Section 3

Deforming Earth’s Crust

Key Concept Tectonic plate motions deform Earth’s crust. Deformation causes rock layers to bend and break and causes mountains to form.

What You Will Learn

- Stress is placed on rock as plates move. The stress causes rock to fold and break.
- The formation of mountains results from the motion of tectonic plates.

Why It Matters

Tectonic plate motion shapes and reshapes Earth’s surface.

Have you ever tried to bend something, only to have it break? Take long, uncooked pieces of spaghetti, and bend them very slowly and only a little. Now, bend them again, but this time, bend them much farther and faster. What happened?

Deformation

How can a material bend at one time and break at another time? The answer is that the stress you put on the material was different each time. *Stress* is the amount of force per unit area on a given material. The same principle applies to the rocks in Earth’s crust. Rock reacts differently when different amounts of stress are applied.

The process by which the shape of a rock changes in response to stress is called *deformation.* In the example above, the spaghetti deformed in two different ways—by bending and by breaking. **Figure 1** illustrates this concept. The same process happens in rock layers. Rock layers bend when stress is placed on them. But when enough stress is placed on rocks, the rocks may break.

Figure 1 When a small amount of stress is placed on uncooked spaghetti, the spaghetti bends. Additional stress causes the spaghetti to break.

Standards Check Describe two ways in which rock layers can deform when stress is placed on them.

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Folding

The bending of rock layers in response to stress in Earth’s crust is called **folding**. Scientists assume that all rock layers started as horizontal layers. So, when scientists see a fold, they know that deformation has taken place. All folds have a hinge and two limbs. Limbs are the sloping sides of a fold. A hinge is the bend where the two limbs meet.

Anticlines and Synclines

Two of the most common types of folds—anticlines and synclines—are shown in **Figure 2.** An *anticline* is a fold in which the oldest rock layers are in the center of the fold. In many anticlines, the rock limbs slope down from the center to form an arch. In the diagram, a syncline is shown between two anticlines. A *syncline* is a fold in which the youngest rock layers are in the center of the fold. In many synclines, the limbs slope up from the center to form a trough. Folds can be large or small. Anticlines can be from tens of meters wide to hundreds of kilometers wide. Small folds are measured in centimeters.

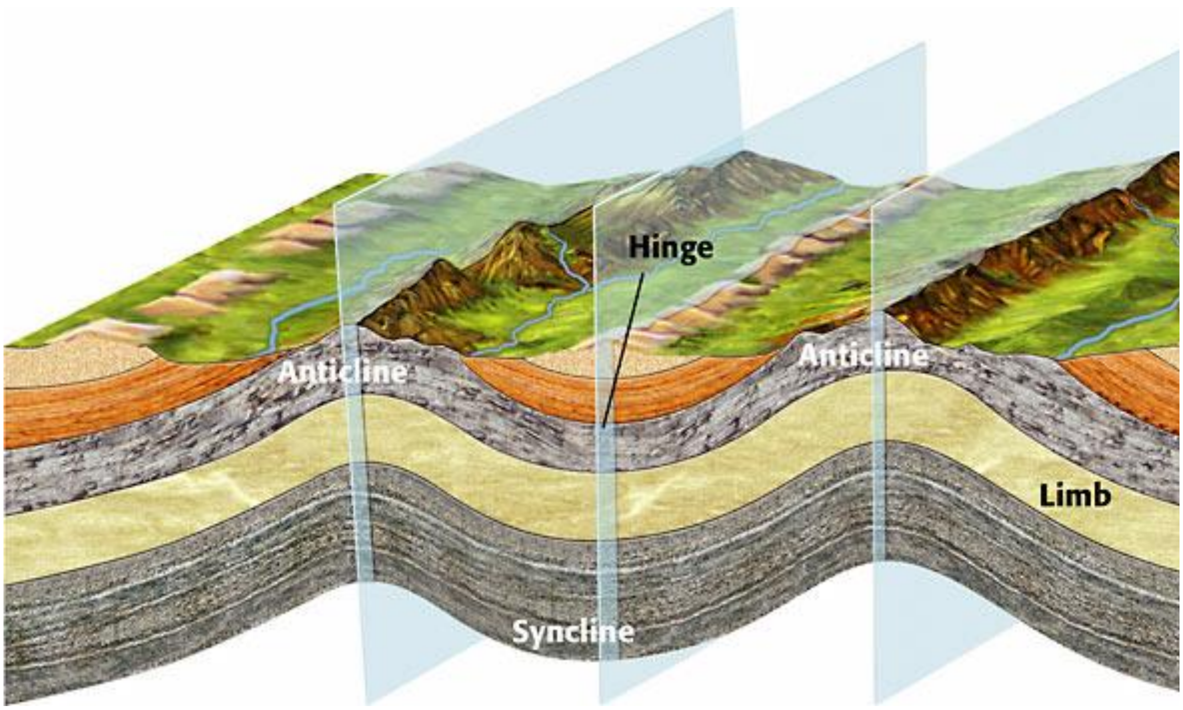


Figure 2 Anticlines and synclines are two types of folds. The folds to the left and right are anticlines. The fold in the center is a syncline. The blue planes represent surfaces that run through each hinge and divide the folds into two limbs. How many limbs does each fold have?

Shapes of Folds

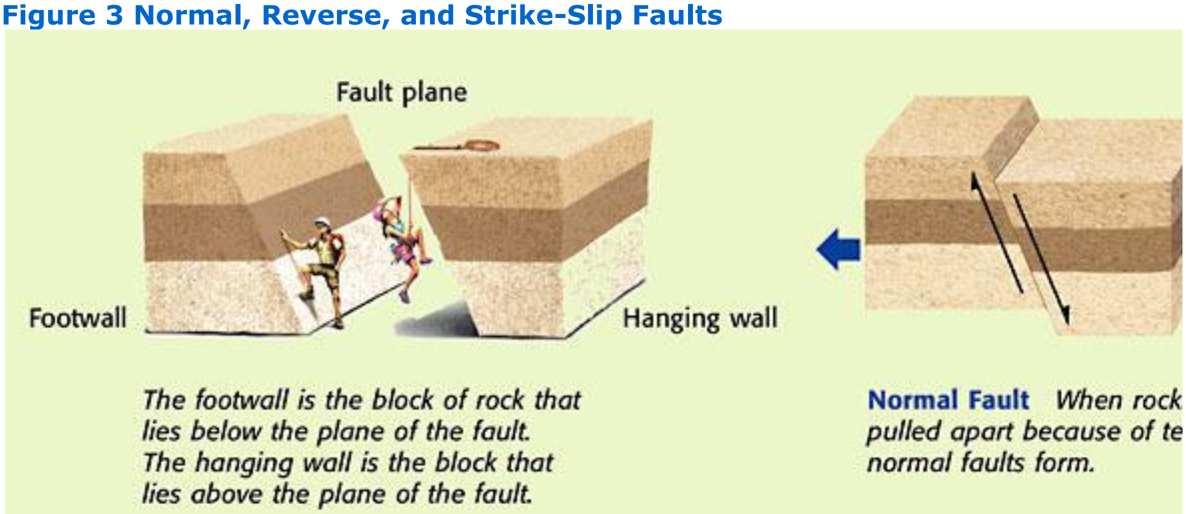
The rock layers in the folds shown in **Figure 2** bend symmetrically. But rock layers can bend into folds that are not symmetrical. Such folds are *asymmetrical* (AY suh ME tri kuhl) *folds.* In an asymmetrical fold, one limb may dip more steeply than the other limb does. An *overturned fold* is a fold in which one limb is tilted beyond 90°. Rock layers may also be bent so much that a fold appears to be lying on its side. Geologists call this type of lying-down fold a *recumbent fold.*

Faulting

When rock is placed under so much stress that it can no longer stretch or flow, it may break. The surface along which rocks break and slide past each other is called a **fault**. The blocks of crust on each side of the fault are called *fault blocks.*

When a fault is not vertical, there are two kinds of fault blocks—the *hanging wall* and the *footwall.* The illustration at the far left of **Figure 3** shows the difference between a hanging wall and a footwall. Faults are classified into three categories according to how the fault blocks move relative to each other. The type of fault that forms can be used to determine the type of stress that caused the fault.

Figure 3 Normal, Reverse, and Strike-Slip Faults



Standards Check How do faults form?

Normal Faults

A *normal fault* is shown in **Figure 3.** Along a normal fault, the hanging wall moves down relative to the footwall. Normal faults usually form where tectonic plate motions cause tension. Tension is stress that pulls rocks apart. Therefore, normal faults are common at mid-ocean ridges. At mid-ocean ridges, plate separation causes oceanic lithosphere to break into fault blocks.

Reverse Faults

A *reverse fault* is shown in **Figure 3.** Along a reverse fault, the hanging wall moves up relative to the footwall. This movement is the reverse of a normal fault. Reverse faults usually form where tectonic plate motions cause compression. Compression is stress that pushes rocks together. Therefore, reverse faults are common in subduction zones. In subduction zones, oceanic lithosphere descends into the asthenosphere.

Strike-Slip Faults

A *strike-slip fault* is shown in **Figure 3**. Along a strike-slip fault, the two fault blocks move past each other horizontally. Imagine that you are standing on one side of a strike-slip fault looking across the fault. If the fault blocks moved, the ground on the other side of the fault would appear to move to your left or right. Strike-slip faults usually form where tectonic plate motions cause shear stress parallel to Earth’s surface. Shear stress is stress that pushes different parts of the rock in different directions. Therefore, strike-slip faults are common along transform boundaries.

Standards Check Compare how the three types of faults form.

Recognizing Faults

Some faults are only a few meters long. Other faults are several hundred kilometers long. So, how can you recognize a fault when you see one? Movement along faults causes rock layers to become offset. Therefore, layers of different kinds of rock that sit side-by-side indicate offset along a fault. In addition, features such as grooves, striations, or polished surfaces called *slickensides* indicate where rocks have moved.

Fault offset is particularly obvious along faults that break Earth’s surface for many kilometers. A landform on one side of a fault may be offset on the other side of the fault. For example, streams commonly change the direction they flow at a fault. In addition, manmade objects, such as fences and curbs, may be offset. Another feature that indicates fault offset is a scarp. A *scarp* is a row of cliffs formed by faulting. Scarps form when rock on one side of a fault is raised vertically relative to rock on the other side of the fault. Faults scarps may be several centimeters to tens of meters high.

Plate Tectonics and Mountain Building

As tectonic plates move around Earth’s surface, the edges of the plates grind against each other. These interactions cause a great deal of stress in Earth’s crust because the plates have a great deal of mass. Over long periods of time, this process may crumple and push up the margins of the plates. When this happens, great mountain-building events may occur.

Standards Check How do mountains form?

Folded Mountains

When rock layers are squeezed together and pushed upward, *folded mountains* form. These mountain ranges form at convergent boundaries where continents have collided. When continents collide, compression folds and uplifts the rock. **Figure 4** shows the Appalachian Mountains, an example of folded mountains.

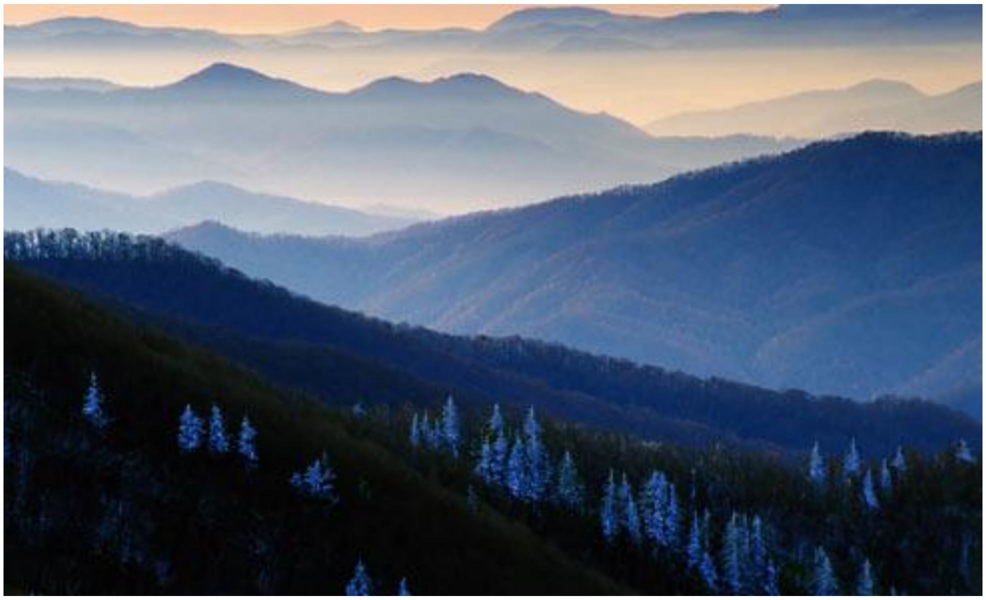


Figure 4 The Appalachian Mountains were once as tall as the Himalaya Mountains. But the Appalachian Mountains have been worn down by hundreds of millions of years of erosion.

Fault-Block Mountains

When tension in Earth's crust causes the crust to break into a large number of normal faults, *fault-block mountains* form. These mountains form when tension causes large blocks of Earth's crust to drop down relative to other blocks. The Tetons, shown in **Figure 5**, are a range of fault-block mountains.

Figure 5 The Tetons in Idaho and Wyoming formed as a result of tension that caused Earth's crust to break into a series of normal faults.

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Volcanic Mountains

When molten rock erupts onto Earth's surface, *volcanic mountains* form. Most of the world's major volcanic mountains are located at convergent boundaries. At convergent boundaries, the motions of the plates causes hot mantle rocks to rise beneath the plate. The molten rock rises to the surface and erupts. Volcanic mountains form both on land and on the ocean floor. Sometimes, these mountains can rise above the ocean surface to become islands. Most of the active volcanic mountains on Earth have formed around the tectonically active rim of the Pacific Ocean. This area is known as the *Ring of Fire.* **Figure 6** shows Mount Shasta in northern California. Mount Shasta is one of the many volcanoes in the Ring of Fire.

Figure 6 Mount Shasta is a volcano that has formed at a subduction zone.

Section Summary

- Deformation structures, such as faults and folds, form as a result of stress in the lithosphere. This stress is caused by tectonic plate motion.
- Folding occurs when rock layers bend because of stress.
- Faulting occurs when rock layers break because of stress and then move on either side of the break.
- Three major fault types are normal faults, reverse faults, and strike-slip faults.
- Mountain building is caused by the movement of tectonic plates. Folded mountains and volcanic mountains form at convergent boundaries. Fault-block mountains form at divergent boundaries.

Chapter Summary

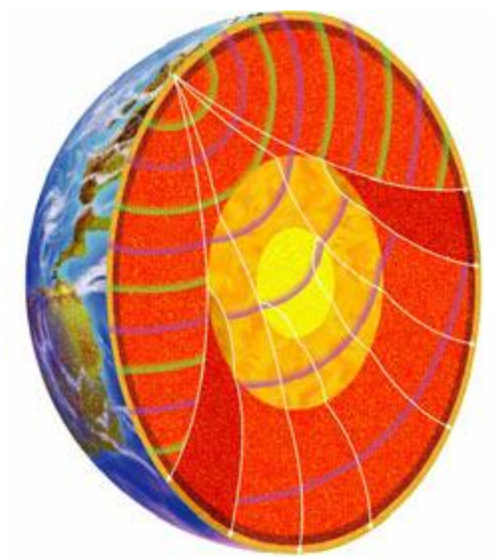
The Big Idea

Plate tectonics accounts for important features on Earth's surface and major geologic events.

Section 1
Earth's Structure

Key Concept Earth is composed of several layers. The continents are part of the uppermost layer, and they move slowly around Earth's surface.

- Earth's interior can be divided into layers based on chemical composition and physical properties.
- Scientists use seismic waves to study Earth's interior.
- Continents are drifting apart from each other now and have done so in the past.



Following an earthquake, seismic waves move through Earth's interior.

Section 2

The Theory of Plate Tectonics

Key Concept Tectonic plates the size of continents and oceans move at rates of a few centimeters per year in response to movements in the mantle.

- Earth's lithosphere is broken into pieces called *tectonic plates*.
- Heat from Earth's interior causes convection in the mantle.
- Tectonic plates move at an average rate of a few centimeters per year.

The South American plate consists of both oceanic and continental lithosphere.

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A fault separates a hanging wall fault block from a footwall fault block.

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