

Thermal energy transfer drives plate tectonics.

Thermal energy transfer moves you—although not the way your favourite song, a sad movie, or a good grade might move you. Due to the transfer of thermal energy beneath your feet, every day your life is spent in motion, whether you are aware of it or not. Deep below British Columbia, forces are churning melted rock and transporting the land you live on westward at about 2 cm per year. Just off the western edge of Vancouver Island, your chunk of land is confronted by another travelling eastward. The results of this interaction can produce some of the most powerful events in nature: volcanic eruptions and earthquakes.

In this chapter, you will explore the theory of plate tectonics, which explains the forces that propel us on our rafts of rock. You will learn how thermal energy transfer above and below Earth's surface has defined our planet, contributing to geological events such as volcanic eruptions and earthquakes and the formation of islands and mountains.

What You Will Learn

In this chapter, you will

- **define, describe,** and **analyze** the processes and features associated with plate tectonics
- **explain** tectonic plate movement and its effects
- **explain** the factors that contribute to the motion of tectonic plates
- **relate** plate tectonics to the layers of Earth
- **identify** sources of heat within Earth

Why It Is Important

The plate tectonic theory provides an explanation for geological events that affect our lives, such as earthquakes and volcanic eruptions. The theory helps explain the formation of mountains and the location of continents. As scientists put together clues about Earth's past, they can make better predictions about our planet's future.

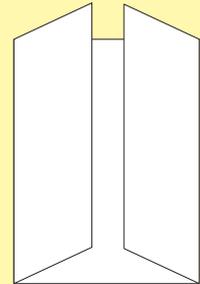
Skills You Will Use

In this chapter, you will

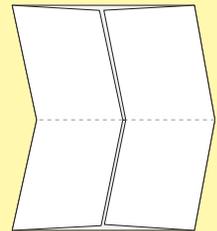
- **explain** tectonic plate movement and its effects
- **communicate** your knowledge of plate tectonics
- **model** tectonic plate movement and volcanic eruptions
- **evaluate information** from a graph of earthquake energy waves

Make the following Foldable and use it to take notes on what you learn in Chapter 12.

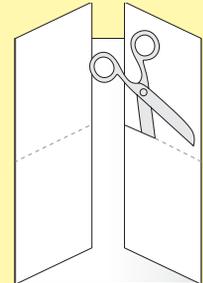
- STEP 1** **Make** a shutterfold using 28 cm x 43 cm paper.



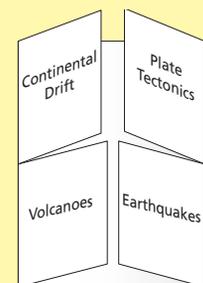
- STEP 2** **Fold** the shutterfold in half like a hamburger. **Crease** well.



- STEP 3** **Open** the paper, and **cut** along the inside valley folds.



- STEP 4** **Label** the four doors as shown.



Organize Beneath the door tabs, record information and define terms. On the back of the Foldable, glue a map of the world and indicate the boundaries of the tectonic plates and significant volcanoes. Use the Internet to research recent earthquakes, and mark their locations on the map as well.

12.1 Evidence for Continental Drift

Various pieces of evidence indicate that the continents were once joined but later drifted to their current positions. First, the coasts of the continents can be aligned. Second, regions of some continents that are far apart have similar rocks, mountain ranges, fossils, and patterns of paleoglaciation. The process of sea floor spreading provides a mechanism for continental drift. The continents are attached to huge slabs of rock, known as tectonic plates. When the tectonic plates move across Earth's surface, they carry the continents with them.

Words to Know

continental drift theory
earthquakes
hot spot
magnetic reversal
paleoglaciation
plate tectonic theory
spreading ridge
tectonic plate
volcanoes

Did You Know?

Scientists can learn a lot about the land we live on by studying the sea floor. In order to study the area off the west coast of North America, scientists have placed 800 km of fibre optic cable on the sea floor. From depths of up to 2.8 km, the cable transmits video recordings and other data to a University of Victoria shore station. From there, the data are sent to scientists around the world.

Humans are passengers on the solid rock slabs we call continents. However, the idea that these huge land masses move may seem hard to believe. In fact, in the early 20th century, when German scientist Alfred Wegener proposed the continental drift theory, the idea was revolutionary. The **continental drift theory** states that the continents have not always been in their present locations but have “drifted” there over millions of years. Wegener’s first clue that the continents were in motion came from his and others’ observations of world maps (Figure 12.1).

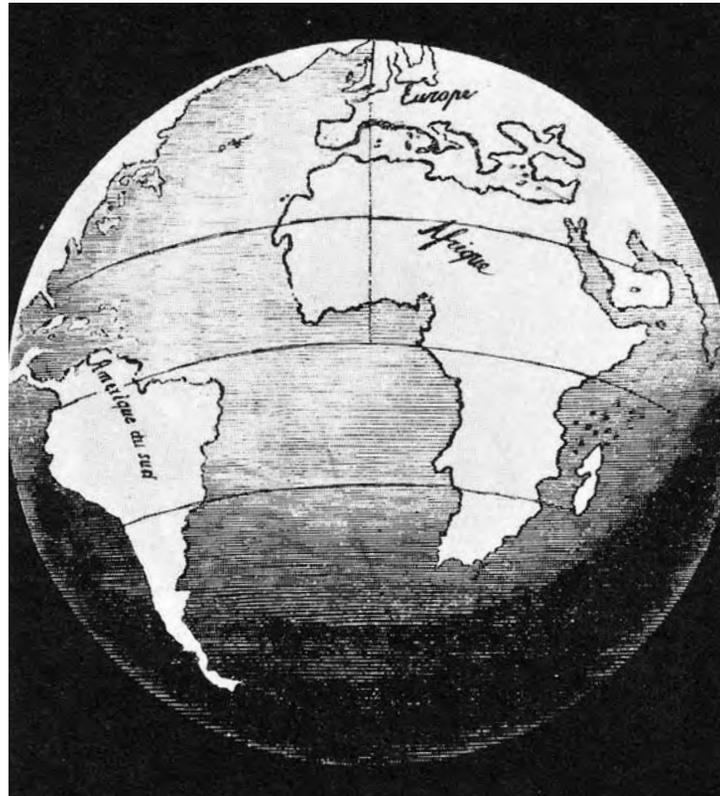


Figure 12.1 The first piece of evidence for continental drift was the matching shapes of the continents, as shown in the earliest reliable world maps.

For as long as there have been reliable world maps, people have noticed a striking feature—the shapes of the continents relative to one another. In this activity, you will take on the role of an early cartographer (map maker). You will make an hypothesis to explain the way the continents appear.

What to Do

1. Examine Figure 12.1 on the previous page, an early map showing South America and Africa. What do you notice about the east coast of South America relative to the west coast of Africa?

2. Suggest an hypothesis that would explain your observation in Step 1.
3. Suppose you wanted to find other evidence to support your hypothesis. What would you need to find out about the plants, animals, and geography of eastern South America and western Africa?

What Did You Find Out?

1. What evidence from world maps supports the continental drift theory?

The Jigsaw Puzzle Fit

The apparent match on a world map between South America's eastern coastline and Africa's western coastline gave Wegener his first piece of evidence for continental drift. To Wegener and many others, the fit appeared too close to be coincidental. Wegener suggested that, millions of years ago, all the continents were joined as a “supercontinent.” He named the giant land mass Pangaea, from the Greek words *pan*, meaning all, and *gaea*, meaning Earth. In truth, the continental edges do not match as perfectly as pieces of a puzzle. A better alignment is obtained by matching the continental shelves, which are the submerged original shorelines of continents.

Wegener also compared geological structures, fossils, and evidence of ancient glaciers on different continents. These clues did not seem significant until Wegener placed the continents together (Figure 12.2).

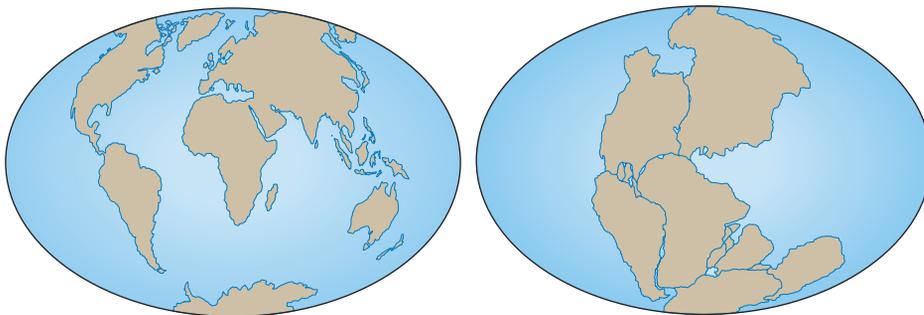


Figure 12.2 Wegener noted similar features in distant continents. These features matched across continents that appeared to fit together.

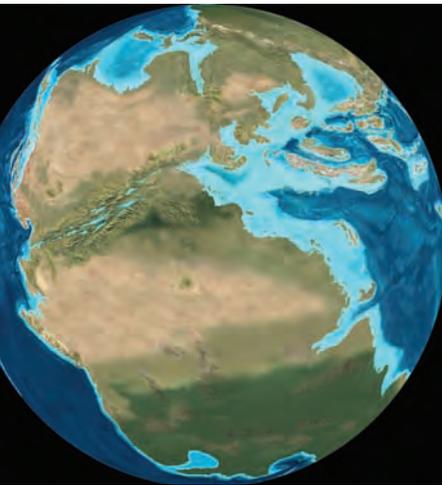


Figure 12.3 Modern scientists created this map to show how worldwide mountain ranges might have looked on Pangaea over 200 million years ago.

Matching Geological Structures and Rocks

Wegener's analysis of rocks and mountain ranges supported his idea that the continents were once joined. He noted mountain ranges that begin on one continent, end at the coastline, and then appear to continue on a continent across an ocean. There are also many similarities between rock structures, such as folds, and the ages of rocks on continents that are separated by thousands of kilometres of ocean. For example, rocks found in Newfoundland are the same type and age as rocks found in Greenland, Ireland, Scotland, and Norway.

Wegener reasoned that the world's major mountain ranges would have been continuous when the continents were joined as Pangaea (Figure 12.3).

Matching Fossils

Wegener was intrigued by the fact that similar fossils occur in various locations around the world. One fossil that particularly interested him was that of a sharp-toothed, freshwater reptile called *Mesosaurus*. Fossils of *Mesosaurus* have been found in only two places: southeastern South America and southwestern Africa. Because *Mesosaurus* was a small, freshwater animal, it seemed unlikely the animal would have survived crossing the 6000 km of open ocean between the two continents. Furthermore, the fossils of two land-dwelling animals, *Cynognathus* and *Lystrosaurus*, have been found throughout the continents in the southern hemisphere, separated by vast oceans. Given that these land animals could not have swum so far, the existence of Pangaea seemed the best explanation for the fossil findings (Figure 12.4). Members of the same species would have been separated when the giant landmass broke apart.

Another fossil of interest was that of *Glossopteris*, a fern. Wegener could not understand why fossils of this plant would be found so widely spread apart, from South America and Africa to Australia, India, and Antarctica. Ferns do not grow in cold climates, and there was no evidence

Figure 12.4 Alfred Wegener used the locations of similar fossils and rocks on separate continents to formulate his hypothesis that all continents were once joined. His hypothesis makes sense in light of the theory of evolution, which explains that members of the same species share the same ancestors.



that, 200 million years ago, polar climates were milder. If, however, the continents were once joined as Pangaea, the location of the fossilized ferns made sense: In the past, Antarctica must have been closer to the equator and thus had a warmer climate. Since then, Antarctica has moved to its present location at the South Pole.

Climatic Evidence for Continental Drift

Work by many scientists added support to the evidence for continental drift that Wegener had collected. The effects of ice ages on Earth's surface are one example. Glaciers are vast masses of ice, found in our time at the poles and high in the mountains. During ice ages, however, glaciers covered large areas of land. When glaciers advance or retreat, they mark the land with proof of their existence, leaving behind large, U-shaped valleys, deeply scratched rocks, and various types and patterns of rock formations. **Paleoglaciation** refers both to the extent of ancient glaciers and to the rock markings they have left behind.

Scientists were puzzled by evidence of glaciers in parts of the world that are now tropical, such as parts of India and Africa. They wondered how glaciers could have formed in places where temperatures were rarely known to dip below freezing. If the continents were once joined, however, with much of the land mass sitting towards the South Pole, then evidence of glaciers across South America, Africa, and India made sense (Figure 12.5).

Coal deposits in Antarctica are another piece of evidence that was hard to account for. Coal forms from the decomposition of once living things—usually tropical swamp material. The South Pole has never had a tropical climate, which suggests that Antarctica was once in a warmer location than it is now. If the mystery could be explained by massive global climate change, evidence for warmer climates would be found on all continents, which it was not. Instead, as Wegener concluded almost a century ago, each continent contained clues about an ancient super continent that had broken into smaller pieces. The best explanation for the Antarctic coal deposits was that the continents were once situated in very different locations.

Word Connect

The prefix "paleo-" originates from the Greek word meaning old or ancient. What do you think paleobiologists, paleontologists, and paleoclimatologists study?

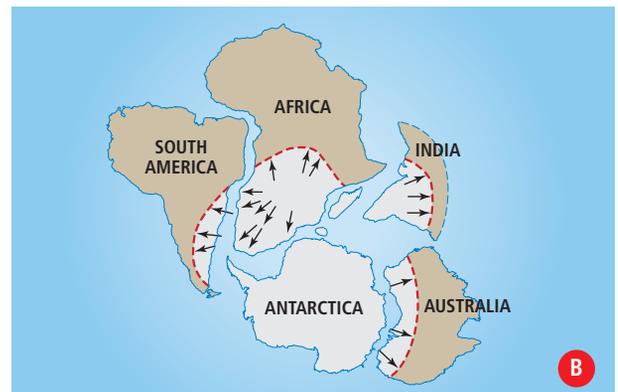
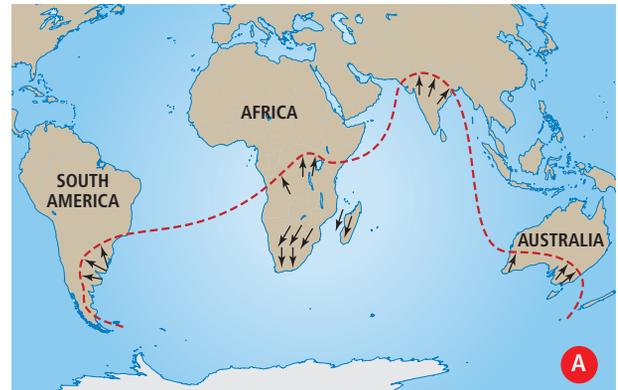


Figure 12.5 There seems to be no pattern to paleoglaciation found around the world (A). A pattern emerges when the continents are fitted together to form Pangaea (B).

Reading Check

1. What did Wegener observe in maps that supported his concept of continental drift?
2. What land mass does Pangaea refer to?
3. How did Wegener explain the fact that there are mountain ranges that appear to start on one continent and continue on another?
4. Why was Wegener interested in fossils of *Mesosaurus*, *Cynognathus*, and *Lystrosaurus*?
5. What is the term for the features left on the land by ancient glaciers?

internet connect

The Ring of Fire is a zone around the Pacific Ocean with many earthquakes and volcanic eruptions. To learn more about the Ring of Fire, visit www.bcsce10.ca.

How Can Continents Move?

Although Wegener had gathered a great deal of evidence for continental drift, the scientific community did not receive his idea with enthusiasm. In order for Wegener's hypothesis to become an accepted theory, he needed to answer a key question: What makes continents drift? It would take over 30 years, major technological advancements, and the research of a Canadian geophysicist before the continental drift theory was accepted.

A Possible Mechanism

In the years following Wegener's death in 1930, new findings made scientists reflect on his hypothesis. As with many great scientific discoveries, a series of seemingly unrelated events combined to generate support for an idea once considered far-fetched.

In Wegener's time, scientists did not know that the surface of Earth is broken into large, movable slabs of rock called **tectonic plates**. Since the early part of the 20th century, however, much has been discovered about the large, rigid plates that move around the surface of Earth, sliding over a layer of partly molten rock.

One observation that turned out to be related to the movement of tectonic plates was the locations of volcanic eruptions and earthquakes around the world. **Volcanoes** are openings in Earth's surface, that, when active, spew out gases, chunks of rock, and melted rock. An **earthquake** is a sudden, ground-shaking release of built-up energy at or under Earth's surface. Volcanic eruptions and earthquakes are dramatic events, and it would be reasonable to assume they occur everywhere. In fact, a plot of volcanoes and earthquake zones on a map reveals a particular pattern—one that outlines the boundaries between tectonic plates (Figure 12.6).

Another intriguing observation was the depth of the oceans. In 1872, the British vessel HMS *Challenger* set sail on a scientific expedition. One of the voyagers' goals was to map the ocean floors. Oceanographers were amazed to discover a long mountain range running north to south down the length of the Atlantic Ocean. This range lay right along the middle of the ocean floor, which earned it the name **Mid-Atlantic Ridge** (Figure 12.7). Scientists wondered what forces could have produced the underwater mountain range. The relationship among ocean mountain ranges, earthquakes, volcanoes, and continental drift became clearer with the development of new technologies that allowed greater ocean exploration.

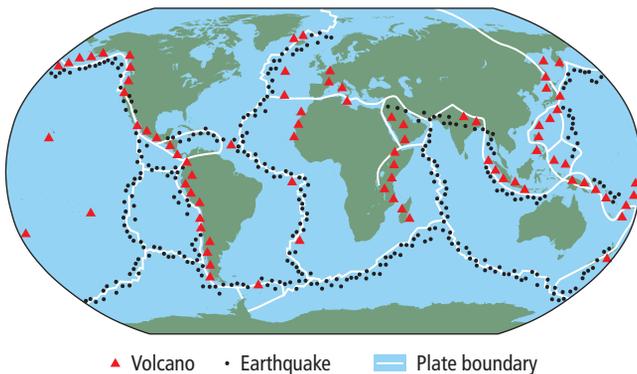


Figure 12.6 Earthquakes and volcanoes occur most often at the boundaries between tectonic plates.

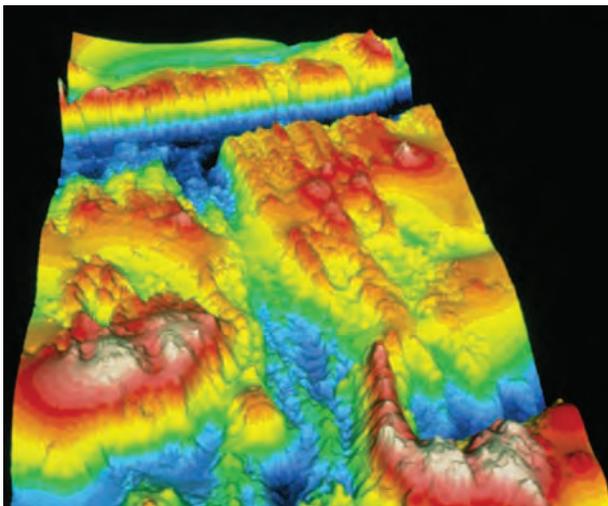


Figure 12.7 The Mid-Atlantic Ridge is a mountain range in the Atlantic Ocean. This image was made using sonar data. The colours represent the ocean's depth, from white (shallowest) to dark blue (deepest). The top of the image is the northern end.

Evidence from ocean rock and sediments

From the 1940s onwards, the drive to map the ocean floor led to many discoveries. Oceanographers made one such discovery when they took rock samples from the Mid-Atlantic Ridge to determine the age of the ocean floor. A peculiar pattern emerged: the youngest rocks were found closest to the ridge (Figure 12.8). In addition, the layer of ocean sediment—the small particles of silt and organic debris deposited on the ocean floor—became thicker the farther it was from the ridge. Initially, scientists could not explain these observations.

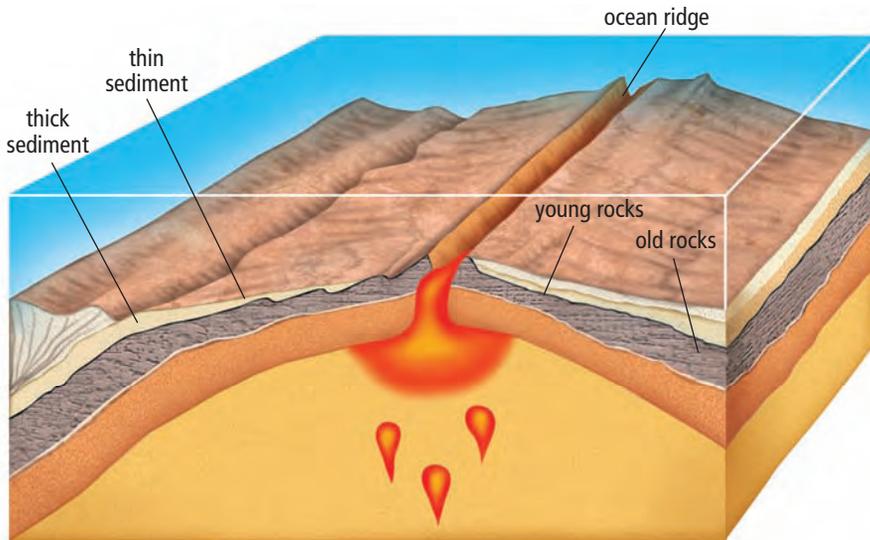


Figure 12.8 With increasing distance from the centre of a ridge, rocks on the sea floor are older and the ocean sediment is thicker.

Evidence from paleomagnetism

Like a bar magnet, Earth has north and south magnetic poles and a magnetic field. In fact, the reason that a compass needle points north is because the needle aligns with Earth's magnetic field lines (Figure 12.9). Iron and other magnetic metals in rocks also usually align with these field lines.

Earth's magnetic field is not unchanging, however. It not only changes in strength from time to time but, over thousands of years, its direction can completely reverse, a process known as **magnetic reversal**. Why this seemingly random event occurs is not well understood, but scientists think that Earth's magnetic field is produced by the motion of liquid iron in the planet's interior. If the motion of this material changes in some way, Earth's magnetic north pole becomes its magnetic south pole, and vice versa. Magnetic reversal does not affect Earth's physical appearance, and so Earth's geographic North and South Poles do not change. In the past 10 million years, Earth's magnetic poles have shifted an average of four or five times per million years.

Much like a compass needle that has been frozen in place, ancient rocks often preserve the strength and direction of Earth's magnetic field as it was when the rocks were formed. **Paleomagnetism** is the study of

Did You Know?

At the south or north magnetic pole, the needle of a compass will spin wildly! Compass readings are also affected by magnetic fields due to nearby electric transmission lines or rocks containing magnetic metals.

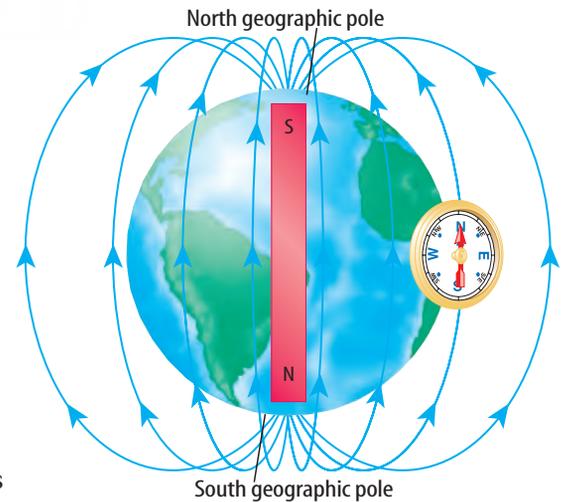


Figure 12.9 Earth is like a large bar magnet. When Earth's magnetic poles are similar to its geographic poles, as they are now, the direction of Earth's magnetic field is called normal polarity. When Earth's magnetic poles reverse so that they are opposite to Earth's geographic poles, the orientation is called reverse polarity. During a period of reverse polarity, a compass needle would point in the general direction of the geographic South Pole.

Suggested Activity

Find Out Activity 12-1B on page 514

the magnetic properties of ancient rocks. In the 1950s, oceanographers began surveying the magnetic polarity across the bottom of the Atlantic Ocean using a device called a magnetometer, which detects variations in magnetic fields. The scientists discovered a surprising pattern of stripes in the direction that iron-containing minerals pointed on the sea floor. The pattern, which they named **magnetic striping**, was repeated on both sides of the Mid-Atlantic Ridge (Figure 12.10).

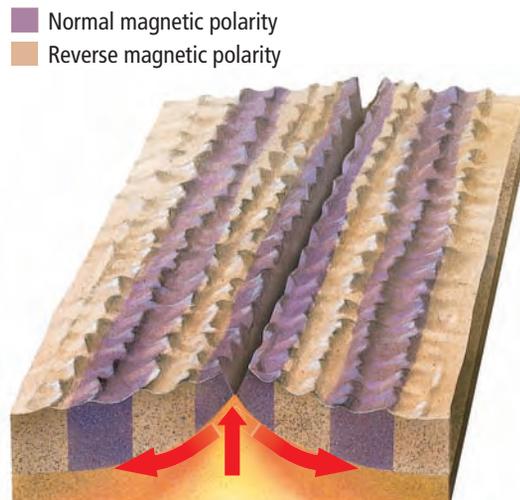


Figure 12.10 Over time, the orientation of Earth's magnetic field has reversed many times. Periods of normal polarity and reverse polarity can be detected by measuring the magnetic fields of rocks on the sea floor.

Sea floor spreading: an explanation

In 1960, an American geology professor named Harry Hess proposed an explanation that tied together data on the age of ocean rocks, sediment thickness, and magnetic striping. He suggested that **magma**—molten rock from beneath Earth's surface—rises because it is less dense than the material that surrounds it. The magma cools and hardens when it breaks through Earth's surface, at a **spreading ridge**, forming new sea floor. As convection currents cause more magma to rise, the new magma forces apart the hardened material and, like a conveyor belt, continuously pushes older rock aside (Figure 12.11). Understanding this process, which Hess called **sea floor spreading**, was an important step in developing a theory about tectonic plate movement.

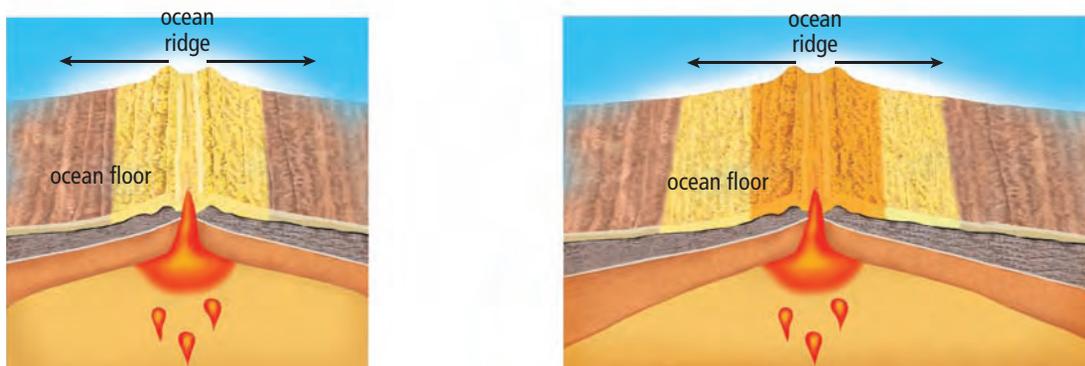


Figure 12.11 Convection currents under Earth's surface may cause magma to rise, which causes the sea floor to spread apart.

Table 12.1 Hess's Evidence for Sea Floor Spreading

1. Earth is like a large bar magnet and has two poles.
2. New ocean floor forms when magma from under Earth's surface rises, cools, and hardens at an ocean ridge. New magma pushes older rock away from the ridge.
3. The magma is molten basalt, a dark rock that is rich in iron. As the basalt cools, it becomes magnetic.
4. The magnetic minerals in the hardened basalt are like tiny compass needles that align with Earth's magnetic field.
5. Earth's magnetic poles reverse over hundreds of thousands of years.
6. Minerals in the basalt keep the alignment they had when the rock cooled. Therefore, some portions of hardened rock will have normal polarity, and others will have reverse polarity.
7. Rocks with magnetic striping, alternating bands of normal and reverse polarity, surround ocean ridges.
8. The pattern of magnetic striping is the same in rocks on either side of an ocean ridge.
9. Ocean sediments are thicker the farther away they are from a ridge. This is because the oldest rock is farthest from the ridge and has had the most time to accumulate sediments.

In the mid-1960s, Canadian geologist J. Tuzo Wilson released a scientific paper that combined the concepts of sea floor spreading and paleomagnetism to explain continental drift. Wilson suggested that chains of volcanic islands, such as the Hawaiian Islands, were formed when a tectonic plate passed over a stationary hot spot (Figure 12.12). A geologic **hot spot** is an area where molten rock rises to Earth's surface. The figure shows a map view of the Hawaiian Islands, which are in a row.

Wilson thought that continents must break up at certain areas, move across Earth's surface, and then rejoin. His hypothesis explained the formation of mountains and ocean basins and the cause of earthquakes and volcanic eruptions. Wilson's hypothesis also gave a reason for the movement of tectonic plates and helped explain the transformation of rocks from one type to another in the rock cycle. Later named the **plate tectonic theory**, it is considered the unifying theory of geology.

Reading Check

1. What is a tectonic plate?
2. What is the Mid-Atlantic Ridge?
3. Describe the orientation of Earth's magnetic field during a period of normal polarity.
4. What is a geologic hot spot?



Figure 12.12 J. Tuzo Wilson was the first person to suggest that the Hawaiian Islands were formed by a tectonic plate passing over a hot spot, where magma rose up from under Earth's surface. As the tectonic plate moved in the direction of the arrow, new islands formed, resulting in a chain of islands.

Explore More

The break-up of Pangaea about 200 million years ago was not the first time tectonic plate movement has rearranged Earth's continents. Geologists believe there were two, or possibly three, supercontinents before Pangaea. Find out how the continents have shifted over time. Start your search at www.bcsience10.ca.

12-1B Sea Floor Spreading and Magnetic Striping

Find Out ACTIVITY

Sea floor spreading provides a basis for the process of continental drift. In this activity, you and a partner will analyze the pattern of magnetic stripes on opposite sides of a ridge.

Safety

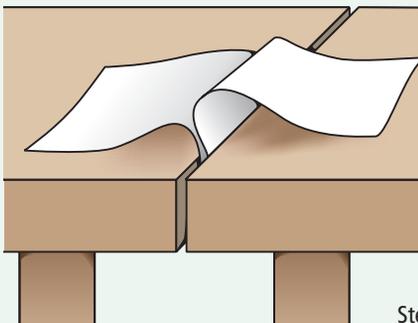


- Be careful when handling the scissors.

Materials

- 28 cm × 43 cm piece of paper
- scissors
- 2 different colour felt pens or paints
- 2 small tables
- ruler
- calculator (optional)

What to Do



Step 4

1. Fold the sheet of paper in half lengthwise. Cut the sheet along the fold.
2. Put a tick mark on each paper strip every 2 cm. The distance between each tick mark will represent an interval of 1 million years.
3. Push together two small tables, leaving a small (0.5 cm) gap between them. The gap will represent a spreading ridge.
4. Place the two strips of paper with the marked sides together. From underneath the tables, thread the paper strips through the gap. Pull up the paper strips so that about 3 cm of paper is exposed. Bend the paper so that the end of one strip lies flat on the left side of the gap and the other lies flat on the right side of the gap.
5. Have one partner colour across the gap between the tables and onto both pieces of paper. The width of the coloured section of paper should be no more than 3 cm on either side. This colour will be associated with a period of normal polarity.
6. Have the other partner pull the paper strips in opposite directions across each tabletop. Pull the paper strips only a few centimetres at a time. The exposed paper simulates the new ocean floor, which continuously forms at a spreading centre. As new sea floor is formed, older material is pushed away from the ridge.
7. Repeat steps 5 and 6, this time using a different colour. This colour will be associated with a reversal of Earth's magnetic field to reverse polarity.
8. Repeat steps 5 to 7, alternating between the two colours, until you have used the full length of the paper strips. Once finished, leave the papers laid end to end across the gap while you complete the following questions.
9. Clean up and put away the equipment you have used.

What Did You Find Out?

1. (a) Compare the pattern of stripes on the two strips of paper. In this model, how often did magnetic reversals occur?
(b) What does the pattern of stripes indicate about the direction of the motion of tectonic plates on either side of a ridge?
2. How can you use the striped pattern to measure the rate of sea floor spreading?
3. Rate = $\frac{\text{distance}}{\text{time}}$ In order to calculate the rate of sea floor spreading (that is, the rate at which the plates are moving away from one another), what information would you have to obtain about the sea floor?
4. How convincing do you find magnetic striping to be as evidence for sea floor spreading? Explain.
5. In this activity, you eventually reached the end of the paper strips. Would sea floor spreading end in the same way? Explain.

Skill Check

- Observing
- Predicting
- Communicating
- Modelling

Safety

- Be careful when handling the scissors.

Materials

- photocopy of continents
- scissors
- 21.5 cm × 28 cm sheet of paper
- glue

Science Skills

Go to Science Skill 2 for help with stating an hypothesis.

Scientists have used many separate lines of evidence to determine how the continents might once have fit together. In this activity, you, too, will use various pieces of evidence to reconstruct the supercontinent Pangaea.

Question

How did the continents fit together before Pangaea broke apart?

Procedure

1. Obtain a photocopy of the continents from your teacher. Cut out each continent, trimming the pieces just to the edge of the dotted lines. The dotted lines represent the true continental edges, the continental shelves.
2. Use the clues provided in the legend below and the shapes of the continents to help you reconstruct Pangaea. Piece together the continent shapes into a supercontinent on a separate piece of paper, but do not glue them down yet.
3. Once you have assembled your pieces, check with your teacher before gluing them to the blank sheet of paper.
4. Copy the legend below onto the paper with your map of Pangaea.
5. Clean up and put away the materials you have used.

Fossils	Glacial Deposits	Matching Folded Mountains	Coal Deposits

Analyze

1. Which continents were easiest to fit together? Explain why.
2. Of the pieces of the evidence that you used to reconstruct Pangaea, which provided the best clues as to how the continents were once joined? Justify your answer.
3. (a) Were there any pieces of Pangaea that you found difficult to place?
(b) If so, what other evidence would have helped you to place these pieces?

Conclude and Apply

1. (a) In a few sentences, summarize the steps you took to reconstruct Pangaea.
(b) How was the process you took similar to the methods Alfred Wegener used to support the continental drift theory?
2. Why did you use several pieces of evidence to reconstruct Pangaea, not just one?
3. (a) Hypothesize where the continents might be situated in 200 million years.
(b) Describe how ecosystems of British Columbia's west coast might change as a result. Justify your answers.

Science Watch

Extracting Earth's Energy

One day, energy from underground may heat, cool, and provide electrical power to homes across British Columbia. With increasing awareness of the environmental impact of fossil-fuel use, more people are looking for cost-effective alternative energy sources. One of the more promising sources is geothermal energy—thermal energy from Earth's core.

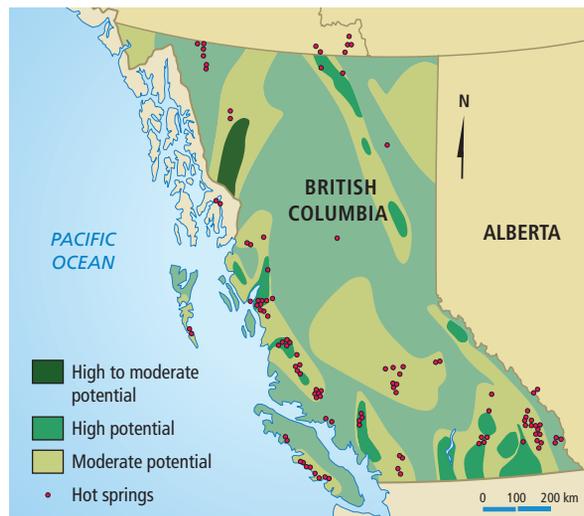
In some areas, molten rock just below Earth's surface heats underground water. This natural process, which occurs at the boundaries between tectonic plates, produces hot springs and steamy spurts of water known as geysers at Earth's surface. The steam can be used to turn turbines in order to generate electrical power. In Iceland, where there are many geysers, geothermal power plants are common. The first geothermal power plant in Canada is the South Meager Geothermal Project near Pemberton, British Columbia, where geologists have found a magma chamber not far underground.



Geothermal power plant in Iceland

Geothermal energy can also be used for heating and cooling buildings. Unlike most heating systems, which burn fuel in order to heat air, geothermal heat pumps transfer hot water from place to place. In order to heat a building, water is sent through pipes underground. Thermal energy from under Earth's surface heats the water, which is pumped back above ground. The hot water releases thermal energy, which warms the building. In order to cool

a building in summer, the geothermal heat pump works in reverse. Warm water from inside the building is sent through pipes to the outside where the ground is relatively cool. Thermal energy is transferred from the water to the ground, and the cooled water is pumped back to the building.



Sources of geothermal energy in British Columbia

Geothermal heat pumps are inexpensive to operate, non-polluting, and use renewable energy. Like geothermal power plants, geothermal heat pumps are gaining popularity with developers in British Columbia. Some researchers suggest these methods could meet about 50 percent of the province's energy needs.

Questions

1. What is geothermal energy?
2. What are two ways in which people can use geothermal energy?
3. List three benefits of using geothermal energy.

Check Your Understanding

Checking Concepts

1. What is a supercontinent?
2. List three pieces of evidence that indicate that continental drift occurred in the distant past.
3. Briefly describe two pieces of evidence that suggest that Antarctica was once located farther from the South Pole than it is today.
4. What is sea floor spreading?
5. What is the relationship between continental drift and earthquakes?
6. Describe the theory of plate tectonics in your own words.

Understanding Key Ideas

7. Coal deposits form when plant matter sinks under water, begins to decompose, and is compressed. Explain how the presence of coal deposits in Siberia, northern Canada, and the Antarctic support the continental drift theory.
8. Despite the evidence Wegener found to support the continental drift theory, the scientific community of his day thought the idea of moving continents was ridiculous. What crucial question could Wegener *not* answer that might have changed other scientists' minds?
9. Why does the thickness of ocean floor sediments increase the farther they are from a ridge?
10. How does sea floor spreading explain the movement of tectonic plates?
11. Suppose a geologist is studying two distinct areas next to a spreading ridge. The magnetic direction of the minerals in the oldest area is opposite to the magnetic direction of minerals in the newest area.
 - (a) Which area is closest to the centre of the ridge, the older or newer area? Explain.
 - (b) What can the geologist conclude about Earth's magnetic field during the time when the two areas formed?

12. In a few sentences, explain how information from paleoglaciology and paleomagnetism support the idea that continental plates have moved over the past several million years.

Pause and Reflect

A marsupial is a type of mammal that carries its undeveloped young in an abdominal pouch. Scientists believe that many kinds of marsupials once lived throughout the world. Today, however, many marsupials are found only in Australia. How does the continental drift theory explain the modern distribution of marsupials? Use the diagram shown here to help you answer this question.



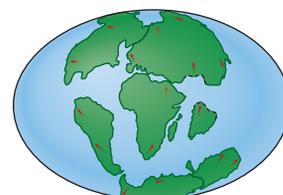
200 million years ago



180 million years ago



135 million years ago



65 million years ago



Present