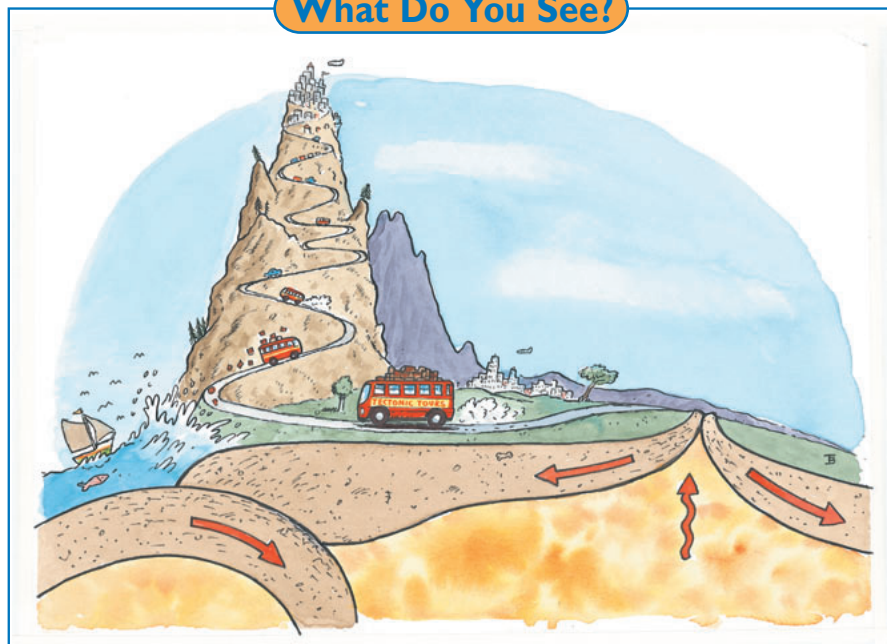


Section 4

Plate Motions and Plate Interactions

What Do You See?



Learning Outcomes

In this section, you will

- **Run** a model of a plate moving beneath another plate (subduction).
- **Describe** several lines of evidence for plate motion.
- **Classify** and label the types of movement at plate boundaries using a world map that shows relative plate motion.
- **Identify** the distribution of plates by means of the world map of relative plate motions.
- **Describe** the present plate tectonic setting of your community.

Think About It

Earth's crust is constantly being formed in some places and destroyed in others. Suppose you could take a ride on a lithospheric plate that was moving at a fast rate.

- Where do you think you would find the most “action” on Earth in regard to crust formation? Why?
- Where would be logical places to look for crust being destroyed? Why do you think that?

Record your ideas about these questions in your *Geo* log. Include sketches as necessary. Be prepared to discuss your responses with your small group and the class.

Investigate

In this *Investigate*, you will simulate (run a model that shows) what happens when one plate moves beneath another. You will also model what happens when plates move apart from one another at a spreading ridge. Finally, you will investigate different types of plate boundaries, including the one closest to your community.



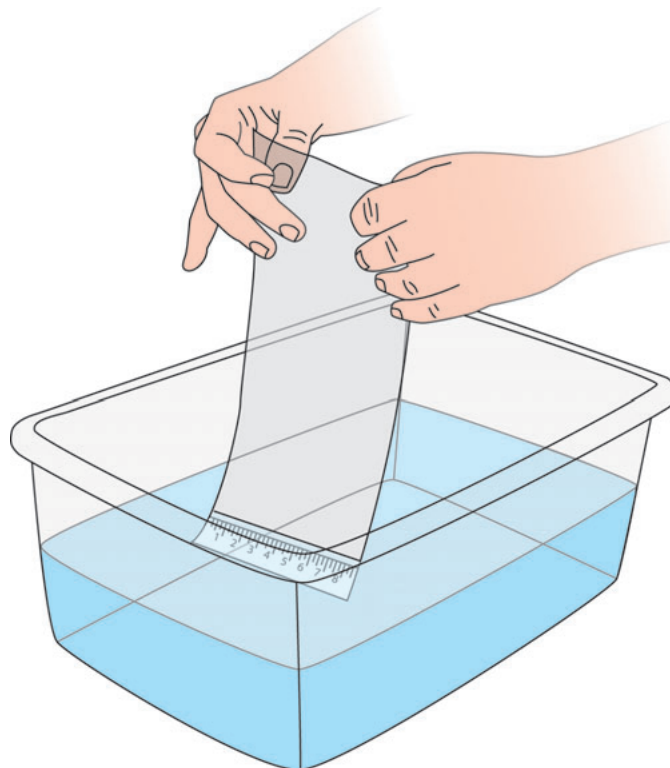
Part A: Forces Causing One Lithospheric Plate to Move Beneath Another (Subduction)

1. Partly fill a large, rectangular tub with warm water. Wait until any tiny air bubbles have disappeared. The water has to be perfectly clear.
2. Very slowly and carefully, put a few ounces of liquid dish detergent in the water and mix it slowly and carefully with a mixing spoon. If any soap bubbles remain on the water surface, scrape them off with a damp sponge.
3. Cut a piece of vinyl plastic to be about 15 cm wide and about 30 cm long. Trim a flat, clear plastic ruler with scissors to be the same width as the plastic sheet. (The ruler should sink in water.) Tape the ruler to one end of the plastic sheet.
4. Dip the ruler end of the plastic sheet into the water to a depth of about 1 cm. Immediately place the plastic sheet on the water surface. Do this by holding the ends up and letting the sagging middle part of the sheet touch the water surface first, to avoid trapping air bubbles under the sheet. Observe what happens. Repeat this step as many times as you need to make careful observations.

- a) Record your observations. Include a description of the motion of the plastic sheet in the water.
- b) What is the force that makes the plastic behave as it did?
- c) How does this demonstration show what happens in a place where one plate moves beneath another plate (*subduction zone*)?



Keep your work area clean and dry. Have paper towels ready for the wet plastic that is taken out of the tub.

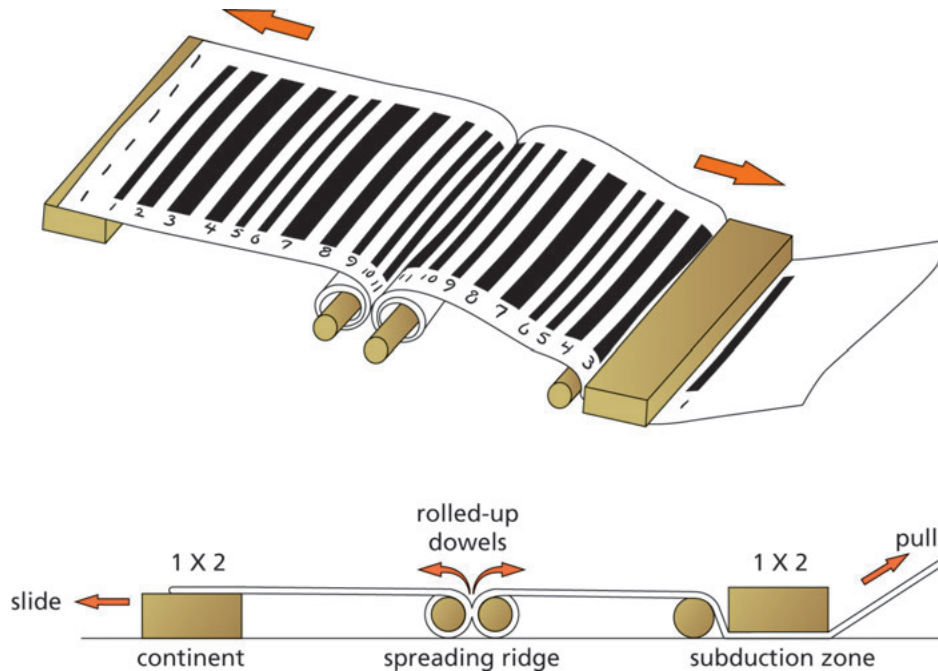


Part B: Modeling Plate Motions and Plate Interactions

1. Obtain the equipment shown in the diagram below.
2. Use the equipment to model a steady seafloor spreading and subduction, as follows. One student holds the two rolled-up dowels in one place, loosely, so that they can turn but not shift their position. Another student holds the stapled piece of 1" × 2" lumber "continent" and pulls it away from the rolled-up dowels. A third student holds the dowel and piece of 1" × 2" lumber "subduction zone" at the other end loosely in place. A fourth student pulls the paper strip from under the piece of 1" × 2" lumber "subduction zone." Be

sure to unroll the paper strips at the same rate, so that the numbers of the stripes stay matched up as they appear.

- a) What do the rolled paper strips on the dowels represent?
- b) What does the section of paper between the dowels and the continental lithosphere (the piece of 1" × 2" lumber) represent?
- c) What happens to the length of this section of paper as the dowels are unrolled?
- d) As the dowels are unrolled, what happens to the width of the section of paper between the dowels and the subduction zone (the other piece of 1" × 2" lumber)?

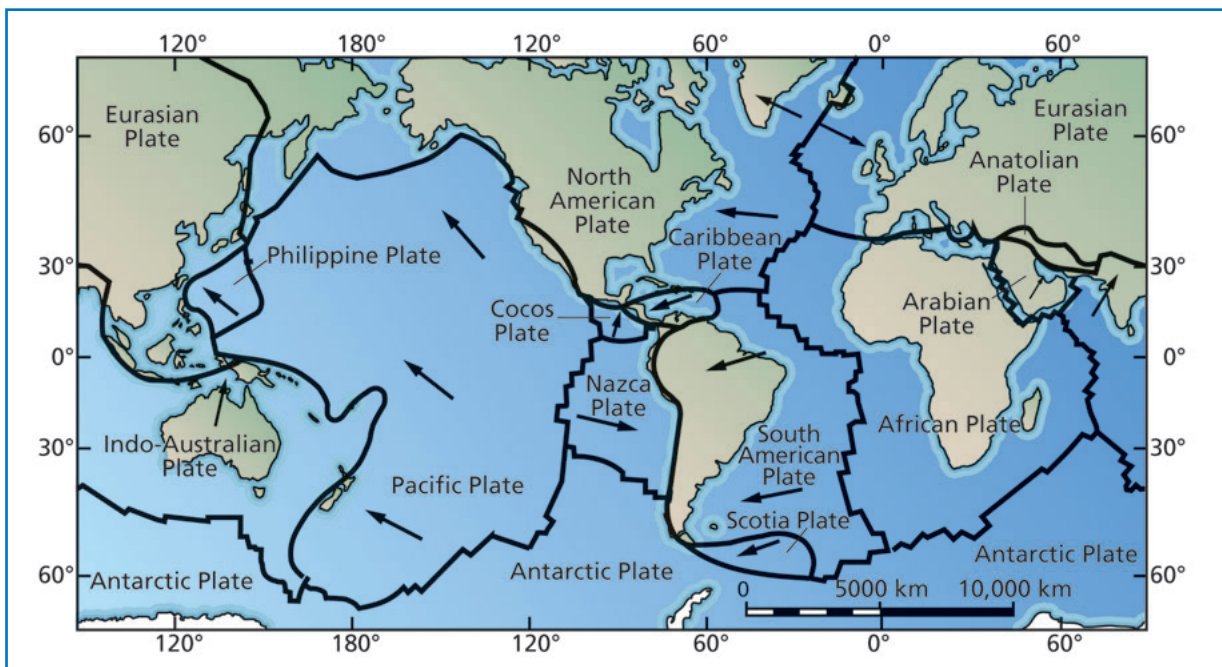









3. Use the equipment to model a collision of a spreading ridge and a subduction zone, as follows: Begin with the materials arranged in the same way as at the end of *Step 1*. While two students pull the paper strips to unwind the two rolled-up dowels, the student holding those dowels slides them slowly toward the subduction zone. The student operating the subduction zone needs to make sure that the stripes appearing at the spreading ridge continue to have their numbers matched up.
 - a) What happens to the length of the strip of paper between the dowels and the “continent” side in this situation?
 - b) What happens to the length of the strip of paper between the dowels and the “subduction zone”?
 - c) At what “place” does the spreading ridge eventually arrive?
4. Think about the following questions and write a brief answer to each in your *Geo log*.
 - a) In the first part of the modeling (*Step 2*), how long will the ocean on the “subduction” side last?
 - b) In the second part of the modeling (*Step 3*), what do you think would happen in real life when the spreading ridge arrives at the subduction zone?
 - c) In the second part of the modeling (*Step 3*), how would the ocean on the “continent” side change after the spreading ridge arrives at the subduction zone?
 - d) In both cases, what do you think would actually happen to Earth’s crust if a continent became blocked in its movement away from the spreading ridge by something happening on the other side of the continent?

Part C: Plate Boundaries on World Maps

1. Look at the following world map that shows the relative motion of the plates. Observe what it shows about how plates move relative to each other.






World map of major lithospheric plates. Arrows show the motions of the plates relative to the African Plate, which happens to be moving most slowly relative to Earth’s axis of rotation.

-  a) Name two plates that are moving toward each other (converging or colliding).
 -  b) Name two plates that are moving apart (diverging or spreading).
 -  c) Name two plates that are sliding past each other (transform).
2. Use a blank world map to make a map that shows the three major types of plate boundaries.
-  a) On the map, color the boundary lines that separate two converging plates (where plates are moving toward each other). Do not outline both of the plates completely. Highlight only the boundary between the two plates.
 -  b) Using two other colors, highlight

the divergent plate boundaries (where plates are moving away from one another) and the transform boundaries (where plates slide past one another). Make a key that shows this color code.

Part D: The Plate Tectonic Setting of Your Community

1. Describe the plate tectonic setting of your community. Refer to your world map and the *This Dynamic Planet* map (USGS) in your description.
 -  a) How far is your community from the nearest plate boundary?
 -  b) What type of plate boundary is it?
 -  c) How might your community change its position relative to plate boundaries in the future?

Digging Deeper


THE MOTION OF LITHOSPHERIC PLATES

Types of Plate Boundaries

Plate boundaries are active. Therefore, they are interesting areas for geologists to study. In the *Investigate*, you ran a model that showed what happens when one plate moves beneath another. This process is called **subduction**. You also modeled what happens when plates move apart from one another. This occurs at a spreading ridge. You also investigated different types of plate boundaries. Geologists use three descriptive terms to classify the boundaries between plates. You read about them in *Section 1*. At divergent plate boundaries two plates move away from each other. At convergent plate boundaries two plates move toward each other. At transform plate boundaries two plates slide parallel to each other.

Seafloor Spreading and Divergent Plate Boundaries

You have already read some things about divergent plate boundaries. You learned that mid-ocean ridges are divergent plate boundaries. The mid-ocean ridges are places where mantle asthenosphere rises slowly upward. As it rises, some of the rock melts to form magma. Why does melting happen there? To understand that, you need to know that the melting temperature of rock decreases as the pressure on the rock decreases. As the mantle rock rises, its temperature stays about the same because cooling takes a long time. However, the pressure from the overlying rock is less so some of the rock melts. The magma then rises up because



Geo Words

subduction: the process of one lithospheric plate moving beneath another.



Geo Words

igneous rock: rock formed by volcanic activity.

basalt: a kind of volcanic igneous rock, usually dark colored, with a high content of iron.

it is less dense than the surrounding rock. It forms volcanoes in the central valley of the mid-ocean ridge. Geologists in deep-diving submersibles can observe these undersea volcanoes.

The water pressure in the deep ocean is very great. Also, water provides a cooling effect on the magma. As a result, the undersea volcanoes behave differently than volcanoes on land. The lava oozes out of cracks in the rocks, like toothpaste out of a tube. Some of the magma stays below the seafloor and crystallizes into rock there. All of these new rocks formed by volcanic activity (called **igneous rocks**), at the seafloor and below, make new oceanic crust. This crust then moves away from the crest of the ridge.

In the *Investigate*, you modeled how the “continent” moved farther and farther from the “spreading ridge.” Look back at the world map of lithospheric plates from *Part C*. In both the North Atlantic Ocean and the South Atlantic Ocean, there is no plate boundary along the coastlines on either side of the ocean. That tells you that the Atlantic Ocean is getting wider as time goes on. Why? Because new lithosphere is being created all the time at the mid-ocean ridge but is not being consumed at the edges of the continents. Does that make you wonder what would happen if you could go back in time and watch the ocean shrink? At some time in the past, there was no Atlantic Ocean.

At mid-ocean ridges, lava cools to form new crust made of **basalt**. (Basalt is an iron-rich volcanic rock that makes up the ocean floor.) Its iron

minerals (such as magnetite) become magnetized. These magnetic minerals have been able to “lock in” the polarity of Earth’s magnetic field. All magnets and materials that have magnetism have magnetic polarity. That is, they have a north and south direction. Rocks with normal magnetic polarity match that of Earth’s magnetic field. (The north end of the rock’s “compass needle” points toward magnetic north.) Other rocks have magnetic minerals with reversed polarity. (The north end of the rock’s compass needle points toward magnetic south.)

Beginning in the 1950s, scientists began noting patterns in the magnetism of rocks on the ocean floor. This pattern is shown in

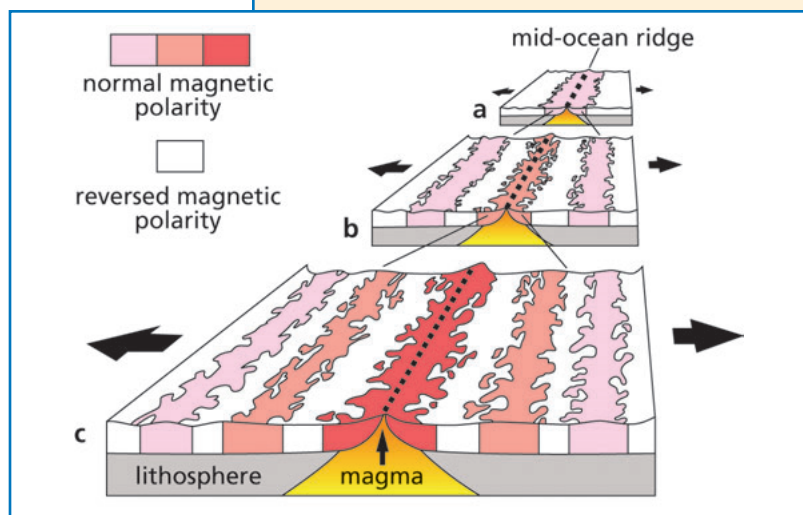


Figure 1 The formation of magnetic striping. New oceanic crust forms continuously at the crest of the mid-ocean ridge. It cools and becomes increasingly older as it moves away from the ridge crest with seafloor spreading: **a.** the spreading ridge about 5 million years ago, **b.** about 2 to 3 million years ago, and **c.** present day.

Figure 1. They noticed alternating belts of higher and lower-than-average magnetic field strength. The belts with the higher polarity were of normal polarity. The bands with lower polarity were reversed.

In 1963, F. J. Vine and D. H. Matthews proposed the theory of seafloor spreading to explain this pattern. They thought that the matching patterns on either side of the mid-ocean ridge could be explained by new ocean crust forming. The new crust formed at the ridge and then spread away from it. As ocean crust forms, it obtains the polarity of Earth's magnetic field at that time. Over time, the strength of Earth's magnetic field changes. When new ocean crust forms at the center of the spreading, it obtains a new kind of magnetic polarity. A series of magnetic "stripes" are formed over time. The rolled paper strips on the dowels of your seafloor-spreading model represented this process with alternating black and white stripes.

Since the theory of seafloor spreading was proposed, core samples of volcanic rock have been taken from the ocean floor. The samples have shown that the age of the rock increases from the crest of the ridge. This is just as the theory predicts. Geologists have also measured both the age and magnetic polarity of rocks on land. They have developed a time scale that shows when the magnetic field has reversed its polarity. The magnetic striping on the ocean floor records the reversals of Earth's magnetic field.

As a result, geologists can calculate the average rate of plate movement during a given time. These rates range widely. The Arctic Ridge has the slowest rate. It moves less than 2.5 cm/yr. The East Pacific Ridge has the fastest rate. It moves more than 15 cm/yr.

Geologic data are also used to find the direction of movement of the plates. Surveys of the depth of the ocean floor, mainly since the 1950s, reveal a great mountain range on the ocean floor. This range encircles Earth, as shown in *Figure 2*. This mid-ocean ridge zigzags between the continents. It winds its way around the globe like the seams on a baseball.

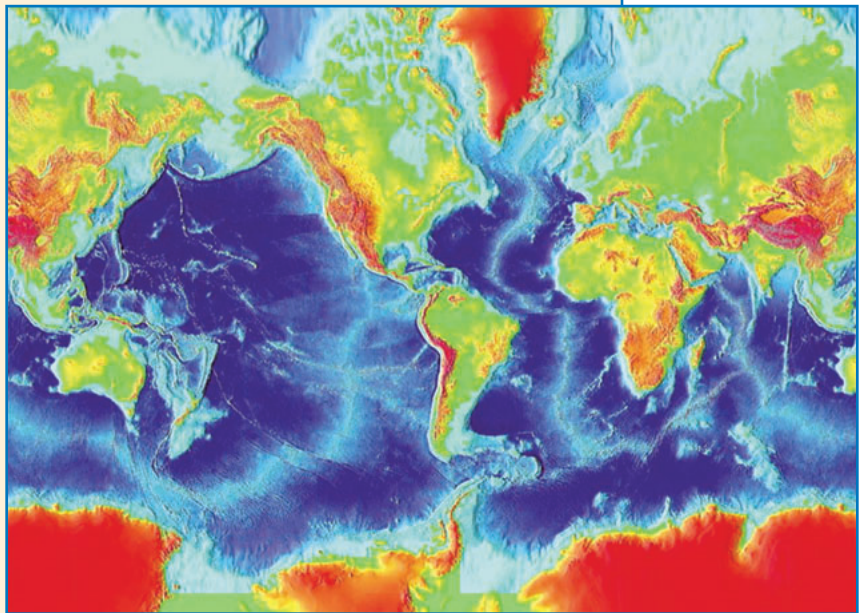


Figure 2 Map of the world's ocean floor. The crest of the mid-ocean ridge system is shown as a broad, light blue line throughout the ocean floor. The flanks of the mid-ocean ridges slope gradually down to the deeper part of the oceans, nearer to the continents.





The mid-ocean ridge is not straight. It is offset in many places. (See *Figure 3*.) The offsets are perpendicular to the axis of the ridge. Geologists combined these findings with knowledge that the ocean floor is spreading apart at mid-ocean ridges. They realized that the offsets are parallel to the direction the plates are moving. They mapped the orientations of these offsets and entered this data into a computer model. From this information, scientists are able to determine the directions of plate motions. Comparisons between GPS measurements and results from geologic computer models show very good agreement.

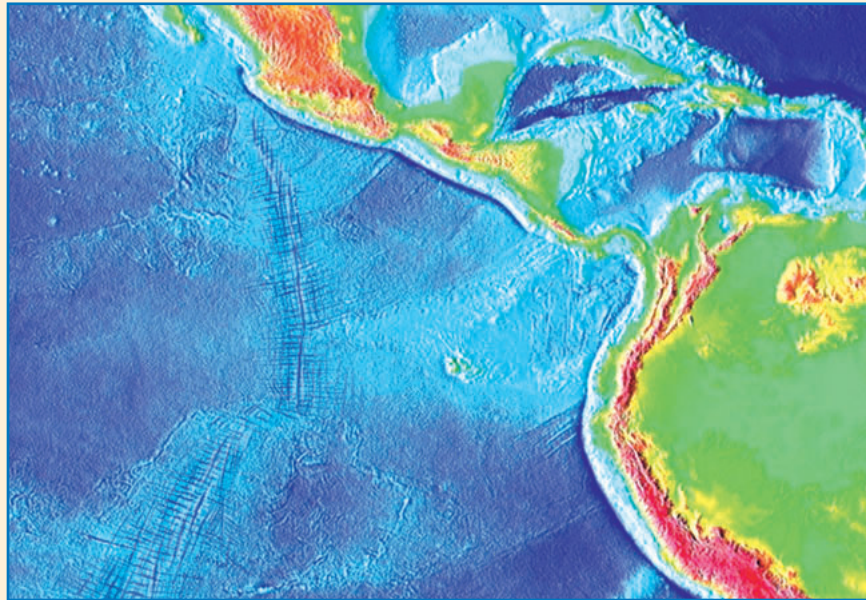


Figure 3 This map shows the network of fractures along the mid-ocean ridge in the eastern Pacific Ocean floor. Because the ocean floor spreads away from both sides of the ridge, the fractures indicate the direction of plate motion.

Checking Up

1. Name the three types of boundaries between lithospheric plates.
2. What has caused the “zebra pattern” in the rock of the ocean floor?
3. What is the significance of the patterns of offsets along mid-ocean ridges?

Think About It Again

At the beginning of this section, you were asked the following:

- Where do you think you would find the most “action” on Earth in regard to crust formation? Why?
- Where would be logical places to look for crust being destroyed? Why do you think that?

Record your ideas about these questions now. Describe exactly what is happening at your chosen location that makes it have the most “action.”

Reflecting on the Section and the Challenge

You saw that plates can interact in three different ways. They can converge, diverge, or move parallel to each other. You gained some experience in recognizing the three kinds of plate boundaries on world maps. You are better prepared for the next section, about the different kinds of landforms that develop at the different kinds of plate boundaries, and how earthquakes and volcanoes are caused at or near plate boundaries.

Understanding and Applying

1. How do studies of the magnetism of rocks on the seafloor provide evidence that the surface of Earth moves over time?
2. How can ocean basins change in size?
3. Look at the world map of major lithospheric plates from the *Investigate*. This map shows how plates move relative to each other.
 - a) Look at the names of the plates. On what basis does it appear that the plates were named?
 - b) Write down the name of your plate and all the plates that border it. Describe the motion of your plate relative to all the plates that border it.

4. *Preparing for the Chapter Challenge*

What would be some good questions to ask about how plate movements and their interactions at plate boundaries can change the arrangement and shape of continents and ocean basins on Earth? What evidence is there that the surface of Earth moves over time?

Inquiring Further

1. Study animations of plate motions

Visit the *EarthComm* Web site at <http://www.agiweb.org/education/earthcomm2/> for the address of animated images of the motions of lithospheric plates. Describe how the motions shown in the animations match your analysis from this section.