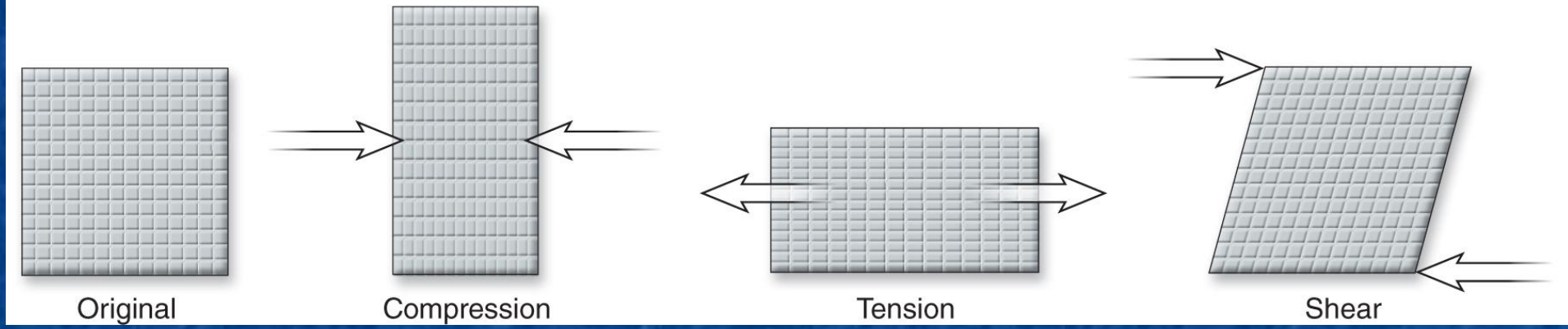
Environmental Geology - Chapter 4
Earth's Structure and Plate Tectonics

Deformation of Rocks

- A force causes stress on rocks
- Rocks near surface are elastic and will return to original form when stress is removed
- Elastic limit – point at which rocks are no longer elastic and deformation becomes permanent
- Rocks can be brittle or ductile
- Rocks deform, slide by each other along point of fracture or ***fault***

Three Types of Stress



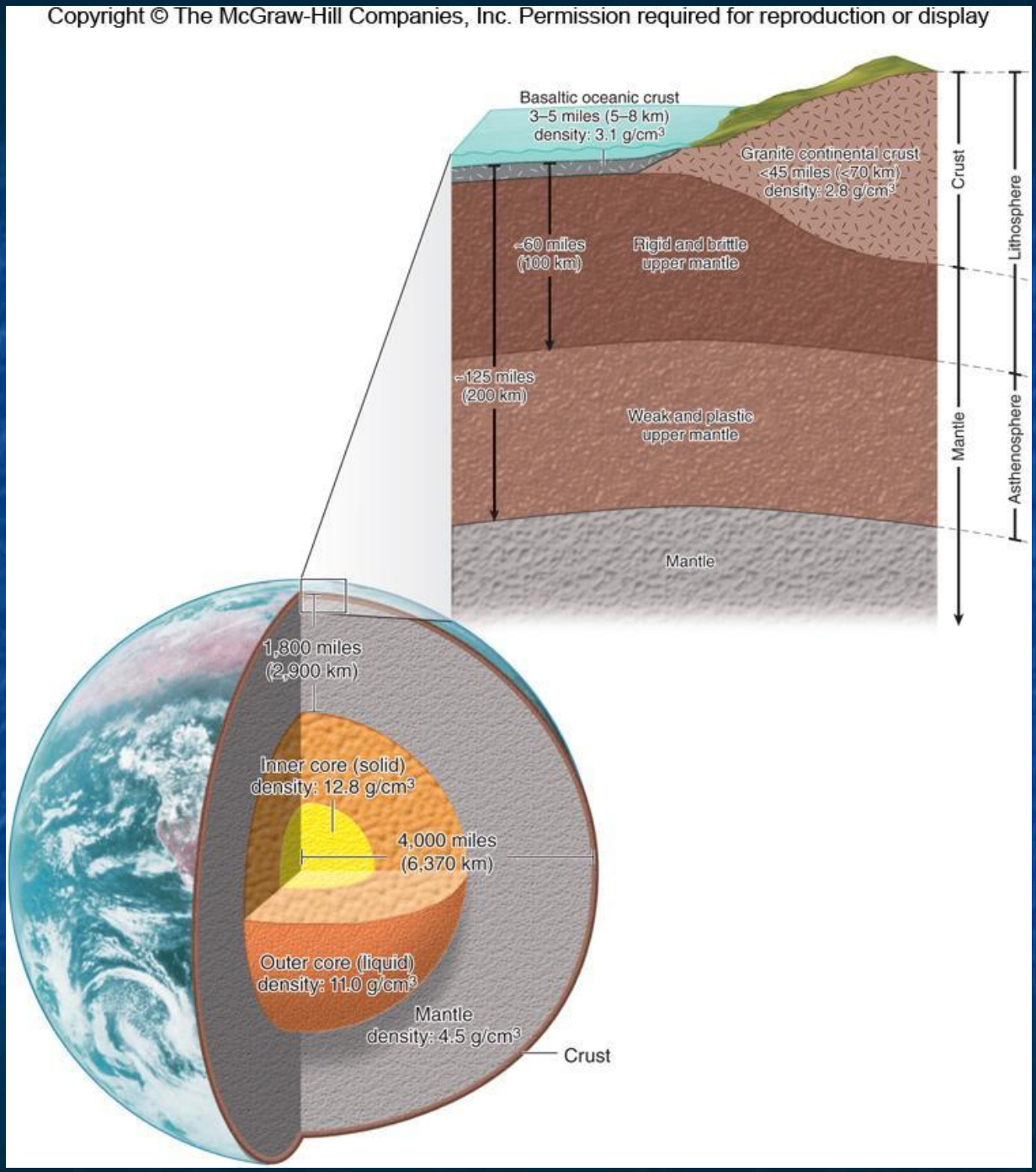
1. Compression – pushes on rocks from opposite directions; shortens rocks
2. Tension – pulls from opposite directions; stretches / lengthens
3. Shear – pressure in uneven manner; rocks become skewed

Temperature, time and pressure are factors in stress.

Earth's Interior

- Internal heat source is energy causing metamorphism, uplift of crust (rock cycle)
- Seismic waves (earthquake waves)
  - Travel at different speeds through different materials
  - Reflect and refract when density changes
  - Has allowed scientists to determine boundaries b/w materials within Earth

Earth's Structure



Earth's Structure

- Crust –
  - Less dense layer
  - Lithosphere < 15 km, brittle rigid, broken into tectonic plates
- Mantle
  - ~2,900 km (1,800 mi) thick
  - Rocky, iron rich silicates, upper layer is asthenosphere
    - Silicates nearer to melting point; usual source of magma

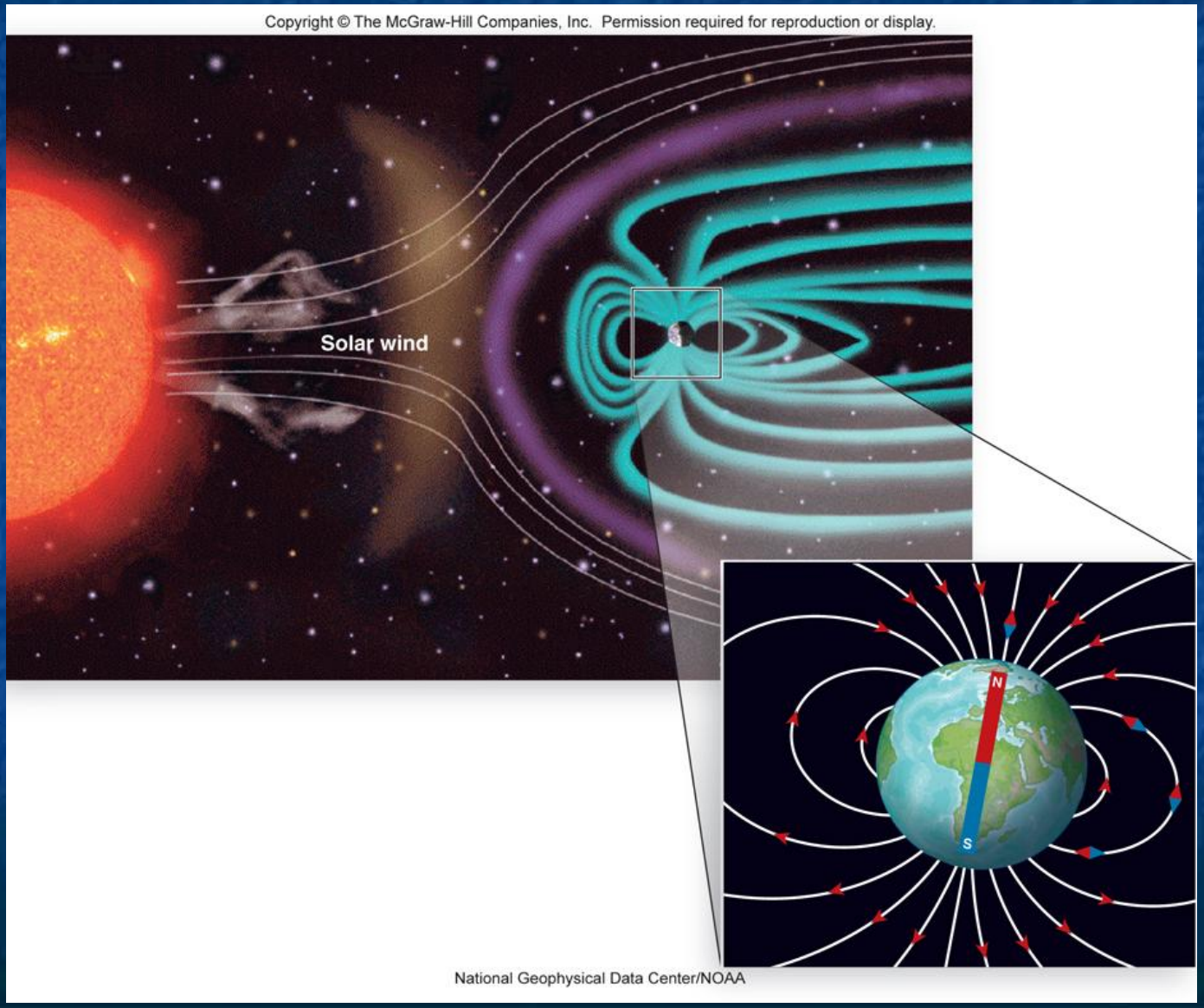
Earth's Interior

- Scientists hypothesize inner and outer core are iron-nickel alloy
- Outer core
  - Metallic liquid
- Inner core
  - Metallic solid

Earth's Magnetic Field

- Inner core is solid, rotates faster than planet
- Electrically charged metallic ions in outer core circulate
- Generates magnetic field
- Used for magnetic north in compasses
- Blocks some solar radiation

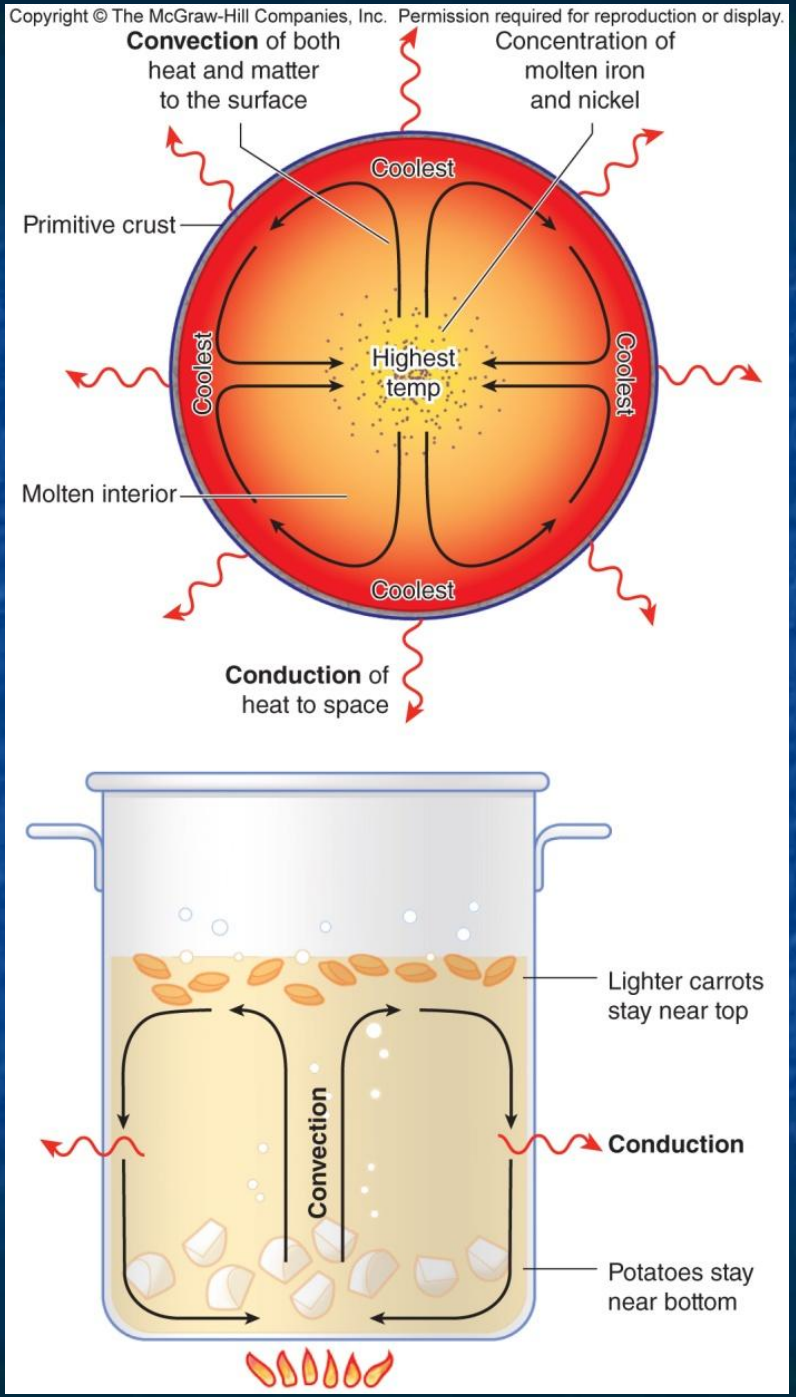
Earth's Magnetic Field



Earth's Internal Heat

- Geothermal gradient 25°C/km – temperature increases with depth
- Heat from radioactive decay of U, Th, & K
- Friction (internal compression) and pressure
- Conduction – heat transferred through atmosphere to space
- Convection transfers heat; driven by temperature induced changes in density

Earth's Internal Heat



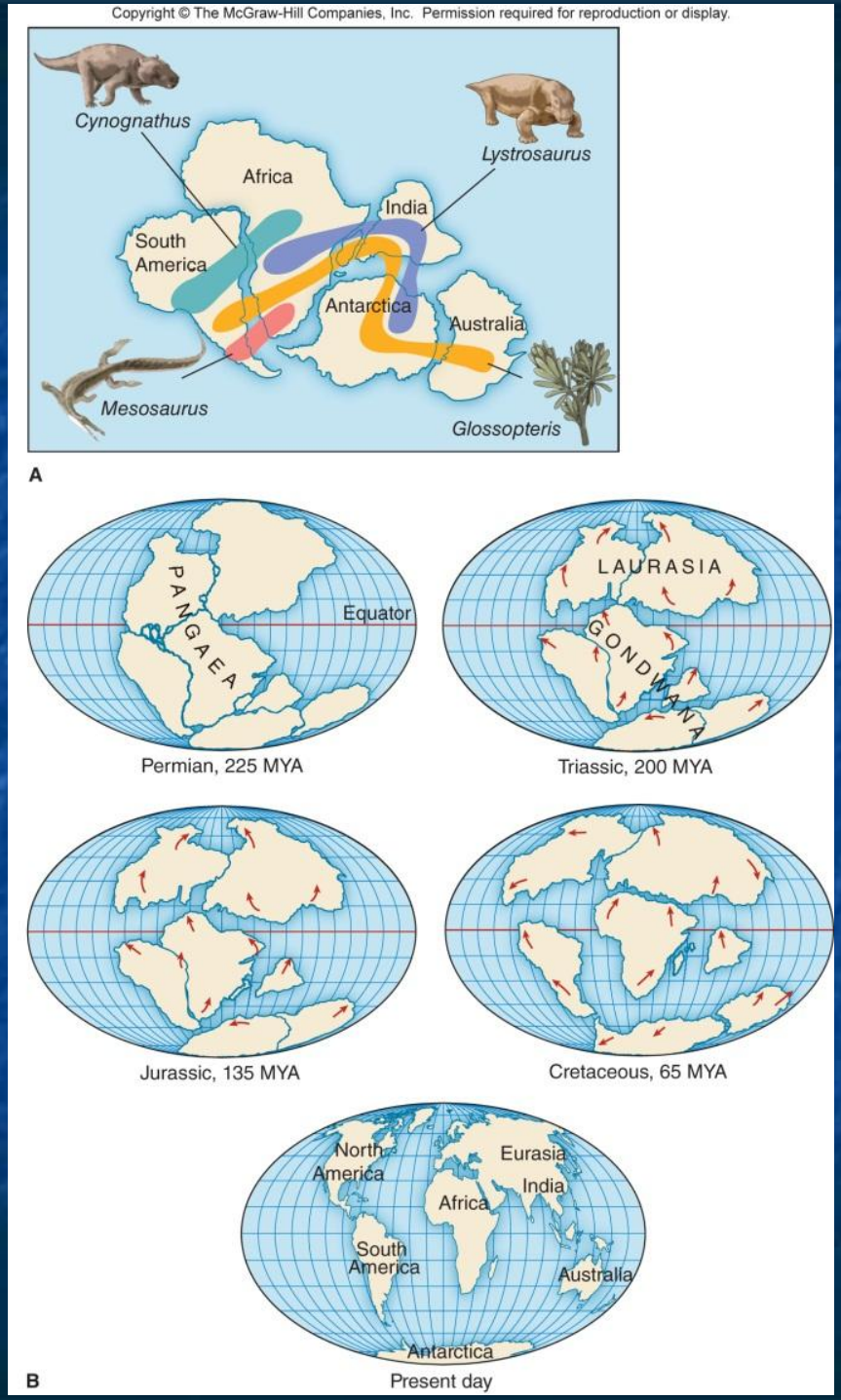
Continental Drift

- Idea that continents were once joined first proposed in 1596 by Dutch mapmaker
- 1850s – American writer noted how S. America and Africa shorelines fit together
- Frank Taylor, American geologist, 1910 suggested the continents were once joined

Continental Drift

- Alfred Wegener 1922 book on theory of continental drift
- More evidence than Taylor –
  - similar sequences of rocks
  - fossil evidence
  - coal in Antarctica
  - evidence of past glaciation in tropical and desert areas
- Proposed supercontinent, Pangaea
- Could not fully explain ***how***

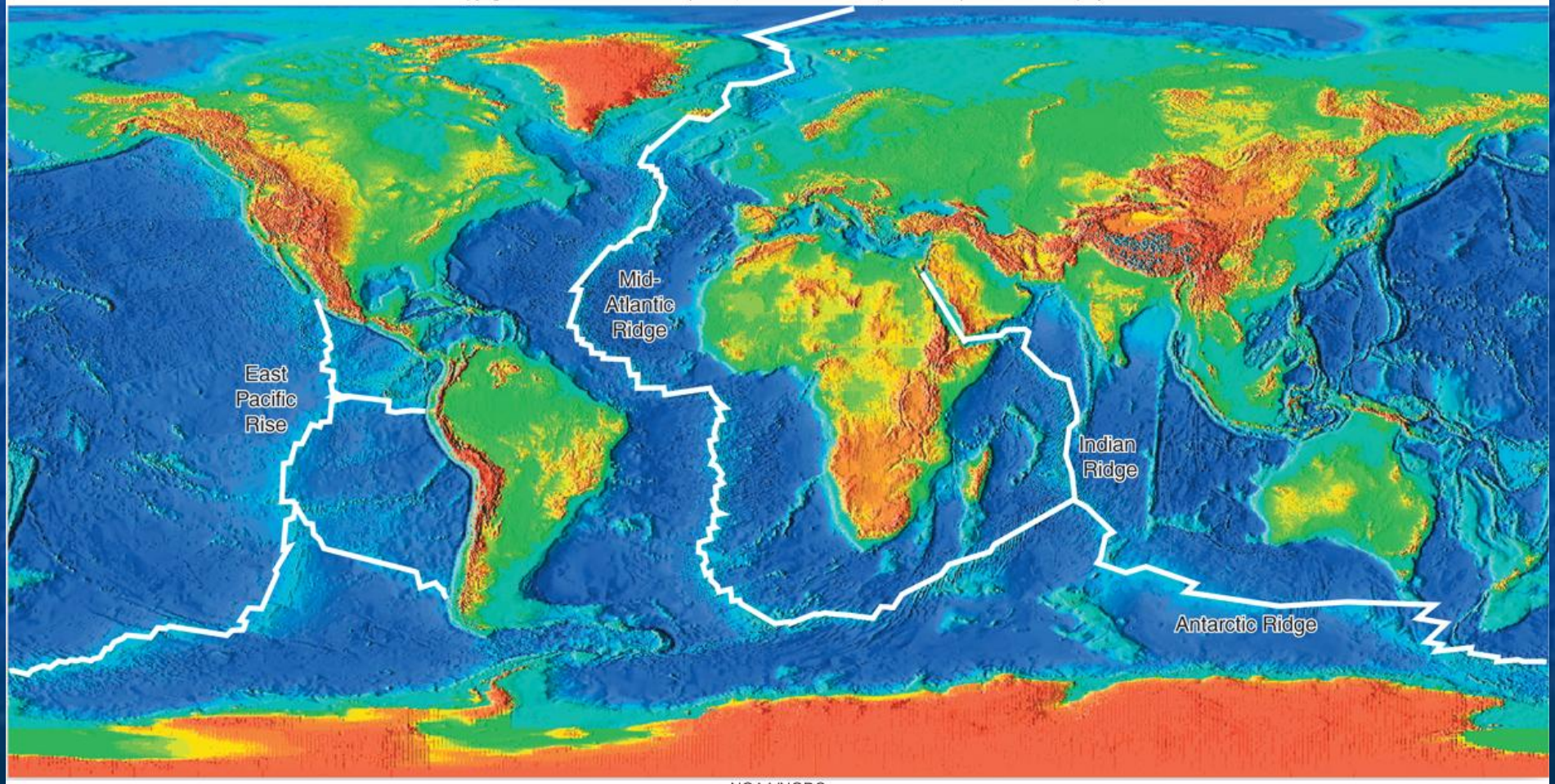
Developing Theory of Plate Tectonics



Developing Theory of Plate Tectonics

- Mapping ocean floor began in 1855 by U.S. Navy
  - WW1 and sonar
  - 1950s many sonar surveys by scientists
  - Mid oceanic ridges – mountain chain in Atlantic Ocean
  - Ocean trenches as deep as 35,000 ft
- Map location and depths of earthquakes
  - Fall on plate boundaries
- Polar wandering
  - Moving poles and continents supported data

Mapping the Ocean Floor



NOAA/NGDC

Magnetic Studies

- Igneous basalts contain iron mineral magnetite (Fe_3O_4)
- Magnetite is naturally magnetic
- Atoms orient parallel to Earth's magnetic field when rock cools
- Field of paleomagnetism studies changes in magnetic poles over geologic time

Magnetic Reversal

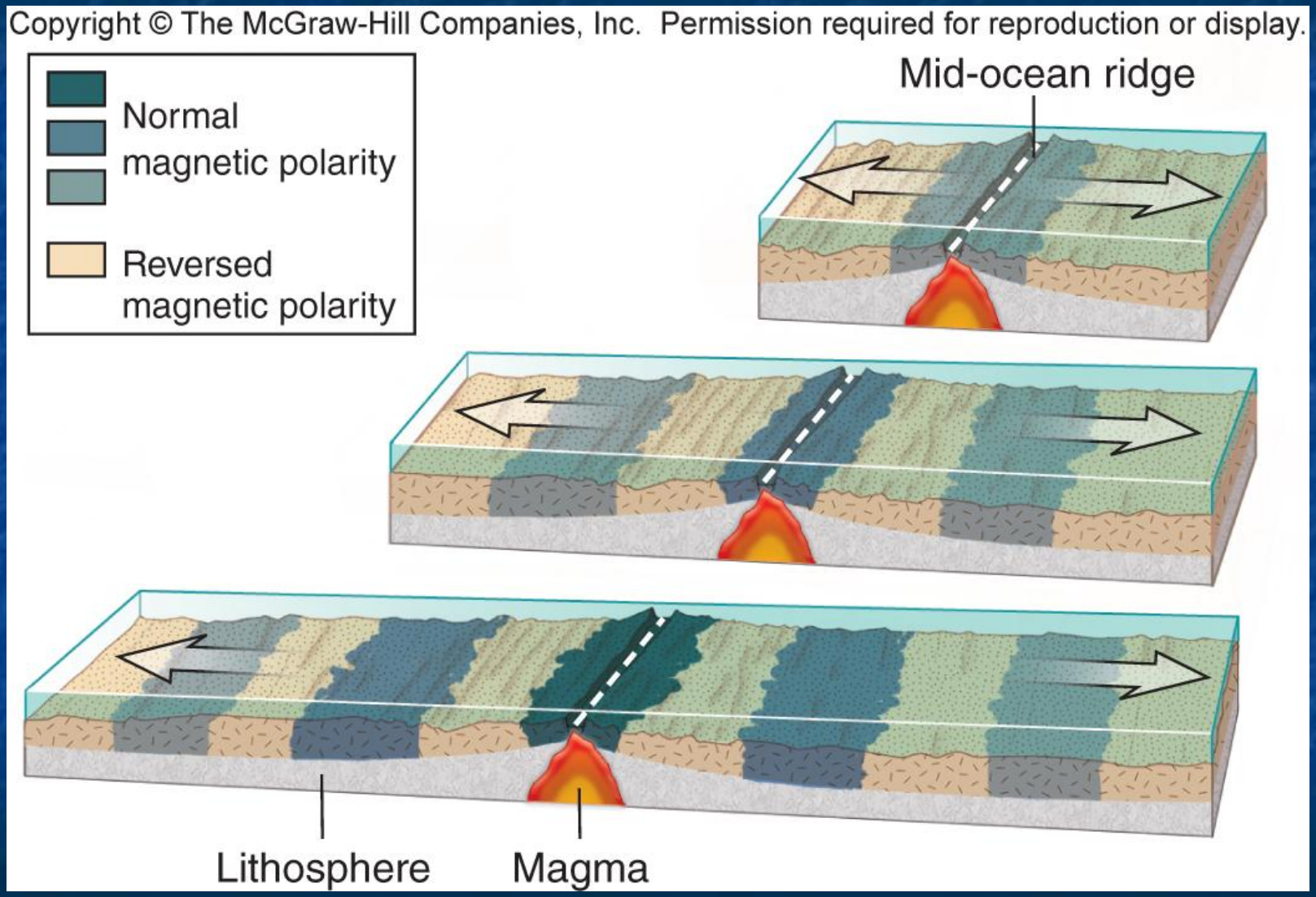
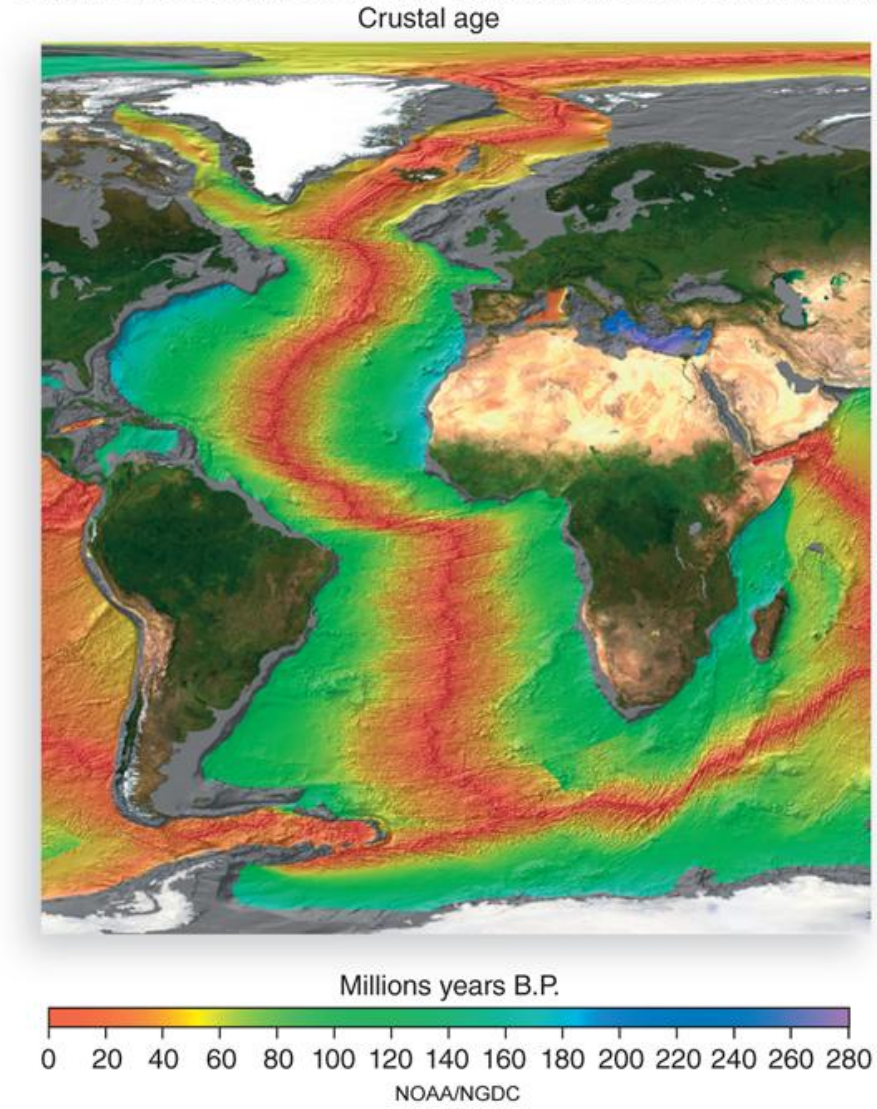


Figure 4.11 Page 101

Sea Floor Spreading



- Mid oceanic ridges – magma erupts forming new ocean crust
- Rocks older farther away from ridge crests
- 1968 – drilling and dating basalts
- Oldest part of sea floor 200 million yrs old
- Atlantic basin growing, crust material destroyed in trenches

Figure 4.12, Page 101

Earthquakes

- **Earthquake** – release of energy that occurs when rocks are deformed past their elastic limit causing a rupture
- Energy travels out in **seismic waves**
- **Epicenter** – point on the surface that directly overlies point where rocks rupture
- 1960s – global network of seismic recording stations

Earthquake Locations

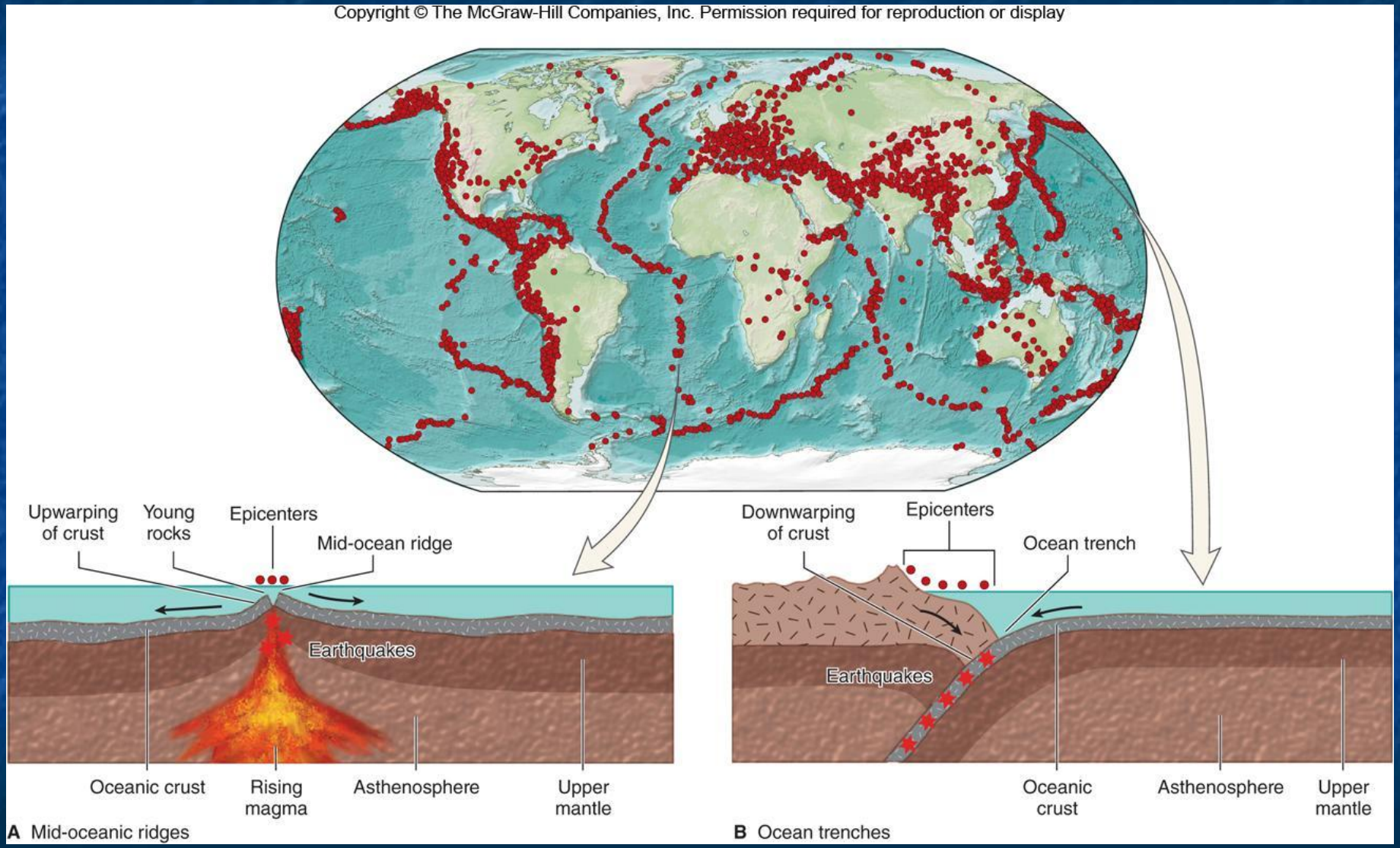


Figure 4.13, Page 102

Earthquake Locations

- Epicenters along Mid Atlantic Ridge – magma rises up, buckles crust forming ridge
- Epicenters coincide with continental mountain ranges
- Subduction occurs when plate is forced downward into mantle; associated with volcanic activity at ocean trenches

Last Piece of Evidence for Continental Drift

- Magnetite rocks form/cool, atoms orient to magnetic north pole
- Throughout geologic time, rocks orient to different location – "polar wandering"
- Different continents had different paths
- Paleomagnetic and sea floor spreading studies prove continents were moving no the N. pole

Polar Wandering

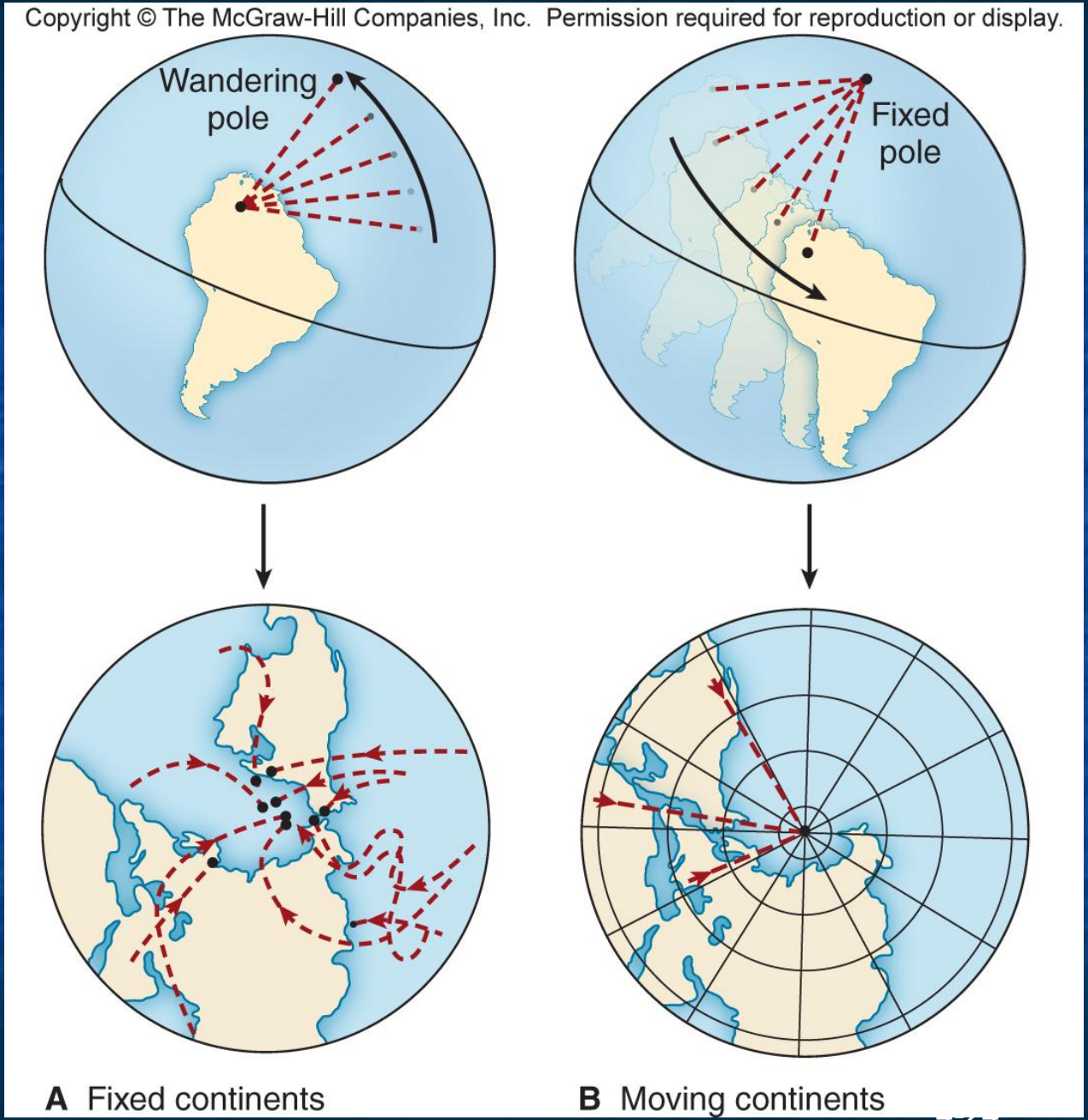


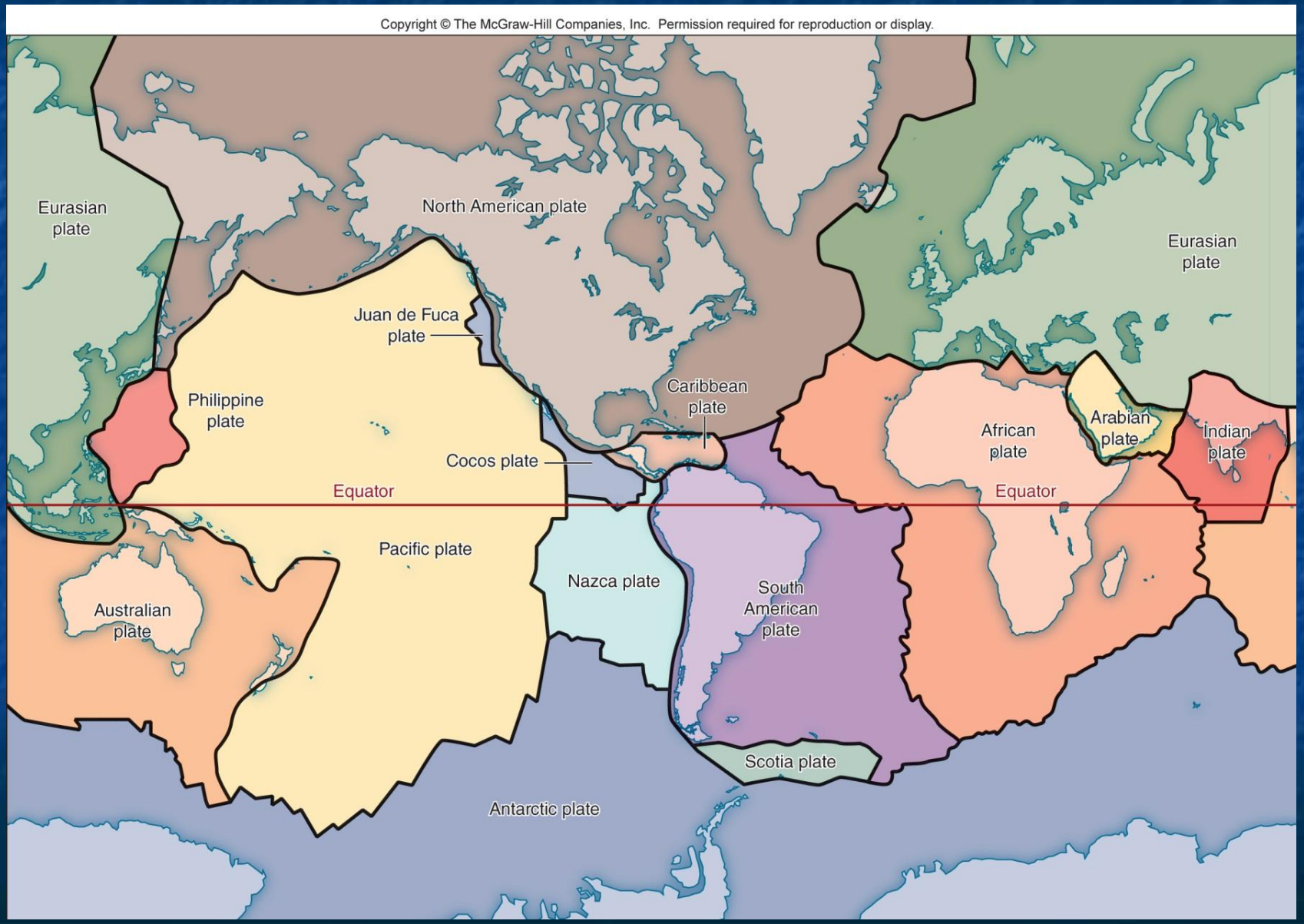
Plate Tectonics and Earth's Systems

- By 1960, 50 years of data proved sea floor spreading at mid ocean ridges
- New crust formed at ridges, and crust destroyed at trenches through subduction
- Tectonic Plates
  - Earth's lithosphere broken up into 7 major plates

Plate Tectonics and Earth's Systems

- Plate Boundaries defined by epicenters
  - Plates move over asthenosphere
  - Slide past
  - Override
  - Tear
  - Push into each other creating pressure ridges
- Plate movement creates volcanic eruptions and mountain ranges

Plates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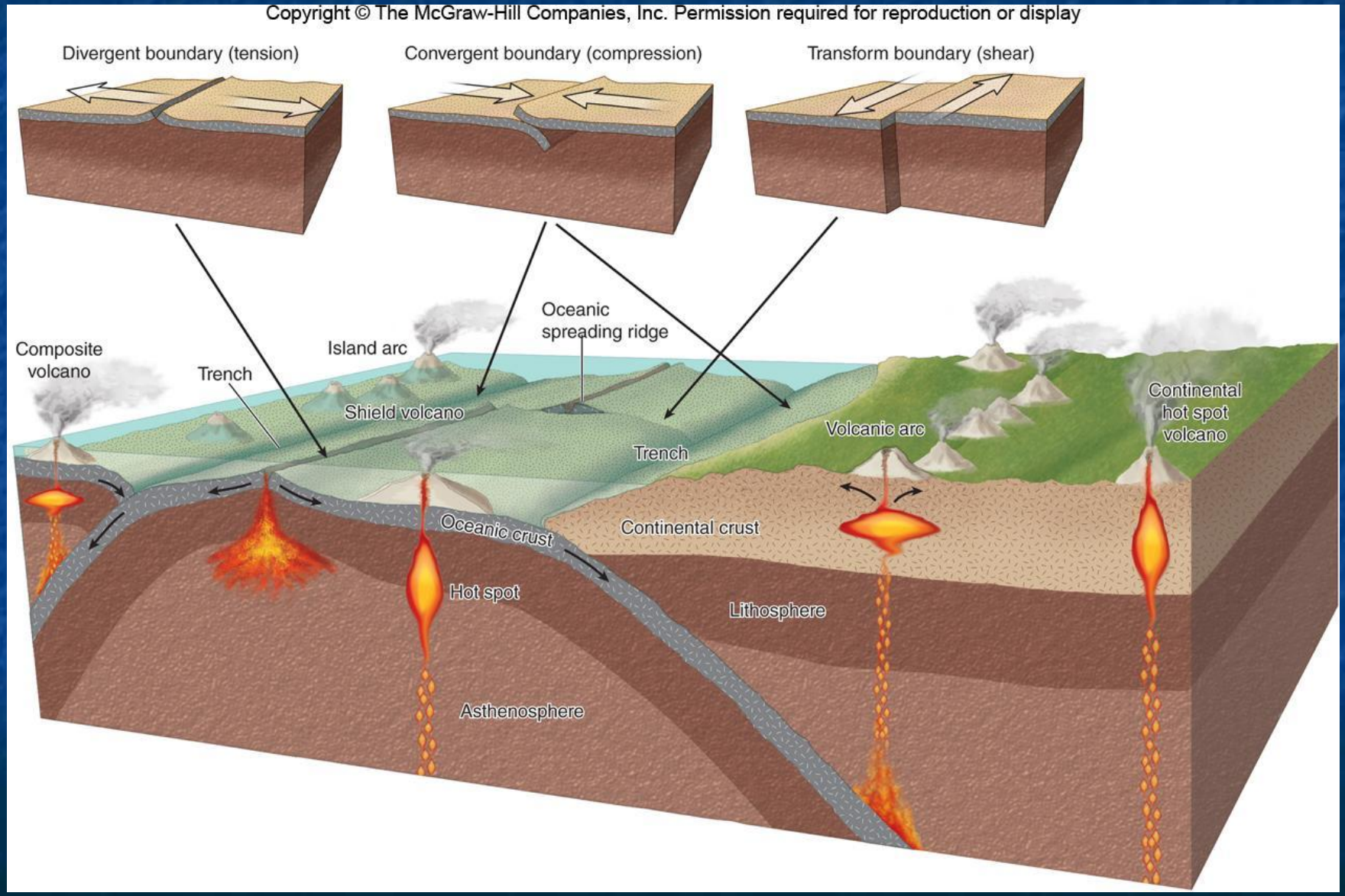
Eurasian plate
North American plate
Eurasian plate
Juan de Fuca plate
Philippine plate
Caribbean plate
Arabian plate
African plate
Indian plate
Cocos plate
Equator
Equator
Pacific plate
Nazca plate
South American plate
Australian plate
Scotia plate
Antarctic plate

Plate Boundaries

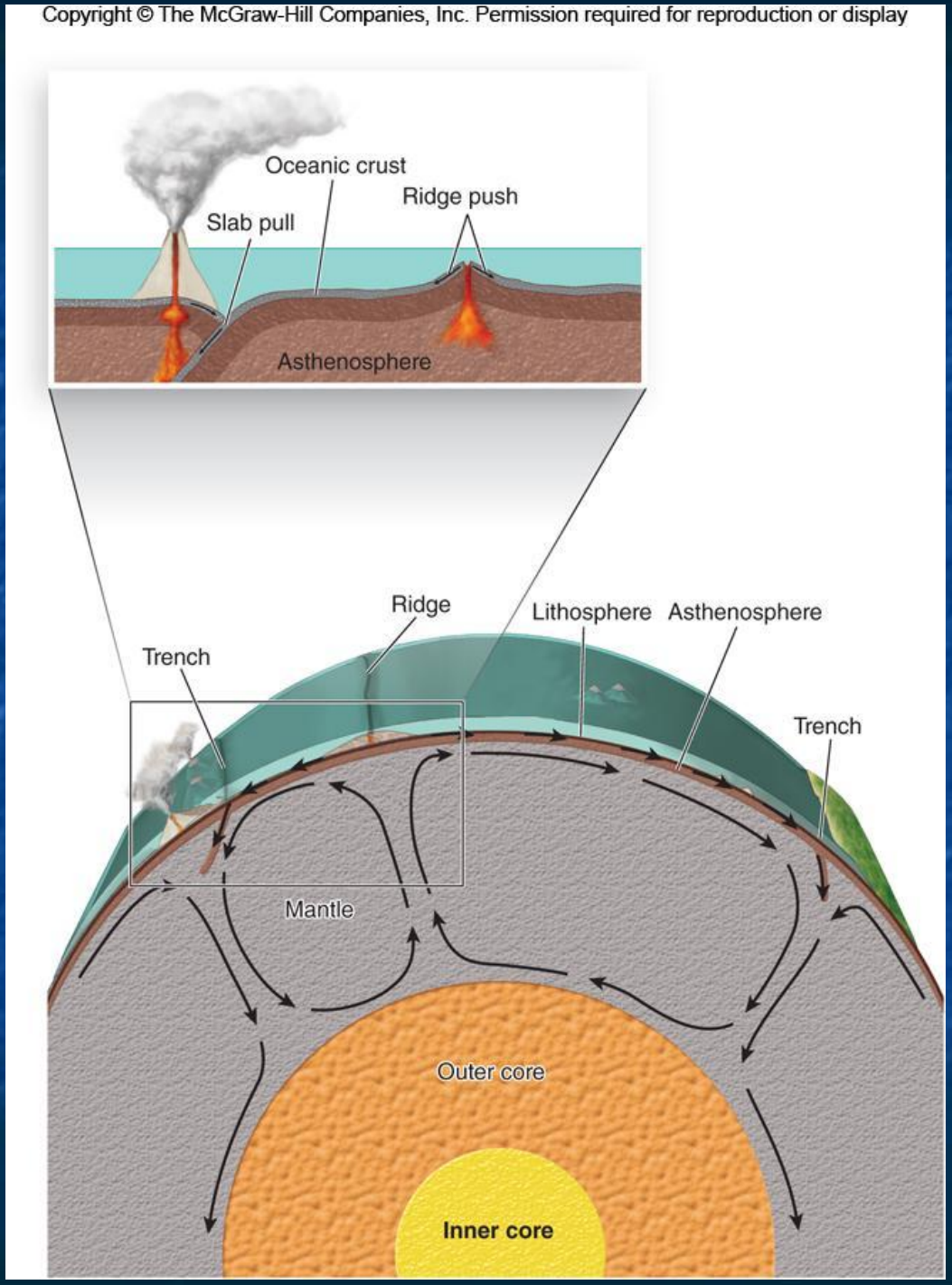
- Movement generates compression, tension or shear
- 3 Types of Boundaries
  1. Divergent
  2. Convergent
  3. Transform
- See Figure 4.19 Page 107

Plate Boundaries



Movement of Plates

Figure 4.17, Page 106



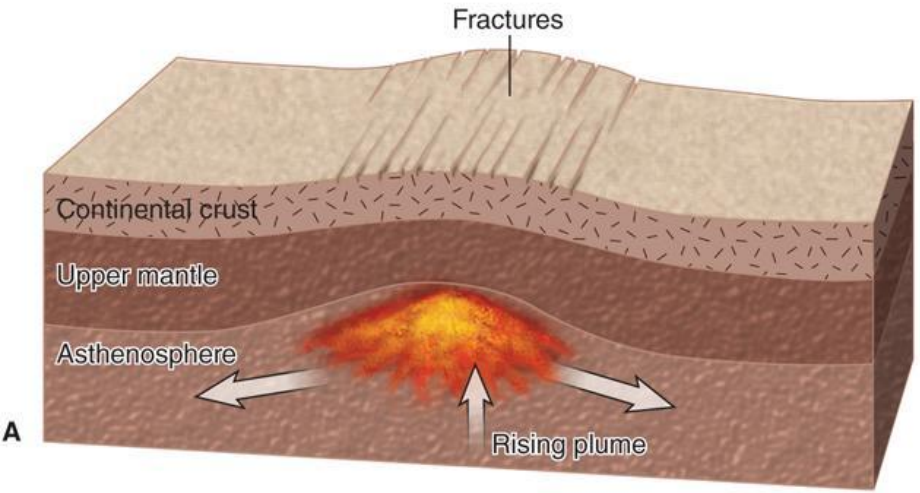
Surface Features & Plate Boundaries

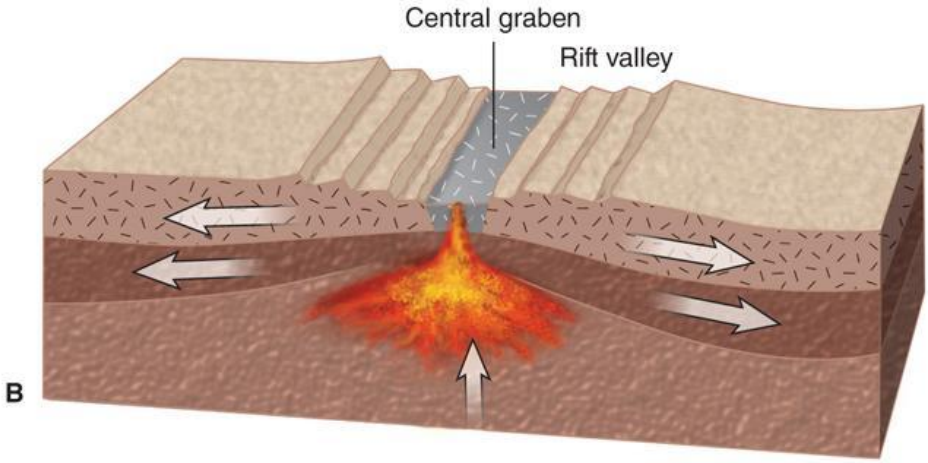
- Convergent
- Oceanic-oceanic island arc; one plates undergoes subduction; may produce an island arc
- Oceanic-continental - continental arc formed; oceanic plate undergoes subduction; volcanic activity
  - Andes Mountains along S. America's west coast
  - Cascades in Pacific Northwest of U.S.
- Continental-continental - mountain belt, both plates are low density continental crust
  - Appalachian Mountains
  - Himalayas in Asia
  - Alps in Europe

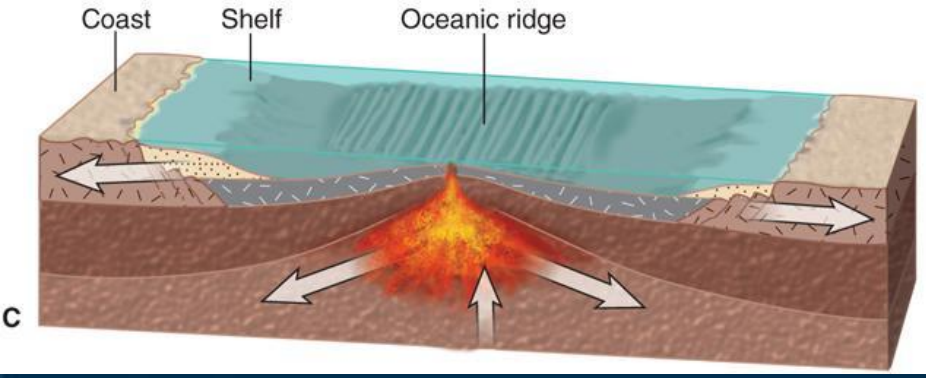
Surface Features & Plate Boundaries

- Divergent
- Ocean ridges
- Rift valleys; may fill in with water
- Transform – plates "side swipe" each other; shear forces; most in ocean plates; no subduction
- San Andreas fault
- See figures on pages 110 - 111

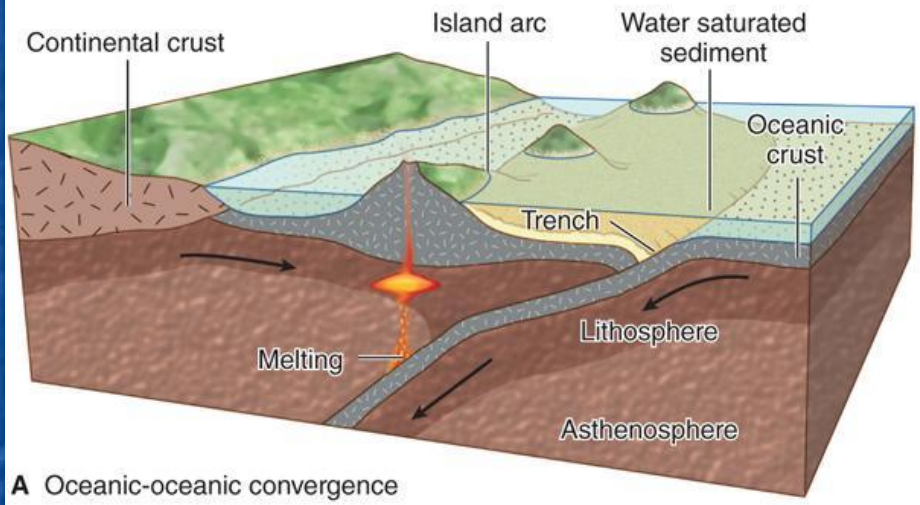
Divergent Plate Boundaries



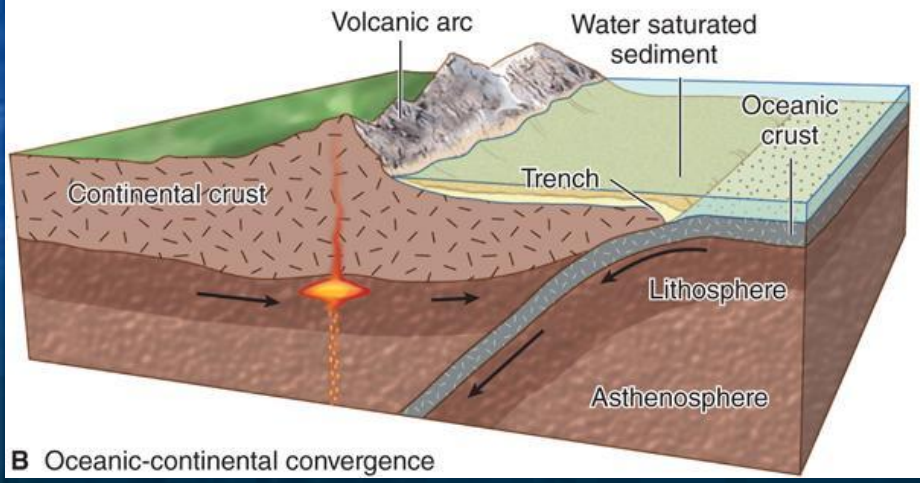




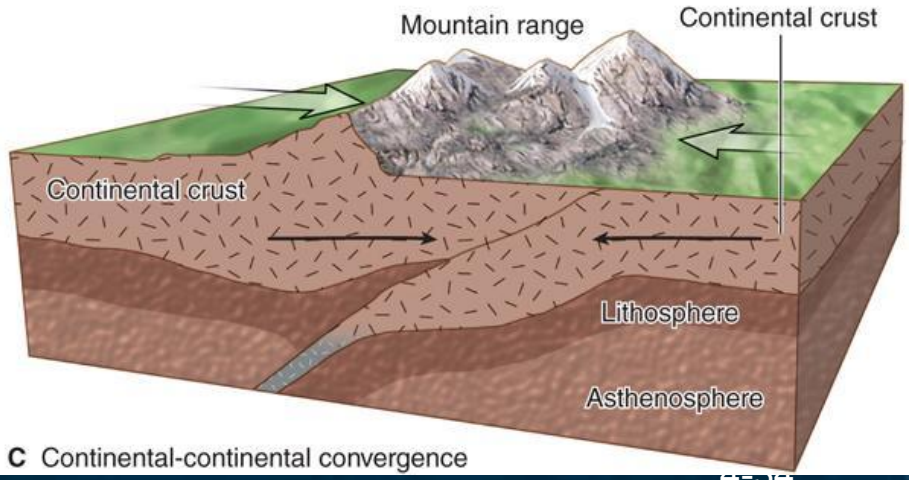
Convergent Plate Boundaries



A Oceanic-oceanic convergence

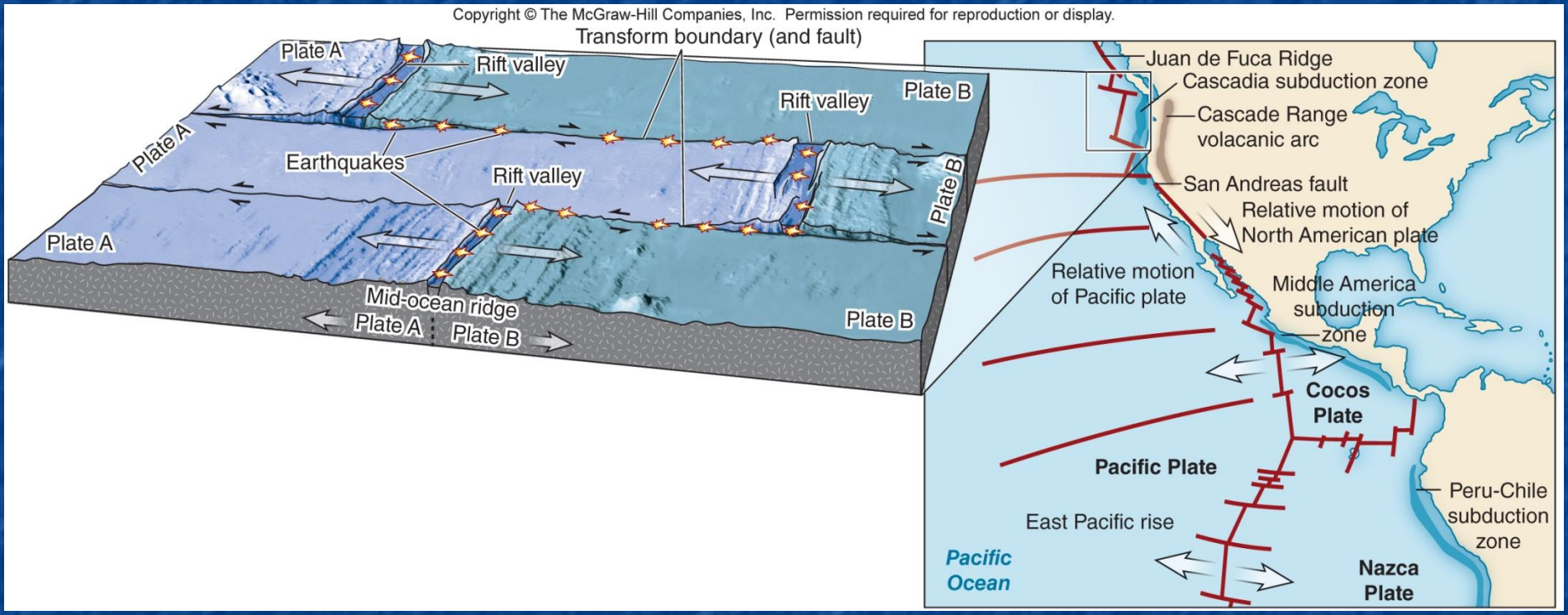


B Oceanic-continental convergence

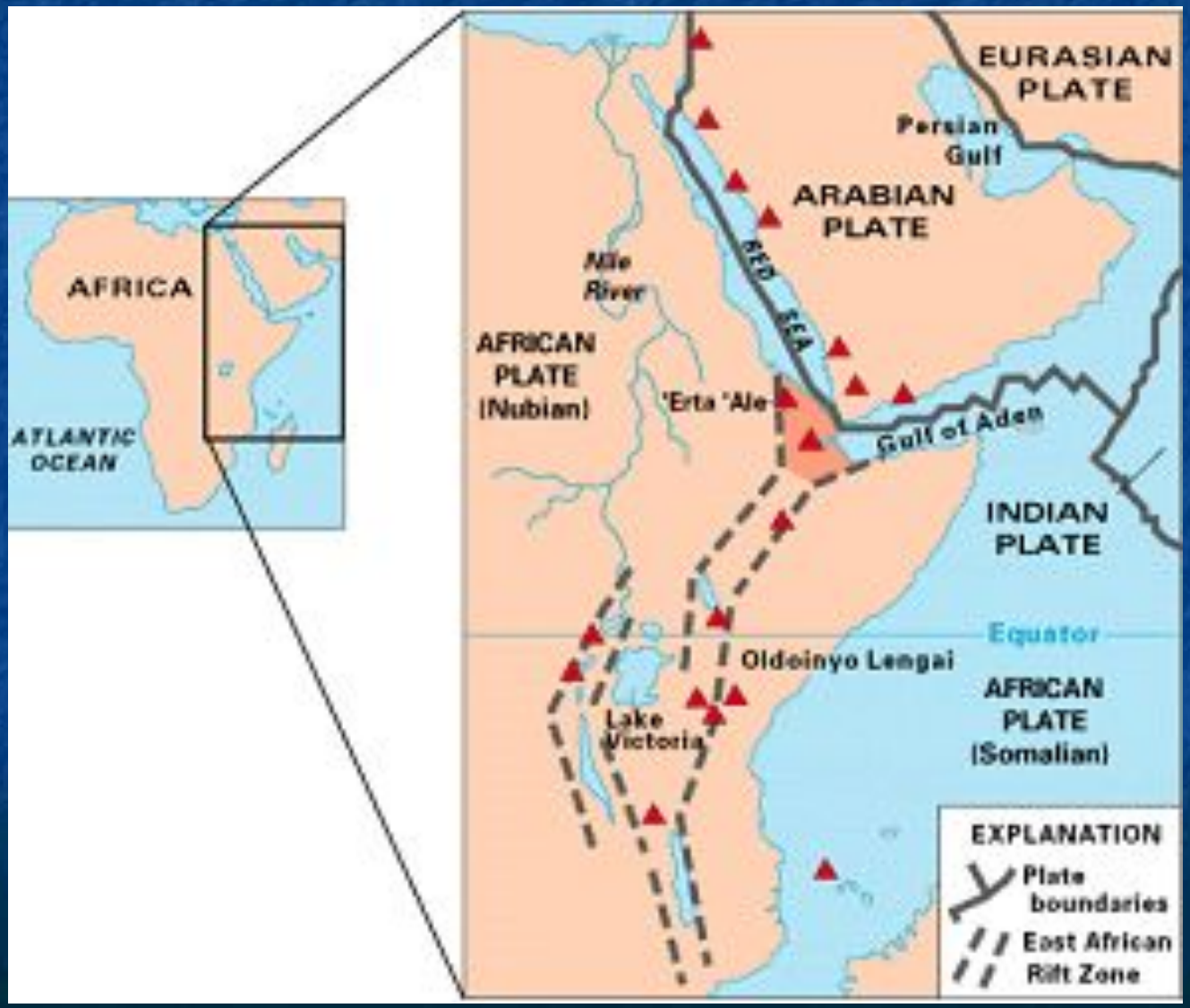


C Continental-continental convergence

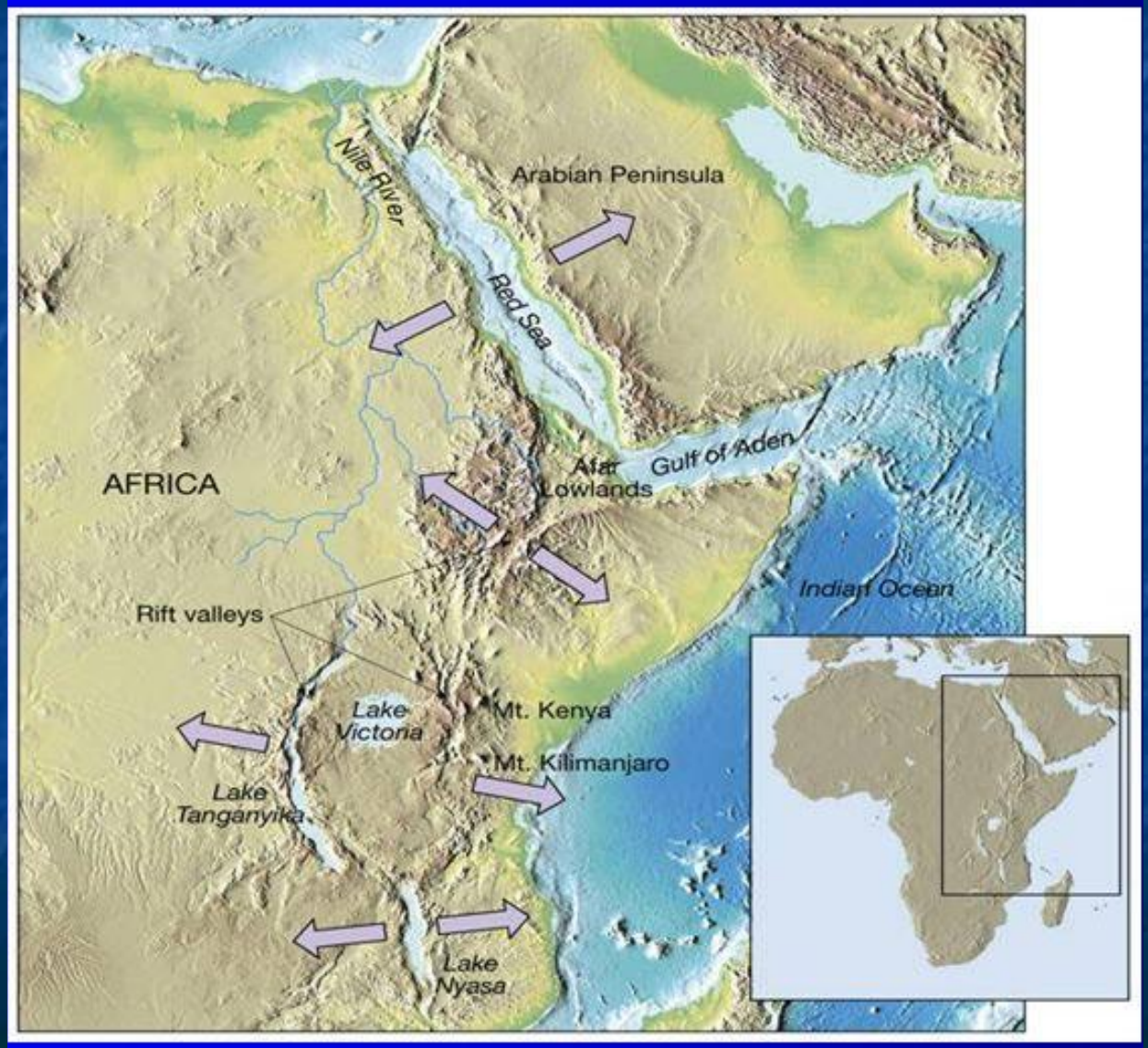
Transform Plate Boundary



East African Rift Valley



East African Rift Valley



Future of African Continent?

http://www.pmfias.com/wp-content/uploads/2015/12/East-African-Rift-Valley-break-up.jpg

Plate Boundaries and People

- Natural hazards
  - Earthquakes, volcanic eruptions, landslides
- Natural resources; minerals form under specific geologic conditions
- Climate – oceans transfer heat, mountain ranges interrupt air masses; volcanic ash
- Development of life