

KEY CONCEPT

18.2

Continents change position over time.

BEFORE, you learned

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

NOW, you will learn

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

VOCABULARY

continental drift p. 618
Pangaea p. 620
mid-ocean ridge p. 620
convection p. 621
convection current p. 621
theory of plate tectonics p. 622

EXPLORE Movements of Continents

How do you put together a giant continent?

PROCEDURE

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

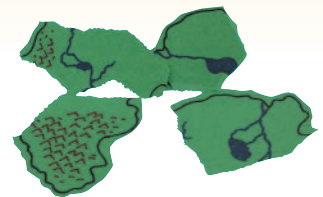
MATERIALS

- sheet of paper
- colored marking pens
- scissors



WHAT DO YOU THINK?

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



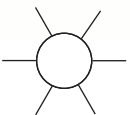
Continents join together and split apart.

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

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

VOCABULARY

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



Evidence for Continental Drift

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

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

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

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

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

READING TIP

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

CHECK YOUR READING

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

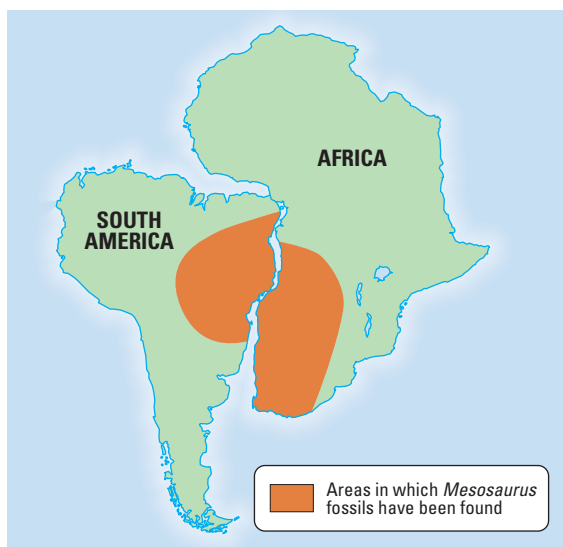


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The reptile *Mesosaurus* was about 45 cm (18 in.) long. This fossil was found in Brazil, South America.

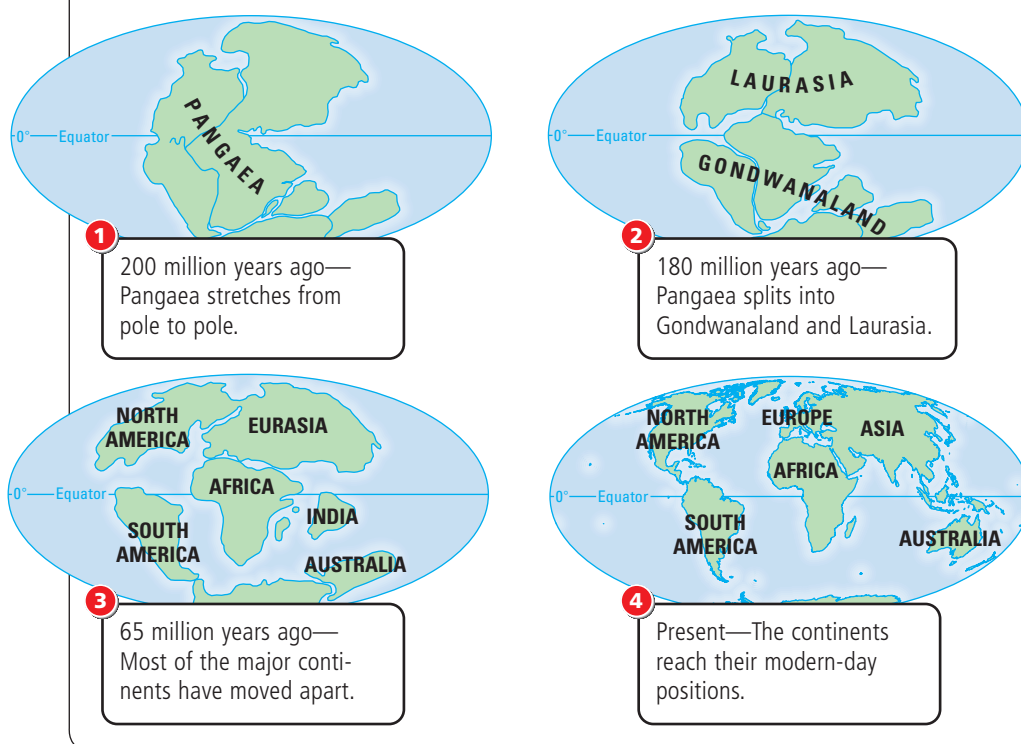


Examine continental movement over the past 150 million years.

Pangaea and Continental Drift

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

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



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

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

Evidence from the Sea Floor

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

Sea-Floor Spreading Scientists learned that the ridges form along cracks in the crust. Molten rock rises through these cracks, cools, and forms new oceanic crust. The old crust is pulled away to make room for new material. In this way, the sea floor slowly spreads apart. Scientists call these areas spreading centers. You will read more about spreading centers in Section 18.3.

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

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

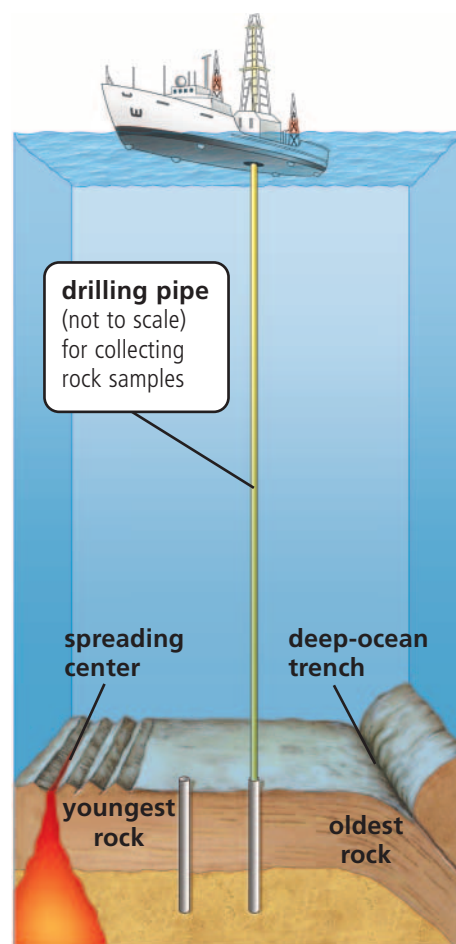
Ocean Trenches Yet, if the sea floor has been spreading for millions of years, why is Earth not getting larger? Scientists discovered the answer when they found huge trenches, like deep canyons, in the sea floor. At these sites, dense oceanic crust is sinking into the asthenosphere. Old crust is being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

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



CHECK YOUR READING

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



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

Causes of Plate Movement

Tectonic plates rest on the asthenosphere, a layer of soft, hot rock. Rock in this layer and in the mantle just below it moves by convection.

Convection is energy transfer by the movement of a material. You have seen convection if you have ever boiled a pot of water. The water at the bottom of the pot heats up, becomes less dense, and rises. At the surface, it cools, becomes denser, and sinks, only to be heated and rise again.

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

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

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

Putting the Theory Together

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

The map on page 623 shows Earth's major tectonic plates and the directions in which they move. They are the African, the Antarctic, the Australian, the Indian, the Eurasian, the Nazca, the North and South American, and the Pacific plates.

REMINDER

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

Causes of Plate Movement

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

Ridge Push Material from mid-ocean ridges pushes the plates.

Slab Pull Gravity pulls cooler, denser plates into the asthenosphere.

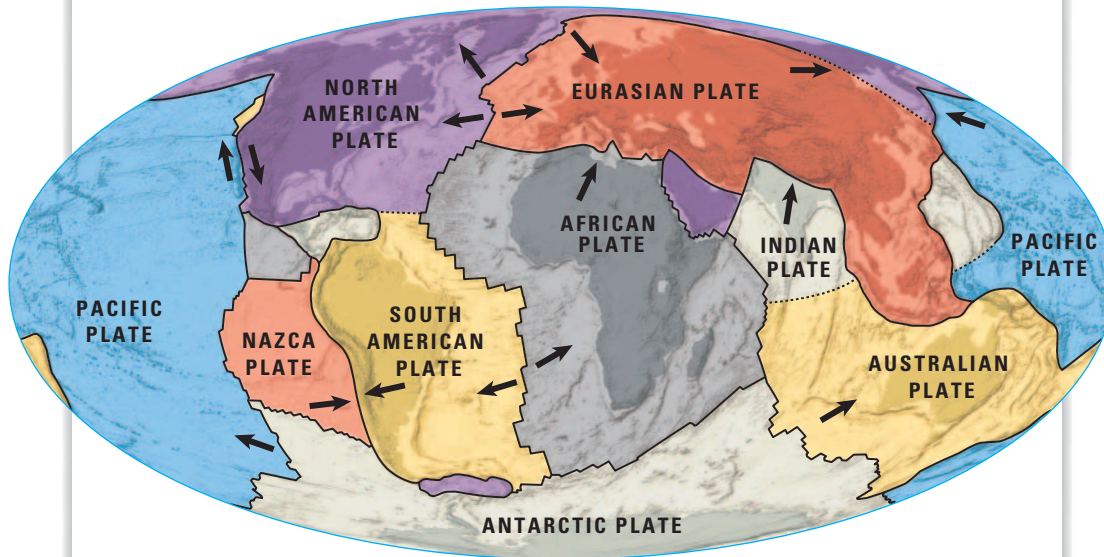
Convection Currents
In the asthenosphere, heated rock constantly rises, cools, sinks, and is heated again.

READING VISUALS

How do temperature changes create convection currents?

Tectonic Plates

Earth's lithosphere is made up of moving plates.



READING VISUALS

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

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

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

18.2 Review

KEY CONCEPTS

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

CRITICAL THINKING

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

CHALLENGE

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