Earth's Interior and Plate Tectonics

David F Dominic
Department of Earth & Environmental Sciences
Wright State University
Dayton, Ohio

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Scientific Revolution: Continental Drift to Plate Tectonics

Hypothesis: Continental Drift

speculation as early as 1600s

Alfred Wegener, 1915:

The Origin of Continents and Oceans

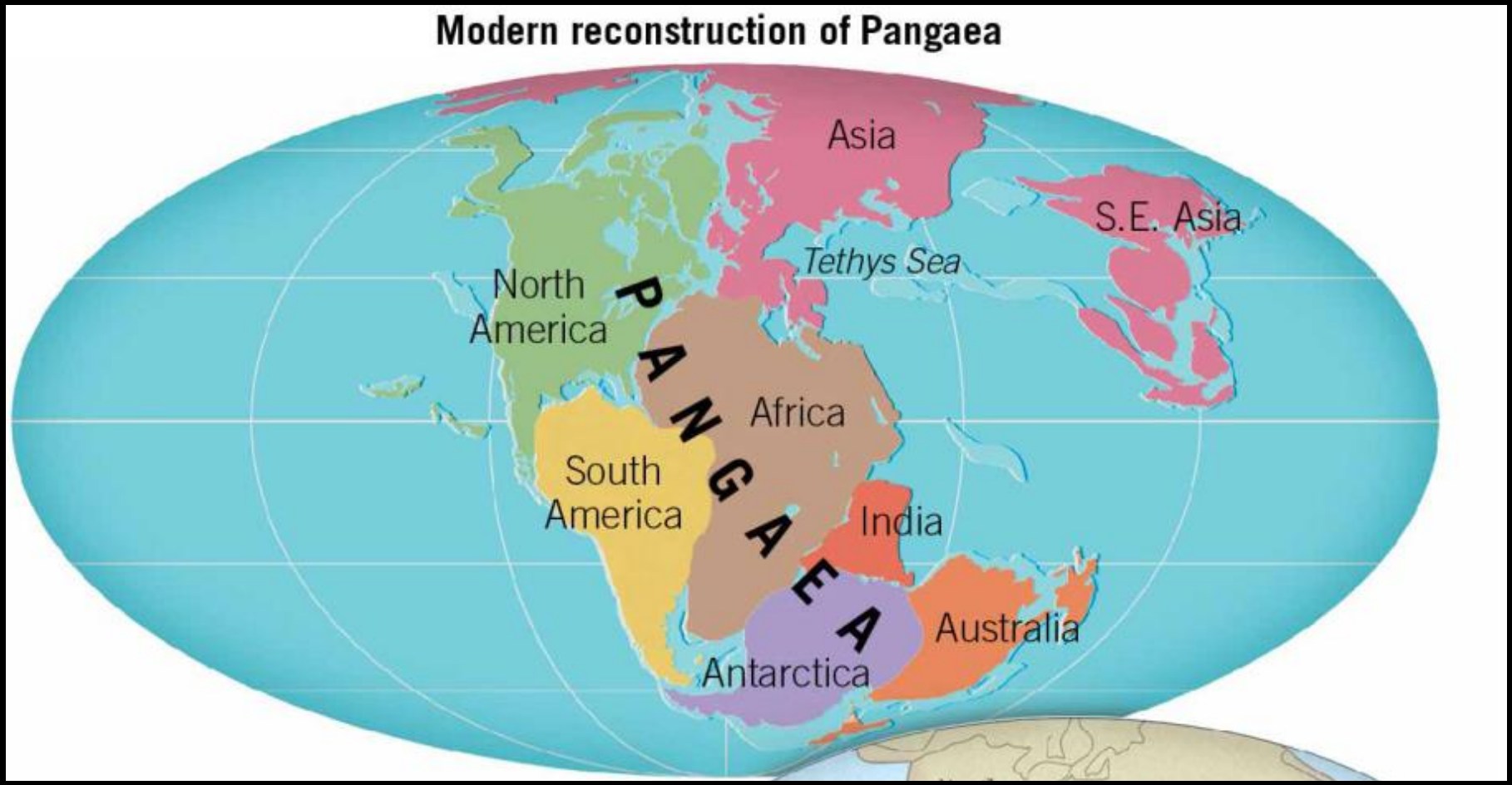
Observations:

1) jigsaw puzzle continents
2) matching fossils
3) matching rocks
4) matching patterns of glaciation

Observations:

1) jigsaw puzzle continents

Wegener proposed that all continents were once together as the supercontinent Pangaea (across the earth)



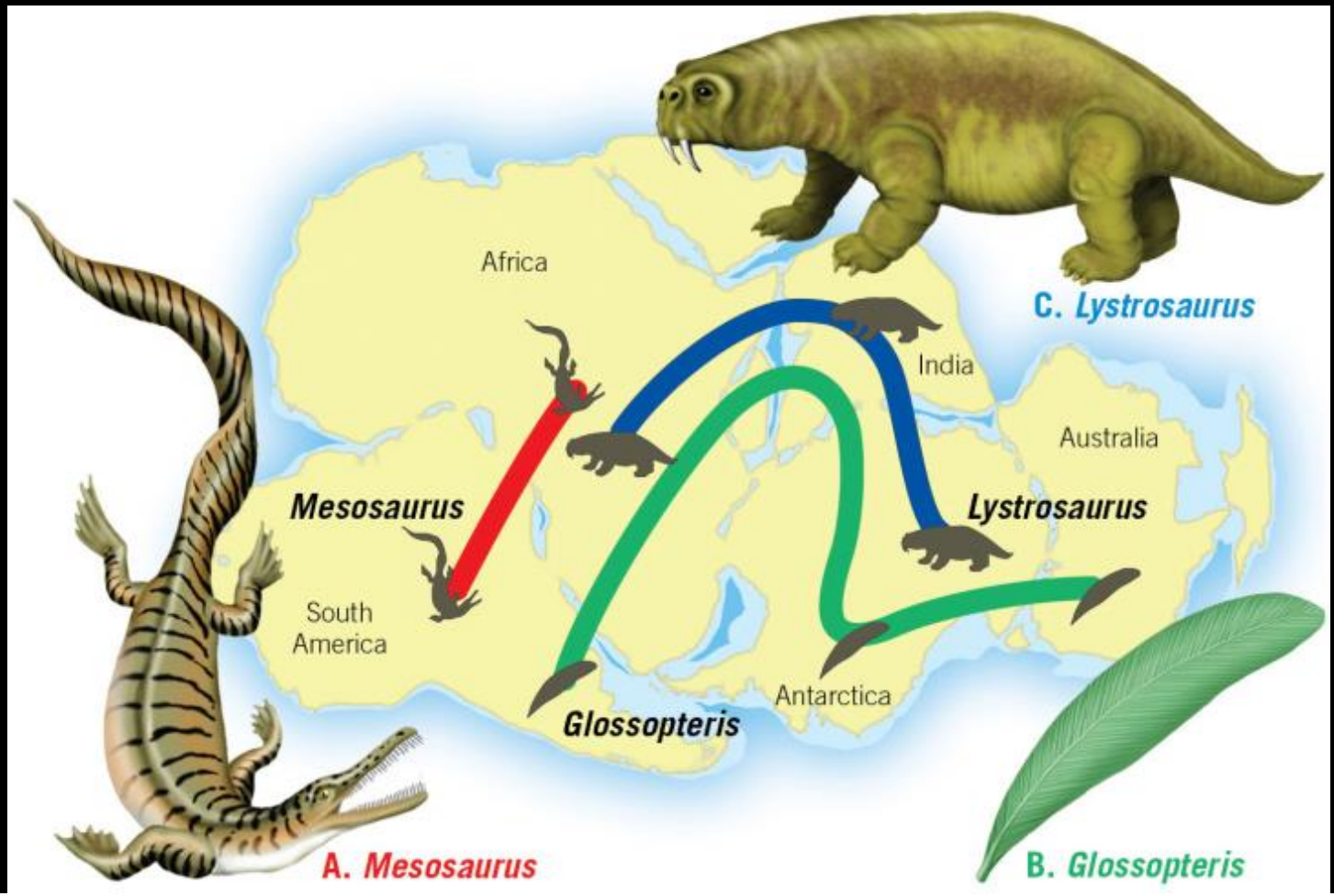
Observations:

2) matching fossils (unexplainable migration)

A) Mesosaurus (freshwater reptile)

B) Glossopteris (plant)

C) Lystrosaurus (saber-toothed mammal)



Observations:
3) matching rocks (types and ages)

Mountain Belts:
Appalachian (N. Amer.) Caledonian (Eur.)
Atlas (Africa)

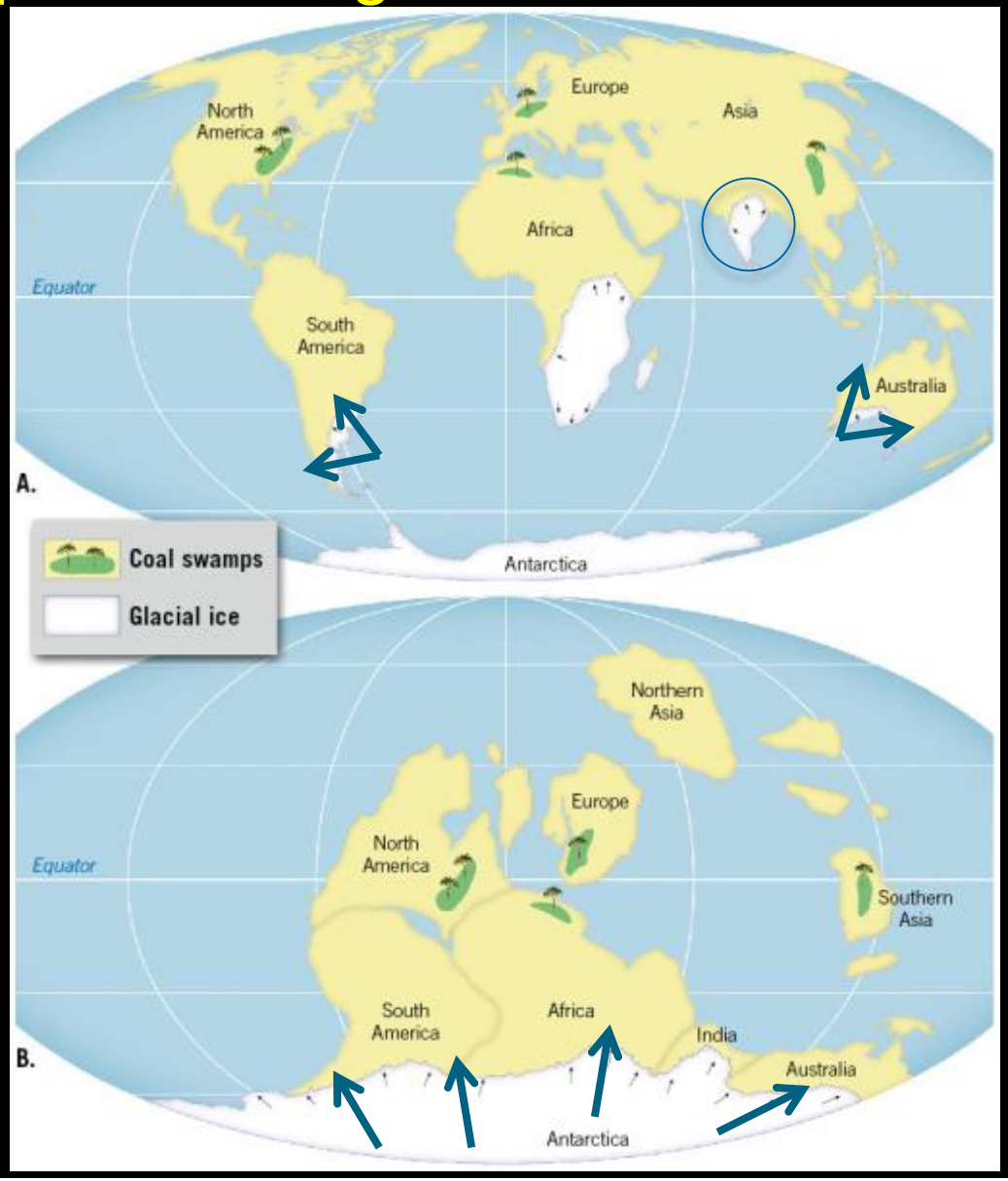
Now

300 million years ago

Observations:
4) matching patterns of glaciation

Present positions:
Glaciers in tropics –or-
appear to move from
oceans to land.

Pangaea: Glaciers
near South Pole and
expand as expected.



Scientific Revolution: Continental Drift to Plate Tectonics

Hypothesis: Continental Drift

Observations: (1) Jigsaw puzzle continents, (2)matching fossils, (3) matching rocks, (4) matching patterns of glaciation

Debate: (1920-1960) No clear cause or mechanism = doubt

Wegener thought gravitational forces could move continents

Calculations showed this is not possible

Wegener thought thick and strong continents plowed through thin oceanic crust (like *icebreakers*).

Calculations showed this is not possible

Scientific Revolution: Continental Drift to Plate Tectonics

Hypothesis: Continental Drift

- Observations: Jigsaw puzzle continents, matching fossils, matching rocks, matching patterns of glaciation

Debate: No clear cause or mechanism = doubt

Mapping of Ocean Floor Provided Clues (1950s)

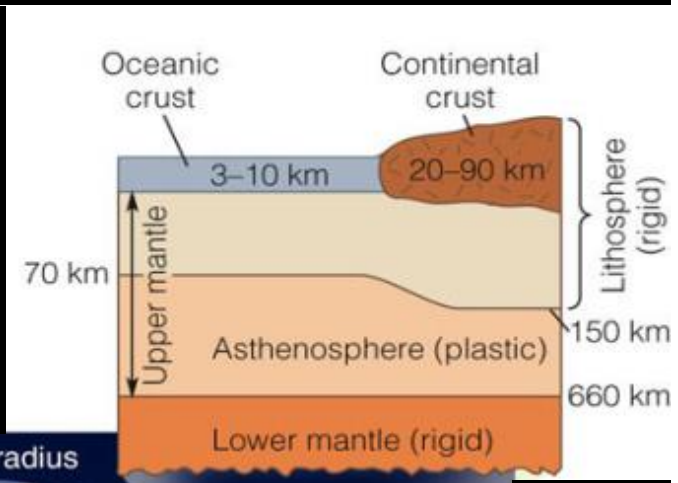
Revised Hypothesis: Plate Tectonics

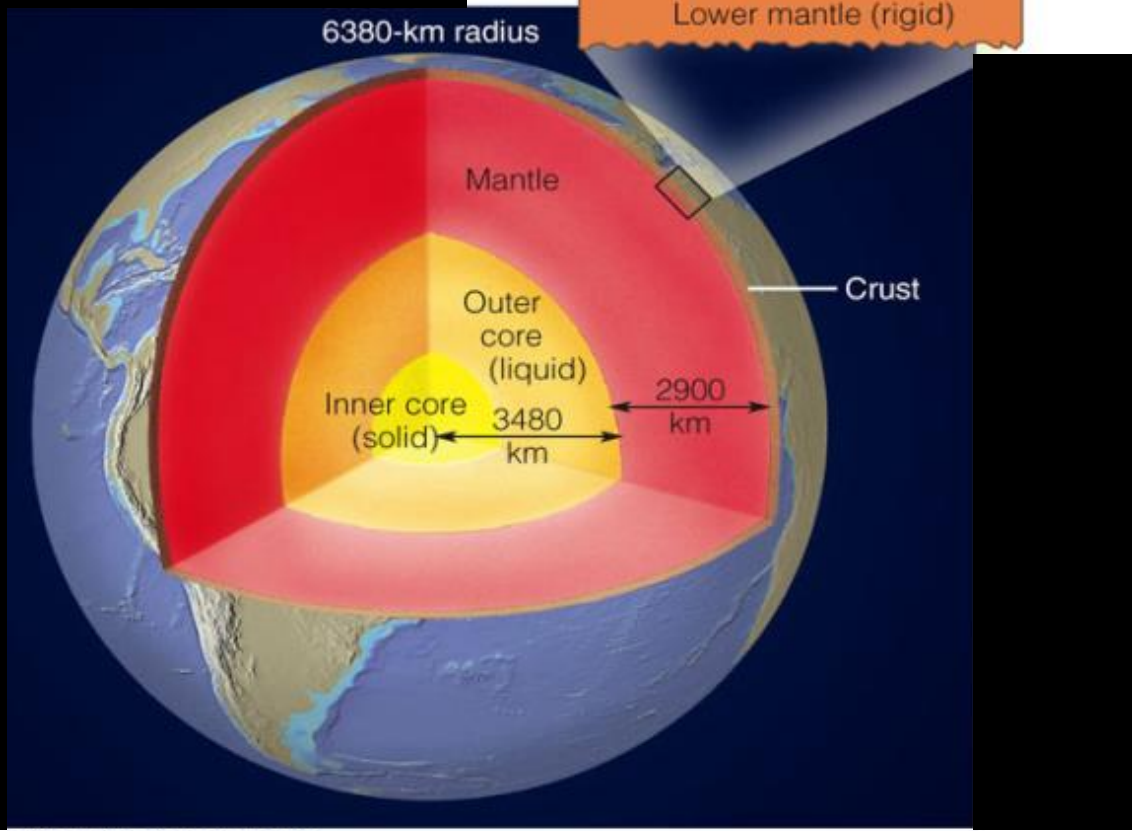
- Continents do not “plow through” oceanic crust
- Plates extend from mid-ocean ridges to trenches
- Contain both continental crust and oceanic crust

What Is Earth's Interior Like?

Layers of Earth

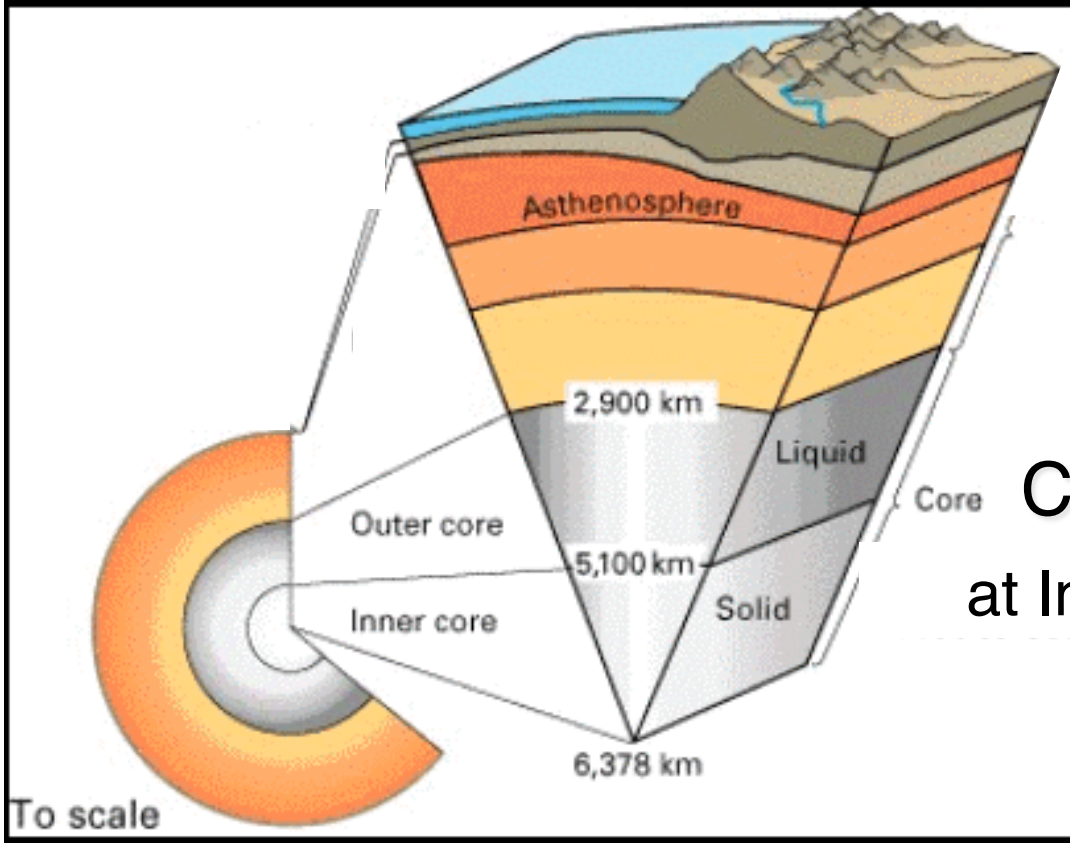
- *Crust*
  - Oceanic
  - Continental
- *Mantle* (rocky)
- *Core* (iron-rich)
  - Liquid outer core
  - Solid inner core





Layers Based on:

Composition

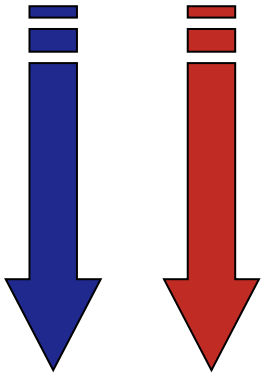


Crust

Mantle

Core

Pressure Temp



increases

at Inner Core, pressure wins

Types of Crust

Continental

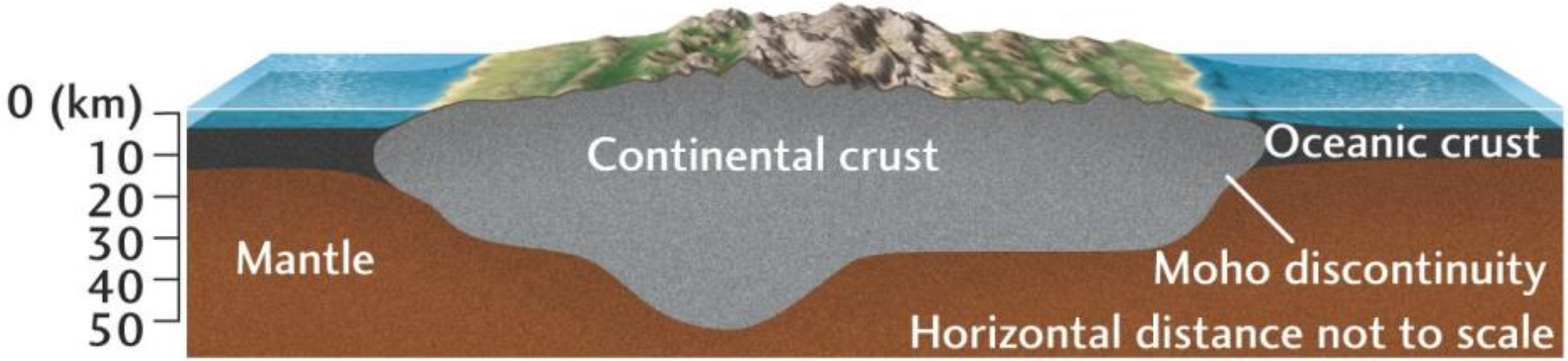
thicker (35 km), less dense

generally older

Oceanic

thinner (7 km), more dense

generally younger



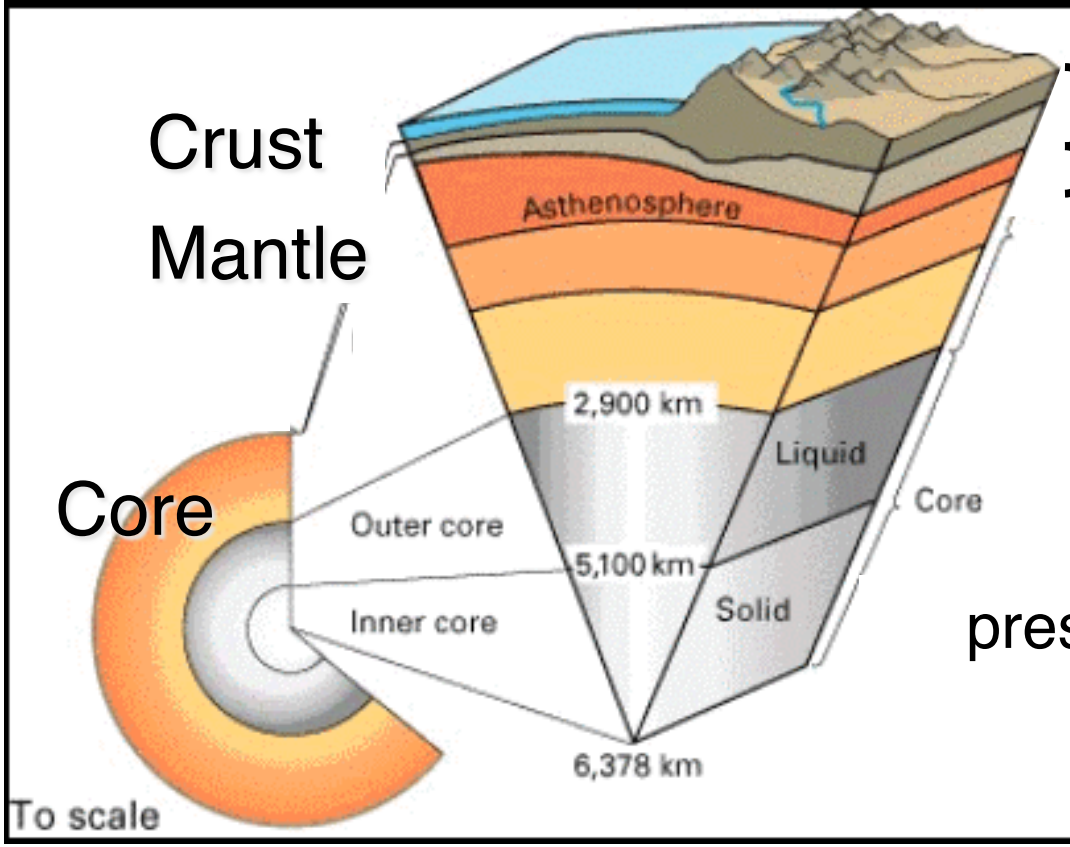
Layers Based on:

Composition

Crust

Mantle

Core



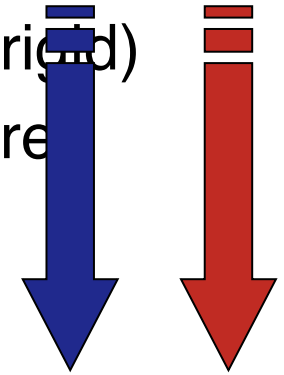
State

Lithosphere (rigid)

Asthenosphere
(partly melted)

Pressure

Melting Temp



increases

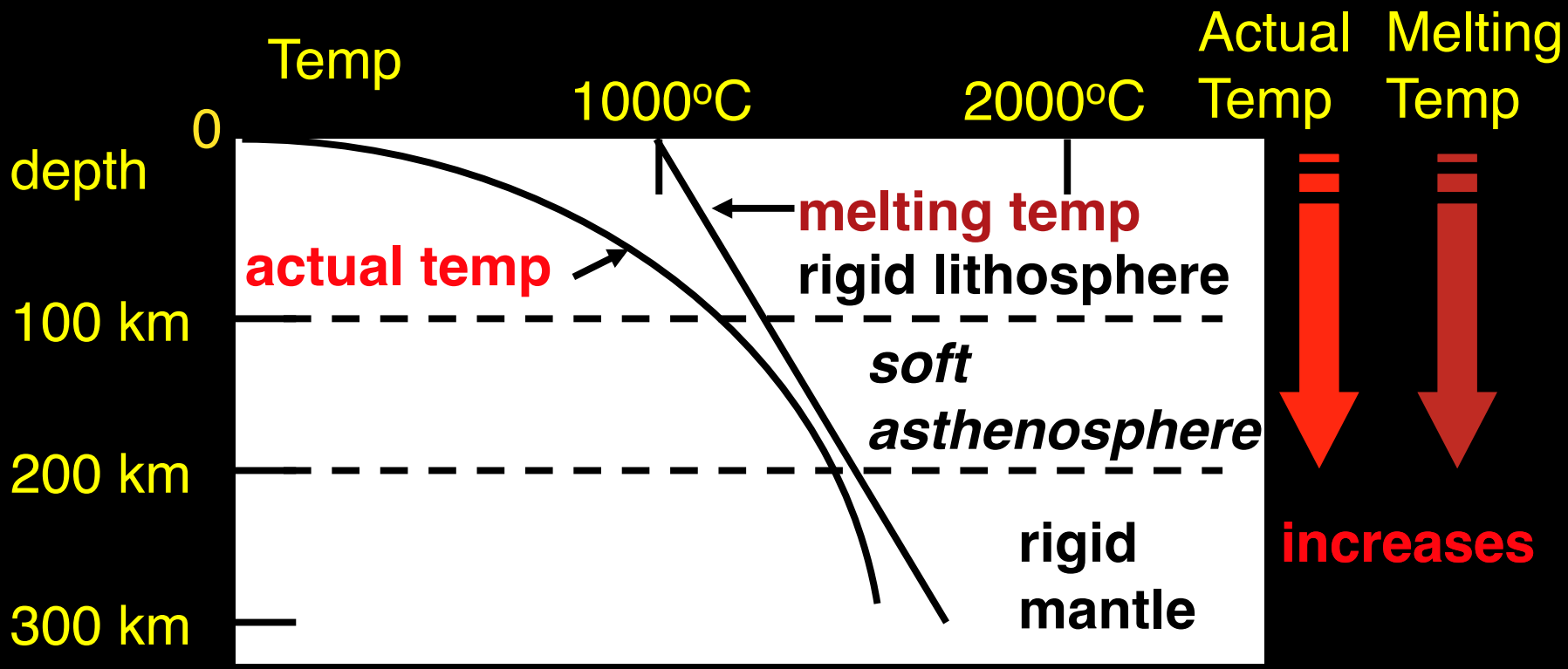
pressure increases melting temp

Layers Based on *State*

Asthenosphere

Partly melted

Actual Temp. approaches Melting Temp.



Layers Based on *State*

Asthenosphere Partly melted

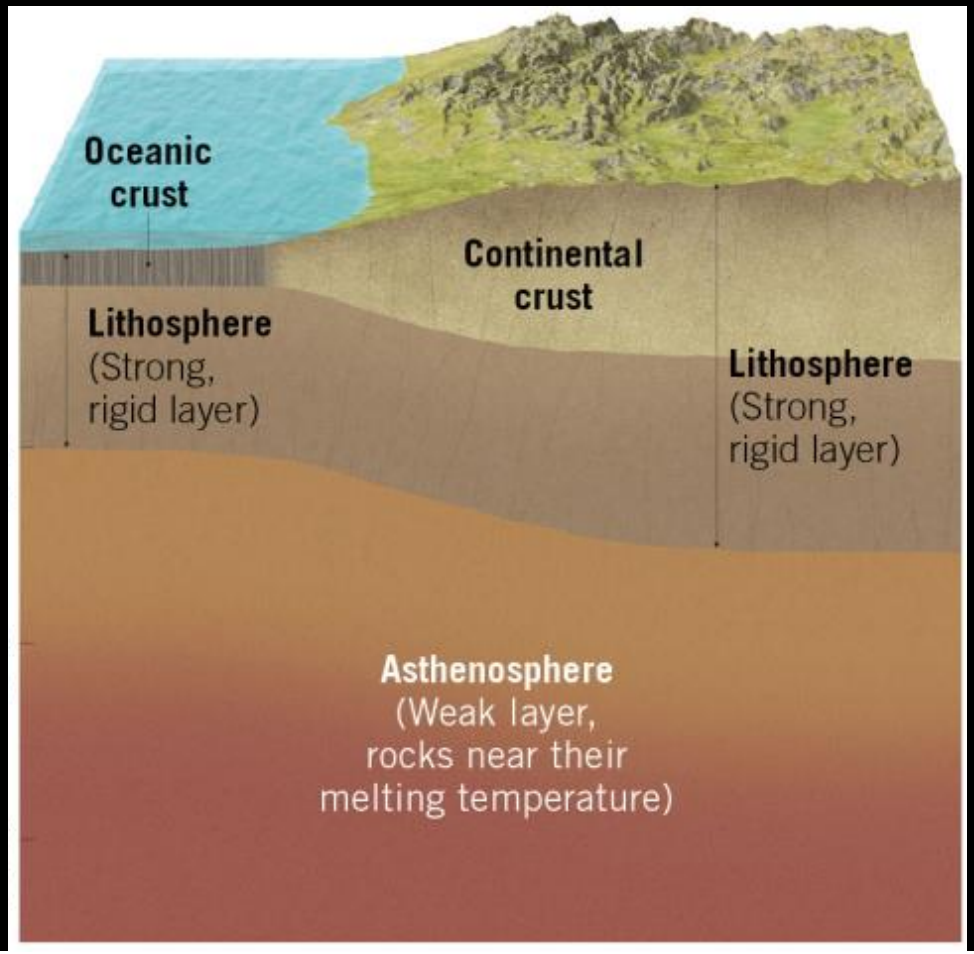
Lithospheric Plates move on top of Asthenosphere

depth

100 km

200 km

300 km



Actual Temp Melting Temp

increases

Layers Based on *State*

Lithosphere

- Rigid
- Brittle
- All Crust and uppermost Mantle (~100 km)

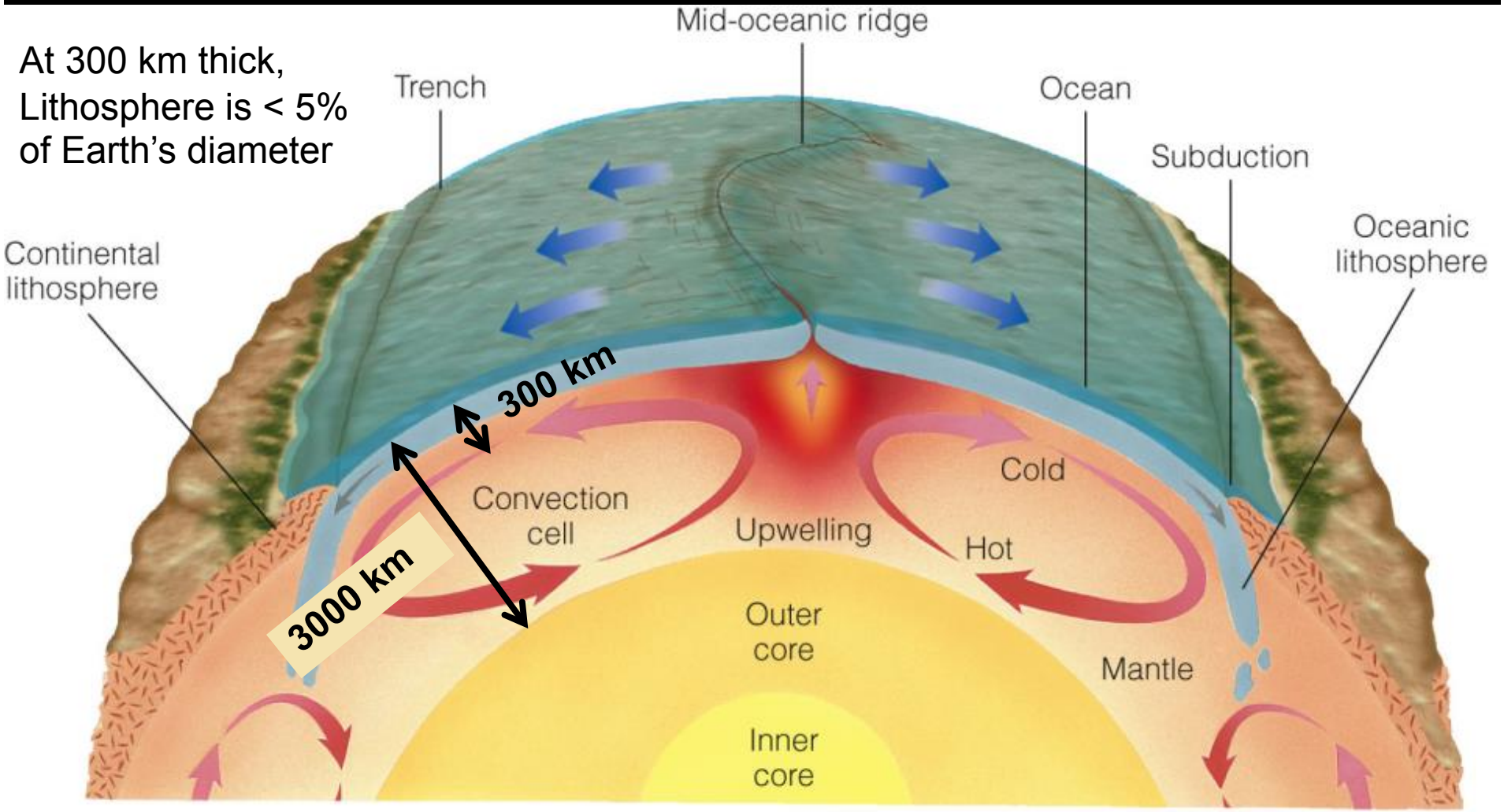
Asthenosphere

- Semi-solid
- Ductile, able to flow (partly melted)
- A portion of the upper Mantle (100-200 km)

Diagram is not to scale

Plate Tectonics

At 300 km thick, Lithosphere is < 5% of Earth's diameter

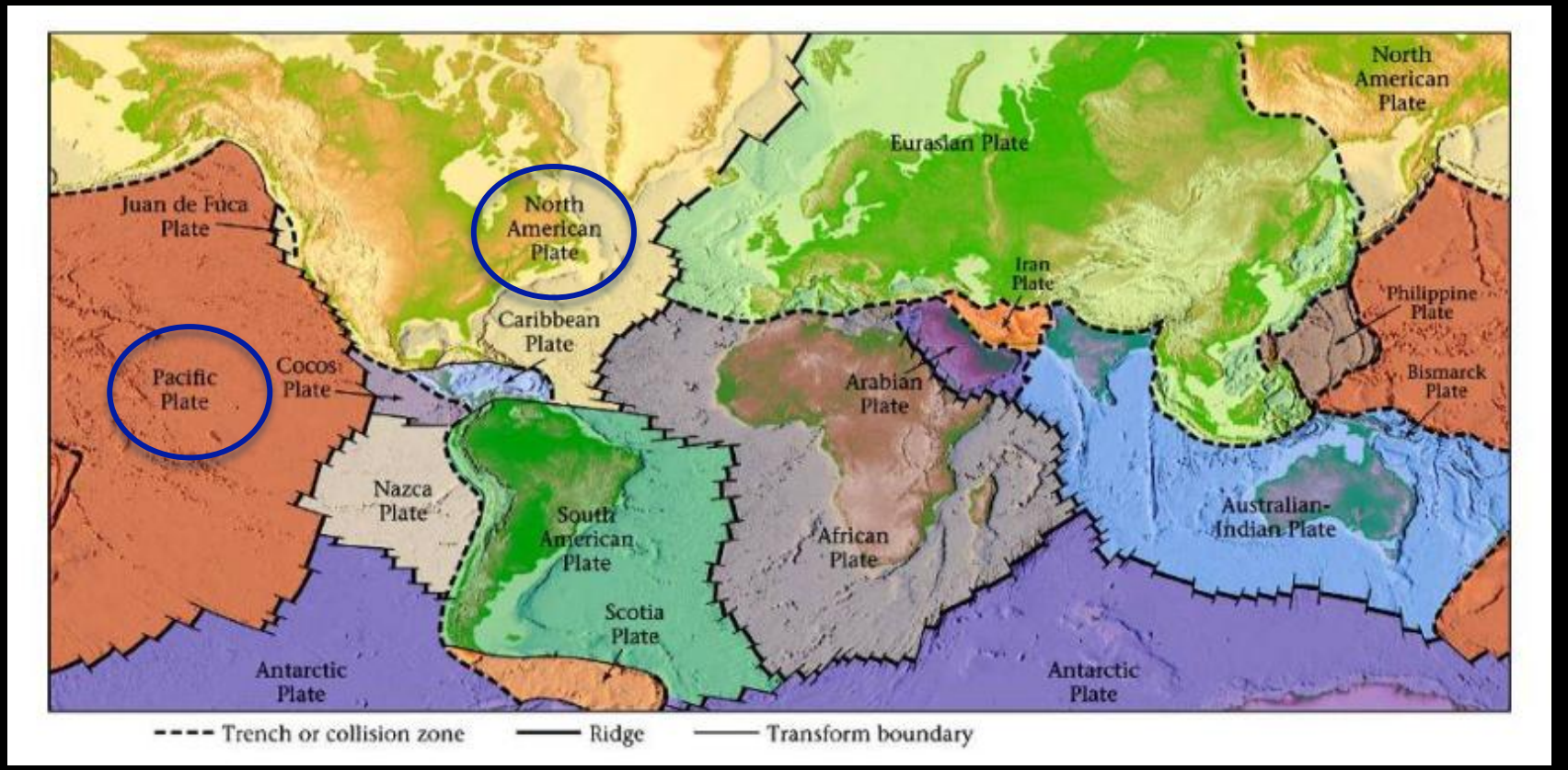


Tectonic Plates

Plate = portion of lithosphere (crust + upper mantle)

Entirely oceanic crust → Pacific Plate

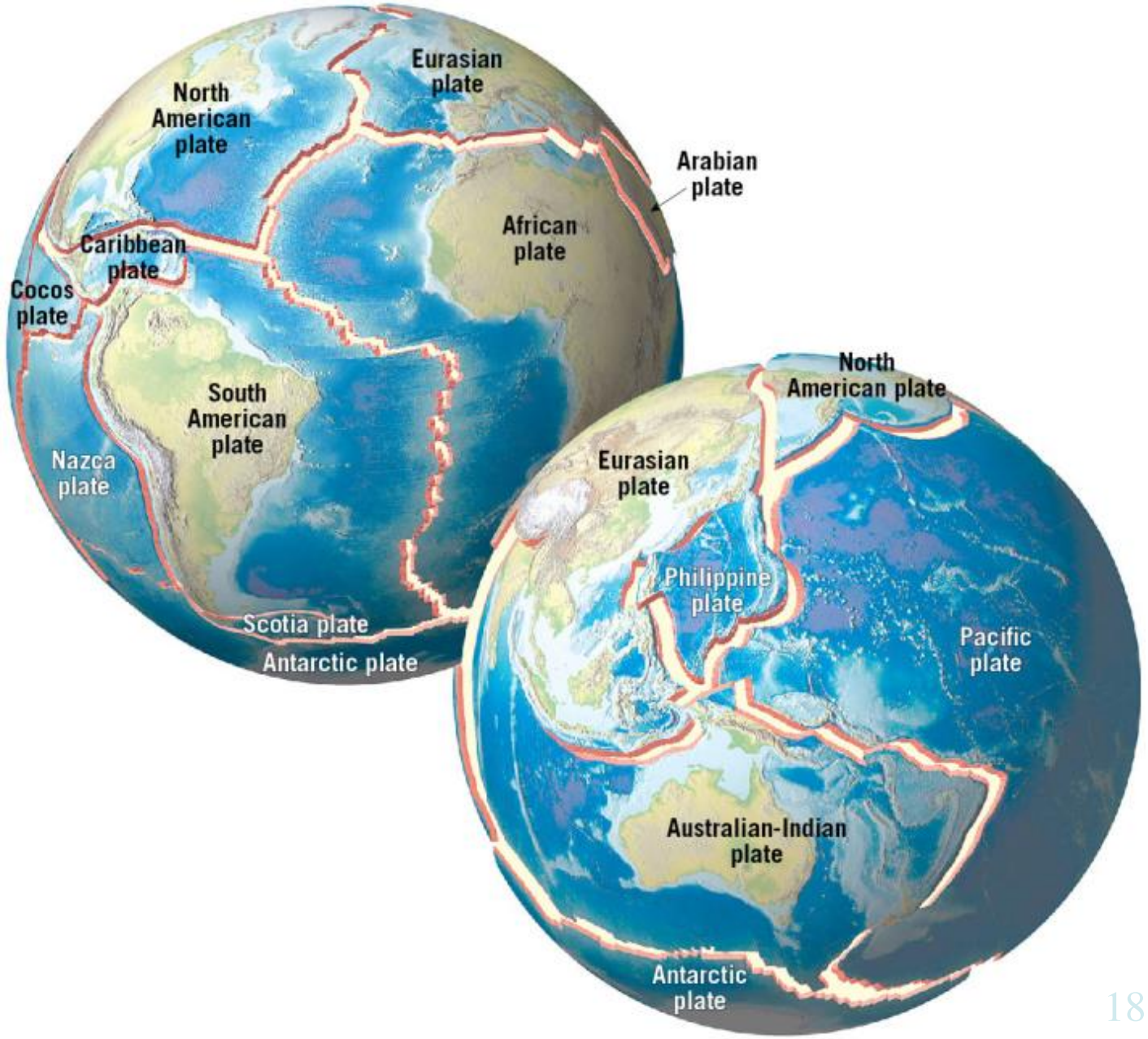
Both oceanic & continental crust → N American Plate



Tectonic Plates

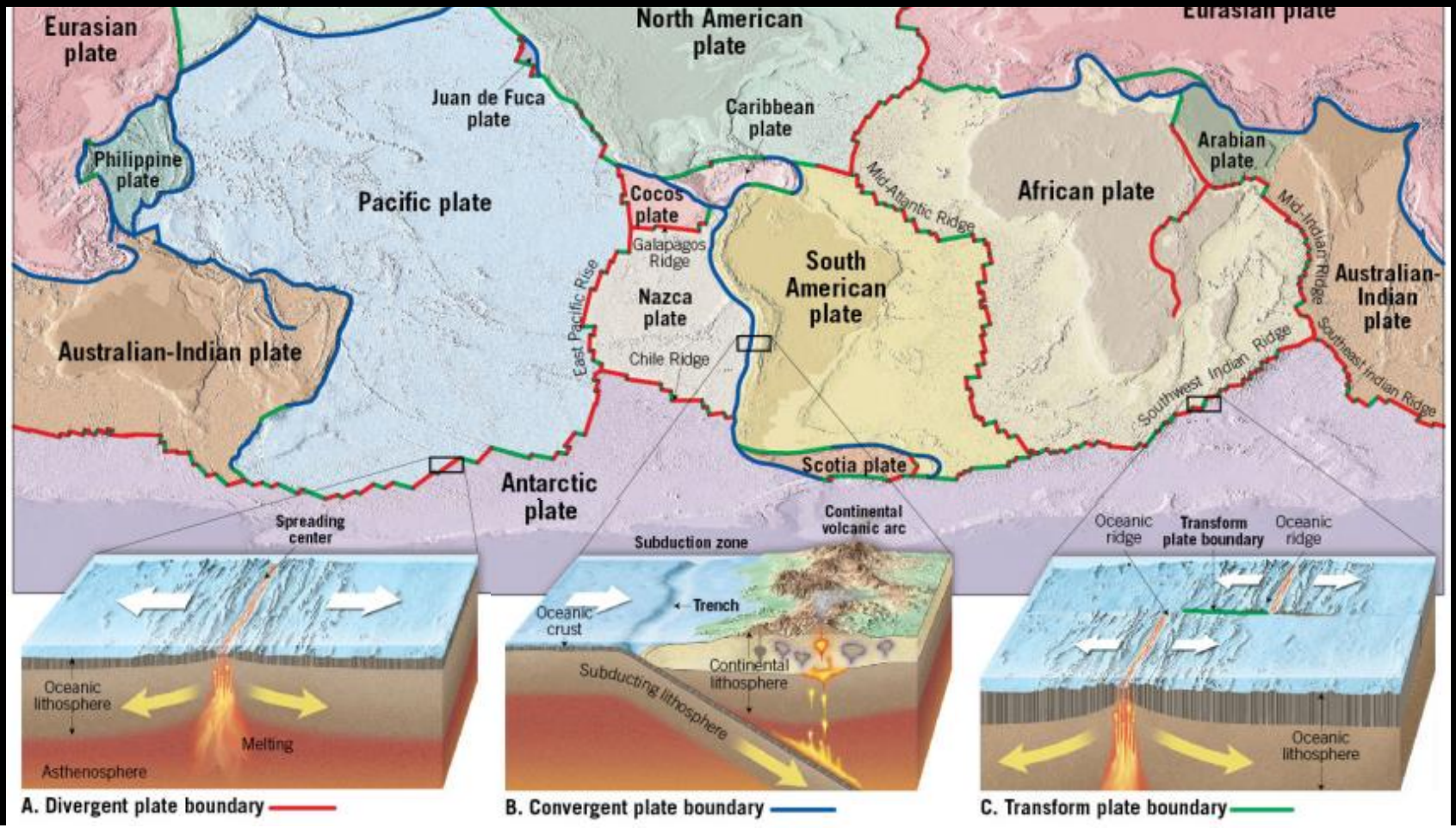
Plate = portion of lithosphere (crust + upper mantle)

Some entirely oceanic crust; most both types



Relative Plate Motion

1) Divergent (mid-ocean ridge; continental rift)
2) Convergent (Trench or collision zone; subduction)
3) Transform (Transform boundary; major fault; offset)

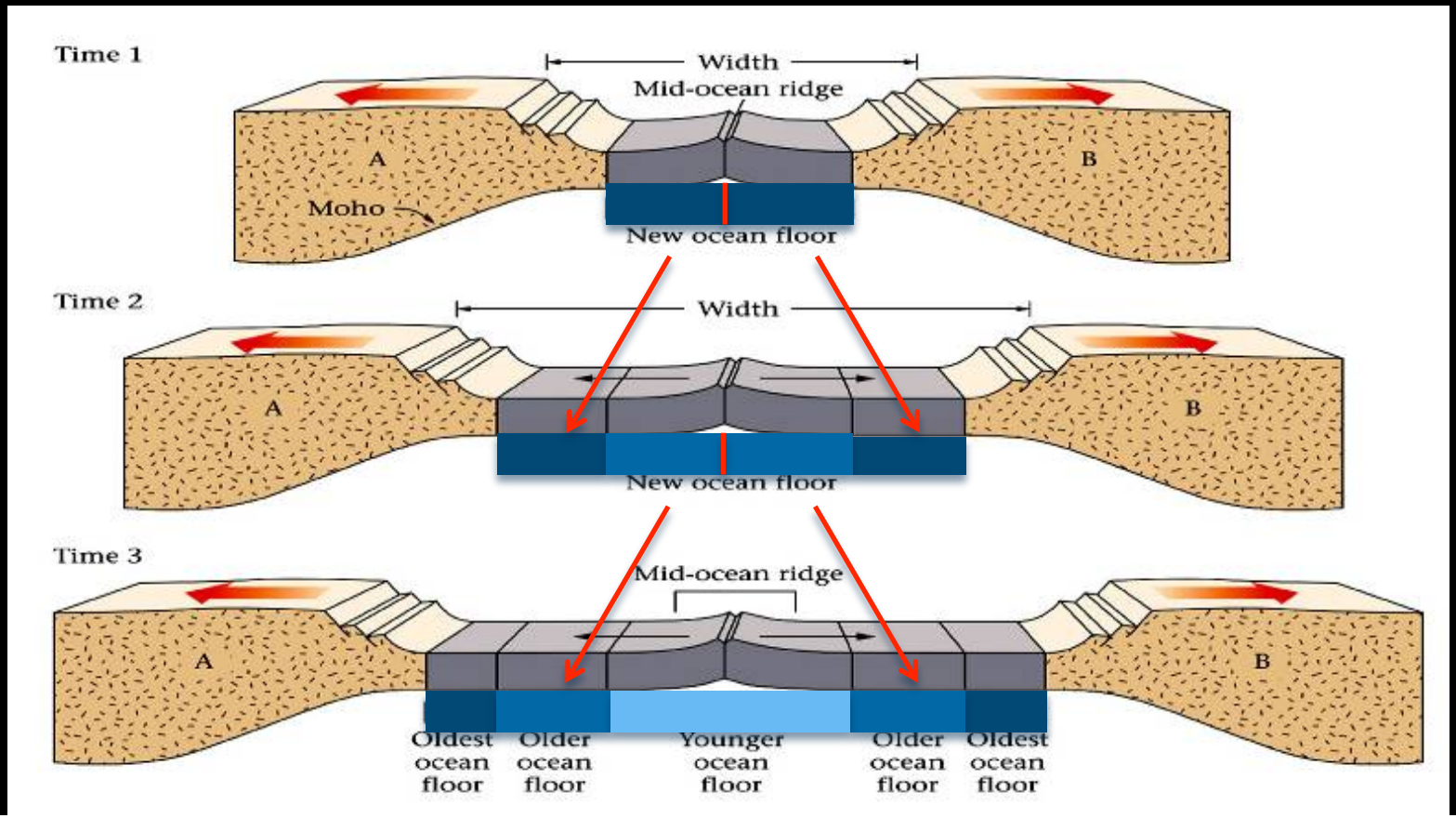


Divergent Boundaries: Seafloor Spreading

New oceanic crust is formed along the mid-ocean ridge when two plates are forced apart by convection.

As spreading continues, older crust moves farther away from the ridge.

Spreading creates stripes of oceanic crust that *match* on either side of ridges.

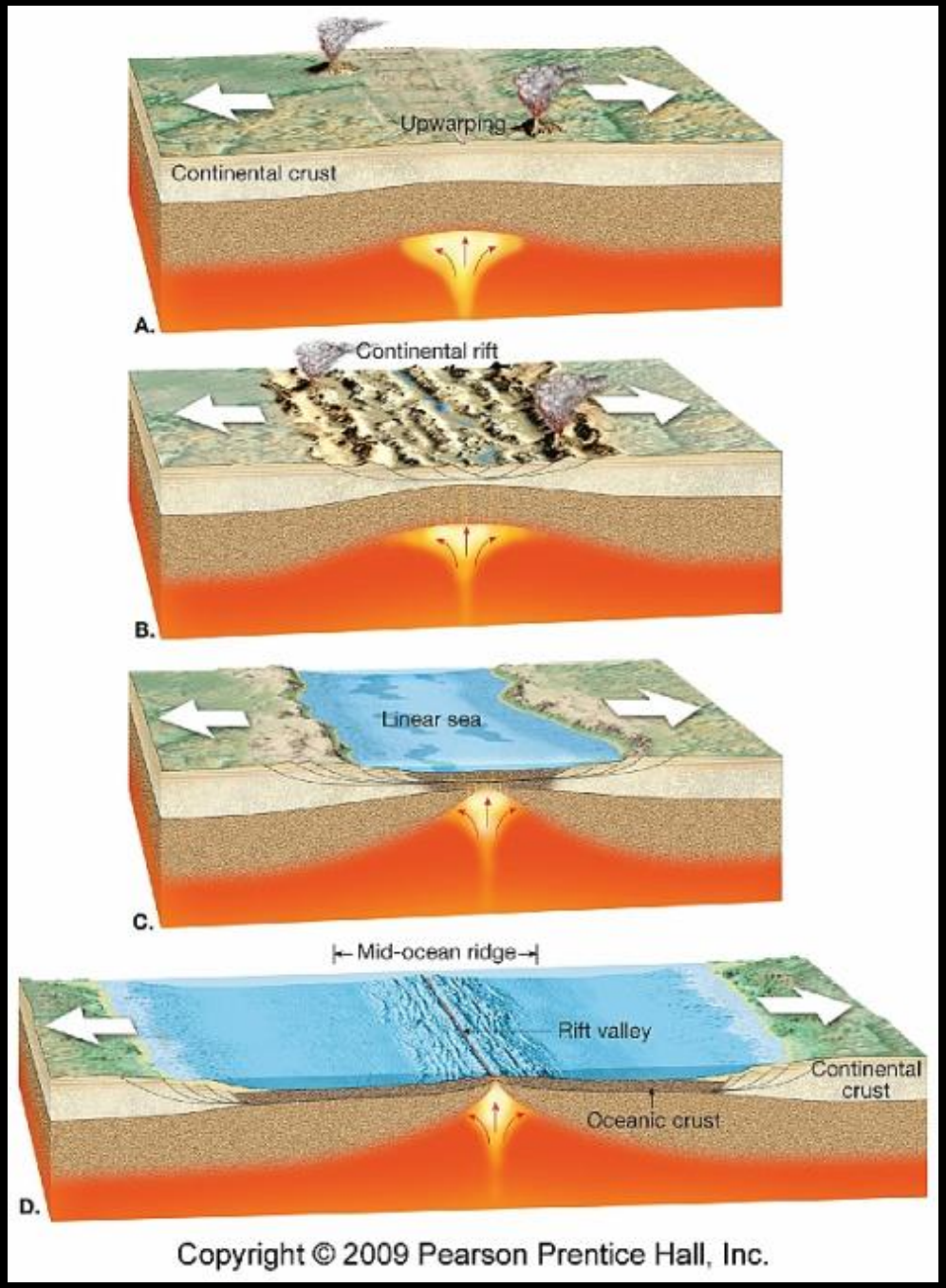


Divergent Boundaries: Continental Rift

Rising heat from convection melts and thins continental crust (volcanoes and rift valleys).

Lateral motion pulls crust apart.

Continued separation splits continent creating new ocean.



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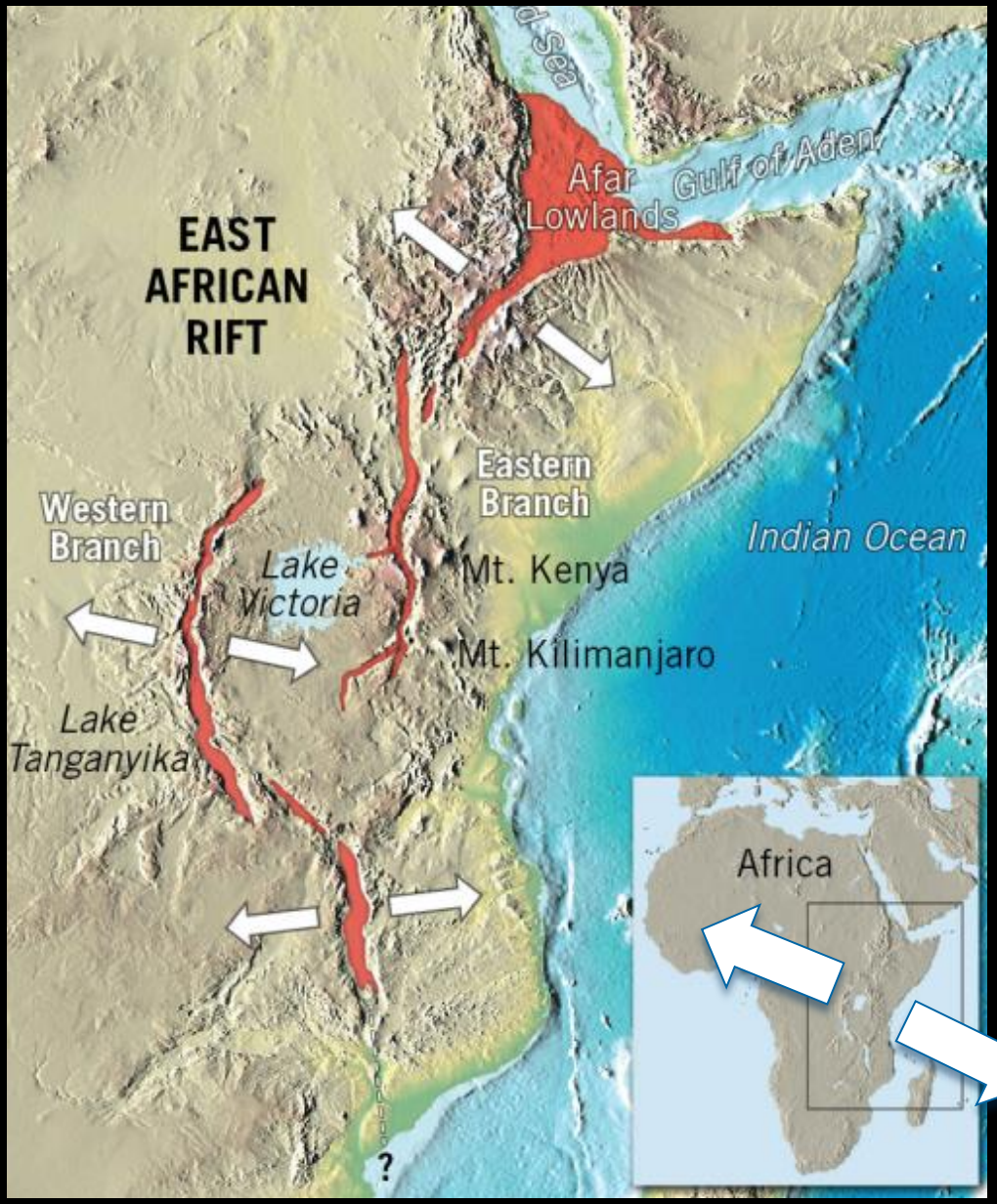
Divergent Boundaries: Continental Rift

East African Rift Valley

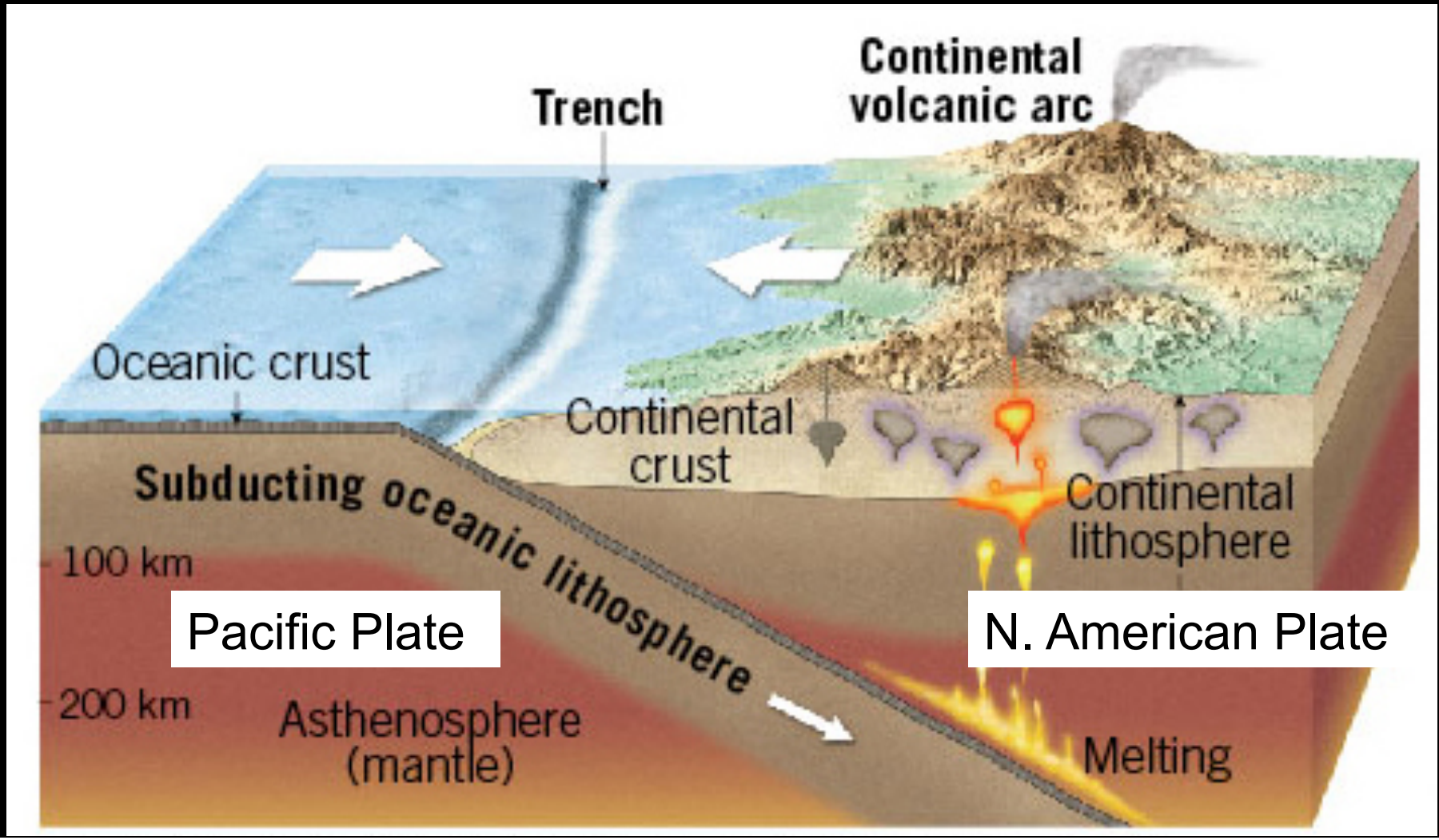


Oldest Hominid Fossils

Convergent Boundaries: Use Your Hands

Where plates come together, results depend on types of crust.

Oceanic (thin, more dense) – Continental (thick, less dense)



Convergent Boundaries: Ocean-Continent

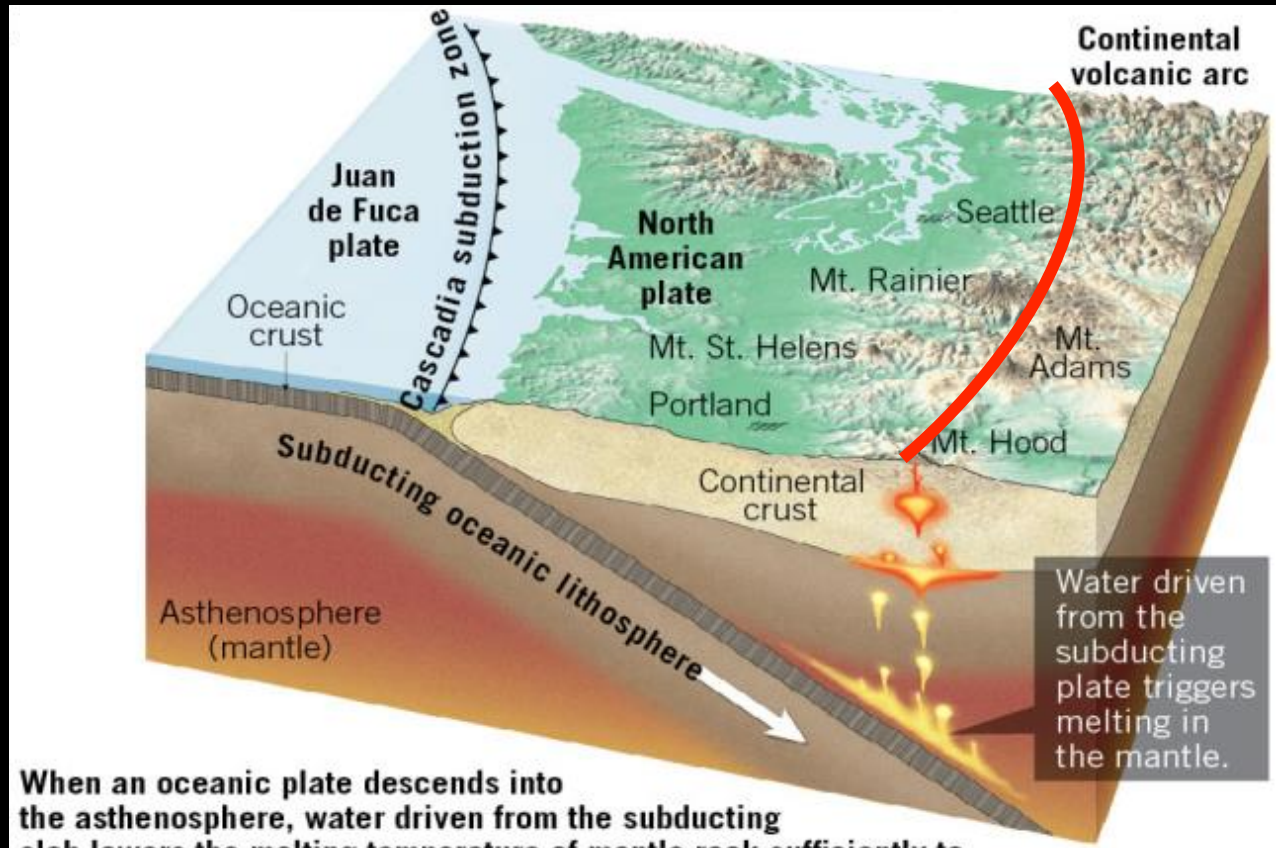
Oceanic crust + sediments + water heated at depth

Partial melting: of the minerals with the lowest melting temperatures

Occurs at depths of 100-150 km.

Magma rises because it is less dense.

If magma reaches the surface, lines or arcs of volcanoes are created.

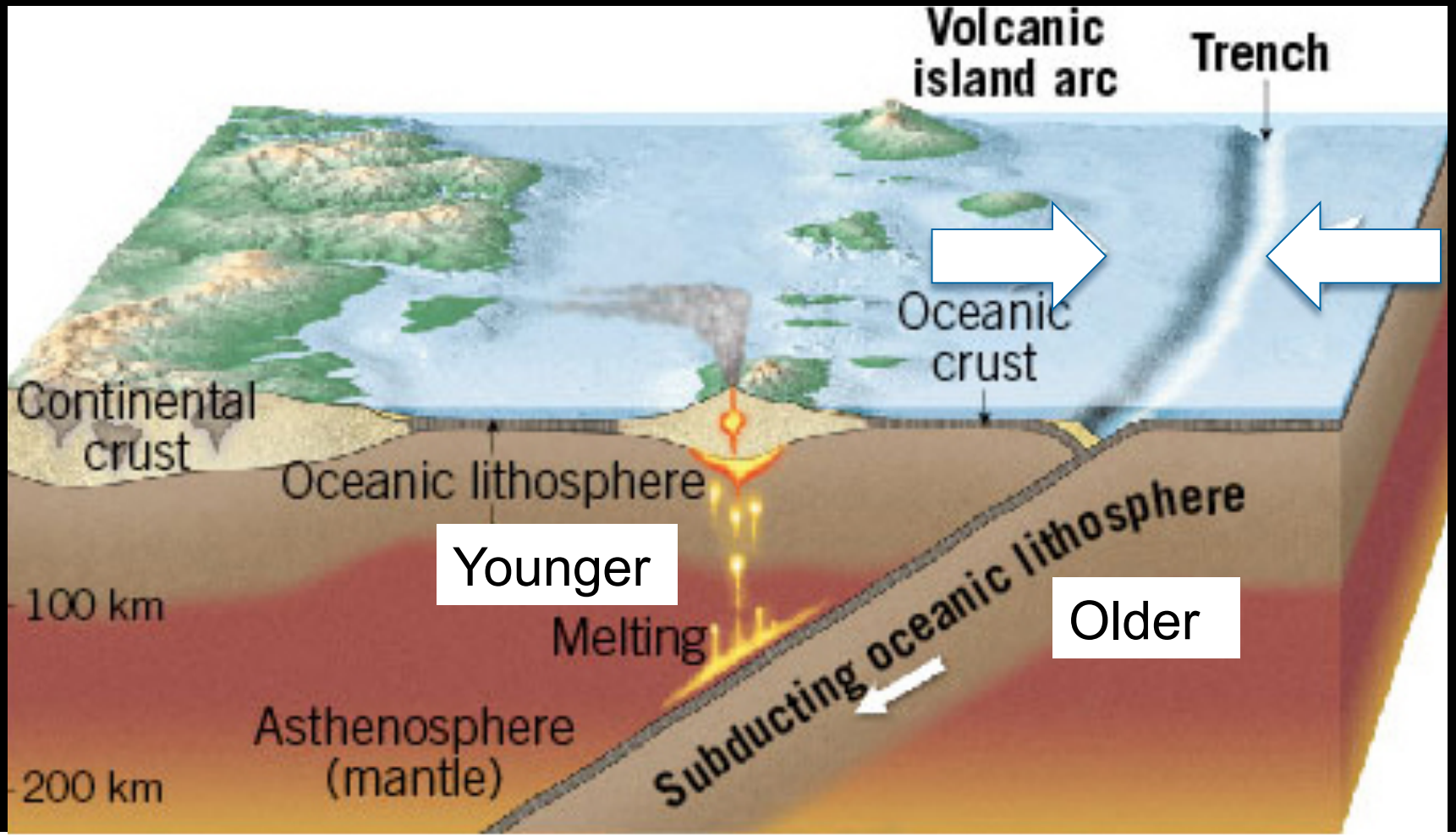


When an oceanic plate descends into the asthenosphere, water driven from the subducting slab lowers the melting temperature of mantle rock sufficiently to generate magma. The Cascade Range is a continental volcanic arc formed by the subduction of the Juan de Fuca plate under the North American plate.

Convergent Boundaries: Oceanic - Oceanic

Oceanic (thin, more dense) – Oceanic (thin, more dense) ????

Younger Oceanic (slightly less dense) – Older Oceanic (slightly more dense)



Convergent Boundaries: Continent - Continent

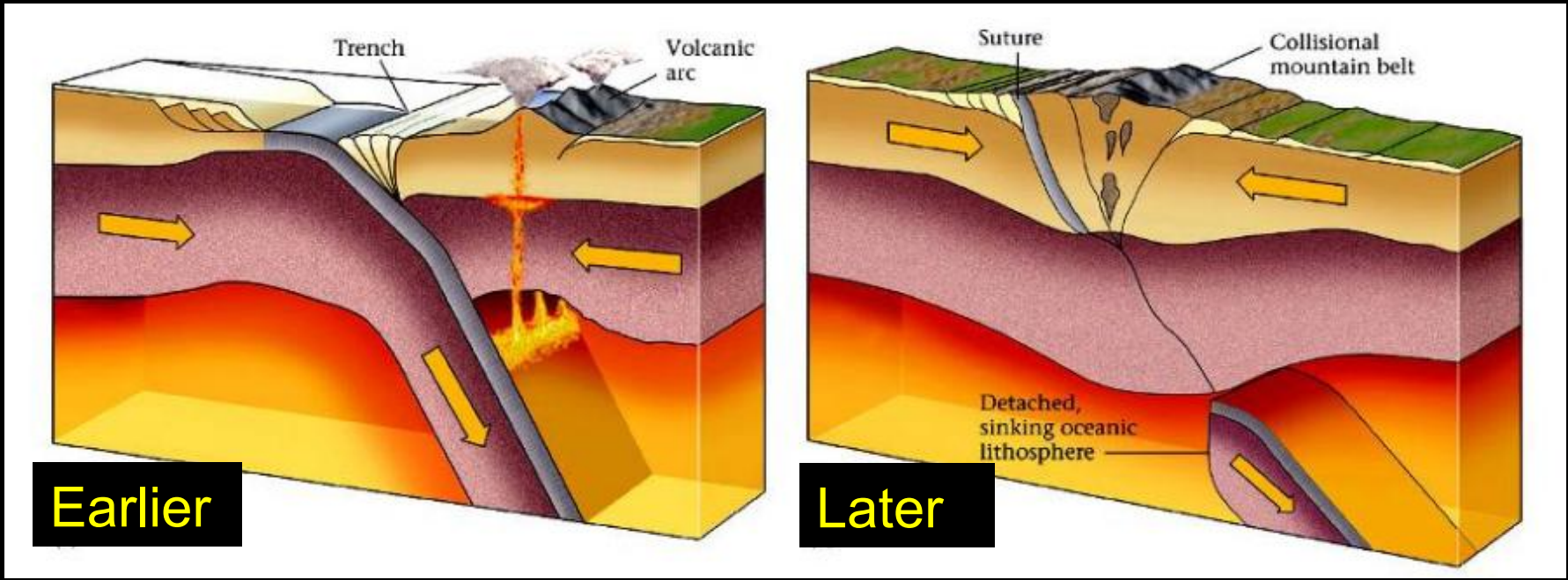
????

Continental crust too thick and light to be subducted.

Collision creates mountain belts

Himalayas today;
Appalachians 300 million years ago.

Once all oceanic crust is subducted, continents collide.



Transform Boundaries: Continent - Continent

also: Oceanic - Oceanic

Lateral motion, no rifting or subduction

Plate motions nearly parallel (adjusting for other motions)

Example: San Andreas Fault

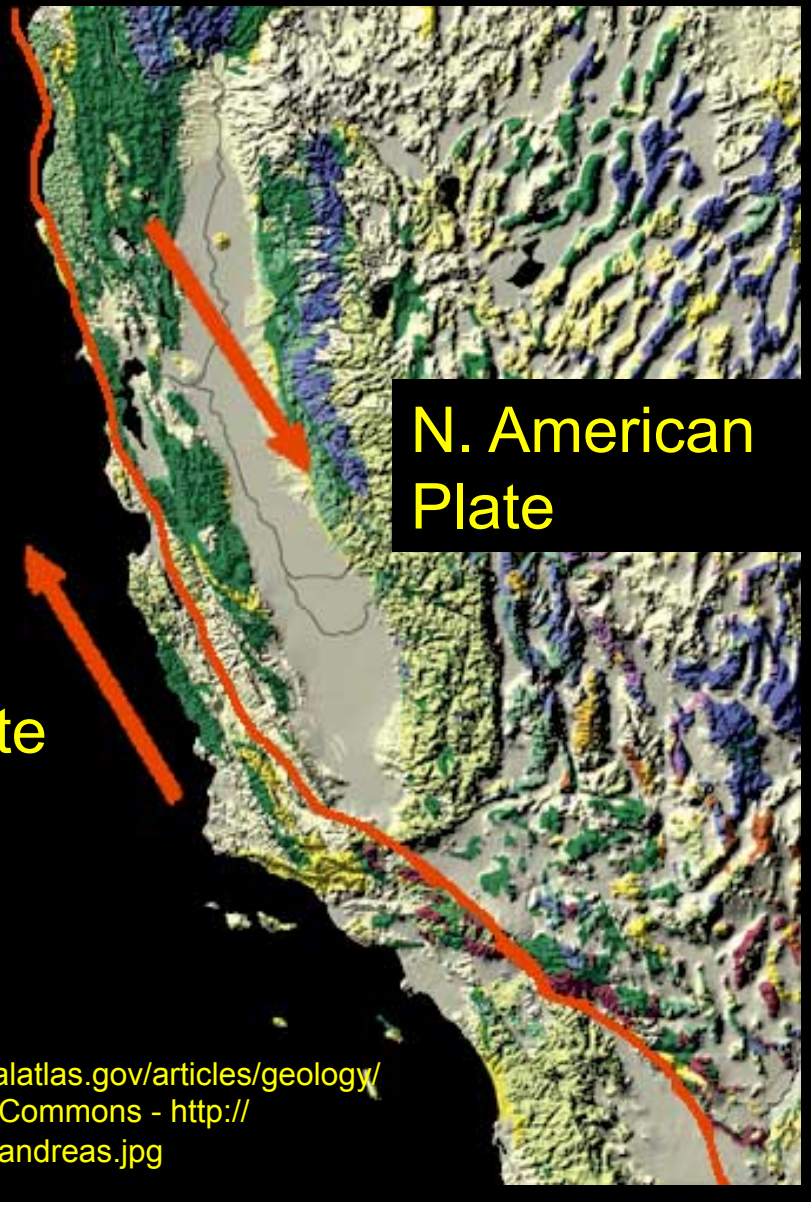


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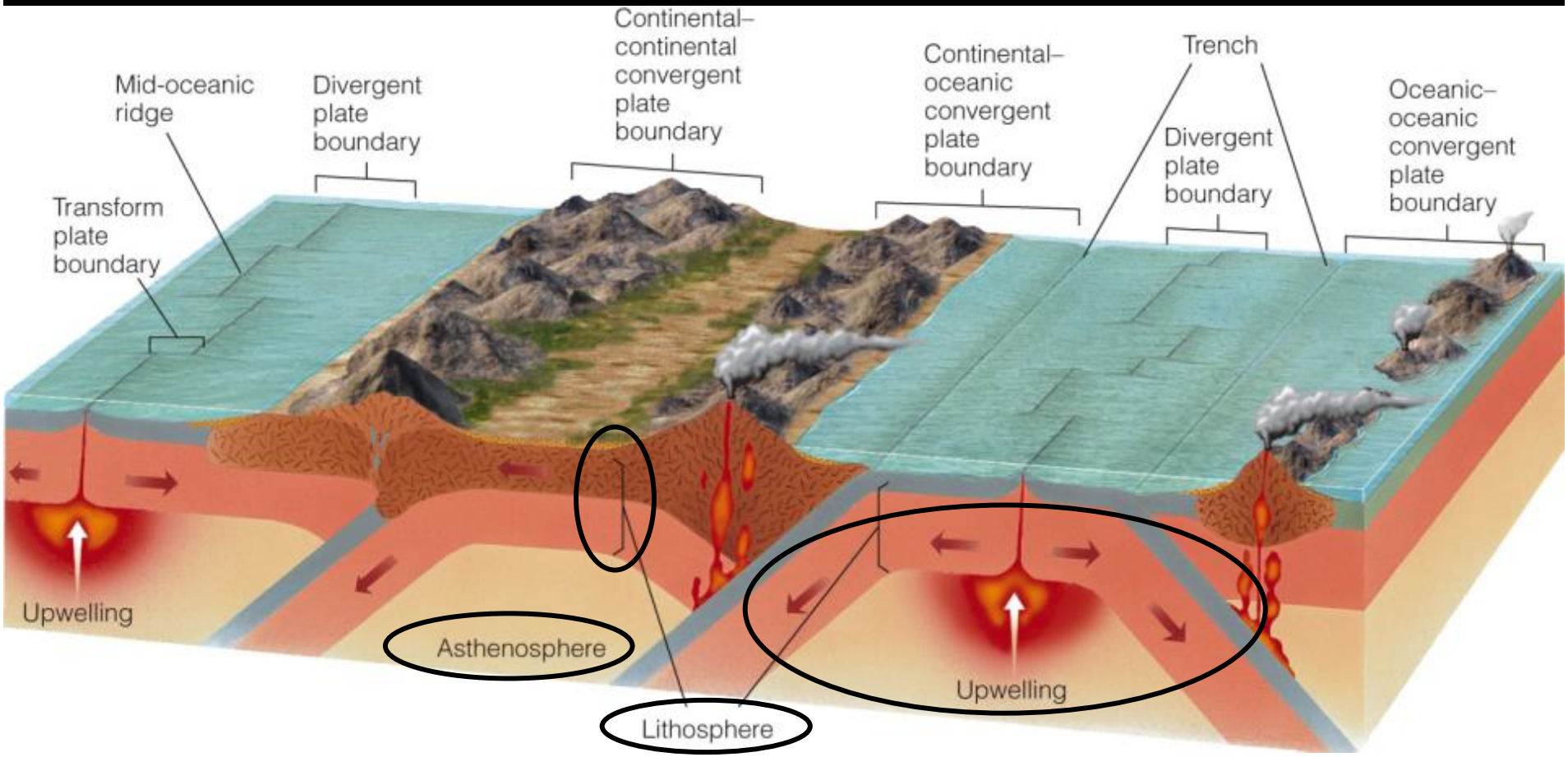
Plate Tectonics: Summary

Lithosphere	lithospheric plates
Asthenosphere	partly melted; allows motion
Convection	driving force

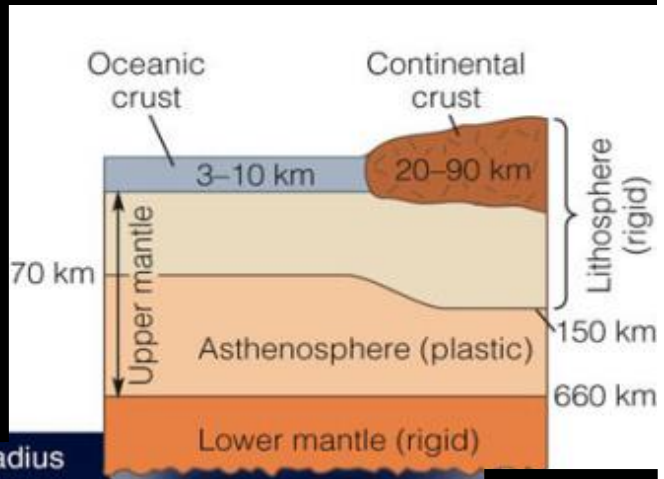


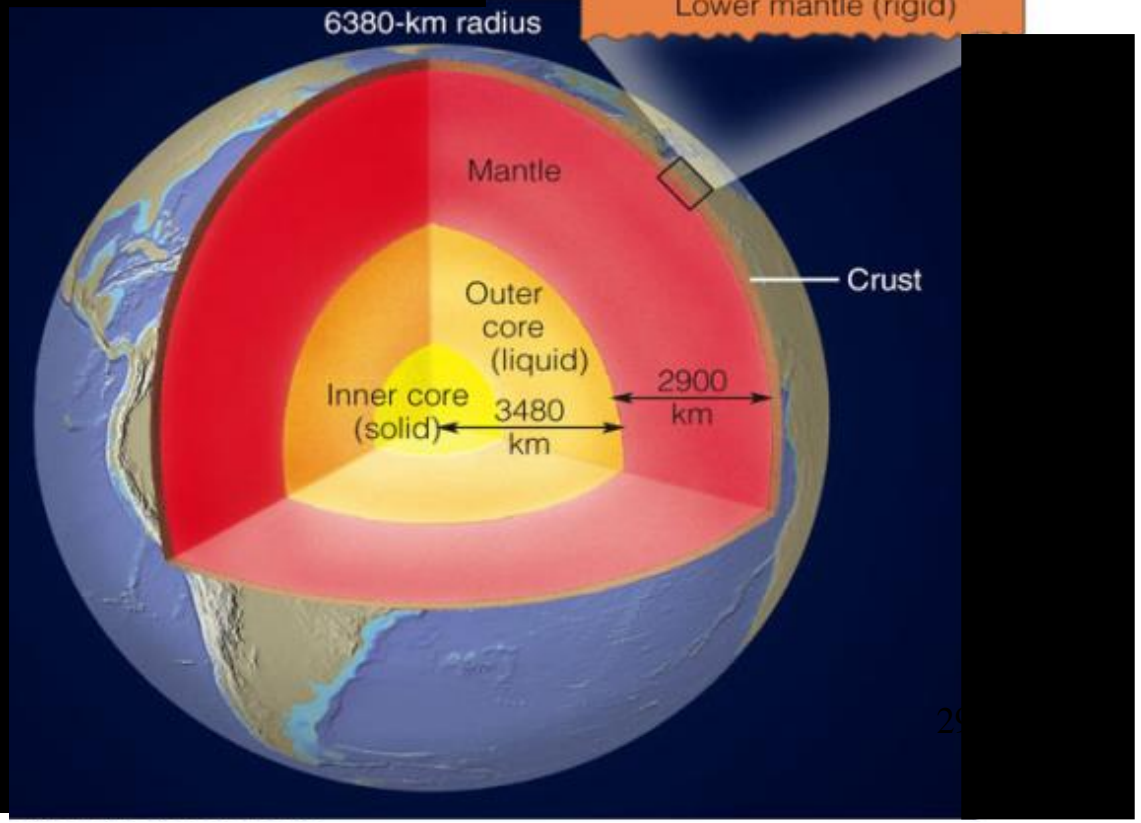
The Big Picture

Plate Motion
Drives Rock Cycle

Asthenosphere
Allows Plate Motions

Convection in Mantle
Drives Plate Motions





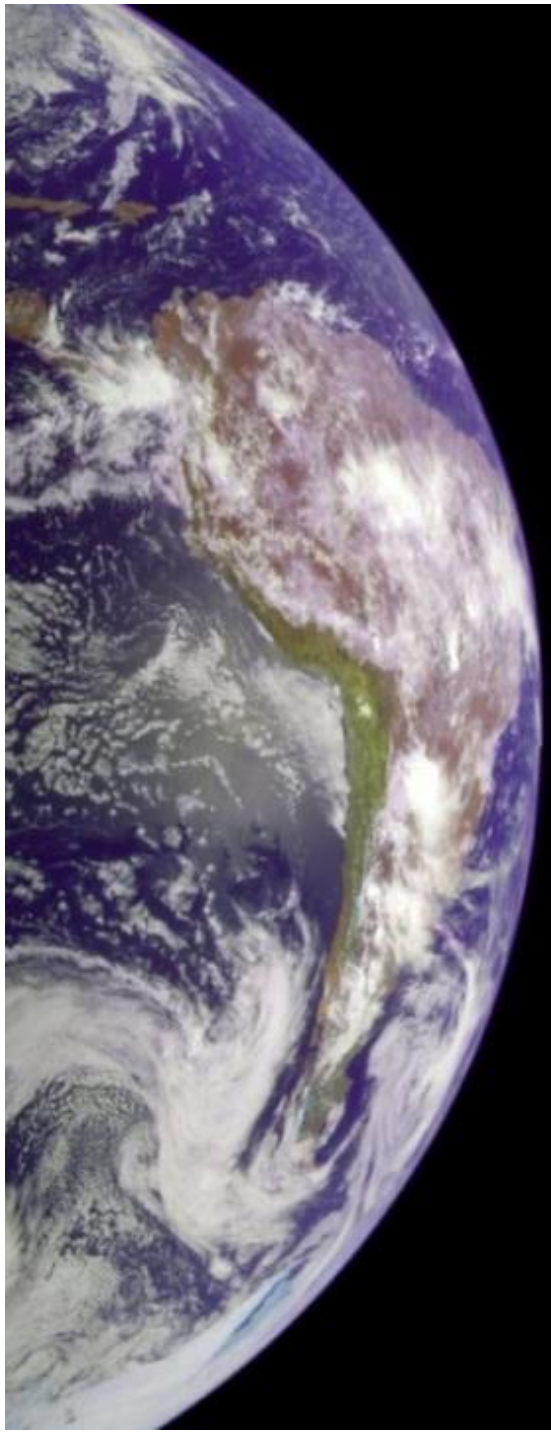


Plate Tectonics

Important Points This Lecture

1) Continental Drift vs. Plate Tectonics

2) Crust, Mantle, Lithosphere, Asthenosphere

3) Divergent Plate Margins

4) Convergent Plate Margins

5) Transform (lateral motion) Plate Margins

6) Big Picture: convection in mantle drives Plate Tectonics; Asthenosphere allows plate motions; Plate motion drives Rock Cycle