New York State
EARTH SCIENCE

Tectonics

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Tectonics
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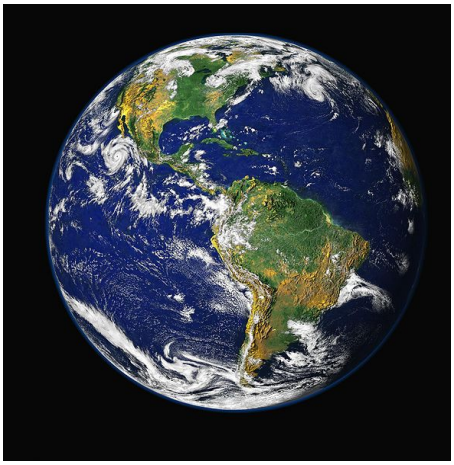
New York State EARTH SCIENCE

1.0 Structure of the Earth



The Earth's interior structure is made up of the following: the core, the mantle and the crust. Each layer is concentric with the core, but has different characteristics and composition.

1.1 Core

The core, which makes up about 15% of the volume of the Earth, is subdivided into two layers: the inner core and the outer core. The boundary between the outer and inner core is called the Lehmann Discontinuity.

Through seismic evidences and deep core drilling, the inner core is estimated to have a radius of about 1,220 km of a densely packed solid that is made of gold, platinum and other iron compounds.

On the other hand, the outer core is liquid and is believe to be made of nickel and other light elements. The liquid core radius extends to approximately 3,400 km.

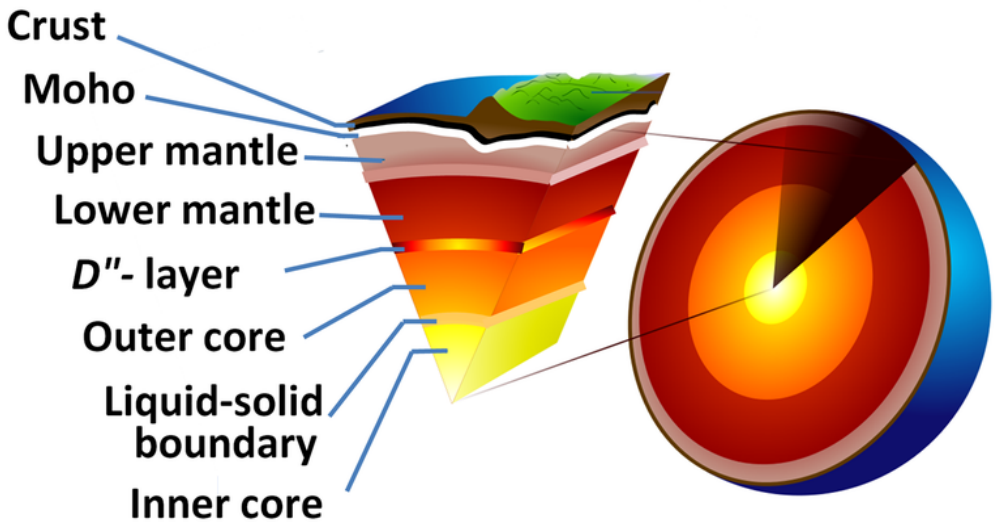


Figure 1.1 The layers of the Earth,
including the discontinuity lines Mohorovicic or Moho, and the D"-layer.

1.2 Mantle

The Earth's mantle is the thickest layer, about 2,890 km thick. It is viscous or semi-solid/liquid. It makes about 80% percent of the Earth's entire volume. The mantle is also made up of two concentric layers: the upper mantle and the lower mantle.

The lower mantle is located near the outer core, and separated by a thin layer called the D'' (double prime) layer, also known as the Gutenburg Discontinuity. The high pressure in this layer causes the material in the layer to be dense and ductile. This pressure causes high temperatures, which melts the rocks, creating a very dense, hot and plastic layer that flows at very slow rates.

The upper mantle is subdivided into two: asthenosphere and lithosphere. The asthenosphere is the outer layer, about 200 km thick, and is composed of plastic flowing rocks. The lithosphere is composed of rigid rocks that extend up to 120 km in thickness.

1.3 Crust

The topmost part of the Earth's terrestrial core is the crust. It is the layer where we human beings stand on; it is about 5 to 70 km thick. It is cool, brittle and rigid. The crust and the mantle are separated by the Mohorovicic Discontinuity layer, also known as the Moho. The crust has two divisions, the oceanic crust and the continental crust.

Oceanic Crust

The oceanic crust composes most of the thin part the entire crust layer, and is located underneath the ocean basins. It has a high density and composed mostly of basalt, gabbro, diabase magnesium and silicate rocks.

Continental Crust

The thick part of the Earth's crust is mostly found in the continental crust. Less dense than the oceanic crust, it is mostly made up of granite or Felsic silicate rocks.

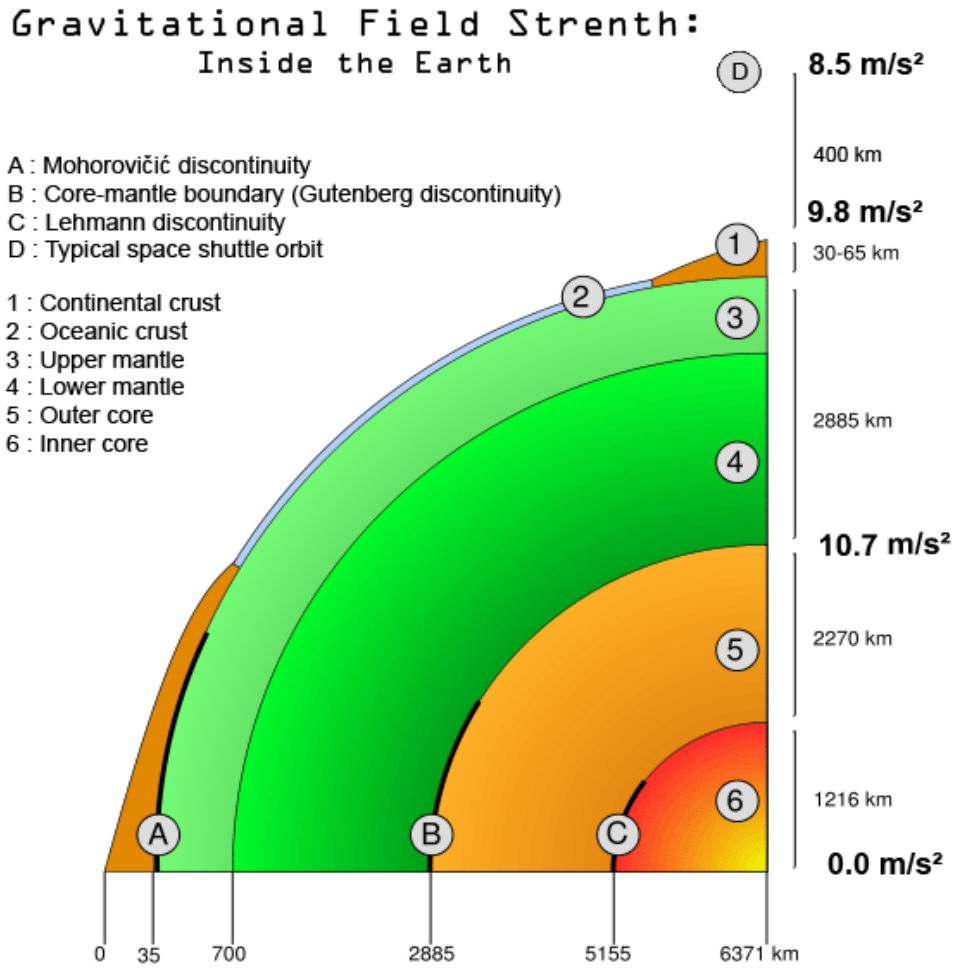


Figure 1.2 The layers and discontinuity boundaries in the Earth, along with their relative acceleration due to gravity.

1.4 Discontinuity Layers

Mohorovicic Discontinuity or Moho

It is the boundary between the Earth's crust and upper mantle. It was identified by Andrija Mohorovicic in 1909 when he detected two distinct output seismic waves. Differences in seismic waves indicate different materials. Geologists used shallow or low seismic *p* and *s* waves and measure the output seismic wave. Every material bounces off these seismic waves and vibrates on very distinct frequencies.

When there are two distinct output waves, it means that the input wave bounced on two different

types of material. It was found that the primary seismic waves emit approximately 6.2-7.2 km/s, distinct in basalt layers, and 7.6-8.6 km/s for peridotitic layers.

D"and G"-layer/ Gutenburg Discontinuity

This is the boundary between the core and the mantle. The name was based on the alphabetical naming of the layers by Keith Bullen, a mathematician and geophysicist from New Zealand. D" pertains to the lower mantle, and G" as the inner core of the Earth. This discontinuity is also known as Gutenburg Discontinuity, after the seismologist Beno Gutenburg.

Lehmann Discontinuity

This discontinuity is located in between the inner and outer core of the Earth. It was named after the Danish seismologist Inge Lehmann who proposed that the core of the Earth has two layers, the solid inner core and the liquid outer core, all of which was confirmed in 1971.

Conrad Discontinuity

It is the border or discontinuity between the continental crust and the lower crust. The difference in the seismic wave's velocities that describes this discontinuity was discovered by seismologist Victor Conrad.

2.0 Plate Tectonics

2.1 Tectonic Plates and Continental Drift

Plate tectonics describes the motion and properties of Earth's solid upper layer, the lithosphere. The theory is based on the Continental Drift, which was formulated by a German scientist named Alfred Wegener. He theorized that all the move, collide and separate. The motion between the continents or plates of the Earth is supported by the following physical observations and evidences:

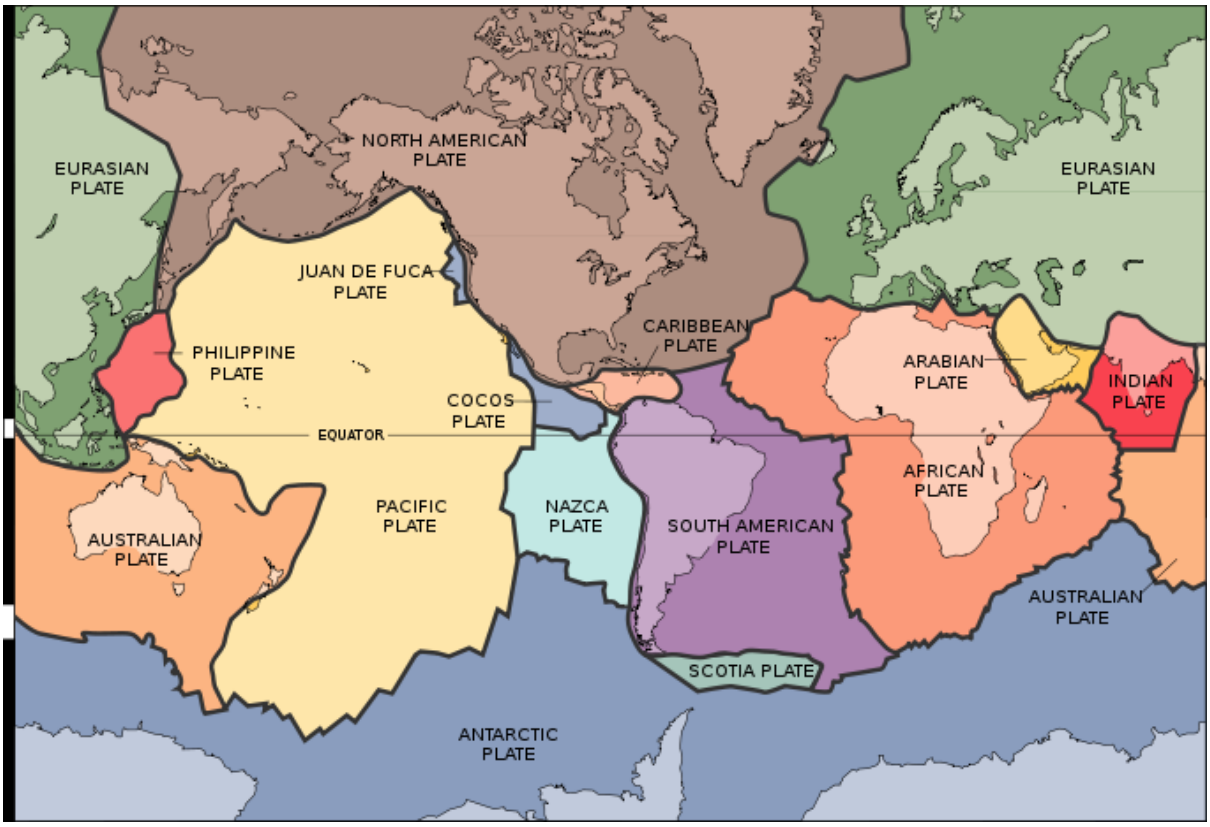


Figure 2.1 Tectonic Plates of Earth (2005)

1. **Shapes of the continents.** When the continents are put together like a jigsaw puzzle, the pieces fit together. It is theorized that before, there was one supercontinent *Pangea* that broke up through drifting which formed the continents we have today.

2. **Rock formations.** The rock formations and properties at the borders of continents match up with other plate borders.

3. **Fossils.** Similar fossils were found between the borders of continents, suggesting that all of the continents together were once a supercontinent (See Figure 2.2).

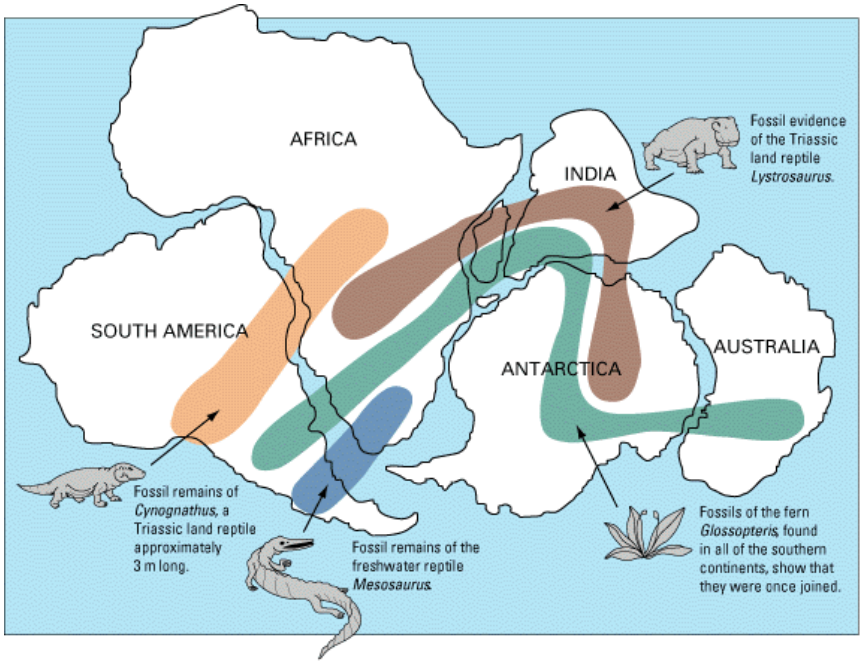


Figure 2.2 Fossil Comparison between continents. Fossil evidences show similarities between continents, which suggests that they were connected before.

4. Age of rocks. Rock dating shows a similar trend on the continents and ridges (where continents broke apart). Data shows that young or newly formed rocks are at the ridges and older rocks within the continents.

5. Alternating magnetic polarity at the ridges. When molten rocks cool down and harden, new minerals and rocks are formed. The newly formed minerals realign their magnetic field with the Earth's own magnetic field. This means that when a continent moves or breaks apart, the ridges form new minerals that have a newly aligned magnetic field.

   The Earth's magnetic field reverses its polarity over hundreds of thousands of years. Geologists can detect and measure the change of polarity on minerals found in between plates and continents. With this, geologists are able to calculate the timeline in which continents move away or towards other continents.

Figure 2.3 The Continental Drift states there was once a supercontinent Pangea, which was made up of all of the continents we have today. This is supported by new evidences and simulations that show that when the continents of the Earth are connected together, everything matches perfectly like a jigsaw puzzle.

2.2 Tectonic Forces

Mantle Convection is the main cause of tectonic plate motion. Heat currents from the molten mantle can cause contraction or expansion of materials within the layers of the Earth. Expansion can push rocky or molten rocks up, which causes motion on the Earth's crust. There are three main driving forces that cause plate motion:

1. Friction between plates
2. Gravitational sliding
3. Earth's rotation and Tidal Friction of the Moon

2.3 Plate Boundaries

Plate boundaries are where plates meet or break apart. This is where tectonic forces and motion takes place. There are three types of Plate Boundaries:

1. Convergent

   From the word converge, this is the type where plates meet or converge. The converging line is called the Collision Boundary.

2. Divergent

   Divergent plate boundaries are where tectonic plates break and move away from each other.

3. Transform Boundaries

   Transform boundaries are where tectonic plates slide or brush against each other.

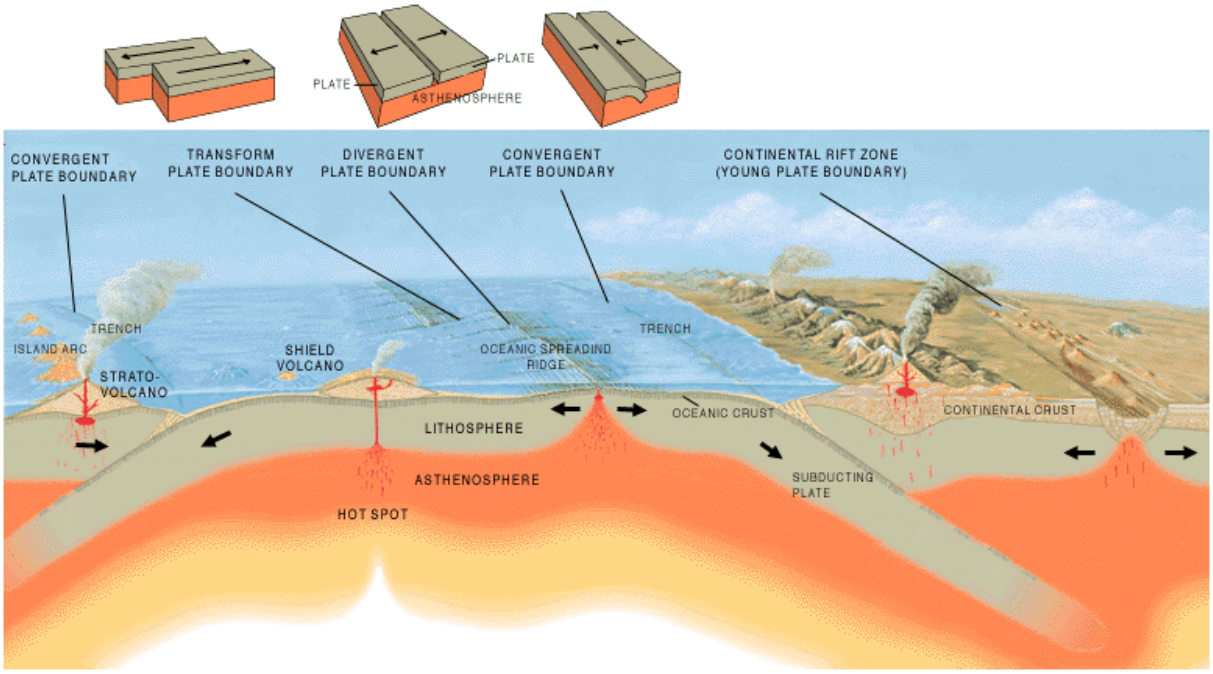


Figure 2.4 Types of Plate Boundaries and the common locations where they are formed. The plate motion on top shows (from left to right):
Transform Boundaries, Divergent Boundaries and Convergent Boundaries

2.4 Hot Spots

Hot spots are volcanic or mantle plumes. It is the Earth's way of releasing heat to maintain and cool down the core to a stable temperature. They function as stable heat release pipes, and can stay at its original location for millions of years

When a mantle plume releases hot magma to the crust and into an ocean basin, it becomes a volcanic center. Islands may form around the volcano from the magma spills. When the Earth's crust or tectonic plate moves (the magma plume stays at the same location), another volcanic center is formed over the magma plume, and the first volcano becomes dormant or extinct (no longer erupts). Over millions of years, chains of volcanoes are created by these hot spots. Example is the Hawaiian volcanic chain and its group of islands, formed by the magma plume underneath the Pacific Ocean basin.

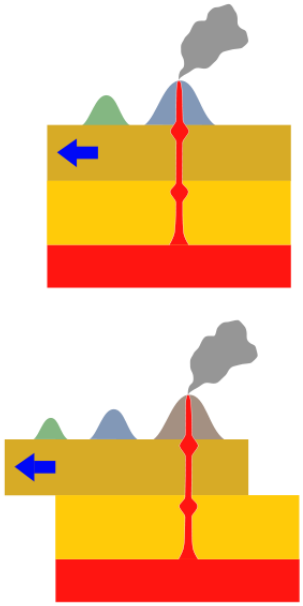


Figure 2.5 When a mantle plume is released to the Earth's lithosphere, it creates volcanoes. When the Earth's crust moves because of plate tectonic forces, it creates another volcano plume, resulting in a volcano chain.

3.0 Quiz

Please fill in the blanks with the correct term or definition.

1. The discontinuity between the Earth's crust and mantle is called _____.
2. _____ is the type of plate boundary where tectonic plates are sliding on each other.
3. The three tectonic driving forces are a) _____, b) _____, and c) _____.
4. _____ is the thickest part of the Earth's crust.
5. The inner core of the Earth is made of _____, while the outer core is _____.
6. The upper mantle is subdivided into two layers, _____ and _____.
7. The discontinuity or boundary between the Earth's inner and outer core is called _____.
8. The person who presented the theory of continental drift is _____.
9. _____ is the part of Earth's crust found below tectonic plates.
10. The line or area where plates meet and converge is called _____.
11. _____ is the type of plate boundary where tectonic plates move away from each other.
12. Ocean trenches came from _____ (convergent, divergent or transform boundaries).
13. Differences in _____ and _____ seismic waves allow seismologists to measure and identify layers in the interior of the Earth.
14. The _____ crust is located underneath the Earth's ocean basins.
15. The upper mantle is subdivided into two parts; _____ and _____.