

17.1 - Drifting Continents



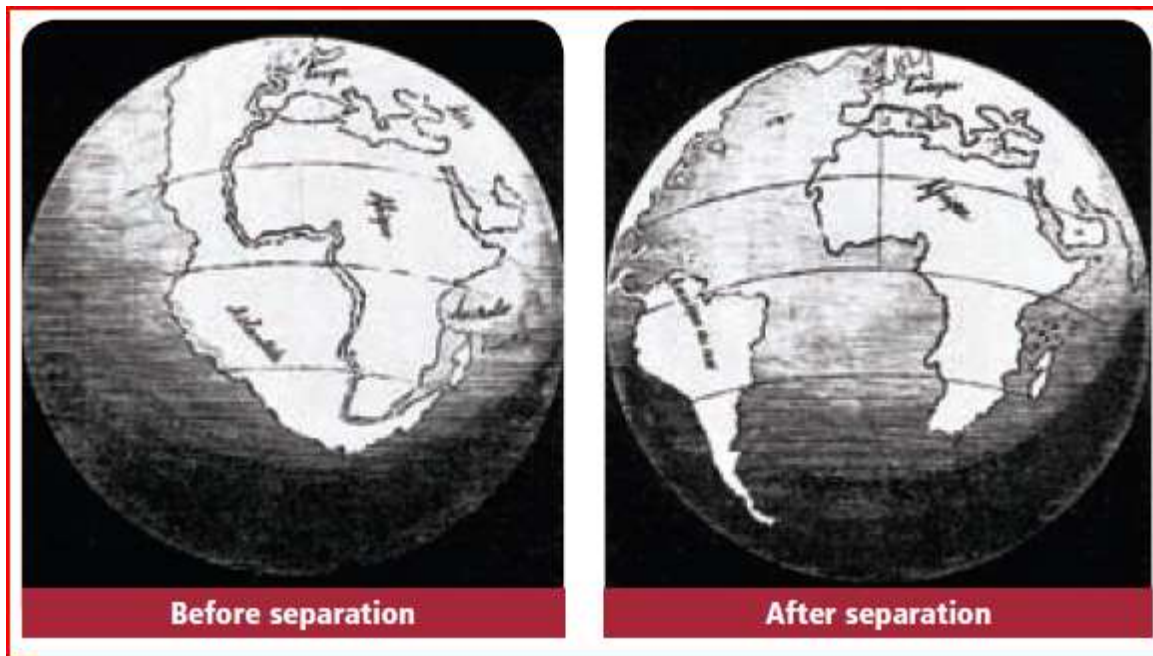
8th Grade Earth & Space Science
Class Notes

Continental Drift



Early Observations

- Most of the Earth's surface remains unchanged during a human's lifespan, but the Earth has changed dramatically over geologic time.
- The first to suggest this was Dutch cartographer Ortelius, who noticed the apparent fit between continents on opposite sides of the Atlantic Ocean.



Ortelius, Suess, & Wegener



Ortelius - Dutch cartographer who noticed the similarities in coastlines on either side of the Atlantic Ocean (late 1500s)



was an Austrian geologist, an expert on the geography of the Alps - proposed Gondwana & Tethys Ocean (1861)



Wegener - astronomer by schooling, well versed in many areas of science - Continental Drift & Pangaea (1912)

Gondwana – Suess - 1861



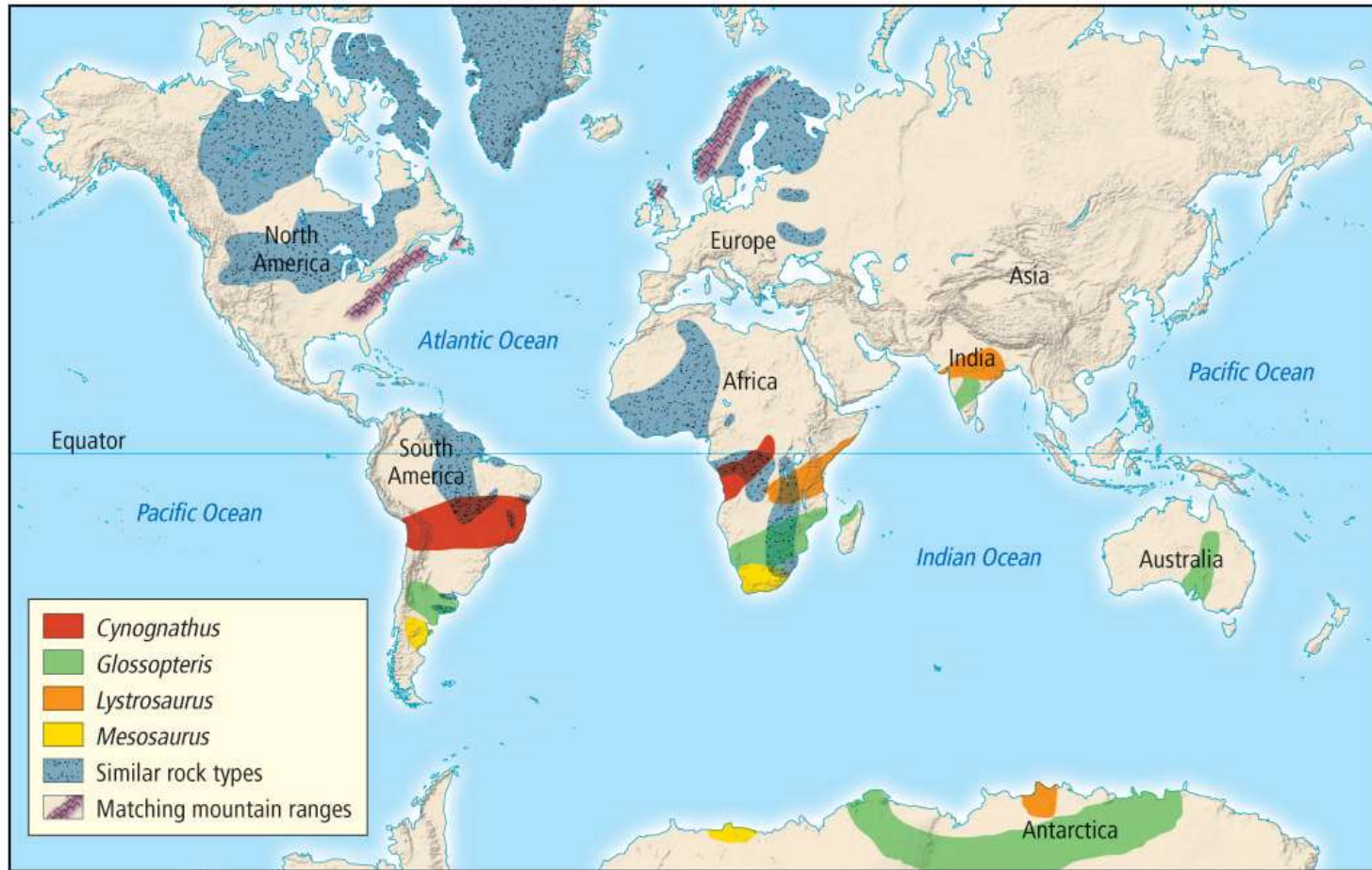
Continental Drift

- *Wegener proposed that the Earth's continents had once been joined as a supercontinent that broke apart. (1912)*
- Wegener called his supercontinent Pangaea.
- He collected and organized rock, climatic, and fossil evidence to support his data.

Evidence from Rock Formations

- Wegener observed that many layers of rock in the Appalachian Mountains in the United States were identical to layers of rock in Greenland and Europe.

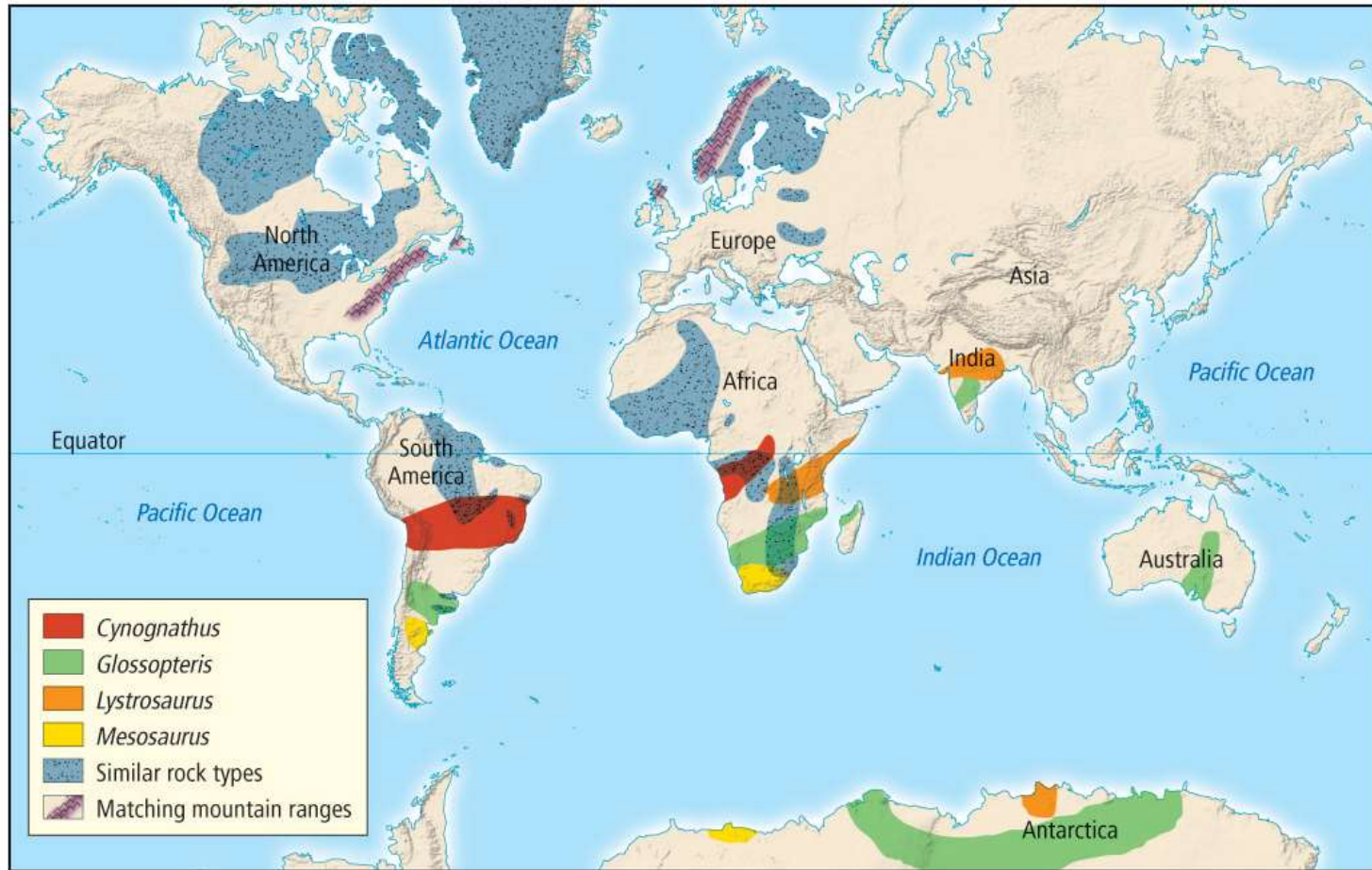
Similar Rock Formations Found in Blue Areas



Evidence from Fossils

- Wegener also gathered similar fossils of several different animals and plants that once lived on or near land had been found on widely separated continents. He believed that this supported the hypothesis of Pangaea.

Fossils from Identical Species Found in Color Coded Areas



Climatic Evidence

- Wegener had a strong background in meteorology, and recognized clues about ancient climates. Found that a particular fern (*Glossopteris*) was found spread throughout the world where it should only been in temperate climates. He reasoned that these areas had temperate climates at one point in time.

Coal Deposits

- Coal deposits were found in Antarctica which shows that it once had a tropical climate. Wegener used this as evidence that climates of some continents had changed considerably.

Glacial Deposits

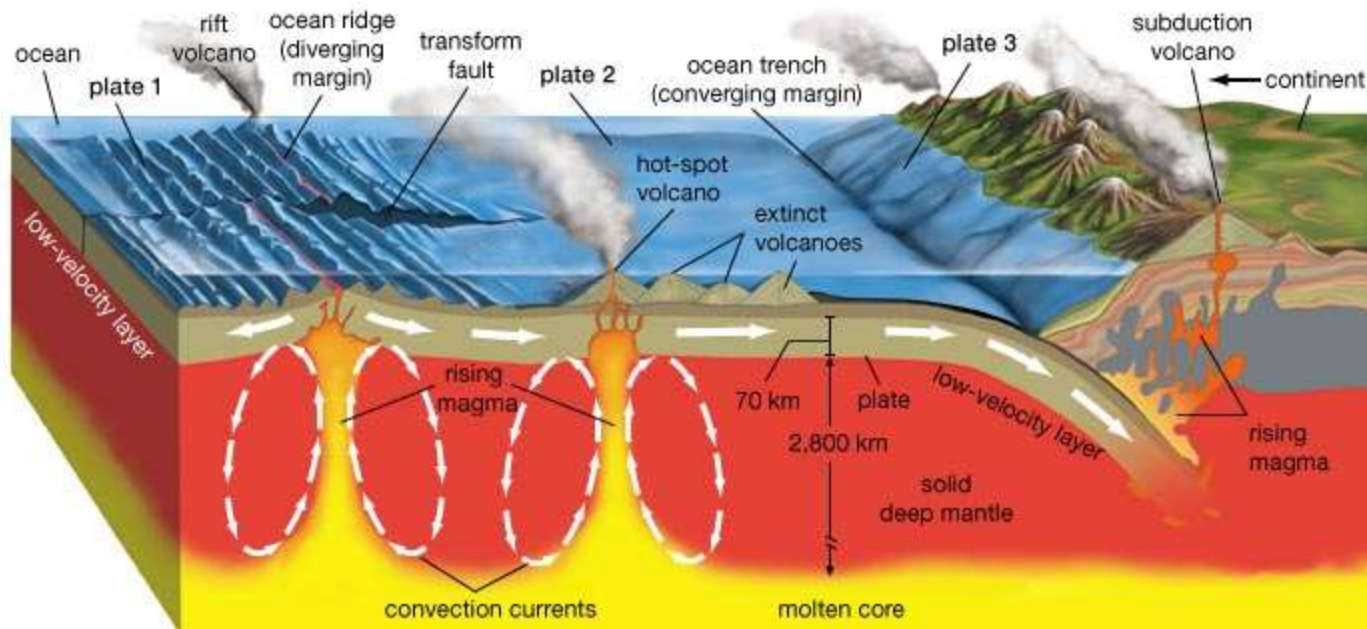
- Evidence of glaciers in Africa, India, Australia, & South America – areas that were too warm for ice to develop, \therefore south pole shifted or landmasses were close to south pole.



A Rejected Notion

- Wegener's ideas were not widely accepted until the 1960's.
- Why?
 - no explanation how a force could be strong enough to move the landmasses
 - no explanation of exactly how solid landmasses were moving through solid ocean crust

Seafloor Spreading



8th Grade Earth and Space
Science
Class Notes

Mapping the Ocean Floor

- Until the mid-1900s scientists assumed the ocean floor was flat
- In the 1940s -1950s technology advanced and showed this was hardly the case!

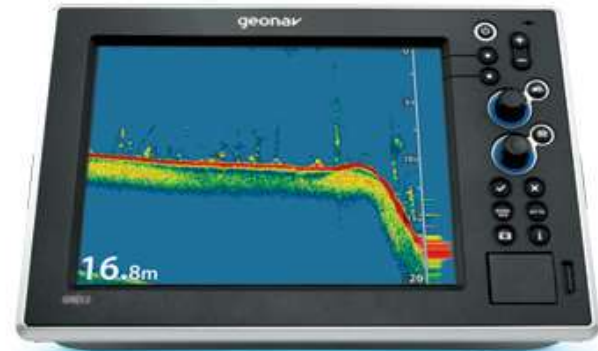
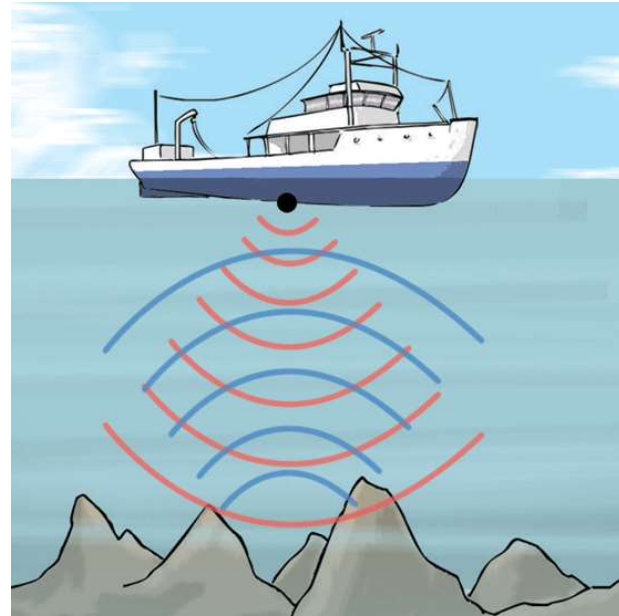
Mapping the Ocean Floor

- Tools that showed the ocean floor was different than expected:
- Magnetometer – device that shows small changes in magnetic fields
- Echo-sounding methods (ex: sonar) – uses sound waves to measure distance by measuring how long it takes sound waves to bounce off of the floor and return

Magnetometer and Sonar



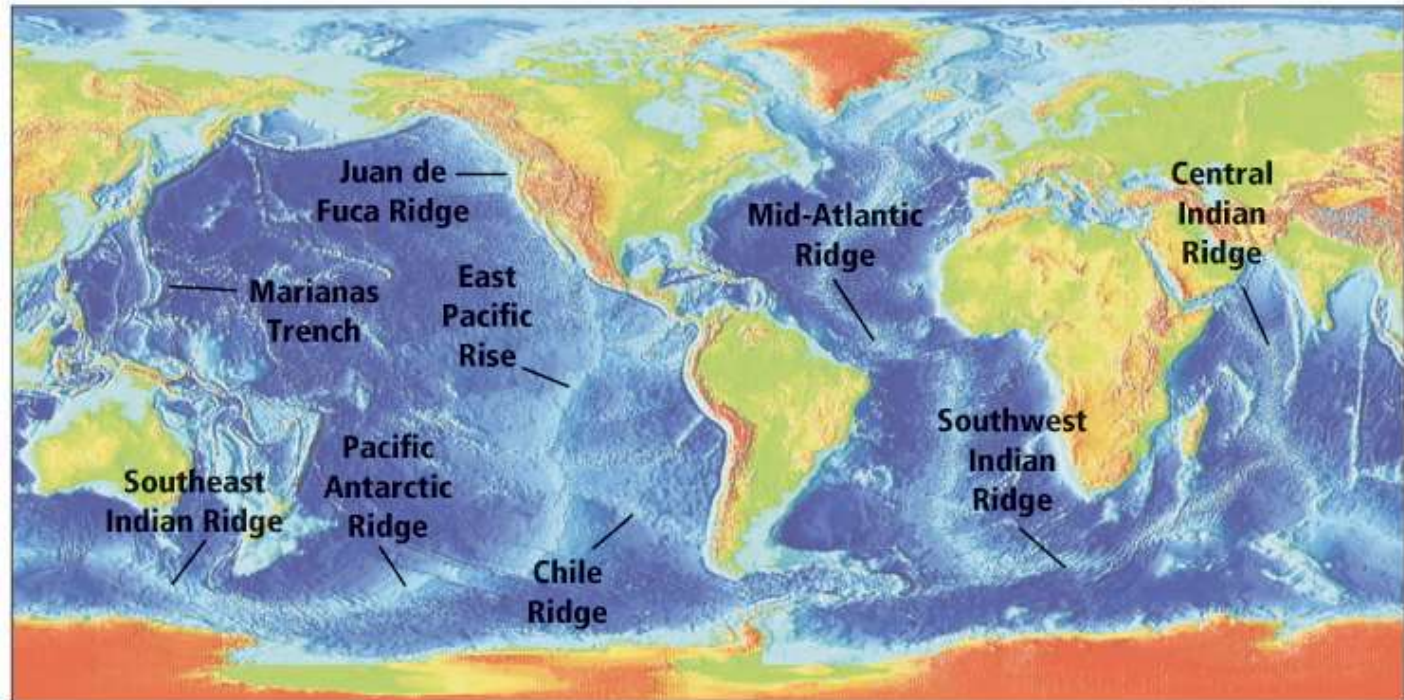
Magnetometer being towed by a ship



Sonar and Sonar Display Screen

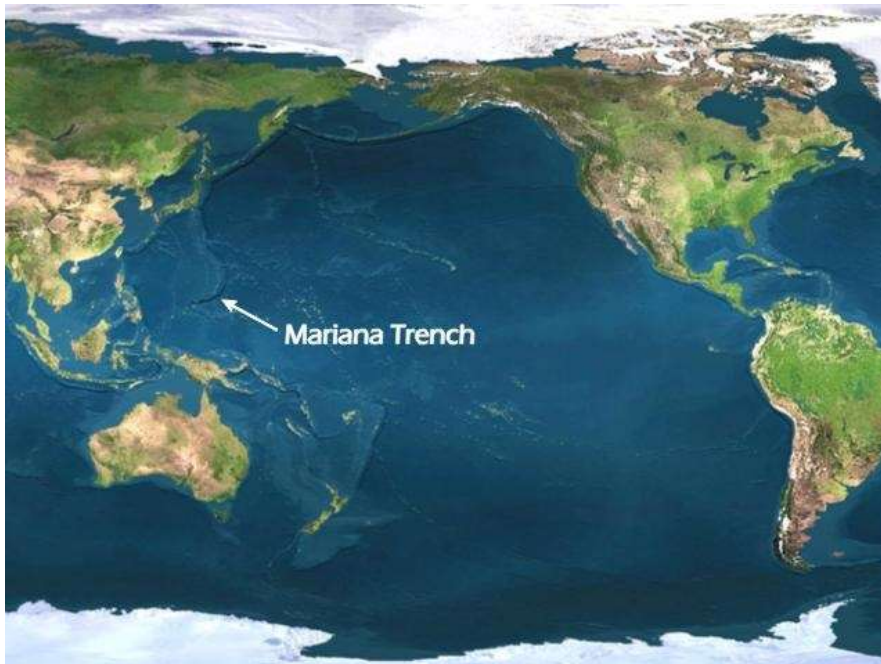
Ocean Floor Topography

- Scientists discovered *ocean ridges* (huge underwater mountain chains)
 - Many volcanoes and earthquakes associated with them



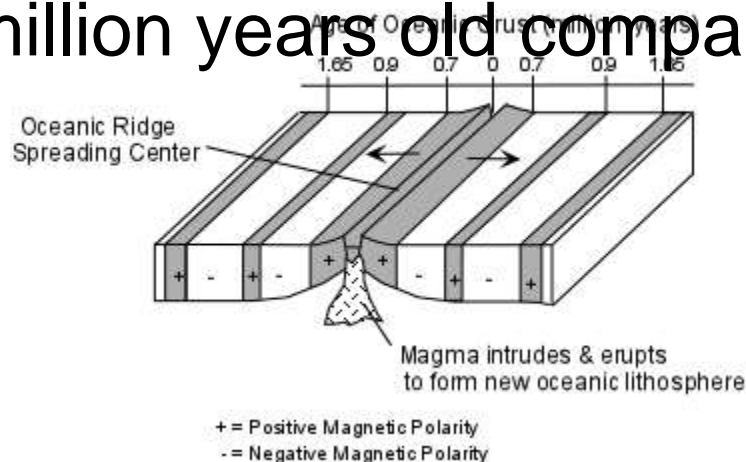
Ocean Floor Topography

- Ocean ridges have counterparts called deep-sea trenches
 - Long, narrow depressions in the sea floor



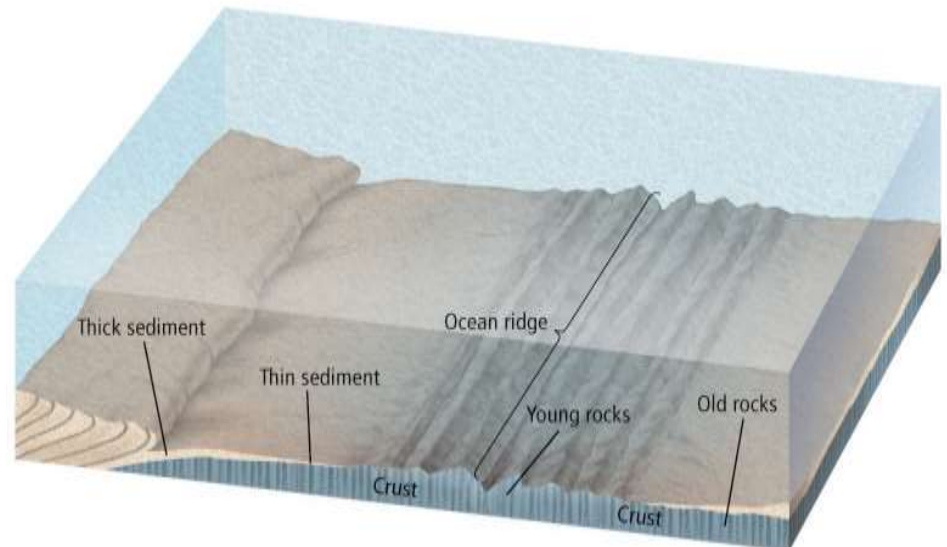
Ocean Rocks and Sediments

- The ages of rocks vary in a predictable way across the sea floor.
 - Near ocean ridge = younger
 - Age of crust increases with distance from the ridge
 - Ocean-floor rocks are geologically young (180 million years old compared in 3.8 billion)



Oceanic Rocks and Sediments

- Ocean-floor sediments are a few hundred meters thick compared to continents which are as much as 20 km thick.
- Thickness varies with distance from the ocean ridge.
 - Closer to ridge = thinner

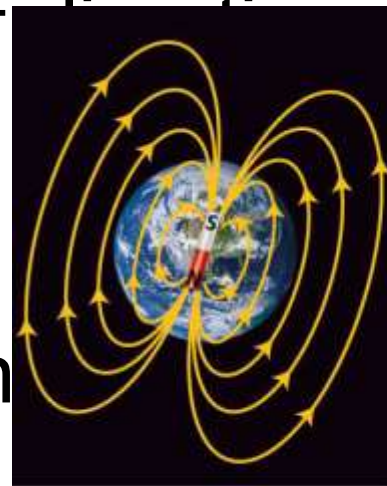


How Do You Determine the Age of Ocean Rocks?

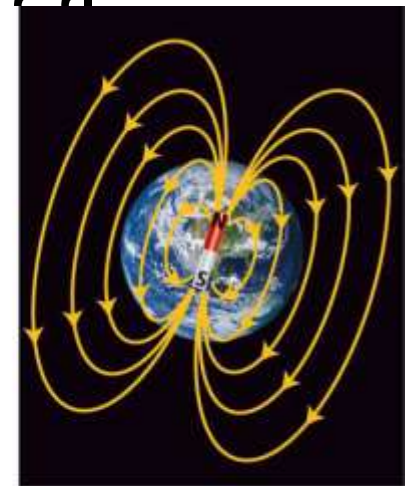
- What type of rock do you think makes up the ocean floor?
- Can you use relative-age dating?
- Can you use radiometric dating?

The Earth's Magnetic Field

- The Earth is surrounded by a magnetic field.
- Caused by flow of molten iron in the outer core.
- Field can be reversed if the flow of molten iron reverses.
- Reversal has occurred many times in the Earth's history.



Normal magnetic field

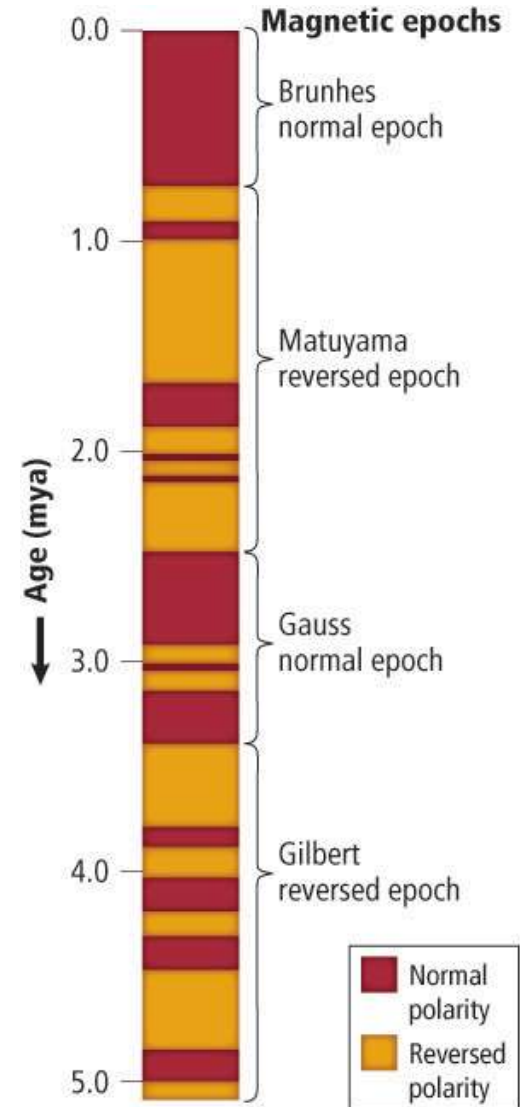
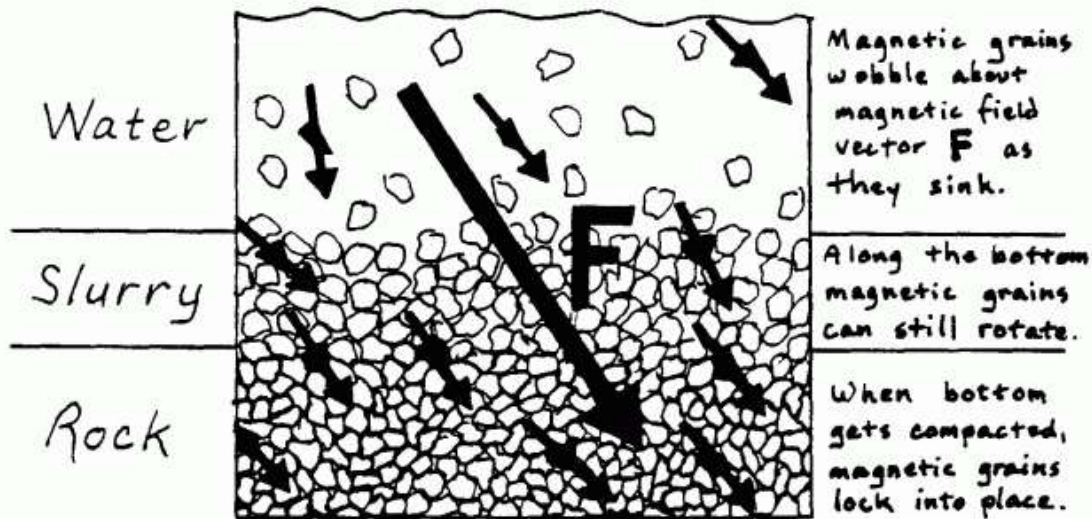


Reversed magnetic field

Magnetic Polarity Time Scale

- Paleomagnetism – study of the history of the Earth's magnetic field
- When lava solidifies minerals with iron crystallize and behave like compasses aligning with the magnetic field.
- Data is put together to create a magnetic polarity time scale.

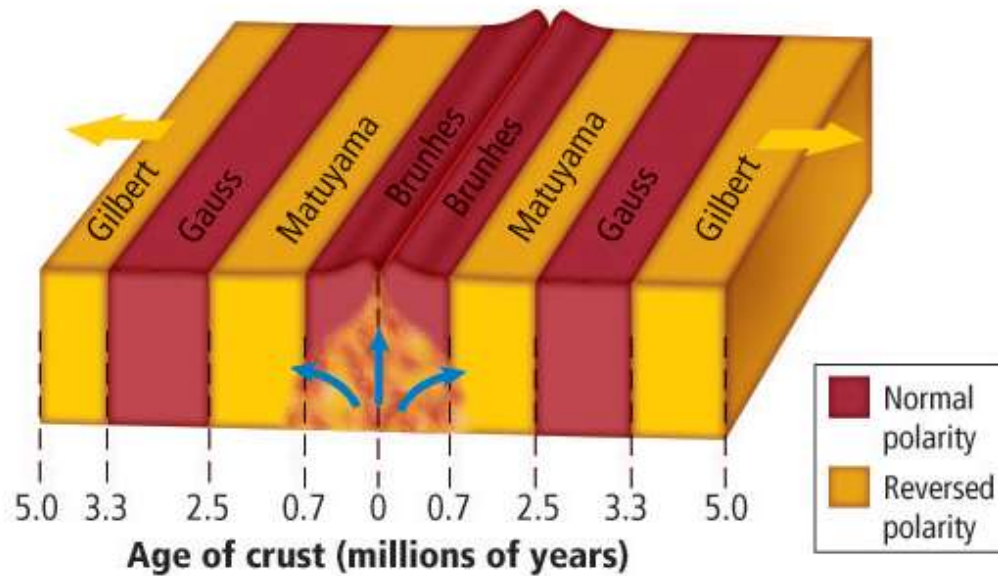
Magnetic Polarity Time Scale



Magnetic Symmetry

- Oceanic crust is mostly basaltic with large amounts of iron.
- Therefore, oceanic crust shows a record of magnetic reversals.
- Scientists found regions with normal and reverse polarity formed a series of stripes across the floor parallel to the ocean ridges.
- Also, the ages and widths of the stripes matched from one side of the ridges to the other.

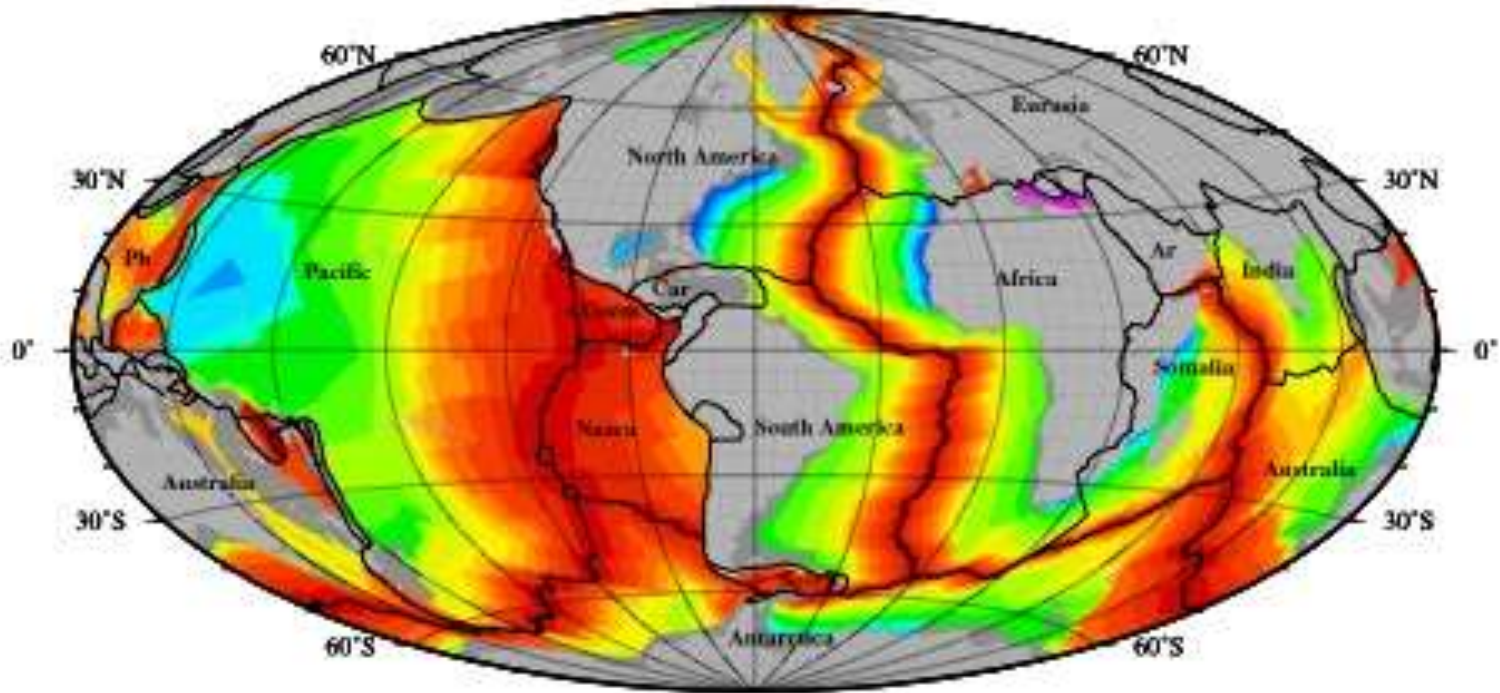
Magnetic Symmetry



Magnetic Symmetry

- By matching the patterns of the seafloor to the known patterns of reversal on land scientists can date the oceanic rocks.
- Isochron maps – use imaginary lines to show points that are the same age

Isochron Map of the Ocean Floor



Red = youngest
Blue = oldest

Seafloor Spreading

- Topographic, sedimentary, and paleomagnetic data was put together to form the theory of seafloor spreading.
- Seafloor spreading explains how new ocean crust is formed at ocean ridges and destroyed at deep sea trenches.

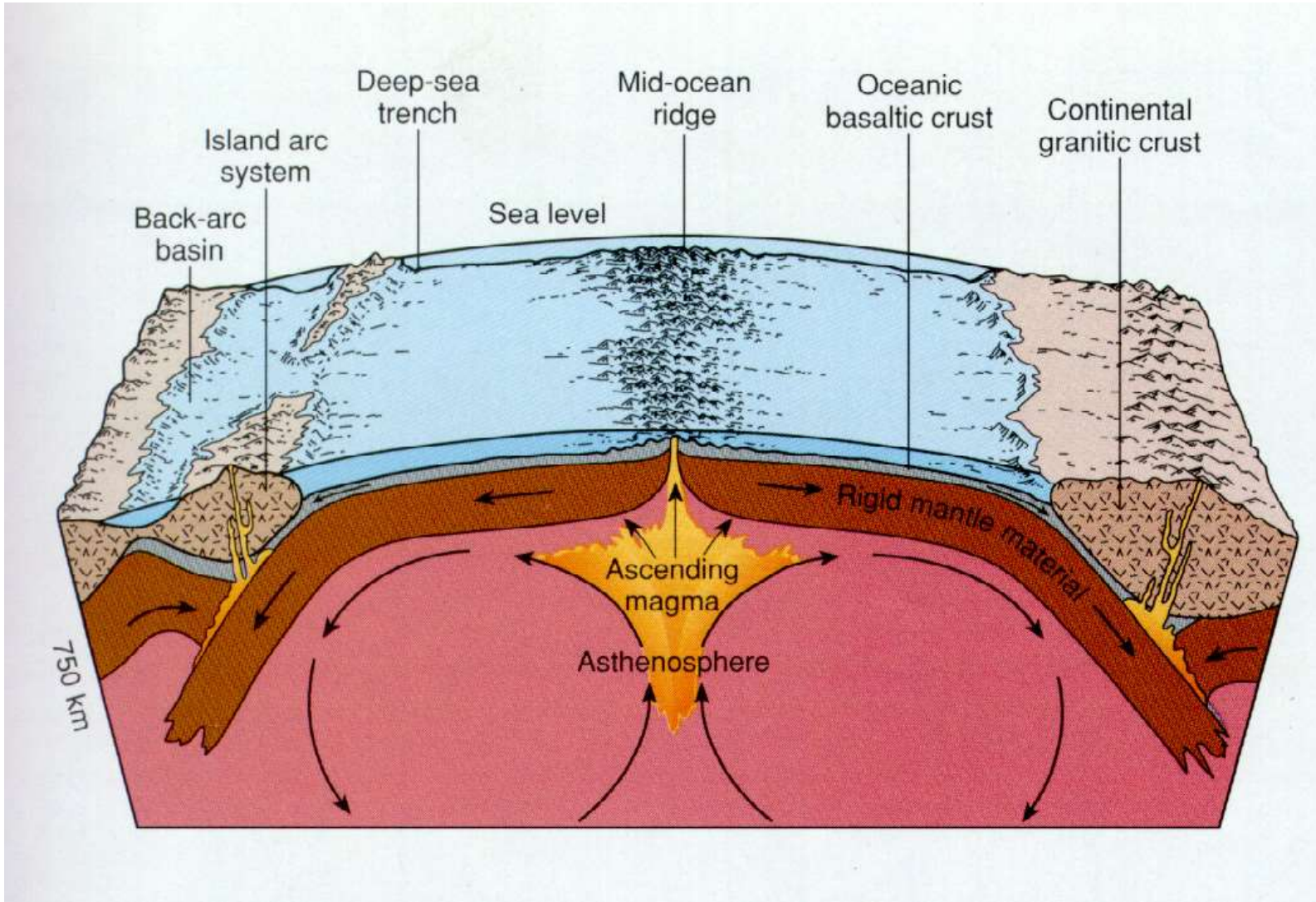
Seafloor Spreading

- Magma is forced toward the surface of the crust along an ocean ridge.
- As the two sides of the ridge spread apart, the rising magma fills the gap that is created.
- When the magma solidifies, a small amount of new ocean floor is added to Earth's surface.

Seafloor Spreading

- As spreading along an ocean ridge continues, more magma is forced upward and solidifies.
- The cycle of spreading and the intrusion of magma continues the formation of ocean floor, which slowly moves away from the ridge.

Seafloor Spreading



Seafloor Spreading and Wegener's Theory

- Continents are not pushing through the ocean's crust.
- They are more like “passengers”.
 - Ride along while ocean crust slowly moves away from the ridges.

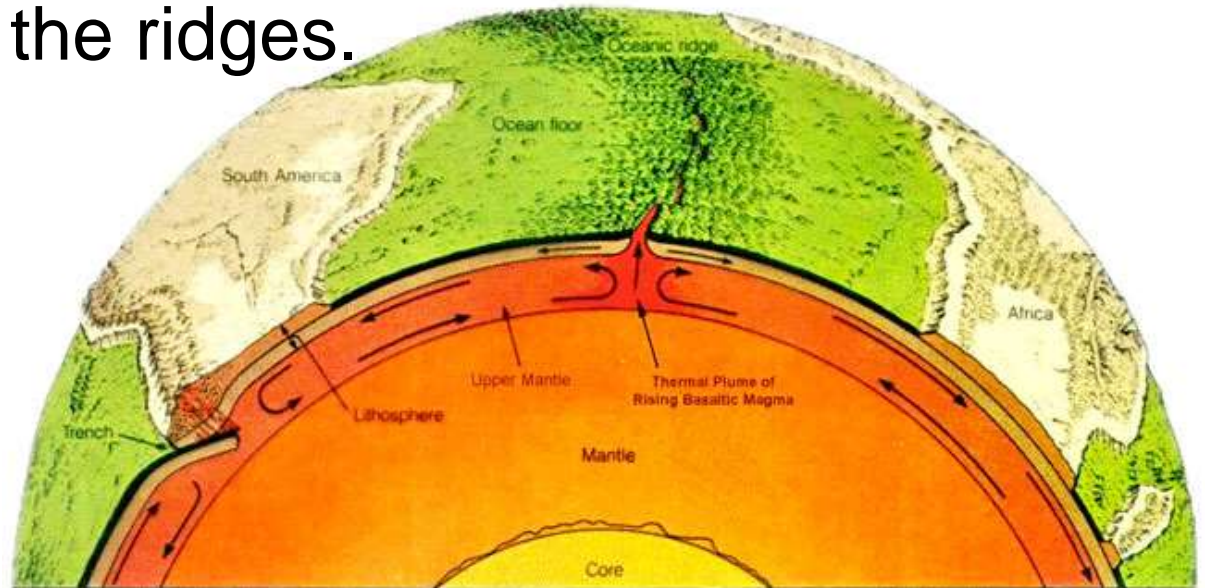
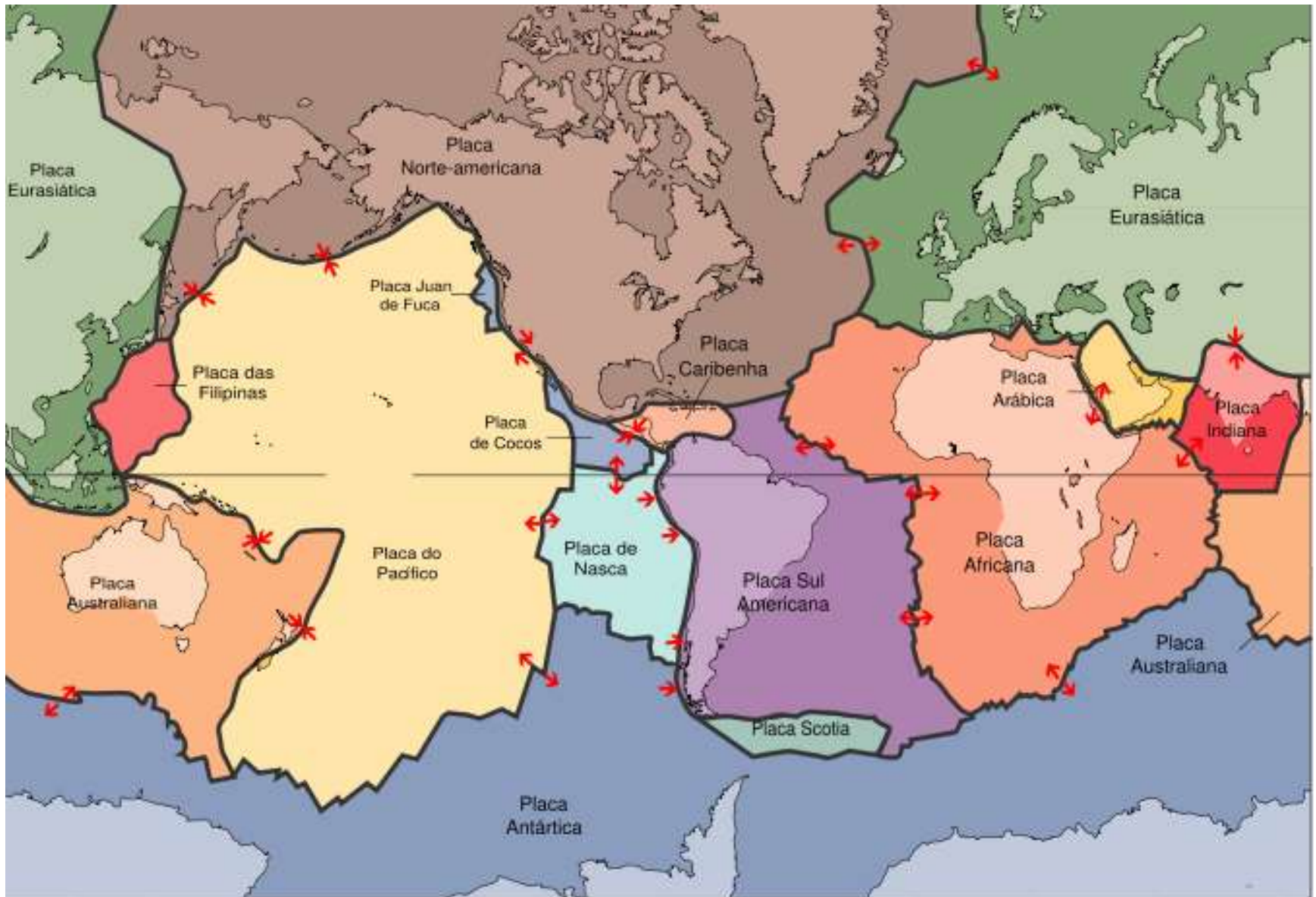
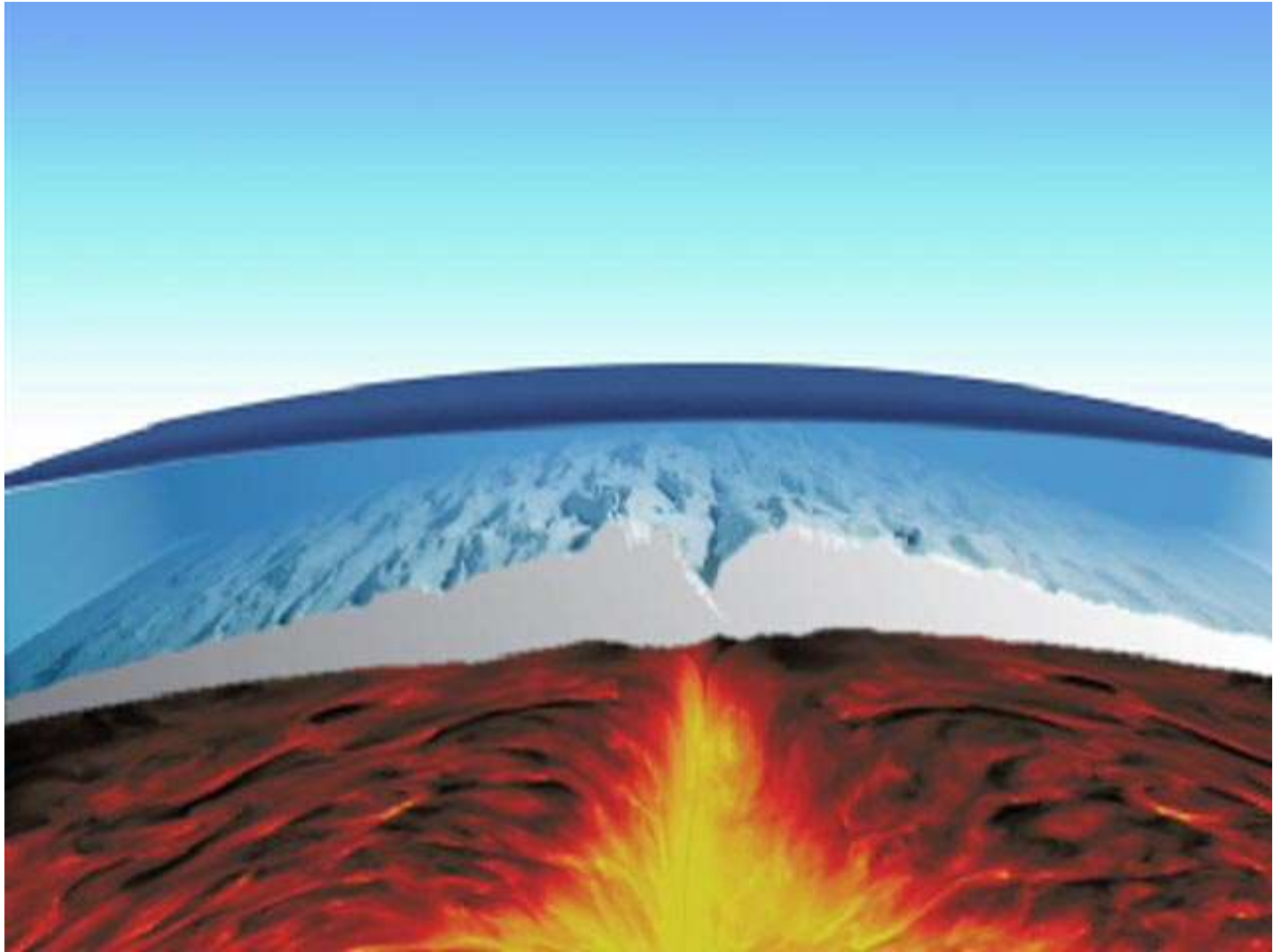


Plate Tectonics - Sections 17.3 & 17.4



Part 1 – Seafloor Spreading



An Underwater Surprise

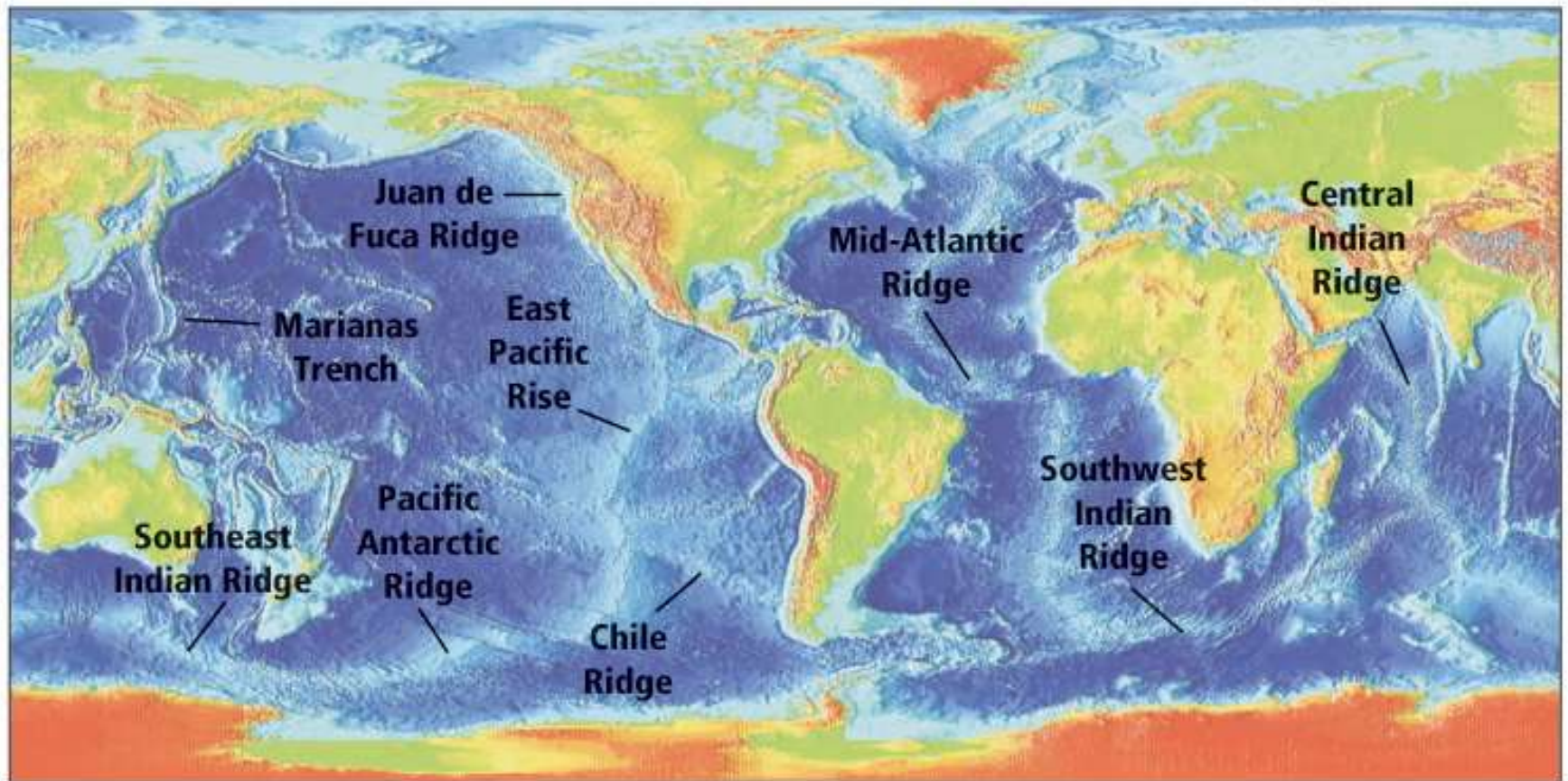
- Until the mid-1900s, many scientists thought that the ocean floors were essentially flat and that oceanic crust was unchanging and was much older than continental crust.
- Advances in technology during the 1940s and 1950s showed that all of these widely accepted ideas were incorrect.
 - Magnetometers
 - Sonar
 - Studies of magnetic reversals

Ocean Floor Topography

- Using the maps made from data collected by sonar and magnetometers, scientists discovered that vast, underwater mountain chains called ocean ridges run along the ocean floors around Earth much like seams on a baseball.

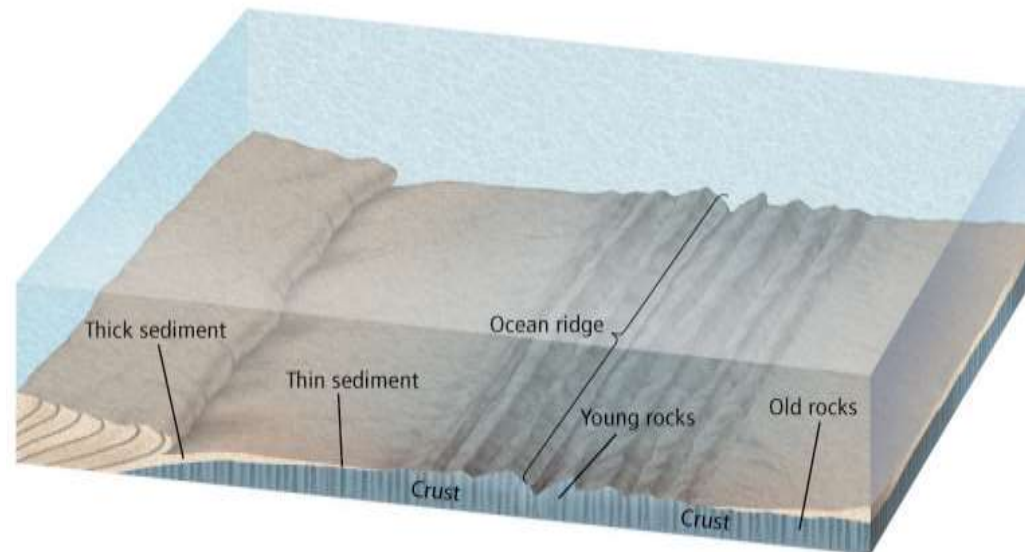
Ocean Floor Topography

- Maps generated with sonar data revealed that underwater mountain chains had counterparts called deep-sea trenches.



The Interesting Ocean Floor...

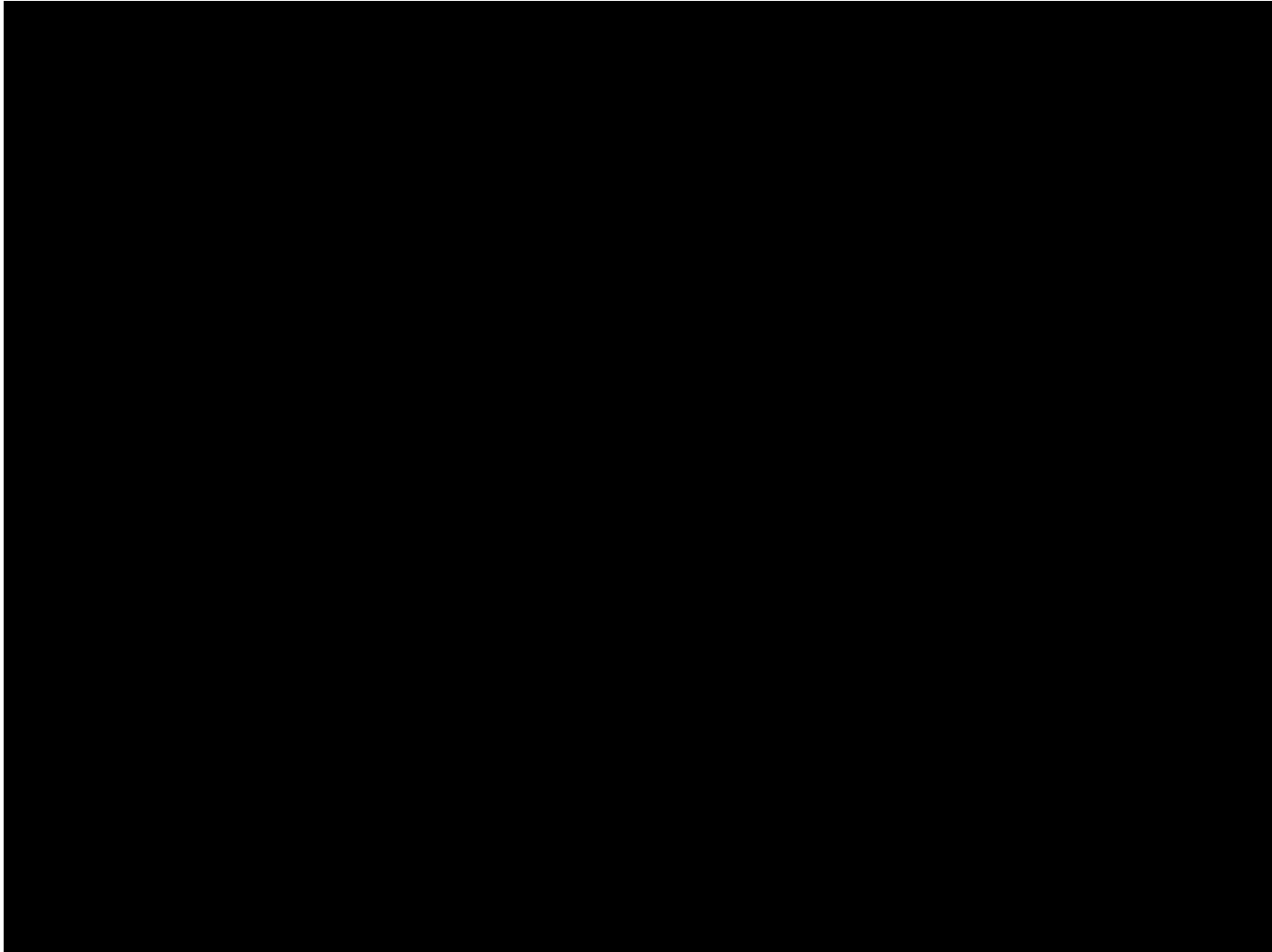
The ages of the rocks that make up the seafloor vary across the ocean floor, and these variations are predictable. The age of oceanic crust consistently increases with distance from a ridge.



What Does It Mean?

- Ocean-floor sediments are typically a few hundred meters thick. Large areas of continents, on the other hand, are blanketed with sedimentary rocks that are as much as 20 km thick.
- **How is this possible?**

Seafloor Spreading



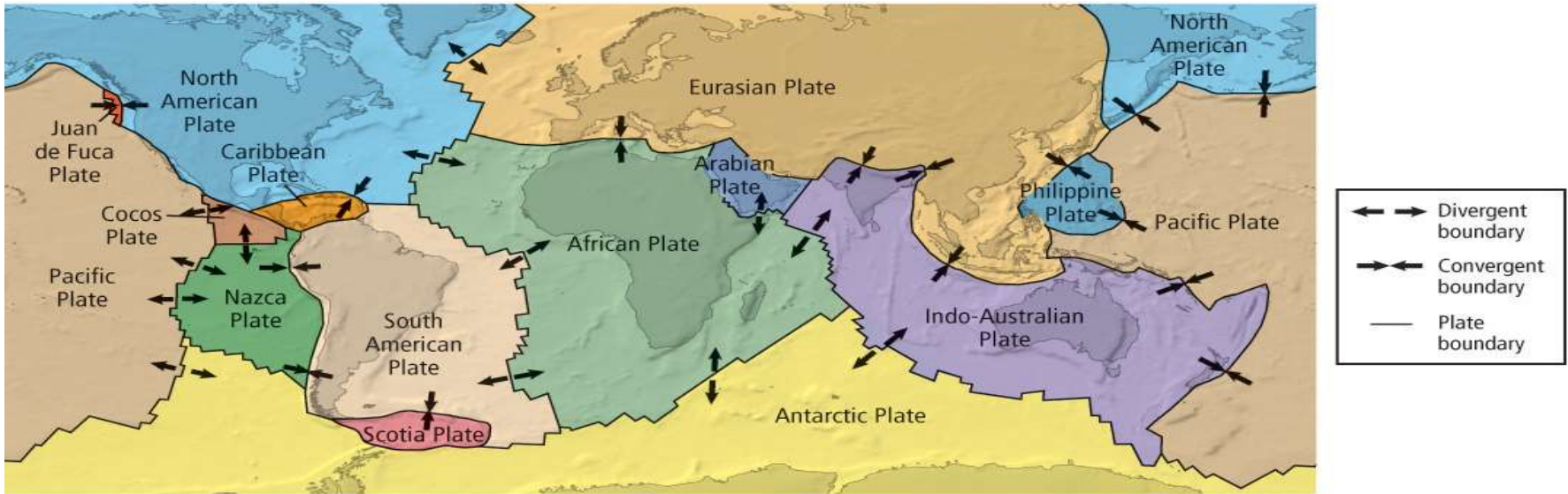
Seafloor Spreading

- During seafloor spreading, magma, which is hotter and less dense than surrounding mantle material, is forced toward the surface of the crust along an ocean ridge.
- As the two sides of the ridge spread apart, the rising magma fills the gap that is created. When the magma solidifies, a small amount of new ocean floor is added to Earth's surface.

Seafloor Spreading

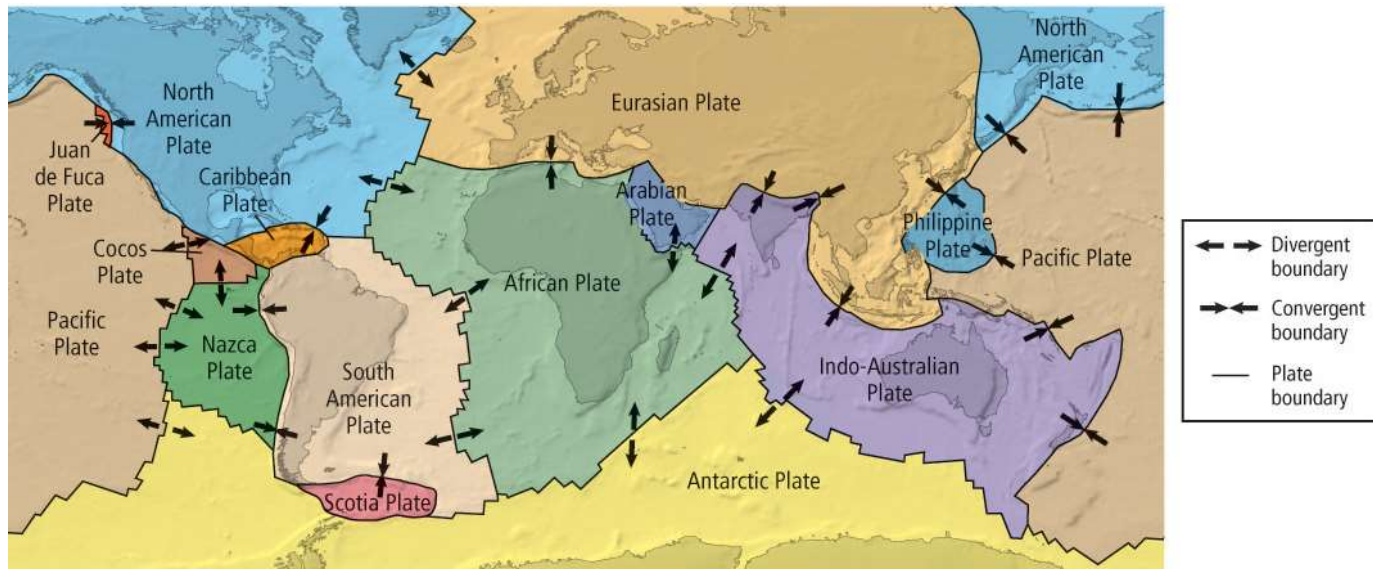
- As spreading along an ocean ridge continues, more magma is forced upward and solidifies.
- The cycle of spreading and the intrusion of magma continues the formation of ocean floor, which slowly moves away from the ridge.

Part 2 – Plate Boundaries



Theory of Plate Tectonics

- **Tectonic plates** are huge pieces of crust and rigid upper mantle that fit together at their edges to cover Earth's surface.



Theory of Plate Tectonics

- Plate tectonics is the theory that describes how tectonic plates move and shape Earth's surface.
- They move in different directions and at different rates relative to one another, and they interact with one another at their boundaries.

Types of Plate Boundaries

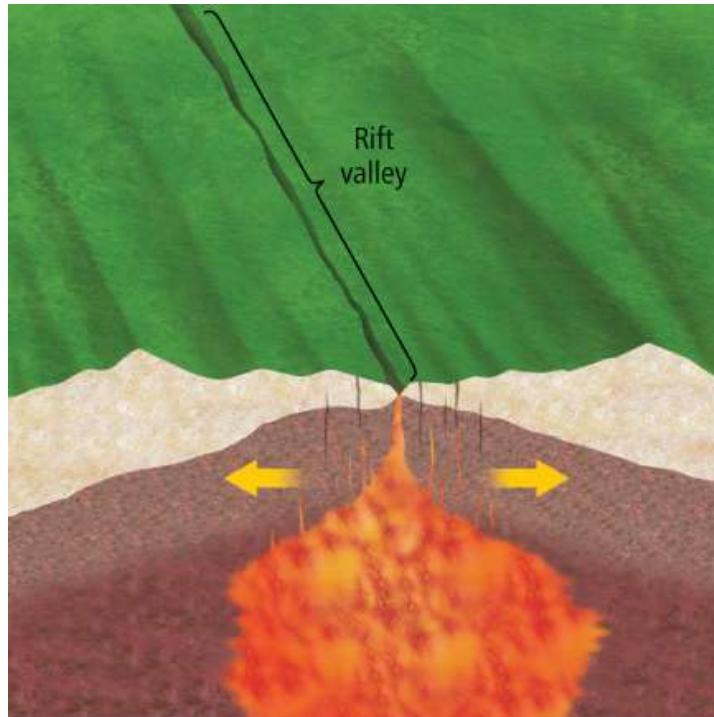
- Divergent Boundaries
- Convergent Boundaries
- Transform Boundaries

Divergent Boundaries

- Regions where two tectonic plates are moving apart are called **divergent boundaries**.
- Most divergent boundaries are found along the seafloor in rift valleys. The formation of new ocean crust at most divergent boundaries accounts for the high heat flow, volcanism, and earthquakes associated with these boundaries.

Divergent Boundaries

- Some divergent boundaries form on continents. When continental crust begins to separate, the stretched crust forms a long, narrow depression called a **rift valley**.



Convergent Boundaries

- At **convergent boundaries**, two tectonic plates are moving toward each other.
- When two plates collide, the denser plate eventually descends below the other, less-dense plate in a process called **subduction**.
- There are three types of convergent boundaries, classified according to the type of crust involved. The differences in density of the crustal material affect how they converge.

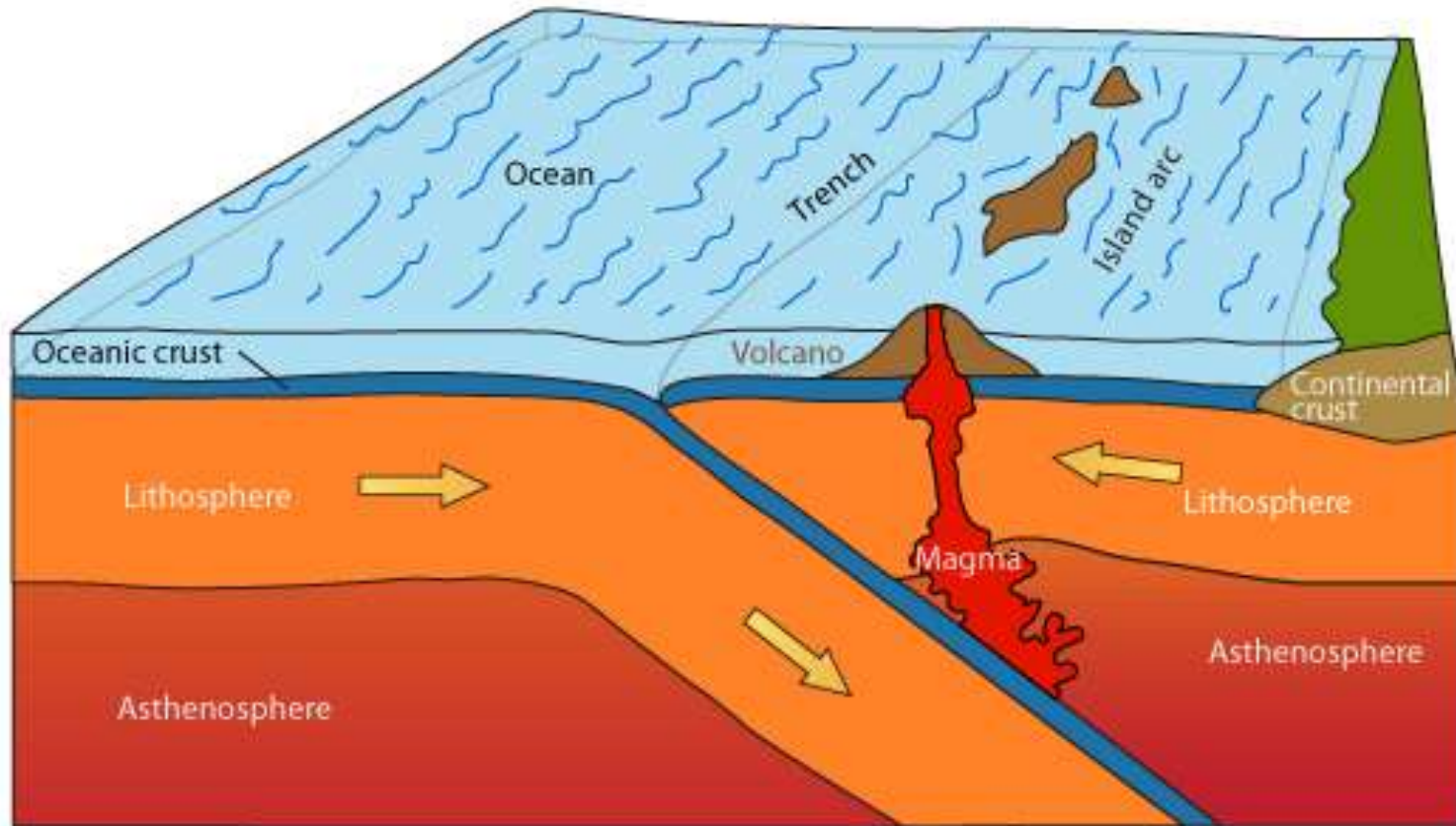
Type 1 – Oceanic-Oceanic

- In the oceanic-oceanic convergent boundary, a subduction zone is formed when one oceanic plate, which is denser as a result of cooling, descends below another oceanic plate.
- The process of subduction creates an ocean trench.

Type 1 – Oceanic-Oceanic

- In an oceanic-oceanic convergent boundary, water carried into Earth by the subducting plate lowers the melting temperature of the plate, causing it to melt at shallower depths.
- The molten material is less dense so it rises back to the surface, where it often erupts and forms an arc of volcanic islands that parallel the trench.

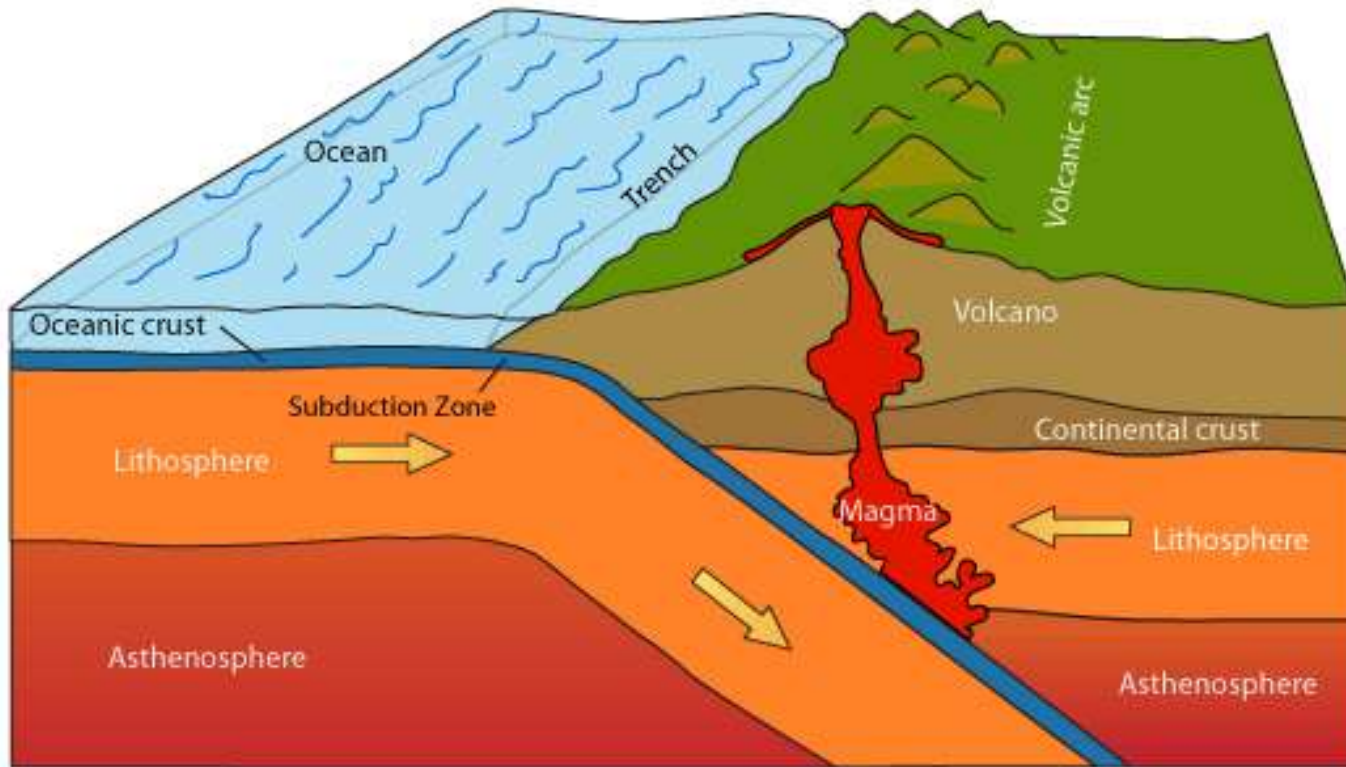
Oceanic-Oceanic



Type 2 – Oceanic-Continental

- When an oceanic plate converges with a continental plate, the denser oceanic plate is subducted.
- Oceanic-continental convergence produces a trench and volcanic arc. The result is a mountain range with many volcanoes.

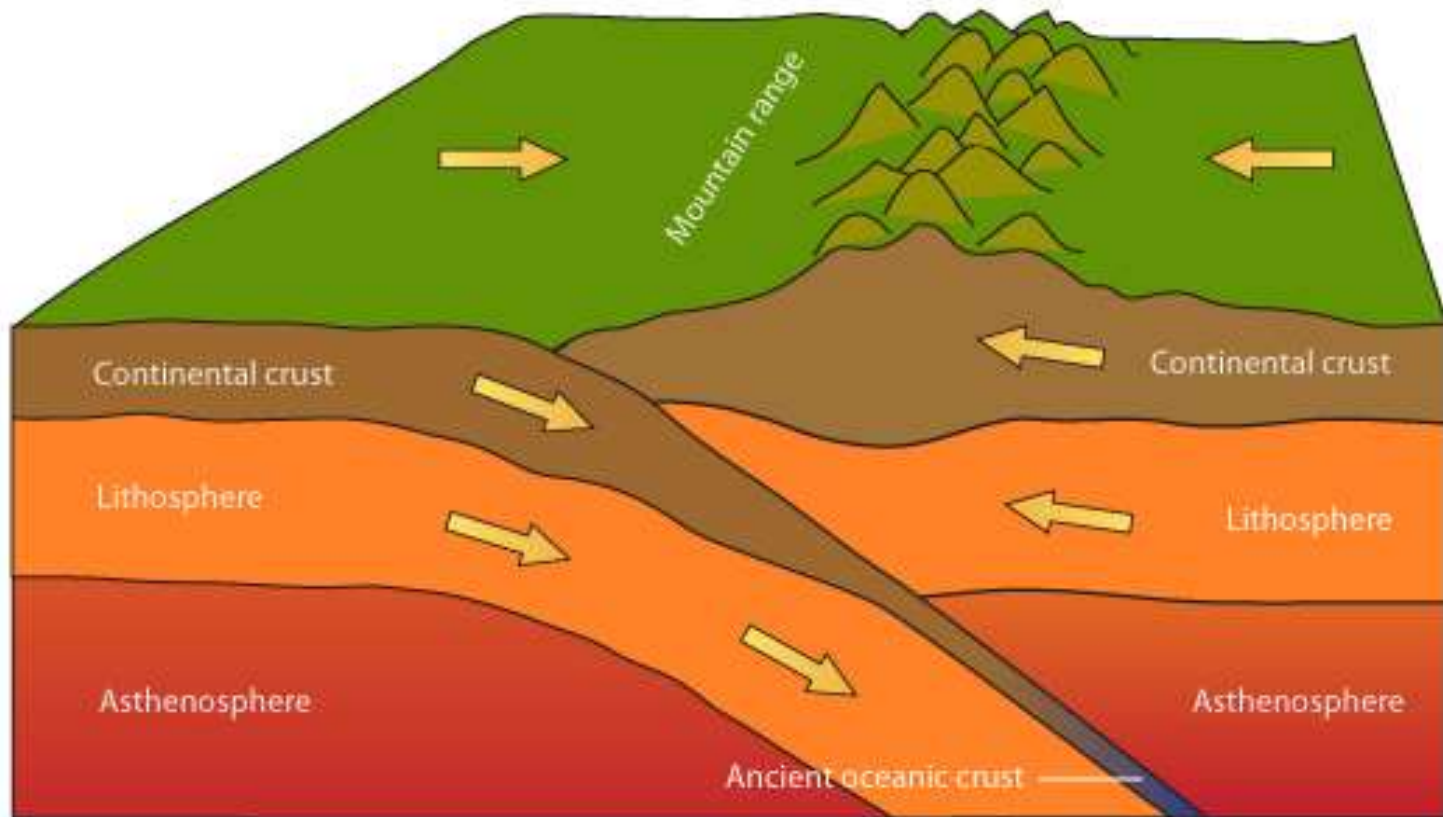
Oceanic-Continental



Type 3 – Continental-Continental

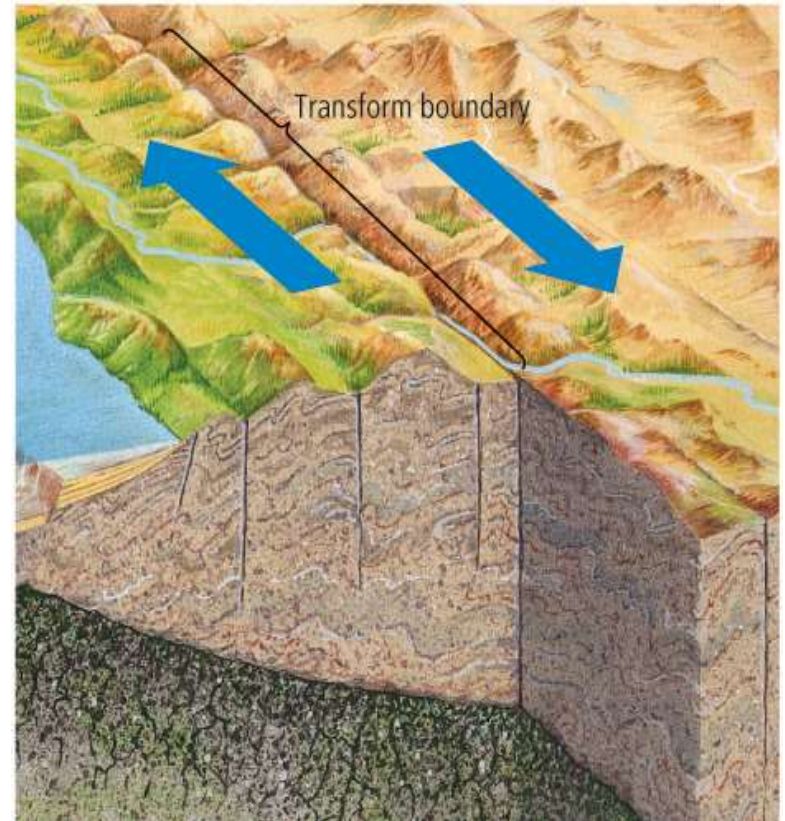
- Continental-continental boundaries form when two continental plates collide, long after an oceanic plate has converged with a continental plate.
- This forms a vast mountain range, such as the Himalayas.

Continental-Continental



Transform Boundaries

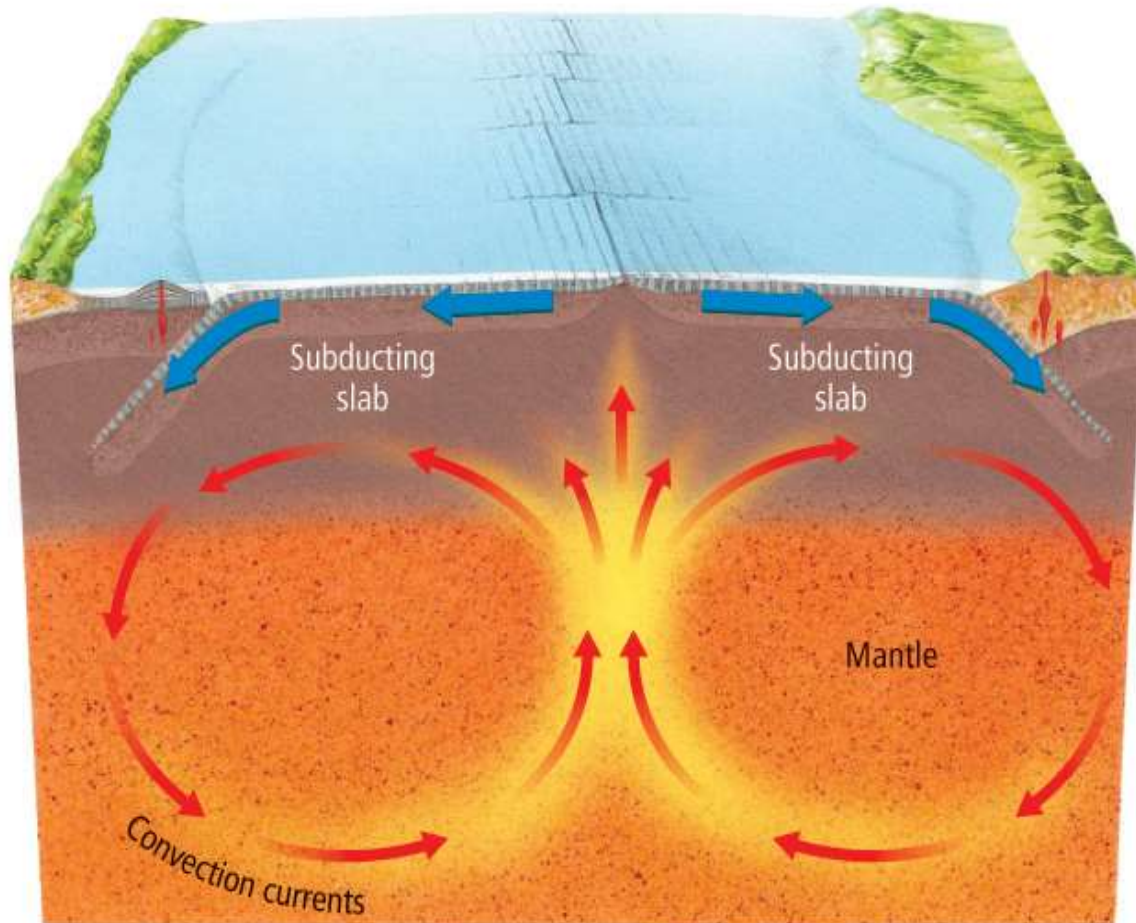
- A region where two plates slide horizontally past each other is a **transform boundary**.



Transform Boundaries

- Transform boundaries are characterized by long faults, sometimes hundreds of kilometers in length, and by shallow earthquakes.
- Most transform boundaries offset sections of ocean ridges. Sometimes transform boundaries occur on continents.
- San Andreas Fault is an example on land.

Part 3 – Causes of Plate Movements



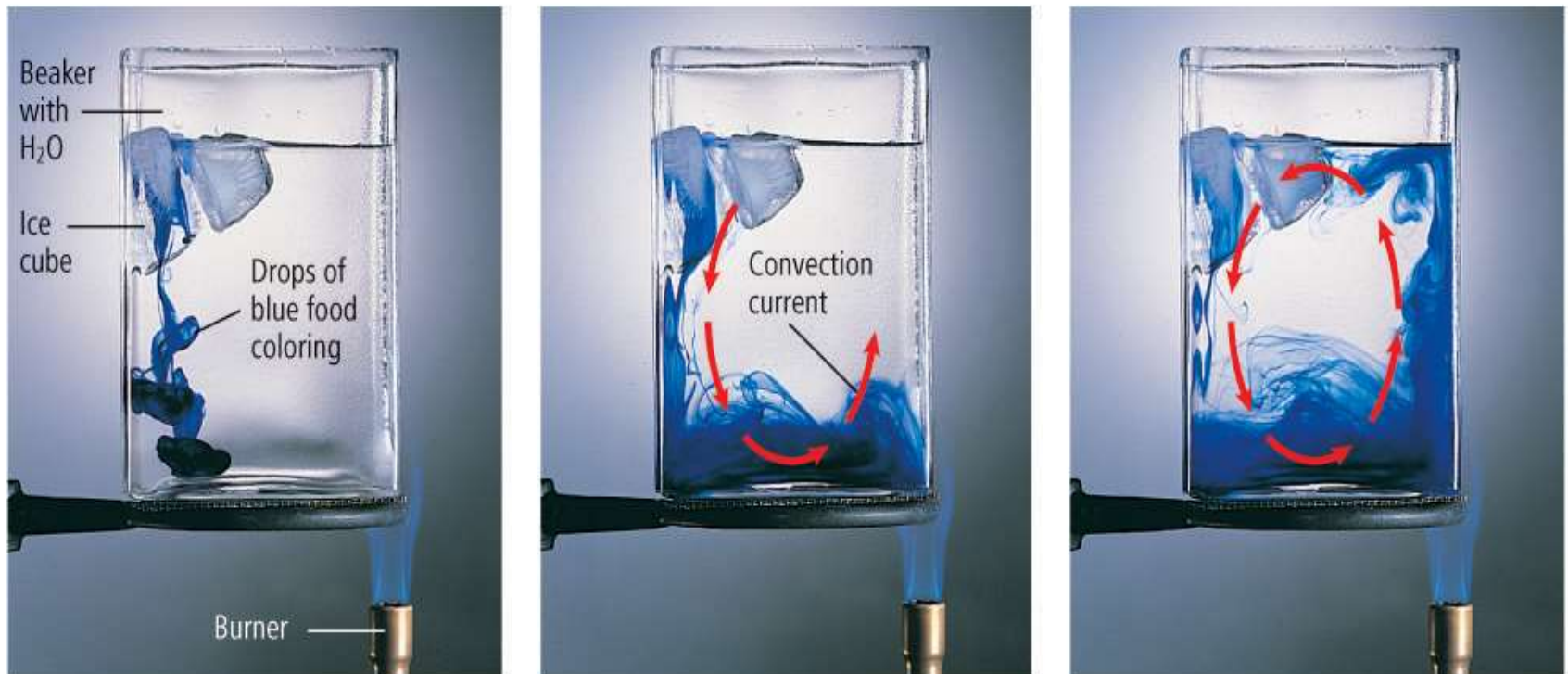
Convection

- Many scientists now think that large-scale motion in the mantle—Earth's interior between the crust and the core—is the mechanism that drives the movement of tectonic plates.
- **Convection** is the transfer of thermal energy by the movement of heated material from one place to another.

Convection Currents

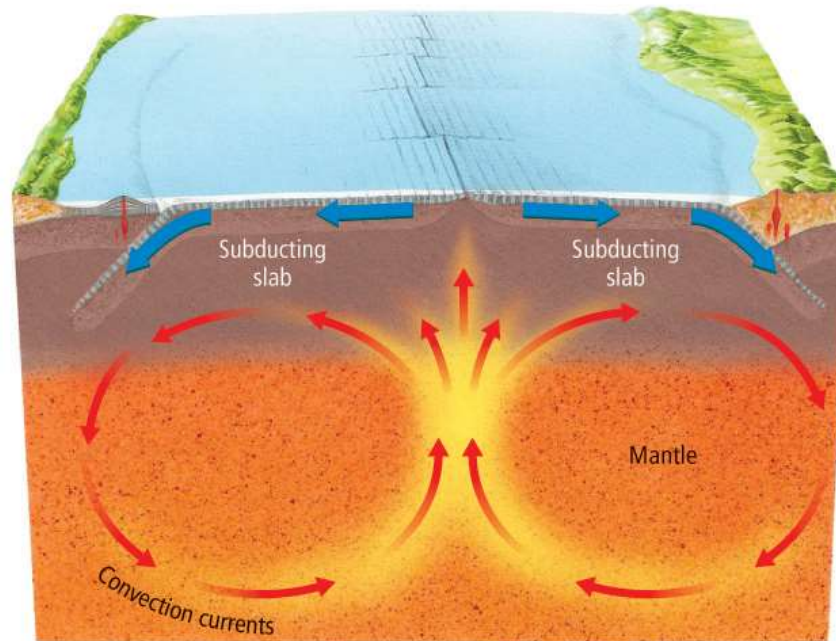
- The cooling of matter causes it to contract slightly and increase in density. The cooled matter then sinks as a result of gravity. Warmed matter is then displaced and forced to rise.
- This up-and-down flow produces a pattern of motion called a **convection current**.

Convection Current



Convection in the Mantle

- Convection currents develop in the mantle, moving the crust and outermost part of the mantle and transferring thermal energy from Earth's interior to its exterior.



Convection and Plate Movement

- The rising material in a convection current spreads out as it reaches the upper mantle and causes both upward and sideways forces, which lift and split the lithosphere at divergent plate boundaries.
- The downward part of a convection current occurs where a sinking force pulls tectonic plates downward at convergent boundaries.

Push and Pull

- **Ridge push** is the tectonic process associated with convection currents in Earth's mantle that occurs when the weight of an elevated ridge pushes an oceanic plate toward a subduction zone.

Push and Pull

- **Slab pull** is the tectonic process associated with convection currents in Earth's mantle that occurs as the weight of the subducting plate pulls the trailing lithosphere into a subduction zone.

Push & Pull

