Theory of Plate Tectonics

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Printed: August 10, 2014

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CHAPTER 1 Theory of Plate Tectonics

Lesson Objectives

- Describe what a plate is and how scientists can recognize its edges.
- Explain how the plates move by convection in the mantle.
- Describe the three types of plate boundaries and the features of each type of boundary.
- Describe how plate tectonics processes lead to changes in Earth's surface features.

Vocabulary

- continental rifting
- convergent plate boundary
- divergent plate boundary
- intraplate activity
- island arc
- plate
- plate boundary
- subduction
- subduction zone
- transform fault
- transform plate boundary

Introduction

The theory of plate tectonics explains most of the features of Earth's surface. Plate tectonics helps us to understand where and why mountains form. Using the theory, we know where new ocean floor will be created and where it will be destroyed. We know why earthquakes and volcanic eruptions happen where they do. We even can search for mineral resources using information about past plate motions. Plate tectonics is the key that unlocks many of the mysteries of our amazing planet.

Earth's Tectonic Plates

The Cold War helped scientists to learn more about our planet. They set up seismograph networks during the 1950s and early 1960s. The purpose was to see if other nations were testing atomic bombs. Of course, at the same time, the seismographs were recording earthquakes.

Earthquake Locations

The scientists realized that the earthquakes were most common in certain areas. In the oceans, they were found along mid-ocean ridges and deep sea trenches. Earthquakes and volcanoes were common all around the Pacific Ocean. They named this region the Pacific Ring of Fire (**Figure** 1.1). Earthquakes are also common in the world's highest mountains, the Himalaya Mountains of Asia. The Mediterranean Sea also has many earthquakes.

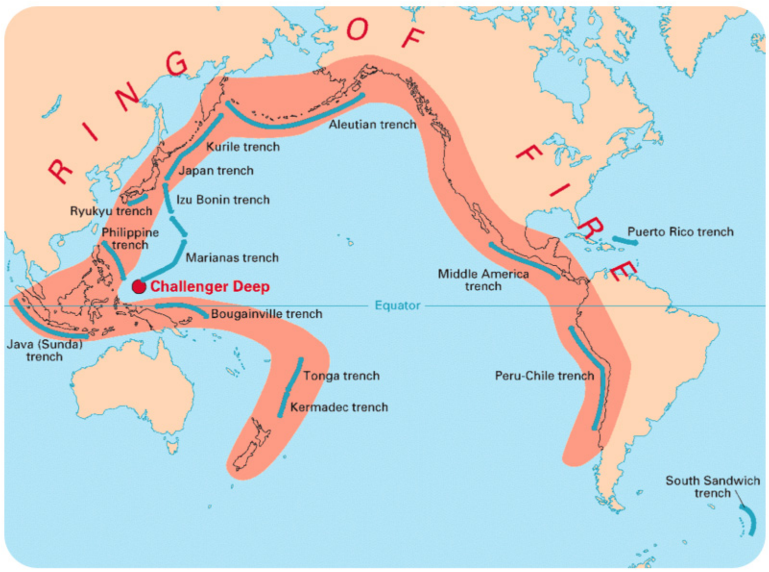

FIGURE 1.1
The Ring of Fire that circles the Pacific Ocean is where the most earthquakes and volcanic eruptions take place.

Earthquakes and Plate Boundaries

Earthquakes are used to identify plate boundaries (**Figure** 1.2). When earthquake locations are put on a map, they outline the **plates**. The movements of the plates are called plate tectonics.

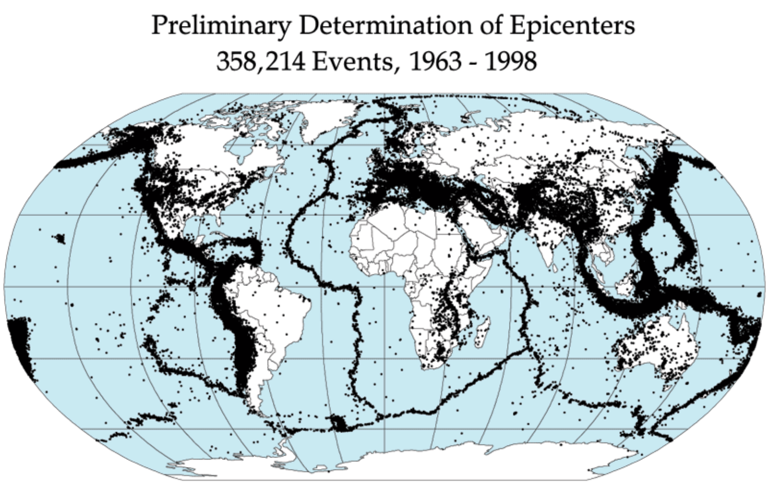

FIGURE 1.2
A map of earthquake epicenters shows that earthquakes are found primarily in lines that run up the edges of some continents, through the centers of some oceans, and in patches in some land areas.

The lithosphere is divided into a dozen major and several minor plates. Each plate is named for the continent or ocean basin it contains. Some plates are made of all oceanic lithosphere. A few are all continental lithosphere. But

most plates are made of a combination of both.

Scientists have determined the direction that each plate is moving (**Figure** 1.3). Plates move around the Earth's surface at a rate of a few centimeters a year. This is about the same rate fingernails grow.

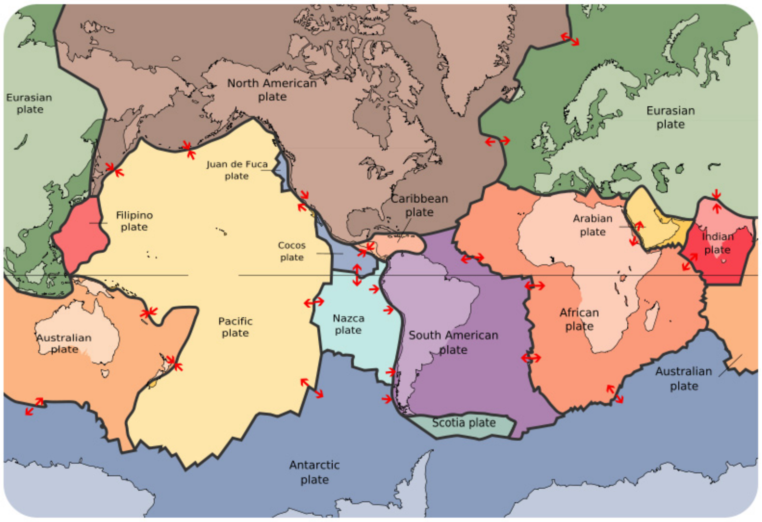

FIGURE 1.3
Earth's plates are shown in different colors. Arrows show the direction the plate is moving.

How Plates Move

Convection within the Earth's mantle causes the plates to move. Mantle material is heated above the core. The hot mantle rises up towards the surface (**Figure** 1.4). As the mantle rises it cools. At the surface the material moves horizontally away from a mid-ocean ridge crest. The material continues to cool. It sinks back down into the mantle at a deep sea trench. The material sinks back down to the core. It moves horizontally again, completing a convection cell.

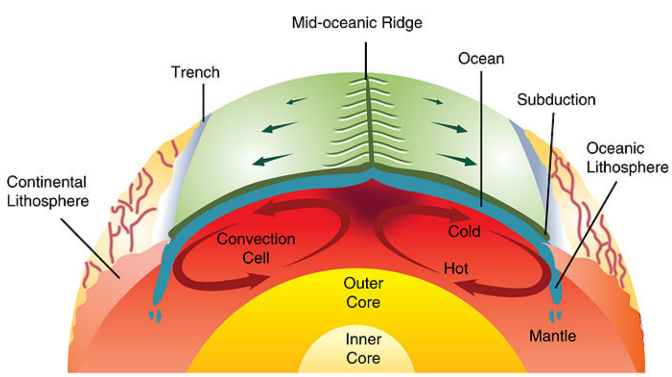

FIGURE 1.4
Plates move for two reasons. Upwelling mantle at the mid-ocean ridge pushes plates outward. Cold lithosphere sinking into the mantle at a subduction zone pulls the rest of the plate down with it.

Plate Boundaries

Plate boundaries are where two plates meet. Most geologic activity takes place at plate boundaries. This activity includes volcanoes, earthquakes, and mountain building. The activity occurs as plates interact. How can plates interact? Plates can move away from each other. They can move toward each other. Finally, they can slide past each other.

These are the three types of plate boundaries:

- **Divergent plate boundaries**: the two plates move away from each other.
- **Convergent plate boundaries**: the two plates move towards each other.
- **Transform plate boundaries**: the two plates slip past each other.

The features that form at a plate boundary are determined by the direction of plate motion and by the type of crust at the boundary.

Divergent Plate Boundaries

Plates move apart at divergent plate boundaries. This can occur in the oceans or on land.

Mid-ocean Ridges

Plates move apart at mid-ocean ridges. Lava rises upward, erupts, and cools. Later, more lava erupts and pushes the original seafloor outward. This is seafloor spreading. Seafloor spreading forms new oceanic crust. The rising magma causes earthquakes. Most mid-ocean ridges are located deep below the sea. The island of Iceland sits right on the Mid-Atlantic ridge (**Figure** 1.5).

FIGURE 1.5
The rift valley in Iceland that is part of the Mid-Atlantic Ridge is seen in this photo.

Continental Rifting

A divergent plate boundary can also occur within a continent. This is called **continental rifting** (**Figure** 1.6). Magma rises beneath the continent. The crust thins, breaks, and then splits apart. This first produces a rift valley. The East African Rift is a rift valley. Eastern Africa is splitting away from the African continent. Eventually, as the continental crust breaks apart, oceanic crust will form. This is how the Atlantic Ocean formed when Pangaea broke up.

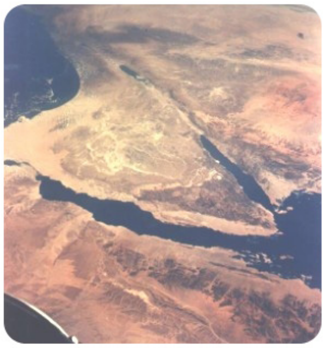

FIGURE 1.6
The Arabian, Indian, and African plates are rifting apart, forming the Great Rift Valley in Africa. The Dead Sea fills the rift with seawater.

Convergent Plate Boundaries

A convergent plate boundary forms where two plates collide. That collision can happen between a continent and oceanic crust, between two oceanic plates, or between two continents. Oceanic crust is always destroyed in these collisions.

Ocean-Continent Convergence

Oceanic crust may collide with a continent. The oceanic plate is denser, so it undergoes **subduction**. This means that the oceanic plate sinks beneath the continent. This occurs at an ocean trench (**Figure** 1.7). **Subduction zones** are where subduction takes place.

As you would expect, where plates collide there are lots of intense earthquakes and volcanic eruptions. The subducting oceanic plate melts as it reenters the mantle. The magma rises and erupts. This creates a volcanic mountain range near the coast of the continent. This range is called a **volcanic arc**. The Andes Mountains, along the western edge of South America, are a volcanic arc (**Figure** 1.8).

Ocean-Ocean Convergence

Two oceanic plates may collide. In this case, the older plate is denser. This plate subducts beneath the younger plate. As the subducting plate is pushed deeper into the mantle, it melts. The magma this creates rises and erupts. This forms a line of volcanoes, known as an **island arc** (**Figure** 1.9). Japan, Indonesia, the Philippine Islands, and the Aleutian Islands of Alaska are examples of island arcs (**Figure** 1.10).

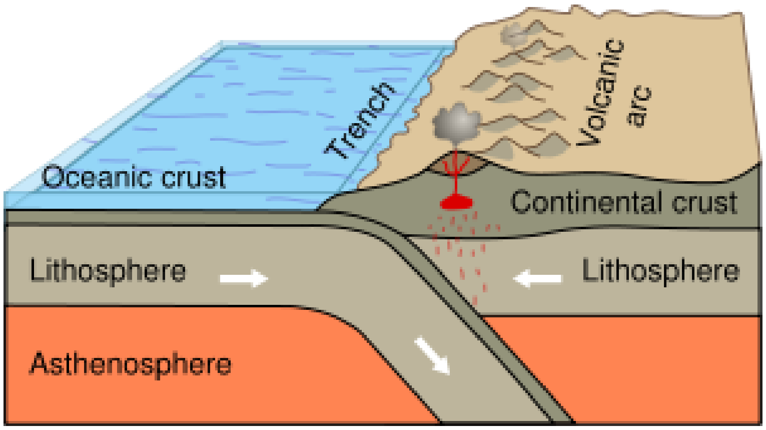

FIGURE 1.7
Subduction of an oceanic plate beneath a continental plate forms a line of volcanoes known as a continental arc and causes earthquakes.

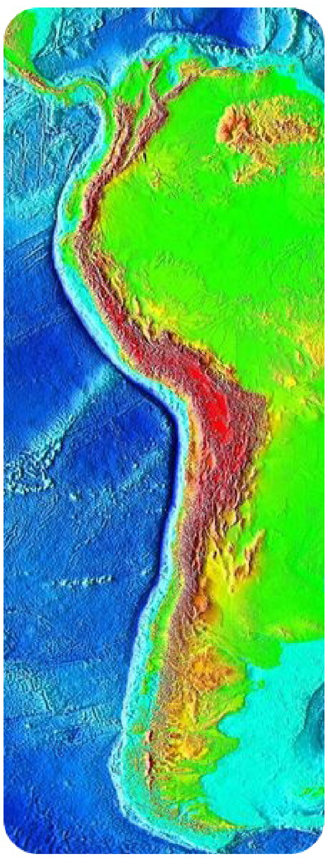

FIGURE 1.8
A relief map of South America shows the trench west of the continent. The Andes Mountains line the western edge of South America.

Continent-Continent Convergence

Continental lithosphere is low in density and very thick. Continental lithosphere cannot subduct. So when two continental plates collide, they just smash together, just like if you put your hands on two sides of a sheet of paper and bring your hands together. The material has nowhere to go but up (**Figure** 1.11)! Earthquakes and metamorphic rocks result from the tremendous forces of the collision. But the crust is too thick for magma to get through, so there are no volcanoes.

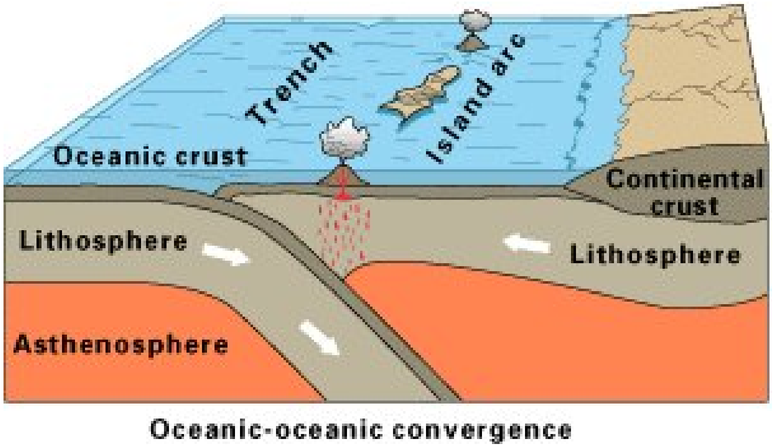

FIGURE 1.9
A convergent plate boundary subduction zone between two plates of oceanic lithosphere. Melting of the subducting plate causes volcanic activity and earthquakes.

FIGURE 1.10
The Aleutian Islands that border southern Alaska are an island arc. In this winter image from space, the volcanoes are covered with snow.

Mountain Building

Continent-continent convergence creates some of the world's largest mountains ranges. The Himalayas (**Figure** 1.12) are the world's tallest mountains. They are forming as two continents collide. The Appalachian Mountains are the remnants of a larger mountain range. This range formed from continent-continent collisions in the time of Pangaea.

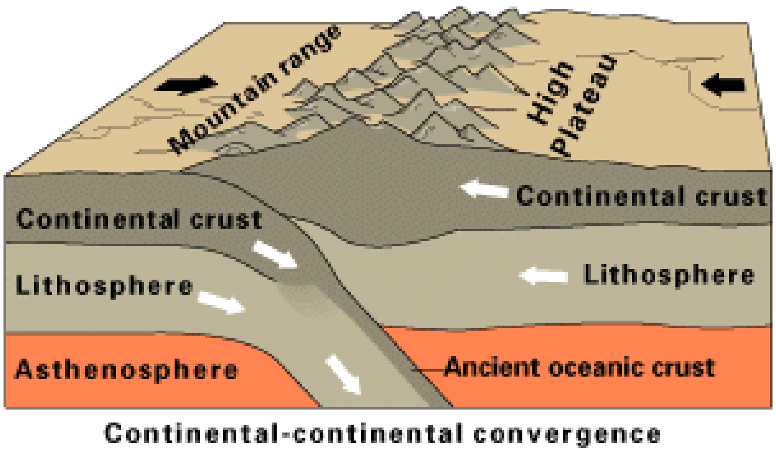

FIGURE 1.11
When two plates of continental crust collide, the material pushes upward, forming a high mountain range. The remnants of subducted oceanic crust remain beneath the continental convergence zone.

FIGURE 1.12
The Karakoram Range is part of the Himalaya Mountains. K2, pictured here, is the second highest mountain the world at over 28,000 feet. The number and height of mountains is impressive.

Transform Plate Boundaries

Two plates may slide past each other in opposite directions. This is called a transform plate boundary. These plate boundaries experience massive earthquakes. The world's best known transform fault is the San Andreas Fault in California (**Figure** 1.13). At this fault, the Pacific and North American plates grind past each other. Transform plate boundaries are most common as offsets along mid-ocean ridges.

Transform plate boundaries are different from the other two types. At divergent plate boundaries, new oceanic crust is formed. At convergent boundaries, old oceanic crust is destroyed. But at transform plate boundaries, crust is not created or destroyed.

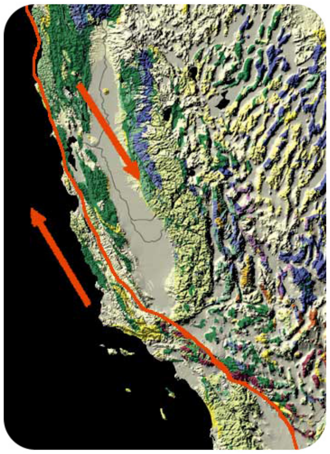

FIGURE 1.13
The red line is the San Andreas Fault. On the left is the Pacific Plate, which is moving northeast. On the right is the North American Plate, which is moving southwest. The movement of the plates is relative to each other.

Earth's Changing Surface

Knowing where plate boundaries are helps explain the locations of landforms and types of geologic activity. The activity can be current or old.

Active Plate Margins

Western North America has volcanoes and earthquakes. Mountains line the region. California, with its volcanoes and earthquakes, is an important part of the Pacific Ring of Fire. This is the boundary between the North American and Pacific Plates.

Passive Plate Margins

Mountain ranges also line the eastern edge of North America. But there are no active volcanoes or earthquakes. Where did those mountains come from? These mountains formed at a convergent plate boundary when Pangaea came together. About 200 million years ago these mountains were similar to the Himalayas today (**Figure** 1.14)! There were also earthquakes.

The Supercontinent Cycle

Scientists think that Pangaea was not the first supercontinent. There were others before it. The continents are now moving together. This is because of subduction around the Pacific Ocean. Eventually, the Pacific will disappear and a new supercontinent will form. This won't be for hundreds of millions of years. The creation and breakup of a supercontinent takes place about every 500 million years.

Intraplate Activity

Most geological activity takes place at plate boundaries. But some activity does not. Much of this **intraplate activity** is found at hot spots. Hotspot volcanoes form as plumes of hot magma rise from deep in the mantle.

FIGURE 1.14
The White Mountains in New Hampshire are part of the Appalachian province. The mountains are only around 6,000 feet high.

Hotspots in the Oceans

A chain of volcanoes forms as an oceanic plate moves over a hot spot. This is how it happens. A volcano forms over the hotspot. Since the plate is moving, the volcano moves off of the hotspot. When the hotspot erupts again, a new volcano forms over it. This volcano is in line with the first. Over time, there is a line of volcanoes. The youngest is directly above the hot spot. The oldest is the furthest away (**Figure** 1.15).

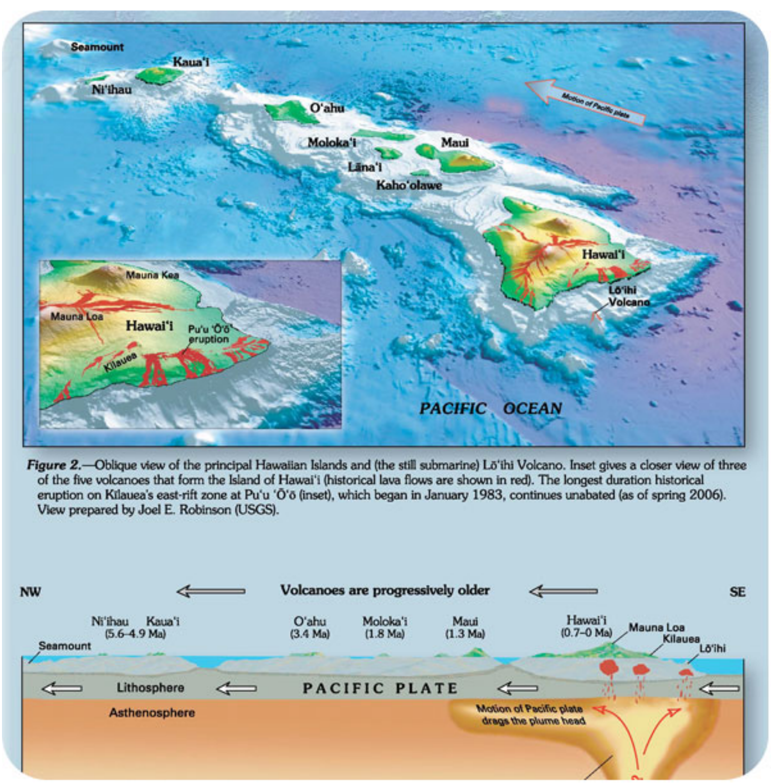

FIGURE 1.15
This view of the Hawaiian islands shows the youngest islands in the southeast and the oldest in the northwest. Kilauea volcano, which makes up the southeastern side of the Big Island of Hawaii, is located above the Hawaiian hotspot.

The Hawaii-Emperor chain of volcanoes formed over the Hawaiian Hotspot. The Hawaiian Islands formed most

recently. Kilauea volcano is currently erupting. It is over the hotspot. The Emperor Seamounts are so old they no longer reach above sea level. The oldest of the Emperor Seamounts is about to subduct into the Aleutian trench off of Alaska. Geologists use hotspot chains to tell the direction and the speed a plate is moving.

Hotspots Beneath Continents

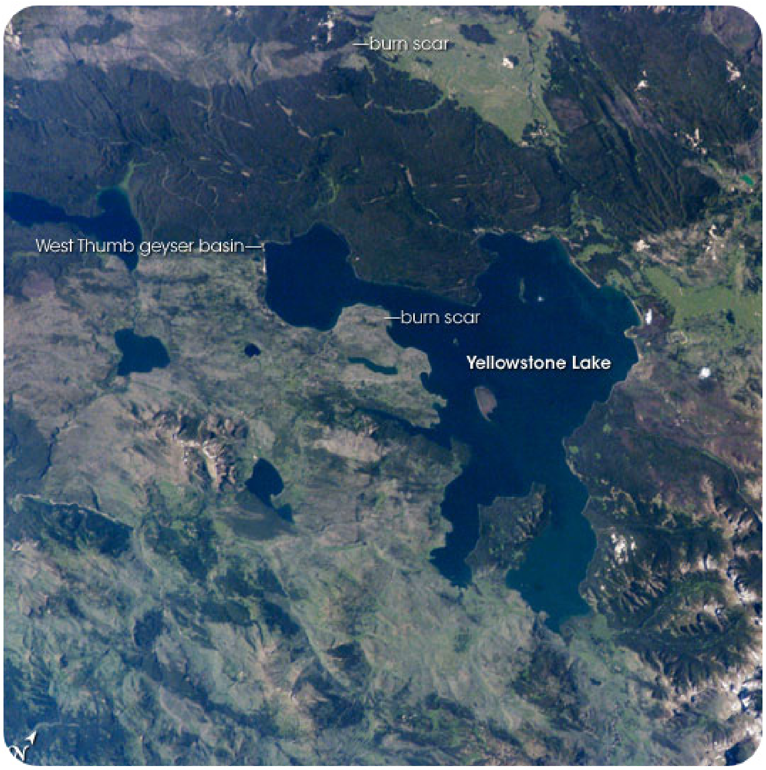

FIGURE 1.16
Yellowstone Lake lies at the center of a giant caldera. This hole in the ground was created by enormous eruptions at the Yellowstone hotspot. The hotspot lies beneath Yellowstone National Park.

Hot spots are also found under the continental crust. Since it is more difficult for magma to make it through the thick crust, they are much less common. One exception is the Yellowstone hotspot (**Figure** 1.16). This hotspot is very active. In the past, the hotspot produced enormous volcanic eruptions. Now its activity is best seen in the region's famous geysers.

Lesson Summary

- Convection in the mantle drives the movement of the plates of lithosphere over the Earth's surface. New oceanic crust forms at the ridge and pushes the older seafloor away from the ridge horizontally.
- Plates interact at three different types of plate boundaries: divergent, convergent and transform fault boundaries, where most of the Earth's geologic activity takes place.
- These processes acting over long periods of time are responsible for the geographic features we see.

Lesson Review Questions

Recall

1. Name the three types of plate boundaries? Which has volcanoes? Which has earthquakes? Which has mountain building?

Apply Concepts

2. Describe convection. How does this work to create plate boundaries?

Think Critically

3. Make some generalizations about which types of plate boundaries have volcanoes and which have earthquakes. Could you look at a plate boundary and determine what geological activity there would be?

4. Why is continental crust thicker than oceanic crust? Why is oceanic crust relatively thin?

Points to Consider

- On the map in **Figure** 1.3, the arrows show the directions that the plates are going. The Atlantic has a mid-ocean ridge, where seafloor spreading is taking place. The Pacific Ocean has many deep sea trenches, where subduction is taking place. What is the future of the Atlantic plate? What is the future of the Pacific plate?
- Using your hands and words, explain to someone how plate tectonics works. Be sure you describe how continents drift and how seafloor spreading provides a mechanism for continental movement.
- Now that you know about plate tectonics, where do you think would be a safe place to live if you wanted to avoid volcanic eruptions and earthquakes?

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