VOCABULARY
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SCIENCE CONCEPTS
- how plate movements cause earthquakes and volcanic activity
- what the different types of volcanoes are

READING FOCUS SKILL
CAUSE AND EFFECT Look for causes of earthquakes and volcanic activity.

cause → effect

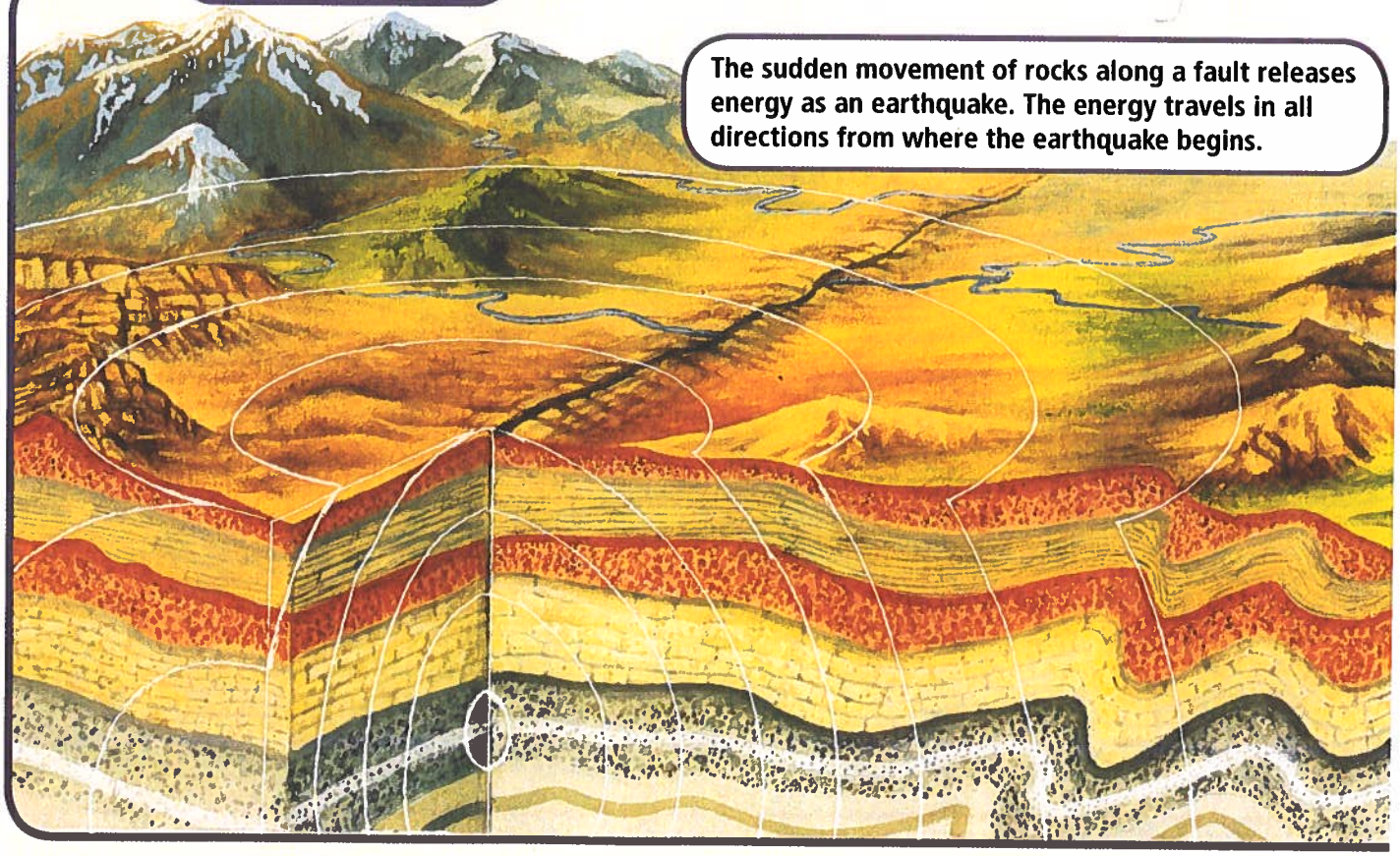
Earthquakes

Suppose you're holding a wooden ruler at both ends. If you put pressure on both ends at the same time, the ruler will bend slightly. If you press very hard, the ruler will snap in two.

Earth's plates behave in a similar way. Under pressure, they bend. When the pressure is great, the rocks that make up a plate break. When the rocks break, a fault is formed. A **fault** is a break in Earth's crust where rocks can slide past each other. Most faults form along plate boundaries because the pressure there is great. However, faults can also form within a plate, far from the edges.

As Earth's plates move, pressure builds up along the plates' faults. The rocks along the faults bend or stretch, almost like rubber bands. And again like rubber bands, if the rocks stretch too far, they will snap and energy will be released as they suddenly slide past each other. The snap and slide of rocks as energy is released in Earth's crust is known as an **earthquake**.

Earthquakes



The sudden movement of rocks along a fault releases energy as an earthquake. The energy travels in all directions from where the earthquake begins.

Earthquakes can occur close to Earth's surface or very deep inside the crust or mantle. The point inside Earth where an earthquake begins is called the **focus**. The point on Earth's surface directly above the focus of an earthquake is the **epicenter**.

When an earthquake begins, the released energy travels away from the focus in waves. The fastest waves caused by earthquakes are primary waves, or *P waves*. These are the first waves to be detected. P waves compress and expand the ground as they travel. Their movement is similar to an accordion's movement. The second-fastest waves caused by an earthquake are secondary waves, or *S waves*. S waves move across the direction in which the P waves are traveling. They can move up and down or side to side.

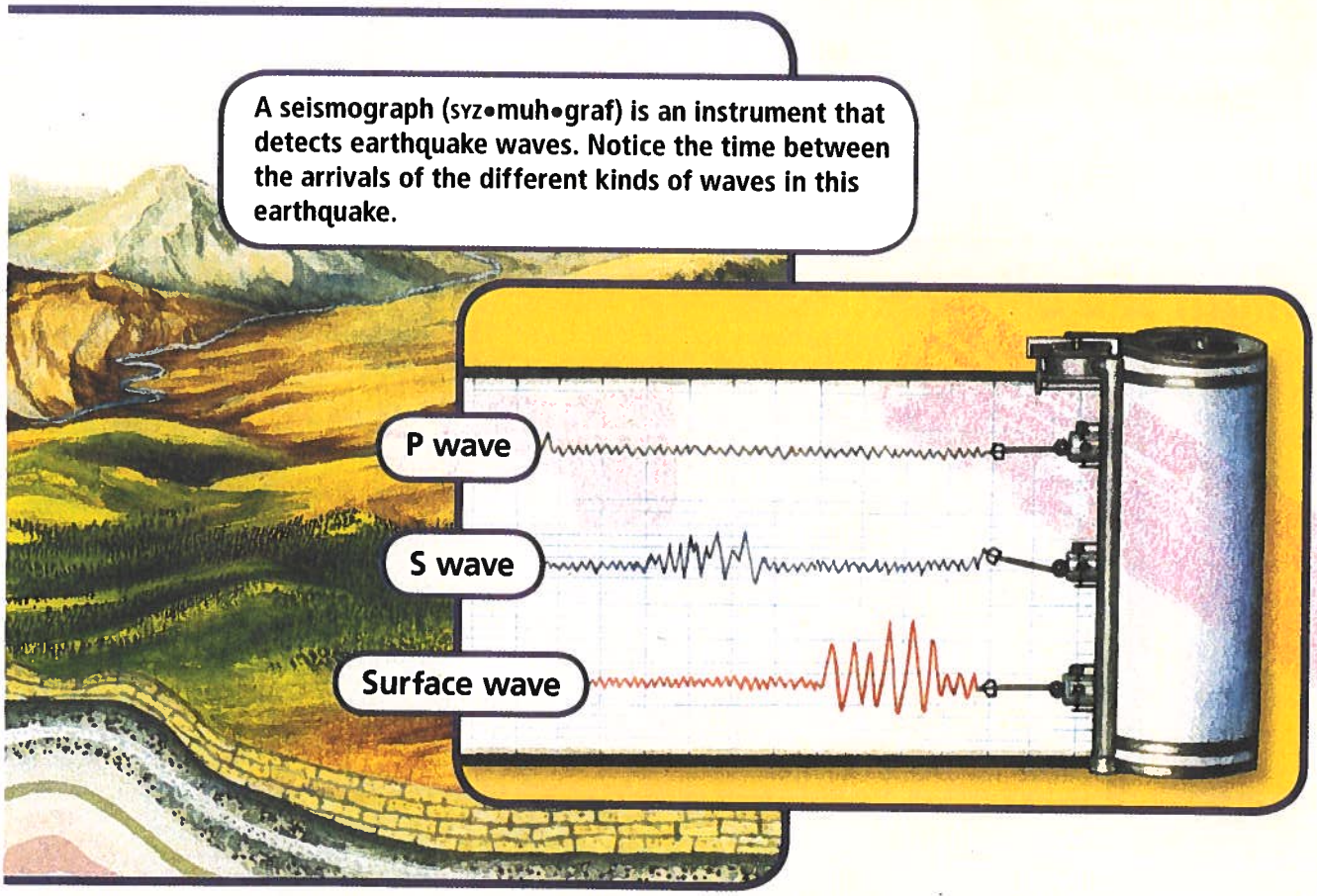
Both P waves and S waves travel through the Earth's interior. In addition, a third type of wave called a *surface wave* travels along Earth's surface. Some surface waves shake the ground from side to side. Other surface waves roll across the land like ocean waves. Both of these types of surface waves cause most of the damage that is done to buildings during an earthquake.

Focus Skill **CAUSE AND EFFECT** **What causes an earthquake?**

Insta-Lab

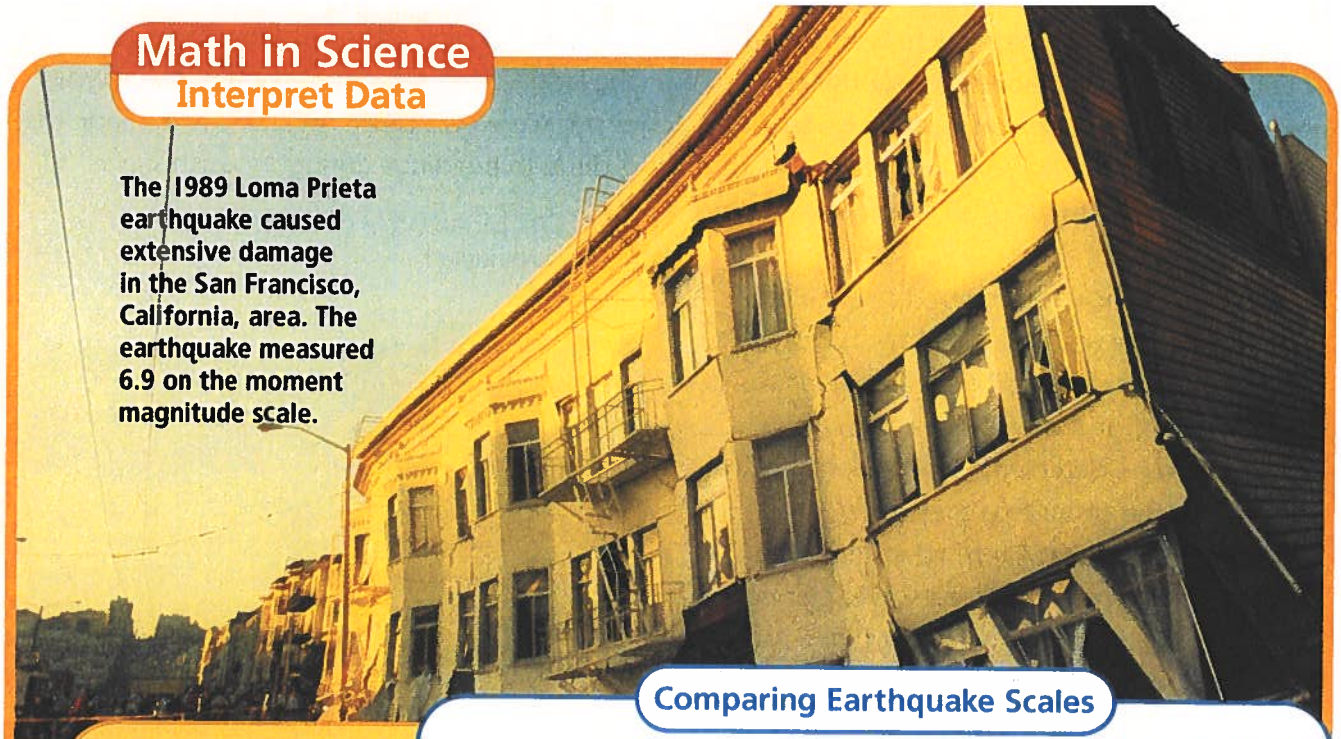
Making Waves

Hook one end of a spring toy to the knob of a closed door. Hold the other end of the spring toy in your hand, and walk backward until the spring doesn't sag much. Quickly jerk your hand toward the door and back toward you. What type of wave did you just model? Now jerk your hand up and down once. What type of wave did you model with this movement?



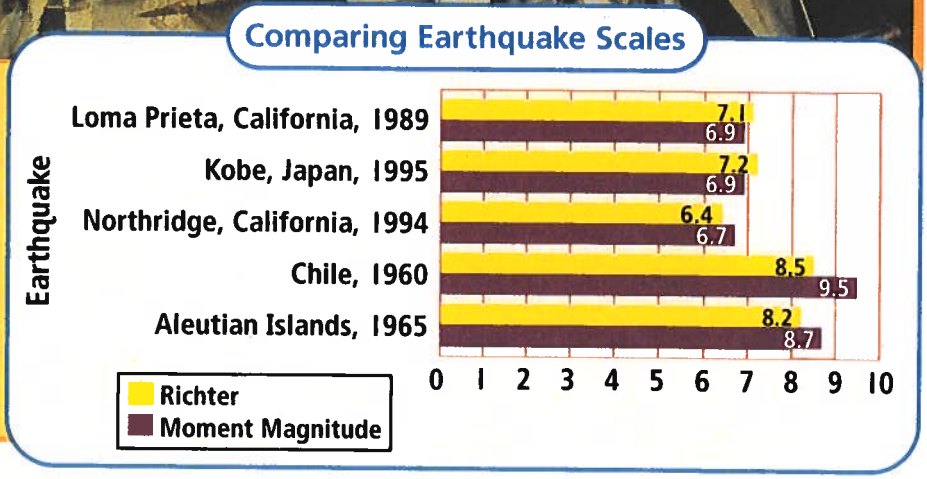
A seismograph (SYZ•muh•graf) is an instrument that detects earthquake waves. Notice the time between the arrivals of the different kinds of waves in this earthquake.

Math in Science
Interpret Data



The 1989 Loma Prieta earthquake caused extensive damage in the San Francisco, California, area. The earthquake measured 6.9 on the moment magnitude scale.

Examine the graph comparing the Richter scale with the moment magnitude scale. Why is the moment magnitude sometimes higher and sometimes lower than the Richter magnitude?



Measuring Earthquake Strength and Damage

Seismographs electronically measure and record the motion caused by an earthquake's energy waves. As you saw in the Investigate, data from seismographs can be used to find an earthquake's location. The time that elapses between the arrival of P waves and S waves at different seismographs is recorded. The more time that elapses, the farther away is the earthquake's epicenter.

Seismographs can also be used to measure an earthquake's strength. In 1935, Charles Richter developed a scale that uses the size of waves recorded on a seismograph to determine how strong an earthquake is. This scale, called the Richter scale, estimates the amount of energy released by an earthquake. On the Richter scale, an earthquake with a magnitude of 2.0 is considered very minor. An earthquake with a magnitude of 4.0 can be felt, but it causes only minor damage. And an earthquake with a magnitude of 6.0 or greater can cause major damage.

Based on seismograph records, the Richter scale only indirectly measures the strength of an earthquake. But scientists have developed a new scale called the *moment magnitude scale* that is not based on seismograph readings. Instead, the energy released during an earthquake is

calculated from measurements of the distance that the rock moved along the fault. The numbers for an earthquake's magnitude on the moment magnitude scale are very similar to the numbers on the Richter scale. However, the moment magnitude scale is considered much more accurate.

Both the Richter scale and the moment magnitude scale measure an earthquake's strength, not the amount of damage it caused. A scale that does measure an earthquake according to the damage is the Mercalli intensity scale. This scale uses Roman numerals. A rating of I to III indicates very minor damage. A rating of IV to VI indicates slight damage. Ratings higher than this indicate that buildings in the area had moderate to heavy damage. A rating of XII indicates that most buildings in the area were completely destroyed.

An earthquake can cause damage to an area even if its epicenter is not nearby. If a powerful earthquake occurs beneath the ocean, it will cause the ocean floor to rise and fall. The effect will be movement of the water above the floor. This may lead to the formation of a large wave called a *tsunami* (tsoo•NAH•mee).

A tsunami can travel great distances. As it approaches land, it may be more than 30 m (100 ft) high. The giant wall of water then slams into the coast. Large tsunamis have been known to carry water hundreds of meters inland. The force of the water is strong enough to cause massive damage to buildings near the shore. It also causes erosion and can even strip the sand from a beach completely.

Focus Skill **CAUSE AND EFFECT** **What are the effects of a tsunami?**

This illustration shows the way a tsunami forms as the result of an earthquake. Notice the buildup of the wave as it nears shore.

▲The city of Banda Aceh, Indonesia, was photographed in June of 2004.

On December 26, 2004, a massive earthquake occurred beneath the Indian Ocean. The earthquake generated a tsunami that battered the city. This photograph shows the same area of Banda Aceh shortly after the wave devastated the city. ▶

Volcanoes

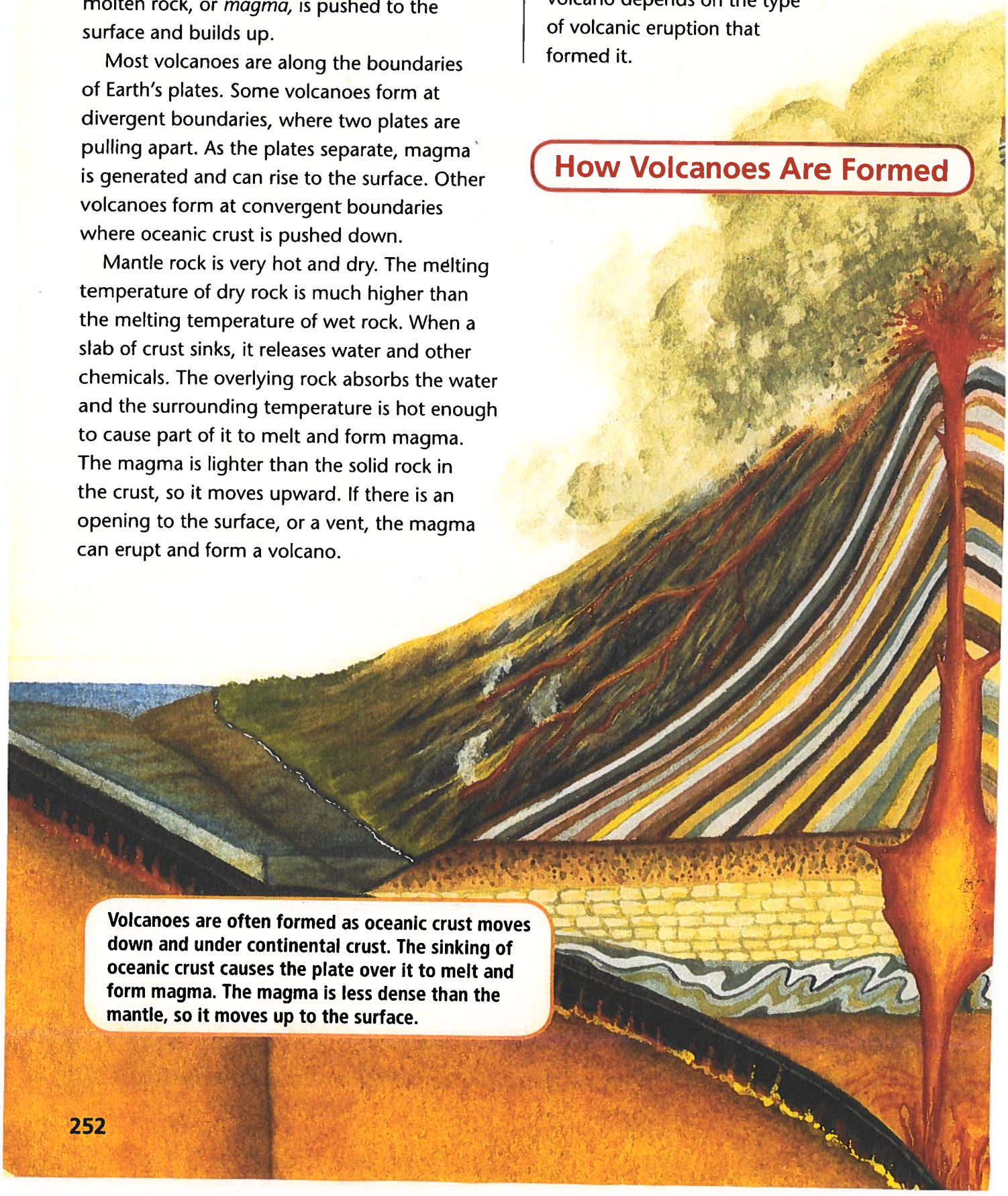
You've learned that mountains form when rocks at convergent boundaries are deformed and lifted. But some mountains form in another way. Mountains called **volcanoes** form when molten rock, or *magma,* is pushed to the surface and builds up.

Most volcanoes are along the boundaries of Earth's plates. Some volcanoes form at divergent boundaries, where two plates are pulling apart. As the plates separate, magma is generated and can rise to the surface. Other volcanoes form at convergent boundaries where oceanic crust is pushed down.

Mantle rock is very hot and dry. The melting temperature of dry rock is much higher than the melting temperature of wet rock. When a slab of crust sinks, it releases water and other chemicals. The overlying rock absorbs the water and the surrounding temperature is hot enough to cause part of it to melt and form magma. The magma is lighter than the solid rock in the crust, so it moves upward. If there is an opening to the surface, or a vent, the magma can erupt and form a volcano.

There are many kinds of volcanoes formed from many kinds of materials. However, volcanoes fall into three basic categories: shield volcanoes, cinder cone volcanoes, and composite volcanoes. The type of volcano depends on the type of volcanic eruption that formed it.

How Volcanoes Are Formed



Volcanoes are often formed as oceanic crust moves down and under continental crust. The sinking of oceanic crust causes the plate over it to melt and form magma. The magma is less dense than the mantle, so it moves up to the surface.

Shield Volcano

Shield volcanoes are broad, slightly dome-shaped volcanoes. They may erupt many times in a period of more than a million years.

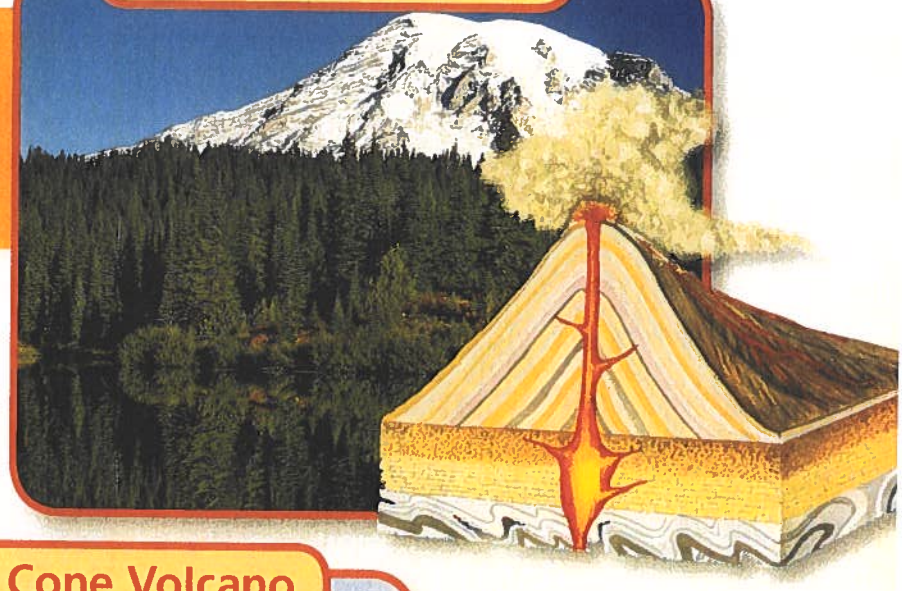
Volcanoes can erupt explosively, with materials being thrown violently out of the vent. Volcanoes can also erupt nonexplosively. The lava, or magma that reaches Earth's surface, flows slowly out of the vent almost the way honey flows out of a jar.

Nonexplosive eruptions form shield volcanoes as layer after layer of lava slowly builds up. Explosive eruptions form cinder cone volcanoes composed of ash and rock thrown out of the vent. Cinder cone volcanoes often erode quickly because their ash and rock are not cemented together by lava. The third type of volcano, the composite volcano, is formed by a mixture of explosive and nonexplosive eruptions.

Focus Skill **CAUSE AND EFFECT** **What causes a volcano to form?**

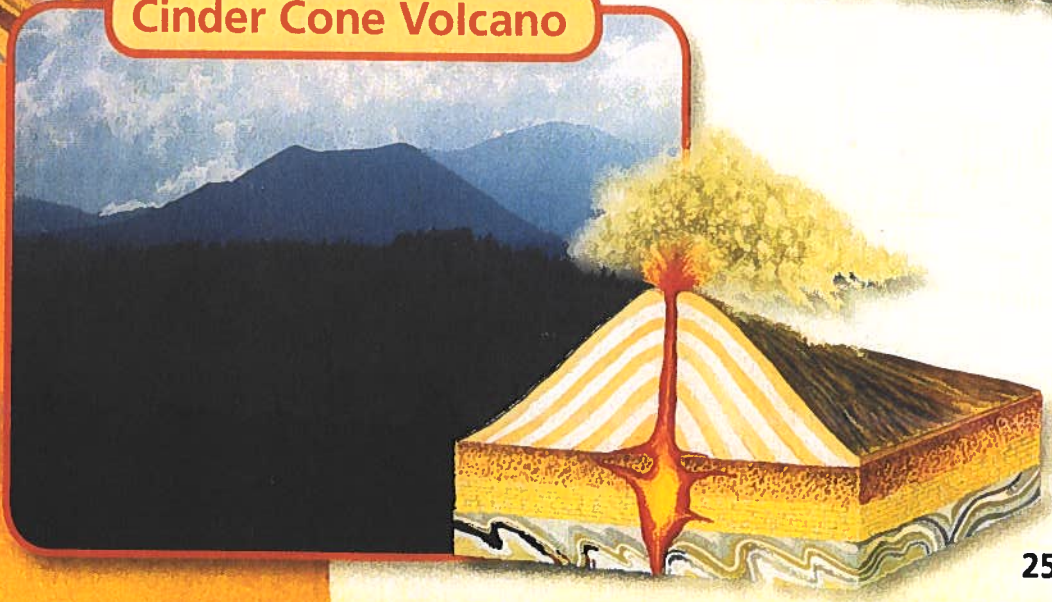
Composite Volcano

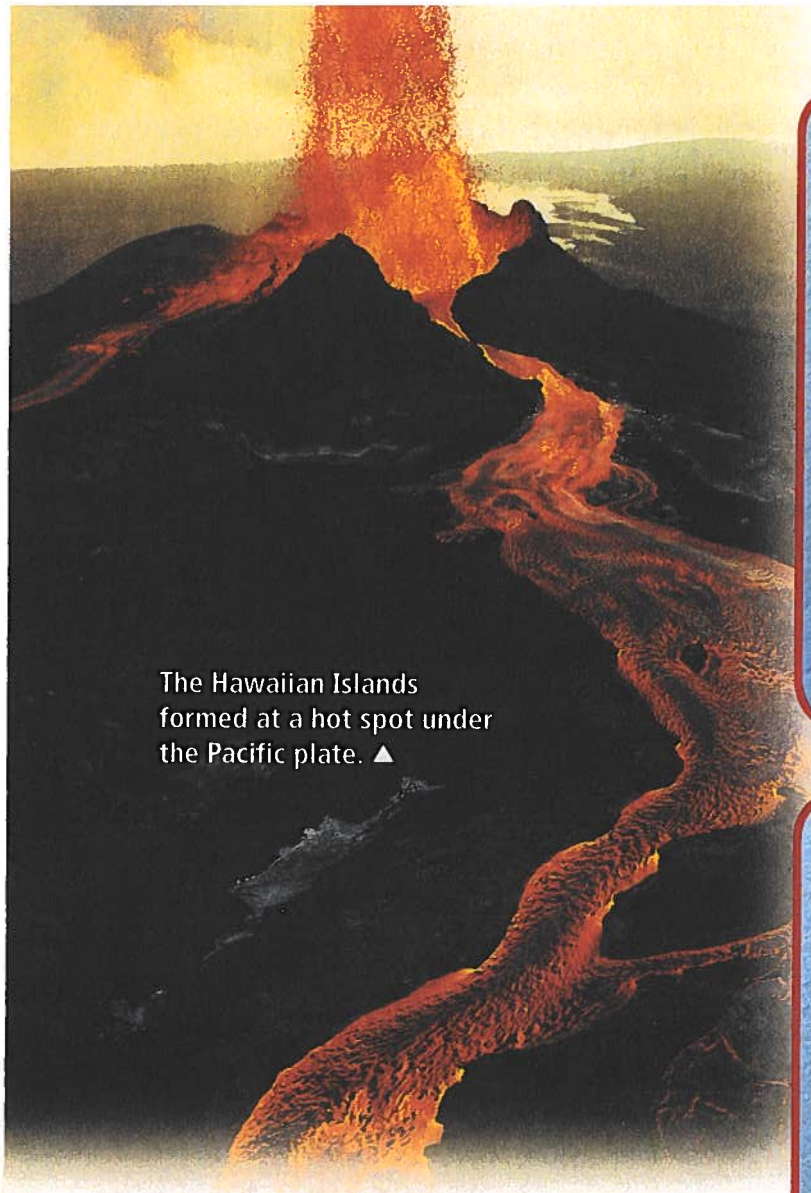
This is a composite volcano. Like shield volcanoes, these may erupt on and off for as long as a million years.



Cinder Cone Volcano

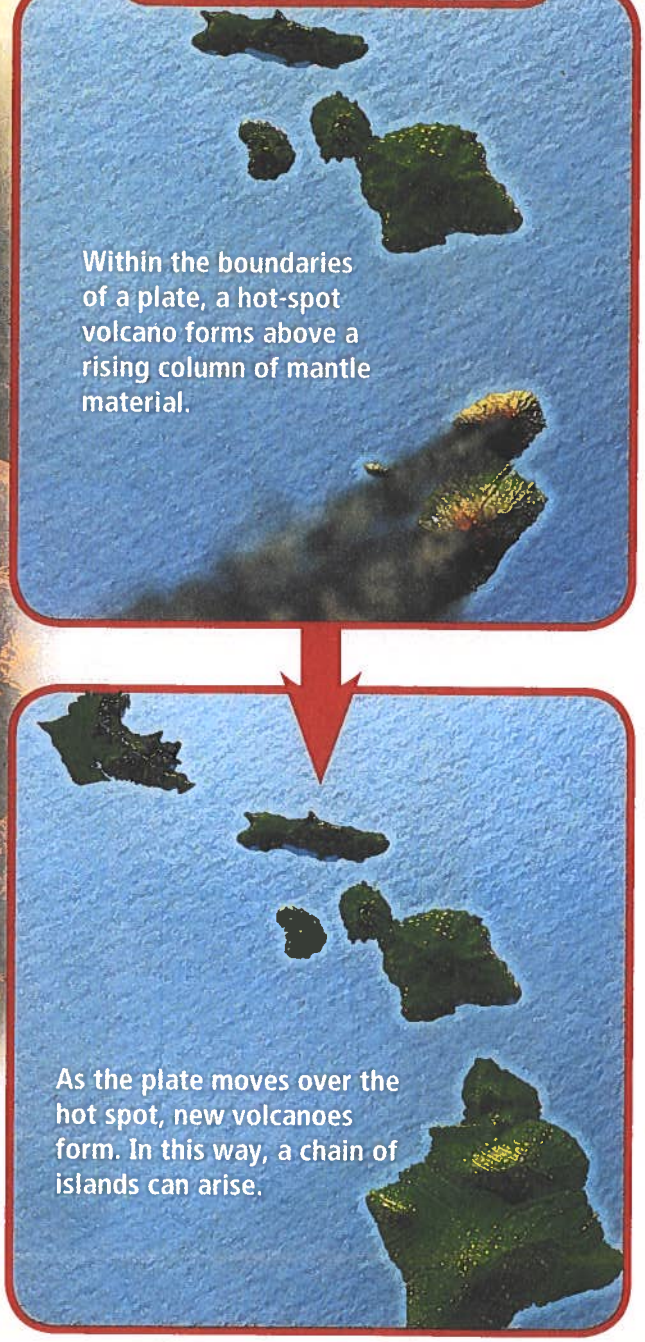
Cinder cone volcanoes have steep sides. They erupt for a short period of time, so most are not taller than about 300 m (1000 ft).





The Hawaiian Islands formed at a hot spot under the Pacific plate. ▲

Birth of an Island



Hawaiian Volcanoes

Not all volcanoes form at plate boundaries. Sometimes magma occurs under another area of a plate. The location of the magma is called a hot spot. The magma is less dense than the solid rock of the lithosphere, so the magma is pushed up toward the surface. If the magma erupts above the surface, it can form a volcano.

As the plate moves over the hot spot, the volcano that was formed stops erupting and a series of new volcanoes may form. If the hot spot lies under oceanic crust, the series of volcanoes may become a chain of islands.

That's how the Hawaiian Islands formed. The Pacific plate moved over a hot spot, and island after island rose up out of the water as magma flowed from inside Earth and hardened. If you look at a map, you can see that the Hawaiian Islands are in line with the northwest movement of the Pacific plate. The youngest island, Hawai'i, currently has three active volcanoes. One of these has been erupting continuously since 1983!

Focus Skill **CAUSE AND EFFECT** **What caused the Hawaiian Islands to form?**