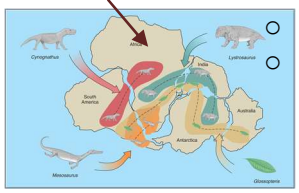
Chapter Outlines

NOTE: This is intended to help students 'organize' their understanding of each topic. It is <u>not</u> a comprehensive study guide for quizzes or midterms, i.e. <u>study your text!</u>

Plate Tectonics

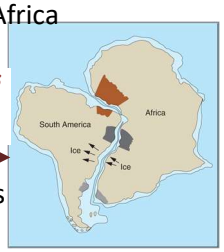
- Magma generation, igneous intrusions, metamorphism, volcanic action, earthquakes, faulting, and folding are usually the result of **plate tectonic** activity. Earth's crust is divided into eight large pieces, and over twenty smaller pieces by deep fault systems. These **crustal plates** are composed of Earth's lithosphere *(both oceanic and continental crust along with the rigid portion of the underlying upper mantle).* Underlying convection currents in the mantle are thought to play a role in the movement of these plates. Intense geologic activity occurs where plates move apart *(divergent boundaries),* collide *(convergent boundaries)* or slide past one another *(transform boundaries).* About 200 million years ago, it is thought, plate tectonic forces began to break a single continental land mass *(once again…in a repeating process)* into pieces that spread apart to form the continents as we know them today.

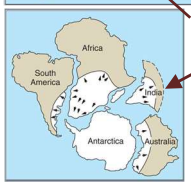
Correlation of fossil records



- **Continental Drift**
  - Early map makers speculated on the matching coastlines of N & S America to Europe & Africa
  - **Alfred Wegener** – in the early 1900's was the first to present evidence scientifically:
    - Matching mountains and rock types on now separate continents
    - Matching fossils on now separate continents
    - Matching records of glaciations on now separate continents
    - Limestone & coal deposits - indicating past warm climates in current cold locations
    - Apparent polar wandering – based on glacial evidence

Fit of rock types and glacial evidence

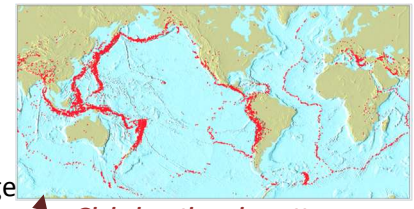




Record of glaciation

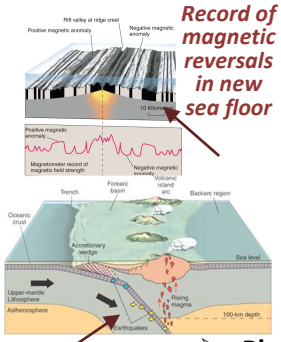
  - Wegener proposed a super continent previously existed that he named **'Pangaea'** consisting of **Laurasia** *(northern portion)* and **Gondwanaland** *(southern portion).* But, evidence to support Wegener's hypothesis was not adequate – no good driving mechanism was offered by Wegener.

- Continental Drift hypothesis evolves to **Plate Tectonics** theory in the 1960's
  - Discoveries during that era included:
    - Mid-oceanic **ridge system** that encircles the entire globe
    - Age of seafloor increases with increasing distance from mid-ocean ridge
    - Transform faults between ridge sections
    - Mid-oceanic ridges parallel continental edges
    - Records of magnetic anomalies *(magnetic reversals)* are symmetrical across seafloor ridges
    - **Benioff zones** of earthquakes and magmatic arcs are associated with deep ocean trenches
    - Continental fit at edge of continental shelf was even better than at the current shoreline
    - Earthquake patterns – shallow at ridge, deep at trenches, and define all plate boundaries
    - Apparent movement of '**hot spots**'



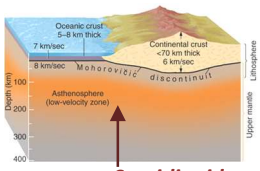
Global earthquake patterns can define plate boundaries

Record of magnetic reversals in new sea floor

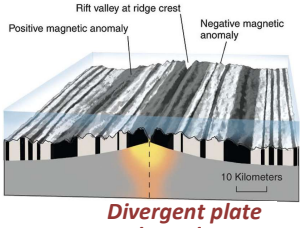


Benioff zone of earthquakes

- **Plate movement**
  - Crustal plates are composed of blocks of lithosphere riding on a ductile *(semi-liquid)* asthenosphere.
  - Average movement range is **1–24cm/year**
  - Most geologic activity occurs at plate edges as a result of plate movement
  - **Plate boundaries types:**
    - **Divergent boundaries** – plates moving apart
      - Mid-oceanic ridge with rift valleys at the summits
      - Can occur within a continent eventually creating new ocean basin

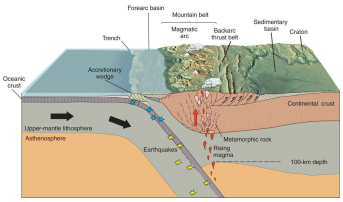


Semi-liquid asthenosphere



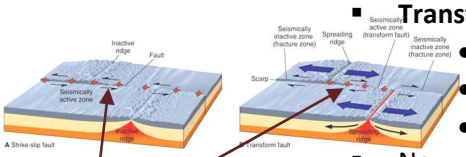
Divergent plate boundary

- Basaltic igneous magma wells up to create new seafloor
- **Convergent boundaries** – plates moving towards each other
  - Various types
    - **Continental-continent** - primary source of large mountain building, occurs at the end of subduction
    - **Ocean-continent** – contains a 'subduction complex' with continental arc
    - **Arc-Continent** – contains a 'subduction complex'. The arc becomes 'pasted' to the continent
    - **Ocean-ocean** - contains a 'subduction complex' with island arc
  - Subduction complex consists of descending plate, deep ocean trench, and overlying andesitic volcanoes



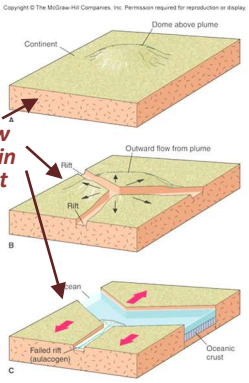
Convergent plate boundary 'ocean-continent'

- **Transform boundaries** – plates sliding horizontally past each other
  - Small transform faults connect ridge sections
  - California's San Andreas fault is a large transform fault
  - Can connect ridge sections, or a ridge section to a trench



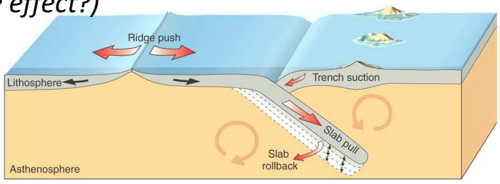
Transform faults between ridge sections

- New **rifting** and failed rifts
  - New rifting is now occurring in East Africa and the Red Sea.
  - Many locations exist where divergence started but never completely separated. One possible failed rift is in Missouri at the site of the powerful 1812 earthquake.



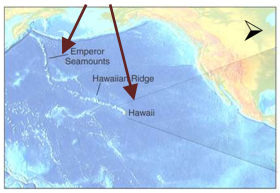
Typical new rifting within a continent

- Mechanism for Plate movement *(likely some combination of the following)*
  - **Mantle convection currents** *(are they the cause or the effect?)*
  - **Slab-pull** – descending cold dense *(heavy)* plate
  - **Ridge-push** – cooling plate sliding 'downhill'
  - **Trench-suction** – contributing effect



Possible plate movement mechanisms

Plate movement over the Hawaii mantle plume



- **Mantle plumes**
  - Narrow columns of hot mantle rock rise through the mantle
  - Location is stationary in relation to the overlying plate motion, thereby showing plate movement direction and rate over time
  - May contribute to mantle convection currents that play a part in plate movement.
  - May contribute/cause new rifting and new divergent boundaries
  - Supplies heat and magma to **hot spots** and chains of volcanoes such as Hawaii and Yellowstone
  - May be a source of past flood basalt eruptions such as those in the United States northwest

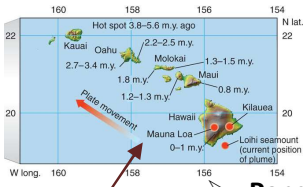
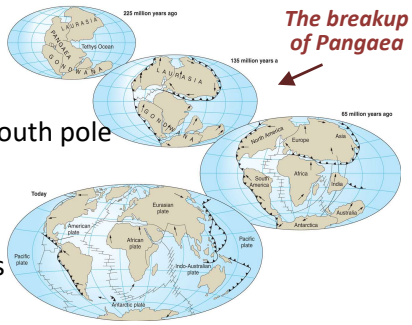


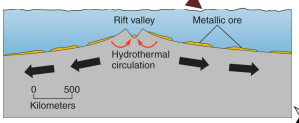
Plate movement over the Hawaii mantle plume

- **Pangaea** – former supercontinent during the early Triassic *(225mya)*
  - **Laurasia** – northern portion of Pangaea
  - **Gondwanaland** – southern portion of Pangaea, formerly located at the south pole
  - Other supercontinents likely existed previous to Pangaea



The breakup of Pangaea

Mineral deposits will eventually reach a continent



- **Metallic ore deposits** – often located near plate boundaries
  - Commonly associated with igneous activity, mineral-rich hot springs ***(black smokers)***, and hydrothermal circulation near island arcs

- The distribution and origin of most volcanoes, earthquakes, mountain belts, and major seafloor features can be explained using plate tectonics

A deep ocean mineral-rich 'black smoker'

- Movement *(relocation)* of plate boundaries – can occur over time
  - mid-oceanic ridge crests can migrate toward or away from subduction zones or abruptly jump to new positions
  - convergent boundaries can migrate if subduction angle steepens or overlying plate has a trenchward motion of its own
  - Transform boundaries can shift as slivers of plate shear off. The San Andreas fault location likely changes occasionally.