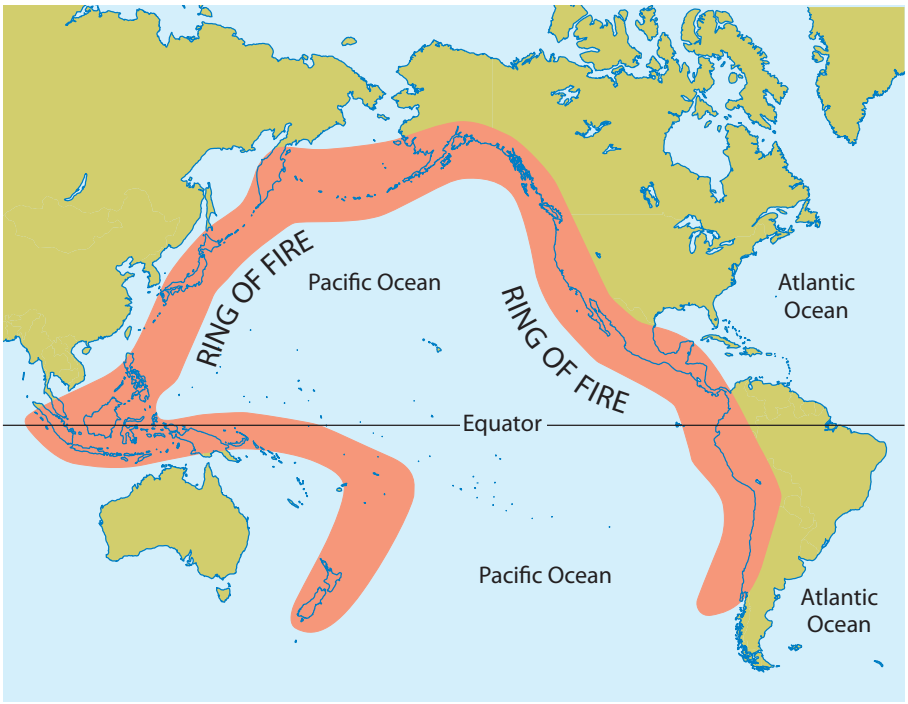
11 Understanding Plate Boundaries

READING

MANY OF THE world's most active volcanoes are located around the edges of the Pacific Ocean. People refer to this area as the "Ring of Fire," shown in the map below. About 90% of the world's earthquakes also occur in this region. These geological processes are caused by interactions between the plates at the plate boundaries that surround the Ring of Fire. Why do so many volcanoes and earthquakes happen at plate boundaries?

GUIDING QUESTION

How can our understanding of geological processes at plate boundaries allow us to predict and prepare for natural hazards?



Map showing the Ring of Fire, an area with frequent volcanic eruptions and earthquakes

MATERIALS

For each student

1 Student Sheet 11.1, "Directed Reading Table: Understanding Plate Boundaries"

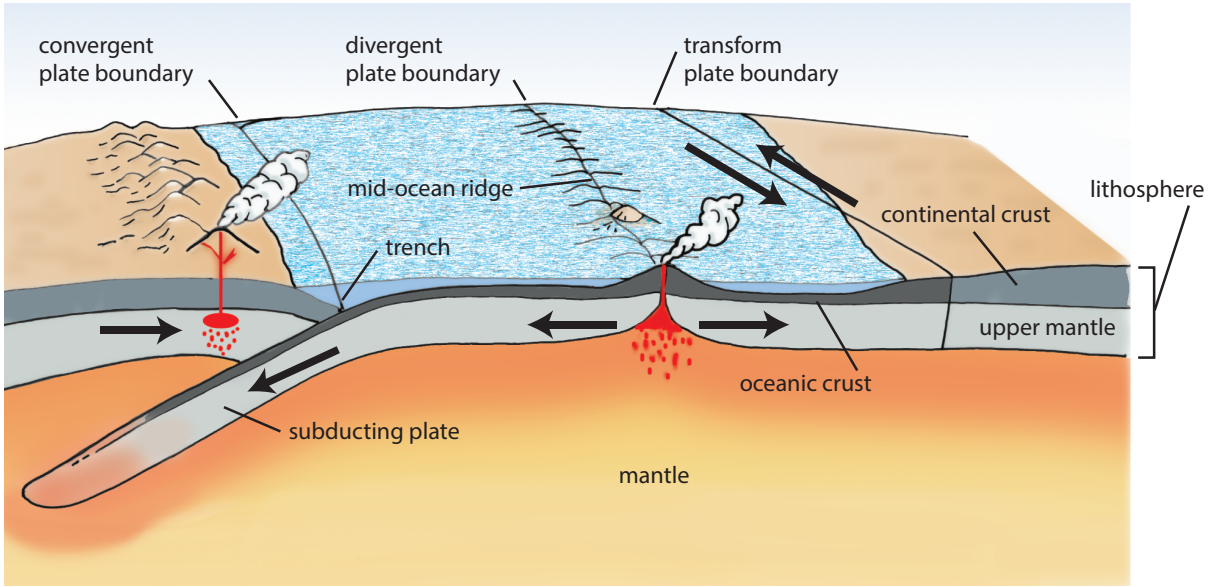
PROCEDURE

1. Read the article with a partner.
2. After you read each section, use evidence from the text to complete Student Sheet 11.1 for that plate boundary.

READING

Earth's lithosphere is broken into plates that are in constant motion. The plates may be moving apart, or moving towards each other, or moving past each other. Over geological time, important geological processes—such as the formation of mountain ranges, earthquakes, and volcanoes—take place along the boundaries where lithospheric plates meet.

Types of Plate Boundaries

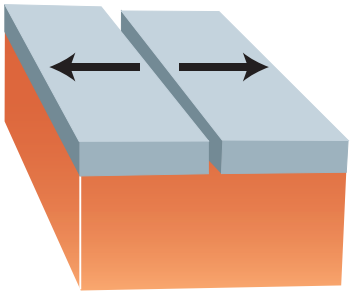


Plates That Move Away From Each Other

Geologists call a region where two plates are spreading apart a **divergent** (dy-VER-junt) **plate boundary.** Volcanoes as well as earthquakes are common along divergent plate boundaries. As the plates move apart, the lithosphere thins and lava erupts onto the surface.

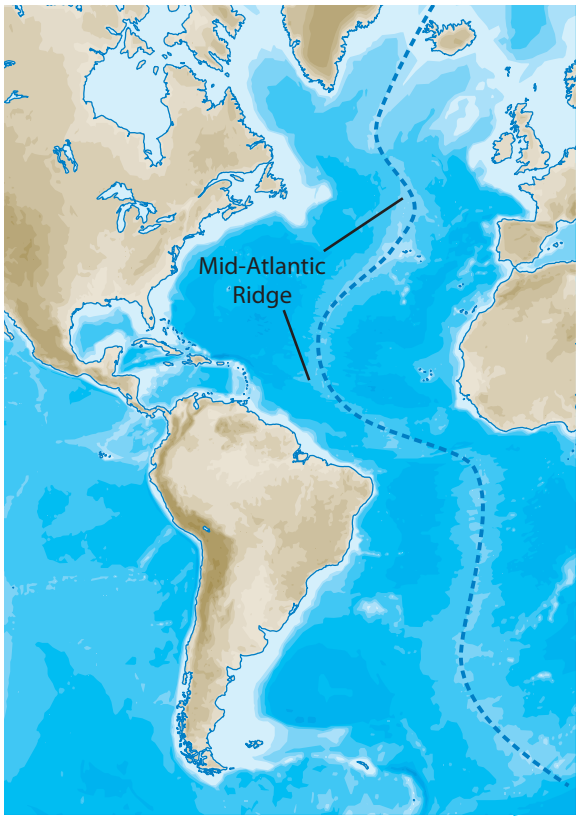
New lithosphere forms as the lava cools and solidifies to form igneous rock. (See the figure on the previous page.)

Often, divergent plate boundaries are under the ocean. Large underwater volcanic mountain chains that form along divergent plate boundaries are called **mid-ocean ridges.** One of the largest mid-ocean ridges is the Mid-Atlantic Ridge. This ridge is between the North American and Eurasian plates in the middle of the Atlantic Ocean.

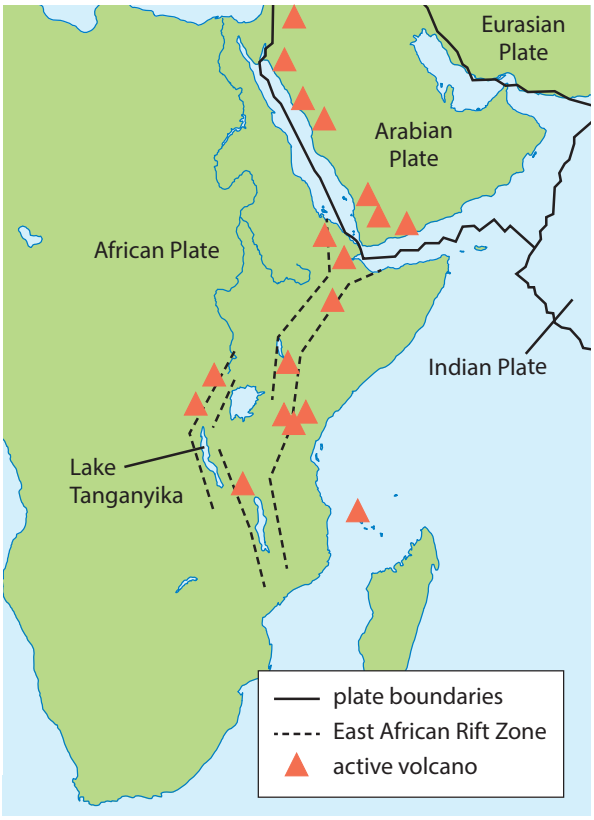


Plates moving away from each other

When the plates move away from each other at divergent plate boundaries, a rift valley forms. A rift valley is a long depression between mountains that forms due to spreading plate movement. In rift valleys where there is active plate movement, earthquakes and volcanoes are common. In 2005, a large earthquake happened near Lake Tanganyika in Africa. This earthquake was caused by divergent plate motion where two sections of the African plate are moving away from each other.

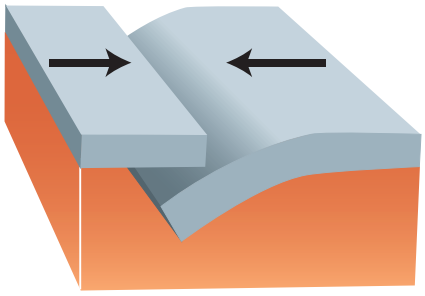


The Mid-Atlantic Ridge stretches from the Arctic Ocean to the Southern Ocean.



The East African Rift Zone is a region where sections of the African Plate are moving away from each other.

Plates That Move Toward Each Other



Plates moving toward each other

Geologists call a region where two plates are moving towards each other a **convergent** (kun-VER-junt) **plate boundary.** The geological processes that happen along a convergent plate boundary depend on the type of lithosphere at the edge of the colliding plates. Earth's lithosphere—which includes the crust and solid upper mantle—varies in thickness and density over Earth's surface. The crust that makes up the oceans is generally thinner than the crust that makes up the continents. Oceanic crust is usually about 10 km thick. Continental crust ranges from 20 to 80 km thick. For this reason, the lithosphere is about 100–150 km thick under the ocean and up to 300 km thick below some continents. Despite being thinner, oceanic lithosphere is denser than continental lithosphere because its crust is made up of denser rock, primarily basalt.

Subduction formed the Villarrica Volcano, a large stratovolcano in Chile.

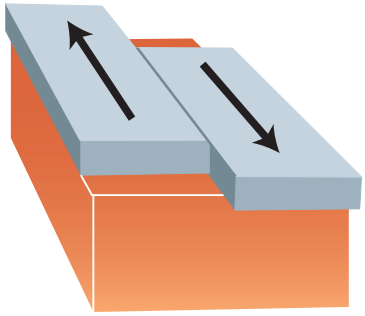
When two plates move towards each other, the denser plate sinks below the less-dense plate. When continental and oceanic lithosphere move towards each other, the denser oceanic lithosphere sinks into the mantle and is destroyed. The same process also happens when two oceanic lithospheric plates move towards each other – the denser plate sinks beneath the less dense plate. The process of one plate being pulled below another plate is known as **subduction** (sub-DUK-shun). Subduction forms a **trench** along the plate boundary. A trench is a deep, narrow depression on the sea floor. At a convergent plate boundary where subduction is occurring, volcanoes form on the surface of the overlying lithospheric plate. The volcanoes that form at convergent plate boundaries where continental and oceanic lithosphere move toward each other are typically *stratovolcanoes*—large volcanoes that erupt violently as a result of more-gassy magma.

The volcanic mountains along the western coast of South America formed by subduction. Oceanic lithosphere of the Pacific plate subducted below continental lithosphere of the South American plate. Subduction formed the Peru–Chile trench on the ocean floor along this boundary. Subduction is also happening in the Pacific Northwest of the United States. Oceanic lithosphere of the Juan de Fuca plate is being pulled under continental lithosphere of the North American plate.

When two plates of continental lithosphere move towards each other, they tend to crumple and are pushed upward. This motion can form very tall mountains and cause earthquakes. The Himalayan mountains formed when continental lithosphere on the Indian Plate met continental lithosphere on the Eurasian plate. Several of the world's highest mountains, including Mt. Everest, are part of the Himalayas and were formed in this collision.

Plates That Move Past Each Other

Geologists call the region where two plates move past each other a **transform plate boundary**. Here, lithosphere is neither created nor destroyed. Earthquakes are common as the plates move past one another.



Plates moving past each other

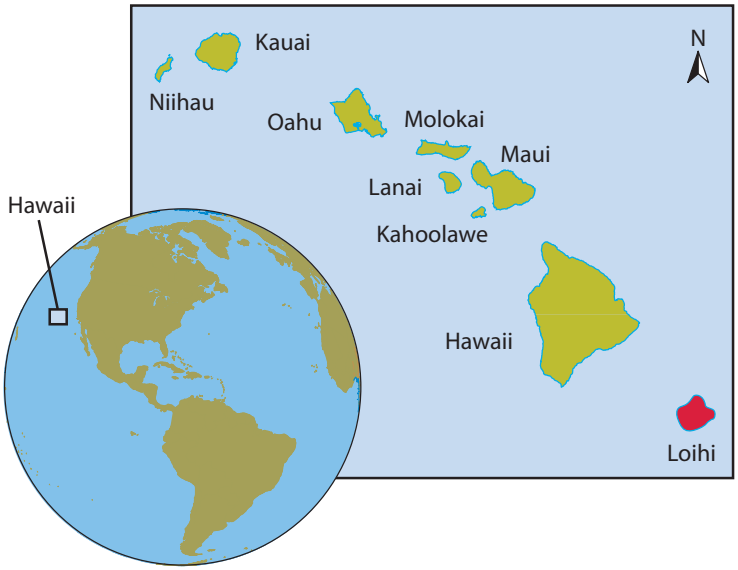
A transform plate boundary exists along the western edge of California. The boundary is between part of the Pacific plate and part of the North American plate. Plate motion causes many earthquakes along this boundary. Two powerful earthquakes happened along this boundary near San Francisco in 1906 and 1989. These earthquakes each lasted less than 1 min. But the ground-shaking and related natural hazards caused heavy damage to the city.

Damage to buildings in San Francisco after the 1906 Earthquake and the fires that followed

Damage to buildings in San Francisco after the 1989 Earthquake

Volcanoes and Plates

Most earthquakes and volcanoes occur along plate boundaries. But sometimes they form elsewhere. For example, volcanoes formed each of the Hawaiian Islands. Lava from eruptions over hundreds of thousands of years built up the islands. Yet the Hawaiian Islands are located far from any plate boundaries. Hawaii, the large island at the southeastern end of the island chain, is the only one of those islands that still has an active volcano.



The volcanoes that formed the islands are called *shield volcanoes*. They are typically large and broad in shape. These volcanoes release swift-moving lava. Because of the less-gassy magma, these volcanoes tend to have less explosive eruptions than other types of volcanoes. People can often safely walk near these erupting volcanoes.

A geologist uses a radar gun to measure how fast the lava is moving during an eruption on the Big Island of Hawaii.

A new island called Loihi [low-EE-Hee] has begun to form beneath the ocean southeast of the island of Hawaii. But don't start making vacation plans to visit Loihi just yet. Scientists predict it will rise above the ocean's surface in about 1 million years.

One argument about how the Hawaiian island chain formed suggests that molten material in a region called a *hot spot* rose to the surface from the deep mantle. According to this argument, movement of the Pacific plate carried each of the islands toward the northwest, away from the hot spot. Other arguments are based on the properties of plates. For example, volcanoes might form when thin or cracked areas of the lithosphere allow hot material from the upper mantle to break through.

The 2011 Earthquake and Fukushima Nuclear Accident in Japan

On March 11, 2011, a huge earthquake rocked Japan. This strong earthquake originated 70 km (43 miles) off the coast of the largest Japanese island, Honshu. This earthquake resulted from a nearby convergent plate boundary where the oceanic Pacific plate was subducting beneath a continental plate. The movement of the sea floor during the earthquake generated a large *tsunami* (tsoo-NAH-mee). A tsunami is a large wave that forms when an earthquake, volcano, landslide, or other event moves a large amount of water. The tsunami hit the coast of Japan soon after the earthquake. At its highest, the wave from the earthquake reached 38 m (125 feet).

The tsunami killed more than 15,000 people and injured over 5,000. It destroyed over 330,000 structures, including buildings, roads, bridges, and railways. The cost of the earthquake and tsunami damage has been estimated at hundreds of billions of U.S. dollars.

The earthquake and resulting tsunami led to a serious accident at a nuclear power plant. The reactor was built to withstand the ground-shaking and it did. However, the seawater from the tsunami caused problems with the electrical power and the back-up generator, which caused the cooling system to fail at three of the six nuclear reactors at the Fukushima Daiichi

power plant on Honshu. The reactors overheated, causing a nuclear fuel meltdown and explosions. Several workers died, and more were exposed to radiation. This incident released radioactive material into the air and water surrounding the plant. The long-term effects of the radiation released to the environment are not yet known. The greatest fear is that exposure to radiation will lead to increased deaths from cancer.

Although nuclear waste does not explode, the accident in Japan has increased concern in the United States and elsewhere about all aspects of nuclear safety.

A damaged building at the Fukushima Daiichi nuclear power plant 1 year after the earthquake and tsunami

ANALYSIS

1. Describe two ways in which the movement of lithospheric plates can result in the formation of mountains.
2. Trenches form at convergent plate boundaries, whereas mid-ocean ridges form at divergent plate boundaries. How are these landforms similar and different?
3. Should nuclear waste be stored deep underground near plate boundaries? Explain your ideas using evidence from this activity.