Name ______________________ Class ______________ Date ______________

CHAPTER 12 Earthquakes

SECTION 1

How and Where Earthquakes Happen

KEY IDEAS

As you read this section, keep these questions in mind:

- What is elastic rebound?
- What are the similarities and differences between body waves and surface waves?
- How does the structure of Earth's interior affect seismic waves?
- Why do most earthquakes happen at plate boundaries?

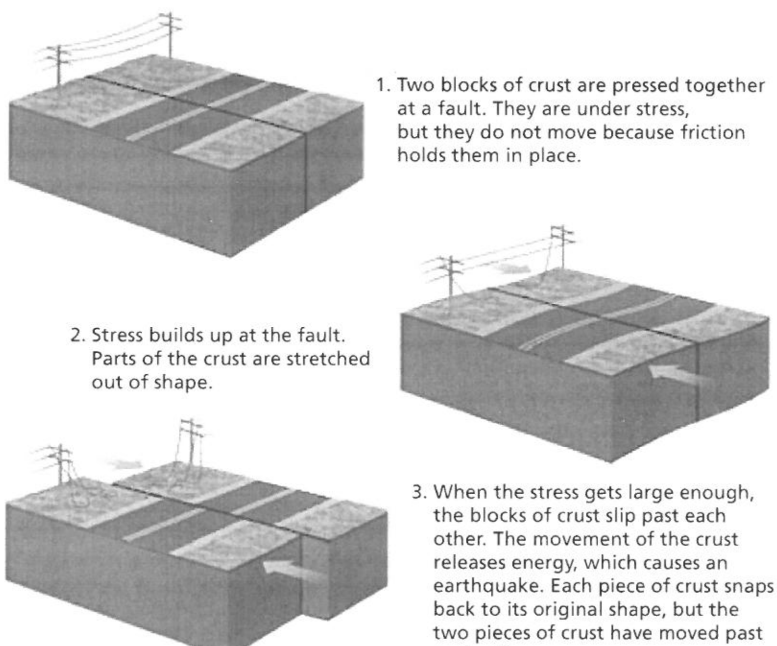
What Makes Earthquakes Happen?

Remember that a *fault* is a crack in rock. If there is pressure on the rock around a fault, the rock is under stress. Friction along the fault keeps the rock from moving. The stress can build up. Eventually, the stress becomes too high. The rock moves suddenly along the fault. It releases a great deal of energy. The energy makes the ground shake. The shaking is an **earthquake**.

Elastic rebound is important in causing earthquakes. **Elastic rebound** happens when a rock that is deformed goes back to its original shape. The diagram below shows an example of elastic rebound.

READING TOOLBOX

Organize As you read this section, create a concept map using the following terms: *P wave, surface wave, seismic wave, S wave, Love wave, body wave, Rayleigh wave, earthquake, focus, epicenter, fault,* and *movement.*



1. Two blocks of crust are pressed together at a fault. They are under stress, but they do not move because friction holds them in place.

2. Stress builds up at the fault. Parts of the crust are stretched out of shape.

3. When the stress gets large enough, the blocks of crust slip past each other. The movement of the crust releases energy, which causes an earthquake. Each piece of crust snaps back to its original shape, but the two pieces of crust have moved past each other.

LOOKING CLOSER

1. Compare How does the road in the middle figure look different from the road in the top figure? Why is it different?

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READING CHECK

2. Describe What is the difference between the epicenter and the focus?

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Talk About It

Visualize Use an atlas or map to find two places on Earth that are about 70 km apart and two places that are about 300 km apart. Talk with a partner about how this information can help you understand shallow-focus, intermediate-focus, and deep-focus earthquakes.

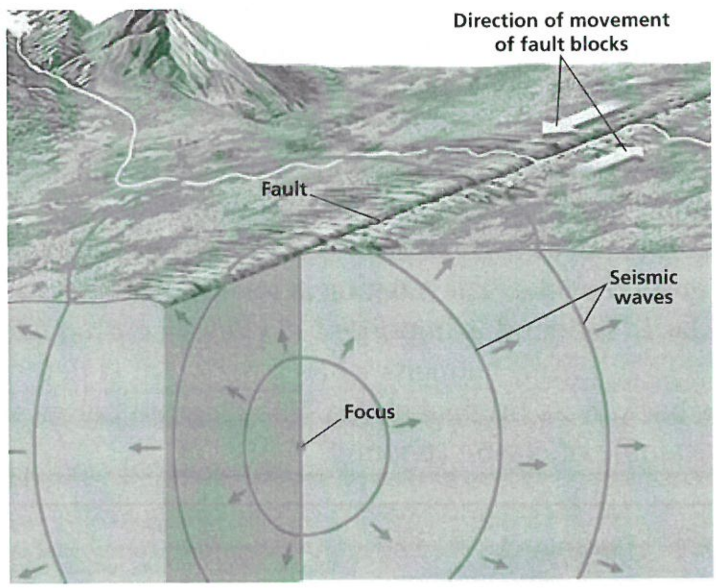
LOOKING CLOSER

3. Identify Label the epicenter on the figure.

FOCUS AND EPICENTER

When rock moves along a fault, the first motion on the fault is generally underground. The **focus** (plural, *foci*) of an earthquake is the point where the first motion occurs. The energy an earthquake releases moves outward in all directions from the focus. The **epicenter** of an earthquake is the point on Earth's surface directly above the focus. ☑

Scientists group earthquakes based on how deep their foci are. A *shallow-focus earthquake* has a focus less than 70 km below Earth's surface. An *intermediate-focus earthquake* has a focus between 70 km and 300 km below Earth's surface. A *deep-focus* earthquake has a focus more than 300 km below Earth's surface.



The vibrations of an earthquake start at the focus and spread out.

What Are Seismic Waves?

Look again at the figure above. You can see that there are seismic waves moving outward from the focus. *Seismic waves* are vibrations caused by the energy released in an earthquake. When a pebble falls into a pond, small waves ripple outward from the point the pebble hits. Similarly, seismic waves ripple outward from the focus of an earthquake. The seismic waves travel in all directions from the focus through the rock around it.

There are two main types of seismic waves: body waves and surface waves. **Body waves** travel through rock. **Surface waves** travel along the surface of Earth.

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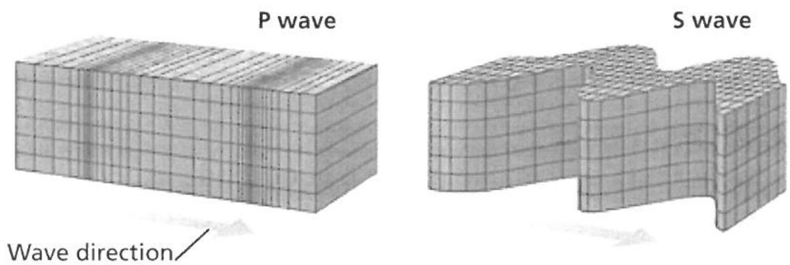
TYPES OF BODY WAVES

There are two types of body waves: P waves and S waves. **P waves** cause rocks to move back and forth, parallel to the direction that the wave is moving. **S waves** cause rocks to move side to side, perpendicular to the direction that the wave is moving. The picture and table below give more information about P waves and S waves.



LOOKING CLOSER

4. Describe Draw arrows on the pictures to show the direction the ground moves when each type of wave passes.

Type of Wave	Other Names	Other Facts
P wave	• primary wave • compression wave	• fastest seismic waves • can move through solids, liquids, and gases
S wave	• secondary wave • shear wave	• slower than P waves • can move only through solids

SURFACE WAVES

Surface waves move along Earth's surface. Surface waves move more slowly than body waves, but surface waves can cause more damage. Most surface waves form in one of two ways:

- movement along a fault that is close to the surface
- change in the way rock moves when a body wave reaches Earth's surface

There are two main types of surface waves: Love waves and Rayleigh waves. The diagram below shows how Love waves and Rayleigh waves move the ground.

Critical Thinking

5. Compare How are a Love wave and an S wave the same? How are they different?

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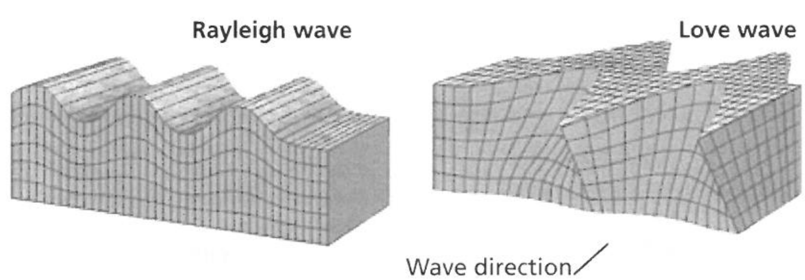

A Rayleigh wave moves the ground in a rolling, up-and-down motion.

A Love wave moves rock back and forth. It also causes rock to twist.

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What Can Seismic Waves Tell Us About Earth's Structure?

Scientists study seismic waves to learn more about Earth's structure. Seismic waves move at different speeds in different substances. In addition, the direction in which a seismic wave travels changes when it moves from one substance to another. By studying how seismic waves change as they move through Earth, scientists can learn about the makeup of Earth's interior. ☑

READING CHECK

6. Explain Why can scientists use seismic waves to learn about Earth's interior?

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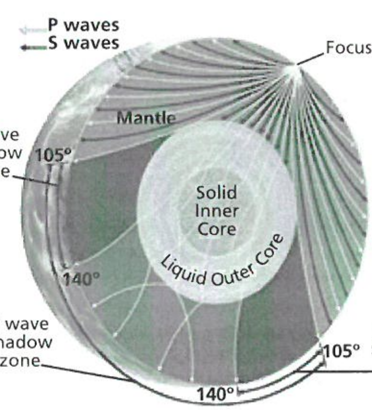
EARTH'S LAYERS

In 1909, a Croatian scientist named Andrija Mohorovičić discovered that seismic waves change speed about 30 km below the continents. The change in speed happens suddenly. The place where this change happens is where the crust and mantle meet. Today, scientists call this boundary the *Mohorovičić discontinuity*, or just the *Moho*. Below the continents, the Moho is about 30 km deep. Below the oceans, it is about 10 km deep.

Scientists have been able to use seismic waves to learn about other layers inside Earth. They now know that Earth has three main compositional zones: the crust, mantle, and core. Earth has five main structural zones: the lithosphere, asthenosphere, mesosphere, outer core, and inner core.

SHADOW ZONES

Remember that seismic waves change speed and direction as they move through Earth. Those changes can bend the waves in specific ways. The bending of the waves produces shadow zones. **Shadow zones** are areas on Earth's surface where waves from an earthquake cannot be detected.



The shadow zones for different earthquakes are different.

Critical Thinking

7. Make Connections Why do the S waves in the diagram stop when they reach the liquid outer core?

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Where Do Earthquakes Happen?

Most earthquakes happen near the boundaries between plates. The movements of the plates put stress on the rock in the plates. The stress can cause the rock to slip and cause earthquakes.

Some earthquakes happen in the oceans. Others happen on land. The table below summarizes the environments where earthquakes can happen.

Type of Environment	Description	Example
Convergent oceanic	places where an oceanic plate collides with another oceanic plate or with a continental plate	Andes Mountains, Aleutian Islands
Divergent oceanic	places where two oceanic plates move apart	Mid-Atlantic Ridge
Continental	places where two continental plates collide, move apart, or slide past each other	San Andreas Fault, Himalaya Mountains

Talk About It

Review With a partner, talk about the different types of plate boundaries that you have learned about. Discuss how the information you know about plate boundaries relates to the information in this section.

FAULT ZONES

Most faults exist in groups. An area that contains a lot of faults that are close together is called a **fault zone**. Fault zones can exist at any kind of plate boundary. One example of a fault zone is the North Anatolian fault zone in Turkey. Movement of the crust along the faults in this fault zone produces many earthquakes in Turkey. ☑

READING CHECK

8. Define What is a fault zone?

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EARTHQUAKES AWAY FROM PLATE BOUNDARIES

Most earthquakes happen at plate boundaries. However, earthquakes can also happen far from plate boundaries. For example, in 1811 and 1812, several large earthquakes happened near New Madrid, Missouri. New Madrid is far from any plate boundaries.

Scientists are not sure why these earthquakes happened. However, they have discovered a very old fault zone underneath New Madrid. The fault zone is more than 600 million years old. It is buried under many layers of rock and sediment. Scientists think the New Madrid earthquakes may have happened when rock around the fault zone moved. However, they are not sure what made the rock move, or whether it might move again in the future.

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Section 1 Review

SECTION VOCABULARY

body wave a seismic wave that travels through the body of a medium

earthquake a movement or trembling of the ground that is caused by a sudden release of energy when rocks along a fault move

elastic rebound the sudden return of elastically deformed rock to its undeformed shape

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

fault zone a region of numerous, closely spaced faults

focus the location within Earth along a fault at which the first motion of an earthquake occurs

P wave a primary wave, or compression wave; a seismic wave that causes particles of rock to move in a back-and-forth direction parallel to the direction in which the wave is traveling

shadow zone an area on Earth's surface where no direct seismic waves from a particular earthquake can be detected

surface wave a seismic wave that travels along the surface of a medium and that has a stronger effect near the surface of the medium than it has in the interior

S wave a secondary wave, or shear wave; a seismic wave that causes particles of rock to move in a side-to-side direction perpendicular to the direction in which the wave is traveling

1. **Describe Relationships** How is elastic rebound related to earthquakes?

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2. **Explain** Why do most earthquakes happen at plate boundaries?

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3. **Compare** Describe three differences between P waves and S waves.

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4. **Describe** What are shadow zones, and why do they exist?

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CHAPTER 12 | Earthquakes

SECTION 2

Studying Earthquakes

KEY IDEAS

As you read this section, keep these questions in mind:

- What tool do scientists use to measure and record earthquakes?
- How do scientists find the epicenter of an earthquake?
- What scales do scientists use to describe the magnitude and intensity of an earthquake?

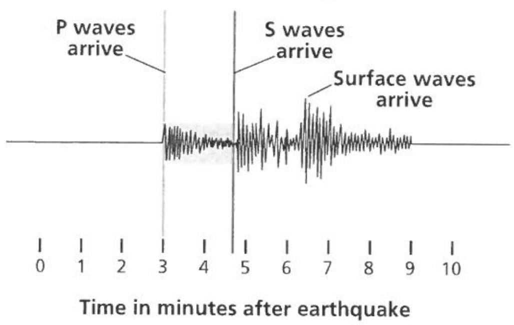
How Do Scientists Record Earthquakes?

Seismology is the study of earthquakes and seismic waves. Scientists who study seismology are called *seismologists*. Seismologists use many different tools to study earthquakes. One of the most important of these tools is a seismograph.

A **seismograph** is a machine that senses vibrations caused by seismic waves. Modern seismographs can detect vibrations in three directions. They can detect north-south vibrations, east-west vibrations, and up-down vibrations.

Seismographs record seismic wave vibrations on a chart called a **seismogram**. Most modern seismograms are produced by computers. The seismograph detects motion and changes it into electrical signals. The computer interprets the electrical signals and creates the seismogram.

Because P waves move more quickly than other seismic waves, a seismograph records P waves first. S waves travel more slowly than P waves, so the seismograph records S waves second. Surface waves are the slowest-moving waves. A seismograph records them last.



This seismogram shows when the three types of waves hit after an earthquake.

READING TOOLBOX

Outline As you read this section, write an outline of the information in the section. Use the heads and subheads as a guide. Make sure to include all of the vocabulary words.

Talk About It

Use Word Parts Use a dictionary to look up the meaning of the word parts *seism-*, *-ology*, *-graph*, and *-gram*. With a partner or small group, talk about how you can use these meanings to help you remember what *seismology*, *seismograph*, and *seismogram* mean.

LOOKING CLOSER

1. Estimate About how many minutes apart were the P waves and S waves of this earthquake?

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How Do Scientists Measure Earthquakes?

When scientists study an earthquake, they measure its magnitude and intensity. An earthquake's **magnitude** is its strength. An earthquake's **intensity** is the amount of damage that it causes.

Critical Thinking

2. Infer How do you think magnitude and intensity are related?

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MAGNITUDE

Scientists find out an earthquake's magnitude by measuring how much the ground moved. They use magnitude scales to describe the magnitude. The two main magnitude scales are the *Richter scale* and the *moment magnitude scale.* These scales are not objects, like a scale you use to weigh yourself. Instead, they are ways of classifying the strength of an earthquake.

For most of the 1900s, scientists used the Richter scale to describe magnitude. However, the moment magnitude scale is more accurate for large earthquakes. Therefore, today, most scientists use the moment magnitude scale. ☑

READING CHECK

3. Identify What scale do most scientists today use to describe the magnitude of an earthquake?

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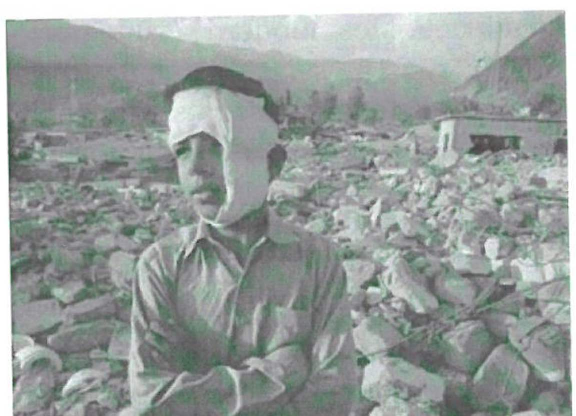
The moment magnitude of an earthquake is expressed as a number. The larger an earthquake's moment magnitude is, the stronger the earthquake is. For example, the largest earthquake that has ever been recorded had a moment magnitude of 9.5.



This boy is standing in front of piles of rubble after an earthquake in northern Pakistan in 2005. The earthquake had a moment magnitude of 7.6. It killed more than 86,000 people, and it left more than 3 million people homeless.

LOOKING CLOSER

4. Apply Concepts Was the earthquake in northern Pakistan in 2005 stronger or weaker than an earthquake with a magnitude of 7.4?

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INTENSITY

Scientists use the effects of an earthquake to determine the earthquake's intensity. Unlike an earthquake's magnitude, its intensity may be different in different places. Scientists use the *modified Mercalli intensity scale* to describe the intensity of an earthquake. The table on the next page shows the modified Mercalli scale.

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Modified Mercalli Intensity Scale

Intensity	Description
I	felt by almost no one
II	felt by a few people who are not moving
III	felt by most people who are inside; feels like a large truck driving by
IV	felt by many people; dishes and windows rattle; feels like something has hit the building
V	felt by nearly everyone; some objects break; some objects fall over
VI	felt by everyone; some heavy objects move; slight damage to some structures
VII	slight to moderate damage to some buildings
VIII	serious damage to ordinary buildings; buildings may partially collapse
IX	serious damage to earthquake-resistant buildings
X	many structures destroyed; railroad tracks bend
XI	almost all structures destroyed; bridges destroyed
XII	total destruction; objects thrown into the air

Several factors affect the intensity of an earthquake in an area, including

- soil type
- distance to the epicenter
- length and magnitude of the earthquake
- types of buildings and other structures in the area

Because areas have different characteristics, they may experience different earthquake intensities.

How Do Scientists Find the Epicenter of an Earthquake?

Scientists use seismograms to identify the epicenter of an earthquake. Remember that P waves travel more quickly than S waves do. As the waves travel farther from the epicenter, the time between them increases. At a seismograph that is close to the epicenter, the P waves and S waves will be close together. At a seismograph that is far from the epicenter, the P waves and S waves will be farther apart.

Seismologists use computers to study the seismograms from different places. The computers use complex calculations to figure out how far each place is from the epicenter. The computers use this information to figure out where the epicenter is.

LOOKING CLOSER

5. Describe An earthquake happens in an area. Almost everyone in the area feels the earth shake, but no buildings are damaged. What is the intensity of the earthquake in that area?

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Talk About It

Reason Talk with a partner or small group about how different factors might affect the intensity of an earthquake. Support your ideas with evidence. If you wish, use the Internet or library to learn more about the factors that affect the intensity of an earthquake. Present your findings to your partner or small group.

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Section 2 Review

SECTION VOCABULARY

intensity in Earth science, the amount of damage caused by an earthquake **magnitude** a measure of the strength of an earthquake	**seismogram** a tracing of earthquake motion that is recorded by a seismograph **seismograph** an instrument that records vibrations in the ground

1. **Describe Relationships** How are a seismograph and a seismogram related?

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2. **Explain** Two different cities experienced the same earthquake. In one city, scientists said that the earthquake had a level V intensity. In the other city, scientists said that the earthquake had a level VII intensity. Explain how this could be true.

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3. **Describe** How do scientists find the location of an earthquake's epicenter?

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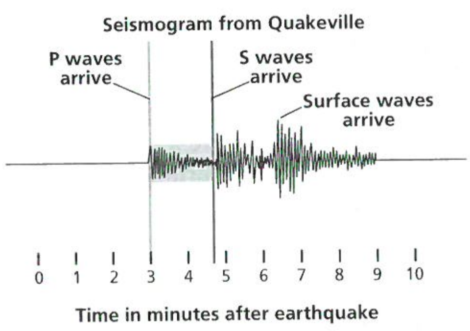
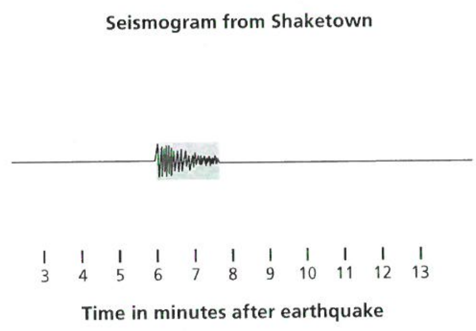
4. **Apply Concepts** An earthquake affected the towns of Quakeville and Shaketown. Quakeville was closer to the epicenter than Shaketown was. The seismogram on the left is from Quakeville. The picture on the right shows part of the seismogram from Shaketown. Complete the seismogram from Shaketown.





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CHAPTER 12 Earthquakes

SECTION 3

Earthquakes and Society

KEY IDEAS

As you read this section, keep these questions in mind:

- How are tsunamis and earthquakes related?
- How can a large earthquake affect buildings?
- How can you stay safe during an earthquake?
- How do scientists predict earthquake risks?

What Effects Can an Earthquake Have?

Very few people are harmed directly by the ground's movement during an earthquake. Most injuries happen for one of the following reasons:

- Buildings collapse.
- Objects and broken glass fly through the air.
- Electric wire and gas lines break.
- Dams collapse and cause a flood.

Many earthquakes cause the ground to rise or fall suddenly. If the epicenter is under the ocean, the ocean water in that area can also rise or fall suddenly. The movement causes a series of waves that get higher and higher as they reach land. Together, these waves form a **tsunami**. Tsunamis can be extremely harmful. They can destroy buildings, roads, and other structures. ☑

READING TOOLBOX

Take Notes As you read this section, make two-column notes to summarize the main ideas. Use the headings to help you think of topics for the first column of the table.

READING CHECK

1. Connect How are tsunamis related to earthquakes?

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DESTRUCTION OF BUILDINGS

Buildings can be damaged by earthquakes. Buildings with weak walls can collapse. Very tall buildings may sway and tip over. Buildings that are built on loose soil can also sway and fall.

How Can You Stay Safe During an Earthquake?

Earthquakes can happen anywhere in the world. However, they are more common in certain places. People who live in those places should have plans for what to do in case an earthquake happens. The table on the next page describes things you can do to stay safe before, during, and after an earthquake.

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Before an Earthquake	Make an earthquake kit.	Include • bottled water • batteries • a radio • flashlights • canned food
	Make a plan.	• Find safe places in each room. • Decide on a meeting place.
	Make your home safe.	• Put heavy things near the floor. • Learn how to turn off the gas, water, and electricity.
During an Earthquake	Stay safe indoors.	• Stand in a doorway. • Crouch under a desk or table. • Stay away from windows and heavy furniture.
	Stay safe in a car.	• Move away from tall buildings, tunnels, power lines, or bridges. • Stop the car and stay in it.
After an Earthquake	Be careful.	• Check for fires. • Wear shoes near broken glass. • Avoid power lines that have fallen. • Be prepared for *aftershocks*, or weaker earthquakes that come after a strong earthquake.

LOOKING CLOSER

2. Apply Concepts If you are in your classroom during an earthquake, what should you do?

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How Can Scientists Predict Earthquakes?

People have tried to predict earthquakes for many years. If scientists could predict when an earthquake would happen, they could save more lives. Scientists today use several different methods to try to predict earthquakes. However, none of these methods is very accurate.

Critical Thinking

3. Infer How could scientists prevent harm if they were able to predict earthquakes?

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SEISMIC GAPS

Active faults have many earthquakes each year. A part of an active fault that hasn't had a strong earthquake in a long time is called a **seismic gap**. Some scientists think that if an active fault hasn't had a strong earthquake in a long time, it will have one soon. In other words, they think that strong earthquakes are more likely to happen in seismic gaps.

Scientists study the earthquakes that happen on active faults. They use this information to identify seismic gaps and to make predictions about where earthquakes might happen. ☑

READING CHECK

4. Define What is a seismic gap?

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FORESHOCKS

Foreshocks are small earthquakes that happen before a much larger earthquake. Some foreshocks come a few seconds before the earthquake. Others can come a few weeks before the earthquake. ☑

In 1975, scientists in China recorded foreshocks near the city of Haicheng. Everyone left the city. The next day, there was a major earthquake. The earthquake destroyed parts of the city, but most people stayed safe because of the warning of the foreshock. However, this was the only recorded time that foreshocks helped predict an earthquake.

READING CHECK

5. Define What is a foreshock?

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CHANGES IN ROCKS

Before an earthquake, the rocks around the fault zone are under a lot of stress. The ground may tilt. Rocks may crack or break into pieces. Water or natural gas may fill the cracks. Scientists cannot yet use this information to predict earthquakes. However, they hope that in the future they will be able to use these clues to predict when an earthquake will happen.

EARTHQUAKE-HAZARD LEVELS

Many earthquakes do not have foreshocks or other clues. Therefore, scientists cannot make exact predictions about earthquakes. However, scientists can use past earthquakes to estimate where future earthquakes are likely to happen. A place that has had a lot of strong earthquakes in the past has a high earthquake-hazard level. A place that has had few or no earthquakes has a lower hazard level.

This map shows the earthquake-hazard levels of places in the United States.

LOOKING CLOSER

6. Explain Put a star next to a state with a high earthquake hazard level. Circle a state that has a very low earthquake hazard level.

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Section 3 Review

SECTION VOCABULARY

seismic gap an area along a fault where relatively few earthquakes have occurred recently but where strong earthquakes are known to have occurred in the past	**tsunami** a giant ocean wave that forms after a volcanic eruption, submarine earthquake, or landslide

1. **Explain** What causes a tsunami?

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2. **Describe** What are seismic gaps, and why are they important?

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3. **Identify** What are two ways an earthquake can damage a building?

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4. **Infer** Scientists examined the rocks at a fault zone, and they predicted that an earthquake might happen there. What do you think they found?

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5. **Identify** In the table below, list steps that people who live in areas that have high earthquake-hazard levels should take. List at least two steps in each box.

Before an Earthquake	During an Earthquake	After an Earthquake

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