CHAPTER

17 Plate Tectonics

BIG Idea **Most geologic activity occurs at the boundaries between plates.**

17.1 Drifting Continents
MAIN Idea The shape and geology of the continents suggests that they were once joined together.

17.2 Seafloor Spreading
MAIN Idea Oceanic crust forms at ocean ridges and becomes part of the seafloor.

17.3 Plate Boundaries
MAIN Idea Volcanoes, mountains, and deep-sea trenches form at the boundaries between the plates.

17.4 Causes of Plate Motions
MAIN Idea Convection currents in the mantle cause plate motions.

GeoFacts

- The San Andreas Fault is a 1200-km-long gash that runs from northern California almost to Mexico.
- Each year, plate movement along the fault brings Los Angeles about 5 cm closer to San Francisco.
- In this photo, the North American Plate is on the right, the Pacific Plate is on the left.

Start-Up Activities

LAUNCH Lab

Is California moving?

Southwestern California is separated from the rest of the state by a system of cracks along which movement takes place. These cracks are called faults. One of these, as you might know, is the San Andreas Fault. Movement along this fault is carrying southwestern California to the Northwest in relation to the rest of North America at a rate of about 5 cm/y.

Procedure

1. Read and complete the lab safety form.
2. Use a **metric ruler** and the **map scale** to determine the actual distance between San Francisco and Los Angeles.
3. At the current rate of movement, when will these two cities be next to each other?

Analysis

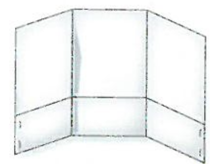
1. **Infer** what might be causing the motion of these large pieces of land.
2. **Calculate** How far will southwestern California move in a 15-year period?

FOLDABLES™ Study Organizer

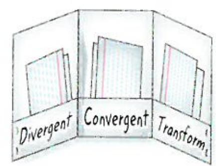
Plate Boundaries Make this Foldable to compare the types of plate boundaries and their features.

STEP 1 Fold up the bottom edge of a legal-sized sheet of paper about 3 cm and crease.

STEP 2 Fold the sheet into thirds.



STEP 3 Glue or staple to make three pockets. Label the pockets *Divergent, Convergent,* and *Transform.*



FOLDABLES **Use this Foldable with Section 17.3.** As you read this section, summarize on index cards or quarter sheets of paper the geologic characteristics of each type of boundary and the processes associated with it.

Earth Science Online

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Section 17.1

Objectives

- **Identify** the lines of evidence that led Wegener to suggest that Earth's continents have moved.
- **Discuss** how evidence of ancient climates supported continental drift.
- **Explain** why continental drift was not accepted when it was first proposed.

Review Vocabulary

hypothesis: testable explanation of a situation

New Vocabulary

continental drift
Pangaea

Drifting Continents

MAIN Idea The shape and geology of the continents suggests that they were once joined together.

Real-World Reading Link When you put together a jigsaw puzzle, what features of the puzzle pieces do you use to find matching pieces? Scientists used features such as shape and position to help them piece together the way the continents were arranged millions of years ago.

Early Observations

With the exception of events such as earthquakes, volcanic eruptions, and landslides, most of Earth's surface appears to remain relatively unchanged during the course of a human lifetime. On the geologic time scale, however, Earth's surface has changed dramatically. Some of the first people to suggest that Earth's major features might have changed were early cartographers. In the late 1500s, Abraham Ortelius (or TEE lee us), a Dutch cartographer, noticed the apparent fit of continents on either side of the Atlantic Ocean. He proposed that North America and South America had been separated from Europe and Africa by earthquakes and floods. During the next 300 years, many scientists and writers noticed and commented on the matching coastlines. **Figure 17.1** shows a proposed map by a nineteenth-century cartographer.

The first time that the idea of moving continents was proposed as a scientific hypothesis was in the early 1900s. In 1912, German scientist Alfred Wegener (VAY guh nur) presented his ideas about continental movement to the scientific community.

Reading Check **Infer** why cartographers were among the first to suggest that the continents were once joined together.

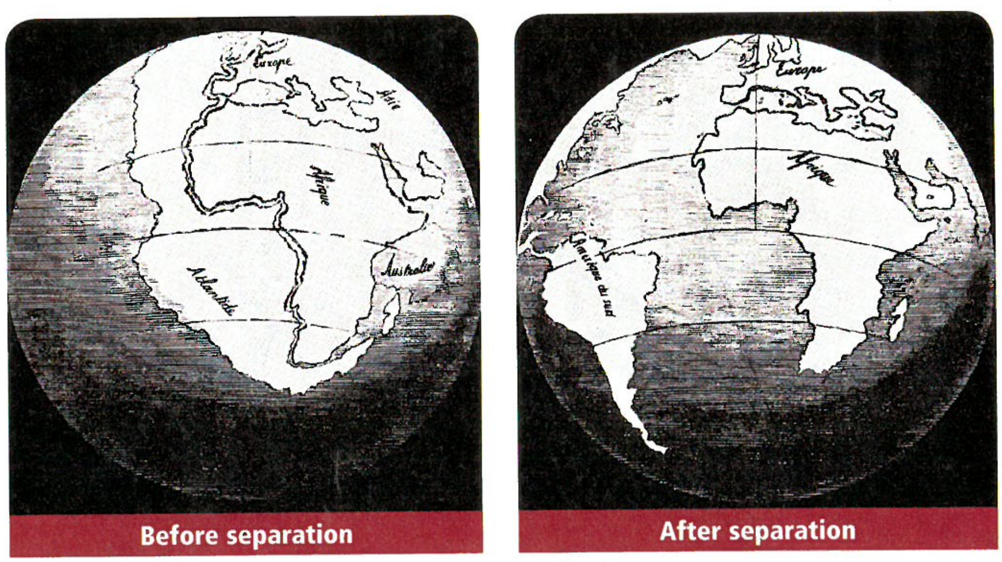


Figure 17.1 Many early cartographers, such as Antonio Snider-Pelligrini, the author of these 1858 maps, noticed the apparent fit of the continents.

Continental Drift

Wegener developed an idea that he called **continental drift,** which proposed that Earth's continents had once been joined as a single landmass that broke apart and sent the continents adrift. He called this supercontinent **Pangaea** (pan JEE uh), a Greek word that means *all the earth,* and suggested that Pangaea began to break apart about 200 mya. Since that time, he reasoned, the continents have continued to slowly move to their present positions, as shown in **Figure 17.2.**

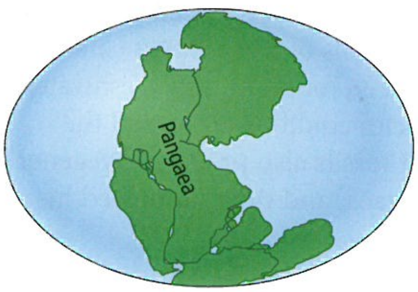
Of the many people who had suggested that continents had moved around, Wegener was the first to base his ideas on more than just the puzzlelike fit of continental coastlines on either side of the Atlantic Ocean. For Wegener, these gigantic puzzle pieces were just the beginning. He also collected and organized rock, climatic, and fossil data to support his hypothesis.

Concepts In Motion

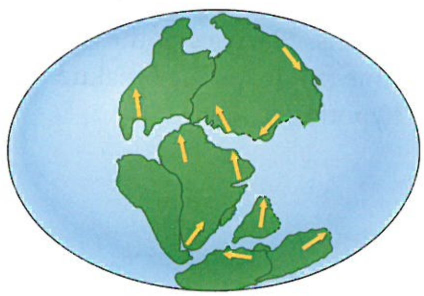
Interactive Figure To see an animation of the breakup of Pangaea, visit glencoe.com.

Figure 17.2 Wegener hypothesized that all the continents were once joined together. He proposed that it took 200 million years of continental drift for the continents to move to their present positions.

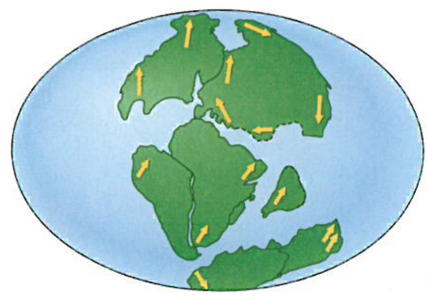
Locate ***the parts of Pangaea that became North and South America. When were they joined? When were they separated?***



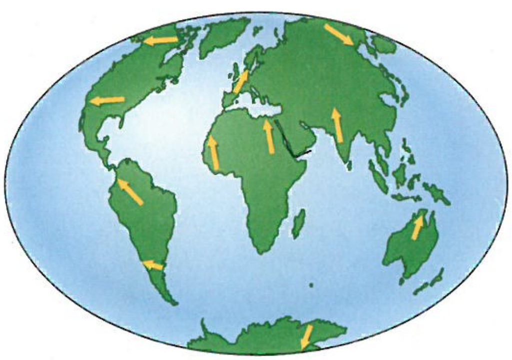
200 mya: All the continents assembled in a single landmass that Wegener named Pangaea.



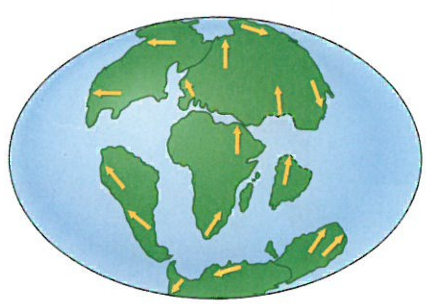
180 mya: Continental rifting breaks Pangaea into several landmasses. The North Atlantic Ocean starts to form.



135 mya: Africa and South America begin to separate.



Present: India has collided with Asia to form the Himalayas and Australia has separated from Antarctica. A rift valley is forming in East Africa. Continents continue to move over Earth's surface.

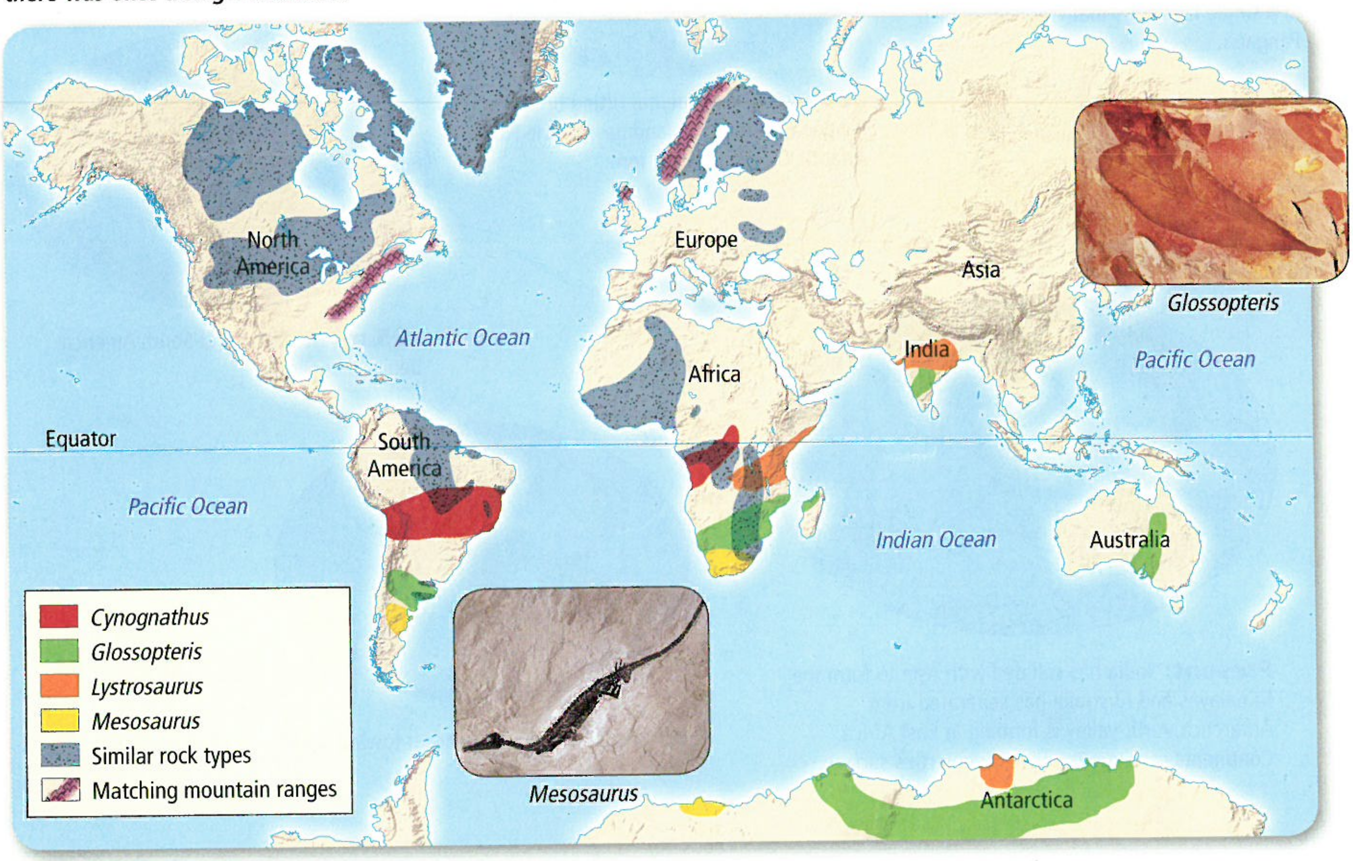


65 mya: India moves north toward Asia.

Evidence from rock formations Wegener reasoned that when Pangaea began to break apart, large geologic structures, such as mountain ranges, fractured as the continents separated. Using this reasoning, Wegener thought that there should be areas of similar rock types on opposite sides of the Atlantic Ocean. He observed that many layers of rocks in the Appalachian Mountains in the United States were identical to layers of rocks in similar mountains in Greenland and Europe. These similar groups of rocks, older than 200 million years, supported Wegener's idea that the continents had once been joined. Some of the locations where matching groups of rock have been found are indicated in **Figure 17.3.**

Evidence from fossils Wegener also gathered evidence of the existence of Pangaea from fossils. Similar fossils of several different animals and plants that once lived on or near land had been found on widely separated continents, as shown in **Figure 17.3.** Wegener reasoned that the land-dwelling animals, such as *Cynognathus* (sin ug NATH us) and *Lystrasaurus* (lihs truh SORE us) could not have swum the great distances that now exist between continents. Wegener also argued that because fossils of *Mesosaurus* (meh zoh SORE us), an aquatic reptile, had been found in only freshwater rocks, it was unlikely that this species could have crossed the oceans. The ages of these different fossils also predated Wegener's time frame for the breakup of Pangaea, and thus supported his hypothesis.

Figure 17.3 Alfred Wegener used the similarity of rock layers and fossils on opposite sides of the Atlantic Ocean as evidence that Earth's continents were once joined.
Identify ***groupings that suggest that there was once a single landmass.***



Climatic evidence Because he had a strong background in meteorology, Wegener recognized clues about ancient climates from the fossils he studied. One fossil that Wegener used to support continental drift was *Glossopteris* (glahs AHP tur us), a seed fern that resembled low shrubs, shown in **Figure 17.3.** Fossils of this plant had been found on many parts of Earth, including South America, Antarctica, and India. Wegener reasoned that the area separating these fossils was too large to have had a single climate. Wegener also argued that because *Glossopteris* grew in temperate climates, the places where these fossils had been found were once closer to the equator. This led him to conclude that the rocks containing these fossil ferns had once been joined.

Reading Check **Infer** how Wegener's background in meteorology helped him to support his idea of continental drift.

Figure 17.4 A coal deposit in Antarctica indicates that swamp plants once thrived in this area.
Explain ***How did coal, which forms from ancient swamp material, end up in Antarctica?***

Coal deposits Recall from Chapter 6 that sedimentary rocks provide clues to past environments and climates. Wegener found evidence in these rocks that the climates of some continents had changed markedly. For example, **Figure 17.4** shows a coal deposit found in Antarctica. Coal forms from the compaction and decomposition of accumulations of ancient swamp plants. The existence of coal beds in Antarctica indicated that this frozen land once had a tropical climate. Wegener used this evidence to conclude that Antarctica must have been much closer to the equator sometime in the geologic past.

Glacial deposits Another piece of climatic evidence came from glacial deposits found in parts of Africa, India, Australia, and South America. The presence of these 290-million-year-old deposits suggested to Wegener that these areas were once covered by a thick ice cap similar to the one that covers Antarctica today. Because the traces of the ancient ice cap are found in regions where it is too warm for them to develop, Wegener proposed that they were once located near the south pole, as shown in **Figure 17.5.** Wegener suggested two possibilities to explain the deposits. Either the south pole had shifted its position, or these landmasses had once been closer to the south pole. Wegener argued that it was more likely that the landmasses had drifted apart rather than Earth changing its axis.

Figure 17.5 Glacial deposits nearly 300 million years old on several continents led Wegener to propose that these landmasses might have once been joined and covered with ice. The extent of the ice is shown in white.

■ **Figure 17.6** Wegener collected further evidence for his theory on a 1930 expedition to Greenland. He died during this expedition, many years before his data became the basis for the theory of plate tectonics.

A Rejected Notion

In the early 1900s, many people in the scientific community considered the continents and ocean basins to be fixed features on Earth's surface. For the rest of his life, Wegener continued travelling to remote regions to gather evidence in support of continental drift. **Figure 17.6** shows him in Greenland on his last expedition. Although he had compiled an impressive collection of data, the continental drift hypothesis was never accepted by the scientific community.

Continental drift had two major flaws that prevented it from being widely accepted. First, it did not satisfactorily explain what force could be strong enough to push such large masses over such great distances. Wegener thought that the rotation of Earth might be responsible, but physicists were able to show that this force was not nearly enough to move continents.

Second, scientists questioned how the continents were moving. Wegener had proposed that the continents were plowing through a stationary ocean floor, but it was known that Earth's mantle below the crust was solid. So, how could continents move through something solid? These two unanswered questions—what forces could cause the movement and how continents could move through solids—were the main reasons that continental drift was rejected. It was not until the early 1960s when new technology revealed more evidence about how continents move that scientists began to reconsider Wegener's ideas. Advances in seafloor mapping and in understanding Earth's magnetic field provided the necessary evidence to show how continents move, and the source of the forces involved.

Section 17.1 Assessment

Section Summary

- The matching coastlines of continents on opposite sides of the Atlantic Ocean suggest that the continents were once joined.
- Continental drift was the idea that continents move around on Earth's surface.
- Wegener collected evidence from rocks, fossils, and ancient climates to support his theory.
- Continental drift was not accepted because there was no explanation for how the continents moved or what caused their motion.

Understand Main Ideas

1. MAIN Idea **Draw** how the continents were once adjoined as Pangaea.
2. **Explain** how ancient glacial deposits in Africa, India, Australia, and South America support the idea of continental drift.
3. **Summarize** how rocks, fossils, and climate provided evidence of continental drift.
4. **Infer** what the climate in ancient North America must have been like as a part of Pangaea.

Think Critically

5. **Interpret** Examine **Figure 17.5.** Oil deposits that are approximately 200 million years old have been discovered in Brazil. Where might geologists find oil deposits of a similar age?
6. **Evaluate** this statement: The town where I live has always been in the same place.

WRITING in Earth Science

7. Compose a letter to the editor from a scientist in the early 1900s arguing against continental drift.

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