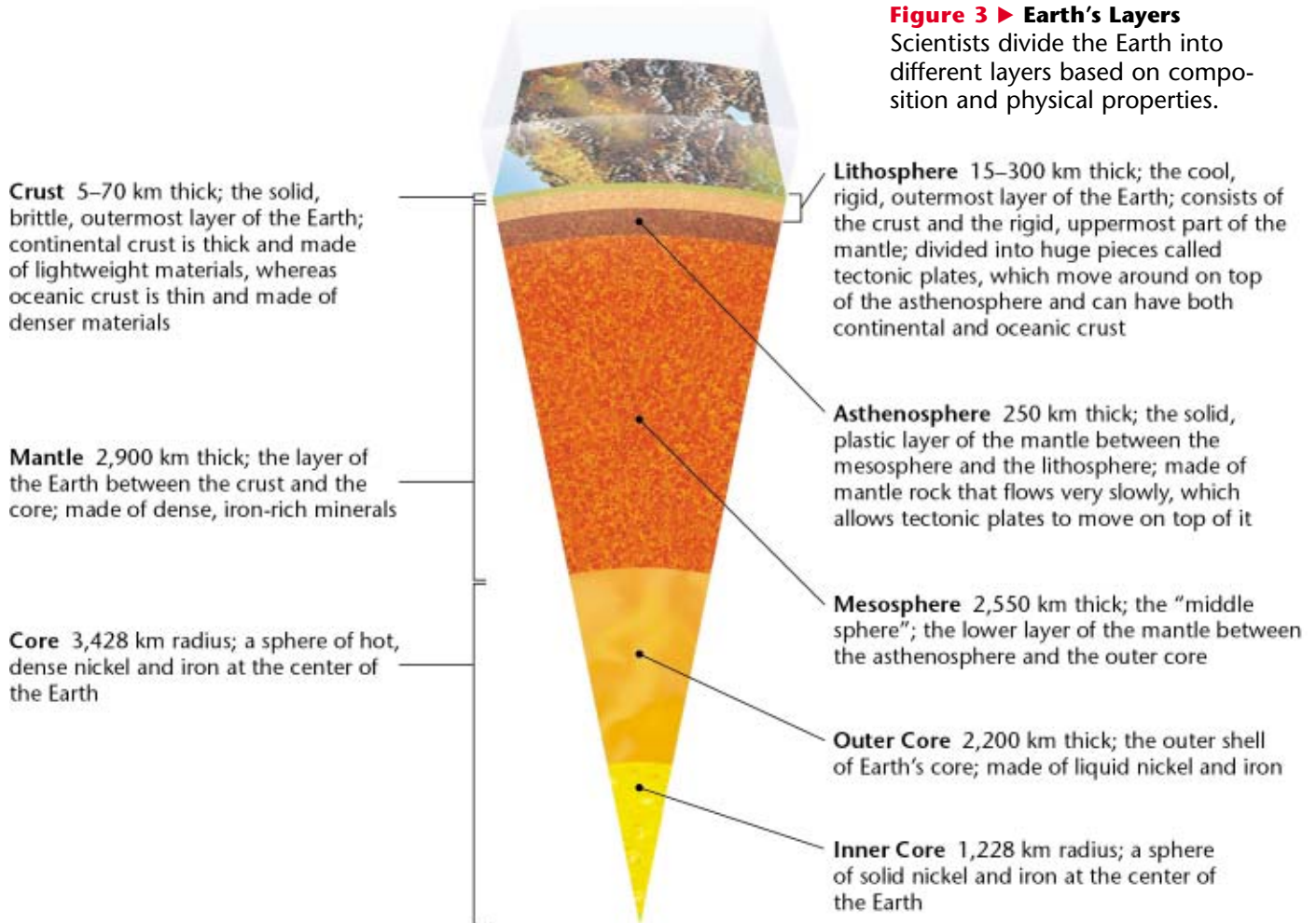


Figure 3 ▶ **Earth's Layers**

Scientists divide the Earth into different layers based on composition and physical properties.

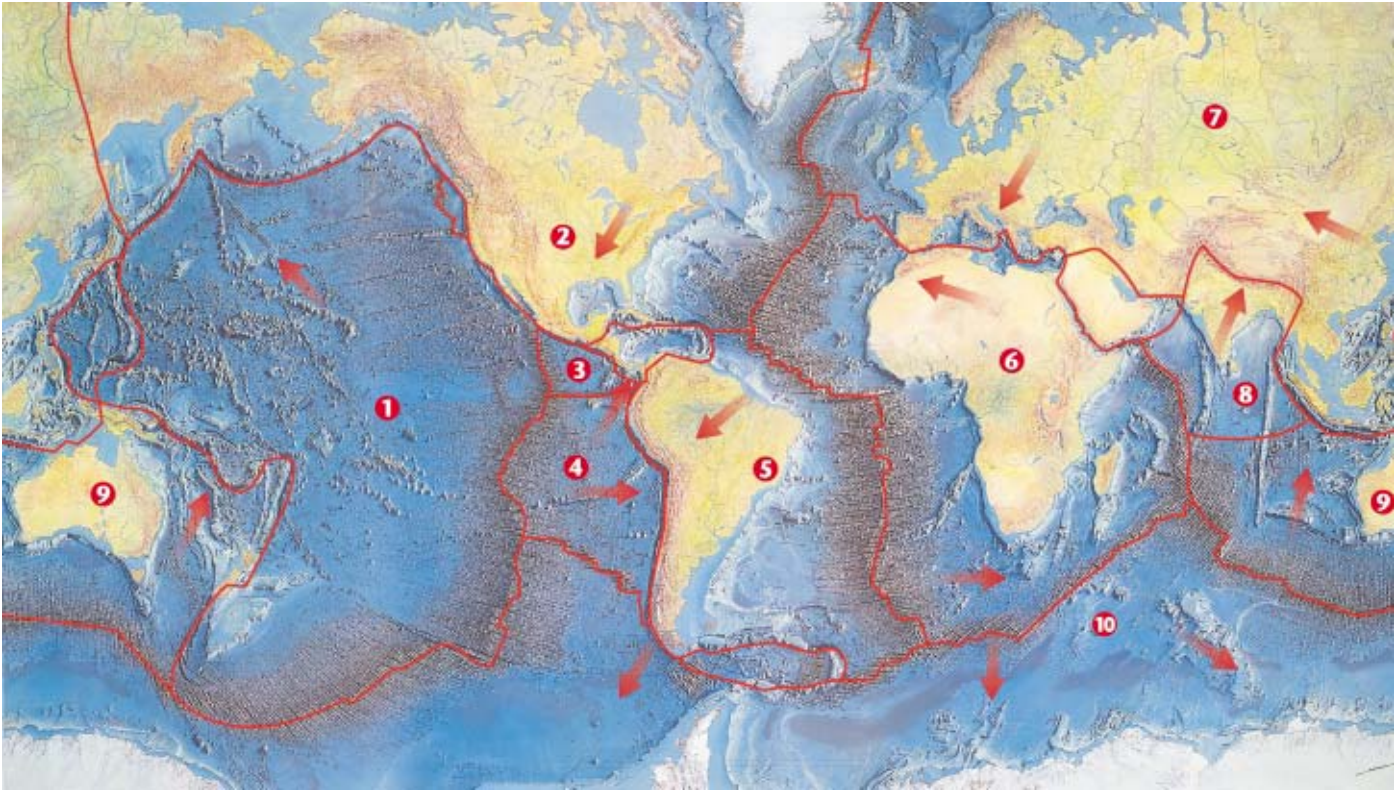


Figure 4 ▶ Earth's lithosphere is divided into pieces called *tectonic plates*. The tectonic plates are moving in different directions and at different speeds.

Major Tectonic Plates

- 1 Pacific plate
- 2 North American plate
- 3 Cocos plate
- 4 Nazca plate
- 5 South American plate
- 6 African plate
- 7 Eurasian plate
- 8 Indian plate
- 9 Australian plate
- 10 Antarctic plate

Plate Tectonics

You learned that the lithosphere—the rigid, outermost layer of the Earth—is divided into pieces called **tectonic plates**. These plates glide across the underlying asthenosphere in much the same way as a chunk of ice drifts across a pond. The continents are located on tectonic plates and move around with them. The major tectonic plates include the Pacific, North American, South American, African, Eurasian, and Antarctic plates. **Figure 4** illustrates the major tectonic plates and their direction of motion.

Plate Boundaries Much of the geologic activity at the surface of the Earth takes place at the boundaries between tectonic plates. Plates may separate from one another, collide with one another, or slip past one another. Enormous forces are generated at tectonic plate boundaries, where the crust is pulled apart, is squeezed together, or is constantly slipping. The forces produced at the boundaries of tectonic plates can cause mountains to form, earthquakes to shake the crust, and volcanoes to erupt.

Plate Tectonics and Mountain Building Tectonic plates are continually moving around the Earth's surface. When tectonic plates collide, slip by one another, or pull apart, enormous forces cause rock to break and buckle. Where plates collide, the crust becomes thicker and eventually forms mountain ranges. The Himalaya Mountains, as shown in **Figure 5**, began to form when the tectonic plate containing Asia and the tectonic plate containing India began to collide 50 million years ago.

Earthquakes

A *fault* is a break in the Earth's crust along which blocks of the crust slide relative to one another. When rocks that are under stress suddenly break along a fault, a series of ground vibrations is set off. These vibrations of the Earth's crust caused by slippage along a fault are known as *earthquakes*. Earthquakes are occurring all of the time, but many are so small that we cannot feel them. Other earthquakes are enormous movements of the Earth's crust that cause widespread damage.

The Richter scale is used by scientists to quantify the amount of energy released by an earthquake. The measure of the energy released by an earthquake is called *magnitude*. The smallest magnitude that can be felt is approximately 2.0, and the largest magnitude that has ever been recorded is 9.5. Each increase of magnitude by one whole number indicates the release of 31.7 times more energy than the whole number below it. For example, an earthquake of magnitude 6.0 releases 31.7 times the energy of an earthquake of magnitude 5.0. Earthquakes that cause widespread damage have magnitudes of 7.0 and greater.

Where Do Earthquakes Occur? Areas of the world where earthquakes occur are shown on the map in **Figure 6**. As you can see from the map, the majority of earthquakes take place at or near tectonic plate boundaries because of the enormous stresses that are generated when tectonic plates separate, collide, or slip past each other. Over the past 15 million to 20 million years, large numbers of earthquakes have occurred along the San Andreas fault, which runs almost the entire length of California. The San Andreas fault is the line where parts of the North American plate and the Pacific plate are slipping past one another.

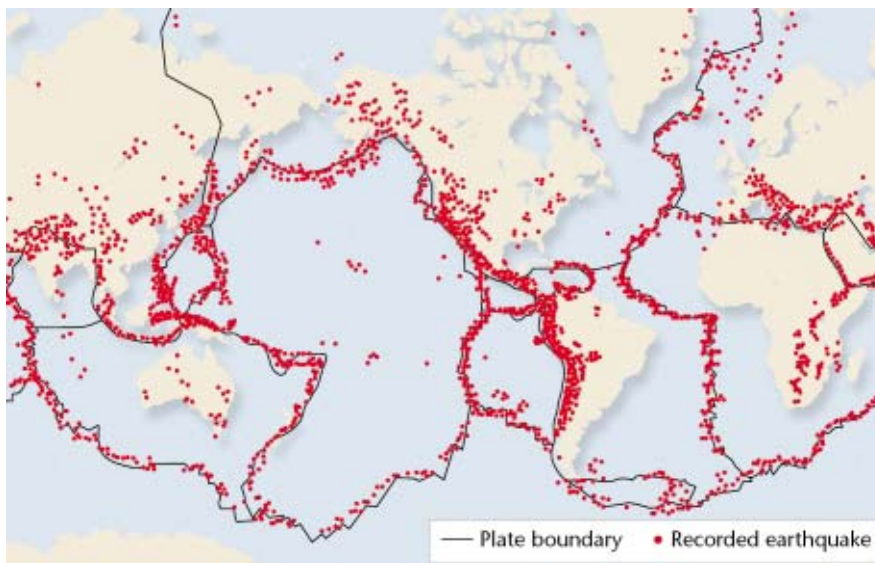


Figure 5 ► The Himalaya Mountains are still growing today because the tectonic plate containing Asia and the tectonic plate containing India continue to collide.

Figure 6 ► The largest and most active earthquake zones lie along tectonic plate boundaries.

Connection to Biology

Can Animals Predict Earthquakes? Can animals that live close to the site of an earthquake detect changes in their physical environment prior to an earthquake? Documentation of unusual animal behavior prior to earthquakes can be found as far back as 1784. Examples of this odd behavior include zoo animals refusing to enter shelters at night, snakes and small mammals abandoning their burrows, and wild birds leaving their usual habitats. These behaviors reportedly happened within a few days, hours, or minutes of earthquakes.

Earthquake Hazard Despite much study, scientists cannot predict when earthquakes will take place. However, information about where they are most likely to occur can help people prepare for them. An area's earthquake-hazard level is determined by past and present seismic activity. The Maps in Action activity located at the end of this chapter shows earthquake-hazard levels for the contiguous United States.

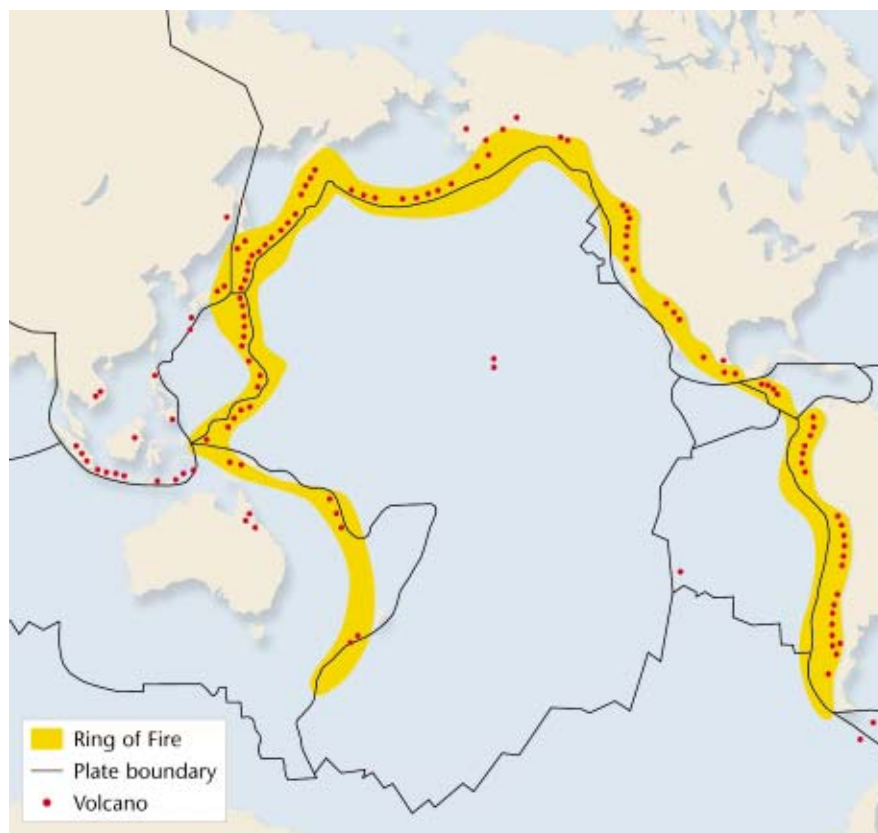
Earthquakes are not restricted to high-risk areas. In 1886, an earthquake shook Charleston, South Carolina, which is considered to be in a medium-risk area. Because the soil beneath the city is sandy, this earthquake caused extensive damage. During shaking from a strong earthquake, sand acts like a liquid and causes buildings to sink. In areas that are prone to earthquakes, it is worth the extra investment to build bridges and buildings that are at least partially earthquake resistant. Earthquake-resistant buildings are slightly flexible so that they can sway with the ground motion.

Volcanoes

A *volcano* is a mountain built from magma—melted rock—that rises from the Earth's interior to the surface. Volcanoes are often located near tectonic plate boundaries where plates are either colliding or separating from one another. Volcanoes may occur on land or under the sea, where they may eventually break the ocean surface as islands. As **Figure 7** shows, the majority of the world's active volcanoes on land are located along tectonic plate boundaries that surround the Pacific Ocean.

Figure 7 ► The Ring of Fire

Tectonic plate boundaries are places where volcanoes usually form. The Ring of Fire contains nearly 75 percent of the world's active volcanoes that are on land. A large number of people live on or near the Ring of Fire.





Local Effects of Volcanic Eruptions Volcanic eruptions can be devastating to local economies and can cause great human loss. Clouds of hot ash, dust, and gases can flow down the slope of a volcano at speeds of up to 200 km/hr and sear everything in their path. During an eruption, volcanic ash can mix with water and produce a mudflow. In 1985, Nevado del Ruiz in Colombia erupted, melting ice at the volcano's summit. A mudflow raced downhill and engulfed the town of Armero. In addition, ash that falls to the ground can cause buildings to collapse under its weight, bury crops, and damage the engines of vehicles. Volcanic ash may also cause breathing difficulties.

Global Effects of Volcanic Eruptions Major volcanic eruptions, such as the eruption of Mount St. Helens shown in **Figure 8**, can change Earth's climate for several years. In large eruptions, clouds of volcanic ash and sulfur-rich gases may reach the upper atmosphere. As the ash and gases spread across the planet, they can reduce the amount of sunlight that reaches the Earth's surface. This reduction in sunlight can cause a drop in the average global surface temperature. In the 1991 eruption of Mount Pinatubo in the Philippines, large clouds of ash and gases entered the Earth's atmosphere. The amount of sunlight that reached the Earth's surface was estimated to have decreased by 2 to 4 percent. As a result, the average global temperature dropped by several tenths of a degree Celsius over a period of several years.

Figure 8 ▶ On May 18, 1980, Mount St. Helens in Washington State erupted. Sixty-three people lost their lives, and 400 km² of forest were destroyed in an eruption that blew away the top 410 m of the volcano.

Erosion

Forces at the boundaries of tectonic plates bring rock to the surface of the Earth. At the Earth's surface, rocks are altered by other forces. The Earth's surface is continually battered by wind and scoured by running water, which moves rocks around and changes their appearance. The removal and transport of surface material is called **erosion**. Erosion wears down rocks and makes them smoother as time passes. The older a mountain range is, the longer the forces of erosion have acted on it. This information helped geologists learn that the round-topped Appalachian Mountains in the eastern United States are older than the jagged Rocky Mountains in the west.

Figure 9 ▶ Over long periods of time, erosion can produce spectacular landforms on Earth's surface.



Water Erosion Erosion by both rivers and oceans can produce dramatic changes on Earth's surface. Waves from ocean storms can erode coastlines to give rise to a variety of spectacular landforms. Over time, rivers can carve deep gorges into the landscape, as shown in Figure 9.

Wind Erosion Like moving water, wind can also change the landscape of our planet. In places where plants grow, their roots hold soil in place. But in places where there are few plants, wind can blow soil away very quickly. Beaches and deserts, which have loose, sandy soil, are examples of places where few plants grow. Soft rocks, such as sandstone, erode more easily than hard rocks, such as granite, do. In parts of the world, spectacular rock formations are sometimes seen where pinnacles of hard rock stand alone because the softer rock around them has eroded by wind and/or water.

SECTION 1 Review

1. **Name** and describe the physical and compositional layers into which scientists divide the Earth.
2. **Explain** the main cause of earthquakes and their effects.
3. **Describe** the effects that a large-scale volcanic eruption can have on the global climate.
4. **Describe** how wind and water alter the Earth's surface.

CRITICAL THINKING

5. **Analyzing Processes** How might the surface of the Earth be different if it were not divided into tectonic plates?
6. **Compare and Contrast** Read about the effects of erosion on mountains on this page. From what you have read, describe the physical features you would associate with a young mountain range and an old mountain range. **READING SKILLS**