

Section 1

Earth's Structure

Key Concept Earth is composed of several layers. The continents are part of the uppermost layer, and they move slowly around Earth's surface.

What You Will Learn

- Earth's interior can be divided into layers based on chemical composition and physical properties.
- Scientists use seismic waves to study Earth's interior.
- Continents are drifting apart from each other now and have done so in the past.

Why It Matters

The way Earth's layers interact causes major geologic events, such as earthquakes and volcanoes, to happen.

If you tried to dig to the center of Earth, what do you think you would find? Would Earth be solid or hollow? Would it be made of the same material throughout?

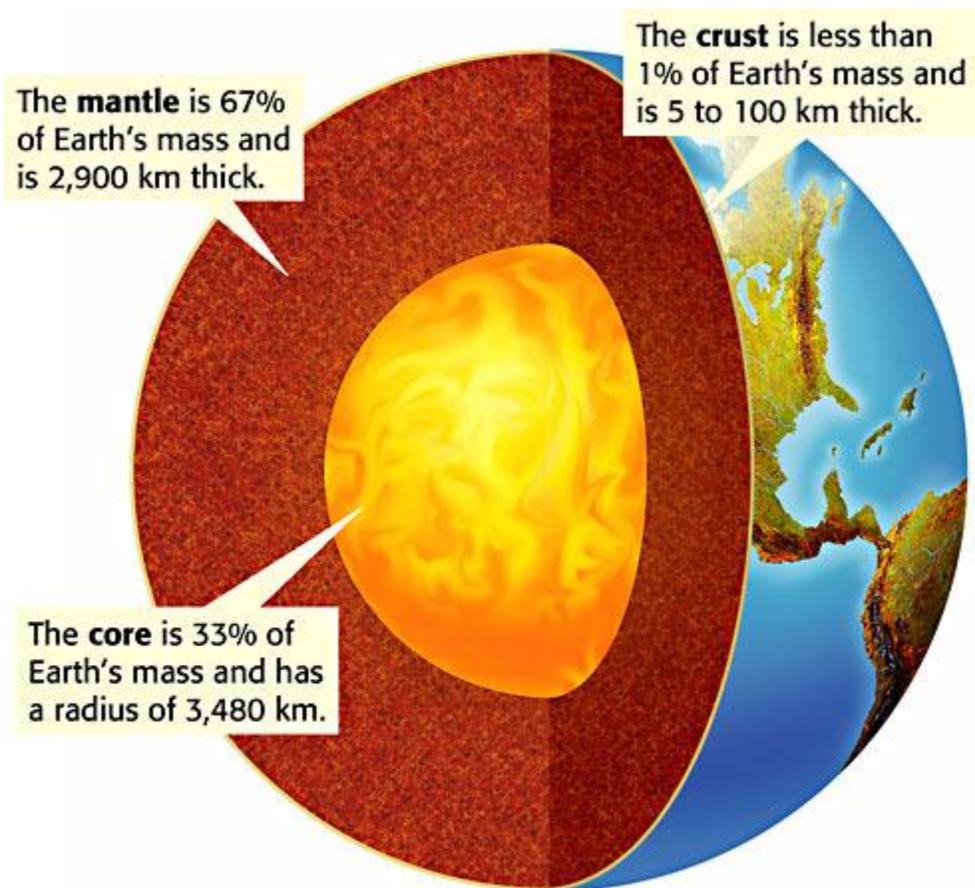
The Layers of Earth

Actually, Earth is made of several layers. The types of materials that make up each layer vary from layer to layer. The materials in each layer have characteristic properties. Scientists think about Earth's layers in two ways—in terms of their chemical composition and in terms of their physical properties.

The Compositional Layers of Earth

Figure 1 shows how Earth is divided into three layers based on chemical composition. In Earth's center is the dense, metallic **core**, which is made up mainly of the metal iron. The dense, thick middle layer is the **mantle**. The mantle is made up largely of silicon, oxygen, and magnesium. The surface layer, or **crust**, is composed mostly of silicon, oxygen, and aluminum.

Figure 1 Earth's Compositional Layers



Standards Check Describe Earth's compositional layers.

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Continental and Oceanic Crust

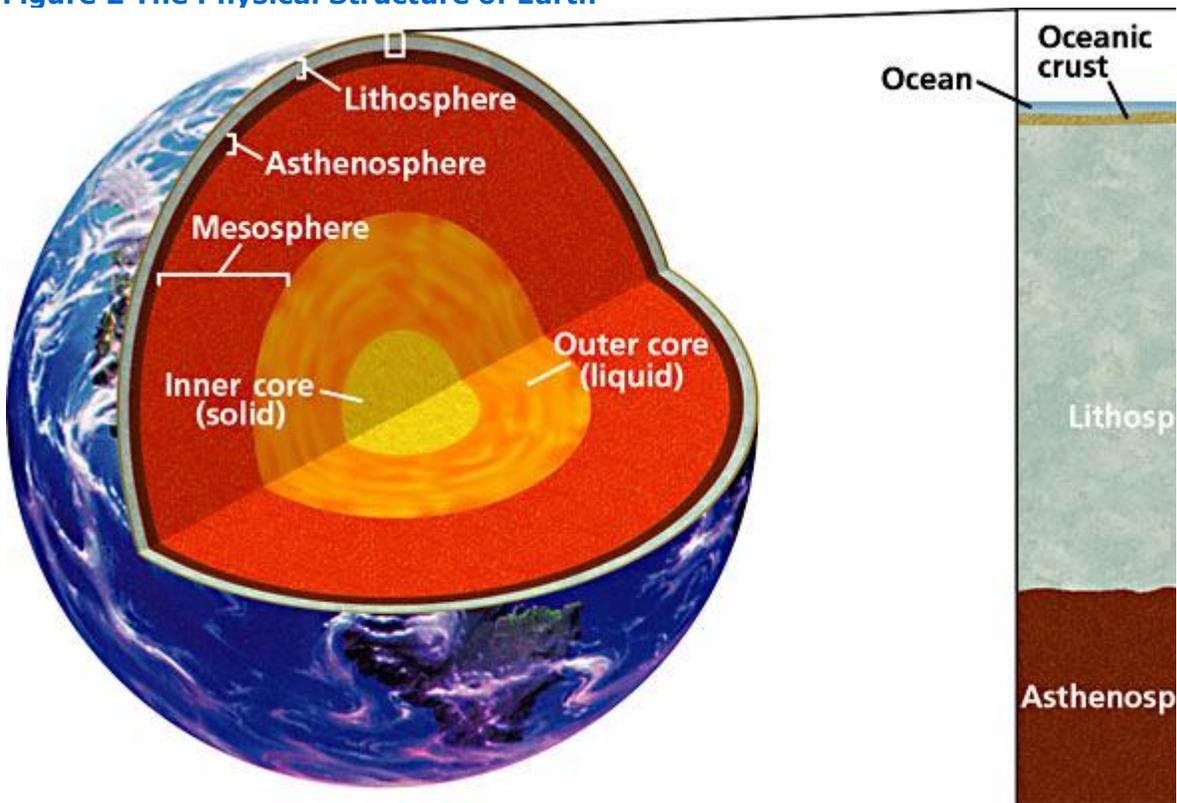
There are two types of crust: continental and oceanic. Continental crust is thicker than oceanic crust. Both types are made mainly of the elements oxygen, silicon, and aluminum. But oceanic crust has almost twice as much iron, calcium, and magnesium as continental crust does. These three elements form minerals that are denser than the

minerals in continental crust. These dense minerals make the thin, oceanic crust heavier than the thicker continental crust. But compared with Earth's other layers, both types of crust are rocky, thin, and fractured.

The Physical Structure of Earth

Figure 2 shows how Earth is divided into five layers based on physical properties. Earth's outer layer is the **lithosphere**, which is a cool, rigid layer that includes the crust and the upper part of the mantle. The lithosphere is divided into pieces called *tectonic plates*. Below the lithosphere is the **asthenosphere**, which is a layer of the mantle that is made of very slow-flowing solid rock. This property of flow allows tectonic plates to move on top of the asthenosphere. Below the asthenosphere is the *mesosphere*, which is the lower part of the mantle. The mesosphere flows even more slowly than the asthenosphere.

Figure 2 The Physical Structure of Earth



Earth's core has two layers. The *outer core* is a layer of liquid iron and nickel. At Earth's center is the solid *inner core*. This layer is made mostly of iron and nickel. The inner core's temperature is estimated to be between 4,000°C and 5,000°C. The inner core is very hot, but it is solid because it is under enormous pressure.

Mapping Earth's Interior

How do scientists know about the interior parts of Earth? They have never even drilled through the crust, which is only a thin skin on the surface of the planet. So, how do we know about Earth's mantle and core?

Some of the answers to these questions come from earthquakes. An earthquake produces vibrations called *seismic waves*. Seismic waves travel through Earth at various speeds. Machines called *seismometers* measure the time seismic waves take to travel various distances from an earthquake's center. Scientists use these distances and times to calculate the density and thickness of Earth's layers.

The speed of seismic waves is affected by the type of material that the waves are traveling through. For example, some types of waves can travel through rock but not through liquids. Scientists have found that such waves do not reach seismometers on the side of Earth opposite the earthquake. So, part of Earth's interior must be liquid. This liquid layer is the outer core. **Figure 3** shows how seismic waves travel through Earth.

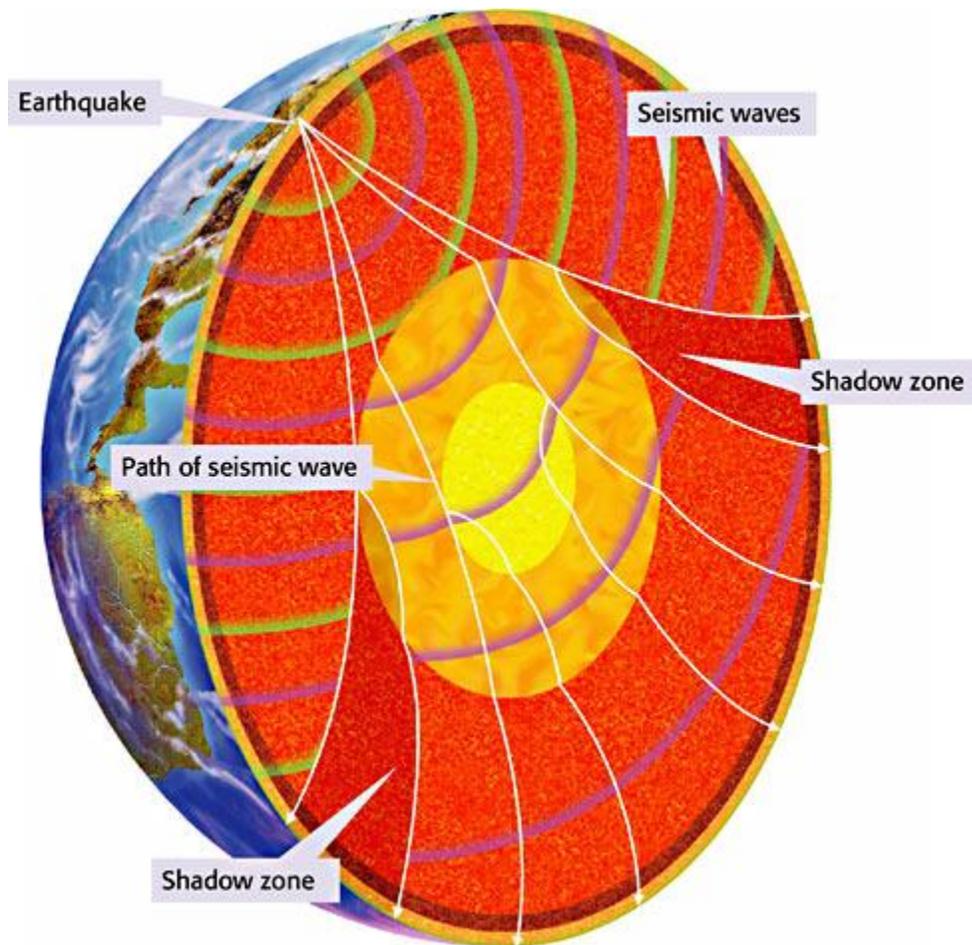


Figure 3 By measuring changes in the speed of seismic waves that travel through Earth's interior, scientists have learned that Earth is made up of several layers. Shadow zones are places where no seismic waves are detected. Each earthquake has its own shadow zone.

Standards Check How are seismic waves used to map Earth's interior?

□



Continental Drift

Have you ever looked at a map of the world and noticed how the coastlines of continents on opposite sides of the oceans appear to fit together like the pieces of a puzzle? Is it just coincidence that the coastlines appear to fit together well?

Restless Continents

Alfred Wegener (VAY guh nuhr), a scientist, studied these puzzle pieces. In the early 1900s, he wrote about his hypothesis of *continental drift*. **Continental drift** is the idea that a single large landmass broke up into smaller landmasses to form the continents, which then drifted to their present locations. This idea explains how the continents seem to fit together.

Evidence for Continental Drift

Continental drift also explained why fossils of the same plant and animal species are found on continents that are far from each other. Many of these ancient species could not have crossed an ocean. **Figure 4** shows that continental drift explains such a pattern of fossil locations. The locations of mountain ranges and of similar types of rock also show this pattern. Scientists have used rock and fossil evidence to reconstruct past patterns of climate regions. The distribution of these ancient climatic zones supports the idea of continental drift, too.

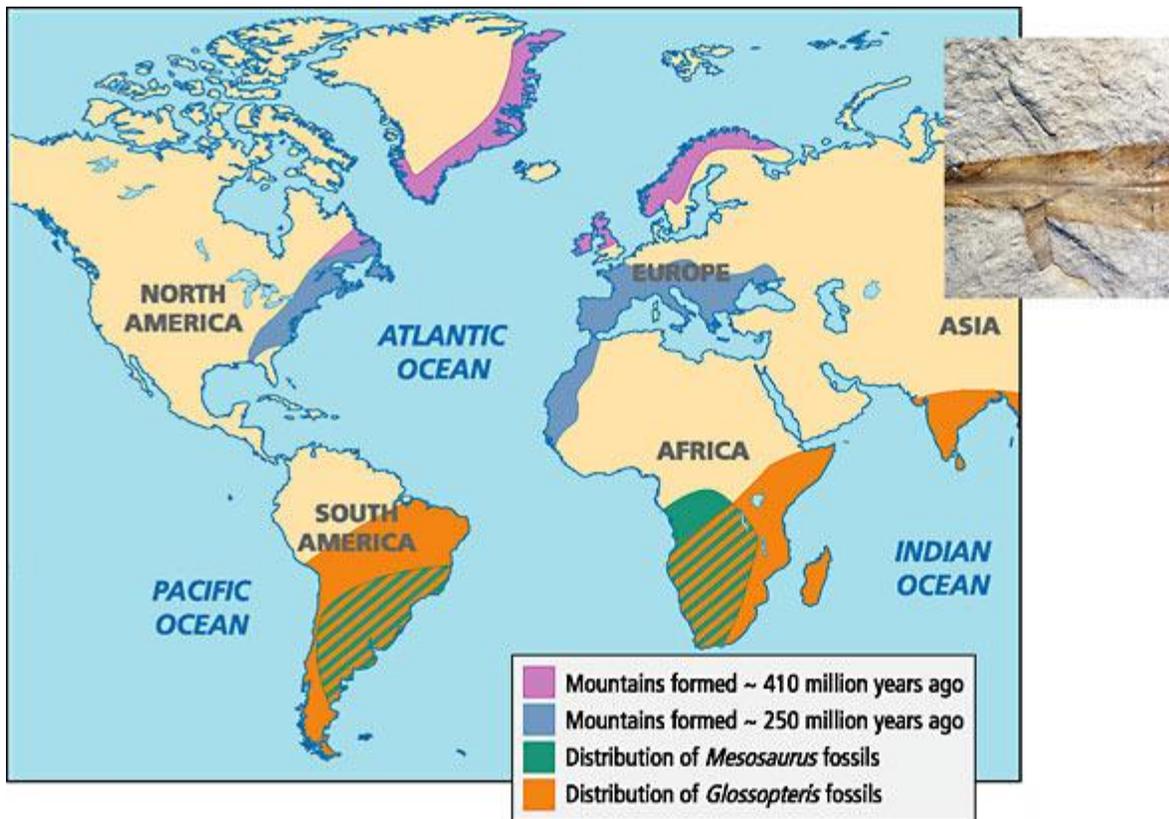


Figure 4 Fossils of organisms such as *Mesosaurus* and *Glossopteris* were found in both South America and western Africa. The map shows mountain chains of similar ages that exist on separate continents that are far from each other.

Standards Check List three lines of evidence for continental drift.

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The Breakup of Pangaea

Wegener made many observations before proposing that a single large continent gave

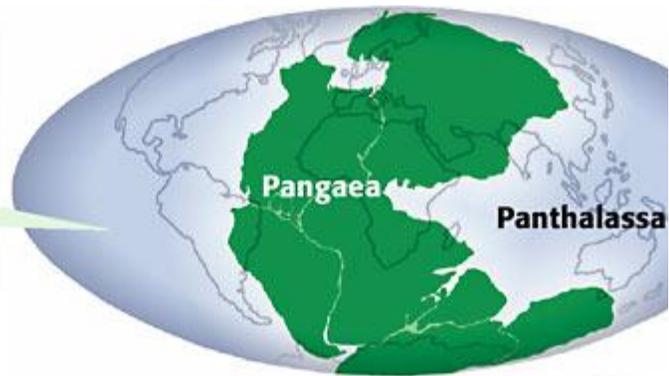
rise to today's continents. He called this single large continent *Pangaea* (pan JEE uh), which is Greek for "all Earth."

By using many geological observations, scientists have determined that Pangaea existed about 245 million years ago. Pangaea split into two continents—Laurasia and Gondwana—about 135 million years ago. As shown in **Figure 5**, these two continents split again and formed the continents of today. The continents slowly moved to their present positions. As the continents drifted, they collided with each other, which caused landforms such as mountain ranges, volcanoes, ocean trenches, and midocean ridges to form.

Figure 5 The Drifting Continents

245 Million Years Ago

Pangaea existed when some of the earliest dinosaurs were roaming Earth. The continent was surrounded by a sea called *Panthalassa*, which means "all sea."



135 Million Years Ago

Gradually, Pangaea broke into two big pieces. The northern piece is called *Laurasia*. The southern piece is called *Gondwana*.



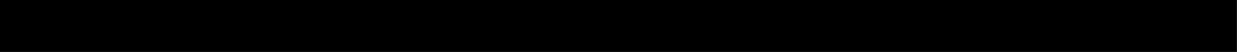
65 Million Years Ago

By the time the dinosaurs became extinct, Laurasia and Gondwana had split into smaller pieces.



Standards Check Briefly describe the movement of the continents over the past 245 million years.

□



Sea-Floor Spreading

When Wegener put forth his hypothesis of continental drift, many scientists would not accept his hypothesis. The calculated strength of rock made such movement of Earth's crust seem impossible. During Wegener's life, no one was able to prove his hypothesis. Not until many years after Wegener's death did scientists find evidence of forces that moved continents.

Mid-Ocean Ridges—a Magnetic Mystery

A chain of submerged mountains runs through the center of the Atlantic Ocean. This mountain chain is part of a worldwide system of mid-ocean ridges. Mid-ocean ridges are underwater mountain chains that run through Earth's ocean floor.

In the 1960s, scientists who were studying the ocean floor discovered a strange property of mid-ocean ridges. As part of their research, these scientists dragged a magnetic recorder through the water above a mid-ocean ridge. They discovered patterns of magnetism in the sea-floor rocks! The pattern they observed on one side of the ridge was a mirror image of the pattern on the other side of the ridge, as shown in **Figure 6**. Why were the rocks magnetized? What could have caused this pattern in the rocks? The scientists determined that the magnetism of the rocks aligned with Earth's magnetic field as it was when the rocks formed.

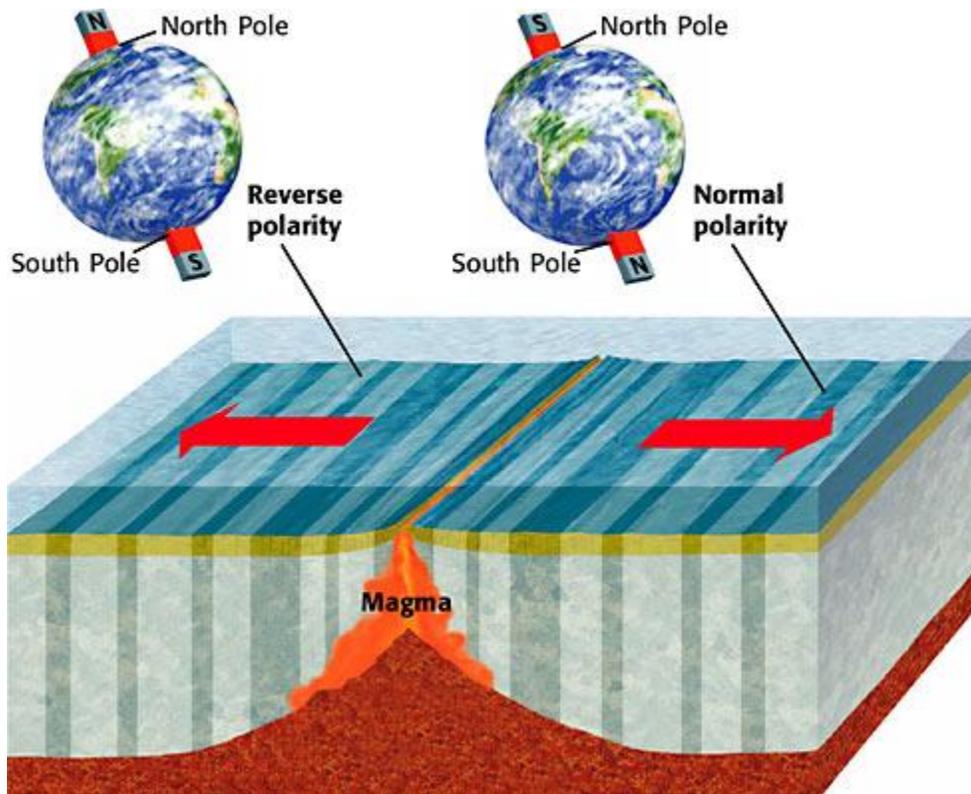


Figure 6 Magnetic reversals in the lithosphere are shown as bands of dark blue and light blue. Dark blue bands indicate rocks whose magnetism matches today's magnetic field. Light blue bands indicate rocks whose magnetism is opposite to today's magnetic field.

Magnetic Reversals—Mystery Solved

Throughout Earth's history, the north and south magnetic poles have changed places many times. The process by which Earth's magnetic poles change places is called *magnetic reversal*. So, how does this process explain the magnetic patterns on the sea floor?

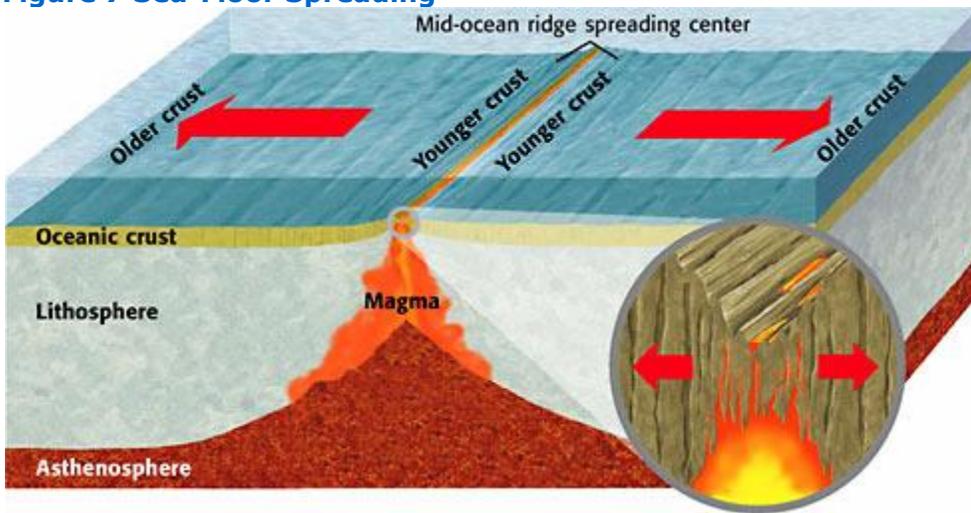
As rock forms from magma, or molten rock, minerals that contain iron form. Some of these minerals are magnetic and act like compasses.

They form so that their magnetic fields align with the magnetic field of Earth. When the molten rock cools, these tiny compasses are locked in position in the rock. After Earth's magnetic field reverses, new magnetic minerals that align in the opposite direction form.

Sea-Floor Spreading

At a mid-ocean ridge, magma rises through fractures in the sea floor. As the magma cools, it forms new rock. As this new rock forms, the older rock gets pulled away from the mid-ocean ridge. The process by which new sea floor forms as old sea floor is pulled away is called **sea-floor spreading**, and is shown in **Figure 7**.

Figure 7 Sea-Floor Spreading



As it spreads away from a mid-ocean ridge, the sea floor carries with it a record of magnetic reversals. This record of magnetic reversals provides evidence that the continents are moving. Sea-floor spreading is now known to be a mechanism by which continents move.

Section Summary

- Earth is made up of three layers—the crust, the mantle, and the core—based on chemical

composition. Of these three layers, the core is made up of the densest materials. The crust and mantle are made up of materials that are less dense than the core.

- Earth is made up of five layers—the lithosphere, the asthenosphere, the mesosphere, the outer core, and the inner core—based on physical properties.
- Knowledge about the layers of Earth comes from the study of seismic waves caused by earthquakes.
- Wegener hypothesized that continents drift apart from one another now and that they have drifted in the past.
- Magnetic reversals that occur over time are recorded in the magnetic pattern of the oceanic crust, which provides evidence of sea-floor spreading and continental drift.
- Sea-floor spreading is the process by which new sea floor forms at mid-ocean ridges.

