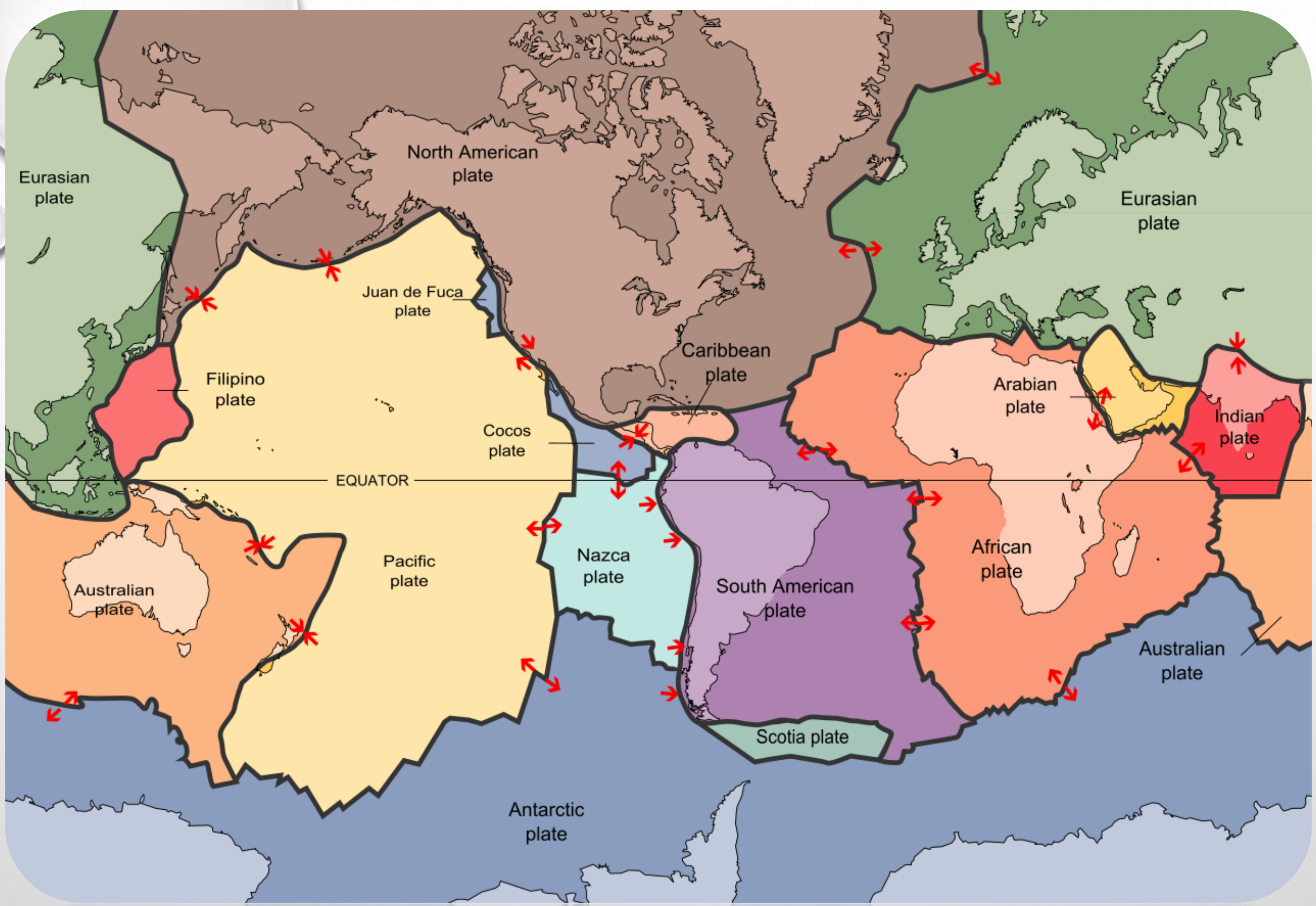


UNIT 5: PLATE TECTONICS

GEO 281: GEOLOGY FOR ENGINEERS

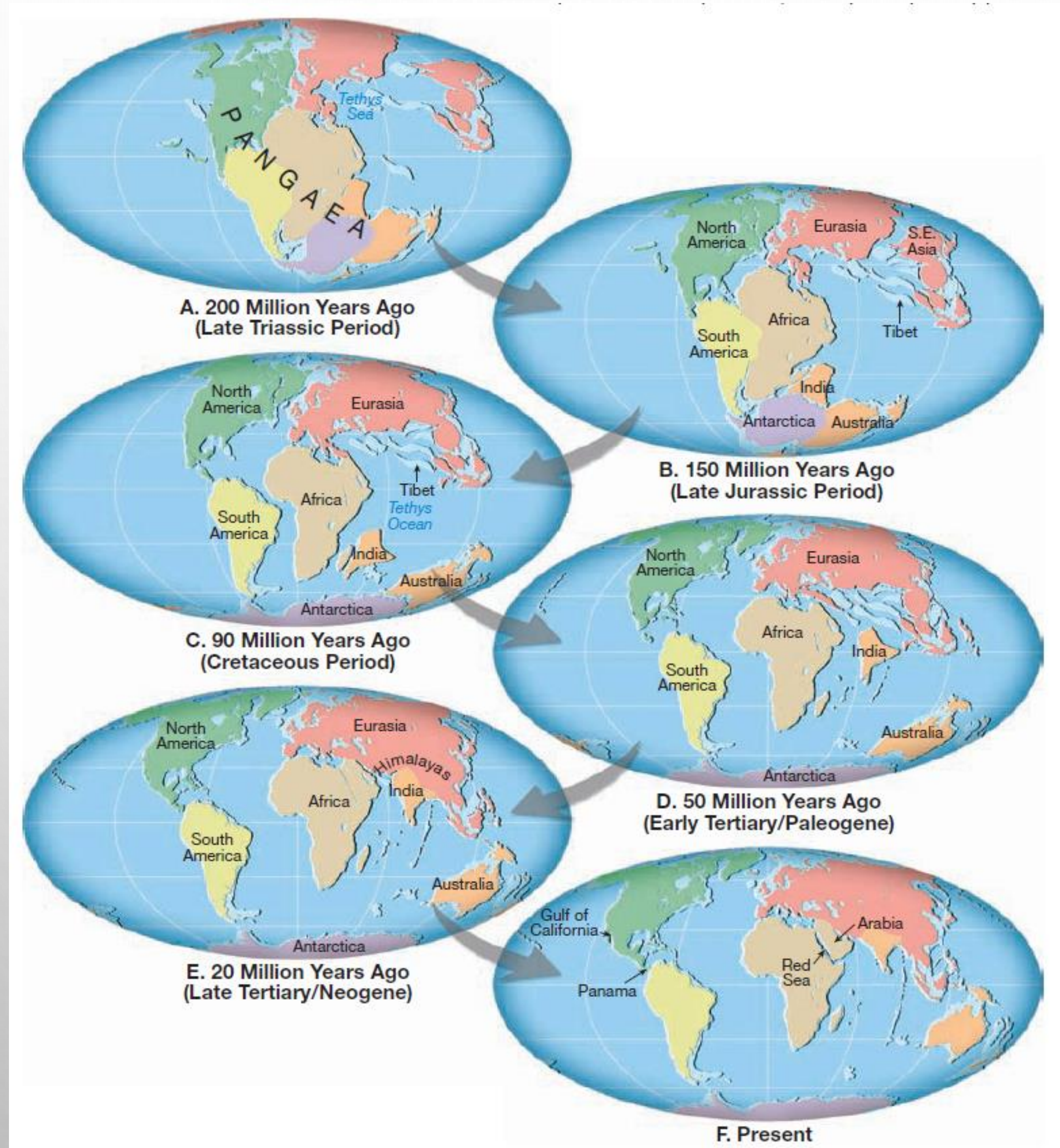
GEOLOGY AND GEOPHYSICS DEPARTMENT

KING SAUD UNIVERSITY

CONTINENTAL DRIFT

- Alfred Wegener (1880–1930), a German meteorologist and geophysicist challenged the long held assumption that the continents and ocean basins had fixed geographic positions.
- Wegners hypothesis known as the "**Continental Drift**" suggested that a **single supercontinent consisting of all Earth's landmasses once existed**.
- He named this giant landmass **Pangaea**.
- Wegener further hypothesized that about **200 million years ago**, during the **early part of the Mesozoic era**, this supercontinent began to fragment into smaller landmasses.
- These continental blocks then "drifted" to their present positions over a span of millions of years.

CONTINENTAL DRIFT



EVIDENCES OF CONTINENTAL DRIFT

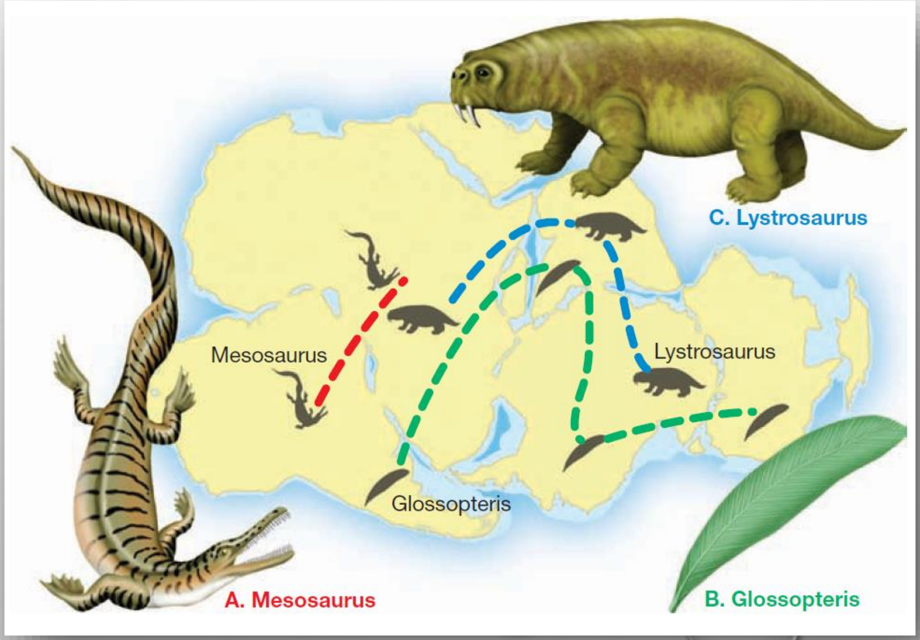
Evidence: The Continental Jigsaw Puzzle

- Like a few others before him, Wegener suspected that the continents might once have been joined when he noticed the remarkable similarity between the coastlines on opposite sides of the Atlantic Ocean.

EVIDENCES OF CONTINENTAL DRIFT

Evidence: Fossils Match across the Seas

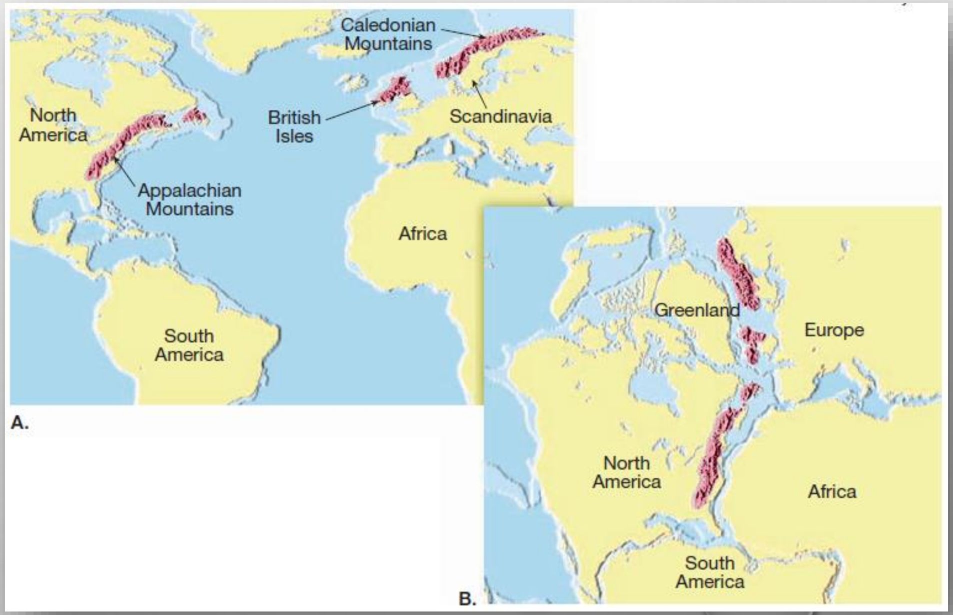
- Through a review of the literature, Wegener learned that most paleontologists (scientists who study the fossilized remains of ancient organisms) were in agreement that **some type of land connection was needed to explain the existence of similar Mesozoic age life forms on widely separated landmasses**.



EVIDENCES OF CONTINENTAL DRIFT

Evidence: Rock Types and Geologic Features

- Wegener found evidence of 2.2-billion-year-old igneous rocks in Brazil that closely resembled similarly aged rocks in Africa.
- The mountain belt that includes the Appalachians trends northeastward through the eastern United States and disappears off the coast of Newfoundland.
- Mountains of comparable age and structure are found in the British Isles, and Scandinavia. When these landmasses are reassembled, the mountain chains form a nearly continuous belt.



EVIDENCES OF CONTINENTAL DRIFT

Evidence: Ancient Climates

- Evidence **for a glacial period that dated to the late Paleozoic** had been discovered in southern Africa, South America, Australia, and India.
- This meant that about 300 million years ago, vast ice sheets covered extensive portions of the Southern Hemisphere. How could extensive ice sheets form near the Equator?
- Wegener suggested the explanation for the late Paleozoic glaciation was provided by the supercontinent of Pangaea. In this configuration the southern continents are joined together and located near the South Pole

OBJECTION TO CONTINENTAL DRIFT

- One of the **main objections to Wegener's hypothesis** stemmed from his inability to **identify a credible mechanism for continental drift**.
- *Wegener proposed that gravitational forces of the Moon and Sun that produce Earth's tides were also capable of gradually moving the continents across the globe.*
- However, the prominent physicist Harold Jeffreys correctly countered that tidal forces of the magnitude needed to displace the continents would bring Earth's rotation to a halt in a matter of a few years.
- *Wegener also incorrectly suggested that the larger and sturdier continents broke through thinner oceanic crust, much like ice breakers cut through ice*.
- However, no evidence existed to suggest that the ocean floor was weak enough to permit passage of the continents without the continents being appreciably deformed in the process.

PLATE TECTONICS

- By 1968, these developments, among others, led to the unfolding of a far more encompassing theory than continental drift, known as plate tectonics.
- **According to the plate tectonics model**, the uppermost mantle and the overlying crust behave as a strong, rigid layer, known as the lithosphere, **which is broken into segments commonly referred to as plates.**
- The **lithosphere is thinnest in the oceans** where it varies from as little as a few kilometers along the axis of the oceanic ridge system to about 100 kilometers (60 miles) in the deep-ocean basins.

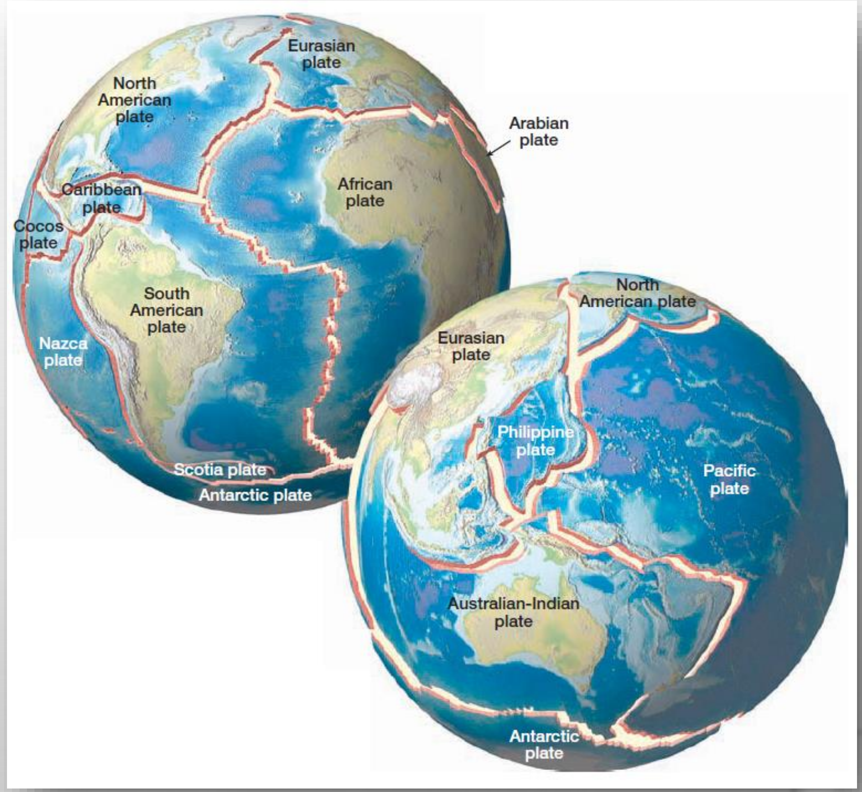
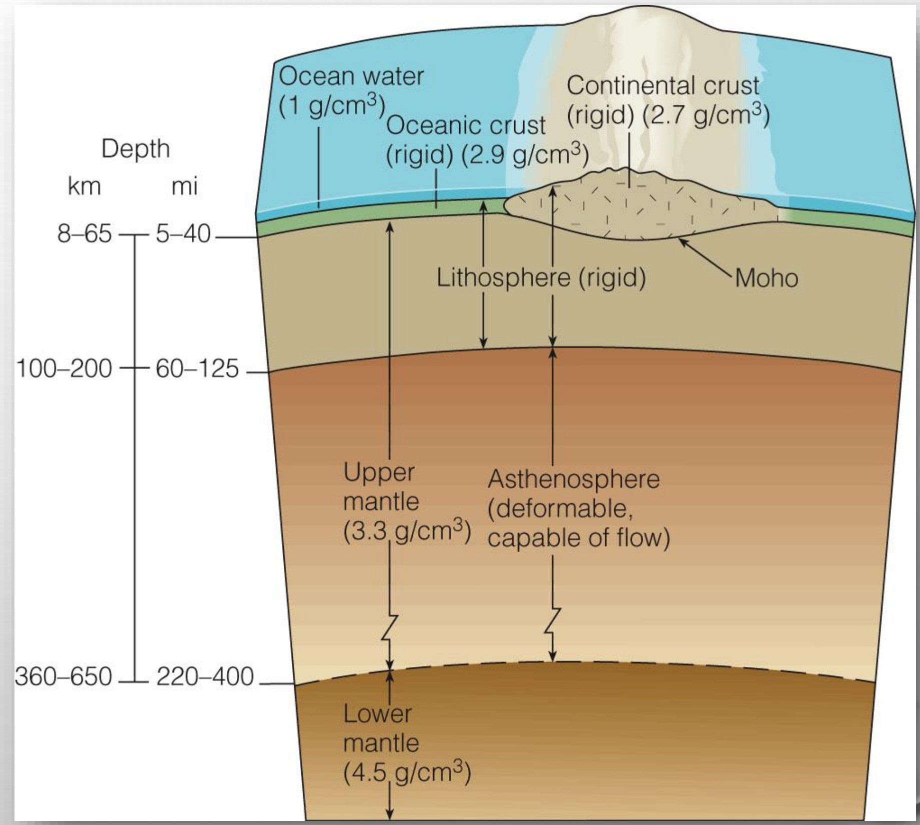


PLATE TECTONICS

- By contrast, **continental lithosphere is generally thicker than 100 kilometers** and may extend to a depth of 200 to 300 kilometers beneath stable continental cratons.
- The lithosphere, in turn, overlies **a weak region in the mantle known as the asthenosphere.** The temperatures and pressures in the upper asthenosphere (100 to 200 kilometers in depth) are such that the **rocks there are very near their melting temperatures and, hence, respond to stress by flowing.**
- As a result, Earth's rigid outer shell is effectively detached from the layers below, which permits it to move independently.



EARTHS MAJOR PLATES

- The lithosphere is composed of about two dozen segments having irregular sizes and shapes called lithospheric plates or tectonic plates that are in constant motion with respect to one another.
- **Seven major lithospheric plates are recognized.**
- These plates, which account for 94 percent of Earth's surface area, include the ***North American, South American, Pacific, African, Eurasian, Australian-Indian, and Antarctic plates.***
- **The largest is the Pacific plate**.
- *Intermediate-sized plates include the Caribbean, Nazca, Philippine, Arabian, Cocos, Scotia, and Juan de Fuca plates.* These plates, with the exception of the Arabian plate, are composed mostly of oceanic lithosphere.

EARTH MAJOR PLATES

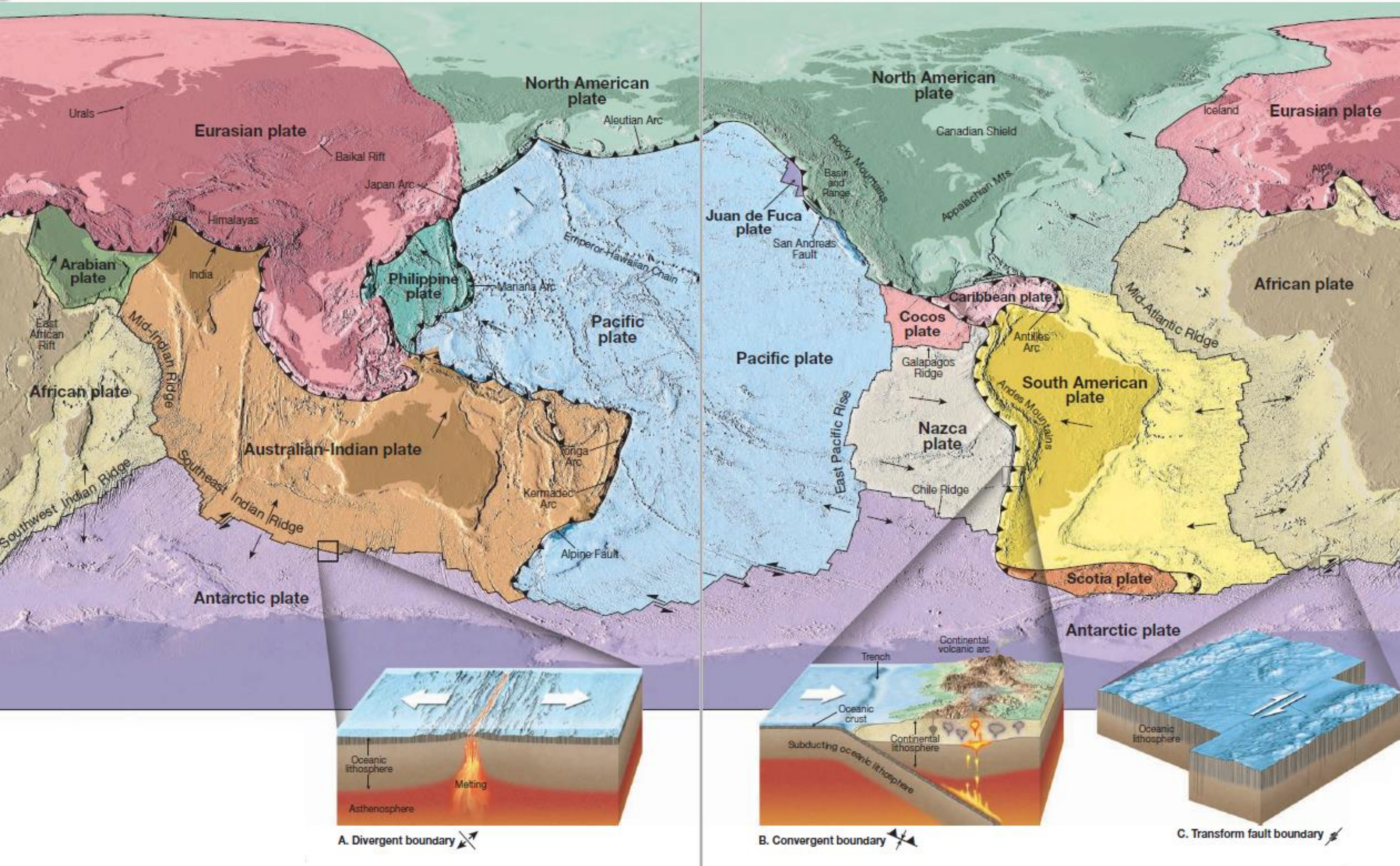


PLATE BOUNDARIES

- Because plates are in constant motion relative to each other, most major interactions among them (and, therefore, most deformation) occur along their boundaries.
- **In fact, plate boundaries were first established by plotting the locations of earthquakes and volcanoes.**
- Plates are bounded by three distinct types of boundaries, which are differentiated by the type of movement they exhibit.

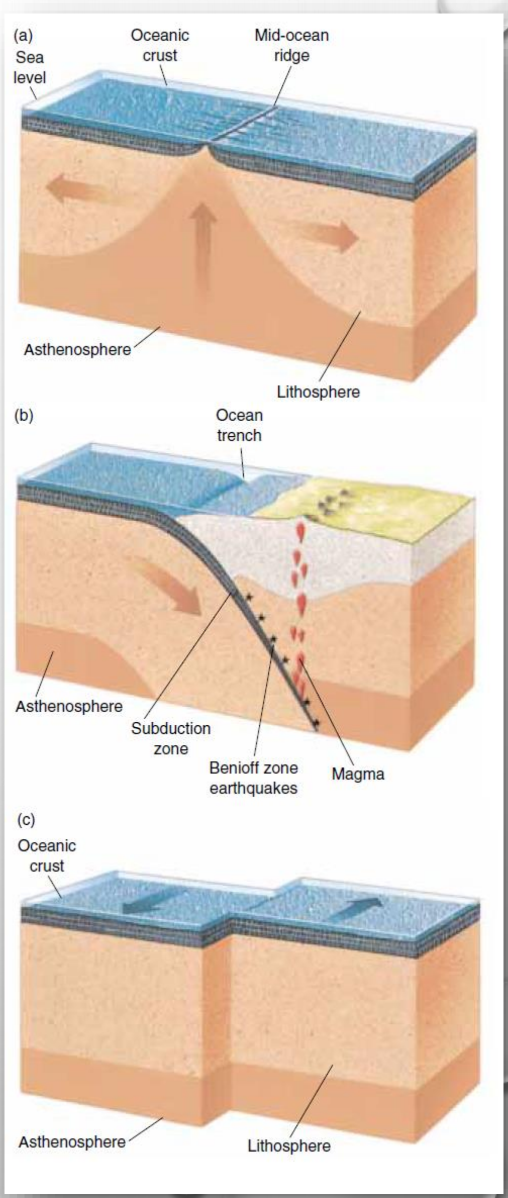
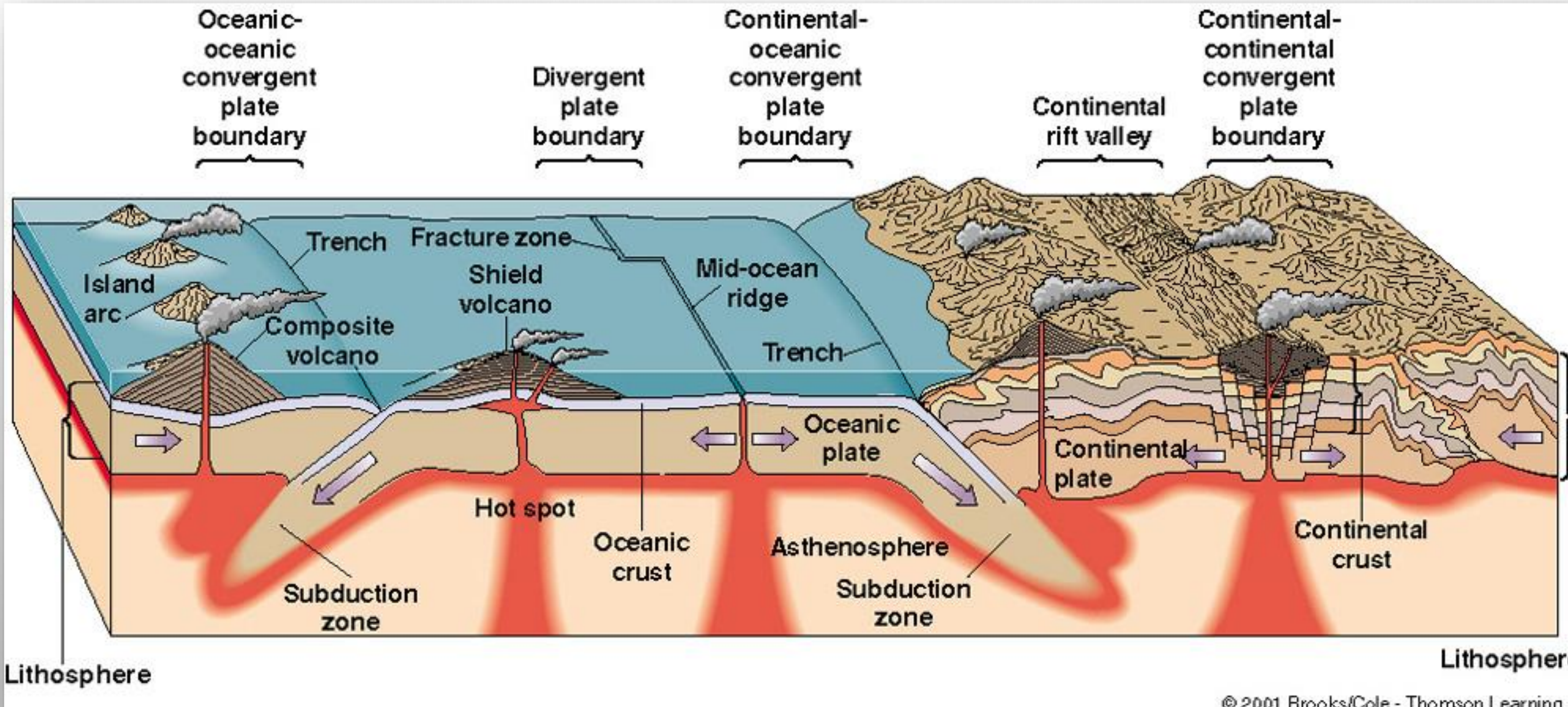


PLATE BOUNDARIES

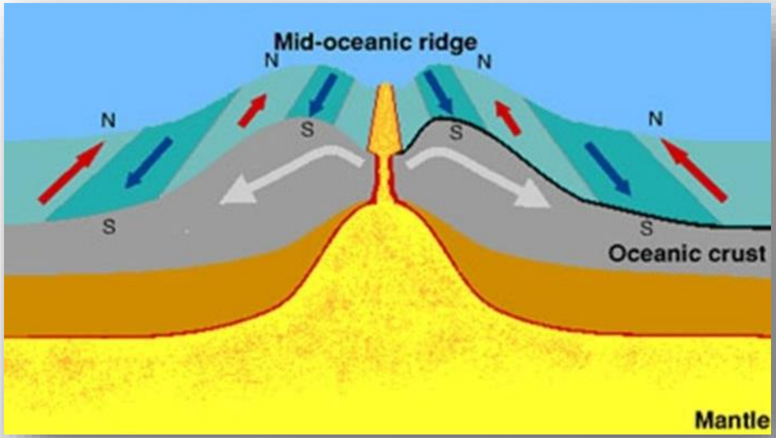
- 1. **Divergent boundaries** (***constructive margins***)—where two plates move apart, resulting in upwelling of hot material from the mantle to create new seafloor.
- 2. **Convergent boundaries** (***destructive margins***)—where two plates move together, resulting in oceanic lithosphere descending beneath an overriding plate, eventually to be reabsorbed into the mantle or possibly in the collision of two continental blocks to create a mountain system
- 3. **Transform fault boundaries** (***conservative margins***)—where two plates grind past each other without the production or destruction of lithosphere.

TYPE OF PLATE BOUNDARIES



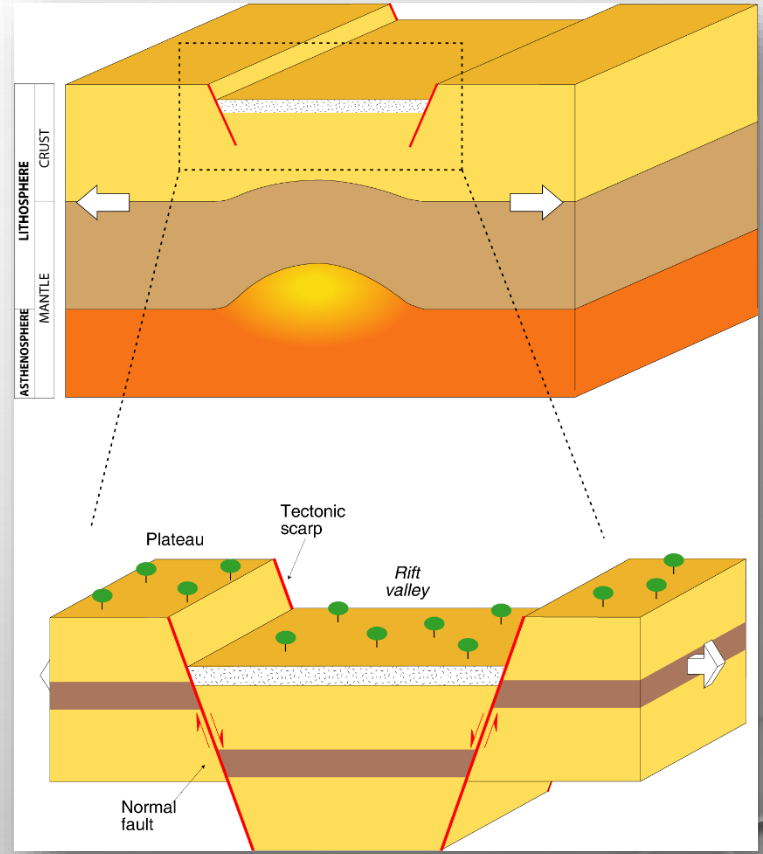
DIVERGENT PLATE BOUNDARIES
OCEAN RIDGE AND SEA FLOOR SPREADING

- Most divergent boundaries are located along the crests of oceanic ridges and can be thought of as constructive plate margins because this is where new ocean floor is generated.
- **Divergent boundaries are also called spreading centers, because seafloor spreading occurs at these boundaries.**
- **Most divergent plate boundaries are associated with OCEANIC RIDGES: elevated areas of the seafloor that are characterized by high heat flow and volcanism.**



DIVERGENT PLATE BOUNDARIES
RIFT VALLEY

- Divergent boundaries can also develop within a continent, in which case the landmass may split into two or more smaller segments separated by an ocean basin.
- Continental rifting occurs where opposing tectonic forces act to pull the lithosphere apart.
- As the tectonic forces continue to pull the crust apart, these crustal fragments sink, generating an elongated depression called a **continental rift.**
- **A modern example of an active continental rift is the East African Rift**



CONVERGENT PLATE BOUNDARIES

- New lithosphere is constantly being produced at the oceanic ridges; however, our planet is not growing larger—its total surface area remains constant.
- A balance is maintained because older, denser portions of oceanic lithosphere descend into the mantle at a rate equal to seafloor production.
- At a **convergent plate boundary, two lithospheric plates move toward each other**. Convergence can occur in three different ways

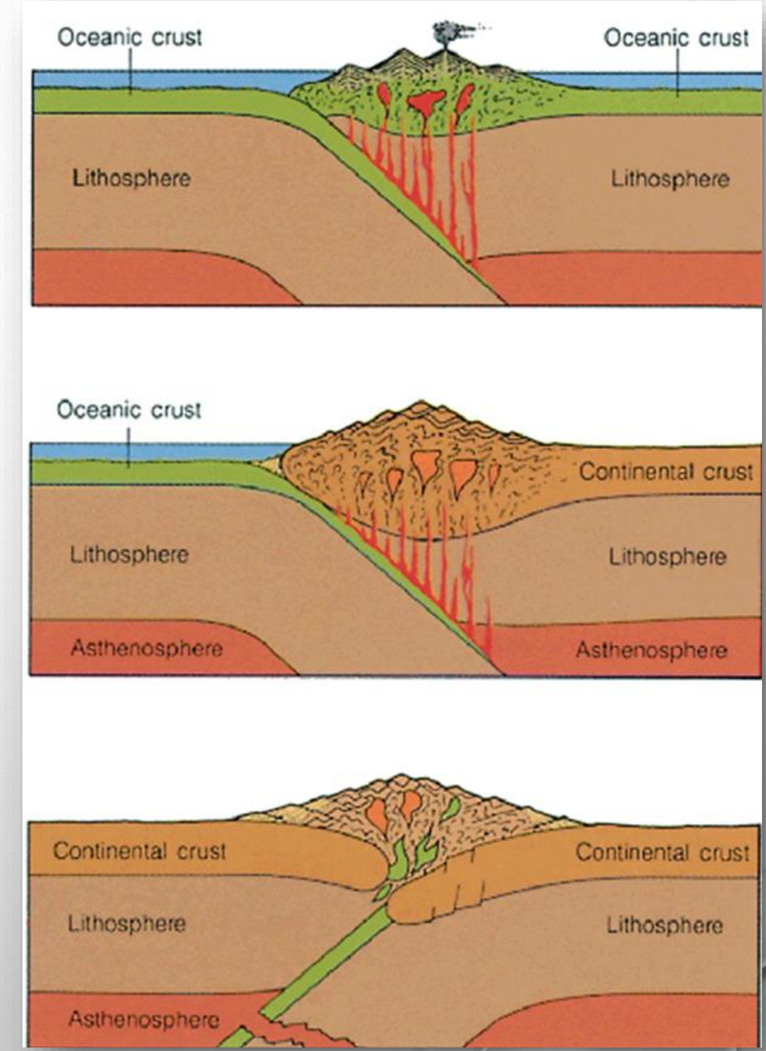
  (1) **between a plate carrying oceanic crust and another carrying continental crust,**

  (2) **between two plates carrying oceanic crust, and**

  (3) **between two plates carrying continental crust**

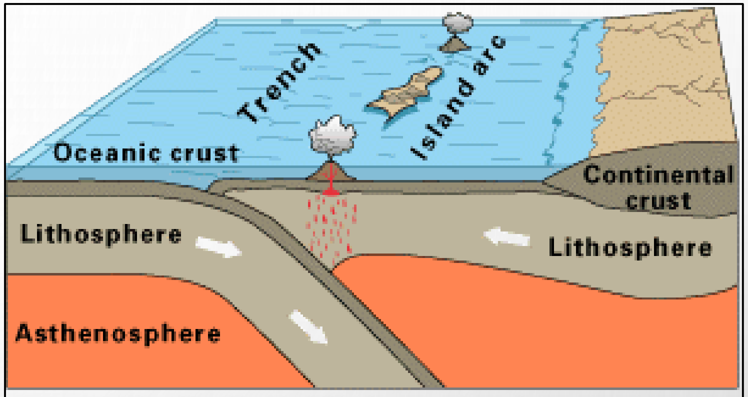
CONVERGENT PLATE BOUNDARIES

- **Convergent boundaries are also called subduction zones**, because **they are sites where lithosphere is descending (being subducted) into the mantle**.
- **Subduction occurs because the density of the descending tectonic plate is greater than the density of the underlying asthenosphere.**
- Differences in density determine what happens where two plates converge.
- When two plates converge, the denser plate dives beneath the lighter one and sinks into the mantle. This process is called subduction.
- **A subduction zone is a long, narrow belt where a lithospheric plate is sinking into the mantle**.

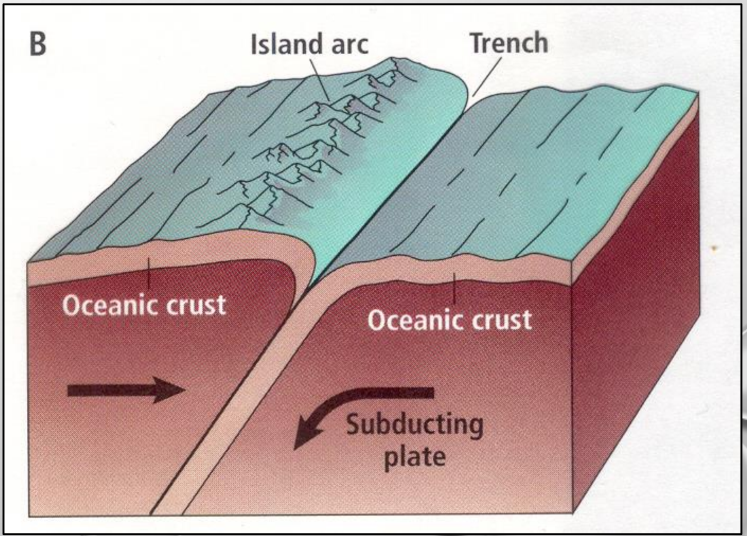


CONVERGENCE OF TWO PLATES CARRYING OCEANIC CRUST

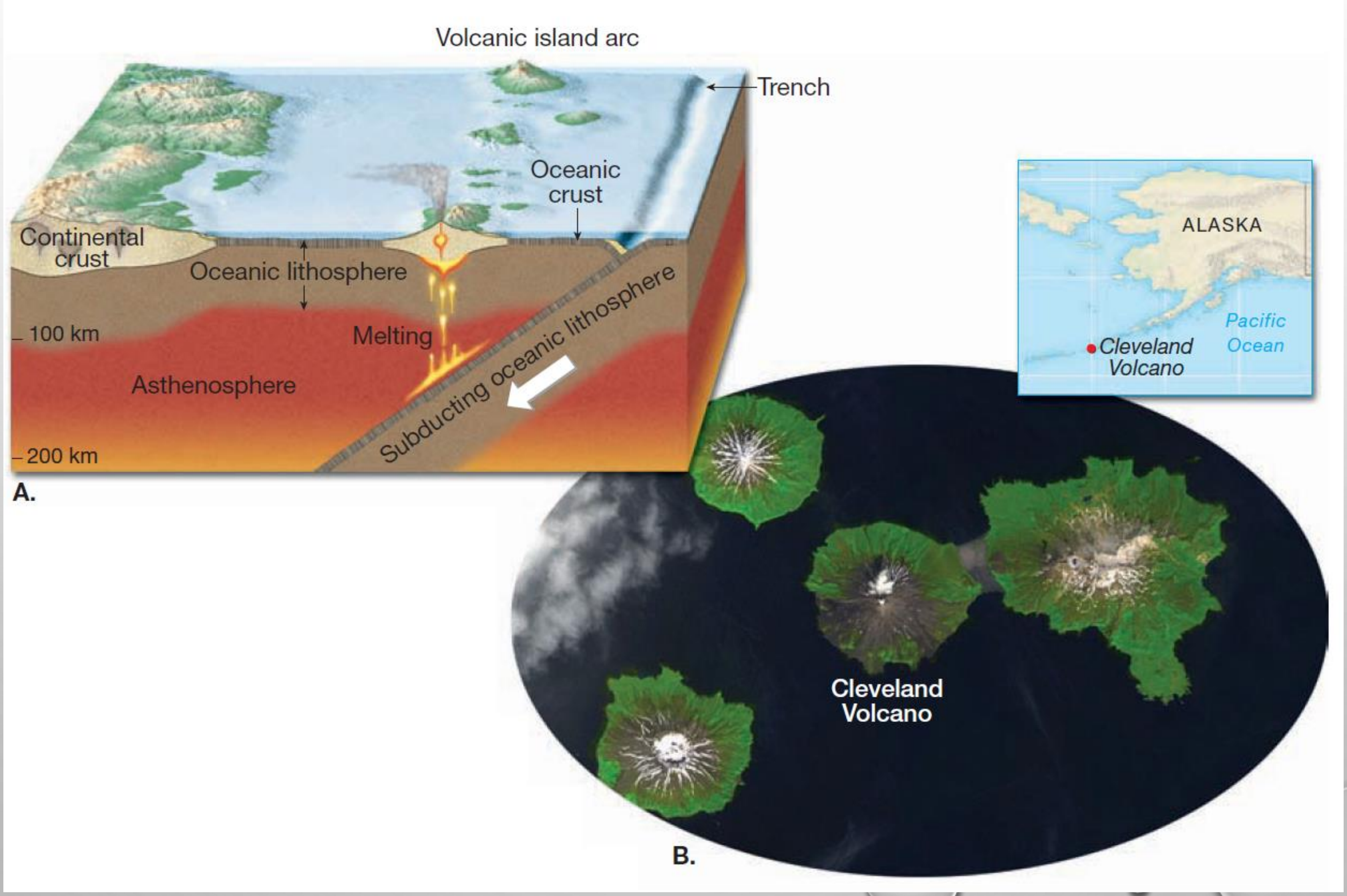
- Newly formed oceanic lithosphere is hot, thin, and light.
- As it spreads away from the mid-oceanic ridge, it becomes older, cooler, thicker, and denser.
- Thus the density of oceanic lithosphere increases with its age. When two oceanic plates converge, the denser one sinks into the mantle.
- **Convergence of two oceanic plates creates an island arc and trench. e.g. Japan**



Oceanic-oceanic convergence

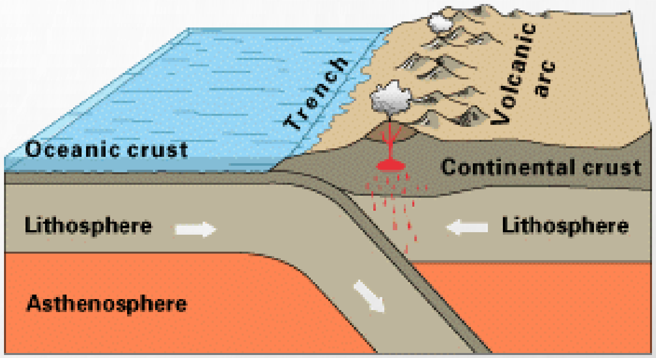


CONVERGENCE OF TWO PLATES CARRYING OCEANIC CRUST

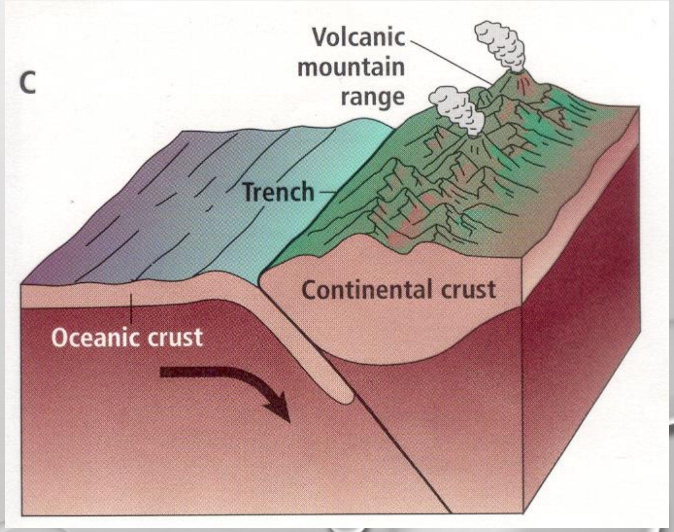


CONVERGENCE OF OCEANIC CRUST WITH CONTINENTAL CRUST

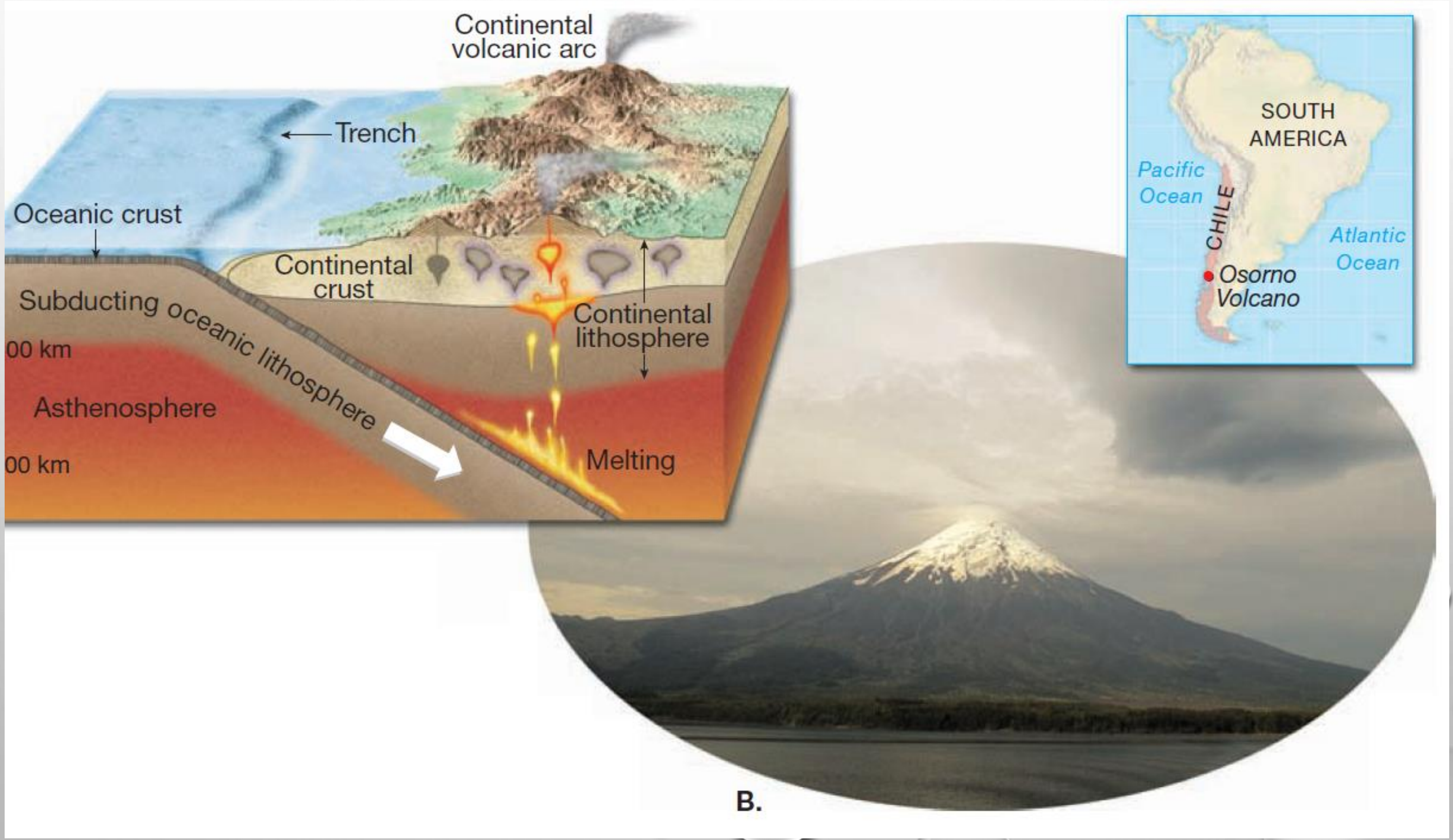
- When an oceanic plate converges with a continental plate, the denser oceanic plate sinks into the mantle beneath the edge of the continent.
- As a result, many subduction zones are located at continental margins.
- Convergent boundary of an oceanic and continental plates forms a volcanic mountain range and trenches. **e.g. Andes Mountains**



Oceanic-continental convergence

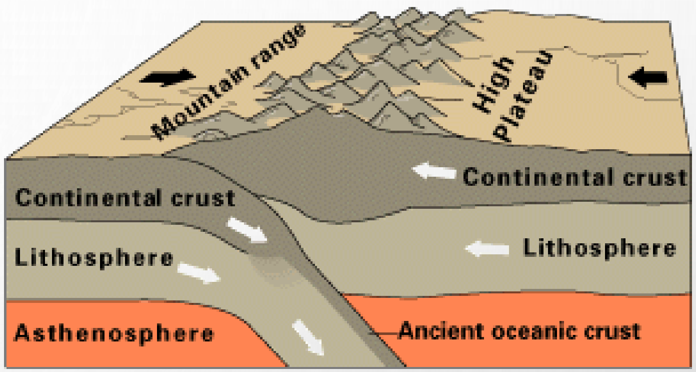


CONVERGENCE OF OCEANIC CRUST WITH CONTINENTAL CRUST

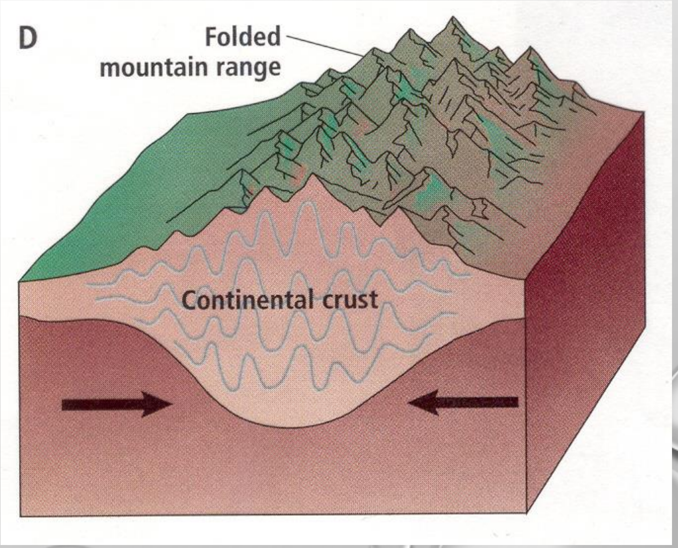


CONVERGENCE OF TWO PLATES CARRYING CONTINENTS

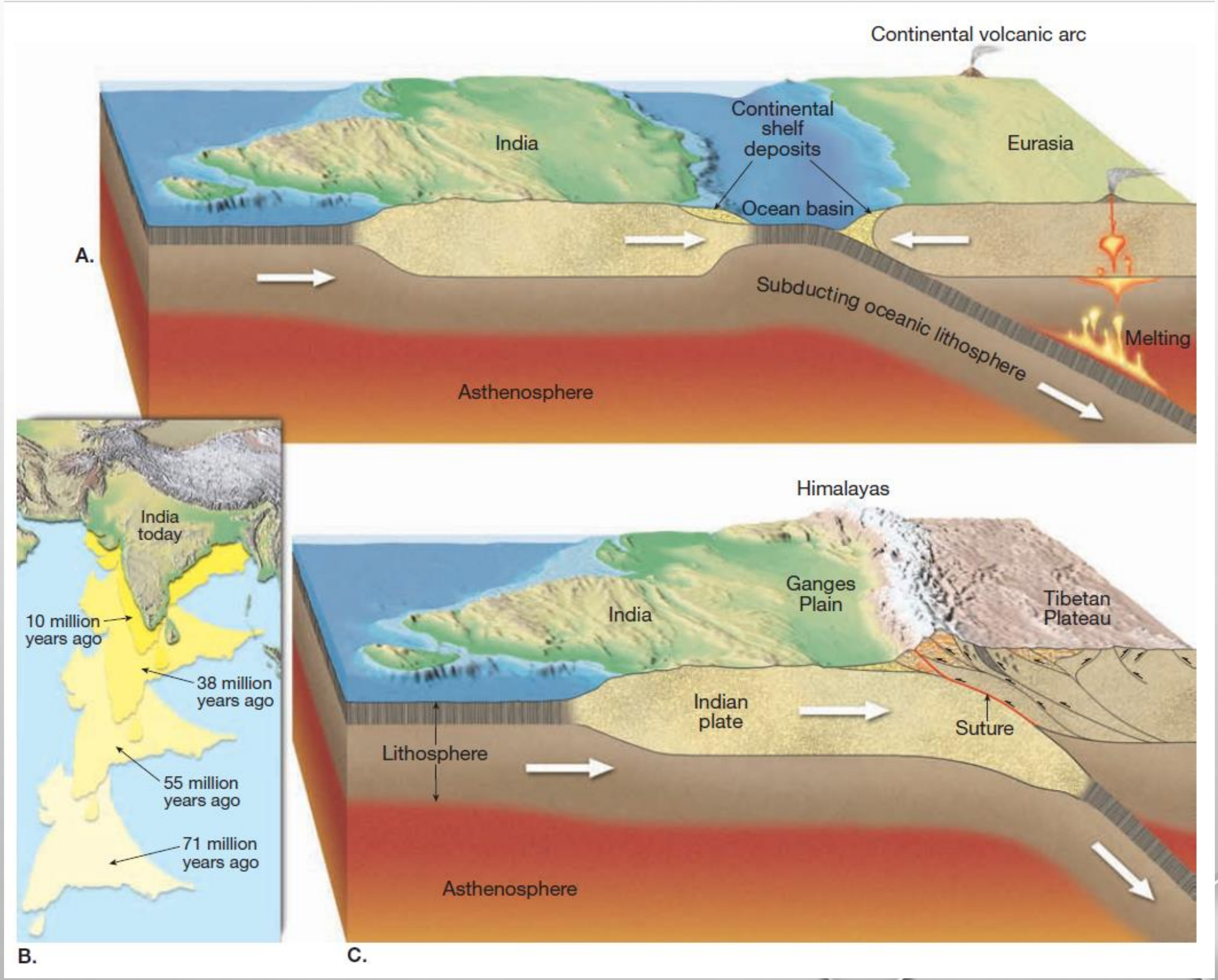
- If two converging plates carry continents, neither can sink into the mantle because of their low densities.
- In this case, the two continents collide and crumple against each other, forming a huge mountain chain.
- The **Himalayas, the Alps, and the Appalachians** all formed as results of continental collisions.



Continental-continental convergence



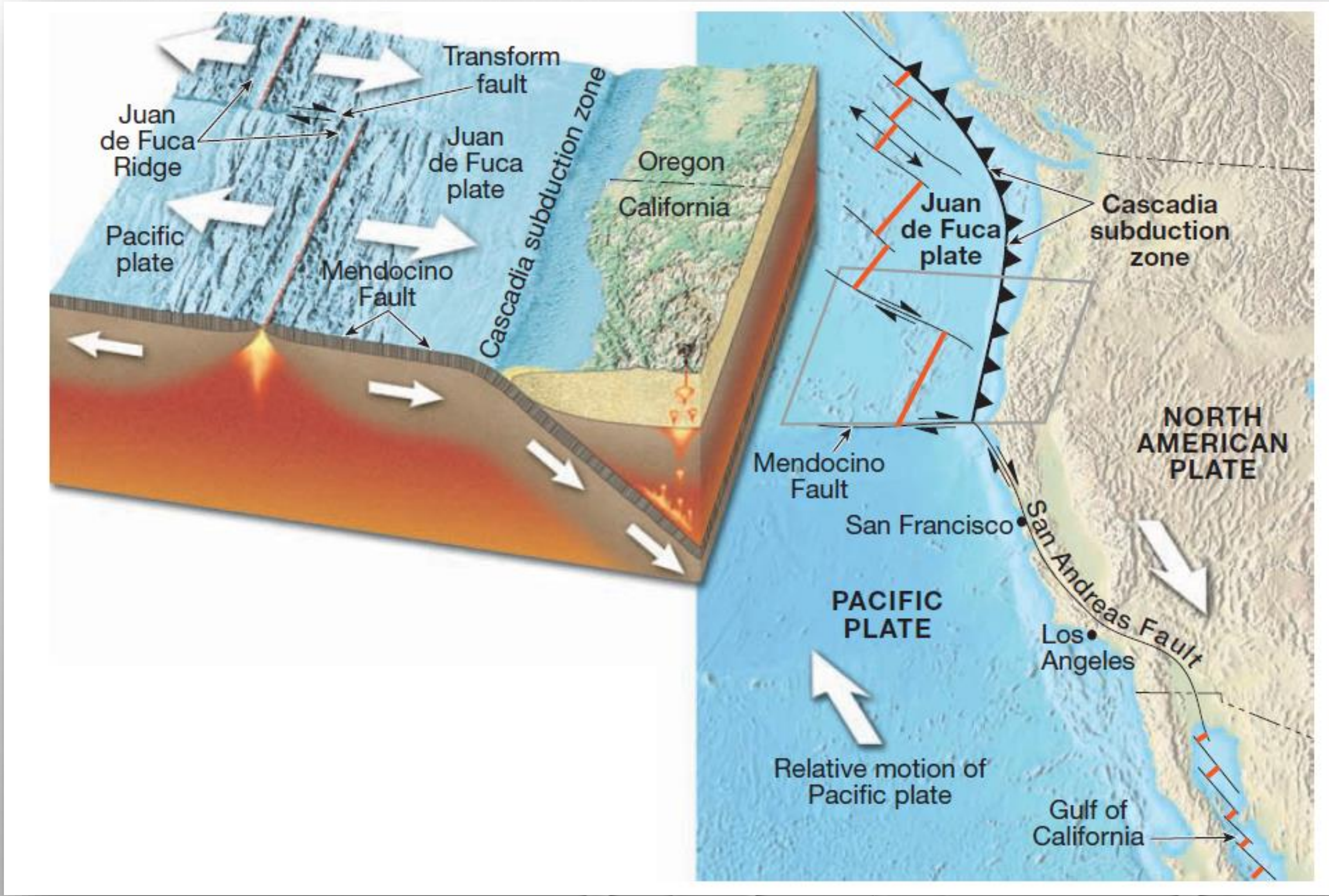
CONVERGENCE OF TWO PLATES CARRYING CONTINENTS



TRANSFORM PLATE BOUNDARY

- **Along a transform fault boundary, plates slide horizontally past one another without the production or destruction of lithosphere (conservative plate margins).**
- The nature of transform faults was discovered in 1965 by Canadian geologist J. Tuzo Wilson, who proposed that these large faults connected two spreading centers (divergent boundaries) or less commonly two trenches (convergent boundaries).
- **Most transform faults are found on the ocean floor**.
- Like the Mendocino Fault, most transform fault boundaries are located within the ocean basins; however, a few cut through continental crust.
- Two examples are the earthquake-prone **San Andreas Fault of California and New Zealand's Alpine Fault**.

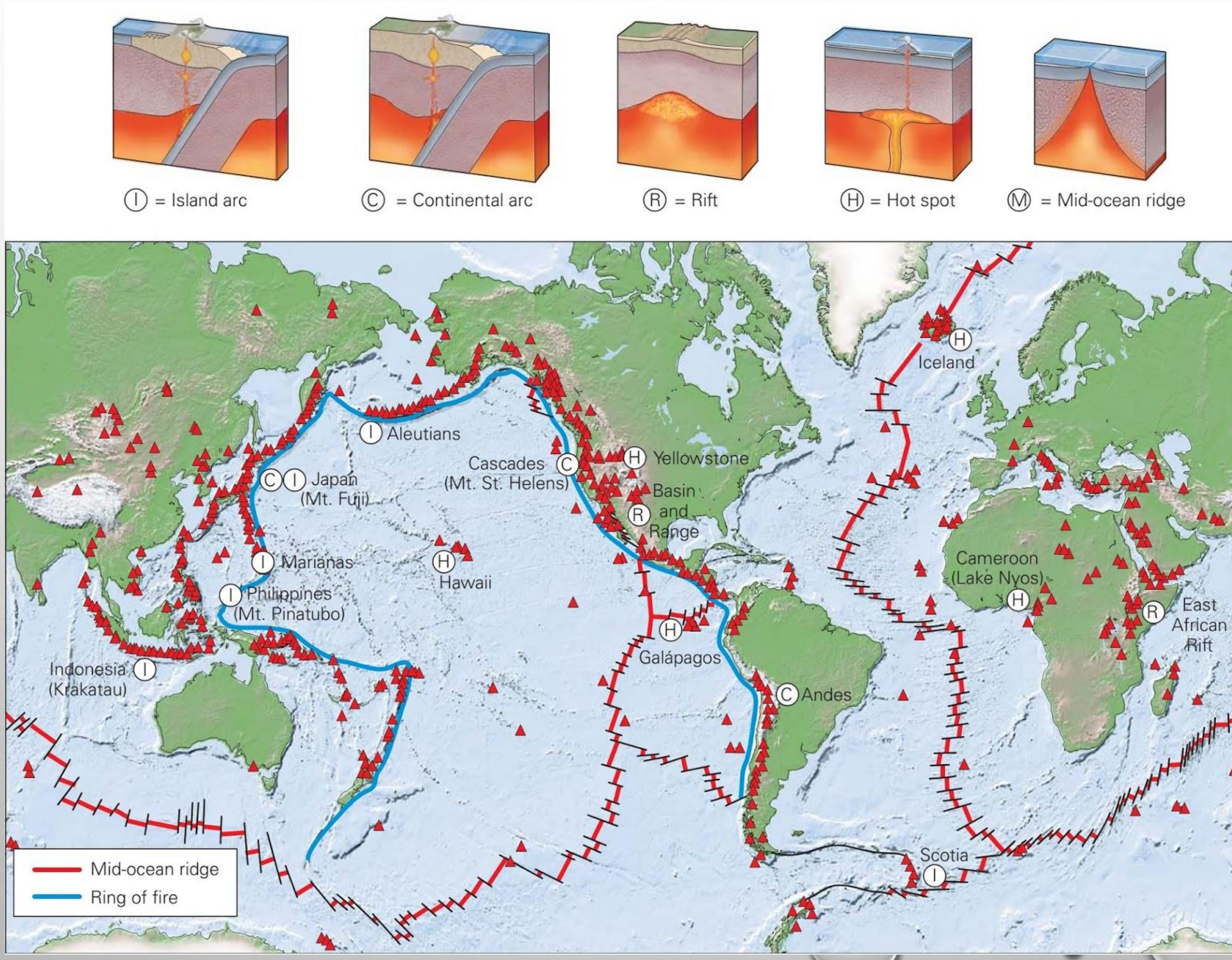
TRANSFORM PLATE BOUNDARY



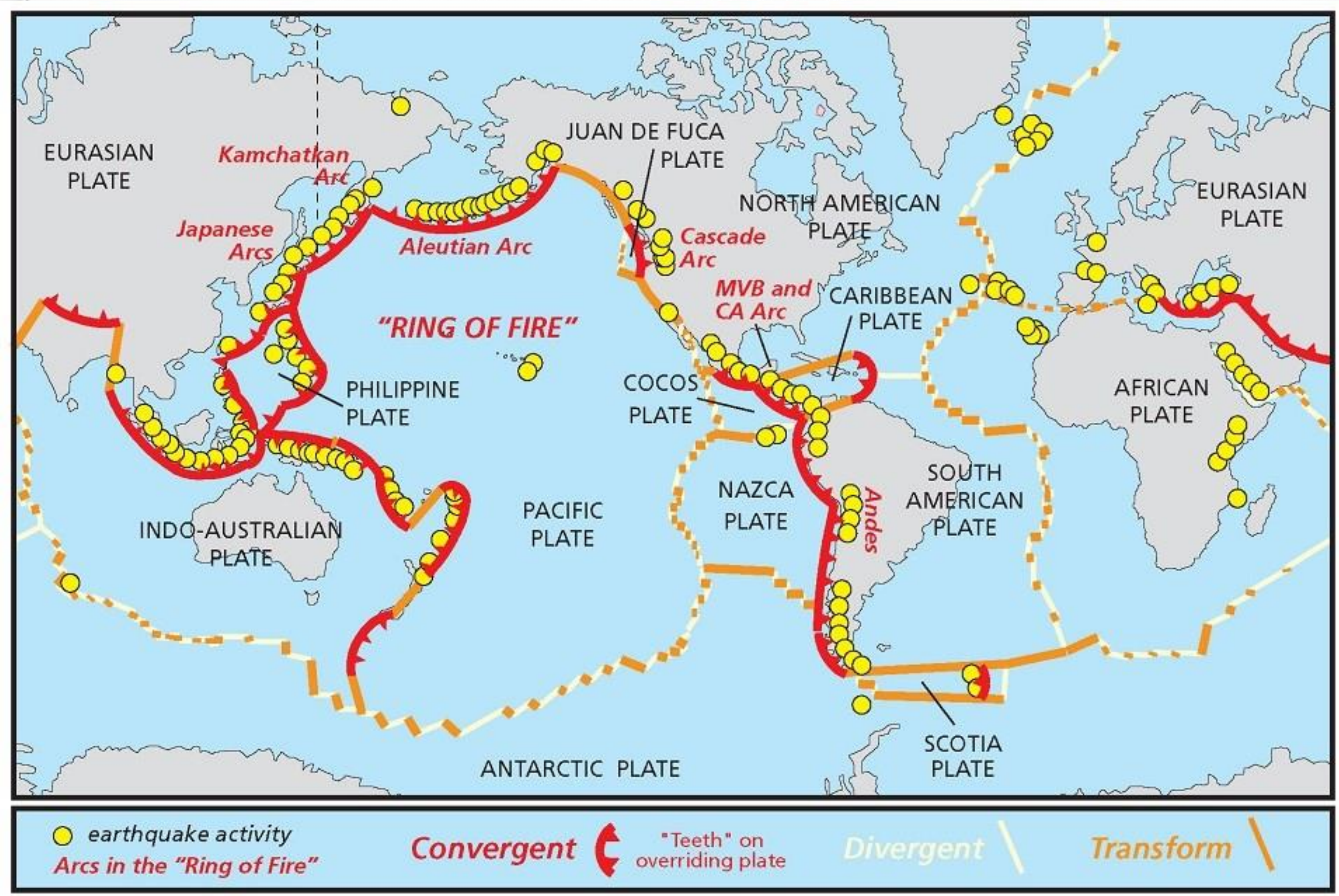
CHARACTERISTICS OF LITHOSPHERIC PLATES

- A plate is a segment of the lithosphere; thus, it includes the uppermost mantle and all of the overlying crust.
- **A single plate can carry both oceanic and continental crust.**
- A plate is composed of hard, mechanically strong rock.
- A plate floats on the underlying hot, plastic asthenosphere and glides horizontally over it.
- A plate behaves like a large slab of ice floating on a pond. In general, however, each plate moves as a large, intact sheet of rock.
- **A plate margin is tectonically active.**
- **Earthquakes and volcanoes are common at plate boundaries. In contrast, the interior of a lithospheric plate is normally tectonically stable.**
- Tectonic plates move at rates that vary from less than 1 to 16 centimeters per year.

VOLCANOES AND PLATE BOUNDARIES



EARTHQUAKES AND PLATE BOUNDARIES



MOUNTAINS, MID OCEANIC RIDGE AND PLATE BOUNDARIES

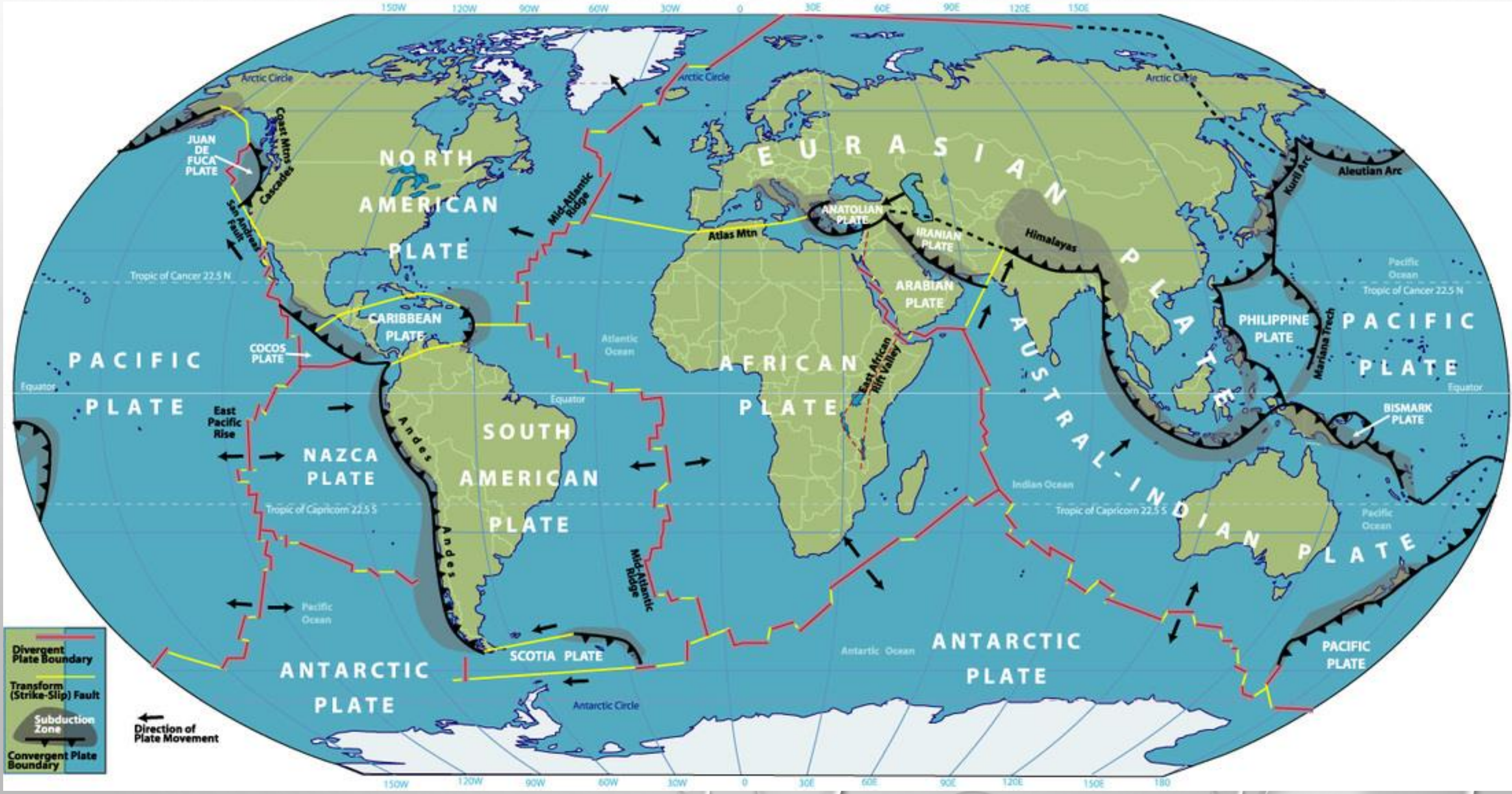
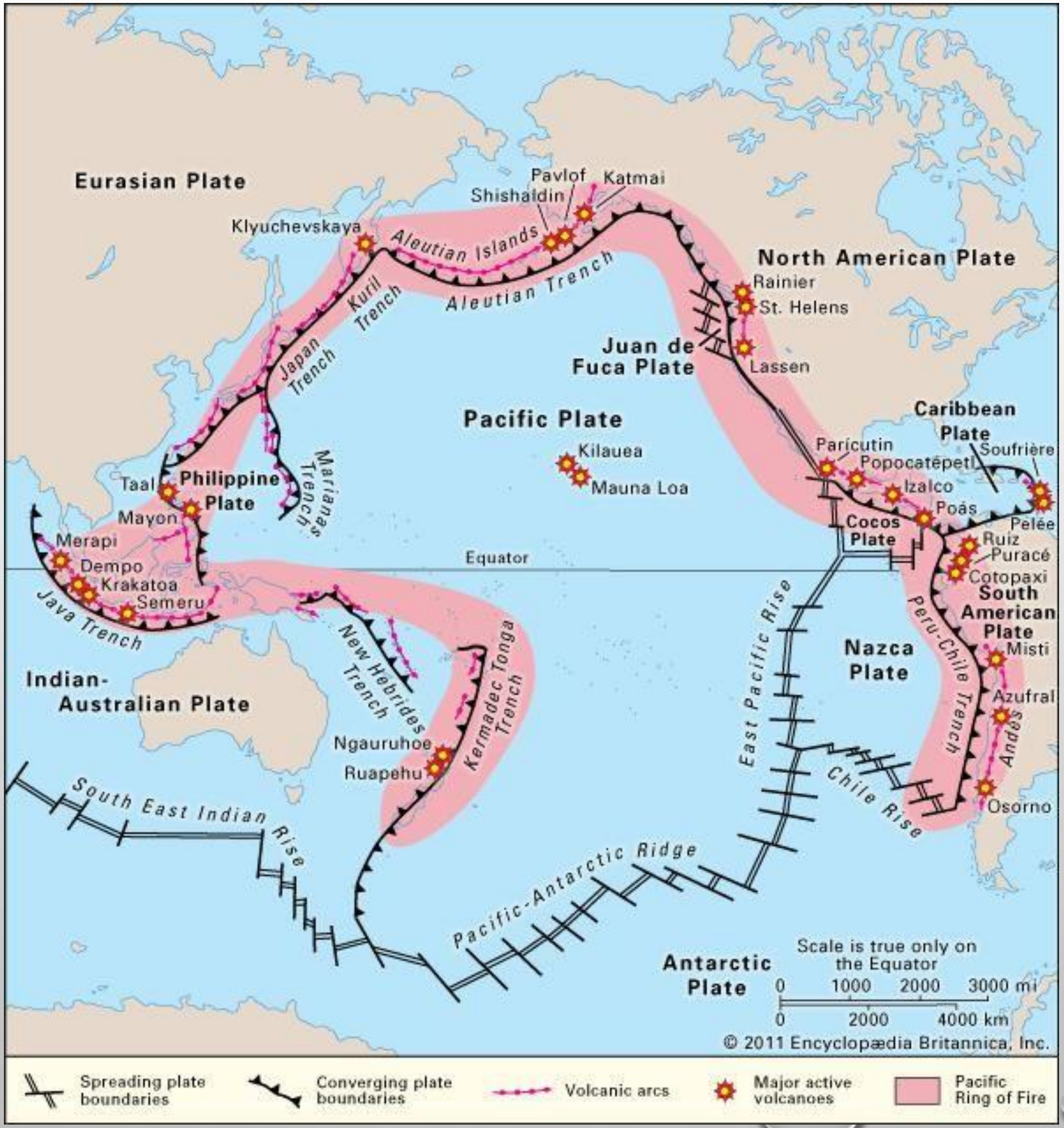


PLATE BOUNDARIES AND OCEAN TRENCHES



https://youtu.be/p0dWF_3PYh4

WHAT DRIVES PLATE MOTION

- From geophysical evidence, we have learned that although the mantle consists almost entirely of solid rock, it is hot and weak enough to exhibit fluid like convective flow.
- **Mantle convection may cause plate movement.**
- Mantle convection is driven by a combination of three thermal processes: **heating at the bottom by heat loss from Earth's core**; **heating from within by the decay of radioactive isotopes**; and **cooling from the top that creates thick, cold lithospheric slabs that sink into the mantle**.