

Lesson 4 - A Deeper Look at Plate Movement

Overview

The Theory of Plate Tectonics includes scientific evidence that the Earth's continents were once joined as a supercontinent called *Pangaea* (pronounced pan-JEE-ah). Students explore each piece of evidence and learn how and why the plates moved and continue to move on Earth today.

This helps students to understand the reasons why plates cause various boundary types as explained in the prior lessons. Understanding movement also sheds light on the reason why Earth's crust is renewed at divergent boundaries and destroyed at convergent boundaries.

Students investigate beneath the surface of the Earth to identify Earth's layers and how heat from convection in the Earth drives plate movement. Students conclude the lesson by making predictions about how Earth's geography will change due to plate movements and underlying convection cells.

TIME: 2 CLASS PERIODS

Students will:

- **Engage** by piecing together Earth's continents.
- **Explore** by considering evidence for the Theory of Plate Tectonics.
- **Explain** by identifying Earth's interior layers.
- Elaborate by relating the movement of plates to heat from within the Earth.
- Evaluate by predicting how Earth's geography will change in the future.

Content Background

What is Pangaea?

Scientists believe that approximately 200 million years ago, all of the continents were joined together in a giant land mass, or supercontinent, called **Pangaea**.

Africa



Over millions of years, Pangaea slowly broke apart into smaller pieces, and the plates of the Earth moved and pushed the continents into their current locations. The **Theory of Continental Drift** explains how and why the Earth's plates move and will continue to move.

What are the six main pieces of evidence that Pangaea existed?

1. The *coastlines* of the continents look like pieces of a giant puzzle that were once connected and could still fit together.

2. Scientists have identified the same types of *plant and animal fossils* along coastlines of different continents. Since these plants and animals travel across an ocean, scientists believe they were once living next to each other on continents that were once touching, such as Africa and South America.

3. Scientists have discovered that the same kinds of *rock layers* can be found on the continents of South America, Africa, India, Antarctica and Australia. They believe this exists because the rock layers formed when the continents were touching each other, before Pangaea broke apart.

4. There is evidence that ice sheets, or **glaciers**, existed 200 million years ago on parts of South America, southern Africa, India (part of Asia) and southern Australia. Each of these areas has matching marks, called striations, left by these moving glaciers. These striations are evidence that the glaciers moved from Africa toward the Atlantic Ocean and onto South America. If the Atlantic Ocean were as wide as it is today, that glacial movement could not have happened. The *striations* suggest that all the current continents were connected, as Pangaea, long ago.

South America

5. Scientists have discovered *fossils of tropical plants* in Antarctica. This is evidence that the continent of Antarctica used to be located closer to the equator than it is now. Other continents were also closer to the equator 200 million years ago, therefore other areas do not show evidence of ice.

6. Scientists collect evidence of current plate movement with the help of *satellites*.





What are the layers of Earth?

Approximately 4.6 billion years ago, there was a huge explosion of gas and matter in Space which caused material to condense and form giant balls that circled our Sun. Over time, these giant balls of gas and matter cooled and became the planets of our Solar System, including Earth. As the Earth cooled, a solid crust formed around the outside. The material beneath the solid crust separated into different layers in response to the force of gravity on different types of matter. The result was the formation of four major layers of the Earth: crust, mantle, outer core and inner core.

<u>The Crust:</u> The top layer of the Earth is the crust. The crust includes the solid material that makes up the continents and the ocean floor. The crust is thin, cool and made of solid rock.

<u>The Mantle</u>: Beneath the crust is soft putty-like material reacting to the high temperature and pressure that make up Earth's next layer: the **mantle**. In the upper part of the mantle, the asthenosphere, rocks melt into **magma**. Sometimes the heat and pressure of the mantle force some magma up onto the surface of the Earth. When the magma is on the surface of Earth, we call it **lava**.

<u>The Outer and Inner Core</u>: Beneath the mantle is the Earth's **core**, the hottest layer of Earth. Unlike the crust and mantle, the core is not made of rock, but iron and nickel. The core is divided into two separate layers because of physical differences. The **outer core** is liquid metal, and the **inner core** is solid metal. The intense heat from the core is what causes the rocks in the mantle to soften.

The lithosphere is the name we use to describe the solid part of the Earth. The lithosphere is made up of the crust and the upper-most part of the mantle, the asthenosphere. The rocks in the asthenosphere are so hot they begin to melt into magma.

What causes the plates to move?

It is the heat from inside the Earth that drives plate movement. The interior of the Earth is extremely hot. In addition to heat left over from Earth's formation, heat is released from the breakdown of the **radioactive decay** of rocks and minerals within the Earth. Heat from Earth's inner and outer core rises toward the surface and causes liquid rock in the mantle to move with it. Hot and light liquid rock moves upward and cool, heavy rock sinks downward. This circular movement within the mantle is called **convection**. As material in the mantle moves in these convection currents or cells, it pushes against the plates floating on the mantle and forces the plates to move as well.



Convection inside the Earth is very similar to hot water boiling in a pot on a stove. The hot water in the pot rises to the top and then cools. It spreads out to the sides and then sinks to the bottom of the pot to be reheated. Of course, convection occurs much faster in a pot of boiling water than it does inside the Earth.

It is the convection cells in the upper part of the mantle that drive the renewal of Earth's crust. At convergent boundaries where one plate is subducting below another, the crust is destroyed due to the tremendous heat and pressure. At the



same time, convection currents are pushing plates apart in a different location. At divergent boundaries, magma from the asthenosphere pushes into the crust and to the surface where it becomes lava. The lava hardens into brand new crust.

The idea that the plates are moving due to convection cells in the mantle is known as the **Theory of Plate Tectonics**.

Interior Earth and Pangaea

Millions of years ago, convection currents, which cause Earth's plates to move, broke up the supercontinent, Pangaea, into the separate continents we have today. Our continents are continuing to move, riding on the underlying convection cells, and scientists are monitoring their movement. While most plates are only moving a few centimeters a year, some move more quickly than others.

Misconception Alert:

Students have difficulty understanding that Earth has changed a lot throughout its history. They also commonly think that changes on Earth happen abruptly rather than over long periods of time, particularly geologic time. The activities and animations related to the supercontinent of Pangaea and how the continents have moved throughout our planet's history are meant to challenge these naïve conceptions.

Heat energy is another tough concept for students. When learning about convection, students often believe that the heat itself is a 'thing' that moves. Be sure to stress to students that the molecules of rock, air, and water themselves are affected by the heat and literally moving within the convection current.





Aim:

How and why do the Earth's plates move?

Materials Needed:

- Puzzles
- Scissors
- Tape or glue

Engage

• Distribute puzzles and scissors to students.

Instructions:

1. Cut out the puzzle pieces.

2. Separate the large shapes from the small pictures. Set the small pictures aside. You will use them shortly.

3. Fit the large shape together as best you can.

<u>Ask:</u>



What do the puzzle pieces look like?

Students may identify them as continents. If not, direct them to this answer.

<u>Say:</u>

"Let's label the seven continents appropriately."

North America, South America, Europe, Asia, Africa, Australia, Antarctica.

<u>Say:</u>

"Have you ever noticed that the continents seem to 'fit' together? Well, scientists have noticed that as well, and they have developed an explanation of what they think has happened with the continents throughout history."

Objectives:

Students will be able to:

- ✓ Model and describe the supercontinent Pangaea.
- ✓ Discuss the evidence supporting the Theory of Plate Tectonics.
- Explain that heat energy from the Earth's interior drives plate movement.
- ✓ Identify the layers of the Earth and how they relate to plate movement.







Explore

Vatch the *3D Continental Drift Animation* with students.



- Launch the 3D-VIEW menu by double-clicking on the desktop icon.
- Click on: Lithosphere.
- Click on: Lesson 4 A Deeper Look At Plate Movement.
- Click on the *3D Continental Drift Animation*.



3D Continental Drift Animation





<u>Ask:</u>



What do you see happening in this animation?

The continents are moving apart.

◊ Read the following with your students:





TRASSIC 200 million years ago



JURASSIC 135 million years ago



CRETACEOUS 65 million years ago



PRESENT DAY

• Students should answer the question below independently.

1. Describe the changes you see in these diagrams and in the animation.

The supercontinent of Pangaea broke apart. The continents moved until they formed the ones that we know today, in their current locations.



The first piece of evidence was demonstrated by fitting the continents together. You will use your puzzle to continue to identify evidence for the **Theory of Continental Drift**. In science, an idea only becomes a **theory** when there are lots of scientific evidence and data to support it.

Students should work in pairs for this activity and to answer questions 2 and 3.

Student Lab

Continue using the puzzle from the **Engage** section. Use the small pictures that you set aside earlier to complete the rest of the activity.

Each picture represents a different piece of evidence for the Theory of Continental Drift. The shapes of the continents fitting together are the <u>first</u> piece of evidence.

Read and follow the instructions in the following steps.

Answer Key:

North Am

Scientists identified the same fossils along coastlines of matching continents, such as Africa and South America. It is unlikely that these organisms could have traveled across the Atlantic Ocean as wide as it is today.

A. Place the fossil pictures on the appropriate continents to demonstrate where the fossils were found.

Scientists discovered that the same rock layers exist on South America, Africa, India, Antarctica and Australia. They believe that the rock formed before the continents broke apart.

B. Use the pictures of rocks to demonstrate how layers span the continents.

There is evidence that 200 million years ago, there were large ice sheets on South America, southern Africa, India (part of Asia) and southern Australia. Parts of each of these continents have matching marks, called striations. Striations were made by moving glaciers.

The marks show that at one time, a glacier moved from Africa onto South America. This made scientists believe that the Atlantic Ocean did not always separate these two continents.



Student Lab

Unit 1: Lithosphere

C. Show the locations of striations on your puzzle pieces of Africa and South America.

Scientists discovered fossils of tropical plants in Antarctica. This shows that Antarctica used to be located closer to the equator. Northern continents were also closer to the equator 200 million years ago. Therefore they do not show evidence of ice during that time period.

D. Place the tropical plant pictures on the correct continent.

In recent years, NASA scientists have begun to collect data about plate movement using satellite technology. You may recall that human-made satellites orbit the Earth in a polar or geostationary path to collect data.



LAGEOS satellite measures Earth's crustal movement Credit: NASA



Satellite Laser Ranging Credit: NASA

Satellites collect data by sending signals in the form of laser beams from Earth to the satellite (LAGEOS) and back again. There are Earth-based signal stations located on the continents of North America, South America, Eurasia and Australia. The time it takes for the laser beam to travel to the satellite and back to Earth is recorded and used to measure movement of Earth's plates.

E. Place the picture of a satellite on the continents with Earth-based signal stations.

2. What are the six pieces of evidence for the Theory of Continental Drift?

- -The continents fit together like puzzle pieces.
- -Fossils of animals found on different continents.
- -Similar rock layers on different continents.
- -Striations left from glacial movement.
- -Fossils of same plant types found on different continents.
- -Satellite technology collects data about plate movement.



3. Which piece of evidence proves that the plates are moving by using advanced instruments. How do these instruments work?

Satellites are advanced instruments that orbit the Earth and collect data. A signal is sent between the satellite and a station on Earth. The time it takes for the signal to be received shows the distance between the station and the satellite. By recording this distance over time, scientists can study plate movement.

Explain

Say:

"Let's learn more about our home planet as we discuss why scientists believe that the continents move."

Read the following information as a class.

All of the evidence above supports why scientists believe that the continents move and were at one time joined as Pangaea. However, there is more to the story. Scientists also investigate how the plates moved from their positions in Pangaea to their positions today. Therefore, scientists knew that the continents were moving, but, of course, wanted to know why. They began to make observations and collect lots of data. Eventually, scientists developed an explanation that the continents are sitting on big pieces of crust called tectonic plates. They call this explanation the **Theory of Plate Tectonics**.

In Lesson 3 - Investigating Plate Tectonics you learned about the evidence for plates and plate boundaries. The evidence includes all of the earthquake and volcanic activity that you observed occurring in predictable patterns along plate boundaries.

Why do the plates move?

In order to answer this question, we need to investigate inside the Earth, the planet's interior. The interior includes layers of material that came together as the Earth formed. Scientists believe that over 4.6 billion years ago, there was a huge explosion of gas and matter in Space. Over time, large balls of gas and matter collected together to form planets that circled the Sun. Planet Earth formed as gas and its matter cooled. A layer of solid matter or a crust formed around the outside of the ball. Lighter, or less dense, matter stayed at the outside of the ball and formed the crust while more dense matter moved toward the center. Four main layers formed as the Earth cooled and its matter separated. Each layer has unique properties. Let's investigate the characteristics of each layer of the Earth.



Crust. This outermost layer of the Earth includes soil, sand and rocks, deep rocks. The crust is very thin and brittle, like peanut brittle, when compared to the other layers of Earth. It is about 70 kilometers (~40 miles) thick all around the World. All of the land and oceans lie on top of the crust.

Unit 1: Lithosphere

Mantle. Just below the crust, temperatures are so extremely hot that the rocks are soft like putty. This is another thin layer called the *asthenosphere*. From this point and deeper the layer of Earth below the crust is called the **mantle**. It is the thickest layer of Earth, about 2,800 kilometers (~1,700 miles). This distance is about the same as the distance from New York City to Denver, Colorado. This trip takes almost four hours on an airplane! The range of temperature in the hot mantle is from 870-3,700 °C (1,600-6,700 °F). The mantle is made up of melted rock.



Melted rock, called magma, moves toward the surface of the Earth because of the high temperatures and pressure in the mantle. At the crust, gases that have been trapped with plate movement cause volcanoes to erupt! When magma reaches the surface of the Earth, it is then called lava.

Outer core and Inner core. Beneath the mantle and through to the center of the Earth is the **core**. The core is divided into two different layers. The **outer core** is hotter than the mantle and made up of the liquid metals: iron and nickel. Its thickness is about 2,200 kilometers (\sim 1,400 miles). At the center of the Earth is a solid dense ball of iron and nickel, called the **inner core**. It is the hottest layer at about 7,200 °C (13,000 °F). Weight from all of the layers above the inner core put extreme pressure on the core, causing it to remain solid even at very hot temperatures. The inner core is about 1,300 kilometers (\sim 800 miles) thick.

Teacher Tip: Make certain that students understand that what comes out of volcanoes comes from the **mantle**.

Teacher Tip: Give students concrete examples of how far the given distances are. For example: 70 kilometers (~40 miles) is as far as it is from our school to where? Students should answer the following questions individually or in pairs.

4. On which of Earth's layers do we live?

The crust.

Unit 1: Lithosphere

5. How do the inner and outer core differ?

The inner core is solid iron and nickel. The outer core is liquid iron and nickel. The inner core is the hotter layer.

6. Describe the connection between the mantle and volcanoes.

The mantle is made up of melted rock, called magma. Heat and pressure from the mantle move upward and are released when volcanoes erupt. This upward movement forces magma to rise and explode or flow from volcanoes.

7. Compare lava and magma.

Lava is liquid rock at the surface of the Earth and magma is the same rock beneath the surface.

Teacher Tip: The process where materials and substances in the Earth, such as rocks, minerals, etc., break down and release heat is known as radioactive decay. The heat released from radioactive decay keeps molten rock in the mantle moving.

Elaborate

Read the following information as a class:

Movement within the layers

The inside of the Earth remains extremely hot even after billions of years of cooling. Its heat comes from matter inside the Earth that breaks down over time and releases energy in the form of heat. Heat slowly rises from deep within the Earth toward the surface in circular patterns. This is very similar to hot water boiling in a pot on a stove where the source of heat is the stove. Water closest to the flame becomes hot and rises to the surface. The hot water spreads out to the sides and then sinks again to be reheated.



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Say:

"The same thing happens beneath the surface of the Earth. Let's watch how it happens."

Vatch the *3D Convection* animation with students.





- Launch the 3D-VIEW menu by
- double-clicking on the desktop icon.
- Click on: Lithosphere.
- Click on: Lesson 4 A Deeper Look At Plate Movement.
- 3D-VIEW
- Click on the *3D Convection Animation*.

<u>Ask:</u>



What do you see happening in this animation?

There are circular convection currents in the mantle. The plates 'ride' on the convection currents. There is magma coming up to the surface where the plates move apart from one another.

<u>Say:</u>

"Let's read about what we just saw in the 3D Animation."

Inside the Earth, the source of the heat is the extremely hot core. This heat from the interior rises toward the surface of the Earth. It causes liquid rock in the mantle to move with it. Hot and less dense liquid rock moves upward. Cool heavy rock sinks downward. This circular movement of matter is known as **convection**. Convection occurs within the liquid rock of the lithosphere's mantle. In other Project 3D-VIEW units, we will see convection with *air in the atmosphere* and *water in the hydrosphere*.



3D Convection Animation

Scientists believe that convection in the mantle is the reason why the crustal plates move. The plates 'ride' on convection currents. The plate motions, of course, result in volcanoes, earthquakes, and mountain building. Convection caused Pangaea to break up. The convection currents pushed the continents to where they are today.

Unit 1: Lithosphere

Convection causes the crust to be destroyed, or recycled. This happens at convergent boundaries when the edges of the plates are forced deep into the Earth.

At divergent boundaries, convection currents push magma from inside the Earth to the surface. That magma forms lava which hardens into new crust. In other words, crust is renewed at divergent boundaries.

Scientists continue to study convection to determine why plates move. They are observing that some plates move more quickly than others. Most plates move only a few centimeters per year. Based on what scientists are observing, there could be interesting changes to Earth's geography millions of years from now.

For example, eventually, the Mediterranean Sea will disappear and Africa and Europe will be connected. India will continue to push into the southern Asian continent, pushing the Himalayas higher. The city of Los Angeles will continue its journey north to join with the city of San Francisco, but this will take several million vears to occur. Maybe in another 200 million years there will be no need to cross the Pacific Ocean



Credit: NASA World Wind

when going from North America to Asia!

Students should answer the questions below individually or in pairs.

8. Draw a diagram illustrating convection. Use arrows to show the movement of matter.

Answers will vary.

9. How do convection cells relate to plate tectonics?

Heat from the Earth's interior causes the circular movement or convection of material inside the Earth. Convection cells cause plates to move and form convergent, divergent and transform boundaries because plates ride on the convection currents.





10. Explain how Earth recycles its crust. How is crust destroyed and then renewed again?

At convergent boundaries, one plate is pushed below another. That crust melts and becomes magma.

At divergent boundaries, the plates move apart and magma from below comes up. It hardens into new crust.

◊ Review these questions with students.

Teacher Tip: Take the time to discuss these questions with students as they represent important enduring understandings for this unit.

Evaluate

(May be completed for homework)



- 1. Based on the map above, predict:
 - a. What will happen to the size of the Atlantic Ocean over the next 1,000 years?

The Atlantic Ocean will continue to get bigger because of the diverging plates at the Mid-Atlantic Ridge.

b. What will happen to the size of the Pacific Ocean over the next 1,000 years?

The Pacific Ocean will shrink as oceanic plates push under continental ones in the western part of the Ocean.



Unit 1: Lithosphere

The continents fit together like puzzle pieces.
Striations left from glacial movement indicate that areas once covered by the same glacier have since moved apart.
Similar rock layers on different continents indicate that the layers formed together.
Fossils of same plant and animal types found on different continents. It is unlikely that these species crossed the ocean.
Fossils of tropical plants found in Antarctica indicate that Antarctica was not always so close to the South Pole.
Satellite technology collects data about plate movement.

3. How does convection in the mantle help to recycle (destroy and renew) Earth's crust?

Convection currents in the mantle drive crustal plate movements.

As plates <u>diverge</u>, new crust is created or renewed because convection currents are moving the plates apart from one another. This allows magma to emerge from the mantle. The resulting lava hardens into new crust.

At many <u>convergent</u> boundaries, where convection cells push plates toward one another, one crustal plate is pushed below another, where it melts due to the tremendous heat and pressure, into magma. That crust is destroyed only to become part of the mantle and be renewed somewhere else some day.