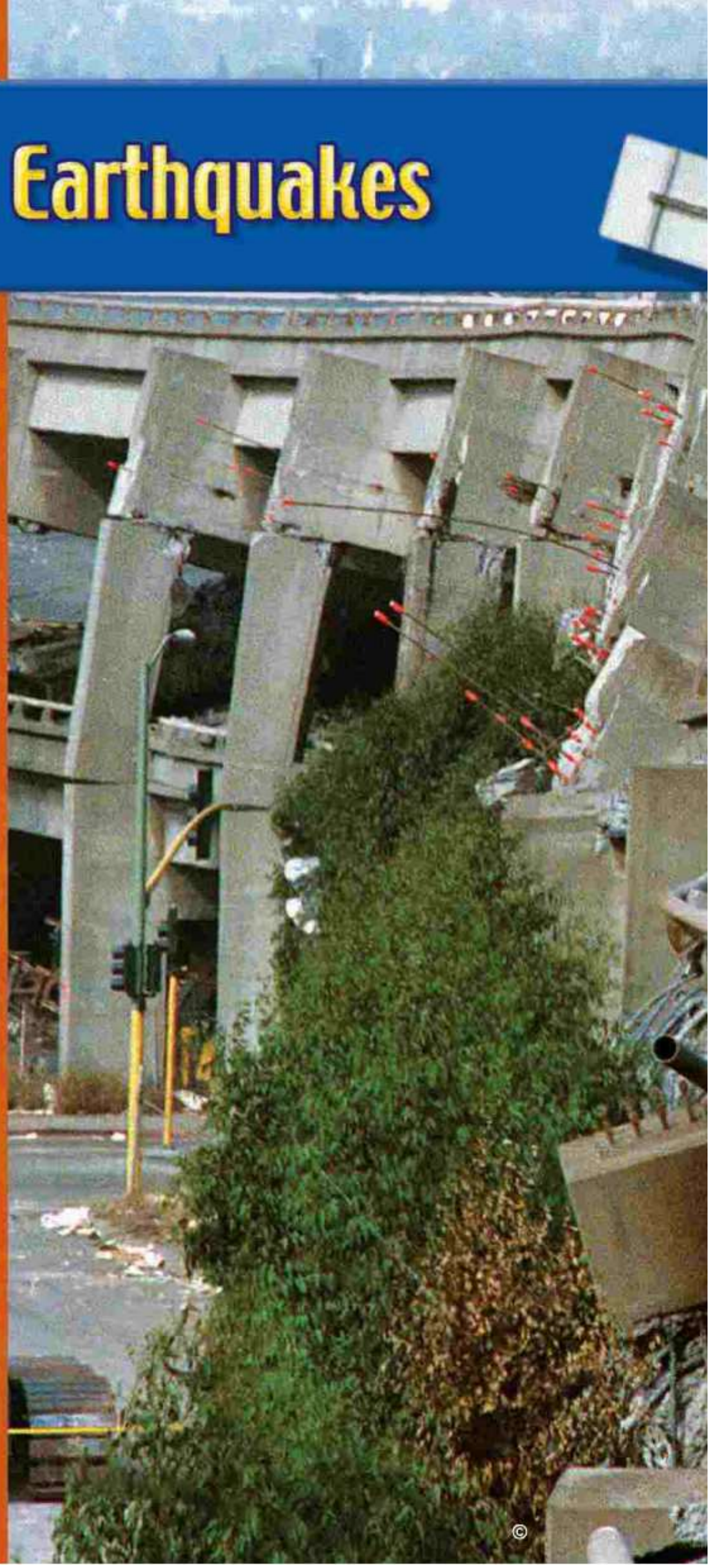
Chapter 5

Earthquakes



CALIFORNIA Standards Preview

S 6.1 Plate tectonics accounts for important features of Earth s surface and major geologic events. As a basis for understanding this concept:

d. Students know that earthquakes are sudden motions along breaks in the crust called faults and that volcanoes and fissures are locations where magma reaches the surface.

e. Students know major geologic events, such as earthquakes, volcanic eruptions, and mountain building, result from plate motions.

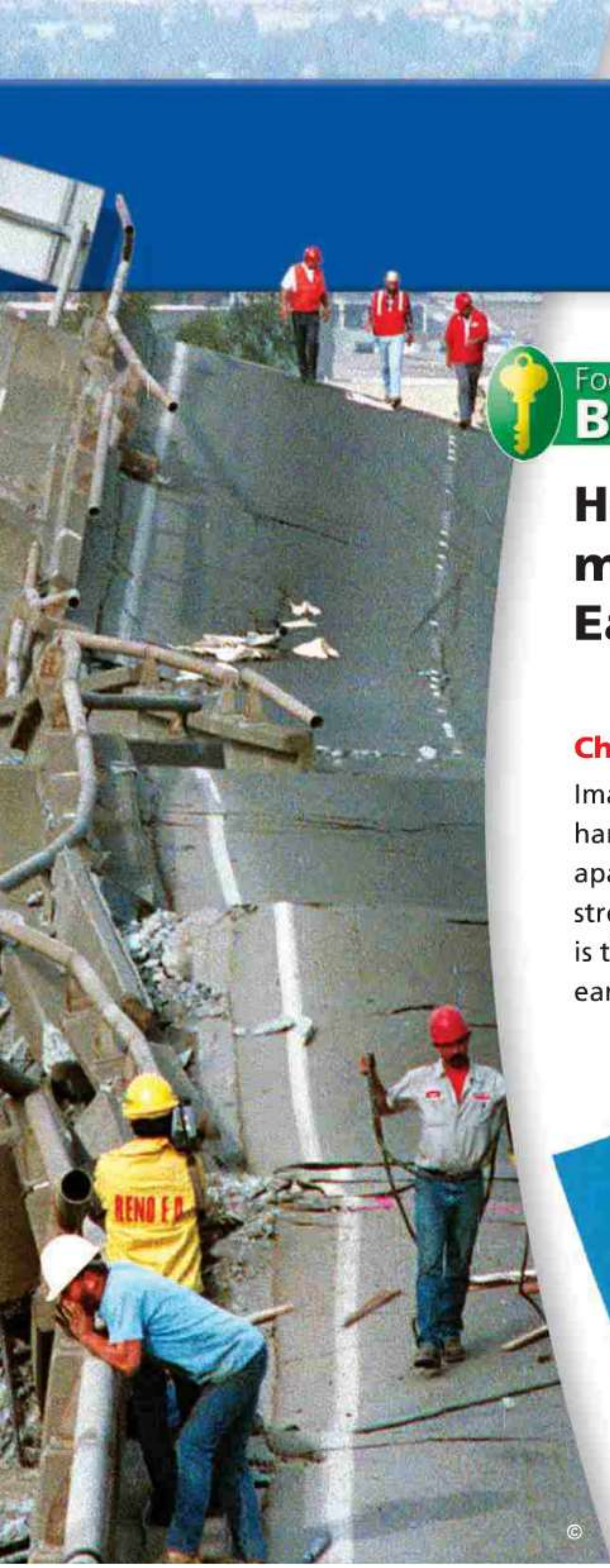
f. Students know how to explain major features of California geology (including mountains, faults, and volcanoes) in terms of plate tectonics.

g. Students know that the effects of an earthquake on any region vary, depending on the size of the earthquake, the distance of the region from the epicenter, the local geology, and the type of construction in the region.

S 6.2 Topography is reshaped by the weathering of rock and soil and by the transportation and deposition of sediment. As a basis for understanding this concept:

d. Students know earthquakes, volcanic eruptions, landslides, and floods change human and wildlife habitats.

An earthquake destroyed this freeway in Oakland, California, in 1989. ▶



Video Preview
Discovery Channel School
Earthquakes

Focus on the **BIG Idea**

S 6.1.d

How do plate motions affect Earth's crust?

Check What You Know

Imagine grasping a paper towel in both hands and slowly pulling your hands apart. At first, you see the paper towel stretch. Then, suddenly, it tears! How is the tearing paper towel similar to an earthquake? How is it different?

Build Science Vocabulary

The images shown here represent some of the key terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some key terms in this chapter.

Vocabulary Skill

High-Use Academic Words

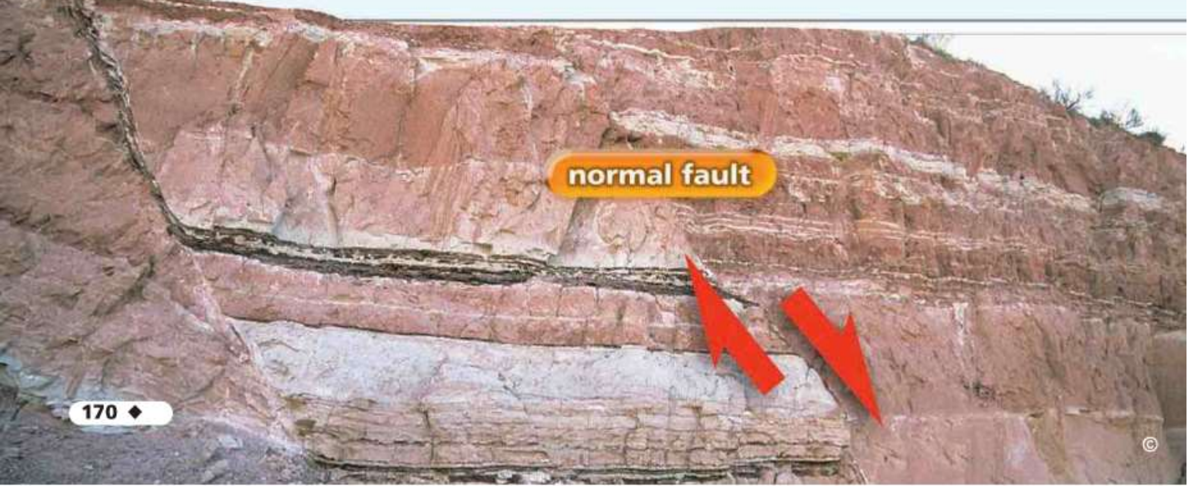
High-use academic words are words that are used frequently in academic reading, writing, and discussions.

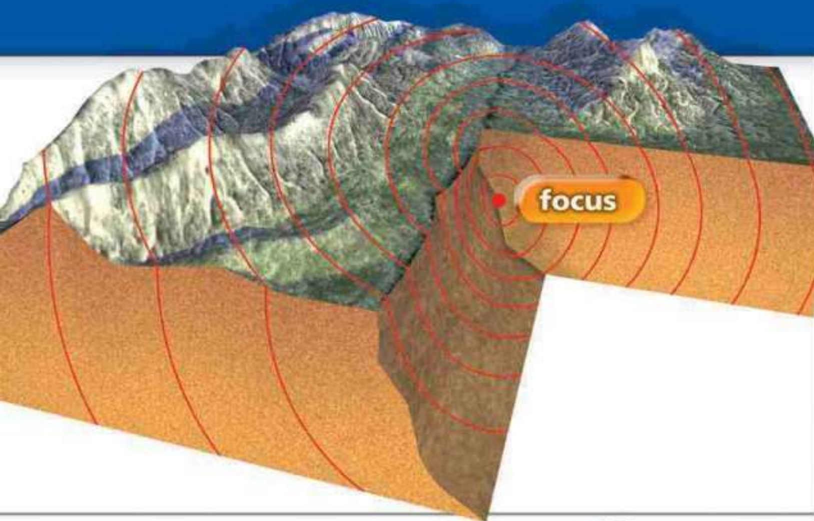
Word	Definition	Example Sentence
category (KAT uh gawr ee) p. 184	*n.* A class or group of things	The books on the shelf are separated into two categories—math and science.
construct (kun STRUCT) p. 205	*v.* To build	The goal was to construct a building that would stand up during an earthquake.
expand (ek SPAND) p. 185	*v.* To spread out	The experiment expanded into a long-term scientific investigation.
method (METH ud) p. 186	*n.* A way or system of doing things	Writing a letter and sending an e-mail are two methods of sharing information.

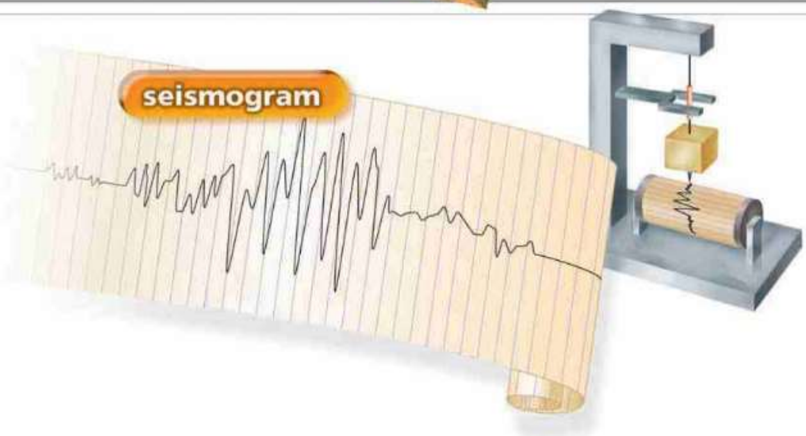
Apply It!

From the list above, choose the word that best completes the sentence.

1. A balloon will __________ until it breaks.
2. The work crew will ____________ the bridge to be safe during an earthquake.







Chapter 5 Vocabulary

Section 1 (page 174)

stress
tension
compression
shearing
normal fault
hanging wall
footwall
reverse fault
strike-slip fault
plateau

Section 2 (page 181)

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

Section 3 (page 190)

seismogram
friction

Section 4 (page 196)

liquefaction
aftershock
tsunami
base-isolated building

Interactive Textbook
Build Science Vocabulary *Online*
Use interactive flashcards

How to Read Science

Reading Skill

Identify Main Idea

The main idea in a paragraph is the most important, or biggest, idea. Sometimes the main idea is stated directly. At other times you must identify the main idea yourself.

Here are some tips.

- Look at the heading or subheading.
- Read carefully the first and last few sentences in the paragraph.
- Identify the main idea of the paragraph.
- Identify a few important details about the topic.

Read the paragraph below. Then identify the main idea. In your notebook, write the main idea in the first box and a few supporting details and examples in the boxes under it.

Earthquake-Safe House

There are ways to make a house safer before an earthquake occurs. Supporting brick chimneys with metal brackets adds strength. Fastening bookshelves and cabinets to wood in the wall keeps them from falling. Adding plywood boards to walls strengthens them.

Main Idea		

Detail	Detail	Detail
Supporting brick chimneys with metal brackets adds strength.		

Apply It!

Look for main ideas and supporting details in paragraphs in this chapter.

©

Lab zone

Standards Investigation

S 6.1.g

Design and Build an Earthquake-Safe House

Earthquakes are proof that our planet is subject to great forces from within. Earthquakes remind us that we live on the moving pieces of Earth's crust. In this chapter you will design a structure that can withstand earthquakes.

Your Goal

To design, build, and test a model structure that is earthquake resistant

Your structure must

- be made of materials that have been approved by your teacher
- be built to specifications agreed on by your class
- be able to withstand several "earthquakes" of increasing intensity
- be built following the safety guidelines in Appendix A

Plan It!

Before you design your model, find out how earthquakes damage structures such as homes, office buildings, and highways. Preview the chapter to find out how engineers design structures to withstand earthquakes. Then choose materials for your structure and sketch your design. When your teacher has approved your design, build and test your structure.

Section 1

Forces in Earth's Crust

CALIFORNIA Standards Focus

S 6.1.e Students know major geologic events, such as earthquakes, volcanic eruptions, and mountain building, result from plate motions.

S 6.1.f Students know how to explain major features of California geology (including mountains, faults, and volcanoes) in terms of plate tectonics.

- How does stress in the crust change Earth's surface?
- Where are faults usually found, and why do they form?
- What land features result from the forces of plate movement?

Key Terms

- stress
- tension
- compression
- shearing
- normal fault
- hanging wall
- footwall
- reverse fault
- strike-slip fault
- plateau

Lab zone Standards Warm-Up

How Does Stress Affect Earth's Crust?

1. Put on your goggles.
2. Holding a popsicle stick at both ends, slowly bend it into an arch.
3. Release the pressure on the popsicle stick and observe what happens.
4. Repeat Steps 1 and 2. This time, however, keep bending the ends of the popsicle stick toward each other. What happens to the wood?

Think It Over

Predicting Think of the popsicle stick as a model for part of Earth's crust. What do you think might eventually happen as the forces of plate movement bend the crust?

The movement of Earth's plates creates great forces that squeeze or pull the rock in the crust as if it were a caramel candy bar. These forces are examples of **stress,** a force that acts on an area of rock to change its shape or volume. (A rock's volume is the amount of space the rock takes up.) Because stress is a force, it adds energy to the rock. The energy is stored in the rock until the rock changes shape or breaks.

If you try to break a caramel candy bar in two, it may only bend and stretch at first. Like a candy bar, many types of rock can bend or fold. But beyond a certain limit, even these rocks will break.

FIGURE 1
Effects of Stress
Powerful forces in Earth's crust caused the ground beneath this athletic field in Taiwan to change its shape.

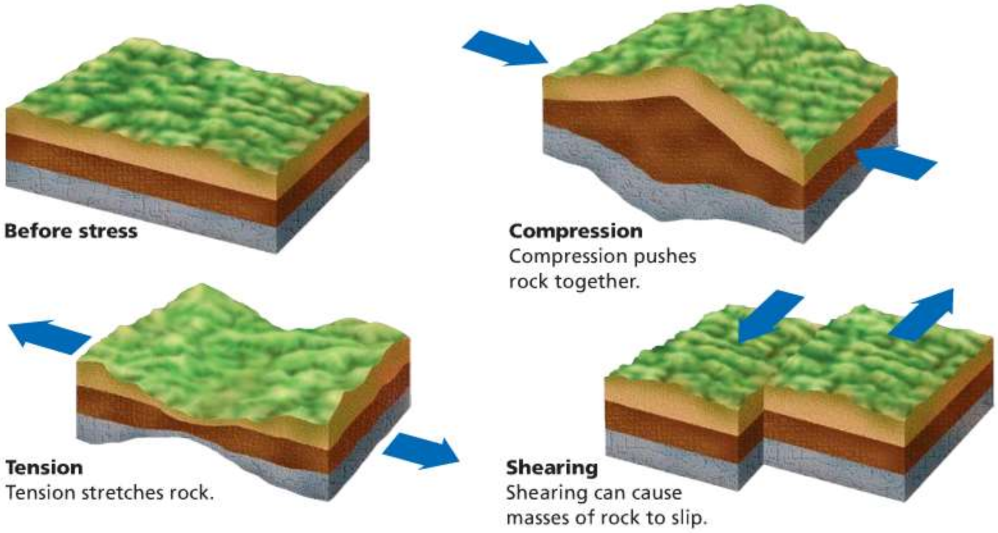


FIGURE 2
Stress in Earth's Crust
Stress pushes, pulls, or twists the rocks in Earth's crust.
Relating Cause and Effect *Which type of stress tends to shorten part of the crust?*

Types of Stress

Three different kinds of stress can occur in the crust—tension, compression, and shearing. **Tension, compression, and shearing work over millions of years to change the shape and volume of rock.** Stress causes some rocks to become brittle and snap. Other rocks bend slowly, like road tar softened by the sun. Figure 2 shows how stress affects the crust.

Most changes in the crust occur so slowly that they cannot be observed directly. But if you could speed up time so a billion years passed by in minutes, you would see the crust bend, stretch, break, tilt, fold, and slide. The slow shift of Earth's plates causes these changes.

Tension The type of stress called **tension** pulls on the crust, stretching rock so that it becomes thinner in the middle. The effect of tension on rock is somewhat like pulling apart a piece of warm bubble gum. Tension occurs where two plates are moving apart.

Compression A type of stress called **compression** squeezes rock until it folds or breaks. One plate pushing against another can compress rock like a giant trash compactor.

Shearing Stress that pushes a mass of rock in two opposite directions is called **shearing.** Shearing can cause rock to break and slip apart or to change its shape.

Reading Checkpoint **How does shearing affect rock in Earth's crust?**

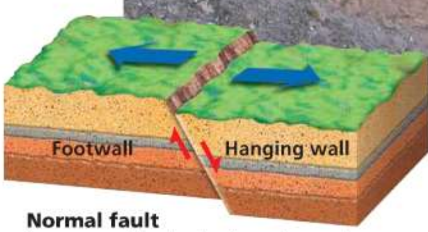
Kinds of Faults

When enough stress builds up in rock, the rock breaks, creating a fault. Recall that a fault is a break in the rock of the crust where rock surfaces slip past each other. The rocks on both sides of a fault can move up or down or sideways. **Most faults occur along plate boundaries, where the forces of plate motion push or pull the crust so much that the crust breaks. There are three main types of faults: normal faults, reverse faults, and strike-slip faults.**

Normal Faults Tension in Earth's crust pulls rock apart, causing **normal faults.** In a normal fault, the fault is at an angle, so one block of rock lies above the other block of rock. The block of rock that lies above is called the **hanging wall.** The rock that lies below is called the **footwall.** Look at Figure 3 to see how the hanging wall lies above the footwall. When movement occurs along a normal fault, the hanging wall slips downward. Normal faults occur where plates diverge, or pull apart. For example, normal faults are found along the Owens Valley in California where Earth's crust is under tension.

FIGURE 3
Kinds of Faults
There are three main kinds of faults: normal faults, reverse faults, and strike-slip faults.
Inferring *Which half of a normal fault would you expect to form the floor of a valley? Why?*

Key
Force deforming the crust
Movement along the fault



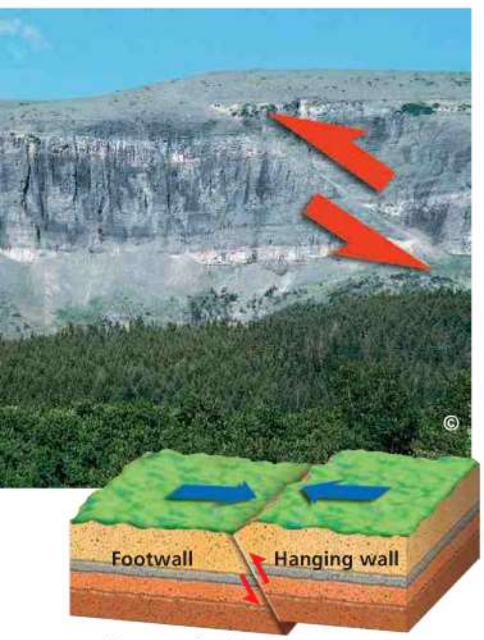
Normal fault
In a normal fault, the hanging wall slips down relative to the footwall.

Reverse Faults In places where the rock of the crust is pushed together, compression causes reverse faults to form. A **reverse fault** has the same structure as a normal fault, but the blocks move in the opposite direction. Look at Figure 3 to see how the rocks along a reverse fault move. As in a normal fault, one side of a reverse fault lies at an angle above the other side. However, in a reverse fault, the rock forming the hanging wall slides up and over the footwall. Movement along reverse faults produced part of the northern Rocky Mountains in the western United States and Canada. Reverse faults also helped produce the Klamath Mountains in northern California.

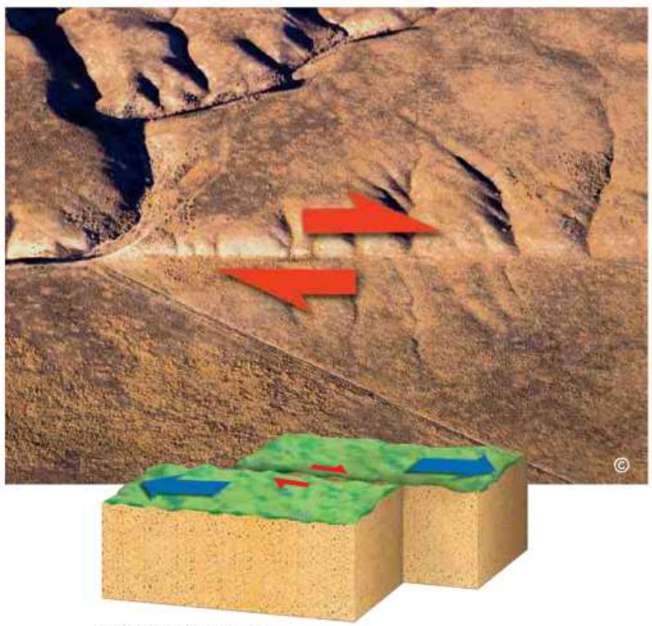
Strike-Slip Faults In places where plates move past each other, shearing creates strike-slip faults. In a **strike-slip fault,** the rocks on either side of the fault slip past each other sideways, with little up or down motion. A strike-slip fault that forms the boundary between two plates is called a sliding boundary. The San Andreas fault in California is an example of a strike-slip fault that is a sliding boundary.

Reading Checkpoint **What is the difference between a hanging wall and a footwall?**

Go Online
SCiLINKS NSTA
For: Links on faults
Visit: www.SciLinks.org
Web Code: scn-1021

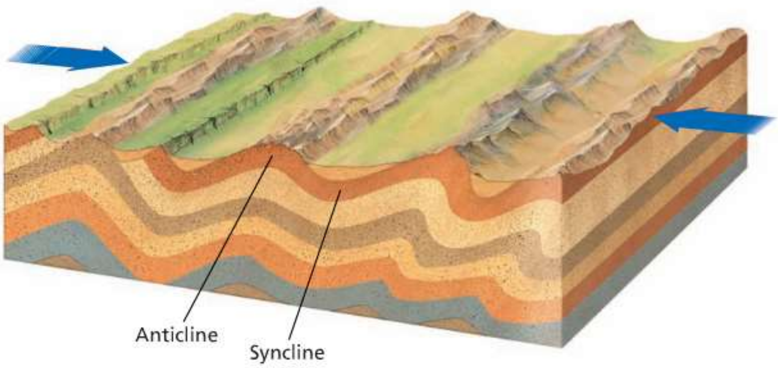


Reverse fault
In a reverse fault, the hanging wall moves up relative to the footwall.



Strike-slip fault
Rocks on either side of a strike-slip fault, such as the San Andreas fault (above), slip past each other.

FIGURE 4
Effects of Folding
Compression and folding of the crust produce anticlines, which arch upward, and synclines, which dip downward. Over millions of years, folding can push up high mountain ranges.
Predicting *If the folding in the diagram continued, what kind of fault might form?*



Changing Earth's Surface

The forces produced by the movement of Earth's plates can fold, stretch, and uplift the crust. **Over millions of years, the forces of plate movement can change a flat plain into landforms produced by folding, stretching, and uplifting Earth's crust. These landforms include anticlines and synclines, folded mountains, fault-block mountains, and plateaus.**

Folding Earth's Crust Sometimes plate movement causes the crust to fold. Have you ever skidded on a rug that wrinkled up as your feet pushed it across the floor? Much as the rug wrinkles, rock stressed by compression may bend without breaking. Folds are bends in rock that form when compression shortens and thickens part of Earth's crust. A fold can be only a few centimeters across or hundreds of kilometers wide. You can often see small folds in the rock exposed where a highway has been cut through a hillside.

Geologists use the terms anticline and syncline to describe upward and downward folds in rock. A fold in rock that bends upward into an arch is an anticline, shown in Figure 4. A fold in rock that bends downward to form a valley is a syncline. Anticlines and synclines are found in many places where compression forces have folded the crust.

The collision of two plates can cause compression and folding of the crust over a wide area. Folding produced some of the world's largest mountain ranges, such as the Himalayas in Asia and the Alps in Europe. The mountains in California's northern Coast Range are partly the result of folding.

Reading Checkpoint **What is an anticline?**

Lab zone Try This Activity

Modeling Stress

You can model the stresses that create faults.

1. Knead a piece of plastic putty until it is soft.
2. Push the ends of the putty toward the middle.
3. Pull the ends apart.
4. Push half of the putty one way and the other half in the opposite direction.

Classifying Which step in this activity models the type of stress that would produce anticlines and synclines?

Stretching Earth's Crust When two normal faults cut through a block of rock, a fault-block mountain forms. You can see a diagram of this process in Figure 5. How does this process begin? Where two plates move away from each other, tension forces create many normal faults. When two of these normal faults form parallel to each other, a block of rock is left lying between them. As the hanging wall of each normal fault slips downward, the block in between moves upward, forming a fault-block mountain. The Panamint Range, which forms the western side of Death Valley, is an example of a fault-block mountain range in California.

If you traveled by car from Salt Lake City to Los Angeles, you would cross the Great Basin. This region contains many ranges of fault-block mountains separated by broad valleys, or basins. This "basin and range" region covers much of Nevada and western Utah. The region extends into California's Mojave Desert and the area east of the Sierra Nevada.

FIGURE 5
Fault-Block Mountains
As tension forces pull the crust apart, two parallel normal faults can form a range of fault-block mountains.

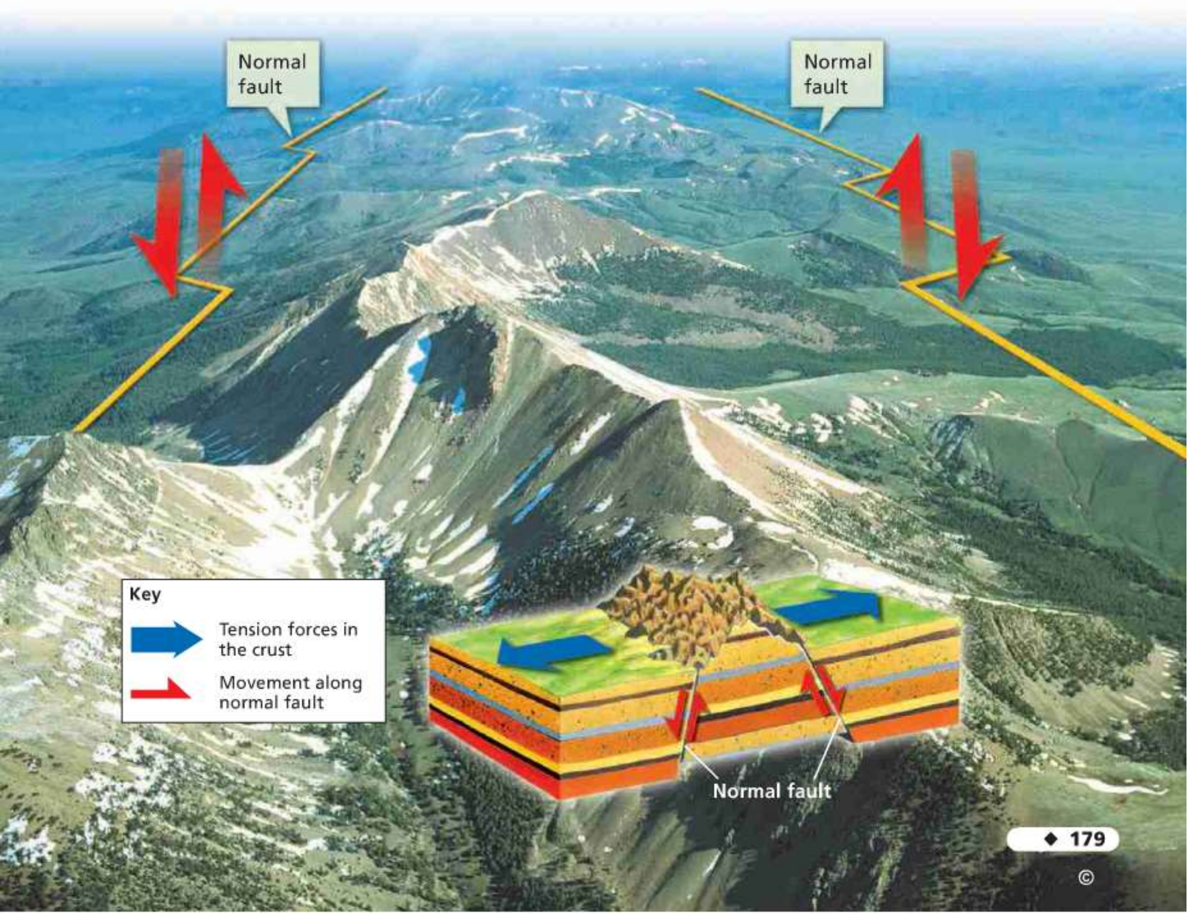


FIGURE 6
The Kaibab Plateau
The flat land on the horizon is the Kaibab Plateau, which forms the North Rim of the Grand Canyon in Arizona. The Kaibab Plateau is part of the Colorado Plateau.

Uplifting Earth's Crust The forces that raise mountains can also uplift, or raise, plateaus. A **plateau** is a large area of flat land elevated high above sea level. Some plateaus form when forces in Earth's crust push up a large, flat block of rock. Like a fancy sandwich, a plateau consists of many different flat layers, and is wider than it is tall.

Forces deforming the crust uplifted the Colorado Plateau in the "Four Corners" region of Arizona, Utah, Colorado, and New Mexico. Much of the Colorado Plateau lies more than 1,500 meters above sea level. Figure 6 shows one part of that plateau in northern Arizona.

Section 1 Assessment

S 6.1.e, 6.1.f; E-LA: Reading 6.2.3

Target Reading Skill **Identify Main Ideas** Review the text under Types of Stress. Identify three details that support the main idea that different types of stress can occur in Earth's crust.

Reviewing Key Concepts

HINT 1. a. **Reviewing** What are the three main types of stress in rock?

HINT b. **Relating Cause and Effect** How does tension change the shape of Earth's crust?

HINT c. **Comparing and Contrasting** Compare the way that compression affects the crust to the way that tension affects the crust.

HINT 2. a. **Describing** What is a fault?

HINT b. **Explaining** Why do faults often occur along plate boundaries?

HINT c. **Relating Cause and Effect** What type of fault is formed when plates diverge, or pull apart? What type of fault is formed when plates are pushed together?

3. a. **Listing** Name five kinds of landforms caused by plate movement. HINT

b. **Relating Cause and Effect** What are three landforms produced by compression in the crust? What landform is produced by tension? HINT

Lab zone At-Home Activity

Modeling Faults To model Earth's crust, roll modeling clay into layers and then press the layers together to form a rectangular block. Use a plastic knife to slice through the block at an angle, forming a fault. Explain which parts of your model represent the land surface, the hanging wall, and the footwall. Then show the three ways in which the sides of the fault can move.

Section 2

Earthquakes and Seismic Waves

CALIFORNIA Standards Focus

S 6.1.d Students know that earthquakes are sudden motions along breaks in the crust called faults and that volcanoes and fissures are locations where magma reaches the surface.

S 6.1.g Students know that the effects of an earthquake on any region vary, depending on the size of the earthquake, the distance of the region from the epicenter, the local geology, and the type of construction in the region.

- 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

Lab zone Standards Warm-Up

How Do Seismic Waves Travel?

1. Stretch a spring toy across the floor while a classmate securely holds the other end. Do not stretch the toy too much.
2. Have a third classmate measure and record the distance along the stretched-out toy.
3. Gather together about four coils of the spring toy and release them. Observe the coils' motion. Repeat this step, having a classmate use a stopwatch to time one wave's movement along the spring toy, and then record the time.
4. Jerk one end of the toy from side to side once. Observe the coils' motion. Repeat this step, again having a classmate time and record one wave's movement. (Keep the distance along the spring toy the same as in Step 3).

Think It Over

Calculating Calculate the speed of the waves in Steps 3 and 4. (*Hint:* Divide the distance along the spring toy by the time the wave took to travel that distance.) Which type of wave traveled faster? How can you explain this difference?

Earth is never still. Every day, worldwide, there are several thousand earthquakes. An **earthquake** is the shaking that results from the sudden movement of rock along a fault. Most earthquakes are too small to notice. But a large earthquake can change 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 a large 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).

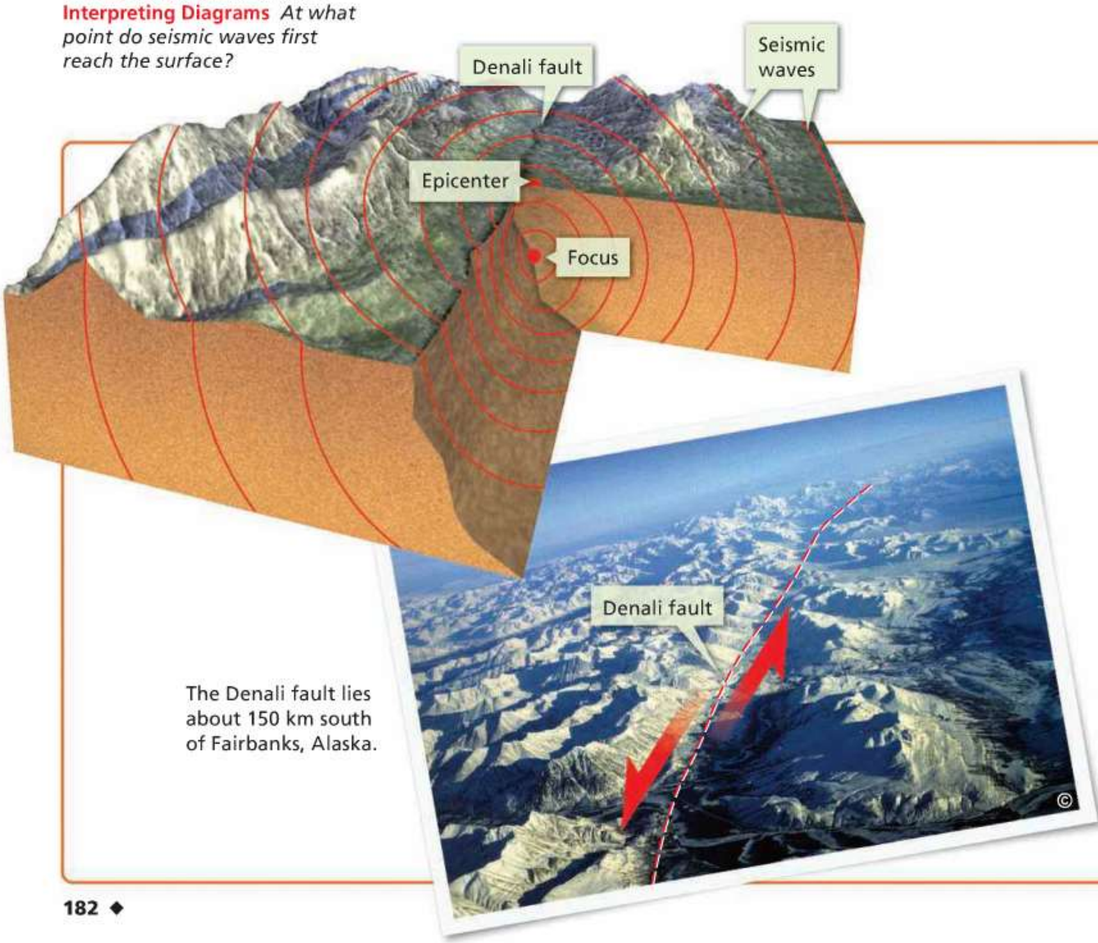
Types of Seismic Waves

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. **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, shown in Figure 7. **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. P waves can move through solids and liquids.

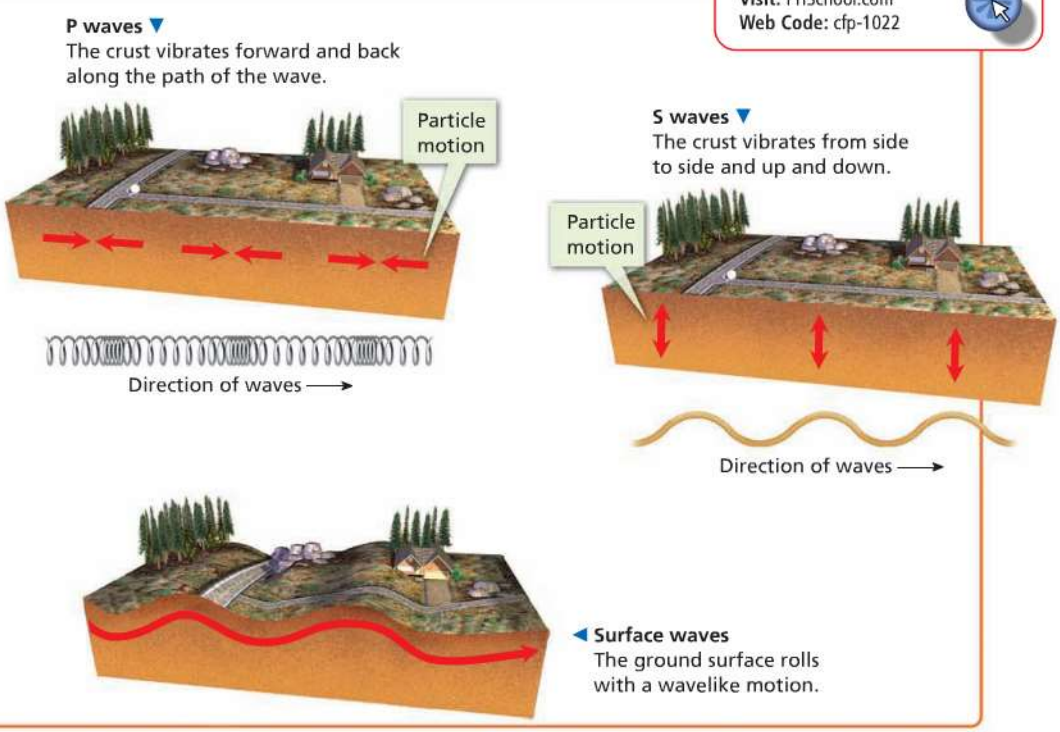
S Waves After P waves come secondary waves, or S waves. **S waves** are seismic waves that vibrate from side to side as well as up and down. They shake the ground back and forth. When S waves reach the surface, they shake structures violently. Unlike P waves, S waves cannot move through liquids.

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
Web Code: cfp-1022



Video Field Trip
Discovery Channel School
Earthquakes

Measuring Earthquakes

When an earthquake occurs, people want to know "How big was the quake?" **There are three commonly used methods of measuring earthquakes: the Mercalli scale, the Richter scale, and the moment magnitude scale.**

The Mercalli Scale The **Mercalli scale** was developed to rate earthquakes according to their intensity, or strength at a given place. The 12 steps of the Mercalli scale, shown in Figure 9, describe the levels of damage an earthquake can cause. The same earthquake can have different Mercalli ratings because its intensity varies at different locations.

For example, an earthquake's intensity generally decreases with distance from the epicenter. This happens because Earth materials absorb some of the waves' energy. Also, the earthquake's energy spreads over a wider area as the waves move out from the epicenter.

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** assigns a magnitude number to an earthquake based on the size of 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.

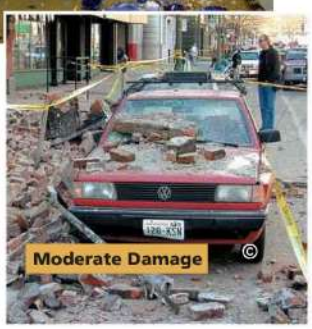
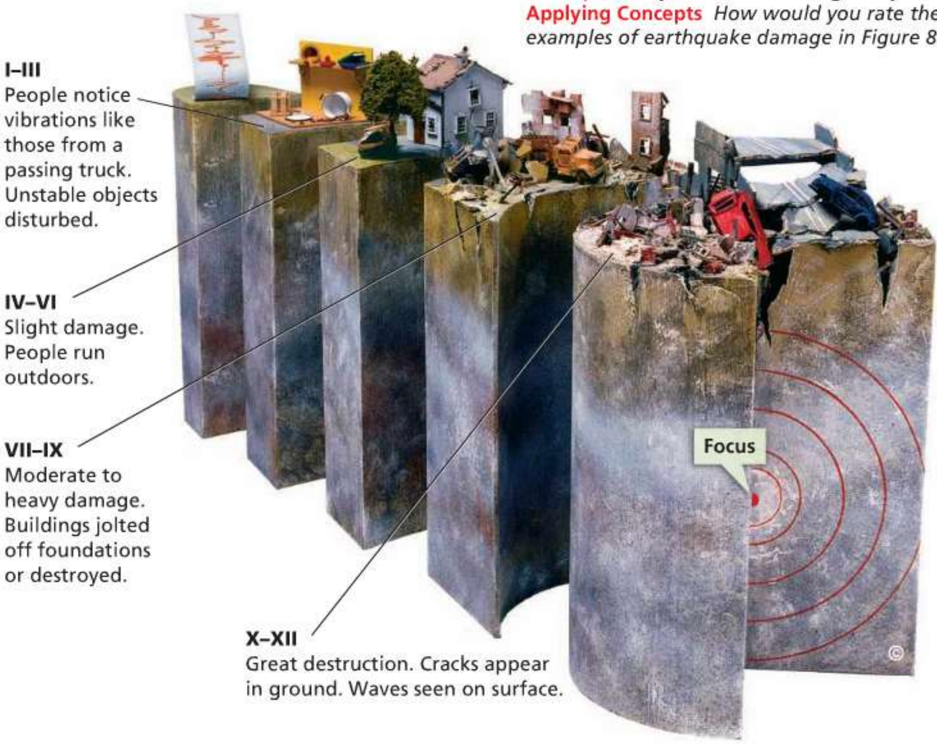


FIGURE 8
Levels of Earthquake Damage
The level of damage caused by an earthquake varies depending on the magnitude of the earthquake and the distance from the epicenter.

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. They also use data on how much movement occurred along the fault and the strength of the rocks that broke when the fault slipped.

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.

Comparing Earthquakes An earthquake's magnitude tells geologists how much stored energy was released by the earthquake. Magnitude values can range from near zero to between 9.0 and 10.0. For each one number increase in magnitude, ground shaking increases by a factor of 10. But for each one number increase in magnitude, the amount of energy released increases by a factor of about 30! A magnitude 8 quake releases 30 times as much energy as a magnitude 7 quake, and about 1,000,000 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.

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.

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: Mathematical Reasoning 6.2.4

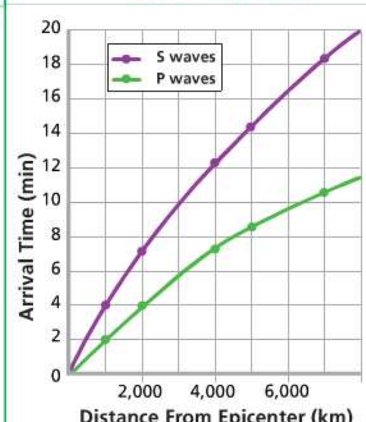
Math Analyzing Data

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?

P and S Waves



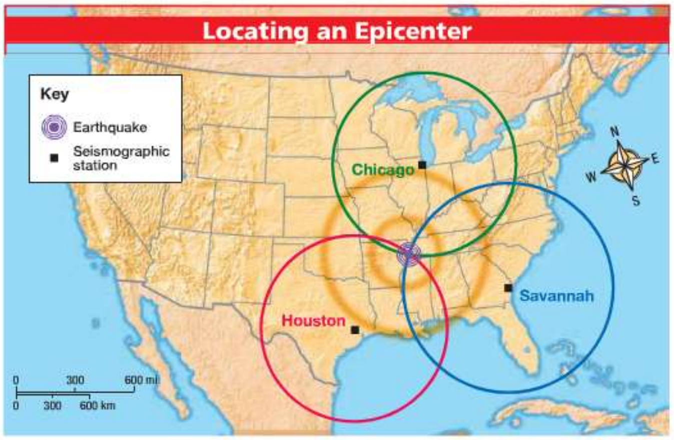


FIGURE 11
The map shows how to find the epicenter of an earthquake using data from three seismographic stations. **Measuring** *Use the map scale to determine the distances from Savannah and Houston to the epicenter. Which is closer?*

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

S 6.1.d, 6.1.g; E-LA: Reading 6.1.0, Writing 6.2.1

Vocabulary Skill **High-Use Academic Words**
Explain the difference between *expand* and *compress* in the following sentence: P waves are seismic waves that compress and expand the ground.

Reviewing Key Concepts

HINT
1. a. **Reviewing** How does energy from an earthquake reach Earth's surface?

HINT
b. **Describing** What kind of movement is produced by each of the three types of seismic waves?

HINT
c. **Sequencing** When do P waves arrive at the surface in relation to S waves and surface waves?

HINT
2. a. **Defining** What is magnitude?

HINT
b. **Describing** How is magnitude measured using the Richter scale?

HINT
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? HINT

b. **Interpreting Maps** Study the map in Figure 11 above. Then describe the method that scientists use to determine the epicenter of an earthquake. HINT

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.)

Lab zone **Skills Lab**
Directed Inquiry

S 6.1.g

Finding the Epicenter

Materials


drawing compass with pencil


outline map of the United States

Problem
How can you locate an earthquake's epicenter?

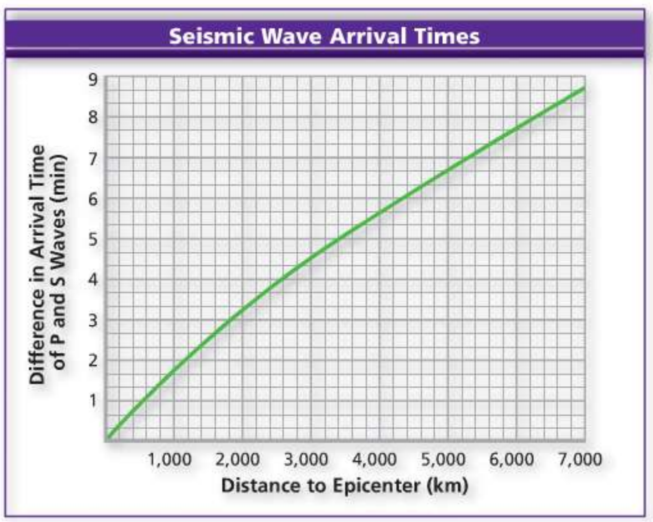
Skills Focus
interpreting data, drawing conclusions

Procedure

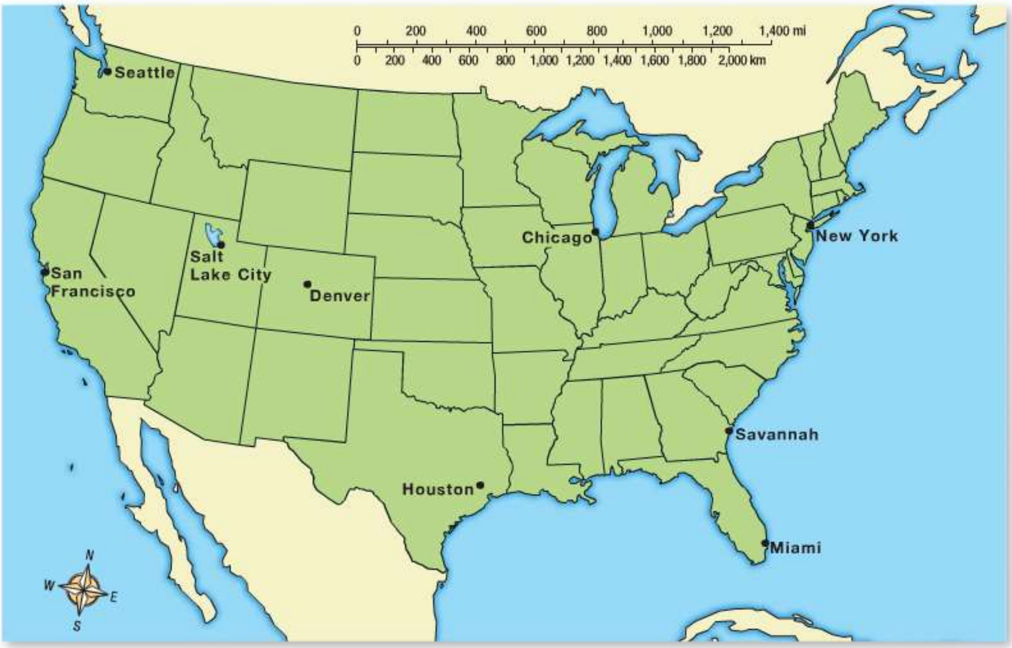
1. Make a copy of the data table showing differences in earthquake arrival times.

Data Table		
City	Difference in P and S Wave Arrival Times	Distance to Epicenter
Denver, Colorado	2 min 40 s	
Houston, Texas	1 min 50 s	
Chicago, Illinois	1 min 10 s	

2. The graph shows how the difference in arrival time between P waves and S waves depends on the distance from the epicenter of the earthquake. Find the difference in arrival time for Denver on the *y*-axis of the graph. Follow this line across to the point at which it crosses the curve. To find the distance to the epicenter, read down from this point to the *x*-axis of the graph. Enter this distance in the data table.
3. Repeat Step 2 for Houston and Chicago.
4. Set your compass at a radius equal to the distance from Denver to the earthquake epicenter that you previously recorded in your data table.



5. Draw a circle with the radius determined in Step 4, using Denver as the center. Draw the circle on your copy of the map. (*Hint:* Draw your circles carefully. You may need to draw some parts of the circles off the map.)
6. Repeat Steps 4 and 5 for Houston and Chicago.



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 (Figure 18). What is the risk of earthquakes in the area of this quake?

Now look at the map of Earth's Lithospheric Plates (Figure 22 in the chapter "Plate Tectonics"). What conclusions can you draw from this map about the cause of earthquakes in this area?

Section 3

Monitoring Earthquakes

CALIFORNIA Standards Focus

S 6.1.g Students know that the effects of an earthquake on any region vary, depending on the size of the earthquake, the distance of the region from the epicenter, the local geology, and the type of construction in the region.

- How do seismographs work?
- How do geologists monitor faults?
- How are seismographic data used?

Key Terms

- seismogram
- friction

Lab zone **Standards Warm-Up**

How Can Seismic Waves Be Detected?

1. Using scissors, cut 4 plastic stirrers in half. Each piece should be about 5 cm long.
2. Your teacher will give you a pan containing gelatin. Gently insert the 8 stirrer pieces into the gelatin, spacing them about 2–3 cm apart in a row. The pieces should stand upright, but not touch the bottom of the pan.
3. At the opposite end of the pan from the stirrers, gently tap the surface of the gelatin once with the eraser end of a pencil. Observe the results.

Think It Over

Inferring What happened to the stirrer pieces when you tapped the gelatin? What was responsible for this effect?

Look at the beautiful vase in the photo. You might be surprised to learn that the vase is actually a scientific instrument. Can you guess what it was designed to do? Zhang Heng, an astronomer, designed and built this earthquake detection device in China nearly 2,000 years ago. It is said to have detected an earthquake centered several hundred kilometers away.

Earthquakes are dangerous, so people want to monitor them. To *monitor* means to "watch closely." Like the ancient Chinese, many societies have used technology to determine when and where earthquakes have occurred. During the late 1800s, scientists developed seismographs that were much more sensitive and accurate than any earlier devices.

FIGURE 12
Earthquake Detector
Nearly 2,000 years ago, a Chinese scientist invented this instrument to detect earthquakes.

The Seismograph

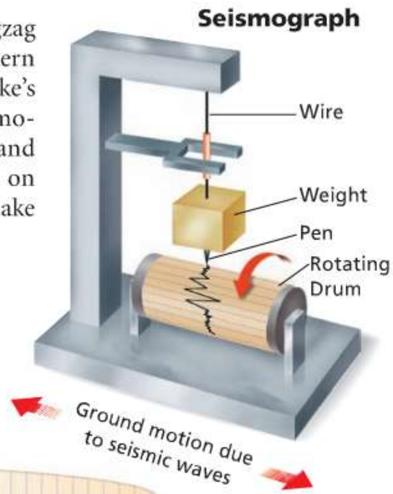
A simple seismograph can consist of a heavy weight attached to a frame by a spring or wire. A pen connected to the weight rests its point on a drum that can rotate. As the drum rotates slowly, the pen draws a straight line on paper wrapped tightly around the drum. **Seismic waves cause the seismograph's drum to vibrate. But the suspended weight with the pen attached moves very little. Therefore, the pen stays in place and records the drum's vibrations.**

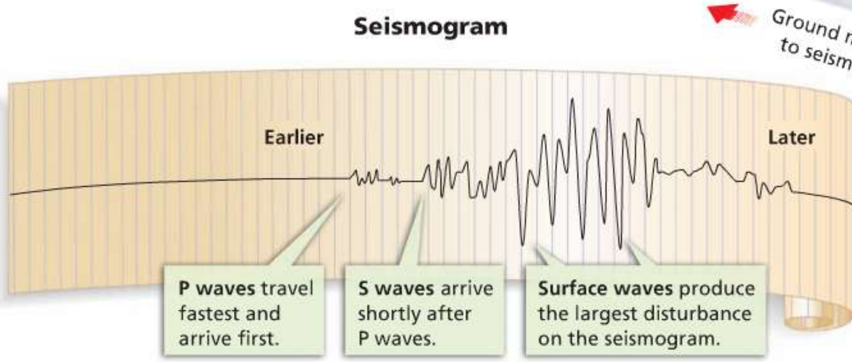
Measuring Seismic Waves When you write a sentence, the paper stays in one place while your hand moves the pen. But in a seismograph, it's the pen that remains still while the paper moves. Why is this? All seismographs make use of a basic principle of physics: Whether it is moving or at rest, every object resists any change to its motion. A seismograph's heavy weight resists motion during a quake. But the rest of the seismograph is anchored to the ground and vibrates when seismic waves arrive.

Reading a Seismogram You have probably seen a zigzag pattern of lines used to represent an earthquake. The pattern of lines, called a **seismogram,** is the record of an earthquake's seismic waves produced by a seismograph. Study the seismogram in Figure 13 and notice when the P waves, S waves, and surface waves arrive. The height of the jagged lines drawn on the seismograph's drum is greater for a more severe earthquake or for an earthquake close to the seismograph.

Reading Checkpoint **What is a seismogram?**

FIGURE 13
Recording Seismic Waves
A seismograph records seismic waves, producing a seismogram. Today, electronic seismographs contain sensors instead of pens.
Interpreting Diagrams *What is the function of the weight in the seismograph?*





Instruments That Monitor Faults

Along a fault, scientists may detect a slight rise or fall in the elevation and tilt of the land. Geologists think that such changes signal a buildup of stress in rock. Increasing stress could eventually lead to an earthquake. **To monitor faults, geologists have developed instruments to measure changes in elevation, tilting of the land surface, and ground movements along faults.** Some of the instruments that geologists use to monitor these movements include tiltmeters, creep meters, laser-ranging devices, and satellites.

Tiltmeters A tiltmeter measures tilting or raising of the ground. If you have ever used a carpenter's level, you have used a type of tiltmeter. The tiltmeters used by geologists consist of two bulbs that are filled with a liquid and connected by a hollow stem. Notice that if the land rises or falls slightly, the liquid will flow from one bulb to the other. Each bulb contains a measuring scale to measure the depth of the liquid in that bulb. Geologists read the scales to measure the amount of tilt occurring along the fault.

Creep Meters A creep meter uses a wire stretched across a fault to measure horizontal movement of the ground. On one side of the fault, the wire is anchored to a post. On the other side, the wire is attached to a weight that can slide if the fault moves. Geologists determine how much the fault has moved by measuring how much the weight has moved against a scale.

Laser-Ranging Devices A laser-ranging device uses a laser beam to detect horizontal fault movements. The device times a laser beam as it travels to a reflector and back. Thus, the device can detect any change in distance to the reflector.

GPS Satellites Scientists can monitor changes in elevation as well as horizontal movement along faults using a network of Earth-orbiting satellites called GPS. GPS, the Global Positioning System, was developed to help ships and planes find their routes. As shown in Figure 14, GPS can also be used to locate points on Earth's surface with great precision. Using GPS, scientists measure tiny movements of markers set up on the opposite sides of a fault.

Reading Checkpoint How does a creep meter work?

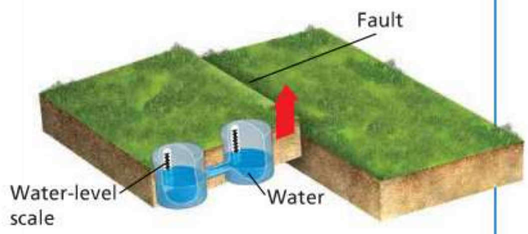
Go Online SCI LINKS NSTA
For: Links on earthquake measurement
Visit: www.SciLinks.org
Web Code: scn-1023

Figure 14

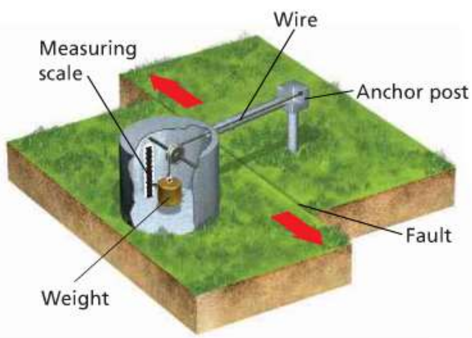
Monitoring Faults

To detect slight motions along faults in California, geologists use several types of devices.

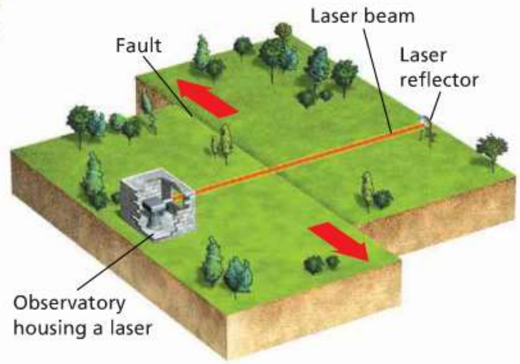
Comparing and Contrasting *Which of these devices measure horizontal movement? Which ones measure vertical movement?*



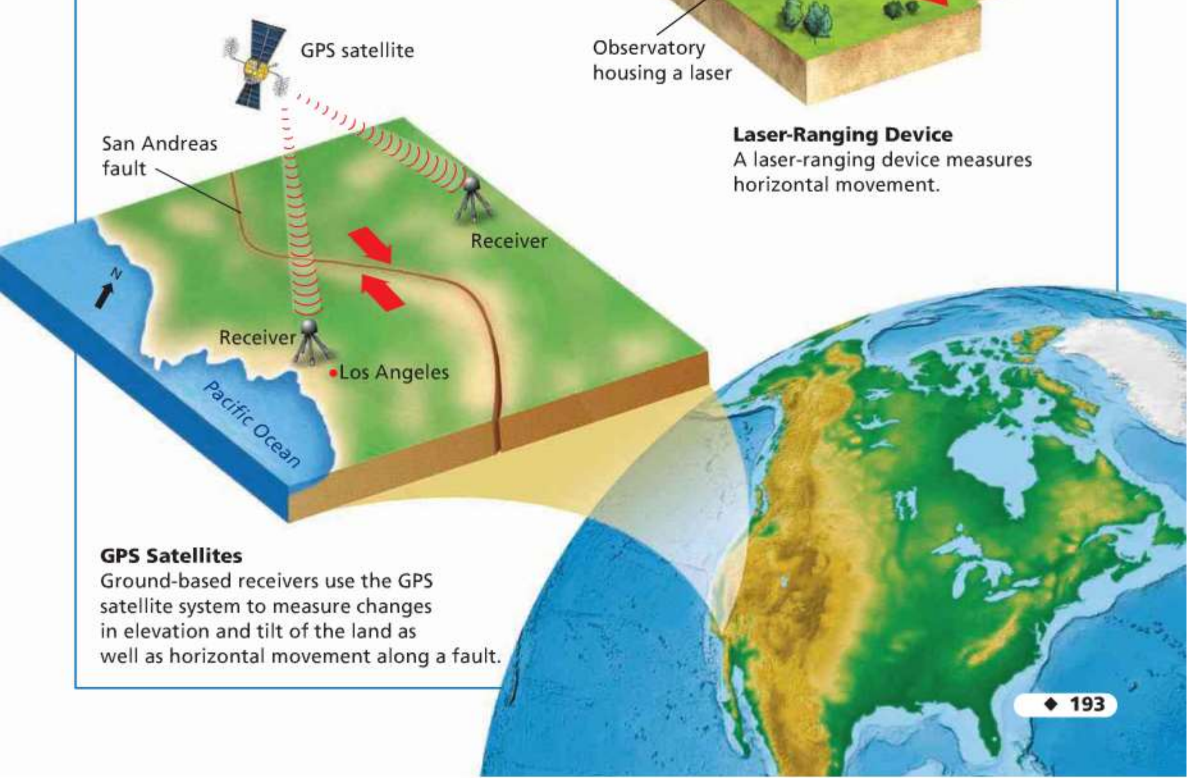
Tiltmeter
A tiltmeter measures vertical movement.



Creep Meter
A creep meter measures horizontal movement.



Laser-Ranging Device
A laser-ranging device measures horizontal movement.



GPS Satellites
Ground-based receivers use the GPS satellite system to measure changes in elevation and tilt of the land as well as horizontal movement along a fault.

Lab zone Skills Activity

Measuring Friction

You can measure the force of friction.

1. Place a small weight on a smooth, flat tabletop. Use a spring scale to pull the weight across the surface. How much force is shown on the spring scale? (*Hint:* The unit of force is newtons.)
2. Tape a piece of sandpaper to the tabletop. Repeat Step 1, pulling the weight across the sandpaper.

Is the force of friction greater for a smooth surface or for a rough surface?

Using Seismographic Data

Scientists collect and use seismographic data in a variety of ways. **Seismographs and fault-monitoring devices provide data used to map faults and detect changes along faults. Geologists are also trying to use these data to develop a method of predicting earthquakes.**

Mapping Faults Faults are often hidden by a thick layer of rock or soil. How can geologists map a hidden fault?

When seismic waves hit a fault, the waves are reflected off the fault. Seismographs can detect these reflected seismic waves. Geologists then use these data to map the fault's length and depth. Knowing the location of hidden faults helps scientists determine the earthquake risk for the area.

Monitoring Changes Along Faults Geologists study the types of movement that occur along faults. How rocks move along a fault depends on how much friction there is between the sides of the fault. **Friction** is the force that opposes the motion of one surface as it moves across another surface. Friction exists because surfaces are not perfectly smooth.

Where friction along a fault is low, the rocks on both sides of the fault slide by each other without much sticking. Therefore stress does not build up, and big earthquakes are unlikely. Where friction is moderate, the sides of the fault jam together. Then from time to time they jerk free, producing small earthquakes. Where friction is high, the rocks lock together and do not move. In this case, stress increases until it is strong enough to overcome the friction force. For example, in most places along the San Andreas fault in California, friction is high and the plates lock. Stress builds up until an earthquake occurs.

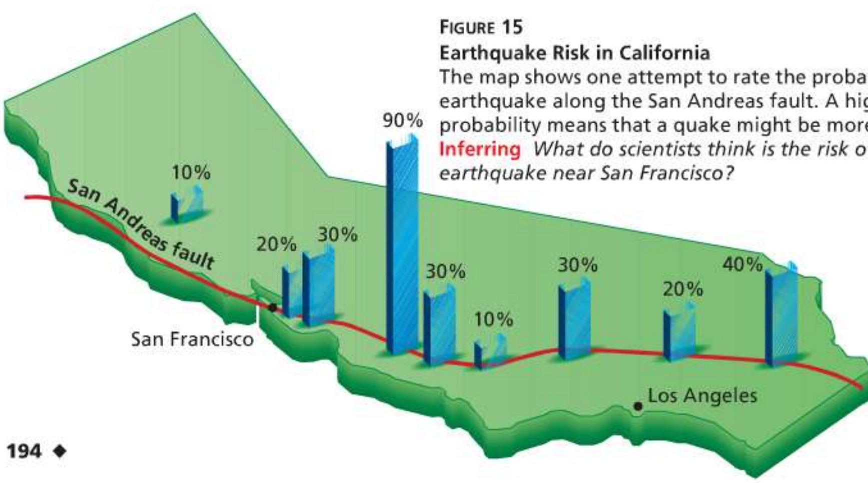


FIGURE 15
Earthquake Risk in California
The map shows one attempt to rate the probability of a strong earthquake along the San Andreas fault. A high percent probability means that a quake might be more likely to occur.
Inferring *What do scientists think is the risk of a strong earthquake near San Francisco?*

Figure 15 shows how geologists in California have used data about how the San Andreas fault moves. They have tried to estimate the earthquake risk along the fault. Unfortunately, this attempt at forecasting earthquakes has not worked yet.

Trying to Predict Earthquakes Even with data from many sources, geologists can't predict when and where a quake will strike. Usually, stress along a fault increases until an earthquake occurs. Yet sometimes stored energy builds up along a fault, but an earthquake fails to occur. Or, one or more small earthquakes would relieve only some of the stored energy along the fault. There is always the chance that a large, destructive earthquake will suddenly release most of the stored energy. So exactly what will happen remains uncertain.

The problem of predicting earthquakes is one of many scientific questions that remain unsolved. If you become a scientist, you can work to find answers to these questions. Much remains to be discovered!

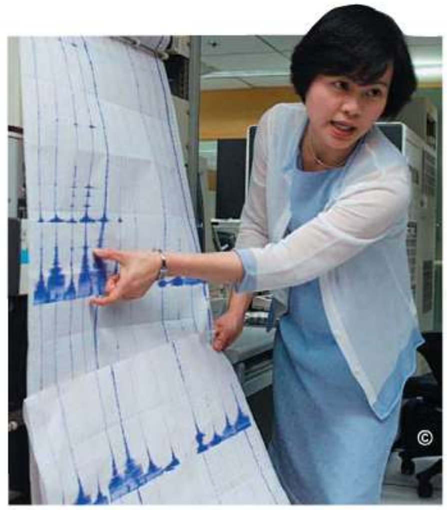


FIGURE 16
Seismographic Data
A geologist interprets a seismogram. Understanding changes that precede earthquakes may help in efforts to predict them.

Reading Checkpoint **Why is it difficult to predict earthquakes?**

Section 3 Assessment

S 6.1.g; E-LA: Reading 6.2.3, Writing 6.2.2

Target Reading Skill Identify Main Ideas
Review the text under Monitoring Changes Along Faults. Identify two or three details that support the main idea that friction along faults helps to determine the risk of earthquakes.

Reviewing Key Concepts

HINT
1. a. Defining What is a seismograph?
HINT
b. Explaining How does a seismograph record seismic waves?
HINT
c. Predicting A seismograph records a strong earthquake and a weak earthquake. How would the seismograms for the two earthquakes compare?
HINT
2. a. Reviewing What four instruments are used to monitor faults?
HINT
b. Describing What changes does each instrument measure?
HINT
c. Inferring A satellite that monitors a fault detects an increasing tilt in the land surface along the fault. What could this change in the land surface indicate?

3. a. Listing What are three ways in which geologists use seismographic data? HINT
b. Explaining How do geologists use seismographic data to make maps of faults? HINT
c. Making Generalizations Why do geologists collect data on friction along the sides of faults? HINT

Writing in Science

Patent Application You are an inventor who has created a simple device that can detect an earthquake. To protect your rights to the invention, you apply for a patent. In your patent application, describe your device and how it will indicate the direction and strength of an earthquake. You may include a sketch.

Section 4

Earthquake Safety

CALIFORNIA Standards Focus

S 6.1.g Students know that the effects of an earthquake on any region vary, depending on the size of the earthquake, the distance of the region from the epicenter, the local geology, and the type of construction in the region.

S 6.2.d Students know earthquakes, volcanic eruptions, landslides, and floods change human and wildlife habitats.

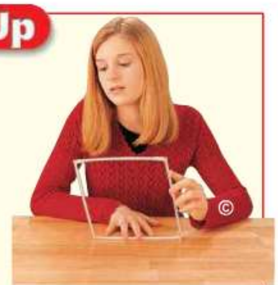
- How do geologists determine earthquake risk?
- What kinds of damage does an earthquake cause?
- What can be done to increase earthquake safety and reduce earthquake damage?

Key Terms

- liquefaction
- aftershock
- tsunami
- base-isolated building

Lab zone Standards Warm-Up

Can Bracing Prevent Building Collapse?



1. Tape four straws together to make a square frame. Hold the frame upright on a flat surface.
2. Hold the bottom straw down with one hand while you push the top straw to the left with the other. Push it as far as it will go without breaking the frame.
3. Tape a fifth straw horizontally across the middle of the frame. Repeat Step 2.

Think It Over

Predicting What effect did the fifth straw have? What effect would a piece of cardboard taped to the frame have? Based on your observations, how would an earthquake affect the frame of a house?

Imagine being sound asleep in your bed in the middle of the night. Suddenly, you are jolted wide awake as your home begins to rattle and shake. As objects fall off shelves and walls crack, you crouch under a desk for protection. Around the city, large buildings collapse and fires break out. The quake lasts less than a minute, but leaves behind great damage. That's what happened in September 1999 when a magnitude 7.6 earthquake hit Taipei, Taiwan. The effects of an earthquake on any region vary, depending on the size of the earthquake, distance from the epicenter, local geology, and the type of construction in the region.

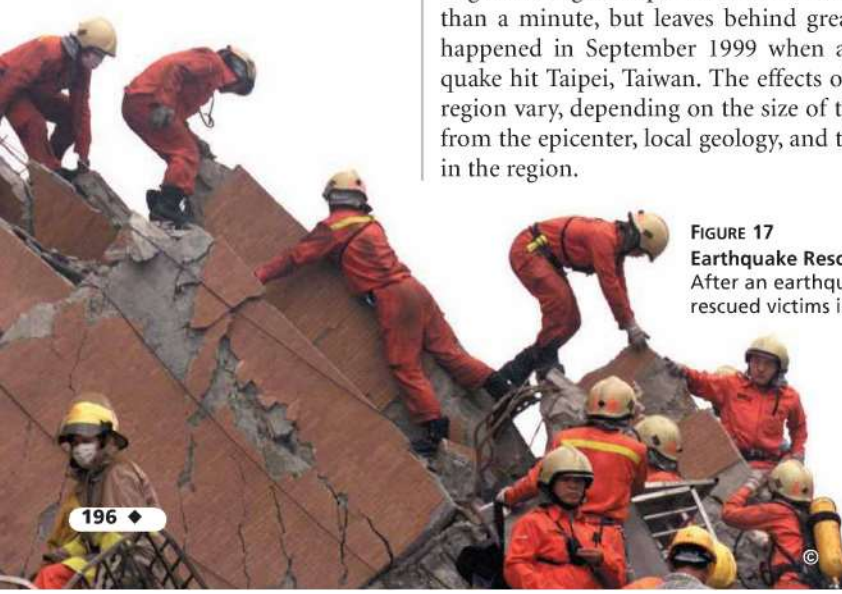


FIGURE 17
Earthquake Rescue
After an earthquake in Taipei, crews rescued victims in collapsed buildings.

Earthquake Risk in the United States

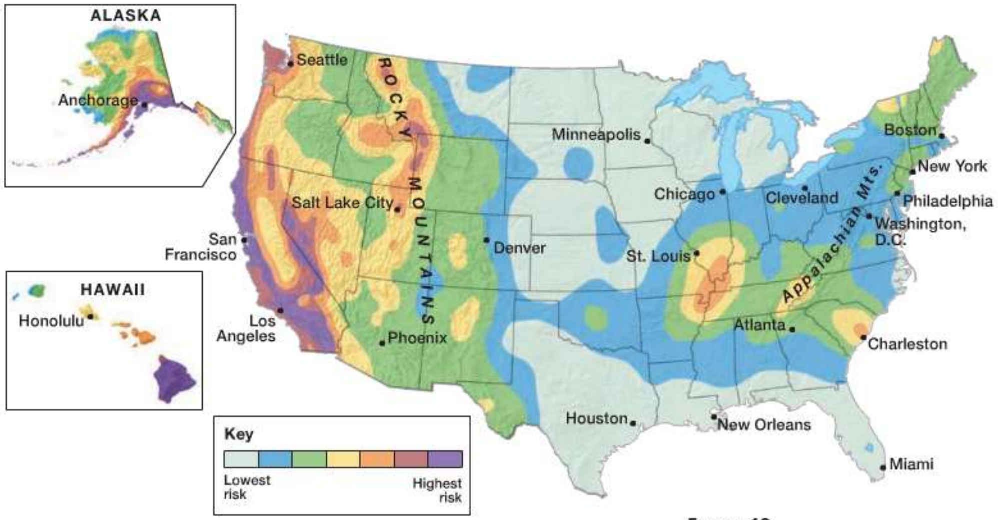


FIGURE 18
The map shows areas where serious earthquakes are likely to occur, based on the locations of previous earthquakes.
Interpreting Maps *Where are damaging earthquakes least likely to occur? Most likely to occur?*

Earthquake Risk

Geologists know that earthquakes are likely wherever plate movement stores energy in the rock along faults. **Geologists can determine earthquake risk by locating where faults are active, where past earthquakes have occurred, and where the most damage was caused.**

Plate Boundaries and Faults Look at Figure 18. In the United States, the risk is highest along the Pacific coast in California, Washington, and Alaska. Plates meet along the Pacific coast, causing many active faults. In California, the Pacific plate and North American plate meet along the San Andreas fault. In Washington, earthquakes result from the subduction of the Juan de Fuca plate. In Alaska, subduction of the Pacific plate causes many earthquakes.

The eastern United States mostly has a low risk of earthquakes because this region lies far from plate boundaries. But the East has had some of the most powerful quakes in the nation's history. Scientists think that the continental plate forming most of North America is under stress. This stress could disturb faults hidden beneath soil and rock.

Reading Checkpoint **What areas of the United States have the highest earthquake risk?**

Go Online
PLANET DIARY
For: More on earthquake risk
Visit: PHSchool.com
Web Code: cfd-1024

Intensity	Shaking	Damage
I	Not felt	None
II-III	Weak	None
IV	Light	None
V	Moderate	Very light (some windows break)
VI	Strong	Light (some plaster falls)
VII	Very Strong	Moderate (chimneys break)
VIII	Severe	Moderate to heavy (chimneys and walls fall)
IX	Violent	Heavy (building foundations shift; ground cracks)
X+	Extreme	Very heavy (most structures destroyed; rails bend)

FIGURE 19
Loma Prieta Earthquake
The 1989 Loma Prieta earthquake struck along the San Andreas fault. The map shows the intensity of shaking felt in areas affected by the earthquake.

Major Earthquakes	
Earthquake	**Moment Magnitude**
San Francisco, California, 1906	7.8
Messina, Italy, 1908	7.2
Tokyo, Japan, 1923	7.9
Southern Chile, 1960	9.5
Anchorage, Alaska,1964	9.2
Loma Prieta, California, 1989	6.9
Northridge, California, 1994	6.7
Indian Ocean, near Sumatra, Indonesia, 2004	9.0

FIGURE 20
Major Earthquakes
The table shows strong earthquakes of the past 100 years and their magnitudes.
Calculating *About how much more powerful is a magnitude 9.0 earthquake than a magnitude 7.0 earthquake?*

Mapping Earthquake Intensity Geologists can use modified Mercalli scale data to map the intensity of an earthquake. Intensity maps show how the ground shaking and damage from an earthquake vary from place to place. You can see an example of this type of map in Figure 19.

Why are intensity maps important? These maps show that areas near faults generally suffer the most serious earthquake damage. And the same areas might suffer damage again if struck by another strong quake.

Historic Earthquakes Why do geologists study earthquakes that happened many years ago? Past earthquakes can help geologists estimate the risk of future earthquakes. One way that geologists learn about past earthquakes is from historic reports. These reports may describe where the quake was strongest and what damage it caused. Geologists also study the rock and soil along faults for evidence of past earthquakes. Geologists can use these data to estimate the magnitudes of earthquakes that occurred before the seismograph was invented.

Reading Checkpoint **Why do geologists make intensity maps?**

How Earthquakes Cause Damage

When a major earthquake strikes, it can cause great damage. But distance from an earthquake's epicenter is not the only factor involved. **Causes of earthquake damage include shaking, liquefaction, aftershocks, and tsunamis.**

Shaking The shaking produced by seismic waves can trigger landslides or avalanches. These disasters can bury and destroy both human-made buildings and the natural areas wildlife need in order to live. Shaking itself can also damage or destroy buildings and bridges, topple utility poles, and fracture gas and water mains. S waves and surface waves, with their side-to-side and up-and-down movement, can cause severe damage to buildings near the epicenter.

The types of rock and soil determine where and how much the ground shakes. The most violent shaking may occur kilometers away from the epicenter. Loose soil shakes more violently than solid rock. This means a house built on sandy soil will shake more than a house built on solid rock.

Liquefaction In 1964, when a powerful earthquake roared through Anchorage, Alaska, wide cracks opened in the ground. The cracks were created by liquefaction. **Liquefaction** (lik wih FAK shun) occurs when an earthquake's violent shaking suddenly turns loose, soft soil into liquid mud. Liquefaction is likely where the soil is full of moisture. As the ground gives way, buildings sink and pull apart.

Aftershocks Sometimes, buildings weakened by an earthquake collapse during an aftershock. An **aftershock** is an earthquake that occurs after a larger earthquake in the same area. Aftershocks may strike hours, days, or even months later.

Lab zone Try This Activity

Mapping Magnitude

1. Obtain an outline map of the world with latitude and longitude.
2. Use reference sources to find out the locations of the earthquakes in Figure 20 and plot them on the map. Use a different symbol to mark quakes with a magnitude of 9.0 or more.
3. Compare your map with the map of plate boundaries in Figure 22 on p. 159. Notice what type of plate boundary lies near the magnitude 9.0 earthquakes.

Inferring What process takes place at the plate boundaries near the 9.0 magnitude earthquakes? How does this help to explain why these quakes are so powerful?

FIGURE 21
Liquefaction Damage
An earthquake caused the soil beneath this building to liquefy. Liquefaction can change soil to liquid mud.
Posing Questions *What are some questions people might ask before building in a quake-prone area?*

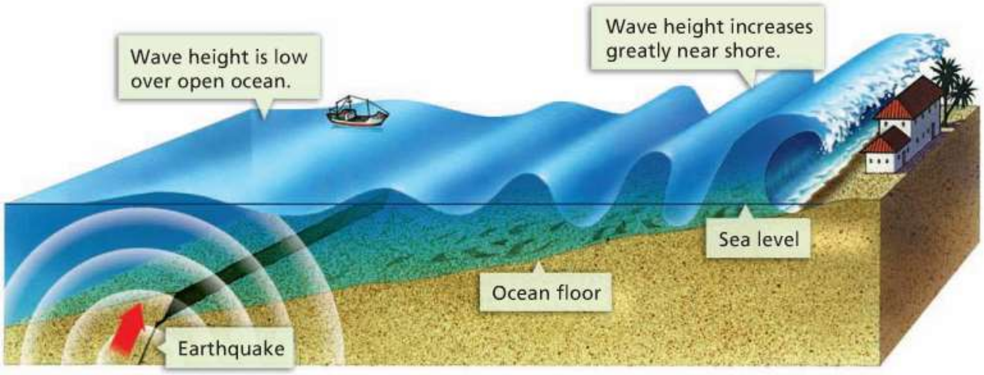


FIGURE 22
How a Tsunami Forms
A tsunami begins as a low wave, but turns into a huge wave as it nears the shore. In 2004, a powerful earthquake in the Indian Ocean triggered several tsunamis. The tsunamis caused great loss of life and destruction to coastal areas around the Indian Ocean.

Tsunamis When an earthquake jolts the ocean floor, plate movement causes the ocean floor to rise slightly and push water out of its way. The water displaced by the earthquake may form a large wave called a **tsunami** (tsoo NAH mee), shown in Figure 22. A tsunami spreads out from an earthquake's epicenter and speeds across the ocean. In the open ocean, the height of the wave is low. As a tsunami approaches shallow water, the wave grows into a mountain of water.

Steps to Earthquake Safety

What should you do if an earthquake strikes? The main danger is from falling objects and flying glass. **The best way to protect yourself is to drop, cover, and hold.**

If you are indoors when a quake strikes, drop down and crouch beneath a sturdy table or desk and hold on to it. If no desk or table is available, crouch against an inner wall, away from the outside of a building, and cover your head and neck with your arms. Avoid windows, mirrors, wall hangings, and furniture that might topple.

If you are outdoors, move to an open area such as a playground. Avoid vehicles, power lines, trees, and buildings. Sit down to avoid being thrown down.

After a quake, water and power supplies may fail, food stores may be closed, and travel may be difficult. People may have to wait days for these services to be restored. To prepare, store an earthquake kit containing canned food, water, and first aid supplies where it is easy to reach.

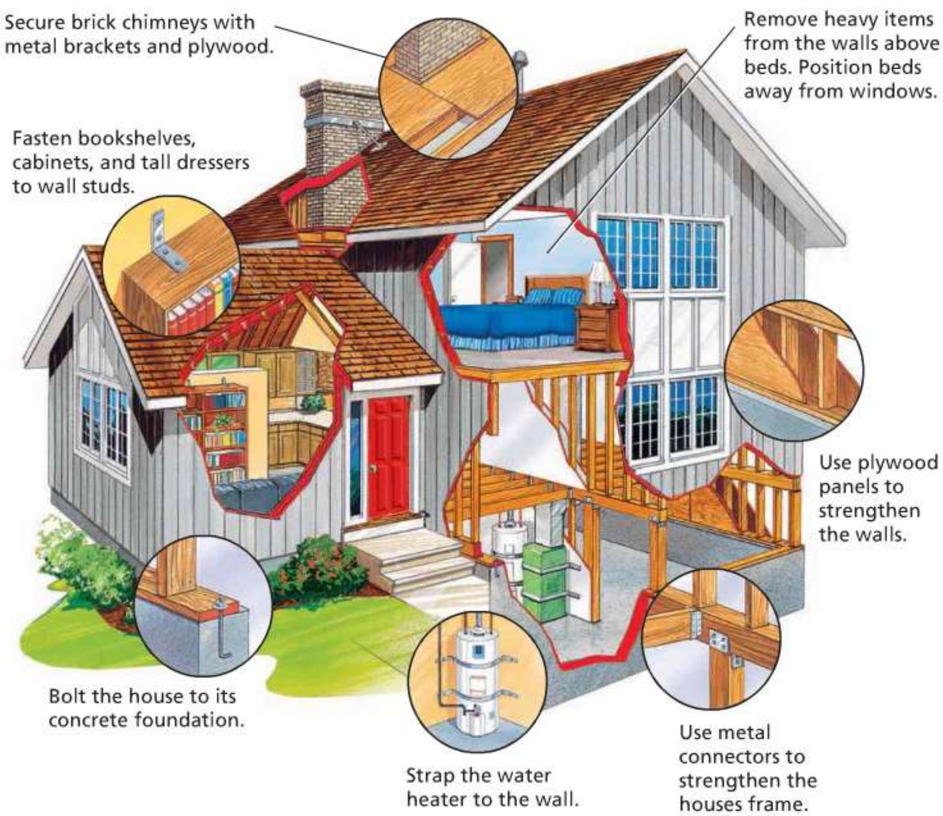
Reading Checkpoint **How can furniture be dangerous during a quake? How can it protect you?**

Designing Safer Buildings

Most earthquake-related deaths and injuries result from damage to buildings or other structures. **To reduce earthquake damage, new buildings must be made stronger and more flexible. Older buildings may be modified so as to withstand stronger quakes.** Figure 23 shows some of the steps that can make houses earthquake-safe.

Generally, the effects of an earthquake depend of the type of construction. Buildings made of brittle materials such as concrete or brick suffer the most damage in an earthquake. Buildings made of more flexible materials, such as wood, tend to suffer less damage. Tall buildings are more subject to damage than single-story buildings.

FIGURE 23
An Earthquake-Safe House
People can take a variety of steps to make their homes safer in an earthquake.
Predicting *During a quake, what might happen to a house that was not bolted to its foundation?*



Lab zone Try This Activity

Stable or Unstable?

1. Make a model of a fault by placing two small, folded towels side by side on a flat surface.
2. Pile a stack of books on the fault by placing light books on the bottom and heavy ones on top.
3. Gently pull the towels in opposite directions until the pile topples.
4. Repeat the process, but this time with the heavier books on the bottom.

Relating Cause and Effect Which one of your structures was more stable? Why?

Protecting Structures The way in which a building is constructed determines whether it can withstand an earthquake. During an earthquake, brick buildings and some wood-frame buildings may collapse if their walls have not been reinforced, or strengthened. To combat damage caused by liquefaction, new homes built on soft ground should be anchored to solid rock below the soil. Bridges and highway overpasses can be built on supports that go through soft soil to firmer ground. To find out more about how buildings can withstand earthquakes, look at *Seismic-Safe Buildings* on the following pages.

A **base-isolated building** is designed to reduce the amount of energy that reaches the building during an earthquake. A base-isolated building rests on shock-absorbing rubber pads or springs. Like the suspension of a car, the pads and springs smooth out a bumpy ride. During a quake, the building moves gently back and forth without any violent shaking.

Making Utilities Safer Earthquakes can cause fire and flooding when gas pipes and water mains break. Flexible joints can be installed in gas and water lines to keep them from breaking. Automatic shut-off valves also can be installed on these lines to cut off gas and water flow.

Reading Checkpoint How can utilities be protected from earthquake damage?

Section 4 Assessment

S 6.1.g, 6.2.d; E-LA: Reading 6.1.0

Vocabulary Skill **High-Use Academic Words** What are two things you would do to construct a building so that it could withstand an earthquake? Use the word *construct* in your answer.

Reviewing Key Concepts

HINT 1. a. **Identifying** What factors help geologists determine earthquake risk for a region?

HINT b. **Comparing and Contrasting** Why does the risk of quakes vary across the United States?

HINT 2. a. **Listing** What are four ways that earthquakes cause damage?

HINT b. **Relating Cause and Effect** How does liquefaction cause damage during an earthquake?

HINT c. **Developing Hypotheses** How might heavy rain before an earthquake affect the danger of liquefaction?

3. a. **Reviewing** How can you protect yourself during an earthquake? HINT

b. **Describing** What will happen to a base-isolated building when seismic waves strike the building during an earthquake? HINT

Lab zone At-Home Activity

Quake Safety Plan Work with an adult family member to develop an earthquake safety plan. The plan should tell family members what to do during an earthquake. It should list items your family would need if a quake cut electrical power and water lines. It should also explain where to shut off the gas if your home has a natural gas line. Share your earthquake safety plan with the rest of your family.

Lab zone **Skills Lab**
Guided Inquiry

S 6.1.g, 6.7.f

Earthshaking Events

Problem

How can you use a map of faults and historic earthquakes to analyze earthquake risk in California?

Skills Focus

interpreting maps, inferring

Procedure

1. Using a piece of tracing paper and a pencil, trace the outline of California in Figure 18 on page 237. Trace and label the latitude and longitude lines and the map scale. Mark the location of your community on your map.
2. In a second color, trace the state's active faults. Label the faults.
3. Use the map scale to measure the distance from your community to the nearest fault. Record the distance.
4. In a third color, plot the epicenters of the earthquakes in the table. Also draw lines to shade approximately the parts of the San Andreas fault that moved during the Fort Tejon and San Francisco earthquakes.
5. Measure the distance from your community to the nearest epicenter of a historic earthquake. Record the distance.

Analyze and Conclude

1. **Interpreting Maps** What major fault is closest to your community?
2. **Interpreting Maps** What historic earthquake was closest to your community? What was the earthquake's magnitude?
3. **Inferring** Based on your distance from an active fault and historic earthquake, how would you rate the earthquake risk in your area?
4. **Communicating** Write a paragraph explaining the earthquake risk in your community. In your answer, include factors such as the role of plate tectonics, active faults, and historic earthquakes.

More to Explore

You can further analyze earthquake risk in your community. Conduct research on nearby active faults and past earthquake activity, ground motion, and faulting. Write a report based on your research findings.

Earthquake	Epicenter	Magnitude
Fort Tejon, 1857	southern San Andreas fault	7.9
Owens Valley, 1872	118° W, 37° N	7.9
San Francisco, 1906	northern San Andreas fault	7.8
Calaveras fault, 1911	122° W, 37° N	6.5
Long Beach, 1933	118° W, 33° N	6.4
Imperial Valley, 1940	116° W, 33° N	7.1
Concord, 1954	122° W, 38° N	5.4
San Fernando, 1971	118° W, 34° N	6.7
Gorda Plate, 1980	125° W, 41° N	7.2
Loma Prieta, 1989	122° W, 37° N	6.9
Northridge, 1994	119° W, 34° N	6.7
Parkfield, 2004	120° W, 36° N	6.0

Technology and Society

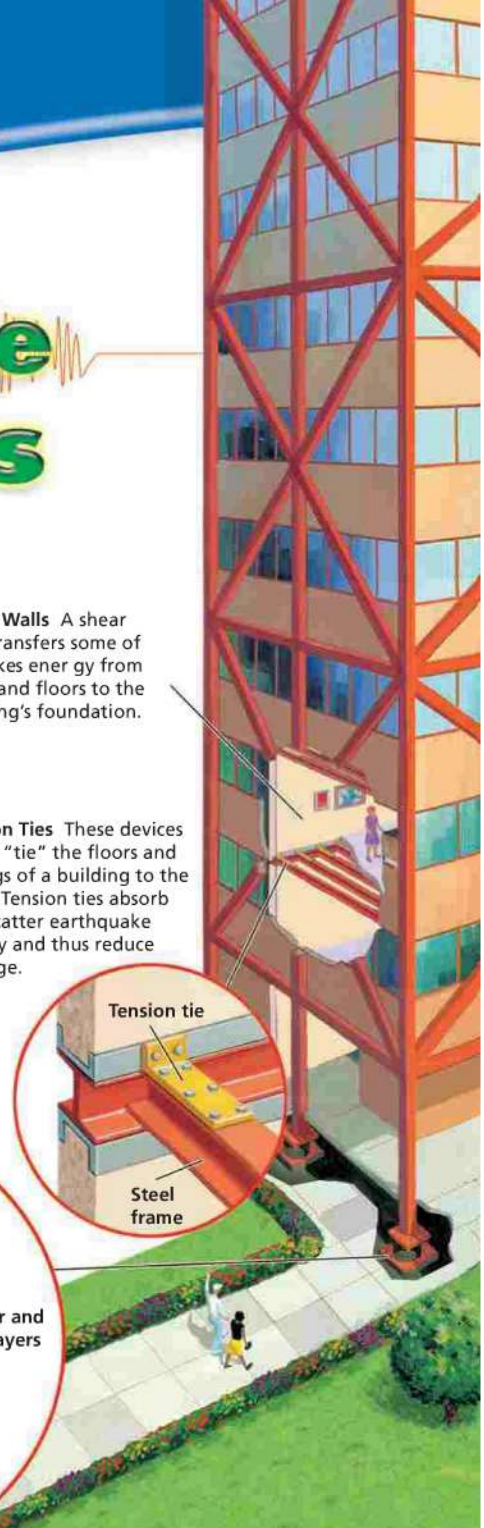
S 6.1.g

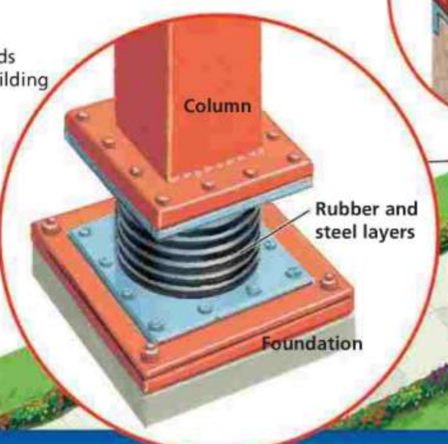
Seismic-Safe Buildings

Breaking one thin twig doesn't require much force. Breaking a bundle of twigs does. Like one thin twig, the walls, beams, and other supporting parts of a building can snap as seismic energy travels through the structure. Reinforcing a building's parts makes them more like the bundle of twigs—stronger and less likely to snap when a quake occurs.

What Are Seismic-Safe Buildings?

Seismic-safe buildings have types of construction that reduce earthquake damage. Some of these features strengthen a building. Others allow the building to move, or shield the building from the energy of seismic waves. In earthquake-prone areas, most tall steel-frame buildings may have one or more of the seismic-safe features shown here.





Seismic-Safe, But at What Cost?

Seismic-safe buildings save lives and reduce damage. Despite these benefits, the technologies have drawbacks. Seismic-safe features, such as cross braces, may reduce the amount of usable space in a building. It is also expensive to add seismic-safe features to an existing building. Communities must make trade-offs between the benefits and the costs of seismic-safe buildings.

Cross Braces Steel cross braces are placed between stories to stiffen a buildings frame an d absorb energy during an earthquake.

Dampers Dampers work like the shock absorbers in a car to absorb some of the energy of seismic waves.

Even steel-frame buildings need seismic-safe design features.

Flexible Pipes Water and gas pipes have flexible joints. Flexible pipes bend as energy passes through them, greatly reducing damage.

Weigh the Impact

1. **Identify the Need** Your city has hired you to decide which buildings or other structures most need to be able to withstand an earthquake. List three types of structures that you think need to be seismic-safe.
2. **Research** Research how the structures on your list can be made safe. Choose one structure from your list and make notes on how it can be made safe.
3. **Write** Using your notes, write a report that explains how your structure can be designed or modified to withstand earthquakes.

Go Online PHSchool.com

For: More on seismic-safe buildings
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Chapter 5

Study Guide

The BIG Idea **Plate motions produce stress in Earth's crust that leads to faults, mountain building, and earthquakes.**

1 Forces in Earth's Crust

Key Concepts S 6.1.e, 6.1.f

- Tension, compression, and shearing work over millions of years to change the shape and volume of rock.
- Faults usually occur along plate boundaries, where the forces of plate motion push or pull the crust so much that the crust breaks. There are three main types of faults: normal faults, reverse faults, and strike-slip faults.
- Over millions of years, the forces of plate movement can change a flat plain into landforms such as anticlines and synclines, folded mountains, fault-block mountains, and plateaus.

Key Terms

stress
tension
compression
shearing
normal fault
hanging wall
footwall
reverse fault
strike-slip fault
plateau

2 Earthquakes and Seismic Waves

Key Concepts S 6.1.d, 6.1.g

- Seismic waves carry energy from an earthquake away from the focus, through Earth's interior, and across the surface.
- Three commonly used ways of measuring earthquakes are the Mercalli scale, the Richter scale, and the moment magnitude scale.
- Geologists use seismic waves to locate an earthquake's epicenter.

Key Terms

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

3 Monitoring Earthquakes

Key Concepts S 6.1.g

- During an earthquake, seismic waves cause the seismograph's drum to vibrate. But the suspended weight with the pen attached moves very little. Therefore, the pen stays in place and records the drum's vibrations.
- To monitor faults, geologists have developed instruments to measure changes in elevation, tilting of the land surface, and ground movements along faults.
- Seismographs and fault-monitoring devices provide data used to map faults and detect changes along faults.

Key Terms

seismogram
friction

4 Earthquake Safety

Key Concepts S 6.1.g, 6.2.d

- Geologists can determine earthquake risk by locating where faults are active, where past earthquakes have occurred, and where past earthquakes have caused the most damage.
- Causes of earthquake damage include shaking, liquefaction, aftershocks, and tsunamis.
- The best way to protect yourself is to drop, cover, and hold.
- To reduce earthquake damage, new buildings must be made stronger and more flexible. Older buildings may be modified to withstand stronger quakes.

Key Terms

liquefaction
aftershock
tsunami
base-isolated building

Review and Assessment

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Target Reading Skill

Identifying Main Ideas Reread the text under the heading Kinds of Faults in Section 1. Complete the graphic organizer.

Kinds of Faults

Detail	Detail	Detail
Normal faults—hanging wall slips down relative to footwall		

Reviewing Key Terms

Choose the letter of the best answer.

HINT **1.** The force that causes part of the crust to become shorter and thicker is
a. tension.
b. compression.
c. shearing.
d. normal force.

HINT **2.** When the hanging wall of a fault slips down with respect to the footwall, the result is a
a. reverse fault.
b. syncline.
c. normal fault.
d. strike-slip fault.

HINT **3.** Which of the following is a rating of earthquake damage at a particular location?
a. moment magnitude scale
b. focus scale
c. Mercalli scale
d. Richter scale

HINT **4.** The largest waves on a seismogram are
a. P waves.
b. S waves.
c. surface waves.
d. tsunamis.

HINT **5.** In the hours after an earthquake, people should not go inside a building, even if it appears undamaged, because of
a. aftershocks. **b.** liquefaction.
c. tsunamis. **d.** deformation.

Complete the following sentences so that your answers clearly explain the key terms.

6. **Compression** is a force that changes Earth's crust by __________ . HINT

7. Tension in Earth's crust can produce a **normal fault,** which is __________ . HINT

8. Beneath an earthquake's epicenter lies the quake's **focus,** which is __________ . HINT

9. After an earthquake, the first seismic waves to arrive are **P waves,** which are __________ . HINT

10. An earthquake beneath the ocean floor can trigger a **tsunami,** which is __________ . HINT

Writing in Science

Cause-and-Effect Paragraph Now that you have learned about the awesome power of earthquakes, write a paragraph about how earthquakes cause damage. Discuss both the natural and human-made factors that contribute to an earthquake's destructive power.

Video Assessment
Discovery Channel School
Earthquakes

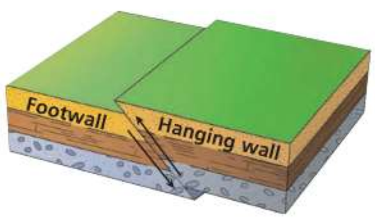
Review and Assessment

Checking Concepts

11. What process causes stress in Earth's crust?
12. Explain how a fault-block mountain forms.
13. What type of stress in the crust results in the formation of folded mountains? Explain.
14. What are plateaus, and how do they form?
15. Describe what happens along a fault beneath Earth's surface when an earthquake occurs.
16. How is the amount of energy released by an earthquake related to its magnitude?
17. What does the height of the jagged lines on a seismogram indicate?
18. How can homes and other structures be protected from liquefaction?

Thinking Critically

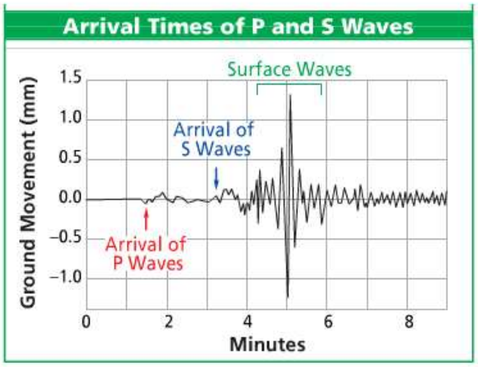
19. **Classifying** Look at the diagram of a fault below. Describe how the hanging wall moves in relation to the footwall. What kind of fault is this?



20. **Analyzing Data** A geologist has data about an earthquake from two seismographic stations. Is this enough information to determine the location of the epicenter? Why or why not?
21. **Predicting** A community has just built a street across a strike-slip fault that has frequent earthquakes. How will movement along the fault affect the street?
22. **Making Generalizations** How can filled land and loose, soft soil affect the amount of damage caused by an earthquake? Explain.

Applying Skills

Use the graph to answer Questions 23–26.



23. **Interpreting Diagrams** In what order did the seismic waves arrive at the seismograph station?
24. **Interpreting Diagrams** Which type of seismic wave produced the largest ground movement?
25. **Analyzing Data** What was the difference in arrival times for the P waves and S waves?
26. **Predicting** What would the seismogram look like several hours after this earthquake? How would it change if an aftershock occurred?

Lab zone Standards Investigation

Performance Assessment Before testing how your model withstands an earthquake, explain to your classmates how and why you changed your model. When your model is tested, observe how it withstands the earthquake. How would a real earthquake compare with the method used to test your model? If it were a real building, could your structure withstand an earthquake? How could you improve your model?

CALIFORNIA Standards Practice

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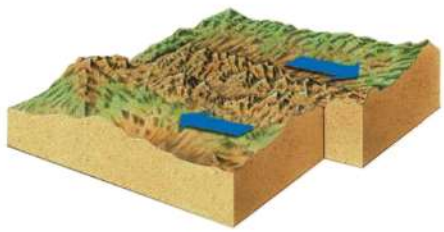
Choose the letter of the best answer.

1. The diagram below shows how stress affects a mass of rock in a process called
A compression
B tension.
C squeezing.
D shearing **S 6.1.d**

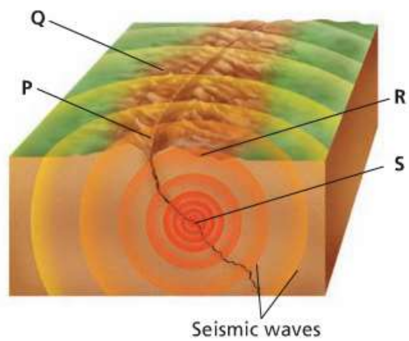
2. The diagram below shows a strike-slip fault like the San Andreas fault in California. Movement along the fault occurs because of
A tension in the crust.
B uplift of the crust.
C plate motions.
D volcanic activity. **S 6.1.f**



3. Stress will build until an earthquake occurs if friction along a fault is
A decreasing.
B high.
C low.
D changed to heat. **S 6.1.e**

4. To estimate the total energy released by an earthquake, a geologist should use the
A Mercalli scale.
B Richter scale.
C epicenter scale.
D moment magnitude scale. **S 6.1.g**

Use the information below and your knowledge of science to answer Questions 5 and 6.



5. In the diagram, the epicenter is located at point
A Q.
B P.
C R.
D S. **S 6.1.g**

6. When an earthquake occurs, seismic waves travel
A from P in all directions.
B from R to S.
C from S in all directions.
D from Q to P. **S 6.1.g**

7. Which answer best explains how earthquakes can change an area where wild animals live?
A A landslide covers a forest.
B A tsunami washes away a sand dune.
C Soil turns to liquid mud.
D All of the above **S 6.2.d**

Apply the BIG Idea

8. Plate motions can cause tension in Earth's crust. Explain how tension could lead to the formation of a fault, a type of mountain, and an earthquake. **S 6.1.d**