SECTION 2

Earthquake Measurement

Imagine walls shaking, windows rattling, and glassware and dishes clinking and clanking. After only seconds, the vibrating stops and the sounds die away.

Within minutes, news reports give information about the strength, the time, and the location of the earthquake. You are amazed at how scientists could have learned this information so quickly.

What You Will Learn

- Explain how earthquakes are detected.
- Describe how to locate an earthquake's epicenter.
- Explain how the strength of an earthquake is measured.
- Explain how the intensity of an earthquake is measured.

Vocabulary

seismograph
seismogram
epicenter
focus

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

seismograph an instrument that records vibrations in the ground and determines the location and strength of an earthquake

seismogram a tracing of earthquake motion that is created by a seismograph

epicenter the point on Earth's surface directly above an earthquake's starting point, or focus

focus the point along a fault at which the first motion of an earthquake occurs

Locating Earthquakes

How do seismologists know when and where earthquakes begin? They depend on earthquake-sensing instruments called seismographs. **Seismographs** are instruments located at or near the surface of the Earth that record seismic waves. When the waves reach a seismograph, the seismograph creates a seismogram. A **seismogram** is a tracing of earthquake motion and is created by a seismograph.

Determining Time and Location of Earthquakes

Seismologists use seismograms to calculate when an earthquake began. Seismologists find an earthquake's start time by comparing seismograms and noting the differences in arrival times of P waves and S waves. Seismologists also use seismograms to find an earthquake's epicenter. An **epicenter** is the point on the Earth's surface directly above an earthquake's starting point. A **focus** is the point inside the Earth where an earthquake begins. **Figure 1** shows the location of an earthquake's epicenter and its focus.

Reading Check **How do seismologists determine an earthquake's start time?** *(See the Appendix for answers to Reading Checks.)*

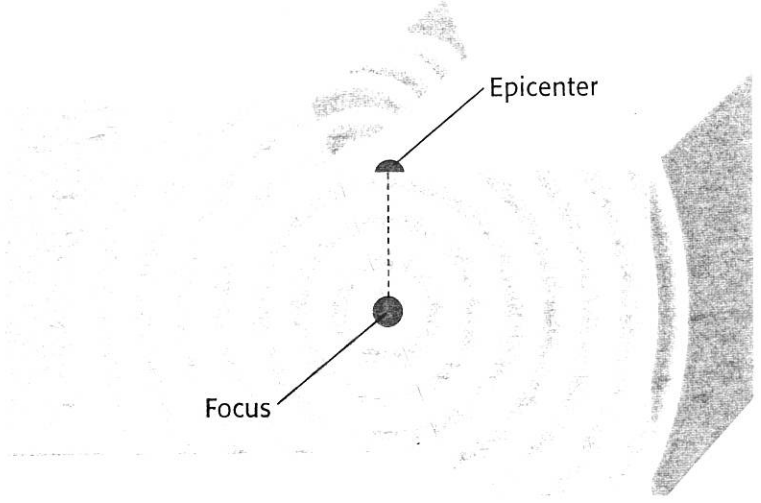


Figure 1 *An earthquake's epicenter is on the Earth's surface directly above the earthquake's focus.*

Plotting Seismograms on a Time-Distance Graph

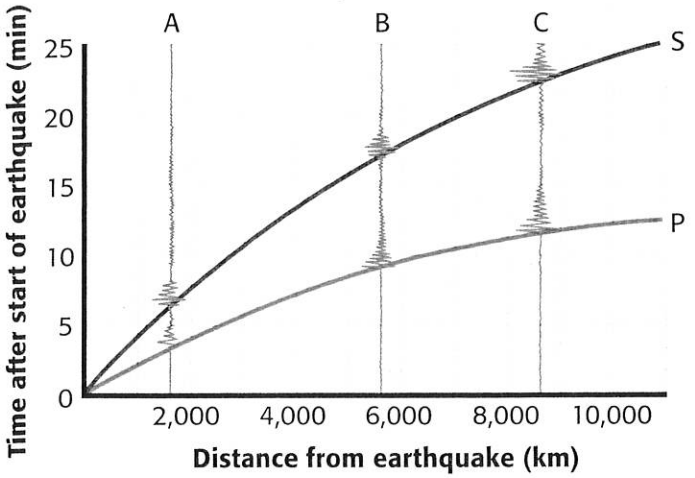


Figure 2 *After identifying P and S waves, seismologists can use the time difference to determine an earthquake's start time and the distance from the epicenter to each station. The vertical axis tells how much time passed between the start of the earthquake and the arrival of seismic waves at a station. The horizontal axis tells the distance between a station and the earthquake's epicenter.*

The S-P Time Method

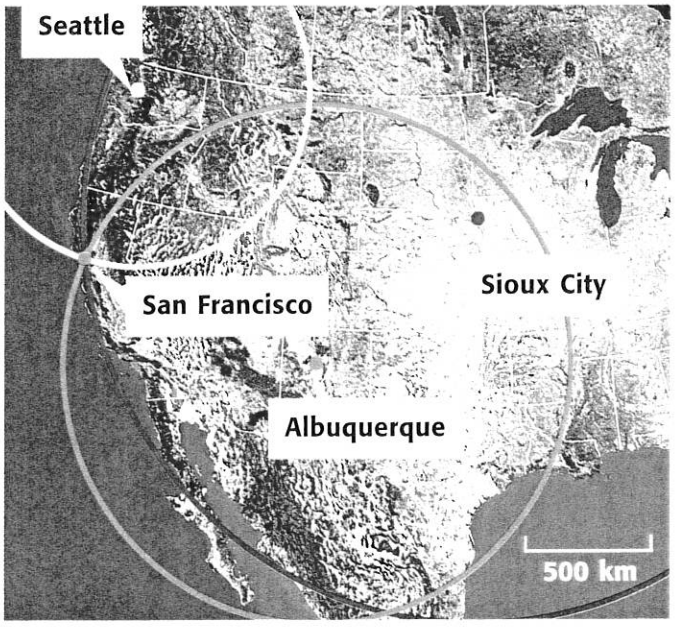
Perhaps the simplest method by which seismologists find an earthquake's epicenter is the *S-P time method*. The first step in this method is to collect several seismograms of the same earthquake from different locations. Then, the seismograms are placed on a time-distance graph. The seismogram tracing of the first P wave is lined up with the P-wave time-distance curve, and the tracing of the first S wave is lined up with the S-wave curve, as shown in **Figure 2.** The distance of each station from the earthquake can be found by reading the horizontal axis. After finding out the distances, a seismologist can locate an earthquake's epicenter, as shown in **Figure 3.**

Figure 3 Finding an Earthquake's Epicenter

1. A circle is drawn around a seismograph station. The radius of the circle equals the distance from the seismograph to the epicenter. (This distance is taken from the time-distance graph.)

2. When a second circle is drawn around another seismograph station, the circle overlaps the first circle in two spots. One of these spots is the earthquake's epicenter.

3. When a circle is drawn around a third seismograph station, all three circles intersect in one spot—the earthquake's epicenter. In this case, the epicenter was in San Francisco.



Measuring Earthquake Strength and Intensity

"How strong was the earthquake?" is a common question asked of seismologists. This question is not easy to answer. But it is an important question for anyone living near an earthquake zone. Fortunately, seismograms can be used not only to determine an earthquake's epicenter and its start time but also to find out an earthquake's strength.

The Richter Magnitude Scale

Throughout much of the 20th century, seismologists used the *Richter magnitude scale*, commonly called the Richter scale, to measure the strength of earthquakes. Seismologist Charles Richter created the scale in the 1930s. Richter wanted to compare earthquakes by measuring ground motion recorded by seismograms at seismograph stations.

Earthquake Ground Motion

A measure of the strength of an earthquake is called *magnitude*. The Richter scale measures the ground motion from an earthquake and adjusts for distance to find its strength. Each time the magnitude increases by one unit, the measured ground motion becomes 10 times larger. For example, an earthquake with a magnitude of 5.0 on the Richter scale will produce 10 times as much ground motion as an earthquake with a magnitude of 4.0. Furthermore, an earthquake with a magnitude of 6.0 will produce 100 times as much ground motion (10 × 10) as an earthquake with a magnitude of 4.0. **Table 1** shows the differences in the estimated effects of earthquakes with each increase of one unit of magnitude.

Reading Check **How are magnitude and ground motion related in the Richter scale?**

Table 1 Effects of Different-Sized Earthquakes

Magnitude	Estimated effects
2.0	can be detected only by seismograph
3.0	can be felt at epicenter
4.0	can be felt by most people in the area
5.0	causes damage at epicenter
6.0	can cause widespread damage
7.0	can cause great, widespread damage

CONNECTION TO Social Studies

WRITING SKILL **New Madrid Earthquakes**

During the winter of 1811–1812, three of the most powerful earthquakes in U.S. history were centered near New Madrid, Missouri, thousands of miles from the nearest tectonic plate boundary. Research the New Madrid earthquakes, and summarize your findings in a one-page essay.

Modified Mercalli Intensity Scale

A measure of the degree to which an earthquake is felt by people and the amount of damage caused by the earthquake, if any, is called *intensity*. Currently, seismologists in the United States use the Modified Mercalli Intensity Scale to measure earthquake intensity. This scale is a numerical scale that uses Roman numerals from I to XII to describe increasing earthquake intensity levels. An intensity level of I describes an earthquake that is not felt by most people. An intensity level of XII indicates total damage of an area. **Figure 4** shows the type of damage caused by an earthquake that has a Modified Mercalli intensity level of XI.

Because the effects of an earthquake vary from place to place, any earthquake will have more than one intensity value. Intensity values are usually higher near an earthquake's epicenter.

Figure 4 *Intensity values for the 1906 San Francisco earthquake varied from place to place. The maximum intensity level was XI.*

SECTION Review

Summary

- Seismologists detect seismic waves and record them as seismograms.
- The S-P time method is the simplest method to use to find an earthquake's epicenter.
- Seismologists use the Richter scale to measure an earthquake's strength.
- Seismologists use the Modified Mercalli Intensity Scale to measure an earthquake's intensity.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *epicenter* and *focus*.

Understanding Key Ideas

2. What is the difference between a seismograph and a seismogram?
3. Explain how earthquakes are detected.
4. Briefly explain the steps of the S-P time method for locating an earthquake's epicenter.
5. Why might an earthquake have more than one intensity value?

Math Skills

6. How much more ground motion is produced by an earthquake of magnitude 7.0 than by an earthquake of magnitude 4.0?

Critical Thinking

7. **Making Inferences** Why is a 6.0 magnitude earthquake so much more destructive than a 5.0 magnitude earthquake?
8. **Identifying Bias** Which do you think is the more important measure of earthquakes, strength or intensity? Explain.
9. **Making Inferences** Do you think an earthquake of moderate magnitude can produce high Modified Mercalli intensity values?

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