Plate tectonics explains the formation of many of Earth’s features and geologic events.

**LESSON 1**

**Continental Drift**

(Main Idea) Despite the evidence that supported continental drift, it was rejected by most scientists.

**LESSON 2**

**Seafloor Spreading**

(Main Idea) New discoveries led to seafloor spreading as an explanation for continental drift.

**LESSON 3**

**Theory of Plate Tectonics**

(Main Idea) Earth’s lithosphere is broken into large brittle pieces, which move as a result of forces acting on them.

**A Growing Country**

Pingvellir, Iceland, is located on the Mid-Atlantic Ridge, where the North American Plate and the Eurasian Plate are slowly being pulled apart. This process causes Iceland’s intense earthquakes and volcanic activity. Iceland is one of the few places where the Mid-Atlantic Ridge can be seen above sea level.

(Science Journal) Write three questions you would ask a geologist about plate tectonics.
Can you put it back together?

Earth’s plates are not in the same places as they used to be. Can you match the plates from an orange if someone scrambles them up?

**Procedure**
1. Read and complete a lab safety form.
2. Make oceans basins in an orange by gently carving away some of the top layer of the skin with a citrus peeler.
3. Draw continents on the orange with a ballpoint pen.
4. Use the pen tip to cut the skin into six or seven irregularly-shaped plates.
5. Peel the plates away from the orange.
6. Trade oranges with a classmate, and try to put each other’s oranges back together.

**Think About This**
List the clues you used to put the plates back together.

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**Foldables Study Organizer**

**Plate Tectonics**
Make the following Foldable to help you monitor your understanding of plate tectonics.

**STEP 1** Fold a sheet of paper in half lengthwise. Make the back edge about 2 cm longer than the front edge.

**STEP 2** Fold into thirds.

**STEP 3** Unfold and cut along the folds of the top flap to make three flaps.

**STEP 4** Label the flaps as shown.

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**Monitoring**
As you read this chapter, use the Reading Checks to help you monitor your understanding of what you are reading. Write the Reading Check questions and answers for each lesson under its tab.
1 Learn It! An important strategy to help you improve your reading is monitoring, or finding your reading strengths and weaknesses. As you read, monitor yourself to make sure the text makes sense. Discover different monitoring techniques you can use at different times, depending on the type of test and situation.

2 Practice It! The paragraph below appears in Lesson 1. Read the passage and answer the questions that follow. Discuss your answers with other students to see how they monitor their reading.

Fossils are the remains, imprints, or traces of once-living organisms. If an organism dies and is buried in sediment, then it can become preserved in various ways. Eventually, the fossil becomes part of a sedimentary rock. Fossils help scientists learn about species from past times. Wegener collected fossil evidence to support his continental drift hypothesis.

—from page 169

- What questions do you still have after reading?
- Do you understand all of the words in the passage?
- Did you have to stop reading often? Is the reading level appropriate for you?

3 Apply It! Identify one paragraph that is difficult to understand. Discuss it with a partner to improve your understanding.
Target Your Reading

Use this to focus on the main ideas as you read the chapter.

1 Before you read the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.
   • Write an A if you agree with the statement.
   • Write a D if you disagree with the statement.

2 After you read the chapter, look back to this page to see if you’ve changed your mind about any of the statements.
   • If any of your answers changed, explain why.
   • Change any false statements into true statements.
   • Use your revised statements as a study guide.

<table>
<thead>
<tr>
<th>Before You Read A or D</th>
<th>Statement</th>
<th>After You Read A or D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Most oceanic crust is made of granite.</td>
<td></td>
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<tr>
<td>2 The density of rock increases as its temperature increases.</td>
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<tr>
<td>3 Earth’s lithosphere is broken into 100 large pieces called plates.</td>
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<tr>
<td>4 A slab is less dense than continental crust.</td>
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<td>5 Fossils of sharks provide evidence for Pangaea.</td>
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<tr>
<td>6 Harry Hess proposed the continental drift hypothesis in the mid-1950s.</td>
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<tr>
<td>7 Earthquakes and volcanic eruptions occur at boundaries of lithospheric plates.</td>
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<tr>
<td>8 Heat is currently escaping from the interior of Earth.</td>
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<tr>
<td>9 Seafloor spreading provided part of an explanation of how continents could move on Earth’s surface.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 The theory of plate tectonics is well established, so scientists no longer study it.</td>
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Print a worksheet of this page at ca6.msscience.com.
Despite the evidence that supported continental drift, it was rejected by most scientists.

Real-World Reading Connection Maybe you’ve had an idea that was really outrageous and exciting. Because your idea seemed so impossible, your friends might have rejected it. You still might have tried hard to convince them that it was a great idea. This is what happened to Alfred Wegener (VAY guh nur) when he tried to convince other scientists that continents slowly drift parallel to Earth’s surface.

Drifting Continents

About five hundred years ago, during the age of exploration, European explorers sailed across the Atlantic Ocean. They discovered continents they had never seen before. These continents were North and South America. New maps that included the Americas were drawn. People who studied these maps, such as the one shown in Figure 1, observed something strange. The edges of the American continents look as if they might fit into the edges of Europe and Africa. This observation inspired Alfred Wegener’s controversial idea.

Figure 1 Antique Maps This map was published in 1680. Maps like this made people question why the edges of continents appeared as if they could fit together.

Identify the east coast of South America and the west coast of Africa.
**A Controversial Idea**

Alfred Wegener thought the edges of continents looked like they might fit together because they once had been attached as one huge landmass.

In the early 1900s, he proposed a hypothesis to explain this. Wegener’s hypothesis, **continental drift**, is the idea that the continents move very slowly, over millions of years, parallel to Earth’s surface.

**Pangaea Breaks Apart**

Wegener’s continental drift hypothesis proposed that the continents have slowly drifted to their present-day locations. **Figure 2** shows how scientists think the continents broke into pieces as they slowly drifted apart.

1. Wegener proposed that millions of years ago, the continents formed one huge landmass. He named this ancient supercontinent **Pangaea** (pan JEE uh). The top panel of **Figure 2** shows how Pangaea might have appeared about 255 million years ago. According to Wegener, Pangaea started to break apart about 200 million years ago.

   **What is Pangaea?**

2. About 152 million years ago, the Atlantic Ocean began to open up between North America and Africa. The southern continents of Pangaea were still mostly intact.

3. India moved toward the ancient Asian continent about 66 million years ago. Oceans widened, and much of the southern continents of Pangaea broke apart. The landmass positions appear much as they do today.

4. The world as you know it is presented here.

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**Figure 2 Fragmenting Landmass** These maps show the way scientists think Pangaea broke into pieces and drifted apart millions of years ago.

1. **255 Million Years Ago**

2. **152 Million Years Ago**

3. **66 Million Years Ago**

4. **Present-Day**
Evidence for Continental Drift

In order to support his continental drift hypothesis, Wegener collected data from different scientific fields. In 1915, he published this information in a book called *The Origin of Continents and Oceans*. In his book, Wegener presented four major types of evidence for his hypothesis. This evidence included the geographic fit of the continents, fossils, rocks and mountain ranges, and ancient climate records.

**Fit of the Continents**

The most obvious evidence for continental drift is the geographic fit of the continents. If you were to remove the present-day Atlantic Ocean, the continents would fit back together. The east coast of South America fits into the notch on the west coast of Africa. And, the bulge on northwest Africa fits into the space between North and South America. This is shown in **Figure 3**.

**Visual Check**

**Figure 3** List the continents on which *Glossopteris* lived during the time of Pangaea.

This geographic fit of the continents suggests ways to look for even more evidence for Pangaea. Imagine the continents pieced back together, like pieces of a puzzle. Some rock types and fossils are the same because the continents were connected at the time of Pangaea.
**Fossil Evidence**

Fossils are the remains, imprints, or traces of once-living organisms. If an organism dies and is buried in sediment, then it can become preserved in various ways. Eventually, the fossil becomes part of a sedimentary rock. Fossils help scientists learn about species from past times. Wegener collected fossil evidence to support his continental drift hypothesis. He wanted to learn where the plants and animals from the time of Pangaea lived.

**Glossopteris** One plant Wegener studied was *Glossopteris* (glahs AHP tur us), a seed fern. Fossils of this fern have been discovered in South America, Africa, India, Australia, and Antarctica. The heavy seeds could not have been blown by the wind, nor could they have floated, across the wide oceans separating these continents.

What is *Glossopteris*?

So, Wegener concluded that all those continents must have been attached when *Glossopteris* was alive. As shown in Figure 3, *Glossopteris* was not the only species that lived on several continents. Wegener used the present-day locations of these various fossils to support the idea that there was a supercontinent when the animals and plants were alive.
Figure 4 Connecting Landforms  Rock types and mountain ranges match up across the continents when they are arranged to form Pangaea.

Rock Types and Mountain Ranges

The locations of rock types and mountain ranges from the time of Pangaea also provide evidence for continental drift. Geologists can identify groups of rocks, much like you can match pieces of a puzzle. Wegener showed that certain types of rocks on the continents would match up if the continents were arranged to form Pangaea.

Rock Types  Wegener realized that the oldest rocks on the African and South American continents were next to each other when the continents were assembled as Pangaea. Figure 4 shows how the types of rocks match up across the Atlantic Ocean. Ancient rocks in North America, Greenland, and Europe also match up if you move the continents to form Pangaea.

Mountain Ranges  Some mountain ranges also look as if they were once connected. The Appalachian Mountains in eastern North America are similar to the mountains in Greenland, Great Britain, and Scandinavia. Figure 4 shows how they would look like a single, long mountain range.

List two locations with mountains similar to those of the Appalachian Mountains.
**Ancient Climate Evidence**

Wegener was a meteorologist. Meteorologists are scientists who study weather and climate. Wegener traveled the planet looking for rocks that contained evidence of past climates.

**Recording Climate** When sedimentary rocks form, clues about the climate are preserved within the rock. Hot, wet climates produce lots of plants. As plants die, they form coal deposits in the rocks. Tropical seas leave behind fossil reefs. Hot, dry climates produce rocks with preserved sand dunes. Glaciers form in cold climates, leaving ancient glacial formations. Rocks often indicate an ancient climate that is very different from the present-day climate.

**Changing Climate** Spitsbergen is currently located above the arctic circle, east of Greenland. Rocks that formed during the time of Pangaea show that this island once had a tropical climate. Wegener suggested that the island drifted from the warm tropics to its current arctic location. Wegener also found ancient rocks made by glaciers across Africa, India, and Australia. These places are now too warm to have glaciers. *Figure 5* shows evidence of ancient glaciers in South America, Africa, India, and Australia. The ancient climate evidence supports the existence of Pangaea.

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**Figure 5** *Ancient Glaciers* Some rocks located in warm climates today were deposited by glaciers about 300 million years ago. **Explain** why rocks formed in tropical climates in Spitsbergen suggest that this island has moved to its present-day location.
A Hypothesis Rejected

Wegener presented this evidence for continental drift to other scientists. Wegener had difficulty explaining how, when, or why the continents slowly drifted across Earth’s surface.

He proposed that the continents drifted by plowing through the seafloor. He thought the same forces of gravity that produced tides in the ocean had moved the continents.

What did Wegener think caused the continents to drift?

Wegener knew these forces were not very strong. But, he thought that over millions of years, they could cause the continents to drift. Most other scientists did not accept this explanation. Because these scientists could not think of any forces strong enough to make continents drift, Wegener’s hypothesis was rejected.

Why wasn’t continental drift accepted by the scientific community?

Alfred Wegener did not give up when his hypothesis was rejected. He continued to search for evidence to support his continental drift hypothesis.

Wegener died in 1930 with little recognition for his accomplishments. He disappeared in a storm while on an expedition studying the weather in Greenland. The controversy over his hypothesis remained for several decades after his death. He did not live long enough to see the new evidence that made scientists reconsider his controversial idea.

Scientists reconsidered Wegener’s controversial idea because of advances in technology, such as sonar and deep-sea drilling. These technological advances helped scientists develop new ideas and evidence that related to continental drift.
**Continental Drift Hypothesis**

Alfred Wegener thought that the edges of the continents looked like they fit together because they had once been attached as an entire landmass. Wegener’s continental drift hypothesis is the idea that the continents move very slowly across Earth’s surface. Wegener’s evidence included the geographic fit of the continents, fossils, rocks and mountain ranges, and ancient climate records.

Wegener presented this evidence for continental drift to other scientists. Scientists could not think of forces strong enough to make continents drift, so Wegener’s hypothesis was rejected.

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**LESSON 1 Review**

**Summarize**

Create your own lesson summary as you write a script for a television news report.

1. **Review** the text after the red main headings and write one sentence about each. These are the headlines of your broadcast.

2. **Review** the text and write 2–3 sentences about each blue subheading. These sentences should tell who, what, when, where, and why information about each red heading.

3. **Include** descriptive details in your report, such as names of reporters and local places and events.

4. **Present** your news report to other classmates alone or with a team.

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**Standards Check**

Using Vocabulary

Complete the sentences using the correct term.

Pangaea    continental drift

1. Mesosaurus is a fossil that supports the ______ hypothesis. 1.a

2. A supercontinent that existed about 200 million years ago is ______. 1.a

Understanding Main Ideas

3. Why is Glossopteris evidence for continental drift?
   A. Its leaves produced coal.
   B. It was exceptionally large.
   C. Its seeds were heavy.
   D. It was found only in Antarctica. 1.a

4. **Explain** how rocks can preserve a record of ancient climates. 1.a

5. **Decide** whether or not continental drift would have been accepted if Wegener had collected more evidence. 1.a

6. **Organize** Draw a diagram like the one below. List evidence for continental drift into two categories. 1.a

![Diagram]

Applying Science

7. **Imagine** a fossil organism that might indicate an ancient tropical reef deposit. 1.a

8. **Decide** whether scientists were justified in rejecting continental drift. 1.a

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Seafloor Spreading

(Main Idea) New discoveries led to seafloor spreading as an explanation for continental drift.

Real-World Reading Connection Do you know how to do a magic trick? When you first see a good trick, it seems impossible. Then, when you learn how the trick works, it doesn’t seem impossible any more. In the decades after continental drift was rejected, scientists discovered new technology that helped explain how continents could move.

Investigating the Seafloor

Wegener collected most of his evidence for continental drift at Earth’s surface. But, there is also evidence on the seafloor. Scientists began investigating the seafloor by collecting samples of rocks. They knew that most rocks on the seafloor are made of basalt. Recall from Chapter 2 that basalt is an igneous rock that is made of highly dense minerals such as olivine and magnetite.

Scientists wondered why rocks on the seafloor were so different from rocks on land. By the 1950s, new technologies were being developed to explore the seafloor. An example of this technology is shown in Figure 6.

Figure 6 The bottom of the ocean is complicated. In this colorized image of the seafloor off the central California coast, the coastline is outlined in white.

Determine whether features colored yellow are above or under water.
**Mapping the Seafloor**

During World War II, a new method was developed for mapping the seafloor. This new method used technology called sonar. **Figure 7** shows how sonar works. Scientists emit sound waves from a boat. The sound waves bounce off the seafloor. Then, a receiver records the time it takes for the waves to return. Because scientists know the speed of sound waves in water, they can use the data to calculate the depth of water. With this new technology, the topography of the seafloor was mapped.

**Mid-Ocean Ridges**

**Figure 8** shows what scientists discovered when they mapped the topography of the seafloor. Hidden under ocean waters are the longest mountain ranges on Earth. These mountain ranges, in the middle of the seafloor, are called **mid-ocean ridges**. The mountains wrap around Earth much like seams wrap around a baseball.

Maps of the seafloor made scientists want to learn even more about it. They studied temperatures on the seafloor. They discovered that there is more heat escaping from Earth at the mid-ocean ridges than at other locations in the oceans. The closer you move toward a mid-ocean ridge, the more heat flows from the mantle, as shown in **Figure 9**.

**Figure 7** Seafloor Mapping
Sonar uses sound waves bounced off the seafloor to measure ocean depths.

**Name** an animal that uses sound waves to navigate.

**Figure 8** Depth Changes
The light-blue color on the map shows locations with shallow water.

**Figure 9** The flow of heat from the mantle increases the closer you get to a mid-ocean ridge.
The Seafloor Moves

Harry Hess was an American geologist. He studied the seafloor, trying to understand how mid-ocean ridges were formed. He proposed it was hot beneath the mid-ocean ridges because lava erupted there and made new seafloor. Hess suggested a new hypothesis describing this process.

**Seafloor spreading** is the process by which new seafloor is continuously made at the mid-ocean ridges. Convection brings hot material in the mantle toward the surface, causing magma to form. The magma flows out as lava through cracks along the ridge. When the lava cools, it forms new seafloor. Then, the seafloor moves sideways, away from the center of the mid-ocean ridge.

Where does new seafloor form?

Seafloor spreading seemed to explain continental drift. **Figure 10** shows seafloor moving away from the mid-ocean ridge as new oceanic crust is formed. Notice how the seafloor becomes older as the distance from the mid-ocean ridge increases. Adding new seafloor makes the ocean wider. As a result, continents drift apart as the ocean grows. Scientists looked for evidence that could test the new seafloor spreading hypothesis. Studies of mid-ocean ridges continue today, as shown in **Figure 11**.

**Academic Vocabulary**

**hypothesis** (hi PAH thuh sus) (noun) a tentative explanation that can be tested with a scientific investigation

Michael made a hypothesis that he would have no cavities because he did a good job of brushing and flossing his teeth.

**Figure 10** Seafloor spreading forms new oceanic crust. The older oceanic crust moves away from the ridge as new oceanic crust forms.
**Figure 11**

Mid-ocean ridges are vast, underwater mountains that form the longest continuous mountain ranges on Earth. Earthquakes and volcanoes commonly occur along the ridges. An example of a mid-ocean ridge is the Mid-Atlantic Ridge. The Mid-Atlantic Ridge was formed when the North and South American Plates pulled apart from the Eurasian and African Plates.

New oceanic crust is formed as seafloor moves away from the mid-ocean ridge. The seafloor becomes older as the distance from the mid-ocean ridge increases.

Scientists have made many new discoveries on the seafloor. Hydrothermal vents, also known as black smokers, form along mid-ocean ridges. The “smoke” that rises from the hydrothermal vent is actually a hot fluid that is rich in metals.

Some species, such as these giant tube worms, live next to the hydrothermal vents. The heat and minerals allow them to survive without sunlight.

*Contributed by National Geographic*
Evidence for Spreading

New evidence connected the ages of seafloor rocks to how Earth’s magnetic field was oriented at those times.

Magnetic Polarity Reversals

Whenever you use a compass, the north-seeking end of the needle points to Earth’s magnetic north pole. But, Earth’s magnetic field has not always had the same orientation. Sometimes the magnetic poles reverse. If you happened to be living at a time after the magnetic poles switched, your compass needle would point south instead of north.

Orientation  The top diagram of Figure 12A shows the orientation of the magnetic field the way it is today. This is called normal. When it points in the opposite direction, it is called reversed. Scientists learned the ages of each of these reversals. They used this information to produce a magnetic time scale, which is like a calendar for part of Earth’s history.

Recording Reversals  Igneous rocks can record these reversals, as illustrated below in Figure 12B. This happens along a mid-ocean ridge as oceanic crust forms from lava and cools. Tiny crystals record the magnetic field orientation that existed when the crust cooled.
Magnetic Stripes on the Seafloor

As shown in Figure 13, scientists can measure Earth’s magnetic field with instruments called magnetometers. These instruments can travel over large areas of Earth’s surface by ship, plane, and satellite. As they move over the ocean, they measure the strength of the magnetic field. The oceanic crust makes a striped pattern when graphed because it contains alternating strips of rock with normal and reversed polarity.

These magnetic stripes are shown in Figure 12. Just as Hess hypothesized, the seafloor is youngest at the mid-ocean ridge. By measuring the distance of a stripe of rock from the mid-ocean ridge and determining its age, scientists can calculate the velocity of seafloor movement.

How is the velocity of seafloor movement calculated using magnetic polarity reversals?

The seafloor and continents move slowly, only centimeters per year. Learning about seafloor spreading was like learning how a magic trick is done. Scientists finally understood how the continents could move and accepted Wegener’s continental drift hypothesis.
Seafloor Drilling

Not long after scientists learned how to determine the age of the seafloor, they developed deep-sea drilling. They designed a boat that could drill and collect samples from the seafloor. This boat, named the Glomar Challenger, made its first voyage in 1968.

Scientists used drill pipes several kilometers long to cut through rock at the bottom of the sea and bring up samples. Figure 14 shows how the drill pipe extended all the way from the ship to the seafloor. The photo in Figure 14 shows how the drill bit, with diamonds glued in it, was attached to the bottom of the drill pipe. Recall from Chapter 2 that diamond is the hardest mineral. A diamond-tipped drill can cut through the hardest rock.

Why are diamonds used in drill bits?

The ages of the samples showed that the oldest rocks were farthest from the mid-ocean ridge. And, the youngest rocks are found in the center of the mid-ocean ridge. This seafloor drilling supported the seafloor-spreading hypothesis.
Seafloor Spreading Hypothesis

By the 1950s, new methods and technologies, such as sonar, were being developed to map and explore the seafloor. When scientists mapped the topography of the seafloor they discovered underwater mountain ranges known as mid-ocean ridges. Harry Hess studied the seafloor trying to understand how mid-ocean ridges were formed. He proposed the seafloor spreading hypothesis, which is the process by which new seafloor is continuously made at the mid-ocean ridges. New evidence from around the world showed that the seafloor was spreading, as Hess had thought. Seafloor spreading seemed to explain continental drift. Studies of mid-ocean ridges continue today.

LESSON 2 Review

Summarize
Create your own lesson summary as you organize an outline.
1. Scan the lesson. Find and list the first red main heading.
2. Review the text after the heading and list 2–3 details about the heading.
3. Find and list each blue subheading that follows the red main heading.
4. List 2–3 details, key terms, and definitions under each blue subheading.
5. Review additional red main headings and their supporting blue subheadings. List 2–3 details about each.

ELA6: R 2.4

Standards Check

Using Vocabulary
1. Use the terms mid-ocean ridge and seafloor spreading in the same sentence.
2. Write a definition for the term mid-ocean ridge in your own words.

Understanding Main Ideas
3. Sequence Draw a diagram like the one below. List the process of seafloor spreading beginning with convection bringing hot material in the mantle toward the surface.

4. Illustrate the symmetry of magnetic polarity stripes on the seafloor.

5. Assess how new data supported the seafloor spreading hypothesis.

Applying Science
6. Suggest what scientists’ reactions to the continental drift hypothesis might have been if data from the seafloor were available in the 1910s.

7. Interpret the high temperatures measured at mid-ocean ridges to formation of basalt at the ridges.

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How fast does seafloor spread?

Scientists use their knowledge of seafloor spreading and magnetic polarity reversals to estimate the rate of seafloor spreading.

**Data**

1. Study the magnetic polarity graph.
2. Place a ruler vertically on the graph so that it lines up with the center of peak 1 west of the Mid-Atlantic Ridge.
3. Determine and record the distance and age. Repeat this process for peak 1 east of the ridge.
4. Calculate the average distance and age for this pair of peaks.
5. Repeat steps 2 through 4 for the remaining pairs of normal polarity peaks.
6. Calculate the rate of movement for the six pairs of peaks. Use the formula rate = distance/time. Convert kilometers to centimeters. For example, to calculate a rate using normal polarity peak 5, west of the ridge:

   \[
   \text{rate} = \frac{125 \text{ km}}{10 \text{ million years}} = \frac{1,250,000 \text{ cm}}{1,000,000 \text{ years}} = 1.25 \text{ cm/year}
   \]

**Data Analysis**

1. Compare the age of igneous rock found near the ridge with that of igneous rock found farther away from the ridge.
2. Calculate how long ago a point on the coast of Africa, now 2,400 km away from the ridge, was at or near the Mid-Atlantic Ridge.

**Science Content Standards**

1. Students know evidence of plate tectonics is derived from the fit of the continents; the location of earthquakes, volcanoes, and mid-ocean ridges; and the distribution of fossils, rock types, and ancient climatic zones.
7. Interpret events by sequence and time from natural phenomena (e.g., the relative ages of rocks and intrusions).

MA6: AF 2.2, AF 2.3
Theory of Plate Tectonics

Main Idea Earth’s lithosphere is broken into large brittle pieces, which move as a result of forces acting on them.

Real-World Reading Connection The next time you eat a hard-boiled egg, hit it on the table. Even though the shell breaks up, it stays on the egg. Gently slide one of the broken pieces of shell along the surface of the egg. As the pieces move on top of the softer layer of egg, they bump into each other.

Earth’s Plates

Canadian geologist J. Tuzo Wilson first used the term plates to describe the large pieces of Earth’s crust that move horizontally. Much like the pieces of the broken eggshell, Wilson thought the plates were brittle and outlined by cracks. A model of Earth’s brittle crust is shown in Figure 15. The large brittle pieces of Earth’s outer shell are called lithospheric plates. Figure 16 shows scientists’ current mapping of Earth’s lithospheric plates.

Vocabulary
lithospheric plate
plate tectonics
ocean trench
slab
Global Positioning System (GPS)

Review Vocabulary
convection: heat transfer by the movement of matter from one place to another (p. 147)
Development of a Theory

The discoveries you have read about and many more were combined in a new theory. The theory of plate tectonics explains how lithospheric plates move and cause major geologic features and events on Earth’s surface. This theory includes ideas from continental drift and seafloor spreading.

What does the theory of plate tectonics explain?

Scientists from many countries developed the theory of plate tectonics. Figure 17 summarizes some important studies that contributed to the development of the theory of plate tectonics. Both successes and failures were valuable in developing the theory of plate tectonics. By the end of the 1960s, there was so much evidence supporting it that the theory gained acceptance by most scientists. Aspects of the theory are still being tested and modified today.
Boundaries of Lithospheric Plates

How can you tell where one lithospheric plate ends and another begins? Mid-ocean ridges show the boundaries of some lithospheric plates. Where would you go to find other boundaries of lithospheric plates?

You would need to find more evidence of forces in Earth such as earthquakes and volcanic eruptions. These geologic features and events occur where the edges of plates are pushed together, pulled apart, or scraped sideways past each other as they move.

Examine Figure 18 to find the locations of earthquakes and volcanic eruptions. Notice that they are not evenly distributed around the world. There are some places that have many earthquakes and volcanoes. There are other places that have almost none.

Figure 18 Identify five locations of earthquakes or active volcanoes in North America.

Thin lines of earthquakes and volcanic eruptions define the mid-ocean ridges. But, there are thick bands of both earthquakes and volcanoes in other places. Around the edges of the Pacific Ocean, there are some thick bands of earthquakes and volcanoes. These earthquakes and volcanoes are located near long, deep parts of the seafloor called ocean trenches. Seafloor that is formed at mid-ocean ridges is destroyed at ocean trenches.

**Academic Vocabulary**

**define** (de FINE) (verb) to fix or mark the limits of

*The surveyor defined the limits of the property before the house was sold.*
Types of Lithosphere

The word *lithosphere* is based on the Greek word *lithos*, which means “rock”—which is what makes up the lithosphere. In Chapter 2, you read that the lithosphere is made of both crust and the upper mantle. Recall that both the crust and the upper mantle are made of rigid and brittle rocks. They do not flow as much as the warmer, weaker rocks below them in the asthenosphere.

**Table 1** shows a slice through a lithospheric plate. Just like there are two different types of crust, there are two different types of lithosphere. These types of lithosphere, like the types of crust, are oceanic and continental.

What are the two types of lithosphere?

**Thickness** Table 1 shows that the thickness of a lithospheric plate varies. Oceanic lithosphere is much thinner than continental lithosphere. When oceanic lithosphere first forms near a mid-ocean ridge, it is about 10 km thick. As the oceanic lithosphere ages and cools after it forms at Earth’s surface, it thickens and becomes much denser.

**Composition** Thickness is not the only difference between oceanic and continental lithosphere. Their compositions also differ, as shown in **Table 1**. Oceanic lithosphere contains oceanic crust, which is made mainly of the dense igneous rocks basalt and gabbro. A relatively thin layer of sediment also occurs on oceanic lithosphere in many places.

In contrast, continental lithosphere contains the continental crust, which is made of igneous rocks such as granite and metamorphic rocks such as gneiss. It also has a covering of sedimentary rocks in many places. Most of the rocks in the continental lithosphere are less dense than the rocks in the oceanic lithosphere. You will read in the next chapter that this difference in density is important when lithospheric plates are pushed together.

**Visual Check** Table 1 Infer the density of peridotite using the data in Table 1.

Most of the major plates contain both oceanic and continental lithosphere. An example of this is the North American Plate. It contains both the continent of North America and much of the Atlantic Ocean. An exception is the Pacific Plate, which contains only oceanic lithosphere.
<table>
<thead>
<tr>
<th>Type of Lithosphere</th>
<th>Components</th>
<th>Common Rocks</th>
<th>Approximate Densities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceanic</td>
<td>oceanic crust</td>
<td>crust: basalt, gabbro</td>
<td>crust: 3.0 g/cm³</td>
</tr>
<tr>
<td></td>
<td>upper mantle</td>
<td>upper mantle: peridotite</td>
<td>mantle: 3.3 g/cm³</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continental</td>
<td>continental crust</td>
<td>crust: granite, gneiss, sedimentary</td>
<td>crust: 2.65 g/cm³</td>
</tr>
<tr>
<td></td>
<td>upper mantle</td>
<td>rocks</td>
<td>mantle: 3.3 g/cm³</td>
</tr>
</tbody>
</table>

**Interactive Table**: Organize information about the lithosphere at [ca6.mssscience.com](http://ca6.mssscience.com).
What controls plate movement?
In the past, scientists generally agreed that convection currents in Earth’s mantle control the movement of lithospheric plates. Convection currents, which you read about in Chapter 3, passively move the lithospheric plates above them. Today, scientists think that other forces might exist that control the movement of lithospheric plates.

Escaping Heat
Heat has been escaping from Earth since it first formed. One way heat is transferred from Earth’s deep interior to the surface is by convection. As a result, convection currents in the mantle provide matter and energy for the motion of the plates.

Internal Heat Source
In order for convection currents in the mantle to continue, a supply of internal heat is required in Earth. Temperature in Earth increases with increasing depth. One important source of internal heat is radioactive decay. Some elements, such as uranium and potassium, are radioactive. As radioactive elements decay, they produce heat, along with radiation, in rocks that contain them. The heat increases the temperature of the surrounding rock, causing its density to decrease. This causes movement of both rock and heat from inside Earth toward the surface.

Convection
You can’t see convection currents directly, but you can see convection in a pot of water, like the one in Figure 19. As a flame heats the water from the bottom of the pot, this water becomes warmer and less dense than the cooler water above. The warmer water moves upward and starts to circulate in the pot, forming convection currents.

Reading Check
Why does the density of the surrounding rock decrease?
Plate Movement and Convection

Some scientists hypothesize that convection currents in Earth’s mantle drive plate movement. The arrows in Figure 21 show the direction of flow for convection currents. In this model, the brittle lithospheric plates float on top of the weak asthenosphere. This happens in much the same way that a sheet of ice floats along on slowly moving water. Figure 21 also shows the cooler, denser lithospheric plate sinking down into the mantle. A plate that sinks back into the mantle is called a slab. The slab bends and breaks as it sinks down, causing earthquakes.

Density Changes  Along a mid-ocean ridge, less dense rock is brought near the surface and melts. At the surface, new oceanic lithosphere forms at the ridge. As the rock cools, it becomes denser. The new plate starts to move away from the ridge with the convection current.

What happens to the density of new oceanic lithosphere when it cools?

Historical Model  This model of convection currents in Earth’s mantle convinced scientists to accept the theory of plate tectonics. Convection is still thought to play a role in the movement of plates. Recent studies are making scientists consider new ideas about what makes plates move.
**Ridge Push and Slab Pull**

Some scientists think that ridge push and slab pull are two forces that might be important in controlling the movement of plates. These forces are related to the lithospheric plates themselves. *Figure 22* shows how these forces are thought to work.

A mid-ocean ridge is higher in elevation than most parts of the seafloor. The force of gravity tends to move things downhill. For example, if you stand on a skateboard, even on a very gentle slope, you will start to roll downhill. That is what scientists think happens to a lithospheric plate along a ridge. The force of gravity moves the plate downward and away from the ridge. This force is known as ridge push.

**Sinking Into the Mantle**  Slab pull occurs when a lithospheric plate sinks into the mantle. The slab is dense and cool as it sinks into the mantle, as shown in *Figure 22*. Again, the force of gravity acts on the plate. The denser slab acts like a sinker on a fishing line. A sinker will pull your line and hook down into the water where a fish might see it. In the same way, the dense slab pulls the plate deep into the mantle.

**Future Work**  Scientists are currently studying individual plates, mid-ocean ridges, slabs, and velocities of complex waves that travel through Earth. They hope to learn which forces are most effective in controlling how plates move. There is still much to discover about the dynamic Earth and plate tectonics.

*Figure 22* Ridge push and slab pull are forces that might move plates. Of the two, slab pull is thought to be the more important force.
Measuring Plate Movement

Since the 1960s, scientific studies have continued to strengthen the theory of plate tectonics. An example is the ability to directly measure plate movement. Originally, scientists had to estimate the velocities of the plates by using the ages of rocks. Now they use satellites.

Global Positioning System

Global Positioning System (GPS) is a network of satellites used to determine locations on Earth. A receiver on Earth collects radio signals from several satellites that circle the planet as shown in Figure 23. Then, a computer inside the receiver calculates the latitude, longitude, and elevation of the receiver’s location. Today, airplane pilots, sailors, people driving cars, and even hikers use GPS.

What is GPS?

Because GPS can be used to accurately measure distances, it can also be used to measure the movement of plates. Scientists have set up a group of receivers to monitor plate movement around the world.

Satellite Laser Ranging

GPS is not the only satellite system that is used to measure plate movement. Satellite laser ranging (SLR) uses pulses of light instead of radio waves to measure distances. These pulses of light are laser beams, as shown in Figure 24.

Rates of Plate Movement

Using satellite data from these methods, scientists have estimated the rates at which lithospheric plates move. The measurements made using GPS and SLR show similar results. The plates are moving only centimeters per year. This is about as fast as your fingernails grow.
Plate Tectonics and the Rock Cycle

Reading about plate tectonics makes it easier to understand how the rock cycle works. Figure 25 shows the rock cycle from Chapter 2. Imagine where you might find magma, sediment, and the three rock types in a plate tectonic setting.

**Figure 25** Explain why magma is shown at the bottom of the rock cycle.

Rocks are always moving through the rock cycle. Magma will rise up to Earth’s surface to become igneous rock at a mid-ocean ridge. A plate will slowly move away from the ridge and cool. It will carry the igneous rock with it. Eventually the plate will sink into the mantle.

While some rocks erode on mountaintops, others form on the seafloor. Earth’s lithospheric plates move slowly, but they have millions of years to travel long distances and get where they are going. As plates move, they recycle material by keeping it moving through the rock cycle.
Plate Movements

Earth’s outer shell is broken into large, brittle pieces called lithospheric plates. The thickness and composition of a lithospheric plate varies. The thickness and composition depends upon whether the plate is made of oceanic or continental material. Forces in Earth, such as earthquakes and volcanoes, occur along the boundaries of the lithospheric plates.

The theory of plate tectonics explains how lithospheric plates move and cause major geologic features and events on Earth’s surface. Some scientists hypothesize that convection currents in Earth’s mantle drive the movement of plates. And, some scientists think that ridge push and slab pull are two forces that control the movement of plates.
How can you observe convection in water?

Convection in Earth’s mantle is difficult to model and cannot be seen directly. However, you can observe movement of convection currents in water.

**Procedure**

1. Read and complete a lab safety form.
2. Pour water into a clear, colorless casserole dish until the water level is about 5 cm from the top of the dish.
3. Center the dish on a hot plate and heat it.
4. Add a few drops of food coloring to the water above the center of the hot plate.
5. Looking in from one side of the dish, observe what happens in the water.
6. Illustrate your observations by making a labeled sketch.

**Analysis**

1. **Determine** whether any currents form in the water. Support your answer with the illustration from step 6.
2. **Infer** what caused the water to behave the way it did.
3. **Infer** why convection in Earth’s interior is important.

**Science Content Standards**

- 4.c Students know heat from Earth’s interior reaches the surface primarily through convection.
- 7.e Recognize whether evidence is consistent with a proposed explanation.
Percentage of Minerals in Rocks in the Lithosphere

The five major rocks in Earth’s oceanic and continental lithosphere are basalt, diorite, gneiss gabbro, granite, and peridotite. The table shows the composition of each type of rock.

Example

How does the percentage of amphibole in basalt differ from the percentage of amphibole in gabbro?

What you know:
- The percentage of amphibole in basalt: 45%
- The percentage of amphibole in gabbro: 15%

What you need to find:
- The difference in the percentages

Subtract:
45 – 15 = 30%

Answer: There is 30% more amphibole in basalt than in gabbro.

<table>
<thead>
<tr>
<th>Rock</th>
<th>Mineral</th>
<th>Composition %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basalt</td>
<td>amphibole</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>calcium feldspar</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>olivine</td>
<td>15</td>
</tr>
<tr>
<td>Diorite</td>
<td>sodium feldspar</td>
<td>50</td>
</tr>
<tr>
<td>Gneiss</td>
<td>amphibole</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>biotite</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>orthoclase feldspar</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>quartz</td>
<td>10</td>
</tr>
<tr>
<td>Gabbro</td>
<td>pyroxene</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>olivine</td>
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</tr>
<tr>
<td></td>
<td>amphibole</td>
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<td></td>
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<td>sodium feldspar</td>
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<td>Peridotite</td>
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<td>25</td>
</tr>
<tr>
<td></td>
<td>calcium feldspar</td>
<td>5</td>
</tr>
</tbody>
</table>

Practice Problems

1. How much more calcium feldspar is found in basalt than gabbro?
2. How much more quartz is found in granite than diorite gneiss?

For more math practice, visit ca6.msscience.com.
Use the Internet: Inferring Plate Tectonic Activity

**Problem**
The movement of lithospheric plates causes forces that build up energy in rocks. Some of this energy is released as earthquakes. Earthquakes occur every day. Many are too small to be felt by humans, but each event tells scientists something more about Earth. Can you infer plate tectonic activity by plotting locations of recent earthquakes on a world map?

**Form a Hypothesis**
Think about how earthquakes define the boundaries of lithospheric plates. There are some places that have many earthquakes, and other places that have almost none. Make a hypothesis about whether the locations of earthquakes can be used to infer plate tectonic activity.

**Collect Data and Make Observations**
1. Make a data table like the one shown below.
2. Visit ca6.msscience.com to collect and record data for earthquake locations from the last two weeks.
3. Plot the locations on a copy of a map of the world. This map should include lines of latitude and longitude to guide your plotting.

<table>
<thead>
<tr>
<th>Locations of Earthquakes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location Description</strong></td>
</tr>
<tr>
<td>_________________________</td>
</tr>
<tr>
<td>_________________________</td>
</tr>
<tr>
<td>_________________________</td>
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<tr>
<td>_________________________</td>
</tr>
<tr>
<td>_________________________</td>
</tr>
</tbody>
</table>

**Science Content Standards**

1c Students know lithospheric plates the size of continents and oceans move at rates of centimeters per year in response to movements in the mantle.

7a Develop a hypothesis.

7e Recognize whether evidence is consistent with a proposed explanation.
Analyze and Conclude

1. **Infer** where plate tectonic activity occurs on Earth today.
2. **Compare and contrast** the active plate tectonic areas to the plate boundary map shown below.
3. **Identify** lithospheric plates that are represented by the earthquake locations you plotted.
4. **Explain** how data from a longer period of time might help you better identify plate tectonic activity.

Communicate

**WRITING in Science**

**ELA6: W 1.2**

*Write a Paragraph* Select one of the earthquakes you plotted. Research the details of the event, including the geography of the area near the earthquake, and whether the lives of humans or other organisms were impacted by the event.
**Paleontologists Validate Wegener in Dinosaur Cove**

Fossil remains unearthed by paleontologists in Dinosaur Cove are all that remain of dinosaurs that lived in southeastern Australia 100 million years ago. Paleontologists believe these “polar dinosaurs” had keen night vision and were warm-blooded. This allowed them to find food in the dark and below-freezing temperatures. The discovery provides convincing evidence of Australia’s northward movement toward the equator during the past 100 million years.

**What’s your opinion?** Do you think studying fossils in Dinosaur Cove is important to understanding life on Earth today? Prepare an oral argument describing your opinion.

---

**Defining Plate Boundaries**

The boundary between the Eurasian and North American Plates passes through Eastern Siberia, where seismic detection equipment and people are scarce. Researchers from Columbia University, Massachusetts Institute of Technology, the University of California, and the Russian Academy of Sciences collaborated to pinpoint the boundary. Using GPS, the team monitored 50 points in the region over six years and defined the boundary.

**Analyze the Map** Compare a plate boundary map to a regional map. Identify features in Russia that are near the boundary.
Behind a Revolutionary Theory

Historians agree that Alfred Wegener was not alone in considering Earth as a shifting, dynamic world. In 1858, 57 years before Wegener published *The Origin of Continents and Oceans*, French scientist Antonio Snider-Pellegrini made maps illustrating how the American and African continents may once have fit together, and then moved apart. Pellegrini supported his hypothesis with evidence from identical plant fossils in Europe and the United States.

Creating a Continental Drift Time Line
Visit History at [ca6.msscience.com](http://ca6.msscience.com) to research the contributions of Wegener and other scientists. Create a time line illustrating key individuals and events.

HOLE 504B

Off the west coast of South America, scientists study Earth through the deepest hole ever drilled into the oceanic crust. Hole 504B bores into the Costa Rica Rift, the zone along which the Cocos and Nazca Plates are pulling apart. First drilled in 1979, the hole is now 2,111 m deep, exposing 6 million years of oceanic crust. Scientists at the drilling site investigate oceanic crust properties at various depths, including thermal conductivity, density, and velocity. Hole 504B is a unique underwater laboratory that allows scientists to study how oceanic crust forms and evolves over time.

Visit Society at [ca6.msscience.com](http://ca6.msscience.com) to learn about the history of the Integrated Ocean Drilling Program. Use the information you gather to write a brief paper discussing key events in the history of deep ocean drilling.
Plate tectonics explains the formation of many of Earth’s features and geologic events.

### Lesson 1 Continental Drift

**Main Idea** Despite the evidence that supported continental drift, it was rejected by most scientists.

- The continental drift hypothesis states that the continents move slowly across Earth’s surface.
- The fit of the continents, fossils, rock types, mountain ranges, and ancient climate evidence support Pangaea’s existence.
- Continental drift was rejected by some scientists because Wegener could not explain what forces move continents.

- continental drift (p. 167)
- Pangaea (p. 167)

### Lesson 2 Seafloor Spreading

**Main Idea** New discoveries led to seafloor spreading as an explanation for continental drift.

- Sonar allowed scientists to map the topography of the seafloor.
- Mid-ocean ridges, the longest mountain ranges on Earth, were found to be regions of high heat flow.
- Harry Hess proposed the seafloor spreading hypothesis, a process by which new seafloor is continuously formed at mid-ocean ridges.
- Magnetic polarity reversals supply data for approximating the ages of rocks on the seafloor.
- Seafloor drilling confirmed the increasing age of the seafloor with distance from mid-ocean ridges.

- mid-ocean ridge (p. 175)
- seafloor spreading (p. 176)

### Lesson 3 Theory of Plate Tectonics

**Main Idea** Earth’s lithosphere is broken into large, brittle pieces, which move as a result of forces acting on them.

- Earth’s surface is covered by the brittle lithosphere, which is broken into numerous large plates.
- The locations of earthquakes, volcanoes, and mid-ocean ridges help define the boundaries of plates.
- Plates can be composed of either thin oceanic crust, thick continental crust, or both.
- Scientists use satellites to directly measure the speed and directions of plate movement.

- Global Positioning System (GPS) (p. 191)
- lithospheric plate (p. 183)
- ocean trench (p. 185)
- plate tectonics (p. 184)
- slab (p. 189)

Download quizzes, key terms, and flash cards from ca6.msscience.com.
Linking Vocabulary and Main Ideas

Use vocabulary terms from page 200 to complete this concept map.

Plates Tectonics

a theory that developed from

Wegener's hypothesis

involves movement of

Hess's hypothesis

involves evidence from underwater ranges

continental drift

involve evidence for the breakup of

movements measured directly by

some sink back into the mantle as

slabs which bend to form

mid-ocean ridges

Using Vocabulary

Fill in each blank with the correct vocabulary term.

When scientists discovered __________ 6., which are mountain ranges in the middle of the seafloor, they finally had found a way for __________ 7. to have broken apart. This process, by which continents could separate and drift apart as new seafloor forms, is __________ 8. It was an important discovery that led to the rapid development of the theory of __________ 9.
Understanding Main Ideas

Choose the word or phrase that best answers the question.

1. Which evidence did Alfred Wegener propose to support his continental drift hypothesis?
   A. ancient climate belts
   B. seafloor spreading
   C. ancient drift scars on the seafloor
   D. fish fossils  

2. Why was Wegener’s hypothesis rejected?
   A. He collected too little evidence.
   B. He could not find fossils from the time of Pangaea.
   C. He did not publish his ideas.
   D. He could not explain what forces could move the continents.

3. Which modern technology is used to directly measure plate movement?
   A. ATV
   B. GPS
   C. MTV
   D. sonar

4. The illustration below shows the distribution of some fossils among southern continents of Pangaea.

What are the life-forms shown in the picture?
   A. modern land-based animals
   B. fossil sea creatures
   C. fossil land-based species
   D. ancient life-forms migrating to Asia

5. The illustration below shows an area where new seafloor is forming.

What do the stripes of rock represent?
   A. changes in rock composition
   B. changes of rock type
   C. changes in magnetic polarity orientation
   D. changes in ocean-water depth

6. Who developed the theory of plate tectonics?
   A. Alfred Wegener
   B. American scientists
   C. Harry Hess
   D. scientists from many countries

7. Which of these is used to map seafloor topography?
   A. magnetic seafloor stripes
   B. sonar
   C. GPS
   D. scuba divers

8. Which is NOT a major difference between oceanic and continental lithosphere?
   A. density
   B. composition
   C. thickness
   D. rigid, or brittle, behavior

9. At what rate do lithospheric plates move?
   A. centimeters per year
   B. centimeters per week
   C. kilometers per year
   D. kilometers per week
Applying Science

10. **Suggest** a reason that explains why there is no continental drift on the Moon.  

11. **Decide** which was more important in advancing the acceptance of the theory of plate tectonics: GPS or seafloor spreading.

12. **Give** an example of something that, like lithospheric plates, moves so slowly you cannot see it move.

13. **Compare and contrast** the locations of volcanoes with the locations of ocean trenches.

14. **Describe** how heat from Earth’s interior reaches the surface.

15. **Identify** the continental lithosphere and oceanic crust in the illustration below.

16. **Write** a paragraph summarizing the theory of plate tectonics, including features on the seafloor that provide evidence for the locations of plate boundaries.  

**WRITING in Science**

Cumulative Review

17. **Evaluate** the usefulness of a road map that has no scale.

18. **List** seven minerals that are valuable resources.

19. **Infer** why you can keep cooler on a sunny day if you sit under a tree or an umbrella.

Applying Math

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<td>25</td>
</tr>
<tr>
<td></td>
<td>Calcium feldspar</td>
<td>5</td>
</tr>
</tbody>
</table>

20. How much more amphibole is found in basalt than in gabbro?  

21. How much more calcium feldspar is found in basalt than in peridotite?  

22. How much more calcium feldspar is found in gabbro than in peridotite?  

23. How much more olivine is found in gabbro than in basalt?
1. Which is believed to cause plate movement?
   A. compression
   B. convection
   C. isostasy
   D. tension

2. Which hypothesis states that continents slowly moved to their present-day positions on Earth?
   A. subduction
   B. erosion
   C. continental drift
   D. seafloor spreading

3. The illustration below shows an ancient supercontinent.
   What is the name of the ancient supercontinent?
   A. Pangaea
   B. Gondwanaland
   C. Laurasia
   D. North America

4. Who developed the continental drift hypothesis?
   A. Harry Hess
   B. J. Tuzo Wilson
   C. Alfred Wegener
   D. W. Jason Morgan

5. Which term includes Earth’s crust and part of the upper mantle?
   A. asthenosphere
   B. lithospheric plate
   C. lower mantle
   D. core

6. About how fast do plates move per year in response to movements in the mantle?
   A. a few millimeters per year
   B. a few centimeters per year
   C. a few meters per year
   D. a few kilometers per year

7. This diagram shows magnetic polarity.
   What happens to Earth’s magnetic field over time?
   A. It continually strengthens.
   B. It changes its polarity.
   C. It stays the same.
   D. It weakens and goes away.
8 Which feature is evidence that many continents were at one time near Earth’s south pole?
A glacial deposits
B earthquakes
C volcanoes
D mid-ocean ridges

9 What evidence in rocks supports the seafloor spreading hypothesis?
A plate movement
B magnetic reversals
C subduction
D convergence

10 Alfred Wegener described continental drift in 1912. Why weren’t Wegener’s ideas accepted by scientists until the 1950s?
A Wegener was not respected because he was not a geologist.
B The fossil evidence of the time did not support Wegener’s ideas.
C The continents Wegener proposed do not actually fit together well.
D Wegener could not explain how or why the continents moved.

11 What is the main cause of convection currents in Earth’s mantle?
A Energy from the Sun heats the upper part of the mantle more than the lower part.
B Earthquakes produce cracks in Earth’s crust, allowing hot, plasticlike rock to rise up from the mantle.
C Heat released by volcanoes melts rock at the surface, and the molten rock sinks through cracks in the mantle.
D Warmer, less dense rock rises toward the surface and cooler, denser rock sinks back toward the core.

12 The graph shows how seafloor depth changes with age.

How does seafloor depth change with age?
A depth decreases
B depth increases
C depth remains the same
D depth varies

13 Which observation best supports the continental drift hypothesis?
A Blue whales can be found in every ocean on Earth.
B Limestone often contains fossils of animals that lived in the sea.
C Some mammal species in Australia are found nowhere else on Earth.
D Fossils of the same species of land lizard are found on continents separated by an ocean.

14 What theory states that plates move around on the asthenosphere?
A continental drift
B seafloor spreading
C subduction
D plate tectonics