Section 2
Earthquake Measurement

Key Concept Studying the properties of seismic waves can help scientists determine an earthquake's starting point, strength, and intensity.

What You Will Learn

- To find an earthquake's epicenter, you must triangulate by using data from three or more seismometers.
- Magnitude is a measure of an earthquake's strength.
- The intensity of an earthquake depends on four main factors.

Why It Matters

Quickly determining the location and intensity of an earthquake helps reduce the harm that an earthquake can cause.

Imagine walls shaking, windows rattling, glasses and dishes clinking. After only seconds, the vibrating stops and the sounds die away. Within minutes, news reports give information about the strength and the location of the earthquake. How could scientists have learned this information so quickly?

Studying Earthquakes

Scientists use earthquake-sensing instruments called *seismometers,* or *seismographs,* to record seismic waves. Seismometers record the vibrations of P waves, S waves, and surface waves as the waves travel through Earth. Seismometers also record the time that seismic waves take to arrive at a seismometer station. Seismometers create a tracing of earthquake motion called a *seismogram.*

Determining Location

Scientists use the data from seismograms to find an earthquake's epicenter. An **epicenter** is the point on Earth's surface directly above an earthquake's starting point. A **focus** is the point inside Earth where an earthquake actually begins. **Figure 1** shows the relative locations of an earthquake's epicenter and focus.

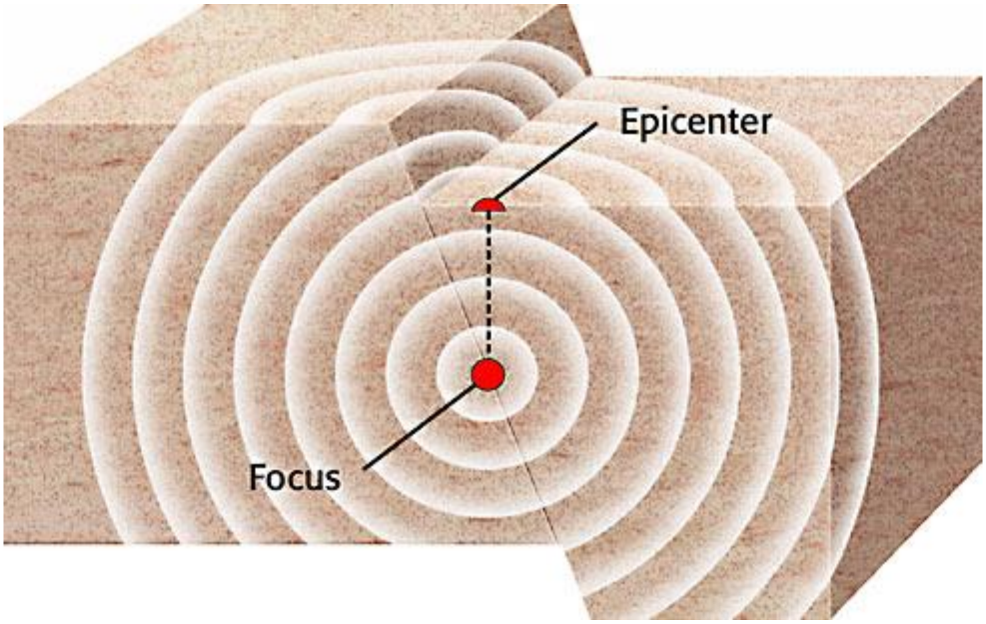

Figure 1 An earthquake's epicenter is located on Earth's surface directly above the focus.

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Triangulation

The time between the arrival of the P waves and the arrival of the S waves, called *lag time,* tells scientists how far the waves traveled. The epicenter can then be located by drawing circles around at least three seismometer stations, as **Figure 2** shows. The radius of each circle is equal to the distance from that seismometer to the epicenter. The point at which all of the circles intersect is the epicenter. This process is called *triangulation*. Today, computers perform all of these calculations.

Figure 2 Finding an Earthquake's Epicenter

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Earthquake Magnitude

Seismograms can also provide information about an earthquake's strength. The size of the waves on a seismogram indicates the amount of ground motion. The amount of ground motion can be used to calculate magnitude. **Magnitude** is the measure of an earthquake's strength.

The larger the magnitude of an earthquake is, the stronger the earthquake is. A map of earthquakes that had a magnitude of 4.5 or greater and that happened in California between 1965 and 2005 is shown in **Figure 3.**

Figure 3 This map shows the locations of California earthquakes of magnitude 4.5 or greater during a 40-year period. Compare this map with the fault map on page 234. **Where are most earthquakes located?**

Standards Check What is magnitude?

The Richter Scale

In the past, scientists used the Richter scale to describe magnitude. The Richter scale measures the ground motion from an earthquake and adjusts for distance to find the earthquake’s magnitude. On the Richter scale, each increase of one number, such as from 1 to 2, represents a tenfold increase in ground shaking. Richter-scale values generally range from 0 to 9.

The Moment Magnitude Scale

Today, scientists use the moment magnitude scale instead of the Richter scale. The moment magnitude scale is a more accurate measure of the strength of earthquakes. *Moment magnitude (Mw)* represents the size of the area of the fault that moves, the average distance that the fault blocks move, and the rigidity of the rocks in the fault zone. The moment magnitude scale is more closely related to the physical effects that take place at the source of an earthquake than the Richter scale is.

Earthquake Intensity

The effects of an earthquake and how the earthquake is felt by people are known as the earthquake's **intensity** An earthquake's magnitude is different from its intensity. Magnitude measures how much energy is released by an earthquake. Intensity measures the effects of an earthquake at Earth's surface.

Standards Check What is intensity?

The Modified Mercalli Scale

The Modified Mercalli scale is used to describe an earthquake's intensity. As shown in **Table 1,** the scale ranges from I to XII. Level I earthquakes are barely noticeable, and level XII earthquakes cause total destruction. Intensity values vary from place to place and are usually higher near the epicenter of the earthquake. **Figure 4** shows the damage caused by an earthquake that had a maximum intensity of level IX.

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

Table 1 Modified Mercalli Intensity Scale

Intensity	Description
I	is not felt except by very few under especially favorable conditions

II	is felt by only few people at rest; delicately suspended items may swing
III	is felt by most people indoors; vibration is similar to the passing of a large truck
IV	is felt by many people; dishes and windows rattle; sensation is similar to a building being struck
V	is felt by nearly everyone; some objects are broken; and unstable objects are overturned
VI	is felt by all people; some heavy objects are moved; causes very slight damage to structures
VII	causes slight to moderate damage to ordinary buildings; some chimneys are broken
VIII	causes considerable damage (including partial collapse) to ordinary buildings
IX	causes considerable damage (including partial collapse) to earthquake-resistant buildings
X	destroys some to most structures, including foundations; rails are bent
XI	causes few structures, if any, to remain standing; bridges are destroyed and rails are bent
XII	causes total destruction; distorts lines of sight; objects are thrown into the air

Mapping Earthquake Intensity

Earthquake intensity maps show the level of ground shaking that may be expected to occur in different areas that experience the same earthquake. Data used to make earthquake intensity maps are obtained from information recorded during previous earthquakes. In the San Francisco Bay area, information has been obtained from records of the 1989 Loma Prieta earthquake and even from the 1906 earthquake. These data are used to model differences in the amount of ground shaking that may occur during a future earthquake.

The Effects of Earthquakes

The effects of an earthquake can vary over a wide area. In addition to the size of the earthquake, three other factors determine the effects of an earthquake on a given area. Those factors are the distance from the epicenter, the local geology, and the type of construction in a region.

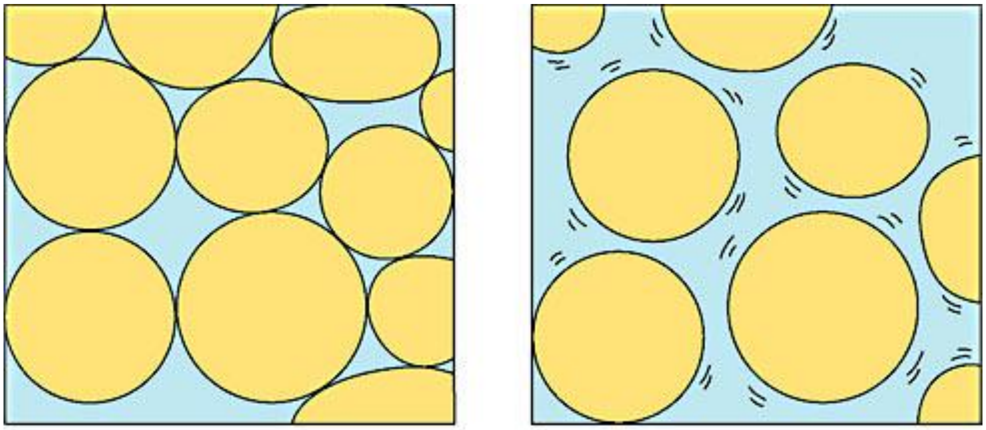
Distance from the Epicenter

Have you ever tossed a pebble into a pond? The circles that surround the pebble grow larger, or expand, as they move outward. The same is true of seismic waves as they move away from an epicenter. The total energy in a seismic wave stays relatively constant as the wave travels. So, the amount of energy at any point on the wave decreases as the wave grows increasingly larger. In general, the farther an area is from the epicenter, the less destructive the earthquake will be.

Local Geology

The amount of damage that will be caused by an earthquake depends on the material through which seismic waves travel. In general, solid rock is not likely to increase the intensity or the time that the ground shakes. However, seismic waves are particularly dangerous when they travel through loose soils and sediments that contain large amounts of water. When water-saturated soil or sediment is shaken by seismic waves, the grains that make up the sediment lose contact with one another and are surrounded by water. This process, which is shown in **Figure 5,** is called *liquefaction.* Liquefaction can intensify ground shaking. Liquefaction can also cause the ground to settle. Settling can cause structures to tilt or even collapse.

Figure 5 Liquefaction



In sandy soils that lie beneath the water table, sand grains are normally in contact with one another.

An earthquake causes sand grains to lose contact with one another and to vibrate more violently.

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Earthquake-Resistant Construction

Structures that are made of brick or concrete are not very flexible and are easily damaged by earthquakes, as **Figure 6** shows. Wood and steel are more flexible. Flexible structures are more likely to survive strong ground shaking. In addition, taller buildings are more susceptible to damage than shorter buildings are. Structures that have solid foundations that are firmly anchored in the ground are most likely to be left undamaged by earthquakes.

Figure 6 This apartment building in Hollywood, California, was damaged by the Northridge earthquake in January 1994.

Standards Check What four factors affect intensity?

Section Summary

- An epicenter is the point on Earth’s surface directly above where an earthquake started.
- The distance from a seismometer to an epicenter can be determined by using the lag time between P waves and S waves.
- An earthquake’s epicenter can be located by triangulation.
- Magnitude is a measure of an earthquake’s strength.
- Intensity is the effects of an earthquake.
- Important factors that determine the effects of an earthquake on a given area are magnitude, distance from the epicenter, local geology, and the type of construction.