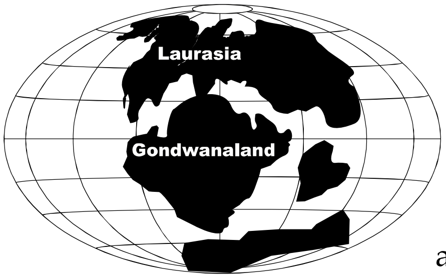
Introduction

Earth's **crust** is subject to strong forces within and on the surface of Earth. Some of these forces are pushing, pulling, pressure from within, and sliding movements. When these stresses are released, violent events often occur. **Earthquakes** and **volcanoes** are some of the results. Although Earth's crust was once thought to be stationary, we now know that it is in constant motion. This movement results in new formations on Earth's surface, including hot springs, **lava** flows, and fractured valley walls. Understanding **continental drift** and **plate tectonics**, and their theoretical effects on topography, may help us solve the mystery behind the features we see on the surface of Earth.

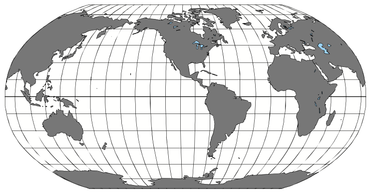
Continental Drift

The surface of Earth has seven major landmasses called **continents**. People have believed throughout history that the location of the continents was fixed. As world maps were improved, many noted that the shapes of the continents seemed to fit together like pieces of a jigsaw puzzle. This idea seemed foolish because no one understood how continents could move.



In 1912, the German meteorologist Alfred Wegener described his hypothesis of *continental drift*. He suggested that at one time all of the continents were one large landmass called **Pangaea**. Wegener believed that this giant landmass split apart and broke into two large landmasses he called *Laurasia* and *Gondwanaland*. These landmasses then broke apart and, over time, *drifted* across the ocean floor until they reached their present positions.

This hypothesis was based on several kinds of evidence. One was how the coastlines of the continents seemed to *fit* like pieces of a jigsaw puzzle. Wegener also noted that similar rock structures and fossils were found in neighboring continents across the ocean. Similarities in ancient climate were indicators, as well. His hypothesis was rejected at first, because there was no explanation for the movement of the continents.



the continents today

Further evidence in support of Wegener's hypothesis continued to be discovered. Glacial deposits and erosional scratches caused by glaciers were found in both South America and Africa. A 200-million-year-old reptile fossil was found in Antarctica that matched ones found in India and South Africa. Since Alfred Wegener's death, the theory has been generally accepted because more evidence has been found.

Earth scientists now realize that the positions of the continents are not permanent. Continents gradually move over the surface of the globe. During the 1950s and 1960s, new developments led to a broader theory known as *plate tectonics*.

Plate Tectonics

New discoveries showed that the sea floor seemed to be cracked and spreading apart. This discovery led to the theory of **plates** and plate movement. This most recent theory is called the *theory of plate tectonics*, which suggests that Earth is separated into large sections called plates—nine large ones and several smaller ones. The large plates include both continental and oceanic crust.

These plates may have separated because of **convection currents**. Convection currents transfer heat through liquids or gases. The heated material rises, and the cooler material takes its place. The difference in temperatures of the gases and liquids under Earth's crust caused movement of the plates. The plates floated on an ocean of liquid rock and gases. As the plates separated, they moved at different speeds and in different directions. Today, the plates are still moving. Scientists have measured plate movement using lasers. The plates are drifting about one to 10 centimeters a year depending on the location.

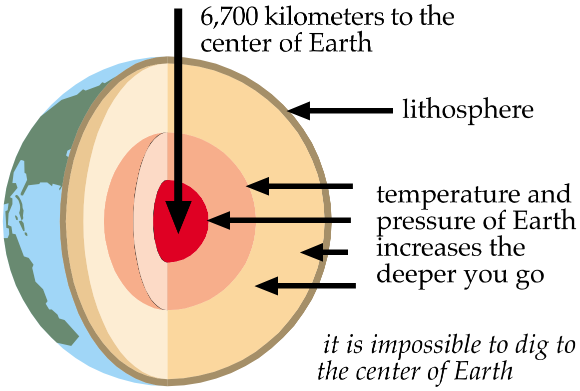
Plates may move apart (form divergent boundaries), move together (form convergent boundaries), or slide past one another (transform boundaries). These movements help explain some of the topographic features we see as well as earthquakes and volcanoes. Changes are always taking place along the edges of the plates. Divergent boundaries, plates moving away from each other, create **mid-ocean ridges** and **rift** valleys. The Mid-Atlantic Ridge, the Rift Valley in Africa, and the Red Sea are examples of divergent boundaries. Convergent boundaries, plates moving toward or underneath one another, form mountain ranges, **trenches** and volcanic island arcs. Subduction occurs when one plate is forced underneath another plate forming a trench. Many examples of these features can be found in the Pacific Ocean. Transform boundaries result from the sliding of plates along their edges. The San Andreas **fault** in California is an example of this type of boundary.

Volcanoes and earthquakes are often found in areas where the plates are sliding past each other, running into each other, or moving apart. Movement of the San Andreas fault caused the San Francisco earthquakes of 1906 and 1989.

Scientists continue to test theories about Earth's crust. Their tests and studies will lead to a better understanding of the structure of Earth.

Lithosphere

There are three major layers of Earth. They are the crust, mantle, and **core**. Each of these layers is made up of different materials. The **lithosphere** is the rigid outer layer of Earth, which includes the crust and the very top of the **mantle**. To get an idea of the lithosphere, think about digging straight down into Earth. You would pass through several different solid layers and would have to dig down about 6,700 kilometers before you would reach the center of Earth. Only about the first 100 kilometers would be the lithosphere.

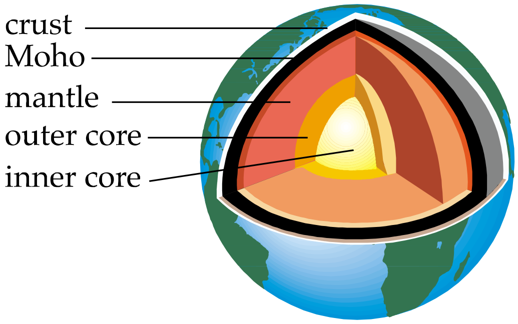


Of course, it is impossible to dig to the center of Earth. Scientists have had to use indirect means to learn about the inside of Earth. Indirect means are ways of finding out about Earth without actually touching or seeing the rocks.

Scientists have learned Earth is not the same composition all the way to the center. Scientists draw conclusions from earthquake and volcanic information recorded by instruments. This is how the depth and the temperature of Earth is estimated. Scientists have also found that the temperature and the pressure in Earth increases the deeper you go.

The ground you stand on is called the soil. The soil is a very thin layer, about six meters deep. Underneath the soil is *bedrock*, which contains minerals, rocks of various kinds, and ores. Together, soil and bedrock act like the skin of Earth. This skin is called Earth's *crust*. The crust is hard and thin. It can be as thick as 67 kilometers and as thin as eight kilometers in some spots. The crust is thickest under the continents and thinnest under the oceans.

On the diagram below of Earth's lithosphere, there is a very dark line labeled *Moho*. This is short for Mohorovicic discontinuity, the boundary between Earth's crust and mantle. It is named after Andrija Mohorovicic (1857-1936), a Yugoslav geologist. The Moho averages about three miles under the ocean basin floors and 25 miles under the continents. The Moho is not a layer, but a boundary line between the crust and the mantle.



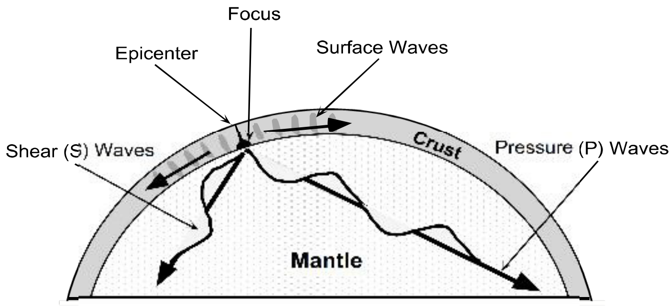
Below the crust is a layer of rock which is heavier and contains more iron than the rock found in the crust. This layer is called the *mantle*. The mantle is between 2,800 and 3,000 kilometers thick. The rock in the mantle seems to be able to flow and move about like a fluid.

The third layer of Earth, the core, is beneath the mantle and has two parts. The *outer core* is about 2,000 kilometers thick. The outer core contains melted iron and nickel. At the center of Earth is the *inner core*. It is 2,800 kilometers in diameter at the thickest point. From where the inner core begins to the very center of Earth is about 1,400 kilometers. Scientists believe the inner core is solid and contains iron mixed with some nickel and cobalt.

Earthquakes

An *earthquake* is the shaking of Earth's crust caused by plates moving inside Earth. Earth's crust is not one big piece. It is really several plates which float on the liquid, molten part of the mantle. As the plates drift or move, their edges may rub and grind against each other. This grinding, along with an upward push of the rock layers, causes earthquakes.

Earthquakes occur along a *fault*, which is a break or crack in Earth's crust. As Earth's crust bends on both sides of a fault, pressure builds up. When the rocks cannot stand the pressure anymore, they break. *Faulting* can be caused either by an uplifting that causes the surface to break or by horizontal forces that rip the crust apart. The zone inside Earth where the actual movement in the rocks occurs is called the **focus**. The place on the crust of Earth's surface directly above the focus is called the **epicenter**.



During an earthquake, energy moves away from the focus in all directions releasing energy in the form of **seismic waves**. These waves are felt as the shocks of an earthquake.

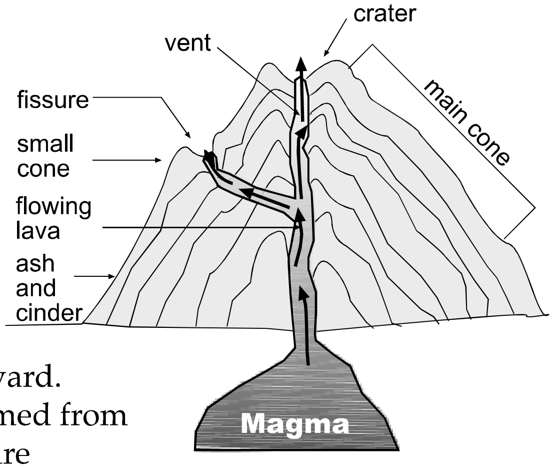
Scientists called **seismologists** study the inner structure of Earth and the changing surface of Earth in an effort to predict future earthquakes. A **seismograph** is an instrument used to measure the force of an earthquake. Some earthquakes are so slight that they go unnoticed. Other earthquakes are so powerful that the tremors cause rockslides, buildings to fall, the ground to open up, fires and explosions from broken electric and gas lines, and floodwaters released from collapsing dams.

When an earthquake is recorded, it is given a number on the **Richter scale**. The Richter scale uses numbers from one to 10 to measure the relative strength of an earthquake. The largest earthquakes ever recorded have Richter magnitudes near 8.6. The energy released from these great shock waves is about the same as one billion tons of TNT (an ingredient in explosives). Earthquakes with a magnitude less than 2.5 are not normally felt by humans.

earthquake damage

In 1906, an earthquake with a Richter scale rating of 8.25 nearly destroyed the city of San Francisco. An earthquake with a magnitude of 8.4–8.6 occurred in Alaska and lasted three–four minutes. In 1989, another major earthquake occurred in San Francisco. It measured 7.1 on the Richter scale and caused major destruction.

Volcanoes



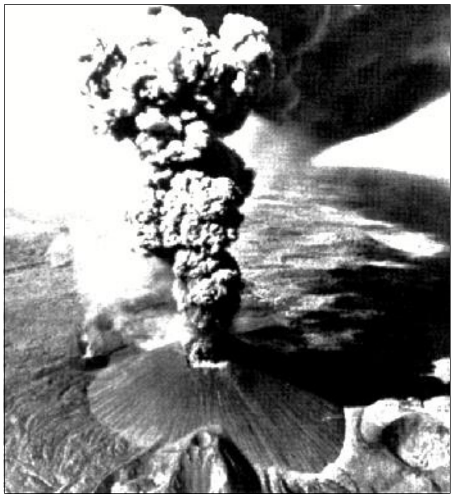
A *volcano* is an opening in Earth's surface through which melted rock, called **magma**, erupts from inside Earth. Magma beneath the surface of Earth builds up great pressure. Scientists believe that it collects in pockets and builds up pressure. This pressure forces the magma upward. Sometimes dome mountains are formed from the pressure. Other times, the pressure becomes so great that the magma is pushed out onto the surface of Earth. When this happens, it is called an eruption. Once the magma flows out of the opening of the volcano, it is called *lava*. A hill or mountain builds up as the lava cools. This is how volcanic mountains are formed.

Volcanoes can also form in the oceans. The **Ring of Fire** is an area in the Pacific Ocean where many of the world's active volcanoes are found. Sometimes the tops of volcanoes stick out above the surface of the ocean forming islands. The Hawaiian Islands are really the tops of volcanoes.

Volcanoes affect Earth in many ways. They are responsible for changing the surface of Earth by building volcanic mountains. The lava and ash from volcanic eruptions form fertile land that can be farmed. Scientists study volcanoes to learn more about the interior of Earth.

a quiet volcano

Volcanic mountains are sometimes quiet. A quiet volcano is one where the lava oozes out and spreads over the land. Quiet volcanoes have gently sloping sides. They do not explode.



an active volcano

Explosive volcanoes are ones where the magma blasts to the surface. For the magma to come to the surface with such force, it must be held underground for a long time. The pressure builds up and becomes so great that the magma is pushed out of Earth explosively. With the magma comes rocks, cinders, ash, dust, steam, and poisonous gases. The dust and ash can cause breathing problems in humans and can even cause changes in the weather. Volcanoes can destroy property and lives. Some volcanic eruptions have triggered large earthquakes.

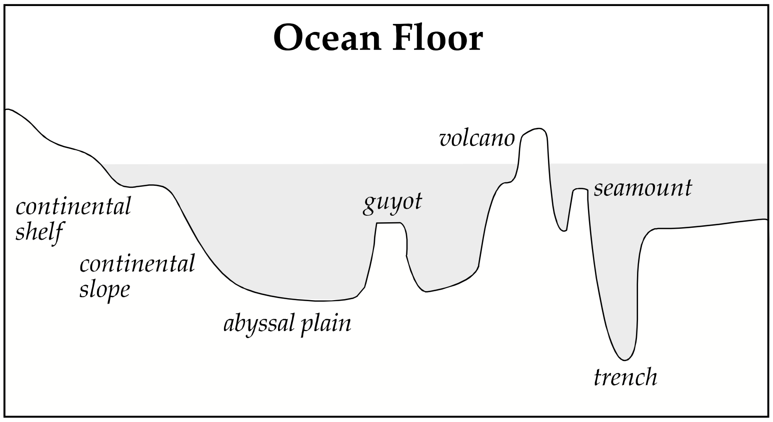
Some volcanoes are dormant, which means that they have erupted in human history but not within the past 50 years or so. They are inactive but may erupt at any time. Other volcanoes are active, like Kilauea in Hawaii, which has erupted more than 50 times in recorded history. Mount St. Helens on the Pacific Coast of the United States is an active volcano which erupted in 1980.

The Ocean Floor

Earth's ocean floor has been studied for more than 100 years. In the 1950s and 1960s, scientists invented new instruments, such as the precision depth recorder, to more accurately study and map the ocean floors. Using these instruments, scientists discovered that the land areas of the ocean floor had many of the same features as the continents.

The area where the land and the ocean water meet is called the *shoreline*. Beyond the shoreline the ocean floor begins to slope gently downward. This is called the **continental shelf**. The width of the continental shelf varies from 200 to 1200 kilometers. At the edge of the continental shelf, the ocean floor drops off at a very steep angle for four or five kilometers. This marks the boundary between the crust of the continent and the crust of the ocean basin. It is called the **continental slope**. Deep V-shaped valleys called **canyons** are found along the continental slope. Some of these underwater canyons are deeper than any found on the surface of Earth.

The ocean basin, or floor, begins at the bottom of the continental slope. There are plains on the ocean basin that are larger and flatter than any found on Earth's surface. They are called **abyssal plains**. The deepest parts of the ocean floor are long, narrow cracks called *trenches*, which cut into the abyssal plain. Most of these trenches are found in the Pacific Ocean. The Marianas Trench in the Pacific Ocean is the deepest spot on Earth. It is over 11,000 meters deep.



Many volcanic peaks rise from the plain. Some peaks rise above sea level to form islands like the Hawaiian Islands. Many old volcanic islands are now underwater. Underwater cone-shaped volcanic mountains are called **seamounts**. Seamounts with flat tops are called **guyots**.

Some of the highest mountain ranges on Earth are located under the ocean. These underwater mountain chains, rising from the plain, are called *mid-ocean ridges*. On the floor of the Atlantic Ocean are underwater mountains named the Mid-Atlantic Ridge. The Mid-Atlantic Ridge is the longest fracture on Earth. It runs around the world from the North Atlantic to the South Atlantic, into the Indian Ocean, across the Pacific, and northward to the Atlantic. This mountain chain is about 65,000 kilometers long. Underwater ridges vary greatly in size and shape. Many ridges in the Pacific Ocean are flat-topped mountains. The Mid-Atlantic Ridge is really two parallel chains of mountains separated by a wide valley called a *rift*.

Important differences between the continents and the seafloor have been noted, too. The ocean basins have many more volcanoes and earthquakes than the continents. The rocks found there differ from the rocks found on Earth's surface. Ocean basins are made of basalt; continents are made of granite. In addition, the crust of Earth is much thinner on the ocean floor than on the surface of Earth.

Summary

Scientists have collected evidence to show that Earth's continents were once one large landmass. Over time the continents separated and drifted to their present locations. By the 1960s, a theory known as plate tectonics suggested that Earth is separated into plates. These plates are still moving, and this movement helps explain volcanoes and earthquakes. The ocean floor has many of the same features as the continents, including mountains and earthquakes, even though there are important differences.

The lithosphere, or solid part of Earth, has three major layers—crust, mantle, and core. The plates of Earth's crust move. This movement along a fault in the crust may cause earthquakes. The pressure beneath the surface of Earth may cause molten rock to flow from an opening in Earth's crust and form a volcano.