Section 2

Earthquakes and Seismic Waves

Reading Preview

Key Concepts

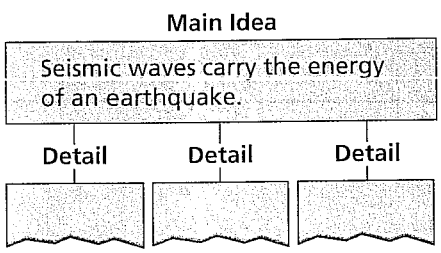
- How does the energy of an earthquake travel through Earth?
- What are the scales used to measure the strength of an earthquake?
- How do scientists locate the epicenter of an earthquake?

Key Terms

- earthquake • focus
- epicenter • P wave
- S wave • surface wave
- Mercalli scale • magnitude
- Richter scale • seismograph
- moment magnitude scale

Target Reading Skill

Identifying Main Ideas As you read Types of Seismic Waves, write the main idea in a graphic organizer like the one below. Then write three supporting details. The supporting details further explain the main idea.



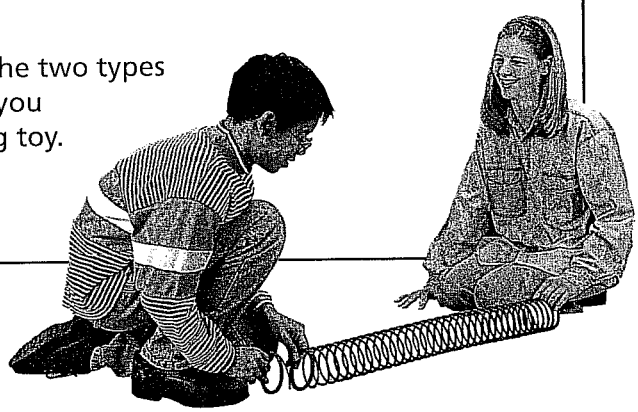
Lab zone **Discover Activity**

How Do Seismic Waves Travel Through Earth?

1. Stretch a spring toy across the floor while a classmate holds the other end. Do not overstretch the toy.
2. Gather together about four coils of the spring toy and release them. In what direction do the coils move?
3. Once the spring toy has stopped moving, jerk one end of the toy from side to side once. Be certain your classmate has a secure grip on the other end. In what direction do the coils move?

Think It Over

Observing Describe the two types of wave motion that you observed in the spring toy.



Earth is never still. Every day, worldwide, there are several thousand earthquakes. An **earthquake** is the shaking and trembling that results from the movement of rock beneath Earth's surface. Most earthquakes are too small to notice. But a large earthquake can produce dramatic changes in Earth's surface and cause great damage.

The forces of plate movement cause earthquakes. Plate movements produce stress in Earth's crust, adding energy to rock and forming faults. Stress increases along a fault until the rock breaks. An earthquake begins. In seconds, the earthquake releases an enormous amount of stored energy.

Most earthquakes begin in the lithosphere within about 100 kilometers of Earth's surface. The **focus** (FOH kus) is the area beneath Earth's surface where rock that is under stress breaks, triggering an earthquake. The point on the surface directly above the focus is called the **epicenter** (EP uh sen tur).

Types of Seismic Waves

Like a pebble thrown into a pond, an earthquake produces vibrations called waves. These waves carry energy as they travel outward. During an earthquake, seismic waves race out from the focus in all directions. Seismic waves are vibrations that travel through Earth carrying the energy released during an earthquake. The seismic waves move like ripples in a pond. **Seismic waves carry energy from an earthquake away from the focus, through Earth's interior, and across the surface.** That's what happened in 2002, when a powerful earthquake ruptured the Denali fault in Alaska, shown in Figure 7.

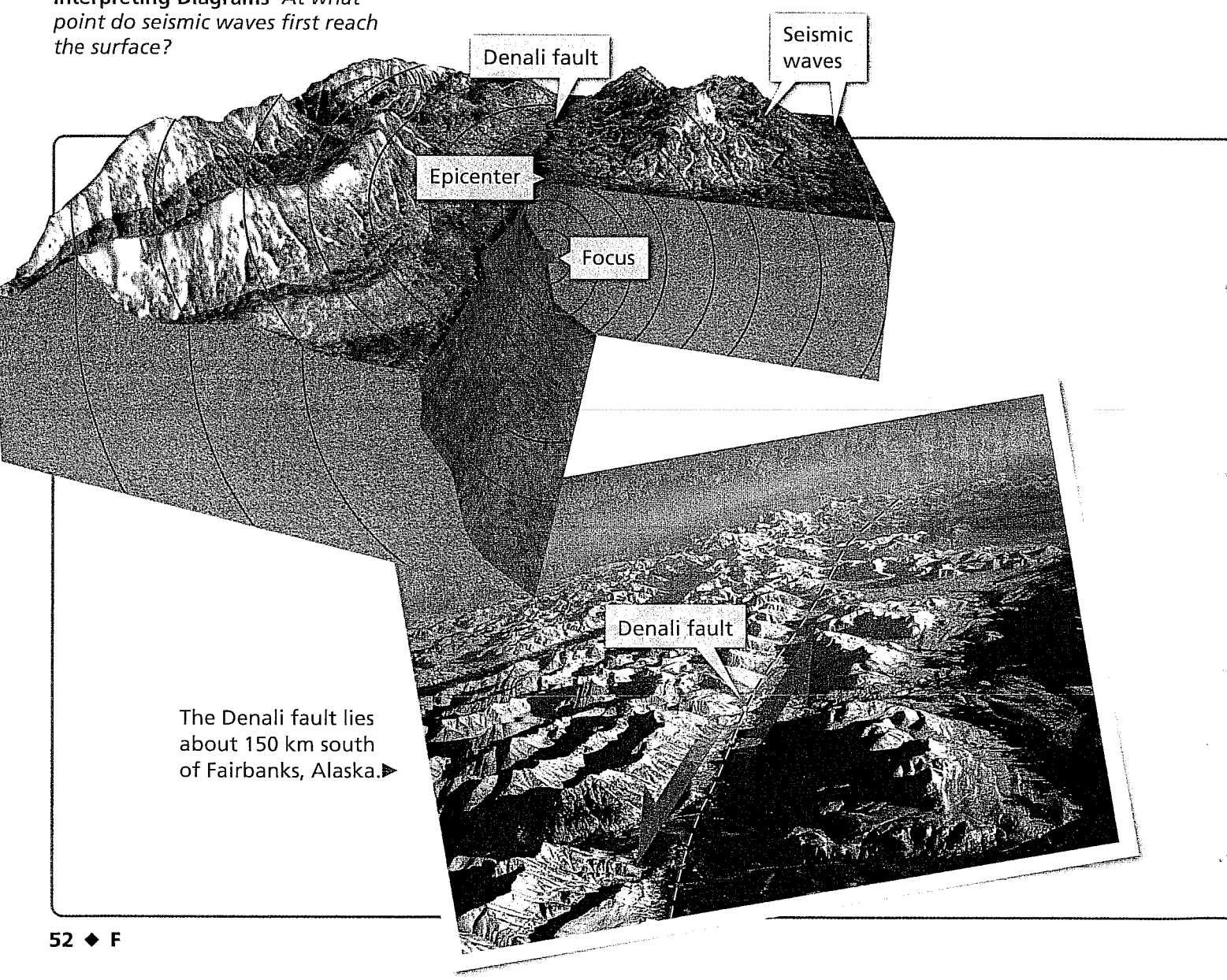
There are three main categories of seismic waves: P waves, S waves, and surface waves. An earthquake sends out two types of waves from its focus: P waves and S waves. When these waves reach Earth's surface at the epicenter, surface waves develop.

FIGURE 7

Seismic Waves

This diagram shows an earthquake along the Denali fault. An earthquake occurs when rocks fracture deep in the crust. The seismic waves move out in all directions from the focus.

Interpreting Diagrams *At what point do seismic waves first reach the surface?*



The Denali fault lies about 150 km south of Fairbanks, Alaska.▶

P Waves The first waves to arrive are primary waves, or P waves. **P waves** are seismic waves that compress and expand the ground like an accordion. Like the other types of seismic waves, P waves can damage buildings. Look at Figure 7 to see how P waves move.

S Waves After P waves come secondary waves, or S waves. **S waves** are seismic waves that vibrate from side to side as well as up and down. They shake the ground back and forth. When S waves reach the surface, they shake structures violently. Unlike P waves, which travel through both solids and liquids, S waves cannot move through liquids.

Surface Waves When P waves and S waves reach the surface, some of them become surface waves. **Surface waves** move more slowly than P waves and S waves, but they can produce severe ground movements. Some surface waves make the ground roll like ocean waves. Other surface waves shake buildings from side to side.

Reading Checkpoint **Which type of seismic wave causes the ground to roll like ocean waves?**

Go Online *active art*

For: Seismic Waves activity
Visit: PHSchool.com
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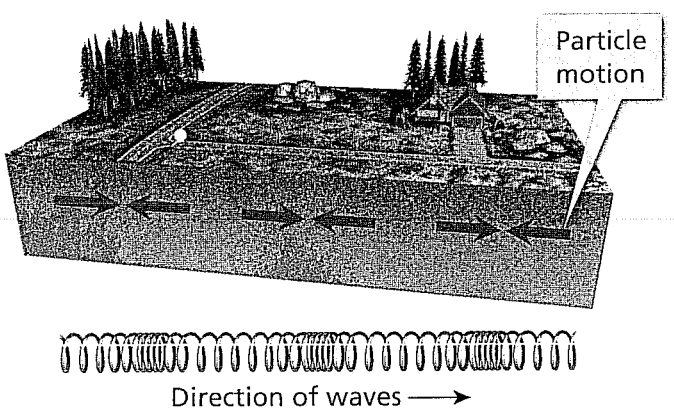
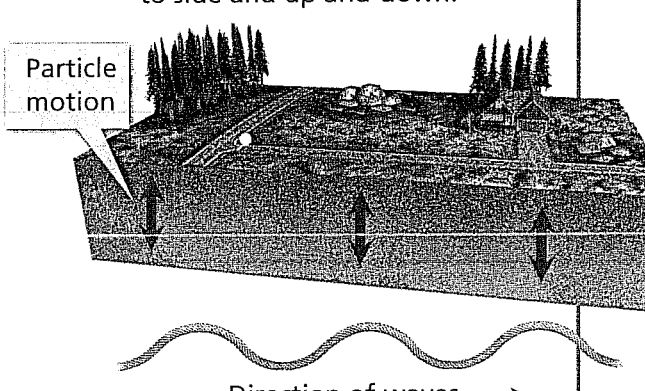
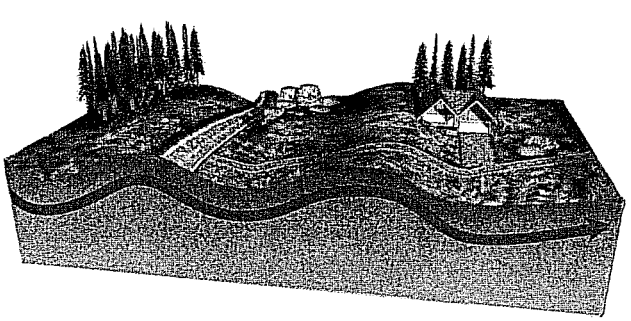
P waves ▼
The crust vibrates forward and back along the path of the wave.



S waves ▼
The crust vibrates from side to side and up and down.





◀ Surface waves
The ground surface rolls with a wavelike motion.

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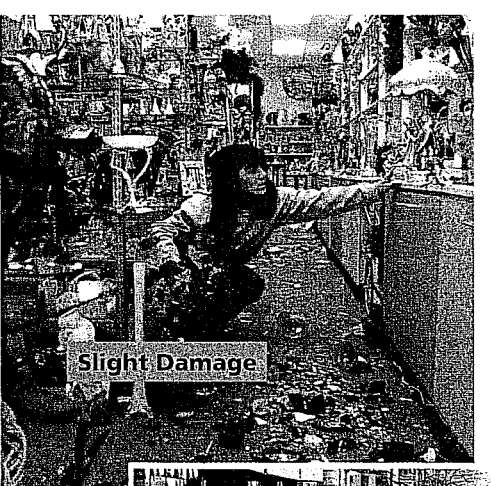
Earthquakes
Video Preview
▶ Video Field Trip
Video Assessment

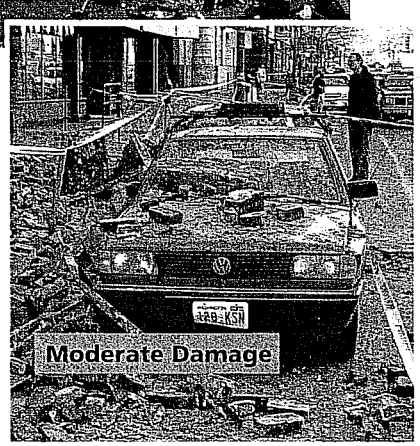
Measuring Earthquakes

When an earthquake occurs, people want to know "How big was the quake?" and "Where was it centered?" When geologists want to know the size of an earthquake, they must consider many factors. As a result, there are at least 20 different measures for rating earthquakes, each with its strengths and shortcomings. **Three commonly used methods of measuring earthquakes are the Mercalli scale, the Richter scale, and the moment magnitude scale.**

The Mercalli Scale The **Mercalli scale** was developed to rate earthquakes according to the level of damage at a given place. The 12 steps of the Mercalli scale, shown in Figure 9, describe an earthquake's effects. The same earthquake can have different Mercalli ratings because it causes different amounts of ground motion at different locations.

The Richter Scale An earthquake's **magnitude** is a number that geologists assign to an earthquake based on the earthquake's size. Geologists determine magnitude by measuring the seismic waves and fault movement that occur during an earthquake. The **Richter scale** is a rating of an earthquake's magnitude based on the size of the earthquake's seismic waves. The seismic waves are measured by a **seismograph.** A seismograph is an instrument that records and measures seismic waves. The Richter scale provides accurate measurements for small, nearby earthquakes. But it does not work well for large or distant earthquakes.





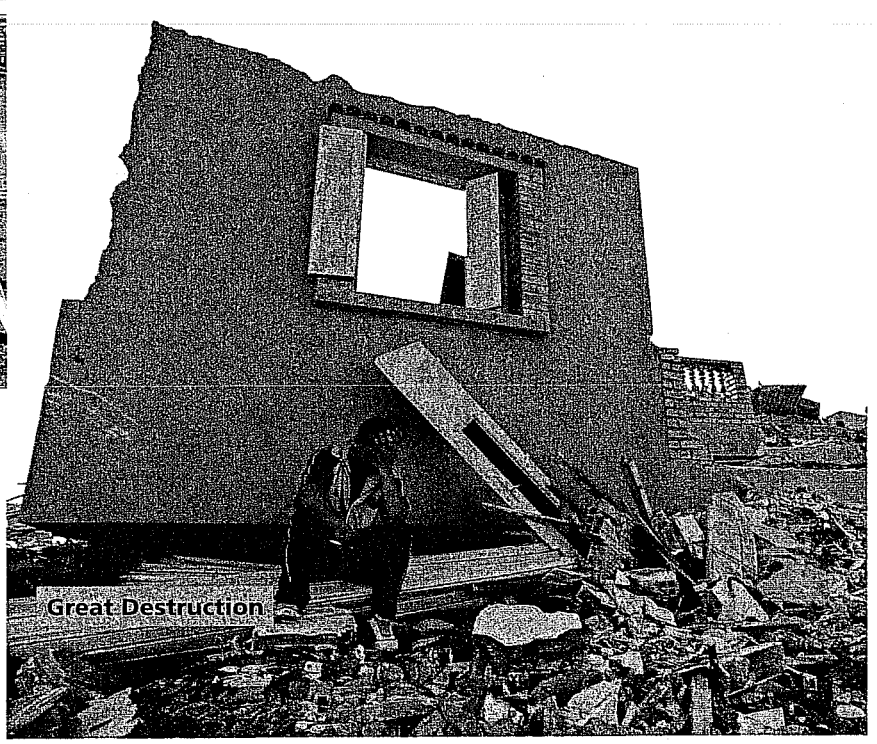
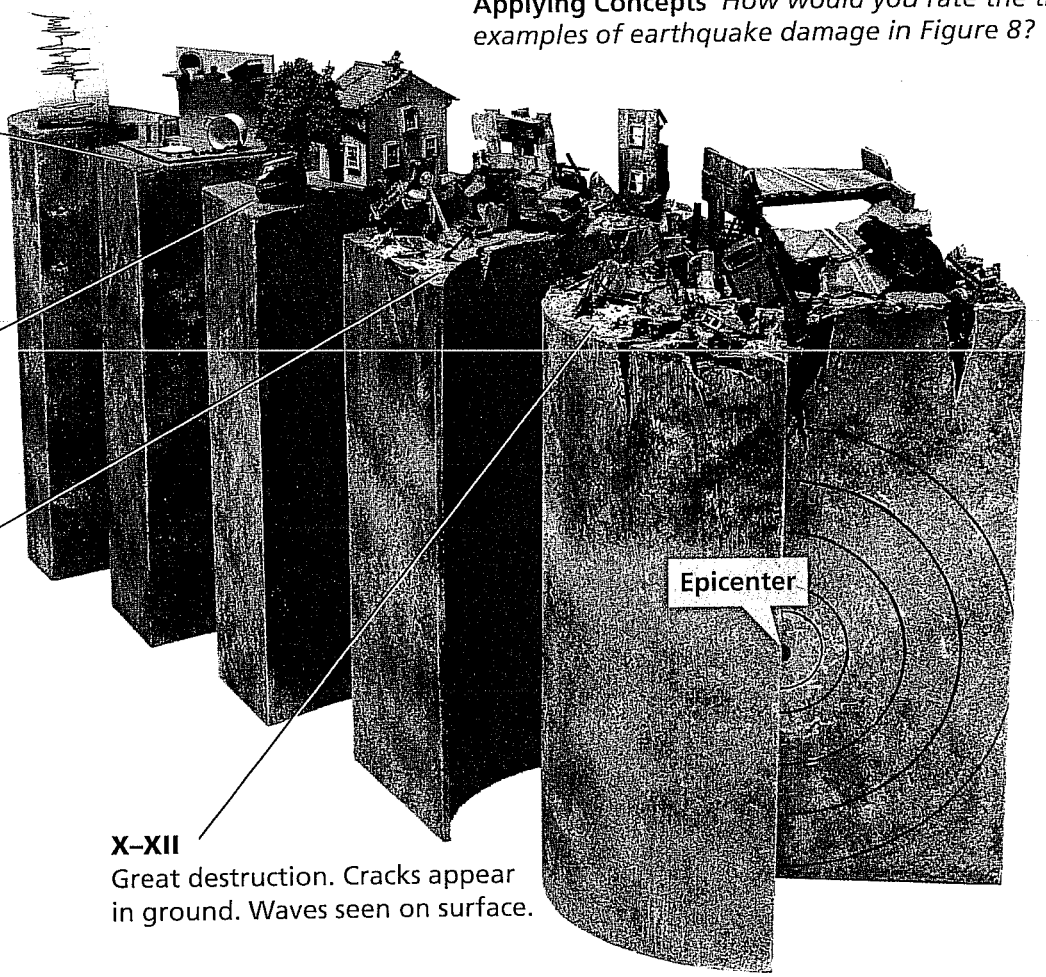


FIGURE 8
Levels of Earthquake Damage
The level of damage caused by an earthquake varies depending on the magnitude of the earthquake and the distance from the epicenter.

FIGURE 9
The Mercalli Scale
The Mercalli scale uses Roman numerals to rank earthquakes by how much damage they cause.
Applying Concepts *How would you rate the three examples of earthquake damage in Figure 8?*



The Moment Magnitude Scale Geologists today often use the **moment magnitude scale,** a rating system that estimates the total energy released by an earthquake. The moment magnitude scale can be used to rate earthquakes of all sizes, near or far. You may hear news reports that mention the Richter scale. But the number they quote is almost always the moment magnitude for that earthquake.

To rate an earthquake on the moment magnitude scale, geologists first study data from seismographs. The data show what kinds of seismic waves the earthquake produced and how strong they were. The data also help geologists infer how much movement occurred along the fault and the strength of the rocks that broke when the fault slipped. Geologists use all this information to rate the quake on the moment magnitude scale.

Reading Checkpoint **What evidence do geologists use to rate an earthquake on the moment magnitude scale?**

Lab zone Skills Activity

Classifying

Classify the earthquake damage at these locations using the Mercalli scale.

1. Many buildings are destroyed; cracks form in the ground.
2. Several old brick buildings and a bridge collapse.
3. Canned goods fall off shelves; walls crack; people go outside to see what's happening.

FIGURE 10
Collecting Seismic Data
This geologist is checking data collected after an earthquake. These data can be used to pinpoint the epicenter of an earthquake.

Comparing Magnitudes An earthquake's magnitude tells geologists how much energy was released by the earthquake. Each one-point increase in magnitude represents the release of roughly 32 times more energy. For example, a magnitude 6 quake releases 32 times as much energy as a magnitude 5 quake, and about 1,000 times as much as a magnitude 4 quake.

The effects of an earthquake increase with magnitude. People scarcely notice earthquakes with magnitudes below 3. Earthquakes with a magnitude below 5 are small and cause little damage. Those with a magnitude between 5 and 6 can cause moderate damage. Earthquakes with a magnitude above 6 can cause great damage. Fortunately, the most powerful earthquakes, with a magnitude of 8 or above, are rare. During the twentieth century, only two earthquakes measured above 9 on the moment magnitude scale. These earthquakes occurred in Chile in 1960 and in Alaska in 1964.

Locating the Epicenter

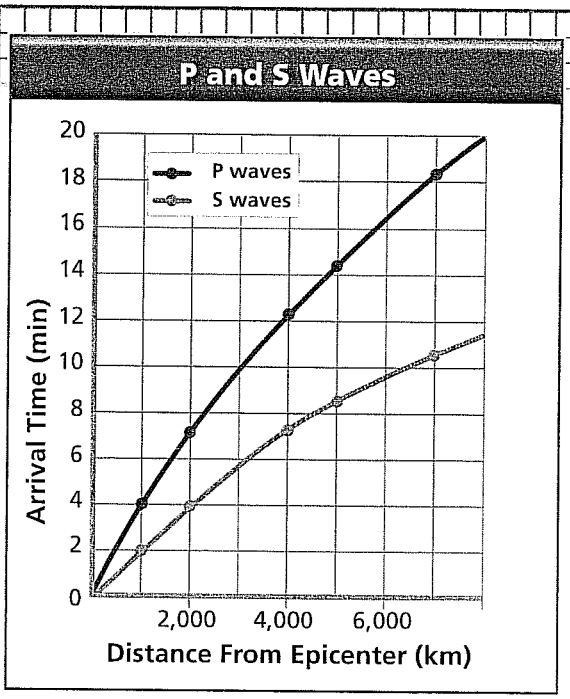
Geologists use seismic waves to locate an earthquake's epicenter. Seismic waves travel at different speeds. P waves arrive at a seismograph first, with S waves following close behind. To tell how far the epicenter is from the seismograph, scientists measure the difference between the arrival times of the P waves and S waves. The farther away an earthquake is, the greater the time between the arrival of the P waves and the S waves.

Math Analyzing Data

Seismic Wave Speeds

Seismographs at five observation stations recorded the arrival times of the P and S waves produced by an earthquake. These data are shown in the graph.

1. **Reading Graphs** What variable is shown on the *x*-axis of the graph? The *y*-axis?
2. **Reading Graphs** How long did it take the S waves to travel 2,000 km?
3. **Estimating** How long did it take the P waves to travel 2,000 km?
4. **Calculating** What is the difference in the arrival times of the P waves and the S waves at 2,000 km? At 4,000 km?



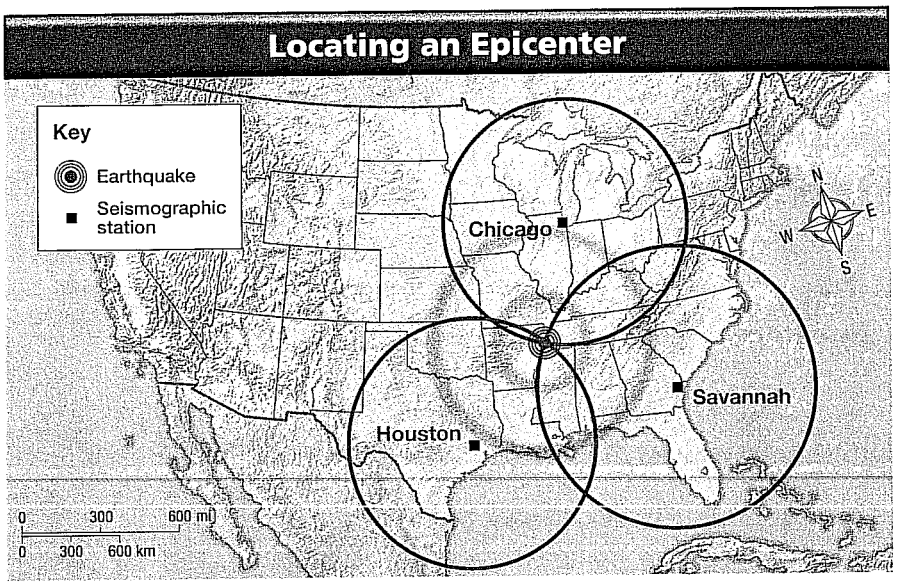


FIGURE 11
The map shows how to find the epicenter of an earthquake using data from three seismographic stations. **Measuring** *Use the map scale to determine the distances from Savannah and Houston to the epicenter. Which is closer?*

Geologists then draw at least three circles using data from different seismographs set up at stations all over the world. The center of each circle is a particular seismograph's location. The radius of each circle is the distance from that seismograph to the epicenter. As you can see in Figure 11, the point where the three circles intersect is the location of the epicenter.

Reading Checkpoint **What do geologists measure to determine the distance from a seismograph to an epicenter?**

Section 2 Assessment

Target Reading Skill

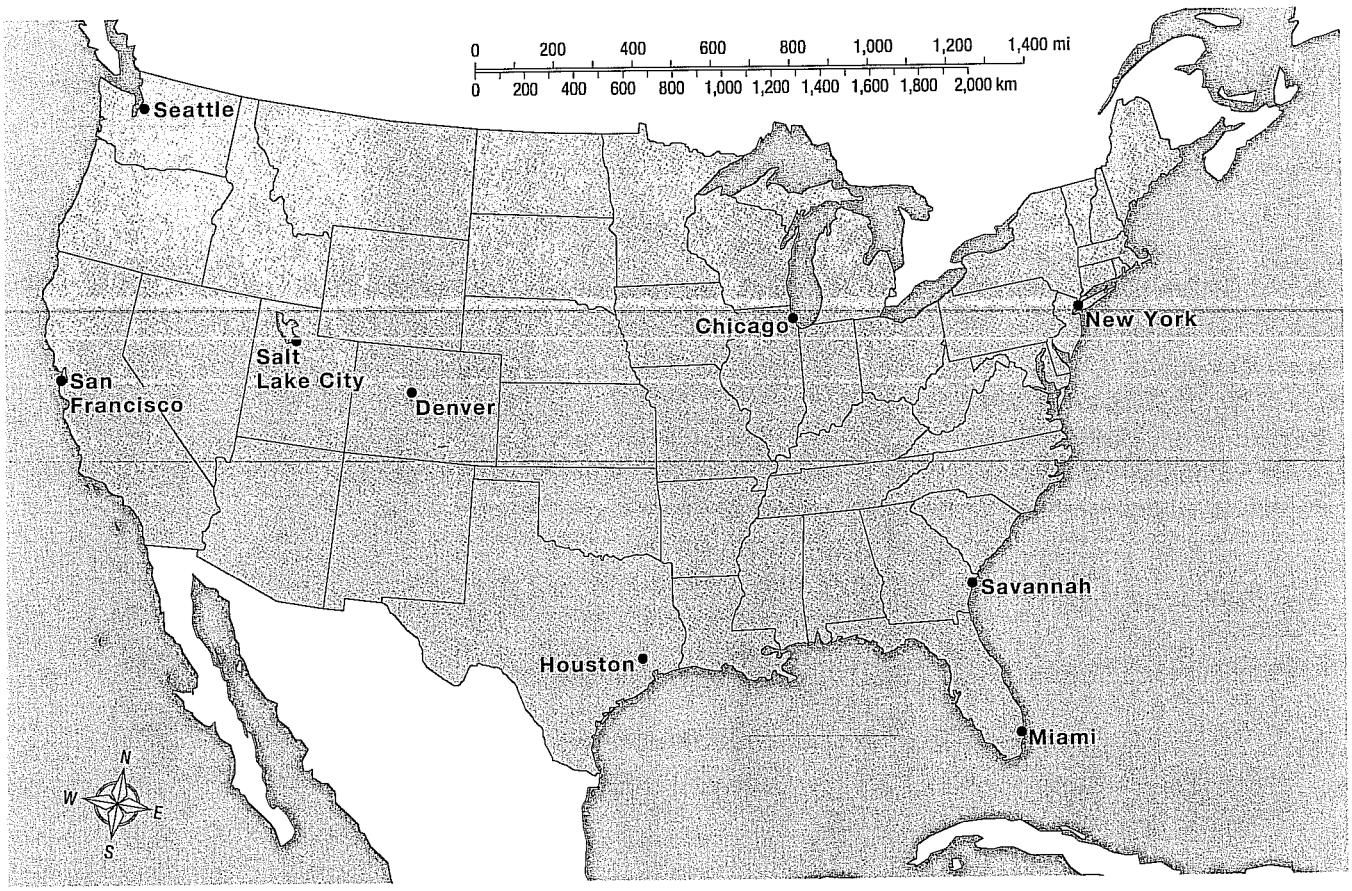
Identifying Main Ideas Use your graphic organizer to help you answer Question 1 below.

Reviewing Key Concepts

1. a. **Reviewing** How does energy from an earthquake reach Earth's surface?
   b. **Describing** What kind of movement is produced by each of the three types of seismic waves?
   c. **Sequencing** When do P waves arrive at the surface in relation to S waves and surface waves?
2. a. **Defining** What is an earthquake's magnitude?
   b. **Describing** How is magnitude measured using the Richter scale?
   c. **Applying Concepts** What are the advantages of using the moment magnitude scale to measure an earthquake?
3. a. **Explaining** What type of data do geologists use to locate an earthquake's epicenter?
   b. **Interpreting Maps** Study the map in Figure 11 above. Then describe the method that scientists use to determine the epicenter of an earthquake.

Writing in Science

News Report As a television news reporter, you are covering an earthquake rated between IV and V on the Mercalli scale. Write a short news story describing the earthquake's effects. Your lead paragraph should tell *who, what, where, when,* and *how.* (*Hint:* Refer to Figure 9 for examples of earthquake damage.)



Analyze and Conclude

1. **Drawing Conclusions** Observe the three circles you have drawn. Where is the earthquake's epicenter?
2. **Measuring** Which city on the map is closest to the earthquake epicenter? How far, in kilometers, is this city from the epicenter?
3. **Inferring** In which of the three cities listed in the data table would seismographs detect the earthquake first? Last?
4. **Estimating** About how far from San Francisco is the epicenter that you found? What would be the difference in arrival times of the P waves and S waves for a recording station in San Francisco?
5. **Interpreting Data** What happens to the difference in arrival times between P waves and S waves as the distance from the earthquake increases?
6. **Communicating** Review the procedure you followed in this lab and then answer the following question. When you are trying to locate an epicenter, why is it necessary to know the distance from the epicenter for at least three recording stations?

More to Explore

You have just located an earthquake's epicenter. Find this earthquake's location on the map of Earthquake Risk in the United States on page 69. What is the risk of earthquakes in the area of this quake?

Now look at the map of Earth's Lithospheric Plates on page 33. What conclusions can you draw from this map about the cause of earthquakes in this area?