## 2.4 Read

# *What Do Scientists Know About Earth's Surface and Interior?*

**composition:** the parts, ingredients, or elements that form a whole.

Earth's crust is very thick, and scientists may never be able to observe Earth's interior directly by going through the crust. But when a volcano erupts, material is ejected. When scientists examine these materials, they can learn more about what materials make up the layers of Earth.

Scientists also use data collection tools to gather information about the movement of Earth's crust. Areas where earthquakes occur provide much of this data. Using all these observations, geologists have inferred a great deal about the structure and characteristics of the crust and interior layers of Earth.

You have read that Earth consists of three main layers—the crust, mantle, and core. The crust is the rocky, outermost layer. The mantle is the midsection, and the core is the center. Each layer has its own characteristics and **composition** —the parts, ingredients, or elements that form a whole. As you read this section, make note of the differences and similarities among the layers, the order of the layers, and how they might interact with one another.

*Seismologists study Earth's interior by making inferences from their observations of Earth's surface using several tools and techniques. This seismologist is checking the temperature under the surface at a volcano.*

Be a Scientist

## How Do Scientists Study Earth's Interior?

Studying Earth's interior is a challenge to geologists because they cannot observe it directly. Geologists must make inferences about Earth's interior based on observations made at Earth's surface. You used observations made outside of the mystery boxes to identify the object inside. But what can geologists observe?

The main tool geologists use to probe Earth's interior is **seismology,** the study of the **seismic waves** from earthquakes that travel through Earth. Seismic waves change speed and bend as they cross the boundary between two substances that differ in **density**.

One type of earthquake wave can travel through solids but not through liquids. After a large earthquake, there are places where none of these waves are detected. From this, geologists have inferred that the outermost part of the Earth's core is a liquid.

Scientists make some inferences about the composition of Earth's interior by studying pieces of Earth's interior carried to the surface in volcanic eruptions. These pieces may include chunks of mantle material. These chunks of mantle rock can be studied for their composition and structure. Unfortunately, these chunks come only from the uppermost parts of the mantle. Therefore, geologists still cannot observe samples from the deepest parts of Earth.

**seismology:** the study of earthquakes and the structure of Earth, using information from seismic waves.

**seismic waves (earthquake waves):** a general term for waves produced by earthquakes or artificially through explosions.

**density:** the mass of quantity of a substance per unit volume.

*Shiprock Peak, located in New Mexico, is what remains of an extinct volcano. The rocks, contain chunks of mantle rock. This is rock that scientists can observe to make inferences about Earth's interior composition.*

Another way scientists infer what is beneath Earth's surface is by subjecting rocks on the surface to the extremely high temperatures and pressures of Earth's interior and observing what happens. To do this, they build machines that model the high temperatures and pressures of Earth's mantle and core. Using these machines, they examine what happens to rocks under these conditions. They pass vibrations through these experimental rocks in the lab to see if the vibrations match observations of seismic waves that pass through actual rocks in the mantle and core.

*This lab is like an extreme kitchen, where furnaces and pressure vessels that simulate the temperatures and pressures of Earth's mantle are used to "cook" rocks.*

Scientists also make inferences about Earth's composition based on what they know about the origin of our planet. There is much evidence that Earth formed from a cloud of debris, some of which remains in the form of **meteors** and asteroids. A meteor is a streak of light in the night sky that results when a solid object (a meteoroid) hits Earth's atmosphere. Analyzing the composition of **meteorites**, meteors that are large enough to survive passage through Earth's atmosphere and hit the ground, provides evidence of Earth's original composition. Geologists compare Earth's original composition to that of the crust and upper mantle to see what is missing. They then make inferences about what is in the lower mantle and core.

*Earth originally formed from solar system debris such as these iron and stony meteorites. Studying the composition of meteorites provides evidence of Earth's original composition.*

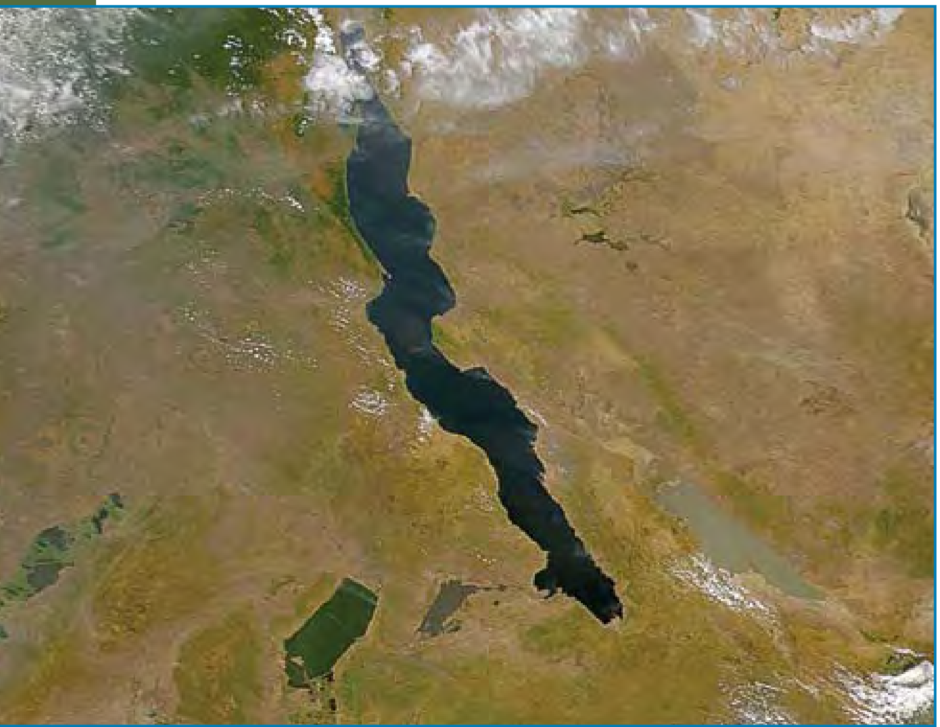
**meteor:** a streak of light in the night sky that results when a small, solid object (a meteoroid) hits Earth's atmosphere.

**meteorite:** a meteor that is large enough to survive its passage through Earth's atmosphere and hit the ground.

# Earth's Crust

## Plates

*The divide seen in the photograph is a plate boundary in the African Rift Valley.*



Imagine Earth's surface with all of the trees, plants, and water removed. You would see a layer of rock forming an outer shell. This layer is brittle compared to the other layers of Earth. You would see large cracks in the surface, making the crust resemble the cracked egg Benny wrote about. The pieces are the plates that make up Earth's surface. These plates are made of the crust along with the solid, uppermost part of the mantle.

The photographs you saw earlier provide evidence of movement on Earth's surface. Using this evidence, you inferred that Earth's plates move. This inference is correct. Other evidence, such as how the plates fit together, indicates that the plates are moving. Plates can move toward or away from other plates. Plates can also slide past other plates. The areas around the edges of Earth's plates are called **plate boundaries**. Plate boundaries are some of the most geologically active parts of Earth's surface. Most earthquakes, volcanoes, and mountain formations occur near plate boundaries.

**plate boundary:** the area along the edges of Earth's plates.

**energy:** the ability to cause matter to move or change.

**fault:** a fracture (break or crack) through rock, along which the masses of rock on either side of the fracture move.

## Plate Movement

The movement of the plates causes several different geologic events. Sometimes one plate slides past another. The rocks at the plate boundary can stick together as the plate slides by the other. The sticking causes great amounts of **energy** to build up at the plate boundary. Energy is the ability to cause matter to move or change. When the plates finally move past each other, the energy is released. This can cause Earth's crust to crack. This crack, or fracture, through rock, along which the masses of rock on either side of the fracture move, is called a **fault**.

When two plates move toward each other, they can collide. This also results in the release of a lot of energy. Imagine the tremendous force resulting from two large sections of Earth's crust colliding. This force puts strain on the rocks, and friction between the two plates results in high heat that may melt the rocks. Over a very long time, this movement, friction, and strain can cause Earth's crust to form **folds,** or bends. These folds are one kind of mountain. Whether or not this happens depends on the temperature, amount of force and strain, and the type of rock. The Appalachian Mountains resulted from many folds forming in Earth's crust. This mountain range extends 2400 km (1500 mi) through the eastern United States, north to Canada.

*You can see the bends, or folds, in the rock that makes up the Appalachian Mountains.*

**fold:** a bend in rocks.

**fault-block mountains:** mountains that form when one side of a fault is lifted above the other side.

Sometimes the changes that result from moving plates are very complicated. For example, mountains may form along faults. When one side of a fault is lifted above the other side, **fault-block mountains** may form. Slowly, over millions of years, the uplifted side may rise miles above the other side. One example of fault-block mountains is the Grand Teton Mountain Range, part of the Rocky Mountains. This mountain range extends 65 km (40 mi) along the western border of Wyoming.

*Faulting in one part of the Rocky Mountains formed the Grand Teton Mountains. Part of the Teton fault can be seen at the base of the small cliff visible near the bottom of the mountain.*

## Characteristics of Earth's Crust

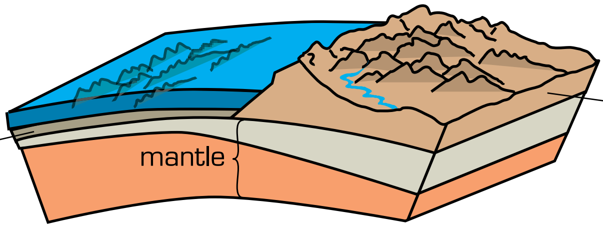
Scientists are constantly making new discoveries about Earth's crust. They use many new technologies to collect data and connect it with what they already thought they knew. Earth's crust is composed of many different minerals and chemical elements. Some of the rocks break more easily than others. Some of Earth's crust is covered with water, and some of it is high above sea level.

**oceanic crust:** the parts of Earth's crust that are under the ocean; these are the thinnest parts.

**continental crust:** the parts of Earth's crust that form the continents.

Earth's crust varies in thickness from 5 to 70 km (3 to 43 mi). The thinnest parts of the crust are under the oceans. These parts are called **oceanic crust**. The thickest parts of the crust are the continents. These parts are called **continental crust**. For example, the crust under the ocean is only about 5 km (3 mi) thick, and the continental crust in the Himalayan Mountains, where Mount Everest is located, is 75 km (47 mi) thick.

Although continental crust is thicker than oceanic crust, geologists know that the rocks making up the continental crust are less dense, with the particles of rock less packed together than those making up the oceanic crust. On average, the continental crust has a density of 2.7g/cm$^3$ and the density of the oceanic crust is 3.0 g/cm$^3$. You will learn more about density later in this *Learning Set*.




*The crust beneath Earth's oceans is much thinner than the crust that makes up the continents.*

## Earth's Mantle

If it were possible for you to travel down through Earth's crust, you would find that the next layer, the mantle, is very different. Mantle rock is made up of minerals that are denser, darker in color, and have higher melting points than those in the crust. Mantle density ranges from 3.3–5.7 g/cm$^3$ compared to 2.7–3.0 g/cm$^3$ in the crust. Scientists cannot directly study materials found here. They can re-create these conditions in the laboratory and study rocks found at the surface that they think come from the interior of Earth.

The mantle is much hotter than the crust and is under tremendous pressure. Rock in the mantle material is so hot it would glow on Earth's surface. This mantle material flows over very long periods of time.

The mantle is also much thicker than the crust. While the thickest part of the crust is 75 km (47 mi), the mantle is about 2700 km (1800 mi) thick. Compared to the crust, the mantle is huge—occupying about 70 percent of Earth's volume compared to the one percent occupied by the crust.

Below 350 km (217 mi), the pressures in the mantle become high enough to force the rock's particles into a denser, more rigid structure. Although stiffer, the rock can still be deformed. Over millions of years, this rock can creep slowly under the influence of changes in temperature and pressure.

**lithosphere:** the rigid outer layer of Earth, made of the crust and the solid, uppermost part of the mantle.

**asthenosphere:** a region of Earth's interior immediately below the lithosphere where mantle rocks are hot enough and under enough pressure to deform, change shape, and flow.

**outer core:** the outer layer of Earth's core made of melted, liquid metal.

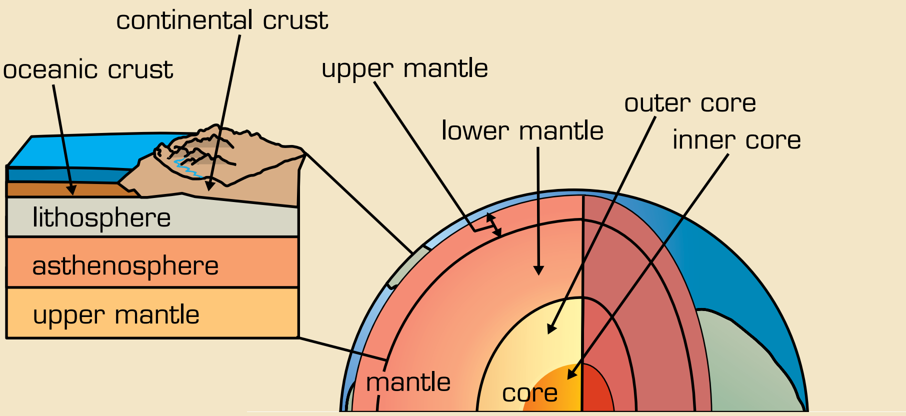
**molten:** made liquid by heat.

**inner core:** the inner layer of Earth's core believed to be made of solid iron and nickel.

### Earth's Layers

Seismologists who study Earth's interior have named layers inside Earth based on how rigid the rocks are. The rocks' rigidity affects how earthquake waves travel through the rock. Earth's outermost 100 km (62 mi) of rocks, which includes the crust and the uppermost part of the mantle, are rigid, brittle solids. This layer is called the **lithosphere**.

From about 100 km (62 mi) to as much as 350 km (217 mi), the high temperatures and pressures make the rock more flexible. Although still a solid, the rock is weak and can be easily deformed. This flexible part of Earth, within the mantle, is called the **asthenosphere**. This is the layer upon which Earth's plates move.




# Earth's Core

Deep within Earth, below the mantle, is Earth's core. Scientists have used seismic and magnetic data to determine that the core is metal, consisting mainly of iron with some nickel. The **outer core** is a layer of **molten** metal that flows very slowly.

Beneath Earth's outer core is the **inner core.** In the inner core, temperature and pressure act together to form a dense ball of solid metal. Temperatures in the inner core reach 5000°C (9032°F). At this temperature, the metals making up the core would normally melt. However, extreme pressure from the weight of the layers above squeezes the particles of iron and nickel together so tightly that they cannot move. The inner core is therefore solid. Both the inner and outer core are far more dense than Earth's mantle and crust.

## Stop and Think

1. Compare Earth's layers. Which one of the layers is the least dense? Which is the most dense? Which layer has the highest temperature? Which layer has the lowest temperature?
2. The mantle is often described as molten. Why is this word used? Compare the molten mantle to the core. The temperature of the core is higher, but it acts more like a solid? Why?

## What's the Point?

Using observations and inferences, Earth scientists have determined that Earth is made of three layers—the crust, the mantle, and the core. The crust is the outer layer, broken into large pieces called plates. The edges of the plates are called plate boundaries. These plates move and shift, resulting in earthquakes, volcanic eruptions, and changes in the topographic features of Earth. The crust is less dense than the layers under it.

Beneath the crust is the mantle. The mantle is hotter than the crust. The thickness of the mantle is also greater than that of the crust. The mantle has two layers. The outer layer is part of the lithosphere, along with the crust. The inner layer is molten. It is a solid, but it flows very slowly. The core is the center of Earth and is also divided into two layers: the outer core, which is molten metal, and the inner core, which is solid. The temperature and pressure in the core makes the inner core solid.

*The continental crust in the Himalayas is 75 km (47 mi) thick. Mount Everest, the highest mountain in the world, is part of the Himalayas.*