Plate Tectonics: A Unifying Theory 17.1

What is Plate Tectonics?

- 7 large tectonic plates and many smaller ones that break up the lithosphere
    - Plates are brittle and float on asthenosphere and glide past each other 2-18cm per year
    - This gliding causes different types of boundaries to occur
        - Three types of plate boundaries are recognized
            - Divergent
            - Convergent
            - Transform
    - Boundaries are zones of earthquakes, volcanoes, mountain building
- Plate Tectonics is the unifying theory of geology
- Considerable geologic, paleontology, and climatologic evidence is used to support the theory
-Interior processes are involved in plate movement

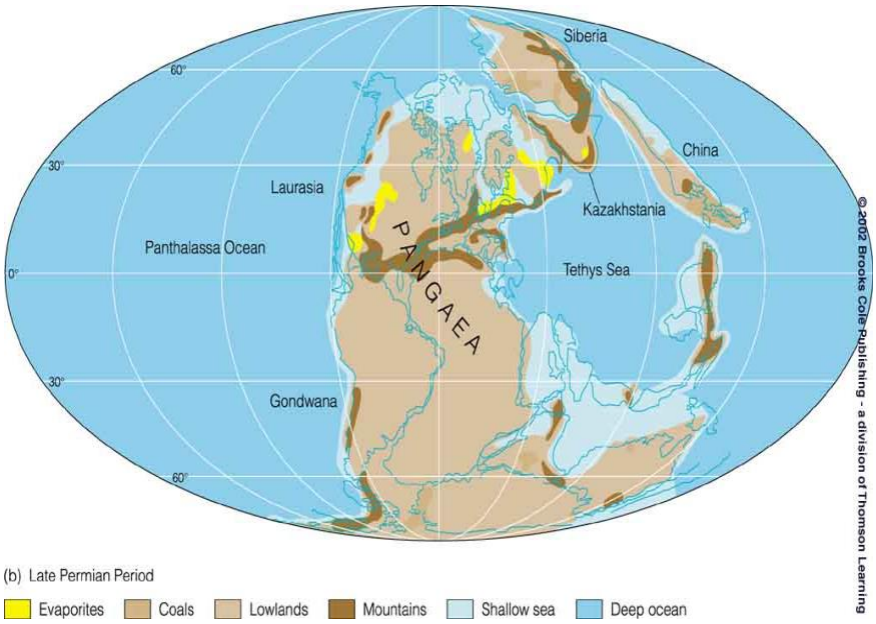
Before Plate Tectonics there was Continental Drift

Evidence for Continental Drift

- Continental Fit

- Abraham Ortelius: Early cartographer noticed the apparent fit of North & South America

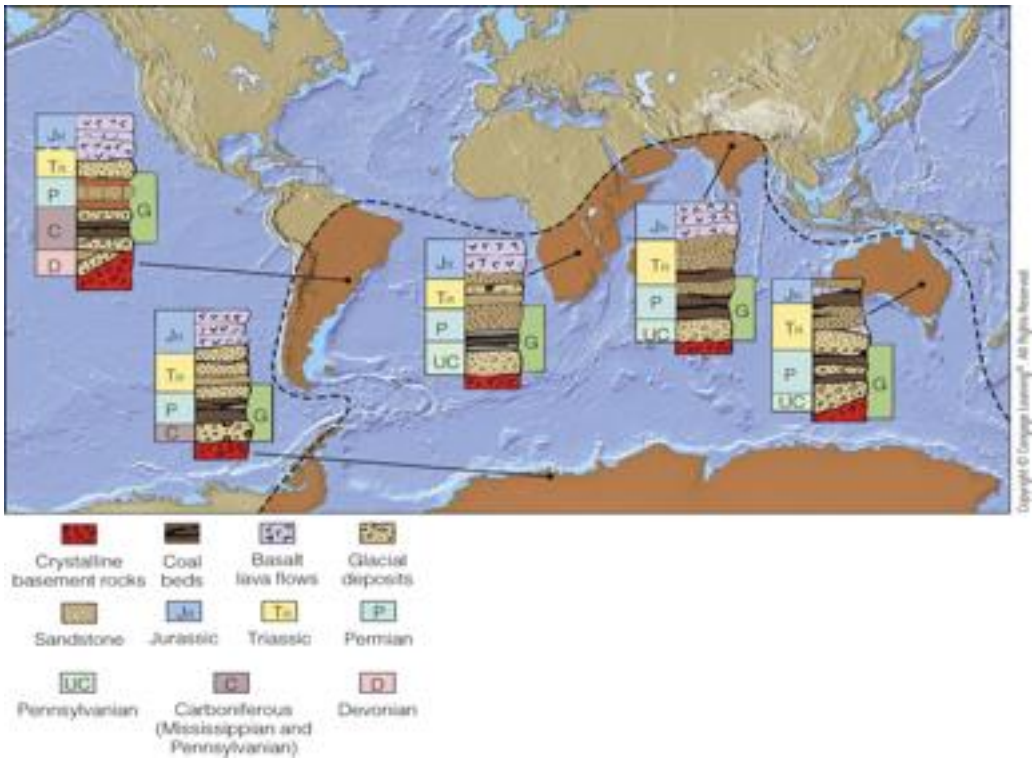
- Alfred Wegener: German meteorologist
    - Developed the idea of ***continental drift***
    - Proposed supercontinent named ***Pangaea***, meaning "all land"



- He portrayed the breakup of Pangaea and the movement of continents to their present position
    - Laurasia: northern hemisphere
    - Gondwanaland: southern hemisphere

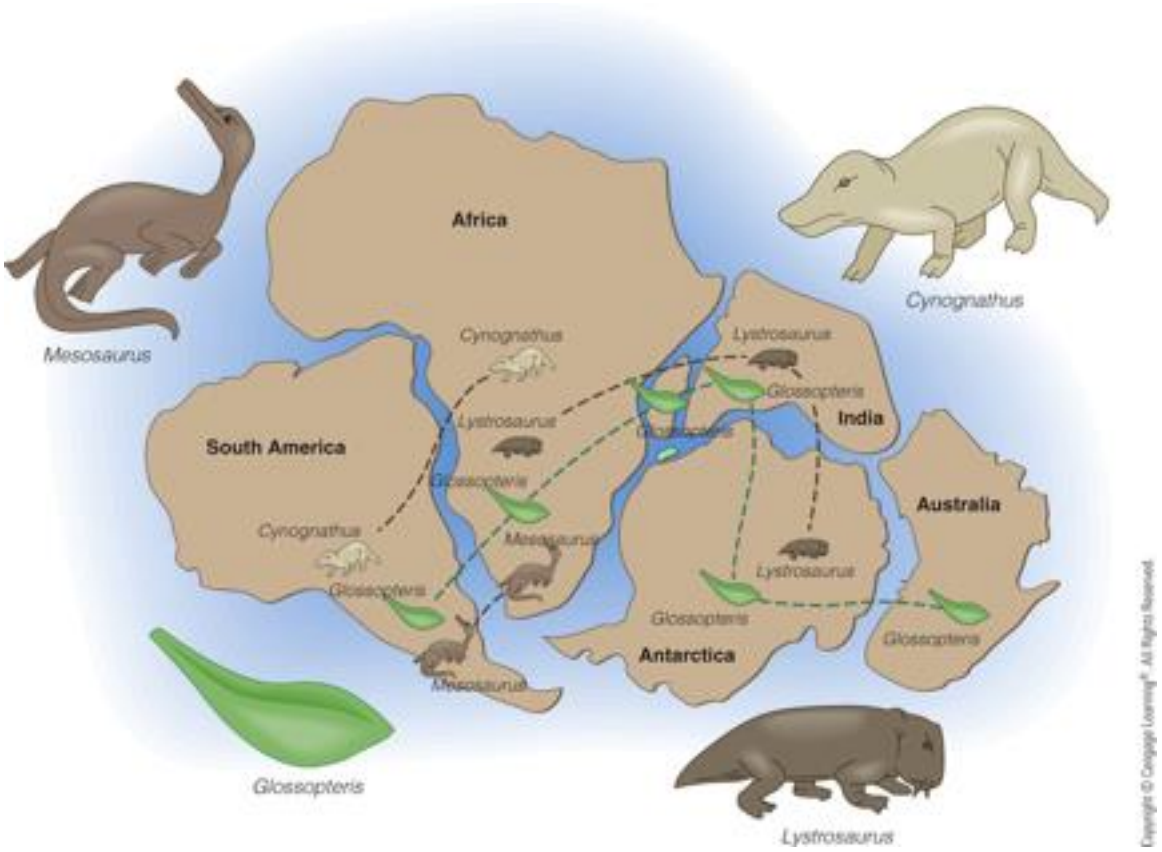
- In 1965 Sir Edward Bullard demonstrated that a better fit between the continents could be made if the continental shelf/slope boundary was used: see above diagram

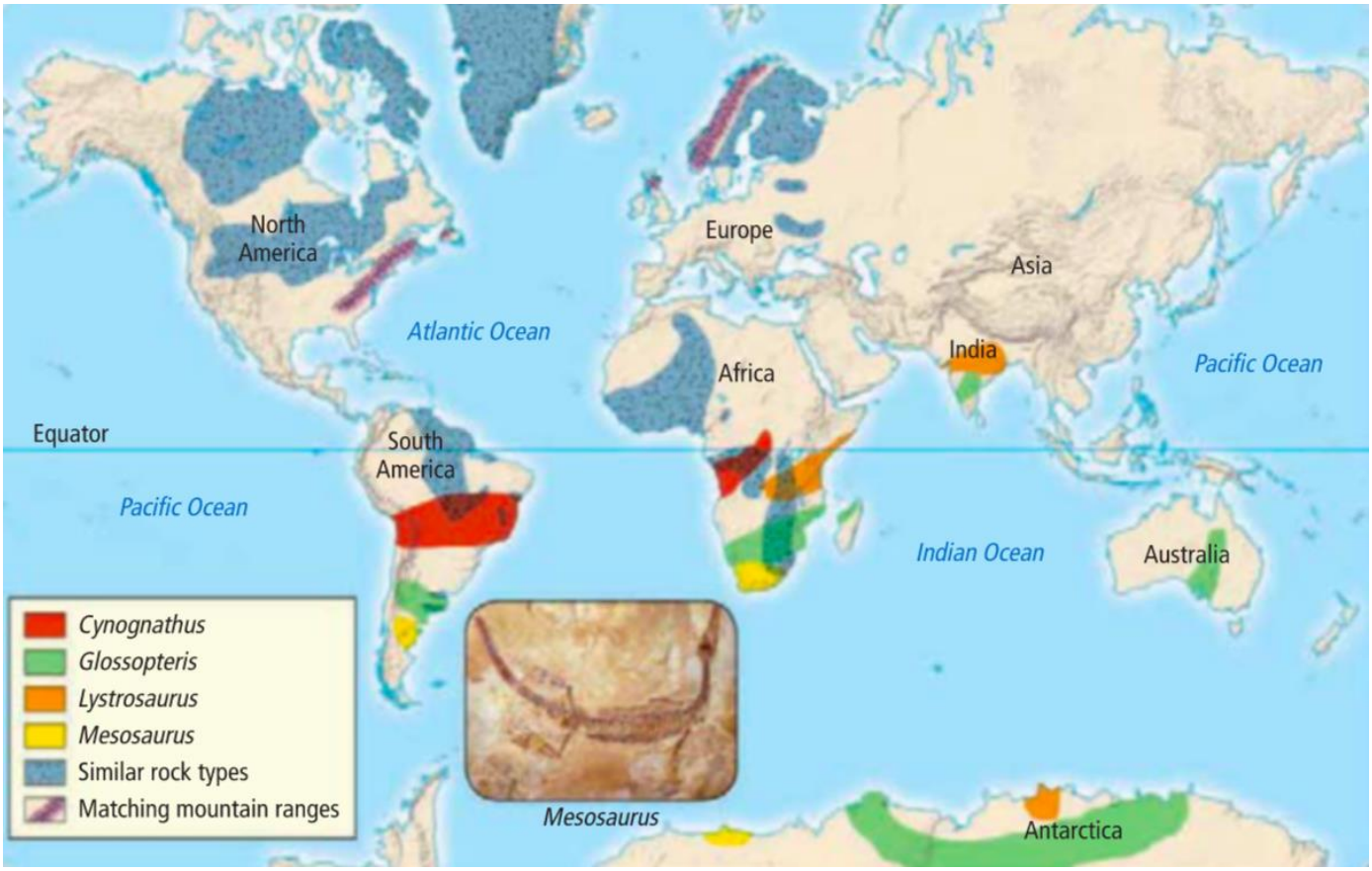
- **Similarity of Rock Sequences and Mountain Ranges**
  marine, nonmarine, and glacial rock sequences are nearly identical for Gondwana continents
    - Trends of several major mountain ranges on separate continents match when the continents are repositioned



- **Fossil Evidence**

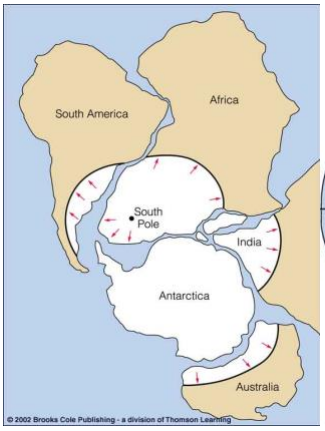
    - Glossopteris: if continents were separated, this plant should not of been widespread 300 million years ago
    - Cynognathus: land reptile
    - Mesosaurus: freshwater reptile that could not of swam across that Atlantic Ocean
    - Lystrosaurus: land reptile
    - Coal: made from compacted and decomposed swamp plants that grew in warm, wet areas.
        - we find coal in Antarctica which suggests that Antarctica was once tropical

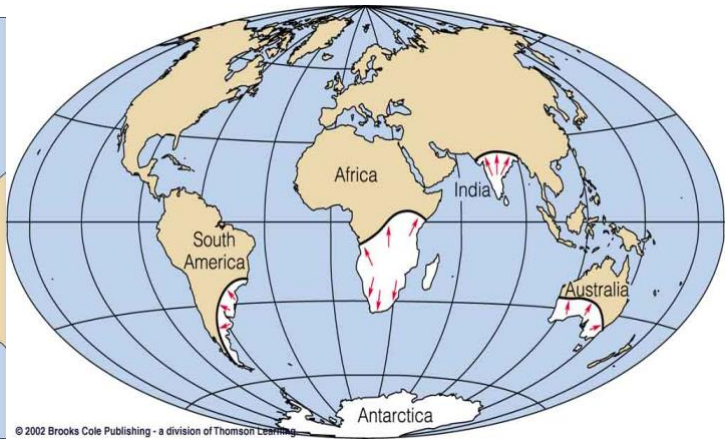

Africa
South America
India
Australia
Antarctica
Mesosaurus
Cynognathus
Lystrosaurus
Glossopteris


North America
Europe
Asia
Atlantic Ocean
India
Africa
Pacific Ocean
Equator
South America
Pacific Ocean
Indian Ocean
Australia
Cynognathus
Glossopteris
Lystrosaurus
Mesosaurus
Similar rock types
Matching mountain ranges
Mesosaurus
Antarctica

- Glacial Evidence

- Striations and glacial deposits of the same age in the five southern continents suggest this reconstruction of Gondwana.





- This reconstruction is consistent with fossil and climatologic evidence from Laurasia

Last 240 million years to next 250 million years: Play 2 minutes to 4:30 minutes
https://www.youtube.com/watch?v=uLahVJNnoZ4&t=580s

- Flaws with Continental drift
  1: Wegner did not explain what force could be strong enough to push continents across large distances.
  2: Wegner did not explain how the continents were moving. How could a solid crust plow over a solid mantle?

The Time Period between Continental Drift and The Theory of Plate Tectonics 16.2

New technology allowed accurate Mapping of the Seafloor or Ocean Basin

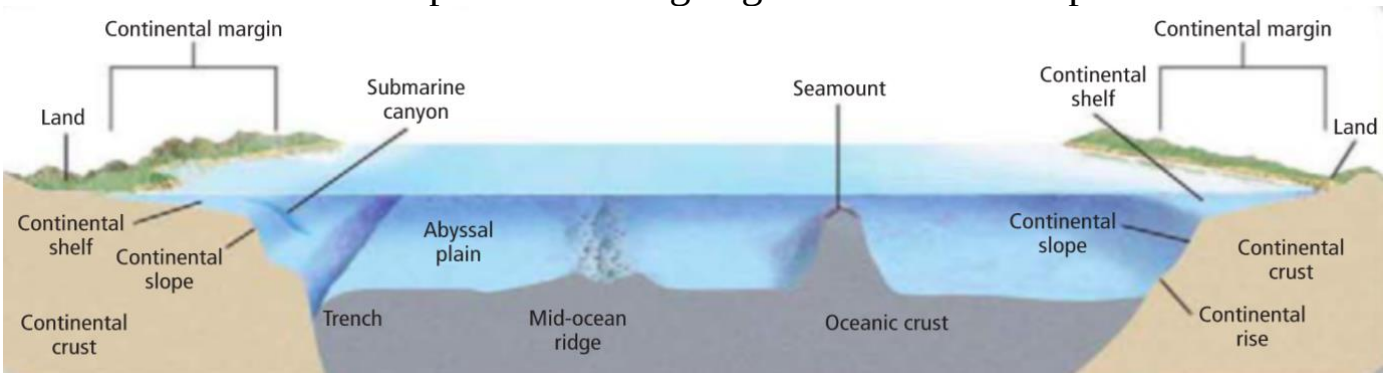
- **Sonar**: sound waves measure distance by measuring the time it takes sound waves to bounce off the seafloor and return to the ship.
- **Magnetometers**: detects small changes in the magnetic field of seafloor rocks

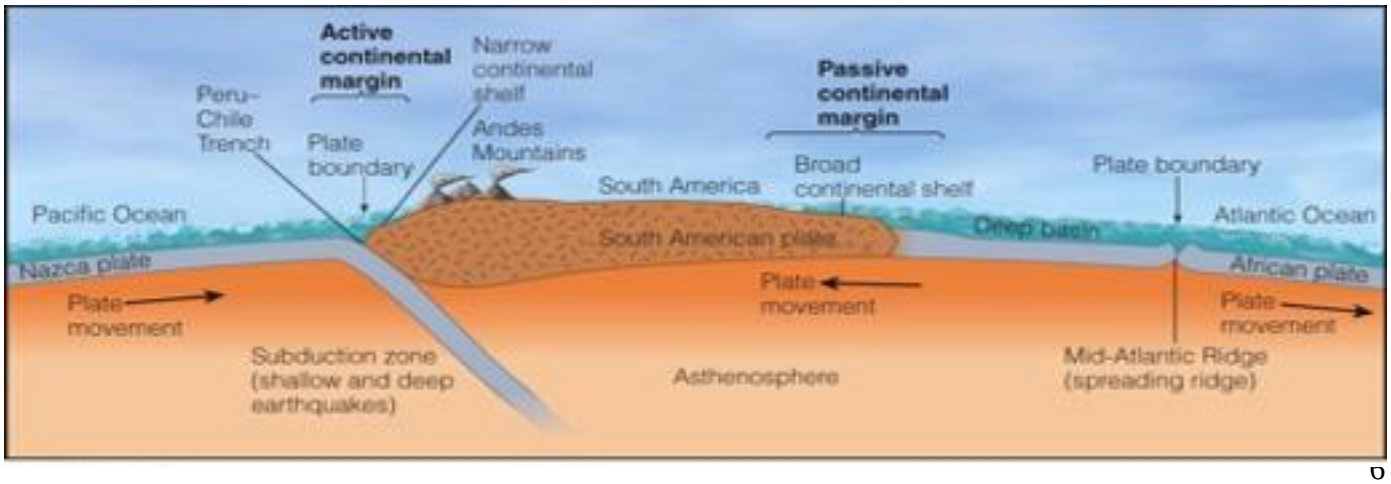
Continental Margins: where continental crust meets oceanic crust

- 2 Types

- *Passive continental margin*: little or no tectonic activity
  - wider, built up from sedimentation
  - found within plates rather than at a boundary

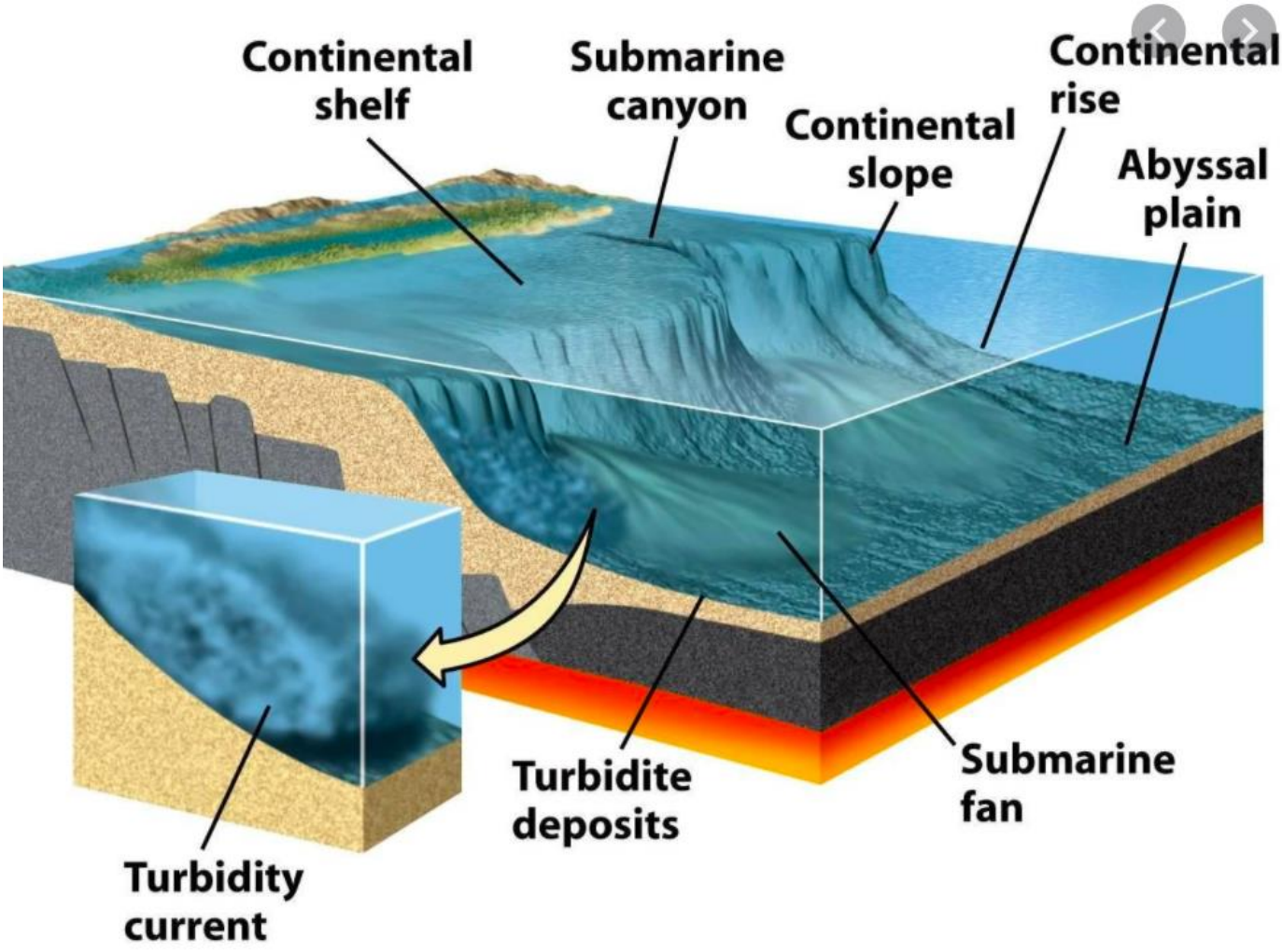
- *Active continental margin*: subduction of an oceanic plate below continental plate
  - narrow, descend into a trench
  - develop at the leading edge of a continental plate





- **Continental Shelf**
    - Between shoreline and continental slope
    - Up to 200 meters deep. Average of 60 km
    - 0.1-1^0 slope
    - Width varies greatly: meters to kilometers
    - Pleistocene glacial cycles exposed great amounts of the slope during cold intervals as sea levels fell

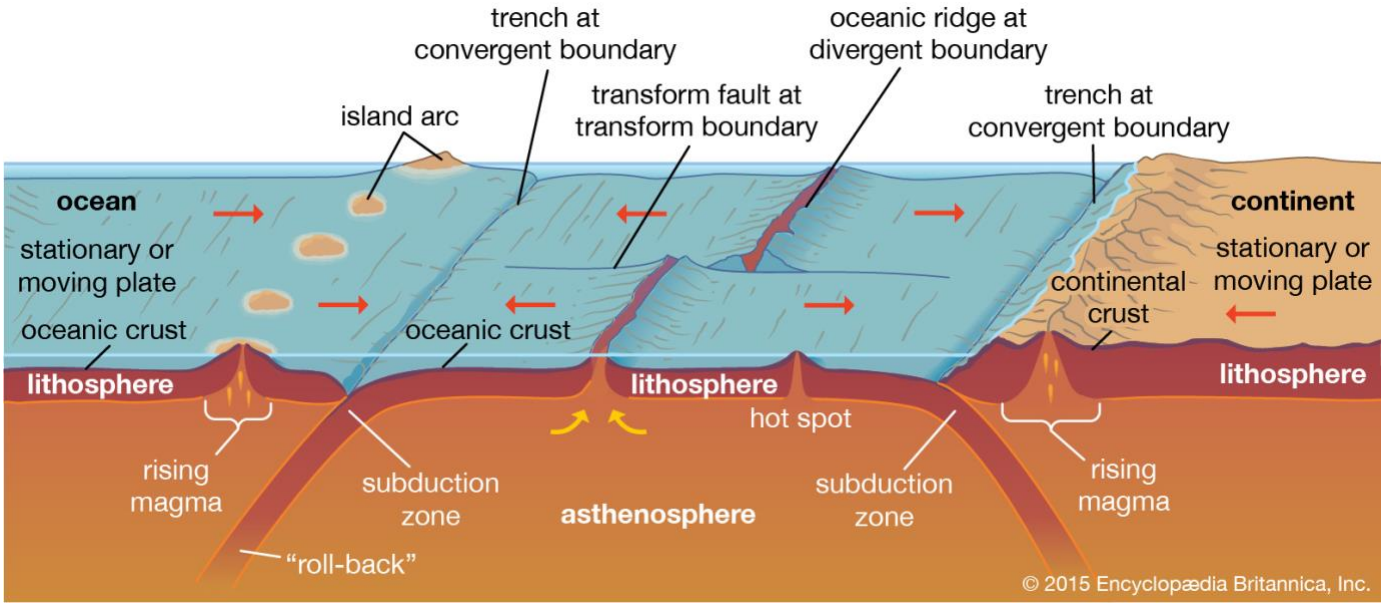
- **Continental Slope**
    - Between continental shelf and continental rise.
    - Slope between 4-6^0; 100m/km
    - May be cut with deep Submarine Canyons. Can be created by turbidity currents.



- **Continental Rise**
    - Between the base of the slope and deep sea floor
    - Can be several kilometers thick
    - Approximately 0.5^0
    - Absent at Active Continental Margin due to Subduction

- **Abyssal Plains**: flat, featureless surfaces adjacent to the rise. Flattest places on earth.
    - Terrigenous sediment: from land
    - Pelagic sediment: from ocean
        - Biogenous sediment: from living organisms
            - shells, diatoms, plankton
            - made from calcium carbonate & silica
            - sediment containing large amount of biogenous sediment are called **oozes**
        - Hydrogenous sediment: derived from elements in seawater
            - examples: salt, manganese nodules containing various types of other metals
    - Crust is smoothed out by this sediment
    - This smoothed out flat, level area is called the *abyssal plain*

- **Deep-sea Trenches**: deepest parts of the ocean basins
    - elongated depressions several kilometers deeper than the adjacent abyssal plain or sea floor
    - lie next to chains of volcanic islands and chains of volcanoes on land.
    - Deepest trench is the Marianas Trench


trench at
convergent boundary
oceanic ridge at
divergent boundary
island arc
transform fault at
transform boundary
trench at
convergent boundary
ocean
continent
stationary or
moving plate
stationary or
moving plate
continental
crust
oceanic crust
oceanic crust
lithosphere
lithosphere
lithosphere
hot spot
rising
magma
subduction
zone
asthenosphere
subduction
zone
rising
magma
"roll-back"
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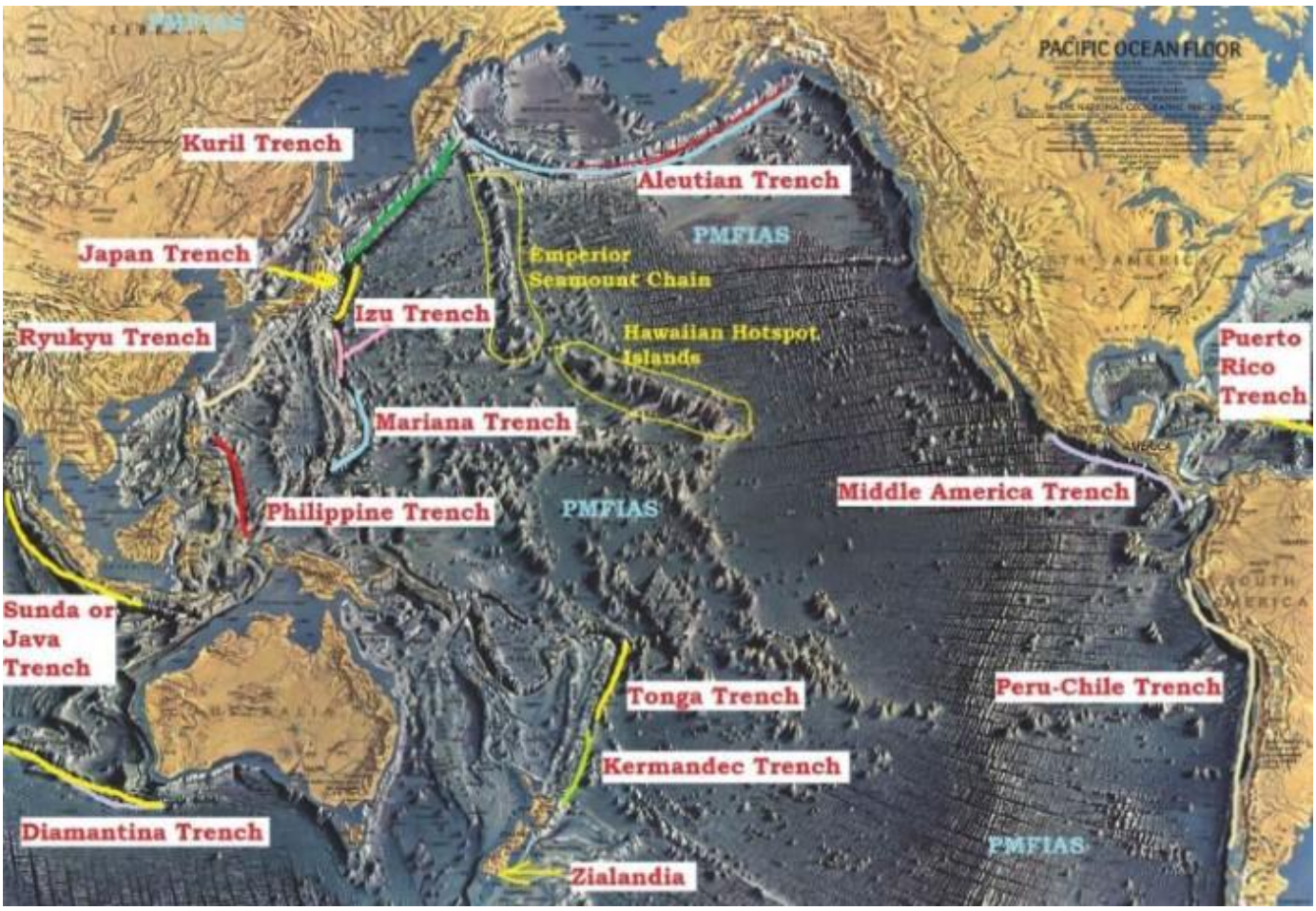
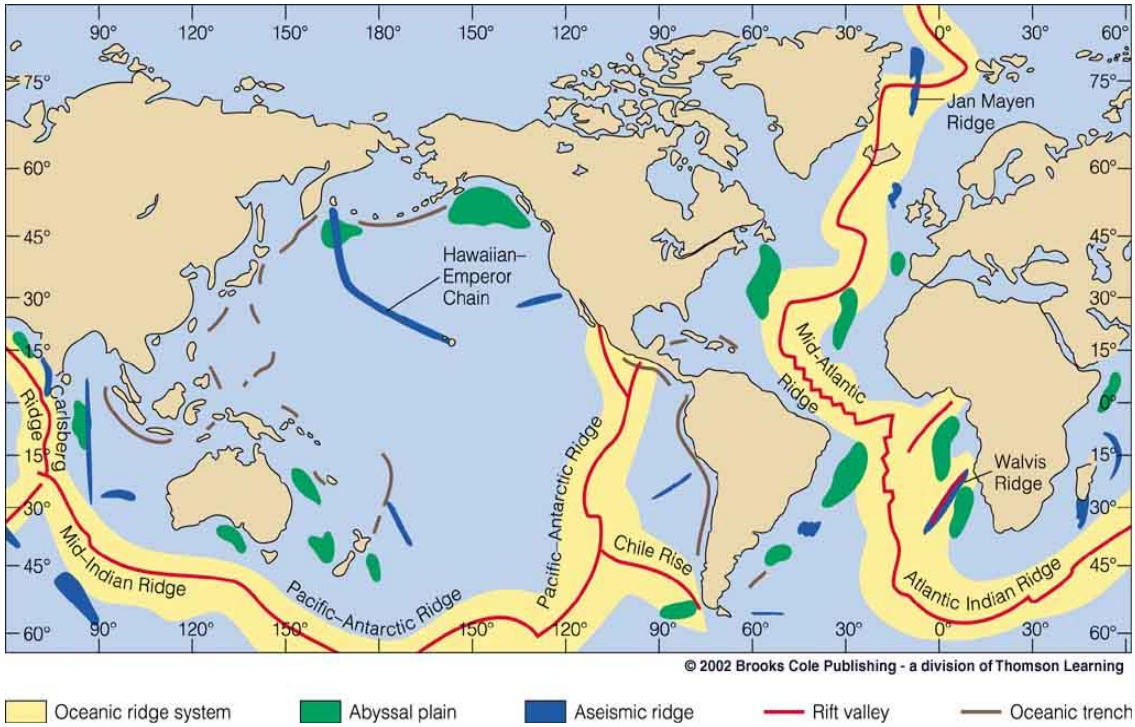
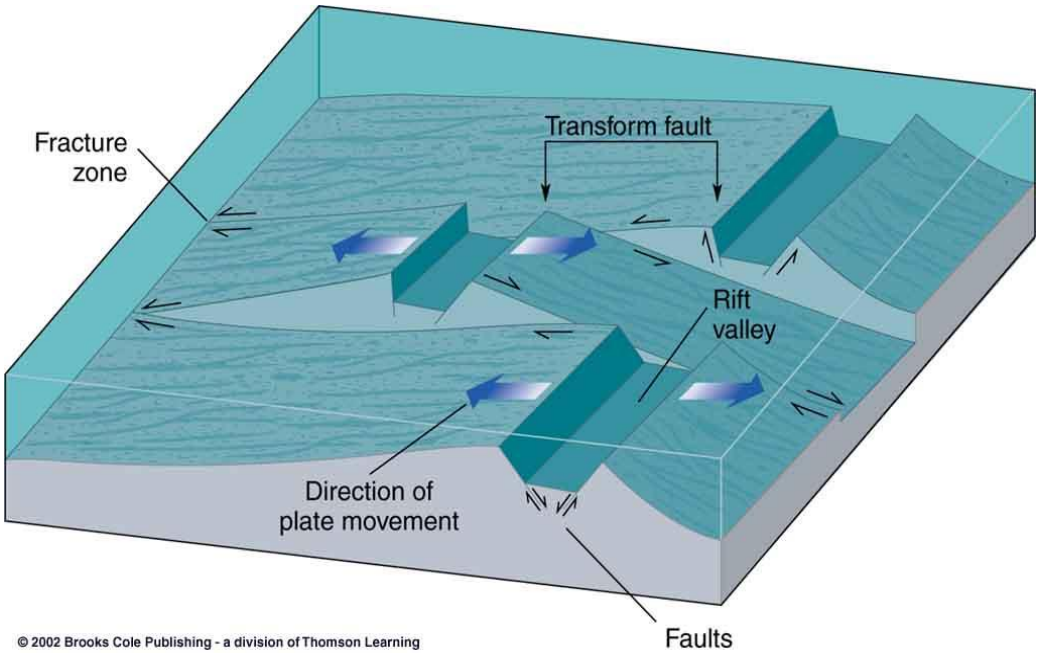

PACIFIC OCEAN FLOOR
Kuril Trench
Aleutian Trench
PMFIAS
Japan Trench
Emperior
Seamount Chain
Izu Trench
Ryukyu Trench
Hawaiian Hotspot
Islands
Puerto
Rico
Trench
Mariana Trench
Middle America Trench
Philippine Trench
PMFIAS
Sunda or
Java
Trench
Tonga Trench
Peru-Chile Trench
Kermandec Trench
Diamantina Trench
PMFIAS
Zialandia

- **Mid-Oceanic Ridge**: underwater mountain chain that circles the earth; forms at divergent boundaries; shallow-focus earthquakes occurs here
    - 65,000 km long,1500 meters high, 1500 meters wide
    - Made of Igneous rock (basalt and gabbro)



- **Rift Valley**: Flat, low laying area found between the ridges
    - 1-2 km thick (deep)

- **Transform Fault**: fault between two offset segments of a mid-oceanic ridge
    - Occurs because of irregular rates of plate movement on earth's sphere
    - may extend for many kilometers from the ridge

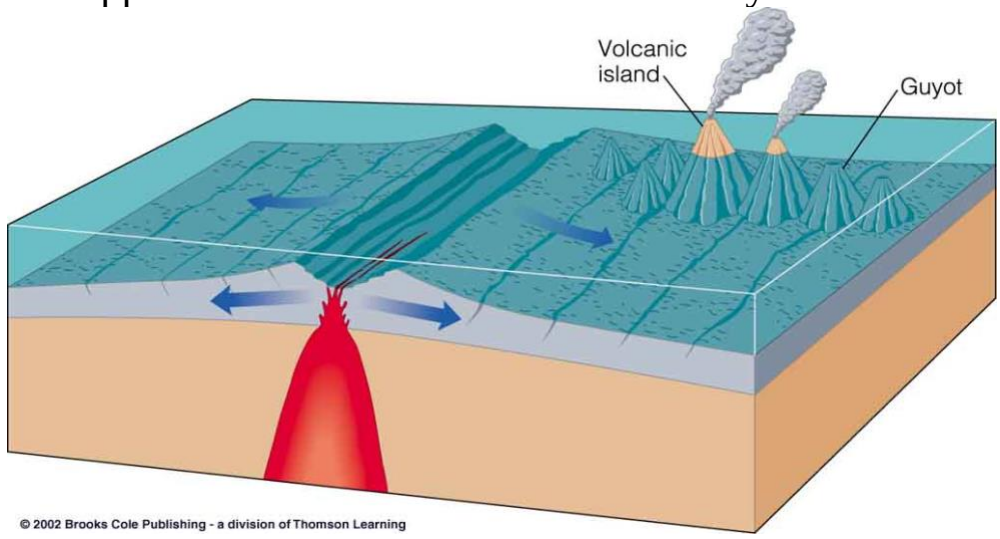


http://earthguide.ucsd.edu/eoc/teachers/t_tectonics/p_seafloorspreading.html

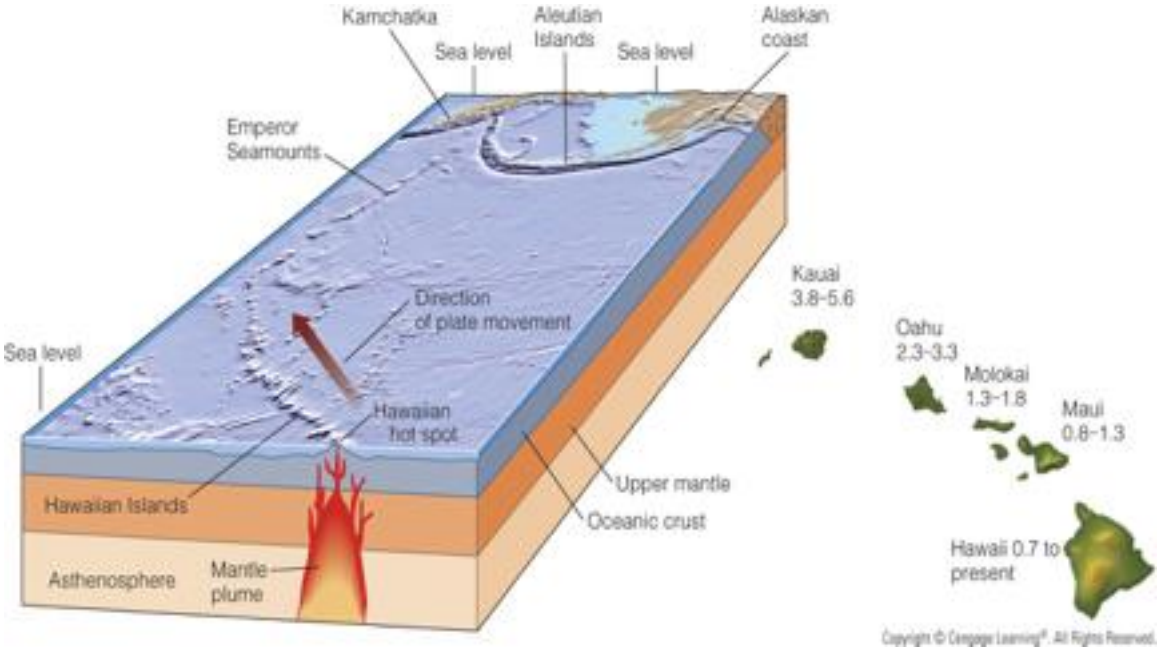
- **Hydrothermal Vents**: a hole in the sea floor through which fluid heated by magma erupts
  - Black smokers: hot water containing metals and precipitating out of the water. 350 ºC or 662 ºF
  - White smokers: cooler water and contain calcium and silica which are lighter in color

- **Seamount**: Submarine mountain that is at least 1 km high that don't rise above sea level. If it rises above the sea, it is called an island.

- **Guyots**: Flat topped seamount that is often covered by reefs



- **Aseismic Ridges**: Chain of mountains where there are no earthquakes. Forms when the lithosphere rides over a mantle plume (hot spot).
    - ex. Hawaiian Island; Emperor Seamount Chain
        - see diagram on page three of notes



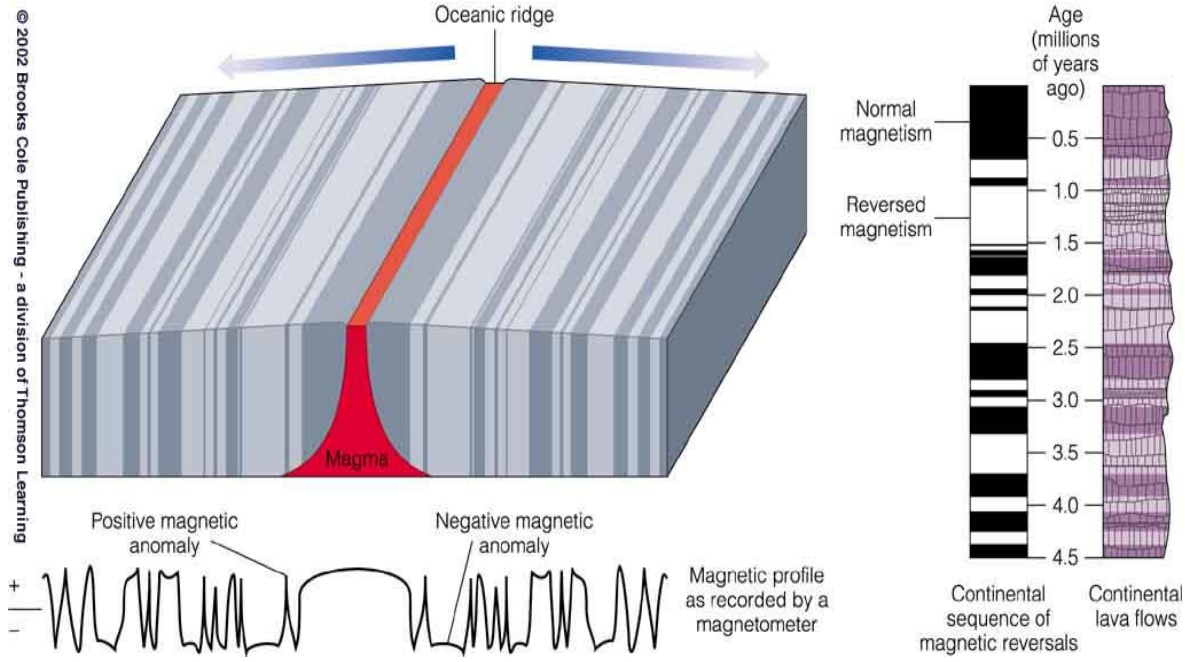
https://www.youtube.com/watch?v=kqWewLmthOA 3:00

17.2

Magnetism: Generated by the flow of molten iron in the outer core. Gives Earth its magnetic North & South

- Magnetic reversals: magnetic field reverses direction
    - compass direction reverses
- Paleomagnetism
    - has occurred thousands of times in the past
    - remnant magnetism in ancient rocks record the direction of Earth's magnetic poles at the time of the rock's formation
    - documents continental movement over time
    - newly formed seafloor basalts record Earth's magnetic field at the time of crystallization
    - Ocean basins are relatively young feature, less than 180 million years old whereas oldest continental crust is 4.3 billion

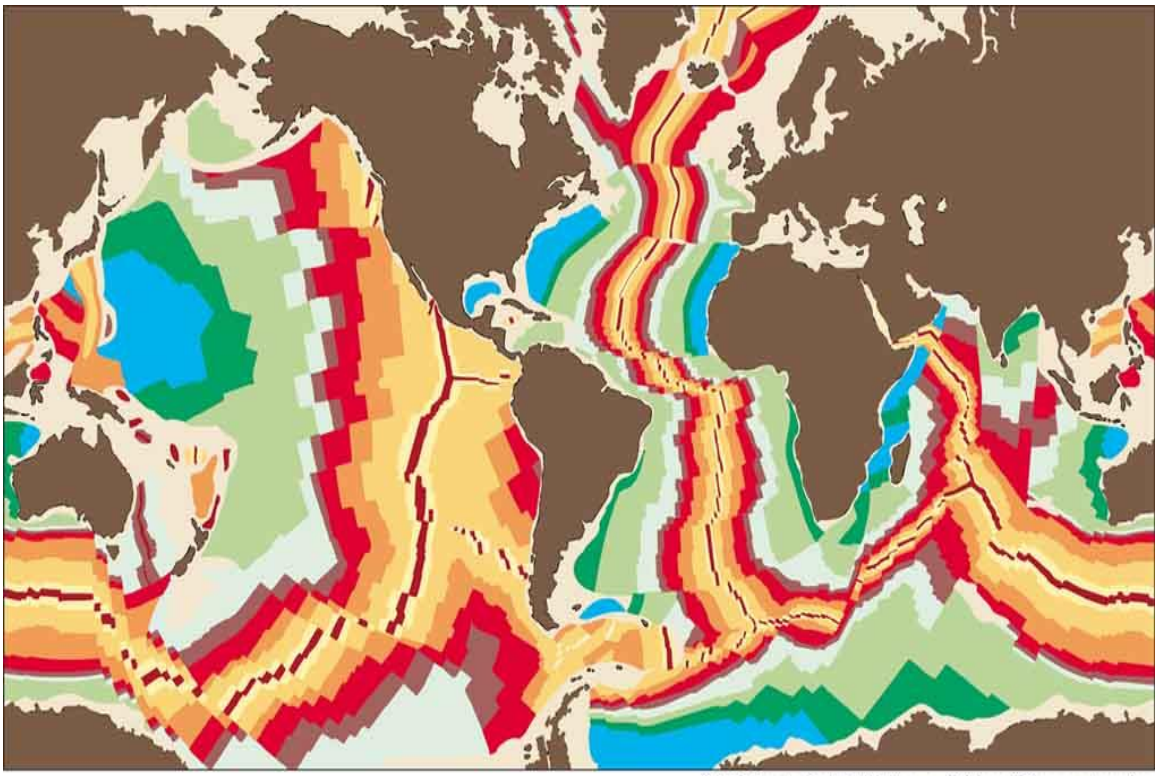
- Patterns of magnetic reversal correlate (width and age) on either side of ridges



Seafloor Spreading; theory that explains how new oceanic crust is formed at oceanic ridges and destroyed at trenches.

- Oceanic crust is youngest at the ridges and becomes progressively older with increasing distance from them
- Seafloor sediments are absent at the ridges and thicken with distance from them
- Seafloor spreading explains how the continents were moving! Continents are not pushing through ocean crust but moving with the ocean crust.
- Seafloor spreading **does not** explain what force could be strong enough to push continents across large distances. That is explained in the next section.

https://www.youtube.com/watch?v=WhiF6IqGACo 1:48 min



Pleistocene to Recent (0–1.6 MYA)
Pliocene (1.6–5 MYA)
Miocene (5–24 MYA)
Oligocene (24–37 MYA)
Eocene (37–58 MYA)
Paleocene (58–66 MYA)
Late Cretaceous (66–88 MYA)
Middle Cretaceous (88–118 MYA)
Early Cretaceous (118–144 MYA)
Late Jurassic (144–161 MYA)

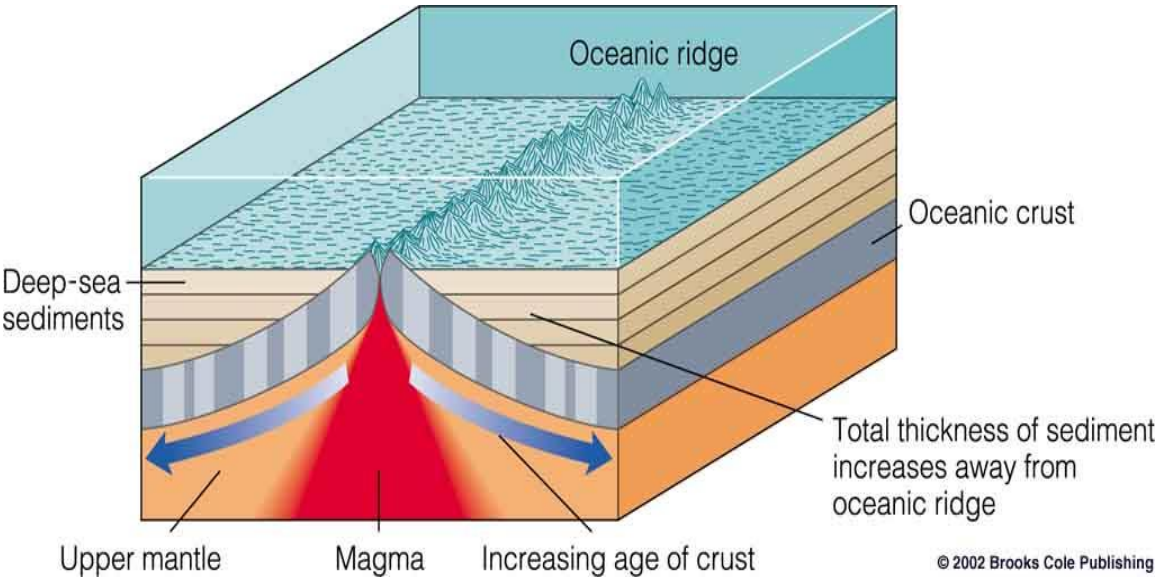


Plate Tectonic Theory 17.3

- Plates of rigid lithosphere (oceanic and continental) move from the energy of heat transfer below; independent segments of the earth's crust
  - move a few centimeters a year
  - 8 major plates and several smaller ones
  - their interactions define the type of boundaries that are created between plates
  - control many surface processes
  - helped define organic evolution

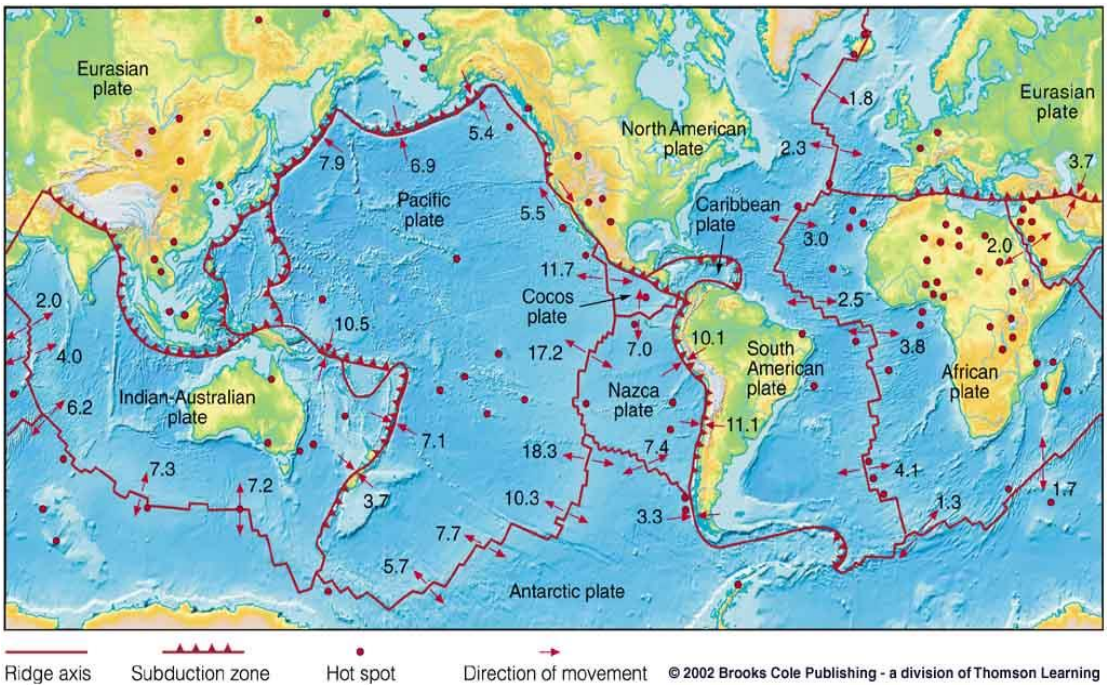
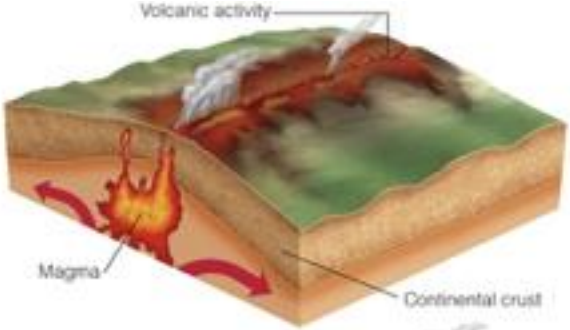
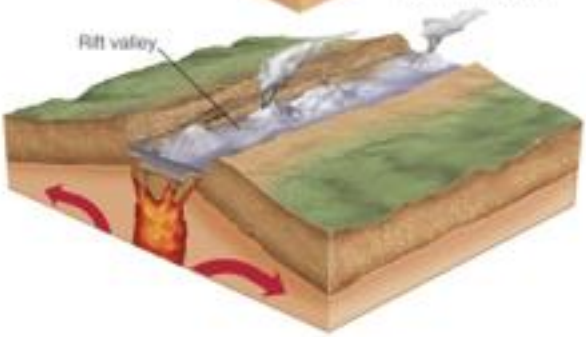


Plate boundaries

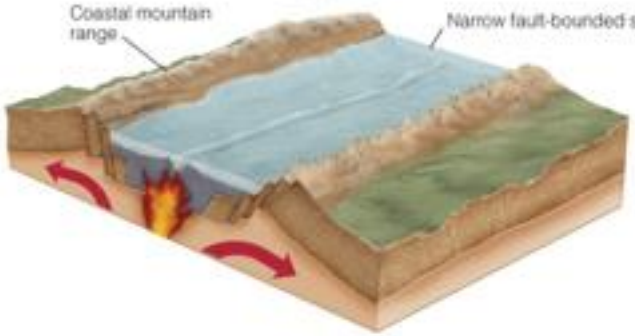
- Place where plates interact
- 3 types
  - **Divergent**
    - occurs where plates are separating
    - may occur under oceanic or continental crust
      - oceanic: ex Mid-Atlantic Ridge
      - continental: ex East Africa Rift
    - Rift Valleys: elongated depression that forms at a divergent boundary



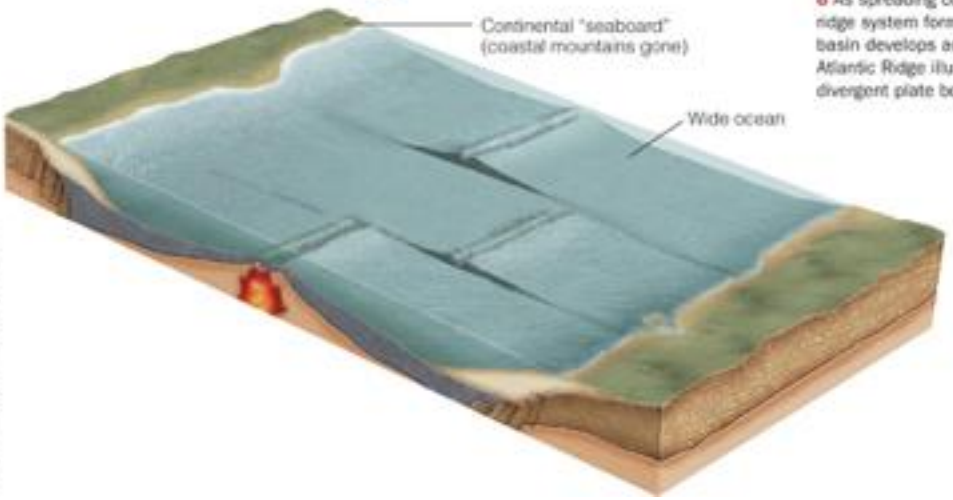
a Rising magma beneath a continent pushes the crust up, producing numerous fractures, faults, rift valleys, and volcanic activity.



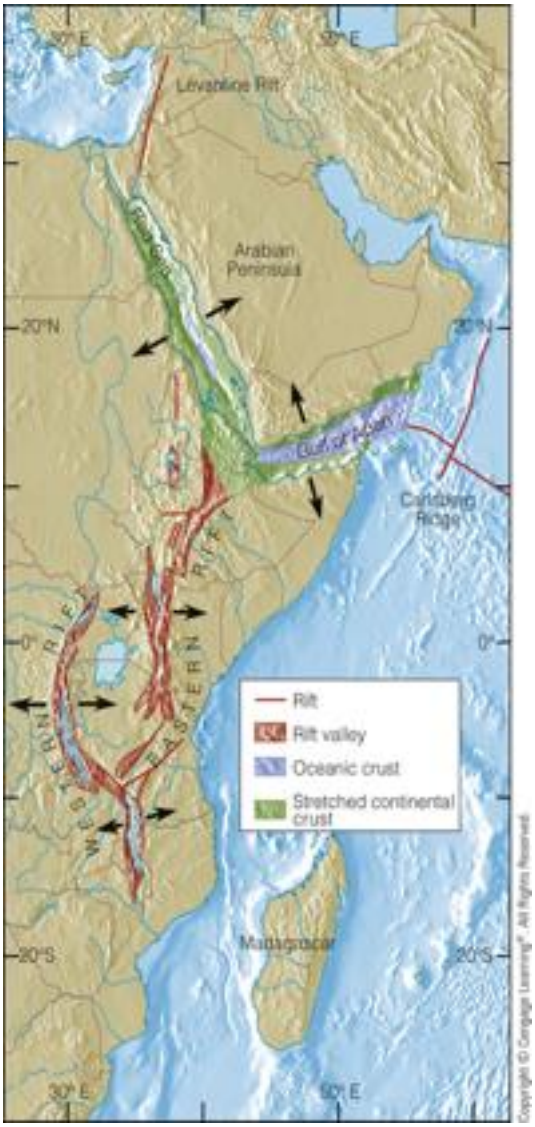
b As the crust is stretched and thinned, rift valleys develop and lava flows onto the valley floors, such as seen today in the East African Rift Valley.



c Continued spreading further separates the continent until it splits apart and a narrow seaway develops. The Red Sea, which separates the Arabian Peninsula from Africa, is a good example of this stage of development.

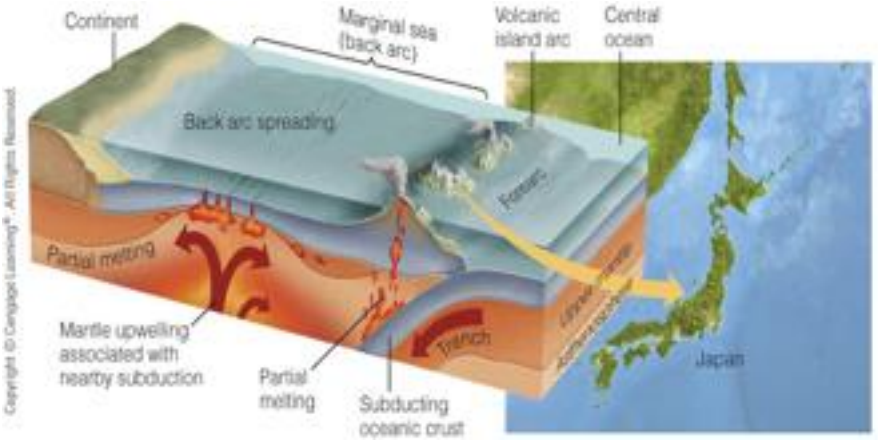


d As spreading continues, an oceanic ridge system forms, and an ocean basin develops and grows. The Mid-Atlantic Ridge illustrates this stage in a divergent plate boundary's history.



- **Convergent**
  - where two plates collide. If one plate is more dense, the leading edge of that plate is subducted underneath the less dense plate creating a subduction zone.

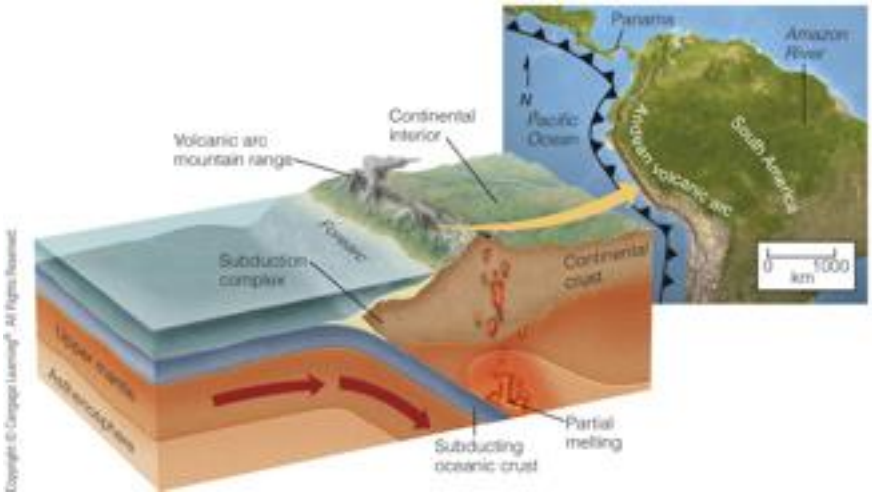
  - *Oceanic - Oceanic*
    - subducting plate bends downward forming an oceanic trench
    - the edge of the nonsubducting (overlaying) plate you get a *volcanic island arc*
      - island arcs run parallel to trench. why?
    - examples: Aleutian trench and islands; Mariana trench and islands



a Oceanic–oceanic plate boundary. An oceanic trench forms where one oceanic plate is subducted beneath another. On the nonsubducted plate, a volcanic island arc forms from the rising magma generated from the subducting plate. The Japanese Islands are a volcanic island arc resulting from the subduction of one oceanic plate beneath another oceanic plate.

https://www.youtube.com/watch?v=3p1N3JzJzFQ 15 sec

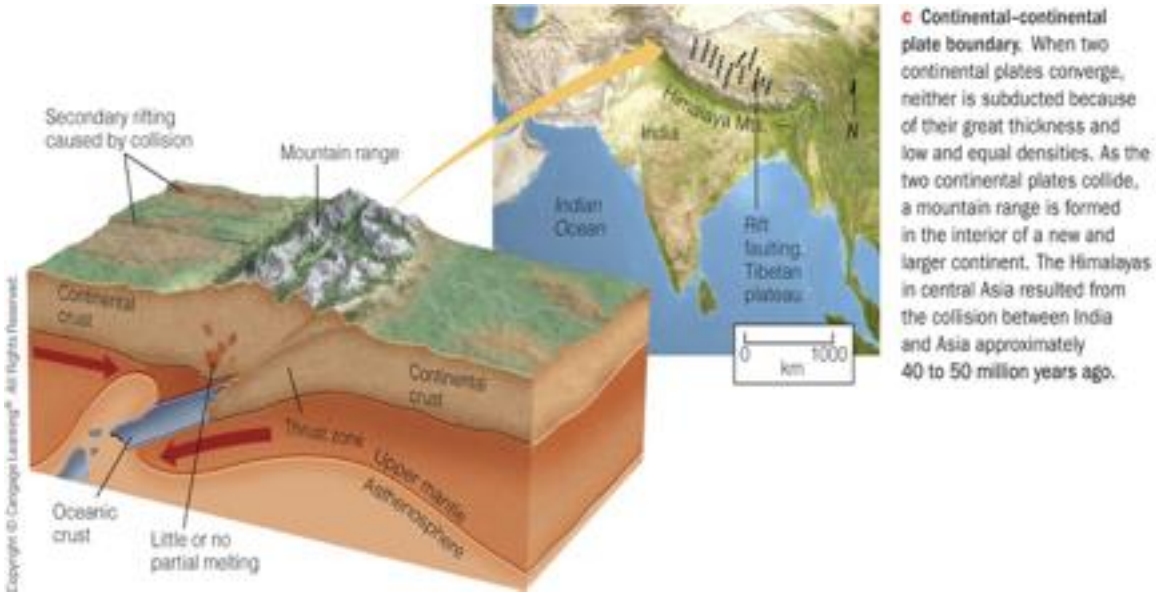
- *Oceanic - Continental*
  - denser oceanic plate is subducted under continental plate
  - andesitic volcanic mountain ranges often form on the continental plate



b Oceanic–continental plate boundary. When an oceanic plate is subducted beneath a continental plate, an andesitic volcanic mountain range is formed on the continental plate as a result of rising magma. The Andes Mountains in Peru are one of the best examples of continuing mountain building along an oceanic–continental plate boundary.

https://www.youtube.com/watch?v=F9uGSuyMclc 10 sec

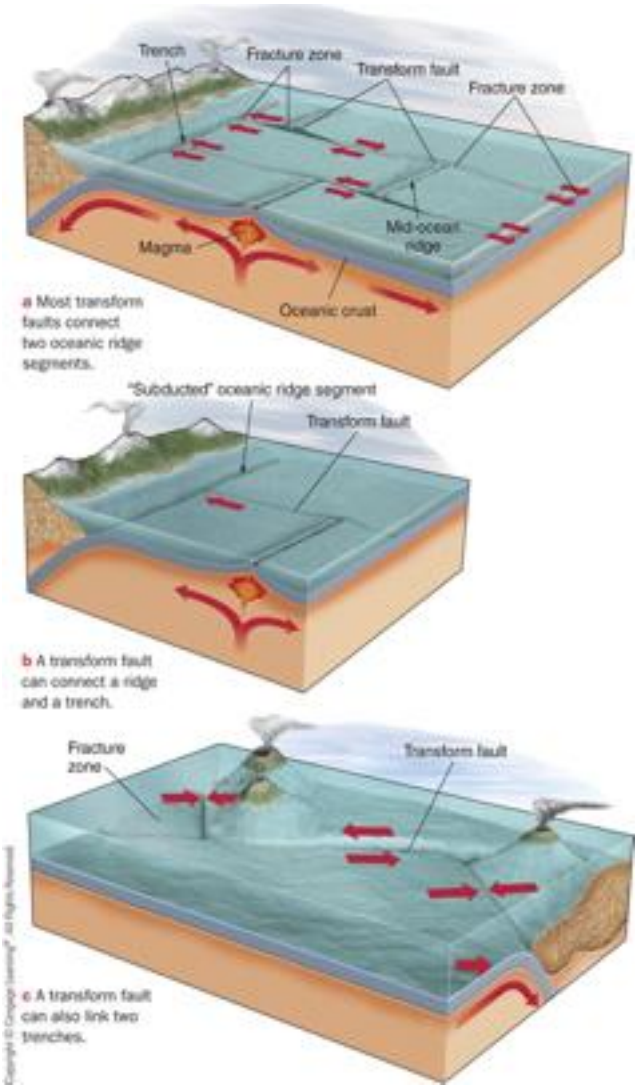
- *Continental – Continental*
  - neither plate is subducted
  - mountain ranges form
  - Himalayas



c Continental–continental plate boundary. When two continental plates converge, neither is subducted because of their great thickness and low and equal densities. As the two continental plates collide, a mountain range is formed in the interior of a new and larger continent. The Himalayas in central Asia resulted from the collision between India and Asia approximately 40 to 50 million years ago.

https://www.iris.edu/hq/inclass/animation/continental_collision__indiaasia 6sec

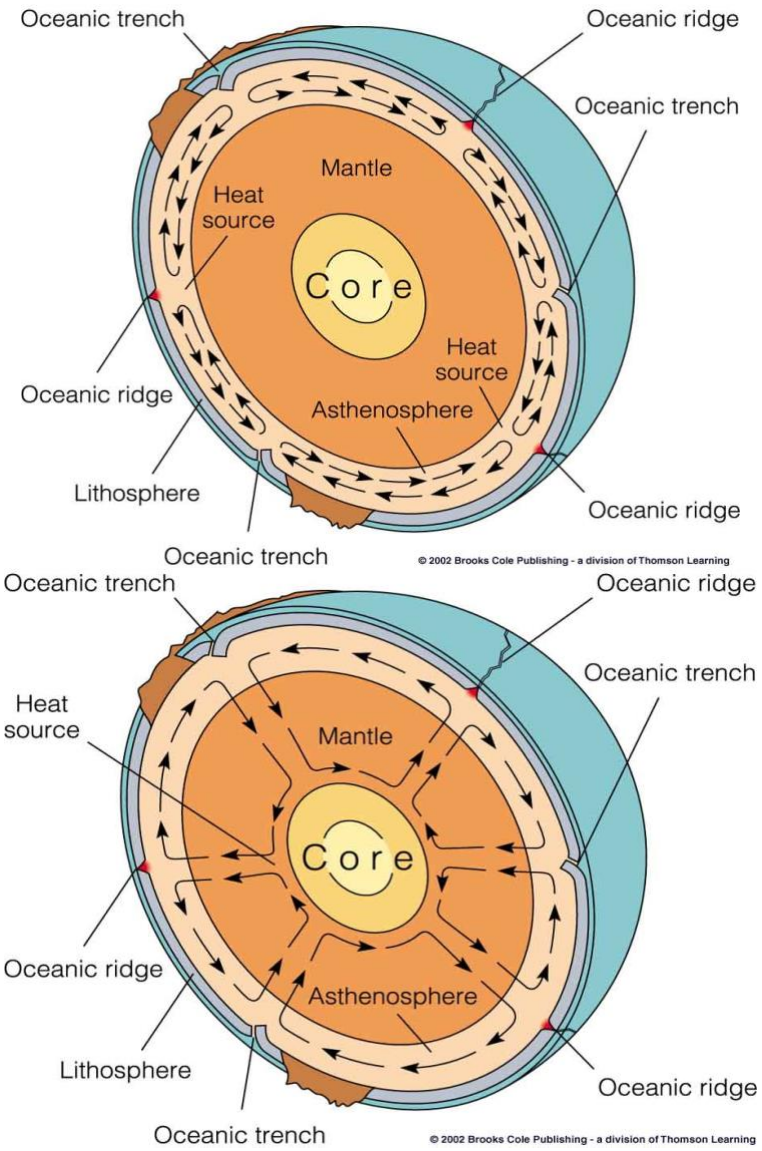
- **Transform Boundaries**
  - plates slide laterally past each other
  - *transform faults*: form because segments of the plates move at different rates
    - most commonly found perpendicular to oceanic ridges
    - *San Andras fault*: Pacific plate/North American plate



https://www.youtube.com/watch?v=kqWewLmthOA 2:30

Driving Mechanism of Plate Tectonics 17.4

- *Convection Cells*: circular movement of the asthenosphere and possible the entire mantle
  - the lithosphere (plates) ride on top of cells
  - when 2 cells meet, they move in the same direction within the asthenosphere/mantle. as a result, the lithospheric plates either collide or move apart



https://www.youtube.com/watch?v=UYs9ZajaLS0 28 sec
https://apl.maps.arcgis.com/apps/MapJournal/index.html?appid=df5f94c0050b4075adfbba54fb13eaeb 1:14 min

- Push and Pull
  - Oceanic crust is pushed at the ridges
  - Oceanic crust is pulled as it is subducted at the trenches
    - pull is twice as effective in plate movement than push