Section 1

Earth's Interior

Reading Preview

Key Concepts

- How have geologists learned about Earth's inner structure?
- What are the characteristics of Earth's crust, mantle, and core?

Key Terms

- seismic waves • pressure
- crust • basalt • granite
- mantle • lithosphere
- asthenosphere • outer core
- inner core

Target Reading Skill

Using Prior Knowledge Before you read, look at the section headings and visuals to see what this section is about. Then write what you know about Earth's interior in a graphic organizer like the one below. As you read, write what you learn.

What You Know
1. Earth's crust is made of rock. 2.

What You Learned
1. 2.

Lab zone Discover Activity

How Do Scientists Find Out What's Inside Earth?

1. Your teacher will provide you with three closed film canisters. Each canister contains a different material. Your goal is to determine what is inside each canister—even though you can't directly observe what it contains.
2. Tape a paper label on each canister.
3. To gather evidence about what is in the canisters, you may tap, roll, shake, or weigh them. Record your observations.
4. What differences do you notice between the canisters? Apart from their appearance on the outside, are the canisters similar in any way? How did you obtain this evidence?

Think It Over

Inferring From your observations, what can you infer about the contents of the canisters? How is a canister like Earth?

Imagine watching an island grow! That's exactly what you can do on the island of Hawaii. On the south side of the island, molten material pours out of cracks in Mount Kilauea (kee loo AY uh) and flows into the ocean. As this lava flows over the land, it cools and hardens into rock.

The most recent eruptions of Mount Kilauea began in 1983. An area of cracks 7 kilometers long opened in Earth's surface. Through the cracks spurted "curtains of fire"—fountains of hot liquid rock from deep inside Earth. Since that time, the lava has covered more than 100 square kilometers of land with a layer of rock. When the lava reaches the sea, it extends the borders of the island into the Pacific Ocean.

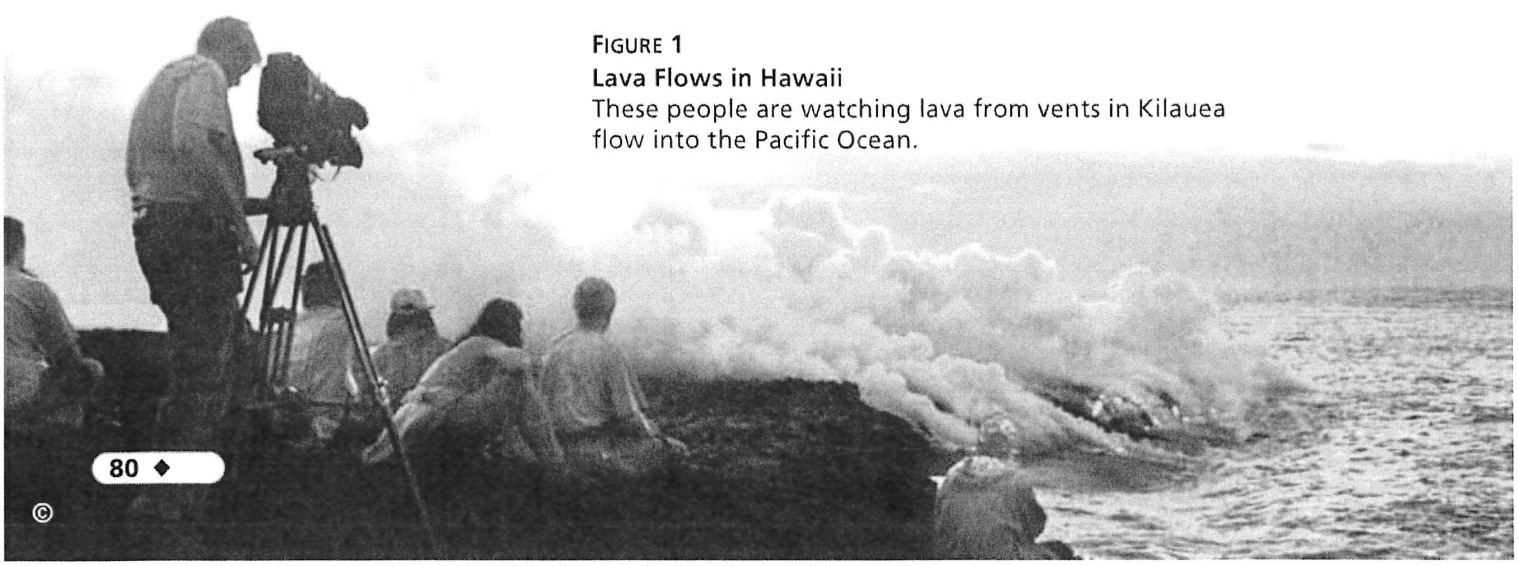


FIGURE 1
Lava Flows in Hawaii
These people are watching lava from vents in Kilauea flow into the Pacific Ocean.

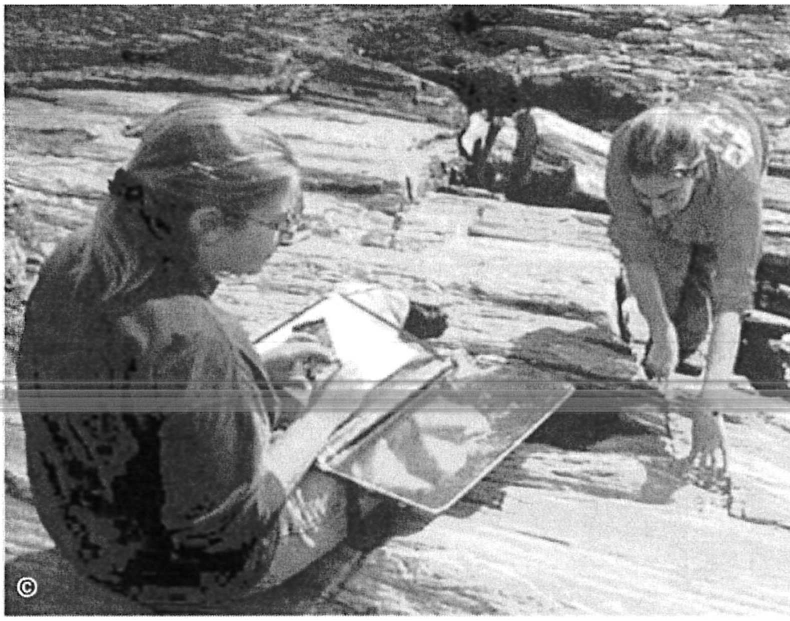


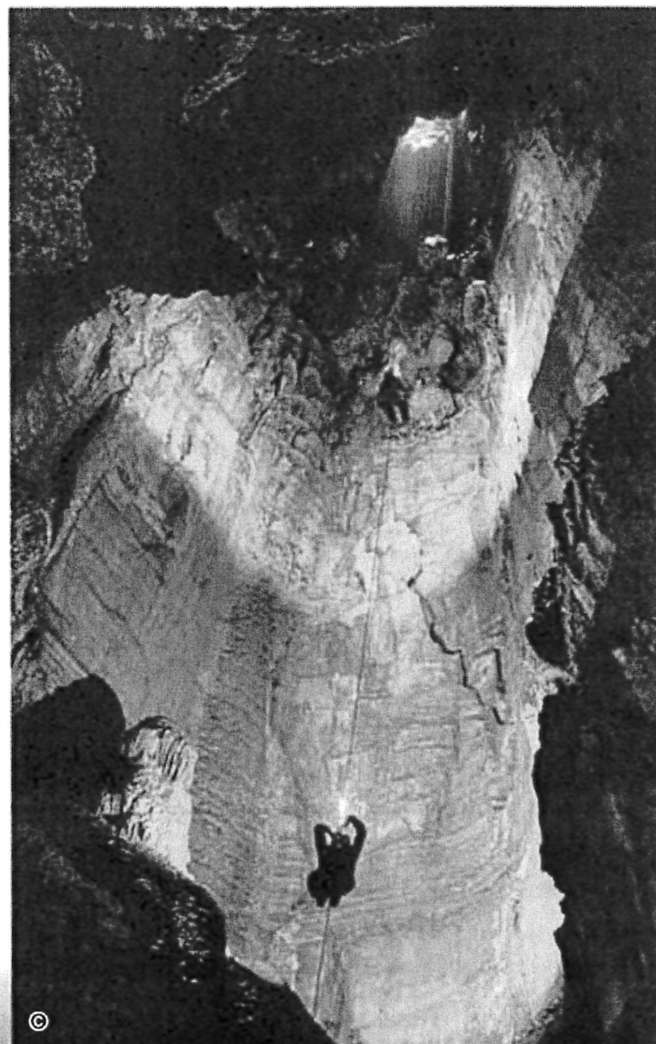
FIGURE 2
Getting Beneath the Surface
Geologists (left) examine rocks for clues about what's inside Earth. Even though caves like this one in Georgia (below) may seem deep, they reach only a relatively short distance beneath the surface.

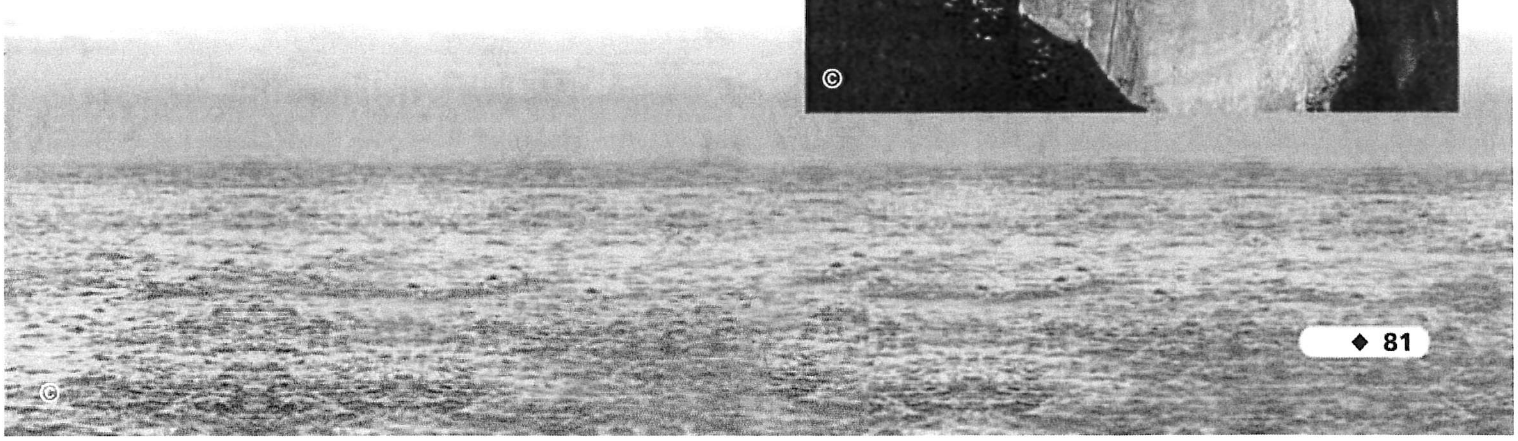
Exploring Inside Earth

Earth's surface is constantly changing. Throughout our planet's long history, its surface has been lifted up, pushed down, bent, and broken. Thus Earth looks different today from the way it did millions of years ago.

Volcanic eruptions like those at Mount Kilauea make people wonder, What's inside Earth? Yet this question is very difficult to answer. Much as geologists would like to, they cannot dig a hole to the center of Earth. The extreme conditions in Earth's interior prevent exploration far below the surface.

The deepest mine in the world, a gold mine in South Africa, reaches a depth of 3.8 kilometers. But that mine only scratches the surface. You would have to travel more than 1,600 times that distance—over 6,000 kilometers—to reach Earth's center. **Geologists have used two main types of evidence to learn about Earth's interior: direct evidence from rock samples and indirect evidence from seismic waves.** The geologists in Figure 2 are observing rock on Earth's surface.





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Evidence From Rock Samples Rocks from inside Earth give geologists clues about Earth's structure. Geologists have drilled holes as much as 12 kilometers into Earth. The drills bring up samples of rock. From these samples, geologists can make inferences about conditions deep inside Earth, where these rocks formed. In addition, forces inside Earth sometimes blast rock to the surface from depths of more than 100 kilometers. These rocks provide more information about the interior.

Evidence From Seismic Waves Geologists cannot look inside Earth. Instead, they must rely on indirect methods of observation. Have you ever hung a heavy picture on a wall? If you have, you know that you can knock on the wall to locate the wooden beam underneath the plaster that will support the picture. When you knock on the wall, you listen carefully for a change in the sound.

To study Earth's interior, geologists also use an indirect method. But instead of knocking on walls, they use seismic waves. When earthquakes occur, they produce **seismic waves** (SYZ mik). Geologists record the seismic waves and study how they travel through Earth. The speed of seismic waves and the paths they take reveal the structure of the planet.

Using data from seismic waves, geologists have learned that Earth's interior is made up of several layers. Each layer surrounds the layers beneath it, much like the layers of an onion. In Figure 3, you can see how seismic waves travel through the layers that make up Earth.

Reading Checkpoint **What causes seismic waves?**

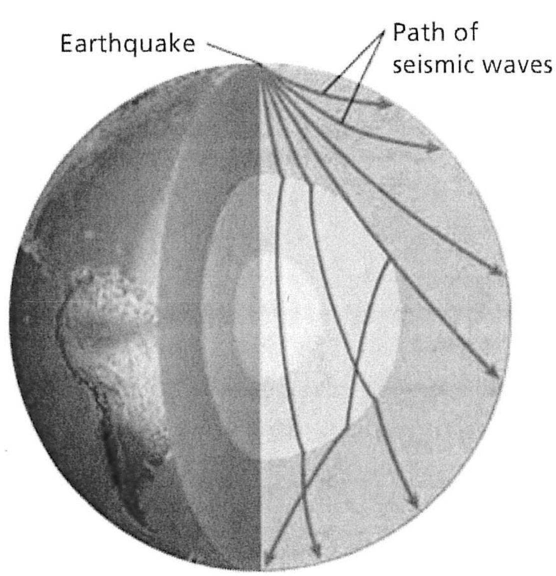
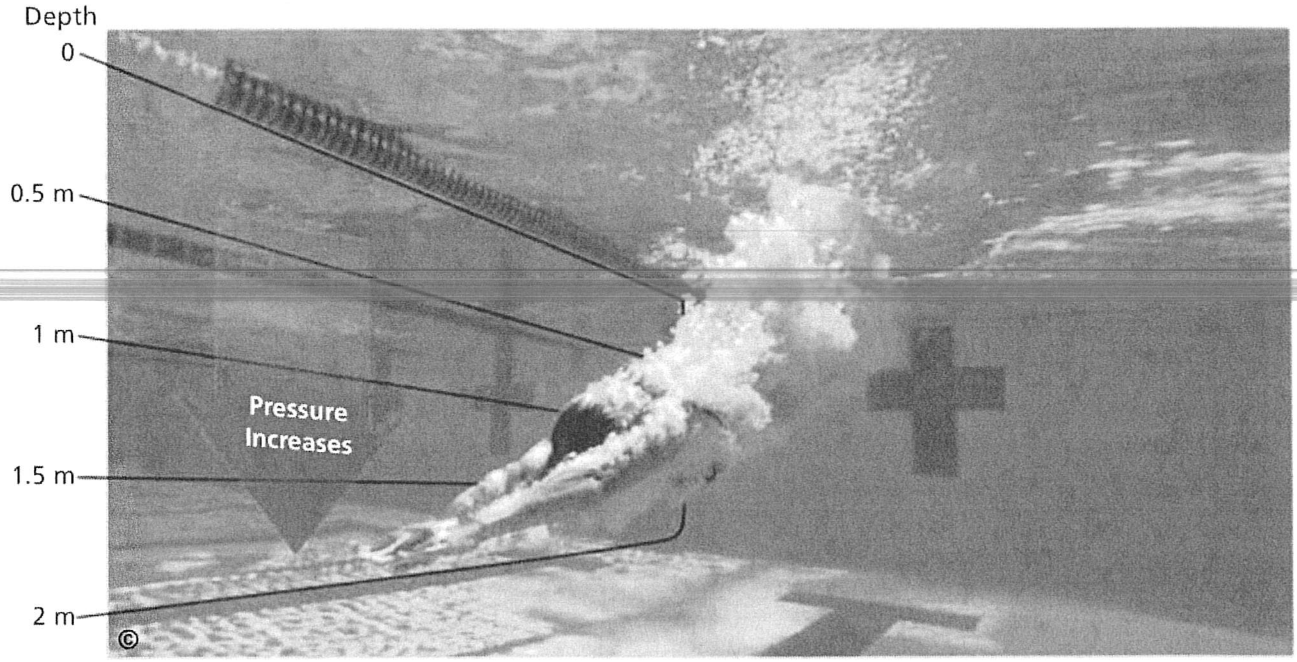


FIGURE 3
Seismic Waves
Scientists infer Earth's inner structure by recording and studying how seismic waves travel through Earth.



A Journey to the Center of Earth

The three main layers of Earth are the crust, the mantle, and the core. These layers vary greatly in size, composition, temperature, and pressure. If you could travel through these layers to the center of Earth, what would your trip be like? To begin, you will need a vehicle that can travel through solid rock. The vehicle will carry scientific instruments to record changes in temperature and pressure as you descend.

Temperature As you start to tunnel beneath the surface, the surrounding rock is cool. Then at about 20 meters down, your instruments report that the rock is getting warmer. For every 40 meters that you descend from that point, the temperature rises 1 Celsius degree. This rapid rise in temperature continues for several tens of kilometers. After that, the temperature increases more slowly, but steadily. The high temperatures inside Earth are the result of heat left over from the formation of the planet. In addition, radioactive substances inside Earth release energy. This further heats the interior.

Pressure During your journey to the center of Earth, your instruments record an increase in pressure in the surrounding rock. **Pressure** results from a force pressing on an area. Because of the weight of the rock above, pressure inside Earth increases as you go deeper. The deeper you go, the greater the pressure. Pressure inside Earth increases much as it does in the swimming pool in Figure 4.

FIGURE 4
Pressure and Depth
The deeper this swimmer goes, the greater the pressure from the surrounding water.
Comparing and Contrasting *How is the water in the swimming pool similar to Earth's interior? How is it different?*

The Crust

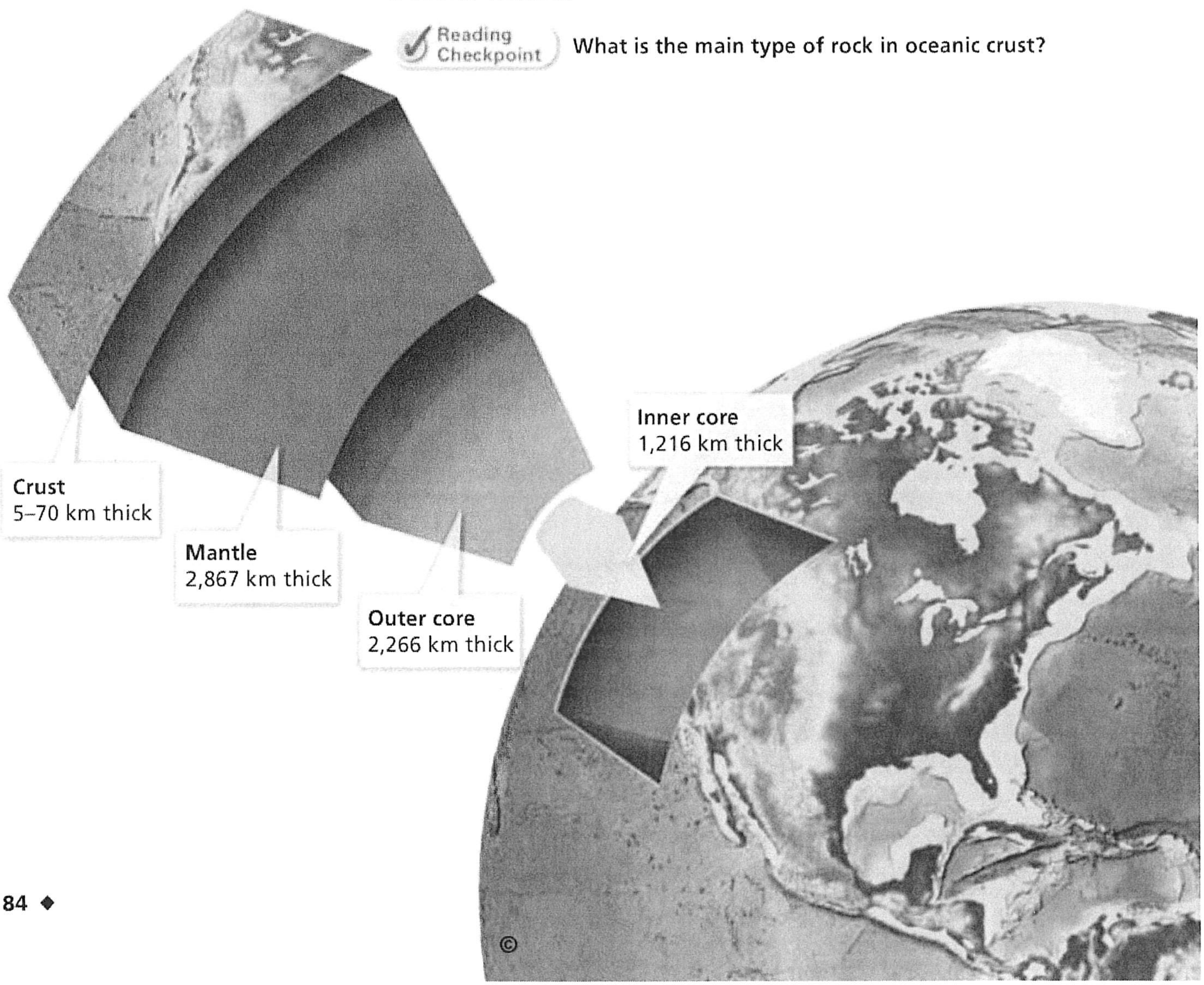
Your journey to the center of Earth begins in the crust. The crust is the layer of rock that forms Earth's outer skin. **The crust is a layer of solid rock that includes both dry land and the ocean floor.** On the crust you find rocks and mountains. The crust also includes the soil and water that cover large parts of Earth's surface.

This outer rind of rock is much thinner than the layer that lies beneath it. In fact, you can think of Earth's crust as being similar to the paper-thin skin of an onion. The crust is thickest under high mountains and thinnest beneath the ocean. In most places, the crust is between 5 and 40 kilometers thick. But it can be up to 70 kilometers thick beneath mountains.

The crust beneath the ocean is called oceanic crust. Oceanic crust consists mostly of rocks such as basalt. Basalt (buh SAWLT) is dark rock with a fine texture. Continental crust, the crust that forms the continents, consists mainly of rocks such as granite. Granite is a rock that usually is a light color and has a coarse texture.

Reading Checkpoint **What is the main type of rock in oceanic crust?**

FIGURE 5
Earth's Interior
Earth's interior is divided into layers: the crust, mantle, outer core, and inner core.
Interpreting Diagrams *Which of Earth's layers is the thickest?*



The Mantle

Your journey downward continues. About 40 kilometers beneath the surface, you cross a boundary. Below the boundary is the solid material of the **mantle**, a layer of hot rock. **Earth's mantle is made up of rock that is very hot, but solid. Scientists divide the mantle into layers based on the physical characteristics of those layers. Overall, the mantle is nearly 3,000 kilometers thick.**

The Lithosphere The uppermost part of the mantle is very similar to the crust. The uppermost part of the mantle and the crust together form a rigid layer called the **lithosphere** (lith UH sphere). In Greek, *lithos* means "stone." As you can see in Figure 6, the lithosphere averages about 100 kilometers thick.

The Asthenosphere Below the lithosphere, your vehicle encounters material that is hotter and under increasing pressure. As a result, the part of the mantle just beneath the lithosphere is less rigid than the rock above. Like road tar softened by the heat of the sun, this part of the mantle is somewhat soft—it can bend like plastic. This soft layer is called the **asthenosphere** (as THEN uh sfeer). In Greek, *asthenes* means "weak." Although the asthenosphere is softer than the rest of the mantle, it's still solid. If you kicked it, you would stub your toe.

The Lower Mantle Beneath the asthenosphere, the mantle is solid. This solid material extends all the way to Earth's core.

Reading Checkpoint **What is the asthenosphere?**

Lab zone Skills Activity

Creating Data Tables

Imagine that you are in a super-strong vehicle that is tunneling deep into Earth's interior. You stop several times on your trip to collect data. Copy the data table. For each depth, identify the layer and what that layer is made of. Then complete the table.

Data Table

Depth	Name of Layer	What Layer Is Made Of
20 km		
150 km		
2,000 km		
4,000 km		
6,000 km		

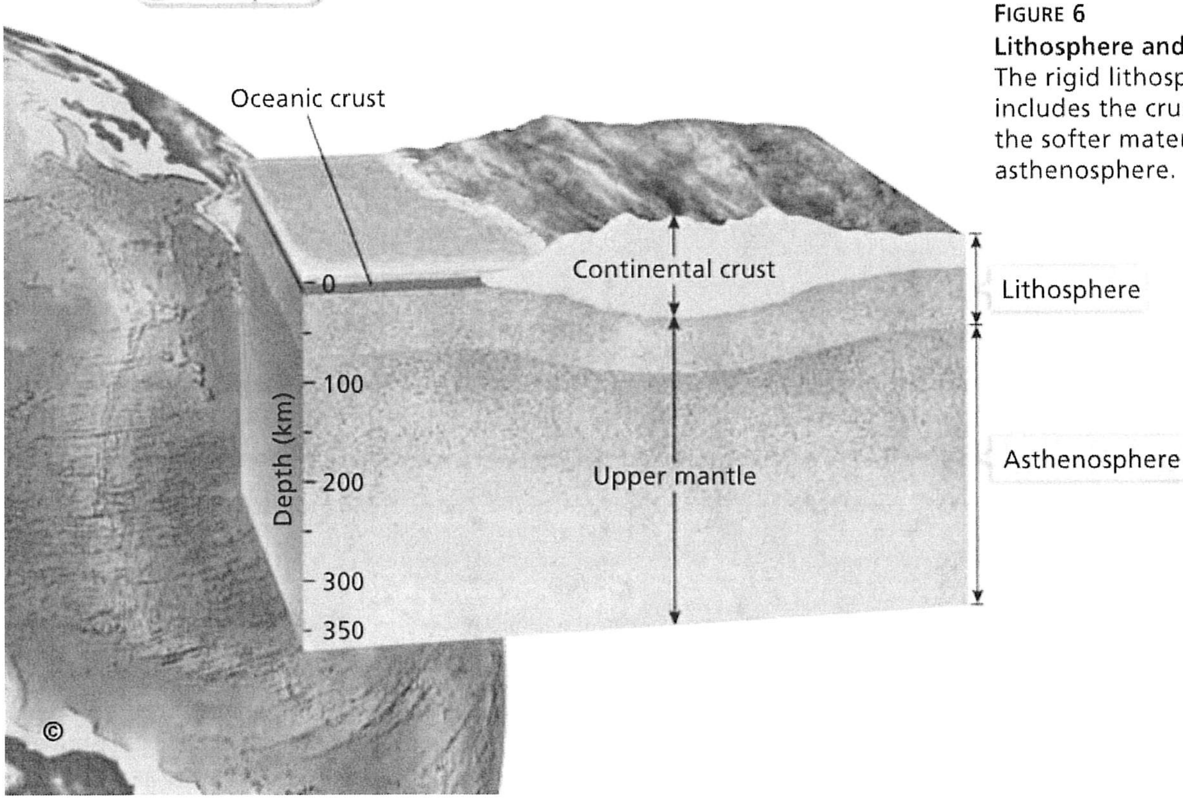


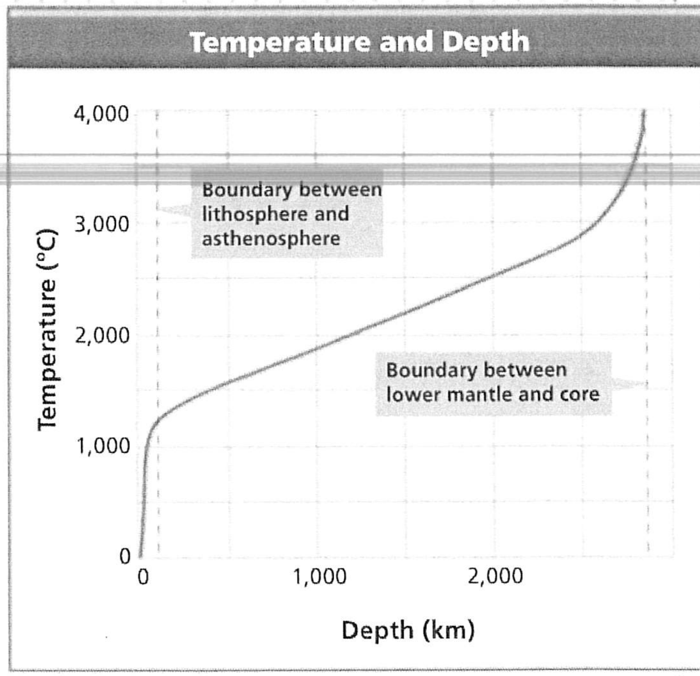
FIGURE 6
Lithosphere and Asthenosphere
The rigid lithosphere, which includes the crust, rests on the softer material of the asthenosphere.

Math Analyzing Data

Temperature Inside Earth

The graph shows how temperatures change between Earth's surface and the bottom of the mantle. On this graph, the temperature at Earth's surface is 0°C. Study the graph carefully and then answer the questions.

1. Reading Graphs As you move from left to right on the x-axis, how does depth inside Earth change?
2. Estimating What is the temperature at the boundary between the lithosphere and the asthenosphere?
3. Estimating What is the temperature at the boundary between the lower mantle and the core?
4. Interpreting Data How does temperature change with depth in Earth's interior?



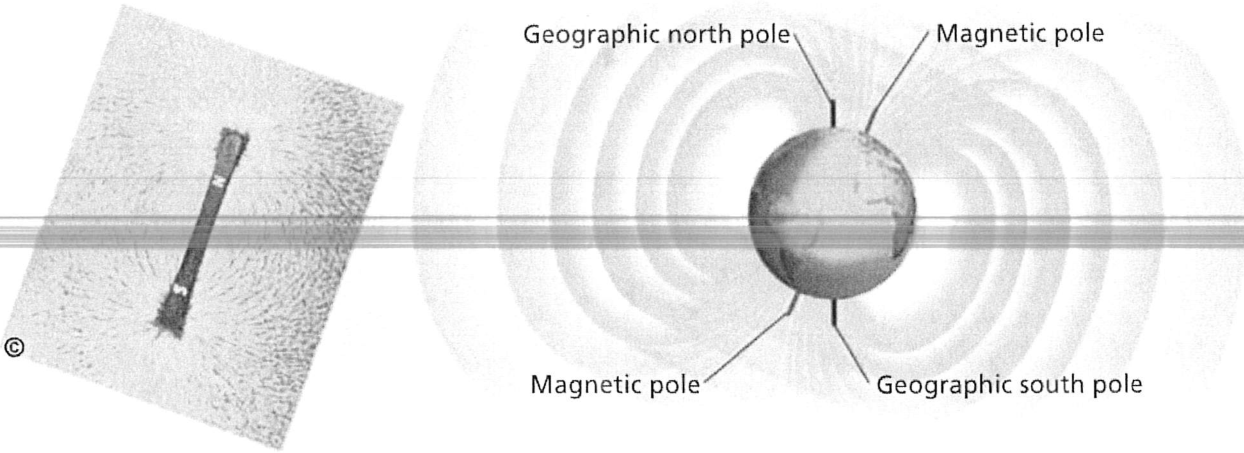
The Core

After traveling through the mantle, you reach Earth's core. **The core is made mostly of the metals iron and nickel. It consists of two parts—a liquid outer core and a solid inner core.** Together, the inner and outer core are 3,486 kilometers thick.

Outer Core and Inner Core The outer core is a layer of molten metal that surrounds the inner core. Despite enormous pressure, the outer core is liquid. The inner core is a dense ball of solid metal. In the inner core, extreme pressure squeezes the atoms of iron and nickel so much that they cannot spread out and become liquid.

Most of the current evidence suggests that both parts of the core are made of iron and nickel. But scientists have found data suggesting that the core also contains substances such as oxygen, sulfur, and silicon. Scientists must seek more data before they decide which of these other substances is most important.

Reading Checkpoint **What is the main difference between the outer core and the inner core?**



Bar Magnet's Magnetic Field
The pattern of iron filings was made by sprinkling them on paper placed under a bar magnet.

Earth's Magnetic Field
Like a magnet, Earth's magnetic field has north and south poles.

FIGURE 7
Earth's Magnetic Field
Just as a bar magnet is surrounded by its own magnetic field, Earth's magnetic field surrounds the planet.
Relating Cause and Effect *If you shifted the magnet beneath the paper, what would happen to the iron filings?*

The Core and Earth's Magnetic Field Scientists think that movements in the liquid outer core create Earth's magnetic field. Because Earth has a magnetic field, the planet acts like a giant bar magnet. As you can see in Figure 7, the magnetic field affects the whole Earth.

Consider an ordinary bar magnet. If you place it on a piece of paper and sprinkle iron filings on the paper, the iron filings line up with the bar's magnetic field. If you could cover the entire planet with iron filings, they would form a similar pattern. When you use a compass, the compass needle aligns with the lines of force in Earth's magnetic field.

Section 1 Assessment

Vocabulary Skill Use Greek Word Origins
Use what you know about the Greek words *asthenes* and *sphaira* to write the definition of *asthenosphere.*

Reviewing Key Concepts

HINT
1. a. Explaining Why is it difficult to determine Earth's inner structure?

HINT
b. Inferring How are seismic waves used to provide evidence about Earth's interior?

HINT
2. a. Listing List Earth's three main layers.

HINT
b. Comparing and Contrasting What is the difference between the lithosphere and the asthenosphere? In which layer is each located?

c. Classifying Classify each of the following layers as liquid, solid, or solid but able to flow slowly: lithosphere, asthenosphere, lower mantle, outer core, inner core. HINT

Writing in Science

Narrative Write a narrative of your own imaginary journey to the center of Earth. Your narrative should describe the layers of Earth through which you travel and how temperature and pressure change beneath the surface.

Section 2

Integrating Physics

Convection and the Mantle

Reading Preview

Key Concepts

- How is heat transferred?
- What causes convection currents?
- What causes convection currents in Earth's mantle?

Key Terms

- radiation
- conduction
- convection
- density
- convection current

Target Reading Skill

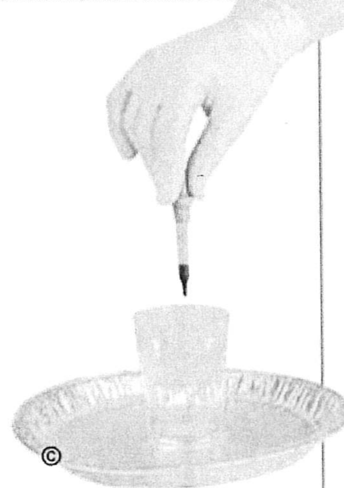
Outlining An outline shows the relationship between major ideas and supporting ideas. As you read, make an outline about heat transfer. Use the red headings for the main topics and the blue headings for the subtopics.

Convection and the Mantle

I. Types of Heat Transfer
  A. Radiation
  B.
  C.
II. Convection Currents

Lab zone Discover Activity

How Can Heat Cause Motion in a Liquid?



1. Carefully pour some hot water into a small, shallow pan. Fill a clear, plastic cup about half full with cold water. Place the cup in the pan.
2. Allow the water to stand for two minutes until all motion stops.
3. Fill a plastic dropper with some food coloring. Then, holding the dropper under the water's surface and slightly away from the edge of the cup, gently squeeze a small droplet of the food coloring into the water.
4. Observe the water for one minute.
5. Add another droplet at the water's surface in the middle of the cup and observe again.

Think It Over

Inferring How do you explain what happened to the droplets of food coloring? Why do you think the second droplet moved in a way that was different from the way the first droplet moved?

Earth's molten outer core is nearly as hot as the surface of the sun. What makes an object hot? Whether the object is Earth's core or a cooking pot, the cause is the same. When an object is heated, the particles that make up the object move faster. The faster-moving particles have more energy.

If you have ever touched a hot pot accidentally, you have discovered for yourself (in a painful way) that heat moves. In this case, it moved from the hot pot to your hand. The movement of energy from a warmer object to a cooler object is called heat transfer. To explain how heat moves from Earth's core through the mantle, you need to know how heat is transferred.

Types of Heat Transfer

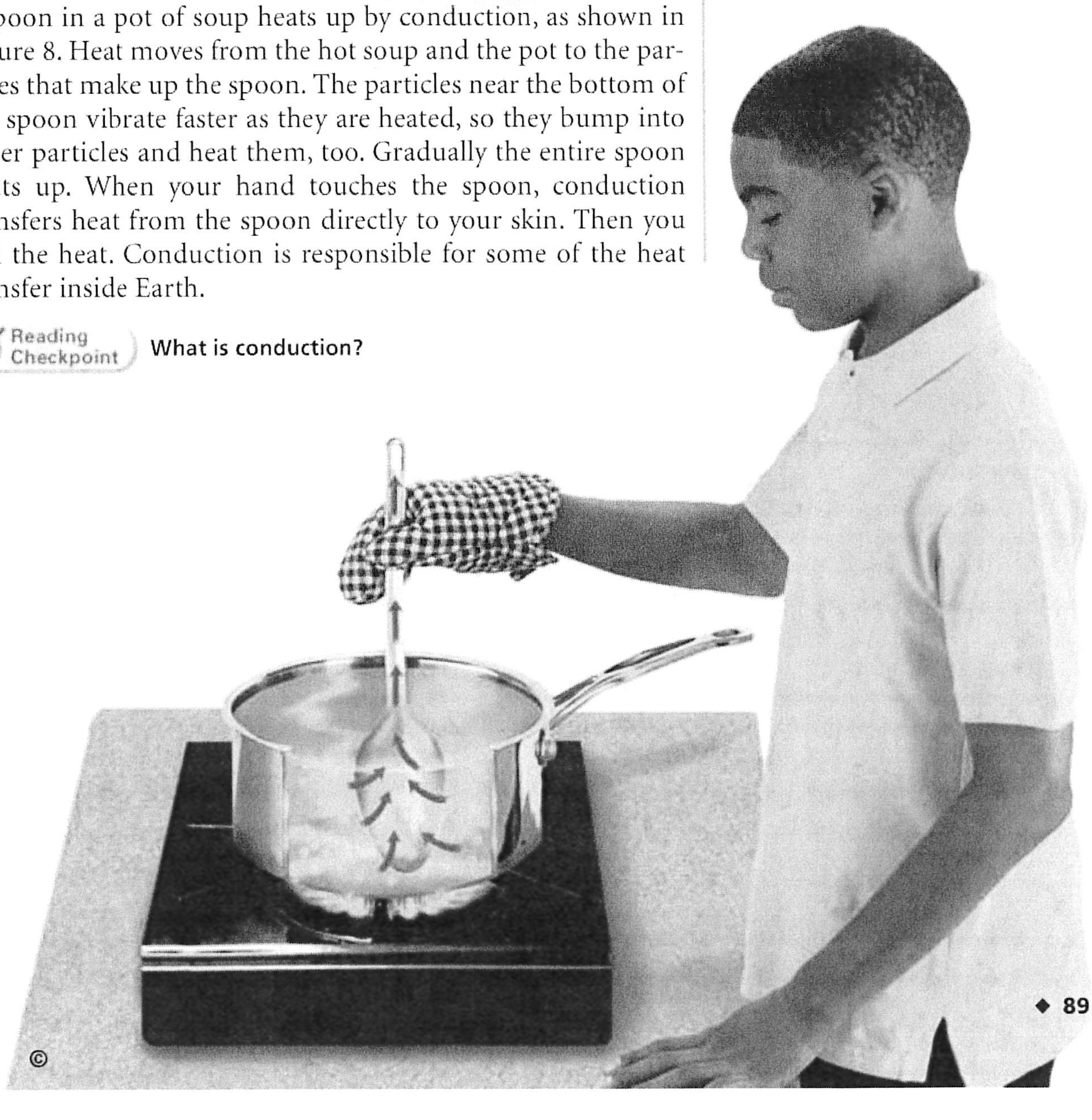
Heat always moves from a warmer substance to a cooler substance. For example, holding an ice cube will make your hand begin to feel cold in a few seconds. But is the coldness in the ice cube moving to your hand? No! Since cold is the absence of heat, it's the heat in your hand that moves to the ice cube. This is one of the ways that heat is transferred. **There are three types of heat transfer: radiation, conduction, and convection.**

Radiation The transfer of energy through space is called **radiation.** Heat transfer by radiation takes place with no direct contact between a heat source and an object. Sunlight is radiation that warms Earth's surface. Other familiar forms of radiation include the heat you feel around a flame or open fire.

Conduction Heat transfer within a material or between materials that are touching is called **conduction.** For example, a spoon in a pot of soup heats up by conduction, as shown in Figure 8. Heat moves from the hot soup and the pot to the particles that make up the spoon. The particles near the bottom of the spoon vibrate faster as they are heated, so they bump into other particles and heat them, too. Gradually the entire spoon heats up. When your hand touches the spoon, conduction transfers heat from the spoon directly to your skin. Then you feel the heat. Conduction is responsible for some of the heat transfer inside Earth.

Reading Checkpoint What is conduction?

FIGURE 8
Conduction
In conduction, the heated particles of a substance transfer heat through contact with other particles in the substance. Conduction heats the spoon and the pot itself. That's why you need a mitt to protect your hand from the hot handle.



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Convection Heat can also be transferred by the movement of fluids—liquids and gases. **Convection** is heat transfer by the movement of currents within a fluid. During convection, heated particles of fluid begin to flow. This flow transfers heat from one part of the fluid to another.

Heat transfer by convection is caused by differences of temperature and density within a fluid. **Density** is a measure of how much mass there is in a volume of a substance. For example, rock is more dense than water because a given volume of rock has more mass than the same volume of water.

When a liquid or gas is heated, the particles move faster and spread apart. As a result, the particles of the heated fluid occupy more space. The fluid's density decreases. But when a fluid cools, its particles move more slowly and settle together more closely. As the fluid becomes cooler, its density increases.

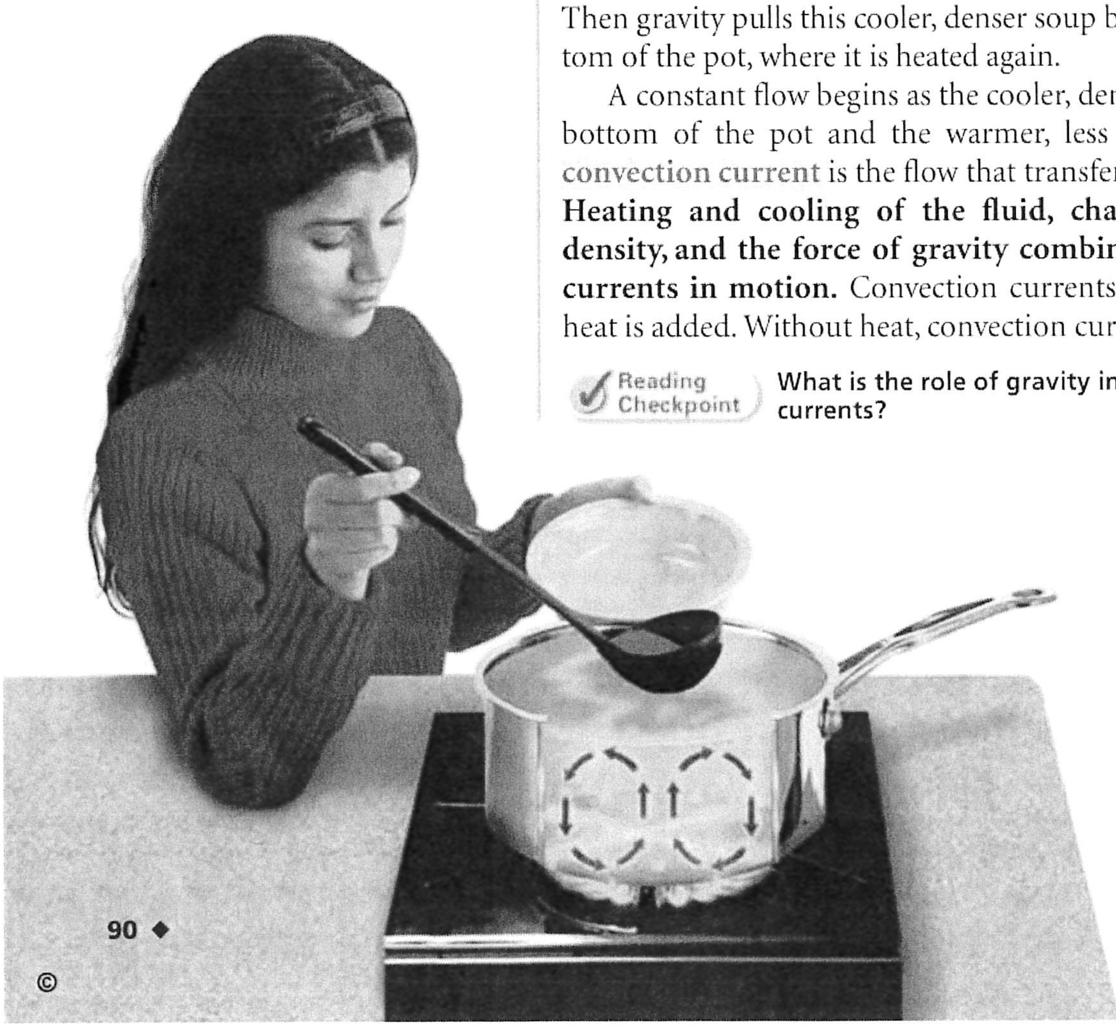
Convection Currents

When you heat soup on a stove, convection occurs in the soup, as shown in Figure 9. As the soup at the bottom of the pot gets hot, it expands and therefore becomes less dense. The warm, less dense soup moves upward and floats over the cooler, denser soup. At the surface, the warm soup cools, becoming denser. Then gravity pulls this cooler, denser soup back down to the bottom of the pot, where it is heated again.

A constant flow begins as the cooler, denser soup sinks to the bottom of the pot and the warmer, less dense soup rises. A **convection current** is the flow that transfers heat within a fluid. **Heating and cooling of the fluid, changes in the fluid's density, and the force of gravity combine to set convection currents in motion.** Convection currents continue as long as heat is added. Without heat, convection currents eventually stop.

Reading Checkpoint — **What is the role of gravity in creating convection currents?**

FIGURE 9
Convection Currents
Differences in temperature and density cause convection currents. In the pot, convection currents arise because the soup close to the heat source is hotter and less dense than the soup near the surface.



Convection Currents in Earth

In Earth's mantle, large amounts of heat are transferred by convection currents, as shown in Figure 10. **Heat from the core and the mantle itself causes convection currents in the mantle.**

How is it possible for mantle rock to flow? Over millions of years, the great heat and pressure in the mantle cause solid mantle rock to flow very slowly. Many geologists think that plumes of mantle rock rise slowly from the bottom of the mantle toward the top. The hot rock eventually cools and sinks back through the mantle. Over and over, the cycle of rising and sinking takes place. Convection currents like these have been moving inside Earth for more than four billion years!

There are also convection currents in the outer core. These convection currents cause Earth's magnetic field.

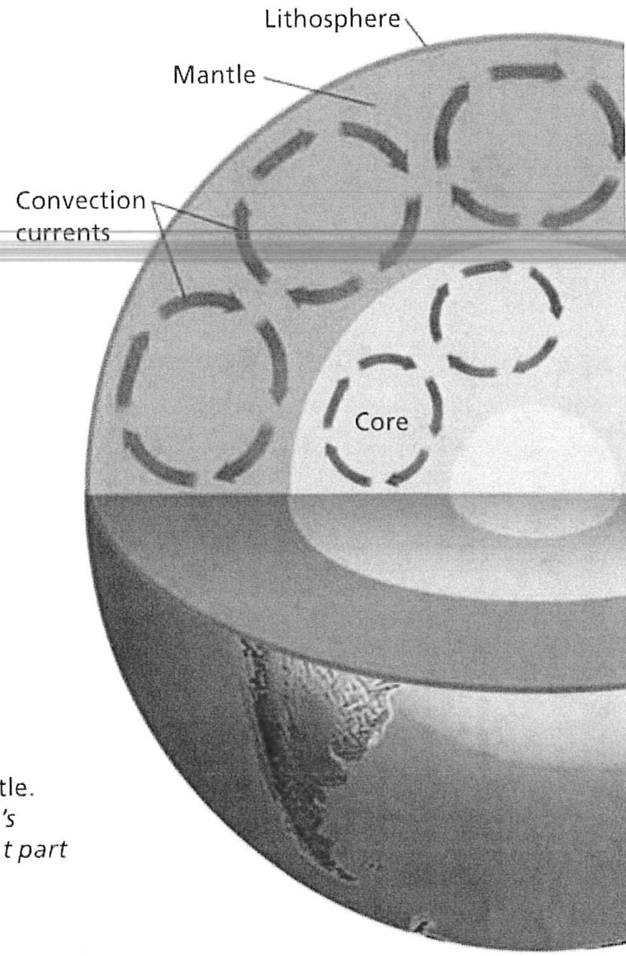


FIGURE 10
Mantle Convection
Most geologists think that convection currents rise and sink through the mantle.
Applying Concepts *What part of Earth's interior is like the soup in the pot? What part is like the burner on the stove?*

Section 2 Assessment

Vocabulary Skill Use Greek Word Origins Use what you know about the Greek words *litho* and *sphaira* to write the definition of *lithosphere*.

Reviewing Key Concepts

HINT 1. a. Listing What are the three types of heat transfer?

HINT b. Explaining How is heat transferred through space?

HINT 2. a. Defining What is a convection current?

HINT b. Relating Cause and Effect In general, what happens to the density of a fluid as it becomes hotter?

HINT c. Summarizing Describe how convection currents form.

HINT 3. a. Identifying Name two layers of Earth in which convection currents take place.

HINT b. Relating Cause and Effect What causes convection currents in the mantle?

HINT c. Predicting What will happen to the convection currents in the mantle if Earth's interior eventually cools down? Explain.

Lab zone At-Home Activity

Tracing Heat Flow Convection currents may keep the air inside your home at a comfortable temperature. Air is made up of gases, so it is a fluid. Regardless of the type of home heating system, heated air circulates through a room by convection. You may have tried to adjust the flow of air in a stuffy room by opening a window. When you did so, you were making use of convection currents. With an adult family member, study how your home is heated. Look for evidence of convection currents.

Section 3

Drifting Continents

Reading Preview

Key Concepts

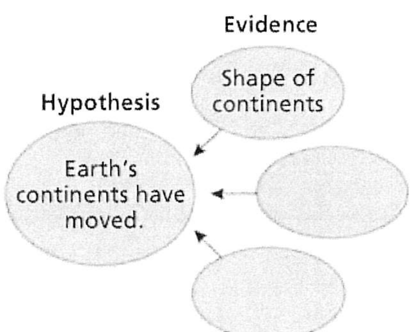
- What was Alfred Wegener's hypothesis about the continents?
- What evidence supported Wegener's hypothesis?
- Why was Wegener's hypothesis rejected by most scientists of his day?

Key Terms

- continental drift
- Pangaea
- fossil

Target Reading Skill

Identifying Supporting Evidence As you read, identify the evidence that supports the hypothesis of continental drift. Write the evidence in a graphic organizer like the one below.



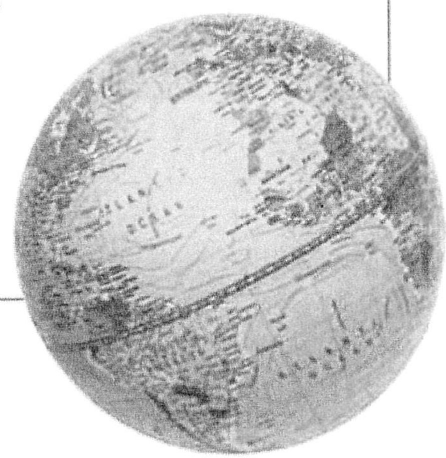
Lab zone Discover Activity

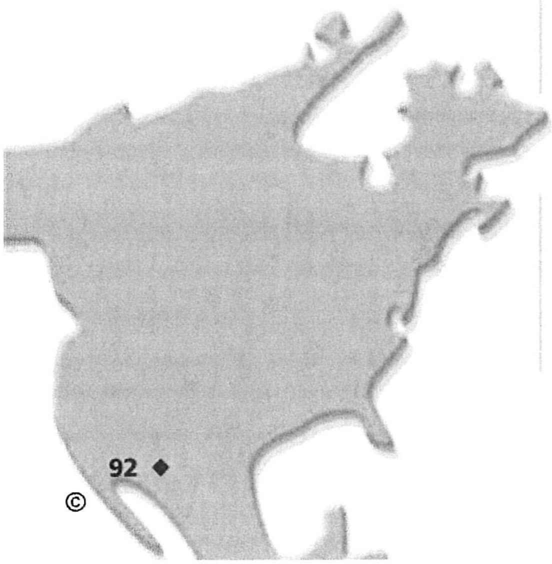
How Are Earth's Continents Linked Together?

1. Find the oceans and the seven continents on a globe showing Earth's physical features.
2. How much of the globe is occupied by the Pacific Ocean? Does most of Earth's dry land lie in the Northern or Southern Hemisphere?
3. Find the points or areas where most of the continents are connected. Find the points at which several of the continents almost touch, but are not connected.
4. Examine the globe more closely. Find the great belt of mountains running from north to south along the western side of North and South America. Can you find another great belt of mountains on the globe?

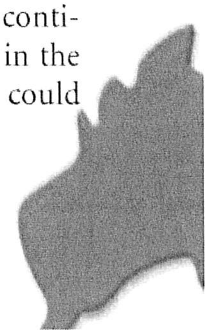
Think It Over

Posing Questions What questions can you pose about how oceans, continents, and mountains are distributed on Earth's surface?





Five hundred years ago, the sea voyages of Columbus and other explorers changed the map of the world. The continents of Europe, Asia, and Africa were already known to mapmakers. Soon mapmakers were also showing the outlines of the continents of North and South America. Looking at these world maps, many people wondered why the coasts of several continents matched so neatly. For example, the coasts of Africa and South America look as if they could fit together like jigsaw-puzzle pieces. In the 1700s, geologists thought that the continents had always remained in the same place. But early in the 1900s, one scientist began to think that the continents could have once been joined in a single landmass.



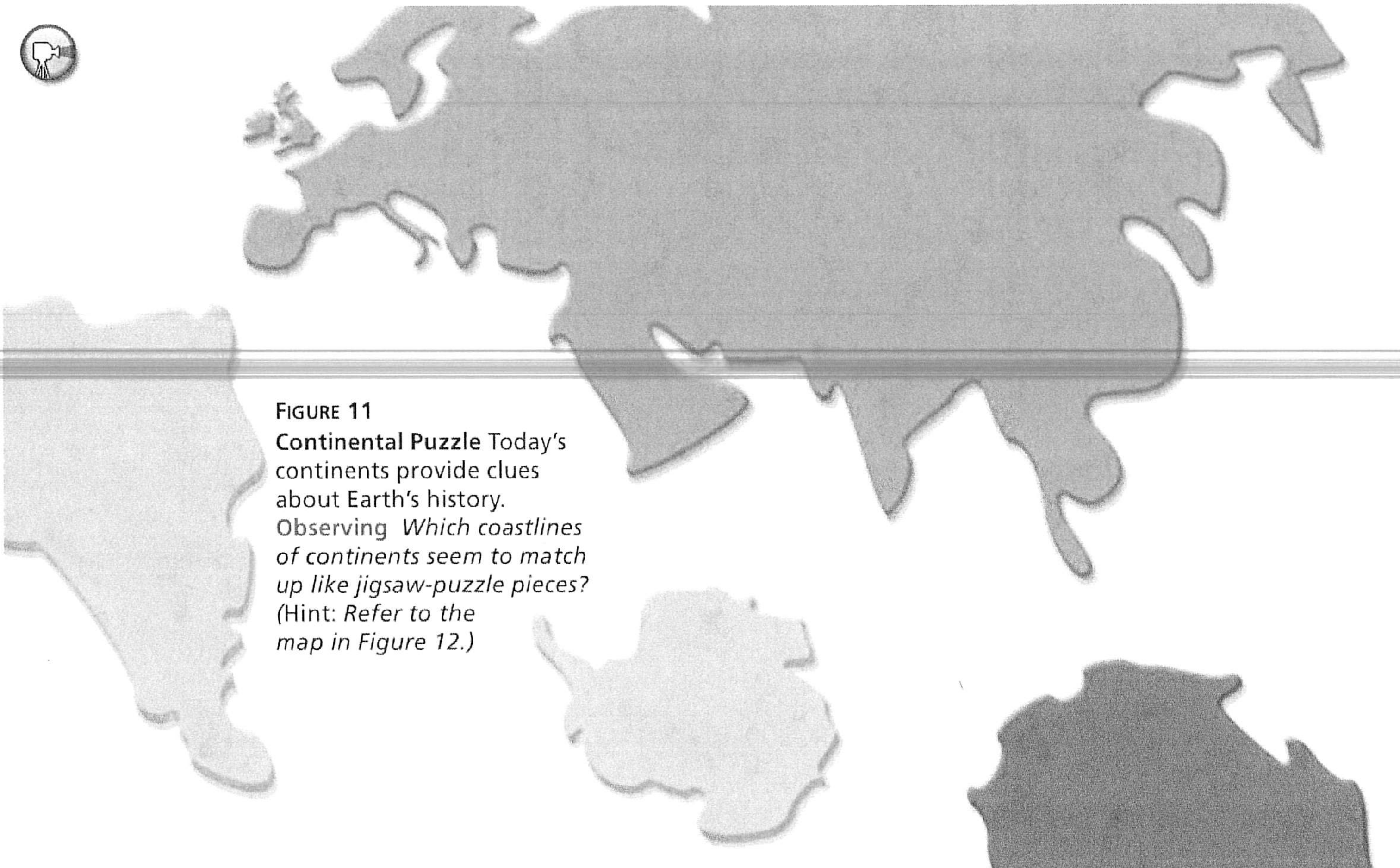


FIGURE 11
Continental Puzzle Today's continents provide clues about Earth's history.
Observing *Which coastlines of continents seem to match up like jigsaw-puzzle pieces?* (Hint: *Refer to the map in Figure 12.)*

Continental Drift

In 1910, a young German scientist named Alfred Wegener (VAY guh nur) became curious about the relationship of the continents. He hypothesized that Earth's continents had moved! **Wegener's hypothesis was that all the continents were once joined together in a single landmass and have since drifted apart.** Wegener's idea that the continents slowly moved over Earth's surface became known as **continental drift.**

According to Wegener, the continents drifted together to form the supercontinent **Pangaea** (pan JEEuh). *Pangaea* means "all lands." According to Wegener, Pangaea existed about 300 million years ago. This was the time when reptiles and winged insects first appeared. Tropical forests, which later formed coal deposits, covered large parts of Earth's surface.

Over tens of millions of years, Pangaea began to break apart. The pieces of Pangaea slowly moved toward their present-day locations. These pieces became the continents as they are today.

Wegener gathered evidence from different scientific fields to support his ideas about continental drift. He studied land features, fossils, and evidence of climate change. In 1915, Wegener published his evidence for continental drift in a book called *The Origin of Continents and Oceans.*

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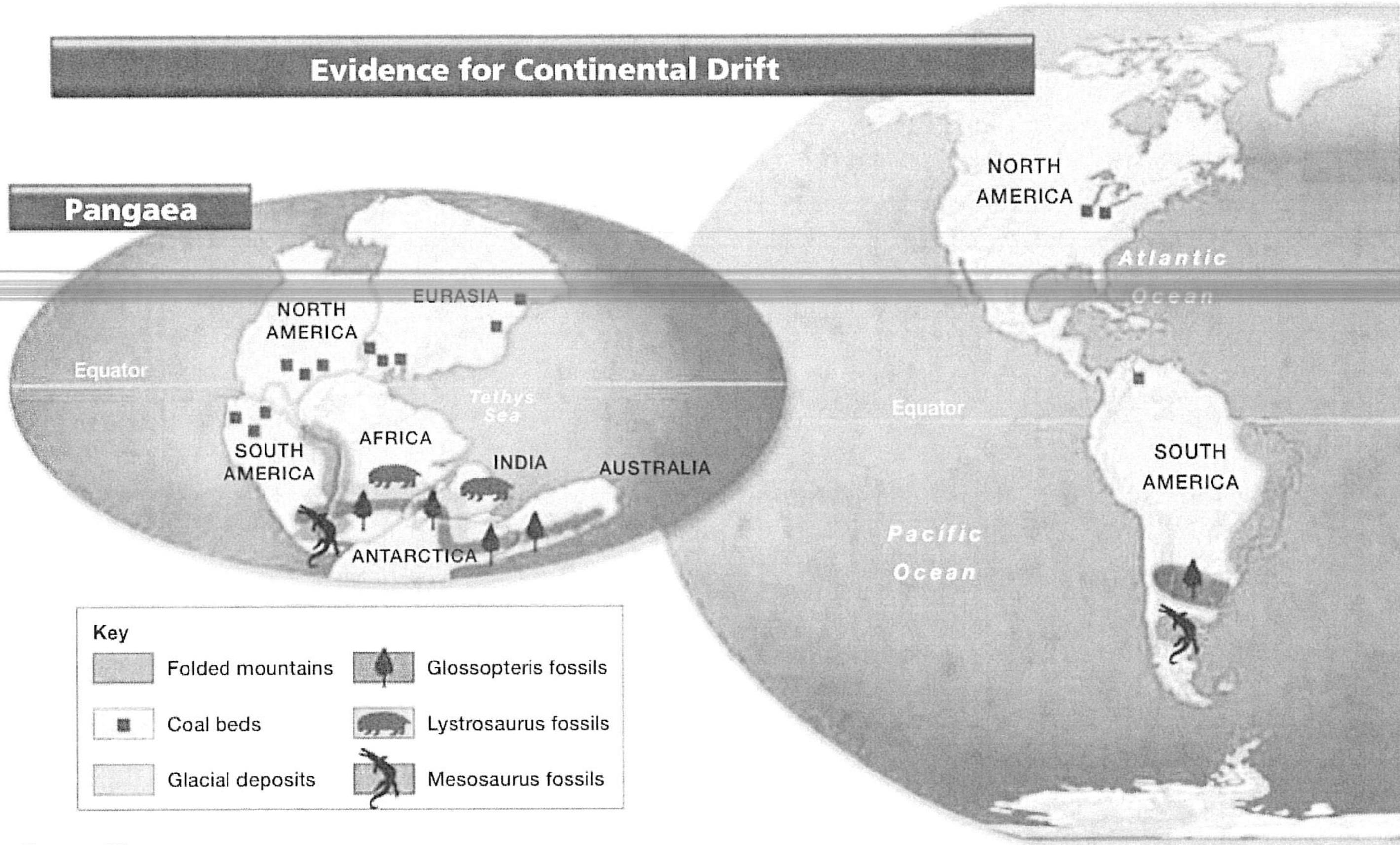


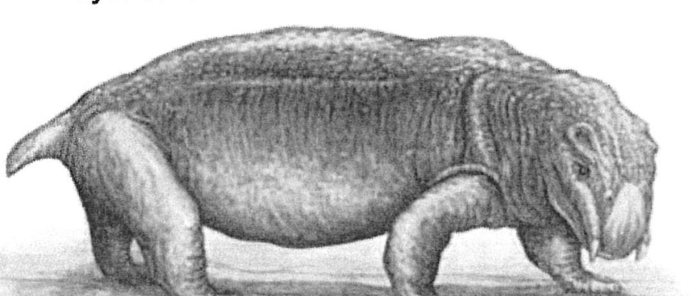
FIGURE 12
Fossils and rocks found on different continents provide evidence that Earth's landmasses once were joined together in the supercontinent Pangaea. **Inferring** *What do the matching mountain ranges in Africa and South America show, according to Wegener's hypothesis?*

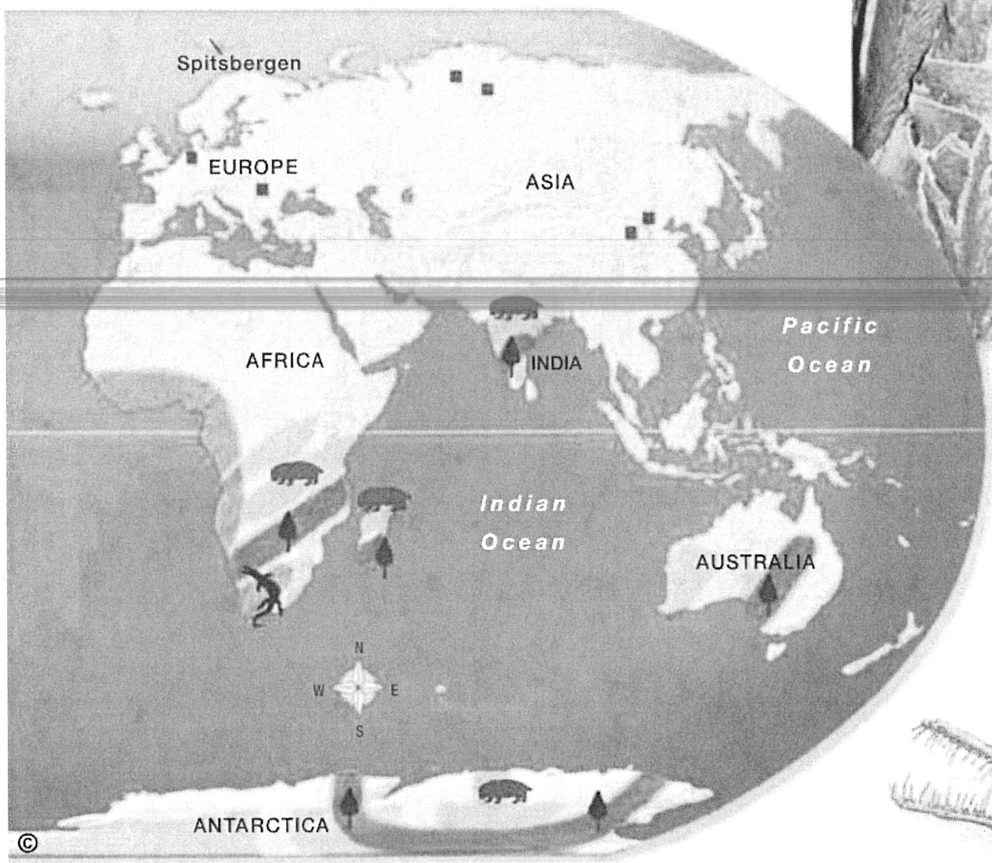
Evidence From Land Features As shown in Figure 12, mountains and other features on the continents provided evidence for continental drift. For example, when Wegener pieced together maps of Africa and South America, he noticed that mountain ranges on both continents line up. He noticed that European coal fields match up with coal fields in North America.

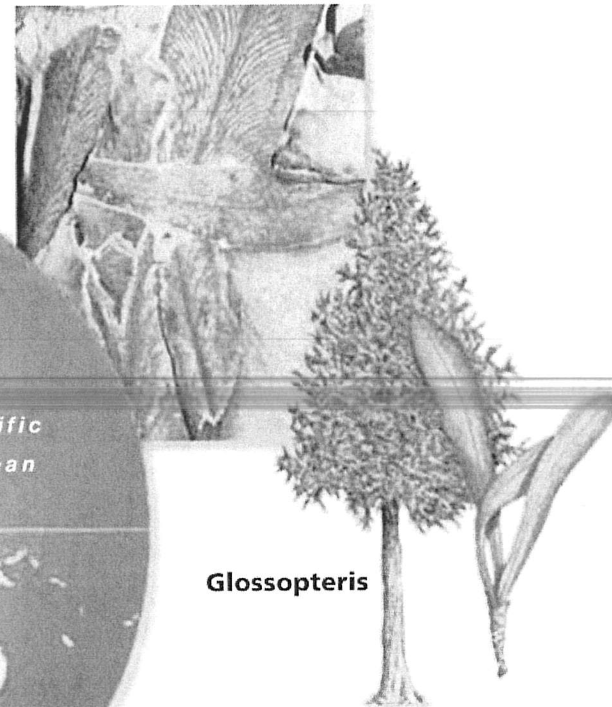
Evidence From Fossils Wegener also used fossils to support his argument for continental drift. A **fossil** is any trace of an ancient organism that has been preserved in rock. For example, *Glossopteris* (glaw SAHP tuh ris), was a fernlike plant that lived 250 million years ago. *Glossopteris* fossils have been found in rocks in Africa, South America, Australia, India, and Antarctica. The occurrence of *Glossopteris* on these widely separated landmasses convinced Wegener that Pangaea had existed.

Other examples include fossils of the freshwater reptiles *Mesosaurus* and *Lystrosaurus*. These fossils have also been found in places now separated by oceans. Neither reptile could have swum great distances across salt water. Wegener inferred that these reptiles lived on a single landmass that has since split apart.

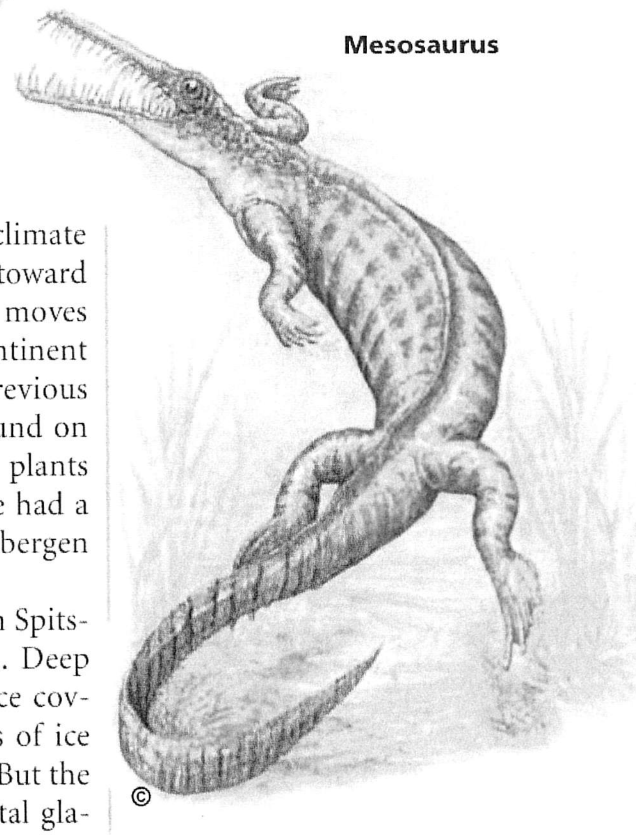
Lystrosaurus







Glossopteris



Mesosaurus

Evidence From Climate Wegener used evidence of climate change to support his hypothesis. As a continent moves toward the equator, its climate becomes warmer. As a continent moves toward the poles, its climate becomes colder. But the continent carries with it the fossils and rocks that formed at its previous locations. For example, fossils of tropical plants are found on Spitsbergen, an island in the Arctic Ocean. When these plants lived about 300 million years ago, the island must have had a warm and mild climate. According to Wegener, Spitsbergen must have been located closer to the equator.

Geologists found evidence that when it was warm in Spitsbergen, the climate was much colder in South Africa. Deep scratches in rocks showed that continental glaciers once covered South Africa. Continental glaciers are thick layers of ice that cover hundreds of thousands of square kilometers. But the climate of South Africa is too mild today for continental glaciers to form. Wegener concluded that when Pangaea existed, South Africa was much closer to the South Pole. According to Wegener, the climates of Spitsbergen and South Africa changed because these landmasses had moved.

Reading Checkpoint **How would continental drift affect a continent's climate?**

FIGURE 13
Alfred Wegener
Although scientists rejected his theory, Wegener continued to collect evidence on continental drift and to update his book. He died in 1930 on an expedition to explore Greenland's continental glacier.

Wegener's Hypothesis Rejected

Wegener attempted to explain how continental drift took place. He suggested that the continents plowed across the ocean floors. **Unfortunately, Wegener could not provide a satisfactory explanation for the force that pushes or pulls the continents.** Because Wegener could not identify the cause of continental drift, most geologists rejected his idea.

For geologists to accept continental drift, they would also have had to change their ideas about how mountains form. In the early 1900s, many geologists thought that mountains formed because Earth was slowly cooling and shrinking. According to this hypothesis, mountains formed when the crust wrinkled like the skin of a dried-up apple.

Wegener said that if these geologists were correct, then mountains should be found all over Earth's surface. But mountains usually occur in narrow bands along the edges of continents. Wegener developed a hypothesis that better explained where mountains occur and how they form. Wegener proposed that when continents collide, their edges crumple and fold. The folding continents push up huge mountains.

Reading Checkpoint **According to Wegener, how do mountains form?**

Section 3 Assessment

Target Reading Skill

Identifying Supporting Evidence Refer to your graphic organizer about continental drift as you answer Question 2 below.

Reviewing Key Concepts

HINT 1. a. **Identifying** Who proposed the concept of continental drift?

HINT b. **Summarizing** According to the hypothesis of continental drift, how would a world map have changed over the last 250 million years?

HINT 2. a. **Reviewing** What evidence supported the hypothesis of continental drift?

HINT b. **Explaining** How did fossils provide evidence for continental drift?

HINT c. **Forming Hypotheses** Deposits of coal have been found beneath the ice of Antarctica. But coal only forms in warm swamps. Use Wegener's hypothesis to explain how coal could be found so near to the South Pole.

3. a. **Explaining** Why did most scientists reject Wegener's hypothesis of continental drift? HINT

b. **Making Judgments** Do you think the scientists of Wegener's time should have accepted his hypothesis? Why or why not? HINT

Lab zone At-Home Activity

Moving the Continents Using a world map and tracing paper, trace the outlines of the continents that border the Atlantic Ocean. Label the continents. Then use scissors to carefully cut your map along the edges of the continents. Throw away the Atlantic Ocean. Place the two remaining pieces on a dark surface and ask family members to try to fit the two halves together. Explain to them about continental drift and Pangaea.

Section 4

Sea-Floor Spreading

Reading Preview

Key Concepts

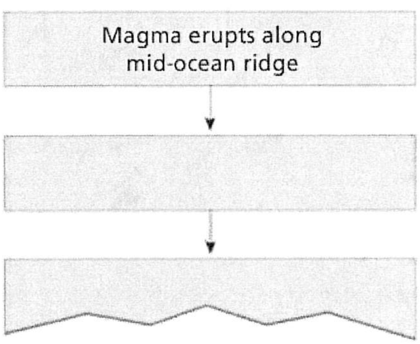
- What is the process of sea-floor spreading?
- What is the evidence for sea-floor spreading?
- What happens at deep-ocean trenches?

Key Terms

- mid-ocean ridge
- sonar
- sea-floor spreading
- deep-ocean trench
- subduction

Target Reading Skill

Sequencing Make a flowchart to show the process of sea-floor spreading.



Lab zone Discover Activity

What Is the Effect of a Change in Density?

1. Partially fill a sink or dishpan with water.
2. Open up a dry washcloth in your hand. Does the washcloth feel light or heavy?
3. Moisten one edge of the washcloth in the water. Then gently place the washcloth so that it floats on the water's surface. Observe the washcloth carefully (especially at its edges) as it starts to sink.
4. Remove the washcloth from the water and open it up in your hand. Is the mass of the washcloth the same as, less than, or greater than when it was dry?

Think It Over

Observing How did the washcloth's density change? What effect did this change in density have on the washcloth?

Deep in the ocean, the temperature is near freezing. There is no light, and living things are generally scarce. Yet some areas of the deep-ocean floor are teeming with life. One of these areas is the East Pacific Rise. This area forms part of the Pacific Ocean floor off the coasts of Mexico and South America. Here, ocean water sinks through cracks, or vents, in the crust. The water is heated by contact with hot material from the mantle. The hot water then spurts back into the ocean.

Around these hot-water vents live some of the most bizarre creatures ever discovered. Giant, red-tipped tube worms sway in the water. Nearby sit giant clams nearly a meter across. Strange spider-like crabs scuttle by. Surprisingly, the geological features of this strange environment provided some of the best evidence for Wegener's hypothesis of continental drift.

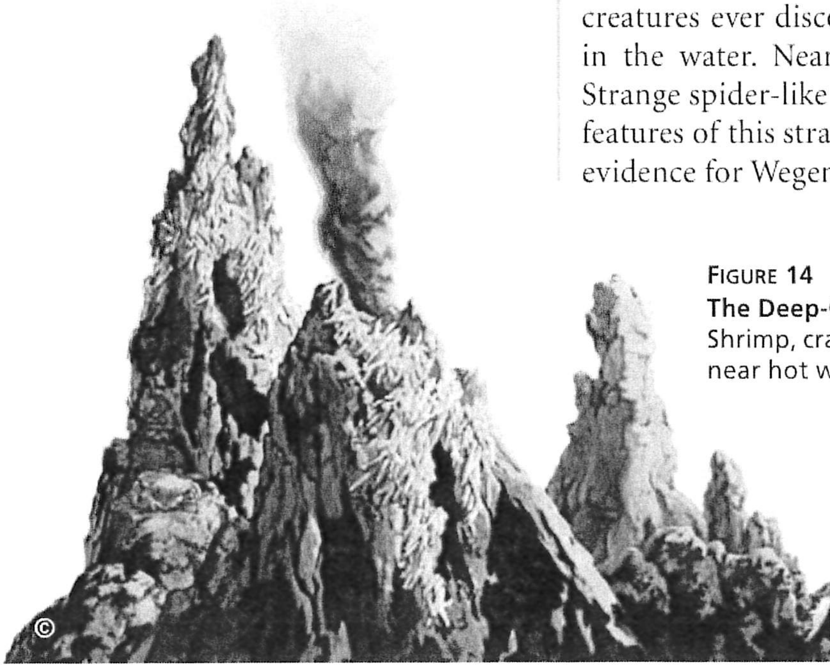


FIGURE 14
The Deep-Ocean Floor
Shrimp, crabs, and other organisms cluster near hot water vents in the ocean floor.

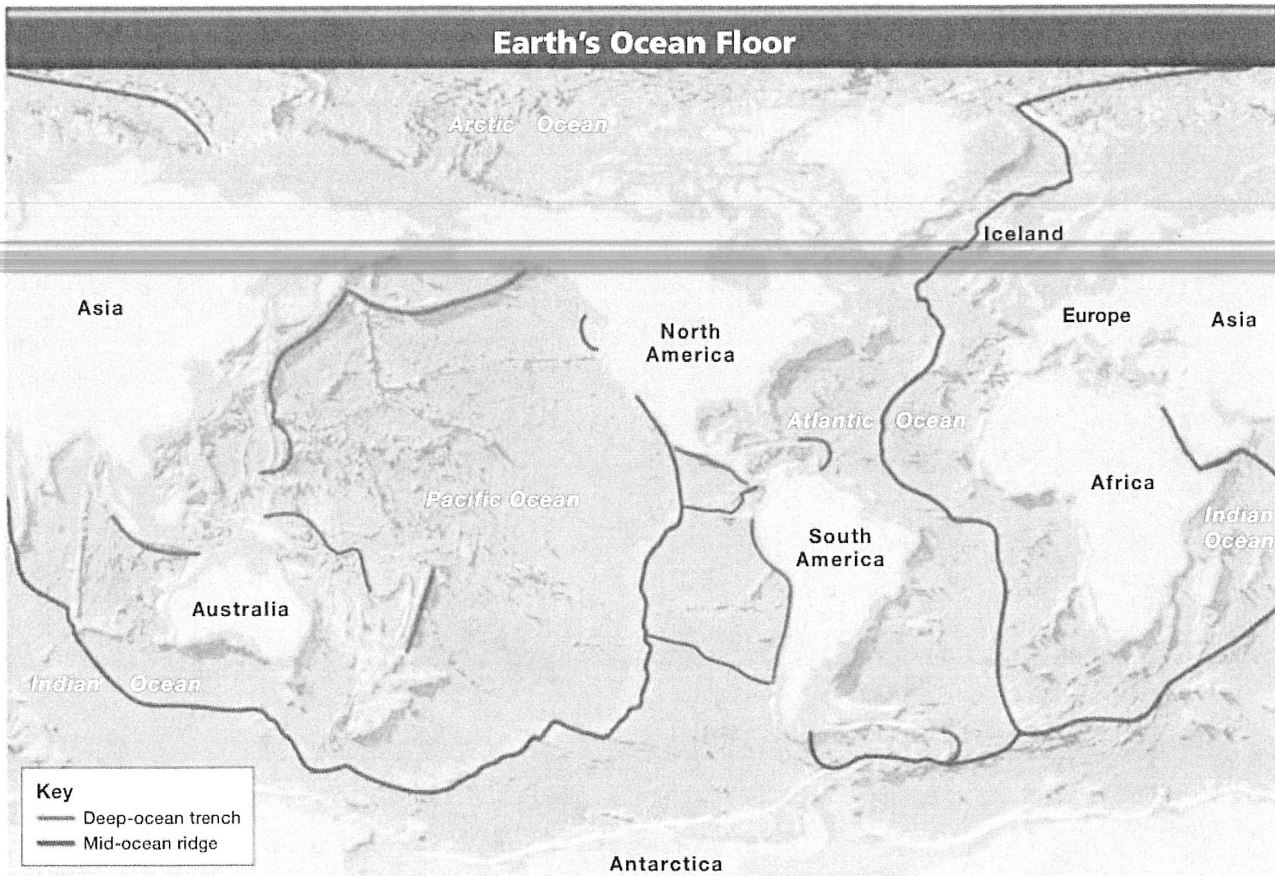


FIGURE 15
The mid-ocean ridge system is more than 50,000 kilometers long.
Interpreting Maps *What is unusual about Iceland?*

Mid-Ocean Ridges

The East Pacific Rise is just one of many **mid-ocean ridges** that wind beneath Earth's oceans. In the mid-1900s, scientists mapped the mid-ocean ridges using sonar. **Sonar** is a device that bounces sound waves off underwater objects and then records the echoes of these sound waves. The time it takes for the echo to arrive indicates the distance to the object.

Mid-ocean ridges curve like the seam of a baseball along the sea floor. They extend into all of Earth's oceans. Figure 15 shows the location of these ridges. Most of the mountains in the mid-ocean ridge system lie hidden under hundreds of meters of water. But in a few places the ridge pokes above the surface. For example, the island of Iceland is a part of the mid-ocean ridge that rises above the surface in the North Atlantic Ocean. A steep-sided valley splits the top of some mid-ocean ridges.

The mapping of mid-ocean ridges made scientists curious to know more about them. What are the ridges? How do they form?

Reading Checkpoint **What device is used to map the ocean floor?**

What Is Sea-Floor Spreading?

Harry Hess, an American geologist, was one of the scientists who studied mid-ocean ridges. Hess carefully examined maps of the mid-ocean ridge system. Then he began to think about the ocean floor in relation to the problem of continental drift. Finally, he reached a startling conclusion: Maybe Wegener was right! Perhaps the continents do move.

In 1960, Hess proposed a radical idea. He suggested that a process he called sea-floor spreading continually adds new material to the ocean floor. **In sea-floor spreading, the sea floor spreads apart along both sides of a mid-ocean ridge as new crust is added. As a result, the ocean floors move like conveyor belts, carrying the continents along with them.** Look at Figure 16 to see the process of sea-floor spreading.

Sea-floor spreading begins at a mid-ocean ridge, which forms along a crack in the oceanic crust. Along the ridge, molten material that forms several kilometers beneath the surface rises and erupts. At the same time, older rock moves outward on both sides of the ridge. As the molten material cools, it forms a strip of solid rock in the center of the ridge. When more molten material flows into the crack, it forms a new strip of rock.

Reading Checkpoint **How does new oceanic crust form?**

Go Online
PHSchool.com
For: More on sea-floor spreading
Visit: PHSchool.com
Web Code: cfd-1014

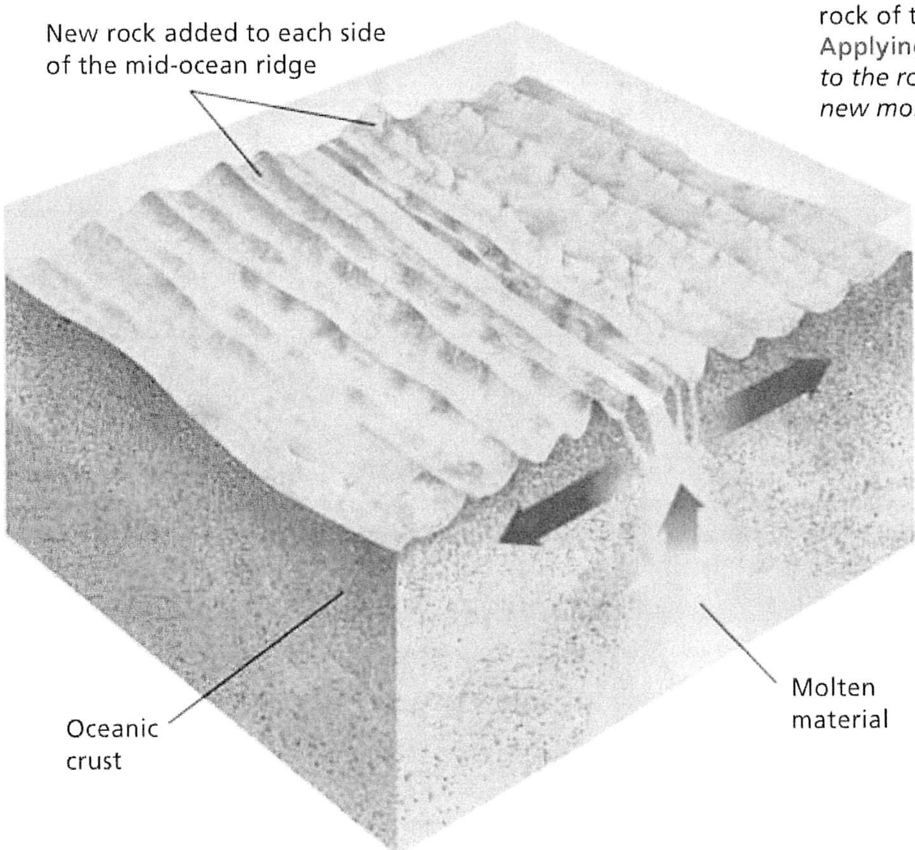


FIGURE 16
Sea-Floor Spreading
Molten material erupts through the valley that runs along the center of some mid-ocean ridges. This material hardens to form the rock of the ocean floor.
Applying Concepts *What happens to the rock along the ridge when new molten material erupts?*

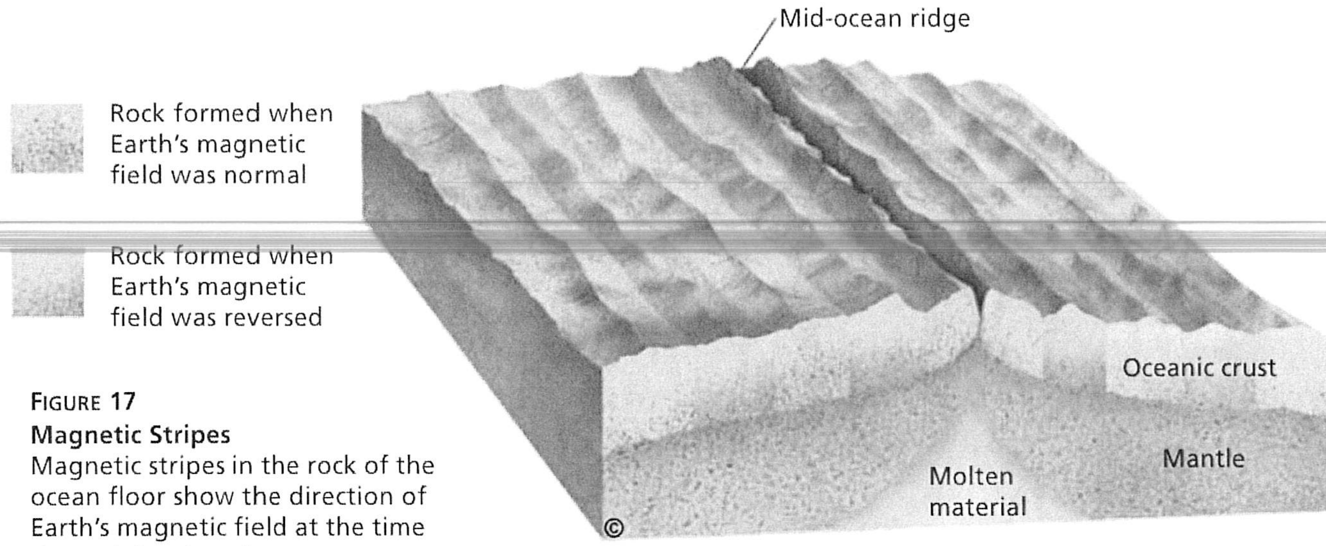


FIGURE 17
Magnetic Stripes
Magnetic stripes in the rock of the ocean floor show the direction of Earth's magnetic field at the time the rock hardened.
Interpreting Diagrams *How are these matching stripes evidence of sea-floor spreading?*

Evidence for Sea-Floor Spreading

Several types of evidence supported Hess's theory of sea-floor spreading: eruptions of molten material, magnetic stripes in the rock of the ocean floor, and the ages of the rocks themselves. This evidence led scientists to look again at Wegener's hypothesis of continental drift.

Evidence From Molten Material In the 1960s, scientists found evidence that new material is indeed erupting along mid-ocean ridges. The scientists dived to the ocean floor in *Alvin*, a small submarine built to withstand the crushing pressures four kilometers down in the ocean. In a ridge's central valley, *Alvin's* crew found strange rocks shaped like pillows or like toothpaste squeezed from a tube. Such rocks form only when molten material hardens quickly after erupting under water. These rocks showed that molten material has erupted again and again along the mid-ocean ridge.

Evidence From Magnetic Stripes When scientists studied patterns in the rocks of the ocean floor, they found more support for sea-floor spreading. You read earlier that Earth behaves like a giant magnet, with a north pole and a south pole. Surprisingly, Earth's magnetic poles have reversed themselves many times during Earth's history. The last reversal happened 780,000 years ago. If the magnetic poles suddenly reversed themselves today, you would find that your compass needle points south.

Scientists discovered that the rock that makes up the ocean floor lies in a pattern of magnetized "stripes." These stripes hold a record of reversals in Earth's magnetic field. The rock of the ocean floor contains iron. The rock began as molten material that cooled and hardened. As the rock cooled, the iron bits inside lined up in the direction of Earth's magnetic poles. This locked the iron bits in place, giving the rocks a permanent "magnetic memory."

Using sensitive instruments, scientists recorded the magnetic memory of rocks on both sides of a mid-ocean ridge. They found that stripes of rock that formed when Earth's magnetic field pointed north alternate with stripes of rock that formed when the magnetic field pointed south. As shown in Figure 17, the pattern is the same on both sides of the ridge.

Evidence From Drilling Samples The final proof of sea-floor spreading came from rock samples obtained by drilling into the ocean floor. The *Glomar Challenger,* a drilling ship built in 1968, gathered the samples. The *Glomar Challenger* sent drilling pipes through water six kilometers deep to drill holes in the ocean floor. This feat has been compared to using a sharp-ended wire to dig a hole into a sidewalk from the top of the Empire State Building.

Samples from the sea floor were brought up through the pipes. Then the scientists determined the age of the rocks in the samples. They found that the farther away from a ridge the samples were taken, the older the rocks were. The youngest rocks were always in the center of the ridges. This showed that sea-floor spreading really has taken place.

Reading Checkpoint **Why does the rock of the ocean floor have a pattern of magnetic stripes?**

Lab zone **Try This Activity**

Reversing Poles

1. Cut six short pieces, each about 2.5 cm long, from a length of audiotape.
2. Tape one end of each piece of audiotape to a flat surface. The pieces should be spaced 1 cm apart and lined up lengthwise in a single row.
3. Touch a bar magnet's north pole to the first piece of audiotape. Then reverse the magnet and touch its south pole to the next piece.
4. Repeat Step 3 until you have applied the magnet to each piece of audiotape.
5. Sweep one end of the magnet about 1 cm above the line of audiotape pieces. Observe what happens.

Making Models What characteristic of the ocean floor did you observe as you swept the magnet along the line of audiotape pieces?

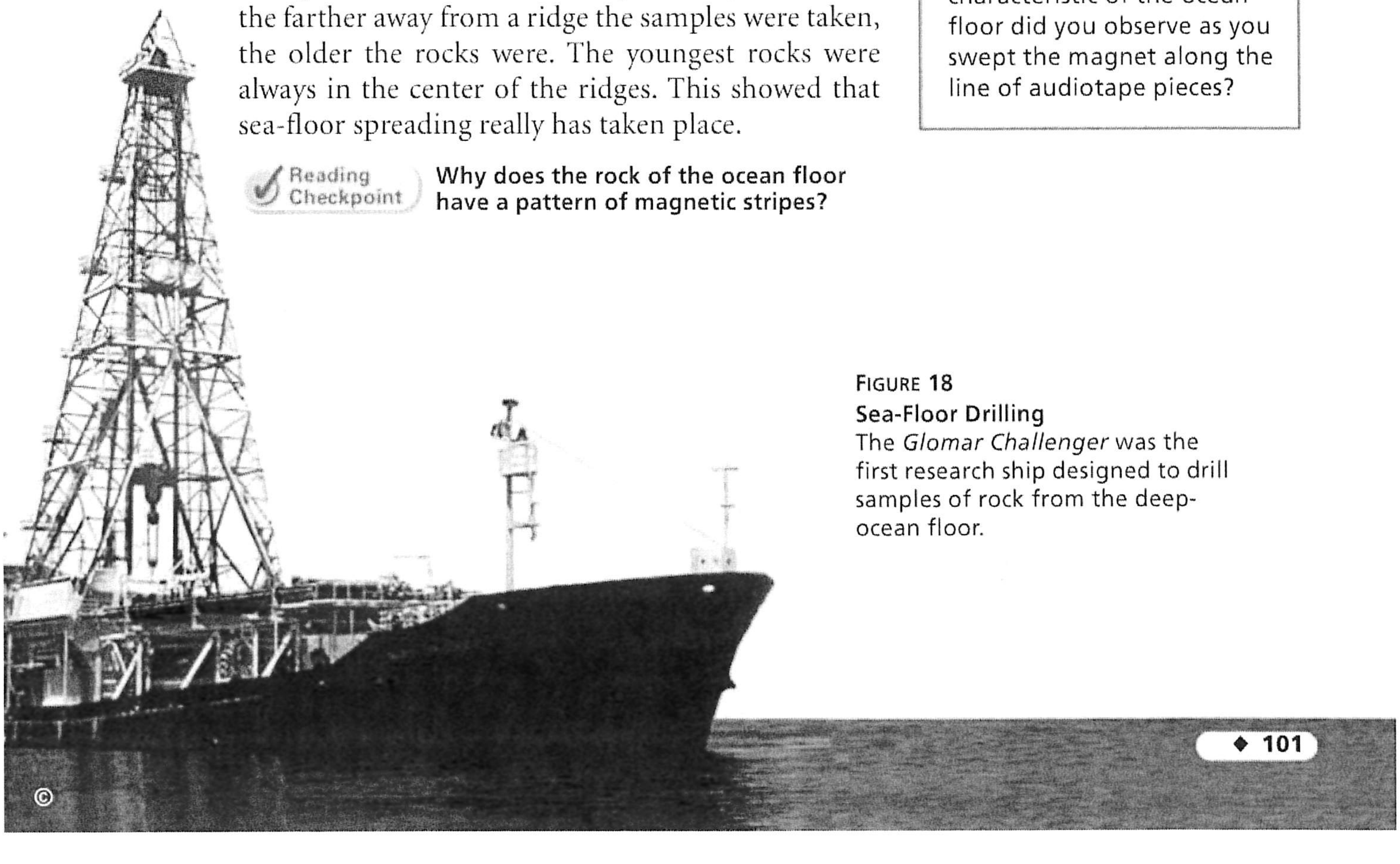


FIGURE 18
Sea-Floor Drilling
The *Glomar Challenger* was the first research ship designed to drill samples of rock from the deep-ocean floor.

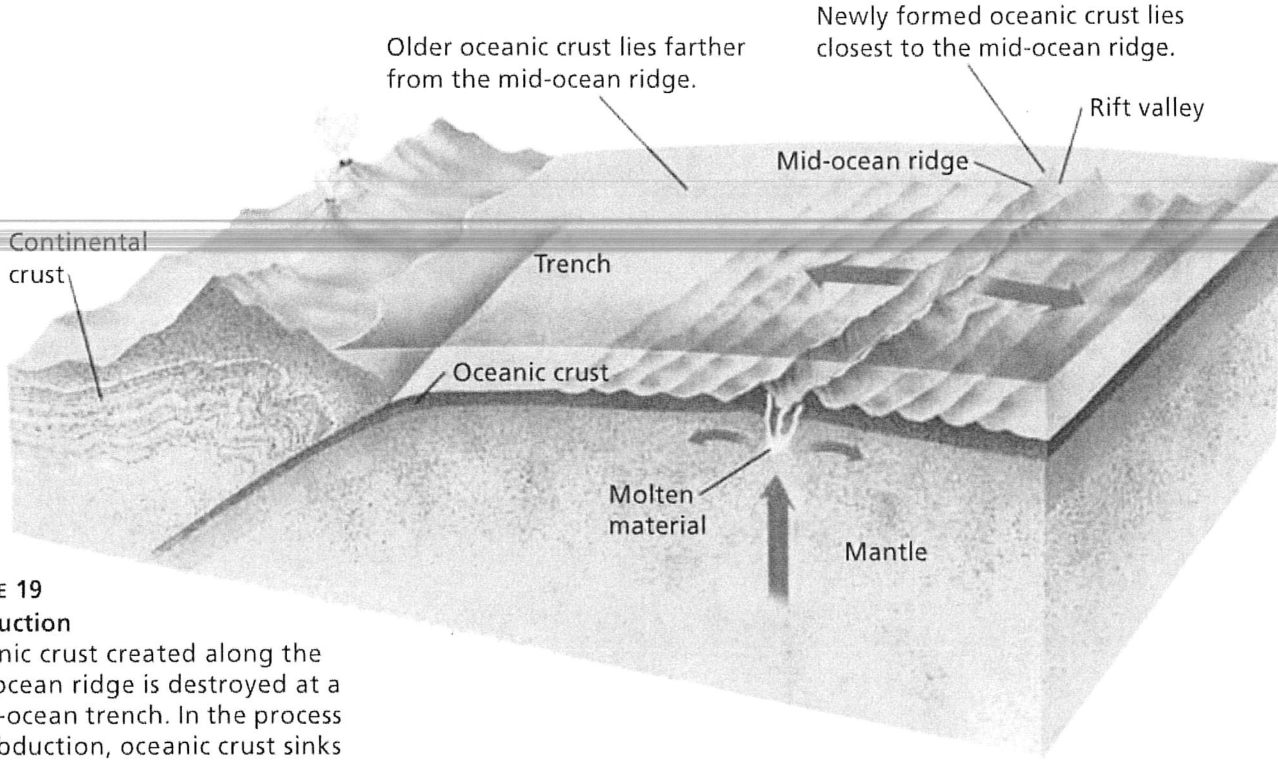


FIGURE 19
Subduction
Oceanic crust created along the mid-ocean ridge is destroyed at a deep-ocean trench. In the process of subduction, oceanic crust sinks down beneath the trench into the mantle.
Drawing Conclusions *Where would the densest oceanic crust be found?*

Subduction at Trenches

How can the ocean floor keep getting wider and wider? The answer is that the ocean floor generally does not just keep spreading. Instead, the ocean floor plunges into deep underwater canyons called deep-ocean trenches. At a deep-ocean trench, the oceanic crust bends downward. What occurs at trenches? **In a process taking tens of millions of years, part of the ocean floor sinks back into the mantle at deep-ocean trenches.**

Discovery Channel School

Plate Tectonics

Video Preview
▶ Video Field Trip
Video Assessment

The Process of Subduction The process by which ocean floor sinks beneath a deep-ocean trench and back into the mantle is called subduction (sub DUC shun). As subduction occurs, crust closer to a mid-ocean ridge moves away from the ridge and toward a deep-ocean trench. Sea-floor spreading and subduction work together. They move the ocean floor as if it were on a giant conveyor belt.

New oceanic crust is hot. But as it moves away from the mid-ocean ridge, it cools and becomes more dense. Eventually, as shown in Figure 19, gravity pulls this older, denser oceanic crust down beneath the trench. The sinking crust is like the washcloth in the Discover activity at the beginning of this section. As the dry washcloth floating on the water gets wet, its density increases and it begins to sink.

Subduction and Earth's Oceans The processes of subduction and sea-floor spreading can change the size and shape of the oceans. Because of these processes, the ocean floor is renewed about every 200 million years. That is the time it takes for new rock to form at the mid-ocean ridge, move across the ocean, and sink into a trench.

The vast Pacific Ocean covers almost one third of the planet. And yet it is shrinking. How can that be? Sometimes a deep ocean trench swallows more oceanic crust than a mid-ocean ridge can produce. Then, if the ridge does not add new crust fast enough, the width of the ocean will shrink. In the Pacific Ocean, subduction through the many trenches that ring the ocean is occurring faster than new crust can be added.

On the other hand, the Atlantic Ocean is expanding. Unlike the Pacific Ocean, the Atlantic Ocean has only a few short trenches. As a result, the spreading ocean floor has virtually nowhere to go. In most places, the oceanic crust of the Atlantic Ocean floor is attached to the continental crust of the continents around the ocean. So as the Atlantic's ocean floor spreads, the continents along its edges also move. Over time, the whole ocean gets wider.

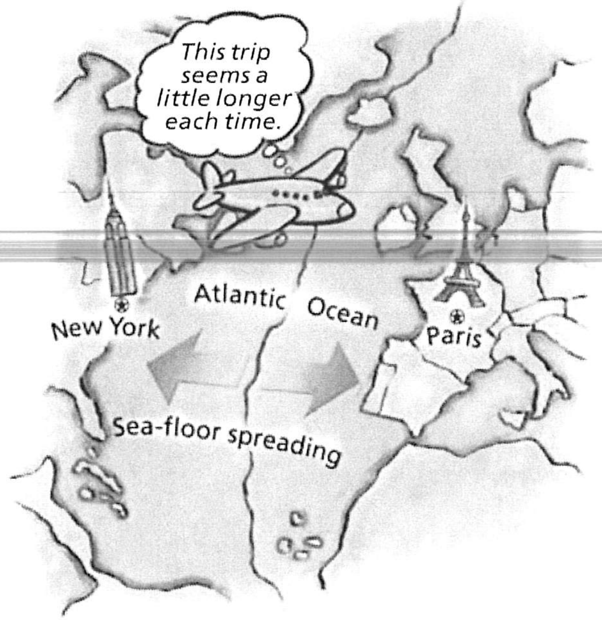


FIGURE 20
Growing an Ocean
Because of sea-floor spreading, the distance between Europe and North America is increasing by a few centimeters per year.

Reading Checkpoint **Why is the Pacific Ocean shrinking?**

Section 4 Assessment

Target Reading Skill Sequencing Refer to your flowchart on sea-floor spreading as you answer the questions below.

Reviewing Key Concepts

HINT 1. a. Naming What scientist helped to discover the process of sea-floor spreading?

HINT b. Identifying Along what feature of the ocean floor does sea-floor spreading begin?

HINT c. Sequencing What are the steps in the process of sea-floor spreading?

HINT 2. a. Reviewing What three types of evidence provided support for the theory of sea-floor spreading?

HINT b. Applying Concepts How do rocks along the central valley of the mid-ocean ridge provide evidence of sea-floor spreading?

HINT c. Predicting Where would you expect to find the oldest rock on the ocean floor?

3. a. Defining What is a deep-ocean trench? HINT

b. Relating Cause and Effect What happens to oceanic crust at a deep-ocean trench? HINT

Writing in Science

Description Write a description of what you might see if you could explore a mid-ocean ridge in a vessel like the *Alvin*. In your description, be sure to include the main features of the ocean floor along and near the ridge.

Lab zone **Skills Lab**

Modeling Sea-Floor Spreading

Problem

How does sea-floor spreading add material to the ocean floor?

Skills Focus

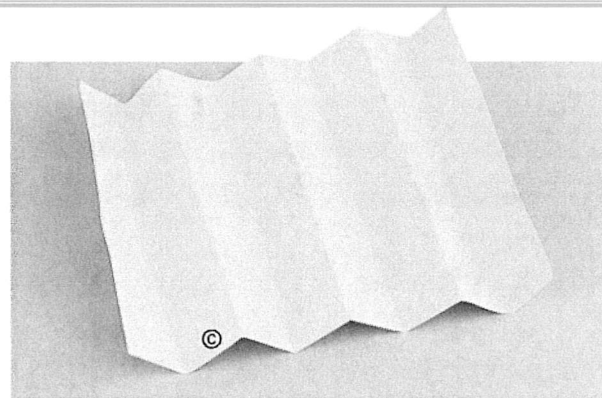
making models

Materials

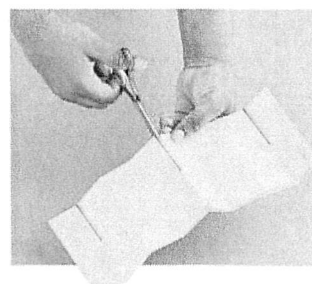
- scissors
- colored marker
- metric ruler
- 2 sheets of unlined paper

Procedure

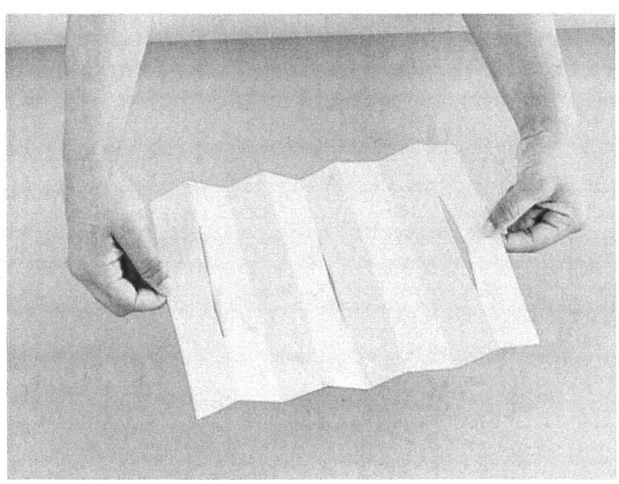
1. Draw stripes across one sheet of paper, parallel to the short sides of the paper. The stripes should vary in spacing and thickness.
2. Fold the paper in half lengthwise and write the word "Start" at the top of both halves of the paper. Using the scissors, carefully cut the paper in half along the fold line to form two strips.

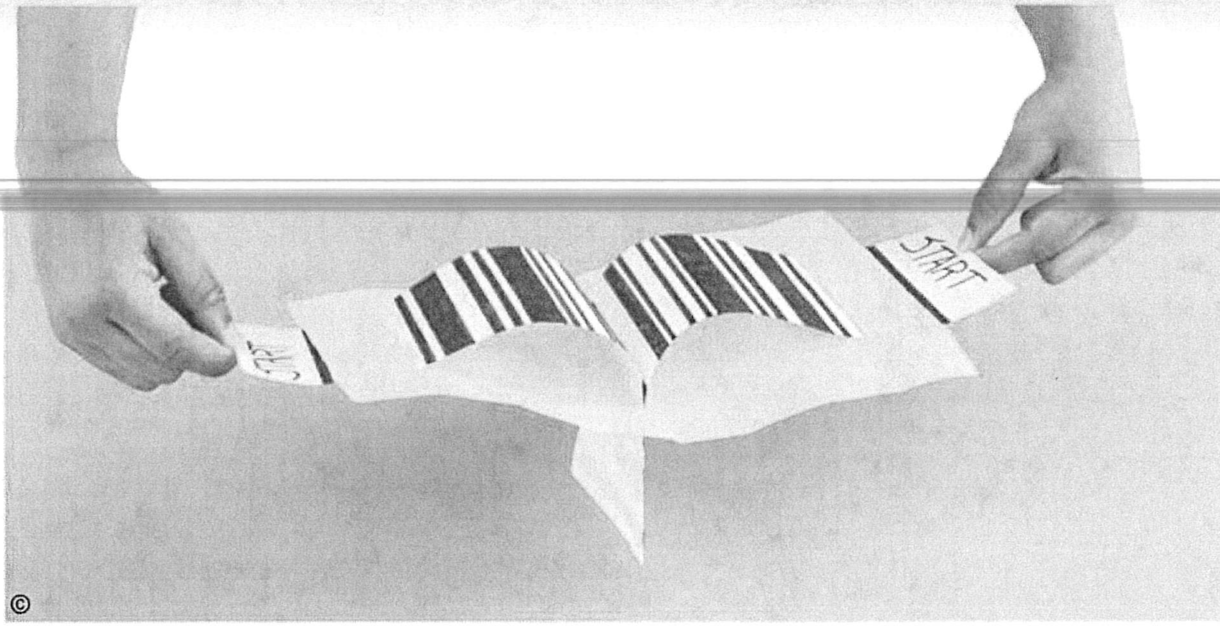


3. Lightly fold the second sheet of paper into eighths. Then unfold it, leaving creases in the paper. Fold this sheet in half lengthwise.
4. Starting at the fold, draw lines 5.5 cm long on the middle crease and the two creases closest to the ends of the paper.



5. Now carefully cut along the lines you drew. Unfold the paper. There should be three slits in the center of the paper.
6. Put the two striped strips of paper together so their Start labels touch one another. Insert the Start ends of the strips up through the center slit and then pull them toward the side slits.





7. Insert the ends of the strips into the side slits. Pull the ends of the strips and watch what happens at the center slit.
8. Practice pulling the strips until you can make the two strips come up through the center and go down through the sides at the same time.

Analyze and Conclude

1. Making Models What feature of the ocean floor does the center slit stand for? What prominent feature of the ocean floor is missing from the model at this point?
2. Making Models What do the side slits stand for? What does the space under the paper stand for?
3. Comparing and Contrasting As shown by your model, how does the ocean floor close to the center slit differ from the ocean floor near a side slit? How does this difference affect the depth of the ocean?
4. Making Models What do the stripes on the strips stand for? Why is it important that your model have an identical pattern of stripes on both sides of the center slit?
5. Applying Concepts Explain how differences in density and temperature provide some of the force needed to cause sea-floor spreading and subduction.
6. Communicating Use your own words to describe the process of sea-floor spreading. What parts of the process were not shown by your model?

More to Explore

How could you modify your model to show an island that formed where a large amount of molten rock erupted from the mid-ocean ridge? How could you show what would happen to the island over a long period of time?

Section 5

Integrating Physics

The Theory of Plate Tectonics

Reading Preview

Key Concepts

- What is the theory of plate tectonics?
- What are the three types of plate boundaries?

Key Terms

- plate
- scientific theory
- plate tectonics
- fault
- divergent boundary
- rift valley
- convergent boundary
- transform boundary

Target Reading Skill

Building Vocabulary A definition states the meaning of a word or phrase by telling about its most important feature or function. After you read the section, reread the paragraphs that contain definitions of key terms. Use all the information you have learned to write a definition of each key term in your own words.

Lab zone Discover Activity

How Well Do the Continents Fit Together?

1. Using a world map in an atlas, trace the shape of each continent and Madagascar on a sheet of paper. Also trace the shape of India and the Arabian Peninsula.
2. Carefully cut apart the landmasses, leaving Asia and Europe as one piece. Separate India and the Arabian Peninsula from Asia.
3. Piece together the continents as they may have looked before the breakup of Pangaea. Then attach your reconstruction of Pangaea to a sheet of paper.

Think It Over

Drawing Conclusions How well did the pieces of your continents fit together? Do your observations support the idea that today's landmasses were once joined together? Explain.

Have you ever dropped a hard-boiled egg? If so, you may have noticed that the eggshell cracked in an irregular pattern of pieces. Earth's lithosphere, its solid outer shell, is not one unbroken layer. It is more like that cracked eggshell. It's broken into pieces separated by jagged cracks.

A Canadian scientist, J. Tuzo Wilson, observed that there are cracks in the continents similar to those on the ocean floor. In 1965, Wilson proposed a new way of looking at these cracks. According to Wilson, the lithosphere is broken into separate sections called **plates.** The plates fit together along cracks in the lithosphere. As shown in Figure 22, the plates carry the continents or parts of the ocean floor, or both. Wilson combined what geologists knew about sea-floor spreading, Earth's plates, and continental drift into a single theory. A **scientific theory** is a well-tested concept that explains a wide range of observations.

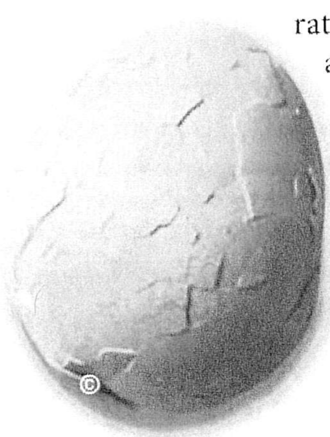


FIGURE 21
A Cracked Eggshell
Earth's lithosphere is broken into plates like the cracked shell of a hard-boiled egg.

How Plates Move

The theory of **plate tectonics** (tek TAHN iks) states that pieces of Earth's lithosphere are in slow, constant motion, driven by convection currents in the mantle. **The theory of plate tectonics explains the formation, movement, and subduction of Earth's plates.**

How can Earth's plates move? What force is great enough to move the heavy continents? Geologists think that movement of convection currents in the mantle is the major force that causes plate motion. During subduction, gravity pulls one edge of a plate down into the mantle. The rest of the plate also moves. This slow movement is similar to what happens in a pot of soup when gravity causes the cooler, denser soup near the surface to sink.

As the plates move, they collide, pull apart, or grind past each other, producing spectacular changes in Earth's surface. These changes include volcanoes, mountain ranges, and deep-ocean trenches.

Lab zone **Skills Activity**

Predicting

Study the map of Earth's plates in Figure 22. Notice the arrows that show the direction of plate movement. Now find the Nazca plate on the map. Which direction is it moving? Find the South American plate and describe its movement. What do you think will happen as these plates continue to move?

FIGURE 22
Plate boundaries divide the lithosphere into large plates.
Interpreting Maps *Which plates include only ocean floor? Which plates include both continents and ocean floor?*

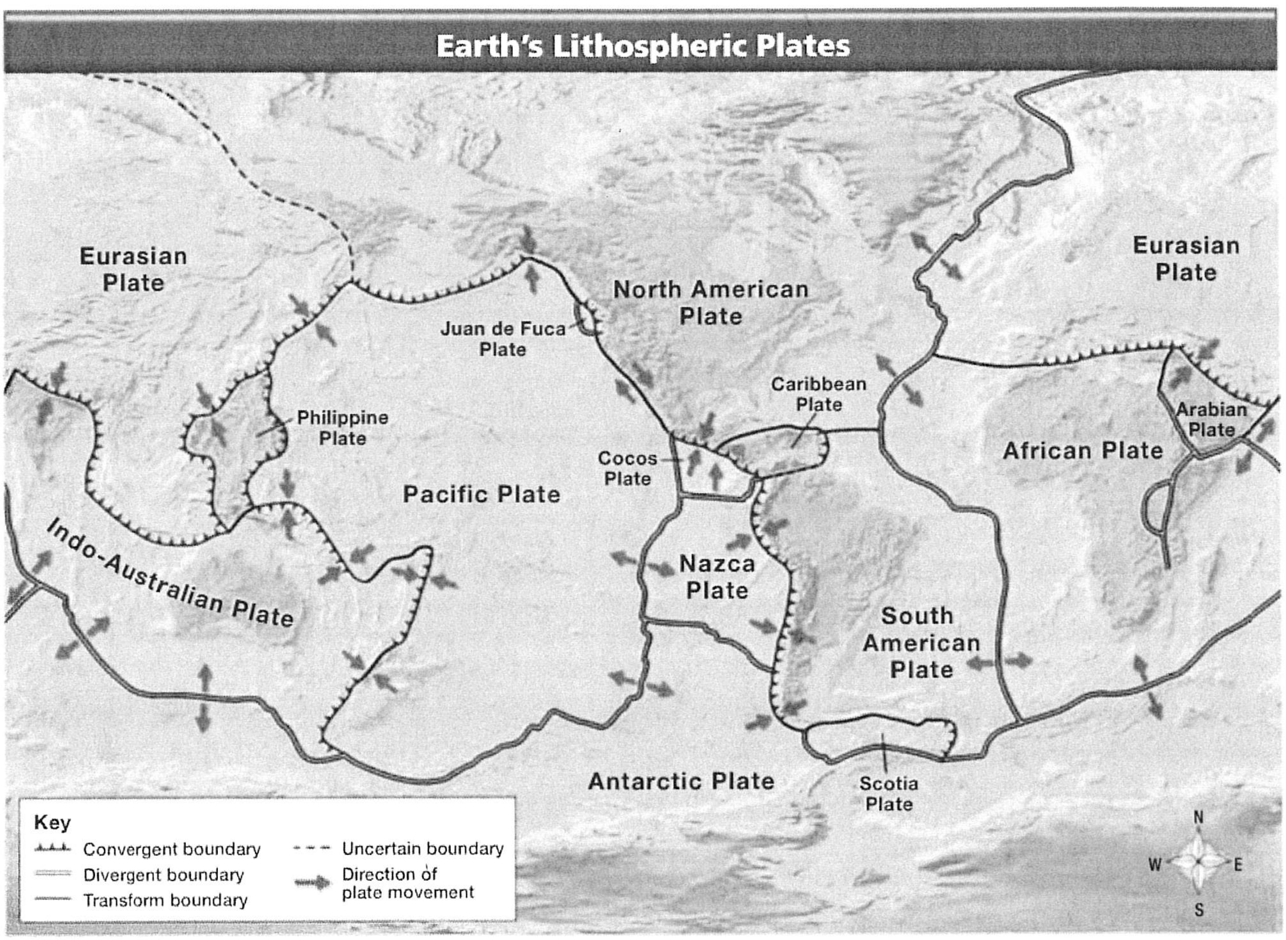


Plate Boundaries

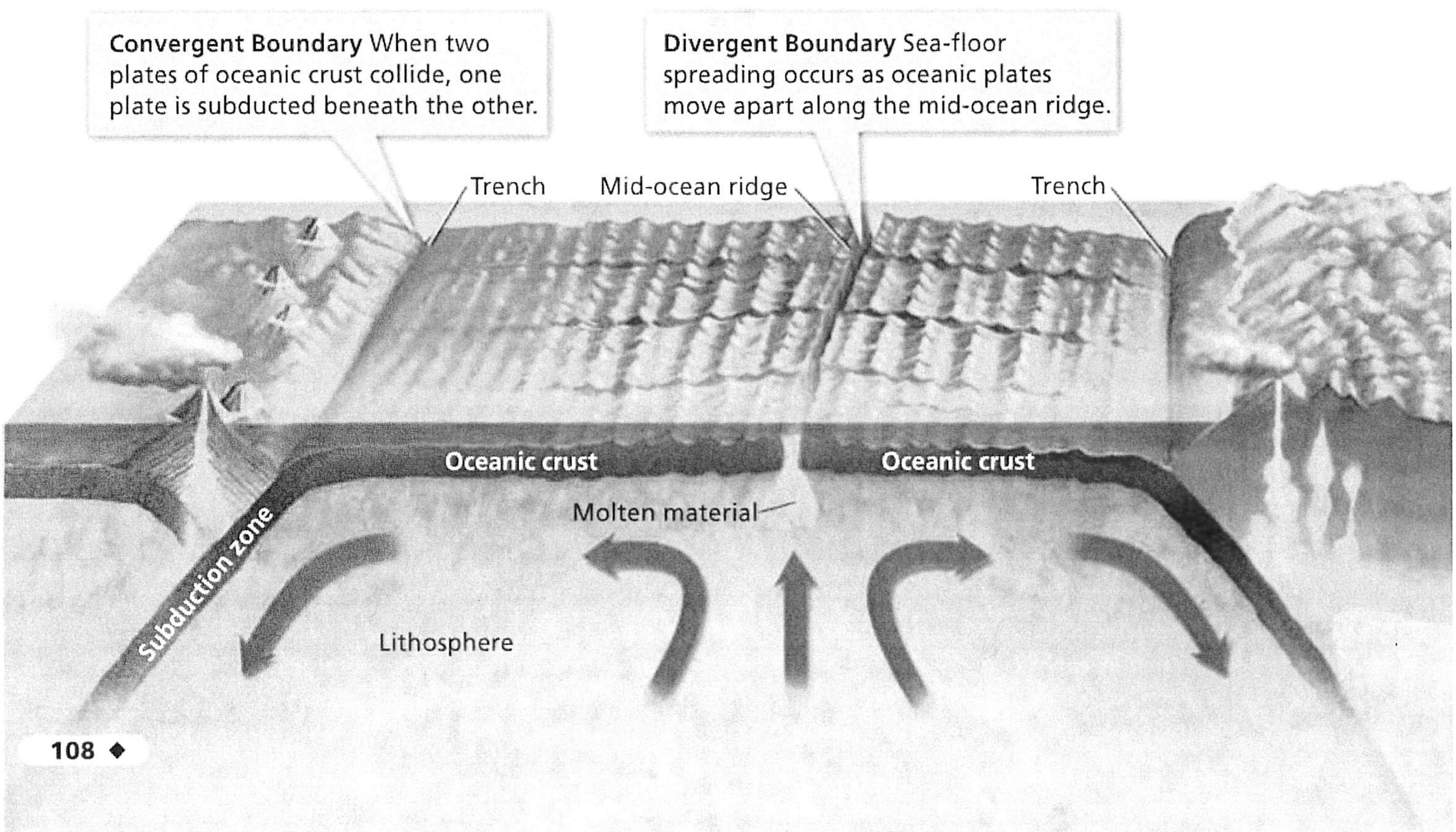
The edges of Earth's plates meet at plate boundaries. Plate boundaries extend deep into the lithosphere. **Faults** —breaks in Earth's crust where rocks have slipped past each other— form along these boundaries. **As shown in Figure 23, there are three kinds of plate boundaries: divergent boundaries, convergent boundaries, and transform boundaries. A different type of plate movement occurs along each type of boundary.**

Scientists have used instruments on satellites to measure plate motion very precisely. The plates move at amazingly slow rates: from about 1 to 24 centimeters per year. The North American and Eurasian plates are moving apart at a rate of 2.5 centimeters per year. That's about as fast as your fingernails grow. This may not seem like much, but these plates have been moving apart for tens of millions of years.

Divergent Boundaries The place where two plates move apart, or diverge, is called a **divergent boundary** (dy VUR junt). Most divergent boundaries occur along the mid-ocean ridges where sea-floor spreading occurs.

Divergent boundaries also occur on land. When a divergent boundary develops on land, two of Earth's plates slide apart. A deep valley called a **rift valley** forms along the divergent boundary. For example, the Great Rift Valley in East Africa marks a deep crack in the African continent.

FIGURE 23
Plate Tectonics
Plate movements have built many of the features of Earth's land surfaces and ocean floors.
Predicting *What will eventually happen if a rift valley continues to pull apart?*



Convergent Boundaries The place where two plates come together, or converge, is called a **convergent boundary** (kun VUR junt). When two plates converge, the result is called a collision. When two plates collide, the density of the plates determines which one comes out on top.

Oceanic crust becomes cooler and denser as it spreads away from the mid-ocean ridge. Where two plates carrying oceanic crust meet at a trench, the plate that is more dense sinks under the other plate.

Sometimes a plate carrying oceanic crust collides with a plate carrying continental crust. Oceanic crust is more dense than continental crust. The less dense continental crust can't sink under the more dense oceanic crust. Instead, subduction occurs as the oceanic plate sinks beneath the continental plate.

When two plates carrying continental crust collide, subduction does not take place. Neither piece of crust is dense enough to sink very far into the mantle. Instead, the collision squeezes the crust into mighty mountain ranges.

Transform Boundaries A **transform boundary** is a place where two plates slip past each other, moving in opposite directions. Earthquakes often occur along transform boundaries, but crust is neither created nor destroyed.

Reading Checkpoint What features form where two continental plates come together?

Math Skills

Calculating a Rate

To calculate the rate of plate motion, divide the distance the plate moves by the time it takes to move that distance.

$$\text{Rate} = \frac{\text{Distance}}{\text{Time}}$$

For example, a plate takes 2 million years to move 156 km. Calculate its rate of motion.

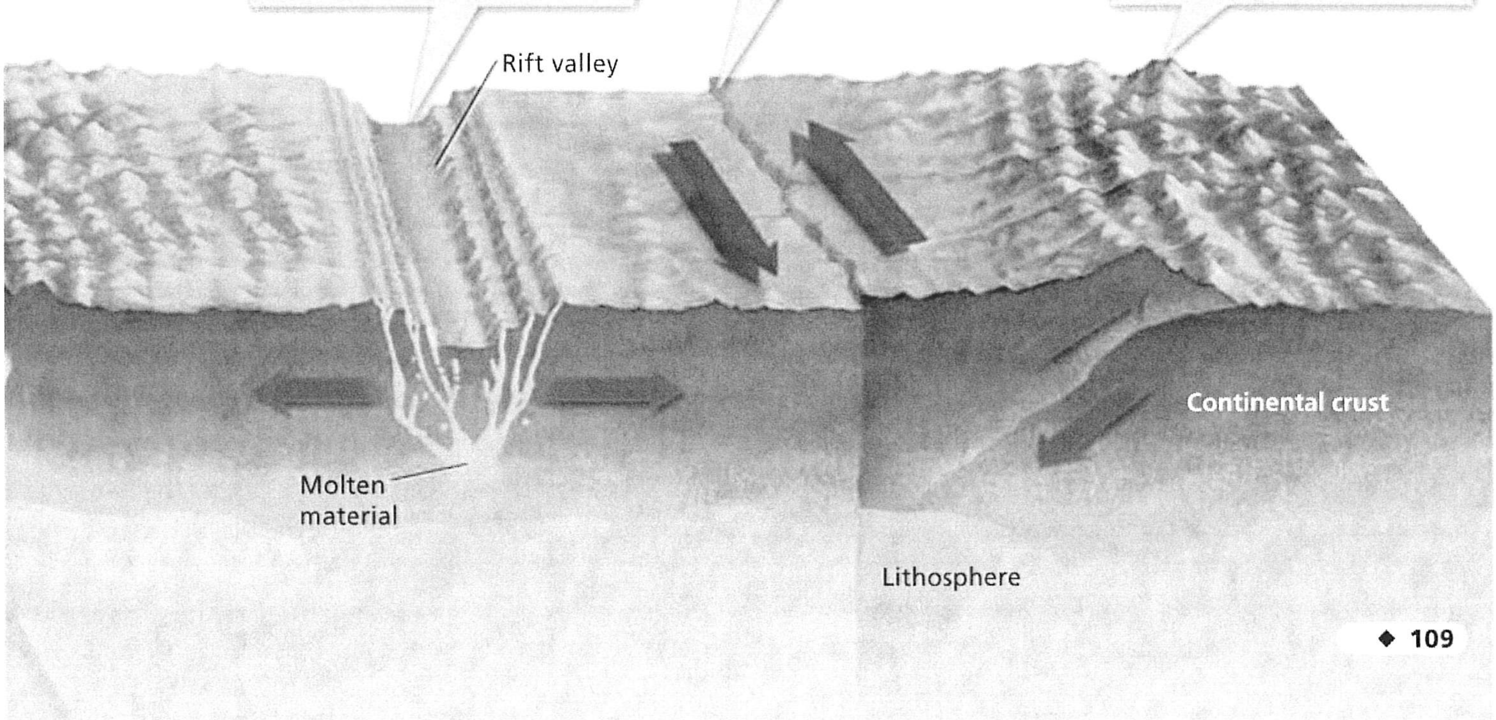
$$\frac{156 \text{ km}}{2{,}000{,}000 \text{ years}} = 7.8 \text{ cm per year}$$

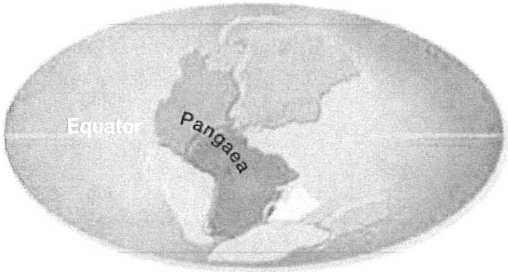
Practice Problem The Pacific plate is sliding past the North American plate. It has taken 10 million years for the plate to move 600 km. What is the Pacific plate's rate of motion?

Divergent Boundary A rift valley forms when two pieces of continental crust pull apart.

Transform Boundary Two plates slide past each other.

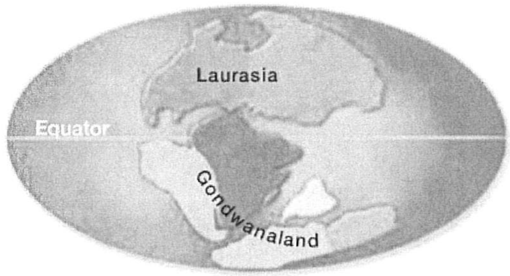
Convergent Boundary Two continental plates collide, forming a mountain range.





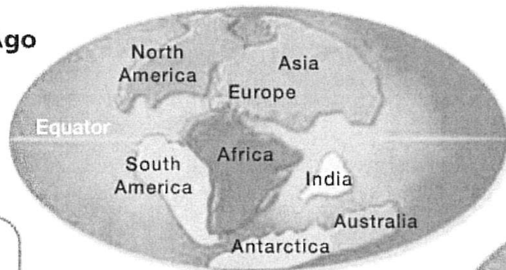
225 Million Years Ago

Plate Motions Over Time The movement of Earth's plates has greatly changed Earth's surface. Geologists have evidence that, before Pangaea existed, other supercontinents formed and split apart over billions of years. Pangaea itself formed when Earth's landmasses drifted together about 260 million years ago. Then, about 225 million years ago, Pangaea began to break apart. Figure 24 shows how major landmasses have moved since the breakup of Pangaea.

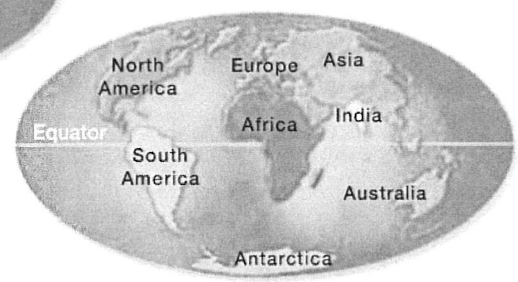


180–200 Million Years Ago

FIGURE 24
Continental Drift
It has taken the continents about 225 million years since the breakup of Pangaea to move to their present locations. Posing Questions *What questions would you need to answer in order to predict where the continents will be in 50 million years?*



135 Million Years Ago



Earth Today

Go Online
active art
For: Continental Drift activity
Visit: PHSchool.com
Web Code: cfp-1015

Section 5 Assessment

Vocabulary Skill Use Greek Word Origins Use what you know about the Greek word origin of *tectonics* to explain the meaning of *plate tectonics*.

Reviewing Key Concepts

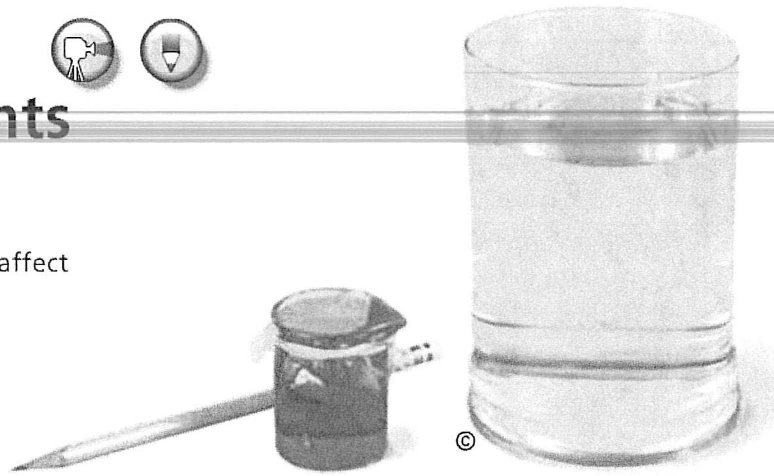
HINT 1. a. Defining What are plates?
HINT b. Summarizing In your own words, what is the theory of plate tectonics?
HINT c. Relating Cause and Effect What do scientists think causes the movement of Earth's plates?
HINT 2. a. Listing What are the three types of plate boundaries?
HINT b. Describing Describe the type of movement that occurs at each type of plate boundary.
HINT c. Predicting What is likely to occur at a plate boundary where oceanic crust collides with continental crust?

Math Practice

3. Calculating a Rate There are two islands on opposite sides of a mid-ocean ridge in the Atlantic Ocean. During the last 8 million years, the distance between the islands has increased by 200 kilometers. Calculate the rate at which the two plates are diverging.

Lab zone **Skills Lab**

Modeling Mantle Convection Currents



Problem

How might convection in Earth's mantle affect tectonic plates?

Skills Focus

making models, observing

Materials

- large plastic bottle • food coloring • small glass jar • aluminum foil or plastic wrap
- rubber band • several paper hole punches or small pieces of paper • tap water

Procedure

1. Fill the large bottle about half full with cold tap water.
2. Partly fill the small jar with hot tap water and stir in 6 drops of food coloring. Carefully add enough hot water to fill the jar to the brim.
3. Cover the top of the jar with aluminum foil or plastic wrap and secure with a rubber band.
4. Carefully lower the jar into the bottle of tap water.
5. Place the pieces of paper on the surface of the water.
6. Without disturbing the water, use the tip of the pencil to make two small holes about 2–4 mm in diameter in the material covering the jar.
7. Predict what will happen to the colored water and to the pieces of paper floating on the surface.
8. Observe the contents of the jar, as well as the paper pieces on the surface of the water.

Analyze and Conclude

1. **Observing** Describe what happened to the colored water and to the pieces of paper after the holes were punched in the material covering the jar.
2. **Drawing Conclusions** How did your prediction compare with what actually happened to the colored water and pieces of paper?
3. **Inferring** What type of heat transfer took place in the bottle? Describe how the transfer occurred.
4. **Making Models** Which part of your model represents a tectonic plate? Which part represents Earth's mantle?
5. **Communicating** How well do you think this lab modeled the movement of Earth's plates? What similarities exist between this model and actual plate movement? What factors weren't you able to model in this lab?

Designing Experiments

Repeat this activity, but develop a plan to measure the temperature of the water inside the large bottle. Is there a difference in temperature between the water's surface and the water near the top of the small jar? Do you observe any change in the convection currents as the water temperature changes? With your teacher's approval, carry out your plan.

Chapter 3

Study Guide

The BIG Idea

Composition and structure of Earth Earth's plates are large pieces of the lithosphere that move slowly, producing faults, mountain ranges, volcanoes, and deep-ocean trenches.

1 Earth's Interior

Key Concepts

Geologists have used two main types of evidence to learn about Earth's interior: direct evidence from rock samples and indirect evidence from seismic waves.

The three main layers of Earth are the crust, the mantle, and the core. These layers vary greatly in size, composition, temperature, and pressure.

The crust is a layer of solid rock that includes both dry land and the ocean floor.

Earth's mantle is made up of rock that is very hot, but solid. Scientists divide the mantle into layers based on physical characteristics.

The core is made mostly of the metals iron and nickel. It consists of two parts—a liquid outer core and a solid inner core.

Key Terms

- seismic waves • pressure • crust • basalt
- granite • mantle • lithosphere
- asthenosphere • outer core • inner core

2 Convection and the Mantle

Key Concepts

There are three types of heat transfer: radiation, conduction, and convection.

Heating and cooling of the fluid, changes in the fluid's density, and the force of gravity combine to set convection currents in motion.

Heat from the core and the mantle itself causes convection currents in the mantle.

Key Terms

- radiation • conduction • convection
- density • convection current

3 Drifting Continents

Key Concepts

Wegener's hypothesis was that all the continents had once been joined together in a single landmass and have since drifted apart.

Wegener gathered evidence from different scientific fields to support his ideas about continental drift. He studied land features, fossils, and evidence of climate change.

Wegener could not provide a satisfactory explanation for the force that pushes or pulls the continents.

Key Terms

- continental drift • Pangaea • fossil

4 Sea-Floor Spreading

Key Concepts

In sea-floor spreading, the sea floor spreads apart along both sides of a mid-ocean ridge as new crust is added. As a result, the ocean floors move like conveyor belts, carrying the continents along with them.

Several types of evidence supported Hess's theory of sea-floor spreading: eruptions of molten material, magnetic stripes in the rock of the ocean floor, and the ages of the rocks.

In a process taking tens of millions of years, part of the ocean floor sinks back into the mantle at deep-ocean trenches.

Key Terms

- mid-ocean ridge • sonar • sea-floor spreading
- deep-ocean trench • subduction

5 The Theory of Plate Tectonics

Key Concepts

The theory of plate tectonics explains the formation, movement, and subduction of Earth's plates.

There are three kinds of plate boundaries: divergent boundaries, convergent boundaries, and transform boundaries. A different type of plate movement occurs along each.

Key Terms

- plate • scientific theory • plate tectonics
- fault • divergent boundary • rift valley
- convergent boundary • transform boundary

Review and Assessment

Go Online
PHSchool.com
For: Self-Assessment
Visit: PHSchool.com
Web Code: cpa-0003

Organizing Information

Comparing and Contrasting Fill in the compare-and-contrast table to compare the characteristics of the different types of plate boundaries. Then give it a title.

Type of Plate Boundary	Type of Motion	Effect on Crust	Feature(s) Formed
a. ___?___ boundary	Plates slide past each other.	b. ___?___	c. ___?___
d. ___?___ boundary	e. ___?___	Subduction or mountain building	f. ___?___
g. ___?___ boundary	h. ___?___	i. ___?___	Mid-ocean ridge, ocean floor

Reviewing Key Terms

Choose the letter of the best answer.

HINT
1. The relatively soft layer of the upper mantle is the
   a. asthenosphere.
   b. lithosphere.
   c. inner core.
   d. continental crust.

HINT
2. The transfer of heat by the direct contact of particles of matter is
   a. pressure.
   b. radiation.
   c. conduction.
   d. convection.

HINT
3. Subduction of the ocean floor takes place at
   a. the lower mantle.
   b. mid-ocean ridges.
   c. rift valleys.
   d. trenches.

HINT
4. The process that powers plate tectonics is
   a. radiation.
   b. convection.
   c. conduction.
   d. subduction.

HINT
5. Two plates collide with each other at
   a. a divergent boundary.
   b. a convergent boundary.
   c. the boundary between the mantle and the crust.
   d. a transform boundary.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

6. Continental crust is made of rocks such as granite. HINT
7. Slow movements of mantle rock called radiation transfer heat in the mantle. HINT
8. The single landmass that broke apart 250 million years ago was Pangaea. HINT
9. Mid-ocean ridges are places where oceanic crust sinks back to the mantle. HINT
10. When two continental plates diverge, a transform boundary forms. HINT

Writing in Science

Prediction Now that you have learned about the theory of plate tectonics, write a paragraph predicting what the shape and positions of Earth's continents will be 50 million years in the future. Include what would happen to the oceans if continental landmasses became connected in new ways or drifted from their present locations.

Discovery Channel School

Plate Tectonics
Video Preview
Video Field Trip
▶ Video Assessment

Review and Assessment

Checking Concepts

11. What kinds of indirect evidence do geologists use to study the structure of Earth?

12. How do temperature and pressure change as you go deeper into Earth?

13. What happens in Earth's interior to produce Earth's magnetic field? Describe the layer where the magnetic field is produced.

14. Why are there convection currents in the mantle?

15. Why are the oldest parts of the ocean floor no older than about 200 million years old?

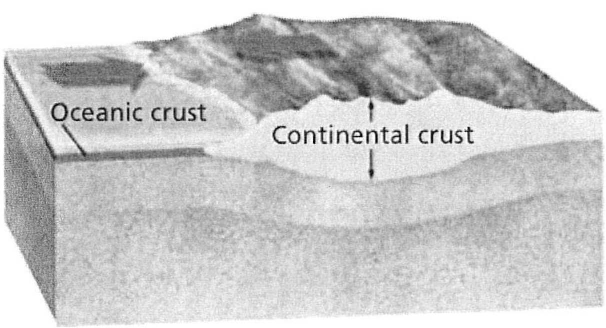
16. How do magnetic stripes form on the ocean floor? Why are these stripes significant?

Thinking Critically

17. Comparing and Contrasting How are oceanic and continental crust alike? How do they differ?

18. Sequencing Place these terms in correct order so they begin at Earth's surface and move toward the center: inner core, asthenosphere, lower mantle, lithosphere, outer core.

19. Predicting In the diagram below, a plate of oceanic crust is colliding with a plate of continental crust. What will happen? Why?



20. Relating Cause and Effect What do many geologists think is the driving force of plate tectonics? Explain.

21. Making Judgments Scientists refer to plate tectonics as a *theory*. What is a theory? How is plate tectonics a theory? Why isn't continental drift considered a theory? (*Hint*: Refer to the Skills Handbook for more on theories.)

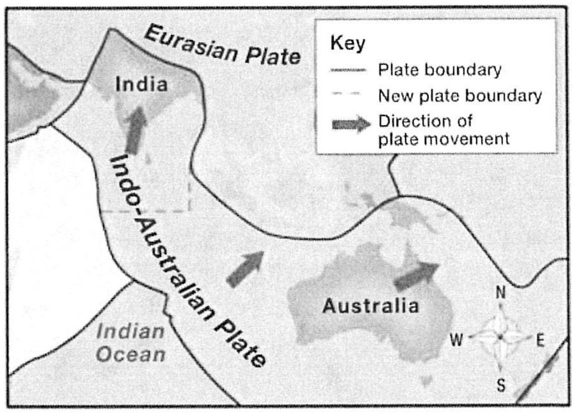
Math Practice

22. Calculating a Rate It takes 100,000 years for a plate to move about 14 kilometers. Calculate the rate of plate motion.

Applying Skills

Use the map to answer Questions 23–25.

Geologists think that a new plate boundary is forming in the Indian Ocean. The part of the plate carrying Australia is twisting away from the part of the plate carrying India.



23. Interpreting Maps In what direction is the part of the plate carrying Australia moving? In what direction is the part carrying India moving?

24. Predicting As India and Australia move in different directions, what type of plate boundary will form between them?

25. Inferring What features could occur where the northern part of the Indo-Australian plate is colliding with the Eurasian plate?

Lab zone Chapter Project

Performance Assessment Present your model to the class. Point out the types of plate boundaries on your model. Discuss the plate motions and landforms that result in these areas.

Preparing for the CRCT

Test-Taking Tip

Using Formulas

Some test questions require you to use a formula to answer a question. For example, in the question below you should recall that speed can be found using the following formula.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

To solve for a quantity in a formula, substitute known values, including units, for the variables. Be sure to include units in your final answer.

Sample Question

An island on the Pacific plate moves a distance of 550 cm in 50 years. What is the plate's rate of speed?

A 44 cm per year
B 110 cm per year
C 2,750 cm per year
D 11 cm per year

Answer

The answer is **D**.

$$\frac{550\text{ cm}}{50\text{ years}} = 11\text{ cm per year}$$

Choose the letter that best answers the question or completes the statement.

1. Which of the following is evidence for sea-floor spreading?
A matching patterns of magnetic stripes in the ocean floor
B volcanic eruptions along mid-ocean ridges
C older rock found farther from mid-ocean ridges
D all of the above **S6E5.e**

2. Wegener thought the continents moved because fossils of the same organisms are found on widely separated continents. Wegener's use of fossil evidence is an example of a(n)
A prediction.
B observation.
C inference.
D controlled experiment. **S6E5.f**

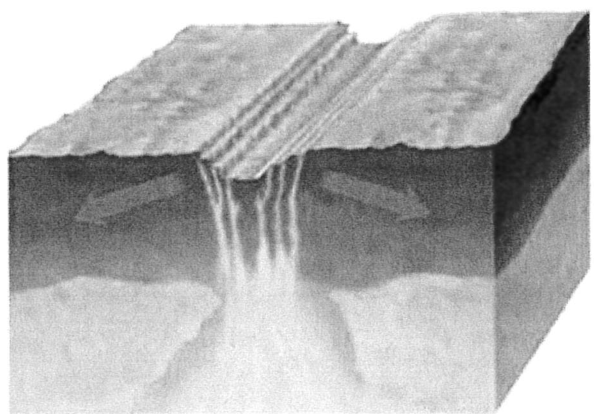
3. The table below shows the movement of rock away from a mid-ocean ridge, and the time in years it takes sea-floor spreading to move the rock that distance.

Distance (meters)	Time (years)
50	4,000
100	8,000
150	12,000

What is the speed of the rock?

A 0.0125 m per year **B** 12.5 m per year
C 80 m per year **D** 200,000 m per year
S6E5.d

4. Which of the following best describes the process in the diagram below?
A Converging plates form a transform boundary.
B Converging plates form volcanoes.
C Diverging plates form a mid-ocean ridge.
D Diverging plates form a rift valley. **S6E5.e**



Constructed Response

5. Today, the Mediterranean Sea lies between Europe and Africa. But the African plate is moving toward the Eurasian plate at a rate of a few centimeters per year. Predict how this area will change in 100 million years. In your answer, first explain how the Mediterranean Sea will change. Then explain what will happen on land. **S6E5.d**