

Chapter 4 Plate Tectonics

Earth's Interior

Earth's surface is constantly changing. Earth looks different today from the way it did millions of years ago. People wonder, "What's inside Earth?" The extreme conditions in Earth's interior prevent exploration far below the surface. **Geologists have used two main types of evidence to learn about Earth's interior: direct evidence from rock samples and indirect evidence from seismic waves.**

Rocks from inside Earth give geologists clues about Earth's structure. Geologists can make inferences about conditions deep inside Earth where these rocks formed. Using data from **seismic waves** produced by earthquakes, geologists have learned that Earth's interior is made up of several layers.

The three main layers of Earth are the crust, the mantle, and the core. These layers vary greatly in size, composition, temperature, and pressure. Beneath the surface, the temperature remains the same for about 20 meters, then increases until the center of Earth is reached. **Pressure** results from a force pressing on an area. Pressure inside Earth increases as you go deeper.

The **crust** is the layer of rock that forms Earth's outer skin. **The crust is a layer of solid rock that includes both dry land and the ocean floor.** Oceanic crust consists mostly of rocks such as basalt, dark rock with a fine texture. Continental crust, the crust that forms the continents, consists mainly of rocks such as granite. Granite is a rock that usually is a light color and has a coarse texture.

Below a boundary about 40 kilometers beneath the surface is the solid material of the **mantle**, a layer of hot rock. **Earth's mantle is made up of rock that is very hot, but solid. Different layers of the mantle have different physical characteristics.** The uppermost part of the mantle and the crust together form a rigid layer called the **lithosphere**. Below the lithosphere is a soft layer called the **asthenosphere**. Beneath the asthenosphere, the mantle is solid. This solid material, called the lower mantle, extends all the way to Earth's core.

The core is made mostly of the metals iron and nickel. It consists of two parts—a liquid outer core and a solid inner core. The **outer core** is a layer of molten metal that surrounds the inner core. The **inner core** is a dense ball of solid metal.

Scientists think that movements in the liquid outer core create Earth's magnetic field. Because Earth has a magnetic field, the planet acts like a giant bar magnet.

Convection and the Mantle *Section 2 Summary*

The movement of energy from a warmer object to a cooler object is called heat transfer. Heat is always transferred from a warmer substance to a cooler substance. **There are three types of heat transfer: radiation, conduction, and convection.**

The transfer of energy through empty space is called **radiation**. Heat transfer by radiation takes place with no direct contact between a heat source and an object. For example, radiation enables sunlight to warm Earth's surface.

Heat transfer within a material or between materials that are touching is called **conduction**. In conduction, the heated particles of a substance transfer heat to other particles through direct contact. An example is when a spoon heats up in a hot pot of soup.

The transfer of heat by the movement of currents within a fluid is called **convection**. Fluids include liquids and gases. During convection, heated particles of a fluid begin to flow, transferring heat energy from one part of the fluid to another.

Heat transfer by convection is caused by differences in temperature and density within a fluid. **Density** is a measure of how much mass there is in a volume of a substance. When a liquid or gas is heated, the particles move faster. As they move faster, they spread apart. Because the particles of the heated fluid are farther apart, they occupy more space. The fluid's density decreases. But when a fluid

cools, the particles move closer together and density increases.

An example of convection occurs in heating a pot of soup on a stove. As soup at the bottom of the pot gets hot, it expands and becomes less dense. The warm, less dense soup moves upward, floating over cooler, denser soup. At the surface, the warm soup spreads out and cools, becoming denser. Then gravity pulls this cooler, denser soup down to the bottom, where it is heated again and begins to rise. This flow that transfers heat within a fluid is called a **convection current**. **Heating and cooling of the fluid, changes in the fluid's density, and the force of gravity combine to set convection currents in motion.** Convection currents continue as long as heat is added to the fluid.

Convection currents flow in the mantle. **Heat from the core and the mantle itself causes convection currents in the mantle.** Hot columns of mantle material rise slowly. At the top of the asthenosphere, the hot material spreads out and pushes the cooler material out of the way. This cooler material sinks back into the mantle. Convection currents like these have been moving inside Earth for most of Earth's history.

Drifting Continents *Section 3 Summary*

In 1910, a young German scientist named Alfred Wegener became curious about why the coasts of several continents matched so well, like the pieces of a jigsaw puzzle. He formed a hypothesis that Earth's continents had moved! **Wegener's hypothesis was that all the continents were once joined together in a single landmass and have since drifted apart.** He named this supercontinent **Pangaea**, meaning "all lands." According to Wegener, Pangaea existed about 300 million years ago. Over tens of millions of years, Pangaea began to break apart. The pieces of Pangaea slowly moved toward their present-day locations, becoming the continents of today. The idea that the continents slowly moved over Earth's surface became known as **continental drift**. **Wegener gathered evidence from different scientific fields to support his ideas about continental drift. He studied land features, fossils, and evidence of climate change.** In a book called *The Origin of Continents and Oceans*, Wegener presented his evidence.

Mountain ranges and other features provided evidence for continental drift. For example, Wegener noticed that when he pieced together maps of Africa and South America, a mountain range running from east to west in Africa lines up with a range in South America. Also, European coal fields match up with coal fields in North America.

Fossils also provided evidence to support Wegener's theory. A **fossil** is any trace of an ancient organism that has been preserved in rock. The fossils of the reptiles *Mesosaurus* and *Lystrosaurus* and a fernlike plant called *Glossopteris* have been found on widely separated landmasses. This convinced Wegener that the continents had once been united.

Wegener used evidence from climate change to further support his theory. For example, an island in the Arctic Ocean contains fossils of tropical plants. According to Wegener, the island once must have been located close to the equator. Wegener also pointed to scratches on rocks in South Africa that were made by glaciers. These scratches show that the mild climate of South Africa was once cold enough for glaciers to form. According to Wegener's theory, Earth's climate has not changed. Instead, the positions of the continents have changed.

Wegener also attempted to explain how the drift of continents took place. **Unfortunately, Wegener could not provide a satisfactory explanation for the force that pushes or pulls the continents.** Because he could not identify the cause of continental drift, most geologists rejected his theory. For nearly half a century, from the 1920s to the 1960s, most scientists paid little attention to the idea of continental drift. Then new evidence about Earth's structure led scientists to reconsider Wegener's bold theory.

Sea-Floor Spreading *Section 4 Summary*

The longest chain of mountains in the world is the system of **mid-ocean ridges**. In the mid-1900s,

scientists mapped the mid-ocean ridges using sonar. **Sonar** is a device that bounces sound waves off underwater objects and then records the echoes of these sound waves. The mid-ocean ridges curve along the sea floor, extending into all of Earth's oceans. Most of the mountains in the mid-ocean ridges lie hidden under hundreds of meters of water. A steep-sided valley splits the top of some mid-ocean ridges.

Earth's ocean floors move, carrying the continents along with them. This movement begins at a mid-ocean ridge. A ridge forms along a crack in the oceanic crust. At a mid-ocean ridge, molten material rises from the mantle and erupts. This process, called **sea-floor spreading**, continually adds new material to the ocean floor. **In sea-floor spreading, the sea floor spreads apart along both sides of a mid-ocean ridge as new crust is added. As a result, the ocean floors move like conveyor belts, carrying the continents along with them.**

Several types of evidence supported the theory of sea-floor spreading: eruptions of molten material, magnetic stripes in the rock of the ocean floor, and the ages of the rocks themselves. Scientists have found strange rocks shaped like pillows in the central valley of mid-ocean ridges. Such rocks can form only if molten material hardens quickly after erupting under water. The presence of these rocks supports the theory of sea-floor spreading. More support came when scientists discovered that ocean floor rock lies in a pattern of magnetized "stripes." The pattern is the same on both sides of the ridge. These stripes hold a record of reversals in Earth's magnetic field. The final proof of sea-floor spreading came from ocean floor rock samples. The farther from a ridge the rocks were taken, the older they were.

The ocean floor does not just keep spreading. Instead, it sinks into deep underwater canyons called **deep-ocean trenches**. Where there are trenches, subduction takes place. **Subduction** is the process by which the ocean floor sinks into a deep-ocean trench and back into the mantle. **In a process taking tens of millions of years, part of the ocean floor sinks back into the mantle at deep-ocean trenches.**

The processes of subduction and sea-floor spreading can change the size and shape of the oceans. Because of these processes, the ocean floor is renewed about every 200 million years. The Pacific Ocean is shrinking. Its many trenches are swallowing more ocean crust than the mid-ocean ridge is producing. The Atlantic Ocean is expanding. In most places, the oceanic crust of the Atlantic Ocean is attached to continental crust. As the Atlantic's floor spreads, the continents along its edges also move.

The Theory of Plate Tectonics *Section 5 Summary*

Earth's lithosphere is broken into separate sections called **plates**. The plates fit closely together along cracks in the crust. They carry the continents, or parts of the ocean floor, or both. **Plate tectonics** is the geological theory that states that pieces of Earth's lithosphere are in slow, constant motion, driven by convection currents in the mantle. A scientific theory is a well-tested concept that explains a wide range of observations. **The theory of plate tectonics explains the formation, movement, and subduction of Earth's plates.**

The plates float on top of the asthenosphere. Convection currents rise in the asthenosphere and spread out beneath the lithosphere, causing the movement of Earth's plates. As the plates move, they produce changes in Earth's surface, including volcanoes, mountain ranges, and deep-ocean trenches. The edges of different pieces of the lithosphere meet at lines called plate boundaries. **Faults**—breaks in Earth's crust where rocks have slipped past each other—form along these boundaries.

There are three kinds of plate boundaries: spreading boundaries, colliding boundaries, and sliding boundaries. The plates move at amazingly slow rates, from about 1 to 24 centimeters per year. They have been moving for tens of millions of years. The place where two plates move apart, or diverge, is called a **spreading boundary**. Most spreading boundaries occur at the mid-ocean ridge. When a spreading boundary develops on land, two slabs of Earth's crust slide apart. A deep valley called a **rift valley** forms along the spreading boundary. The place where two plates come together, or converge, is a **colliding boundary**. When two plates converge, the result is called a collision. When two plates collide, the density of the plates determines which one comes out on top. Oceanic crust is more dense than continental crust. A **sliding boundary** is a place where two plates slip past each other, moving in opposite

directions. Earthquakes occur frequently along these boundaries.

When two plates carrying oceanic crust meet at a trench, the plate that is less dense dives under the other plate and returns to the mantle. This is the process of subduction. When a plate carrying oceanic crust collides with a plate carrying continental crust, the more dense oceanic plate plunges beneath the continental plate through the process of subduction. When two plates carrying continental crust collide, subduction does not take place because both plates are mostly low-density granite rock. Instead, the plates collide head-on. The collision squeezes the crust into mighty mountain ranges.

About 260 million years ago, the continents were joined together in the supercontinent Pangaea. About 225 million years ago, Pangaea began to break apart. Since then, the continents have moved to their present locations.

Chapter 4

The Earth's Interior

Vocabulary and Key Terms

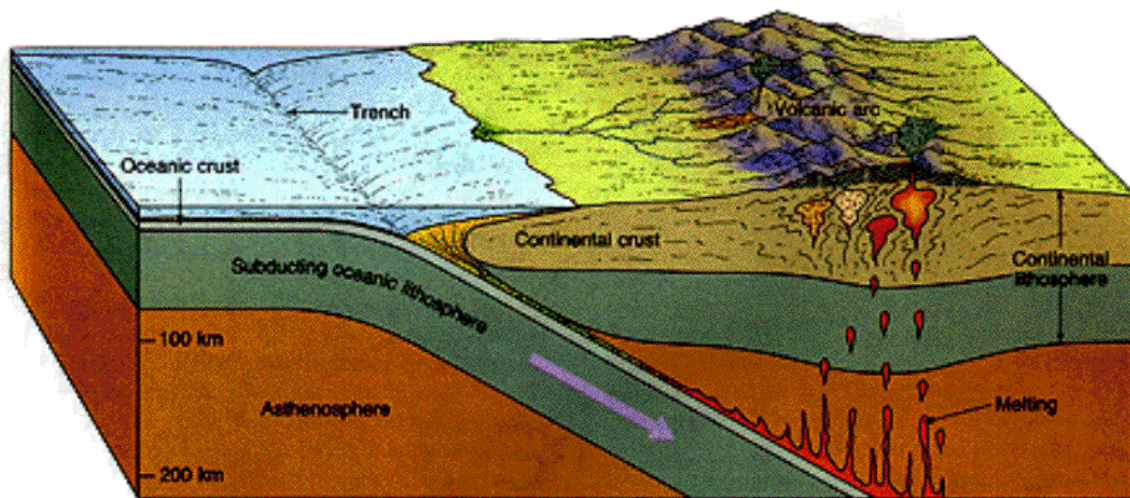
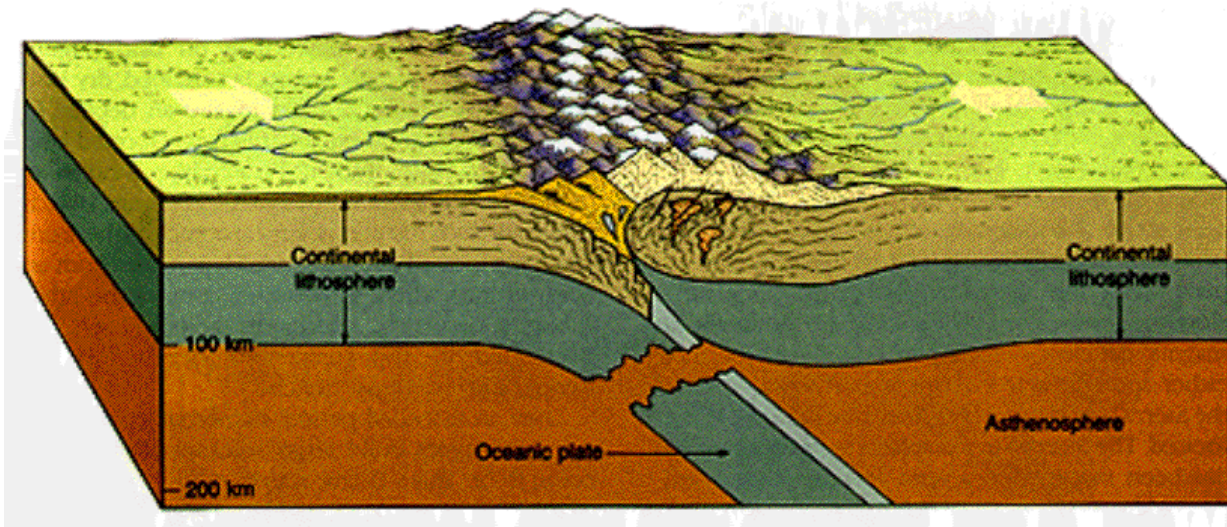
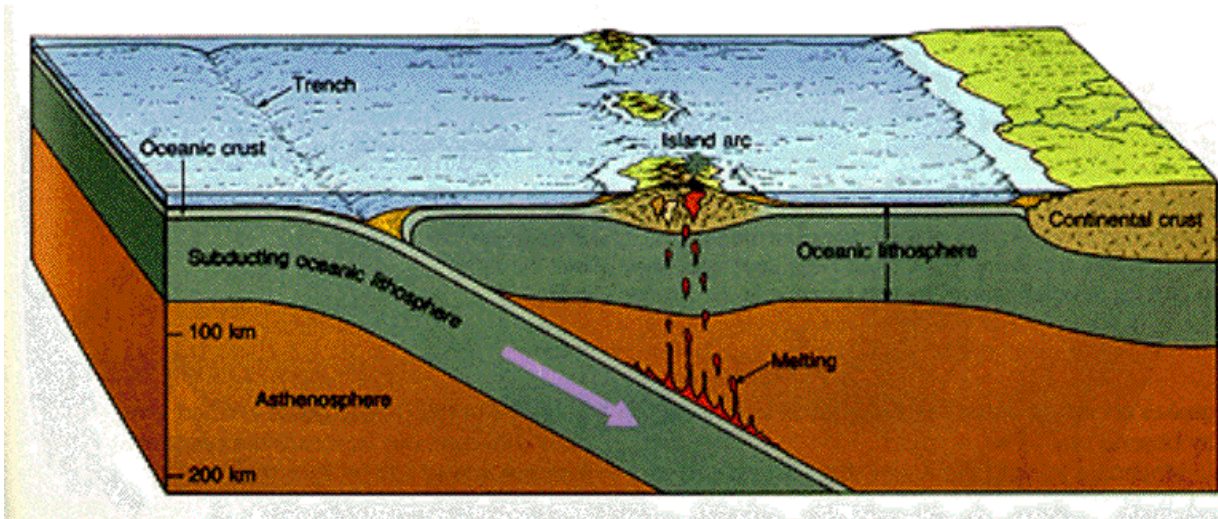
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| 1. Seismic Waves | 6. Moho |
| 2. Seismograph | 7. Plasticity |
| 3. Inner Core | 8. Crust |
| 4. Outer Core | 9. Lithosphere |
| 5. Mantle | 10. Asthenosphere |

Plate Tectonics

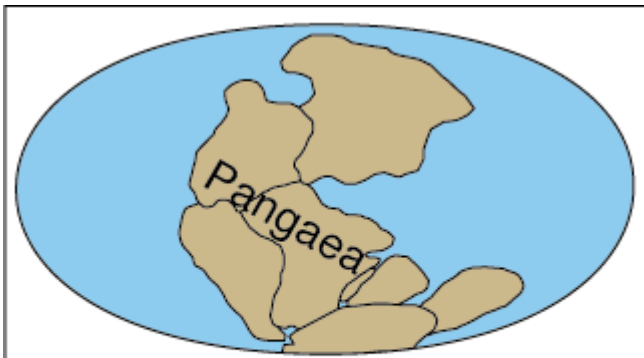
Vocabulary and Key Terms

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| 1. Fossils Evidence | 9. Plate Tectonics | 17. Convection |
| 2. Pangaea | 10. Lithosphere | 18. Magma |
| 3. Continental Drift | 11. Divergent Boundary | 19. Ring of Fire |
| 4. Midoceanic Ridge | 12. Convergent Boundary | |
| 5. Sea Floor Spreading | 13. Ocean – Ocean Convergent Zone | |
| 6. Transform Fault | 14. Ocean – Continent Convergent Zone | |
| 7. Trench | 15. Continent – Continent Convergent Zone | |
| 8. Subduction Zone | 16. Strike – Slip Zone | |

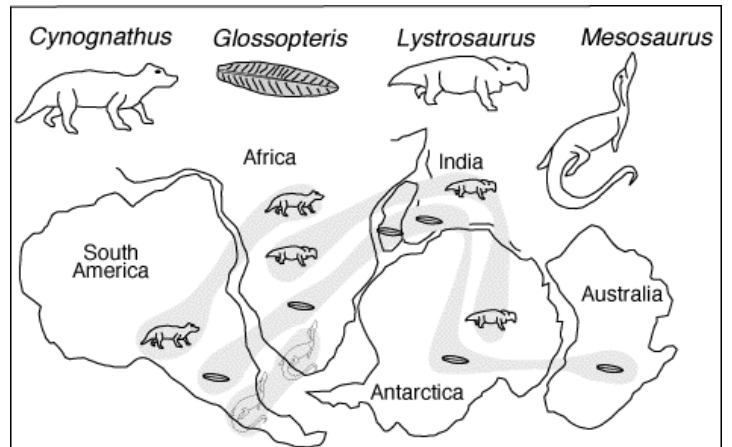
Convergent Tectonic Plates



Pangaea

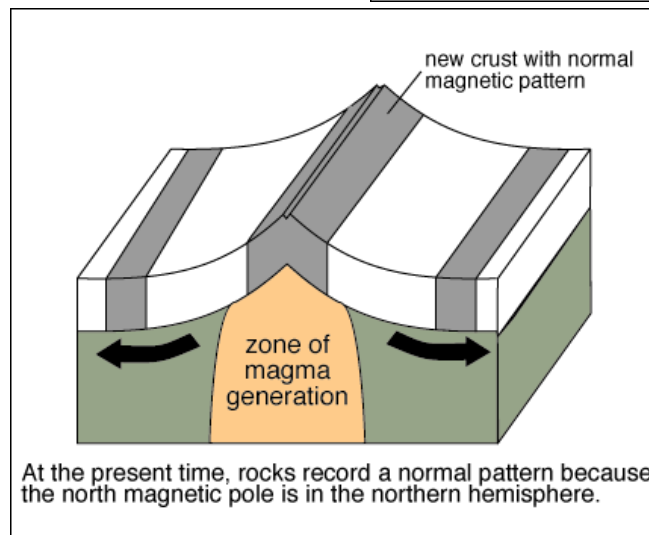
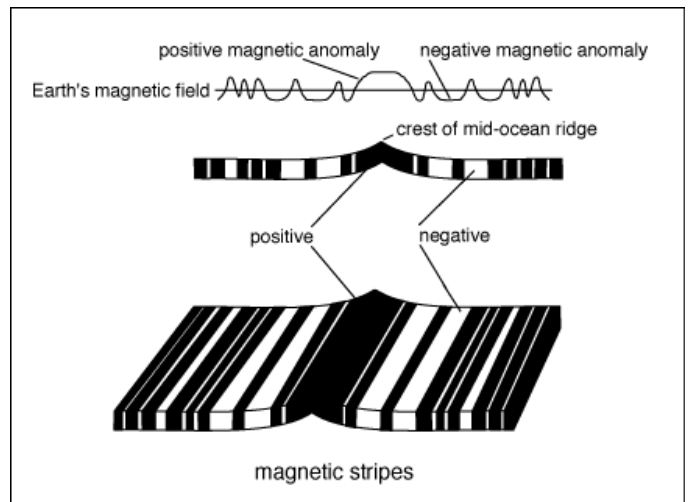
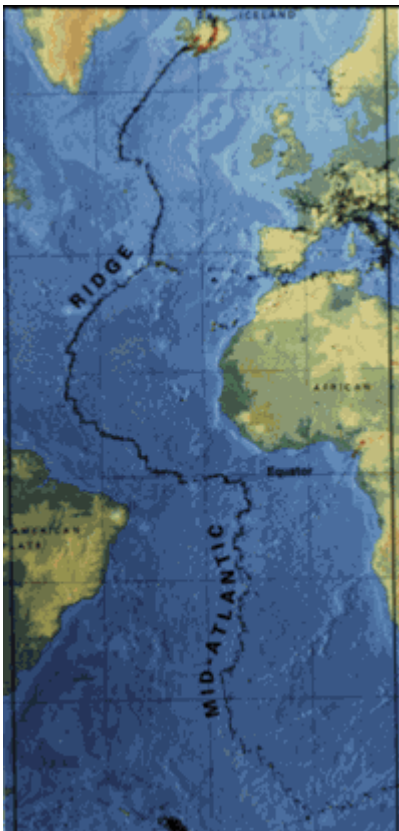


200 million years ago all of the present-day continents combined to form a single supercontinent called Pangaea.

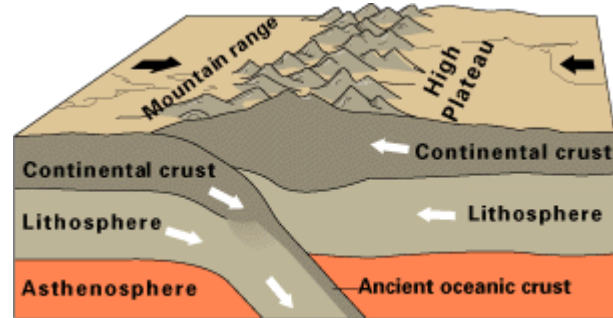
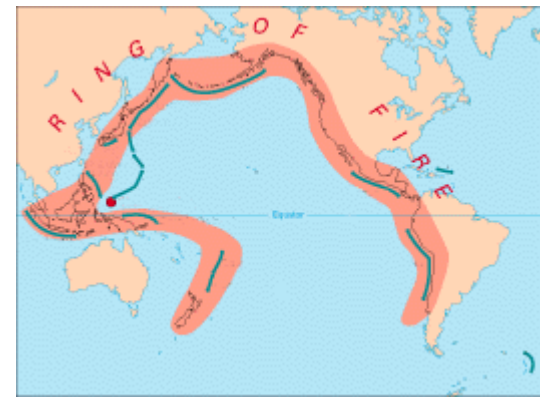
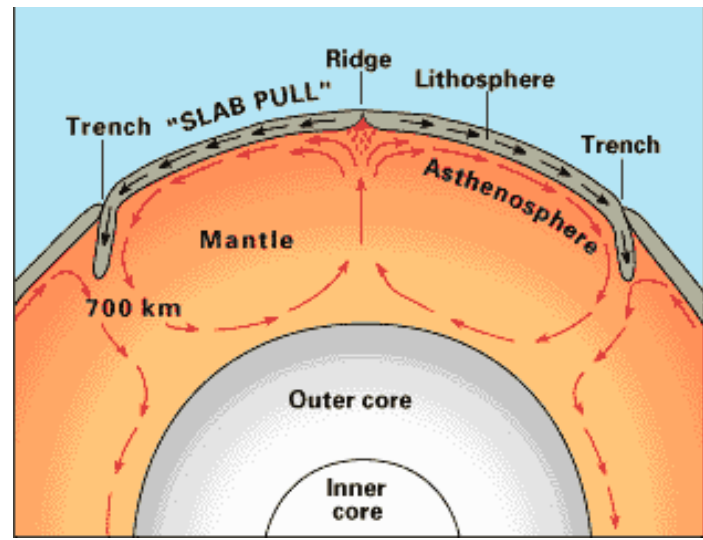


Distribution of fossils across the southern continents of Pangea.

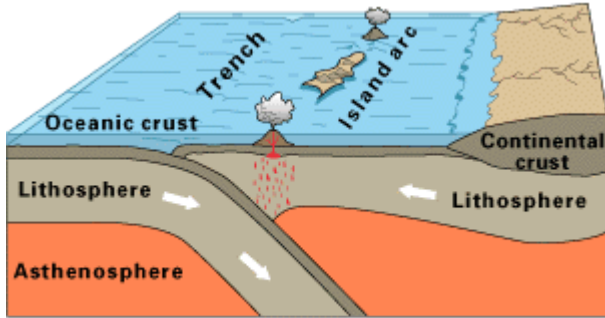
Divergent Tectonic Plates



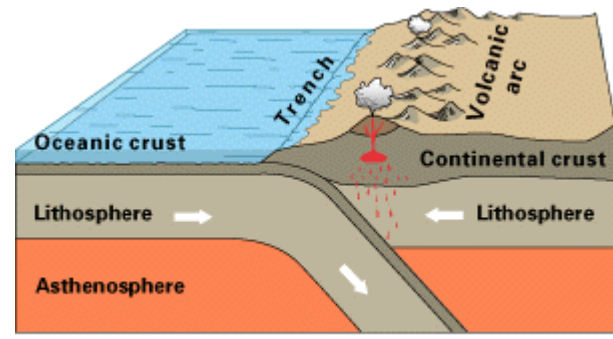
At the present time, rocks record a normal pattern because the north magnetic pole is in the northern hemisphere.



Continental-continental convergence



Oceanic-oceanic convergence



Oceanic-continental convergence