# How to Use This Presentation

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# Resources

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# Objectives

- **Describe** elastic rebound.
- **Compare** body waves and surface waves.
- **Explain** how the structure of Earth's interior affects seismic waves.
- **Explain** why earthquakes generally occur at plate boundaries.

End Of Slide

# How and Where Earthquakes Happen

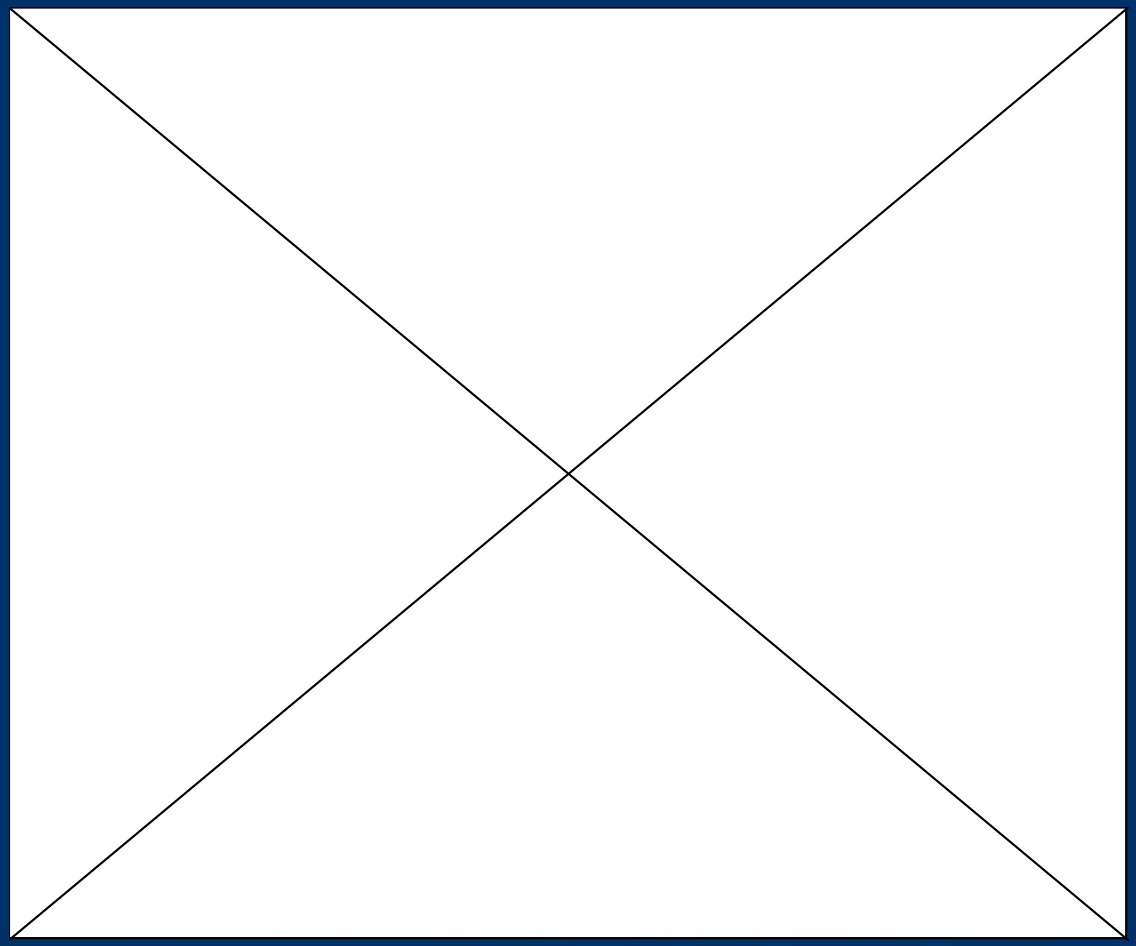
**earthquake** a movement or trembling of the ground that is caused by a sudden release of energy when rocks along a fault move

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

- Earthquakes occur when rocks under stress suddenly shift along a fault.
- A *fault* is a break in a body of rock along which one block moves relative to another.

End Of Slide

# Elastic Deformation and Elastic Rebound



# Why Earthquakes Happen, *continued*

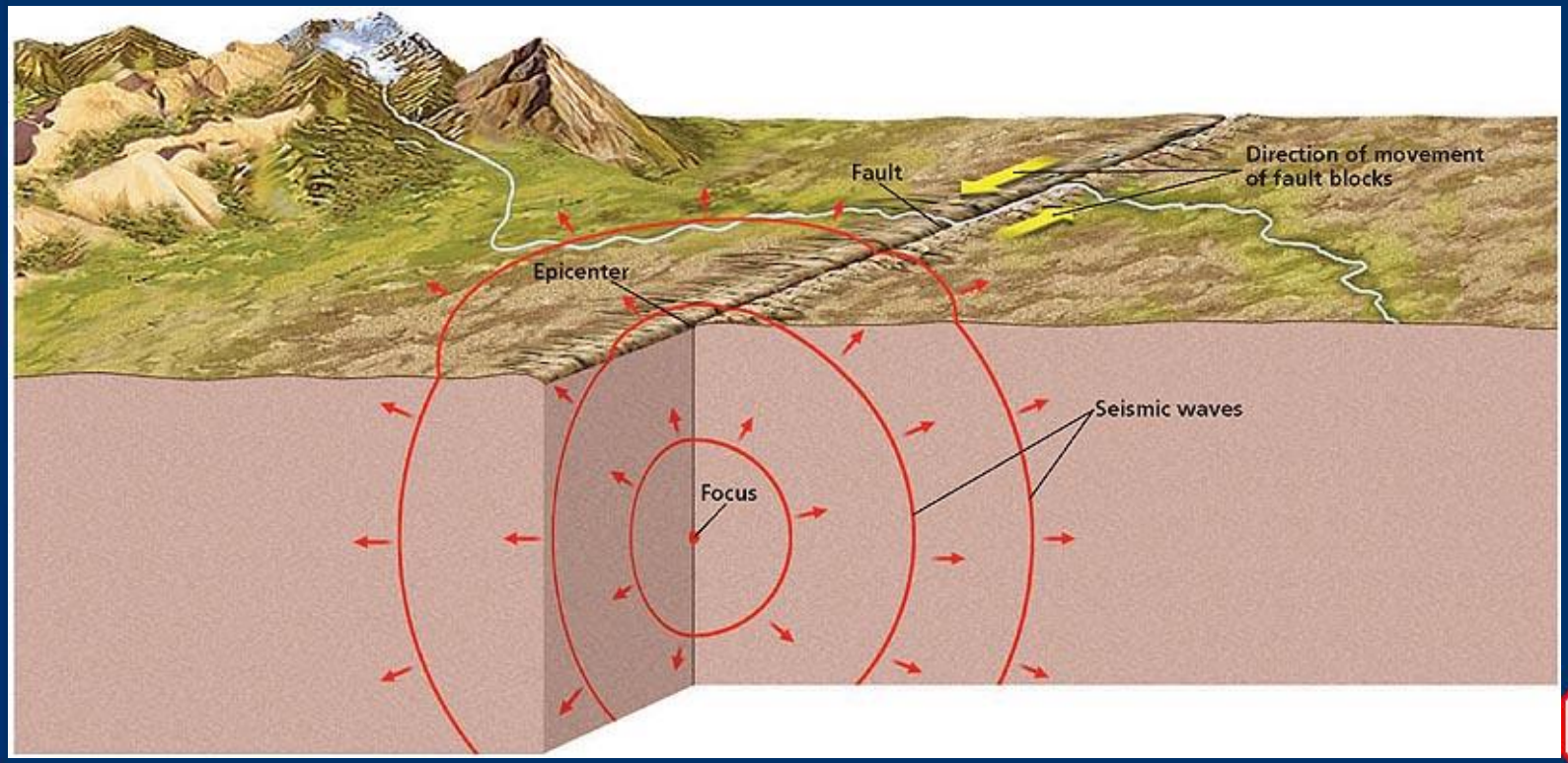
## Anatomy of an Earthquake

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

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

# Why Earthquakes Happen, *continued*

The diagram below shows the parts of an earthquake.

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# Seismic Waves

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

**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

# Seismic Waves, *continued*

## Body Waves

- P waves and S waves are two types of body waves.

**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

- P waves are the fastest seismic waves and can travel through solids, liquids, and gases.
- The more rigid the material is, the faster the P wave travels through it.

End Of Slide

# Seismic Waves, *continued*

## Body Waves

**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

- S waves are the second-fastest seismic waves and can only travel through solids.

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# Seismic Waves, *continued*

## Surface Waves

- Surface waves form from motion along a shallow fault or from the conversion of energy when P waves or S waves reach Earth's surface.
- Although surface waves are the slowest-moving seismic waves, they can cause the greatest damage during an earthquake.
- *Love waves* are surface waves that cause rock to move side-to-side and perpendicular to the direction of the wave.
- *Rayleigh waves* are surface waves cause the ground to move with an elliptical, rolling motion.

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# Seismic Waves, *continued*

## Reading Check

Describe the two types of surface waves.

# Seismic Waves, *continued*

## Reading Check

Describe the two types of surface waves.

Rayleigh waves cause the ground to move in an elliptical, rolling motion. Love waves cause rock to move side-to-side and perpendicular to the direction the waves are traveling.

End Of Slide

# Seismic Waves and Earth's Interior, *continued*

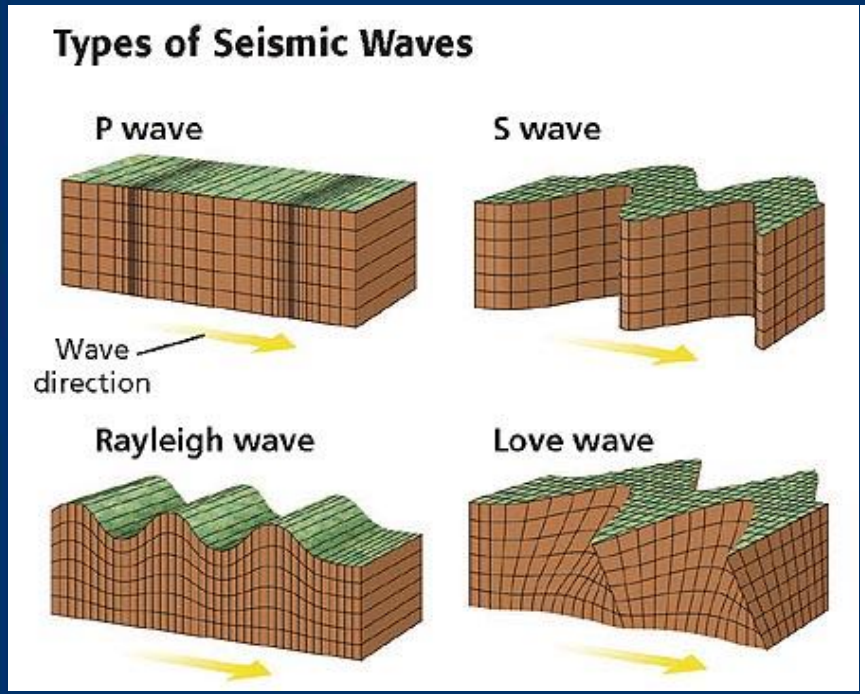
## Shadow Zones

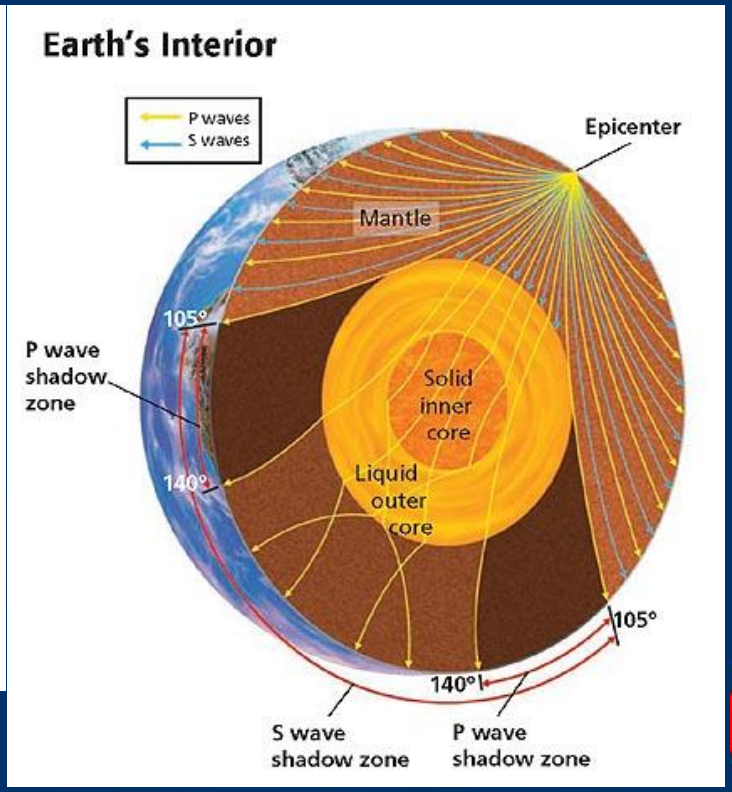
**shadow zone** an area on Earth's surface where no direct seismic waves from a particular earthquake can be detected

- Shadow zones exist because the materials that make up Earth's interior are not uniform in rigidity.

# Seismic Waves and Earth's Interior, *continued*

The diagram below shows how seismic waves interact with Earth's interior.

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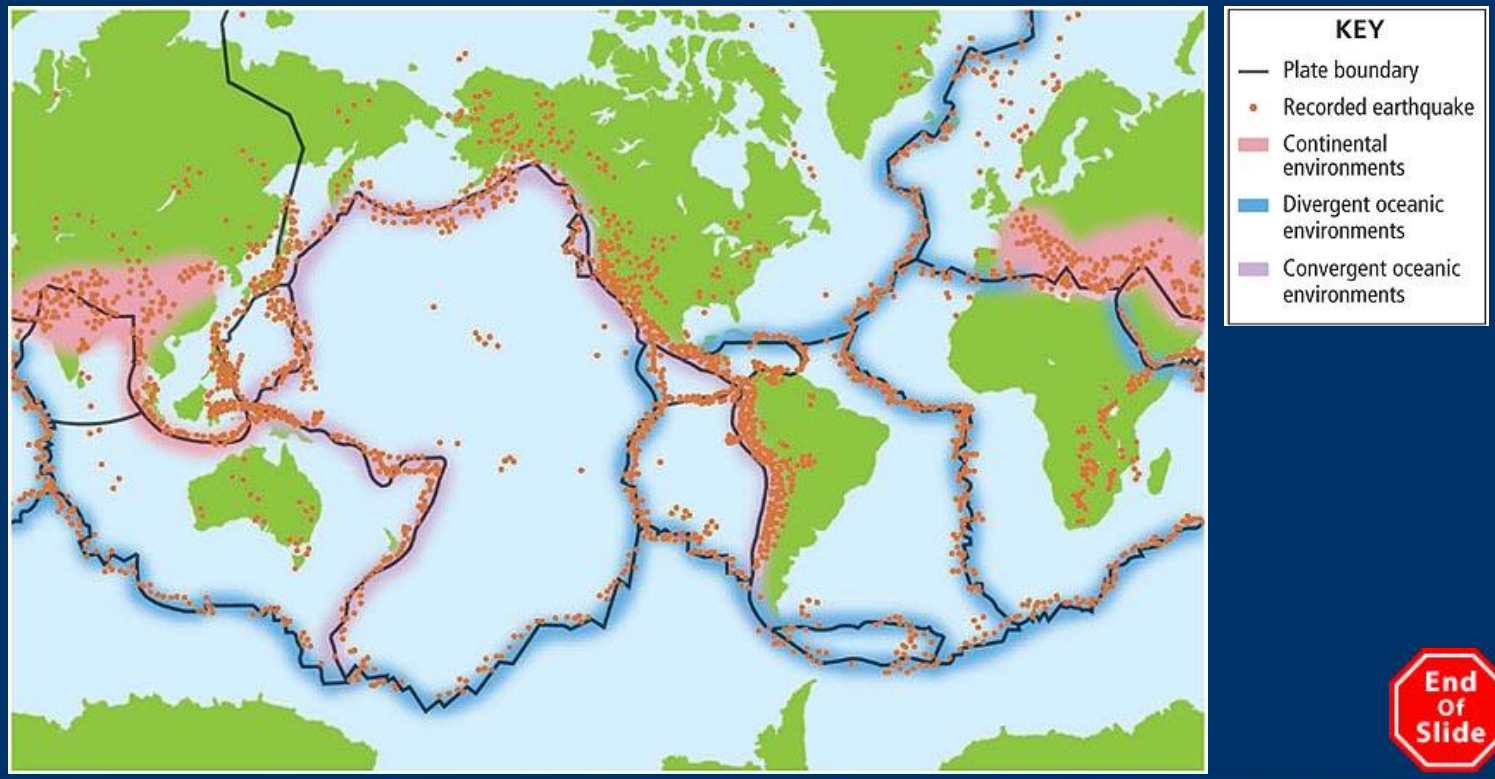
# Earthquakes and Plate Tectonics

- Earthquakes are the result of stresses in Earth's lithosphere.
- Most earthquakes occur at or near tectonic plate boundaries, where stress on the rock is greatest.

End Of Slide

# Earthquakes and Plate Tectonics, *continued*

The diagram below shows the different tectonic boundaries where earthquakes occur.

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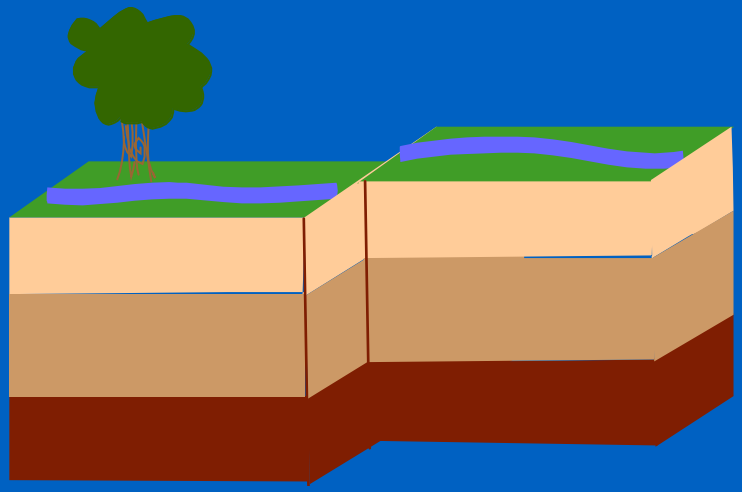
# Fault Zones

**fault zone** a region of numerous, closely spaced faults

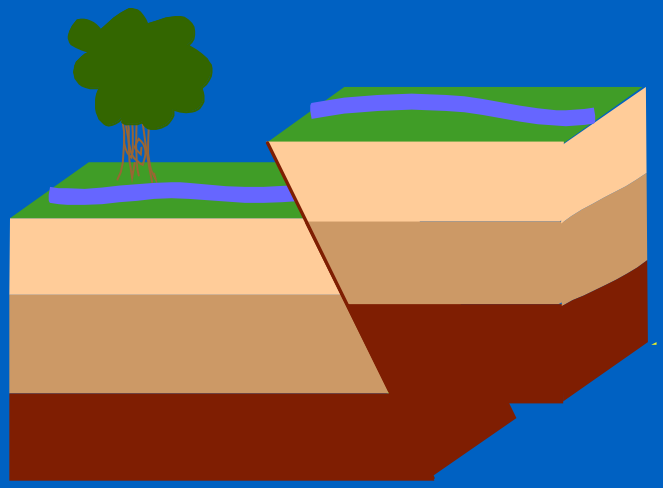
- Fault zones form at plate boundaries because of the intense stress that results when plates separate, collide, subduct, or slide past each other.
- When enough stress builds up, movement occurs along one or more of the individual faults in the fault zone and sometimes causes major earthquakes.

End Of Slide

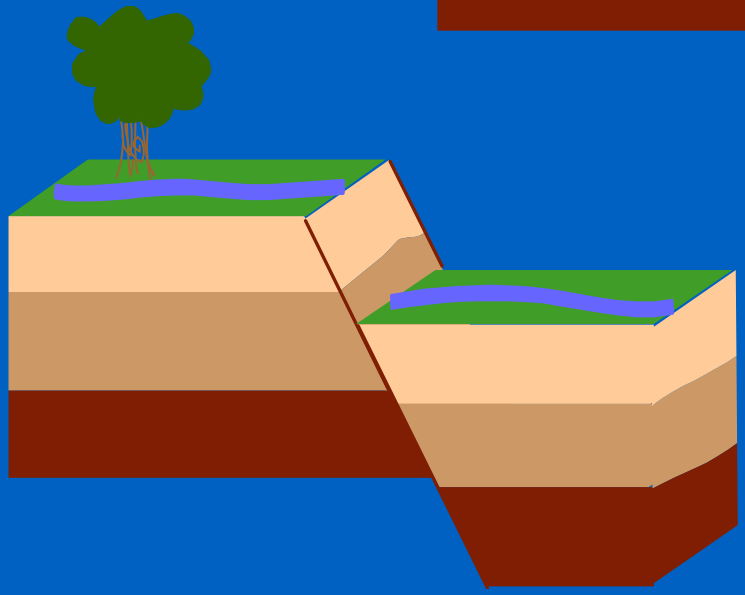
# Three Types of Faults



Strike-Slip



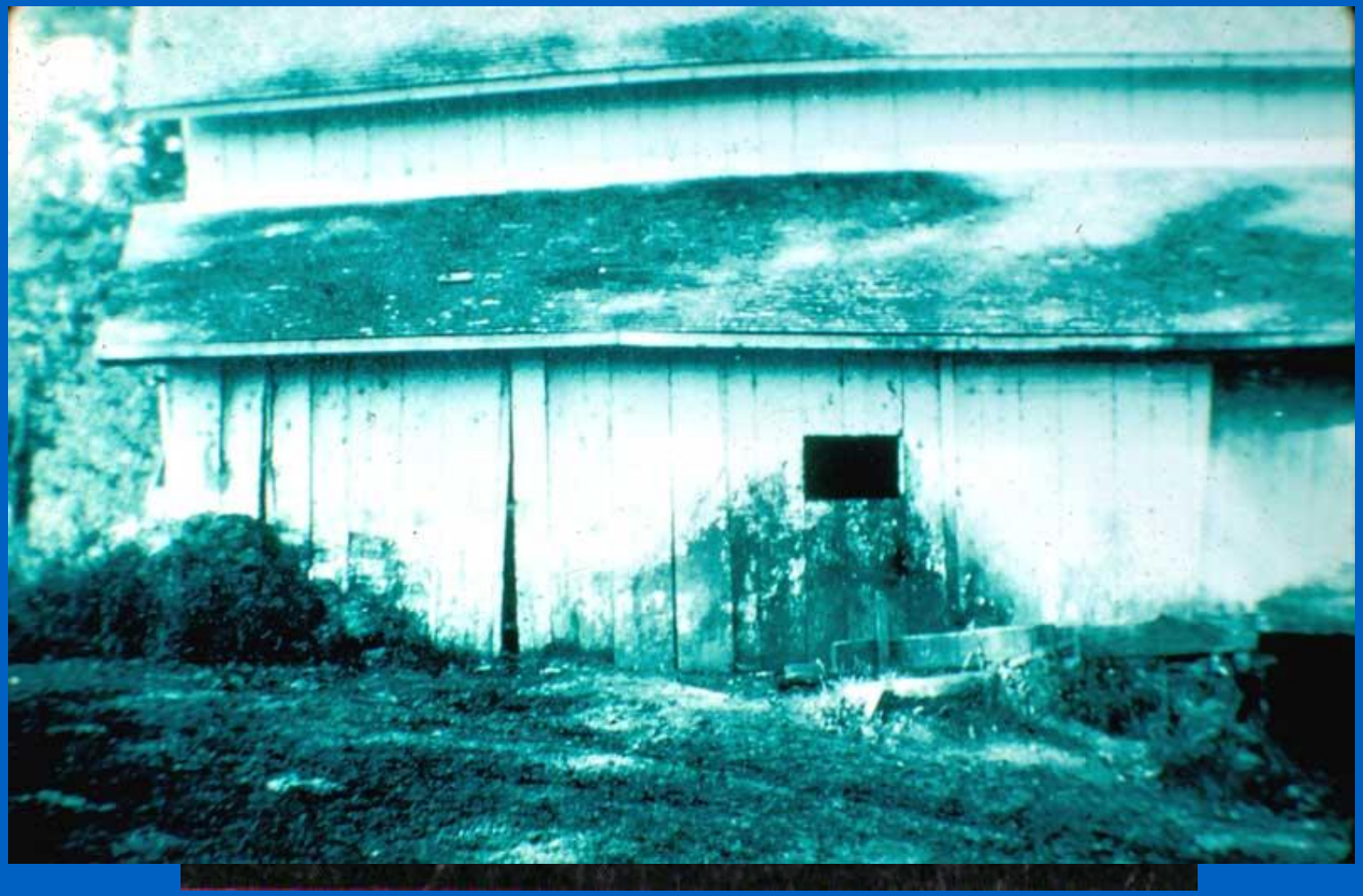
Thrust



Normal

USGS

# Strike-slip  Fault Example



USGS

1906 San Francisco Earthquake

# Normal Fault Example

**Dixie Valley-Fairview Peaks, Nevada earthquake**
**December 16, 1954**

USGS

# Thrust Fault Example

USGS

# TSUNAMI

## Killer waves come ashore

1. Vertical plate movement (earthquake) causes a disturbance in the water. Waves radiate out in all directions from the center of the quake.

2. At sea, tsunami waves travel fast and have long wavelengths. This makes it difficult to know when tsunami are headed to shore. A network of sensors is set up to detect tsunami formation and send warnings to those onshore who are in danger.

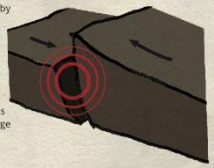
3. When waves approach the shore, the sea floor becomes more shallow, forcing waves to grow taller and move more slowly.

4. There is no way to know which in the series of waves coming ashore will be the tallest or wreak the most destruction. It can be hours between waves. Destruction is especially bad when it is concentrated in geographically enclosed areas such as inlets or harbors. In that situation, the shape of the land concentrates the force of the wave onshore.

## Causes of tsunami

### Earthquakes

Most tsunami are caused by movements in the Earth's plates. When plates beneath the ocean shift, water is displaced. Not every earthquake causes a tsunami, though. The amount of vertical displacement of the plates determines if and how large a tsunami forms.

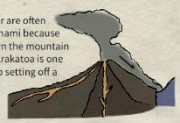


### Meteor impact

The largest tsunami are caused by a meteoric impact. Speed and size of the impact determine how devastating the resultant wave will be.

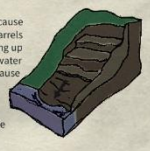
### Volcano

Volcanoes near water are often accompanied by tsunami because the debris flows down the mountain and into the water. Krakatoa is one example of a volcano setting off a tsunami that killed tens of thousands.



### Landslide

Landslides can also cause tsunami when soil barrels into the ocean, kicking up a large wave. Underwater seafloor landslides cause what are called 'suprise tsunami' because they begin undetected under the ocean.



**Speed**

**Normal waves** 5-60 mph

**Tsunami** 500-600 mph

**Time between waves**

**Normal waves** 5-20 seconds

**Tsunami** 10 minutes-2 hours

**Length**

**Normal waves** 300-600 ft

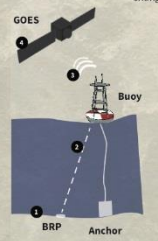
**Tsunami** 60-300 miles

## Megatsunami

The tallest tsunami ever recorded was the Lituya Bay, Alaska megatsunami (1958). A rockslide forced waves up to 1,720 ft. high across the concentrated area of the bay.


## Monitoring

The Deep-ocean Assessment and Reporting of Tsunamis system is a network of buoys, sensors and satellites tracking changes in the Pacific Ocean to alert coastal communities to impending tsunami.




1. Bottom pressure recorders (BPRs) sense changes in water pressure.
2. Using an acoustic modem, BPRs signal buoys on the surface of the water.
3. During normal conditions, buoys relay pressure readings to GOES satellites.
4. Satellites send the data to onshore warning stations, which can alert those onshore is a tsunami is imminent.

## Tsunami risk

Regions most at risk of tsunami are near areas of high levels of tectonic activity. Plate boundaries provide the right conditions for vertical displacement of water, causing tsunami to form. The Pacific Ocean, also known as the 'Ring of Fire' is the most active location for tsunami in the world. **About 59% of all tsunami take place in the Pacific region.**

Red regions indicate area of highest tsunami risk.

## Safety

If you are on a beach and hear a tsunami warning, get to higher ground immediately. Some natural warning signs that a tsunami is approaching include:

- noticeable rise and fall of beach water
- coastal water drains away to reveal coral and/or fish

Even if you think the tsunami is over, don't return to the beach until you're given an all clear signal. Tsunami are unpredictable and very dangerous.

## Historic tsunami

**1755** LISBON,PORTUGAL
A large earthquake destroyed Lisbon, Portugal sending people fleeing on boats. A tsunami followed. ***More than 60,000 killed***

**1883** KRAKATOA
Eruptions of the Krakatoa volcano launched a tsunami. The wave was strong enough to push hundreds of tons of coral onshore. ***36,000 killed***

**1896** JAPAN
An earthquake triggered a tsunami that hit the east coast of Japan. Waves are said to have reached 100 feet high. ***27,000 killed***

**1946** ALASKA/HAWAII
An Alaskan earthquake set off a tsunami that hit Hawaii. ***159 killed***

**1958** LITUYA BAY, ALASKA
The largest tsunami in modern times. An earthquake triggered a landslide, causing a tsunami in the bay that was 1,720 feet high. ***2 killed***

**1960** CHILE
An 8.6 magnitude earthquake in Chile caused a tsunami to reach the Chilean coast within 15 minutes. ***1,500 killed***

**1964** ALASKA
The Good Friday earthquake set off a tsunami more than 200 feet high that traveled more than 400 mph. ***120 killed***

**1976** PHILLIPPINES
A tsunami following an earthquake wreaked destruction on the island of Mindanao. ***8,000 killed***

**1998** PAPUA NEW GUINEA
An earthquake occurred the day after Christmas. The waves stretched from the Indian Ocean around the world. ***230,000 killed***

**2004** INDONESIA
An earthquake occurred the day after Christmas. The waves stretched from the Indian Ocean around the world. ***230,000 killed***

**2011** JAPAN
The most powerful earthquake to ever hit Japan caused waves as high as 133 feet. A nuclear disaster followed. ***16,000 killed***

SOURCE: USGS.GOV, NOAA.GOV, WWW.LIVESCIENCE.COM, NATURAL DISASTERS - PATRICK ABBOTT, WEATHER.GOV, WWW.HOWSTUFFWORKS.COM

KEVIN UHRMACHER

Chapter menu Resources

# Fault Zones, *continued*

## Earthquakes Away from Plate Boundaries

- Not all earthquakes result from movement along plate boundaries.
- In 1811 and 1812 the most widely felt series of earthquakes in United States history occurred in the middle of the continent near New Madrid, Missouri.
- In the late 1970s scientists discovered an ancient fault zone deep within the crust of the Mississippi River region.

End Of Slide

# Objectives

- **Describe** the instrument used to measure and record earthquakes.
- **Summarize** the method scientists use to locate an epicenter.
- **Describe** the scales used to measure the magnitude and intensity of earthquakes.

End Of Slide

# Studying Earthquakes

- The study of earthquakes and seismic waves is called *seismology*.
- Seismologists use special sensing equipment to record, locate, and measure earthquakes.

# Recording Earthquakes

**seismograph** an instrument that records vibrations in the ground

**seismogram** a tracing of earthquake motion that is recorded by a seismograph

- Seismographs record three types of ground motion—vertical, east-west, and north-south.
- Because they are the fastest, P waves are the first seismic waves to be recorded by a seismograph.
- S waves are the second seismic waves to be recorded, and surface waves are the last to be recorded by a seismograph.

End Of Slide

# Locating an Earthquake

- To determine the distance to an epicenter, scientists consult a lag-time graph and analyze the arrival times of the P waves and S waves.
- The start time of an earthquake can also be determined by this graph.
- Scientists use computers to perform complex triangulations based on information from several seismograph stations. These calculations help determine the location of an earthquake.
- Before computers were widely available, scientists used simpler, less precise calculations together with maps to locate earthquakes.

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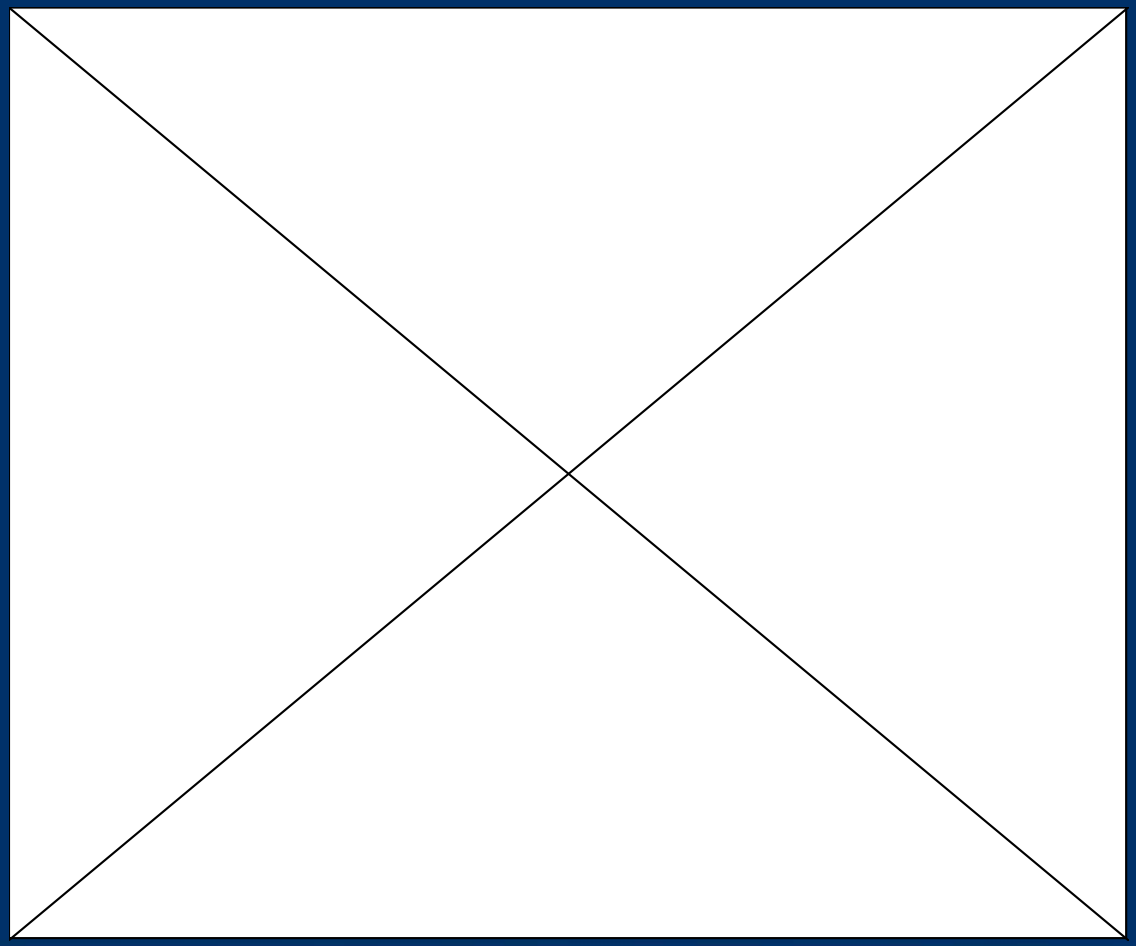
# S-P-Time Method: Finding an Epicenter



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# Earthquake Measurement

## Magnitude

**magnitude** a measure of the strength of an earthquake

- Magnitude is determined by measuring the amount of ground motion caused by an earthquake.
- While the Richter scale was widely used for most of the 20th century, scientists now prefer to use the moment magnitude scale.
- Moment magnitude is a measure of earthquake strength based on the size of the area of the fault that moves, the average distance that the fault blocks move, and the rigidity of the rocks in the fault zone.

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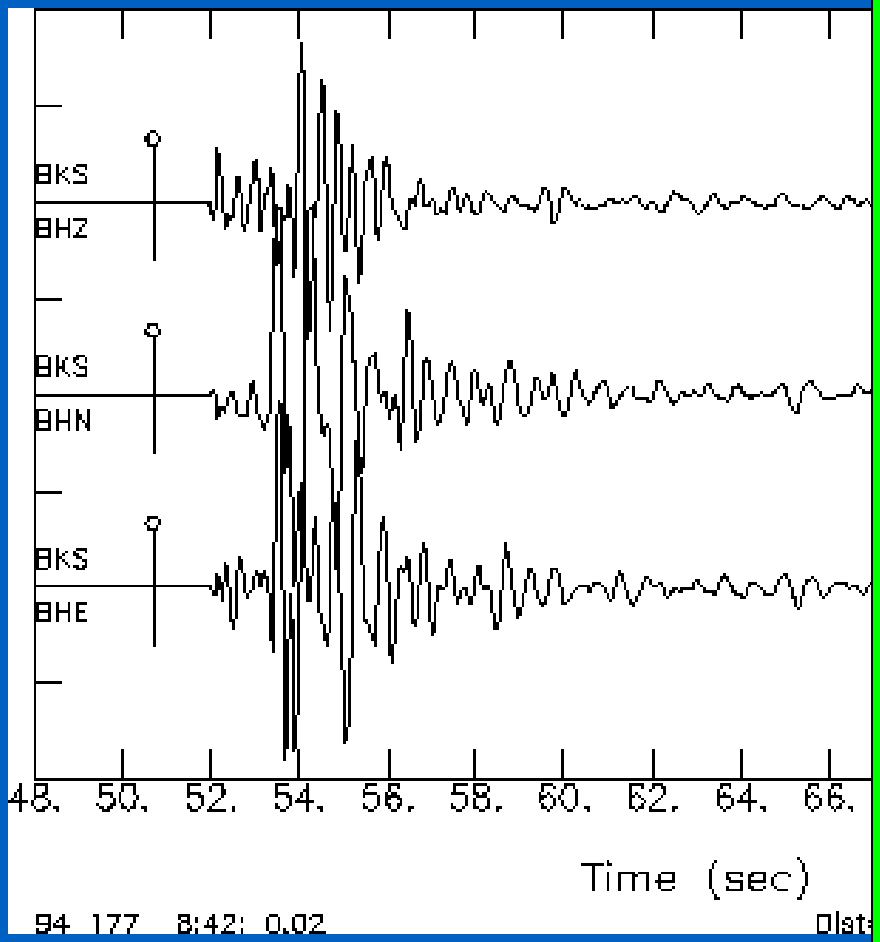
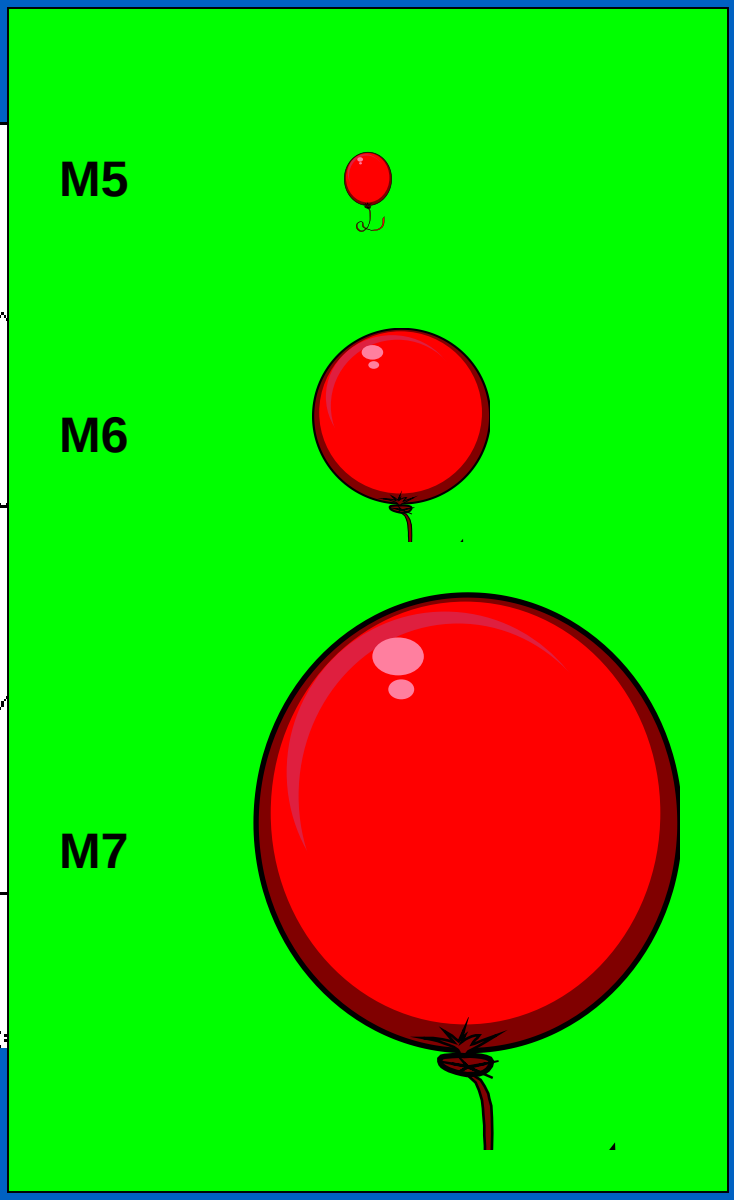
# Earthquake Magnitude




USGS

# Earthquake Measurement

## Intensity

**intensity** the amount of damage caused by an earthquake

- Before the development of magnitude scales, the size of an earthquake was described in terms of the earthquake's effects.
- The modified *Mercalli scale* expresses intensity in Roman numerals from I to XII and provides a description of the effects of each earthquake intensity.

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## Modified Mercalli Scale

| | |
|---|---|
| **I.** | Not felt. |
| **II.** | Felt by persons at rest, on upper floors, or favorably placed. |
| **III.** | Felt indoors. Vibration like passing of light trucks. |
| **IV.** | Vibration like passing of heavy trucks. |
| **V.** | Felt outdoors. Small unstable objects displaced or upset. |
| **VI.** | Felt by all. Furniture moved. Weak plaster/masonry cracks. |
| **VII.** | Difficult to stand. Damage to masonry and chimneys. |
| **VIII.** | Partial collapse of masonry. Frame houses moved. |
| **IX.** | Masonry seriously damaged or destroyed. |
| **X.** | Many buildings and bridges destroyed. |
| **XI.** | Rails bent greatly. Pipelines severely damaged. |
| **XII.** | Damage nearly total. |

# Objectives

- **Discuss** the relationship between earthquakes and tsunamis.
- **Describe** two possible effects of a major earthquake on buildings.
- **List** three safety techniques to prevent injury caused by earthquake activity.
- **Identify** four methods scientists use to forecast earthquake risks.

End Of Slide

# Earthquakes and Society

- Most earthquake injuries result from the collapse of buildings and other structures or from falling objects and flying glass.
- Other dangers include landslides, explosions caused by broken electric and gas lines, and floodwaters released from collapsing dams.

End Of Slide

# Tsunamis

**tsunami** a giant ocean wave that forms after a volcanic eruption, submarine earthquake, or landslide

- A tsunami may begin to form when the ocean floor suddenly crops or rises because of faulting associated with undersea earthquakes.
- A tsunami may also be triggered by an underwater landslide caused by an earthquake.

End Of Slide

# Destruction to Buildings and Property

- Most buildings are not designed to withstand the swaying motion caused by earthquakes.
- A building constructed on loose soil and rock is much more likely to be damaged during an earthquake than a building constructed on solid ground is.

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# Earthquake Safety

- People who live near active faults should be ready to follow a few simple earthquake safety rules to help prevent death, injury, and property damage.

## Before an Earthquake

- Be prepared. Keep an adequate supply of food, water, batteries, flashlights and a radio.
- Prepare an earthquake plan and discuss it with your family.
- Learn how to turn off the gas, water, and electricity in your home.

End Of Slide

# Earthquake Safety, *continued*

## During an Earthquake

- Protect yourself from falling debris by standing in a doorway or crouching under a desk or a table.
- Stay away from windows, heavy furniture, and other objects that might topple over.
- If you are in a car, stop in a place that is away from tall buildings, tunnels, power lines, or bridges and wait until the tremors cease.

End Of Slide

# Earthquake Safety, *continued*

## After an Earthquake

- Be cautious.
- Check for fire and other hazards.
- Always wear shoes when walking near broken glass.
- Avoid downed power lines and objects touched by downed wires.

# Earthquake Warnings and Forecasts

- Scientists study past earthquakes to help them predict where future earthquakes are most likely to occur.
- Using records of past earthquakes, scientists are able to make approximate forecasts of future earthquake risks.
- There is currently no reliable way to predict exactly when or where an earthquake will occur.

End Of Slide

# Earthquake Warnings and Forecasts, *continued*

## Seismic Gaps

**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

- Some scientists think that seismic gaps are likely locations of future earthquakes.
- Several seismic gaps that exist along the San Andreas Fault zone may be sites of major earthquakes in the future.

End Of Slide

# Earthquake Warnings and Forecasts, *continued*

## Reading Check

Why do scientists think that seismic gaps are areas where future earthquakes are likely to occur?

End Of Slide

# Earthquake Warnings and Forecasts, *continued*

## Reading Check

Why do scientists think that seismic gaps are areas where future earthquakes are likely to occur?

Scientists think that stress on a fault builds up to a critical point and is then released as an earthquake. Seismic gaps are areas in which no earthquakes have happened in a long period of time and thus are likely to be under a high amount of stress.

End Of Slide
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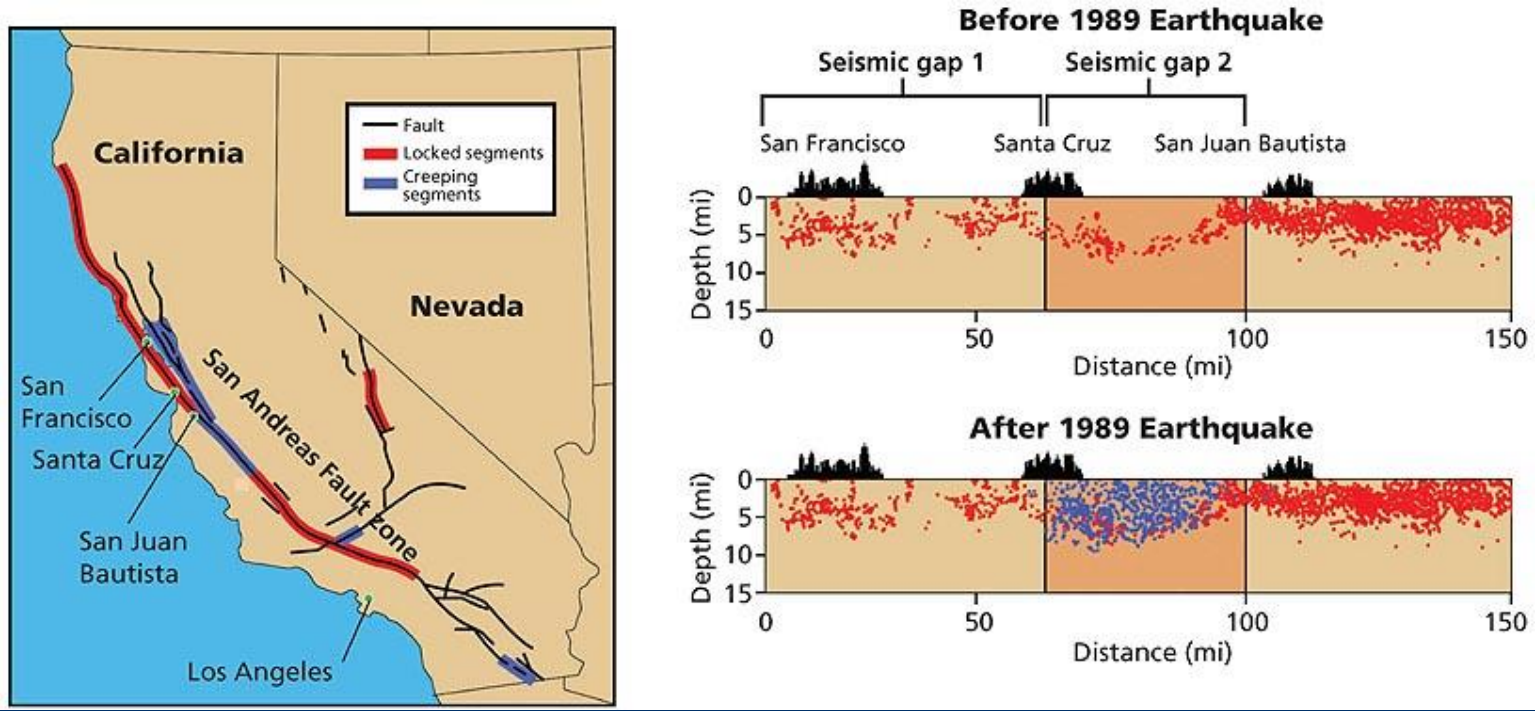
# Earthquake Warnings and Forecasts, *continued*

The diagram below shows how seismic gaps help predict earthquakes.

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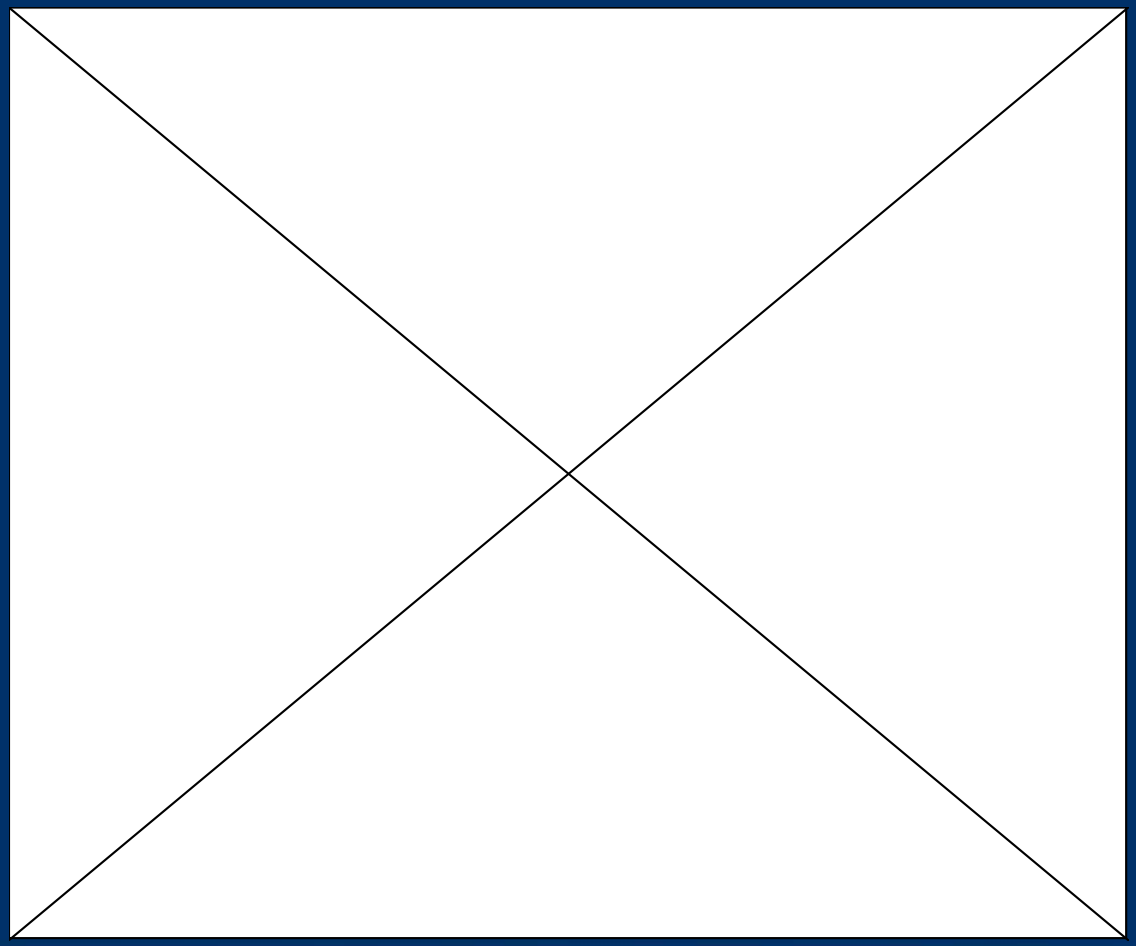
# Gap Hypothesis and Seismic Gaps



# Earthquake Warnings and Forecasts, *continued*

## Foreshocks

- Some earthquakes are preceded by little earthquakes called *foreshocks* that can occur from a few seconds to a few weeks before the main earthquake.
- Only one earthquake has been successfully predicted using foreshocks.

End Of Slide

# Earthquake Warnings and Forecasts, *continued*

## Changes in Rocks

- Scientists use sensors to detect slight tilting of the ground cause by stress that builds up in fault zones.
- When cracks in rock are filled with water, the magnetic and electrical properties of the rock change.
- Scientists also monitor natural gas seepage from rocks that are strained or fractured from seismic activity.
- In the future scientists may be able to use these signals to help predict earthquakes.

End Of Slide

# Earthquake Warnings and Forecasts, *continued*

## Reliability of Earthquake Forecasts

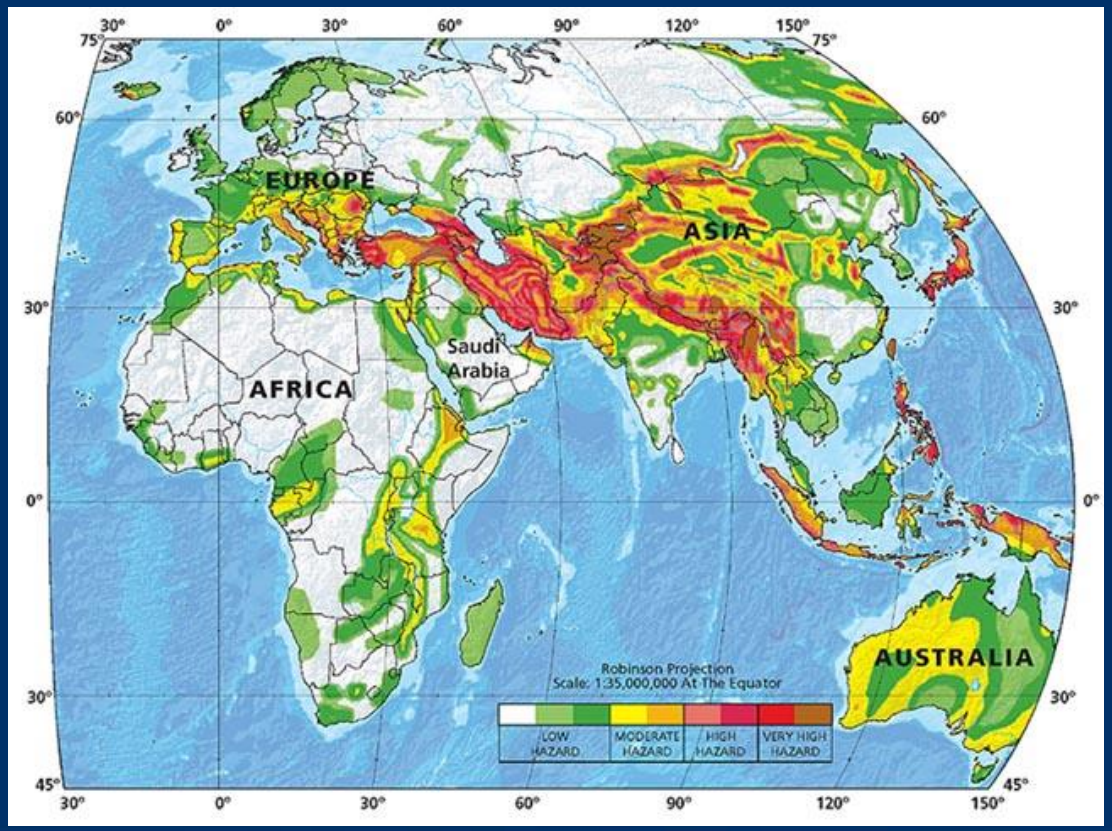
- Not all earthquakes have foreshocks or other precursors, which makes precise earthquake prediction mostly unreliable.
- Scientists continue to study seismic activity so that they may one day make accurate forecasts and save more lives.

End Of Slide

# Brain Food Video Quiz

# Maps in Action

## Earthquake Hazard Map




End Of Slide

## Multiple Choice

1. Energy waves that produce an earthquake begin at what location on or within Earth?

   A. the epicenter
   B. the seismic gap
   C. the focus
   D. the shadow zone

## Multiple Choice

1. Energy waves that produce an earthquake begin at what location on or within Earth?

A. the epicenter
B. the seismic gap
C. the focus
D. the shadow zone

## Multiple Choice, *continued*

2. The fastest moving seismic waves produced by an earthquake are called

F. P waves
G. S waves
H. Raleigh waves
I. surface waves

## Multiple Choice, *continued*

2. The fastest moving seismic waves produced by an earthquake are called

F. P waves
G. S waves
H. Raleigh waves
I. surface waves

## Multiple Choice, *continued*

3. The magnitude of an earthquake can be expressed numerically by using

   A. only the Richter scale
   B. only the Mercalli scale
   C. both the Mercalli scale and the moment magnitude scale
   D. both the Richter scale and the moment magnitude scale

## Multiple Choice, *continued*

3. The magnitude of an earthquake can be expressed numerically by using

   A. only the Richter scale
   B. only the Mercalli scale
   C. both the Mercalli scale and the moment magnitude scale
   D. both the Richter scale and the moment magnitude scale

## Multiple Choice, *continued*

4. Most earthquake-related injuries are caused by

F. tsunamis
G. collapsing buildings
H. rolling ground movements
I. sudden cracks in the ground

## Multiple Choice, *continued*

4. Most earthquake-related injuries are caused by

F. tsunamis
G. collapsing buildings
H. rolling ground movements
I. sudden cracks in the ground

## Multiple Choice, *continued*

5. Which of the following is least likely to cause deaths during an earthquake?

   A. floodwaters from collapsing dams
   B. falling objects and flying glass
   C. actual ground movement
   D. fires from broken gas and electric lines

## Multiple Choice, *continued*

5. Which of the following is least likely to cause deaths during an earthquake?

A. floodwaters from collapsing dams
B. falling objects and flying glass
C. actual ground movement
D. fires from broken gas and electric lines

## Short Response

6. What is the name of the instrument used to detect and record seismic waves?

## Short Response

6. What is the name of the instrument used to detect and record seismic waves?

seismograph

## Short Response, *continued*

7. What is the term for waves that move through a medium instead of along its surface?

## Short Response, *continued*

7. What is the term for waves that move through a medium instead of along its surface?

body waves

## Short Response, *continued*

8. Where is the Ring of Fire located?

## Short Response, *continued*

8. Where is the Ring of Fire located?

The Ring of Fire surrounds the Pacific Ocean.

# Reading Skills

Read the passage below. Then, answer questions 9–11.

## The Loma Prieta Earthquake

At 5:04 P.M. on October 17, 1989, life in California's San Francisco Bay area seemed relatively normal. While more that 62,000 excited fans filled Candlestick Park to watch the third game of baseball's World Series, other people were still rushing home from a long day's work or picking their children up from extracurricular activities. By 5:05 P.M., the situation had changed drastically. The area was rocked by the 6.9 Loma Prieta earthquake. The earthquake lasted 20 seconds and caused 62 deaths, 3,757 injuries, and the destruction of more than 1,000 homes and businesses. By midnight, the city was fighting more than 20 large structural fires resulting from the earthquake. Considering that the earthquake was of such a high magnitude and that it happened during the busy rush hour, it is amazing that more people were not injured or killed.

## Reading Skills, *continued*

9. What type of waves are the most likely to have caused the damage described during the Loma Prieta earthquake?

   A. P waves
   B. S waves
   C. body waves
   D. surface waves

## Reading Skills, *continued*

9. What type of waves are the most likely to have caused the damage described during the Loma Prieta earthquake?

   A. P waves
   B. S waves
   C. body waves
   D. surface waves

## Reading Skills, *continued*

10. Which of the following statements can be inferred from the information in the passage?

F. *Loma Prieta* is the Spanish term for "deadly earthquake."

G. The damage caused by the earthquake continued even after the waves had passed.

H. There were fewer people injured in this earthquake than in most earthquakes.

I. The Loma Prieta earthquake has the highest magnitude of any earthquake ever recorded.

## Reading Skills, *continued*

10. Which of the following statements can be inferred from the information in the passage?

F. *Loma Prieta* is the Spanish term for "deadly earthquake."

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## Reading Skills, *continued*

11. The 6.9 rating of the Loma Prieta earthquake is a rating on what measurement scale?

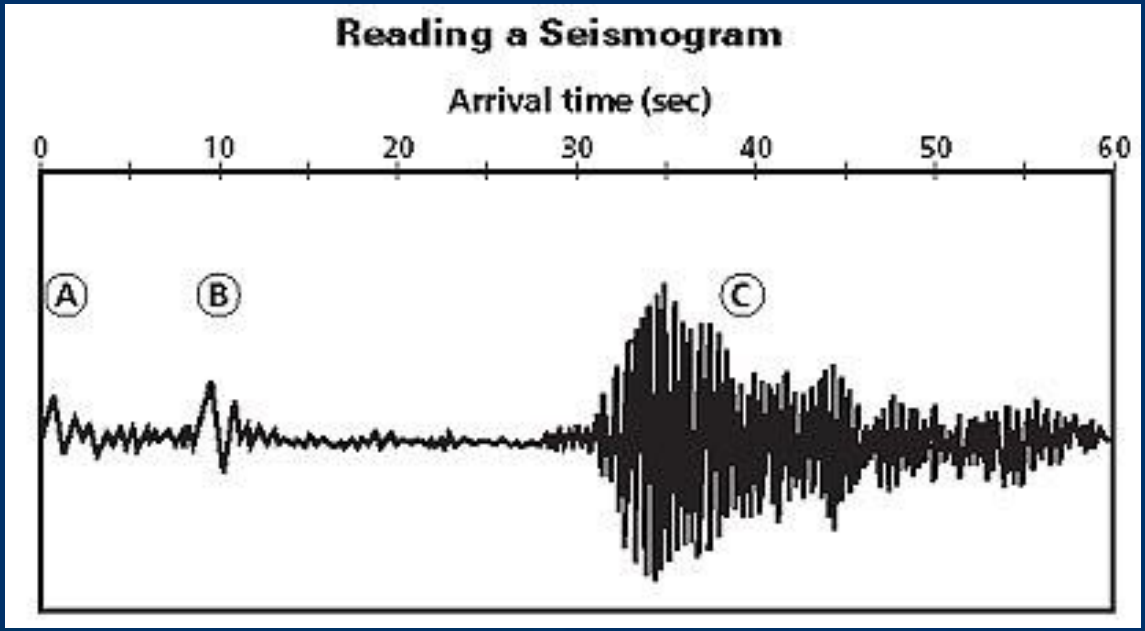
## Reading Skills, *continued*

11. The 6.9 rating of the Loma Prieta earthquake is a rating on what measurement scale?

the Richter scale

# Interpreting Graphics

Use the figure below to answer questions 12-13. The diagram shows a recording of data by a seismograph.



## Interpreting Graphics, *continued*

12. What types of seismic waves are indicated by the points on the seismogram marked by the letter A?

A. Love waves
B. Raleigh waves
C. P waves
D. S waves

## Interpreting Graphics, *continued*

12. What types of seismic waves are indicated by the points on the seismogram marked by the letter A?

A. Love waves
B. Raleigh waves
C. P waves
D. S waves

## Interpreting Graphics, *continued*

13. What type of seismic waves by the point on the seismogram marked by the letter C? How are these waves connected to the smaller waves that precede them?

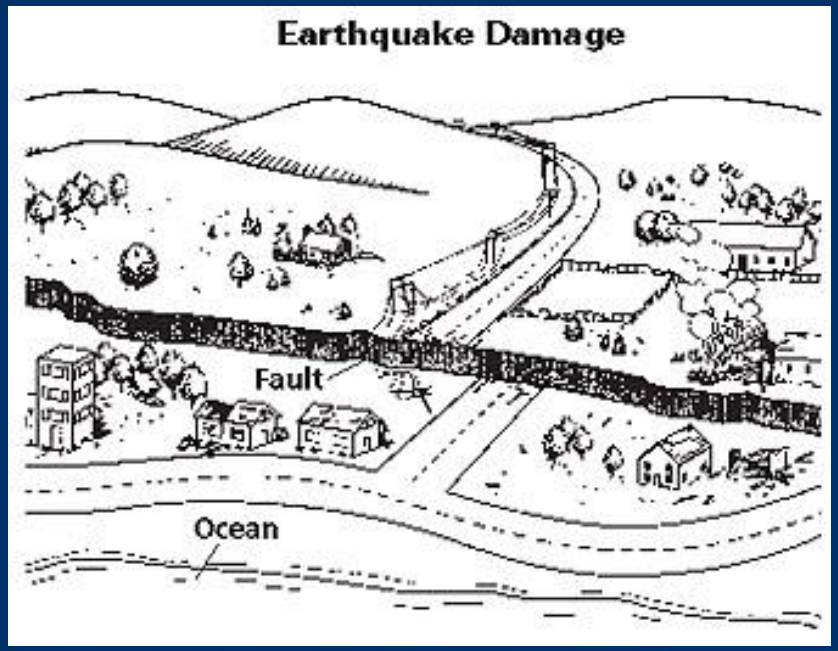
## Interpreting Graphics, *continued*

13. What type of seismic waves by the point on the seismogram marked by the letter C? How are these waves connected to the smaller waves that precede them?

Answer should include the following points: letter C shows the surface waves of an earthquake; these waves are generated when the potential energy of P and S waves are converted into kinetic energy; surface waves are the last waves to form and they are slower-moving than P or S waves and produce drastic vibrations; surface waves cause the most damage to surface features and human constructions.

# Interpreting Graphics, *continued*

Use the figure below to answer question 14. The diagram shows the damage caused by an earthquake.



# Interpreting Graphics, *continued*

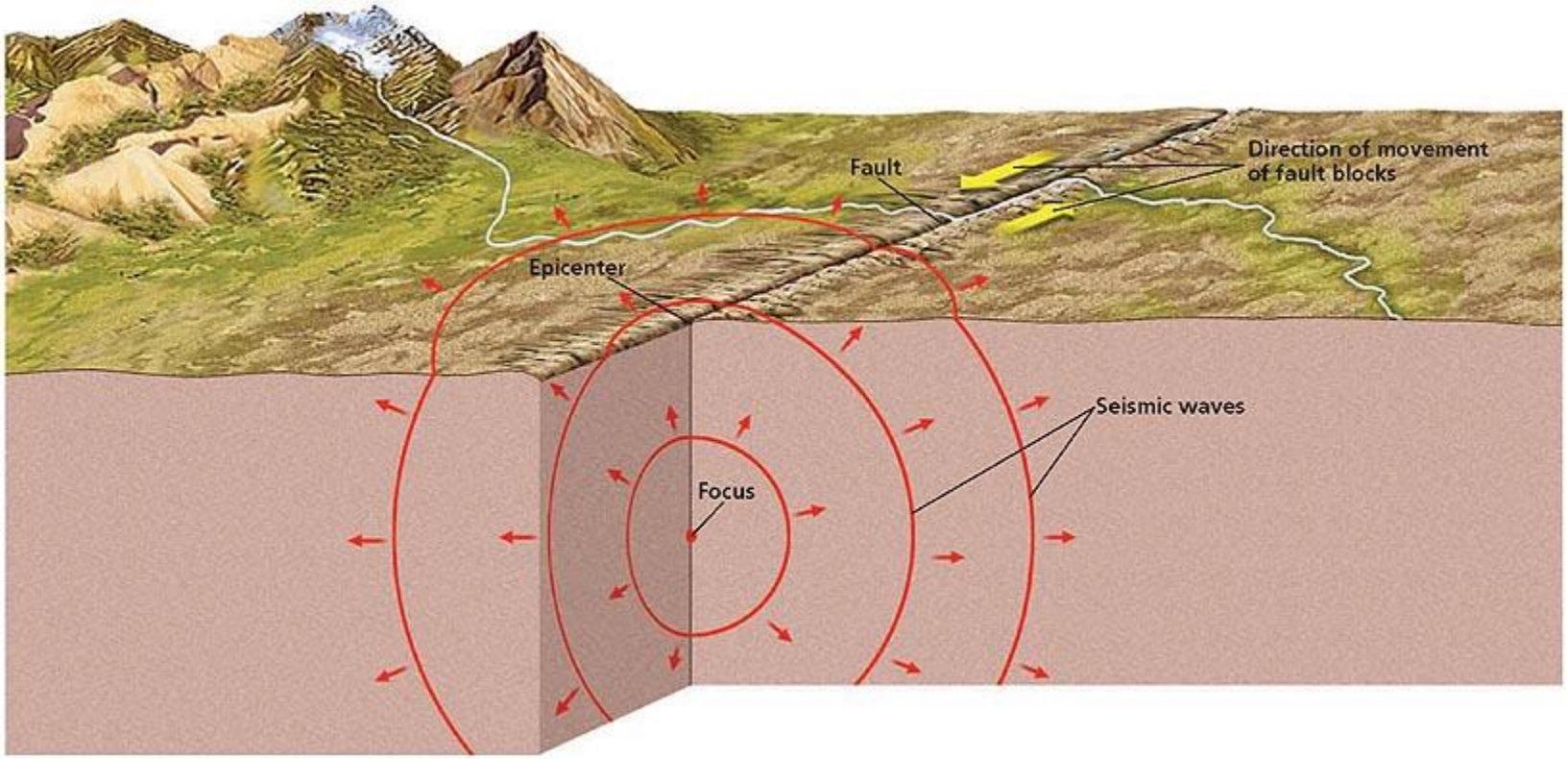
14. What safety hazards can you identify in this scene? What advice would you give to someone approaching the scene above? How should people prepare for dealing with such post-earthquake safety hazards?

# Interpreting Graphics, *continued*

14. What safety hazards can you identify in this scene? What advice would you give to someone approaching the scene above? How should people prepare for dealing with such post-earthquake safety hazards?

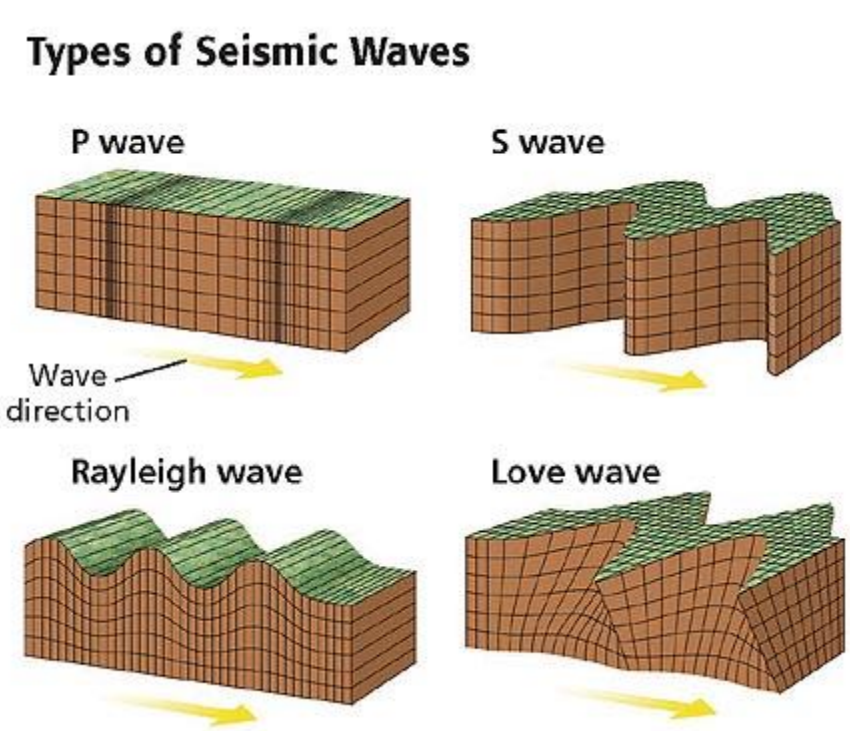
Answer should include the following points: immediate hazards that non-rescue personnel should avoid include power lines, fires, and structural damage; because of the nearby ocean, hidden or delayed dangers may include flooding or tsunamis; people should move inland or find higher ground; people in earthquake-prone areas should always have emergency plans in place, which may include pre-arranged meeting places, emergency supplies for dealing with power outages or injuries, and pre-determined evacuation routes.

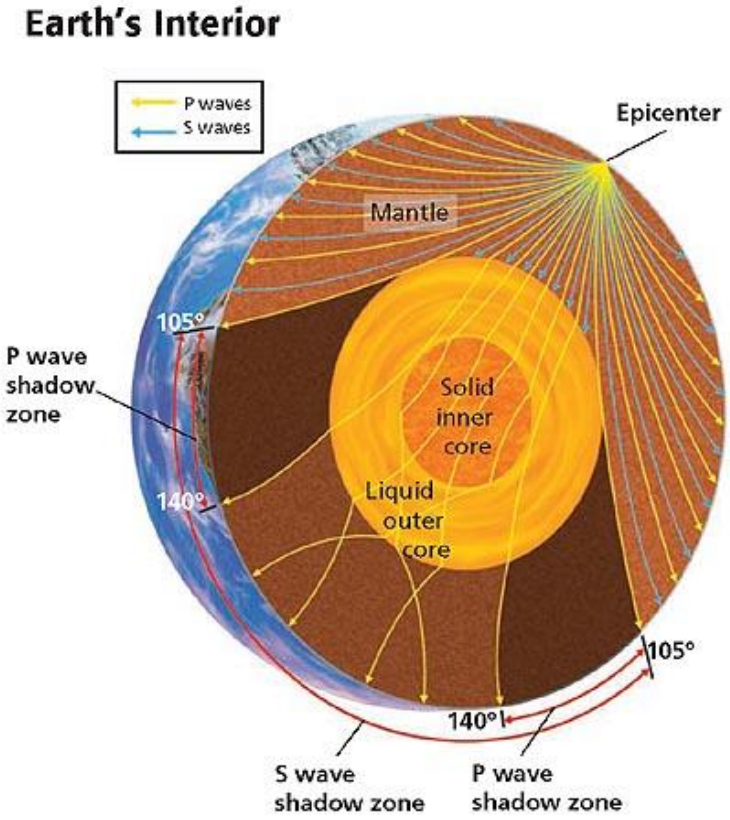
# Anatomy of an Earthquake



Chapter 12

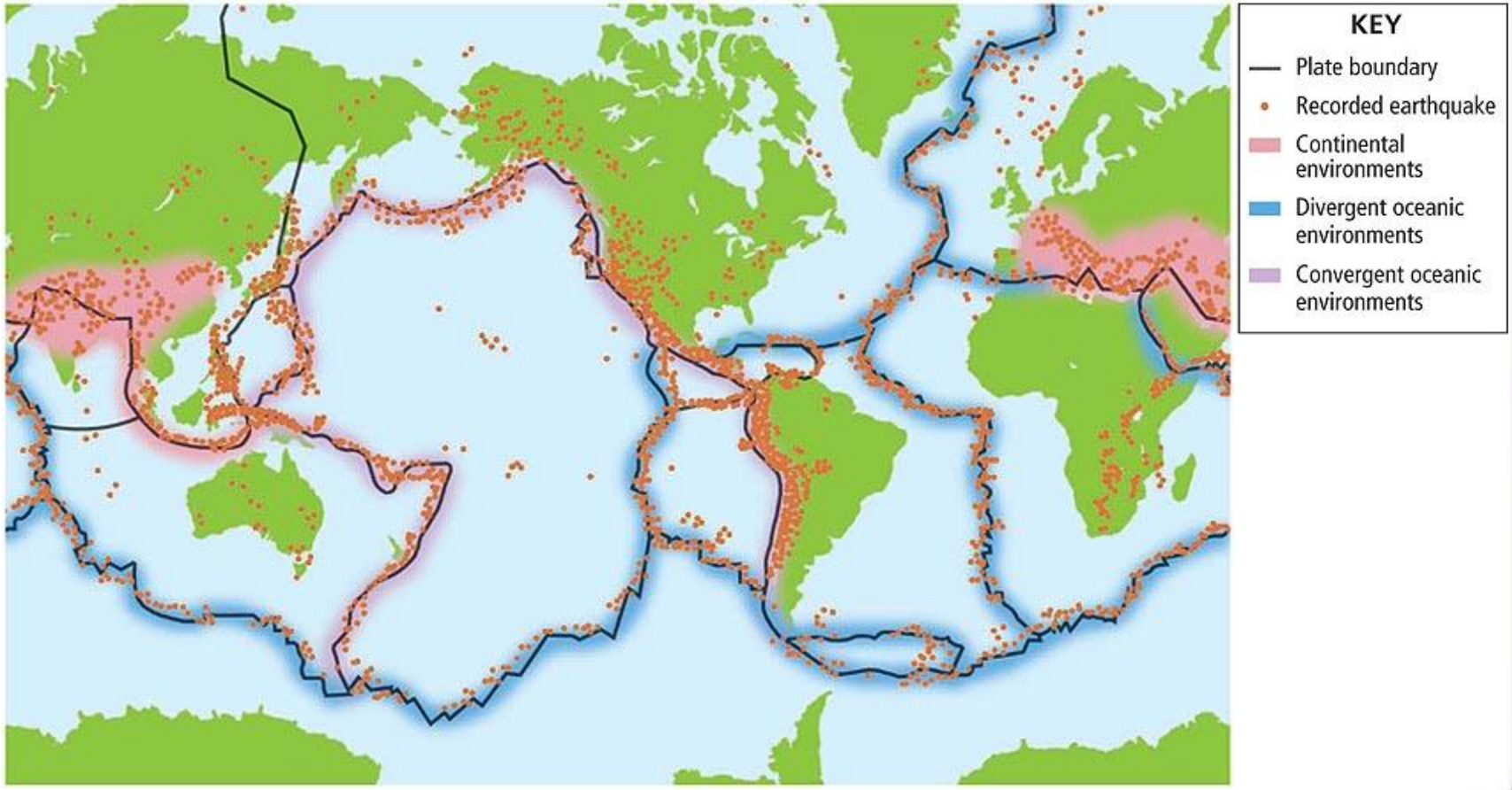
# Seismic Waves and Earth's Interior



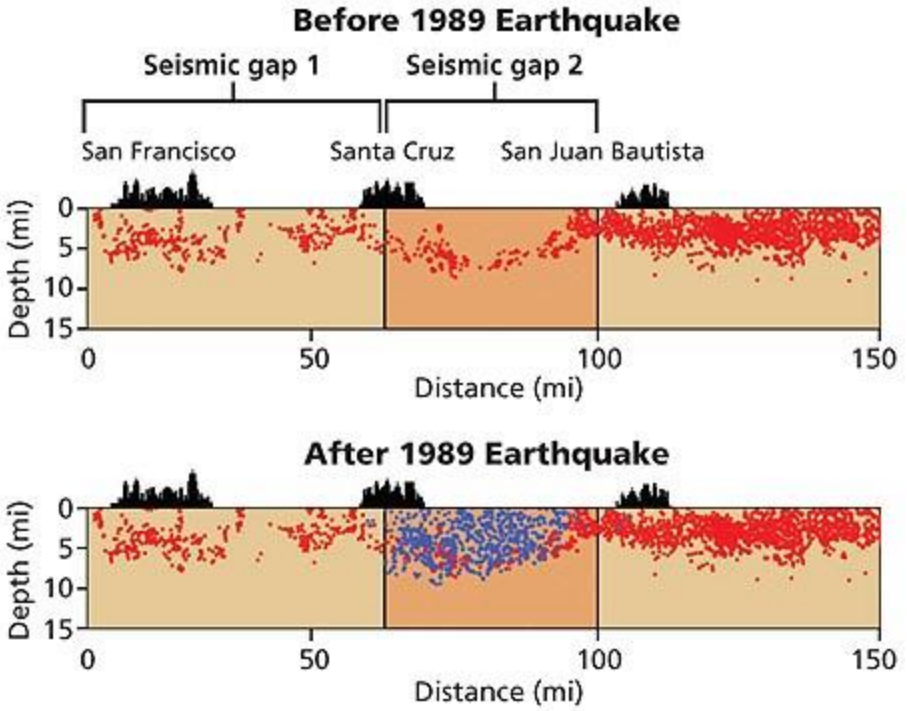



Chapter 12

# Earthquakes and Plate Tectonics



# Seismic Gaps

# Earthquake Hazard Map