SECTION 6 Changing Earth's Surface

DISCOVER ACTIVITY

Where Are Volcanoes Found on Earth's Surface?

1. Look at the map of Earth's active volcanoes on page 351. What symbols are used to represent volcanoes? What other symbols are shown on the map?
2. Do the locations of the volcanoes form a pattern? Do the volcanoes seem related to any other features on Earth's surface?

Think About It

Developing Hypotheses Develop a hypothesis to explain where Earth's volcanoes are located. Are there any volcanoes on the map whose location cannot be explained by your hypothesis?

GUIDE FOR READING

- How does plate movement change Earth's surface?
- How do mountains form?
- What is land subsidence?

Reading Tip Before you read, write the headings in this section. As you read, write down the main point of each heading.

Key Terms stress
• deformation • earthquake
• fault • strike-slip fault
• normal fault
• hanging wall • footwall
• reverse fault
• fault-block mountain
• land subsidence • volcano
• hot spot

In 1983, a fault near Borah Peak in Idaho slipped, causing a powerful earthquake. The earthquake pushed the land along one side of the fault up by nearly 3 meters. The result was a long, clifflike ridge marking where the fault movement occurred. In only a few seconds, the Borah Peak earthquake produced a dramatic change in Earth's surface. More often, changes in the surface take place gradually. But over time, even gradual change can produce new features.

Forces in the Lithosphere

The Borah Peak earthquake is an example of how the forces of plate movement affect the lithosphere. **Plate movement can alter Earth systems and produce changes in Earth's surface. These changes include deformation of the crust, faults, mountain building, land subsidence, and volcanoes.** Scientists try to predict the Earth features, or landforms, that will develop in an area by studying the plates around the area and how they move.

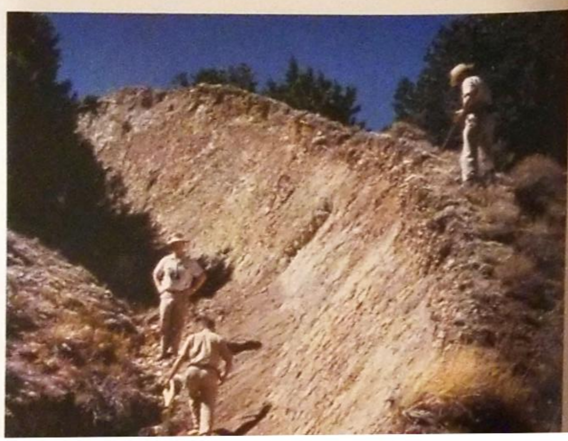


Figure 29 An earthquake pushed up the land along this fault, forming a long ridge.

Plate movements produce powerful forces that push, pull, bend, and twist the lithosphere. They produce stress in rock. **Stress** is a force that adds potential energy to rock until the rock changes shape or breaks and moves. Stress leads to **deformation,** a change in the rock's shape or volume.

Deformation takes place so slowly that you cannot observe it directly. But over a very long time, deformation changes Earth's surface. Stress produces three types of deformation: shearing, tension, and compression. Shearing pushes a mass of rock in two opposite directions. Tension pulls on rock, making it thinner in the middle. Compression squeezes rock, making it thicker in the middle.

Deformation caused by plate movement can put so much stress on the lithosphere that it breaks. Where the lithosphere breaks, a fault forms. During plate movement, stress builds up along the fault, storing potential energy in the rock. Eventually, the rock along the fault suddenly breaks and slides, causing an **earthquake.** Each time an earthquake occurs, potential energy changes to kinetic energy as the rock along the fault moves. In this way, every earthquake changes Earth's surface.

Figure 30 Deformation pushes, pulls, or twists the rocks in Earth's crust. ***Relating Cause and Effect*** Which type of deformation tends to shorten part of the crust?

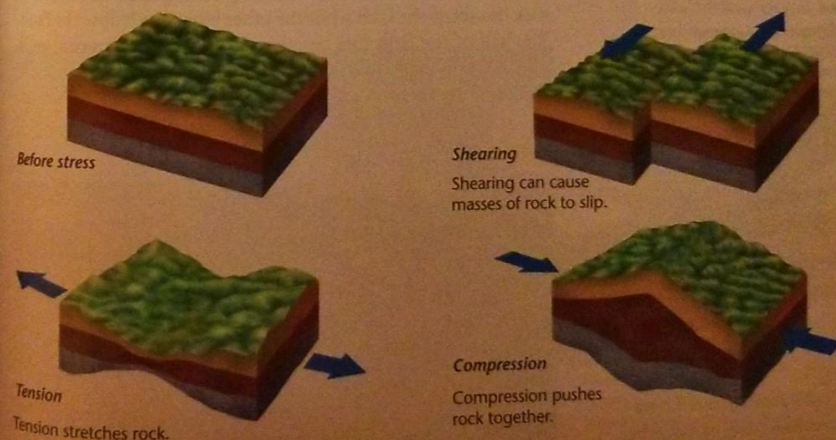
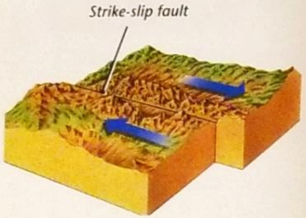


Figure 31 The San Andreas fault is a strike-slip fault that slices through California.



Faults and Fault Movements

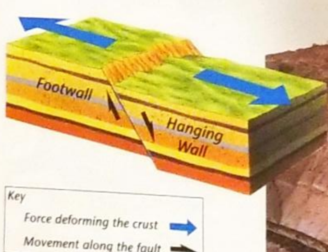
If you try to break a caramel candy bar in two, it may only bend and stretch at first. Like a candy bar, many types of rock can bend or fold. But beyond a certain limit, even these rocks will break. Rocks that easily bend take more stress to break than brittle ones.

When enough stress builds up in rock, the rock breaks, creating a fault. A **fault** is a break in the crust where slabs of crust slip past each other. The rocks on both sides of a fault can move up or down or sideways. **Faults usually occur along plate boundaries, where the forces of plate motion compress, pull, or shear the crust so much that the crust breaks.** There are three main types of faults: strike-slip faults, normal faults, and reverse faults.

Strike-Slip Faults Shearing creates strike-slip faults. In a **strike-slip fault,** the rocks on either side of the fault slip past each other sideways with little up or down motion. Figure 31 shows the type of movement that occurs along a strike-slip fault. As you learned in the previous section, this type of motion results in a transform boundary between plates. The San Andreas fault in California is an example of a transform boundary.

Normal Faults Tension forces in Earth's crust cause normal faults. In a **normal fault,** the fault is at an angle, so one block of rock lies above the fault while the other block lies below the fault. The half of the fault that lies above is called the **hanging wall.** The half of the fault that lies below is called the **footwall.** Look at Figure 32 to see how the hanging wall lies above the footwall.

Figure 32 A normal fault is exposed in this road cut. The rock layers no longer line up because the hanging wall has dropped down relative to the footwall.



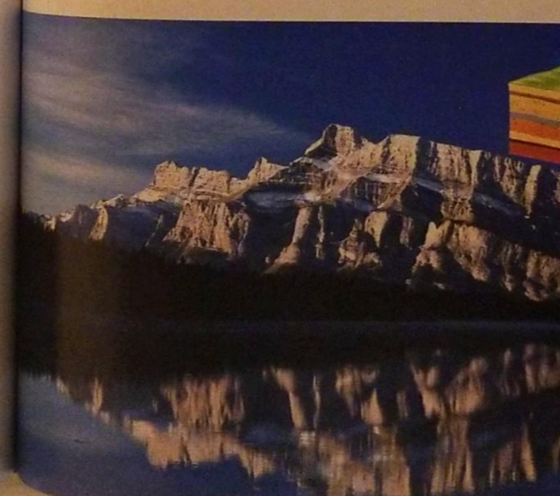
When movement occurs along a normal fault, the hanging wall slips downward. Tension forces create normal faults where plates diverge, or pull apart. For example, normal faults occur along the Rio Grande rift valley in New Mexico, where two pieces of Earth's crust are diverging.

Reverse Faults Compression forces produce reverse faults. A **reverse fault** has the same structure as a normal fault, but the blocks move in the opposite direction. Look at Figure 33 to see how the rocks along a reverse fault move. As in a normal fault, one side of a reverse fault lies at an angle above the other side. The rock forming the hanging wall of a reverse fault slides up and over the footwall. Reverse faults produced mountains in the Canadian Rockies.

Mountain Building

Over millions of years, plate movement can cause folding and faulting. **Folding and faulting driven by plate movement result in mountain building.** A mountain is a landform that rises high above the surrounding land. A mountain range is a group of mountains that are closely related in shape, structure, and age.

Folding When continental plates collide, the collision squeezes the two plates together. Slowly, layers of rock in the plate fold, like a rug when its ends are pushed toward each other. For example, when Pangaea began to form, the North American plate collided with the Eurasian plate. As these huge plates collided, thick layers of rock near the edges of the plates were compressed and folded. This folding formed the Appalachian Mountains.



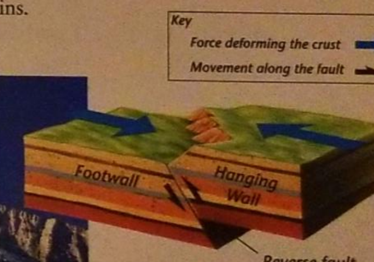
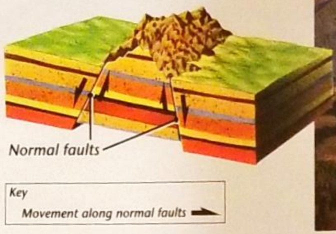
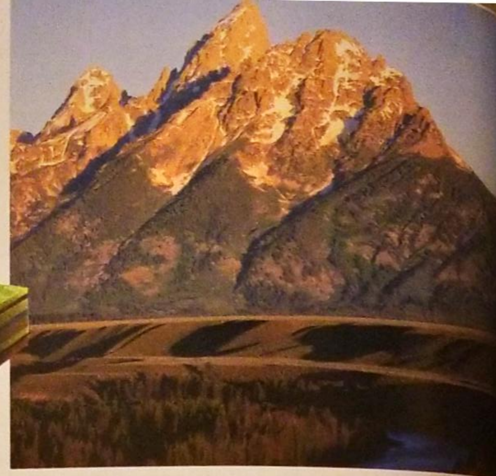


Figure 33 A reverse fault formed this mountain in Alberta, Canada, as compression forces pushed one mass of rock up and over another.

Figure 34 Two normal faults can form fault-block mountains, such as the Teton range in Wyoming.





Faulting Sometimes, plate movements cause tension in the crust. If the tension is great enough the crust breaks, forming a normal fault. Faulting can cause mountains to form. For example, geologists think that plate movements have placed tension on Earth's crust in Nevada and Utah and parts of nearby states. The tension caused many normal faults to form in this region. Blocks of crust then slid along these normal faults, forming mountains called **fault-block mountains.** One example of a fault-block mountain range is shown in Figure 34.

Land Subsidence

When plate movement and deformation of the crust push up a wide area of crust, uplift occurs. These forces also can lead to land subsidence. **Land subsidence occurs when the land surface sinks, or subsides, as a result of geologic processes or human activities.** In Chapter 13, you will learn how certain human activities can cause a different kind of land subsidence.

Plate movements along diverging plate boundaries are one cause of land subsidence. This type of subsidence leads to the formation of rift valleys and ocean basins.

Sometimes, as uplift raises one part of the crust, land subsidence occurs in an adjoining area. In the area of subsidence, the force of plate movement warps the crust downward. The crust may sink until it is below sea level. About 65–70 million years ago, this process resulted in shallow seas covering the central part of North America. The seas extended all the way from Texas to northern Canada!

Volcanic Mountains

Some of Earth's most spectacular mountains are volcanoes. A **volcano** is a weak spot in the crust where molten, rock-forming material called magma comes to the surface. Magma that reaches the surface is called lava. Lava cools to form solid rock. **Volcanic activity builds mountains made of lava rock and other volcanic materials.** Plate movements determine where volcanoes develop on Earth's surface.

Location of Volcanoes

There are about 600 active volcanoes on land. Many more lie beneath the sea. Volcanoes occur in belts that extend across continents and oceans. One major volcanic belt is the Ring of Fire, formed by the many volcanoes that rim the Pacific Ocean.

Volcanic belts form along the boundaries of Earth's plates. Here, the lithosphere is weak and fractured, allowing magma to reach the surface. Most volcanoes occur along diverging plate boundaries, such as the mid-ocean ridge, or in subduction zones around the edges of oceans. But there are exceptions to this pattern. Some volcanoes form far from the boundaries of continental or oceanic plates.

Language Arts CONNECTION

The word *volcano* comes from the name of the Roman god of fire, Vulcan. According to Roman mythology, Vulcan lived beneath Mount Etna, a huge volcano on the island of Sicily in the Mediterranean Sea. Vulcan used the heat of Mount Etna to make metal armor and weapons for the ancient gods and heroes.

In Your Journal

Use the dictionary to find the definition of *plutonic* rock. Explain why the name of another Roman god was used for this term.

Earth's Active Volcanoes

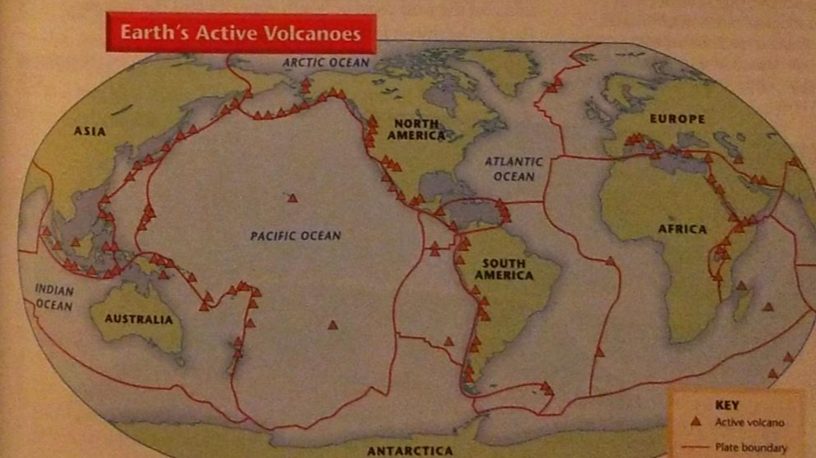


Figure 35 The Ring of Fire is a belt of volcanoes that circles the Pacific Ocean. Observing *What other patterns can you see in the locations of Earth's volcanoes?*

Volcanoes at Diverging Plate Boundaries Volcanoes form along the mid-ocean ridge, which marks a diverging plate boundary. Along the ridge, lava pours out of cracks in the ocean floor. Volcanoes also form along rift valleys, such as the Great Rift Valley in Africa.

Volcanoes at Converging Boundaries Many volcanoes form near the plate boundaries where some oceanic crust returns to the mantle. There, the crust melts and forms magma, which then rises back toward the surface. When the magma from the melted crust erupts as lava, volcanoes are formed.

Many volcanoes occur on islands, near boundaries where two oceanic plates collide. Recall that at such places, the older, denser plate dives under the other plate, creating a deep-ocean trench. The lower plate sinks beneath the deep-ocean trench into the asthenosphere. There it begins to melt, forming magma. Because the magma is less dense than the surrounding rock, it seeps upward through cracks in the crust. Eventually, the magma breaks through the ocean floor, creating volcanoes. The resulting volcanoes create a string of islands called an island arc. Major island arcs include Japan, New Zealand, Indonesia, the Caribbean islands, the Philippines, and the Aleutians.

Subduction also occurs where the edge of a continental plate collides with an oceanic plate. Collisions between oceanic and continental plates produced both the volcanoes of the Andes mountains on the west coast of South America and the volcanoes of the Pacific Northwest in the United States.

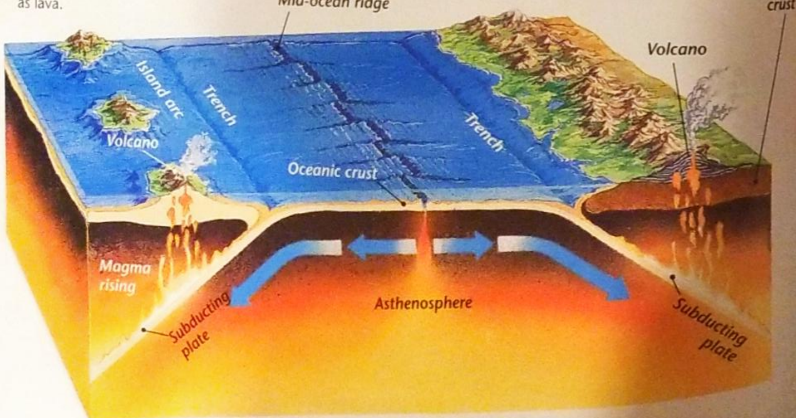


Figure 36 Volcanoes form when two oceanic plates collide or when an oceanic plate collides with a continental plate. In both cases, oceanic crust sinks beneath a deep-ocean trench and melts to form magma that erupts to the surface as lava.

Figure 37 Hawaii sits on the moving Pacific plate. Beneath it is a powerful hot spot. Eventually, the plate's movement will carry the island of Hawaii away from the hot spot. ***Inferring*** *Which island on the map formed first?*

Hot Spot Volcanoes Some volcanoes result from "hot spots" in Earth's mantle. A **hot spot** is an area where magma from deep within the mantle melts through the crust like a blowtorch through steel. Hot spots often lie in the middle of continental or oceanic plates far from any plate boundaries.

A hot spot volcano in the ocean floor can gradually form a series of volcanic mountains. For example, the Hawaiian Islands formed one by one over millions of years as the Pacific plate drifted over a hot spot.

Hot spots can also form under the continents. Yellowstone National Park in Wyoming marks a major hot spot under the North American plate. The last volcanic eruption in Yellowstone occurred about 75,000 years ago.

TRY THIS

Hot Spot in a Box

ACTIVITY

1. Fill a plastic box half-full of cold water. This represents the ocean.
2. Mix red food coloring with hot water in a small, narrow-necked bottle to represent magma.
3. Hold your finger over the mouth of the bottle as you place the bottle in the center of the box with the bottle's mouth under water.
4. Float a flat piece of plastic foam on the water to model a tectonic plate. Make sure the "plate" is floating above the bottle.
5. Take your finger off the bottle and observe what happens to the "magma."

Making Models Move the plastic foam slowly along. Where does the magma touch the "plate"? How does this model a hot spot volcano?

Section 6 Review

1. Explain how the three types of deformation affect Earth's crust.
2. Describe two ways that mountains form.
3. What is land subsidence and why does it occur?
4. Where do most volcanoes occur?
5. **Thinking Critically** **Predicting** If oceanic crust is subducted beneath continental crust, what Earth features will form on the continental crust?

Check Your Progress

CHAPTER PROJECT

Complete the construction of your model by adding the surface features. Be sure to label the features on your model. Include arrows that indicate the direction of plate movement. Predict how Earth's surface features might change along the plate boundaries in your model. Construct a map showing what your plate might look like 20 million years in the future.