

## 11.1 Pangaea

While looking at a map of the world, have you ever noticed that the continents look like pieces of a puzzle? If they were moved closer together across the Atlantic Ocean, they would fit together neatly to form a giant landmass (Figure 11.1). In this section, you will learn about Alfred Wegener and his idea that a “supercontinent” once existed on Earth.

### Movement of continents

**Continental drift** Alfred Wegener was a German scientist and arctic explorer who suggested the concept of continental drift.

**Continental drift** is the idea that the continents move around on Earth’s surface.

### Wegener’s hypothesis

In the early 1900s, Wegener hypothesized that the continents were once connected. Today, after a lot of scientific research and collected evidence, we know that Wegener was right.

### Pangaea—a supercontinent

In 1915, Wegener published his ideas in a book, *Origins of the Continents and Oceans*. Wegener thought that the continents we know today had once been part of an earlier *supercontinent*. He called this great landmass **Pangaea** (Greek for “all land”). According to continental drift, Pangaea broke apart and the pieces moved to their present places, becoming today’s continents.

### What is plate tectonics?

In Chapter 1, you were introduced to plate tectonics, the study of lithospheric plates. You learned that the surface of Earth is broken into many pieces like a giant jigsaw puzzle. **Plate tectonics** describes how these pieces move on Earth’s surface. By the time you finish this chapter, you will know more about this theory than any scientist knew only forty years ago. Wow! You will also learn that the development of this theory is an excellent example of how the scientific process works. Now, let’s return to Wegener and his idea of continental drift.

### Evidence for continental drift

#### Matching coal beds, mountains, and fossils

Wegener was not the only scientist to suggest that continents move. His theory stood out because of the evidence that he gathered to support his idea of continental drift. Wegener’s evidence is presented in the graphic below and listed in Figure 11.2.

### A good hypothesis

Wegener’s theory that the continents were connected in the past was a good idea. It was a *scientific hypothesis based on observations*.

### Continental drift was rejected

Continental drift was a good hypothesis that was rejected by other scientists. A key part of Wegener’s hypothesis was that some unknown force had caused the continents to slide over, or push through, the rocky bottoms of the oceans. Yet, neither he nor anyone else could identify the source of the force needed to move continents. Continental drift helped explain issues in geology—like why South America and Africa seem to fit together. However, continental drift could not be accepted by scientists because there was no evidence to explain how the continents moved.

## 11.1 Section Review

1. What is plate tectonics? Is it an old or a new field of science?
2. Alfred Wegener (Figure 11.3) is featured in this section. Who was he?
3. Alfred Wegener thought that all continents were once connected. Explain one observation that led to this belief.
4. Why did scientists reject Wegener’s idea of continental drift?
5. In this section, you read that the development of the theory of plate tectonics is a good example of the scientific method.
  - a. How did Wegener follow the scientific method?
  - b. When scientists rejected continental drift, were they using the scientific method? Why or why not?
6. Would most scientists in 1900 have thought that Earth’s surface was like a giant jigsaw puzzle? Why or why not?

**Continental drift** - the idea that continents move around on Earth’s surface.

**Pangaea** - an ancient, huge landmass composed of earlier forms of today’s continents; an ancient supercontinent.

**Plate tectonics** - a theory explaining how the pieces of Earth's surface (the plates) move.

## 11.2 Sea-floor Spreading

In Wegener's time, the world's ocean floors were largely unexplored. Mapping the sea floor provided more important evidence for the theory of plate tectonics.

### Undersea mountains discovered

#### A map of the ocean floor

During World War II, the United States Navy needed to locate enemy submarines hiding on the bottom of shallow seas. Because of this, large areas of the ocean floor were mapped for the first time. American geophysicist and naval officer Harry Hess did some of the mapping. His work helped develop the theory of plate tectonics.

**Mid-ocean ridges** The naval maps showed huge mountain ranges that formed a continuous chain down the centers of the ocean floors. These mountain ranges are called **mid-ocean ridges**. Hess wondered if it was possible that new ocean floor was created at mid-ocean ridges. If new ocean floor formed at a ridge, then continents on either side would get pushed apart during the process (Figure 11.4).

### The sea-floor spreading hypothesis

#### A hypothesis is born

Hess thought that Wegener was partly right. The continents *had* separated from a supercontinent, but not by plowing through the sea floor. Instead, continents moved along as part of the growing sea floor! Hess called his hypothesis **sea-floor spreading**.

#### A good idea needs more evidence

Sea-floor spreading was an intriguing hypothesis. But for many years scientists had viewed the continents as permanently fixed in place. Sea-floor spreading would need strong evidence to support it before it would ever be more than just a hypothesis.

#### Rapid scientific progress

A time of tremendously rapid scientific progress followed Hess' sea-floor spreading hypothesis. Many scientists added to each other's work and found the evidence needed to explain sea-floor spreading.

#### Magnetic patterns and the age of rocks

The discovery of *magnetic reversal patterns* in the rocks on both sides of the mid-ocean ridges was a key piece of evidence. These striped patterns are formed as magnetic minerals found within newly formed rock align to Earth's magnetic field as the rock cools. Scientists noticed that the magnetic patterns matched on either side of a ridge (Figure 11.5). They also noticed that the oldest rocks were furthest from the ridge. These observations showed that sea-floor spreading was occurring—the new ocean floor that forms at mid-ocean ridges moves away from the ridges as time passes.

### Moving pieces of the lithosphere

#### After a breakthrough

After the breakthrough discovery of magnetic patterns was understood, there was a lot of interest in the idea of sea-floor spreading. Scientists realized that large pieces of Earth's surface moved about like rafts on a river.

Today we know these "rafts" are pieces of lithosphere called **lithospheric plates** that move over the asthenosphere. Plate tectonics is the study of these lithospheric plates. There are two kinds of lithospheric plates: **oceanic plates** and **continental plates**.

Oceanic plates form the floor of the ocean. They are thin and mostly made of dense basalt. Continental plates are thicker and less dense than oceanic plates. Continental plates are made of andesite and granite.

#### Plate tectonics answers other questions

Science is a process that builds on itself. Early discoveries provide a better understanding that leads to more discoveries. The evidence that Alfred Wegener collected to support an ancient supercontinent is valid today. And our understanding of plate tectonics has allowed us to answer other questions such as:

- Why are volcanoes and earthquakes located where they are?
- Where can we find oil, gas, gold, and other important resources?

### What drives lithospheric plates?

**Convection cells** Convection cells in Earth's lower mantle drive the lithospheric plates on the surface. Earth's core heats the rock material of the lower mantle. As it is heated, it expands and becomes less dense.

#### What happens at mid-ocean ridges?

The lower mantle rock material rises toward Earth's surface. Lithospheric plates move apart over the rising part of a convection cell. Basaltic lava is extruded between the plates along the midocean ridge. The basaltic lava adds to the plates so that they grow in size. Over time, as newly formed plate material moves away from the mid-ocean ridge, it ages, cools, and becomes denser.

**Subduction** The cooler, denser edge of a lithospheric plate eventually sinks below another lithospheric plate and enters the mantle (Figure 11.6). This sinking process is called **subduction**. As the subducting plate enters the mantle, it cools the adjacent mantle material. Cooling makes the nearby material denser and it sinks deeper into the mantle. This sinking completes the mantle convection cell. Subduction also happens when a denser oceanic plate encounters a continental plate. The oceanic plate subducts under the continental plate.

### Hot spots and island chains

Volcanic activity can be found on mid-ocean ridges. Sometimes a single, hot, rising **mantle plume** causes a volcanic eruption in the plate above it. If the eruption is strong and lasts long enough, the volcanic eruption may form an island on the plate. After the island forms, the movement of the plate carries it away from the mantle plume. Without the heat from the mantle plume underneath, the volcano that formed the island becomes dormant. In the meantime, a new volcano begins to form on the part of the plate that is now over the mantle plume.

This process can repeat over and over, forming a chain of islands. The first island formed in the chain is made of old dormant volcanoes, while the most recent island in the chain generally has active volcanoes. Scientists determine the direction and speed of plate movement by measuring these island chains. The speed of moving plates ranges from 1 to 10 centimeters each year. The Hawaiian Islands are a good example of an island chain formed by a mantle plume hot spot.

### 11.2 Section Review

1. Explain why magnetic patterns are important evidence for plate tectonics.
2. How were mid-ocean ridges discovered?
3. What was Harry Hess' hypothesis regarding the ocean floor and how it was made?
4. What two discoveries supported Hess' hypothesis?
5. What is the study of lithospheric plates called?
6. Over what surface do lithospheric plates move?
  - a. lower mantle
  - b. outer core
  - c. inner core
  - d. asthenosphere
7. Name the two types of lithospheric plates and describe them.
8. What are some questions that are answered by plate tectonics?
9. What is the source of energy that drives the movement of the lithospheric plates?
10. Do lithospheric plates move quickly or slowly? Explain your answer.
11. Describe the process of subduction in your own words. What causes subduction to happen?
12. Name an example of an island chain formed by a mantle plume hot spot. Describe/draw the process of how it formed.

**Mid-ocean ridge** - a long chain of undersea mountains.

**Sea-floor spreading** – a hypothesis that new sea floor is created at mid-ocean ridges and that, in the process, the continents are pushed apart from each other.

**lithospheric plates** – large pieces of Earth's lithosphere that move over the asthenosphere.

**oceanic plates** - thin lithospheric plates that are made of basalt and form the ocean floor; denser than continental plates.

**continental plates** – thick lithospheric plates that are made of andesite and granite and form the continents; less dense than oceanic plates.

**subduction** - a process that involves a lithospheric plate sinking into the mantle.

**mantle plume** - heated lower mantle rock that rises toward the lithosphere because it is less dense than surrounding mantle rock.