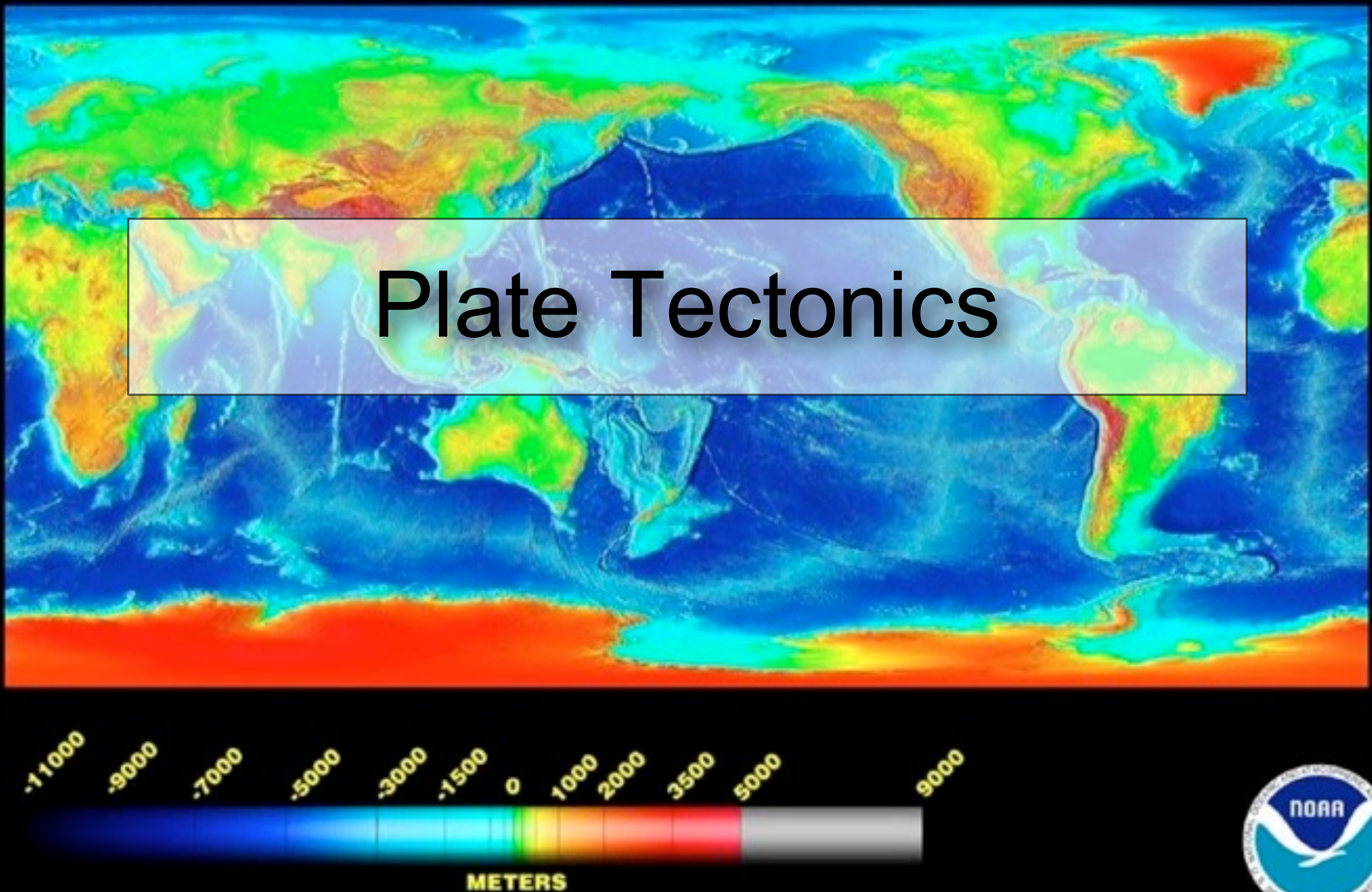
Plate Tectonics



Science Partnership

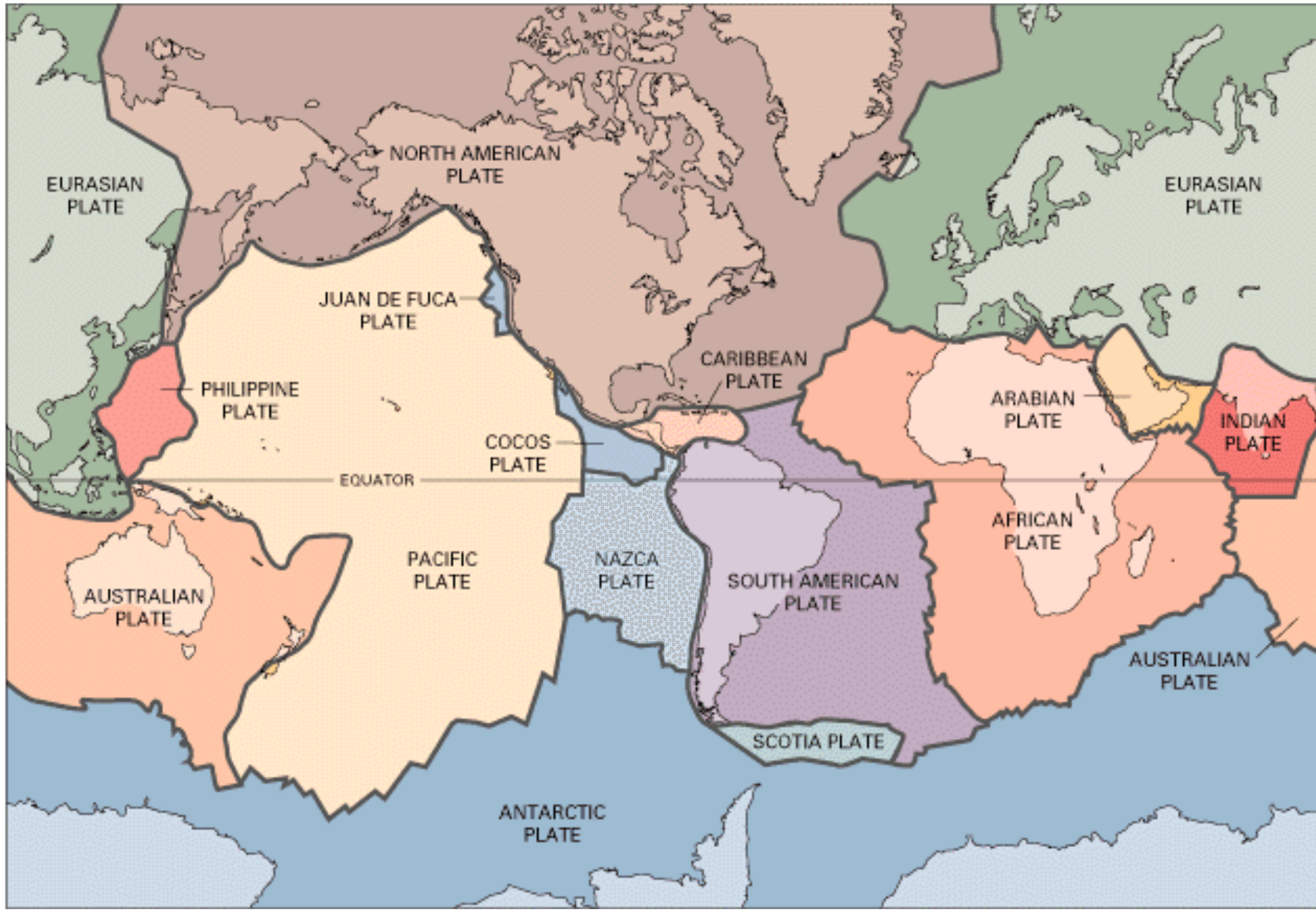
CALIFORNIA STATE UNIVERSITY EAST BAY

ALAMEDA COUNTY OFFICE OF EDUCATION

Plate Tectonics

The concepts of continental drift and seafloor spreading are united into a more encompassing theory known as plate tectonics.

This far reaching theory has become the basis for viewing most geologic processes — mountain building, paleontology, volcanism, earthquakes, etc.



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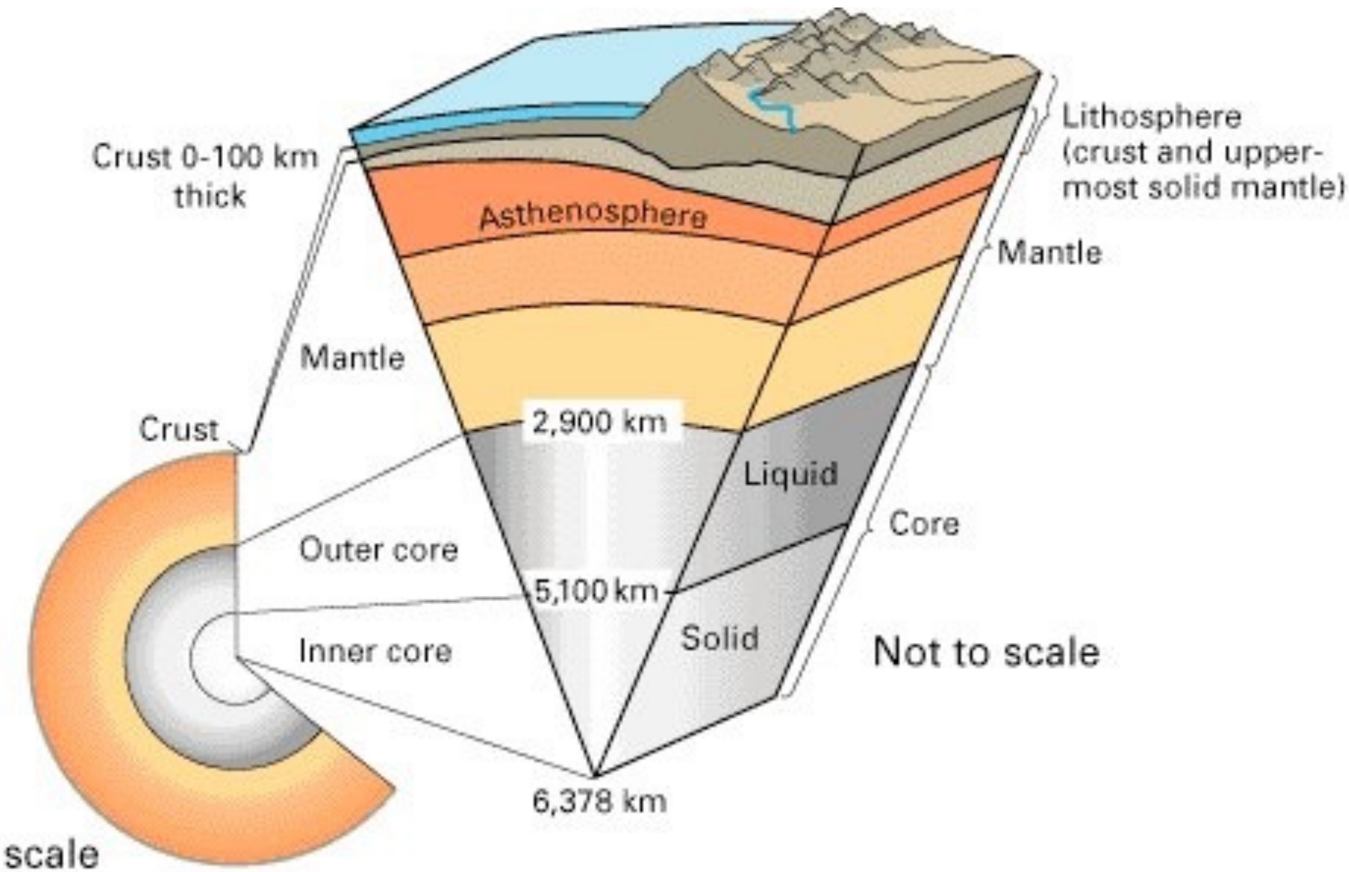
Earth's Interior

Earth has 3 compositional layers – **crust, mantle, core**



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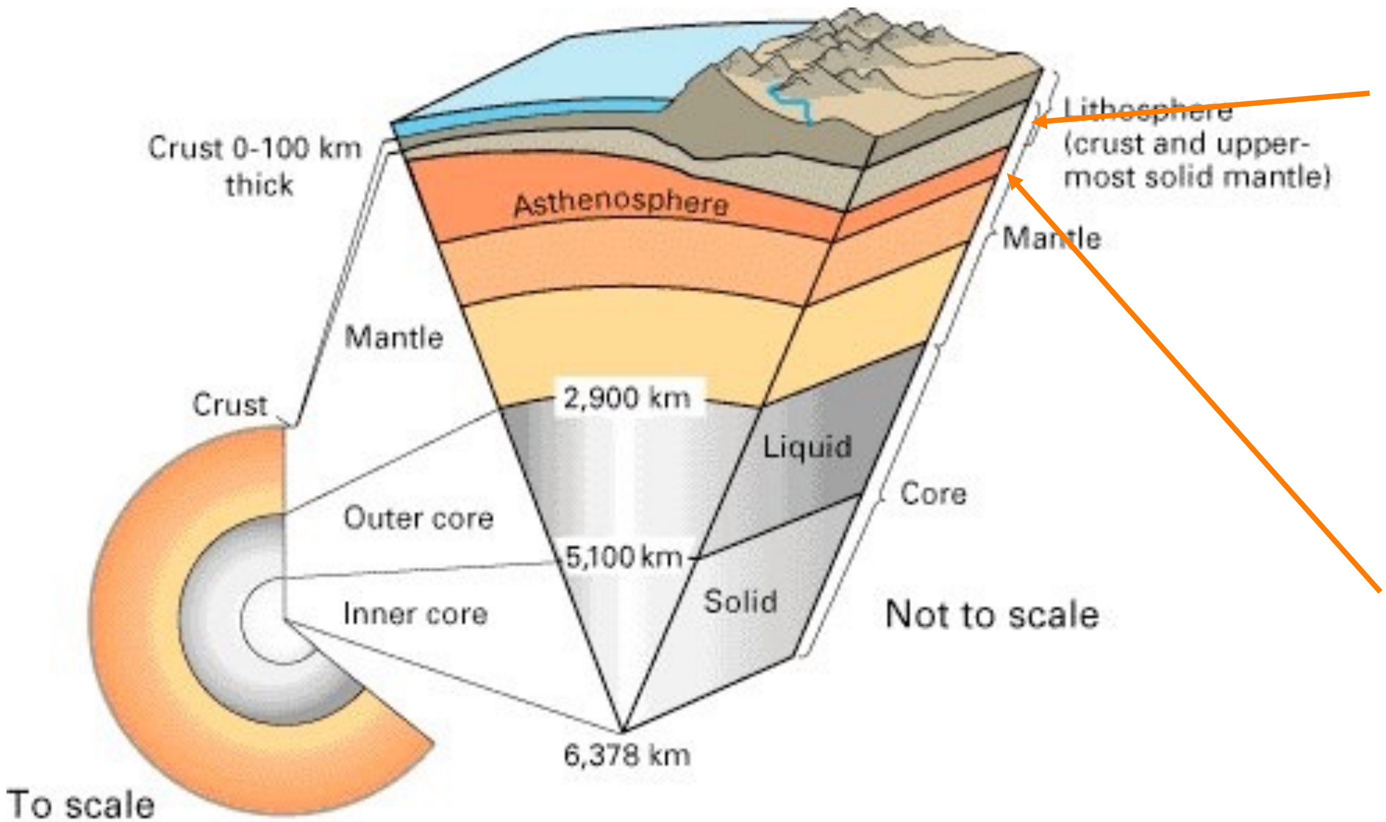
The major features on Earth's surface are the result of processes in the upper few hundred kilometers

Earth's Interior

Two key mechanical layers in crust and upper mantle



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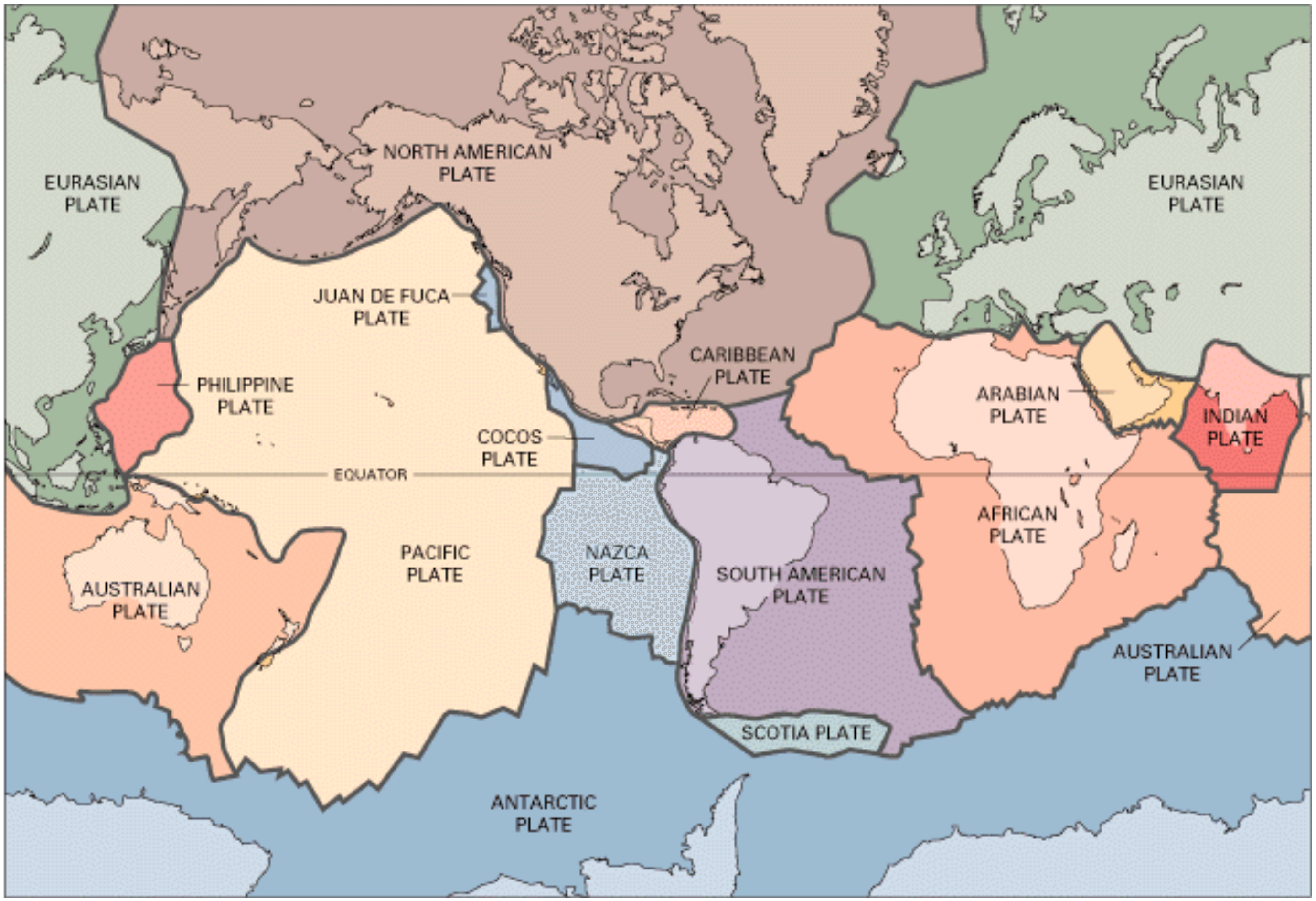
Lithosphere

- *Rigid* layer composed of crust & uppermost mantle
- Divided into mobile **tectonic plates**

Asthenosphere

- Weaker layer found in upper part of mantle
- Flows due to small proportion (1%) of melted minerals

Rigid lithosphere is divided into mobile *tectonic plates*. There are about 9 major plates and numerous smaller plates.



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Major Plates:
African
Antarctic
Eurasian
Indian
Australian
Nazca
North American
Pacific
South American

Smaller Plates:
Arabian,
Caribbean
Cocos
Juan de Fuca,
Philippine
Scotia

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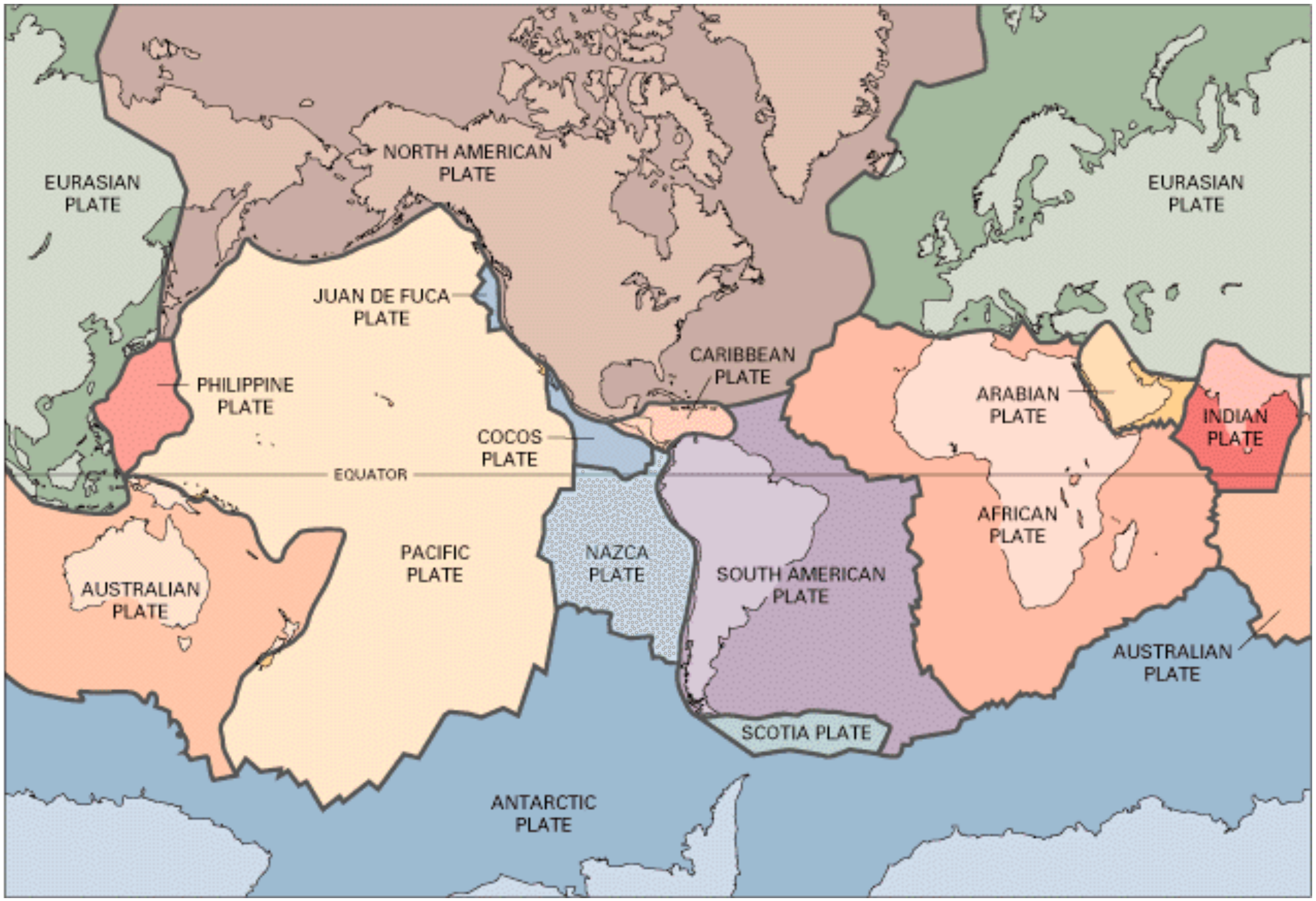

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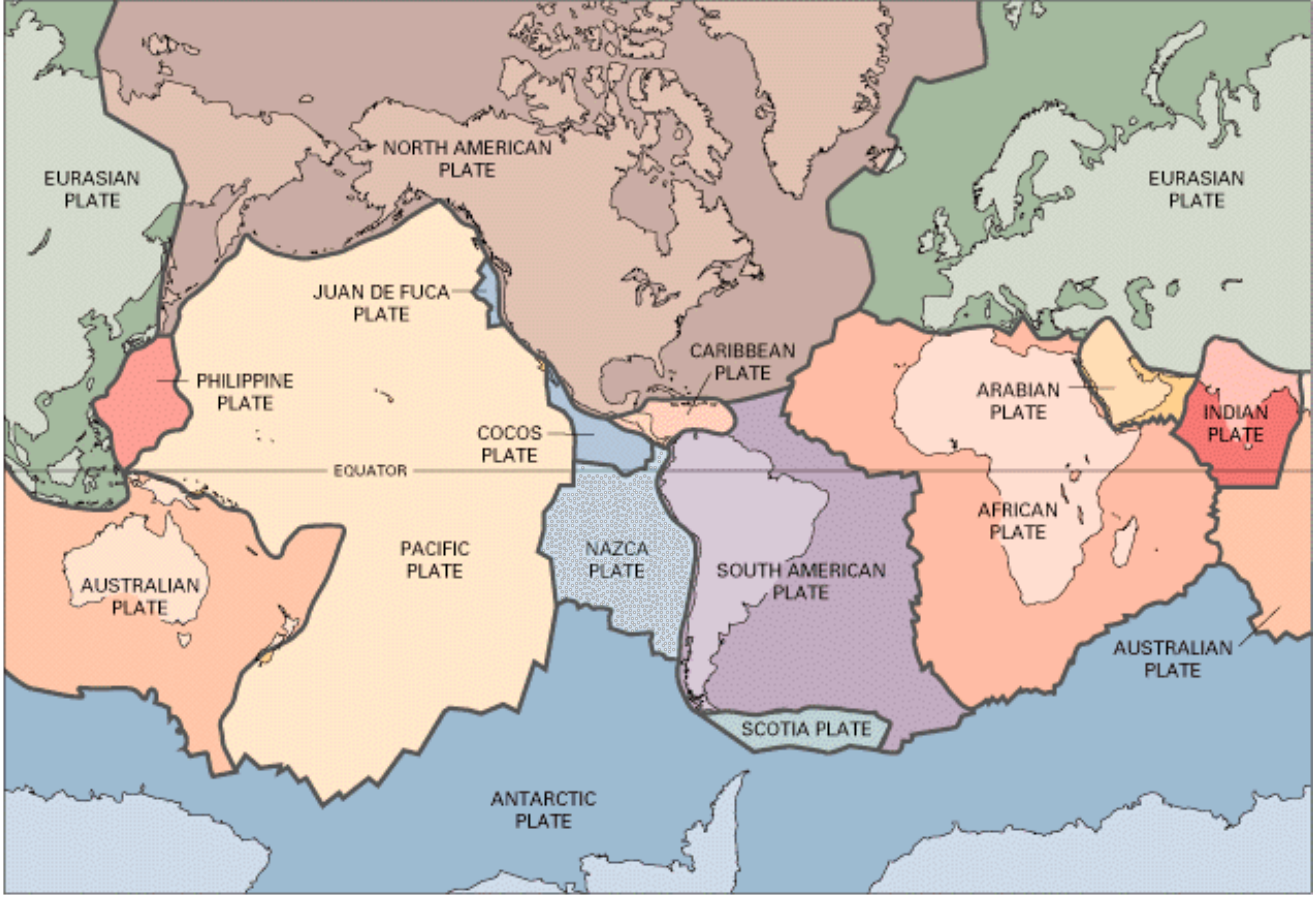

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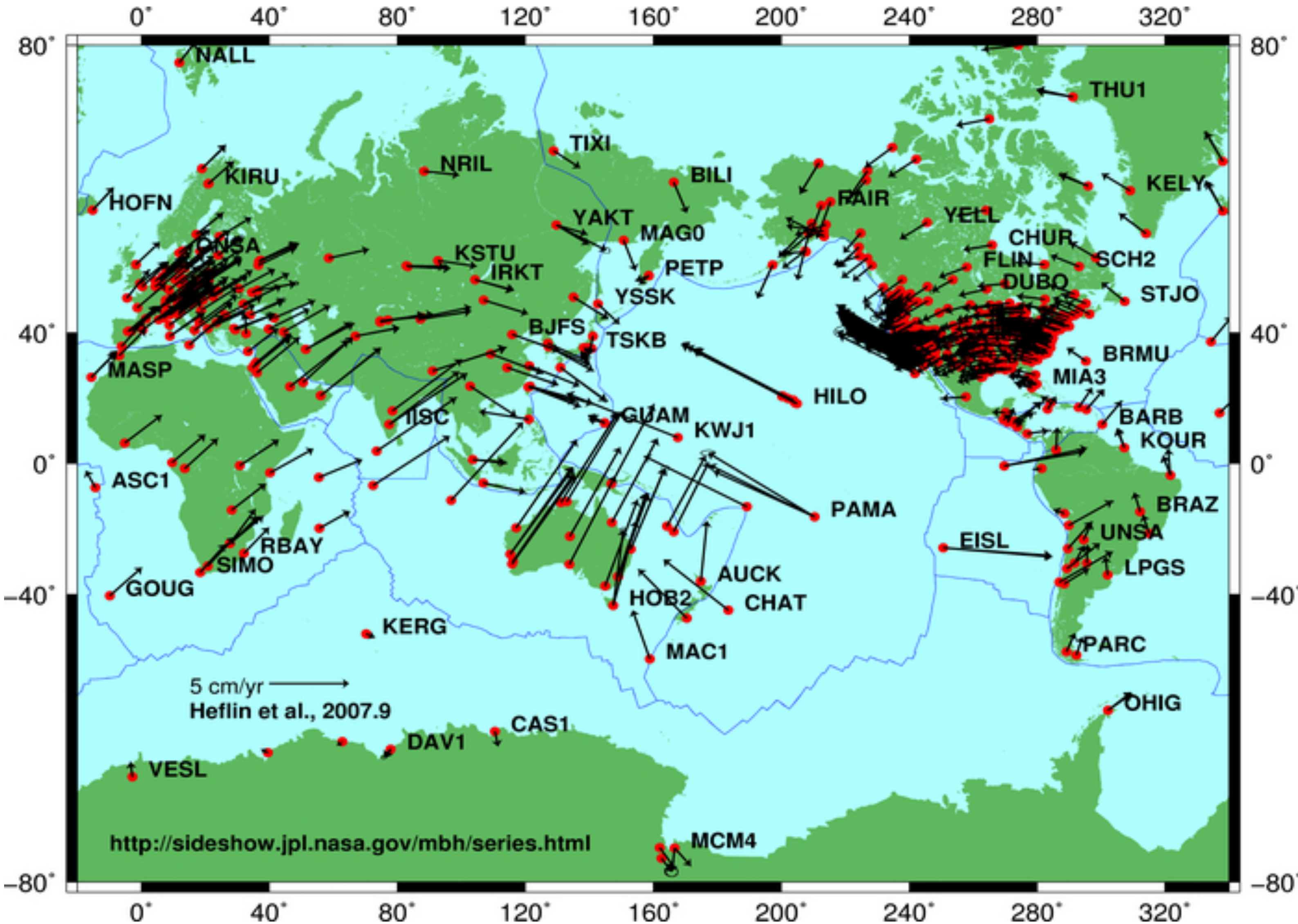
Most plates composed are of both continental and oceanic lithosphere (e.g., Africa, South America)

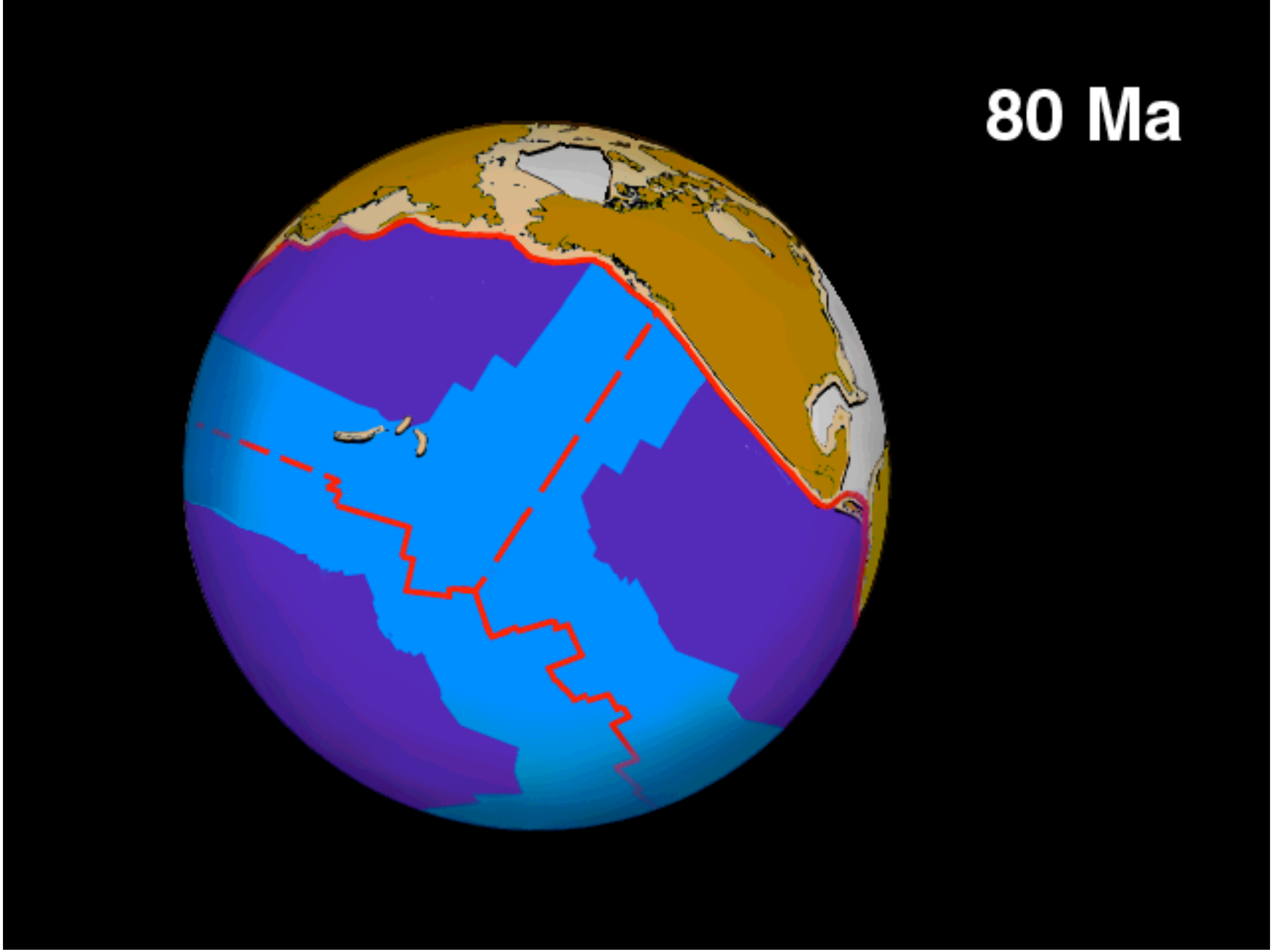
Oceanic ridges and trenches represent most plate boundaries

Rate of Plate Movements

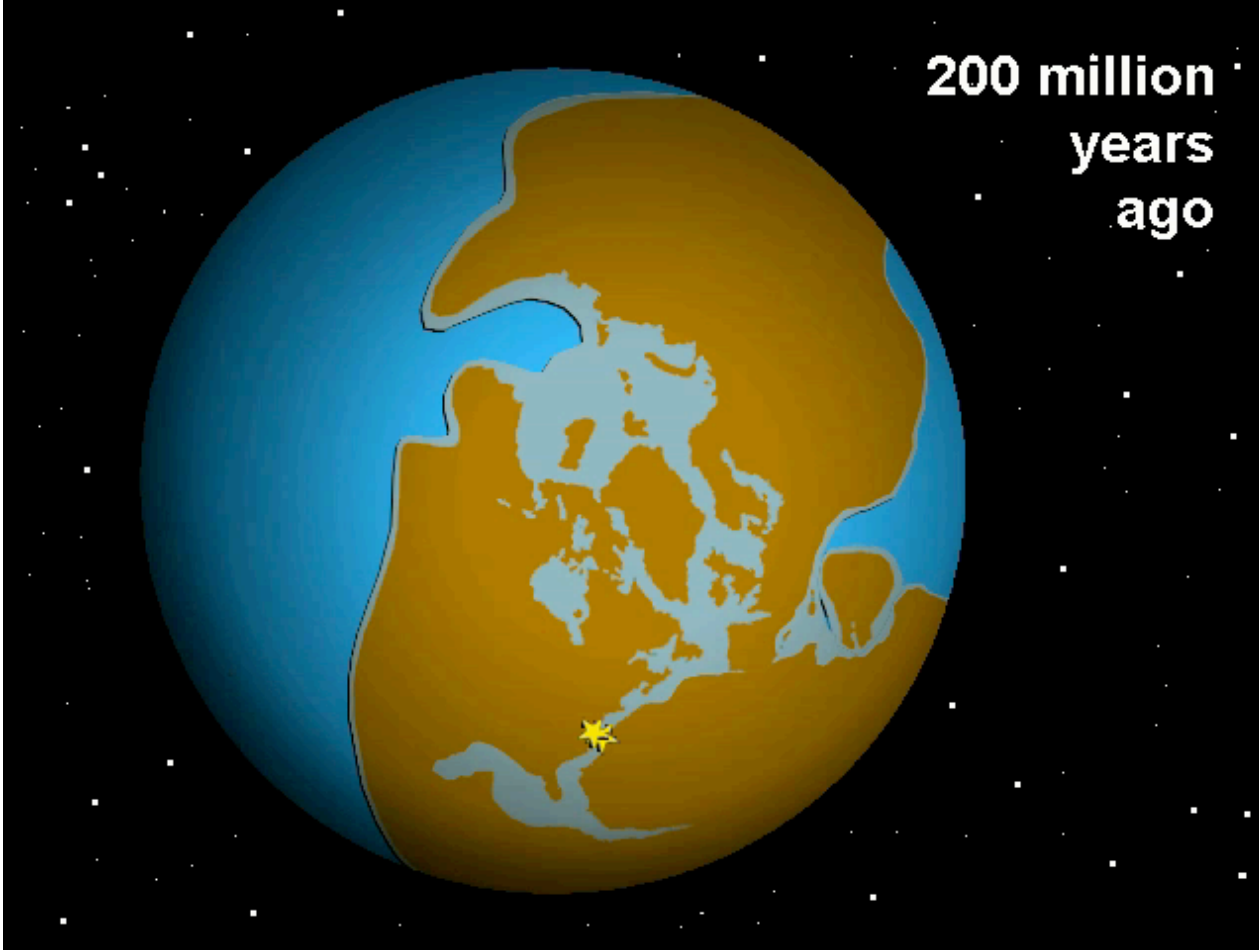
Modern satellite measurements reveal that plates move at rates of ~1-15 centimeters per year



NASA JPL



Tanya Atwater, UCSB



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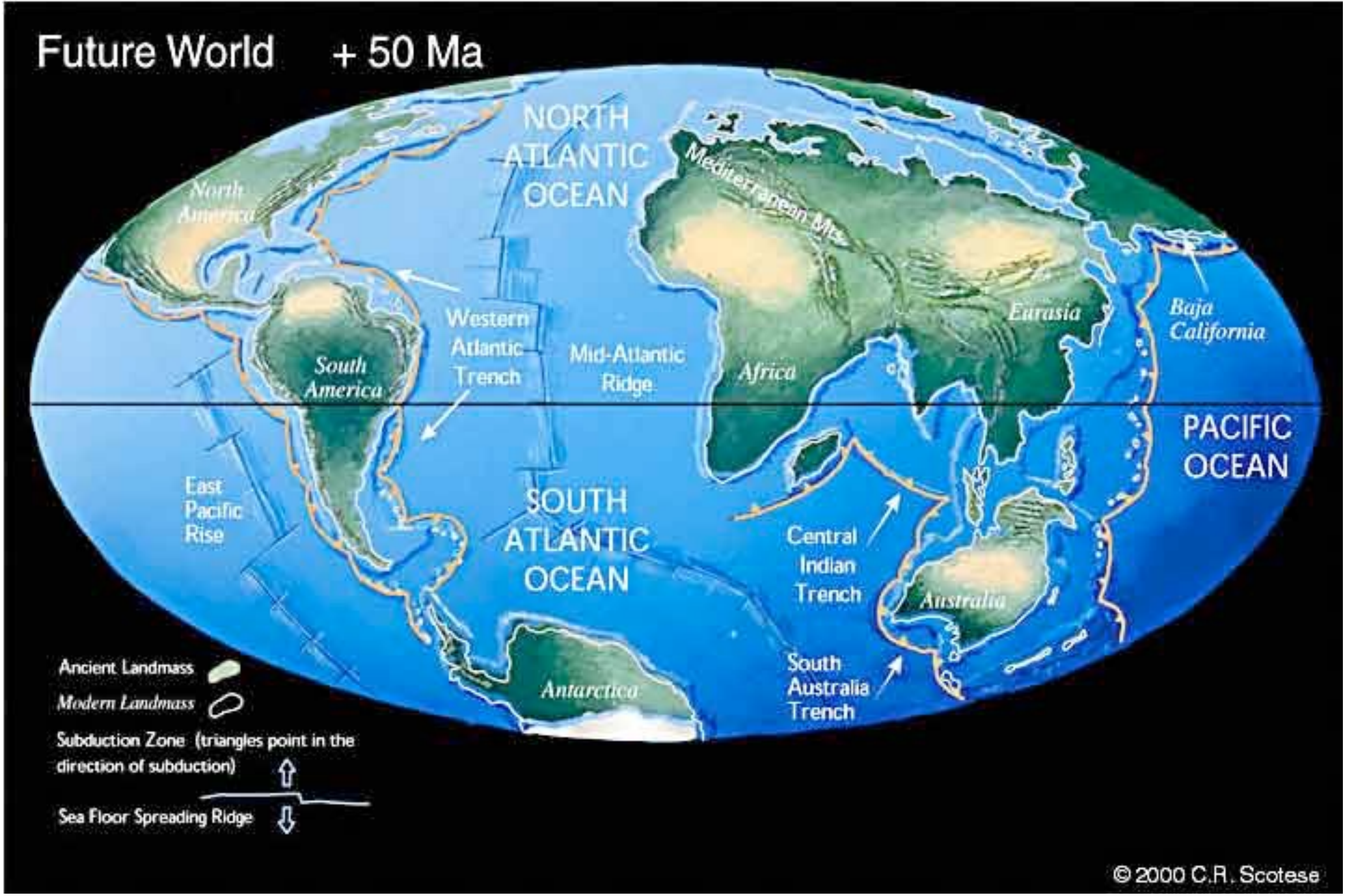
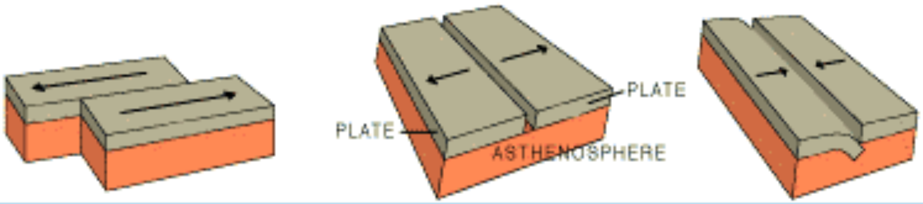


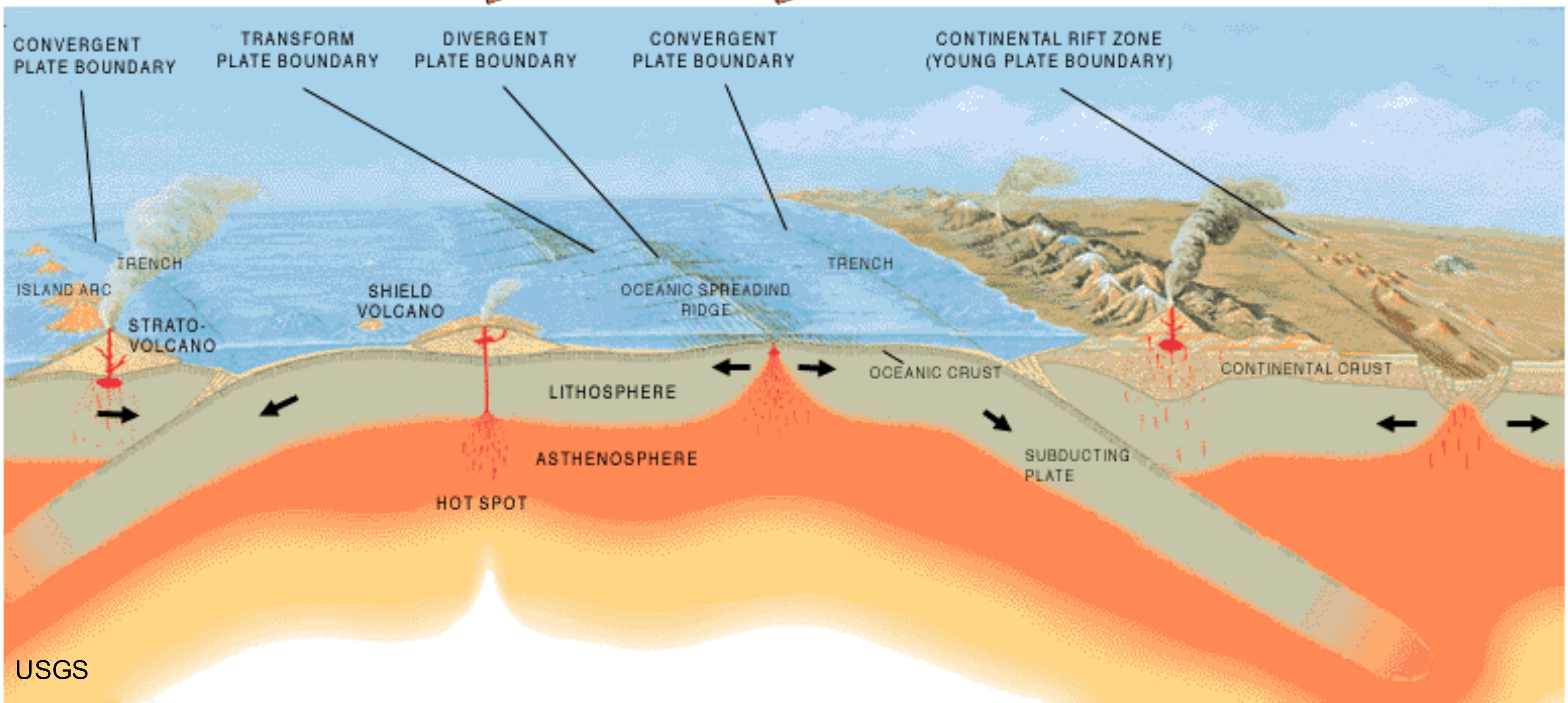
- Atlantic and Indian Oceans will continue to widen
- Subduction along the eastern coasts of North America and South America (Puerto Rican Trough and Scotia Arc may propogate.
- Africa will collide with Europe and Arabia closing the Mediterranean Sea and the Red Sea - Himalayan-scale mountain range will extend from Spain, across Southern Europe, through the Mideast and into Asia.

Plate Boundaries

Three types of plate boundaries:

1. Divergent
2. Convergent
3. Transform





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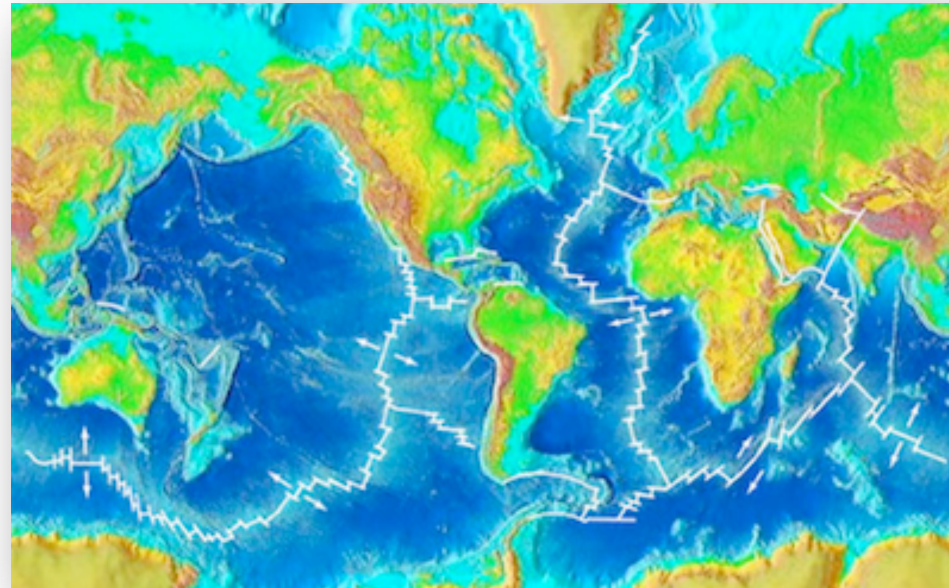
Divergent Plate Boundaries

Most divergent plate boundaries occur along mid-ocean ridges. Where the plates are moving apart, magma may push up from the mantle forming new oceanic crust (basalt). The ocean ridge systems winds around our planet like the seam on a baseball.

Spreading rates range from ~2 to >10 cm/year.

The Atlantic ridge is spreading ~2.5 cm/year. How far would the Atlantic ridge spread in 1 million years?



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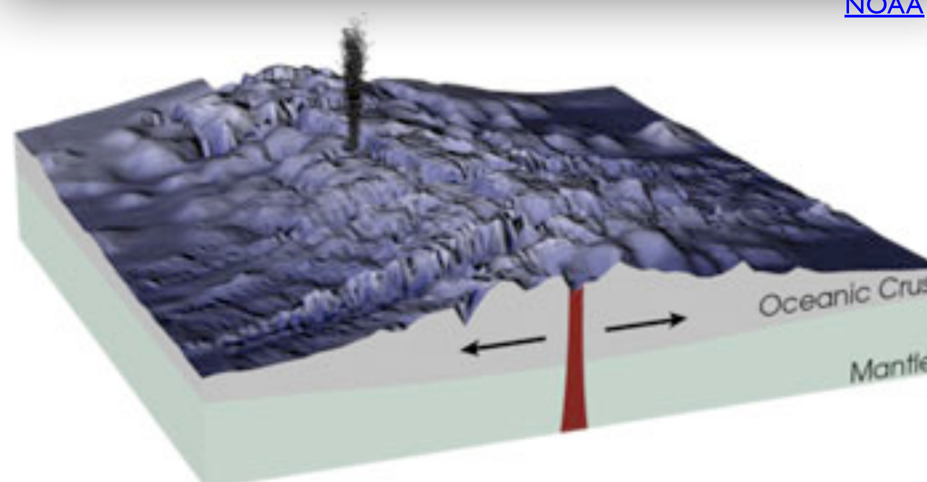


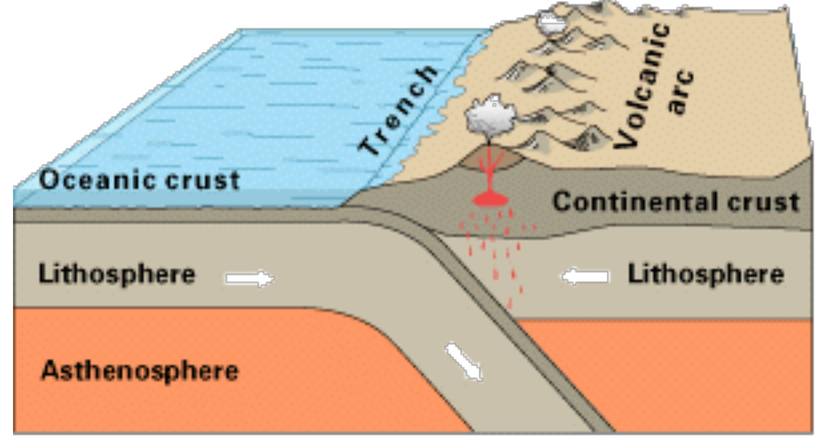
NASA/GSFC/Robert_Simmon

(2.5 cm/year)x(1,000,000 years)x(1 km/ 100,000 cm) = 25 km (~15.5 miles)

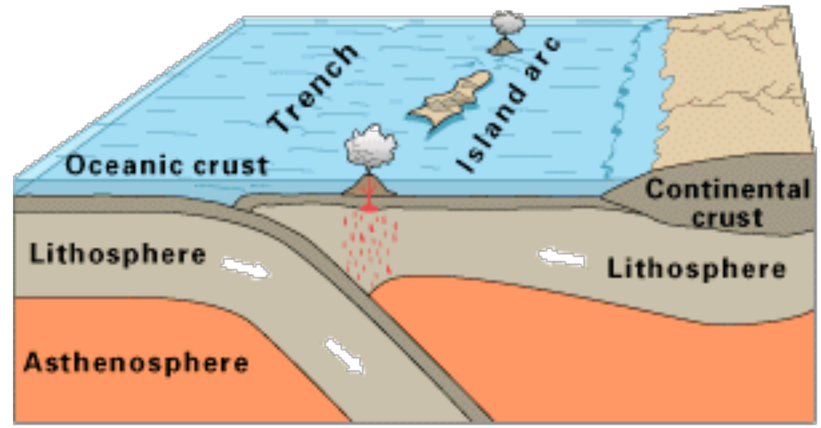
Convergent Plate Boundaries

Convergent plate motion is where plates move toward one another. There are three different types of convergent plate boundaries:

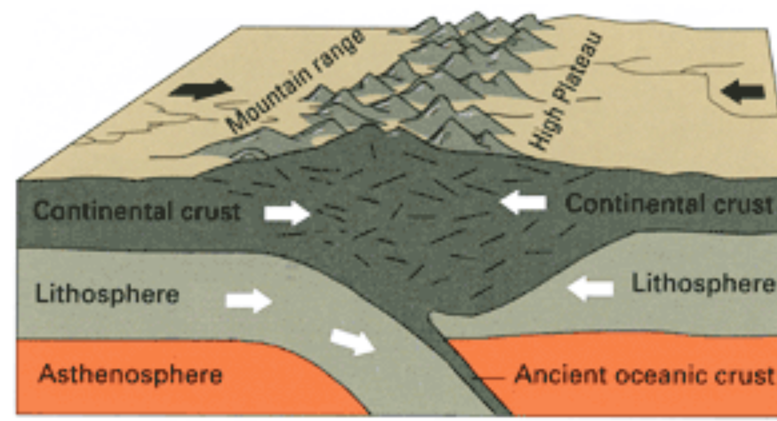
1. oceanic-continental convergence where one plate is an oceanic plate and the other is a continental plate
2. oceanic-oceanic convergence where both plates are oceanic plates
3. continental-continental convergence where both plates are continental plates



Oceanic-continental convergence



Oceanic-oceanic convergence



Continental-continental convergence

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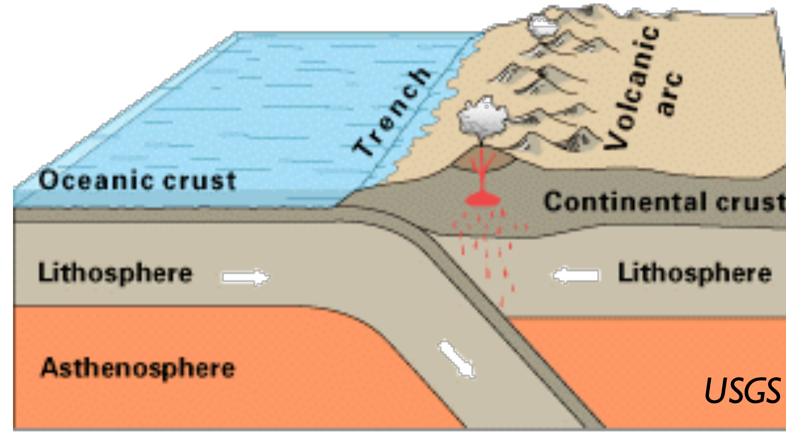
Oceanic-Continental Convergence

Oceanic-continental convergence occurs when leading edge of one plate is composed of continental rocks (granitic) and the other is oceanic (basaltic).



Oceanic-continental convergence

The denser oceanic plate dives beneath (subducts) the lower-density continental plate. Lower density granitic rocks tend to float in the asthenosphere (upper portion of the mantle).

Dewatering of the subducted slab causes melting in the wedge of the asthenosphere above it. The magma that is produced is buoyant and rises through the mantle toward the Earth's surface.

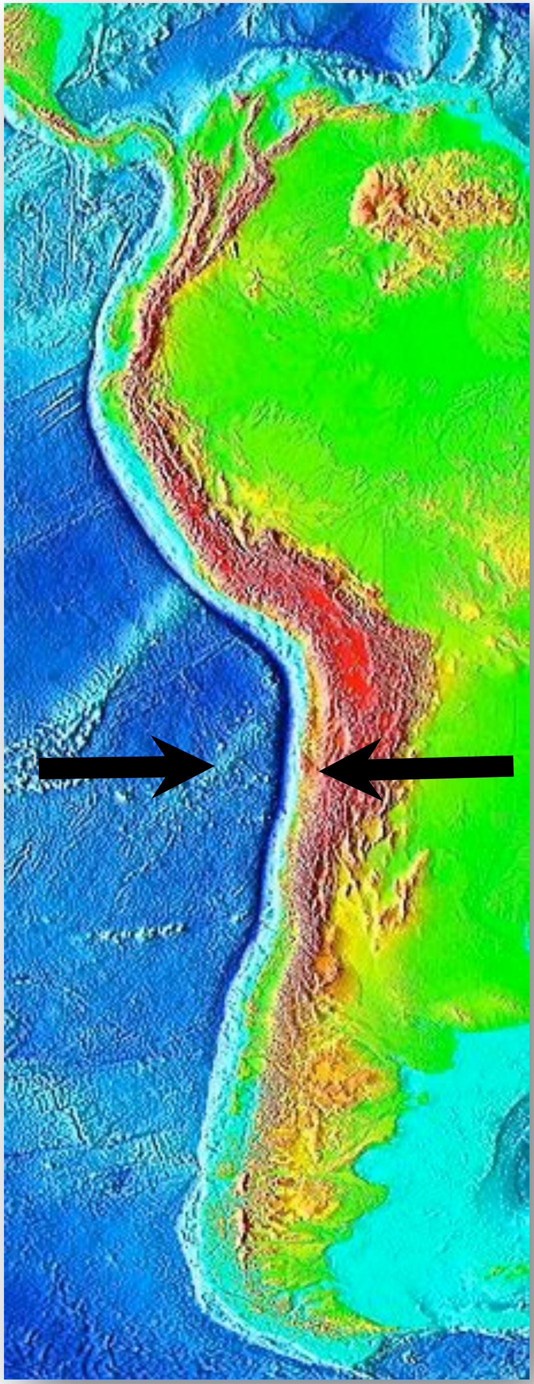
The magma results in volcanic activity along a line parallel to the subduction zone known as a continental volcanic arc.

Examples of continental volcanic arcs include the Cascade volcanoes such as Mt. Rainier and Mt. St. Helens and the volcanoes of the Andes mountains along the west coast of South America.

Oceanic-Continental Convergence

An excellent example of oceanic-continental convergence occurs on the west coast of South America.

The Nazca plate (oceanic) is subducting beneath the South American plate (continental) The Chile trench is the surface expression of the subduction. Along the western coast, the Andes mountains consist of a core of volcanoes that result from the subduction.



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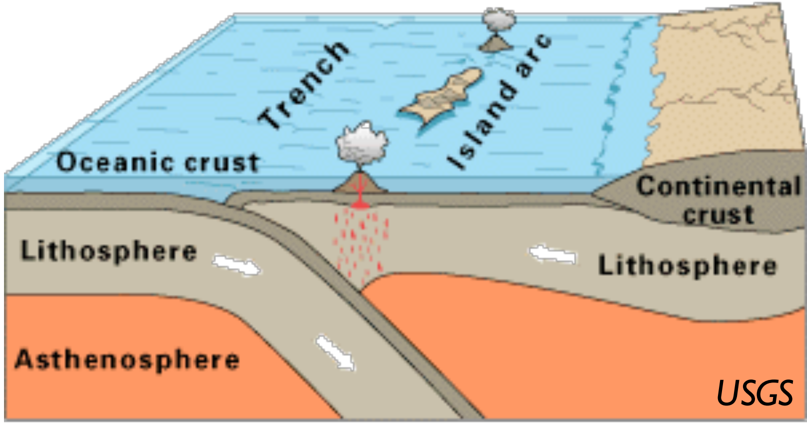
Oceanic-Oceanic Convergence

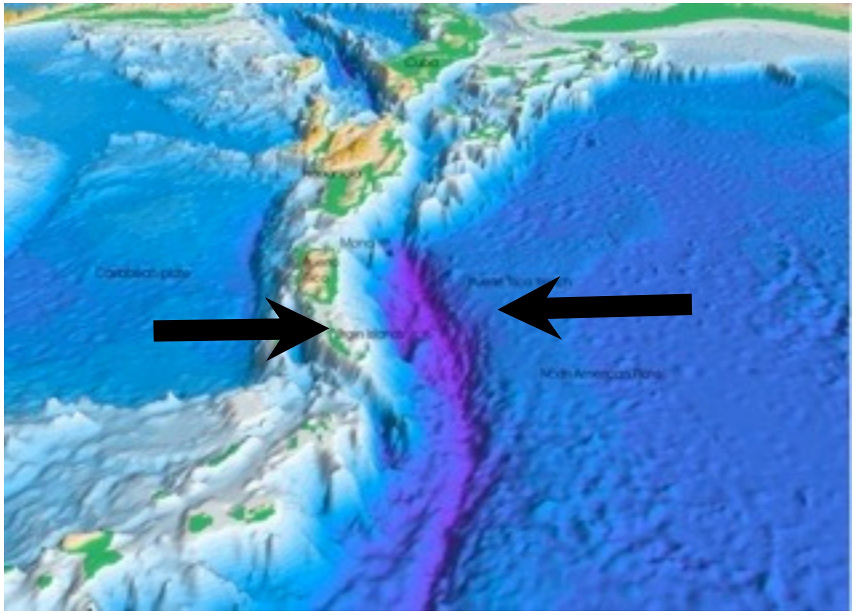
Oceanic-oceanic convergence occurs when the leading edge of both plates consists of oceanic crust. These plate boundaries have many of the same features as in oceanic-continental convergence.



Oceanic-oceanic convergence

In oceanic-oceanic convergence, the line of volcanoes forms a string of islands parallel to the subduction zone known as a volcanic island arc.

The bottom image shows the Puerto Rico trench where the North American plate is subducting beneath the Caribbean plate.



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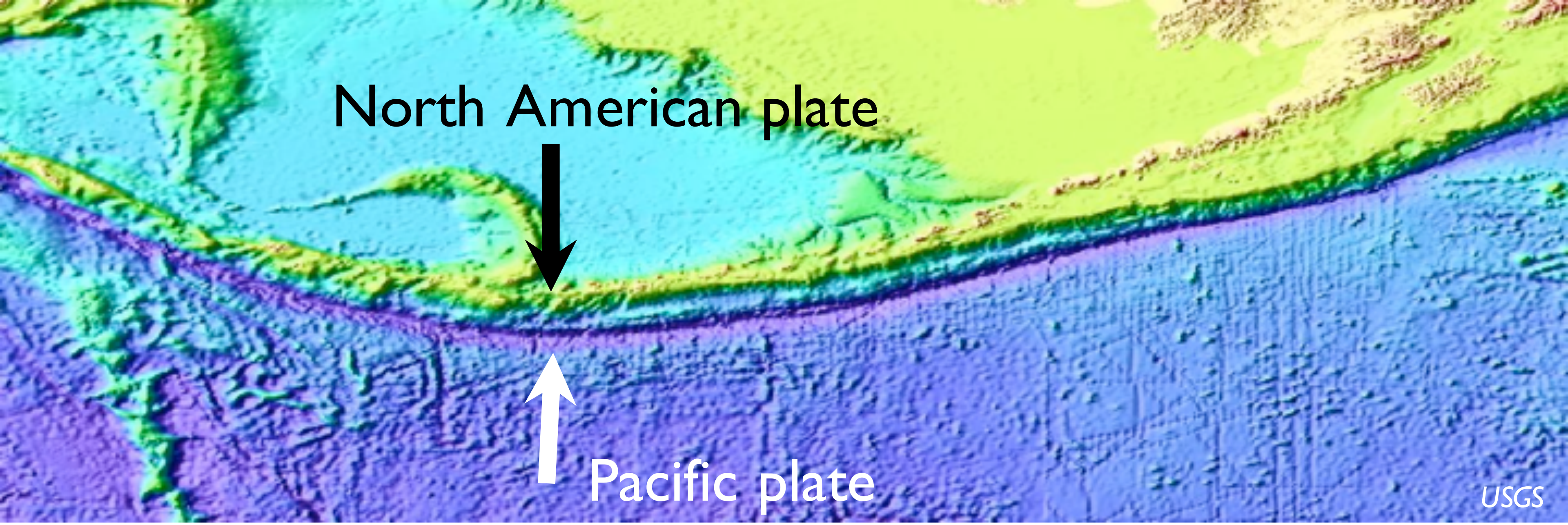
Other examples of island arc systems include the Aleutian Islands, Tonga, Indonesia, and Japan.



An excellent example of convergence is the Aleutian trench where the Pacific plate is subducting beneath the North American plate.

Note the development of the Aleutian volcanic island arc where the North American plate is oceanic and the development of a continental volcanic arc where the North American plate is continental.

Continental-Continental Convergence

Continental-continental convergence defines a plate margin where the leading edge of both plates contains continental crust.

When two continents collide, neither continent is subducted because the continental rocks have a relatively low density. As a result of the convergence, the crust tends to deform and be pushed upward (mountain building).

This type of plate boundary is associated with mountain-building.

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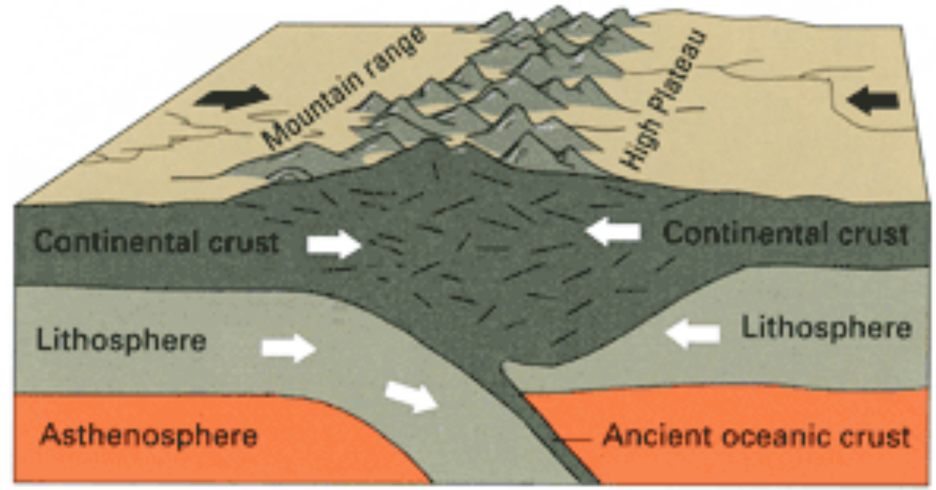

Continental-continental convergence

The Himalayan mountains are a excellent example of this type of convergence where the Himalayan mountains and the Tibetan plateau are result of crustal deformation and thickening from the convergence of the Indian and Eurasian plates.

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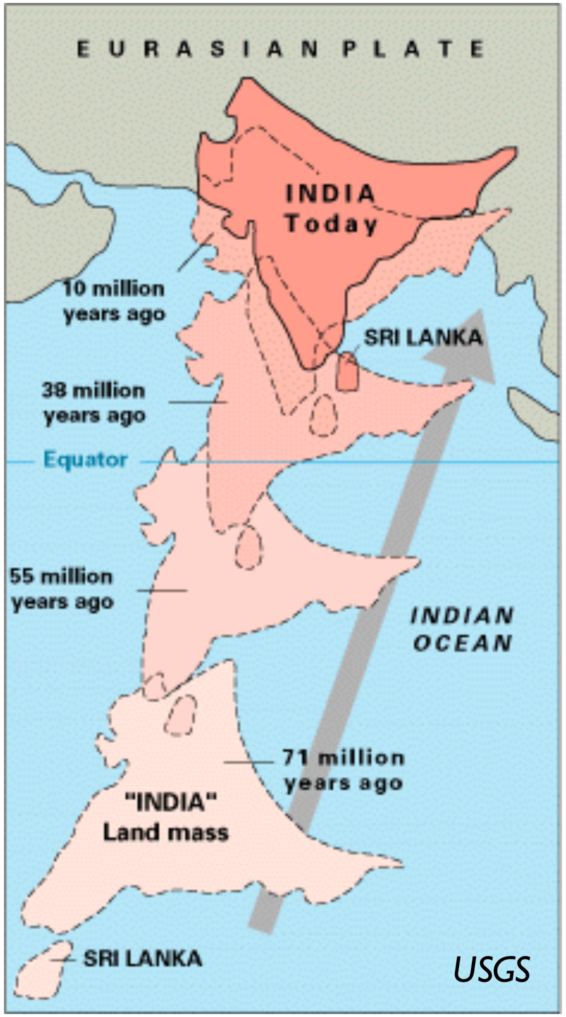
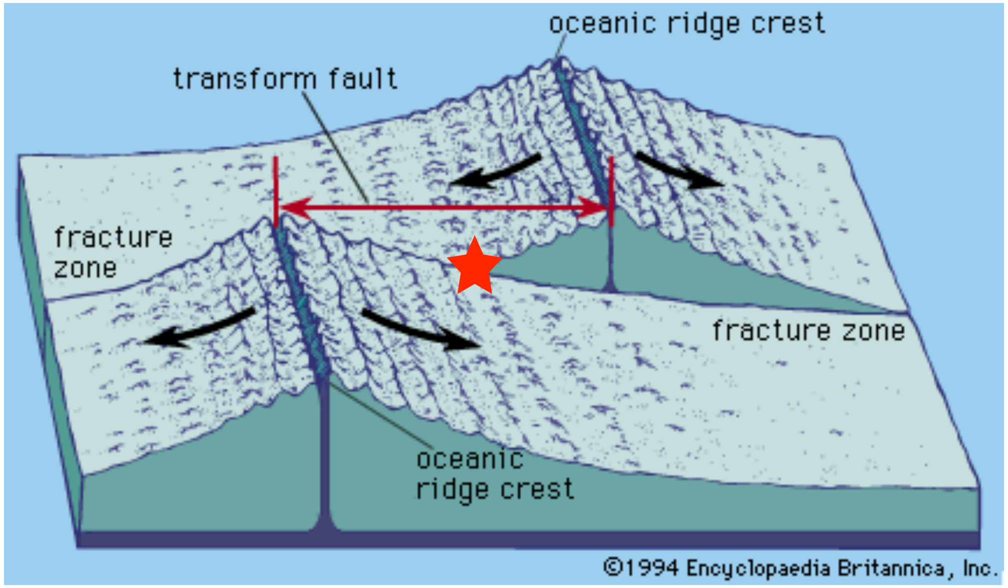


Continental-continental convergence usually begins as oceanic-continental convergence (ex. Andes). As the oceanic crust is subducted, a continental block on the subducting plate may approach the continent.

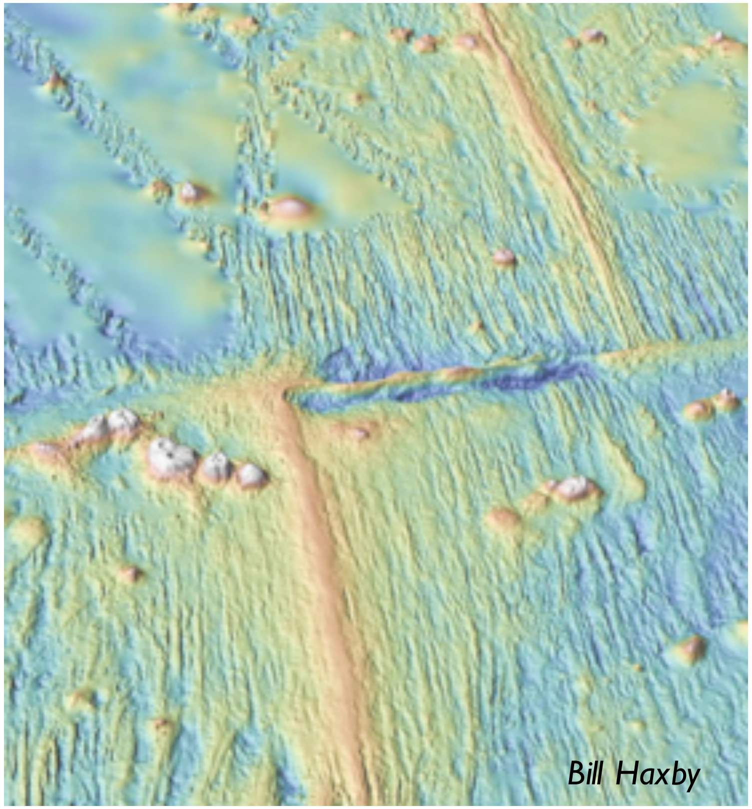
Mt. Everest have risen >9 km in the last 50 million years and continues to rise >1 cm a year.

Transform Plate Boundary

A transform boundary is where plates slide past one another. Most transform faults are found on the ocean floor where they offset the active oceanic ridges. At the red star, the motion of the plate to the top appears to be to the left, whereas the plate to the bottom appears to move to the right.



The bottom image shows a portion of the mid-ocean ridge off the coast of Central America where the spreading ridge is dissected by the transform fault.



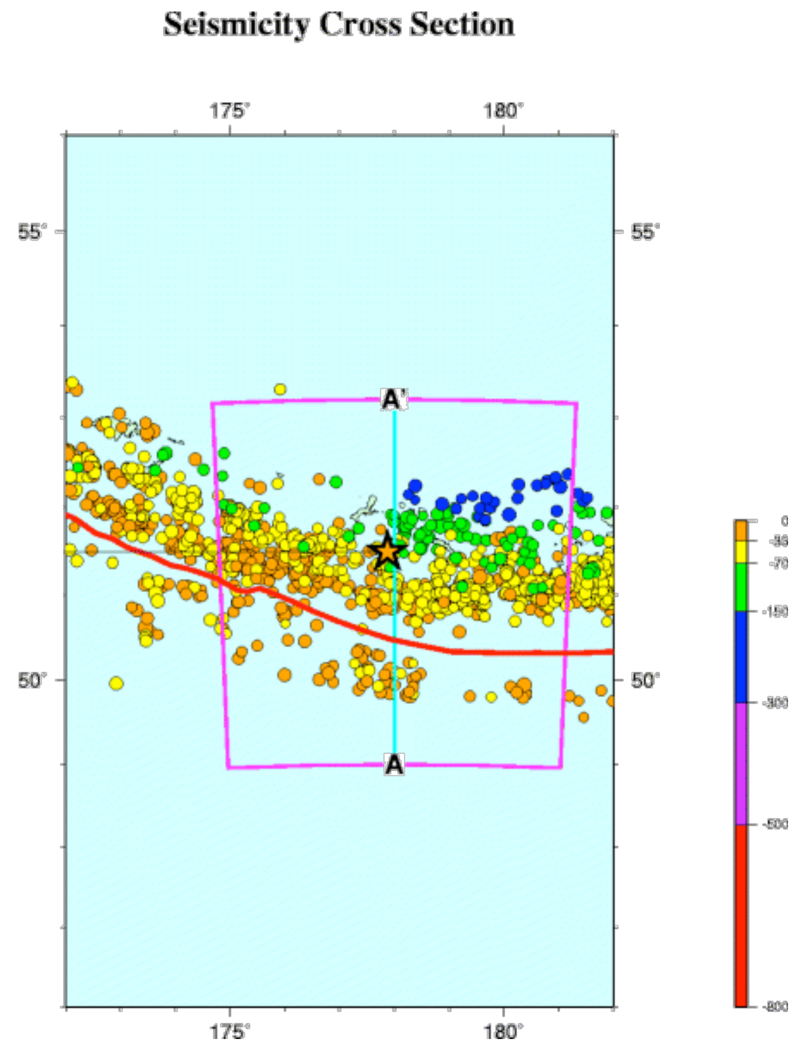
Although most transform boundaries occur in the ocean basins, a few occur on land. The San Andreas fault system is a transform fault that connects two ocean ridge systems - the East Pacific Rise in the south to the Explorer Ridge in the north.

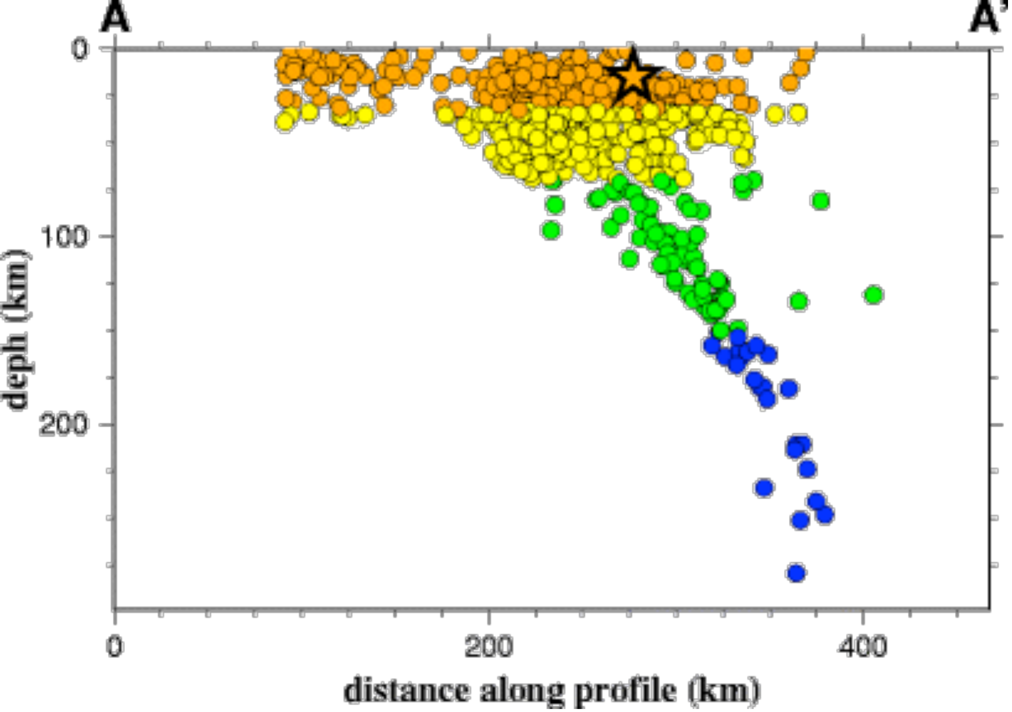
In California, the San Andreas fault is the transform boundary between the North American plate and the Pacific plate.

Look at the map of historic seismicity in the Pacific ocean.

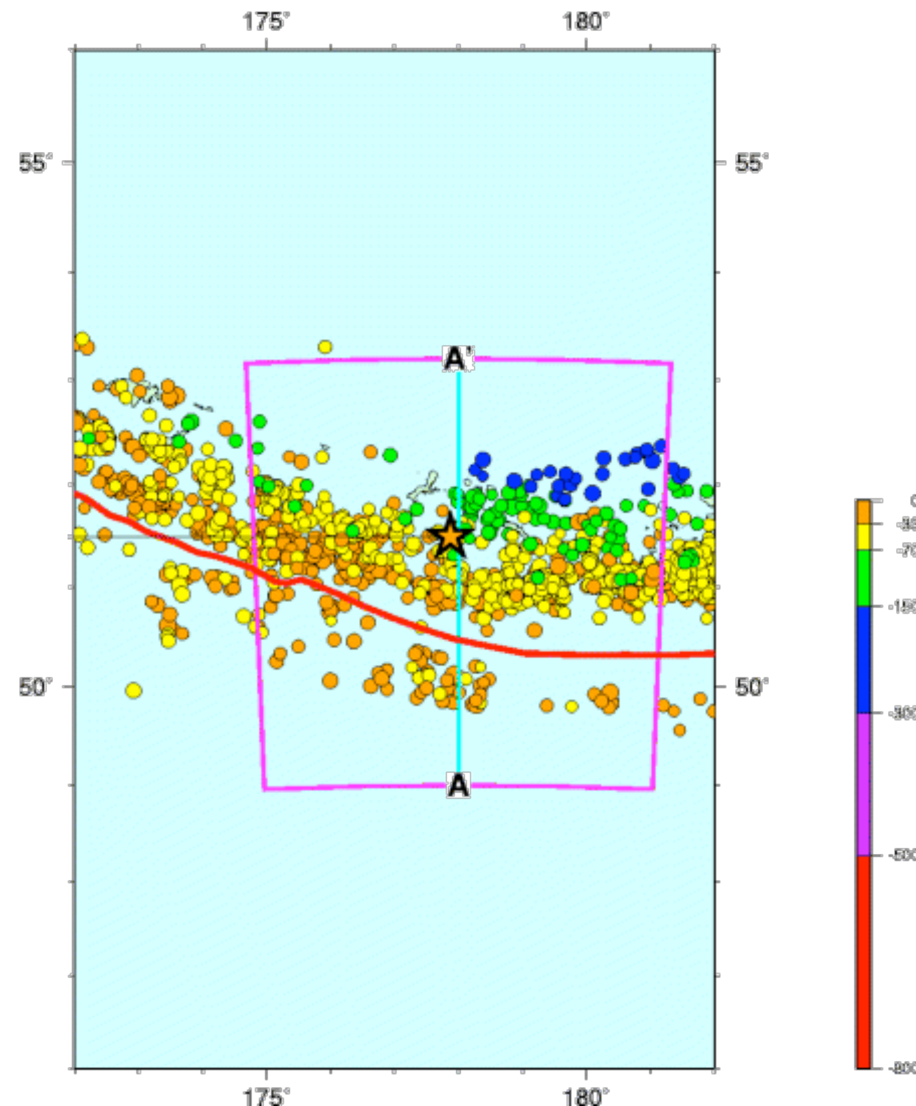
What type of plate boundary does this represent?

Explain your answer.





Seismicity Cross Section

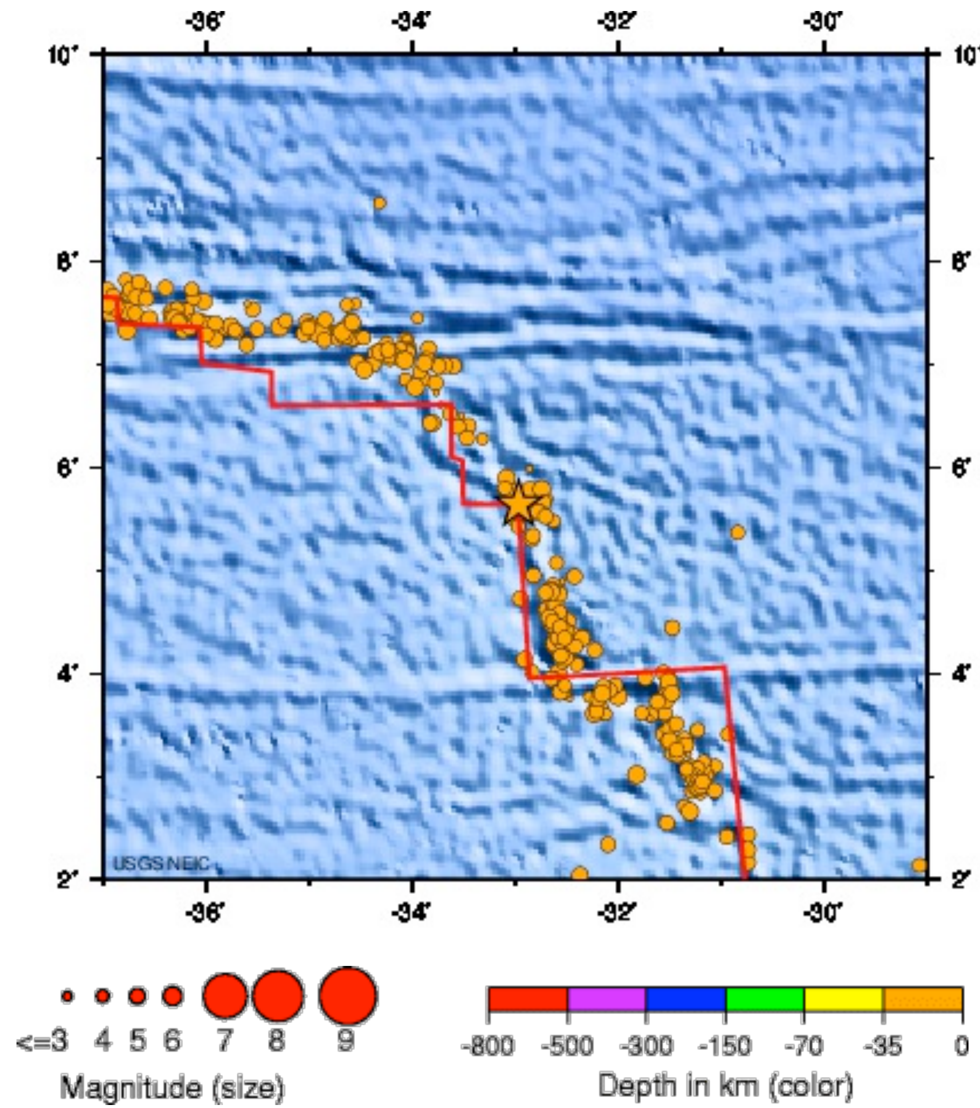


A convergent margin is portrayed (oceanic-oceanic convergence) where the earthquakes become deeper to the north and follow the plunge of the subducted plate.

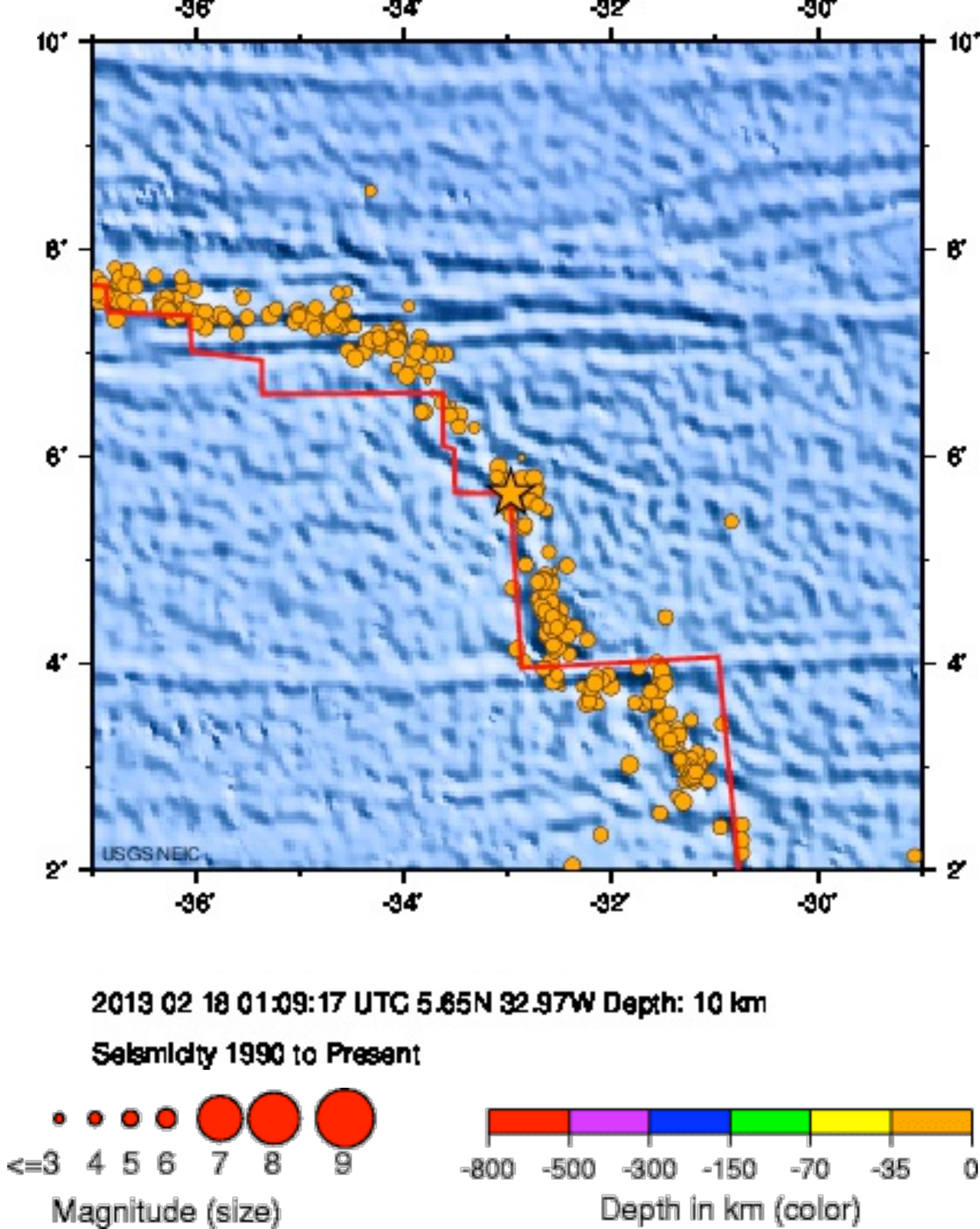
Look at the map of historic seismicity in the Atlantic ocean.

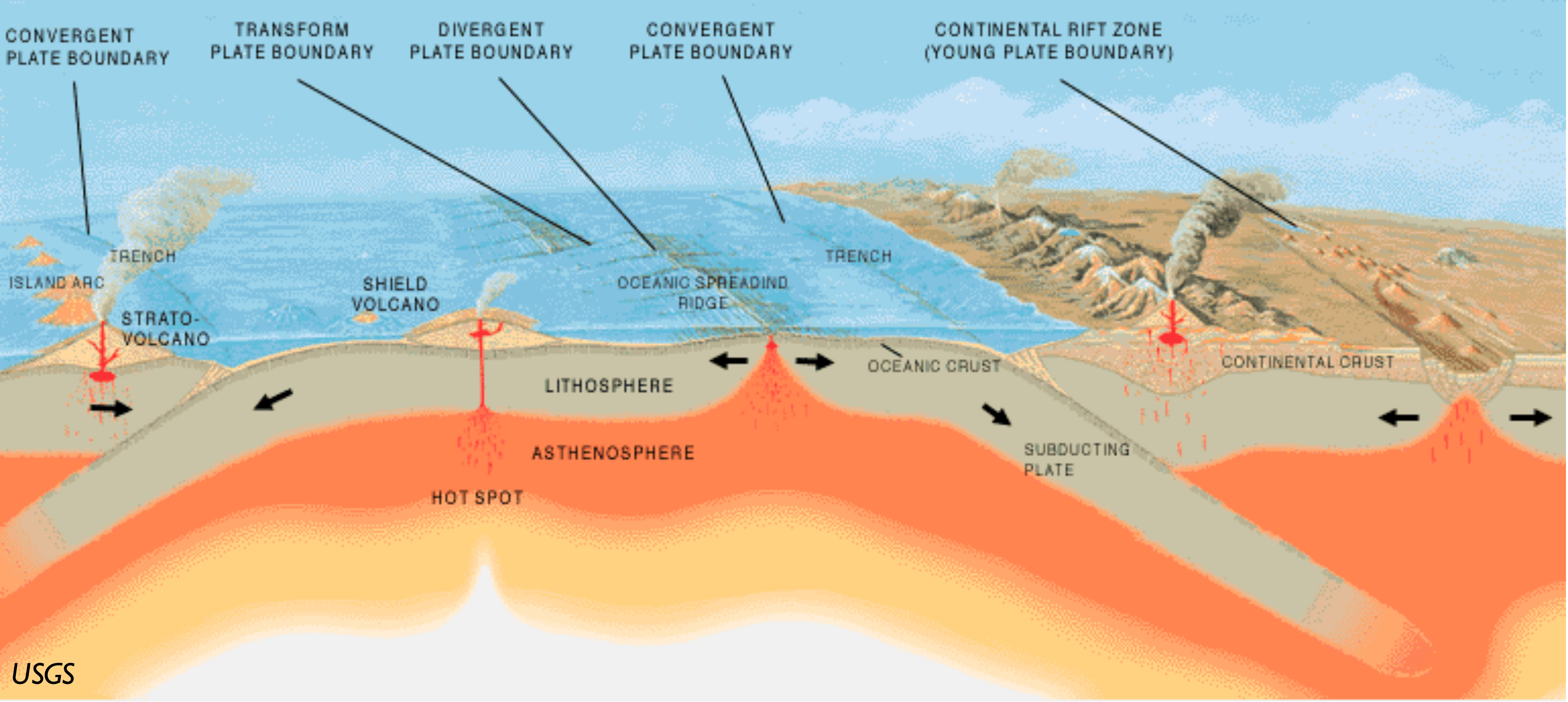
What type of plate boundary does this represent?

Explain your reasoning.



The boundary is along a portion of the Mid Atlantic ridge and represents a divergent boundary along the ridge axis and transform boundaries along the fracture zones. Shallow earthquakes are common along mid ocean ridges.

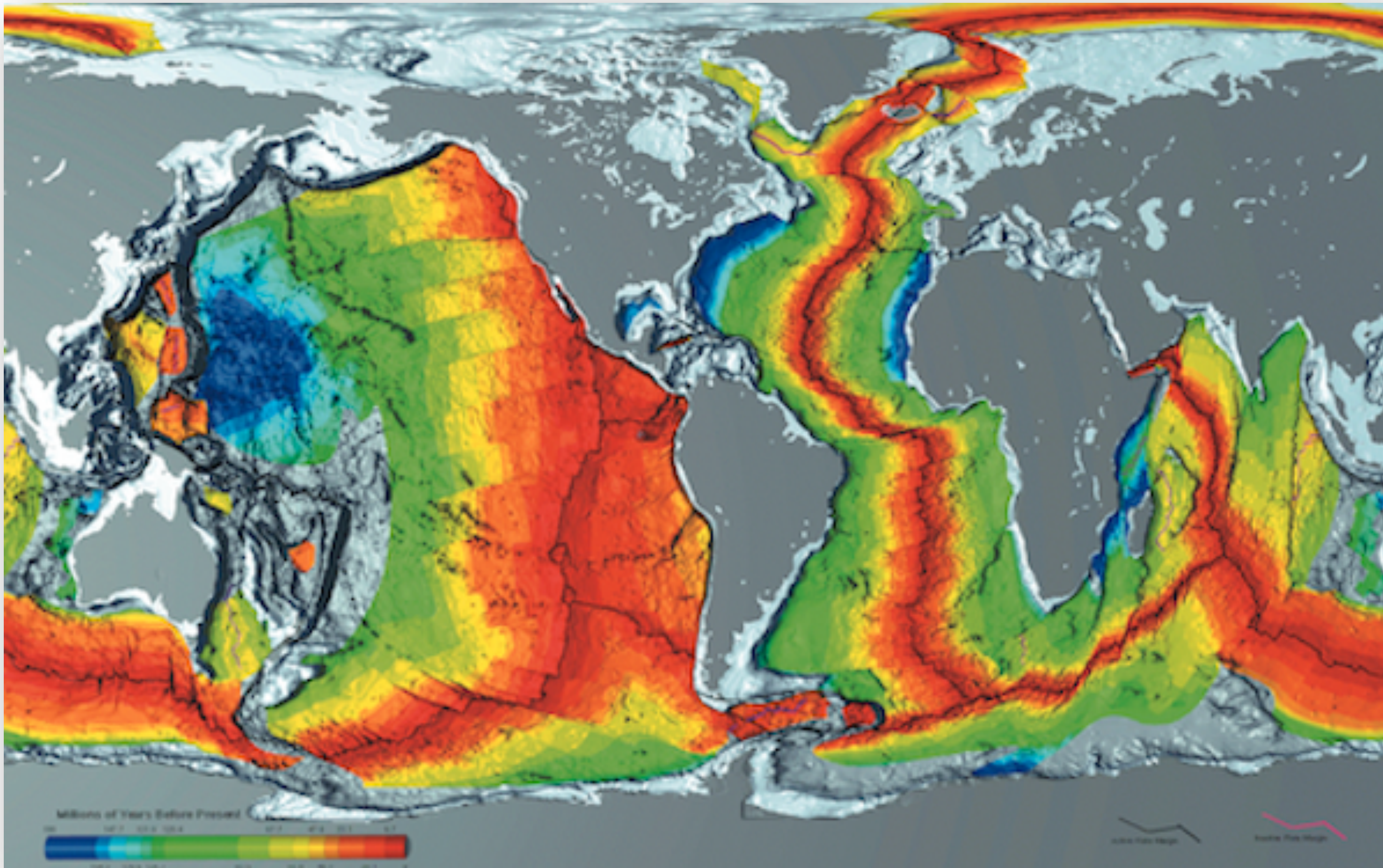




Divergent boundaries are *constructive* margins where crust is formed. Convergent boundaries are *destructive* margins where crust is destroyed through subduction.

Since the size of the Earth has not changed significantly since shortly after it formed, the crust must be destroyed at about the same rate as it is being created. One may think of plate tectonics as a process where the crust is recycled.

Drilling of the seafloor provides evidence for plate tectonics. The age of seafloor rocks varies systematically with distance from the mid ocean ridge.



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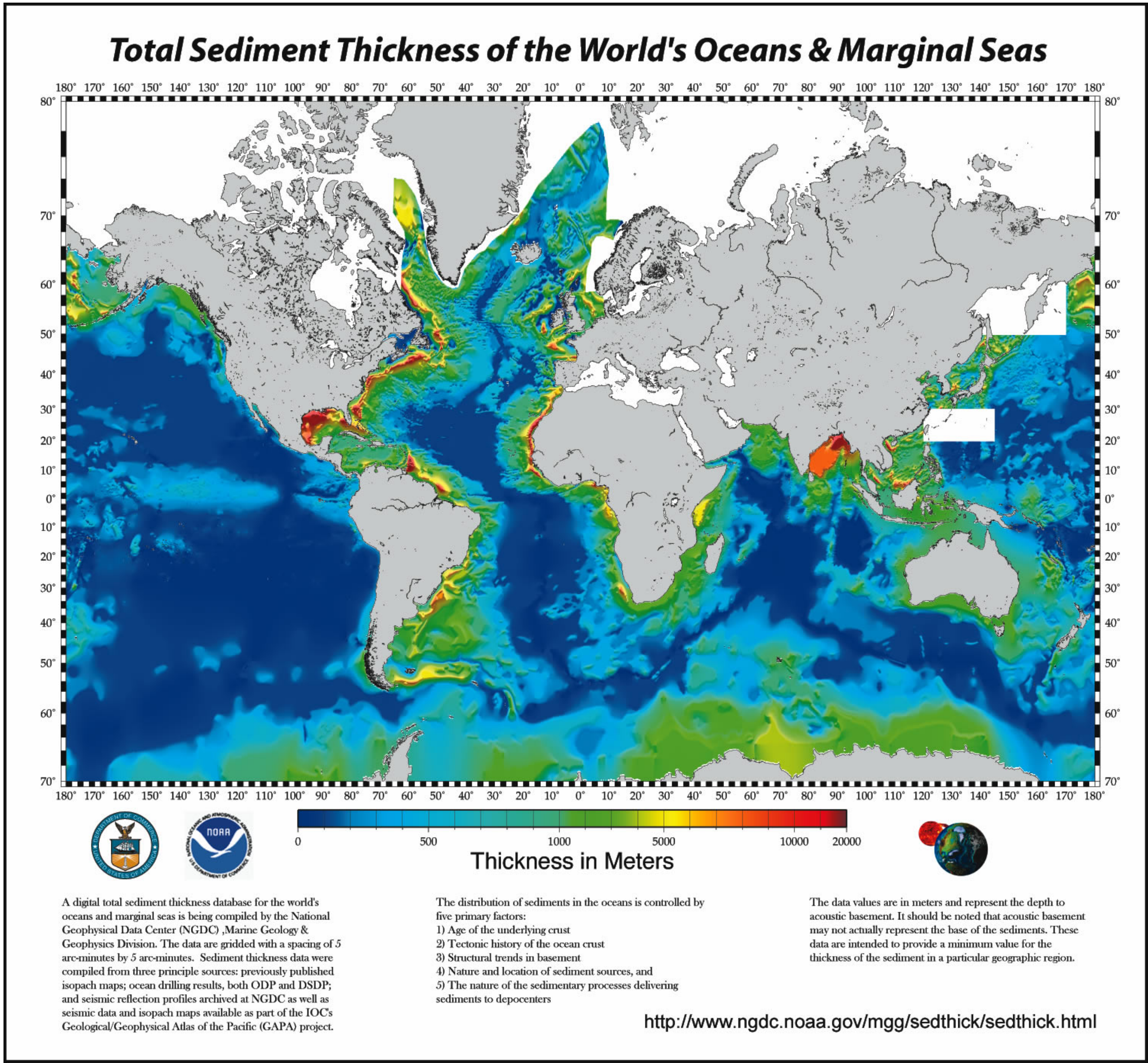
Rocks of the seafloor are young compared to most rocks on the continents

- Rocks on ocean floor younger than 200 million years old
- Rocks on continents as old as 4,000 million years

The figure shows the thickness of sediment on the seafloor throughout the ocean basins.

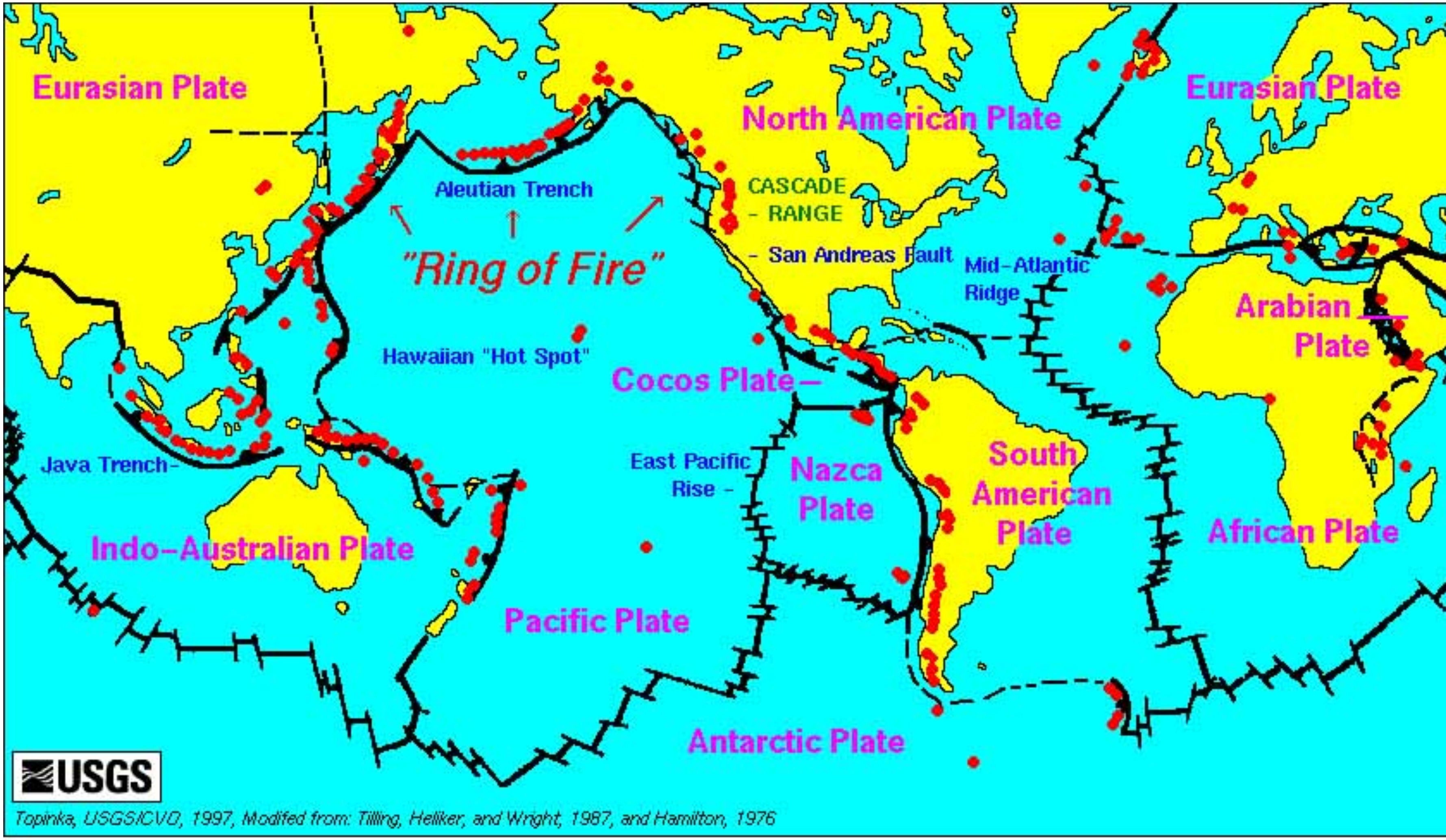
The seafloor at the mid-ocean ridges is young and has essentially no sedimentary cover.

Generally, the sedimentary cover increases with distance from the mid-ocean ridge.

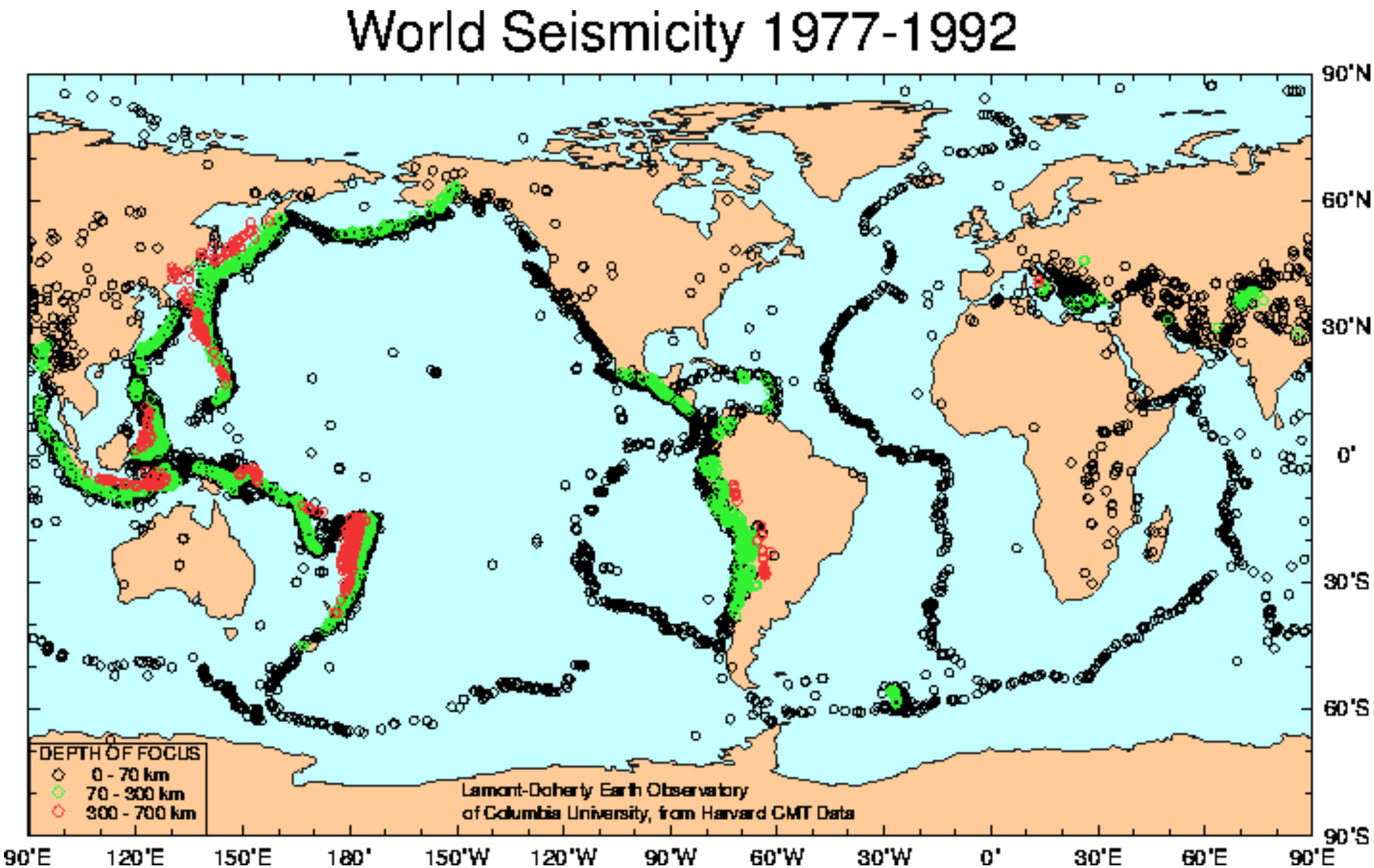


Volcanoes and Plate Tectonics

Most active volcanoes are located around the Pacific rim (Ring of Fire) where they are associated with oceanic trenches.



Earthquakes and Plate Tectonics

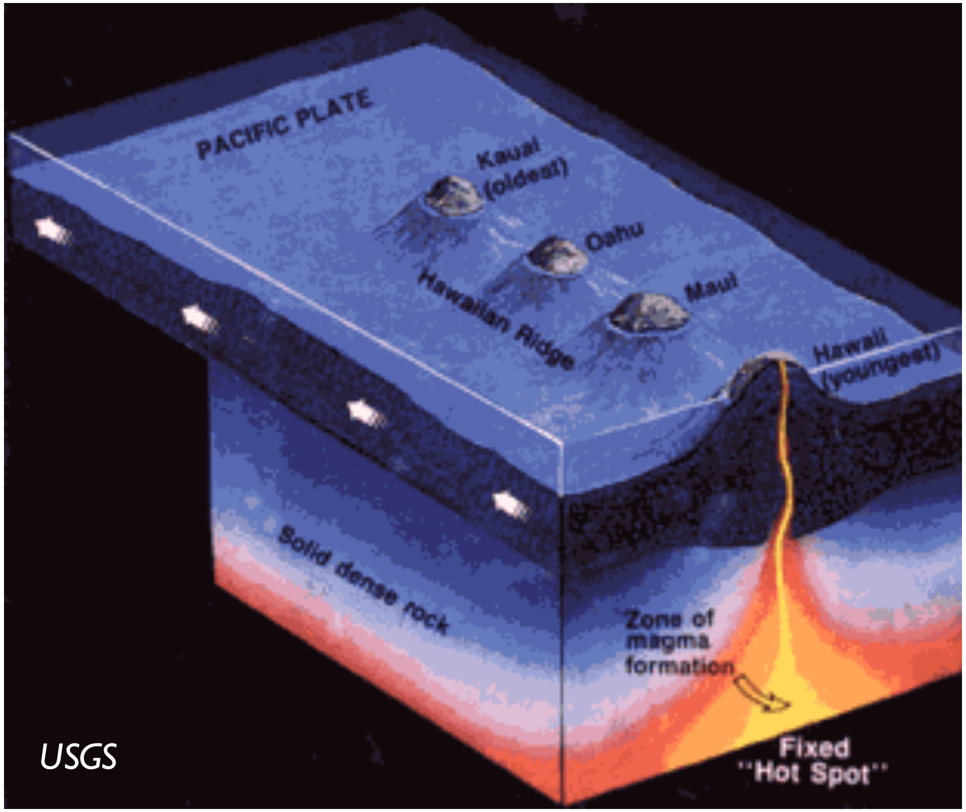


Earthquakes found near oceanic ridges and trenches

- Only shallow earthquakes found near oceanic ridge
- Deep earthquakes found only near oceanic trenches
- Largest earthquakes near trenches

Mantle Hot Spots

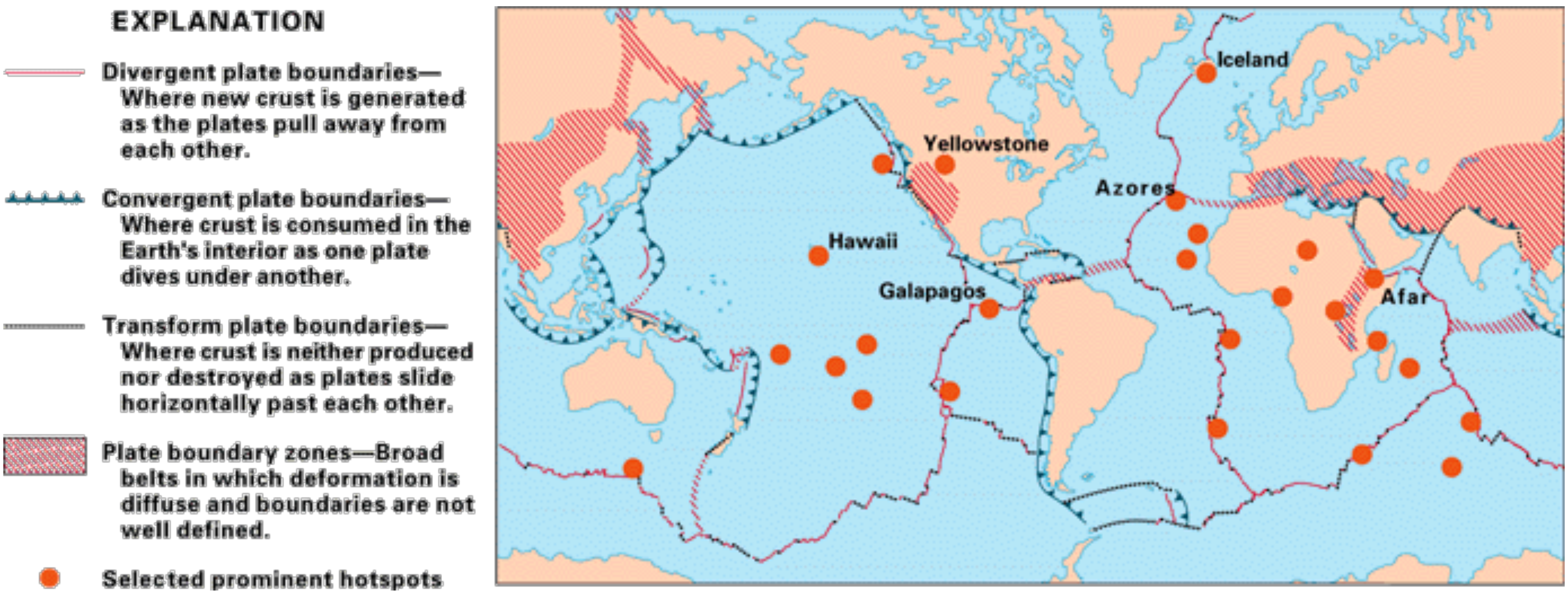
Although most igneous activity occurs along plate boundaries, there are some regions of igneous activities that occur within oceanic and continental plates (ex. Hawaii and Yellowstone). The explanation for these intraplate volcanoes was not adequately explain until the development of the theory of plate tectonics.



There are plumes in the mantle where hot material is rising known as *mantle hot spots*. The *mantle hot spots* remain essentially stationary but when the crust moves over the hot spot, melting can occur resulting in volcanic activity.

This figure shows the location of hot spots and line indicates the apparent motion of the plates over each hotspot.

Note that hot spots occur beneath oceanic and continental crust — Africa seems to be particularly abundant in hot spots.



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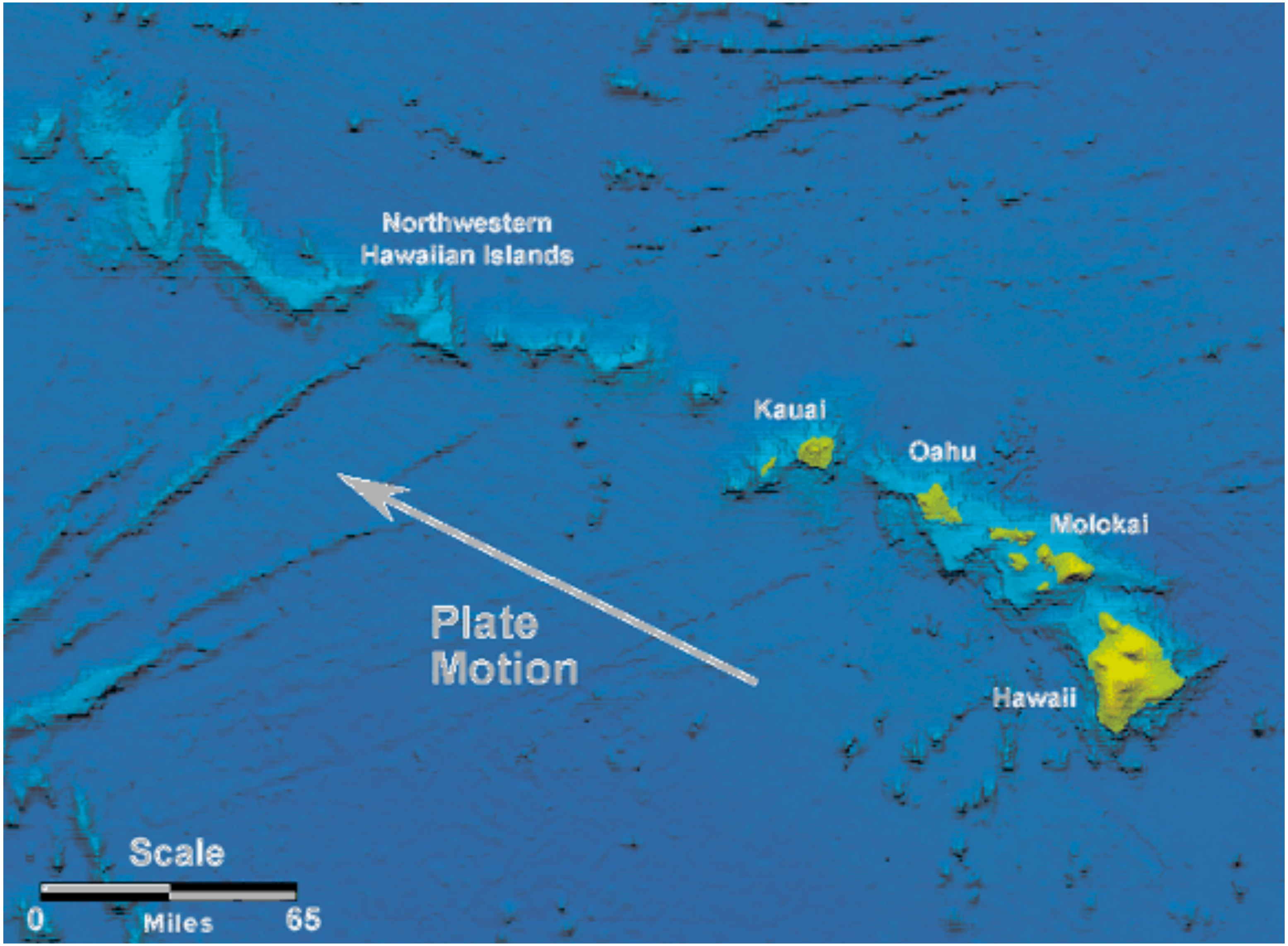
Many of these hot spots are easy to identify as lines of seamounts and volcanoes on the map of the seafloor.

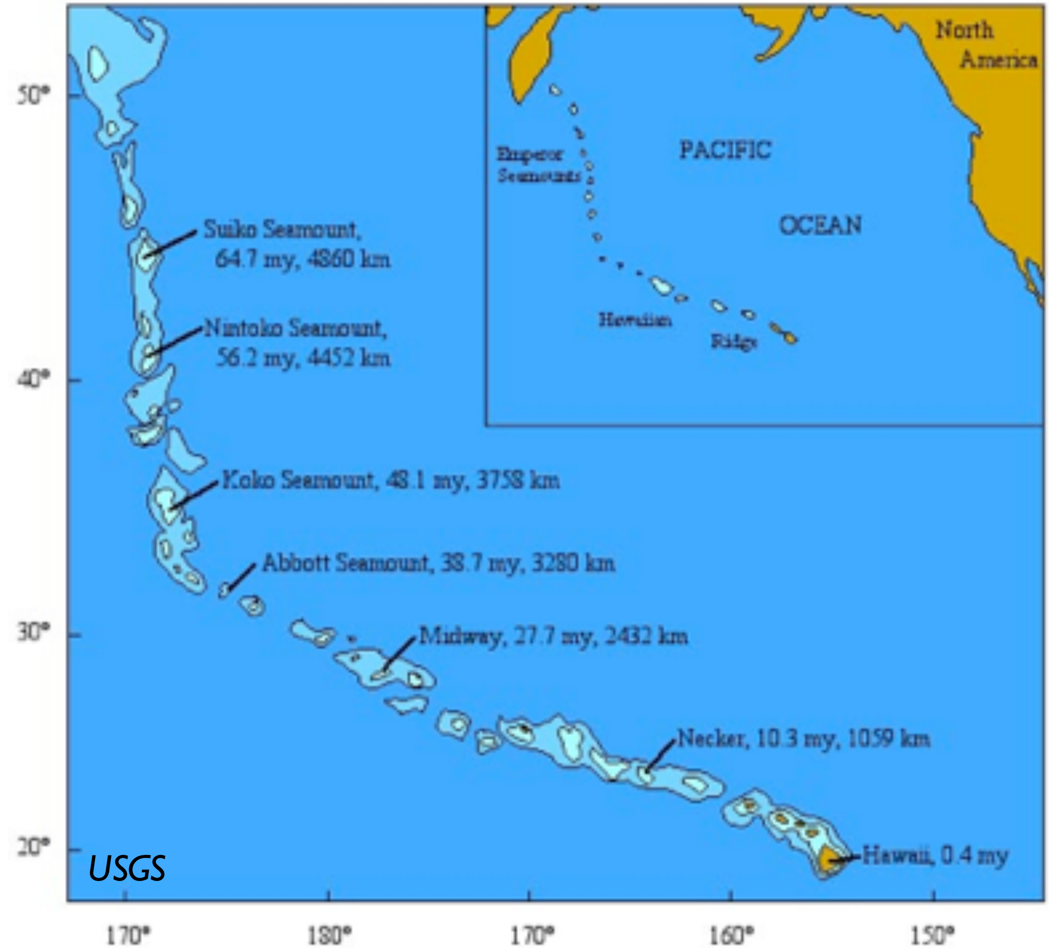


This figure shows the Hawaiian Islands and seamount chain and the Emperor seamount chain.

In addition, the age of each is listed.

Kilauea is currently erupting and is located directly over the hot spot. However, the further the island or seamount is from the hot spot, the older the age.

A new Hawaiian island/seamount, Loihi, is starting to form off the southeast coast of the Big Island.



These data are also excellent evidence in support of the theory of plate tectonics.