Plate tectonics

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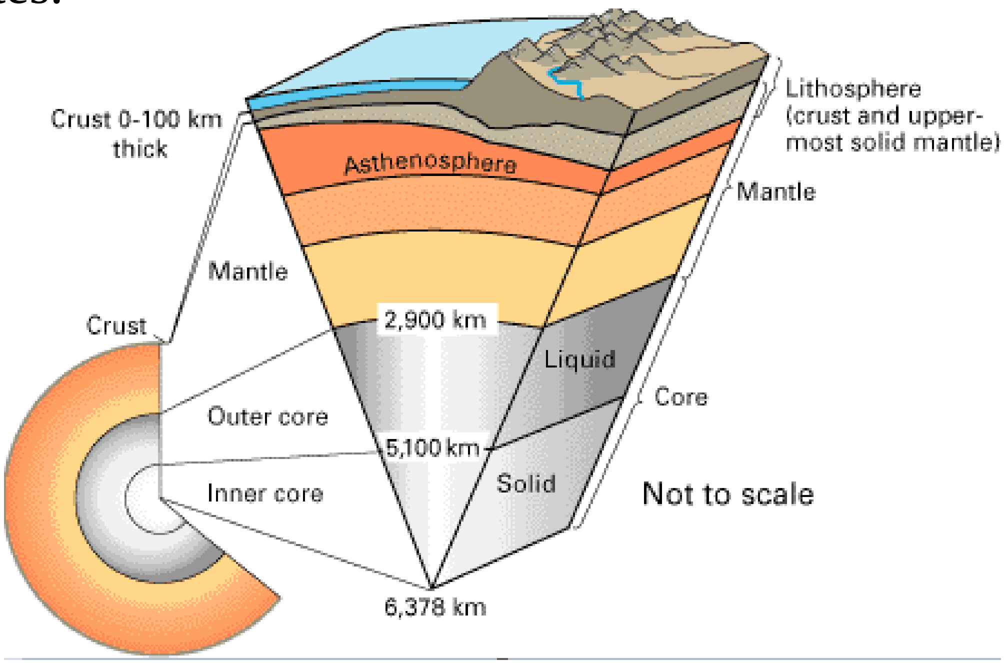
- **Plate tectonics** is a scientific theory which describes the large scale motions of Earth's lithosphere.
- The theory builds on the older concepts of continental drift, developed during the first decades of the 20th century by Alfred Wegener, and seafloor spreading, developed in the 1960s.
- The lithosphere is broken up into what are called **tectonic plates**.
- In the case of Earth, there are currently seven to eight major (depending on how they are defined) and many minor plates.



Major plates

Depending on how they are defined, there are usually seven or eight "major" plates:

1.African Plate

2. Antarctic Plate

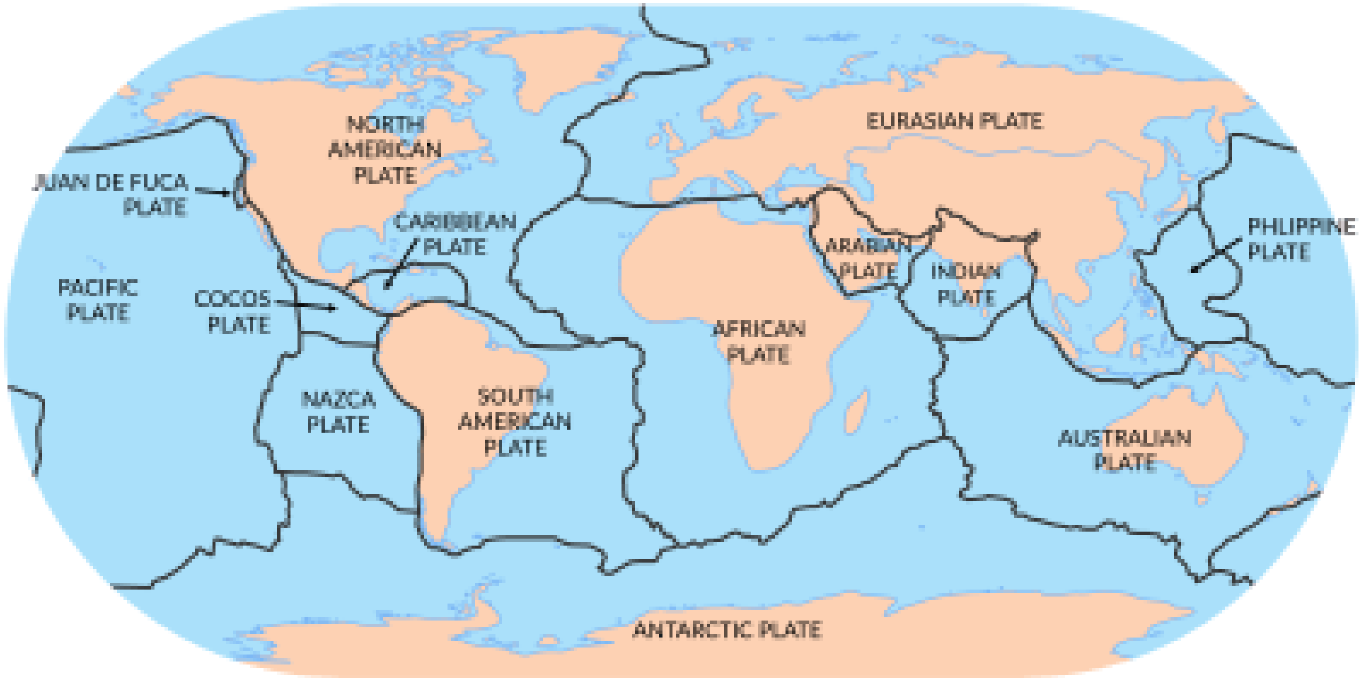
3.Indian-Australian Plate (some times divided into (i) Indian Plate (ii) Australian Plate

4.Eurasian Plate

5.North American Plate

6. South American Plate

7.Eurasian Plate



- There are about 20 nos of smaller plates, the seven largest of which are:

Arabian Plate

Caribbean Plate

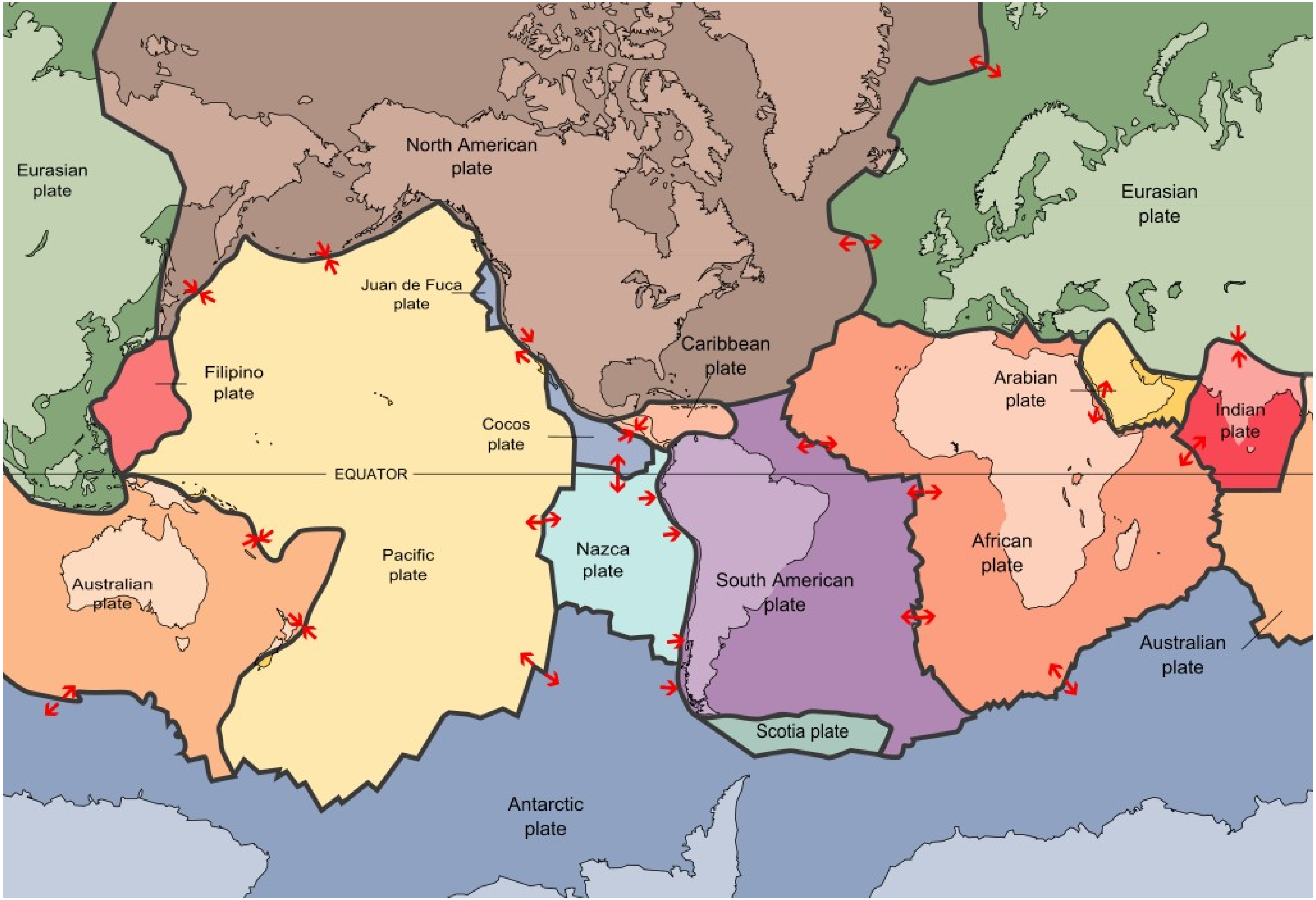
Juan de Fuca Plate

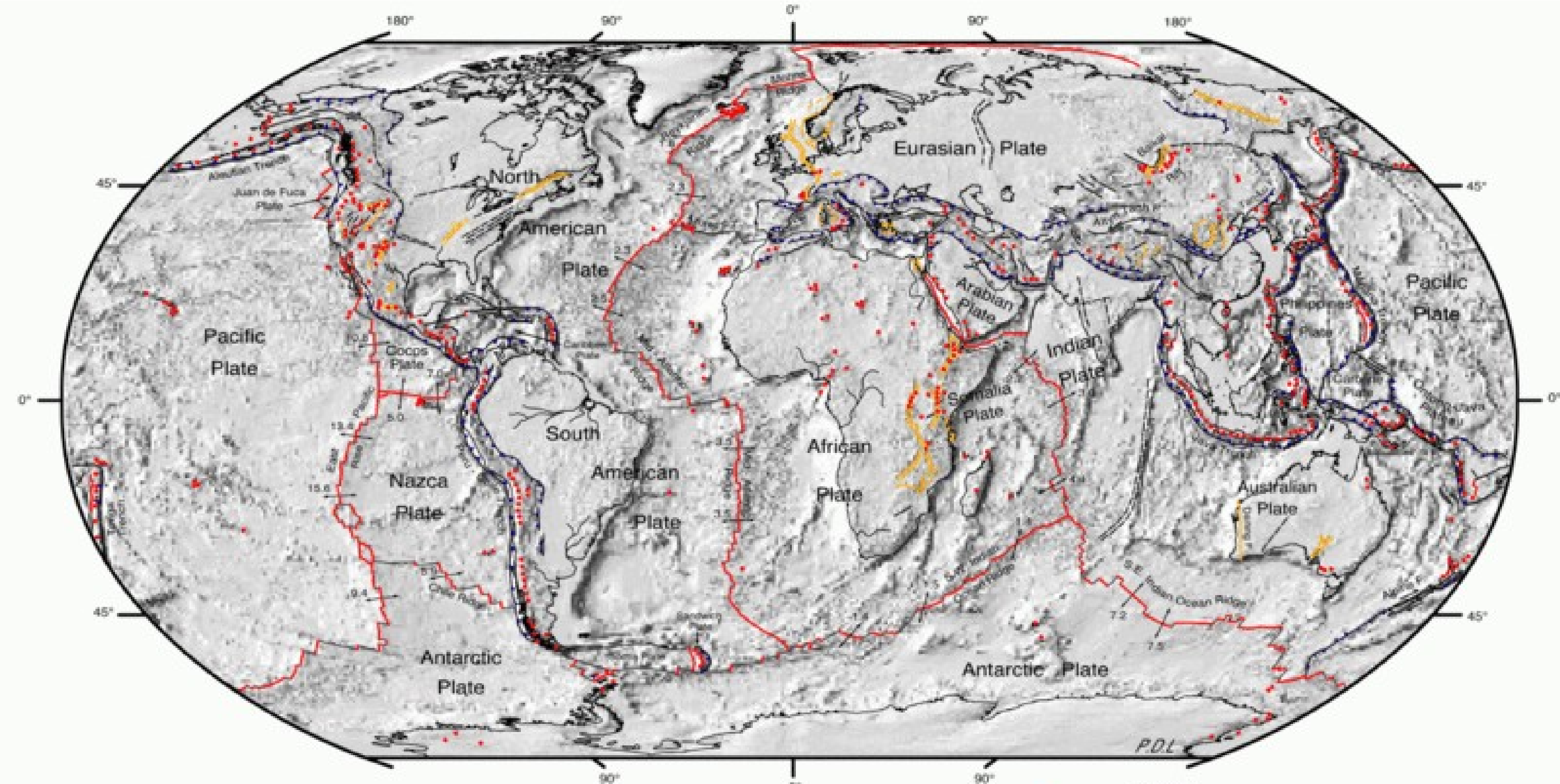
Cocos Plate

Nazca Plate

Philippine Sea Plate

Scotia Plate


Eurasian plate
North American plate
Eurasian plate
Juan de Fuca plate
Caribbean plate
Filipino plate
Arabian plate
Indian plate
Cocos plate
EQUATOR
Nazca plate
Pacific plate
African plate
Australian plate
South American plate
Australian plate
Scotia plate
Antarctic plate



DIGITAL TECTONIC ACTIVITY MAP OF THE EARTH

Tectonism and Volcanism of the Last One Million Years

DTAM

NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

Robinson Projection
October 1998

LEGEND

Actively-spreading ridges and transform faults

Total spreading rate, cm/year, NUVEL-1 model (DeMets et al., Geophys. J. International, 101, 425, 1990)

Major active fault or fault zone; dashed where nature, location, or activity uncertain

Normal fault or rift; hachures on downthrown side

Reverse fault (overthrust, subduction zones); generalized; barbs on upthrown side

Volcanic centers active within the last one million years; generalized. Minor basaltic centers and seamounts omitted.

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- The lithospheric plates ride on the asthenosphere.

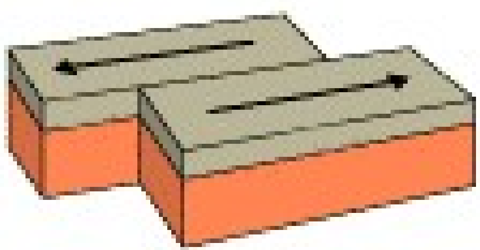
- These plates move in relation to one another at one of three types of plate boundaries:
- (i) Convergent, or collisional boundaries

- (ii) Divergent boundaries, also called spreading centres; and

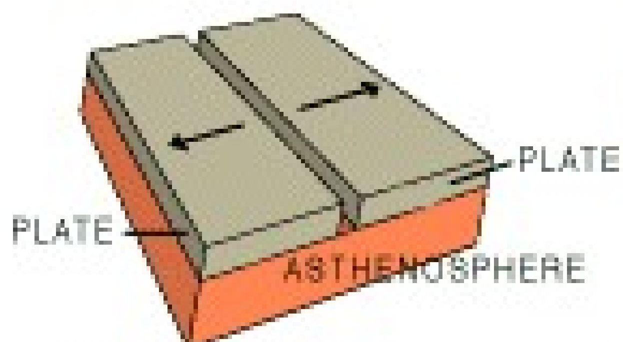
- (iii) Transform fault boundaries.

- Earthquakes, volcanic activity, mountain-building, and oceanic trench formation occur along plate boundaries.

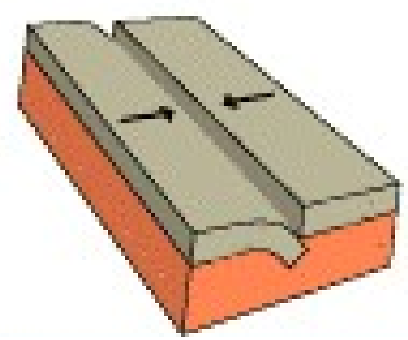
- The lateral relative movement of the plates varies, though it is typically 0-100 mm annually.



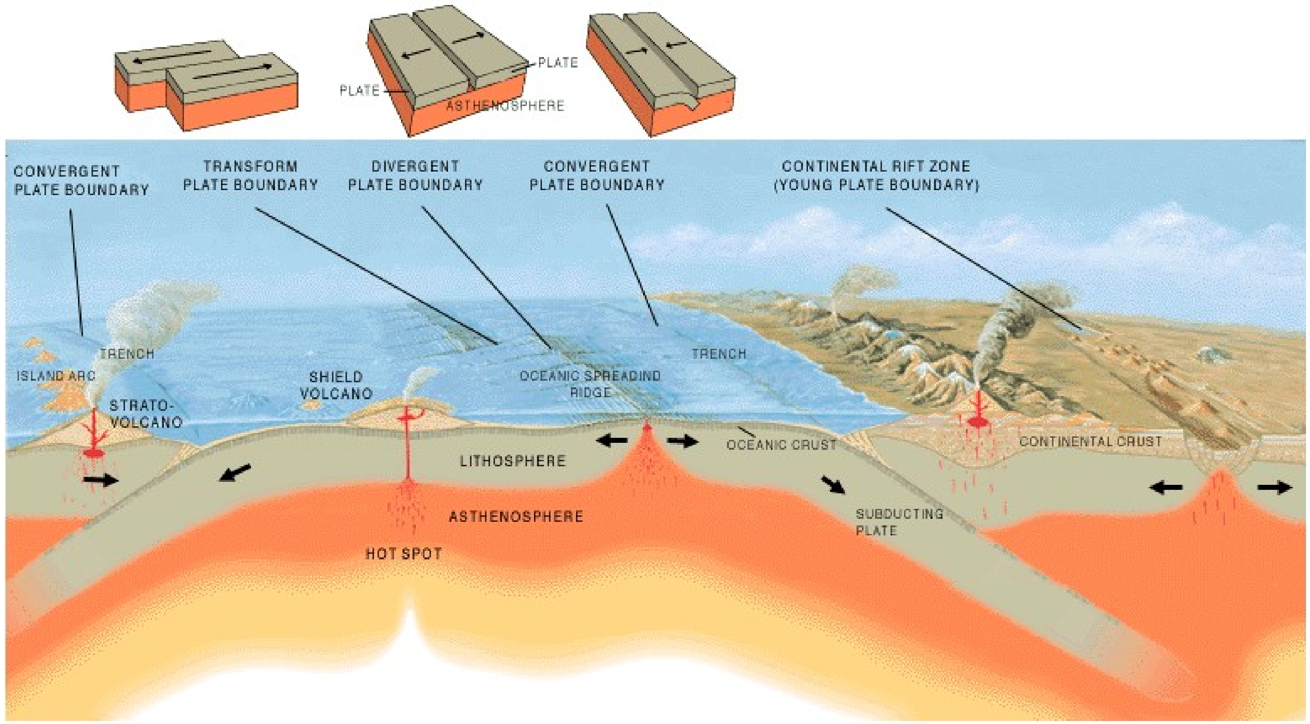
(Transform fault boundaries)



(Divergent boundaries)



(Convergent, or collisional boundaries)



(The Three types of plate boundary)

- Tectonic plates are able to move because the Earth's lithosphere has a higher strength and lower density than the underlying asthenosphere.

- Their movement is thought to be driven by the motion of hot material in the mantle.

- Lateral density variations in the mantle result in convection, which is transferred into tectonic plate motion through some combination of drag, downward suction at the subduction zones, and variations in topography and density of the crust that result in differences in gravitational forces.

Key principles

- The outer layers of the Earth are divided into lithosphere and asthenosphere.

- This is based on differences in mechanical properties and in the method for the transfer of heat.

- Mechanically, the lithosphere is cooler and more rigid, while the asthenosphere is hotter and flows more easily.

- In terms of heat transfer, the lithosphere loses heat by conduction whereas the asthenosphere also transfers heat by convection and has a nearly adiabatic temperature gradient.

- The key principle of plate tectonics is that the lithosphere exists as separate and distinct *tectonic plates*, which ride on the fluid-like (visco-elastic solid) asthenosphere.

- Plate motions range up to a typical 10–40 mm/a (Mid- Atlantic Ridge; about as fast as fingernails grow), to about 160 mm/a (Nazca Plate; about as fast as hair grows).

- Tectonic plates consist of lithospheric mantle overlain by either of two types of crustal material: oceanic crust (in older texts called *sima* from silicon and magnesium) and continental crust (*sial* from silicon and aluminium).

- Average oceanic lithosphere is typically 100 km thick; its thickness is a function of its age: as time passes, it conductively cools and becomes thicker.

- Because it is formed at mid-ocean ridges and spreads outwards, its thickness is therefore a function of its distance from the mid-ocean ridge where it was formed.
- For a typical distance oceanic lithosphere must travel before being subducted, the thickness varies ~6km thick at mid-ocean ridges to greater than 100 km at subduction zones; for shorter or longer distances, the subduction zone (and therefore also the mean) thickness becomes smaller or larger, respectively.

- The location where two plates meet is called a *plate boundary*, and plate boundaries are commonly associated with geological events such as earthquakes and the creation of topographic features such as mountains, volcanoes, mid-ocean ridges, and oceanic trenches.

- The majority of the world's active volcanoes occur along plate boundaries, with the Pacific Plate's Ring of Fire being most active and most widely known.

- These boundaries are discussed in further detail below.

- Tectonic plates can include continental crust or oceanic crust, and many plates contain both.
- For example, the African Plate includes the continent and parts of the floor of the Atlantic and Indian Oceans.

- The distinction between oceanic crust and continental crust is based on their modes of formation.

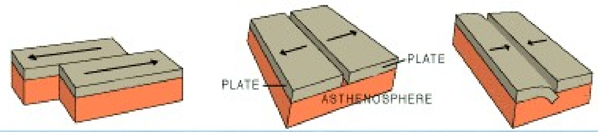
- Oceanic crust is formed at sea-floor spreading centres, and continental crust is formed through arc volcanism and accretion of terranes through tectonic processes;

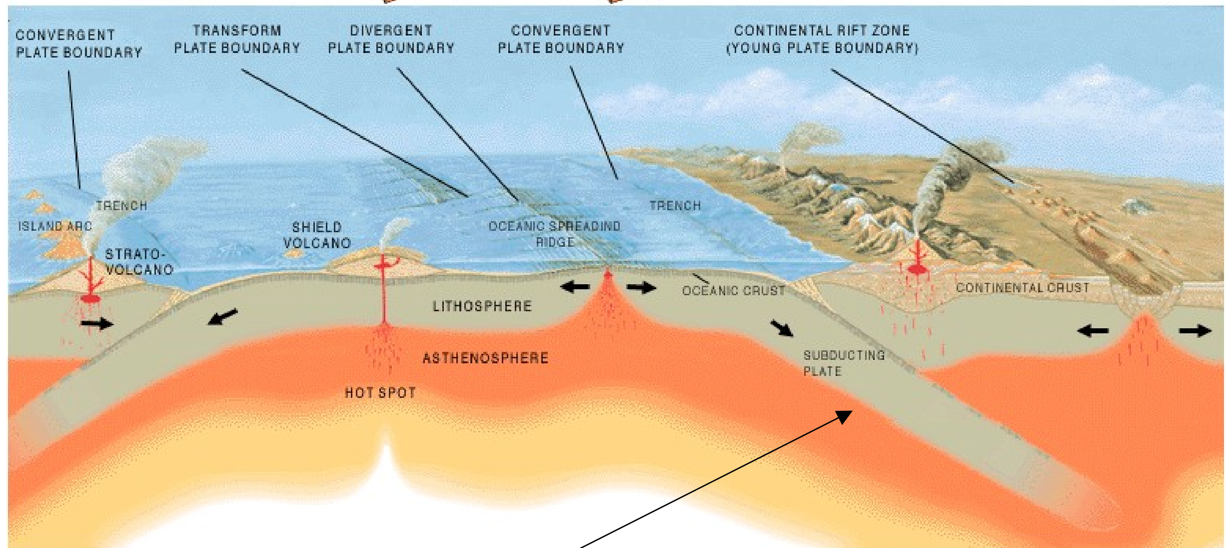
- Oceanic crust is also denser than continental crust owing to their different compositions.

- Oceanic crust is denser because it has less silicon and more heavier elements ("mafic") than continental crust ("felsic").

- As a result of this density stratification, oceanic crust generally lies below sea level (for example most of the Pacific Plate), while the continental crust buoyantly projects above sea level.

Types of plate boundaries

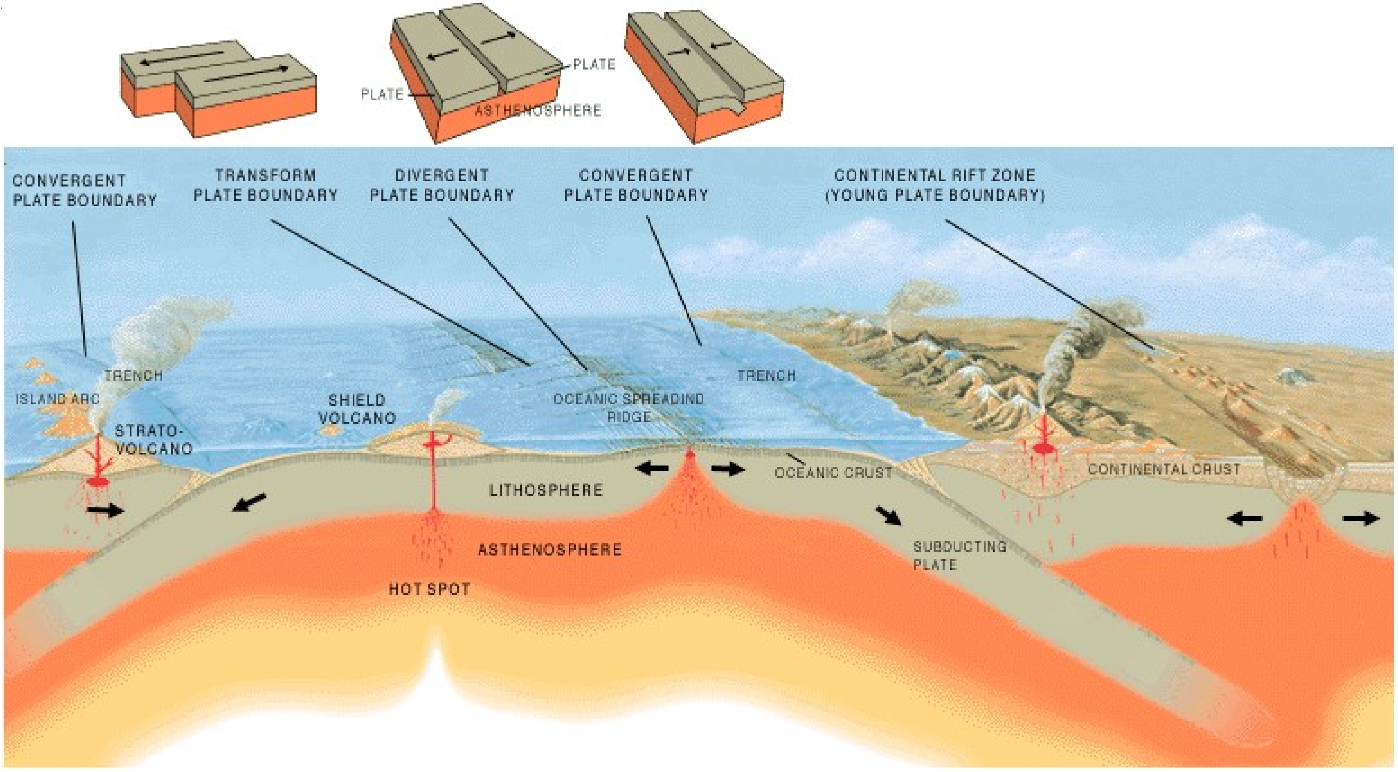


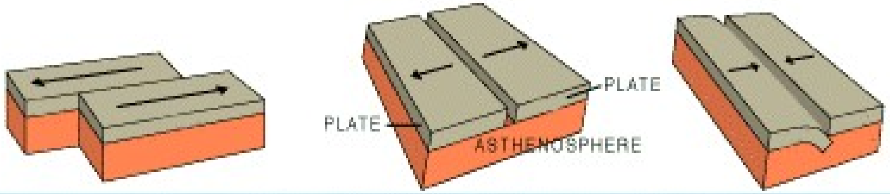


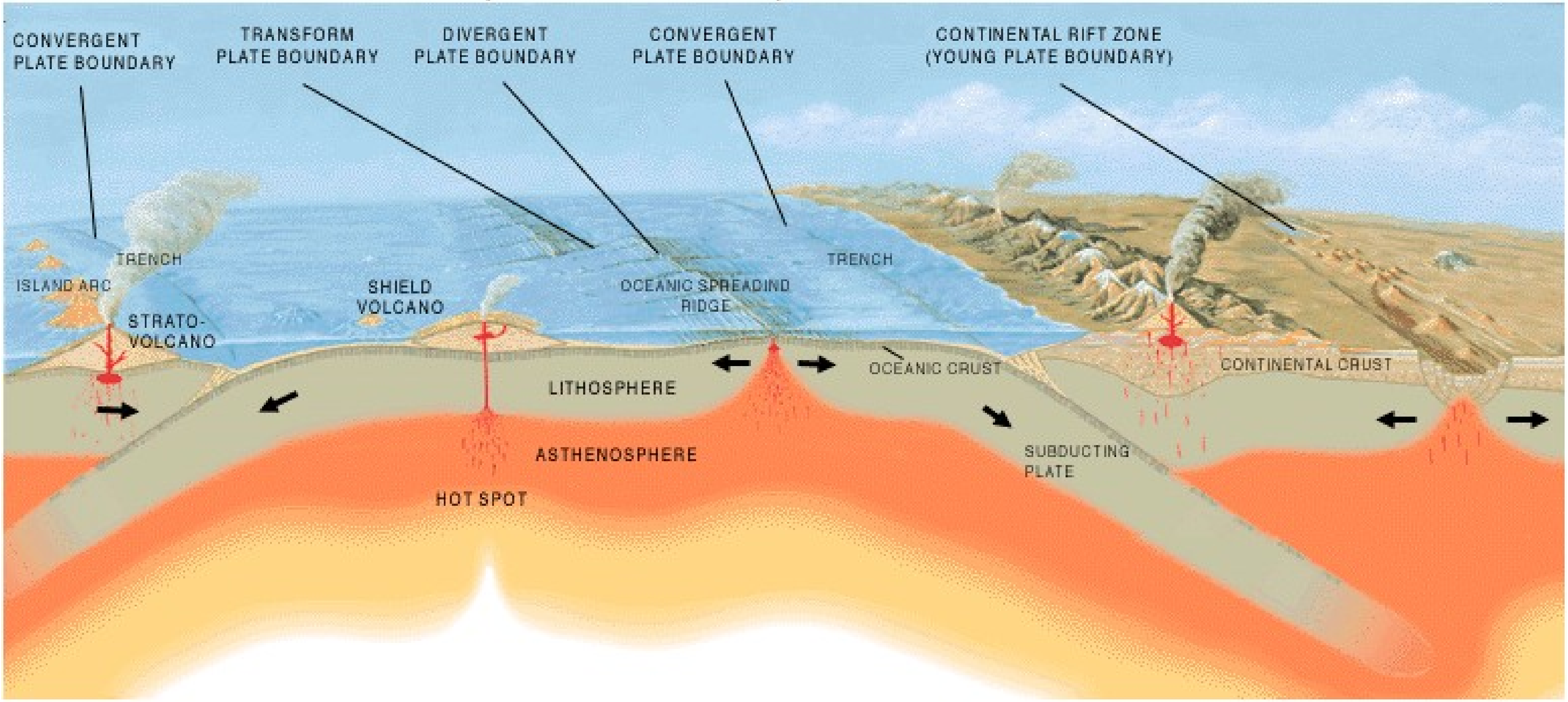
3- Types

- *(i)* ***Convergent boundaries* (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).
- Deep marine trenches are typically associated with subduction zones.
- The subducting slab contains many hydrous minerals, which release their water on heating; this water then causes the mantle to melt, producing volcanism.
- Examples of this are the Andes mountain range in South America and the Japanese island arc.

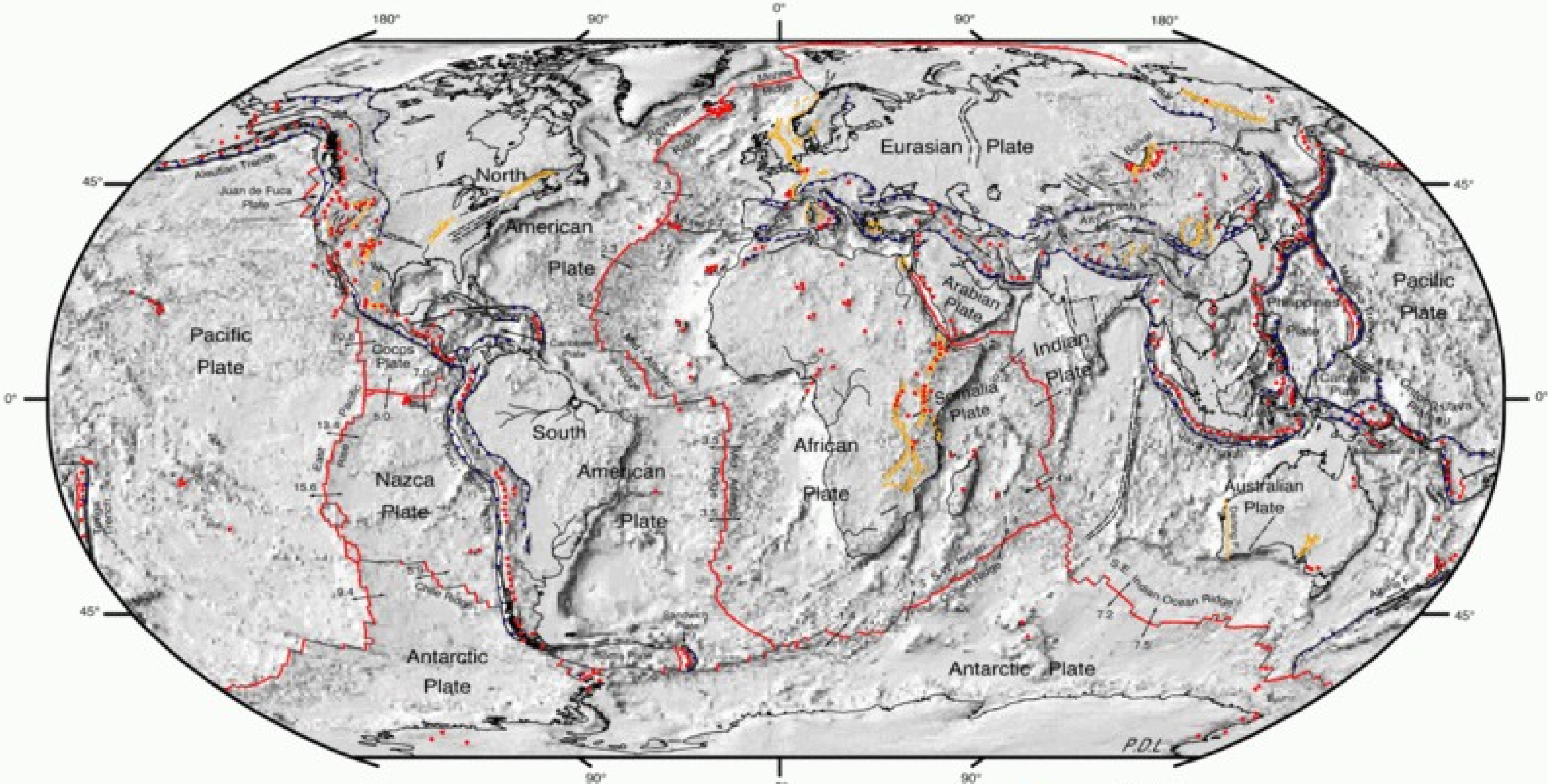
- *(ii) Divergent boundaries* occur where two plates slide apart from each other. Mid-ocean ridges (e.g., Mid-Atlantic Ridge) and active zones of rifting (such as Africa's Great Rift Valley) are both examples of divergent boundaries.
- *(iii) Transform boundaries* occur where plates slide or, perhaps more accurately, grind past each other along transform faults. The relative motion of the two plates is either sinistral (left side toward the observer) or dextral (right side toward the observer).
- The San Andreas Fault in California is an example of a transform boundary exhibiting dextral motion







(Three types of plate boundary)



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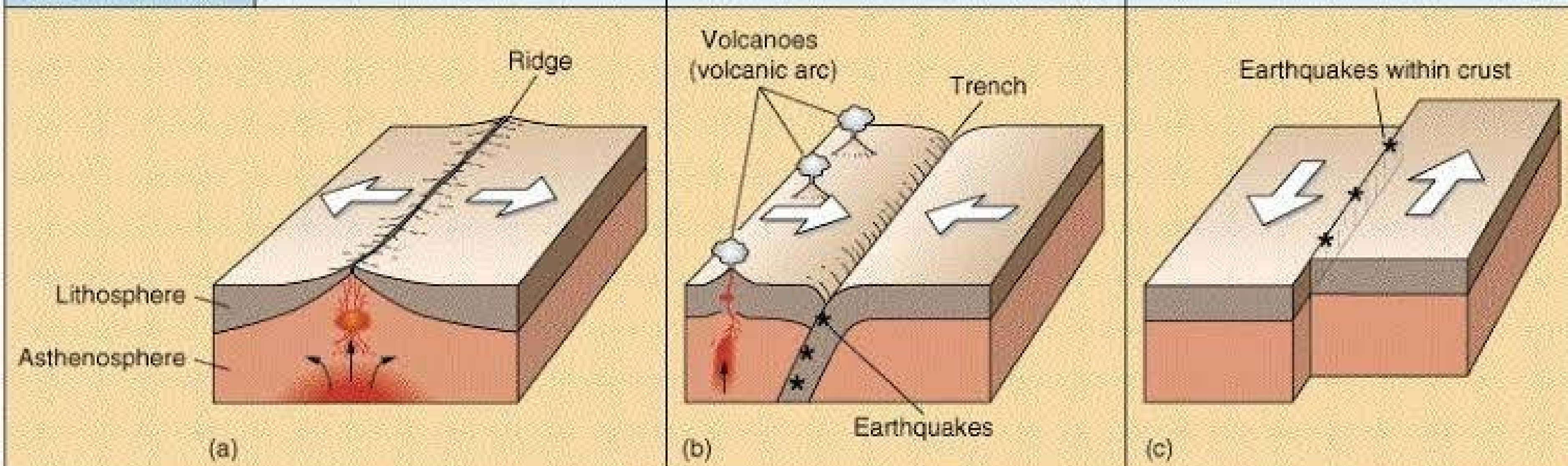
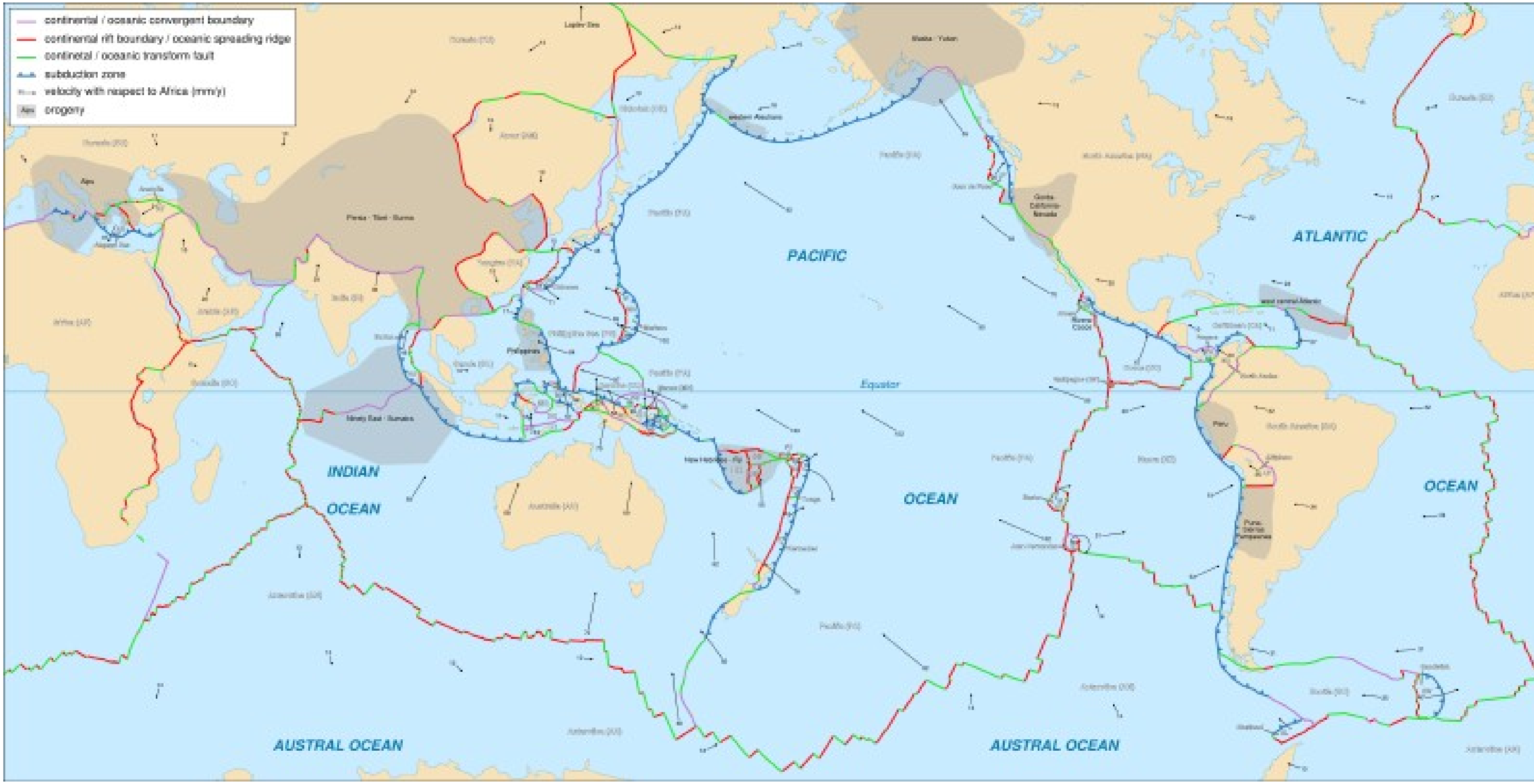
Type of Margin	Divergent	Convergent	Transform
Motion	Spreading	Subduction	Lateral sliding
Effect	Constructive (oceanic lithosphere created)	Destructive (oceanic lithosphere destroyed)	Conservative (lithosphere neither created or destroyed)
Topography	Ridge/Rift	Trench	No major effect
Volcanic activity?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





Detailed map showing the tectonic plates with their movement vectors.

Driving forces of plate motion:

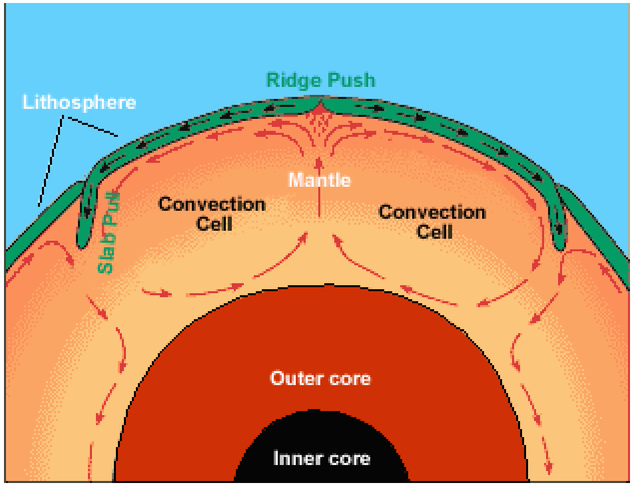
- **The driving forces that are advocated at the moment, can be divided in three categories:**

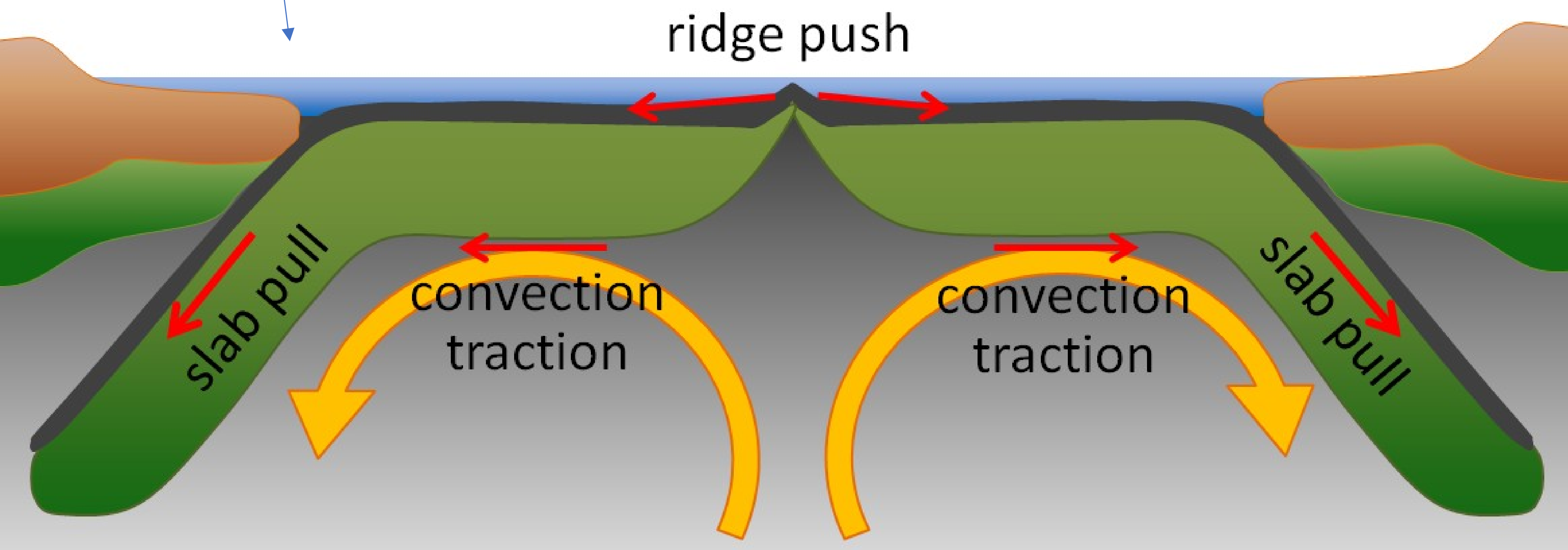
  (i) Mantle Convection related

  (ii) Gravity related

  and

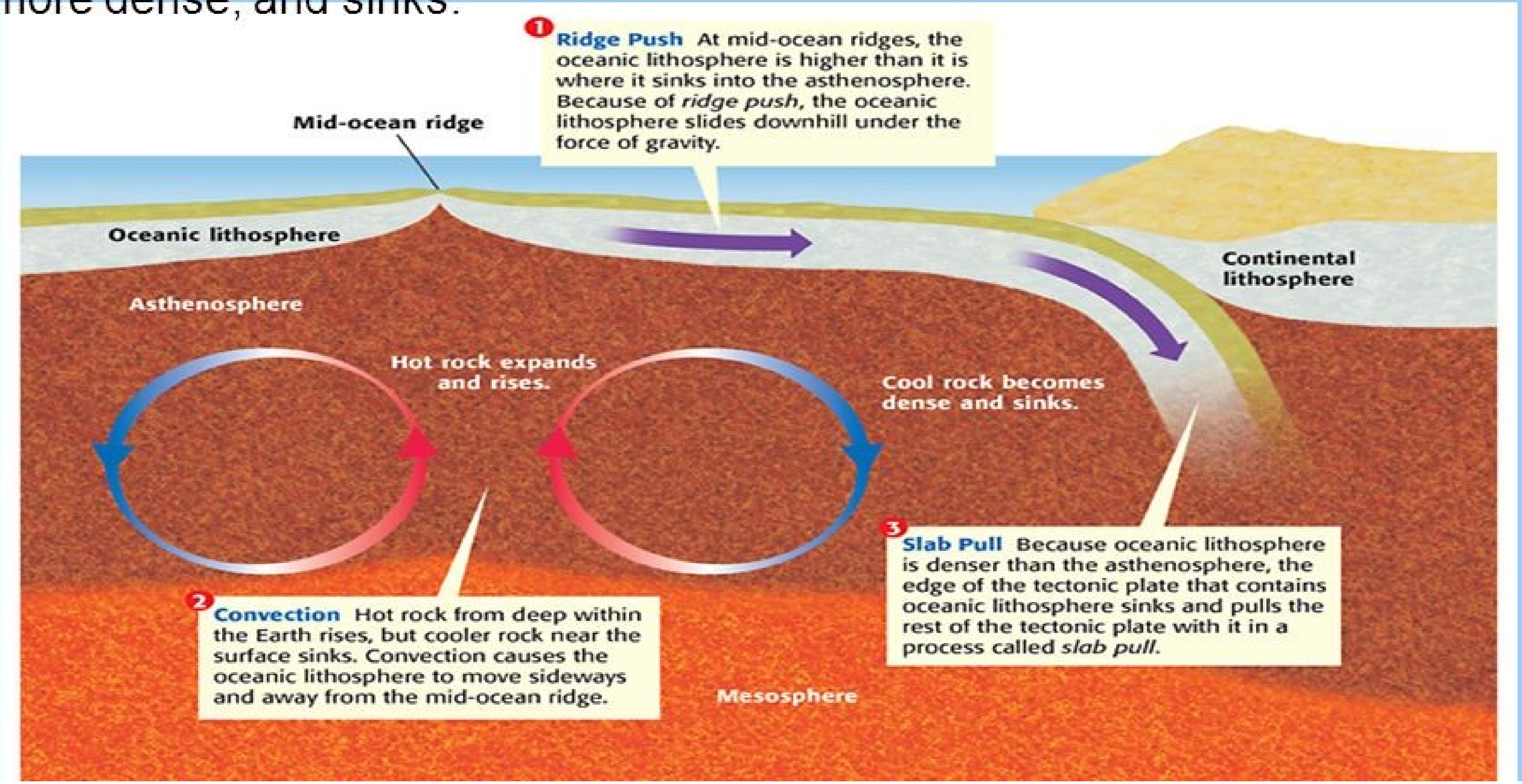
  (iii) Earth Rotation related.

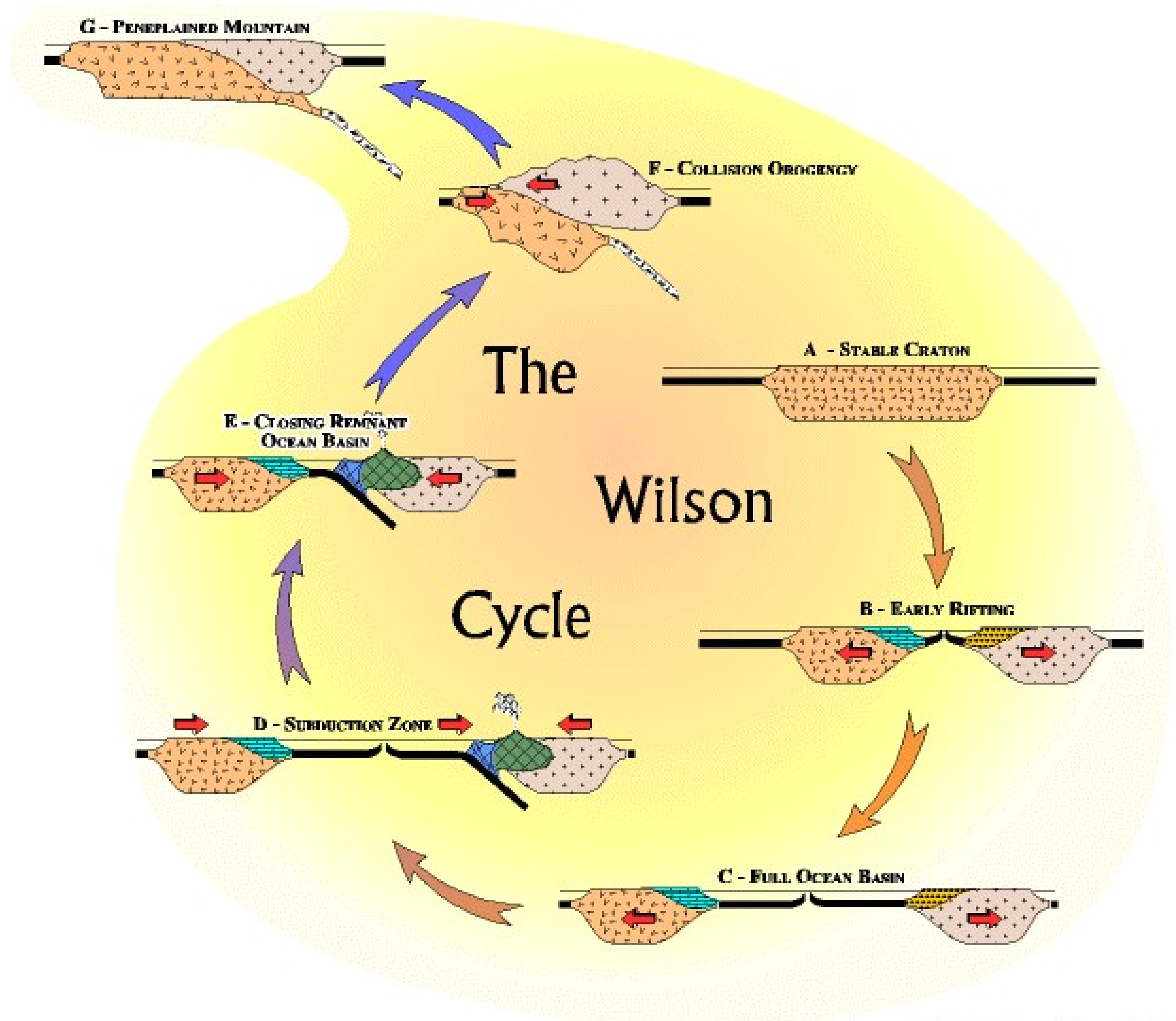




Possible Causes of Tectonic Plate Motion p. 110

What causes the motion of tectonic plates? Remember that the solid rock of the asthenosphere flows very slowly. this movement occurs because of changes in density within the asthenosphere. These density changes are caused by the outward flow of thermal energy from deep within the Earth. When rock is heated, it expands, becomes less dense, and tends to rise to the surface of the Earth. As the rock gets near the surface, it cools, becomes more dense, and sinks.

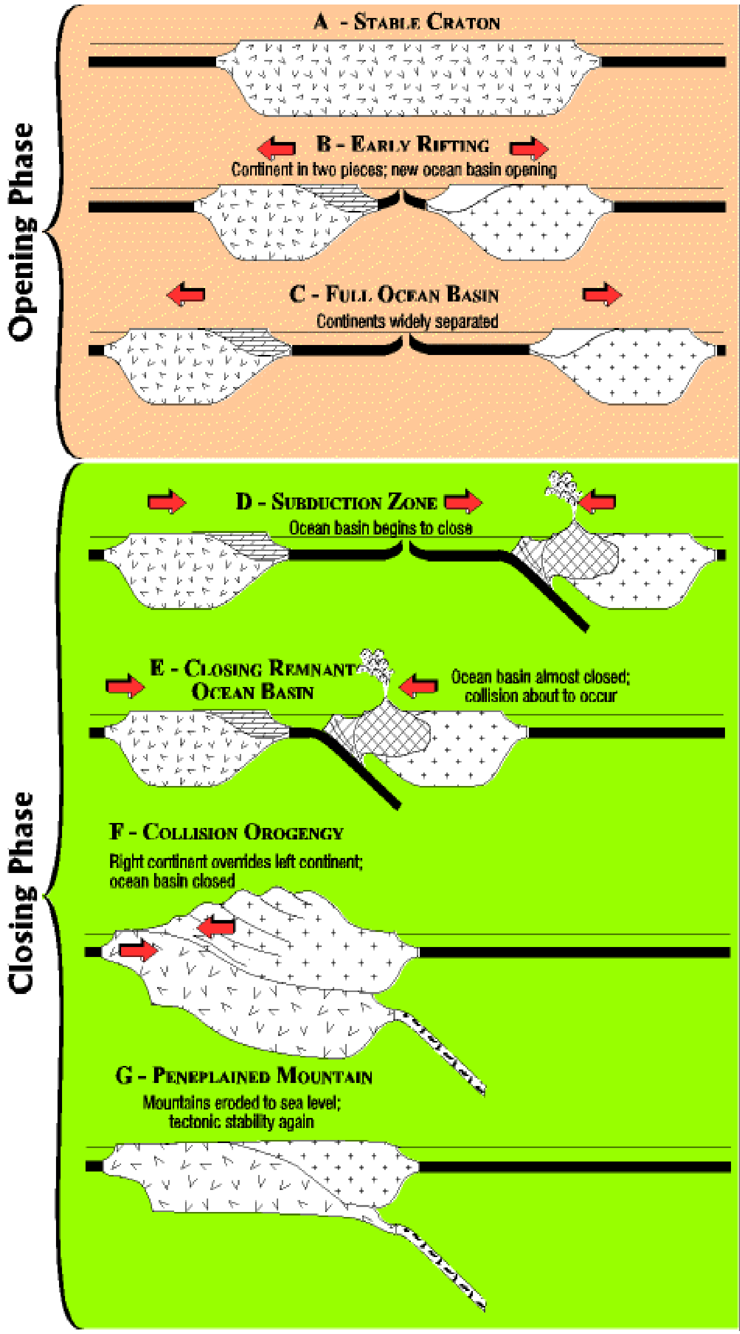




http://geollab.jmu.edu/Fichter/Wilson/wilsoncircl.html

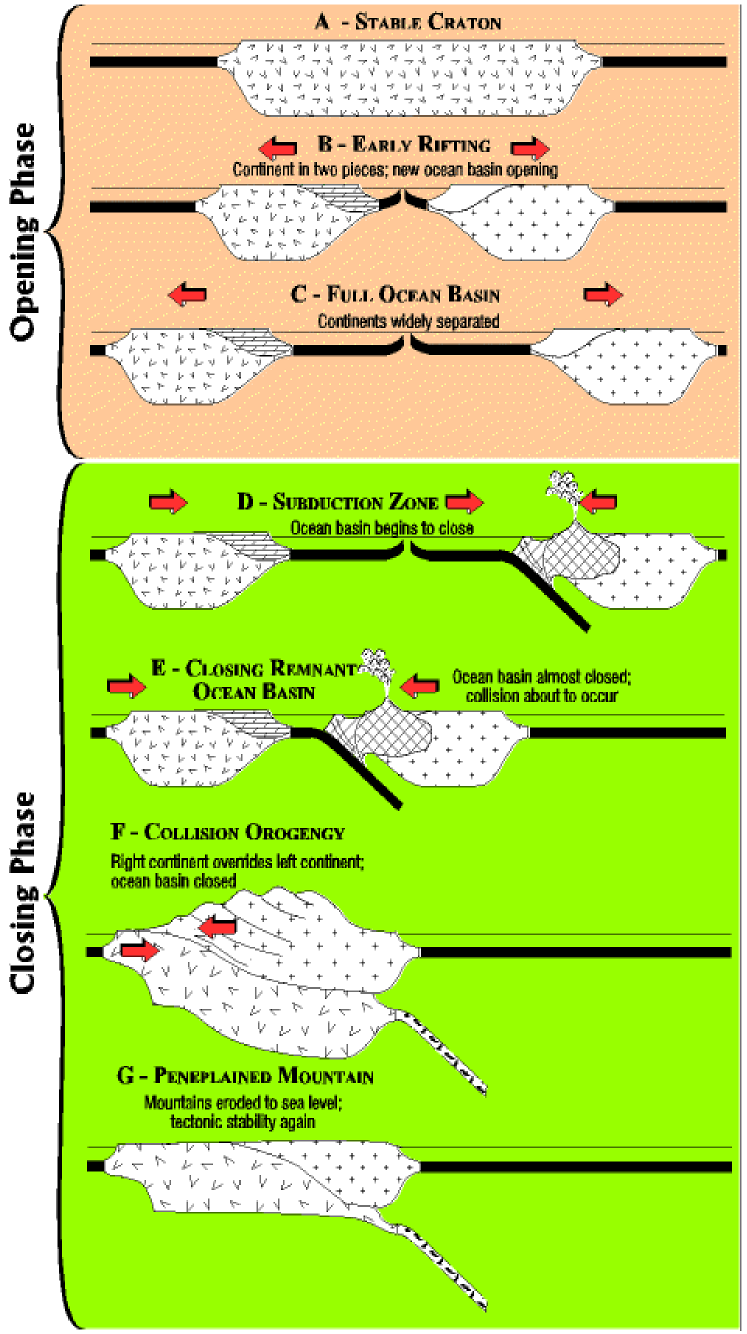
The Wilson cycle begins in Stage A with a stable continental craton. A hot spot (not present in the drawings) rises up under the craton, heating it, causing it to swell upward, stretch and thin like taffy, crack, and finally split into two pieces. This process not only splits a continent in two it also creates a new divergent plate boundary.

Stage B - the one continent has been separated into two continents, east and west, and a new ocean basin (the ophiolite suite) is generated between them. The ocean basin in this stage is comparable to the Red Sea today. As the ocean basin widens the stretched and thinned edges where the two continents used to be joined cool, become denser, and sink below sea level. Wedges of divergent continental margins sediments accumulate on both new continental edges.



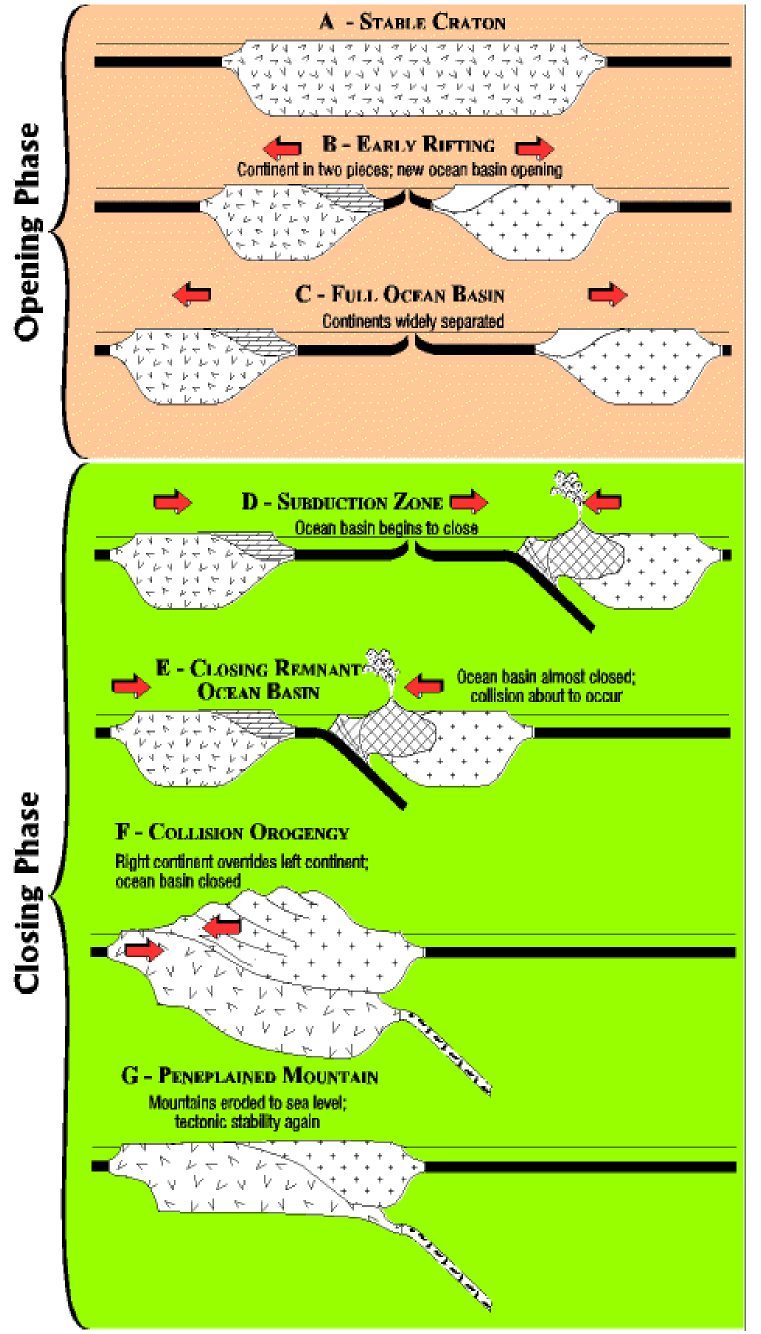
Stage C - the ocean basin widens, sometimes to thousands of miles; this is comparable to the Atlantic ocean today. As long as the ocean basin is opening we are still in the opening phase of the Wilson cycle.

Stage D - the closing phase of the Wilson Cycle begins when a subduction zone (new convergent plate boundary) forms. The subduction zone may form anywhere in the ocean basin, and may face in any direction. In this model we take the simplest situation; a subduction zone developing under the edge of one continent. Once the subduction zone is active the ocean basin is doomed; it will all eventually subduct and disappear. These are remnant ocean basins.



Stage E - most of the remnant ocean basin has subducted and the two continents are about to collide. Subduction under the edge of a continent has a lot of results. Deep in the subduction zone igneous magma is generated and rises to the surface to form volcanoes, that build into a cordilleran mountain range (e.g. the Cascade mountains of Washington, Oregon, and northern California.) Also, a lot of metamorphism occurs and folding and faulting.

Stage F - the two continents, separated in Stages A and B now collide. The remnant ocean basin is completely subducted. Technically the closing phase of the Wilson cycle is over. Because the subduction zone acts as a ramp the continent with the subduction zone (a hinterland) slides up over the edge of the continent without it (a foreland).



Stage G - once the collision has occurred the only thing left for the mountain to do is erode down to sea level - a peneplain. The stage G drawing is a distortion, however. With the collision the continental thickness doubles, and since continental rock is light weight, both will rise as the mountain erodes, much like a boat rises when cargo is taken off of it. Thus, in reality, most of the hinterland continent will be eroded away, and the foreland continent will eventually get back to the earth's surface again.