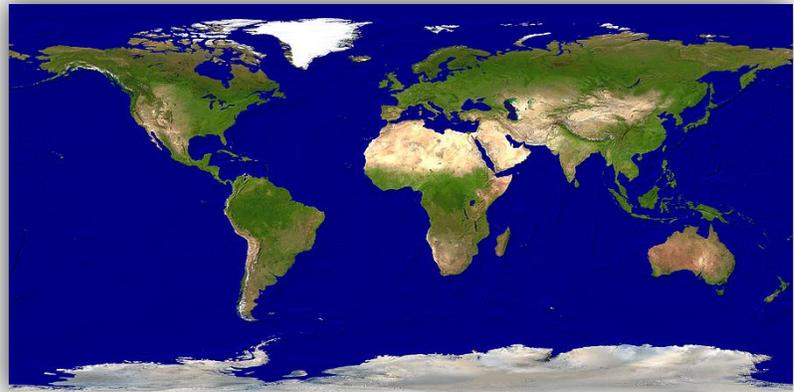


Reflect

Have you ever looked at a world map and noticed the shapes of the continents? Have you ever noticed how some continents appear to fit together like the pieces of a jigsaw puzzle? Why do you think this is? Is it just a coincidence, or do you think it suggests something important about the history of our planet?

Continental Drift

If you've ever noticed how the continents appear to fit together like a jigsaw puzzle, you're not alone. In the early 20th Century, a German scientist named Alfred Wegener noticed this phenomenon. Wegener hypothesized that at one or more points in Earth's history, the continents were connected.

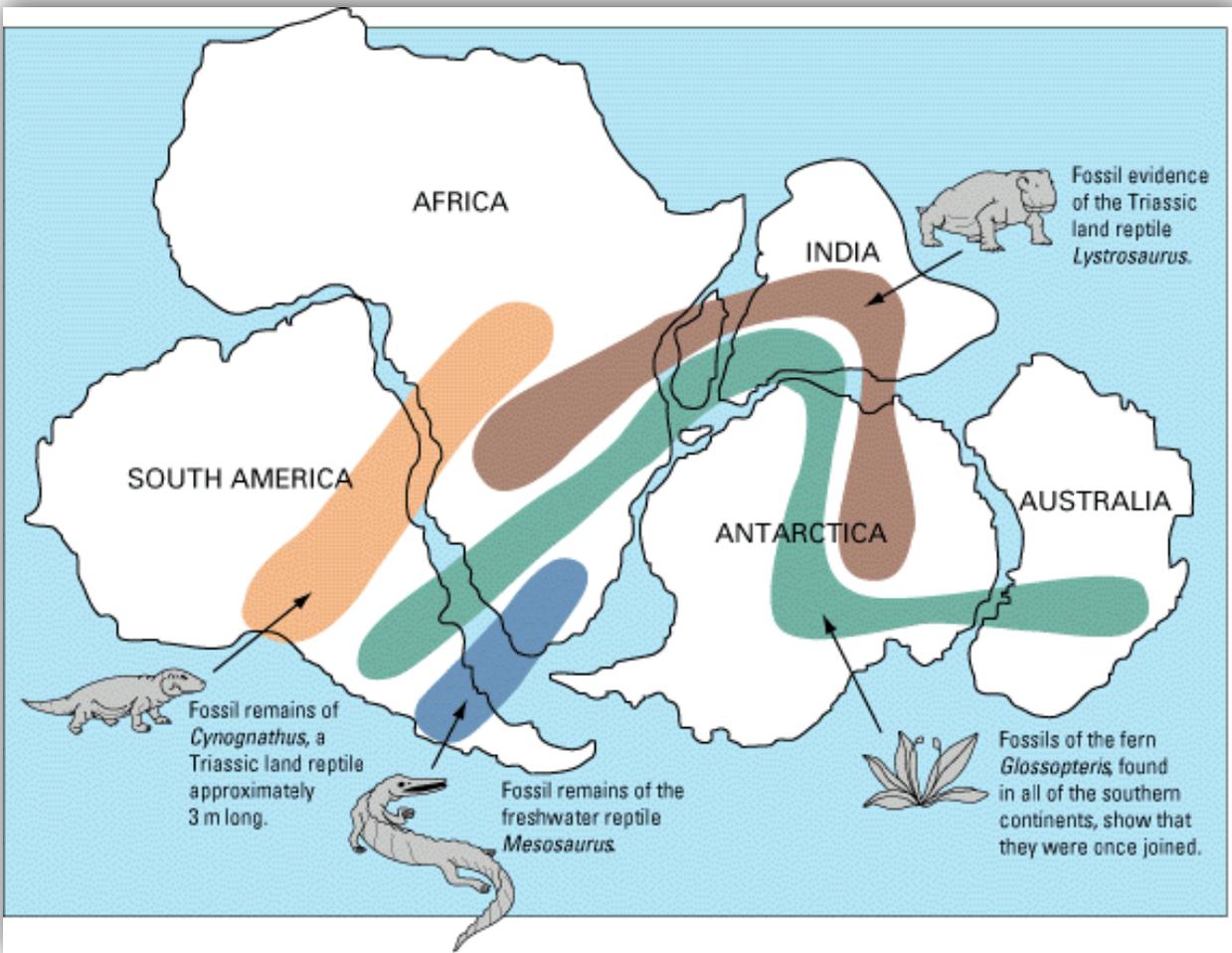


Notice how the continents appear to fit together, especially the eastern coast of South America and the western coast of Africa.

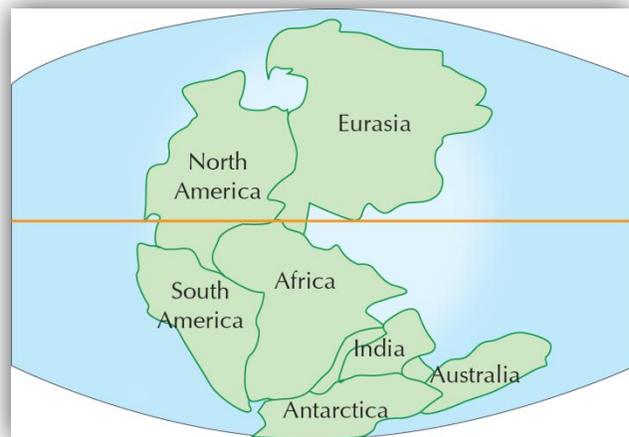
Wegener looked for further evidence that the continents may have once been connected. He looked for other connections between the matching coastlines. Where coastlines appeared to fit together, Wegener noticed that certain geologic formations also appeared to fit together. For example, a mountain range on one coastline appears to connect with a mountain chain on the opposite coastline. Several deposits of sediments left behind by glaciers also line up along the matching coastlines of continents.

In addition to geologic evidence, Wegener found fossil evidence that the continents may have once been connected. Fossils of a freshwater reptile called *mesosaurus* were found on both the eastern coast of South America and the western coast of South Africa. It is highly unlikely these freshwater animals swam across the entire Atlantic Ocean while they were alive. Fossils of a land reptile called *lystrosaurus* were also found along matching coasts of eastern Africa, central India, and Antarctica. These land animals also could not have crossed the oceans separating these continents. Equally unlikely is the possibility that the same species evolved independently on multiple continents. Instead, Wegener reasoned the continents must have once been joined. As the continents moved apart, they took mesosaurs and lystrosaurs with them.

The diagram on the next page shows some of the fossil evidence that supported Wegener's hypothesis.



Wegener concluded from his findings that the continents must move over time. He called this hypothesis *continental displacement*. (Later scientists gave the process its more familiar name, continental drift.) At least once in Earth's history, the continents were connected in large land masses. These large land masses are called *supercontinents*. 250 million years ago, *all* the continents were connected in one giant supercontinent. Wegener named this supercontinent *Pangaea*, which means "all Earth."



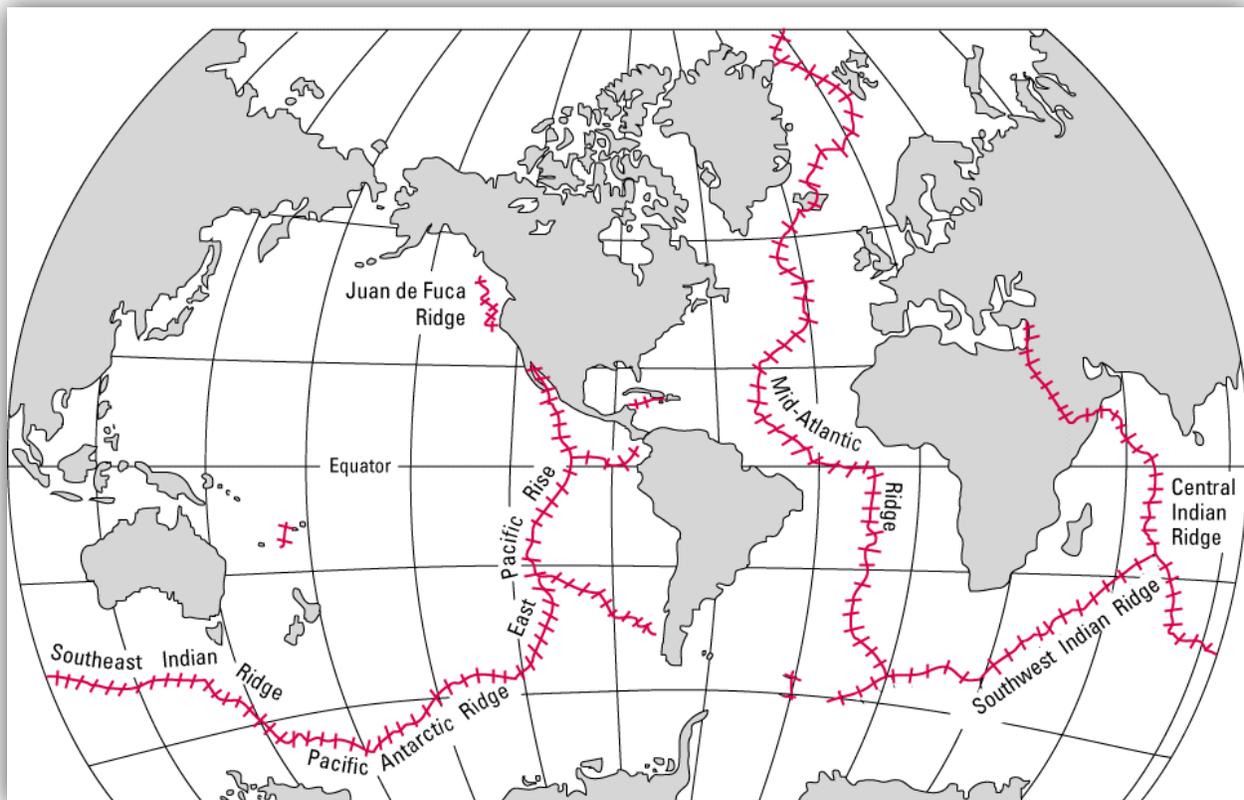
All of Earth's continents were once joined in a supercontinent called Pangaea.

Despite the evidence Wegener collected, he could not provide a theory explaining how the continents moved over time. Partly for this reason, his hypothesis was initially rejected by the scientific community. Then in the 1940s, scientists discovered new evidence suggesting how continents drift. Unfortunately, Wegener did not live to see his work validated. He froze to death on an expedition across the Greenland ice cap trying to prove his hypothesis.

Studying the Ocean Floor

There were many advances in ocean exploration technology in the 1940s and 1950s. This led to new information about the ocean floor. Scientists began to realize the **crust** beneath oceans is not as old as the crust beneath continents. They also learned the ocean floor is not flat and barren. Instead, it contains many topographic features. In fact, one of the largest mountain ranges in the world is at the bottom of the ocean. This mountain range, the *mid-ocean ridge*, is made up of two parallel mountain chains separated by a central valley. It is 50,000 kilometers long and an average of 4,500 meters tall. This map shows the different parts of the mid-ocean ridge.

crust: Earth's surface layer



Scientists discovered other information about the ocean floor as well. For example, sediments at the bottom of the ocean had been building up for a maximum of only 300 million years. If the ocean floor had not changed throughout Earth's history, these sediments would be about 4 billion years old. Similarly, the oldest fossils on the ocean floor are only about 180 million years old. Marine fossils buried in Earth's continents are thought to be much older. Scientists realized that some process must be destroying older sediments and fossils on the ocean floor. Because rocks and fossils on the continents are much older than those on the ocean floor, this process must affect oceanic crust differently than continental crust.

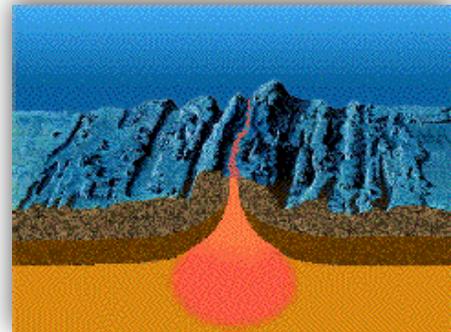
What Do You Think?

If oceanic crust is being destroyed, where do you think it goes? What happens to the crust after it is destroyed? Where does new crust come from? Think about these questions, then read on to learn the answers!

Scientists in the Spotlight: Harry Hess and Seafloor Spreading

Harry Hess was a geologist who served in the U.S. Navy during World War II. Hess used some of the Navy's ocean exploration technology to study the mid-ocean ridge and other ocean features. In the 1950s and early 1960s, Harry Hess used his research of the ocean floor to develop a hypothesis called seafloor spreading.

Seafloor spreading is a phenomenon by which magma from Earth's *mantle*—the layer beneath the crust—wells up between the central valley of the mid-ocean ridge. When the magma pushes up through the center of the mid-ocean ridge, it forces the ocean floor apart. This breaking apart of the crust is called *rifting*. When the magma reaches the surface of the ocean crust, it cools and solidifies into igneous rock. This makes new oceanic crust in the center of the mid-ocean ridge. Hess also reasoned that older crust is destroyed as it sinks into deep ocean basins. Seafloor spreading explains why oceanic crust is younger than continental crust: oceanic crust is continually being recycled.



Seafloor spreading happens as molten rock from Earth's mantle forces its way through openings in oceanic crust. This pushes apart the ocean floor and causes Earth's crust to move.

Hess had better luck than Wegener. He lived long enough to see his hypothesis validated by further scientific evidence and accepted by the scientific community. In the process, Hess finally provided the explanation that Wegener lacked for his

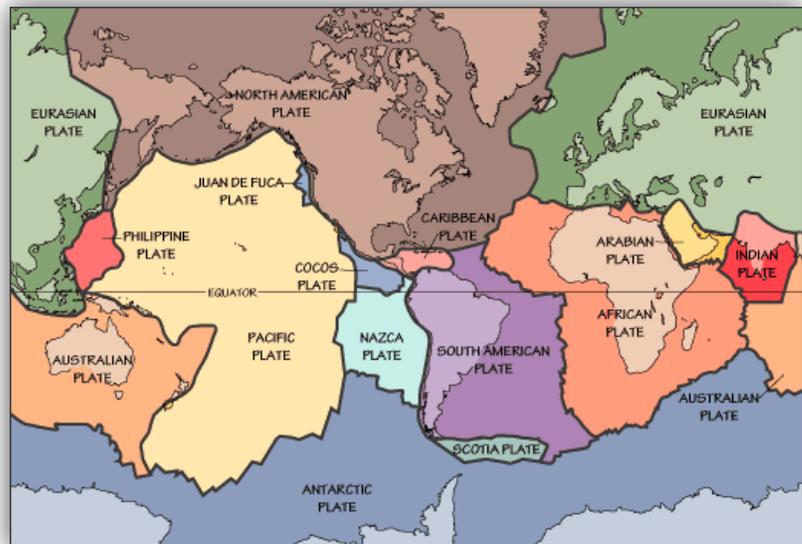
continental drift hypothesis. Continents are dragged along Earth's surface by the motion of oceanic crust as it is recycled.

The Theory of Plate Tectonics

By the 1970s, scientists had learned enough about how Earth's crust moves to develop a comprehensive theory. This theory, called *plate tectonics*, states that Earth's solid, rocky **lithosphere** is broken into pieces called *tectonic plates* (also known as *lithospheric plates*). Where tectonic plates consist of oceanic crust, they are denser. Where tectonic plates consist of continental crust, they are less dense.

lithosphere: the layer of Earth consisting of the crust and upper-mantle

As tectonic plates move, they rub against each other. These movements cause earthquakes. Tectonic plate movements also create openings in Earth's crust where magma can reach the planet's surface; we call these openings *volcanoes*. By mapping the locations of earthquakes and volcanoes, scientists have been able to locate the boundaries of Earth's tectonic plates. This map shows the names and locations of Earth's major tectonic plates, as well as some minor plates.



Earth's major tectonic plates include the African plate, Antarctic plate, Eurasian plate, Indo-Australian plate, North American plate, South American plate, and Pacific plate.

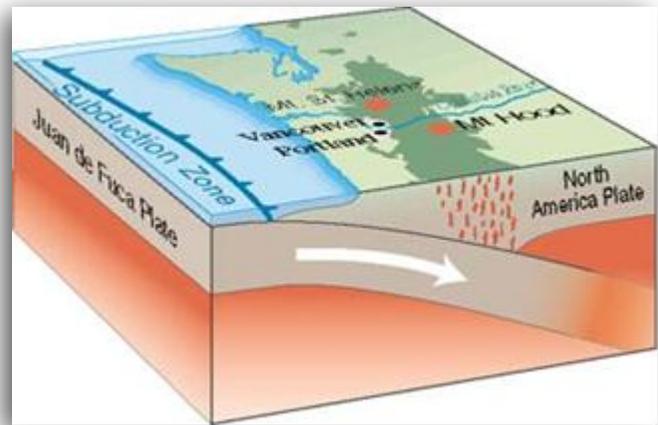
Look Out!

Continental crust is less dense than oceanic crust, so it floats higher as it moves around Earth's surface. All tectonic plates float on Earth's *asthenosphere*, the soft upper layer of the mantle just below the lithosphere. The asthenosphere is solid, yet soft enough to flow. This property is called *plasticity*. Plasticity allows the asthenosphere to flow like dough or putty. Tectonic plates are less dense than the soft material of the asthenosphere, so they float on top of it.

Tectonic Plate Boundaries

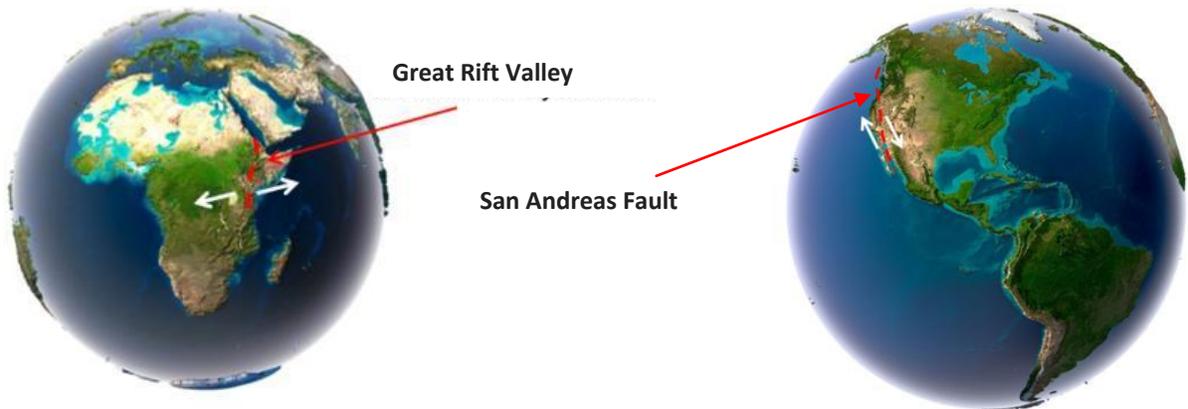
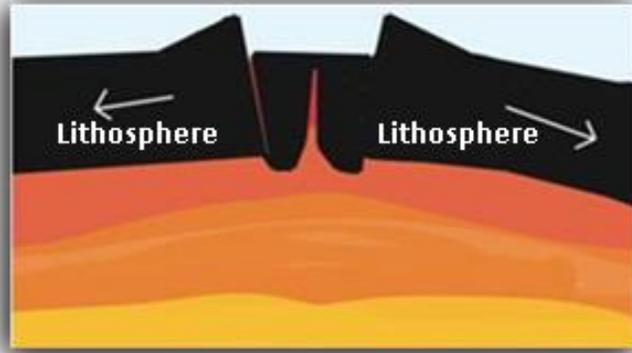
Tectonic plates are constantly moving at different rates and in different directions. They interact with each other in different ways. This results in different types of *tectonic plate boundaries*. Tectonic plate boundaries can be separated into the following three categories:

- **Convergent Plate Boundaries:** At these boundaries, tectonic plates move *toward* each other.
 - When plates of continental crust come together, they can push up the land over time. This can create large mountain chains, such as the Himalayas. These mountains were created millions of years ago when the Indo-Australian plate collided with the Eurasian plate.
 - When plates of oceanic crust come together, they can create a subduction zone. A *subduction zone* is a convergent boundary where the denser of the two plates is pushed beneath the other. Eventually, the denser plate is pushed far enough into the mantle that it begins to melt. Subduction zones also form where oceanic crust collides with continental crust. Because oceanic crust is denser, it is always subducted beneath continental crust at a subduction zone. Volcanoes are common around subduction zones as crust melts into magma. Subduction zones also create the deep ocean trenches where oceanic crust is destroyed.
- **Divergent Plate Boundaries:** At these boundaries, tectonic plates move *away from* each other.
 - This diagram on the next page shows a mid-ocean ridge: a type of divergent boundary between two plates of oceanic crust. Magma rises up between the plates, then cools to form new oceanic crust. The formation of new oceanic crust helps to further push the two plates apart.



At this subduction zone, the denser Juan de Fuca plate is forced beneath the North American plate. This collision formed the mountains and volcanoes of the Cascade Range in the Pacific Northwest.

- Continents can also be pulled apart by divergent boundaries. These are called *rift zones* or *rift valleys*. The Great Rift Valley in East Africa is formed by the motion of tectonic plates at a divergent boundary. Eventually, the plates will move so far apart that part of Africa will be separated from the rest of the continent.
- **Transform Plate Boundaries:** At these boundaries, tectonic plates slide horizontally past each other in opposite directions.
 - The San Andreas Fault cuts across the state of California. The San Andreas Fault is a transform boundary between the Pacific Plate and the North American Plate.
 - When tectonic plates slide against each other at transform boundaries, pressure builds up until the plates suddenly slip. This sudden release of pressure causes an earthquake. This release of pressure can also allow magma to come up from the mantle. This can sometimes result in a volcanic eruption.

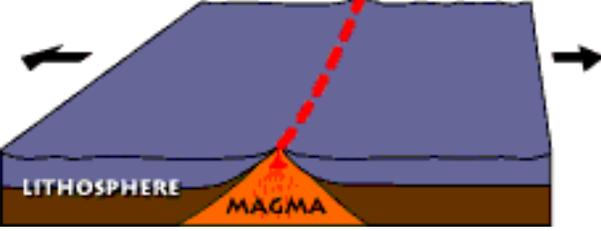
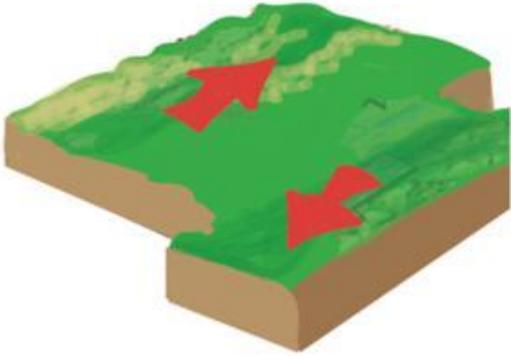
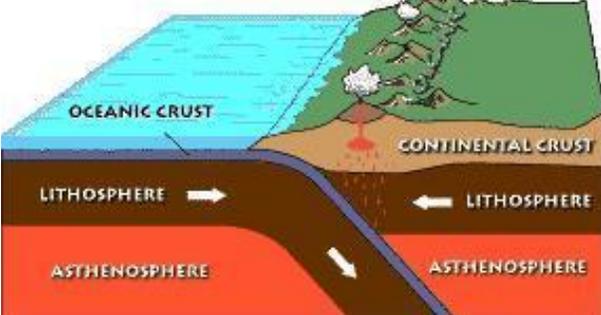


Satellite images have provided evidence for plate tectonics by showing the geologic features that form at the boundaries between tectonic plates. East Africa's Great Rift Valley (left) is so large it can be seen from space. The San Andreas Fault (right) is slowly pulling southern California and part of western Mexico away from the rest of North America.

What Do You Know?

The images on the next page show three different plate boundaries. Identify each boundary as convergent, divergent, or transform. Then, place these features or events beside the boundary type they're commonly associated with. (Some are commonly associated with several boundary types.)

- Mid-ocean ridge
- Subduction zone
- Earthquakes
- Mountain building
- Volcanoes
- Destruction of old crust
- Creation of new crust
- Fault

Boundary	Associated Features or Events
 <p>This is a _____ boundary.</p>	
 <p>This is a _____ boundary.</p>	
 <p>This is a _____ boundary.</p>	

Connecting With Your Child: Observing Convection Currents

Convection currents are the major driving force behind the movement of tectonic plates. To help your child visualize the convection process that drives tectonic plate motion, try doing this simple experiment together.

First, gather a bottle of food coloring and a large, clear glass container. **The container must be safe to heat on a stovetop.** Put the food coloring in the refrigerator for about 20 minutes. Next, fill the container about three-quarters of the way with room-temperature water. Place the container of water on a stove burner, but leave the stove off for the time being. Squirt a few drops of the cold food coloring into the container, instructing your child to carefully observe the way the cold food coloring sinks to the bottom of the container. **Do not stir the food coloring.** Once the food coloring has sunk to the bottom of the container, turn the stove to a very low temperature, just enough to warm the container slowly, but not enough to boil the water. Instruct your child to observe the movement of the food coloring in the water as it warms up. After a few minutes, turn the stove off again, and instruct your child to observe the movement of the food coloring in the water as it cools down again.

Here are some questions to discuss with your child:

- What happens when the cold food coloring is added to the room temperature water?
- What happens to the food coloring as the water warms up?
- What happens to the food coloring as the water cools down again?
- Is the material in the asthenosphere liquid like the water?
- Do you think the material in the asthenosphere moves as quickly as the food coloring in the water?
- How does this experiment relate to what you have learned about tectonic plate movement?