Section 1
What Are Earthquakes?

Key Concept Sudden motions along breaks in Earth's crust can release energy in the form of seismic waves.

What You Will Learn

- Earthquakes are ground motions that result from the release of energy when blocks of rock move.
- Most earthquakes occur along tectonic plate boundaries because the movement of tectonic plates causes stress in Earth's crust.
- Earthquake energy travels through rock as seismic waves.

Why It Matters

Earthquakes can destroy property and endanger human lives.

Have you ever felt the Earth move under your feet? Many people have. Every day, somewhere in the world, earthquakes happen. **Earthquakes** are movements or shaking of the ground that happen when blocks of rock move suddenly and release energy. The transfer of this energy through rock causes the ground to shake.

Standards Check What is an earthquake?

Where Earthquakes Happen

Most earthquakes take place near the boundaries of tectonic plates. However, earthquakes do happen far from tectonic plate boundaries. Large earthquakes have occurred in the interior of the North American plate. For example, earthquakes happened in New Madrid, Missouri, in 1811–1812, and in Charlestown, South Carolina, in 1886. **Figure 1** shows Earth's major tectonic plates and the locations of recent earthquakes.

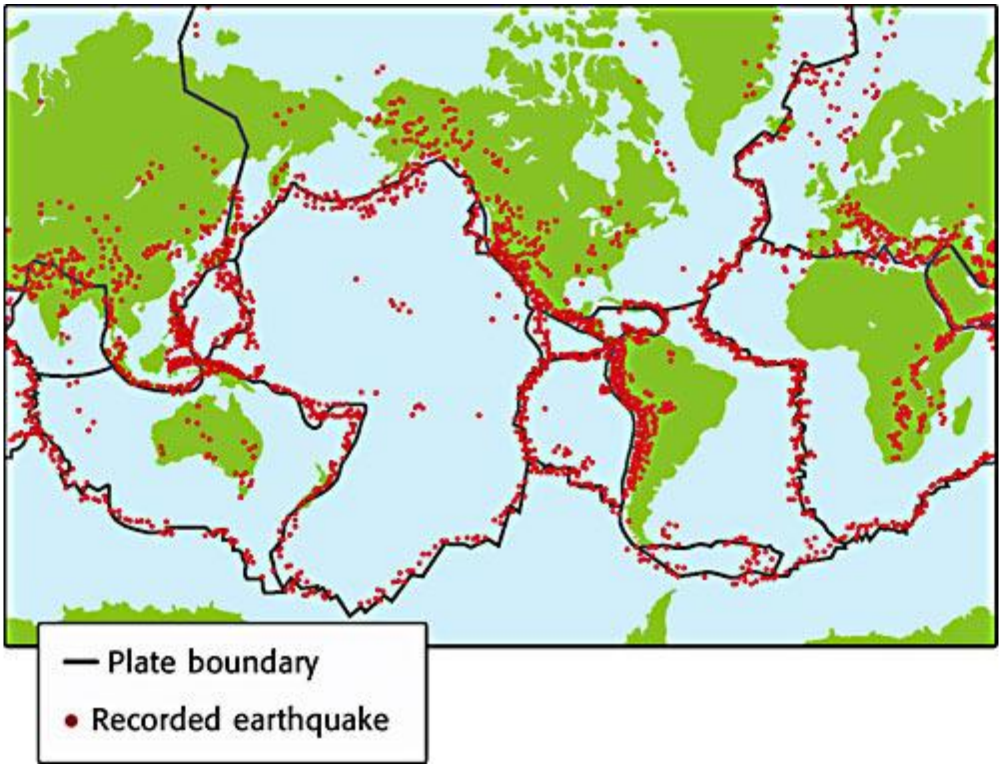

Figure 1 Most earthquakes occur along tectonic plate boundaries.
Tectonic plates move in different directions and at different speeds. Two plates can push toward or pull away from one another. They can also slip slowly past each other horizontally. These movements break Earth's crust into a series of faults. A *fault* is a break in Earth's crust along which blocks of rock slide relative to one another.

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Faults at Tectonic Plate Boundaries

Specific types of plate motion take place at different tectonic boundaries. Each type of motion creates a particular kind of fault. Examine **Figure 2, Figure 3,** and **Figure 4** to learn more about why earthquakes happen at plate boundaries.

Earthquakes at Divergent Boundaries

At divergent tectonic plate boundaries, two tectonic plates pull away from one another. As plates pull away from one another, tension causes the lithosphere to break into a series of fault blocks. Some of these blocks drop down relative to others. The blocks form a series of normal faults. As **Figure 2** shows, earthquakes happen along these normal faults as the blocks move.

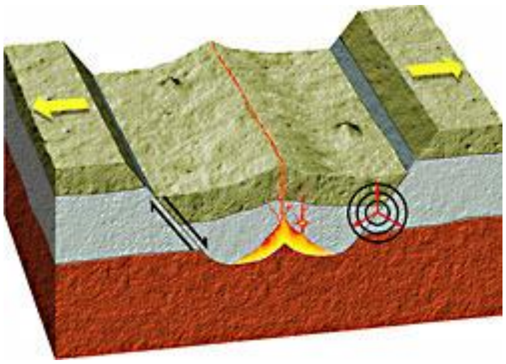

Figure 2 At divergent boundaries, earthquakes happen along normal faults at depths of less than 20 km.

A good example of a divergent boundary is a mid-ocean ridge, which is shown in **Figure 2.** At mid-ocean ridges, the oceanic lithosphere is thin and weak. Because oceanic lithosphere is thin, earthquakes that happen along the normal faults are shallow. At divergent boundaries, earthquakes happen at depths of less than 20 km below the ocean floor.

Earthquakes at Convergent Boundaries

At convergent tectonic plate boundaries, two tectonic plates collide with one another. When tectonic plates collide, two things may happen. Both plates may crumple up to form mountains. Or one plate can move underneath the other plate and sink into the mantle. The process of one plate moving under another is called *subduction.*

During subduction or mountain building, the rocks that make up the two plates are compressed. Compression causes the lithosphere to break into a series of fault blocks. These blocks are thrust over one another as the plates move. The blocks form a series of reverse faults. As **Figure 3** shows, earthquakes happen along reverse faults. Two types of earthquakes occur at subduction zones. Some earthquakes occur between the downgoing and overlying plates at depths of less than 50 km. Earthquakes also happen inside the downgoing plate to depths of as much as 700 km.

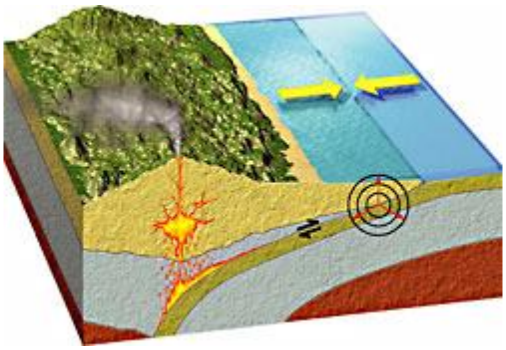

Figure 3 At convergent boundaries, earthquakes can happen along reverse faults at depths of as much as 700 km.

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Earthquakes at Transform Boundaries

At transform boundaries, two plates move past one another horizontally. When plates move past one another, the rocks on both sides of the fault are sheared. In other words, they are broken as they grind past one another in opposite directions. The shear stress causes the rock to break into a series of blocks. The blocks form a series of strike-slip faults. As **Figure 4** shows, earthquakes happen along these strike-slip faults as the blocks move.

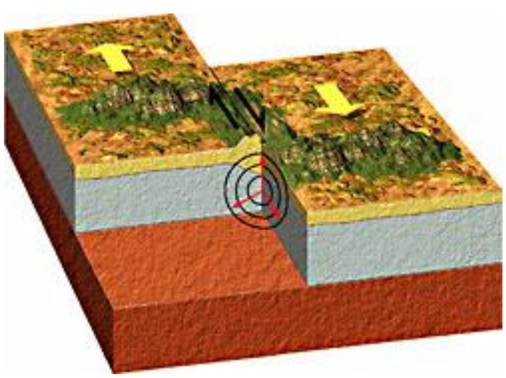


Figure 4 At transform boundaries, earthquakes happen along strike-slip faults at depths of less than 50 km.

Most transform boundaries exist between plates made of oceanic lithosphere. However, some transform boundaries occur between plates made of continental lithosphere. Rocks that are deep below Earth’s surface tend to react to shear stress by folding rather than by breaking. As a result, earthquakes along strike-slip faults generally occur at shallow depths.

Standards Check Why do earthquakes happen at transform boundaries?

Fault Zones

Places along plate boundaries where large numbers of interconnected faults are located are called *fault zones.* Faults in fault zones have different lengths, occur at different depths, and cut through the lithosphere in different directions. Normal faults, reverse faults, and strike-slip faults can all occur in a single fault zone.

The San Andreas fault zone in California is an example of a fault zone along a transform boundary. The San Andreas fault zone is primarily a strike-slip, or transform, fault system. However, normal and reverse faults do occur at bends in the San Andreas fault. A fault map that shows some of the faults that make up the San Andreas fault zone is shown in **Figure 5.**

Figure 5 Numerous faults, some of which are shown here, make up the San Andreas fault zone.

Why Earthquakes Happen

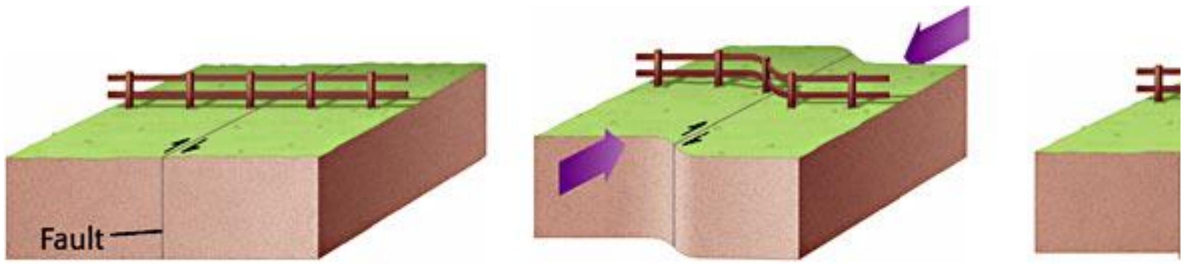
As tectonic plates move, stress on rocks near the edges of the plates increases. In response to this stress, the rock deforms, or changes shape. Rock deforms in mainly two ways. It can deform in a plastic manner, like a piece of clay being molded. Folded rocks, such as the ones shown in **Figure 6,** are a result of *plastic deformation.* Or rock can deform in an elastic manner, like a rubber band being stretched. *Elastic deformation* leads to earthquakes. Think of elastically deformed rock as a stretched rubber band. You can stretch a rubber band only so far before it breaks. When the rubber band breaks, it releases energy as the broken pieces return to their unstretched size and shape. In rock, this elastic movement causes faults to form and releases energy as an earthquake.

Figure 6 The forces that formed the San Andreas fault in Southern California also caused the plastic deformation of these rock layers.

Elastic Rebound

The sudden return of elastically deformed rock to its original shape is called **elastic rebound.** Elastic rebound happens when stress on rock along a fault becomes so great that the rock breaks, or fails. This failure causes the rocks on either side of the fault to jerk past one another, as **Figure 7** shows. During this sudden motion, large amounts of energy are released. This energy travels through rock as **seismic waves.** These waves cause the ground to move. The strength of an earthquake is related to the amount of energy that is released during elastic rebound.

Figure 7 Elastic Rebound



Tectonic forces push rock on either side of a fault in opposite directions. But the rock is locked in place.

The rock deforms in an elastic manner. When enough energy builds up and the rock along the fault slips, the energy is released as an earthquake.

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Standards Check How does elastic rebound cause earthquakes?

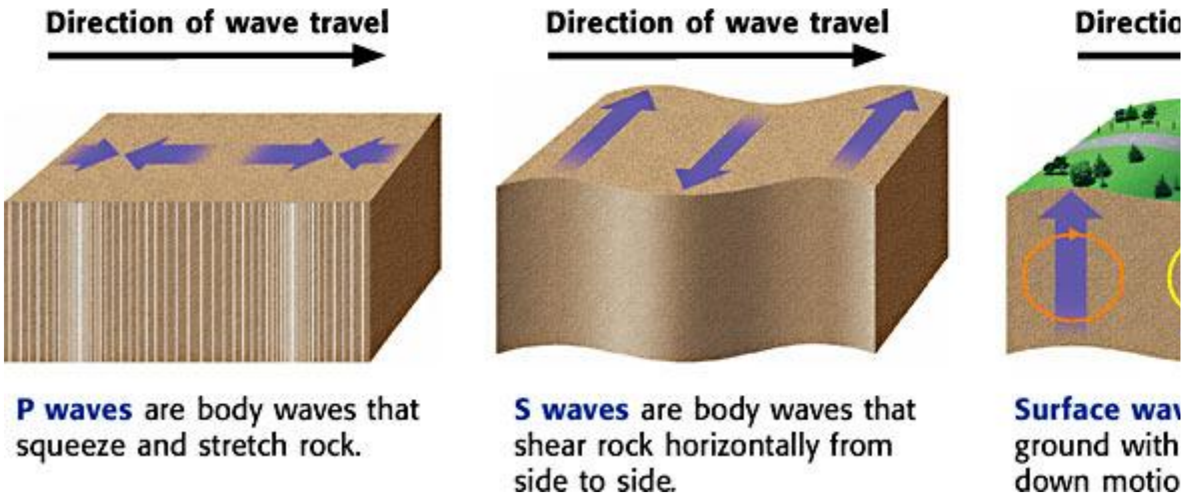
Earthquake Waves

Earthquakes are the physical result of the movement of energy through Earth as seismic waves. Seismic waves that travel through Earth's interior are called *body waves.* There are two types of body waves: P waves and S waves. Seismic waves that travel along Earth's surface are called *surface waves.* Each type of seismic wave travels through Earth's layers in a different way and at a different speed. Also, the speed of a seismic wave depends on the kind of material the wave travels through.

P Waves

P waves, or pressure waves, are the fastest seismic waves. P waves are also called *primary waves* because they are always the first waves of an earthquake to be detected. P waves can travel through solids, liquids, and gases. To understand how P waves affect rock, imagine a cube of gelatin sitting on a plate. Like most solids, gelatin is an elastic material. It wiggles if you tap it. Tapping the cube of gelatin changes the pressure inside the cube, which momentarily deforms the cube. The gelatin then reacts by springing back to its original shape. This process is how P waves affect rock, as **Figure 8** shows.

Figure 8 Types of Seismic Waves



S Waves

S waves, or shear waves, are the second-fastest seismic waves. S waves shear rock side to side, as **Figure 8** shows. Unlike P waves, S waves cannot travel through parts of Earth that are completely liquid. Also, S waves are slower than P waves and always arrive later. Thus, another name for S waves is *secondary waves.*

Standards Check How do P waves and S waves differ in the way that they transfer energy?

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Surface Waves

Surface waves move only along Earth's surface and produce motion only near the top of Earth's crust. Because their energy is focused on Earth's surface, surface waves tend to cause the most damage. In addition, surface waves travel more slowly than body waves do.

There are two types of surface waves. One type of surface wave produces a rolling, up-and-down motion, as **Figure 8** shows. The other type produces a back-and-forth motion like the motion produced by S waves.

Standards Check Explain why surface waves are the most destructive type of seismic wave.

Section Summary

- Earthquakes are motions of the ground that happen as energy travels through rock.
- Earthquakes occur mainly near the edges of tectonic plates.
- Earthquakes are caused by elastic rebound, which is caused by sudden motions along faults. During elastic rebound, rock springs into its original shape and size as stress is released.
- Energy generated by earthquakes travels as body waves through Earth’s interior or as surface waves along the surface of Earth.

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