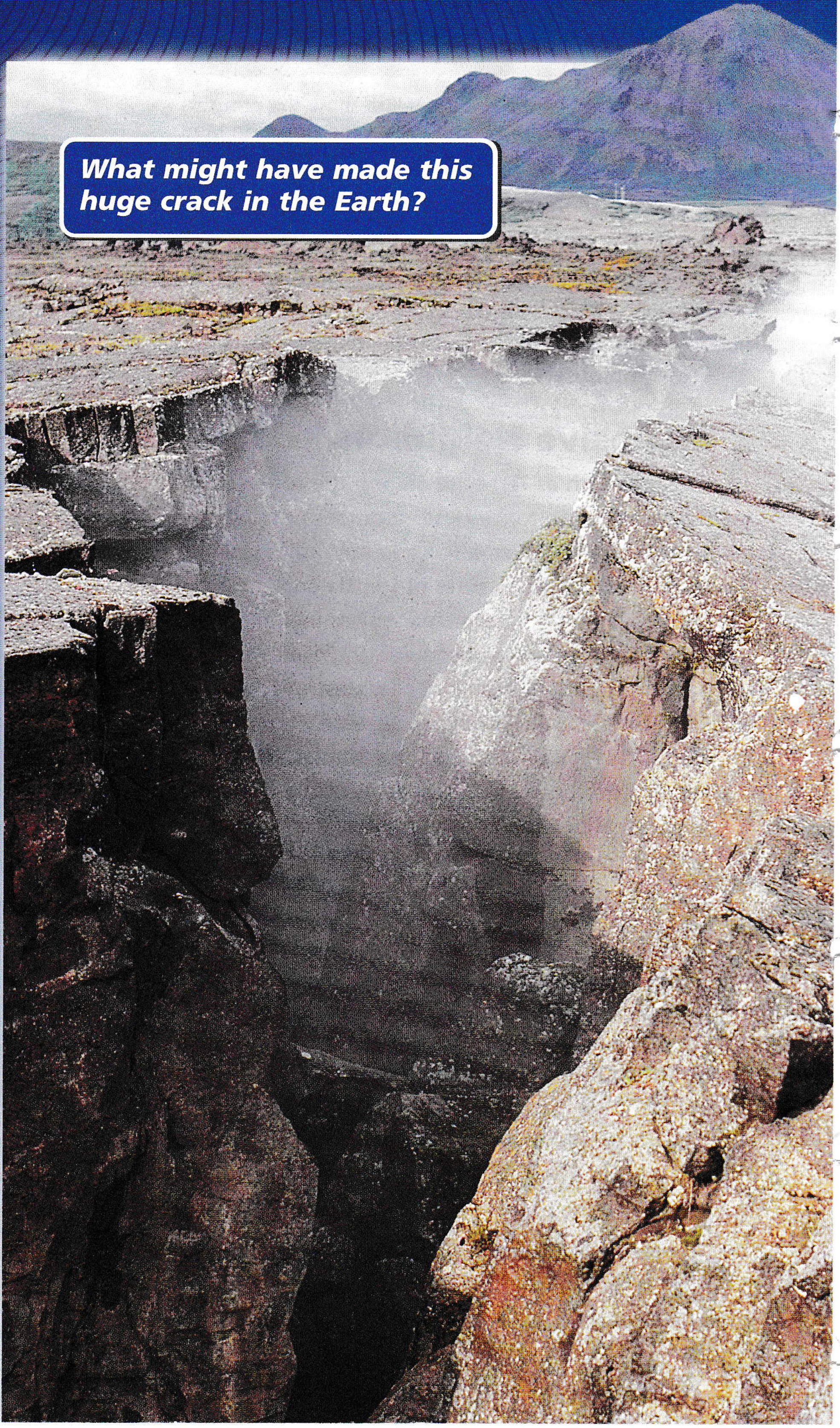
CHAPTER 6

Plate Tectonics

the BIG idea

The movement of tectonic plates causes geologic changes on Earth.



Key Concepts

SECTION 1
Earth has several layers.
Learn about Earth's interior and its rigid surface plates.

SECTION 2
Continents change position over time.
Learn how continental drift and plate tectonics changed the way people view Earth.

SECTION 3
Plates move apart.
Learn about the three types of plate boundaries and what happens when plates move apart.

SECTION 4
Plates converge or scrape past each other.
Learn what geologic events occur at these plate boundaries.

Internet Preview

CLASSZONE.COM

Chapter 6 online resources: Content Review, two Visualizations, one Resource Center, Math Tutorial, and Test Practice

EXPLORE the BIG idea

Watching a Pot Boil

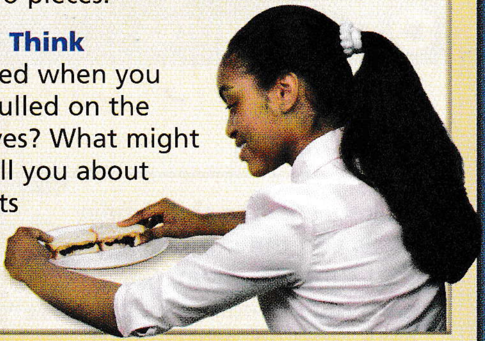
Put a medium-sized pot of water on to boil. Place a small wet sponge on the water. Watch the water and sponge as the water heats.

Observe and Think
What happened to the water as it heated? What happened to the sponge as the water became hotter?

Earth's Moving Surface

Place two halves of a peanut butter and jelly sandwich side by side. Very slowly push them together. Then take one half and very slowly tear it into two pieces.

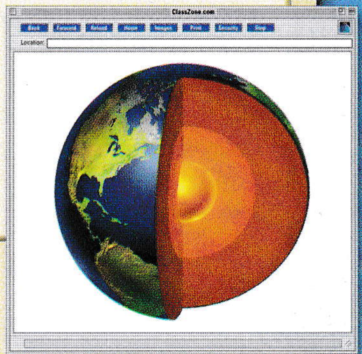
Observe and Think
What happened when you pushed and pulled on the sandwich halves? What might this activity tell you about the movements of Earth's surface?



Internet Activity: Earth's Interior

Go to **ClassZone.com** to explore the makeup of Earth's layers. Find out how scientists learned what the interior of Earth is like.

Observe and Think
Science fiction books and movies show people traveling to the center of Earth. Do you think this can happen any time soon? Why or why not?



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Plates **Code: MDL052**

CHAPTER 6

Getting Ready to Learn

CONCEPT REVIEW

- Most rocks are made of minerals.
- Different types of rocks are formed under different temperatures and pressures.
- Earth's surface has changed over millions of years.

VOCABULARY REVIEW

See Glossary for definitions.

density

mineral

rock

CONTENT REVIEW
CLASSZONE.COM
Review concepts and vocabulary.

TAKING NOTES

SUPPORTING MAIN IDEAS

Make a chart to show main ideas and the information that supports them. Copy each blue heading. Below each heading, add supporting information, such as reasons, explanations, and examples.

VOCABULARY STRATEGY

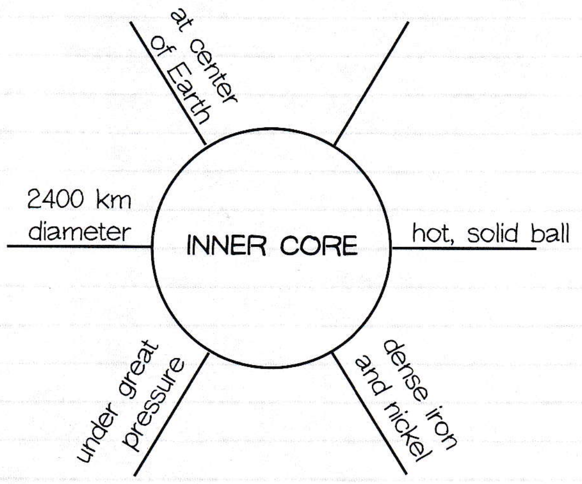
Place each vocabulary term at the center of a **description wheel** diagram. Write some words describing it on the spokes.

See the Note-Taking Handbook on pages R45–R51.

SCIENCE NOTEBOOK

Earth is made up of materials with different densities.

- → Dense materials—such as iron and nickel—sink toward center
- → Less dense materials rise toward surface



6.1

KEY CONCEPT

Earth has several layers.

BEFORE, you learned

- Minerals and rocks are the building blocks of Earth
- Different types of rocks make up Earth's surface

NOW, you will learn

- About the different properties of Earth's layers
- About the plates that make up Earth's outermost layers

VOCABULARY

inner core p. 186
outer core p. 186
mantle p. 187
crust p. 187
lithosphere p. 187
asthenosphere p. 187
tectonic plate p. 188

EXPLORE Density

Will a denser material sink or float?

PROCEDURE

1. Add equal amounts of water to 2 cups. Add 3 spoonfuls of salt to one of the cups and stir until the salt is dissolved.
2. Add 10 drops of food coloring to the same cup in which you dissolved the salt.
3. Gently pour about a third of the colored salt water into the cup of fresh water. Observe what happens.

WHAT DO YOU THINK?

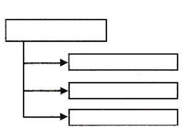
- What did you observe when the two types of water were mixed?
- What does this activity tell you about materials of different density?

MATERIALS

- 2 clear plastic cups
- tap water
- table salt
- plastic spoon
- food coloring

Earth is made up of materials with different densities.

SUPPORTING MAIN IDEAS
Support the main ideas about Earth's layers with details and examples.

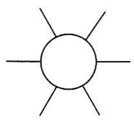


Scientists think that about 4.6 billion years ago, Earth formed as bits of material collided and stuck together. The planet grew larger as more and more material was added. These impacts, along with radioactive decay and Earth's gravity, produced intense heat. The young planet became a glowing ball of melted rock.

In time, denser materials, such as iron and nickel, sank toward the center of Earth. Less dense materials moved toward the surface. Other materials settled between the planet's center and its surface. Slowly, Earth's main layers formed—the core, the mantle, and the crust.

Earth's layers have different properties.

VOCABULARY
Draw a description wheel in your notebook for each term. You might want to include the pronunciation of some terms.



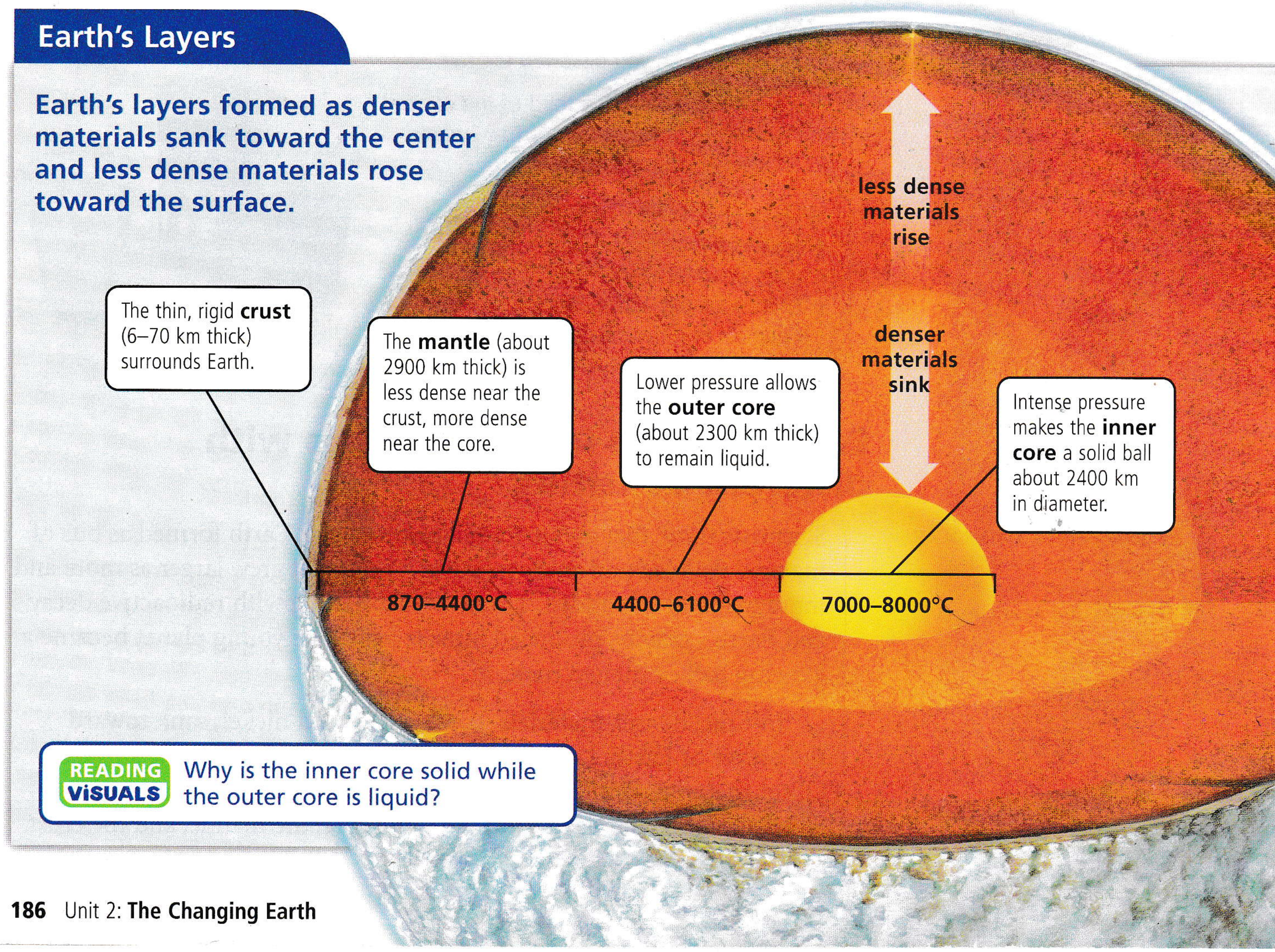
How do scientists know what Earth's deep interior is like? After all, no one has seen it. To explore the interior, scientists study the energy from earthquakes or underground explosions they set off. The energy travels through Earth somewhat like ripples move through a pond. The energy moves slower through less dense materials or liquids and faster through denser materials or solids. In this way, scientists infer what each layer is made of and how thick the layers are, as shown in the diagram below.

Core, Mantle, Crust

The core is Earth's densest region and is made up of two parts. The **inner core** is a ball of hot, solid metals. There is enormous pressure at the center of Earth. This squeezes the atoms of the metals so closely together that the core remains solid despite the intense heat.

The **outer core** is a layer of liquid metals that surrounds the inner core. The temperature and pressure in the outer core are lower than in the inner core. The lower pressure allows the metals to remain liquid.

Earth's Layers



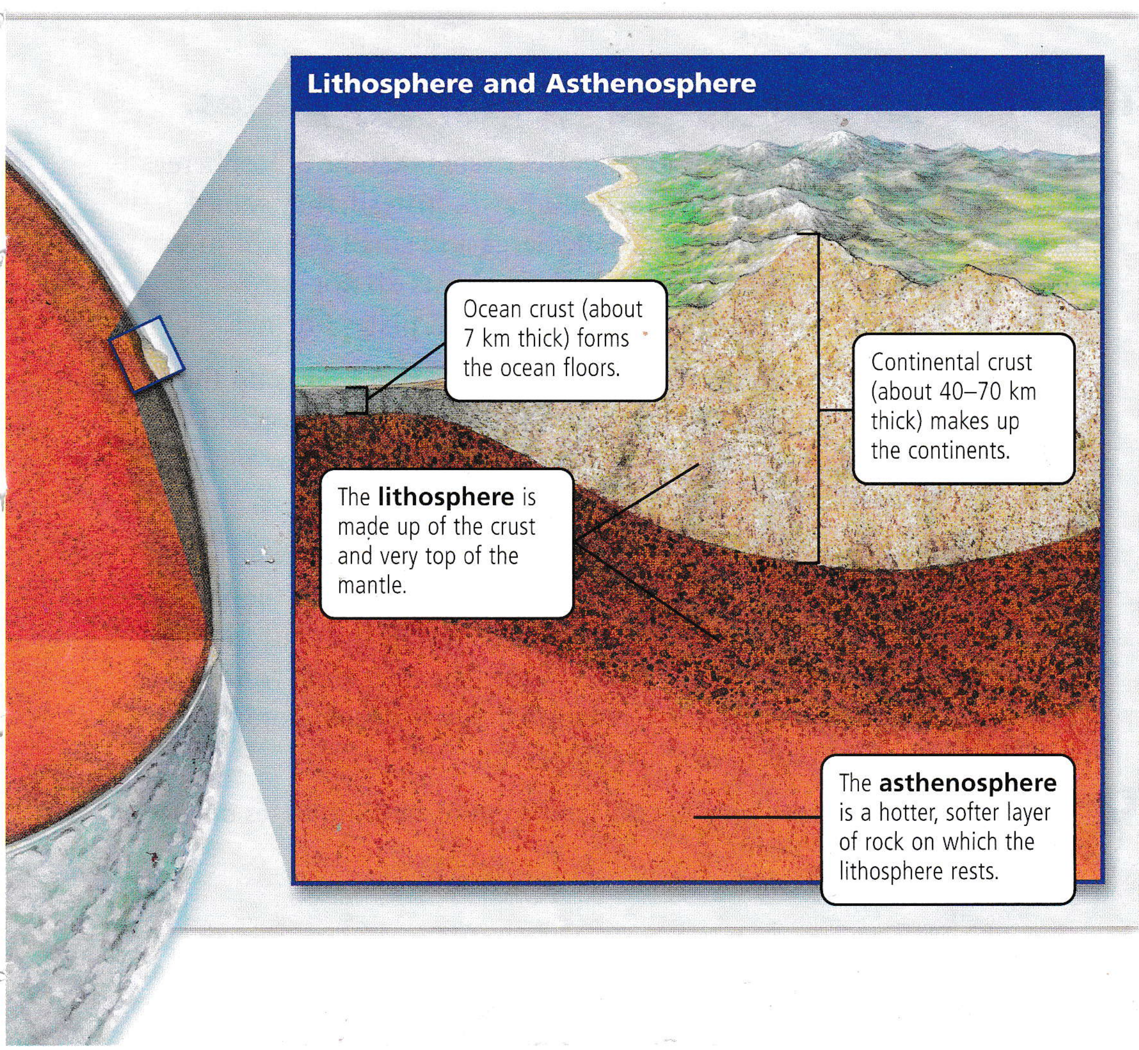
READING VISUALS Why is the inner core solid while the outer core is liquid?

The **mantle** is Earth's thickest layer, measuring nearly 2900 kilometers (1700 mi). It is made of hot rock that is less dense than the metallic core. The very top part of the mantle is cool and rigid. Just below that, the rock is hot and soft enough to move like a thick paste.

The **crust** is a thin layer of cool rock. It surrounds Earth somewhat like a shell surrounds an egg. There are two basic types of crust. Continental crust includes all continents and some major islands. Oceanic crust includes all the ocean floors. As the diagram below shows, Earth's crust is thinnest under the oceans and thickest under continental mountain ranges. The crust is home to all life on Earth.

Lithosphere and Asthenosphere

Earth's crust and the very top of the mantle together form the **lithosphere** (LIHTH-uh-SFEER). The Greek prefix *litho-* means "stone" or "rock." This layer is the most rigid of all the layers. The lithosphere sits on top of the **asthenosphere** (as-THEHN-uh-SFEER), a layer of hotter, softer rock in the upper mantle. The Greek word *asthenés* means "weak." This layer is not actually weak, but it is soft enough to flow slowly like hot tar. You can imagine the lithosphere as solid pieces of pavement resting on hot tar.



INVESTIGATE Earth's Different Layers

How can you model Earth's layers?

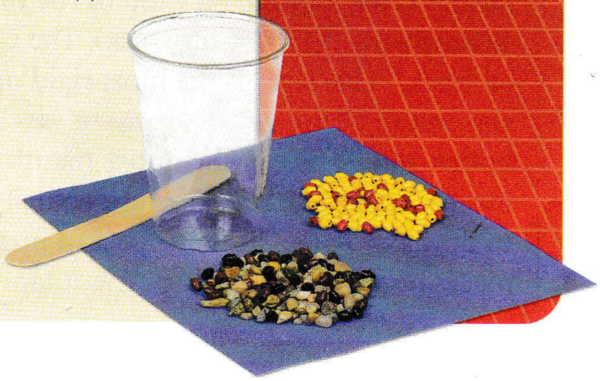
SKILL FOCUS
Modeling

MATERIALS
- clear plastic cup
- small colored wooden beads
- gravel
- stirring stick
- tap water

TIME
15 minutes

PROCEDURE

1. Put a layer of wooden beads about 1 centimeter thick at the bottom of a clear plastic cup or small jar.
2. Put a layer of gravel about 2 centimeters thick on top of the wooden beads. Stir the beads and gravel until they are well mixed.
3. Put another layer of gravel about 1 centimeter thick on top of the mix. Do NOT mix this layer of gravel.
4. SLOWLY fill the cup about two-thirds full of water. Be sure not to disturb the layers in the cup.
5. Stir the beads and gravel with the stick. Observe what happens.



WHAT DO YOU THINK?
- What happened to the materials when you stirred them?
- How do you think this model represents the layers of Earth?

CHALLENGE What could you add to the model to represent Earth's solid core?

The lithosphere is made up of many plates.

READING TIP
The word *tectonic* comes from the Greek *tecktōn,* which means "builder." Tectonic plates are constantly building and changing landforms and oceans around Earth.

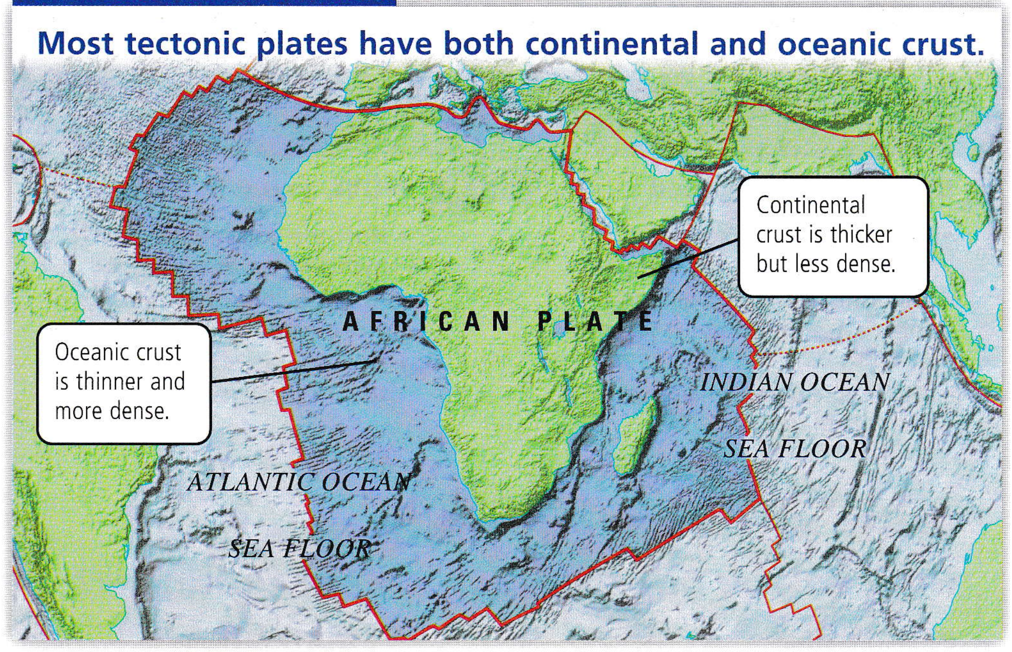
As scientists studied Earth's surface, they discovered that the lithosphere does not form a continuous shell around Earth. Instead, they found that the lithosphere is broken into many large and small slabs of rock called **tectonic plates** (tehk-TAHN-ihk). Scientists do not know exactly how or when in Earth's history these giant plates formed.

Tectonic plates fit together like a jigsaw puzzle that makes up the surface of Earth. You could compare the lithosphere to the cracked shell of a hard-boiled egg. The shell may be broken into many pieces, but it still forms a "crust" around the egg itself.

Most large tectonic plates include both continental crust and oceanic crust, as shown in the diagram on page 189. Most of the thicker continental crust rises above the ocean. The rest of the plate is thin oceanic crust, or sea floor, and is underwater. The next time you look at the continents on a world map, remember you are seeing only the part of Earth's crust that rises above the ocean.

CHECK YOUR READING Why do you see only the dry land areas of tectonic plates on a typical world map?

African Plate



In the diagram above, notice how much of the African Plate, shaded darker blue, lies underwater. The continent of Africa, which looks large on a world map, is actually about half the size of the entire plate. The plate's oceanic crust forms part of the sea floor of the Atlantic and Indian oceans and of the Mediterranean Sea. The ocean crusts of other plates make up the rest of the sea floors.

Earth's layers and tectonic plates are two of the most important discoveries in geology. They helped solve a mystery that had puzzled people for nearly 400 years. The mystery involved two questions. Have the continents always been where they are today? If not, how did they move to their present positions? In Section 6.2, you will find out how scientists are answering these questions.

6.1 Review

KEY CONCEPTS

1. Briefly describe the inner and outer cores, the mantle, and the crust.
2. In what ways is the lithosphere different from the asthenosphere?
3. Describe the structure of most tectonic plates.

CRITICAL THINKING

4. **Draw Conclusions** Suppose you are looking at a scene that has mountains near an ocean. Where do you think the crust would be the thickest? Why?
5. **Hypothesize** What would Earth look like if most of its crust was above sea level?

CHALLENGE

6. **Predict** You have learned that Earth's lithosphere is made up of many plates. How do you think this fact might help scientists solve the mystery of the moving continents?

KEY CONCEPT

6.2 Continents change position over time.

BEFORE, you learned

- Earth's main layers are the core, the mantle, and the crust
- The lithosphere and asthenosphere are the topmost layers of Earth
- The lithosphere is made up of tectonic plates

NOW, you will learn

- How the continental drift hypothesis was developed
- About evidence for plate movement from the sea floor
- How scientists developed the theory of plate tectonics

VOCABULARY

continental drift p. 190
Pangaea p. 192
mid-ocean ridge p. 192
convection p. 193
convection current p. 193
theory of plate tectonics p. 194

EXPLORE Movements of Continents

How do you put together a giant continent?

PROCEDURE

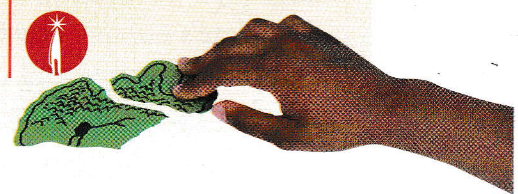
1. Work with a small group. Draw the outline of a large landmass. Fill in mountains, rivers, lakes, and any other features you like.
2. Cut out your landmass, then tear the drawing into several pieces and mix the pieces up. Ask another group to put the puzzle together.

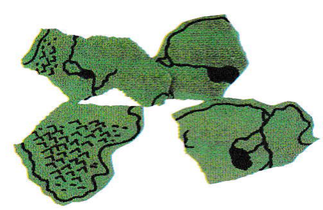
WHAT DO YOU THINK?

- What clues helped you fit the pieces together?
- Do any lands on a world map seem to fit together?

MATERIALS

- sheet of paper
- colored marking pens
- scissors



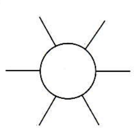


Continents join together and split apart.

The idea that Earth's surface might be moving is not new. As far back as the 1500s, when mapmakers started including North and South America in their world maps, they noticed something curious. The western coast of Africa and the eastern coast of South America seemed to fit together like pieces in a puzzle. Were these continents joined at one time?

In the late 1800s, German scientist Alfred Wegener (VAY-guh-nuhr) began studying this question. In 1912, he proposed a hypothesis known as **continental drift.** According to Wegener's hypothesis, Earth's continents were once joined in a single landmass and gradually moved, or drifted, apart. For many years, people did not accept Wegener's ideas. Not until the mid-1900s did scientists find new evidence that made them consider continental drift more seriously.

VOCABULARY
Draw a description wheel in your notebook for *continental drift.*



Evidence for Continental Drift

Wegener gathered evidence for his hypothesis from fossils, from studies of ancient climate, and from the geology of continents.

Fossils Wegener learned that the fossils of an ancient reptile, *Mesosaurus* (MEHZ-uh-SAWR-uhs), had been discovered in South America and western Africa. This small reptile lived about 270 million years ago. Its fossils were not found anywhere else in the world. Wegener said this fact could easily be explained if South America and Africa were once joined, as shown in the map below.

Climate Evidence of climate change also supported Wegener's hypothesis. For example, Greenland today lies near the Arctic Circle and is mostly covered in ice. Yet fossils of tropical plants can be found on its shores. In contrast, South Africa today has a warm climate. Yet its rocks were deeply scratched by ice sheets that once covered the area.

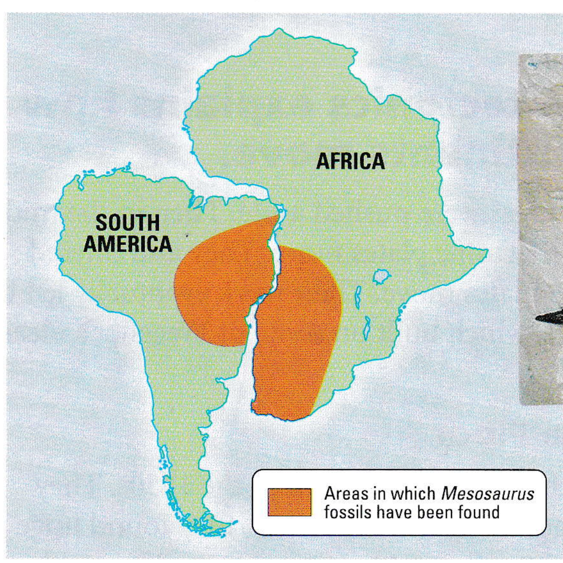
READING TIP

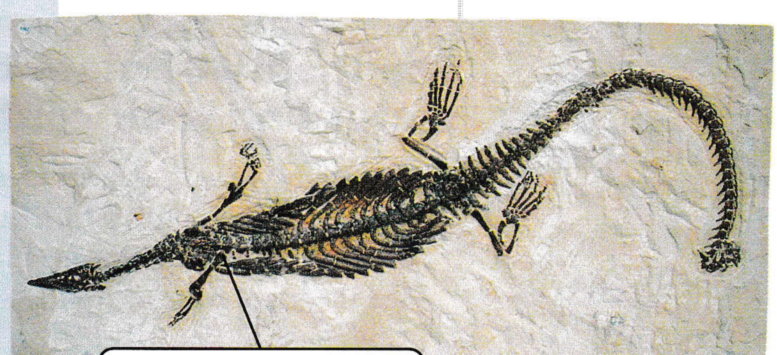
Climate refers to a pattern of wind, temperature, and rain or snow that occurs in a region over time. Earth's climates have changed many times in the planet's long history.

Wegener suggested that these continents had moved, carrying their fossils and rocks with them. Greenland, for example, had once been near the equator and had slowly moved to the Arctic Circle. South Africa, once closer to the South Pole, had moved slowly north to a warmer region.

Geology Wegener's best evidence for continental drift came from the kinds of rocks that make up the continents. He showed that the type of rock found in Brazil matched the rock found in western Africa. Also, limestone layers in the Appalachian Mountains of North America were exactly like the limestone in Scotland's Highlands.

CHECK YOUR READING Which evidence for continental drift do you think is the most convincing? Explain your answer.





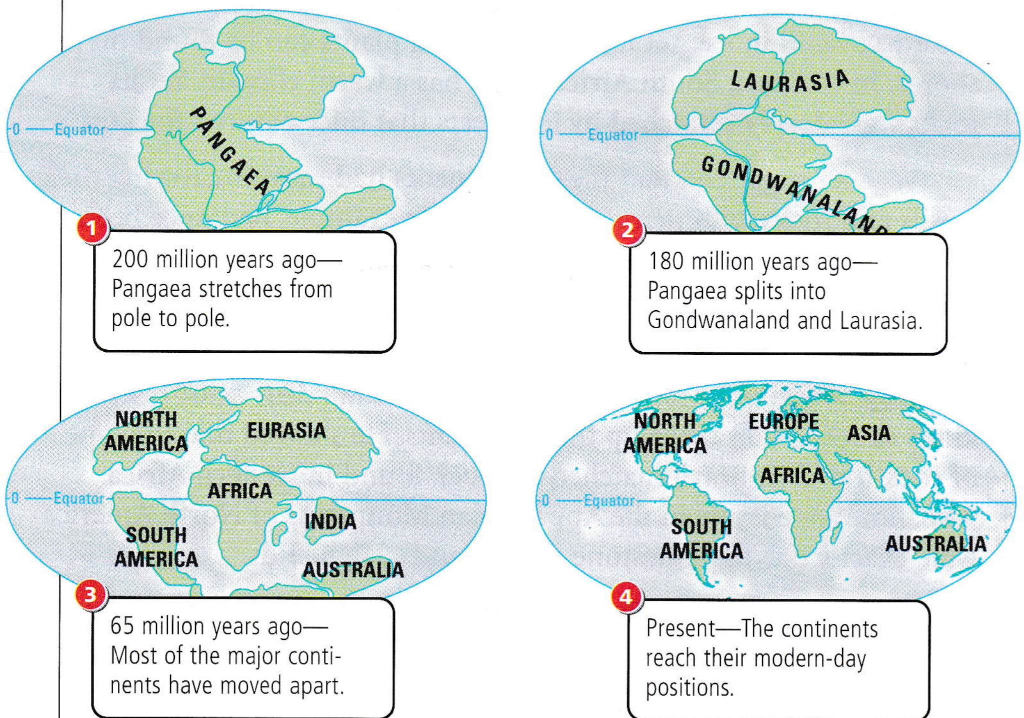
The reptile *Mesosaurus* was about 45 cm (18 in.) long. This fossil was found in Brazil, South America.

Pangaea and Continental Drift

VISUALIZATION
CLASSZONE.COM
Examine continental movement over the past 150 million years.

For Wegener, all the evidence pointed to a single conclusion. The continents had once been joined in a huge supercontinent he called **Pangaea** (pan-JEE-uh). *Pangaea* comes from the Greek word meaning "all lands." This giant continent reached from pole to pole and was centered over the area where Africa lies today.

Pangaea began to split apart some 200 million years ago. In time, the continents moved to where they are today. Yet Wegener could not explain *how* the continents moved. Because of this, his critics called continental drift "a fairy tale" and rejected his hypothesis.



1 200 million years ago—Pangaea stretches from pole to pole.

2 180 million years ago—Pangaea splits into Gondwanaland and Laurasia.

3 65 million years ago—Most of the major continents have moved apart.

4 Present—The continents reach their modern-day positions.

The theory of plate tectonics explains how plates and their continents move.

For many years, Wegener's ideas were pushed aside. Then in the mid-1900s, scientists proved that tectonic plates move. They also offered explanations about how the plates move. Their work eventually led to the theory of plate tectonics, which built on some of Wegener's ideas.

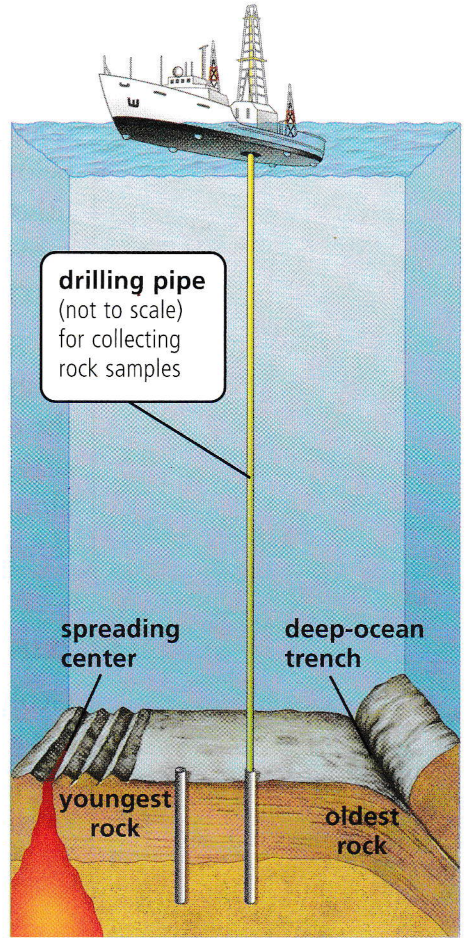
Evidence from the Sea Floor

Scientists began mapping the sea floor in detail in the 1950s. They expected the floor to be smooth and level. Instead, they found huge underwater mountain ranges, called **mid-ocean ridges.** These ridges appeared in every ocean, circling Earth like seams in a baseball.

Sea-Floor Spreading Scientists learned that the ridges form along cracks in the crust. Molten rock rises through these cracks, cools, and forms new oceanic crust. The old crust is pulled away to make room for new material. In this way, the sea floor slowly spreads apart. Scientists call these areas spreading centers. You will read more about spreading centers in Section 6.3.

Age of the Sea Floor Further evidence that the sea floor is spreading apart came from the age of the rocks in the crust. Scientists drilled into the sea floor from a specially equipped vessel called the *Glomar Challenger.* The rock samples revealed that the youngest rock is closest to the ridge, while the oldest rock is farthest away.

The samples also showed that even the oldest ocean floor is young—only 160 to 180 million years old. Continental crust is much older—up to 4 billion years old. These data confirmed that the ocean floor is constantly forming and moving away from the mid-ocean ridges like a conveyor belt. As the sea floor moves, so do the tectonic plates and their continents.



Scientists drill into the sea floor to obtain rock samples. The different ages of the rocks prove that plates move.

Ocean Trenches Yet, if the sea floor has been spreading for millions of years, why is Earth not getting larger? Scientists discovered the answer when they found huge trenches, like deep canyons, in the sea floor. At these sites, dense oceanic crust is sinking into the asthenosphere. Old crust is being destroyed at the same rate that new crust is forming. Thus, Earth remains the same size.

Scientists now had proof that tectonic plates move. But the same question remained. *How* could the plates move thousands of kilometers around the planet? The asthenosphere provided a possible answer.

CHECK YOUR READING How does the age of the sea floor show that plates move?

Causes of Plate Movement

Tectonic plates rest on the asthenosphere, a layer of soft, hot rock. Rock in this layer and in the mantle just below it moves by convection. **Convection** is energy transfer by the movement of a material. You have seen convection if you have ever boiled a pot of water. The water at the bottom of the pot heats up, becomes less dense, and rises. At the surface, it cools, becomes denser, and sinks, only to be heated and rise again.

The rock in the asthenosphere acts in a similar way. The hot, soft rock rises, cools, and sinks, then is heated and rises again. If this sinking and rising motion continues, it is called a **convection current**—a motion that transfers heat energy in a material.

Convection currents in the mantle are much slower than those in boiling water. The rock creeps only a few centimeters a year. The diagram below shows convection currents circulating. The tectonic plates in the lithosphere are carried on the asthenosphere like long, heavy boxes moved on huge rollers. Over millions of years, convection currents carry the plates thousands of kilometers.

Scientists suspect that two other motions—slab pull and ridge push—help move these huge plates. Slab pull occurs where gravity pulls the edge of a cool, dense plate into the asthenosphere, as shown in the diagram below. Because plates are rigid, the entire plate is dragged along. Ridge push occurs when material from a mid-ocean ridge slides downhill from the ridge. The material pushes the rest of the plate.

Putting the Theory Together

REMINDER

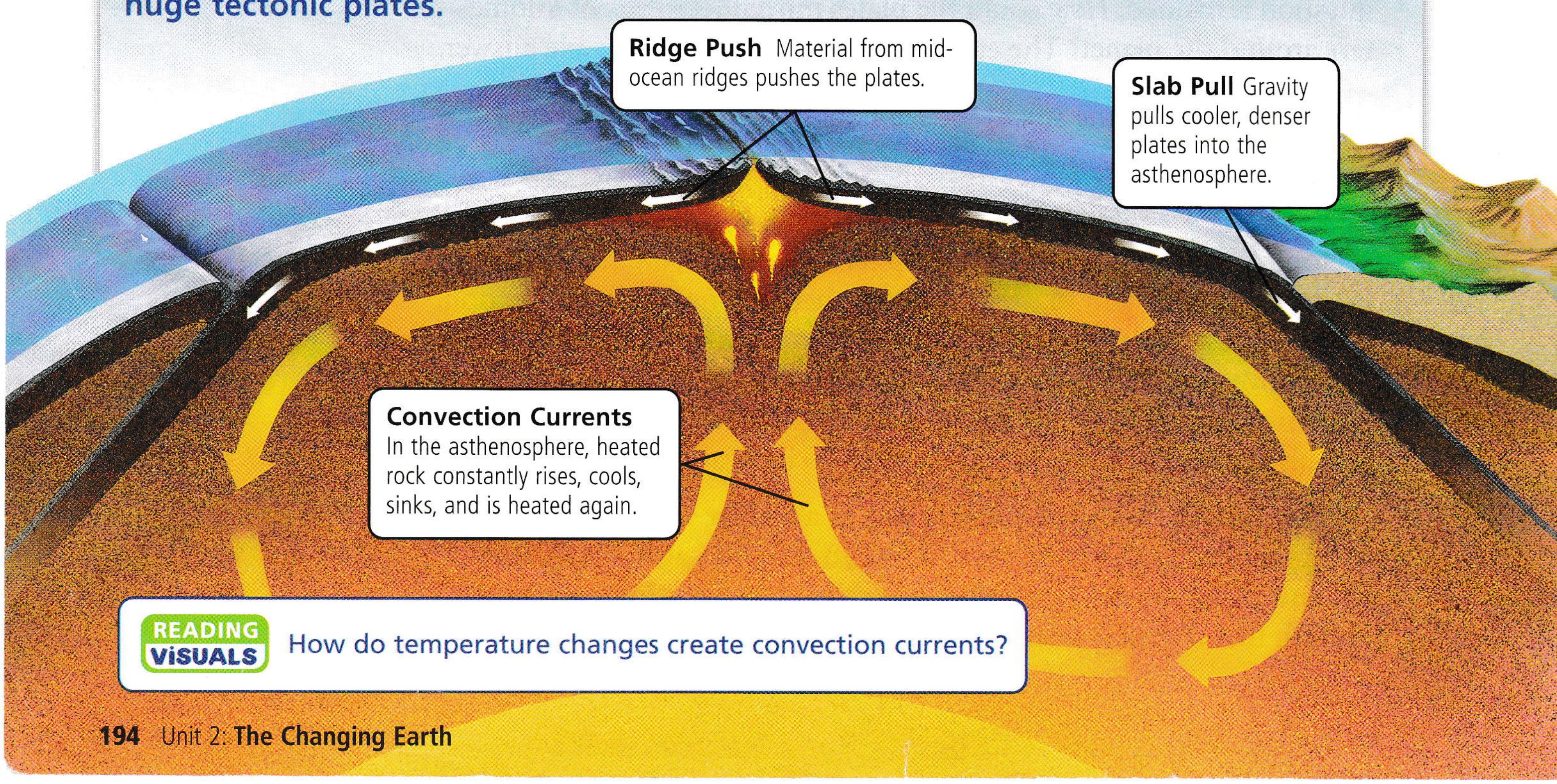
A scientific theory is a well-tested explanation that is consistent with all available evidence.

Geologists combined their knowledge of Earth's plates, the sea floor, and the asthenosphere to develop the **theory of plate tectonics.** The theory states that Earth's lithosphere is made up of huge plates that move over the surface of the Earth.

The map on page 195 shows Earth's major tectonic plates and the directions in which they move. They are the African, the Antarctic, the Australian, the Indian, the Eurasian, the Nazca, the North and South American, and the Pacific plates.

Causes of Plate Movement

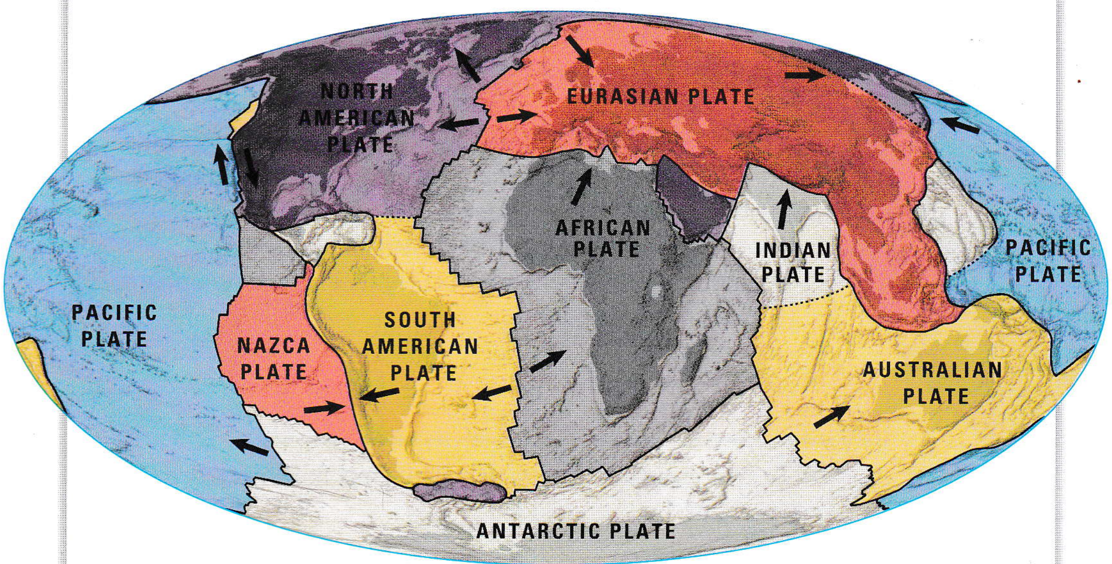
Convection currents, slab pull, and ridge push move Earth's huge tectonic plates.



READING VISUALS How do temperature changes create convection currents?

Tectonic Plates

Earth's lithosphere is made up of moving plates.



READING VISUALS Where on the map are two plates moving apart? pushing together? scraping past each other?

As scientists studied the plates, they realized that one plate could not shift without affecting the others nearby. They found that plates can move apart, push together, or scrape past each other. The arrows on the map above show each type of plate motion.

Plate movements cause great changes in Earth's crust. Most major earthquakes, volcanoes, and mountain ranges appear where tectonic plates meet. You will learn why as you read more about plate movements.

6.2 Review

KEY CONCEPTS

1. What evidence did Wegener gather to support his continental drift hypothesis?
2. Give three types of evidence from the sea floor that prove Earth's tectonic plates move.
3. Explain how motions in the asthenosphere can move tectonic plates around Earth.

CRITICAL THINKING

4. **Apply** A friend tells you he read on a Web site that Earth is getting smaller. What can you tell him that shows Earth's size is not changing?
5. **Evaluate** What other types of scientists, besides geologists, would find the theory of plate tectonics useful in their work?

CHALLENGE

6. **Infer** Use the arrows on the map above and your knowledge of sea-floor spreading and ocean trenches to answer these questions: What is happening to the size of the Atlantic Ocean? What can you infer is happening to the size of the Pacific Ocean? Explain your answers.

CHAPTER INVESTIGATION

Convection Currents and Plate Movement

OVERVIEW AND PURPOSE South America and Africa are drifting slowly apart. What powerful force could be moving these two plates? In this investigation you will
- observe the movement of convection currents
- determine how convection currents in Earth's mantle could move tectonic plates

Problem

Write It Up

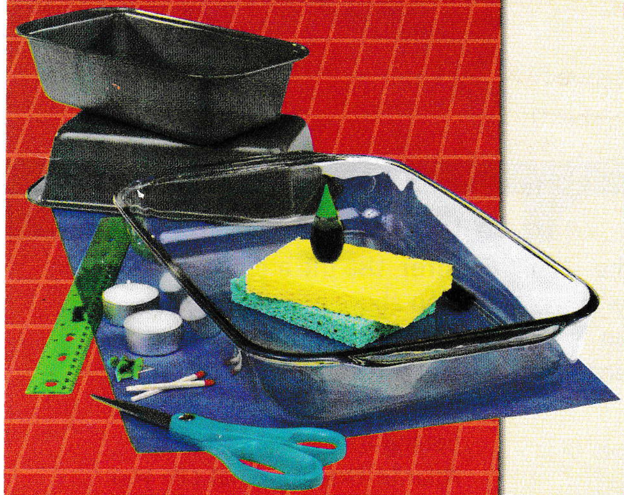
How do convection currents in a fluid affect floating objects on the surface?

Hypothesize

Write It Up

Write a hypothesis to explain how convection currents affect floating objects. Your hypothesis should take the form of an "If . . . , then . . . , because . . ." statement.

MATERIALS
- oven-glass lasagna pan
- 2 bread pans or 2 bricks
- water
- liquid food coloring
- 2 small candles
- matches
- 2 sponges
- scissors
- 3–4 pushpins



Procedure

1. Use two overturned bread pans or two bricks to raise and support the glass lasagna pan. Fill the pan with water to a depth of 4 cm.

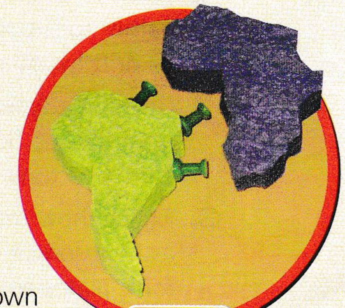
2. Hold the food coloring over the middle of the pan. Squeeze several drops into the water. Be careful not to touch or disturb the water with the plastic tip or your hands. Write down your observations.

step 3

3. Light the two candles and place them beneath the center of the pan. Then squeeze several more drops of food coloring into the middle of the pan.

4. Observe what happens for a few minutes, then write down your observations. After you have finished, blow out the candles and wait until the water cools.

5. Moisten the two sponges. Cut one into the shape of South America and the other into the shape of Africa. Insert the pushpins as shown in the photo.



step 5

6 Place the sponges on top of the water in the center of the pan. Fit the two sponges together along their coastlines.

7 Gently hold the sponges together until the water is still, then let go. Observe them for a few minutes and record what you saw.

8 Light the candles again. Place them under the pan and directly beneath the two sponges.

9 Gently hold the sponges together again until the water heats up. Then carefully let go of the sponges, trying not to disturb the water.

10 Observe the sponges for a few minutes, and then record your observations.

Observe and Analyze

Write It Up

1. **RECORD** Draw diagrams to show how the food coloring and the sponges moved in cold water and in heated water. Use arrows to indicate any motion.
2. **ANALYZE** Did the food coloring and the sponges move more with or without the candles? Use what you have learned about convection to explain the role of the candles.

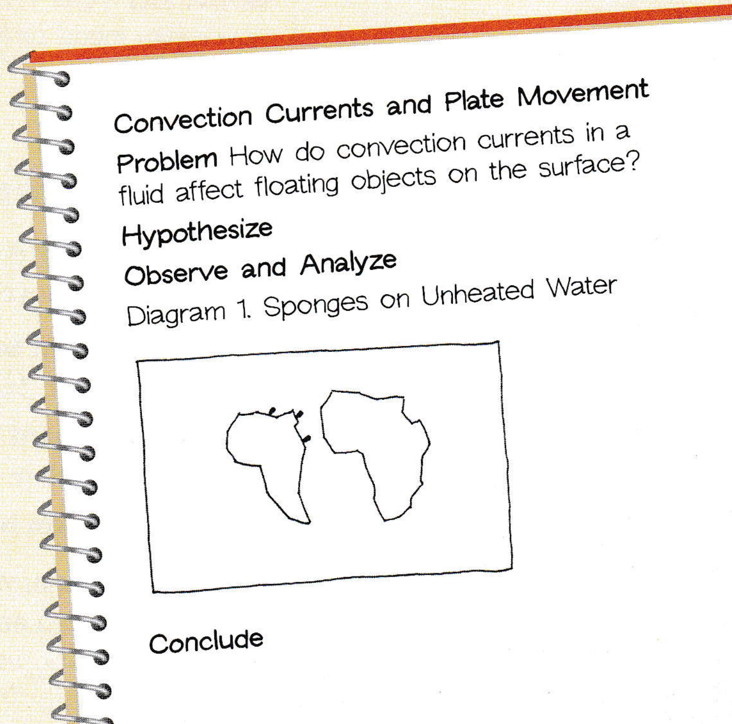
Conclude

Write It Up

1. **EVALUATE** Water is a fluid, but the asthenosphere is not. What properties of the asthenosphere allow it to move like a fluid and form convection currents?
2. **COMPARE AND CONTRAST** In what ways is your setup like Earth's asthenosphere and lithosphere? In what ways is your setup different?
3. **ANALYZE** Compare your results with your hypothesis. Do your observations support your hypothesis? Why or why not?
4. **INTERPRET** Write an answer to your problem statement.
5. **IDENTIFY CONTROLS** Did your experiment include controls? If so, what purpose did they serve here?
6. **APPLY** In your own words, explain how the African continent and the South American continent are drifting apart.
7. **APPLY** Suppose you own an aquarium. You want to make sure your fish are warm whether they swim near the top or near the bottom of the aquarium. The pet store sells two types of heaters. One heater extends 5 cm below the water's surface. The other heater rests on the bottom of the aquarium. Based on what you learned in this activity, which heater would you choose, and why?

INVESTIGATE Further

CHALLENGE Design a new version of this experiment that you think would be a better model of the movements in Earth's asthenosphere and lithosphere. What materials will you need? What changes would you make to the procedure? Sketch your version of the lab, and explain what makes it better.



KEY CONCEPT

6.3 Plates move apart.

BEFORE, you learned

- The continents join and break apart
- The sea floor provides evidence that tectonic plates move
- The theory of plate tectonics helps explain how the plates move

NOW, you will learn

- About different plate boundaries
- What happens when plates move apart
- How the direction and speed of plates can be measured

VOCABULARY

divergent boundary p. 198
convergent boundary p. 198
transform boundary p. 198
rift valley p. 199
magnetic reversal p. 200
hot spot p. 203

EXPLORE Divergent Boundaries

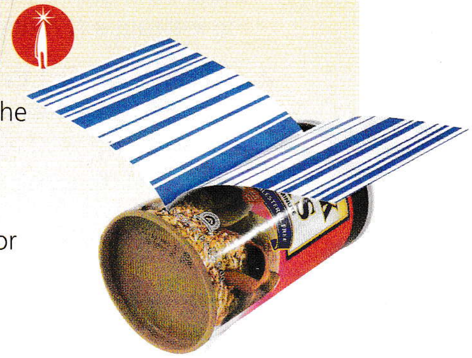
What happens when plates move apart?

PROCEDURE

1. Cut the piece of striped paper into two symmetrical pieces slightly less wide than the slit in the oatmeal box.
2. Match up the lines of the two pieces and tape the pieces together at one edge. Push the taped edge into the box until only a few centimeters of the free edges show at the top.
3. Grasp each piece of paper, one in each hand. Slowly pull the two pieces horizontally out of the cylinder, pulling them in opposite directions.

MATERIALS

- scissors
- piece of striped paper
- tape
- small oatmeal box with slit cut in side



WHAT DO YOU THINK?
How is your model similar to the process of sea-floor spreading?

Tectonic plates have different boundaries.

READING TIP

Use word meanings to help remember science terms.

diverge = to go in different directions

converge = to come together from different directions

transform = to change

A plate boundary is where the edges of two plates meet. After studying the way plates move, geologists identified three types of boundaries.

- A **divergent boundary** (dih-VUR-juhnt) occurs where plates move apart. Most divergent boundaries are found in the ocean.
- A **convergent boundary** (kuhn-VUR-juhnt) occurs where plates push together.
- A **transform boundary** occurs where plates scrape past each other.

In this section, you will discover what happens at divergent boundaries in the ocean and on land. You will read more about convergent and transform boundaries in Section 6.4.

The sea floor spreads apart at divergent boundaries.

In the ocean, divergent boundaries are also called spreading centers. Mid-ocean ridges mark these sites where the ocean floor is spreading apart. As the ridges continue to widen, a gap called a **rift valley** forms. Here molten material rises to build new crust.

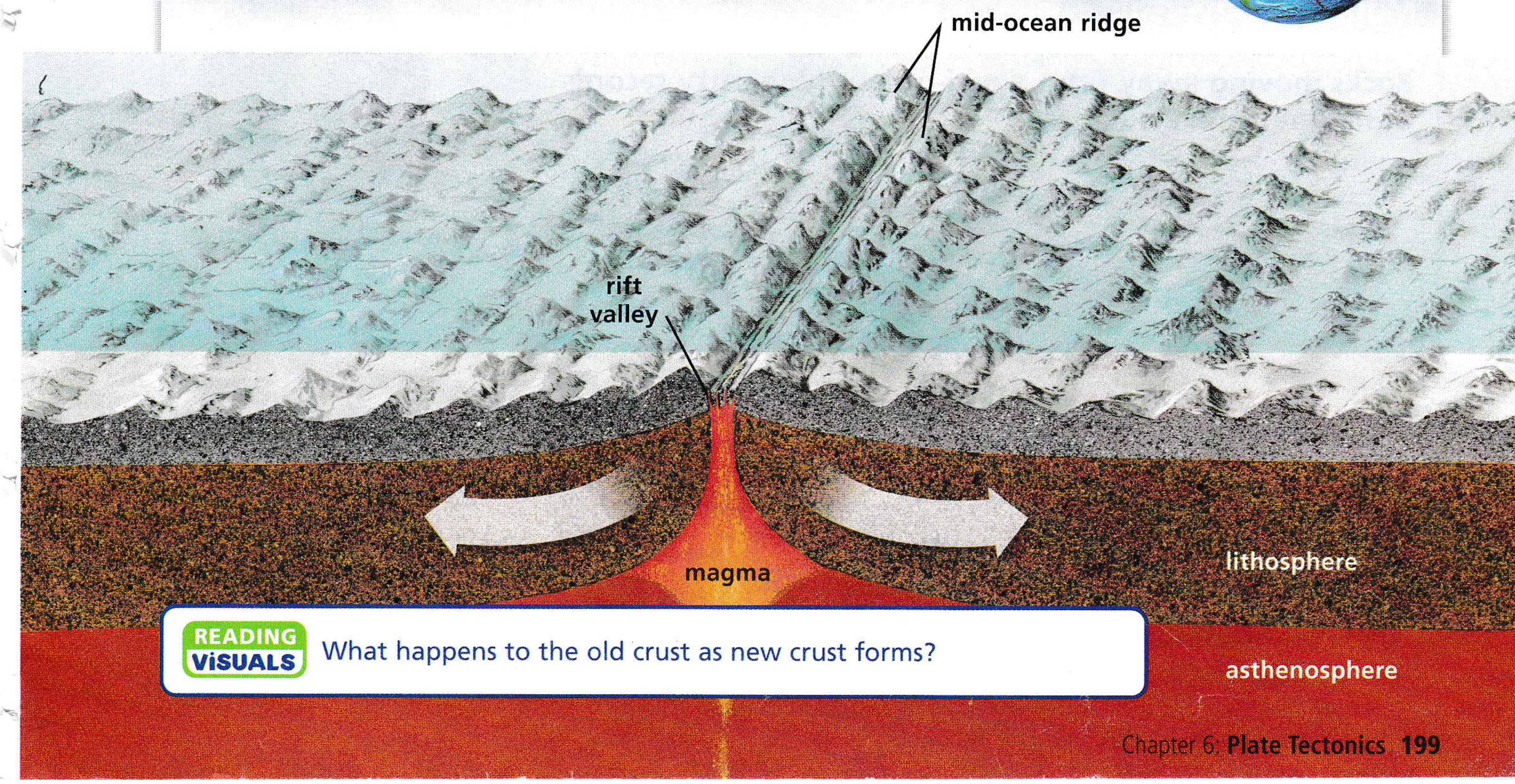
Mid-Ocean Ridges and Rift Valleys

Mid-ocean ridges are the longest chain of mountains on Earth. Most of these ridges contain a rift valley along their center, as shown in the diagram below. When molten material rises from the asthenosphere, cold ocean water cools the rock until it becomes solid. As the plates move apart, new cracks open in the solid rock. More molten material rises and hardens. The growing ridge stands high above the sea floor.

The world's longest ridge, the Mid-Atlantic Ridge, runs the length of the Atlantic Ocean. Here the North and South American plates are moving away from the Eurasian and African plates. The ridge extends nearly 11,000 kilometers (6214 mi) from Iceland to near Antarctica. The rift valley is 24 kilometers (15 mi) wide and 9 kilometers (6 mi) deep—about 7 kilometers (4 mi) deeper than the Grand Canyon!

Divergent Boundary in the Ocean

Mid-ocean ridges, rift valleys, and new crust mark where the sea floor spreads apart.

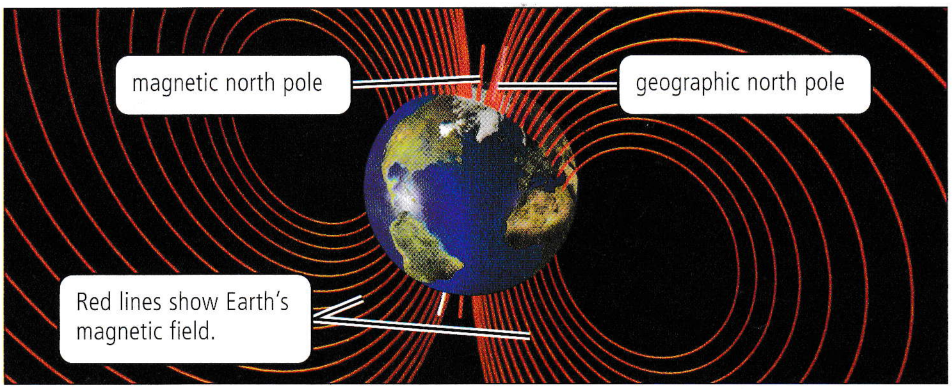


READING VISUALS What happens to the old crust as new crust forms?

Sea-Floor Rock and Magnetic Reversals

You read earlier that the sea floor is younger near a mid-ocean ridge and older farther away. As scientists continued to study the sea-floor rock, they made a surprising discovery about Earth's magnetic field.

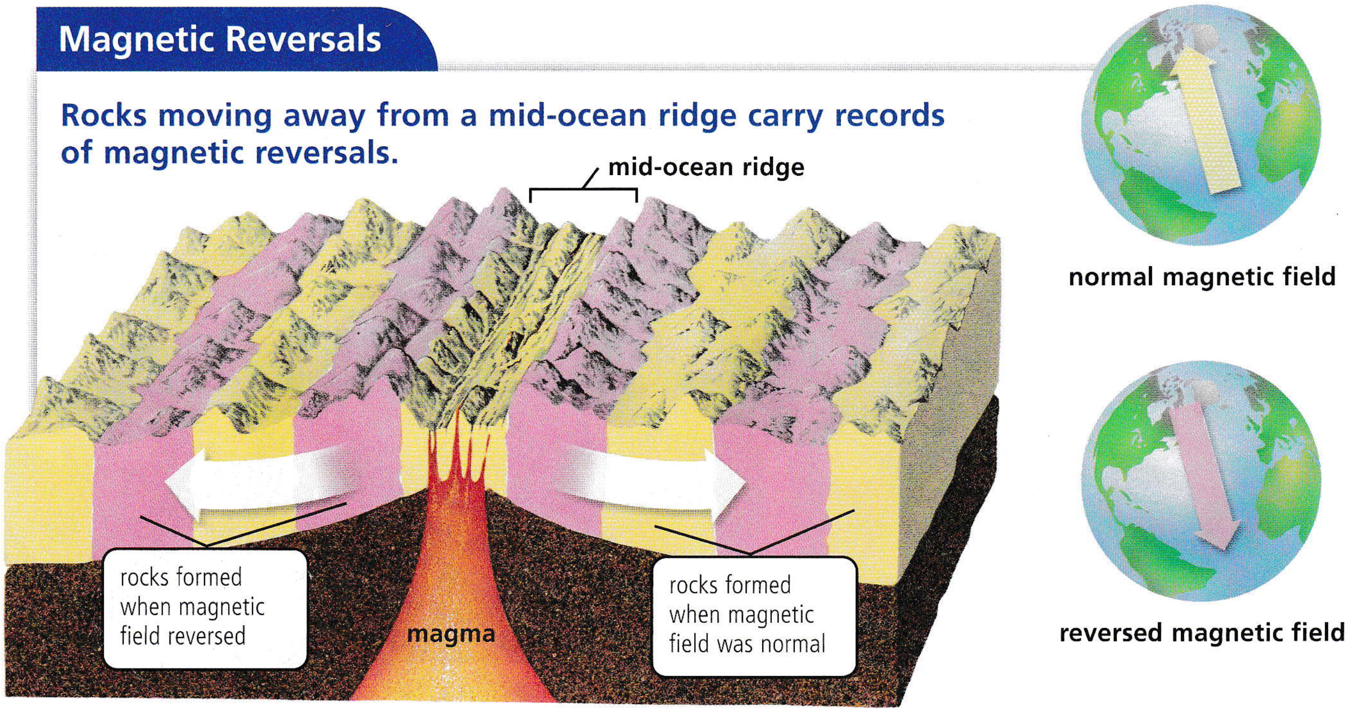
To understand Earth's magnetic field, you can compare the planet to a bar magnet, which has a north and a south pole. Earth's magnetic field affects the entire planet, as shown in the diagram below. Notice that Earth's geographic and magnetic poles are not in the same place.



Unlike a bar magnet, however, Earth's magnetic poles switch places every so often. The north pole becomes the south pole and the south pole becomes the north pole. This switch in direction is called a **magnetic reversal.** Such reversals are caused by changes in Earth's magnetic field. As yet, no one knows why these changes happen. In contrast, Earth's geographic poles never change places.

Magnetic Reversals

Rocks moving away from a mid-ocean ridge carry records of magnetic reversals.



Scientists found that each magnetic reversal is recorded in the sea-floor rock. These records are especially clear at some mid-ocean ridges. As the molten material rises and cools, some magnetic minerals line up with the Earth's magnetic field. When the material hardens, these minerals are permanently fixed like tiny compass needles pointing north and south. Whenever the magnetic field reverses, the cooling minerals record the change.

As shown in the diagram on page 200, the records of magnetic reversals line up like stripes in the rock. As the two plates move away from a mid-ocean ridge, each plate carries a record of magnetic reversals with it. The records are the same on either side of the ridge.

As scientists continued to map the ocean floor, they found more records of these reversals. By dating the rock, scientists had further evidence of plate movement. The youngest rock records the most recent reversal, which happened only about 760,000 years ago. The oldest rock, farthest from the mid-ocean ridge, records reversals that happened more than 150 million years ago.

CHECK YOUR READING Explain how records of magnetic reversals show that plates move apart.

INVESTIGATE Magnetic Reversals

How can you map magnetic reversals?

PROCEDURE

1. Wrap one end of the string around the middle of the bar magnet. Tape the string in place as shown.
2. Place a small piece of tape on one end of the magnet. Label the tape "N" to represent north.
3. Hold the bar magnet over one end of the sea-floor model as shown. Move the magnet SLOWLY toward the other end of the sea-floor model. Record your observations.

WHAT DO YOU THINK?

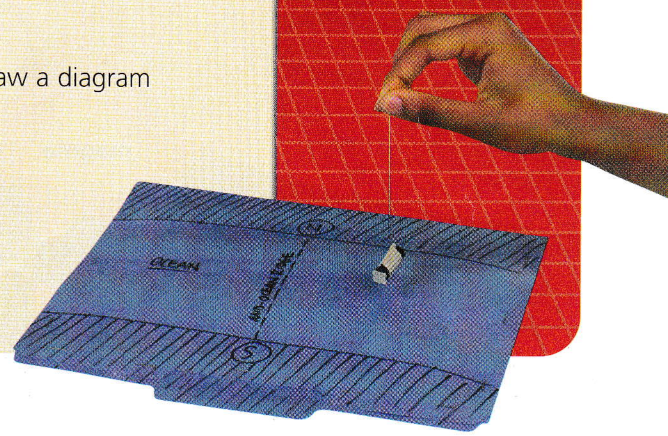
- What did the magnet reveal about the sea-floor model? Draw a diagram showing any pattern that you might have observed.
- Which part of the model represents the youngest sea floor? Which part represents the oldest sea floor?

CHALLENGE If Earth's magnetic field had never reversed in the past, how would the sea-floor model be different?

SKILL FOCUS
Modeling

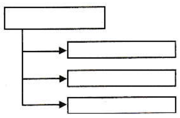
MATERIALS
- string
- bar magnet
- masking tape
- marking pen
- sea-floor model

TIME
20 minutes



Continents split apart at divergent boundaries.

SUPPORTING MAIN IDEAS
Use this diagram to help you take notes on how continents split apart.



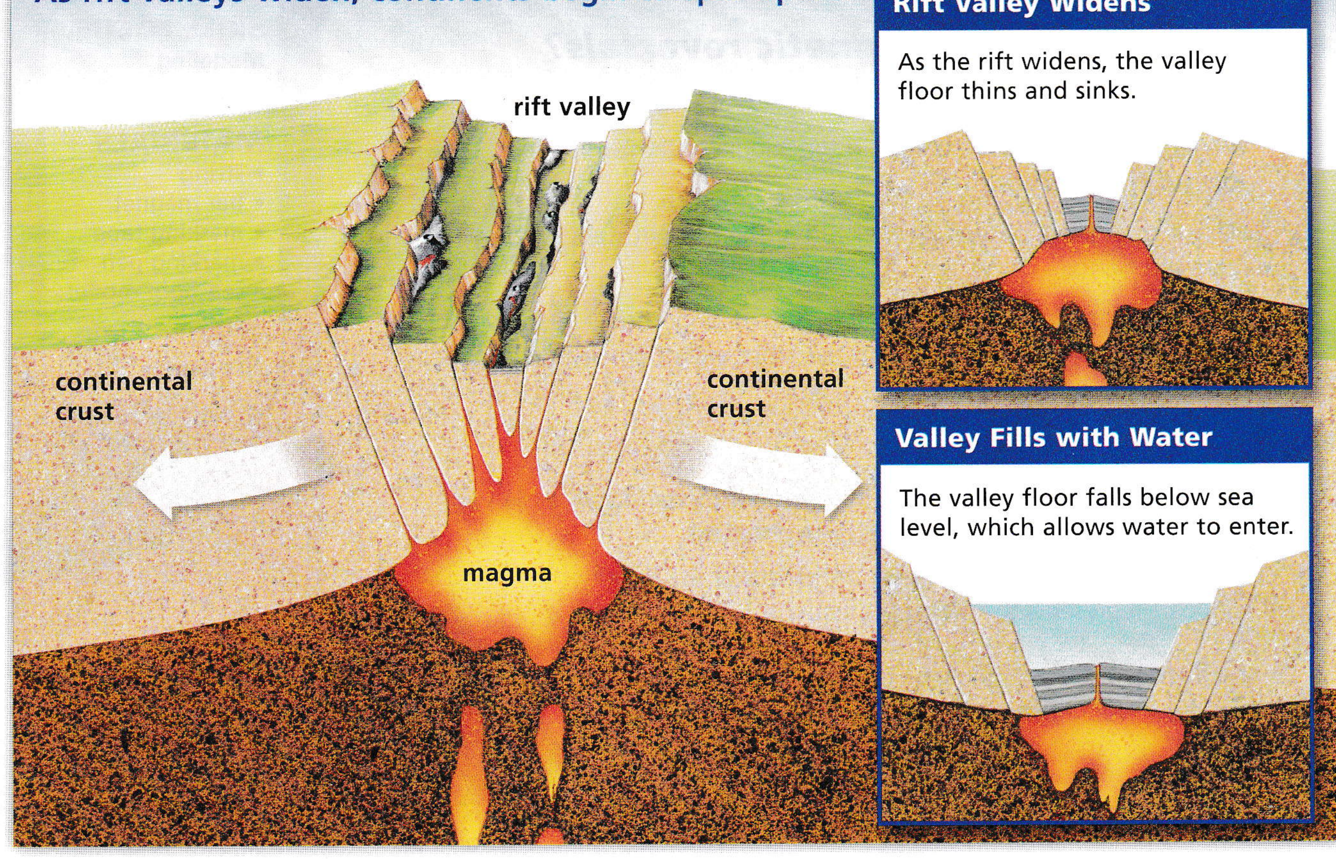
Like the sea floor, continents also spread apart at a divergent boundary. The boundary begins to form when hot material rises from deep in the mantle. This heat causes the crust to bulge upward. The crust cracks as it is stretched, and a rift valley forms, as shown in the diagram below. Magma rises through the cracked, thinned crust, forming volcanoes. As the rift valley grows wider, the continent begins to split apart.

If the rift valley continues to widen, the thinned valley floor sinks lower and lower until it is below sea level. Water from nearby oceans or rivers may fill the valley and form a sea or a lake. In the Middle East, for example, the Arabian Plate and African Plate have been moving apart for several million years. Over time, the waters of the Indian Ocean gradually filled the rift valley, forming the Red Sea. This sea is slowly getting wider as the plates continue to move apart.

CHECK YOUR READING What happens when the floor of a rift valley sinks below sea level?

Divergent Boundary on Land

As rift valleys widen, continents begin to split apart.



The Great Rift Valley in eastern Africa, shown in the photograph above, is a good example of a continental rift valley. It is getting wider as the African Plate splits apart. This huge valley is thousands of kilometers long and as much as 1800 meters (5900 ft) deep.

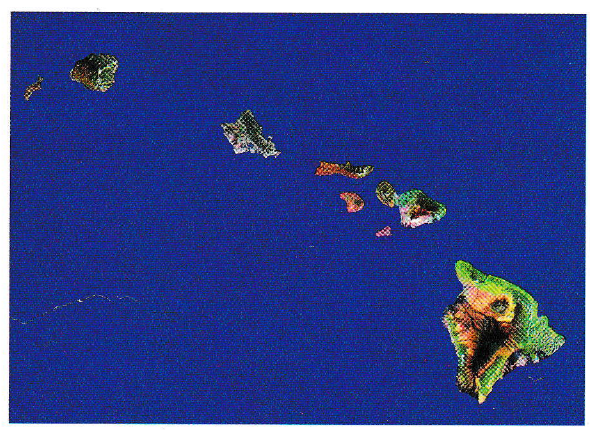
PREDICT Rift valleys, like the Great Rift Valley in Africa, occur where plates are moving apart. What will happen to the Rift Valley when it gets low enough?

Hot spots can be used to track plate movements.

In some places, called **hot spots,** heated rock rises in plumes, or thin columns, from the mantle. Volcanoes often develop above the plume. Although most hot spots occur far from plate boundaries, they offer a way to measure plate movement. This is because a hot spot generally stays in one place while the tectonic plate above it keeps moving.

At a hot spot, the heat from the plume partly melts some of the rock in the tectonic plate above it. It is like holding a candle under a wax tablet. Eventually, the wax above the flame will melt. Likewise, if the plate stays over the hot spot long enough, the rock above it will melt.

In time, a volcano will form at the surface of the plate. The volcano may become high enough to rise above the sea as an island. For example, the Hawaiian Islands are being built as the Pacific Plate moves slowly over a hot spot.

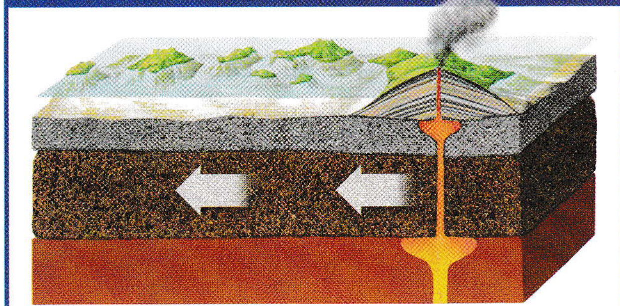


The Hawaiian islands are located in the middle of the Pacific Plate. The largest island, Hawaii, is still over the hot spot.

Hot Spots

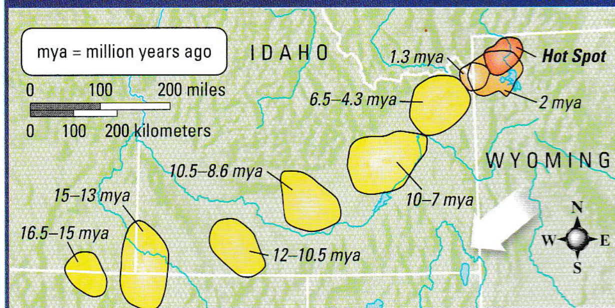
Tectonic plates move over hot spots in the mantle.

Oceanic Hot Spot



The Pacific Plate carries each Hawaiian island away from the hot spot. Eventually, a new volcano forms over the plume.

Continental Hot Spot



The North American Plate moves southwest, carrying each inactive volcano away from the Yellowstone hot spot.

READING VISUALS Which island or landform in each diagram was formed first? How do you know?

When the plate moves on, it carries the first volcano away from the hot spot. Heat from the mantle plume will then melt the rock at a new site, forming a new volcano. The diagram on the left shows this process.

Many hot spots provide a fixed point that scientists can use to measure the speed and direction of plate movements. For example, the Yellowstone hot spot under the North American Plate has formed a chain of inactive volcanoes, as shown in the diagram on the right. Scientists estimate that the North American Plate is moving southwest at about 2.3 cm (1 in.) per year.

CHECK YOUR READING How does a hot-spot volcano form?

6.3 Review

KEY CONCEPTS

1. Name and describe the three types of plate movements.
2. Create a two-column chart with the headings: Divergent boundary; Features. Fill in the chart for divergent boundaries at sea and on land.
3. How are hot spots used to track plate motion?

CRITICAL THINKING

4. **Predict** Suppose a magnetic reversal occurred today. How would new rocks at mid-ocean ridges differ from rocks that formed last year?
5. **Infer** A huge crack runs through Iceland, an island that lies above the Mid-Ocean Ridge. What do you think is happening to this country?

CHALLENGE

6. **Hypothesize** Look carefully at the diagram above and the Hawaiian Islands picture on page 203. Notice that some hot spot islands or landforms are larger than other islands or landforms in the same chain. Develop a hypothesis, based on plate movement, that might explain this fact.

MATH in SCIENCE

SKILL: CALCULATING EQUIVALENT RATES

MATH TUTORIAL
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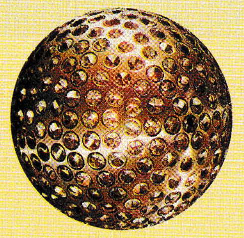
Click on Math Tutorial for more help with rates.

This satellite photograph shows where the Arabian Plate and the African Plate are moving apart. As a result, the Red Sea is slowly growing wider.

Tracking Tectonic Plates

Scientists use lasers to track the movements of tectonic plates. They bounce laser light off satellites and measure the distance from each satellite to the ground. As the plates move, the distance changes. With this tracking system, scientists know exactly how much tectonic plates move each year.



This 0.61-meter-wide satellite is covered with mirrors to reflect laser light back to Earth.

You can use equivalent rates to predict how far two divergent plates will move over a given time. A rate is a ratio of two measures expressed in different units, such as

$$\frac{10 \text{ cm}}{4 \text{ yr}}$$

Example

If Boston, Massachusetts, and Lisbon, Portugal, are moving apart at an average rate of 10 cm every 4 years, how much farther apart will they move in 20 years?

Solution

Write an equivalent rate.

$$\frac{10 \text{ cm}}{4 \text{ yr}} = \frac{?}{20 \text{ yr}}$$

Divide 20 yr by 4 yr to get 5, then multiply 10 cm by 5.

$$20 \div 4 = 5$$

$$10 \times 5 = 50$$

$$\frac{10 \text{ cm}}{4 \text{ yr}} = \frac{50 \text{ cm}}{20 \text{ yr}}$$

ANSWER Boston and Lisbon will move 50 centimeters farther apart in 10 years.

Answer the following questions.

1. If New York, New York, and London, England, are moving apart at an average rate of 5 cm every 2 years, how much farther apart will they move in 8 years?
2. If Miami, Florida, and Casablanca, Morocco, are moving apart at an average rate of 25 cm every 10 years, how much farther apart will they move in 30 years?
3. If Portland, Maine, and Dublin, Ireland, are moving apart at an average rate of 50 cm every 20 years, how much farther apart will they move in 10 years?

CHALLENGE If Halifax, Nova Scotia, and Birmingham, England, are moving apart at an average rate of 5 cm every 2 years, how long will it take them to move 35 cm farther apart?

KEY CONCEPT

6.4 Plates converge or scrape past each other.

BEFORE, you learned
- Plates move apart at divergent boundaries
- In the oceans, divergent boundaries mark where the sea floor spreads apart
- On land, continents split apart at divergent boundaries

NOW, you will learn
- What happens when two continental plates converge
- What happens when an oceanic plate converges with another plate
- What happens when one plate scrapes past another plate

VOCABULARY

subduction p. 206
continental-continental collision p. 207
oceanic-oceanic subduction p. 208
oceanic-continental subduction p. 209

EXPLORE Tectonic Plates

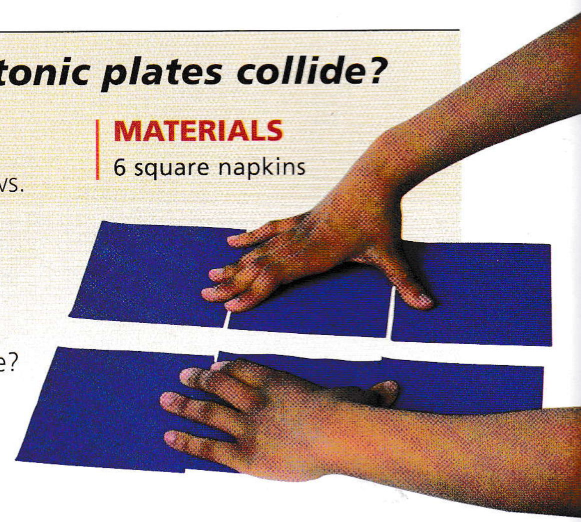
What happens when tectonic plates collide?

PROCEDURE

1. Arrange six square napkins in two rows.
2. Slowly push the two rows of napkins together. Observe what happens.

WHAT DO YOU THINK?
- In what ways did the napkin edges move?
- How might your observations relate to the movement of tectonic plates?

MATERIALS
6 square napkins

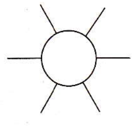


Tectonic plates push together at convergent boundaries.

You read earlier that new crust forms at divergent boundaries where plates move apart. At convergent boundaries, where plates push together, crust is either folded or destroyed.

When two plates with continental crust collide, they will crumple and fold the rock between them. A plate with older, denser oceanic crust will sink beneath another plate. The crust melts in the asthenosphere and is destroyed. When one plate sinks beneath another, it is called **subduction.** The word is based on the Latin prefix *sub-*, meaning "under," and the Latin *ducere,* meaning "to lead." Therefore, subduction is a process in which one plate is "led under" another.

VOCABULARY
Remember to make a description wheel for the terms in this section.



There are three types of convergent boundaries: where two continental plates meet, where two oceanic plates meet, or where an oceanic plate and a continental plate meet. Major geologic events occur at all three types of boundaries.

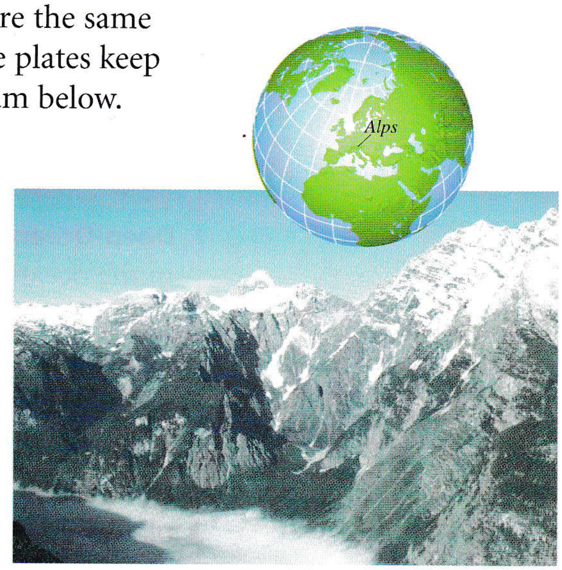
Continental-Continental Collision

A **continental-continental collision** occurs where two plates carrying continental crust push together. Because both crusts are the same density, neither plate can sink beneath the other. If the plates keep moving, their edges crumple and fold, as in the diagram below.

You can see the same effect if you put two blocks of clay on a table and push them together. If you push hard enough, one or both of the blocks will buckle. One cannot sink under the other, so the clay folds under the pressure.

In some cases, the folded crust can be pushed up high enough to form mountains. Some of the world's largest mountains appear along continent-continent boundaries. For instance, the European Alps, shown in the photograph at right, are found where the African and European plates are colliding. The tallest mountains in the world, the Himalayas, first formed when the Indian Plate began colliding with the European Plate.

The Himalayas and the Alps are still forming today. As long as the plates keep moving, these mountains will keep rising higher.

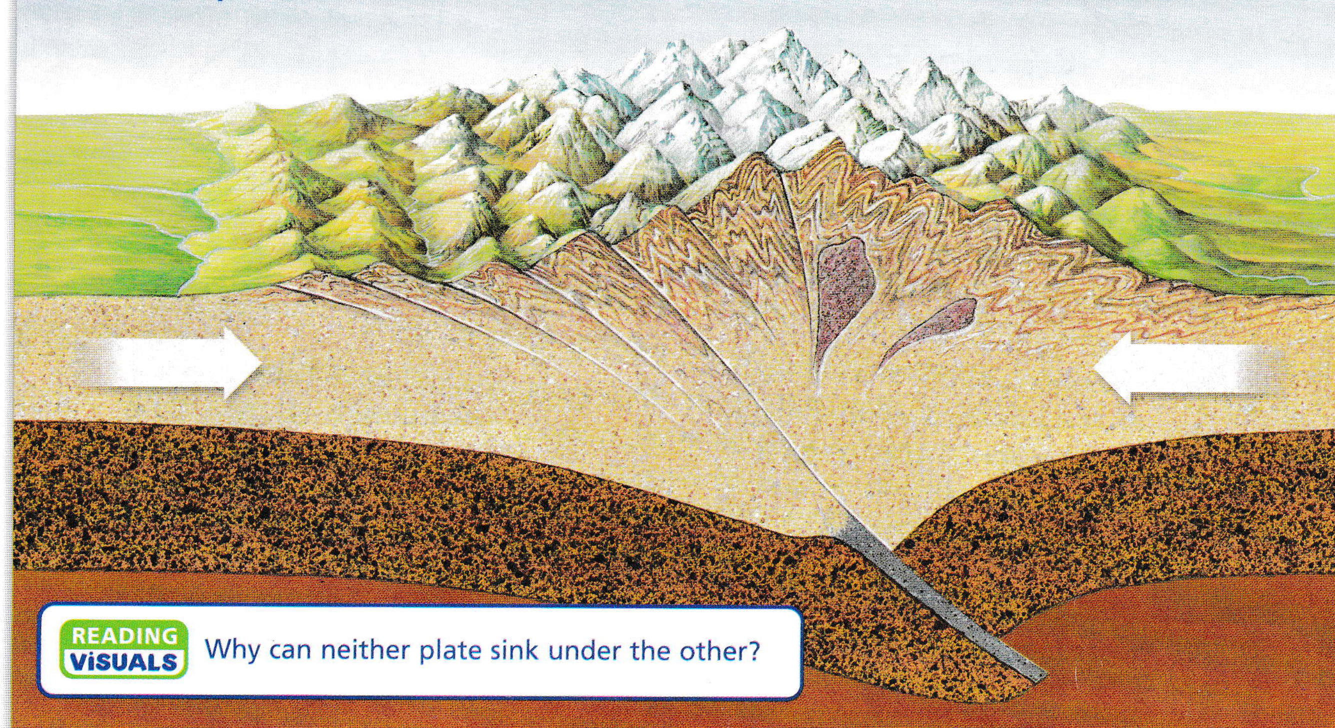


The European Alps began rising nearly 40 million years ago as a section of the African Plate collided with the European Plate.

CHECK YOUR READING Explain how colliding plates form mountain ranges.

Convergent Boundary—Collision

Rocks crumple and fold to form mountains.



READING VISUALS Why can neither plate sink under the other?

Oceanic-Oceanic Subduction

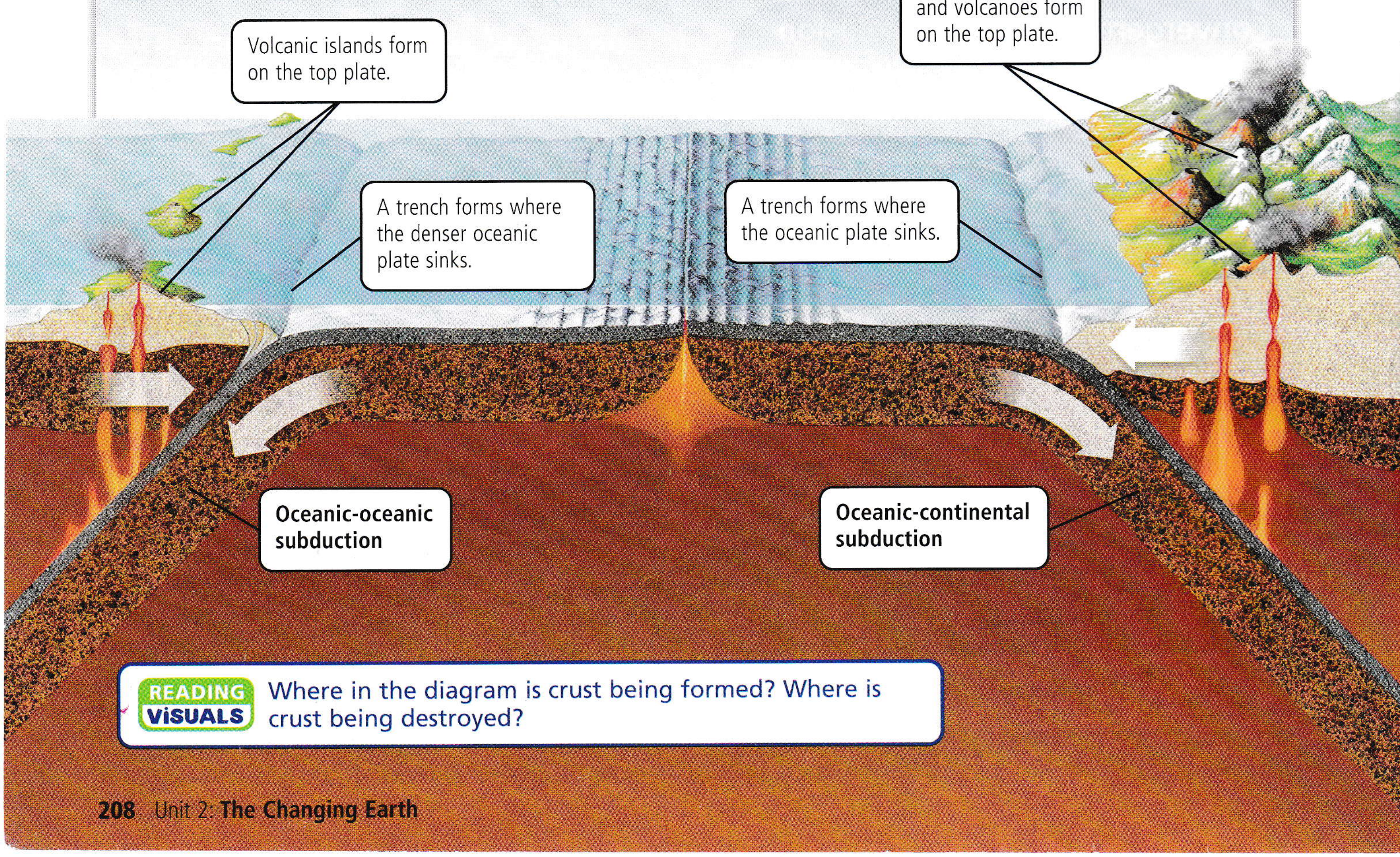
An **oceanic-oceanic subduction** occurs where one plate with oceanic crust sinks, or subducts, under another plate with oceanic crust. The older plate sinks because it is colder and denser than the younger plate. When the older crust reaches the asthenosphere, it melts in the intense heat. Two main features form at oceanic-oceanic subductions: deep-ocean trenches and island arcs.

Deep-Ocean Trenches These trenches are like deep canyons that form in the ocean floor as a plate sinks. Most deep-ocean trenches are found in the Pacific Ocean. For example, at the Mariana Trench, the Pacific Plate is sinking under the Philippine Plate. This trench is the deepest place in the world's oceans, extending nearly 11,000 meters (36,000 ft) into the sea floor.

Island Arcs There are chains of volcanic islands that form on the top plate, parallel to a deep-ocean trench. As oceanic crust of the sinking plate melts, magma rises through the top plate. Over time, the flows build up a series of islands. Island arcs include the Philippine Islands, the Aleutian Islands of Alaska, and the islands of Japan.

Convergent Boundaries—Subduction

Sinking plates form deep-ocean trenches, island arcs, and coastal mountains.



READING VISUALS Where in the diagram is crust being formed? Where is crust being destroyed?

Oceanic-Continental Subduction

An **oceanic-continental subduction** occurs when ocean crust sinks under continental crust, as shown in the diagram on page 208. The oceanic crust sinks because it is colder and denser than the continental crust. At these sites, deep-ocean trenches also form, along with coastal mountains.

VISUALIZATION CLASSZONE.COM
Explore what happens along plate boundaries.

Deep-Ocean Trenches Some of the world's youngest trenches are in the eastern Pacific Ocean. Here, for example, the Pacific Plate is sinking under the North American Plate. As the oceanic crust moves, it often causes underwater earthquakes.

Coastal Mountains As oceanic crust sinks under a continent, the continental crust buckles to form a range of mountains. These mountains, like island arcs, parallel a deep-ocean trench. As the diagram on page 208 shows, some of these mountains are volcanoes, which form as melted oceanic crust rises through the top plate.

The Cascade Mountains in Oregon and Washington are an example of coastal mountains. They began forming as the Juan de Fuca Plate began sinking under the North American Plate. Some of these peaks, such as Mount St. Helens in Washington, are active volcanoes.

CHECK YOUR READING Why do deep-ocean trenches form at both types of subduction?

INVESTIGATE Convergent Boundaries

How can you model converging plates?

Tectonic plates move so slowly and are so large that it may be hard to visualize exactly how they move. Use what you know to design models showing how converging plates collide and subduct.

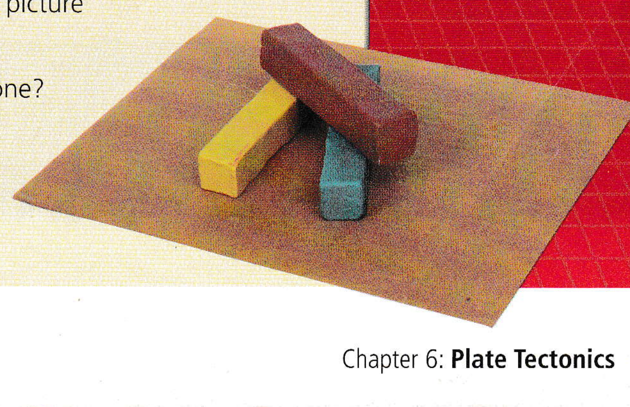
DESIGN — YOUR OWN —

PROCEDURE

1. Design your models using the materials listed. You can use the diagrams on pages 207–208 as a guide.
2. Add more clay to your models if you need it.

WHAT DO YOU THINK?

- Describe how your models worked. You can draw a picture of each model to go along with your description.
- How well did your models represent each type of zone? Did each model work? Why or why not?
- How would you modify your designs now that you have seen the results?



SKILL FOCUS
Designing models

MATERIALS
- clay in three or more colors
- poster board
- marker pens

TIME
30 minutes

Tectonic plates scrape past each other at transform boundaries.

You learned that crust is formed at a divergent boundary and folded or destroyed at a convergent boundary. However, at a transform boundary, crust is neither formed nor destroyed. Here, two plates move past each other in opposite directions, as shown in the diagram below. As the plates move, their edges scrape and grind against each other.

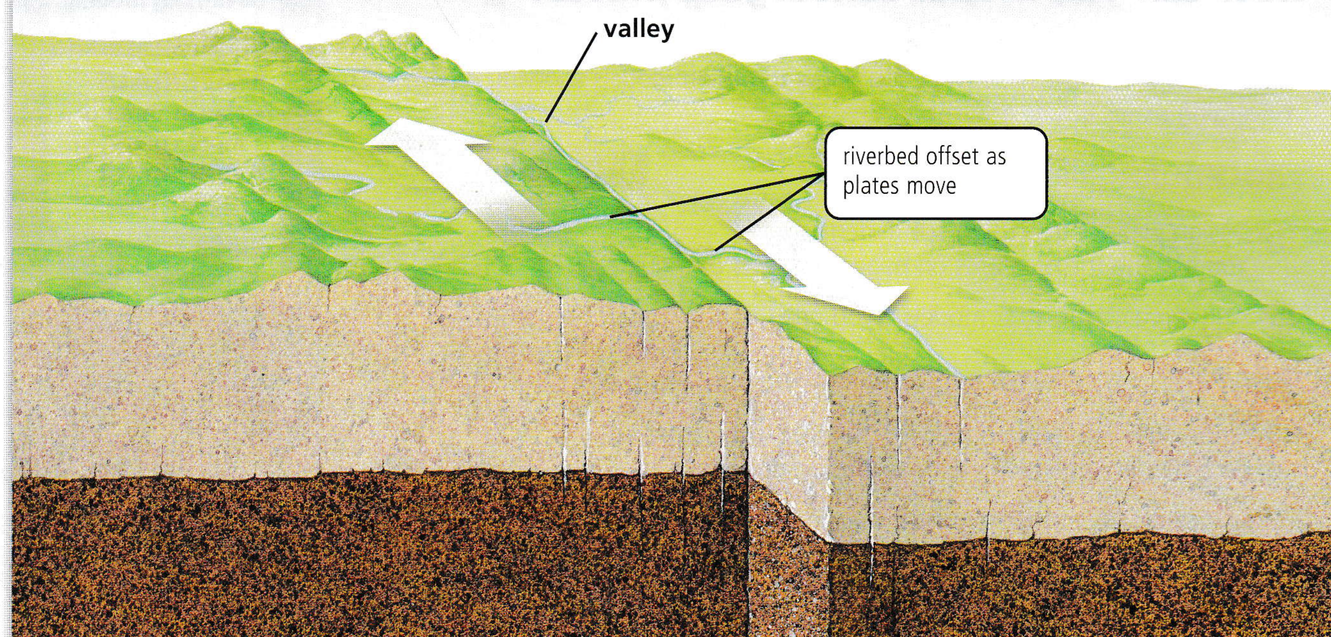
This long crack in the earth reveals the transform boundary known as the San Andreas Fault.

Transform boundaries occur mostly on the sea floor near mid-ocean ridges. They also occur on land, where some are clearly visible as long cracks in Earth's surface. The San Andreas Fault in California is a transform boundary that runs from the Gulf of California through the San Francisco area. It marks where the Pacific Plate and part of the North American Plate are moving in opposite directions. If the plates keep moving at their present rate, Los Angeles will be a suburb of San Francisco in about 10 million years.

CHECK YOUR READING What makes the San Andreas Fault a transform boundary?

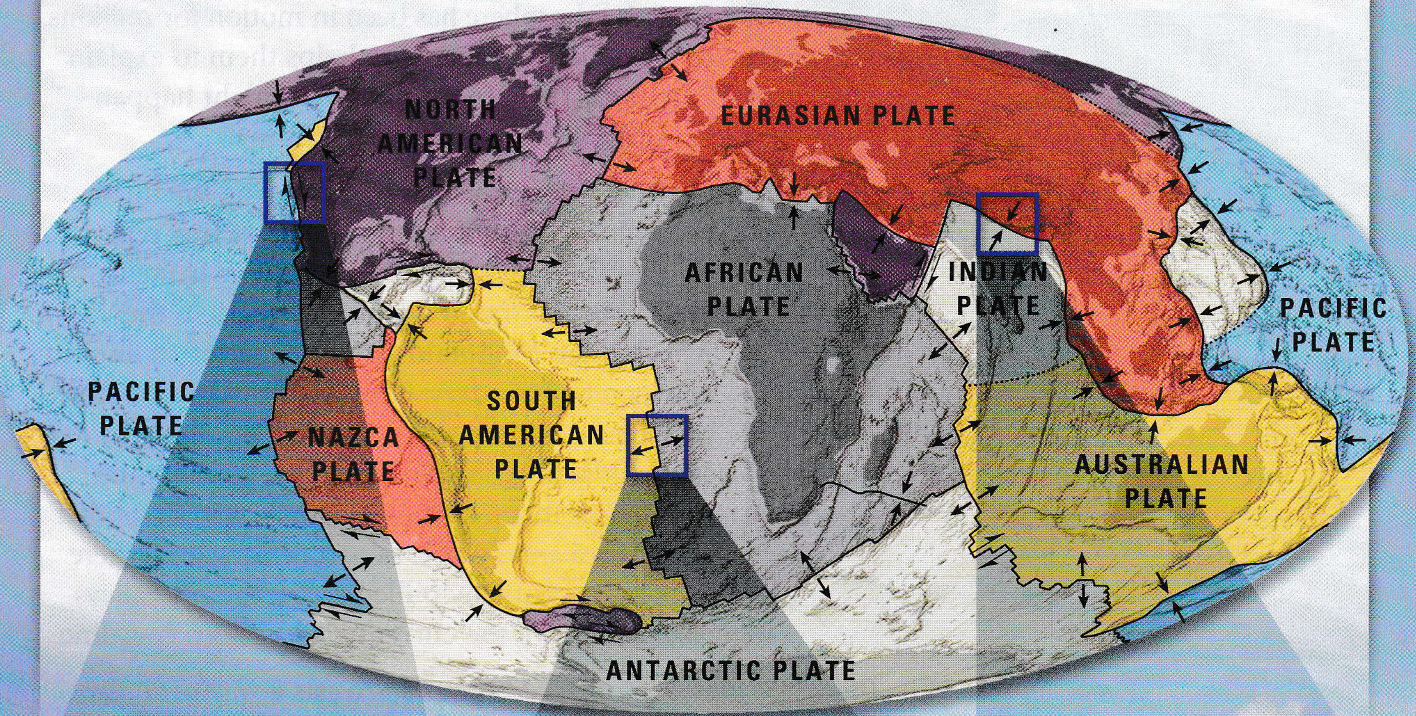
Transform Boundary

Plate edges grind and scrape past each other. Crust is neither formed nor destroyed.

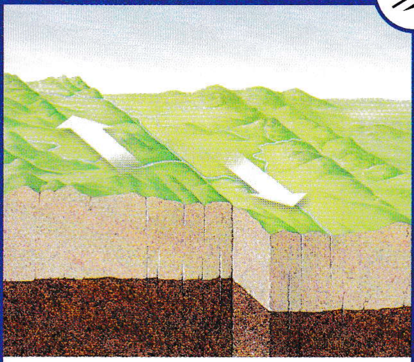


Tectonic Plate Boundaries

There are three types of plate boundaries: transform, divergent, and convergent. Major geologic events occur at all three types.

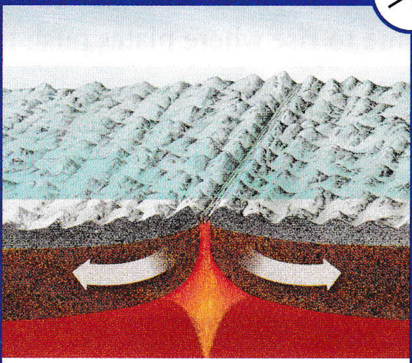


Transform Boundaries



Plates scrape horizontally past each other. Crust is neither formed nor destroyed.

Divergent Boundaries

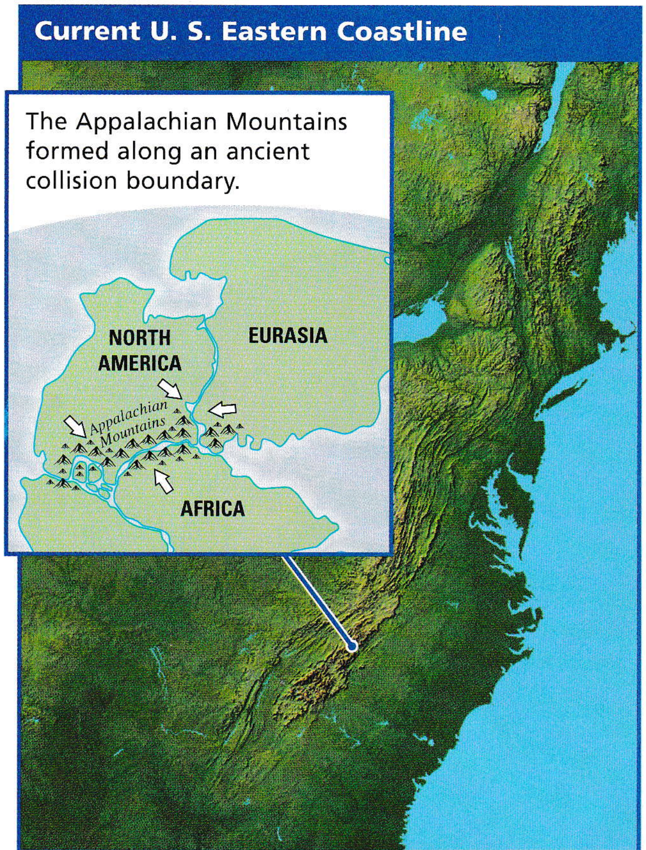


As plates move apart, new crust is built, forming mid-ocean ridges and rift valleys.

Convergent Boundaries

Crust is destroyed where plates subduct. It is folded where plates collide.

READING VISUALS Where else on the map above can you find a transform, divergent, and convergent boundary?



The theory of plate tectonics helps geologists today.

The theory of plate tectonics changed the way that scientists view Earth. They learned that the planet's lithosphere has been in motion for millions of years. Today, the theory helps them to explain Earth's past and to predict what might happen along plate boundaries in the future.

By studying rock layers and using the theory, geologists can uncover the history of any region on Earth. For example, in the eastern United States, the deformed and folded rocks in the Appalachian Mountains are evidence of an ancient convergent boundary. Geologists discovered that these rocks are the same type and age as rocks in northwest Africa. These facts reveal that the mountains formed when North America collided with Africa and Eurasia as part of Pangaea. Where the plates eventually pulled apart, the rift valleys formed part of the current U. S. eastern coastline.

The theory of plate tectonics also gives scientists a way to study and predict geologic events. Scientists can predict, for example, that there are likely to be more earthquakes where plates slide past each other. They can look for volcanic activity where plates are sinking beneath other plates. And they can predict that mountains will continue to rise where plates push together.

CHECK YOUR READING What future events can scientists predict using the theory of plate tectonics? Give two examples.

6.4 Review

KEY CONCEPTS

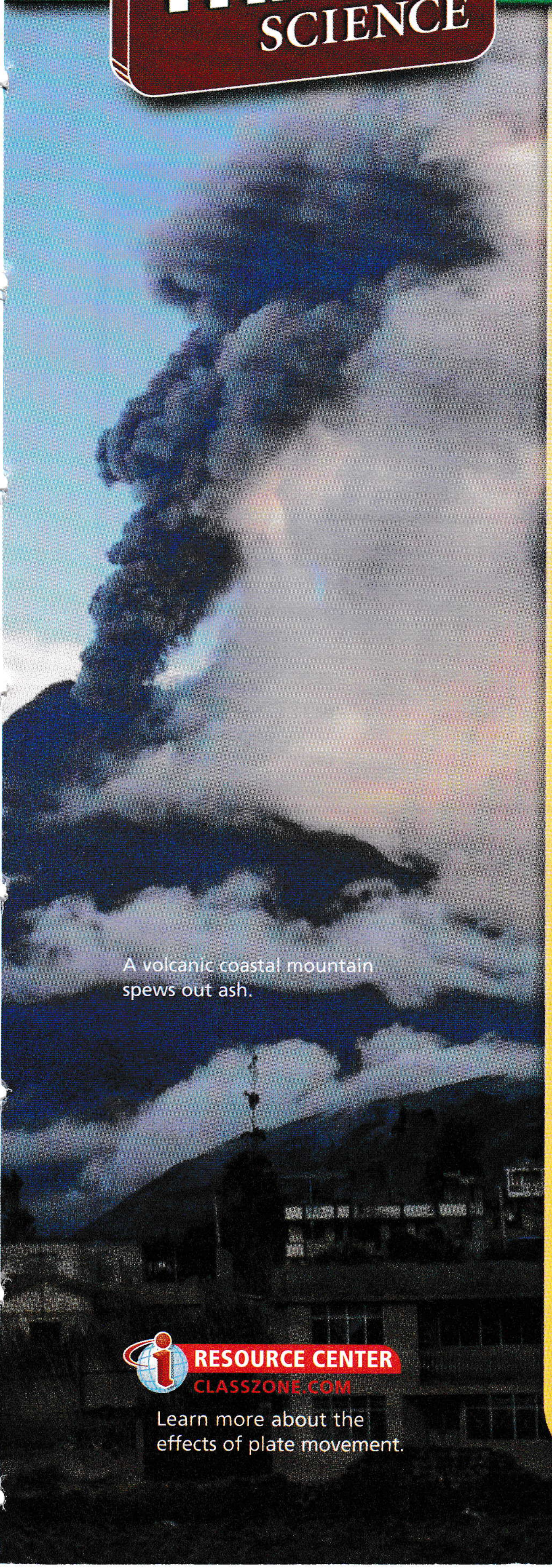
1. What are the three types of convergent boundaries?
2. Describe what happens at a transform boundary.
3. Why is the theory of plate tectonics so important to geologists?

CRITICAL THINKING

4. **Compare and Contrast** Use a Venn diagram to compare and contrast oceanic-oceanic and oceanic-continental subduction boundaries.
5. **Interpreting Visuals** Look again at the map on page 211. Identify the plates and type of boundary that formed the Andes Mountains on the west coast of South America.

CHALLENGE

6. **Synthesize** Sketch a diagram of the following landscape and label all the features. A plate with oceanic crust is sinking beneath a plate with continental crust. Further inland on the continent, a transform boundary can be seen in Earth's crust.



A volcanic coastal mountain spews out ash.

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Learn more about the effects of plate movement.

Think SCIENCE

SKILL: EVALUATING CONCLUSIONS

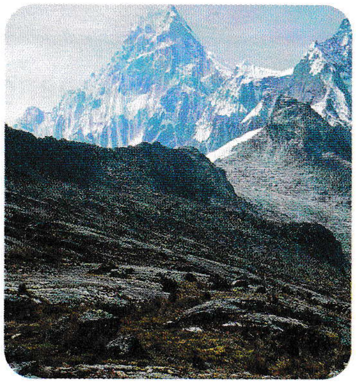
What on Earth Is Happening Here?

When tectonic plates move, they cause major changes in Earth's surface. Among other things, the earth shakes, magma erupts on the surface, crust is built or destroyed, and mountains or islands form. Read the observations about plate movements below, then evaluate the conclusions given.

Observations

Scientists made these observations about a region known for the movement of two major tectonic plates.

a. The region is on the coast of a landmass.
b. Along the coast is a deep-ocean trench.
c. The mountains on the coast are volcanic.
d. A line connecting these mountains is fairly straight.
e. The mountains are getting higher.
f. Far out at sea, a mid-ocean ridge is forming.



Conclusions

Here are three possible conclusions about the movement of tectonic plates in the region.

- One plate is pulling away from the other.
- One plate is sinking under the other.
- One plate is scraping past the other.

Evaluate Each Conclusion

On Your Own Decide how well the observations support each conclusion. Note any observations that indicate that a conclusion is not justified.

As a Group Decide which conclusion is most reasonable. Discuss your ideas in a small group, and see if the group can agree.

CHALLENGE What further observations would support or weaken each conclusion? How could you make these observations? What other phenomena might this conclusion help explain?

6 Chapter Review

the BIG idea

The movement of tectonic plates causes geologic changes on Earth.

CONTENT REVIEW
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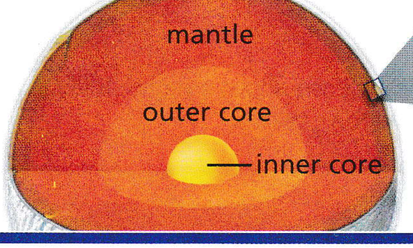
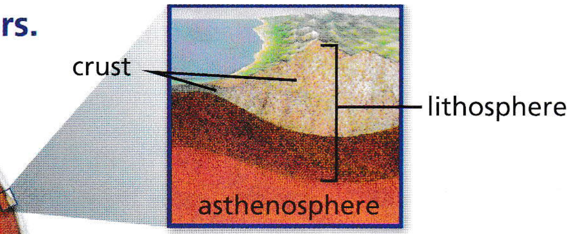
KEY CONCEPTS SUMMARY

1 Earth has several layers.



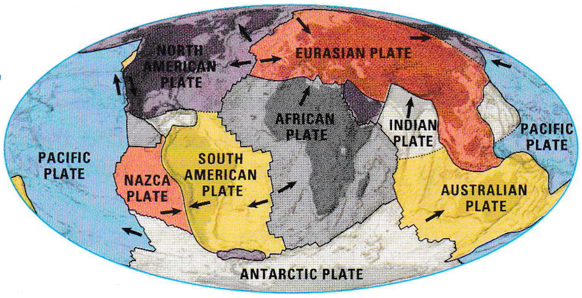


The lithosphere is made up of tectonic plates, which rest on the asthenosphere.

VOCABULARY
inner core p. 186
outer core p. 186
mantle p. 187
crust p. 187
lithosphere p. 187
asthenosphere p. 187
tectonic plate p. 188

2 Continents change position over time.

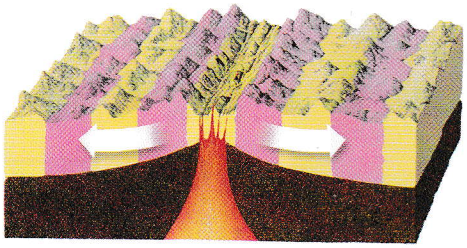
Gravity and motions in the asthenosphere move tectonic plates over Earth's surface.



VOCABULARY
continental drift p. 190
Pangaea p. 192
mid-ocean ridge p. 192
convection p. 193
convection current p. 193
theory of plate tectonics p. 194

3 Plates move apart.

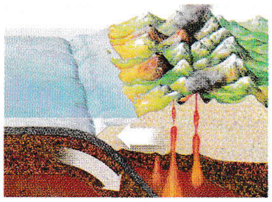
New crust is formed at divergent boundaries. Features include:
- mid-ocean ridges
- records of magnetic reversals
- rift valleys



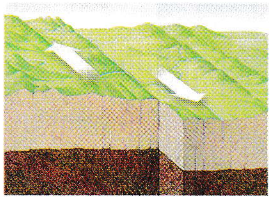
VOCABULARY
divergent boundary p. 198
convergent boundary p. 198
transform boundary p. 198
rift valley p. 199
magnetic reversal p. 200
hot spot p. 203

4 Plates converge or scrape past each other.

Crust is destroyed or folded at convergent boundaries.
- Subduction boundaries form island arcs, deep-ocean trenches, and coastal mountains.
- Collision boundaries can form mountains.



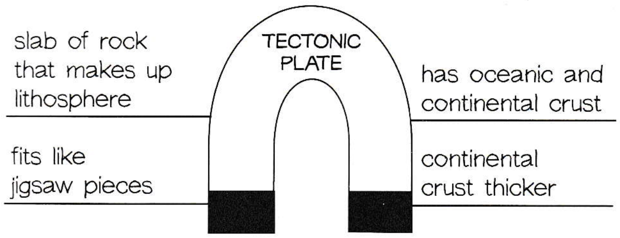
Crust is neither formed nor destroyed at transform boundaries.



VOCABULARY
subduction p. 206
continental-continental collision p. 207
oceanic-oceanic subduction p. 208
oceanic-continental subduction p. 209

Reviewing Vocabulary

Make a magnet word diagram for each of the vocabulary terms listed below. Write the term in the magnet. Write other terms or ideas related to it on the lines around the magnet.



1. mantle
2. lithosphere
3. mid-ocean ridge
4. convection current
5. divergent boundary
6. convergent boundary

Reviewing Key Concepts

Multiple Choice *Choose the letter of the best answer.*

7. Which of the following best describes Earth's mantle?
   - **a.** the densest of Earth's layers
   - **b.** the home of all life on Earth
   - **c.** the thickest layer of hot rock
   - **d.** the thinnest and hottest layer

8. Tectonic plates make up Earth's
   - **a.** lower mantle
   - **b.** lithosphere
   - **c.** asthenosphere
   - **d.** inner core

9. Why did many scientists reject Wegener's continental drift hypothesis?
   - **a.** He could not explain how the continents moved.
   - **b.** The geology of continents did not support his hypothesis.
   - **c.** Fossil evidence showed that the continents were never joined.
   - **d.** The climates of the continents have remained the same.

10. What evidence from the sea floor shows that tectonic plates move?
    - **a.** The sea floor is much older than any of the continents.
    - **b.** The sea floor is youngest near a mid-ocean ridge and older farther away.
    - **c.** Mid-ocean ridges circle Earth like seams in a baseball.
    - **d.** The sea floor is thinner than continental crust.

11. A mid-ocean ridge forms where plates
    - **a.** move apart
    - **b.** push together
    - **c.** scrape past each other
    - **d.** subduct

12. Plate motion is caused partly by
    - **a.** magnetic reversals
    - **b.** convection currents
    - **c.** continental drift
    - **d.** volcanic hot spots

13. Which of the following is formed at a collision zone?
    - **a.** mountain range
    - **b.** volcanic island chain
    - **c.** deep-ocean trench
    - **d.** continental rift valley

14. What happens when two oceanic plates meet?
    - **a.** Both plates sink into the asthenosphere.
    - **b.** The colder, denser plate sinks.
    - **c.** Both plates fold the rock between them.
    - **d.** One plate slides past the other.

15. Where is crust neither formed nor destroyed?
    - **a.** mid-ocean ridge
    - **b.** continental rift valley
    - **c.** transform boundary
    - **d.** subduction zone

Short Answer *Write a short answer to each question.*

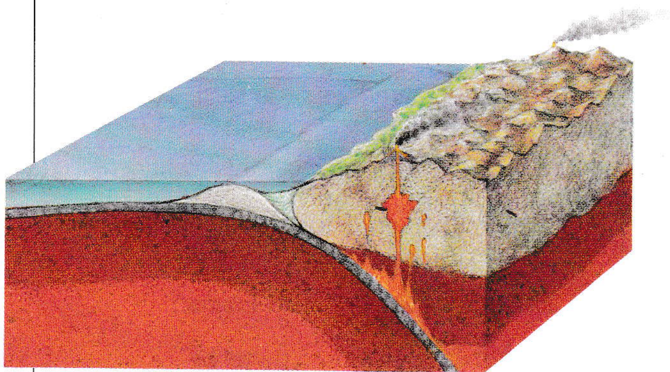
16. How does the theory of plate tectonics help geologists predict future geologic events?

17. How do rocks record changes in Earth's magnetic field?

18. Explain what happens when a continental plate splits apart.

Thinking Critically

Use the diagram to answer the questions below.



19. **ANALYZE** Write your own explanation of how the coastal mountains formed.

20. **PREDICT** Would you expect the volcanoes on this coastline to continue to be active? Why or why not?

21. **APPLY** Looking at the map above, why do you think the coastal mountains are in a fairly straight line?

22. **APPLY** On the map above, where would you expect to find a deep ocean trench? Why?

23. **APPLY** A friend looks at the diagram and tells you that there should be an island arc forming off the coast. Use your own knowledge and the map above to support or reject your friend's statement.

24. **SYNTHESIZE** On a separate piece of paper, extend the diagram to the left. Draw the type of plate boundary that someone might find far out at sea.

25. **PREDICT** Will the Andes Mountains on the west coast of South America become taller or shorter in the future? Use the theory of plate tectonics to explain your answer.

APPLY Copy the chart below. Fill in the type of boundary—divergent, convergent, or transform—where each formation is likely to appear.

Formation	Type of Boundary
26. Mid-ocean ridge	
27. Volcanic island arc	
28. Rift valley on land	
29. Mountains	
30. Deep-ocean trench	
31. Hot-spot volcano	

the BIG idea

32. **IDENTIFY CAUSE AND EFFECT** Look again at the photograph on pages 182–183. Now that you have finished the chapter, explain what may be forming this crack in Earth's surface.

33. **PREDICT** Use the map on page 195, which shows Earth's tectonic plates and the directions in which they are moving. Based on the plate movements, where do you think the continents might be in a few million years? Draw a map that illustrates your prediction. You might want to give your landmasses names.

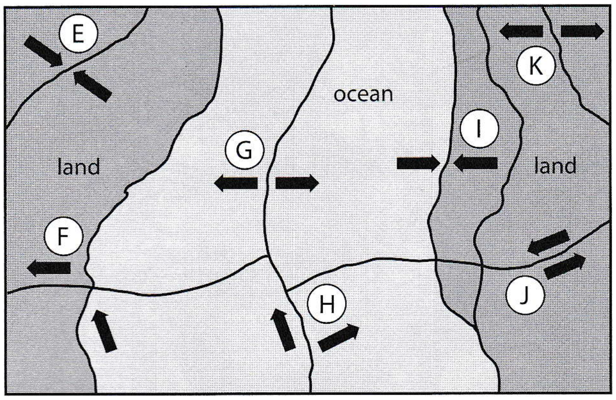
UNIT PROJECTS

If you are doing a unit project, make a folder for your project. Include in your folder a list of the resources you will need, the date on which the project is due, and a schedule to keep track of your progress. Begin gathering data.

Standardized Test Practice

Analyzing a Diagram

The diagram shows several tectonic plates. The arrows indicate the direction each plate is moving. Study the diagram and answer the questions below.



1. Where is an ocean trench most likely to form?
   a. F
   b. G
   c. H
   d. I

2. Where is a continental rift valley most likely to form?
   a. E
   b. F
   c. J
   d. K

3. Where would you find a convergent boundary?
   a. E
   b. F
   c. H
   d. K

4. Where is a mid-ocean ridge most likely to form?
   a. G
   b. H
   c. I
   d. F

5. What is a good example of a transform boundary?
   a. E
   b. I
   c. J
   d. K

6. Which is most likely to happen at I?
   a. Island arcs will form parallel to a trench.
   b. A spreading center will create a rift valley.
   c. Continental crust will be destroyed.
   d. Subduction will cause oceanic crust to melt.

7. Why are earthquakes likely to occur at J?
   a. Two plates are spreading away from each other.
   b. Two plates are colliding with each other.
   c. Two plates are scraping past each other.
   d. One plate is sliding under another plate.

8. Why are mountains likely to form at E?
   a. A rift valley is forming.
   b. Two plates are colliding.
   c. Magma is flowing upward.
   d. One plate is sinking.

9. Which is most likely to happen at G?
   a. Rising magma will create new crust.
   b. Subduction will cause a deep trench.
   c. Colliding plates will cause rocks to crumple.
   d. Moving plates will create island arcs.

Extended Response

Answer the two questions below in detail. Include some of the terms shown in the word box. In your answer, underline each term you use.

tectonic plates	subduction	magma	crust
continental drift	hot spot	mantle	

10. Two island chains are separated by a deep ocean trench. Although they are close to each other, the islands have very different fossils and types of rock. Explain why these island chains have such different geologic features.

11. Andrea lives near a chain of mountains located far from plate boundaries. The closest mountain is an active volcano. The other mountains used to be volcanoes. The farther away a mountain is in the chain, the older it is. Explain these facts.