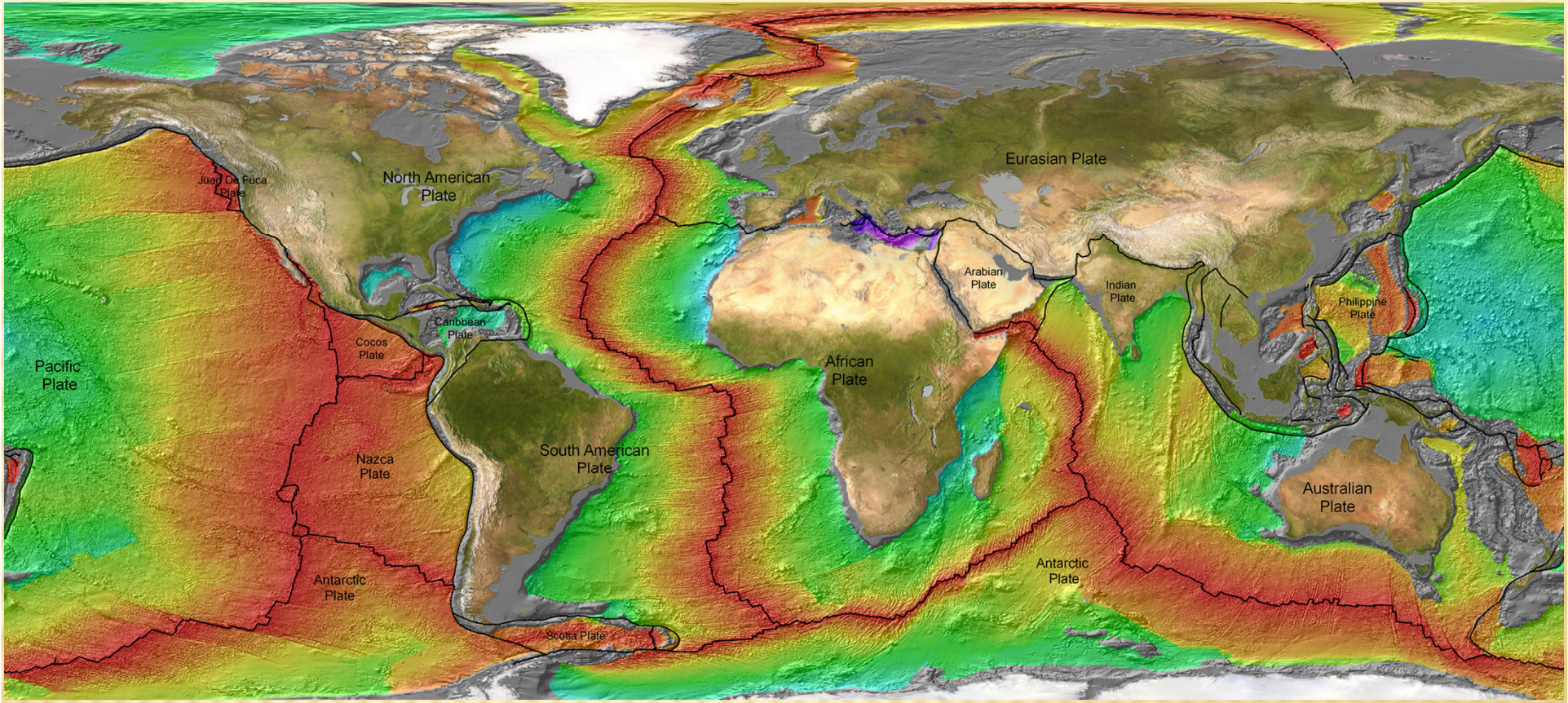
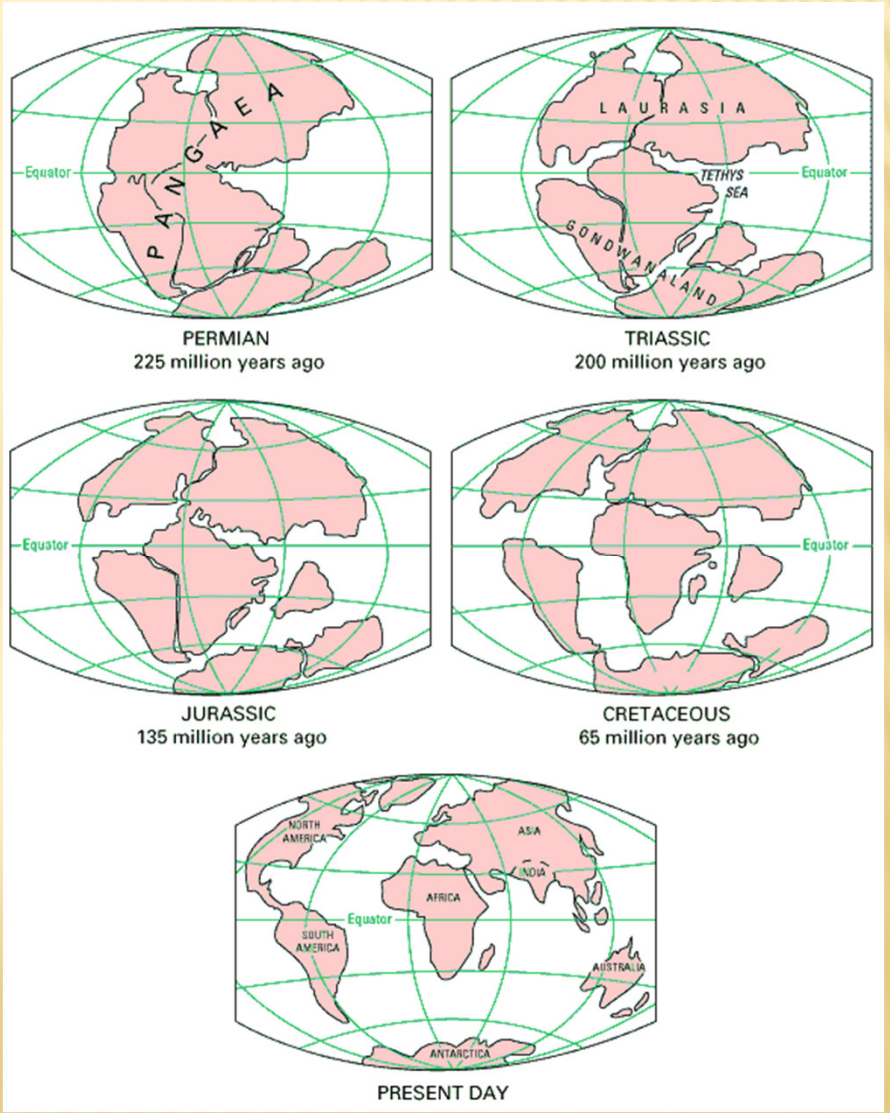


UNIT 6

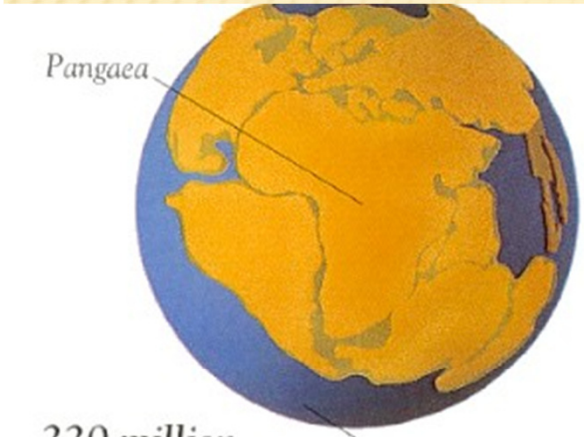
PLATE TECTONICS

CONTINENTAL DRIFT

- Alfred Wegner proposed the theory that the crustal plates are moving over the mantle.
- He argued that today's continents once formed a single landmass, called **Pangaea** (Greek for "all land").
- It broke into pieces due to the weaknesses in the earth's crust as they were made up of less dense materials, which drifted centimeter by centimeter over millions of years until they arrived at where they are now.
- This was supported by fossil and rock type evidence; also matching of coastline shapes.



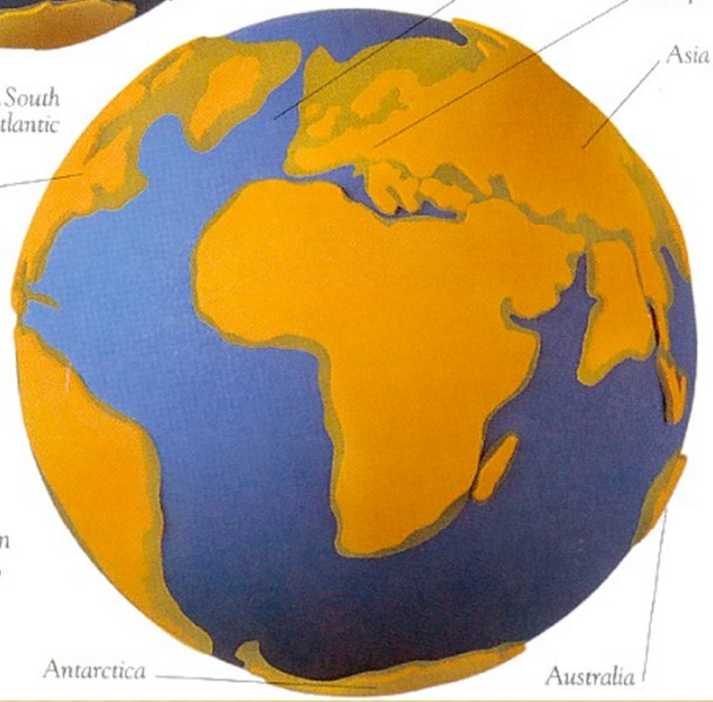
CONTINENTAL DRIFT



220 million years ago
There is only one land mass, Pangaea, in a vast ocean called Panthalassa.

200 million years ago
The growing Tethys Sea splits Pangaea into Gondwanaland and Laurasia.

135 million years ago
Gondwanaland splits into Africa and South America as the South Atlantic opens up. India drifts toward Asia.

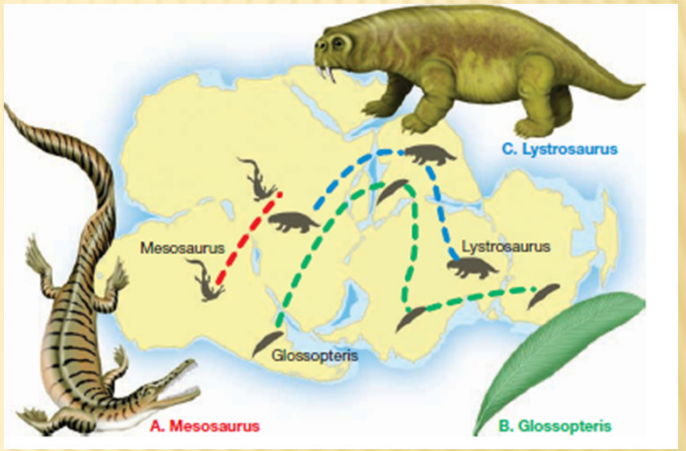


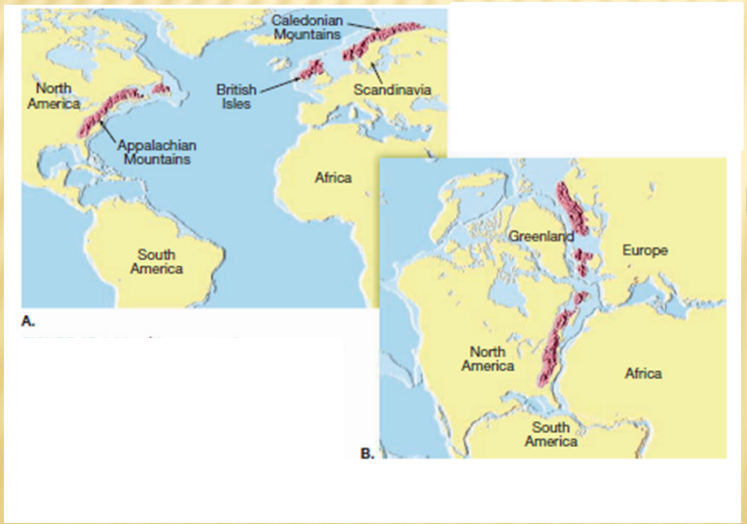
10 million years ago
Antarctica and Australia drift apart. Laurasia breaks up as the North Atlantic opens up, with North America moving away from Europe. The map of the world looks similar to the one we know today.

EVIDENCES OF CONTINENTAL DRIFT

The Continental Jigsaw Puzzle

Fossils Match across the Seas





Rock Types and Geologic Features

Ancient Climates

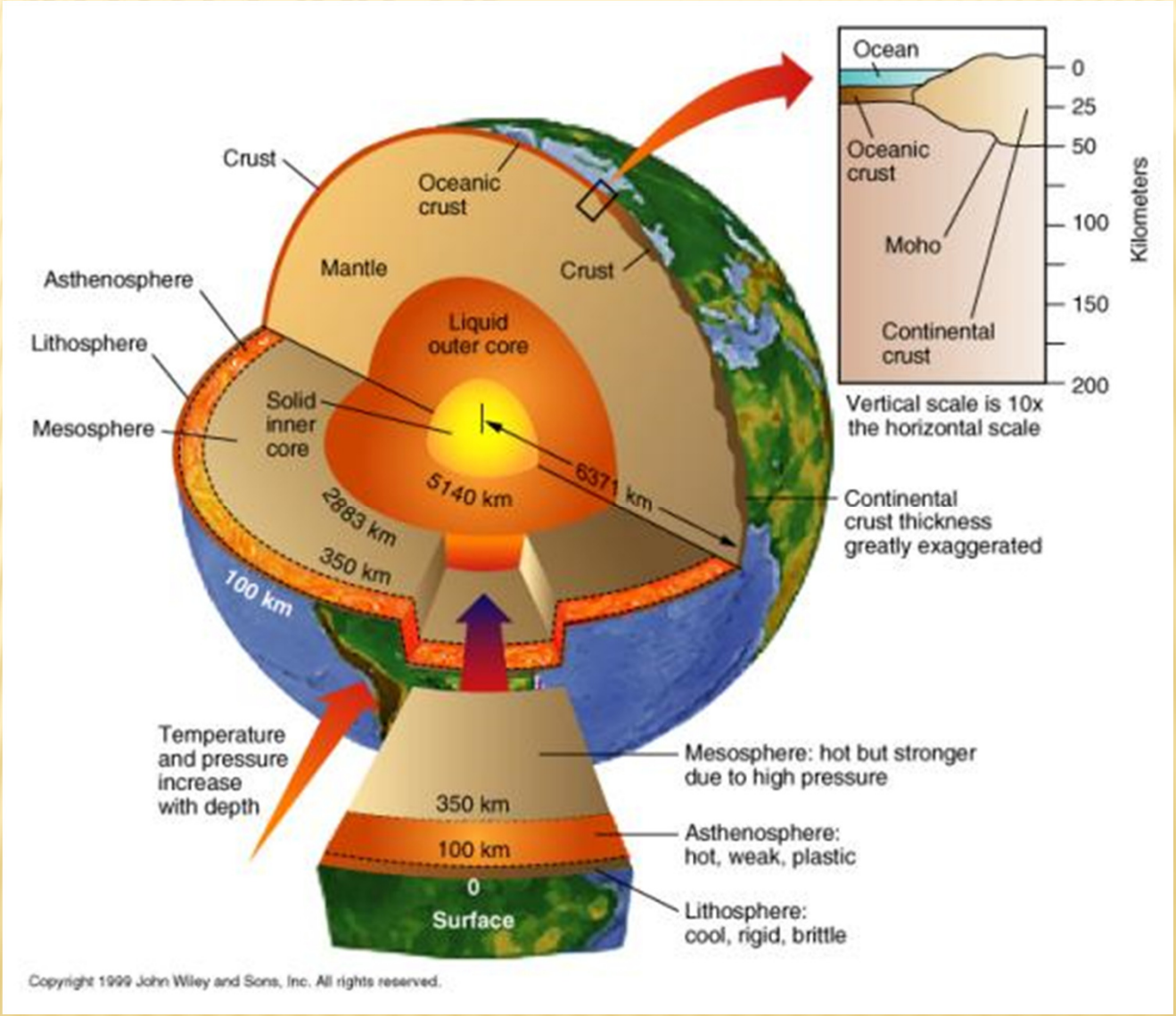
DRAWBACKS OF CONTINENTAL DRIFT HYPOTHESIS

- One of the main objections to Wegener's hypothesis was 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.

THE PLATE TECTONIC THEORY

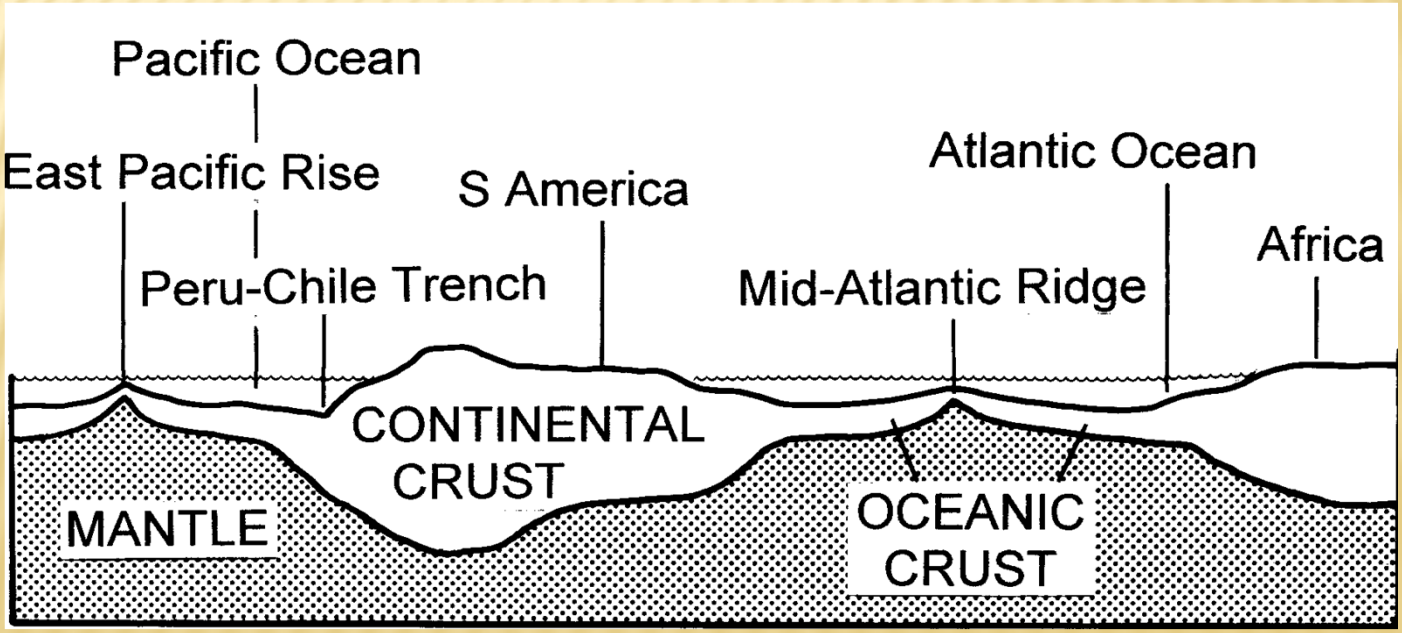
- By 1968, a far more encompassing theory than continental drift, known as plate tectonics.
- According to the plate tectonics model, the uppermost mantle and the overlying crust behave as a strong, rigid layer, known as the lithosphere, which is broken into segments commonly referred to as plates.
- 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 in the deep-ocean basins.
- 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.

THE EARTH LAYERS



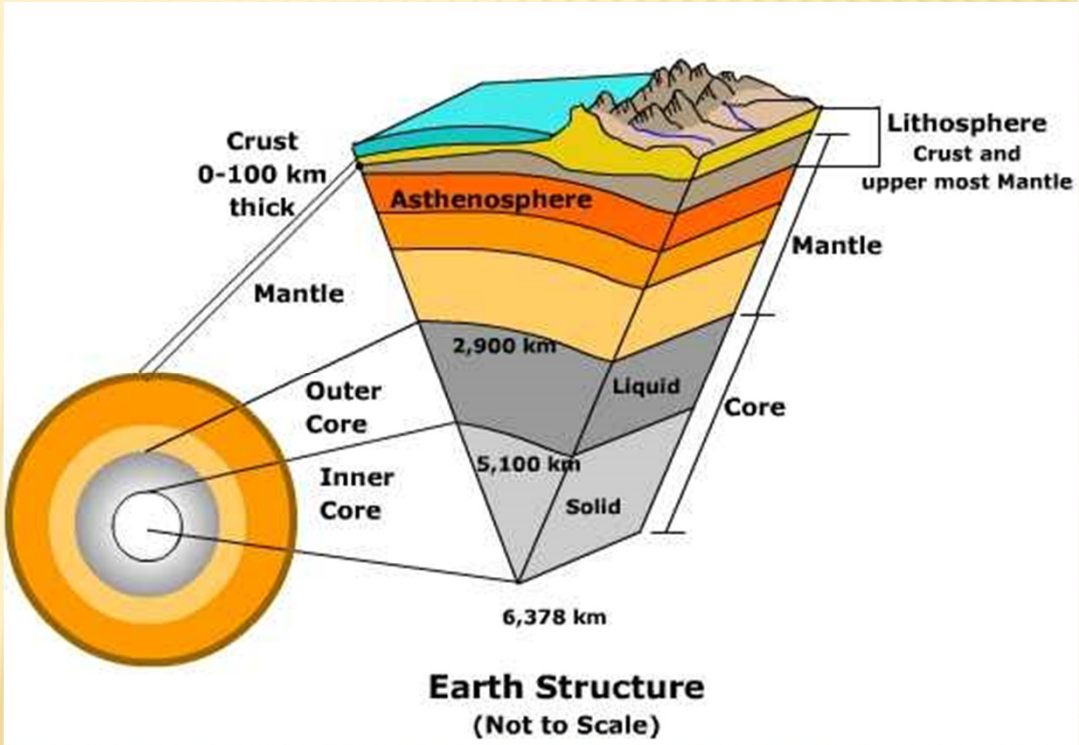
THE EARTH LAYERS

- **Crust:** The crust is the outermost and thinnest layer. Because the crust is relatively cool, it consists of hard, strong rock. Crust beneath the oceans differs from that of continents.
- **Oceanic crust** is 5 to 10 kilometers thick and is composed mostly of a dark, dense rock called **basalt**.
- In contrast, the average thickness of **continental crust** is about 20 to 40 kilometers, although under mountain ranges it can be as much as 70 kilometers thick.
- Continents are composed primarily of a light-colored, less dense rock called **granite**.



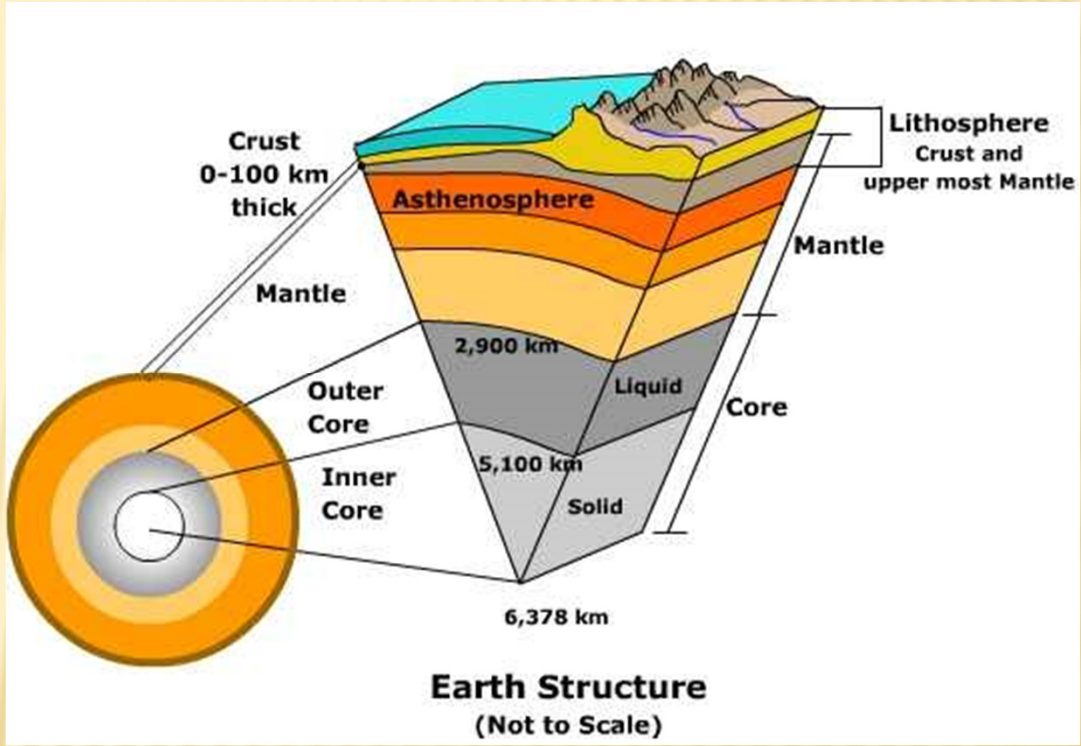
THE EARTH LAYERS

- **Mantle:** The mantle lies directly below the crust.
- It is almost 2900 kilometers thick and makes up 80 percent of the Earth's volume.
- Although the chemical composition may be similar throughout the mantle, Earth temperature and pressure increase with depth.
- These changes cause the strength of mantle rock to vary with depth, and thus they create layering within the mantle.
- The upper part of the mantle consists of two layers.



THE EARTH LAYERS

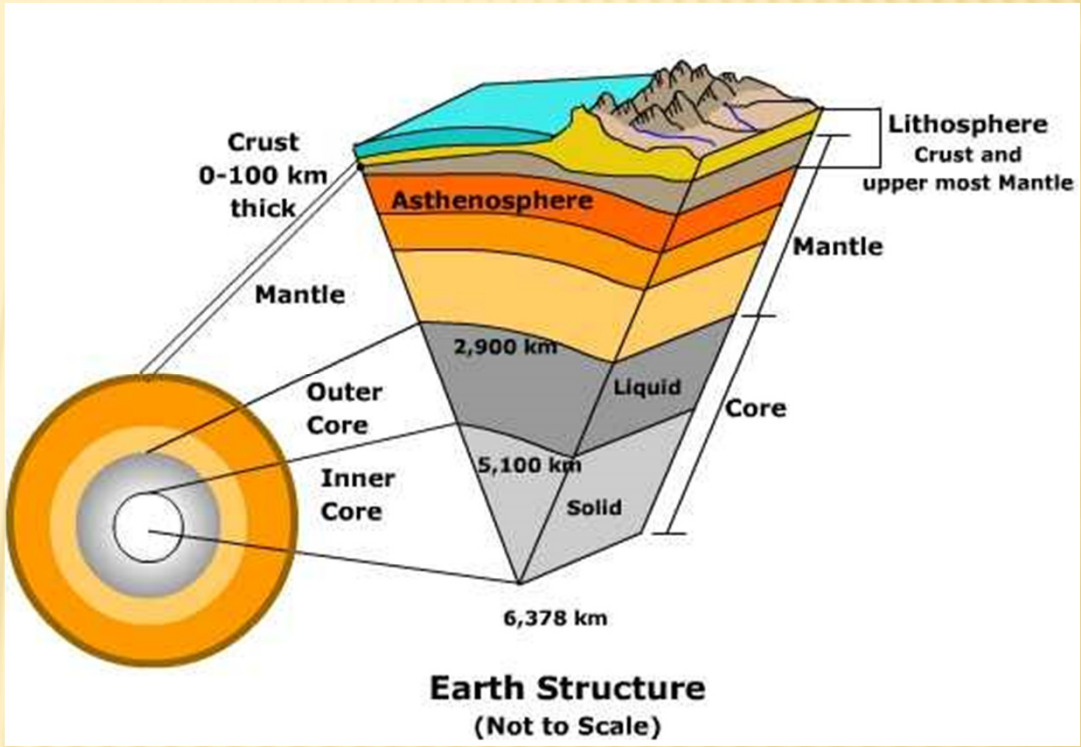
- **The Lithosphere:** The uppermost mantle is relatively cool and consequently is hard, strong rock.
- The outer part of the Earth, including both the uppermost mantle and the crust, make up the lithosphere (Greek for “rock layer”).
- The lithosphere can be as thin as 10 kilometers where tectonic plates separate.
- However, in most regions, the lithosphere varies from about 75 kilometers thick beneath ocean basins to about 125 kilometers under the continents.
- A tectonic (or lithospheric) plate is a segment of the lithosphere.



THE EARTH LAYERS

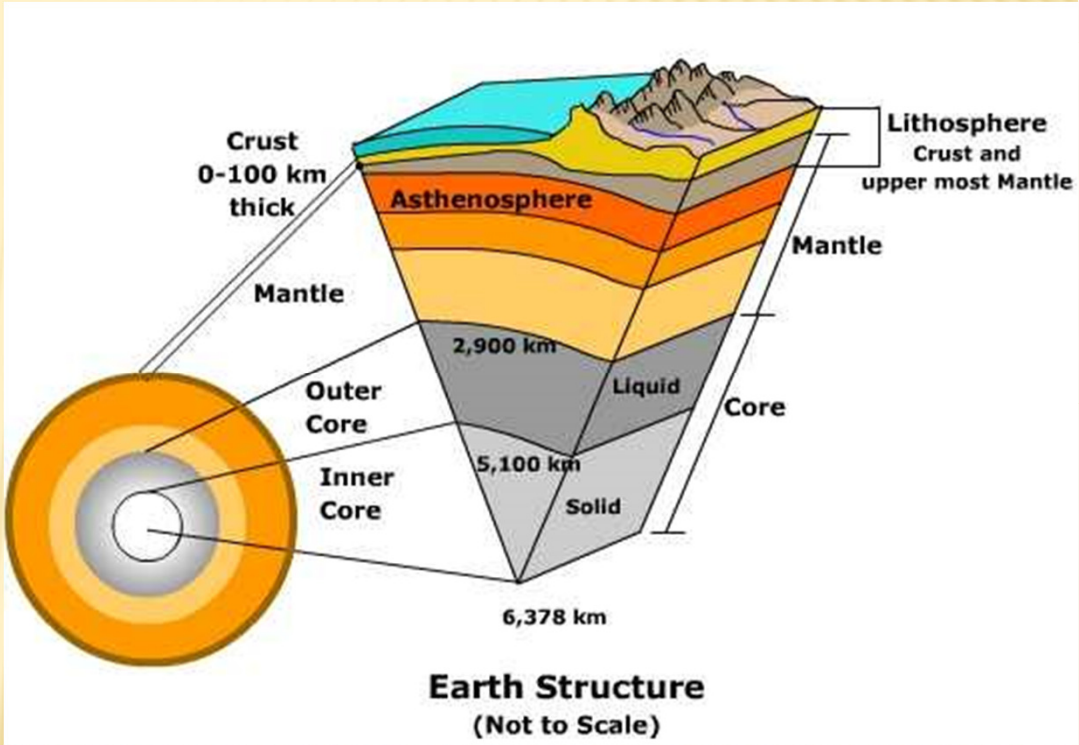
- The Asthenosphere: At a depth varying from about 75 to 125 kilometers, the strong, hard rock of the lithosphere gives way to the weak, plastic asthenosphere.

- The asthenosphere extends from the base of the lithosphere to a depth of about 350 kilometers.



THE EARTH LAYERS

- **The Core**: The core is the innermost of the Earth's layers.
- It is a sphere with a radius of about 3470 kilometers and is composed largely of iron and nickel.
- The outer core is molten because of the high temperature in that region.
- Near its center, the core's temperature is about 6000°C, as hot as the Sun's surface.
- The pressure is greater than 1 million times that of the Earth's atmosphere at sea level.
- The extreme pressure overwhelms the temperature effect and compresses the inner core to a solid.



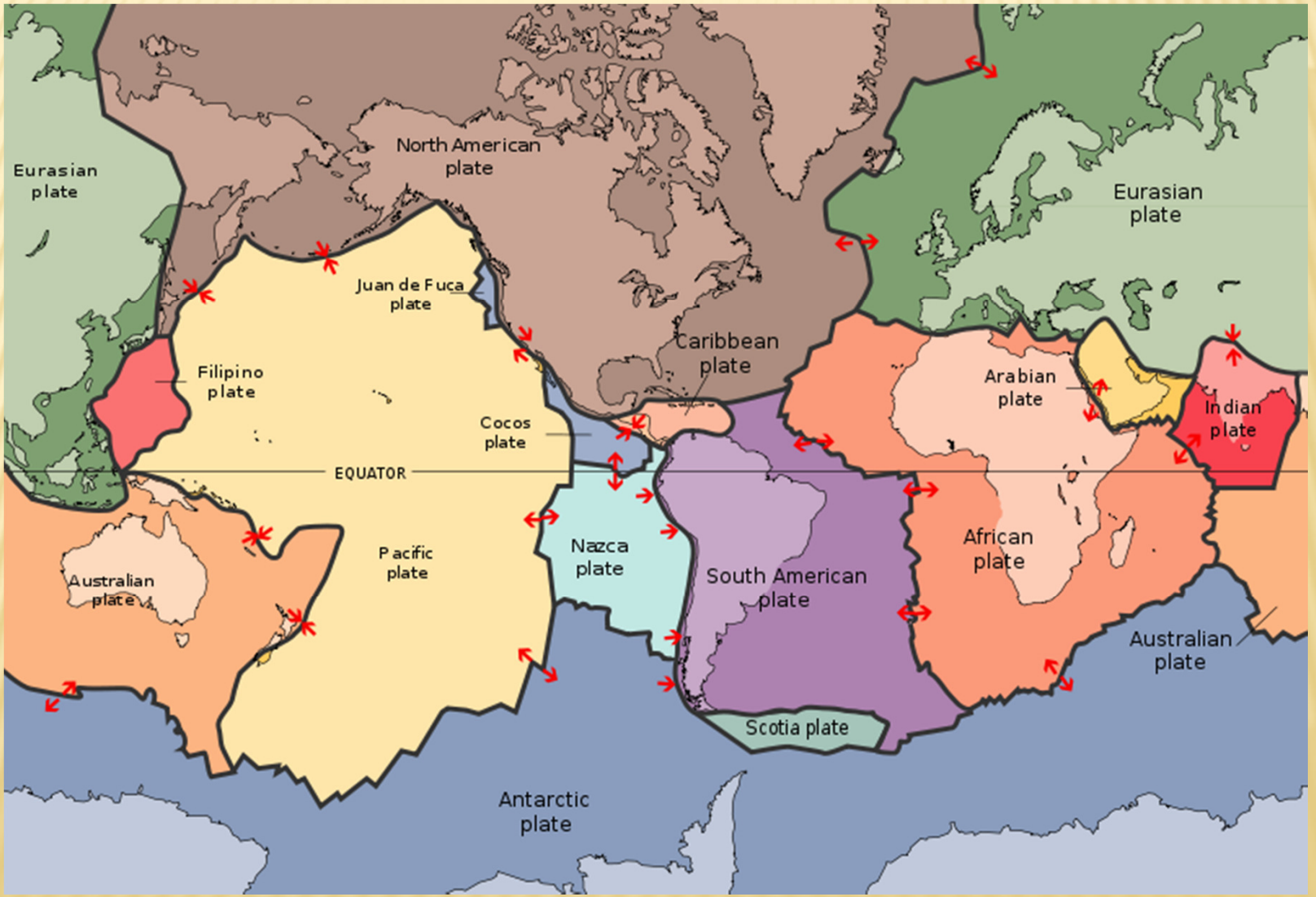
THE EARTH LAYERS

	LAYER	COMPOSITION	DEPTH	PROPERTIES
Crust	Oceanic crust Continental crust	Basalt Granite	5–10 km 20–70 km	Cool, hard, and strong Cool, hard, and strong
Lithosphere	Lithosphere includes the crust and the uppermost portion of the mantle	Varies; the crust and the mantle have different compositions	75–125 km	Cool, hard, and strong
Mantle	Uppermost portion of the mantle included as part of the lithosphere			
	Asthenosphere	Entire mantle is ultramafic rock. Its mineralogy varies with depth	Extends to 350 km	Hot, weak, and plastic, 1% or 2% melted
	Remainder of upper mantle		Extends from 350 to 660 km	Hot, under great pressure, and mechanically strong
	Lower mantle		Extends from 660 to 2900 km	High pressure forms minerals different from those of the upper mantle
Core	Outer core	Iron and nickel	Extends from 2900 to 5150 km	Liquid
	Inner core	Iron and nickel	Extends from 5150 km to the center of the Earth	Solid

PLATES AND PLATE TECTONICS

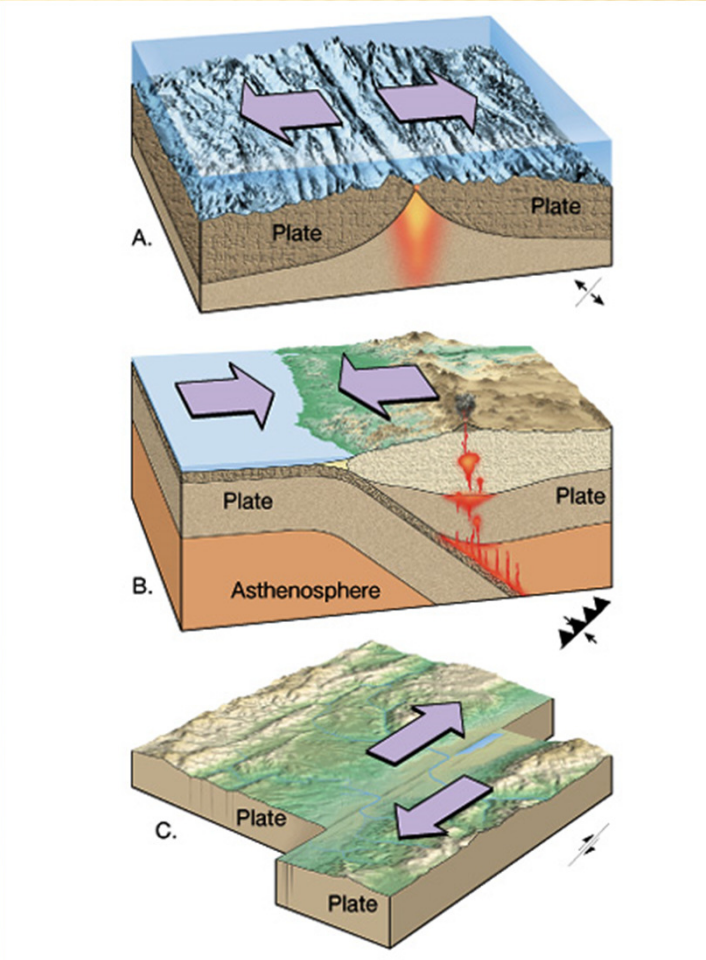
- In most places, the lithosphere is less dense than the asthenosphere. Consequently, it floats on the asthenosphere much as ice floats on water.
- The lithosphere is broken into seven large tectonic plates and several smaller ones.
- The plates move slowly, at rates ranging from less than 1 to about 16 centimeters per year.
- The great forces generated at a plate boundary build mountain ranges and cause volcanic eruptions and earthquakes.
- These processes and events are called tectonic activity.

TECTONIC PLATES

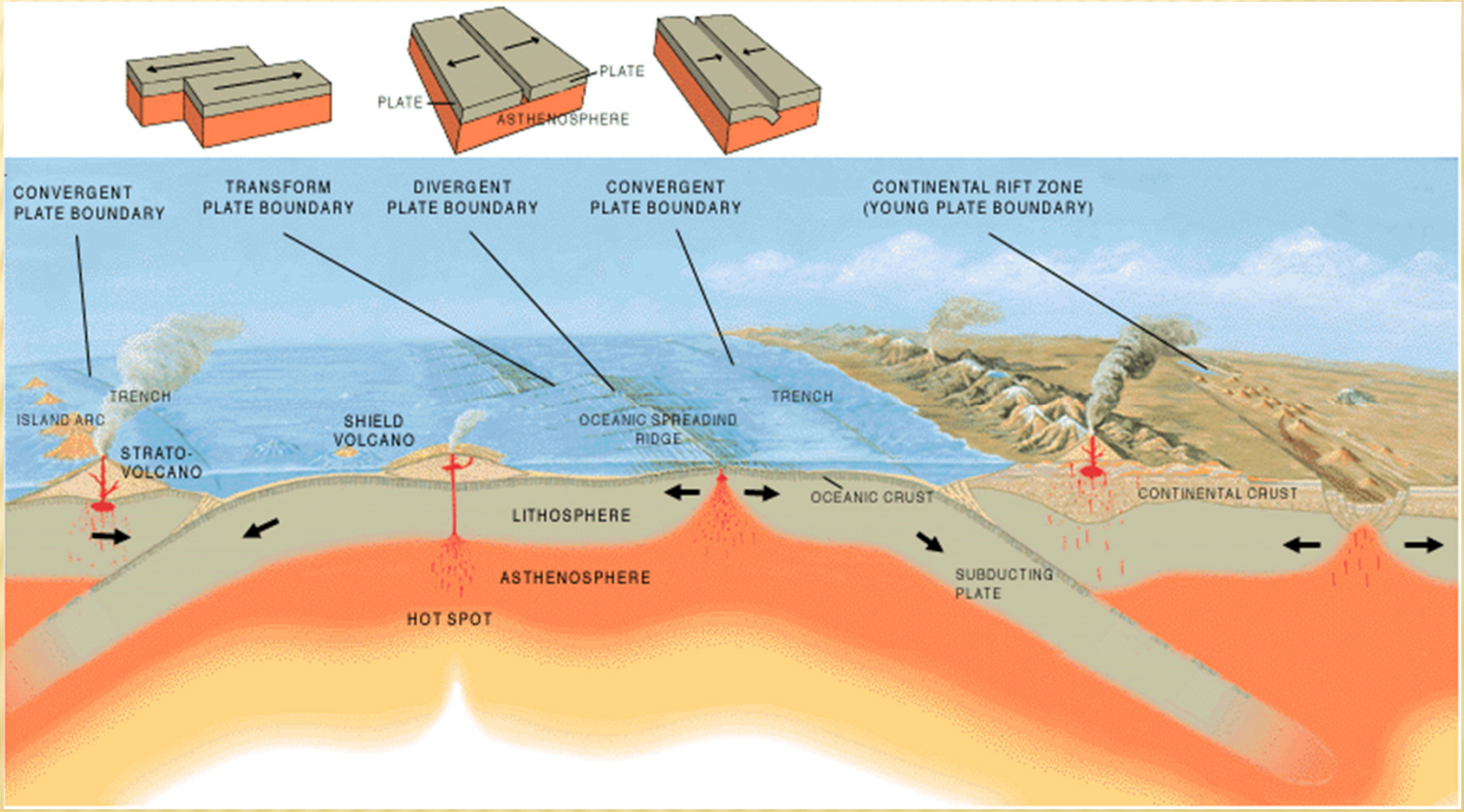


TYPES OF PLATE BOUNDARIES

- Neighboring plates can move relative to one another in three different ways.
- **Divergent boundaries (Constructive)** occur where two plates slide apart from each other. (A)
- **Convergent boundaries (Destructive) (or active margins)** occur where two plates slide towards each other commonly forming either a subduction zone (if one plate moves underneath the other) or a continental collision (if the two plates contain continental crust). (B)
- **Transform boundaries (Conservative)** occur where plates slide or, perhaps more accurately, grind past each other along transform faults. (C)

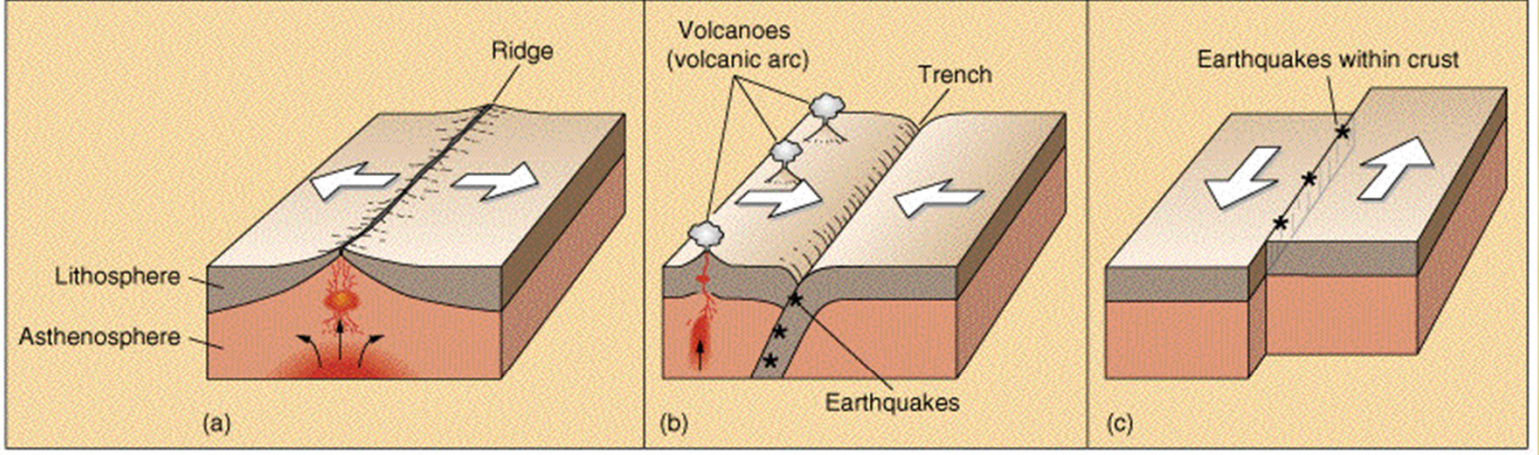


TYPE OF PLATE BOUNDARIES

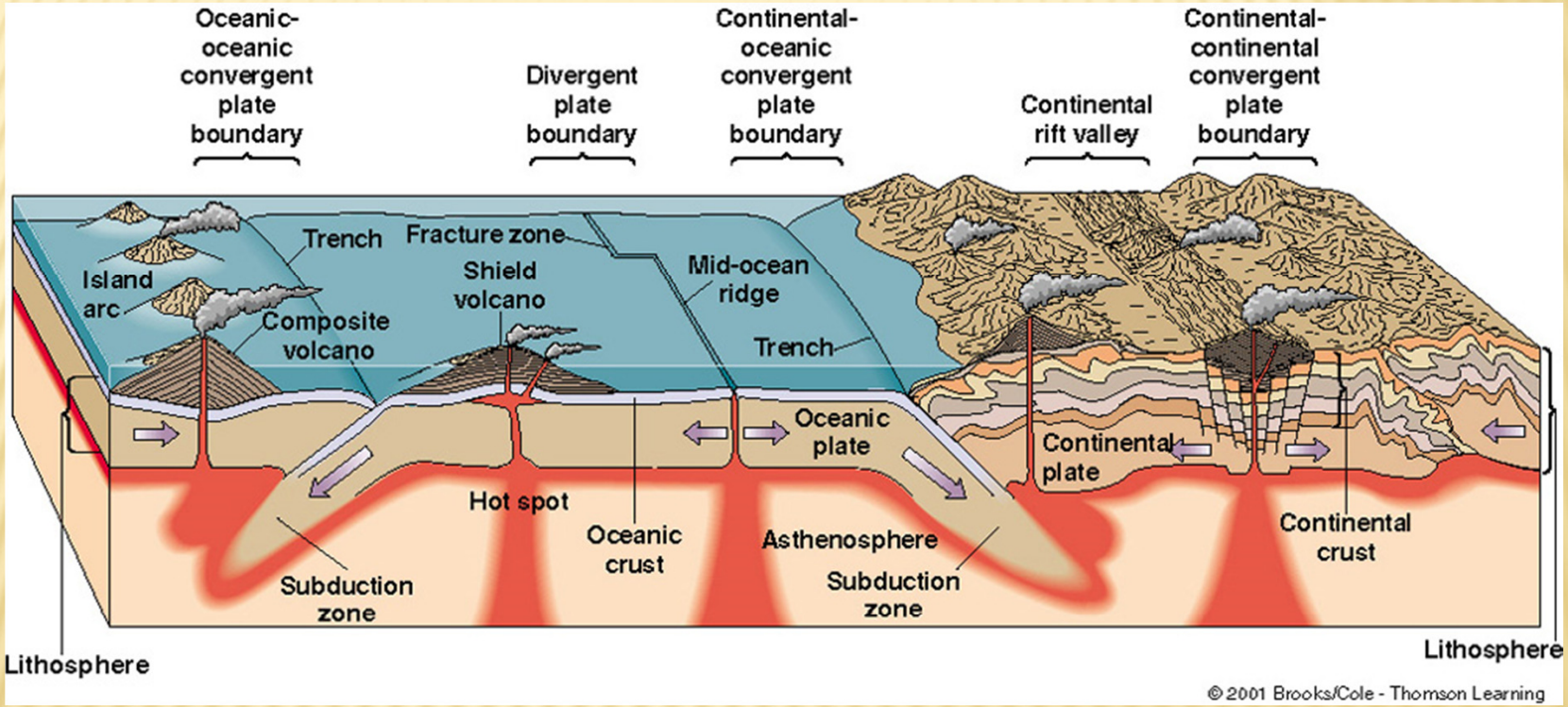


TYPE OF PLATE BOUNDARIES

Type of Margin	Divergent	Convergent	Transform
Motion	Spreading	Subduction	Lateral sliding
Effect	Constructive (oceanic lithosphere created)	Destructive (oceanic lithosphere destroyed)	Conservative (lithosphere neither created or destroyed)
Topography	Ridge/Rift	Trench	No major effect
Volcanic activity?	Yes	Yes	No

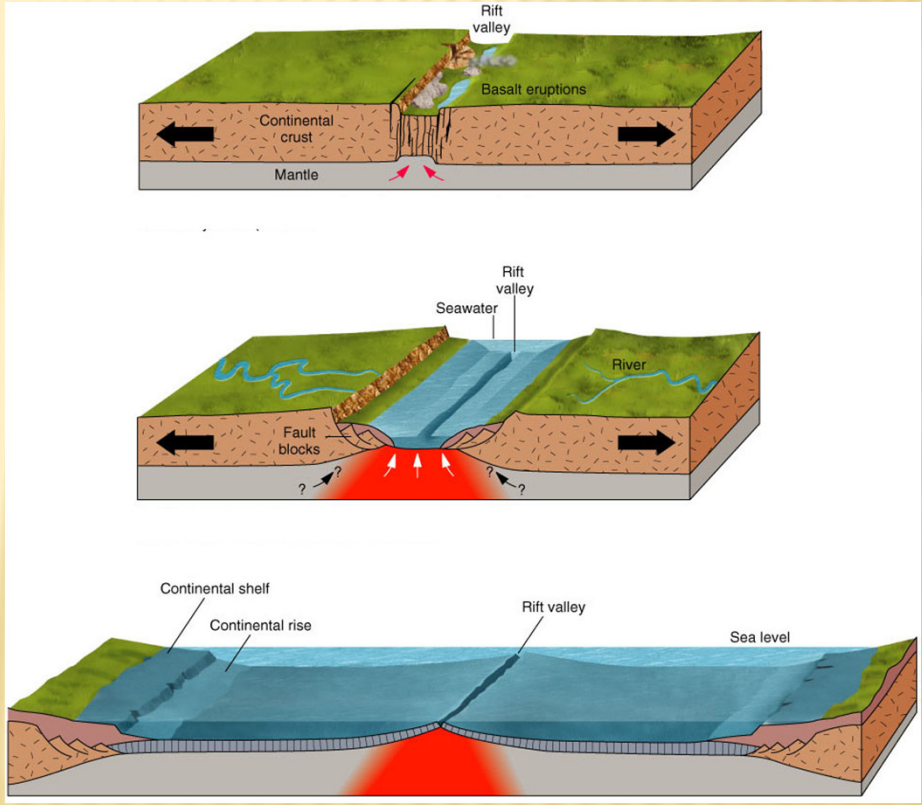


TYPE OF PLATE BOUNDARIES



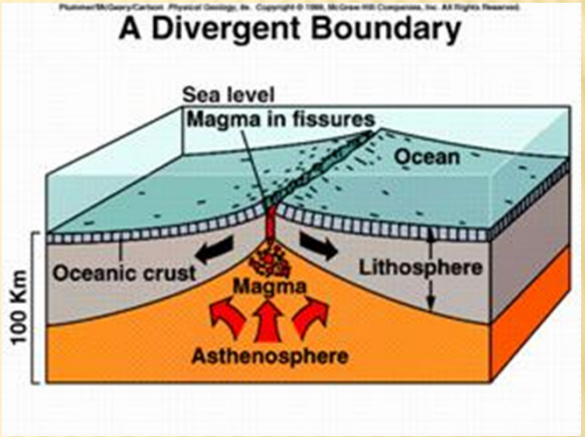
DIVERGENT PLATE BOUNDARIES

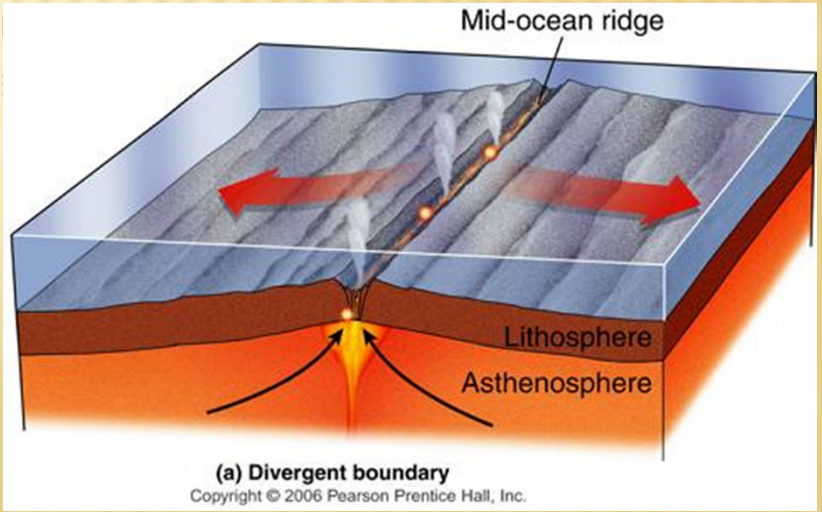
- At a divergent plate boundary, also called a spreading center and a rift zone, two lithospheric plates spread apart.
- The underlying asthenosphere then rises upward to fill the gap between the separating plates.
- As the asthenosphere rises between separating plates, some of it melts to form molten rock called magma.
- Most of this activity occurs beneath the seas because most divergent plate boundaries lie in the ocean basins.



THE MID-OCEANIC RIDGE: RIFTING IN THE OCEANS

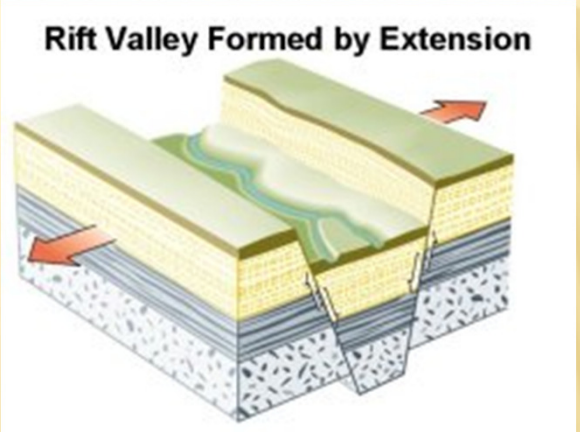
- A spreading center lies directly above the hot, rising asthenosphere.
- The newly formed lithosphere at an oceanic spreading center is hot and therefore of low density.
- As a results, the sea floor at a spreading center floats to a high elevation, forming an undersea mountain chain called the mid-oceanic ridge.

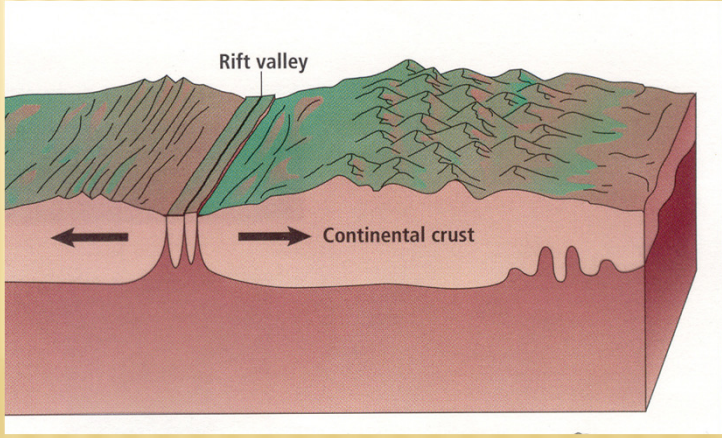




SPLITTING CONTINENTS: RIFTING IN CONTINENTAL CRUST

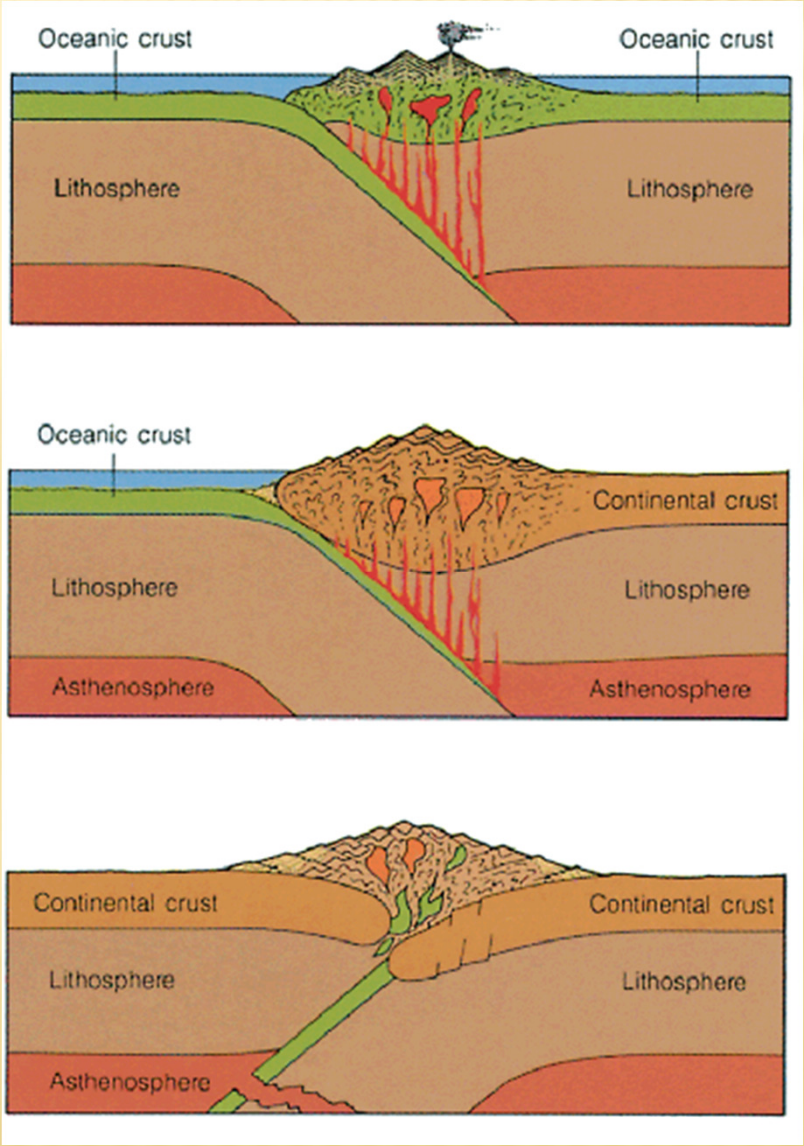
- A divergent plate boundary can rip a continent in half in a process called continental rifting.
- A rift valley develops in a continental rift zone because continental crust stretches, fractures, and sinks as it is pulled apart.
- Continental rifting is now taking place along a zone called the East African rift





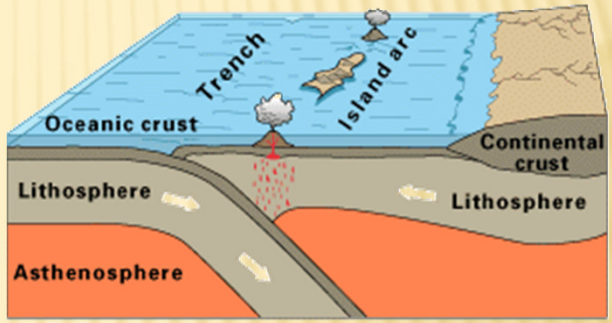
CONVERGENT PLATE BOUNDARIES

- 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.
- 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.

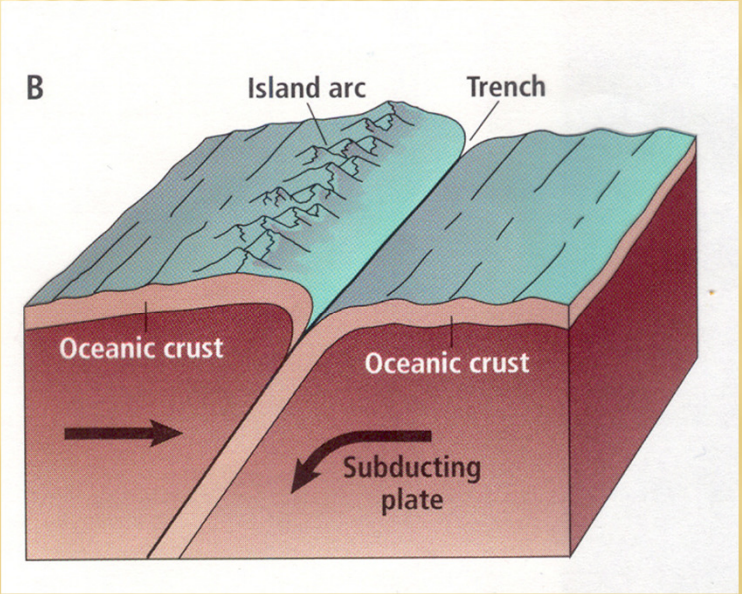


CONVERGENCE OF TWO PLATES CARRYING OCEANIC CRUST

- 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 and island arc and trench. e.g. Japan

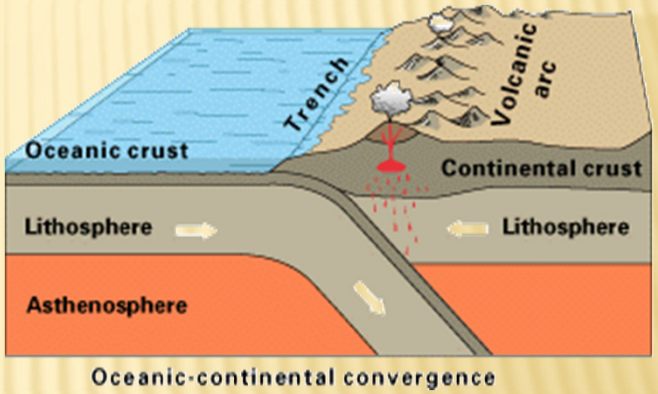


Oceanic-oceanic convergence

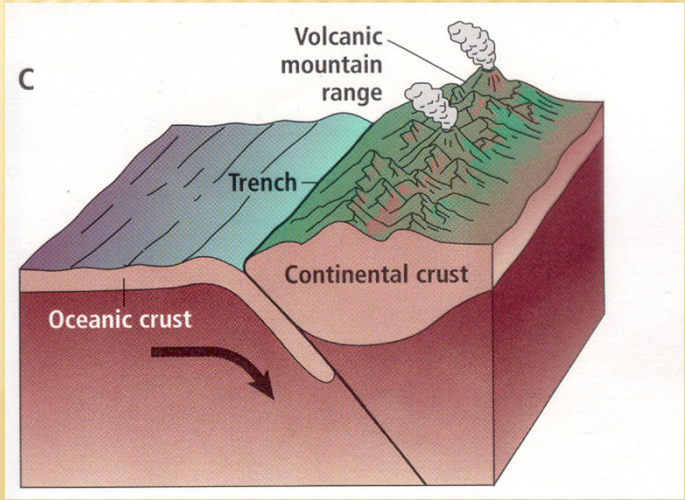


CONVERGENCE OF OCEANIC CRUST WITH CONTINENTAL CRUST

- 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

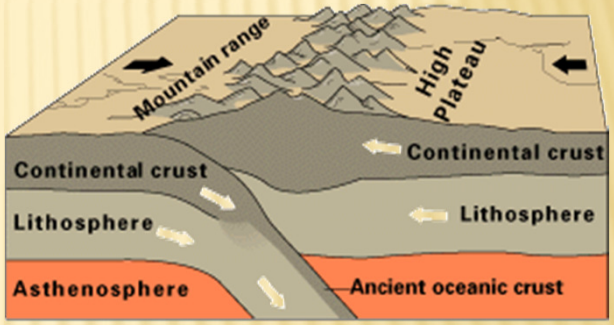


Oceanic-continental convergence

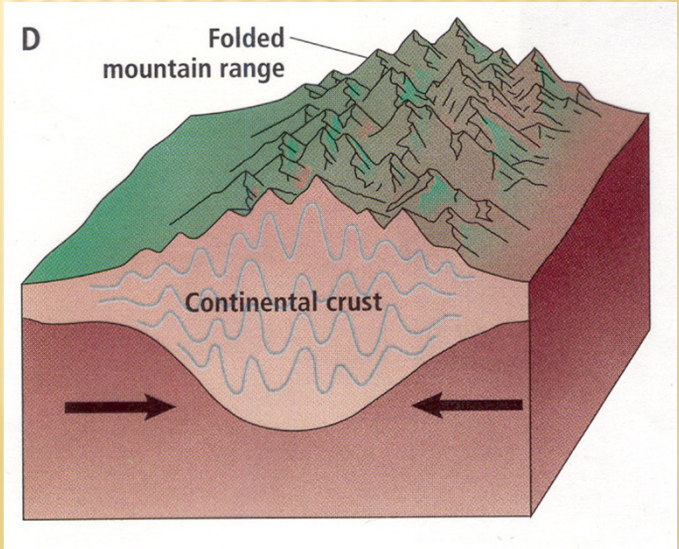


CONVERGENCE OF TWO PLATES CARRYING CONTINENTS

- 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.

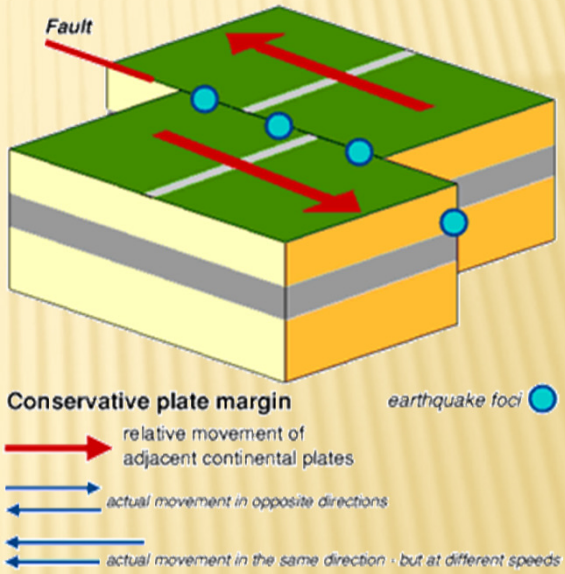


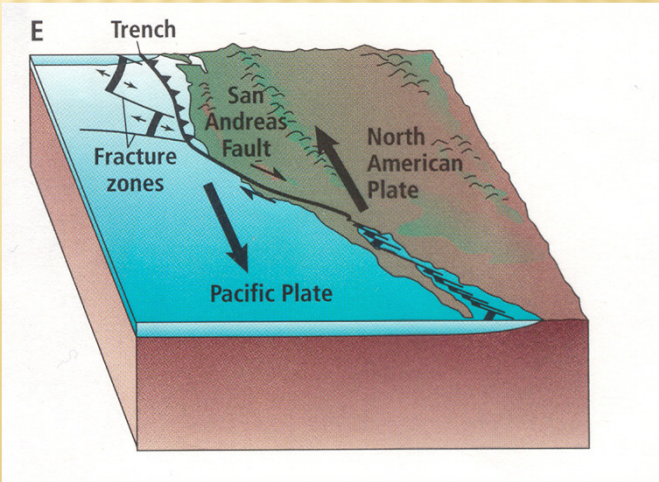
Continental-continental convergence



TRANSFORM PLATE BOUNDARIES

- A transform plate boundary forms where two plates slide horizontally past one another as they move in opposite directions.
- California's San Andreas fault is the transform boundary between the North American plate and the Pacific plate.
- This type of boundary can occur in both oceans and continents.





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.

CONSEQUENCES OF MOVING PLATES

- **Volcanoes**
  - A volcanic eruption occurs where hot magma rises to the Earth's surface.
  - Volcanic eruptions are common at both divergent and convergent plate boundaries.
- **Earthquakes**
  - Earthquakes are common at all three types of plate boundaries, but less common within the interior of a tectonic plate.
  - Quakes concentrate at plate boundaries simply because those boundaries are zones of deep fractures in the lithosphere where one plate slips past another.
- **Mountain Building**
  - Mountains can be formed both at divergent as well as convergent plate margins.
  - Several processes combine to build a mountain chain at a subduction zone.

CONSEQUENCES OF MOVING PLATES

Oceanic Trenches

- An oceanic trench is a long, narrow trough in the sea floor that develops where a subducting plate sinks into the mantle.
- A trench can form wherever subduction occurs—where oceanic crust sinks beneath the edge of a continent, or where it sinks beneath another oceanic plate.
- Trenches are the deepest parts of the ocean basins.
- The deepest point on Earth is in the Mariana trench in the southwestern Pacific Ocean, where the sea floor is as much as 10.9 kilometers below sea level (compared with the average sea-floor depth of about 5 kilometers).

Migrating Continents and Oceans

- Continents migrate over the Earth's surface because they are integral parts of the moving lithospheric plates.
- Measurements of these movements show that North America is now moving away from Europe at about 2.5 centimeters per year, as the mid-Atlantic ridge continues to separate.
- South America is drawing away from Africa at a rate of about 3.5 centimeters per year.
- As the Atlantic Ocean widens, the Pacific is shrinking at the same rate.
- Thus, as continents move, ocean basins open and close over geologic time.

FORCE BEHIND PLATE TECTONICS

- **Mantle convection** may cause plate movement.
- Alternatively, a plate may move because it slides downhill from a spreading center, as its cold leading edge sinks into the mantle and drags the rest of the plate along.
- The concept that the lithosphere floats on the asthenosphere is called **isostasy.**
- When weight such as a glacier is added to or removed from the Earth's surface, the lithosphere sinks or rises.
- This vertical movement in response to changing burdens is called **isostatic adjustment**.