Plate Tectonics

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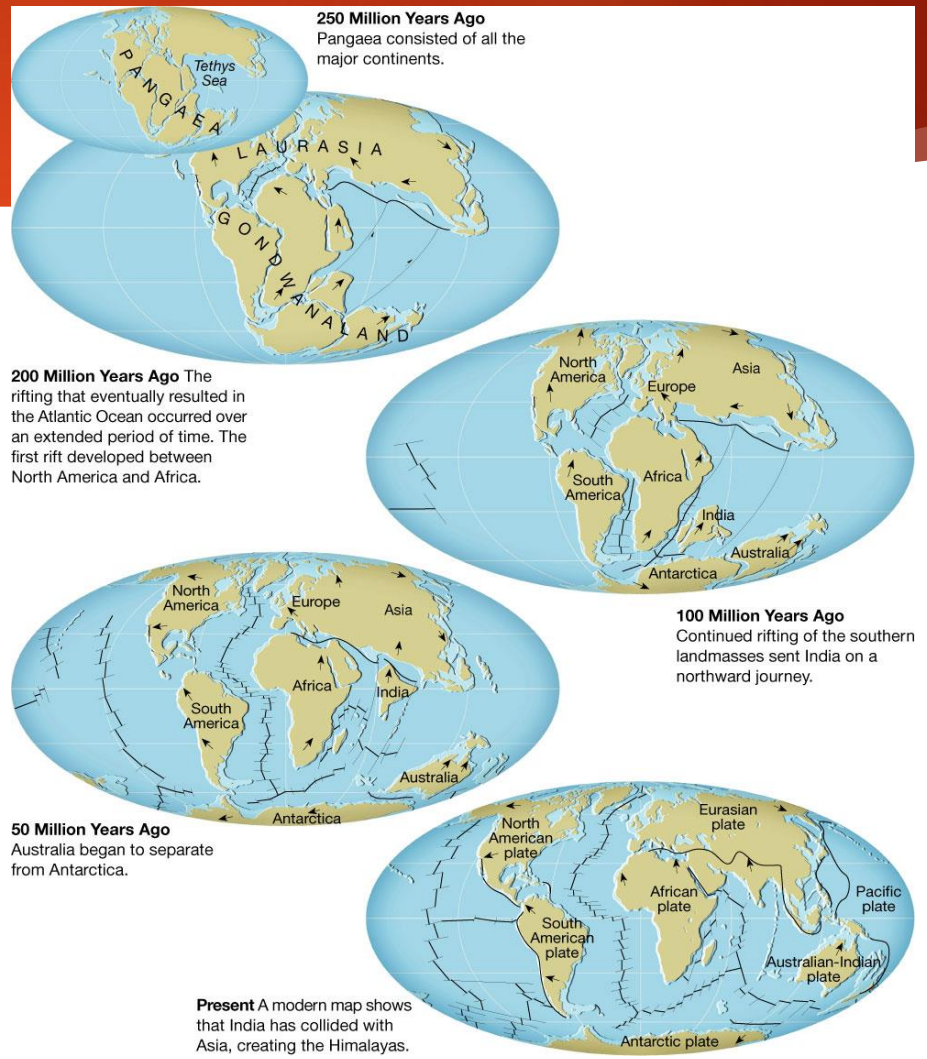
EARTH SCIENCE

Continental Drift

- Wegener's **Continental Drift** hypothesis stated that the continents had once been joined to form a single supercontinent
  - **Pangaea** is the name of the proposed supercontinent

Breakup of Pangaea



250 Million Years Ago
Pangaea consisted of all the major continents.

200 Million Years Ago The rifting that eventually resulted in the Atlantic Ocean occurred over an extended period of time. The first rift developed between North America and Africa.

100 Million Years Ago
Continued rifting of the southern landmasses sent India on a northward journey.

50 Million Years Ago
Australia began to separate from Antarctica.

Present A modern map shows that India has collided with Asia, creating the Himalayas.

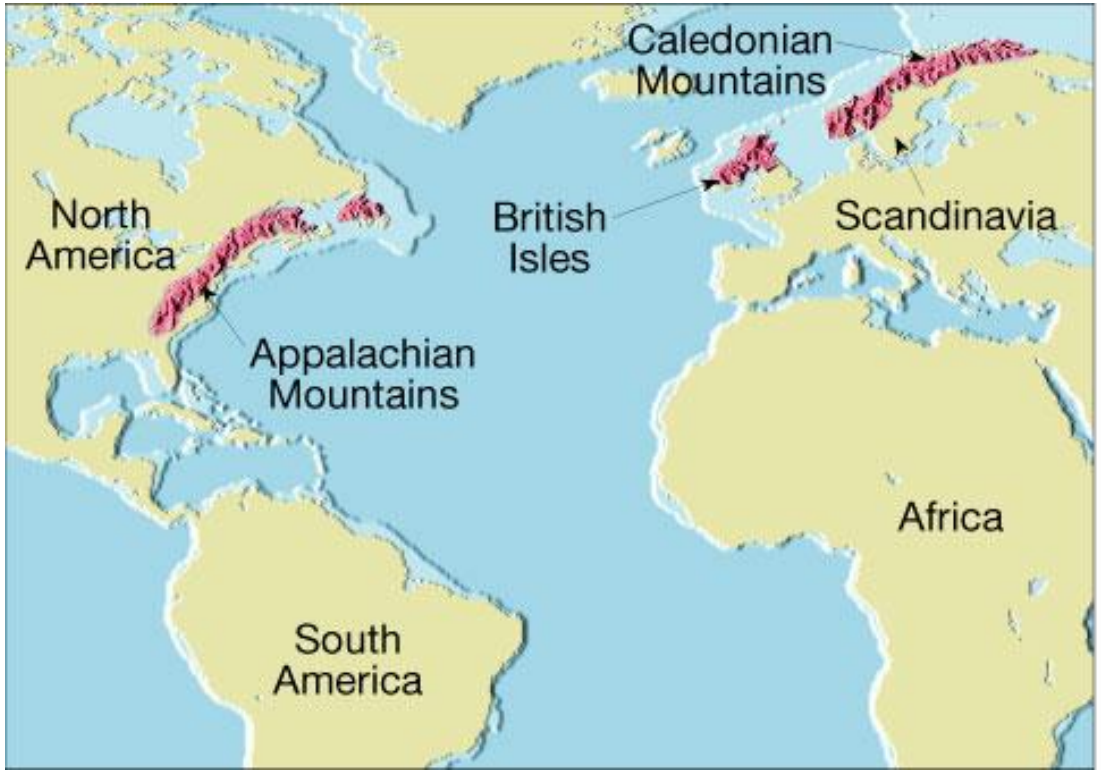
Evidence of Continental Drift

- The Continental Puzzle
- Matching Fossils
  - Fossil evidence for continental drift includes several fossil organisms found on different landmasses

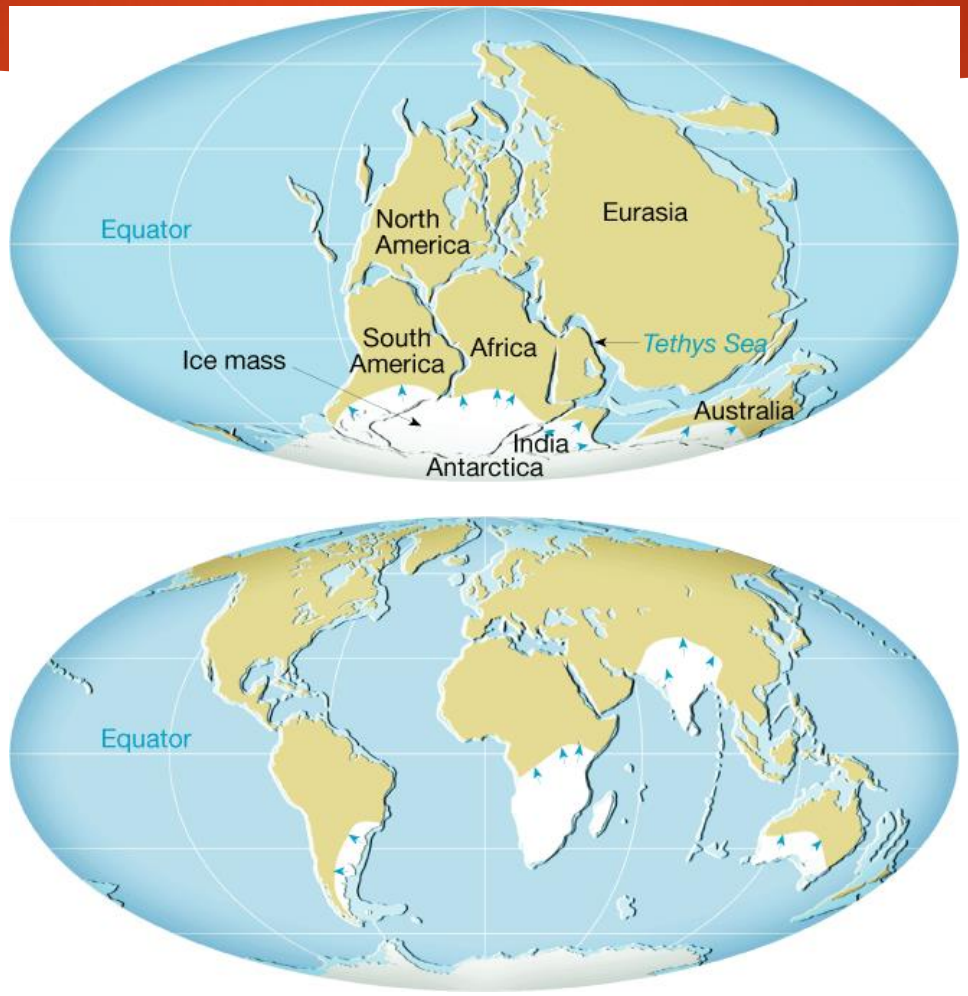
More Evidence

- Rock types and Structures
  - Rock evidence for continental drift exists in the form of several mountain belts that end on one coastline, only to reappear on a landmass across the ocean.
- Ancient Climates
  - Glaciers, for example.

Matching Mountain Ranges



Glacier Evidence



Rejecting the Hypothesis

- Wegener could not provide an explanation of exactly what made the continents move. New technologies lead to findings which then lead to a new theory called **Plate Tectonics**

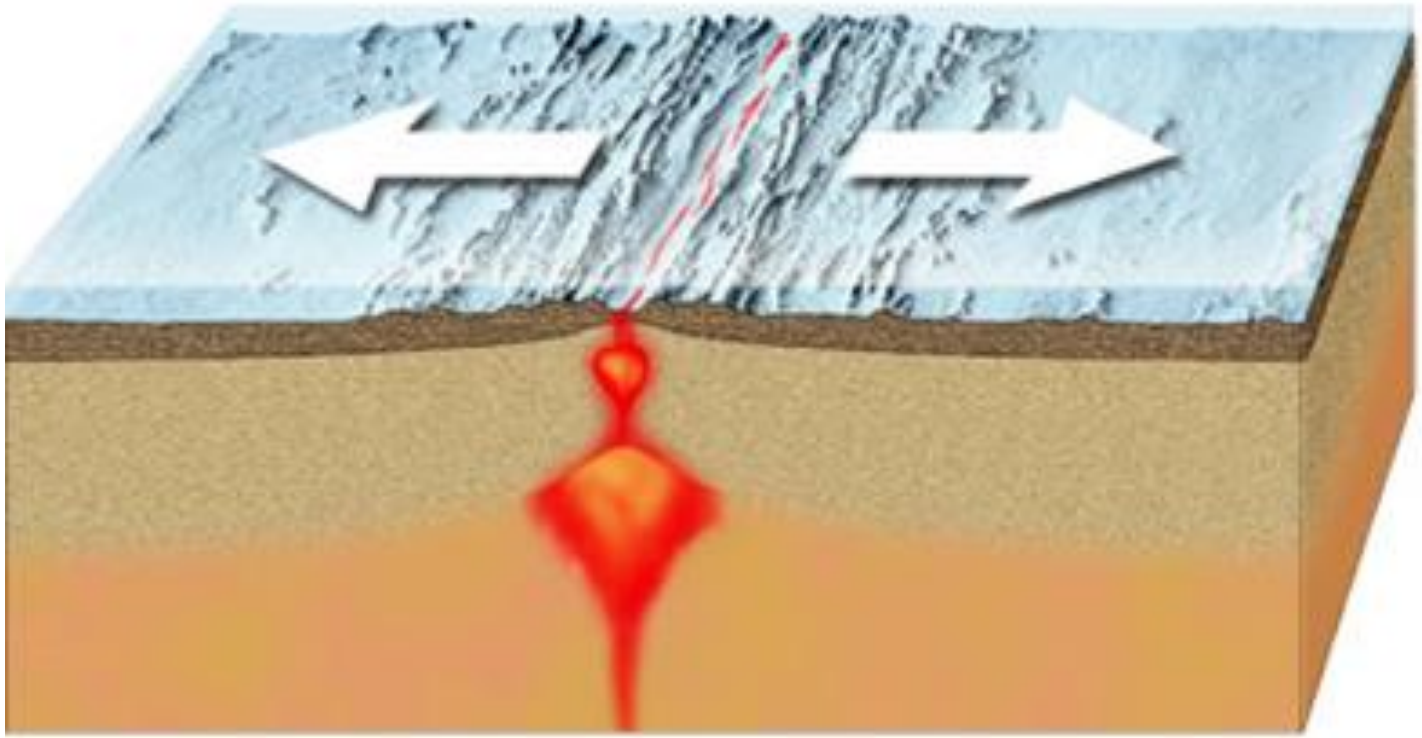
Plate Tectonics

- According to the **plate tectonics** theory, the uppermost mantle, along with the overlying crust, behaves as a strong, rigid layer. This layer is known as the lithosphere.
  - A **Plate** is one of numerous rigid sections of the lithosphere that move as a unit over the material of the asthenosphere.

Types of Plate Boundaries

- **Divergent boundaries** (also called spreading centers) are the place where two plates move apart.

Visualize Divergent Boundaries

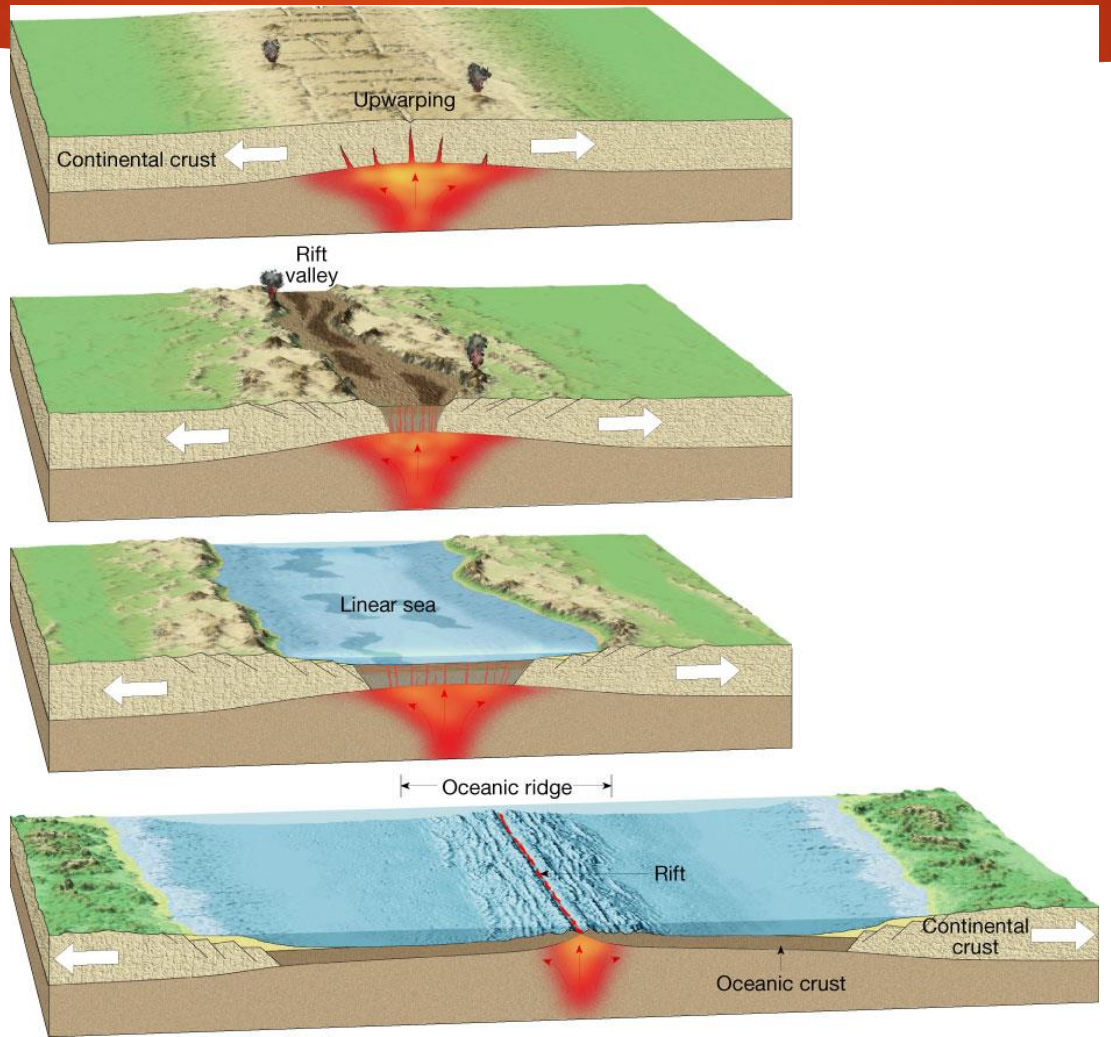


Divergent boundary

Divergent Boundaries

- Oceanic Ridges and Seafloor Spreading
  - **Oceanic ridges** are continuous elevated zones on the floor of all major ocean basins. The rifts at the crest of ridges represent divergent plate boundaries.
  - **Rift valleys** are deep faulted structures found along the axes of divergent plate boundaries. They can develop on the seafloor or on land.
  - **Seafloor spreading** produces new oceanic lithosphere.

Spreading Center (Divergent Boundary)



Continental Rifts

- When spreading centers develop within a continent, the landmass may split into two or more smaller segments, forming a rift.

East African Rift Valley

Second type of Boundary

- **Convergent boundaries** form where two plates move together.

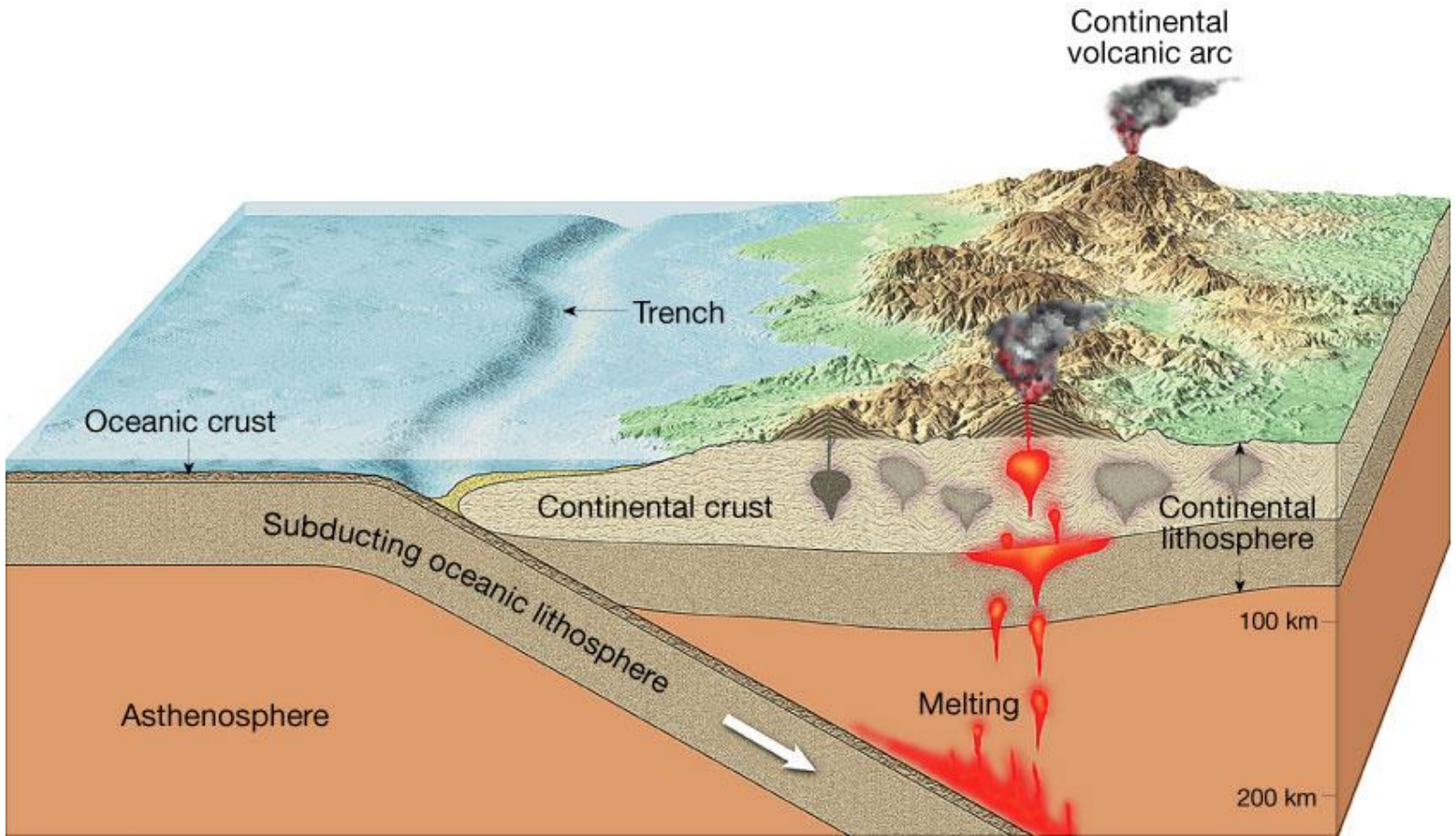
Actions at Plate Boundaries

- Convergent Boundaries
  - A **subduction zone** occurs when one plate is forced down into the mantle beneath a second plate.

Three options of collision

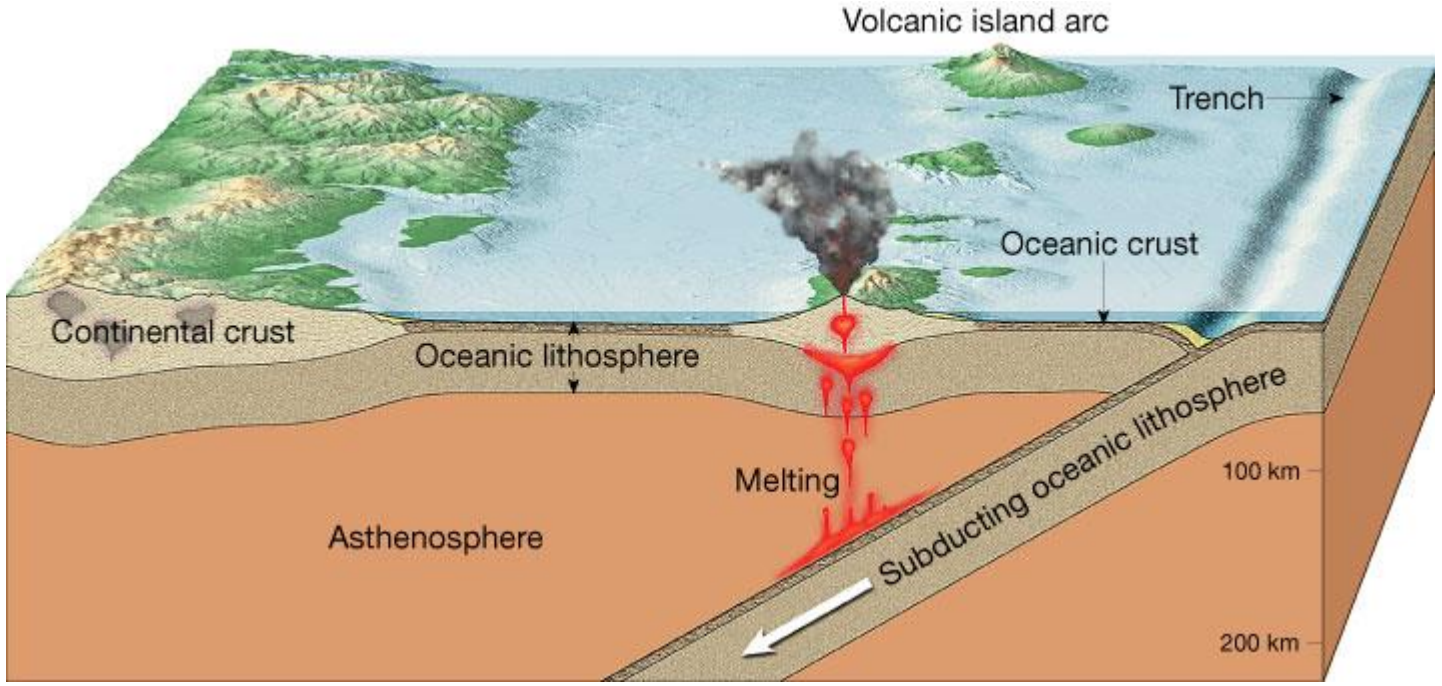
- Oceanic- Continental
  - Denser oceanic slab sinks into the asthenosphere
  - Pockets of magma develop and rise
  - **Continental volcanic arcs** form in part by volcanic activity caused by the subduction of oceanic lithosphere beneath a continent.
  - Examples include the Andes, Cascades, and the Sierra Nevadas.

Oceanic-Continental Convergent Boundary



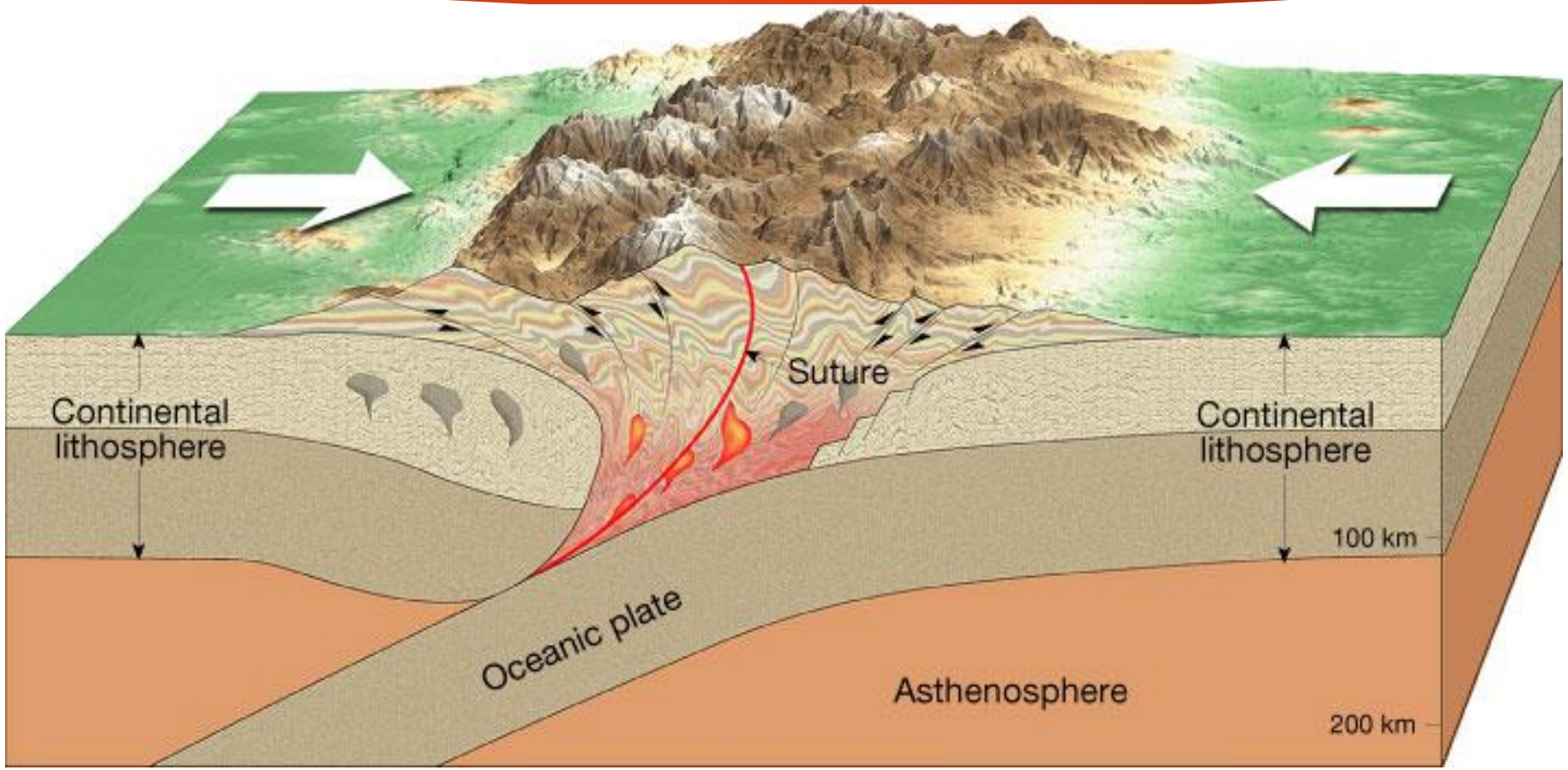
- Convergent Boundaries
  - Oceanic- Oceanic
    - Two ocean slabs converge and one descends beneath the other
    - This kind of boundary often forms volcanos on the ocean floor.
    - **Volcanic island arcs** form as volcanoes emerge from the sea.
    - Examples include the Aleutian, Mariana, and Tonga islands

Oceanic-Oceanic Convergent Boundary

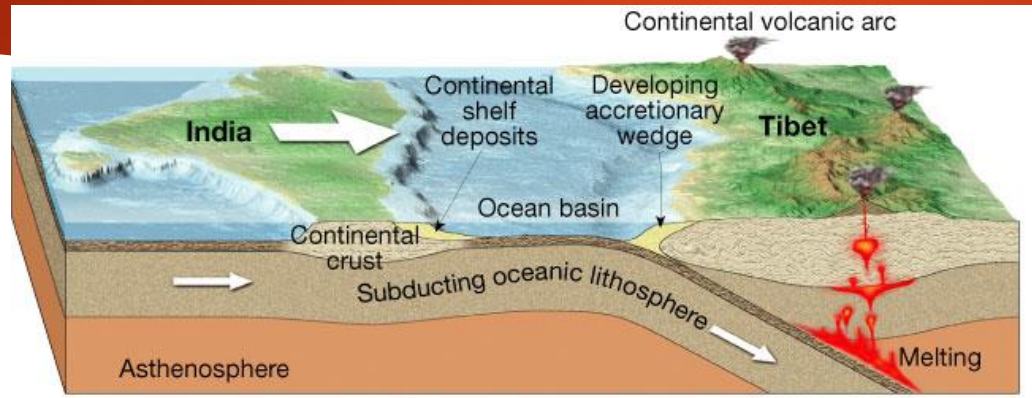


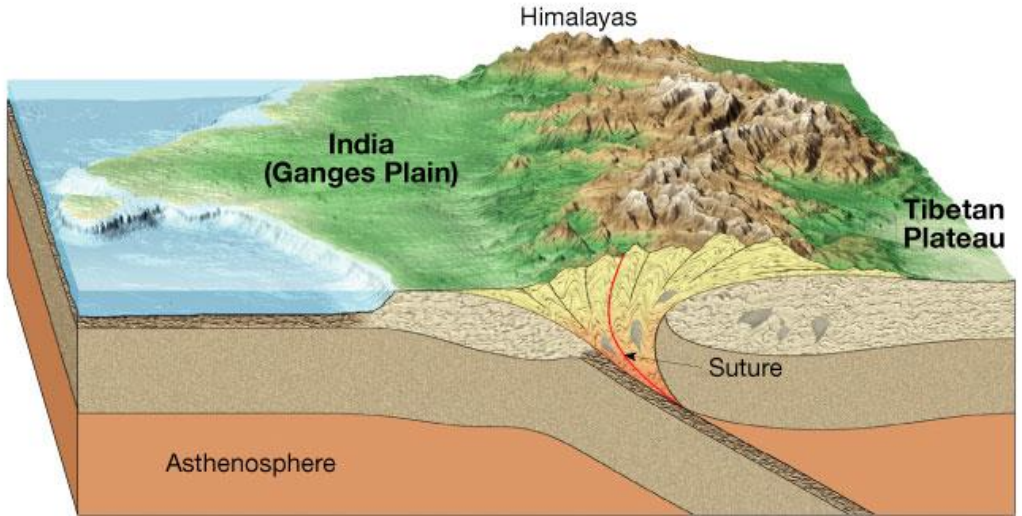
- Convergent Boundaries
  - Continental-Continental
    - When subducting plates contain continental material, two continents collide.
    - This kind of boundary can produce new mountain ranges, such as the Himalayas.

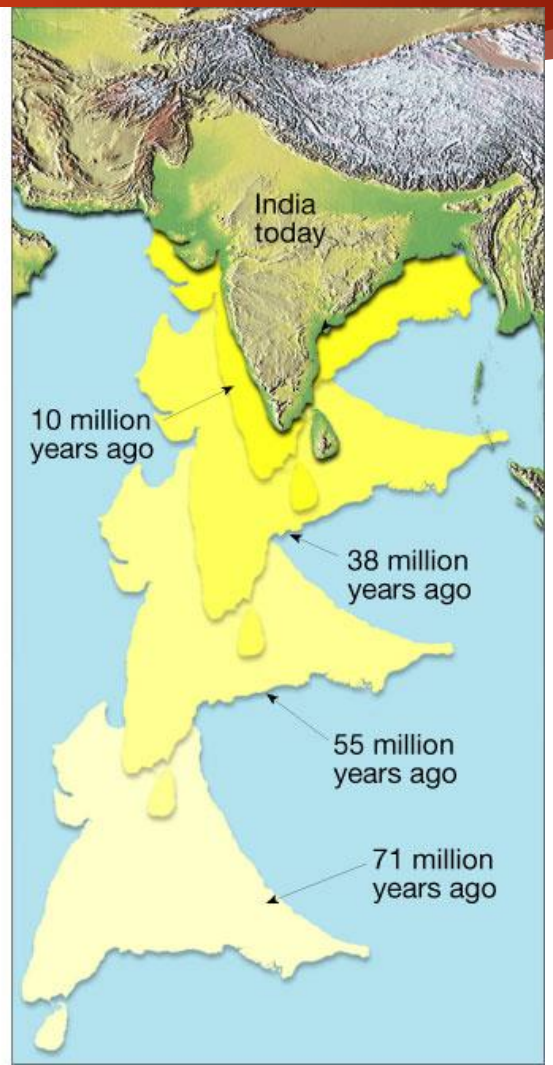
Continental-Continental Convergent Boundary



Collision of India and Asia







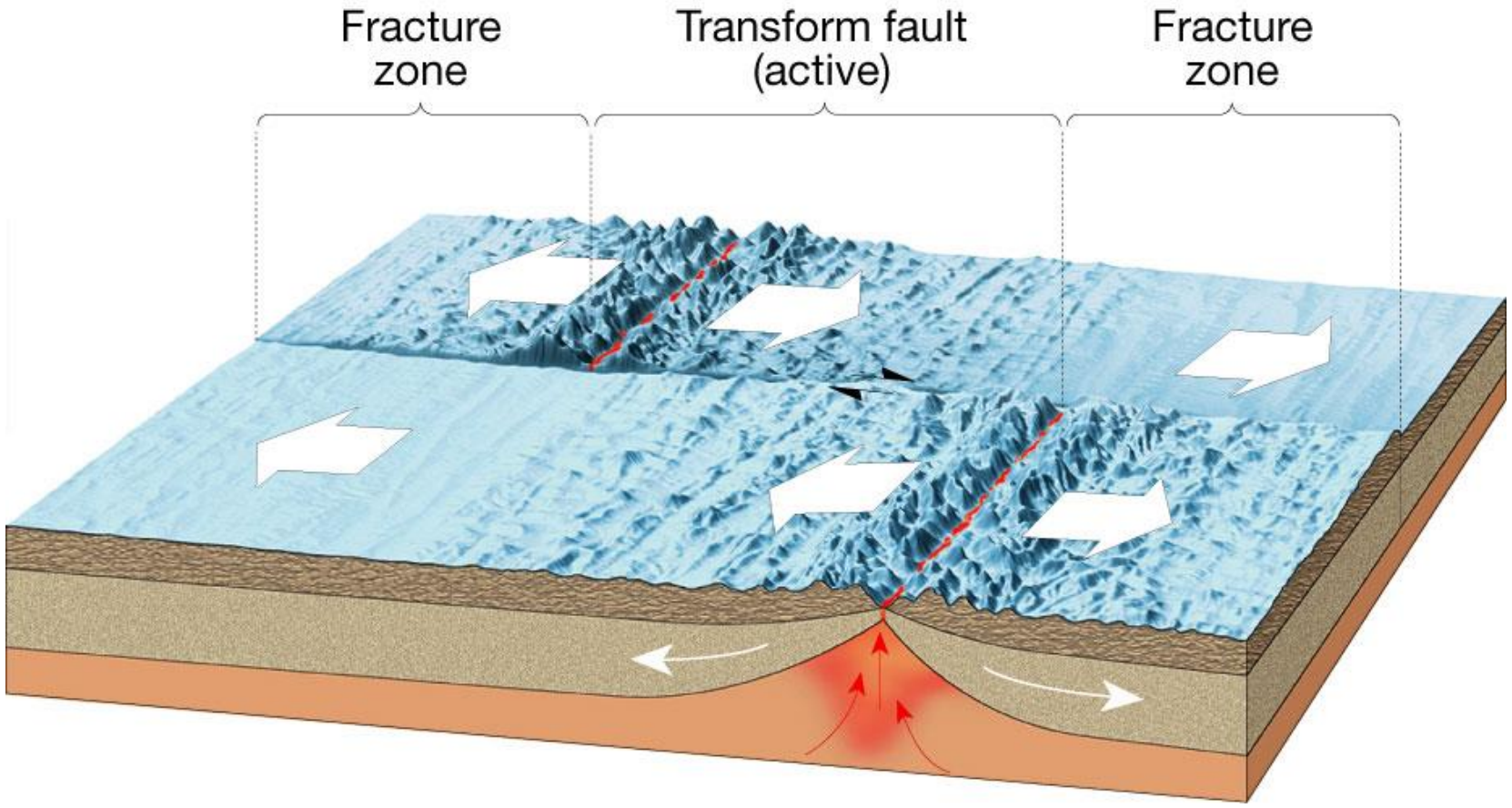
Third Type of Boundary

- **Transform fault boundaries** are margins where two plates grind past each other without the production or destruction of the lithosphere.

Third Type of Boundary

- Transform Fault Boundaries
  - At a transform fault boundary, plates grind past each other without destroying the lithosphere.
- Transform faults
  - Most join two segments of a mid-ocean ridge.
  - At the time of formation, they roughly parallel the direction of plate movement.
  - They aid the movement of oceanic crustal material.

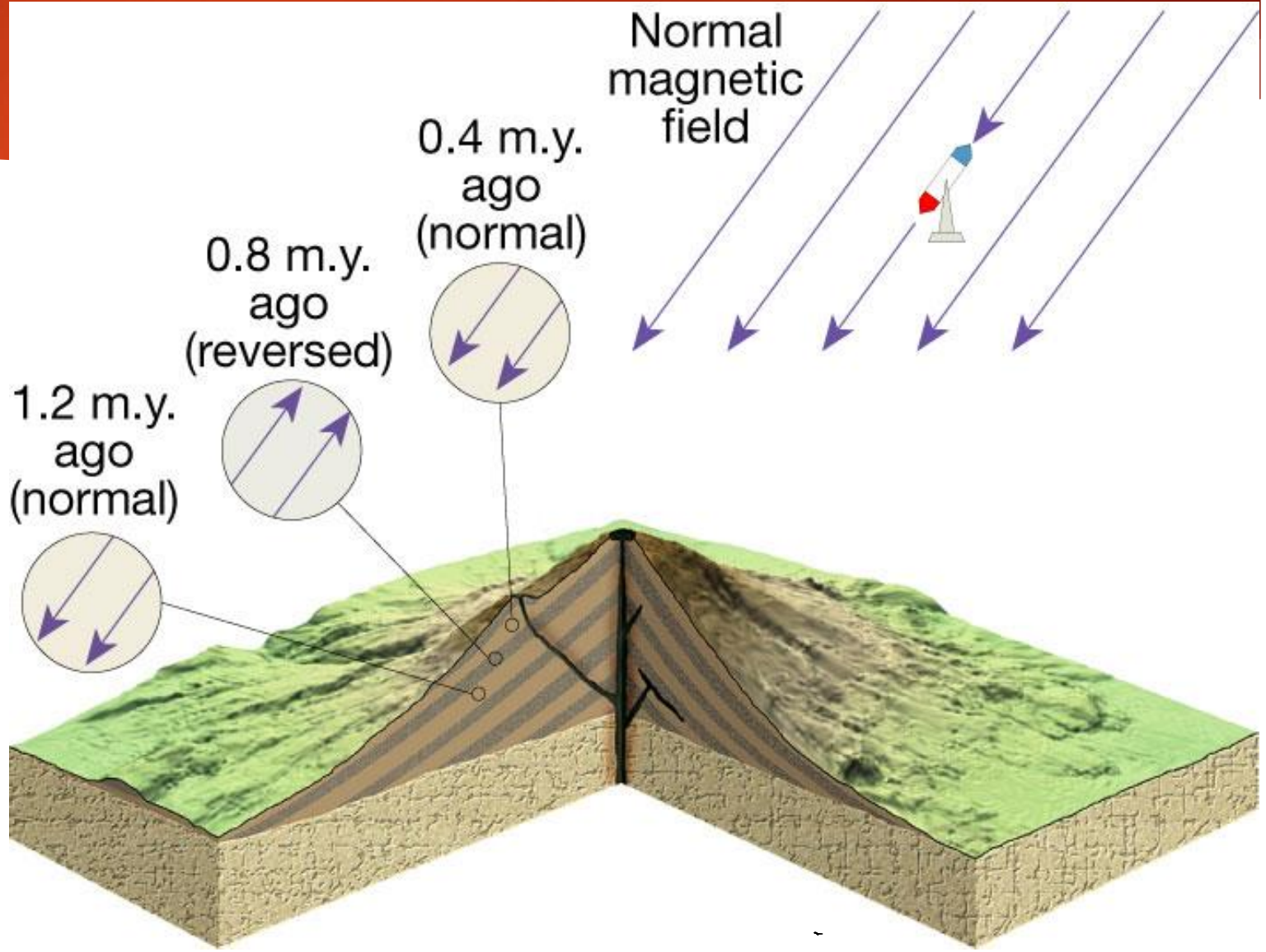
Transform Fault Boundary



Testing Plate Tectonics

- Evidence for Plate Tectonics
  - **Paleomagnetism** is the natural remnant magnetism in rock bodies; this permanent magnetization acquired by rock can be used to determine the location of the magnetic poles at the time the rock became magnetized.
    - **Normal polarity**—when rocks show the same magnetism as the present magnetism field
    - **Reverse polarity**—when rocks show the opposite magnetism as the present magnetism field

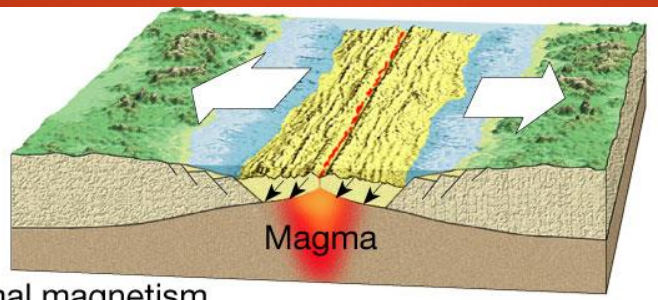
Paleomagnetism Preserved in Lava Flows



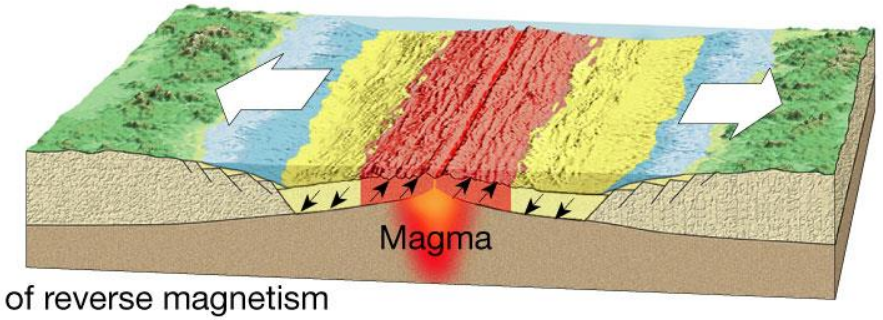
More Evidence

- The discovery of strips of alternating polarity, which lie as mirror images across the ocean ridges, is among the strongest evidence of seafloor spreading.

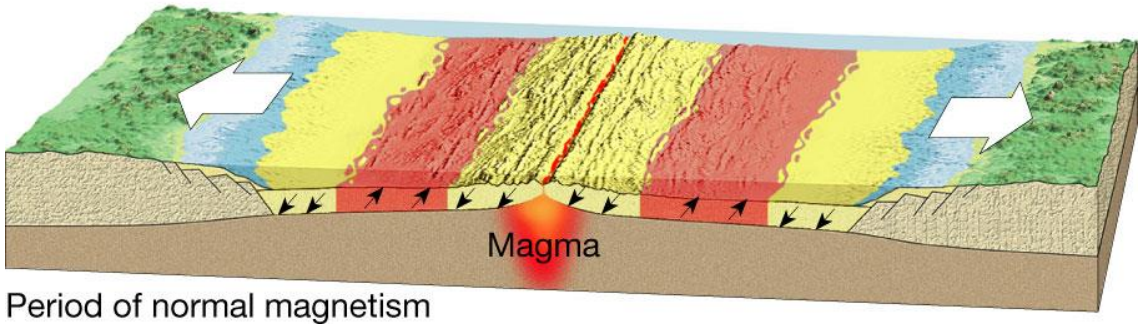
Polarity of The Ocean Crust



Period of normal magnetism



Period of reverse magnetism



Period of normal magnetism

More Evidence!

- Earthquake Patterns
  - Scientists found a close link between deep-focus earthquakes and ocean trenches.
  - The absence of deep-focus earthquakes along the oceanic ridge system was shown to be consistent with the new theory.

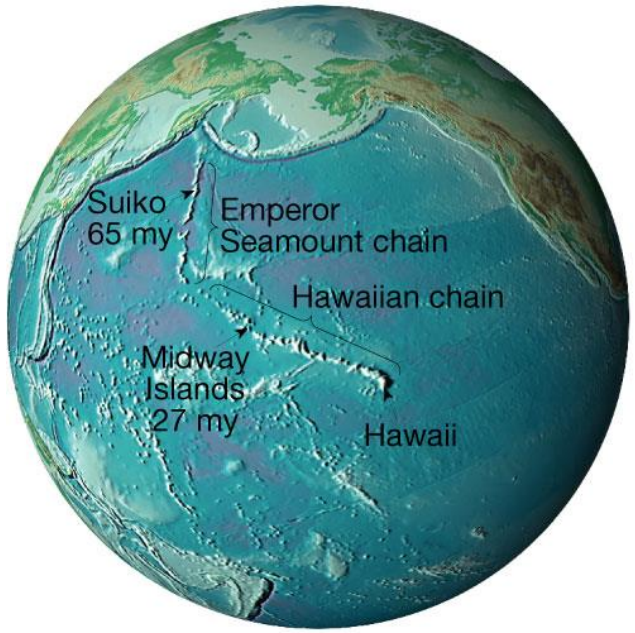
And more evidence!

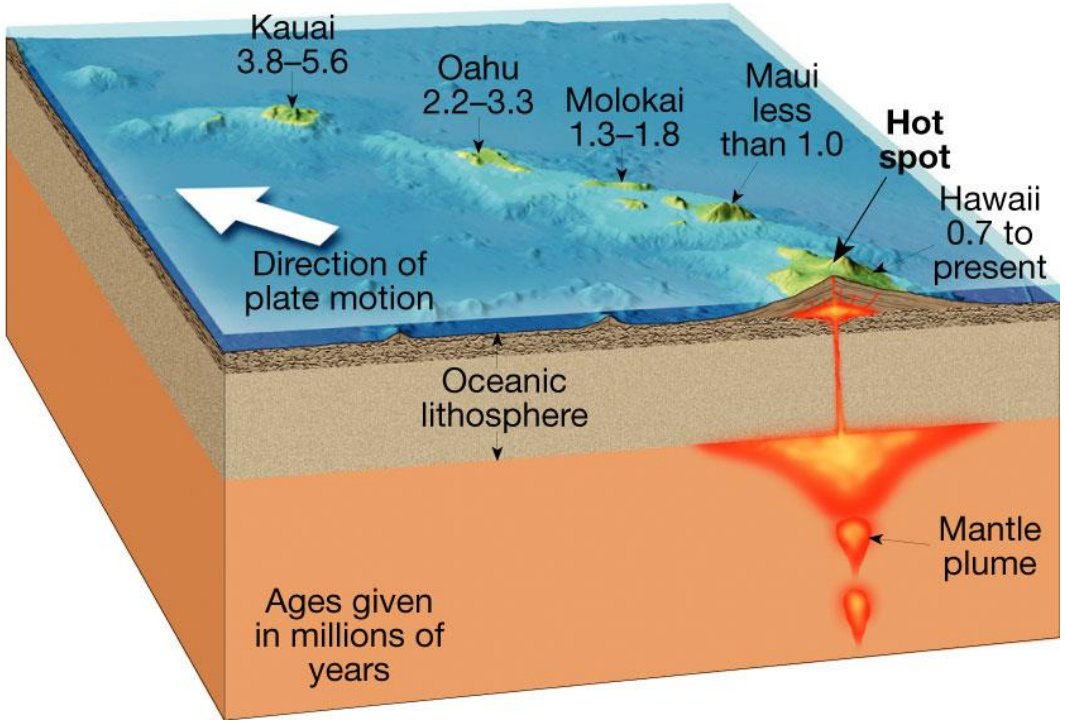
- Ocean Drilling
  - The data on the ages of seafloor sediment confirmed what the seafloor spreading hypothesis predicted.
  - The youngest oceanic crust is at the ridge crest, and the oldest oceanic crust is at the continental margins.

Even MORE evidence!

- Hot Spots
  - A hot spot is a concentration of heat in the mantle capable of producing magma, which rises to Earth's surface; The Pacific plate moves over a hot spot, producing the Hawaiian Islands.
  - Hot spot evidence supports that the plates move over the Earth's surface.

Hot Spot


Suiko
65 my
Emperor
Seamount chain
Hawaiian chain
Midway
Islands
27 my
Hawaii


Kauai
3.8–5.6
Oahu
2.2–3.3
Molokai
1.3–1.8
Maui
less
than 1.0
Hot
spot
Hawaii
0.7 to
present
Direction of
plate motion
Oceanic
lithosphere
Mantle
plume
Ages given
in millions of
years

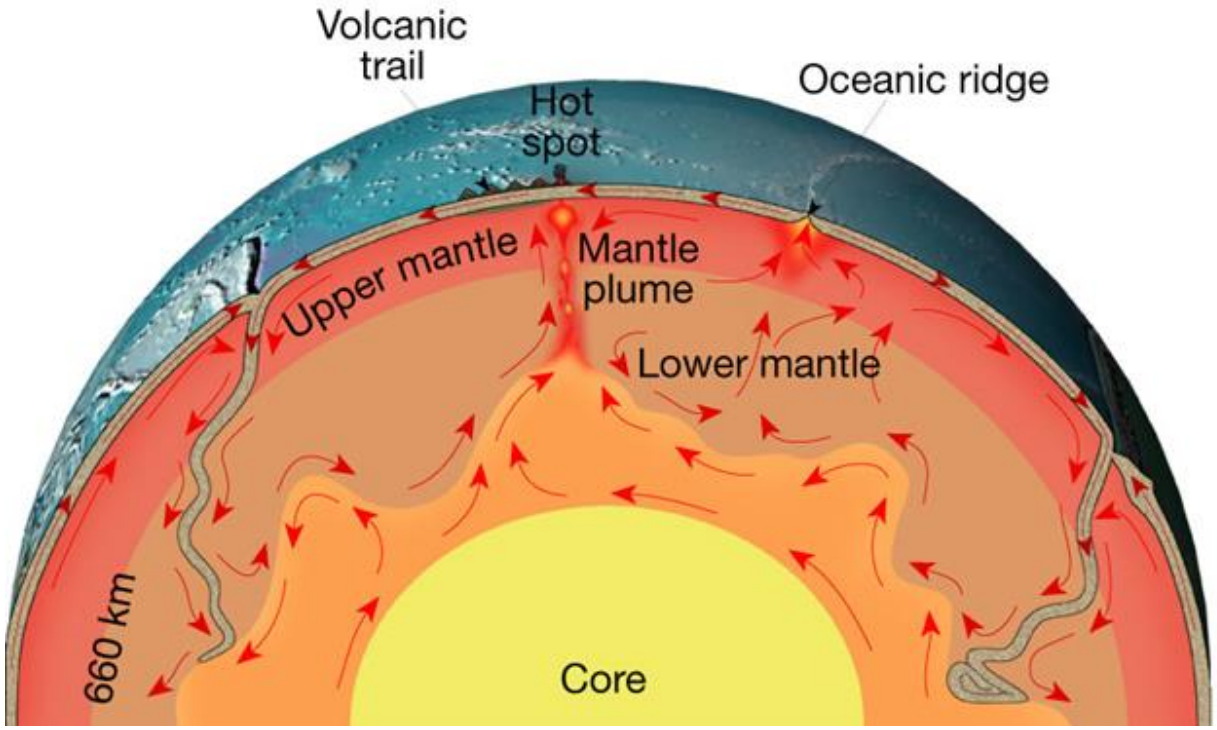
Mechanics of Plate Motion

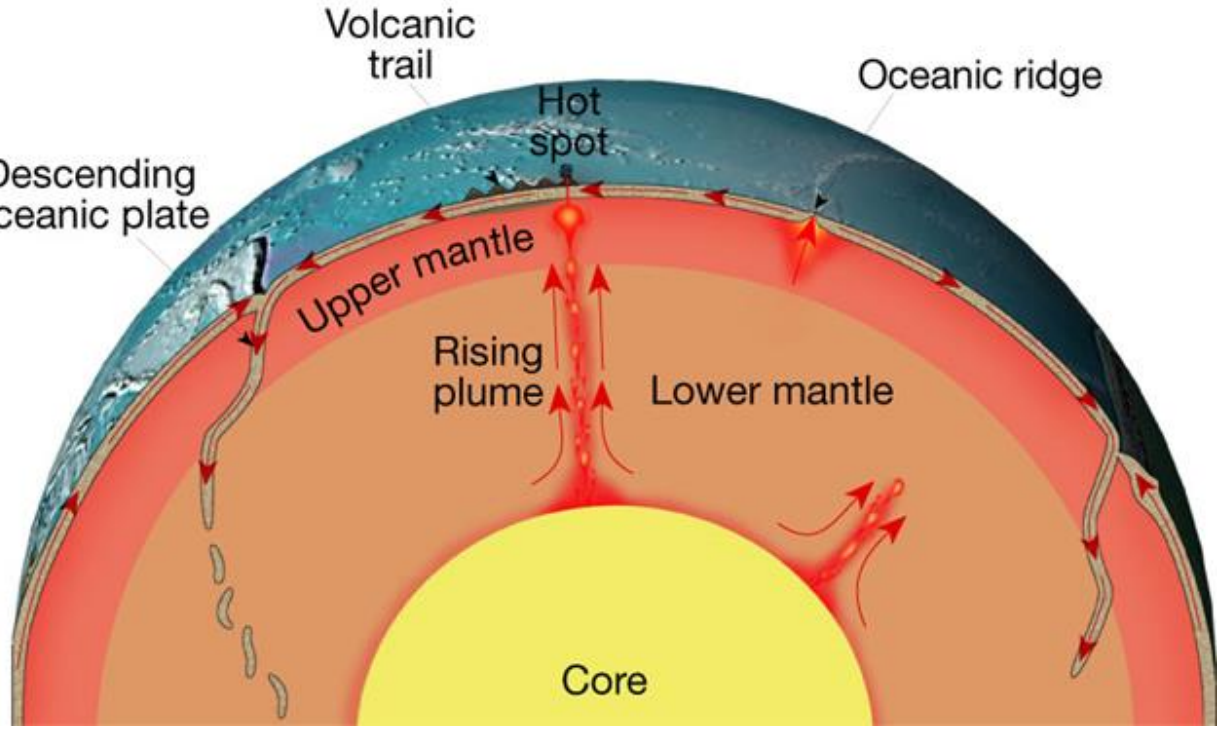
- Causes of Plate Motion
  - Scientists generally agree that convection occurring in the mantle is the basic driving force for plate movement.
    - **Convective flow** is the motion of matter resulting from changes in temperature.

- Slab-Pull and Ridge-Push
  - **Slab-pull** is a mechanism that contributes to plate motion in which cool, dense oceanic crust sinks into the mantle and "pulls" the trailing lithosphere along. It is thought to be the primary downward arm of convective flow in the mantle.
  - **Ridge-push** causes oceanic lithosphere to slide down the sides of the oceanic ridge under the pull of gravity. It may contribute to plate motion

- Mantle Convection
  - **Mantle plumes** are masses of hotter-than-normal mantle material that ascend toward the surface, where they may lead to igneous activity
  - The unequal distribution of heat within Earth causes the thermal convection in the mantle that ultimately drives plate motion.

Mantle Convection Models





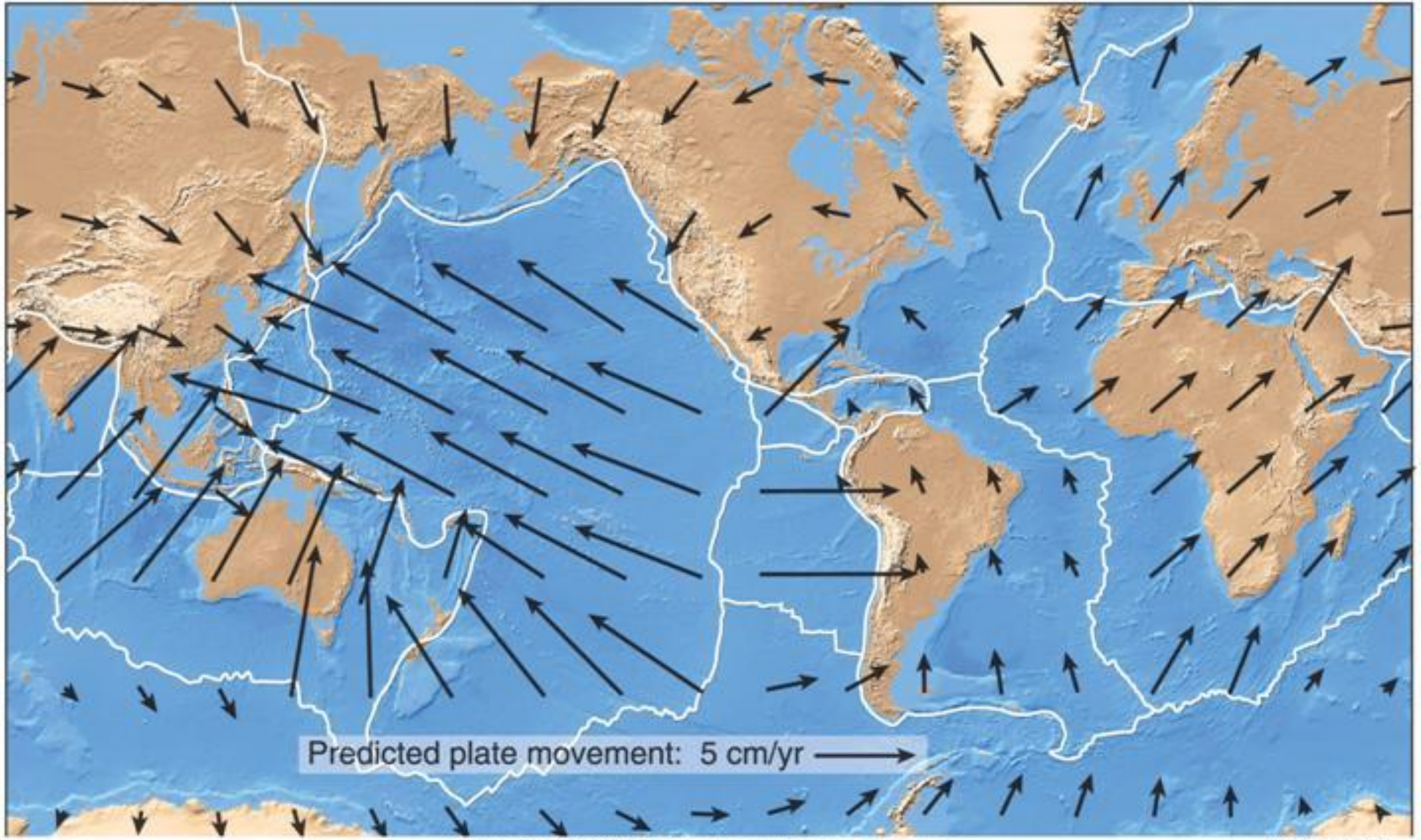
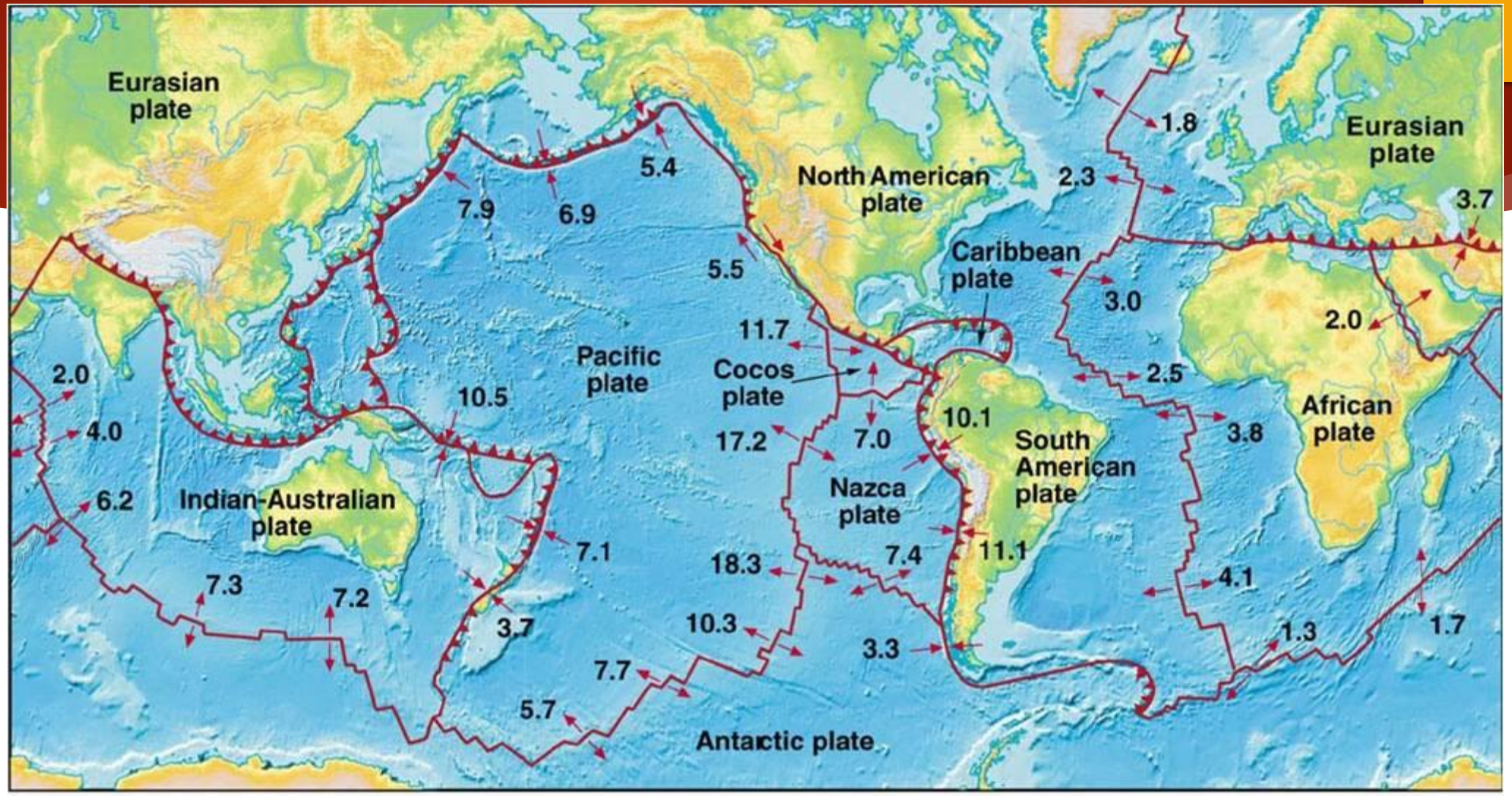


Fig 12.37


Eurasian plate
North American plate
Eurasian plate
Caribbean plate
Pacific plate
Cocos plate
African plate
South American plate
Nazca plate
Indian-Australian plate
Antarctic plate
1.8
2.3
3.7
5.4
7.9
6.9
5.5
3.0
2.0
11.7
2.5
2.0
10.5
4.0
17.2
7.0
10.1
3.8
6.2
7.1
18.3
7.4
11.1
4.1
7.3
7.2
3.7
10.3
3.3
1.3
1.7
7.7
5.7
Ridge axis
Subduction zone
Direction of movement
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