

Chapter 11: Plate Tectonics

	Instructional Sequence	Learning Goals	Activities and Resources	National Standards
Section 11.1: Pangaea Three 45-minute class periods	<ol style="list-style-type: none"> 1. Complete Chapter 11 Pretest. 2. Complete Investigation 11A: Plate Tectonics. 3. Read Section 11.1, pp. 246 to 247 and complete Section Review on page 248. 	<ul style="list-style-type: none"> • Explain the concept of continental drift. • Define Pangaea. • Describe the evidence that supports continental drift theory. 	<p>Laboratory Investigation 11A: Plate Tectonics</p> <p>Teacher’s Resource CD:</p> <ul style="list-style-type: none"> • Chapter 11 Pretest • Skill and Practice: Alfred Wegener Biography <p>Teaching Illustrations CD:</p> <ul style="list-style-type: none"> • Evidence for Continental Drift 	ES.D.1.02 INQ.1.2 INQ.1.3
Section 11.2: Sea-Floor Spreading Three 45-minute class periods	<ol style="list-style-type: none"> 1. Complete Investigation 11B: Evidence for Plate Tectonics. 2. Read Section 11.2, pp. 249 to 253 and complete Section Review on page 254. 	<ul style="list-style-type: none"> • Describe the sea-floor spreading hypothesis. • Explain the moving pieces of the lithosphere. • Recognize examples of subduction. 	<p>Laboratory Investigation 11B: Evidence for Plate Tectonics</p> <p>Teacher’s Resource CD:</p> <ul style="list-style-type: none"> • Skill and Practice: Harry Hess Biography <p>Teaching Illustrations CD:</p> <ul style="list-style-type: none"> • Sea-floor Spreading, Magnetic Reversal Patterns, Mantle Convection 	ES.D.1.02 ES.D.1.03 ES.D.1.04 ES.D.1.11 ES.D.2.1 ES.D.2.2 INQ.1.2 INQ.1.7
Section 11.3: Plate Boundaries One 45-minute class periods	<ol style="list-style-type: none"> 1. Read Section 11.3, pp. 255 to 262 and complete Section Review on page 263. 2. Complete Chapter Assessment, pp. 267 to 268. 	<ul style="list-style-type: none"> • Identify the three types of plate boundaries. • Compare and contrast the features of the three types of plate boundaries. • Distinguish between oceanic and continental plates. 	<p>Connection: Where to Go for Volcanoes</p> <p>Chapter Activity: Make a Plate Tectonics Book</p> <p>Chapter Project: Sea-floor Spreading Model</p> <p>Teacher’s Resource CD:</p> <ul style="list-style-type: none"> • Graphic Organizer: Plate Boundaries • Skill and Practice: John Tuzo Wilson Biography, Earth’s Largest Plates <p>Teaching Illustrations CD:</p> <p>Plate Boundaries, Divergent Boundaries, Convergent Boundary, Formation of the Himalaya Mountains, Transform Fault Boundary</p>	ES.D.1.02 ES.D.1.03 INQ.1.3 INQ.1.4 INQ.1.7

Language Tools	Differentiated Strategies	Materials
<p>Literary Picks</p> <p>Vocabulary: continental drift, Pangaea, plate tectonics</p> <p>Word Origins: Pangaea, tectonic</p>	<p>ELL Strategies: Listed in the ELL Ancillary</p> <p>Learning Strategies:</p> <ul style="list-style-type: none"> • Paired Learning - Motivate: Pieces of the Puzzle • Cooperative Learning - Investigation 11A • Demonstration - Explain: Potato Pangaea Demonstration • Active Learning Active Research - Extend <p>Teaching Tip: Using earthquake and volcano data to find plate boundaries, Exploring on your own</p>	<p>Investigation 11A: bathymetric map, colored pencils, pencil</p> <p>Explain: large baking potato, knife, permanent marker</p> <p>Motivate: laminated colored map of a state, marker, scissors, a large envelop</p>
<p>Vocabulary: mid-ocean ridges, sea-floor spreading, lithospheric plates, oceanic plates, continental plates, subduction, mantle plume</p> <p>Word origins: subduction</p> <p>RAFT Strategy: Paleomagnetism</p>	<p>Learning Strategies:</p> <ul style="list-style-type: none"> • Discussion - Motivate: Tracking the Movements • Cooperative Learning - Investigation 11B • Active Learning - Explain: Paleomagnetism • Active Research and Learning - Extend <p>Teaching Tip: Continental Movement, The Deep Sea-Floor, Magnetic Patterns</p>	<p>Investigation 11B: bathymetric map, fossil data, scissors, tape, construction paper, pencil</p>
<p>Vocabulary: divergent boundary, convergent boundary, transform fault boundary, deep-ocean trench</p> <p>Word Origins: divergent, convergent</p> <p>Closure Cards</p>	<p>Learning Strategies:</p> <ul style="list-style-type: none"> • Discussion - Motivate: Earth's Size • Think-Pair-Share - Explore: Movement of Plates • Demonstration - Explain: Demonstrating Convection Current • Active Research and Learning: Extend <p>Teaching Tip: Predictions and Plate Tectonics, Convection Currents in Earth's Mantle</p>	<p>Explain: Bunsen burner, 2,000-mL glass beaker, box of pasta pieces (large couscous beads work well)</p> <p>Chapter Activity: different types of paper like copier paper, construction paper, or newsprint, stapler and staples, glue, colored pencils, markers, pens, scissors, old magazines</p> <p>Chapter Project: shoe box lid, piece of copy paper, red and black markers, scissors</p>

11.1 Pangaea

About the Lesson

In this lesson, students learn about Alfred Wegener and his concept of continental drift and the idea that a supercontinent called Pangaea once existed on Earth. Students also explore the development of the theory of plate tectonics.

Motivate

Pieces of the Puzzle

Introduce students to the idea of viewing Earth as a puzzle. Obtain a laminated, colored map of your state that shows coastline and mountain regions. Using a marker, divide the map into 20 equal regions. Each region will represent an individual puzzle. Cut each region into oddly shaped puzzle pieces and place them in an envelope. Pair students together and have them assemble their region of the map. Ask students to create a list of clues they used to solve the puzzle.

Explore

Students begin Investigation 11A before reading section 11.1. This investigation introduces students to plate tectonics. It is important to review how to read a bathymetric map before starting the investigation. The skill sheet *Bathymetric Maps* is useful for helping students learn how to read and interpret a bathymetric map.

INVESTIGATION 11A: PLATE TECTONICS

Setup	Materials	Vocabulary
1. This investigation may span several days. You may choose to eliminate certain parts of the investigation if time is a factor or prolong certain aspects until you are ready to discuss specific topics in chapter 11. 2. Students work in small groups.	<ul style="list-style-type: none">bathymetric mapcolored pencilspencil	plate tectonics plate boundary divergent convergent mid-ocean ridge subduction lithosphere

Literary Picks...

Reading Level	Title
3-5	<i>The Island That Moved</i> by Meredith Hopper Hopper is a veteran scientist and children's author that has traveled along the Antarctic Peninsula. She has created an imaginary island along this peninsula in order to provide a vivid introduction to plate tectonics. Includes information on the Earth's interior, continental drift, and Pangaea.
6-8	<i>Pioneers of Geology: Discovering Earth's Secrets</i> by Margaret Carruthers and Susan Clinton These authors have produced an overview of who's who in geology arranged in chronological order. A brief biography of each scientist and their studies, theories and discoveries are discussed. Includes James Hutton, Alfred Wegener, Harry Hess, G.K. Gilbert, and Gene Shoemaker.
9-12	<i>Plate Tectonics</i> by Kay Jackson This book provides an in-depth look at plate tectonics including the modern tragedies and ancient forces. Chapter content includes continental drift, the unified theory of plate tectonics, plate tectonics today, plate tectonics and people, and plate tectonics and the future.

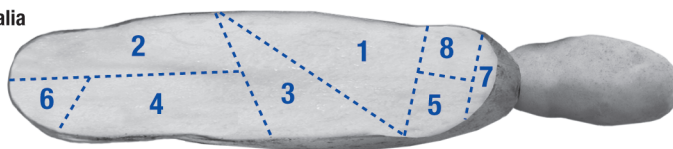
Explain

Potato Pangaea Demonstration

Cut a large baking potato in half, lengthwise. Then cut the potato into eight pieces as shown below. Using a permanent marker, write the landmass number on the skin part of the potato. Separate the skin from the flesh of the potato using a sharp knife. The goal is to have the skin intact for each numbered landmass. Mix up the pieces and place them skin side up on a flat surface. Have a volunteer assemble skin pieces back to the original potato shape. Discuss these questions:

- Why do the potato skin pieces not line up and fit together?
- What do the numbers represent?

- | | |
|------------------|--------------|
| 1. Africa | 7. Australia |
| 2. Eurasia | 8. India |
| 3. South America | |
| 4. North America | |
| 5. Antarctica | |
| 6. Greenland | |



Students should understand the potato is round like Earth, but when the skin is laid flat it covers a greater area due to large gaps between the pieces at the edges. This demonstration illustrates the distortion that occurs with flat maps versus globes. The numbers represent landmasses. Even numbers are the northern hemisphere, and odd numbers represent mostly the southern hemisphere.

Extend

1. Have students use the Internet to observe animations of the breakup of Pangaea and continental drift. Entering a search such as “Pangaea animation” should yield many helpful resources. One particularly great resource is available through the USGS. Learn more by visiting <http://wrgis.wr.usgs.gov/parks/animate/>.
2. Instruct students to create a timeline for the development of the plate tectonic theory.

Assess

Students complete section 11.1 review questions.

Background Information...

Alfred Wegener

Wegener described his theory about the existence of a supercontinent in *The Origin of Continents and Oceans* (1915). Unfortunately, Wegener lived during a time when little to no evidence existed to support his theory. It took decades for scientists to gather enough evidence to assess his beliefs. Currently, evidence suggests there may have been several supercontinents. For example, scientists believe that Rodinia existed before Pangaea. Rodinia is known as the oldest supercontinent and is believed to have formed about one billion years ago. Scientists also hypothesize that Rodinia’s break up lead to the formation of eight continents. Those eight continents then reassembled to form the supercontinent known as Pannotia, which eventually became Pangaea.

This is a great time to emphasize the nature of science and how ideas and theories are continually challenged, tested, and amended. The results of repeated experiments may lead to acceptance or rejection of a theory. Student’s should recognize that a theory must be supported with evidence before the scientific community will accept it.

Word Origins . . .

Pangaea (from Greek meaning “all land” or “all Earth”)

Ask students to think about the literal meaning of Pangaea. Is it appropriate? Have students explain their reasoning.

Tectonic (from Greek *tecton* meaning “builder”)

Plate tectonics explains that Earth’s surface is made up of moving plates. As plates move, they may slide past one another, spread apart, or collide. As students to think about how the movement of plates is a “building process.” What are some examples?

Investigation 11A: Plate Tectonics

1 Setting up

Have students look at their bathymetric maps.

There are three important features that we need to identify on your map. The first is called a mid-ocean ridge. It is a continuous chain of mountains located on the ocean floor. These mountain chains have a deep central valley.

Write the term on the board and its meaning. Allow students time to find an example on the map. Note: a rise is like a mid-ocean ridge.

Next, we will locate deep ocean trenches. These are the deepest part of the ocean floor. Write the name of your example in Table 1. Now find an example of a mountain range.

Students locate examples of each feature. Point out to students that the mountain ranges are the white areas on the continents.

The lithosphere is made up of plates that “float” on top of the asthenosphere. These plates move in a number of ways. For example, they may move toward each other, away from one another, or they may slide past each other. The theory that describes how these plates move and interact is called plate tectonics.

Students note definition.

The place where plates meet is called a plate boundary. We will discuss two types of plate boundaries. The first is called a convergent boundary. Converge means to come together, so when plates move toward one another they form a convergent boundary.

Sketch this on the board.

The second type of boundary is called divergent. What do you think divergent means?

Divergent means move away from or move apart.

Very good answer. When plates move apart from one another, a divergent boundary is formed. Most divergent boundaries are located along the ocean floor. Look at each of the features you selected for Table 1. Which kind of boundary to you think is associated with each feature?

Model the movement of plates to help students infer the correct boundary types. Have students draw arrows showing how the plates move relative to each other at these boundaries. Guide students through the steps to finding plate boundaries (part two). Then read aloud the step for using earthquake activity to find plate boundaries. A brief review of latitude and longitude may be needed at this point. Additional support is also located in the Teaching Tip on the next page.

At deep ocean trenches a specific type of convergent boundary is formed. It is known as a subduction boundary. What do you think subduction means?

Steer students toward understanding that sub- means underneath or below. Subduction occurs when an oceanic plate is drawn beneath another plate. Use this time to talk about the composition of the lithospheric plate.

11A Plate Tectonics

What is plate tectonics?

Earth's crust plus the upper mantle forms the **lithosphere**. Earth's lithosphere is broken in a number of different pieces. How these pieces move and interact is what plate tectonics is all about. In this investigation, you will be an Earth detective and identify lithospheric plates using geologic evidence.

Materials

- Bathymetric map
- Colored pencils
- Pencil

1 Setting up

Part 1: Reading a bathymetric map

1. Examine your map. A bathymetric map shows what land looks like under a body of water like the ocean.
2. Find examples of the following features on your bathymetric map: mid-ocean ridges, deep ocean trenches, and mountain ranges. List one example of each from your map in the second column of Table 1.
3. In the third column of Table 1, list which type of plate boundary, convergent or divergent, is associated with each feature.
4. In the fourth column, there are small diagrams showing two plates and the boundary between these. Draw arrows showing how the plates move relative to each other at these boundaries.

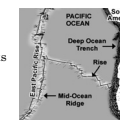


Table 1: Features on a bathymetric map

Features	Examples from the map	Kind of plate boundary (convergent or divergent?)	How do the plates at this boundary move?		
mid-ocean ridge			<table border="1"> <tr> <td>Plate 1</td> <td>Plate 2</td> </tr> </table>	Plate 1	Plate 2
Plate 1	Plate 2				
rise			<table border="1"> <tr> <td>Plate 1</td> <td>Plate 2</td> </tr> </table>	Plate 1	Plate 2
Plate 1	Plate 2				
deep ocean trench			<table border="1"> <tr> <td>Plate 1</td> <td>Plate 2</td> </tr> </table>	Plate 1	Plate 2
Plate 1	Plate 2				

Part 2: Starting to find plate boundaries.

1. Earth has seven to ten large pieces and many small plates. To keep things simple on your map, you will identify seven large plates.
2. Keep in mind that mid-ocean ridges, deep ocean trenches, and mountain ranges are all geologic features that are formed at tectonic plate boundaries.

2 Stop and think

Take a moment to examine what you have done thus far. Share with your classmates as you answer these questions.

Students discuss each question with group members. Then lead a class discussion to clarify any misconceptions. If you choose to do this investigation over several days, this is a good stopping point.

3 Doing the experiment

Now that you have come up with a hypothesis of where the seven major tectonic plates are located, I will help you to distinguish the actual location of these plates.

Hand out the actual locations of these plates. You can use overhead transparencies or a cutout or outline which students can place over their maps.

When you have the actual location of the major tectonic plates, use your colored pencils to shade in each plate. Use a different color for each plate. Also, write the name of each plate.

Students complete the experiment.

4 Thinking about what you observed

Lead a discussion to help students answer these questions. Review the characteristics of each type of plate boundary.

Teaching Tip . . .**Using earthquake and volcano data to find plate boundaries**

North and east are plus; south and west are minus. Set up the bathymetric map this way: Use a pencil to divide the map east-west at 180° and 0° . Divide the map north-south at the equator. The quadrant that contains Europe, northern Africa, and Asia has a positive number for latitude and a positive number for longitude (+,+). The quadrant containing southern Africa and Australia would be (-, +). The quadrant containing North America would be (+, -) and the quadrant containing South America would be (-, -).

As students finish plotting earthquake or volcano data they may struggle with the fact that many of the lines representing the plate boundaries do not connect. Ask them if real-world scientists always have all the evidence when conducting their research. Encourage them to infer the best way the lines would likely connect on their map.

Prepare a completed map or an overhead of a completed map that has the plate boundaries with the names of the tectonic plates. Have students use this to assist them in drawing the location of the actual plate boundaries.

Teaching Tip . . .**Exploring on your own (part 5)**

Have students figure out the directions that the plates will move (they can refer to the graphic on page 262 of the student text). Have them keep the African Plate stationary. Move the other plates 1.5 cm in the direction of the arrow on each of the other plates. This distance is based on a rate of 2.5 cm/year for 50 million years.

11.2 Sea-floor Spreading

About the Lesson

In this lesson students learn about sea-floor spreading and how it has helped to provide evidence for the theory of plate tectonics. They also explore how fossils are used to reconstruct Earth's landmasses as they may have appeared millions of years ago.

Motivate

Tracking the Movements

Ask students, "Are the continents moving today?" Basically you can not feel any movement under your feet or hear any noise that might indicate movement. Nor can you see any movement with your eyes. Explain to students that scientists have come up with a method to measure continental movement. See Teaching Tip (Continental Movement) for additional discussion information.

Explore

Students complete Investigation 11B before reading section 11.2 of the student text. In this investigation students discover how fossils are useful evidence for understanding the past and continental drift.

INVESTIGATION 11B: EVIDENCE FOR PLATE TECTONICS

Setup	Materials	Vocabulary
<ol style="list-style-type: none">1. Allow one class period for students to complete investigation.2. Students work in groups of three to five.	<ul style="list-style-type: none">• bathymetric map• fossil data (included in investigation)• scissors• tape• piece of construction paper• pencil	<p>fossils continental drift</p>

Teaching Tip . . .

Continental Movement

Using two different locations on two continents, scientists use a mirror on a satellite in space to send reflected laser beams to each of the locations. The laser beams travel to each location, and the time can easily be calculated knowing the fixed location on Earth.

A comparison study can be done over a period of time to track the movement of the two continents. Discuss the following scenario:

North America and Greenland are moving away from each other at a yearly rate of 3 centimeters per year (1.2 inches per year). In 2099, how much further apart will these two locations be?

Background Information...

The Geologic Time Scale

Many scientists believe adequate evidence exists to explain the changes in Earth and its living organisms over time. A considerable amount of this evidence is found in rocks.

One geologist, James Hutton, suggested that natural forces, like earthquakes, volcanoes, and weather events greatly affected the land. Since these events happened slowly, Hutton believed that Earth was much older than earlier thinkers had suggested. In the early 1830s, Charles Lyell built upon Hutton's work and concluded that many details of Earth's history could be inferred by observing present-day events. As scientists studied fossils embedded in layers of rock, they were able to employ relative dating techniques to predict Earth's age.

Explain

Paleomagnetism

Paleomagnetism is the study of Earth’s past magnetic field. It has been an important piece in the plate tectonic puzzle. The igneous rock basalt contains the mineral magnetite. Basalt is a melted rock that cools quickly and crystallizes. Its iron-rich minerals like magnetite align to the North Pole. A history of the magnetic poles is created in this way.

Scientists have discovered striped patterns of the magnetic mineral found in basalt in lava flows of different ages. It is important to note that Earth has reversed its poles many times in the past. This is called magnetic reversal and it results in a period of time where the north and south poles are reversed. Rock records along the mid-ocean ridges have provided evidence of these reversals. How does this relate to continental drift? Wegener’s idea could not prove that the continents are indeed moving. However, these paleomagnetic studies have provided evidence that the crust and the lithosphere are in motion. In order to help clarify this concept have students complete a RAFT writing assignment based on the following criteria:

Role	writer and illustrator
Audience	science teacher and students
Format	illustration with a two paragraph explanation
Topic	Choose from one of the following to illustrate and explain: magnetic alignment of rocks, Earth’s magnetic field, paleomagnetism, magnetic pole reversal, magnetic patterns, or forming mid-ocean ridges

Extend

1. Have students research Robert Dietz and his contributions to sea-floor spreading.
2. In 1968 the *Glomar Challenger*, a research vessel, set out to collect core rock samples from the ocean floor. Ask students to create a timeline of the vessel’s mission and findings.

Assess

Students complete section 11.2 review questions.

Teaching Tip . . .

The Deep Sea-Floor

The Deep Sea-Floor by Sneed B. Collard is a quick, but informative read (only 29 pages long) which provides a brief introduction into oceanic geology—complete with diagrams of Earth’s crust and ocean ridges created by hot magma. Obtain a copy of the book to share with your students.

Word Origins . . .

Subduction (from Latin *subducere* meaning “to draw up”)

Subduction involves the sinking of lithospheric plates into the mantle. Ask students to think about what must happen in order for something to sink. Steer students toward understanding that one object or material must be “drawn up” in order for another to sink.

Teaching Tip . . .

Magnetic Patterns

Like a giant magnet, Earth has a magnetic north and south pole. Scientists believe Earth’s magnetism is due to convection currents in the liquid outer core. These currents generate a magnetic field around Earth.

Over geologic time, the magnetic polarity of Earth has switched. Scientist believe the poles switch because of a magnetic interaction between the planet’s inner and outer core. Eventually, the interaction diminishes the magnetic field to a point that encourages the poles to reverse. This reversal recharges the magnetic field. The last time Earth’s polarity switched was about 780,000 years ago. Rocks on Earth act as a record of these switching events.

Investigation 11B: Evidence for Plate Tectonics

Fossils tell stories. As scientists study fossil remains, they are able to piece together valuable clues which help them to understand the history of life on Earth. Fossils are the remains or evidence of living organisms. They come in different forms including casts, molds, imprints, amber, and ice. Fossils are useful in understanding how organisms have evolved over time and also offer insight as to the appearance of continents millions of years ago. In today's investigation, you will use several fossils to reconstruct how Earth's landmasses may have appeared approximately 250 million years ago.

1 Setting up

You can see there are seven fossil types shown in part one. Let's name each fossil and identify where each is located.

Say the name of each fossil type aloud and where it is located. It is a good idea to review the basic principles of bathymetric maps before starting the set up.

Go through the list of locations for each fossil in part one. Then write the letter of each fossil onto the correct location on your map.

Students label the map.

2 Stop and think

Now let's look at your map. Did you have any fossils which were found on Antarctica?

Students note the fossils, *Lystroraurus* and *Labyrinthodont*, are located on Antarctica.

Do you think this is a strange location for these fossils to have been found? Why or why not?

Students share opinions. Considering Antarctica's current location (South Pole), temperatures, and climate, students may not expect to find reptiles like these on Antarctica.

Work with your group members to answer the remaining questions.

Students work together to answer questions. Discuss answers to each question before moving on to part three. Students may not get all of the correct answers at this point. The emphasis here is on getting students to infer that the continents have not always been in the positions students are familiar with. They will discover more as the investigation continues.

3 Doing the experiment

Cut out the landforms from your map. Each landform represents a continent.

Students cut out the landforms from the map. Remind students to be careful when handling the scissors.

Now place each continent onto your piece of construction paper. Use the shape of each continent's coastline and the locations where each type of fossil has been found to reconstruct the continents. Your goal is to form a "supercontinent."

Students work together to create the large continent.

11B Evidence for Plate Tectonics

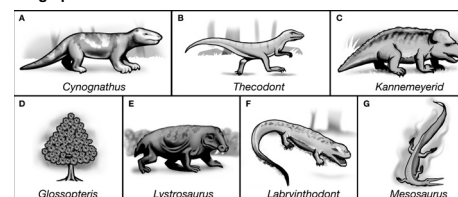
How are fossils useful evidence for continental drift?

Fossils are the remains or evidence of living organisms. Fossils come in different forms, including casts, molds, imprints, amber, and ice. Scientists can learn a great deal about life and the history of Earth using fossils. Fossils are useful evidence for understanding how organisms have evolved over time. They are also used to see how life has changed throughout Earth's history. Fossils have also been used to help scientists understand how the continents appeared millions of years ago. In this investigation, you will use several fossils to try to reconstruct how Earth's landmasses may have appeared approximately 250 million years ago.

Materials

- Bathymetric map
- Fossil data (included in investigation)
- Scissors
- Tape
- A piece of construction paper
- Pen or pencil

Setting up



Fossil Name	Locations found
A	South America, Africa, India, Australia, Antarctica
B	South America, Africa, India, Australia, Antarctica
C	South America, Africa, India, Australia, Antarctica
D	South America, Africa, India, Australia, Antarctica
E	Antarctica
F	Antarctica
G	South America, Africa, India, Australia, Antarctica

1. Using the table above with the locations each fossil has been found, write the letter of each fossil onto the correct locations onto your bathymetric map. Note: the locations given in the table are only approximate locations.

Once you are satisfied with your supercontinent, tape the continents to your construction paper in the same way they were arranged in step three.

Observe how students have arranged the continents. Assist as needed.

How can you explain the arrangement of your supercontinent? How were the fossil locations helpful to you?

Allow students to share their methods for creating the supercontinent. Use students' answers to help them infer that fossils provide evidence for continental drift.

4 Thinking about what you observed

Glossopteris is an extinct type of plant referred to as a seed fern. These plants are more probable to thrive in tropical climates. Look at all the places where this type of fossil was found. Are any of them strange to you?

Each of these locations is probable for *Glossopteris*.

Notice the locations where *Thecodont* fossils were found. Consider the current locations of Europe and North America. Do you think *Thecodont* traveled from Europe to North America (and vice versa)? How might you explain the presence of these types of fossils in both locations?

If the continents were connected at one time, *Thecodont* could have roamed across the land. When the supercontinent broke apart, fossil remains were likely to be found in both locations.

What does the location of *Cynognathus* fossils tell you about South America and Africa?

These continents were connected. Students may also observe that the two continents seem to fit together nicely along the coastlines.

Find Australia on your new map. What observations can you make about Australia?

On the new map Australia is connected to the central part of Africa. This location justifies the presence of *Glossopteris* and *Labyrinthodont* fossils in both locations.

Think about all that you have learned thus far. What other evidence might be useful for connecting the continents together into one giant landmass?

Students may offer a variety of responses. A sample response may include examining the rocks found on each continent for similarities with other continents. Encourage discussion among students.

5 Exploring on your own

Pick two of the organisms from the fossil list you used in this investigation. Use your school library or the Internet to find out more about this organism. Then write a one paragraph summary of what you learned. Be sure to include facts about the organism such as when it lived, what it ate, how it behaved, its size, and habitat. You should also include a sketch.

This is a great library day activity. Talk with the media specialist to arrange a time for your class to visit the school library. Provide the media specialist with background information about the topics students have learned in this unit. In this way, he or she can pull materials for your students in advance. Display students sketches and paragraphs throughout the classroom.

11.3 Plate Boundaries

About the Lesson

In this lesson, students will learn how the movement at the boundaries of lithospheric plates affect Earth's surface. Students will compare and contrast divergent, convergent, and transform boundaries.

Motivate

Earth's Size

Ask students if they know why Earth does not grow bigger if new crust is created at mid-ocean ridges. Diagram and explain that Earth does not get bigger because crust is consumed where two plates come together. New crust is formed where plates move apart. This is where old, dense crust sinks and melts into the mantle. The balance between creating new crust and melting away of old crust also explains the increasing size of the Atlantic Ocean and the decreasing size of the Pacific Ocean.

Explore

Movement of Plates

Using the Think-Pair-Share strategy, have students research and explain one of the following types of plate movement:

1. In a divergent boundary area, the plates pull back away from each other and may cause sea-floor spreading. Sea-floor spreading occurs in areas where hot, molten rock from deep inside Earth rises upward to Earth's surface. For example, this occurs along the Mid-Atlantic Ridge located under the Atlantic Ocean. The Mid-Atlantic Ridge separates the North American Plate from the Eurasian Plate.
2. In a convergent boundary area, the plates move towards each other. One plate may move under while the other plate stays on top—this is a subduction zone. Mountain ranges such as the Himalayas, located between landmasses of India and China, are the result of a convergent boundary between two continental plates that are coming together (colliding).
3. In a transform boundary area, two plates are locked into place with each plate trying to move in the opposite direction. The most well known example of this is the San Andreas Fault. It covers over 1,000 miles from northern to western California, and beneath the waters of the Gulf of California. The Pacific Plate is located to the west of the fault line, and the North American Plate is on the east.

Teaching Tip . . .

Predictions and Plate Tectonics

It is difficult for students to comprehend the magnitude of time when speaking about Earth's crust being billions of years old; or when scientists predict events that will occur millions of years in the future.

Some scientists have used the theory of plate tectonics to hypothesize that Southern California is moving north towards Alaska. In fact, they predict it will occur in about 150 million years. They also predict that the Pacific Ocean will shrink in comparison to the expanding Atlantic Ocean.

Over a long period of time, the Mediterranean Sea will possibly disappear causing Africa to be completely connected to Europe. Other interesting predictions include the northern movement and eventual connection between the cities of Los Angeles and San Francisco. Of course, these events are still millions of years in the future.

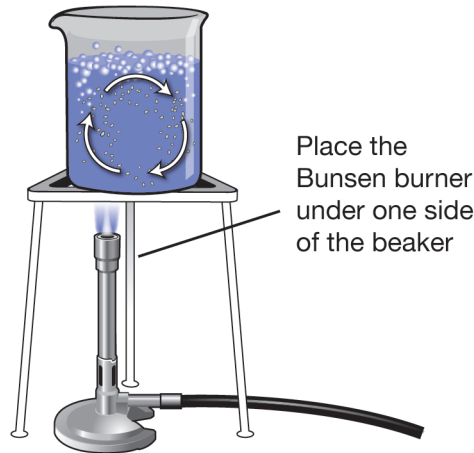
NASA scientists have studied continental drift for years through projects such as LAGEOS I and II, which are managed by Goddard Space Flight Center in Maryland. Additional information can be obtained through the Educators Resource Center for grades five through eight. Visit <http://www.nasa.gov/audience/foreducators/5-8/features/index.html> to learn more. Additional sites to search are NASA Spacelink and NASA CORE.

Explain

Demonstrating Convection Currents

Prior to the demonstration, obtain a Bunsen burner and a 2,000-mL beaker filled with about 1,400 mL of water. Heat the water to a rapid boil. Show students a box of pasta pieces (a box of large couscous grains works well). Then ask, “Can you predict what will happen when the pasta is added to the boiling water?” Pour a small amount of the pasta into the boiling water and ask the students to observe what happens. The effect will be noticeable once the pasta has been in the beaker for a few minutes.

Students learned about convection in previous chapters, and should be readily able to explain what they observe. Students should notice that the heated water rose and carried the pasta pieces upward. As the heated water moved away from the heat source, it cooled just enough to sink back to the bottom, carrying the pieces downward. As the water continues to circulate, a current of pasta becomes visible.



Extend

1. Have students research the three types of convergent boundaries; oceanic-continental boundaries (volcanic range and trench—Andes Mountains, Peru-Chile Trench), continental-continental boundaries (Himalaya Mountains), oceanic-oceanic boundaries (trench and volcanoes, Mariana Trench, Mariana Island Arcs).
2. Pair students together and have them write a song or poem about the three types of plate boundaries and their characteristics.

Assess

Students complete section 11.3 review section.

Teaching Tip . . .

Convection Currents in Earth's Mantle

Convection cells in Earth's lower mantle drive the lithospheric plates on the surface. Here we see the effect of heat on materials. The rocks of the lower mantle are not brittle like the rocks of the lithosphere. They are hot enough so that they flow very slowly. Earth's core heats the rock material of the lower mantle. As it is heated, it expands and becomes less dense.

The lower mantle rock material rises toward Earth's surface as a hot rising plume. This rising mantle plume may divide the lithosphere above and form a mid-ocean ridge. The pieces of separated lithospheric plate will move away from each other on either side of the new mid-ocean ridge.

Steps of convection in the mantle (see Figure 11.6 of the student text): mantle material is heated by the core, mantle material expands and rises as a convection current, the lithospheric plate rides on the moving mantle material, and eventually the mantle material cools, sinks, and gets recycled in the mantle.

Word Origins . . .

Divergent, Convergent (from Latin *vergere* meaning “to bend or turn”)

Both terms, divergent and convergent share the same root origin. The terms are distinguished by the prefixes *di-* and *con-*. Plates pull or “bend” apart at a divergent boundary; while they come together or “turn toward one another” at a convergent boundary.