The tsunami triggered by the 2004 Sumatra earthquake caused extensive damage to coastal areas in Southeast Asia.

An **earthquake** is a movement of Earth's lithosphere that occurs when rocks in the lithosphere suddenly shift, releasing stored energy.

The energy released during an earthquake is carried by vibrations called **seismic waves**.

As a result of the earthquake, nearly 200,000 people died in Asia and Africa. Many people were killed or injured when coastal areas were hit by a tsunami.

- A **tsunami** is a large sea wave generated by an underwater earthquake, volcano, or landslide.
- When the 2004 Sumatra earthquake ruptured the sea floor, it pushed up a large volume of water, resulting in a tsunami.

Stress in Earth's Crust

What causes faults and folds?

Stress is a force that squeezes rocks together, stretches or pulls them apart, or pushes them in different directions.

As tectonic plates move, they cause stress in the crust, which in turn produces faults and folds.

Stress in Earth's Crust

Earthquakes happen because of the ways that plate movements affect the lithosphere.

The forces of plate movement cause deformation, or changes in the shape or volume of a mass of rock.

Stress in Earth's Crust

A **fault** is a break in a mass of rock along which movement occurs.

- The two slabs of rock on either side of a fault move in relation to each other.
- Many faults occur along plate boundaries.

Stress in Earth's Crust

This portion of the San Andreas fault runs through the Carrizo Plain in south-central California.

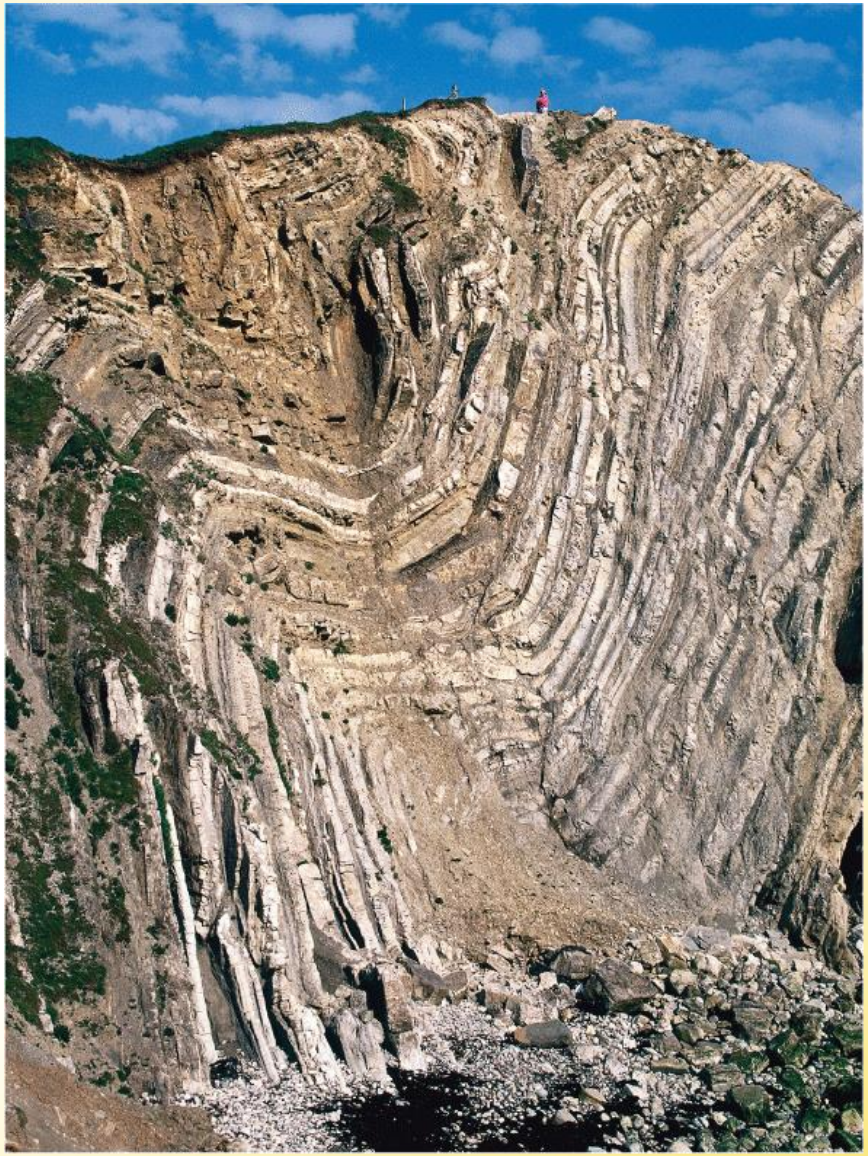
Stress in Earth's Crust

A **fold** is a bend in layers of rock.

- Folds form where rocks are squeezed together but do not break.
- Rocks tend to fold rather than break when they are under high temperature or pressure.

Stress in Earth's Crust

Stress can squeeze rock together, producing folds in layers of rock.



Earthquakes and Seismic Waves

- **What causes earthquakes?**
- **Earthquakes occur because stress forces have exceeded the strength of rock.**

Earthquakes and Seismic Waves

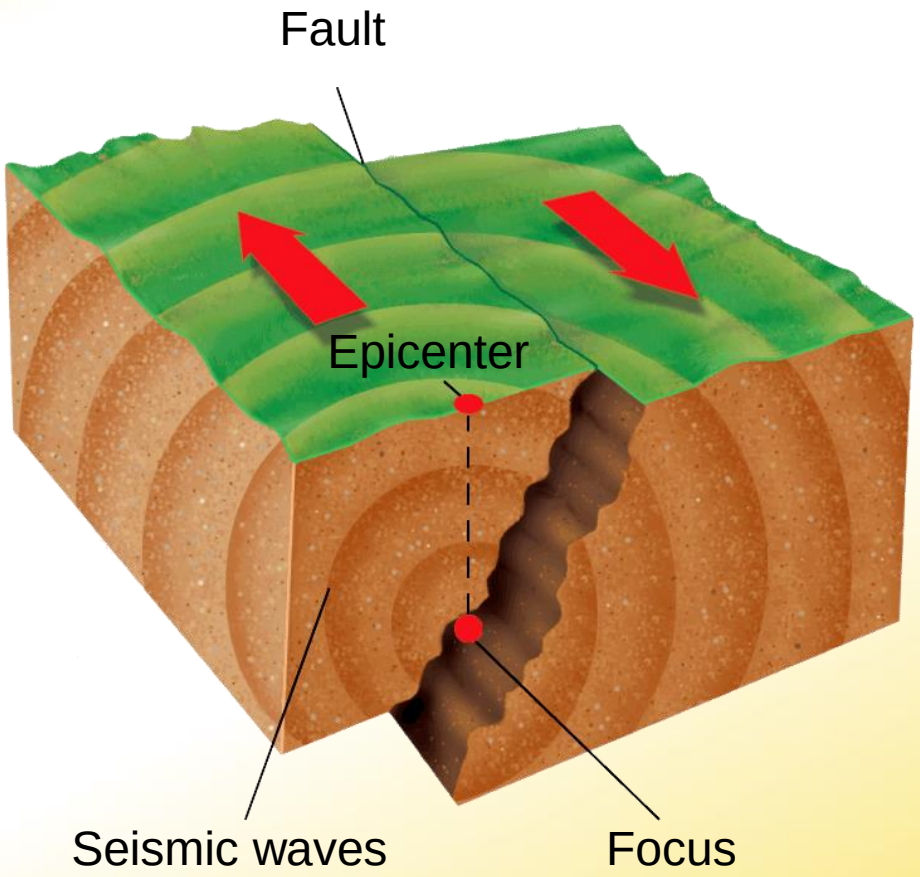
The buildup of stress along a fault provides the energy that powers an earthquake.

- The location beneath Earth's surface where an earthquake begins is called the **focus**, also known as the hypocenter.
- The location on Earth's surface directly above the focus is called the **epicenter.**
- Seismic waves move out in all directions from the focus.

Earthquakes and Seismic Waves

When an earthquake occurs on a fault, seismic waves move out from the focus.

The epicenter lies on the surface, directly above the focus.



Earthquakes and Seismic Waves

The Physics of Earthquakes

Within Earth's crust, forces cause the two sides of a fault to move past each other.

Sometimes the rocks along the two sides of a fault may snag and remain locked because of friction between the two fault surfaces.

Tremendous stress builds up in these areas.

Earthquakes and Seismic Waves

When rocks are strained beyond their limit, they break and grind past each other, releasing huge amounts of energy in the form of an earthquake.

As the rocks break and move, potential energy is transformed into kinetic energy in the form of seismic waves.

Earthquakes and Seismic Waves

Types of Seismic Waves

Earthquakes produce three main types of seismic waves: P waves, S waves, and surface waves.

Earthquakes and Seismic Waves

P waves are longitudinal waves similar to sound waves.

- As longitudinal waves move through a material, particles vibrate in the direction of the waves' motion.
- P waves compress and expand the ground like an accordion.
- P waves are the fastest seismic waves.
- P waves can travel through both solids and liquids.

Earthquakes and Seismic Waves

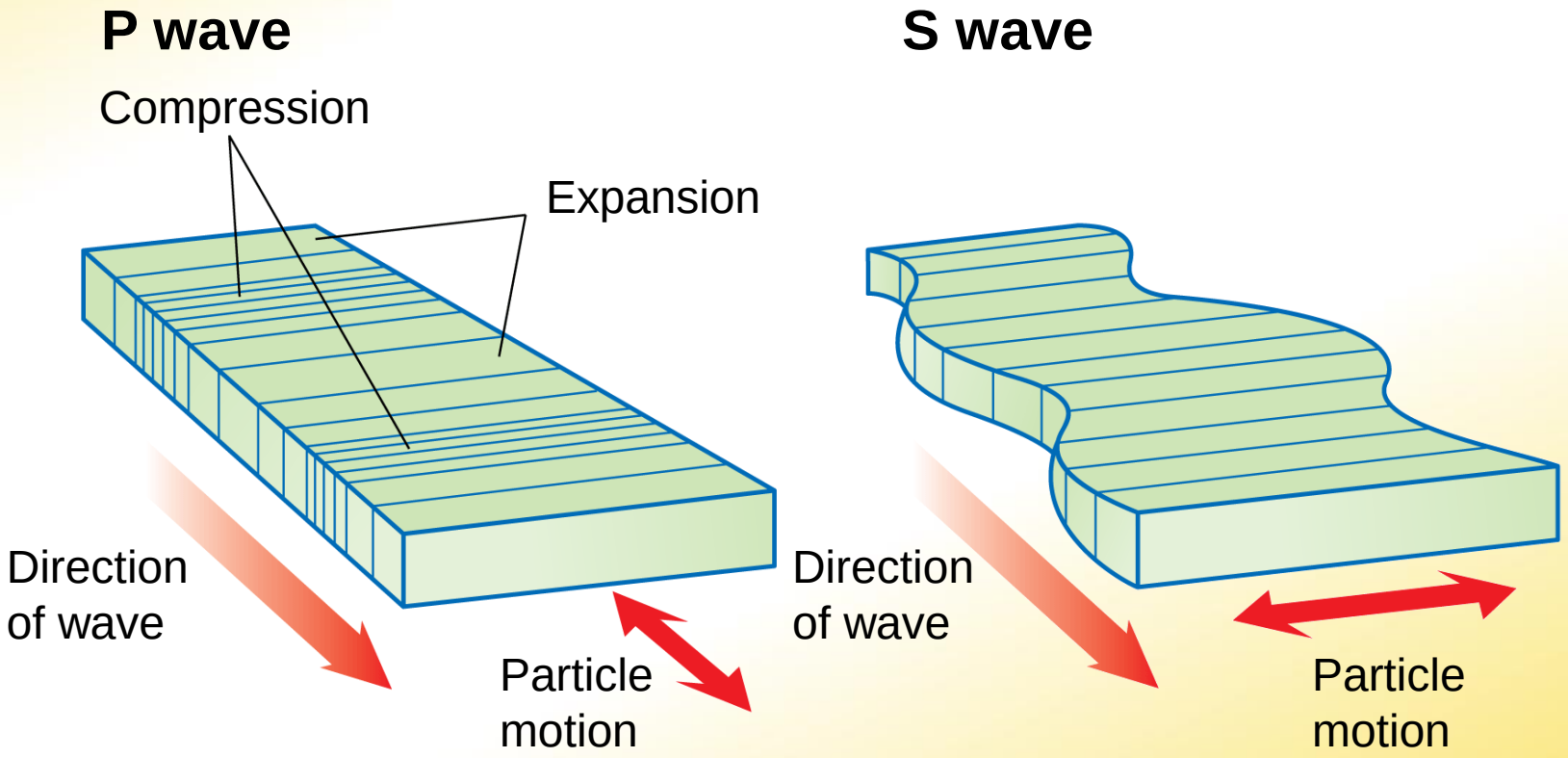
S waves are transverse waves, like light and other electromagnetic radiation.

- S waves cause particles to vibrate at right angles to the direction the waves move.
- Unlike P waves, S waves cannot travel through liquids.

Earthquakes and Seismic Waves

P waves are longitudinal waves.

S waves are transverse waves.



Earthquakes and Seismic Waves

Surface waves are waves that develop when seismic waves reach Earth's surface.

- Surface waves move more slowly than P waves and S waves.
- They usually produce larger ground movements and greater damage.
- Some surface waves are transverse waves, and others have a rolling motion at Earth's surface that is similar to ocean waves.

Measuring Earthquakes

How are earthquakes measured?

A device that can detect and record seismic waves is called a **seismograph.**

To measure earthquakes and pinpoint their epicenters, geologists record seismic waves using seismographs.

Measuring Earthquakes

The record of an earthquake on a seismograph is called a seismogram.

- Earthquakes can be located using the seismic waves recorded by many different seismographs.
- Most earthquakes are too small to be felt by humans, but the largest earthquakes release more energy than the United States consumes in a year.

Measuring Earthquakes

Richter Scale

The most well-known scale is the Richter scale.

The Richter scale rates earthquakes based on measurements of the times and amplitudes of seismic waves by certain seismographs.

Measuring Earthquakes

Moment Magnitude Scale

The most useful scale for geologists is the moment magnitude scale (M_w).

- This scale gives a measure of the amount of energy released by an earthquake.
- Each unit increase on this scale represents about a 32-times increase in the energy.
- The largest earthquake ever recorded was a M_w 9.5 earthquake.

Measuring Earthquakes

Modified Mercalli Scale

The effects of earthquakes can also be rated using the modified Mercalli scale.

This scale ranges from 1 to 12 and is based on observations of the intensity of ground shaking and damage.

Seismographic Data

- **Where do most earthquakes occur?**
- **Most earthquakes are concentrated along plate boundaries, where many faults are found.**

Seismographic Data

A worldwide network of seismographs has provided scientists with a wealth of data on earthquakes.

Some earthquakes occur in the interior of plates, far away from plate boundaries. As a plate moves, it undergoes deformation. The resulting stresses are released as earthquakes.

Seismographic Data

Scientists have mapped Earth's interior, analyzing how seismic waves move through its layers.

- Wave speeds and paths are affected by the temperature, composition, and density of the rocks they pass through.
- Seismic waves interacting with boundaries between different kinds of rock are reflected, refracted, or diffracted.

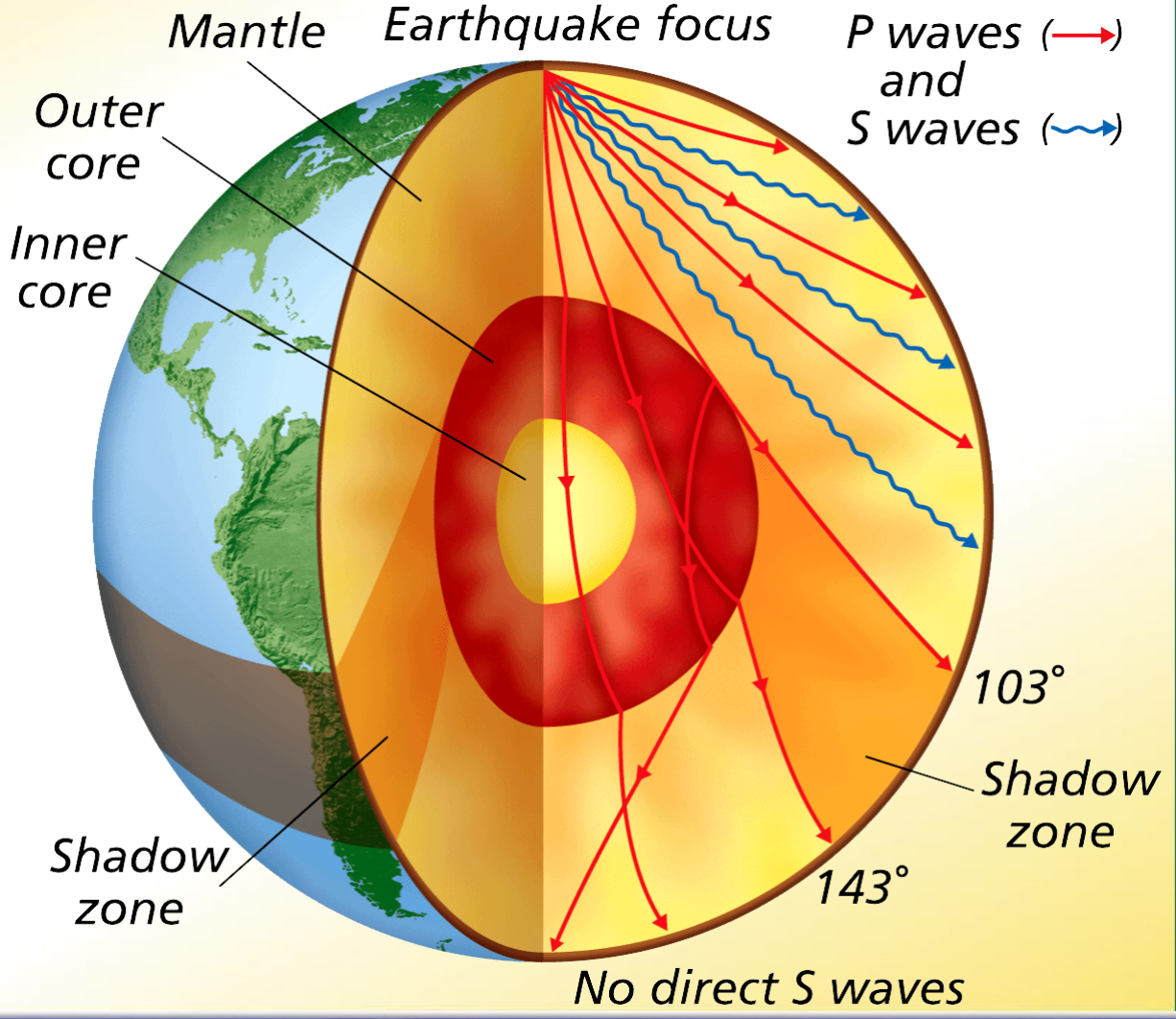
Seismographic Data

Geologists infer that Earth's outer core is liquid because S waves cannot pass through it.

They can also tell that the core is mostly iron because P waves travel through it at a speed that matches laboratory experiments on iron.

Seismographic Data

Earth's liquid outer core blocks S waves and bends P waves. The result is a shadow zone on the surface where no direct seismic waves from an earthquake are detected.



Assessment Questions

1. What causes an earthquake to occur?
   a. Stress forces exceed the strength of rock.
   b. Magma forces the crust apart.
   c. Mountains become to tall and break the surface under them.
   d. The crust releases built-up solar energy.

Assessment Questions

1. What causes an earthquake to occur?
   a. Stress forces exceed the strength of rock.
   b. Magma forces the crust apart.
   c. Mountains become to tall and break the surface under them.
   d. The crust releases built-up solar energy.

   ANS: A

Assessment Questions

2. What information has been deduced from seismograms of earthquakes?
   a. the size and shape of tectonic plates
   b. the location of liquid and solid layers in Earth's interior
   c. the location and strength of Earth's magnetic field
   d. the causes of earthquakes and how to accurately predict them

Assessment Questions

2. What information has been deduced from seismograms of earthquakes?
   a. the size and shape of tectonic plates
   b. the location of liquid and solid layers in Earth's interior
   c. the location and strength of Earth's magnetic field
   d. the causes of earthquakes and how to accurately predict them

ANS: B

Assessment Questions

1. The motion of tectonic plates causes stretching, which produces faults and folds in Earth's crust.

   True
   False

Assessment Questions

1. The motion of tectonic plates causes stretching, which produces faults and folds in Earth's crust.

   True
   False

   ANS: F, stress