SECTION 1

# What Are Earthquakes?

Have you ever felt the earth move under your feet? Many people have. Every day, somewhere within this planet, an earthquake is happening.

The word *earthquake* defines itself fairly well. But there is more to earthquakes than just the shaking of the ground. An entire branch of Earth science, called **seismology** (siez MAHL uh jee), is devoted to studying earthquakes. Earthquakes are complex, and they present many questions for *seismologists,* the scientists who study earthquakes.

### What You Will Learn

- Explain where earthquakes take place.
- Explain what causes earthquakes.
- Identify three different types of faults that occur at plate boundaries.
- Describe how energy from earthquakes travels through the Earth.

### Vocabulary

seismology
deformation
elastic rebound
seismic waves
P waves
S waves

**READING STRATEGY**

**Paired Summarizing** Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

## Where Do Earthquakes Occur?

Most earthquakes take place near the edges of tectonic plates. *Tectonic plates* are giant pieces of Earth's thin, outermost layer. Tectonic plates move around on top of a layer of plastic rock. **Figure 1** shows the Earth's tectonic plates and the locations of recent major earthquakes.

Tectonic plates move in different directions and at different speeds. Two plates can push toward or pull away from each other. They can also slip slowly past each other. As a result of these movements, numerous features called faults exist in the Earth's crust. A *fault* is a break in the Earth's crust along which blocks of the crust slide relative to one another. Earthquakes occur along faults because of this sliding.

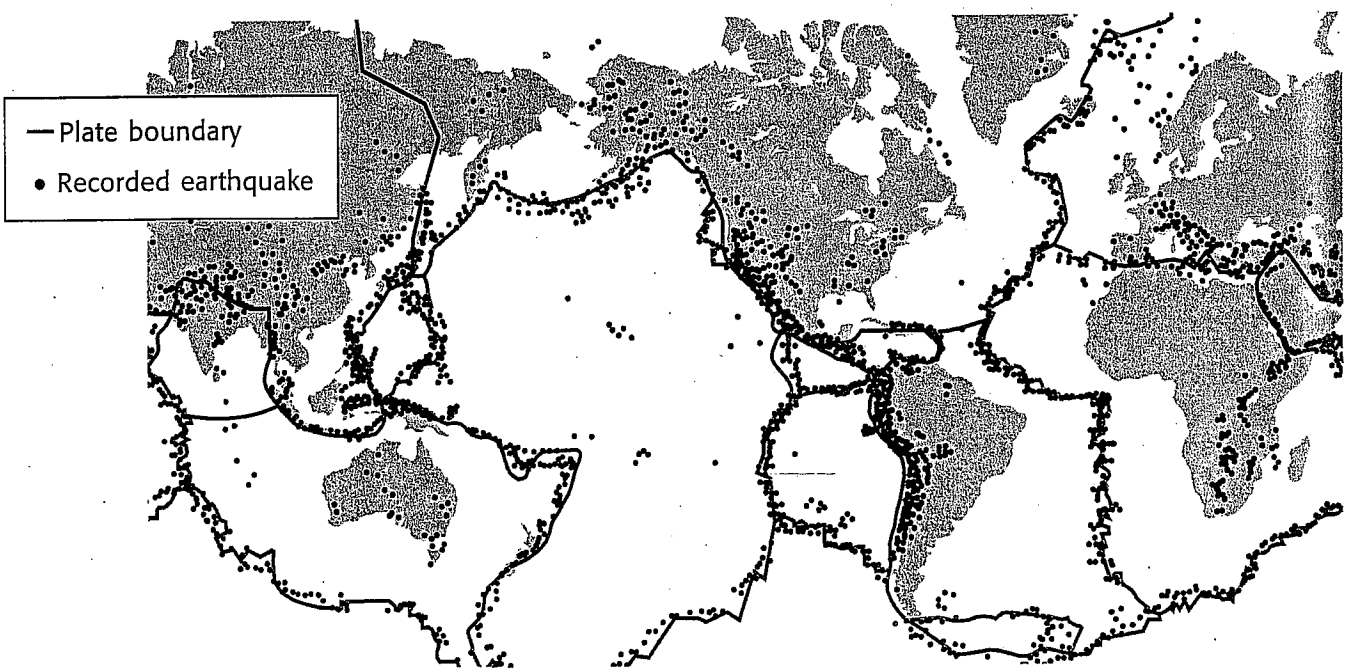



**Figure 1** *The largest and most active earthquake zone lies along the plate boundaries surrounding the Pacific Ocean.*

## What Causes Earthquakes?

As tectonic plates push, pull, or slip past each other, stress increases along faults near the plates' edges. In response to this stress, rock in the plates deforms. **Deformation** is the change in the shape of rock in response to stress. Rock along a fault deforms in mainly two ways. It deforms in a plastic manner, like a piece of molded clay, or in an elastic manner, like a rubber band. *Plastic deformation,* which is shown in **Figure 2,** does not lead to earthquakes.

*Elastic deformation,* however, does lead to earthquakes. Rock can stretch farther without breaking than steel can, but rock will break at some point. 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. Then, the broken pieces return to their unstretched shape.

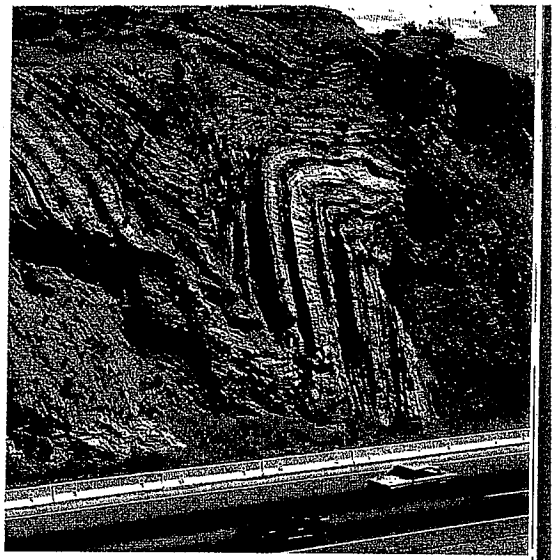


**Figure 2** *This road cut is adjacent to the San Andreas Fault in southern California. The rocks in the cut have undergone deformation because of the continuous motion of the fault.*

### Elastic Rebound

The sudden return of elastically deformed rock to its original shape is called **elastic rebound.** Elastic rebound is like the return of the broken rubber-band pieces to their unstretched shape. Elastic rebound occurs when more stress is applied to rock than the rock can withstand. During elastic rebound, energy is released. Some of this energy travels as seismic waves. These seismic waves cause an earthquake, as shown in **Figure 3.**

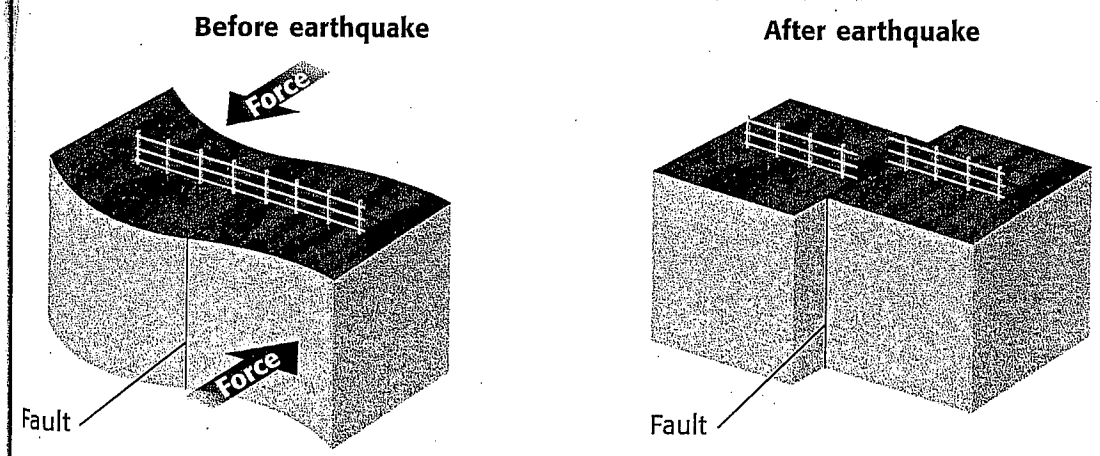
**Reading Check** How does elastic rebound relate to earthquakes? (*See the Appendix for answers to Reading Checks.*)

**seismology** the study of earthquakes

**deformation** the bending, tilting, and breaking of the Earth's crust; the change in the shape of rock in response to stress

**elastic rebound** the sudden return of elastically deformed rock to its undeformed shape

**Figure 3 Elastic Rebound and Earthquakes**




❶ Tectonic forces push rock on either side of the fault in opposite directions, but the rock is locked together and does not move. The rock deforms in an elastic manner.

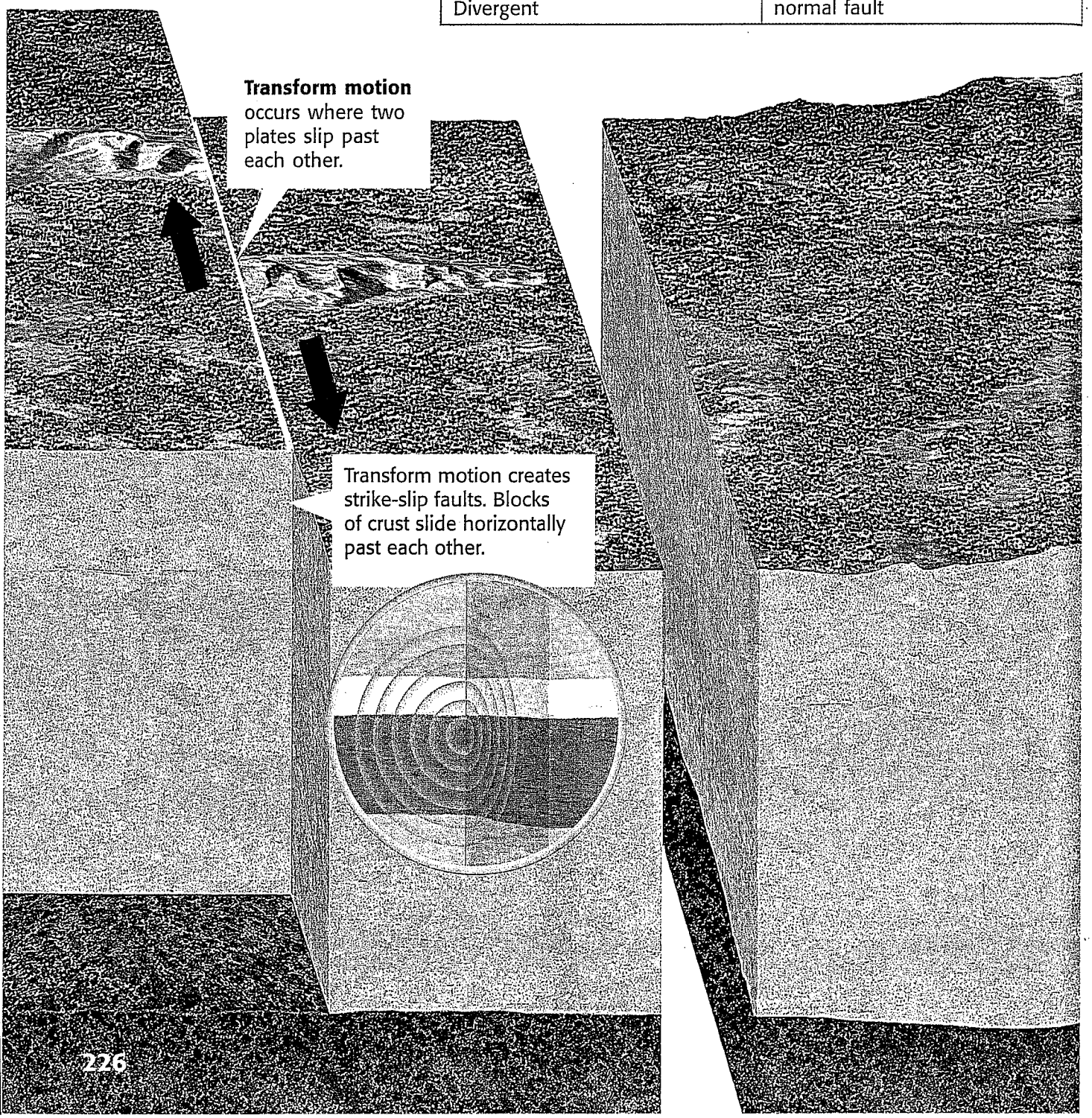
❷ When enough stress is applied, the rock slips along the fault and releases energy.

## Faults at Tectonic Plate Boundaries

A specific type of plate motion takes place at different tectonic plate boundaries. Each type of motion creates a particular kind of fault that can produce earthquakes. Examine **Table 1** and the diagram below to learn more about plate motion.

***Table 1*** **Plate Motion and Fault Types**

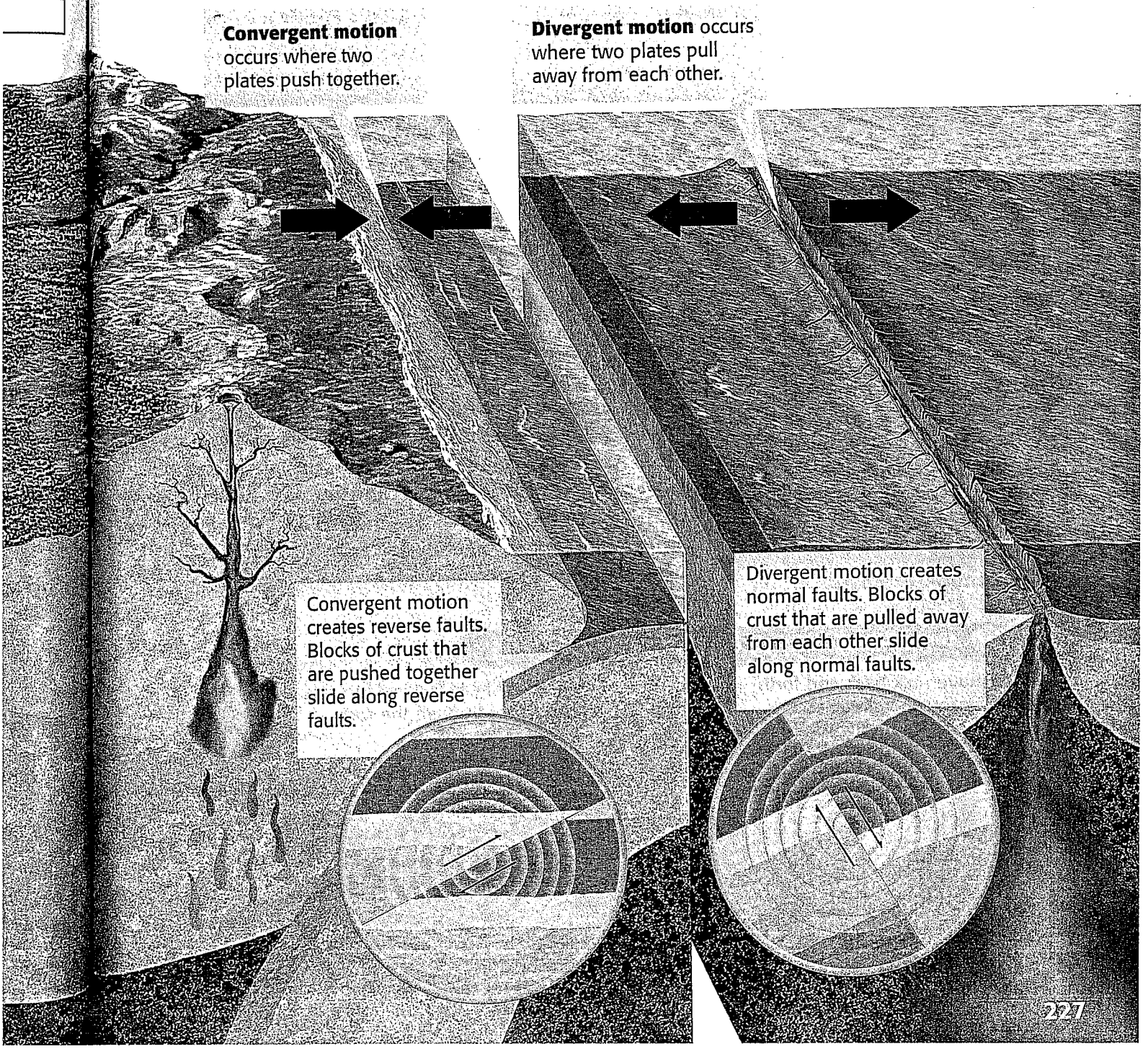
| Plate motion | Major fault type |
|---|---|
| Transform | strike-slip fault |
| Convergent | reverse fault |
| Divergent | normal fault |



## Earthquake Zones

Earthquakes can happen both near Earth's surface or far below it. Most earthquakes happen in the earthquake zones along tectonic plate boundaries. Earthquake zones are places where a large number of faults are located. The San Andreas Fault Zone in California is an example of an earthquake zone. But not all faults are located at tectonic plate boundaries. Sometimes, earthquakes happen along faults in the middle of tectonic plates.

**Reading Check** Where are earthquake zones located?



## How Do Earthquake Waves Travel?

Waves of energy that travel through the Earth are called **seismic waves.** Seismic waves that travel through the Earth's interior are called *body waves*. There are two types of body waves: P waves and S waves. Seismic waves that travel along the 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

Waves that travel through solids, liquids, and gases are called **P waves** (pressure waves). They are the fastest seismic waves, so P waves always travel ahead of other seismic waves. P waves are also called *primary waves*, because they are always the first waves of an earthquake to be detected. 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 shown in **Figure 4.**

### S Waves

Rock can also be deformed from side to side. After being deformed from side to side, the rock springs back to its original position and S waves are created. **S waves,** or shear waves, are the second-fastest seismic waves. S waves shear rock side to side, as shown in **Figure 4,** which means they stretch the rock sideways. Unlike P waves, S waves cannot travel through parts of the 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*.

**QUICK LAB**

**Modeling Seismic Waves**

1. Stretch a **spring toy** lengthwise on a **table.**
2. Hold one end of the spring while a partner holds the other end. Push your end toward your partner's end, and observe what happens.
3. Repeat step 2, but this time shake the spring from side to side.
4. Which type of seismic wave is represented in step 2? in step 3?

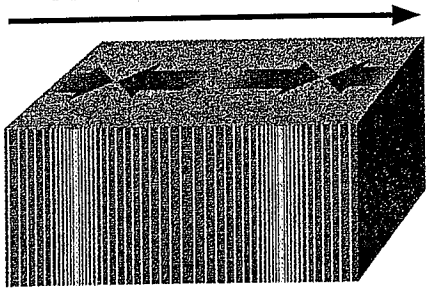
**seismic wave** a wave of energy that travels through the Earth, away from an earthquake in all directions

**P wave** a seismic wave that causes particles of rock to move in a back-and-forth direction

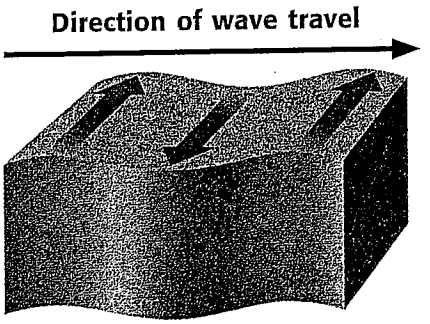
**S wave** a seismic wave that causes particles of rock to move in a side-to-side direction

**Figure 4 Body Waves**

**P waves** move rock back and forth, which squeezes and stretches the rock, as they travel through the rock.




**S waves** shear rock side to side as they travel through the rock.



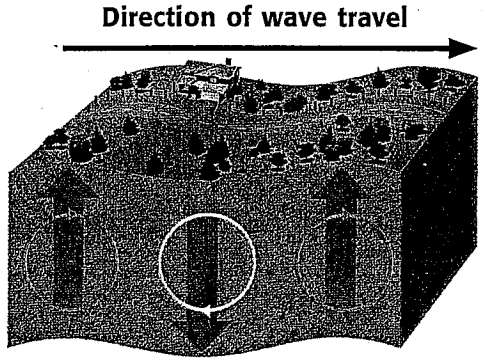
## Surface Waves

Surface waves move along the Earth's surface and produce motion mostly in the upper few kilometers of Earth's crust. There are two types of surface waves. One type of surface wave produces motion up, down, and around, as shown in **Figure 5.** The other type produces back-and-forth motion like the motion produced by S waves. Surface waves are different from body waves in that surface waves travel more slowly and are more destructive.

**Reading Check** Explain the differences between surface waves and body waves.

**Figure 5 Surface Waves**

**Surface waves** move the ground much like ocean waves move water particles.




# SECTION Review

## Summary

- Earthquakes occur mainly near the edges of tectonic plates.
- Elastic rebound is the direct cause of earthquakes.
- Three major types of faults occur at tectonic plate boundaries: normal faults, reverse faults, and strike-slip faults.
- Earthquake energy travels as body waves through the Earth's interior or as surface waves along the surface of the Earth.

### Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

| | |
|---|---|
| Deformation | P waves |
| Elastic rebound | S waves |

1. _____ is the change in shape of rock due to stress.
2. _____ always travel ahead of other waves.

### Understanding Key Ideas

3. Seismic waves that shear rock side to side are called
   - **a.** surface waves.
   - **b.** S waves.
   - **c.** P waves.
   - **d.** Both (b) and (c)
4. Where do earthquakes occur?
5. What is the direct cause of earthquakes?
6. Describe the three types of plate motion and the faults that are characteristic of each type of motion.
7. What is an earthquake zone?

### Math Skills

8. A seismic wave is traveling through the Earth at an average rate of speed of 8 km/s. How long will it take the wave to travel 480 km?

### Critical Thinking

9. **Applying Concepts** Given what you know about elastic rebound, why do you think some earthquakes are stronger than others?
10. **Identifying Relationships** Why are surface waves more destructive to buildings than P waves or S waves are?
11. **Identifying Relationships** Why do you think the majority of earthquake zones are located at tectonic plate boundaries?

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