Section 19.2

Objectives

- **Describe** how a seismometer works.
- **Explain** how seismic waves have been used to determine the structure and composition of Earth's interior.

Review Vocabulary

mantle: the part of Earth's interior beneath the lithosphere and above the central core

New Vocabulary

seismometer
seismogram

Seismic Waves and Earth's Interior

MAIN Idea Seismic waves can be used to make images of the internal structure of Earth.

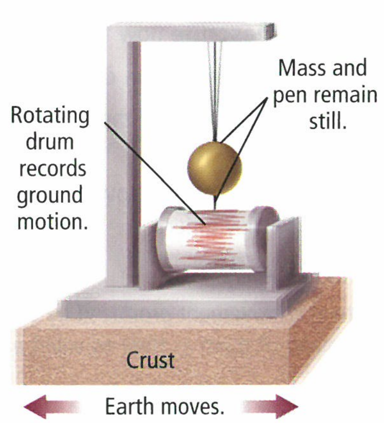
Real-World Reading Link When you look in a mirror, you see yourself because light waves reflect off your face to the mirror and back to your eye. Similarly, seismic waves traveling through Earth reflect off structures inside Earth, which allows these structures to be imaged.

Seismometers and Seismograms

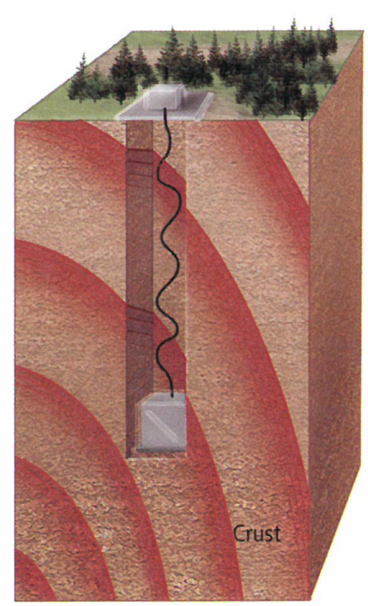
Most of the vibrations caused by seismic waves cannot be felt at great distances from an earthquake's epicenter, but they can be detected by sensitive instruments called **seismometers** (size MAH muh turz). Some seismometers consist of a rotating drum covered with a sheet of paper, a pen or other such recording tool, and a mass, such as a pendulum. Seismometers vary in design, but all include a frame that is anchored to the ground and a mass that is suspended from a spring or wire, as shown in **Figure 19.7.** During an earthquake, the mass and the pen attached to it tend to stay at rest due to inertia, while the ground beneath shakes. The motion of the mass in relation to the frame is then registered on the paper with the recording tool, or is directly recorded onto a computer disk. The record produced by a seismometer is called a **seismogram** (SIZE muh gram). A portion of one is shown in **Figure 19.8.**

Concepts In Motion

Interactive Figure To see an animation of seismometers, visit glencoe.com.

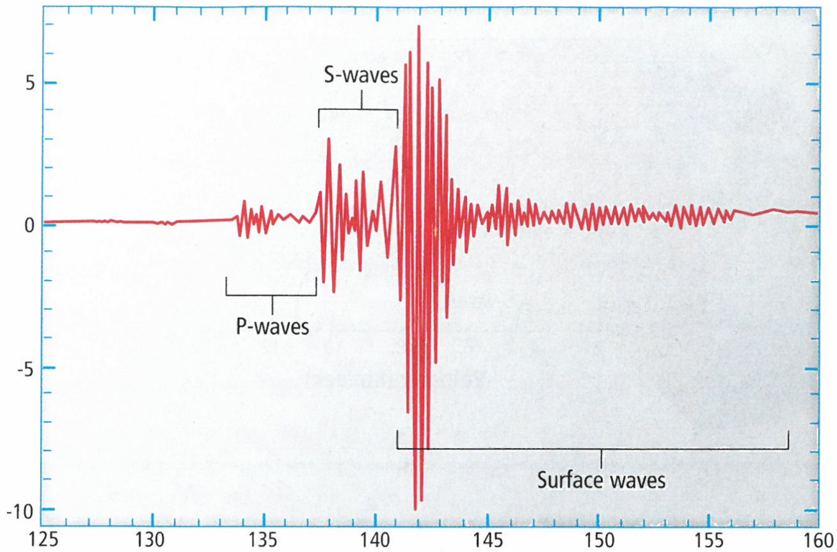


Historic



Modern

Figure 19.7 The frame of a historic seismometer is anchored to the ground. When an earthquake occurs, the frame moves but the hanging mass and attached pen do not. The mass and pen record the relative movement as the recording device moves under them. Compare this to a modern sensor and transmitter.



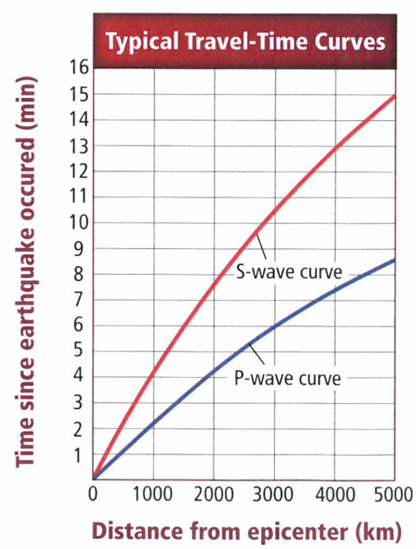
■ **Figure 19.8** Seismograms provide a record of the seismic waves that pass a certain point.

Travel-time curves Seismic waves that travel from the focus of an earthquake are recorded by seismometers housed in distant facilities. Over many years, the arrival times of seismic waves from countless earthquakes at seismic facilities around the world have been collected. Using these data, seismologists have been able to construct global travel-time curves for the arrival of P-waves and S-waves of earthquakes, as shown in **Figure 19.9.** These curves provide the average travel times of all P- and S-waves, from wherever an earthquake occurs on Earth.

Reading Check Summarize how seismograms are used to construct global travel-time curves.

Distance from the epicenter Note that in **Figure 19.9,** as in **Figure 19.8,** the P-waves arrive first, then the S-waves. The surface waves arrive last. With increasing travel distance from the epicenter, the time separation between the curves for the P-waves and S-waves increases. This means that waves recorded on seismograms from more distant facilities are farther apart than waves recorded on seismograms at stations closer to the epicenter. This separation of seismic waves on seismograms can be used to determine the distance from the epicenter of an earthquake to the seismic facility that recorded the seismogram. This method of precisely locating an earthquake's epicenter will be discussed in Section 19.3.

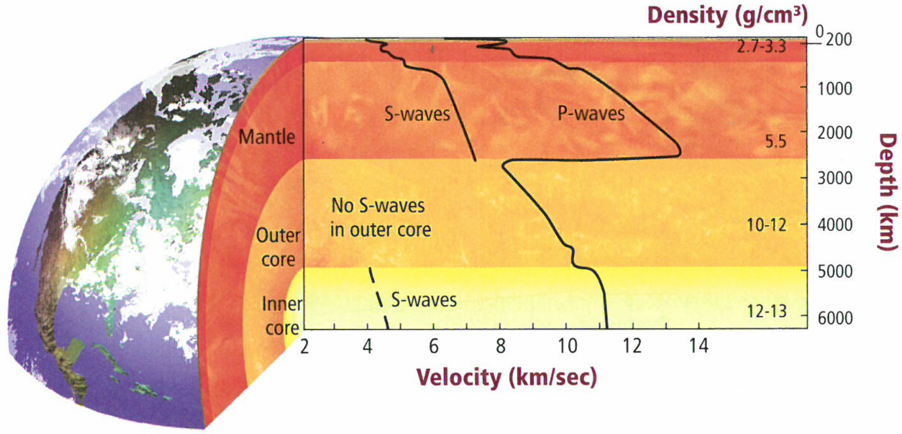
■ **Figure 19.9** Travel-time curves show how long it takes for P-waves and S-waves to reach seismic stations located at different distances from an earthquake's epicenter.
Determine ***how long it takes P-waves to travel to a seismogram 2000 km away. How long does it take for S-waves to travel the same distance?***



■ **Figure 19.10** Earth's layers are each composed of different materials. By examining the behavior of seismic waves moving through different kinds of rock, scientists have determined the composition of layers all the way to Earth's inner core.

Concepts In Motion

Interactive Figure To see an animation of P-waves and S-waves, visit glencoe.com.



Clues to Earth's Interior

The seismic waves that shake the ground during an earthquake also travel through Earth's interior. This provides information that has enabled scientists to construct models of Earth's internal structure. Therefore, even though seismic waves can wreak havoc on the surface, they are invaluable for their contribution to scientists' understanding of Earth's interior.

Earth's internal structure Seismic waves change speed and direction at the boundaries between different materials. Note in **Figure 19.10** that as P-waves and S-waves initially travel through the mantle, they follow fairly direct paths. When P-waves strike the core, they are refracted, which means they bend. Seismic waves also reflect off of major boundaries inside Earth. By recording the travel-time curves and path of each wave, seismologists learn about differences in density and composition within Earth.

What happens to the S-waves generated by an earthquake? To answer this question, seismologists first determined that the right-angle motion of S-waves will not travel through liquid. Then, seismologists noticed that S-waves do not travel through Earth's center. This observation led to the discovery that Earth's core must be at least partly liquid. The data collected for the paths and travel times of the waves inside Earth led to the current understanding that Earth's core has an outer region that is liquid and an inner region that is solid.

Vocabulary

Academic Vocabulary

Encounter

to come upon or experience, especially unexpectedly

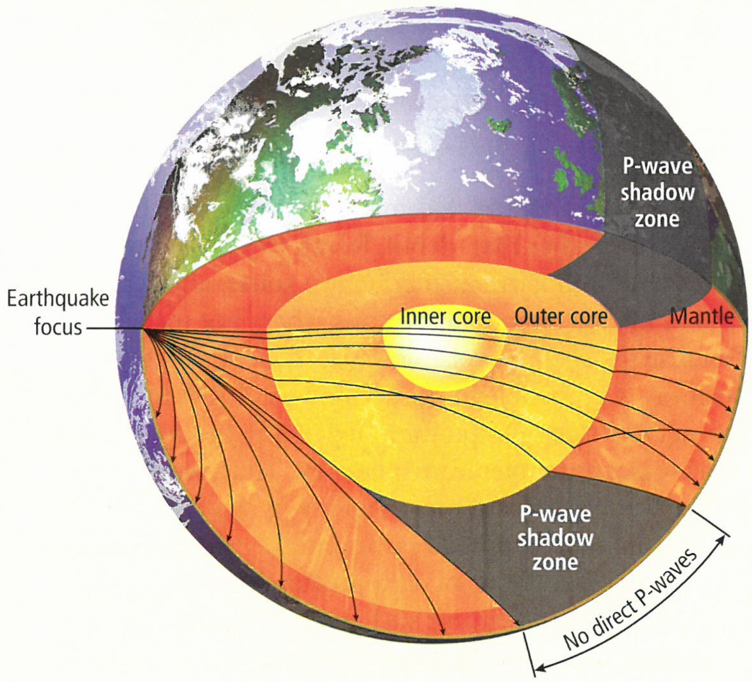
We had never encountered such a violent storm.

Earth's composition **Figure 19.11** shows that seismic waves change their paths as they encounter boundaries between zones of different materials. They also change their speed. By comparing the speed of seismic waves with measurements made on different rock types, scientists have determined the thickness and composition of Earth's different regions. As a result, scientists have determined that the upper mantle is peridotite, which is made mostly of the mineral olivine. The outer core is mostly liquid iron and nickel. The inner core is mostly solid iron and nickel.

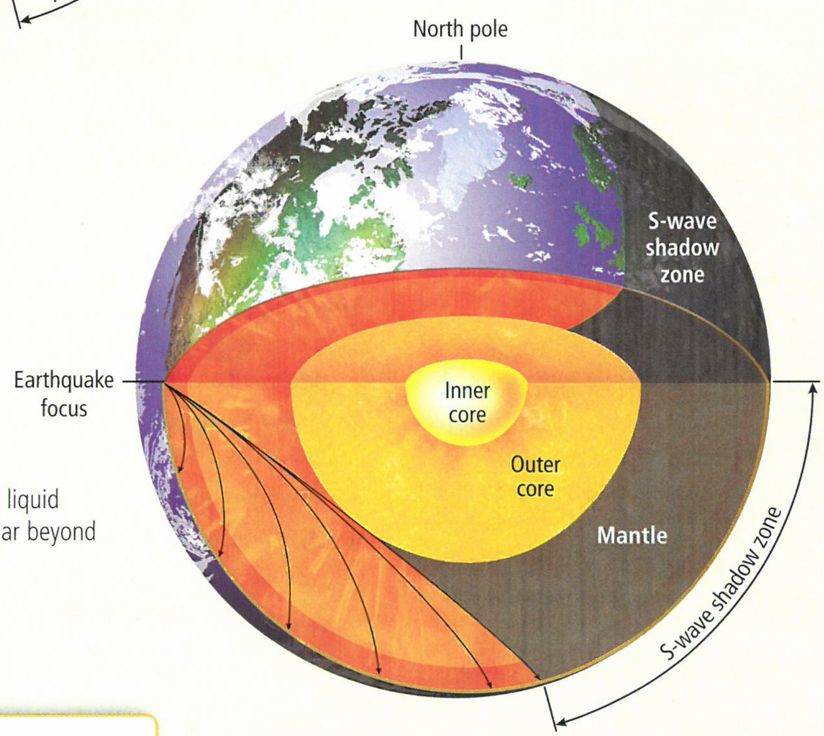
Visualizing Seismic Waves

NATIONAL GEOGRAPHIC

Figure 19.11 The travel times and behavior of seismic waves provide a detailed picture of Earth's internal structure. These waves also provide clues about the composition of the various parts of Earth.



P-waves in the outer core are refracted. This generates a P-wave shadow zone on Earth's surface where no direct P-waves appear on seismograms. Other P-waves are reflected and refracted by the inner core. These can be detected by seismometers on the other side of the shadow zone.

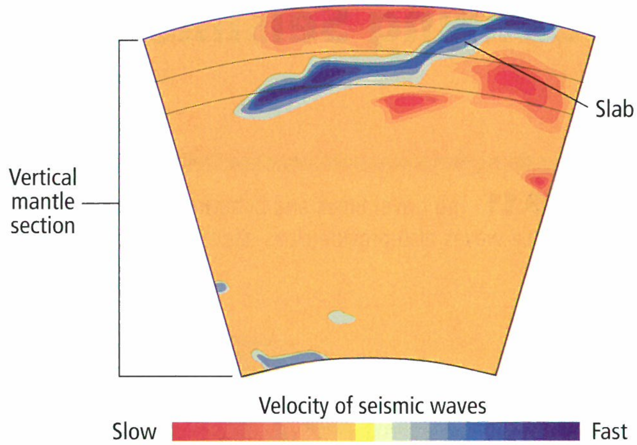


S-waves cannot travel through the liquid outer core and thus do not reappear beyond the S-wave shadow zone.

Concepts In Motion To explore more about seismic waves, visit glencoe.com.

Earth Science Online

Figure 19.12 Images like this one from Japan are generated by capturing the path of seismic waves through Earth's interior. Areas of red indicate seismic waves that are traveling more slowly than average and areas of blue indicate seismic waves that are traveling faster than average. The blue area is a subducted plate.



Imaging Earth's interior Seismic wave speed and Earth's density vary with factors other than depth. Recall from Chapter 17 that cold slabs sink back into Earth at subduction zones, and recall from Chapter 18 that mantle plumes are regions where hot mantle material is rising. Because the speed of seismic waves depends on temperature and composition, it is possible to use seismic waves to create images of structures such as slabs and plumes. In general, the speed of seismic waves decreases as temperature increases. Thus, waves travel more slowly in hotter areas and more quickly in cooler regions. Using measurements made at seismometers around the world and waves recorded from many thousands of earthquakes, Earth's internal structure can be visualized, and features such as slabs can be located in images like the one in **Figure 19.12.** These images are similar to CT scans, except that the images are made using seismic waves instead of X rays.

Section 19.2 Assessment

Section Summary

- Seismometers are devices that record seismic wave activity on a seismogram.
- Travel times for P-waves and S-waves enable scientists to pinpoint the epicenters of earthquakes.
- P-waves and S-waves change speed and direction when they encounter different materials.
- Analysis of seismic waves provides a detailed picture of the composition of Earth's interior.

Understand Main Ideas

1. MAIN Idea **Explain** how P-waves and S-waves are used to determine the properties of Earth's core.
2. **Draw** a diagram of a seismometer showing how the movement of Earth is translated into a seismogram.
3. **Describe** how seismic travel-time curves are used to study earthquakes.
4. **Differentiate** between the speed of waves through hot and cold material.

Think Critically

5. **Infer** Using the seismogram in **Figure 19.8**, suggest why surface waves cause so much damage even though they are the last to arrive at a seismic station.

WRITING in Earth Science

6. Write a newspaper article reporting on the ways scientists have determined the composition of Earth.

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