Section 19.4

Objectives

- **Discuss** factors that affect the amount of damage caused by an earthquake.
- **Explain** some of the factors considered in earthquake-probability studies.
- **Identify** how different types of structures are affected by earthquakes.

Review Vocabulary

geology: study of materials that make up Earth and the processes that form and change these materials

New Vocabulary

soil liquefaction
tsunami
seismic gap

Earthquakes and Society

MAIN Idea The probability of an earthquake's occurrence is determined from the history of earthquakes and knowing where and how quickly strain accumulates.

Real-World Reading Link If, in your city, it rains an average of 11 days every July, how can you predict the weather in your city for July 4 ten years from now? You could estimate that there is a 11/31 chance that it will rain. In the same way, the probability of an earthquake's occurrence can be estimated from the history of earthquakes in the region.

Earthquake Hazards

Earthquakes are known to occur frequently along plate boundaries. An earthquake of magnitude-5 can be catastrophic in one region, but relatively harmless in another. There are many factors that determine the severity of damage produced by an earthquake. These factors are called earthquake hazards. Identifying earthquake hazards in an area can sometimes help to prevent some of the damage and loss of life. For example, the design of certain buildings can affect earthquake damage. As you can see in **Figure 19.19,** the most severe damage occurs to unreinforced buildings made of brittle building materials such as concrete. Wooden structures, on the other hand, are more resilient and generally sustain less damage.

Figure 19.19 Concrete buildings are often brittle and can be easily damaged in an earthquake. The building on the left shifted on its foundation after an earthquake and is held up by a single piece of wood.

■ **Figure 19.20** One type of damage caused by earthquakes is called pancaking because shaking causes a building's supporting walls to collapse and the upper floors to fall one on top of the other like a stack of pancakes.

Structural failure In many earthquake-prone areas, buildings are destroyed as the ground beneath them shakes. In some cases, the supporting walls of the ground floor fail and cause the upper floors, which initially remain intact, to fall and collapse as they hit the ground or lower floors. The resulting debris resembles a stack of pancakes; thus, the process is called pancaking. This type of structural failure, shown in **Figure 19.20,** was a tragic consequence of the earthquake in Islamabad, Pakistan, in 2005.

Reading Check **Explain** what happens when a building pancakes.

Another type of structural failure is related to the height of a building. During the 1985 Mexico City earthquake, for example, most buildings between five and 15 stories tall collapsed or were otherwise completely destroyed, as shown in **Figure 19.21.** Similar structures that were either shorter or taller, however, sustained only minor damage. The shaking caused by the earthquake had the same frequency of vibration as the natural sway of the intermediate buildings. This caused those buildings to sway the most violently during the earthquake. The ground vibrations, however, were too rapid to affect taller buildings, whose frequency of vibration was longer than those of the earthquake, and too slow to affect shorter buildings, whose frequency of vibration was shorter.

■ **Figure 19.21** Many medium-sized buildings were damaged or destroyed during the 1985 Mexico City earthquake because they vibrated with the same frequency as the seismic waves.

■ **Figure 19.22** Soil liquefaction happens when seismic vibrations cause poorly consolidated soil to liquefy and behave like quicksand. The buildings pictured here were built on this type of soil and an earthquake caused the buildings to sink into the ground.

Land and soil failure In addition to their effects on structures made by humans, earthquakes can wreak havoc on Earth's landscape. In sloping areas, earthquakes can trigger massive landslides. For example, most of the estimated 30,000 deaths caused by the magnitude-7.8 earthquake that struck in Peru in 1970 resulted from a landslide that buried several towns. In areas with sand that is nearly saturated with water, seismic vibrations can cause the ground to behave like a liquid in a phenomenon called **soil liquefaction** (lih kwuh FAK shun). It can generate landslides even in areas of low relief. It can cause trees and houses to fall over or to sink into the ground and underground pipes and tanks to rise to the surface. **Figure 19.22** shows tilted buildings that resulted when the soil under them liquefied during an earthquake.

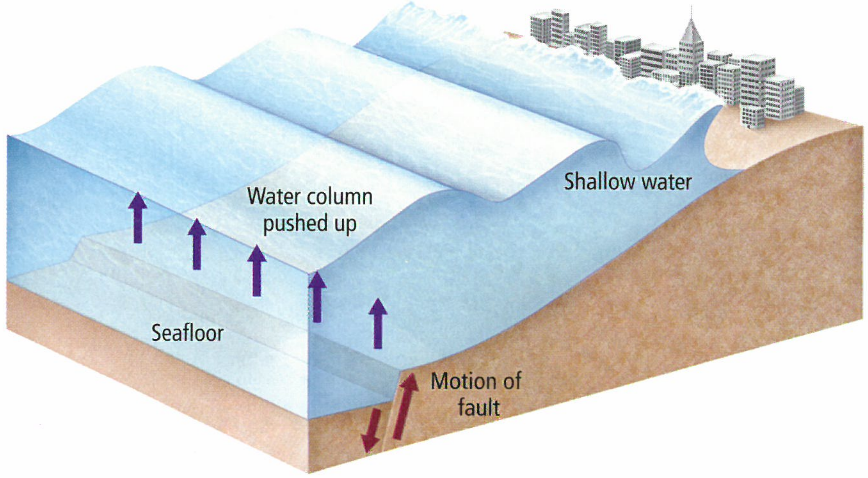
Reading Check **Summarize** how solid ground can take the properties of a liquid.

In addition to determining landslide risks, the type of ground material can also affect the severity of an earthquake in an area. Seismic waves are amplified in some soft materials, such as unconsolidated sediments. They are muted in more resistant materials, such as granite. The severe damage to structures in Mexico City during the 1985 earthquake is attributed to the soft sediments on which the city is built. The thickness of the sediments caused them to resonate with the same frequency as that of the surface waves generated by the earthquake. This produced reverberations that greatly enhanced the ground motion and the resulting damage.

■ **Figure 19.23** A tsunami is generated when an underwater fault or landslide displaces a column of water.

Concepts In Motion

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



Tsunami Another type of earthquake hazard is a **tsunami** (soo NAH mee)—a large ocean wave generated by vertical motions of the seafloor during an earthquake. These motions displace the entire column of water overlying the fault, creating bulges and depressions in the water, as shown in **Figure 19.23.** The disturbance then spreads out from the epicenter in the form of extremely long waves. While these waves are in the open ocean, their height is generally less than 1 m. When the waves enter shallow water, however, they can form huge breakers with heights occasionally exceeding 30 m. These enormous wave heights, together with open-ocean speeds between 500 and 800 km/h, make tsunamis dangerous threats to coastal areas both near to and far from a earthquake's epicenter. The Indian Ocean tsunami of December 26, 2004, originated with a magnitude-9.0 earthquake in the ocean about 160 km west of Sumatra. The 30-m-tall tsunami radiated across the Indian Ocean and struck the coasts of Indonesia, Sri Lanka, India, Thailand, Somalia, and several other nations. The death toll from the tsunami exceeded 225,000, making it one of the most devastating natural disasters in modern history. The aftermath of that catastrophic event is shown in **Figure 19.24.**

VOCABULARY

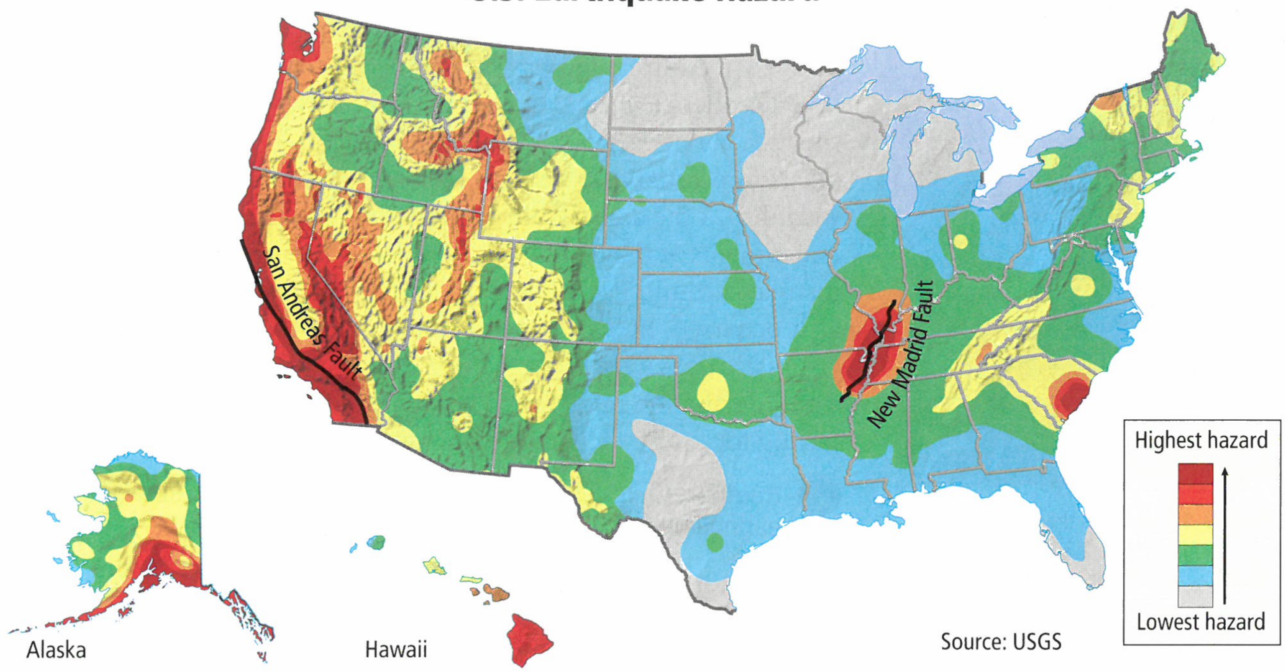
SCIENCE USAGE V. COMMON USAGE

Column

Science usage: a hypothetical cylinder of water that goes from the surface to the bottom of a body of water

Common usage: a vertical arrangement of items

■ **Figure 19.24** The destruction from the December 26, 2004, tsunami in the Indian Ocean was not isolated to the shoreline. As seen here, areas inland were devastated by the tsunami, which took at least 225,000 lives.



■ **Figure 19.25** Areas of high seismic risk in the United States include Alaska, Hawaii, and some of the western states.
Locate ***the areas of highest seismic risk on the map. Locate your own state. What is the seismic risk of your area?***

Earthquake Forecasting

To minimize the damage and deaths caused by earthquakes, seismologists are searching for ways to forecast these events. There is currently no completely reliable way to forecast the exact time and location of the next earthquake. Instead, earthquake forecasting is based on calculating the probability of an earthquake. The probability of an earthquake's occurrence is based on two factors: the history of earthquakes in an area and the rate at which strain builds up in the rocks.

Reading Check **Identify** the two factors seismologists use to determine the probability of an earthquake occurring in a certain area.

Seismic risk Recall that most earthquakes occur in long, narrow bands called seismic belts. The probability of future earthquakes is much greater in these belts than elsewhere on Earth. The pattern of earthquakes in the past is usually a reliable indicator of future earthquakes in a given area. Seismometers and sedimentary rocks can be used to determine the frequency of large earthquakes. The history of an area's seismic activity can be used to generate seismic-risk maps. A seismic-risk map of the United States is shown in **Figure 19.25.** In addition to Alaska, Hawaii, and some western states, there are several regions of relatively high seismic risk in the central and eastern United States. These regions have experienced some of the most intense earthquakes in the past and probably will experience significant seismic activity in the future.

NATIONAL GEOGRAPHIC To read about the challenges of earthquake forecasting, go to the **National Geographic Expedition** on page 916.

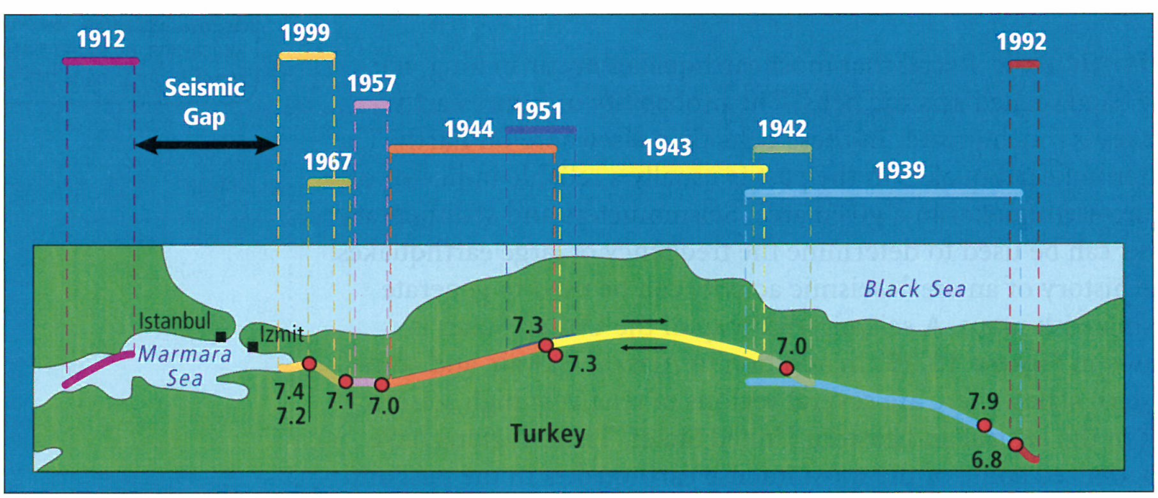
Figure 19.26 This drilling rig was used to drill a hole 2.3 km deep in Parkfield, California. Once completed, the hole was rigged with instruments to record data during major and minor tremors. The goal of the project was to better understand how earthquakes work and what triggers them. This information could help scientists predict when earthquakes will occur.

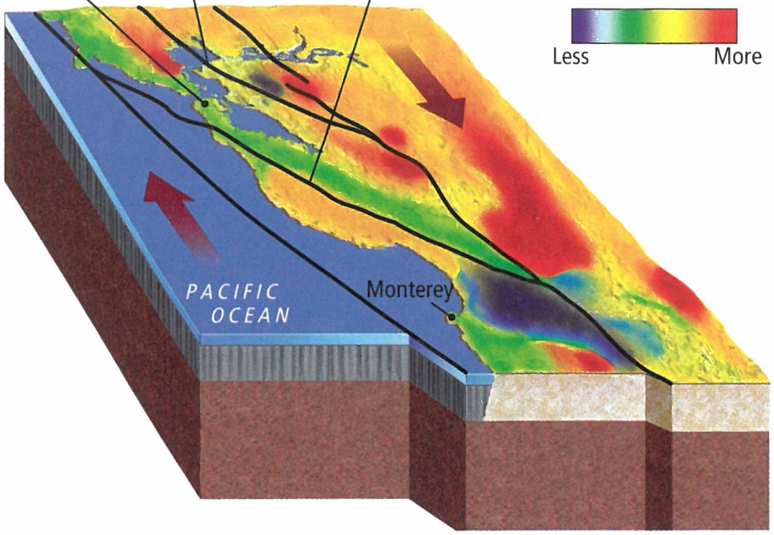
Recurrence rates Earthquake-recurrence rates along a fault can indicate whether the fault ruptures at regular intervals to generate similar earthquakes. The earthquake-recurrence rate along a section of the San Andreas fault at Parkfield, California, for example, shows that a sequence of earthquakes of approximately magnitude 6 shook the area about every 22 years from 1857 until 1966. In 1987 seismologists forecasted a 90-percent probability that a major earthquake would rock the area within the next few decades. Several kinds of instruments at the drilling site, shown in **Figure 19.26,** were installed around Parkfield in an attempt to measure the earthquake as it occurred. In September, 2004, a magnitude-6 earthquake struck. Extensive data were collected before and after the 2004 earthquake. The information obtained will be invaluable for predicting and preparing for future recurrent earthquakes around the world.

Reading Check **Infer** the significance of studying recurrence rates of earthquakes.

Seismic gaps Probability forecasts are also based on the location of seismic gaps. **Seismic gaps** are sections located along faults that are known to be active, but which have not experienced significant earthquakes for a long period of time. A seismic gap in the San Andreas Fault cuts through San Francisco. This section of the fault has not ruptured since the devastating earthquake that struck the city in 1906. Because of this inactivity, seismologists currently forecast that there is a 67-percent probability that the San Francisco area will experience a magnitude-7 or higher earthquake within the next 30 years. **Figure 19.27** shows the seismic-gap map for a fault that passes through an area of Turkey. Like the San Andreas Fault in California, there is a long history of earthquakes along the major fault shown below.

Figure 19.27 Earthquakes in 1912 and 1999 happened on either side of Istanbul, a city of 18 million people. The earthquakes around the city leave a seismic gap that indicates that an earthquake is likely to occur in that area.





■ **Figure 19.28** Stress-accumulation maps help scientists determine the probability of an earthquake in any particular place.
Explain *Why does stress build up in the areas indicated?*

Stress accumulation The rate at which stress builds up in rocks is another factor seismologists use to determine the earthquake probability along a section of a fault. Eventually this stress is released, generating an earthquake. Scientists use satellite-based technology such as GPS to measure the stress that accumulates along a fault. The stress accumulated in a particular part of a fault, together with the amount of stress released during the last earthquake in a particular part of the fault, can be used to develop images like **Figure 19.28.** Another factor is how much time has passed since an earthquake has struck that section of the fault.

Section 19.4 Assessment

Section Summary

- Earthquake forecasting is based on seismic history and measurements of accumulated strain.
- Earthquakes cause damage by creating vibrations that can shake Earth.
- Earthquakes can cause structural collapse, landslides, soil liquefaction, and tsunamis.
- Seismic gaps are sections along an active fault that have not experienced significant earthquakes for a long period of time.

Understand Main Ideas

1. MAIN Idea **List** some examples of how scientists determine the probability of an earthquake occurring.
2. **Summarize** the effects of the different types of hazards caused by earthquakes.
3. **Draw** before-and-after pictures of what can happen when an earthquake ruptures along a fault.
4. **Summarize** the events that lead to a tsunami.

Think Critically

5. **Assess** where an earthquake is most likely to occur: In the same place that a magnitude-7.5 earthquake occurred 20 years ago or at a location between areas that had earthquakes 20 and 60 years ago, respectively.

WRITING in Earth Science

6. Imagine you are on an international aid committee. Write a report suggesting ways to identify areas that are vulnerable to earthquakes.