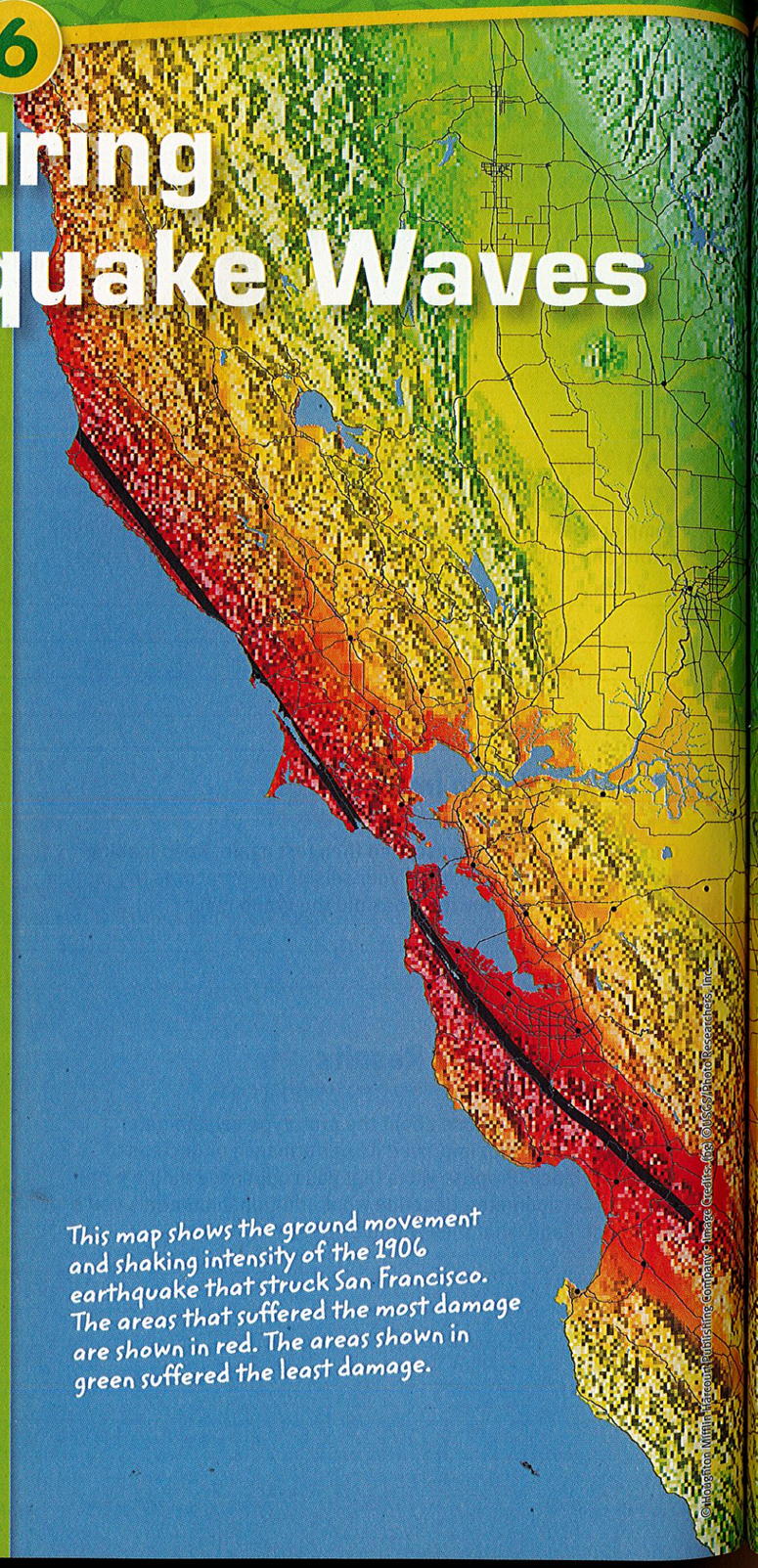
Lesson 6

Measuring Earthquake Waves

ESSENTIAL QUESTION

How are seismic waves used to study earthquakes?

By the end of this lesson, you should be able to understand how seismic waves are useful in determining the strength, location, and effects of an earthquake.



This map shows the ground movement and shaking intensity of the 1906 earthquake that struck San Francisco. The areas that suffered the most damage are shown in red. The areas shown in green suffered the least damage.

Lesson Labs

Quick Labs
- Earthquakes and Buildings
- Locating an Earthquake's Epicenter

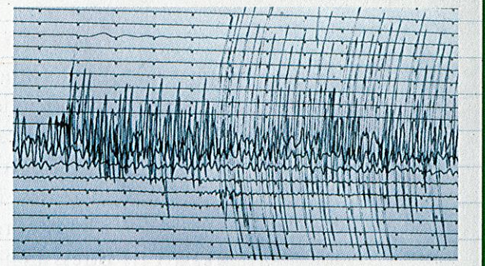
S.T.E.M. Lab
- Use a Seismograph to Determine the Amount of Energy in an Earthquake

Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

T	F	
☐	☐	Earthquakes often occur along faults.
☐	☐	Earthquakes produce two main kinds of seismic waves.
☐	☐	More than one kind of scale can be used to measure the magnitude of an earthquake.
☐	☐	Older buildings tend to withstand earthquakes better than newer buildings.

2 Describe This graph shows the progression of an earthquake. How might this graph indicate the strength of an earthquake?



Active Reading

3 Synthesize Many English words have their roots in other languages. Use the Greek words below to make a guess about the meaning of the words *seismometer* and *seismogram*.

Greek word	Meaning
seismos	earthquake
metron	measure
gramma	writing

Example sentence
The seismometer recorded a series of weak earthquakes.

seismometer:

Example sentence
The seismogram printout indicated that a small earthquake had just occurred.

seismogram:

Vocabulary Terms

- focus
- epicenter
- seismic waves
- seismogram
- magnitude
- intensity

4 Apply As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

Shake, Rattle, and Roll

What happens during an earthquake?

Have you ever felt the ground move under your feet? Many people have. Every day, somewhere in the world, earthquakes happen. An earthquake occurs when blocks of rock move suddenly and release energy. This energy travels through rock as waves.

Movement Takes Place Along a Fault

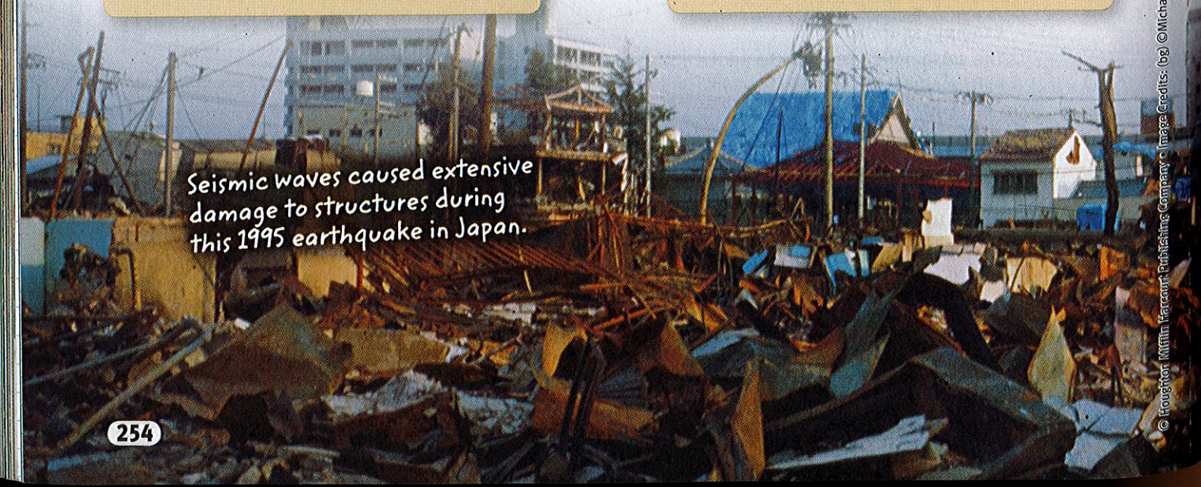
Earth's lithosphere (LITH•uh•sfir) is the rocky outer layer of Earth that includes the crust. The lithosphere is made up of large plates. These plates pull apart, push together, or move past one another. As plates move, stress on rocks at or near the edges of the plates increases. This stress causes faults to form. A *fault* is a break in a body of rock along which one block moves relative to another. Stress along faults causes the rocks to deform, or change from their original shape. If this stress becomes too great, rocks along a fault will break and move along the fault. Once rocks break, the pieces of broken rock return to an undeformed shape. When rocks along a fault break and move along a fault, energy is released into the surrounding rock in the form of waves. This process is what causes earthquakes.

Active Reading

5 Identify As you read, underline the definition of a fault.

6 Sequence Fill in the cause-and-effect chain for earthquakes.

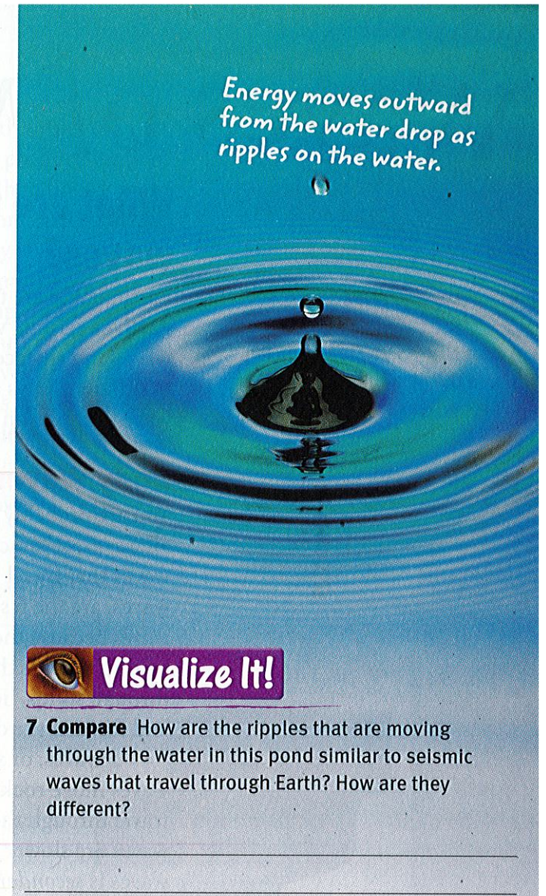
(A) Stress builds up on rocks along a fault, and the rocks deform. The rocks break suddenly, and the pieces return to an undeformed shape. → (B) _____ → (C) Seismic waves travel through Earth and along Earth's surface. → (D) _____



Seismic waves caused extensive damage to structures during this 1995 earthquake in Japan.

Energy Is Released as Seismic Waves

As stress builds up in rocks along a fault, the energy that is stored in the deforming rock increases. When the rock breaks, the rocks on either side of the fault slip past one another and return to an undeformed state. The location along a fault at which the first motion of an earthquake takes place is called the **focus**. The **epicenter** is the point on Earth's surface directly above an earthquake's starting point or focus. A large amount of stored energy is released when rocks along a fault slip. This energy travels away from the focus and through Earth in all directions as seismic (SYZ•mik) waves. **Seismic waves** are vibrations that cause different types of ground motion. The strength of an earthquake is based on the energy that is released as rocks break and return to an undeformed shape.



Energy moves outward from the water drop as ripples on the water.

Visualize It!

7 Compare How are the ripples that are moving through the water in this pond similar to seismic waves that travel through Earth? How are they different?

_____

_____

_____

Waves of Motion

What are two kinds of seismic waves?

Earthquakes are the result of the movement of energy through Earth as seismic waves. There are two kinds of seismic waves, body waves and surface waves. Each kind of wave travels through Earth in different ways and at different speeds. The speed of a seismic wave depends on the material through which the wave travels.

Active Reading

8 Identify As you read this page and the next, underline the properties of seismic waves.

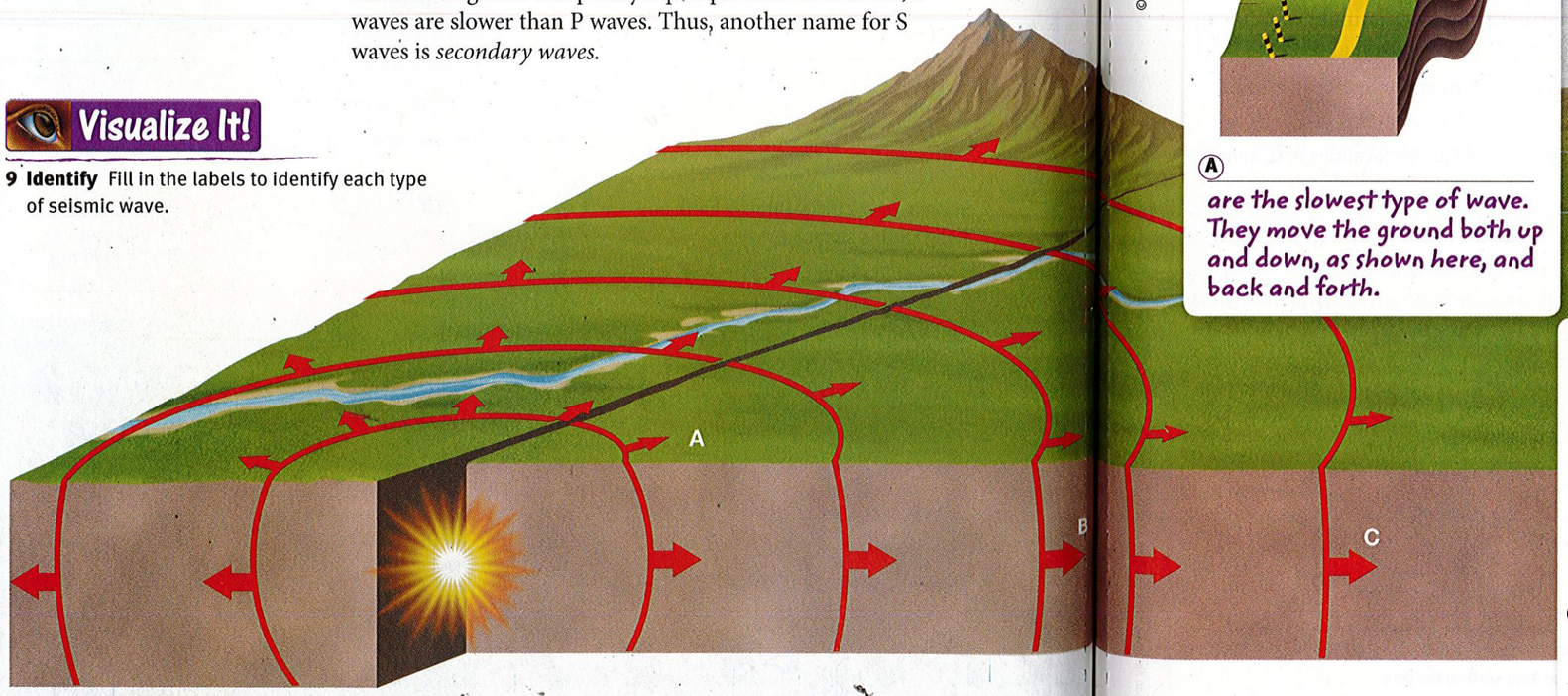
Body Waves

You are probably familiar with ocean waves or sound waves. Like all waves, seismic waves carry energy. *Body waves* are seismic waves that travel through Earth's interior. P waves, or pressure waves, are the fastest body waves. P waves are also called *primary waves* because they are always the first seismic waves to be detected by instruments that monitor earthquakes. P waves can travel through solids, liquids, and gases. They cause rock to move back and forth in the direction the wave is traveling.

S waves, or shear waves, are a second kind of body wave. S waves move rock from side to side. Unlike P waves, S waves cannot travel through the completely liquid parts of Earth. Also, S waves are slower than P waves. Thus, another name for S waves is *secondary waves.*

Visualize It!

9 Identify Fill in the labels to identify each type of seismic wave.



Surface Waves

Seismic waves that travel along the surface of Earth rather than through it are called *surface waves*. Surface waves produce motion only on Earth's surface. Surface waves are slower than both P and S waves. However, because their energy is focused on Earth's surface, surface waves cause more damage than these body waves.

Surface waves produce two types of ground motion as they move along Earth's surface. The first is a rolling, up-and-down motion that dies out with depth. This motion occurs in the same direction as the direction in which the wave is traveling. Surface waves also produce a back-and-forth motion. This motion is perpendicular to the direction in which the wave is traveling.

10 Compare How do surface waves differ from body waves?

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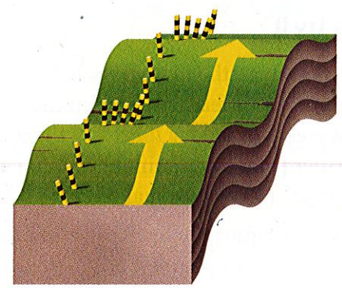
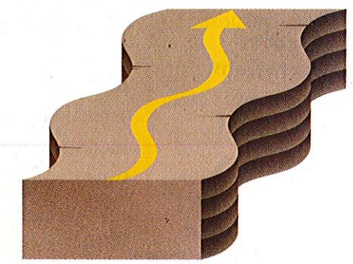
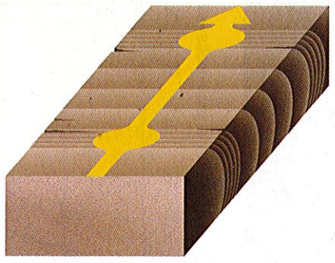


(A) _____ are the slowest type of wave. They move the ground both up and down, as shown here, and back and forth.



(B) _____ are the second-fastest type of wave. They cause rock to move side to side.



(C) _____ are the fastest type of wave. They cause rock to move back and forth.

Wave Action!

How are seismic waves measured?

Imagine walls shaking, windows rattling, and glasses and dishes clinking. After only seconds, the vibrating stops. Within minutes, news reports give information about the strength and the location of the earthquake. How could scientists learn this information so quickly? Scientists use instruments called *seismometers* to record the seismic waves generated by earthquakes. Seismometers are located at seismometer stations that are arranged in networks. When seismic waves reach a seismometer, the seismometer produces a seismogram. A **seismogram** is a tracing of earthquake motion. Seismograms also record the arrival times of seismic waves at a seismometer station. Seismograms are plotted on a graph like the one shown below. Scientists use the graph to pinpoint the location of an earthquake's epicenter.

Seismometers located at seismometer stations produce seismograms that make a tracing of earthquake motion.

Do the Math You Try It

P waves travel faster than S waves and are the first waves to be recorded at a seismometer station. The difference between the arrival times of P waves and S waves is called *lag time*. Lag time increases as the waves travel farther from their point of origin. Lag time can be used to find the distance to an earthquake's epicenter.

Identify

11 Calculate What are the lag times for each of the locations A, B, and C?

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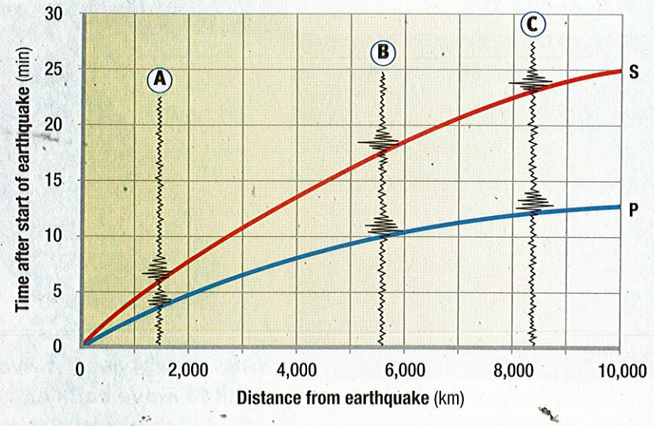
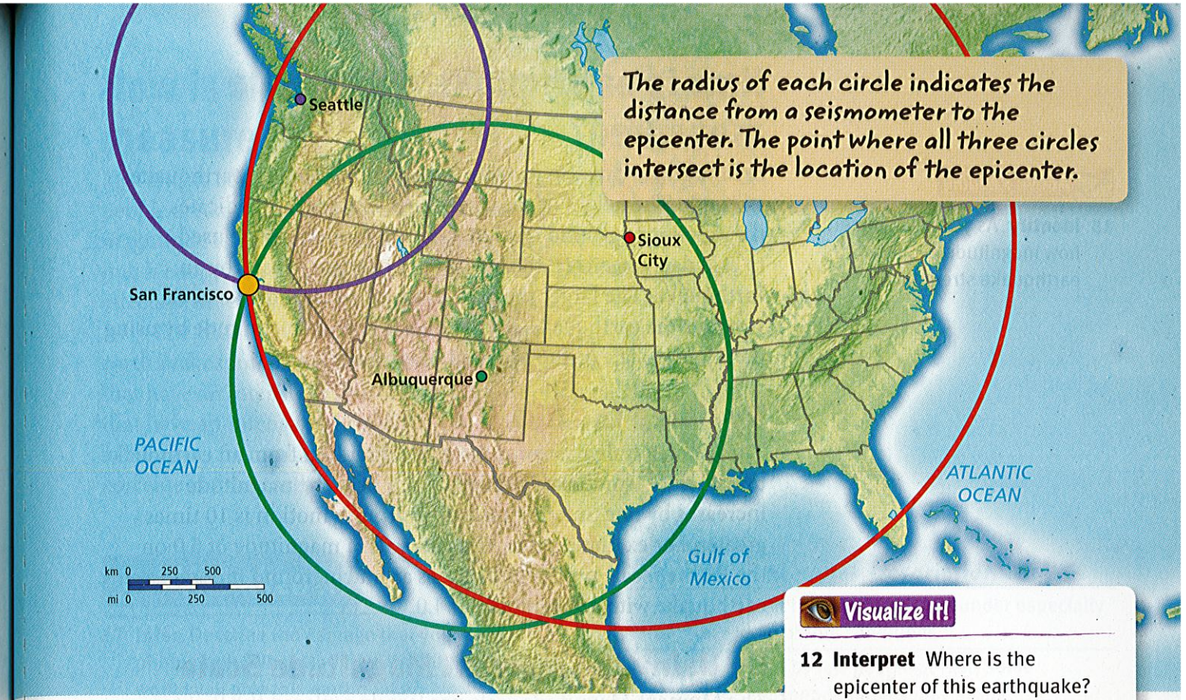
Plotting Seismograms on a Time-Distance Graph





Visualize It!

12 Interpret Where is the epicenter of this earthquake? Explain how you know.

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_____

How is an earthquake's epicenter located?

Scientists use the data from seismograms to find an earthquake's epicenter. The S-P time method is an easy way to locate the epicenter of an earthquake. The method is based on the differences in arrival times of P and S waves, called lag time, at different seismometer stations. Lag time tells scientists how far waves have traveled from the epicenter. The epicenter of the earthquake can then be located by drawing circles around at least three seismometer stations on a map, as shown above. The radius of each circle is equal to the distance from that seismometer station to the earthquake's epicenter. The point at which all of the circles intersect is the epicenter. This process is called *triangulation*. Today, computers perform these calculations.

Active Reading **13 Identify** What is the name of the process used to locate an earthquake's epicenter?

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Think Outside the Book Inquiry

14 Research With a classmate, research recent earthquake activity in your state. Present your findings in an oral report.