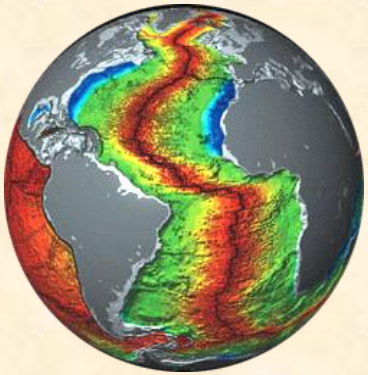
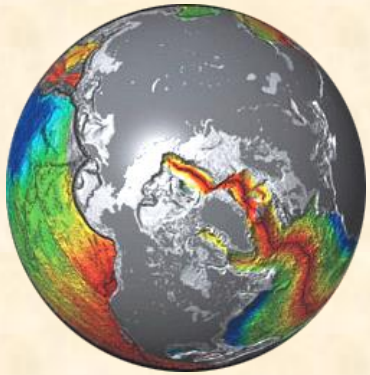
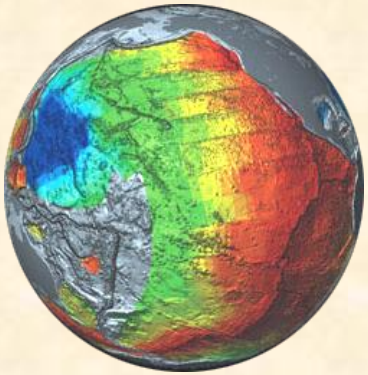
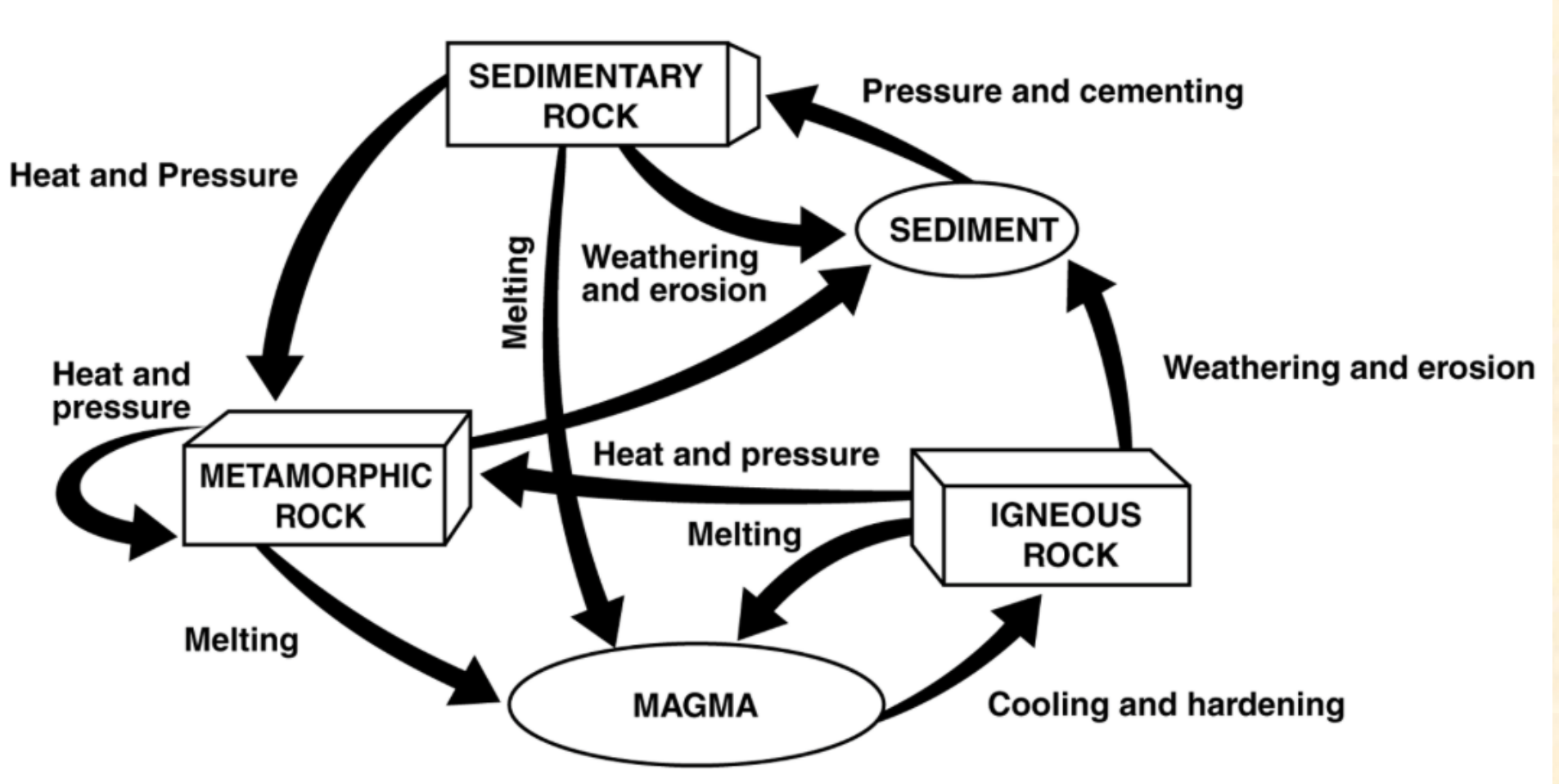
The Structure of the Earth, Plate Tectonics and Landforms

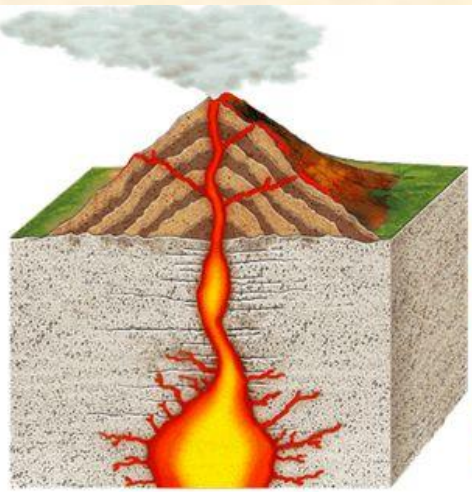
Rock Cycle



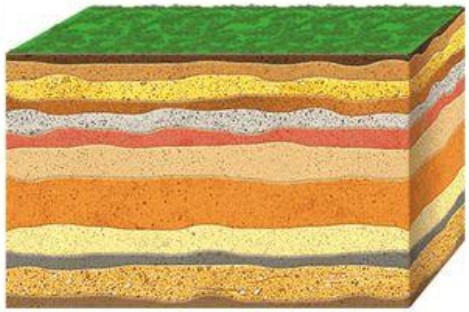
Igneous: formed through cooling and solidification of magma or lava
Metamorphic: transformation of an existing rock through heat and pressure
Sedimentary: formed through deposition and cementation of weathered rock products

CLASSIFICATION OF ROCKS

- **Sedimentary**
  - Clastic
    - Conglomerate
    - Breccia
    - Sandstone
    - Siltstone
    - Mudstone
    - Shale
  - Chemical
    - Limestone
    - Dolostone
    - Evaporites
  - Biologic
    - Coal
    - Chert
- **Igneous**
  - Intrusive
    - Gabbro
    - Diorite
    - Granodiorite
    - Granite
  - Extrusive
    - Basalt
    - Andesite
    - Dacite
    - Rhyolite
- **Metamorphic**
  - Foliated
    - Slate
    - Schist
    - Gneiss
  - Non-foliated
    - Quartzite
    - Marble



Igneous Rock forms when magma or lava cools and hardens.

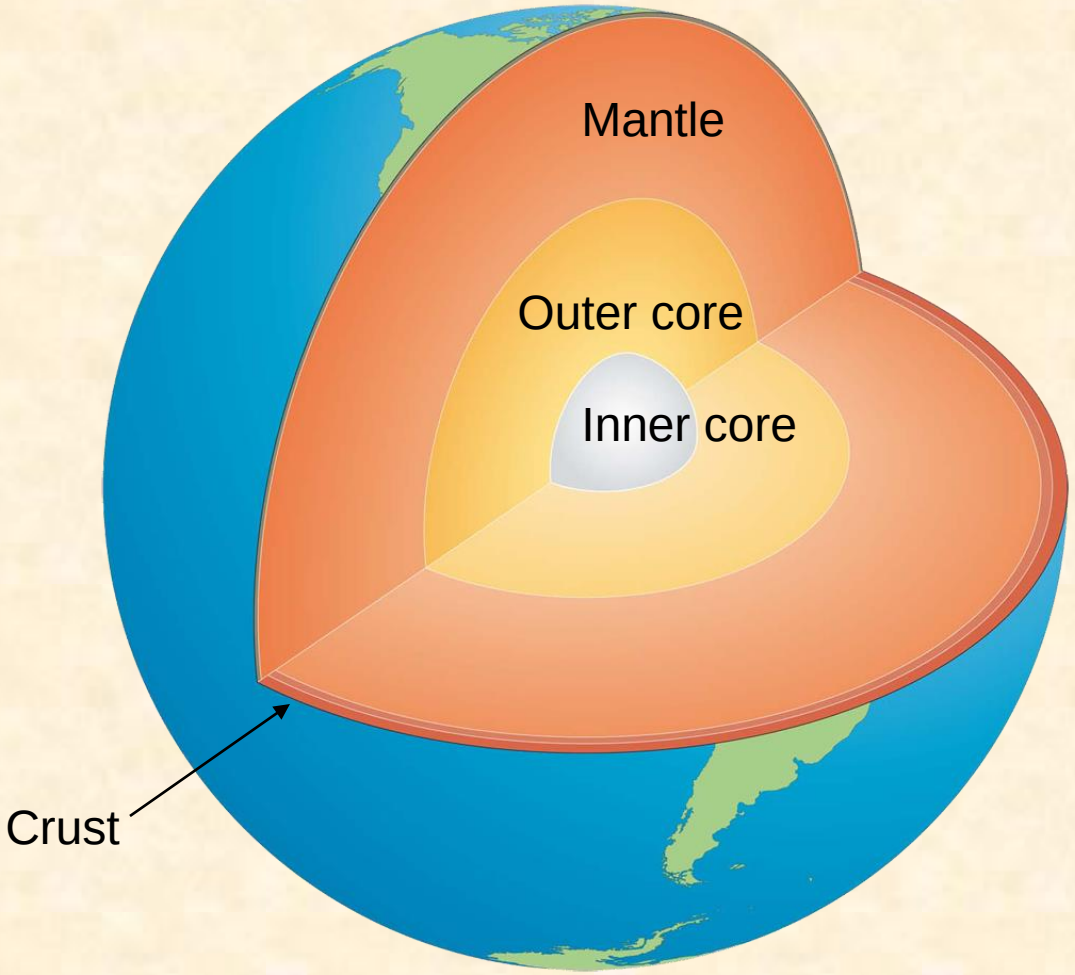


Sedimentary Rock forms when pieces of rock are pressed and cemented together.

Metamorphic Rock forms from other rocks that are changed by heat and pressure.

Structure of the Earth

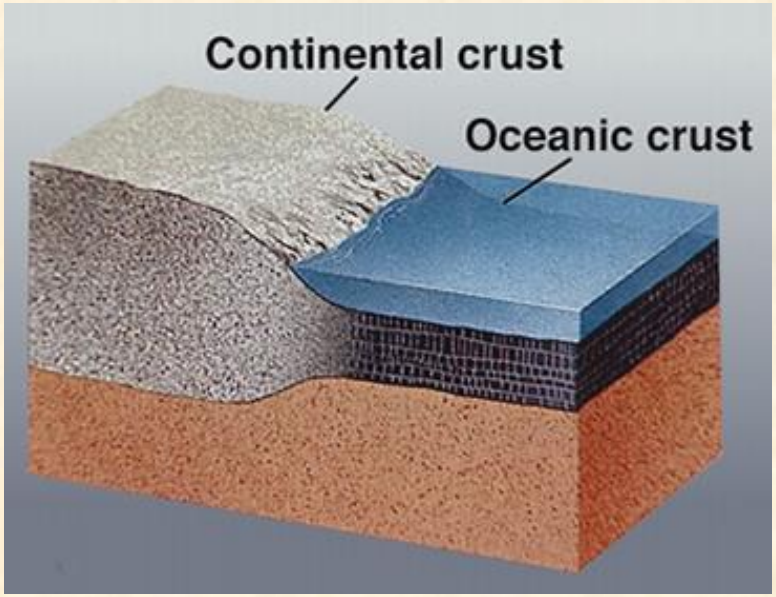
- The Earth is made up of 3 main layers:
  - Core
  - Mantle
  - Crust



The Crust

- Upper thermal boundary layer associated with mantle convection

- The Earth's crust is made of:



Continental Crust

- thick (10-70km)
- buoyant (less dense than oceanic crust)
- mostly old

Oceanic Crust

- thin (~7 km)
- dense (sinks/subducts under continental crust)
- young (Atlantic 200 my)

Earth's Crust: cold, brittle

Thin layer, 0.4% of Earth's mass and 1% of its volume

Continental Crust

- Primarily granitic type rock (Na, K, Al, SiO_2)
- 40 km thick on average
- Relatively light, 2.7 g/cm^3

Oceanic Crust

- Primarily basaltic (Fe, Mg, Ca, low SiO_2)
- 7 km thick
- Relatively dense, 2.9 g/cm^3

cool, solid crust and upper (rigid) mantle "float" and move over hotter, deformable lower mantle

Knowledge of the Earth's Structure

- Geophysical surveys: seismic, gravity, magnetics, electrical, geodesy (geodetics)
  - Acquisition: land, air, sea and satellite
  - Geological surveys: fieldwork, boreholes, mines

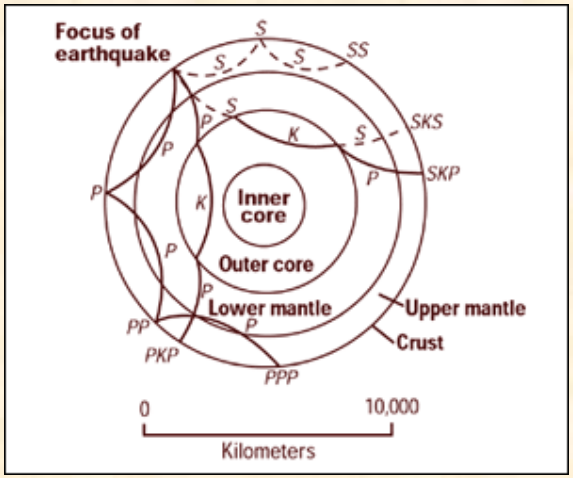


Plate Tectonics

- The Earth's crust is divided into plates which are moved in various directions.
- This plate motion causes them to collide, pull apart, or scrape against each other.
- Each type of interaction causes a characteristic set of Earth structures or "tectonic" features.
- The word, tectonic, refers to the deformation of the crust as a consequence of plate interaction.
- The surface expression of mantle convection

World Plates

Major plates – Pacific, African, Eurasian, North American, Antarctic, South American, Australian

Minor plates – Nazca, Indian, Arabian, Philippine, Caribbean, Cocos, Scotia, Juan de Fuca

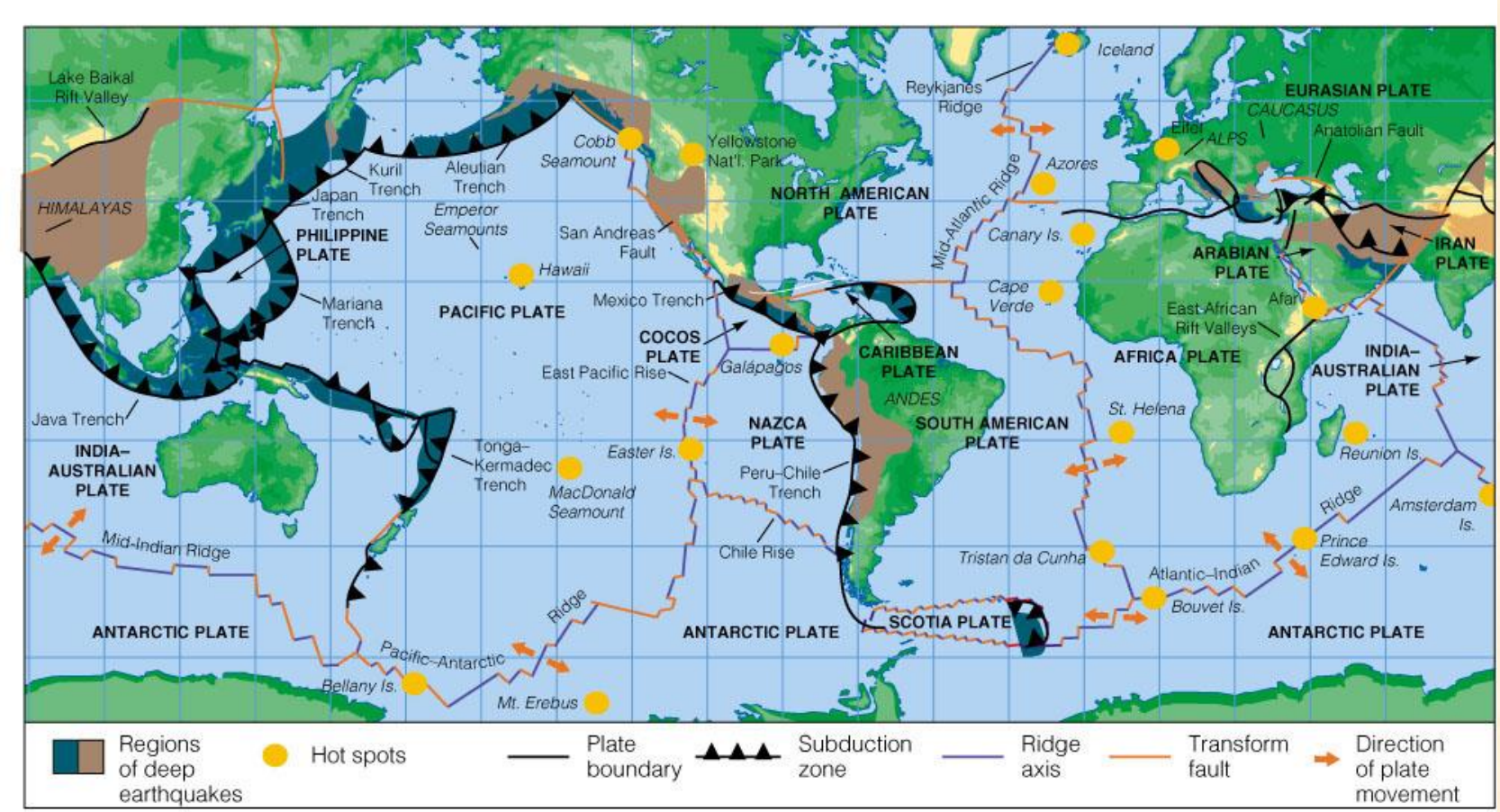
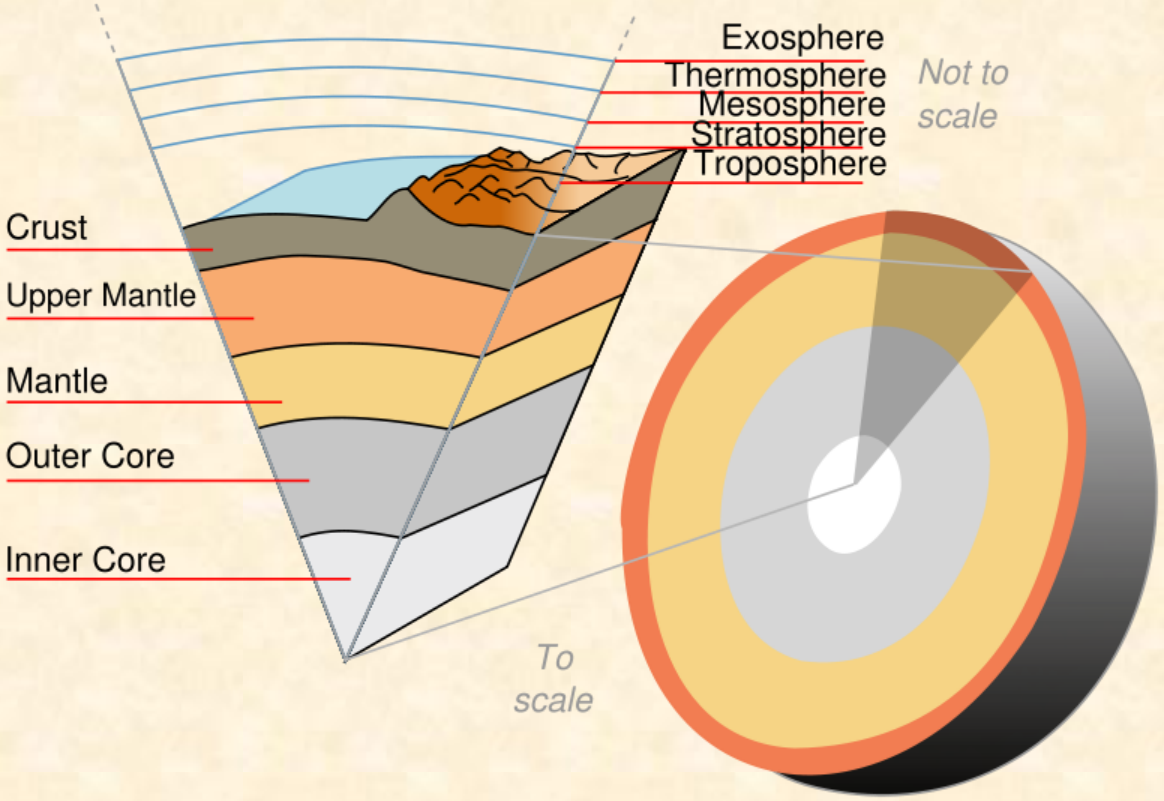


Plate Composition

- Plates are made of rigid **lithosphere**.

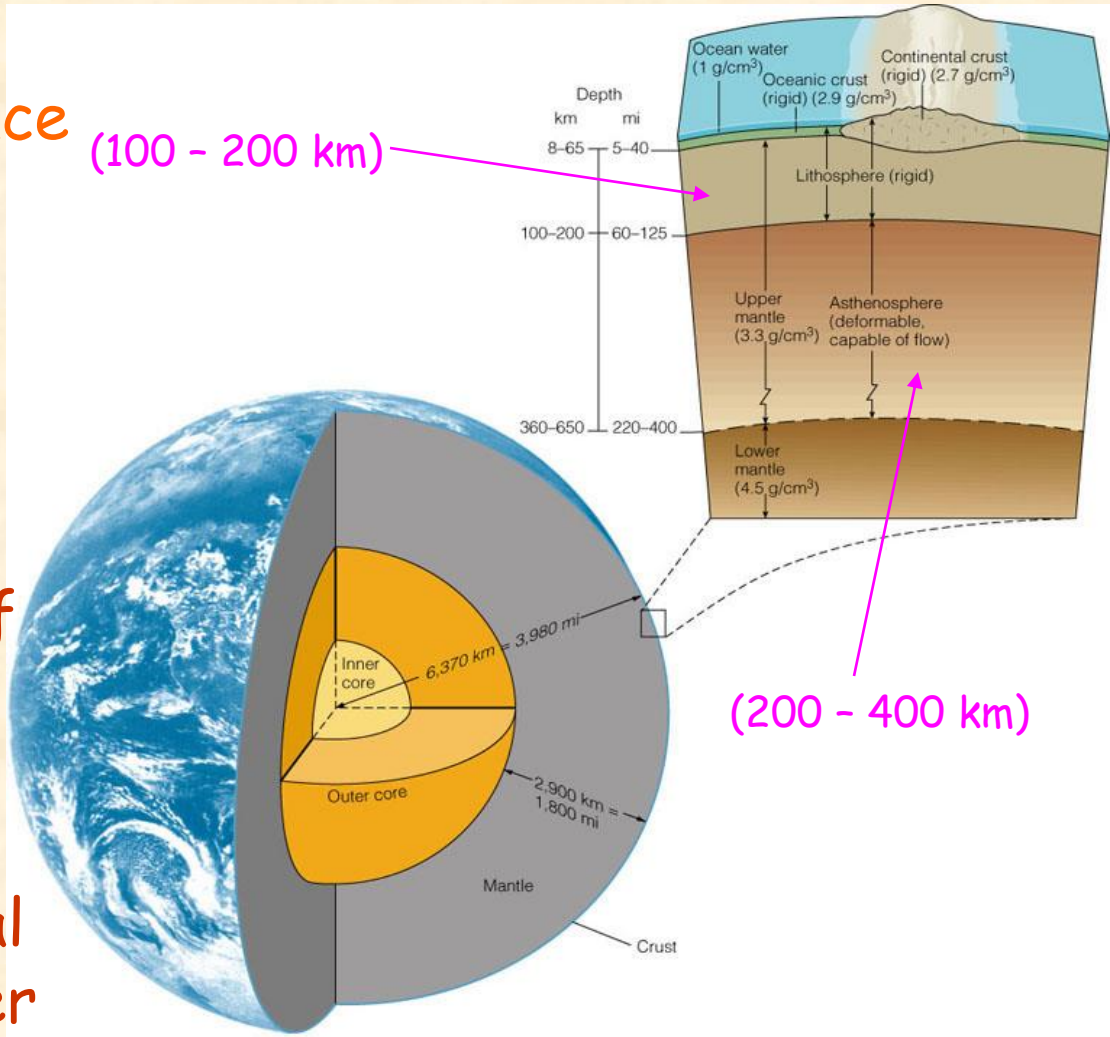
The lithosphere is made up of the crust and the upper part of the mantle.



Lithosphere & Asthenosphere: More detailed description of Earth's layered structure according to mechanical behavior of rocks, which ranges from very rigid to deformable

1. **lithosphere**: rigid surface shell that includes upper mantle and crust (here is where 'plate tectonics' work), cool layer

2. **asthenosphere**: layer below lithosphere, part of the mantle, weak and deformable (ductile, deforms as plates move), partial melting of material happens here, hotter layer

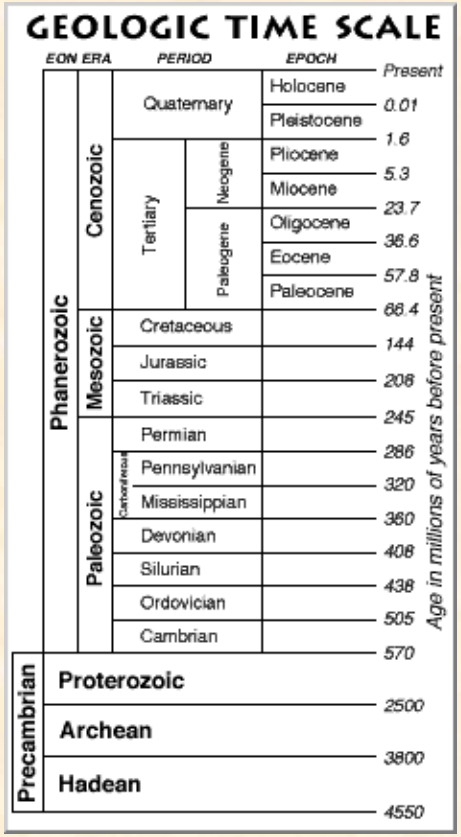


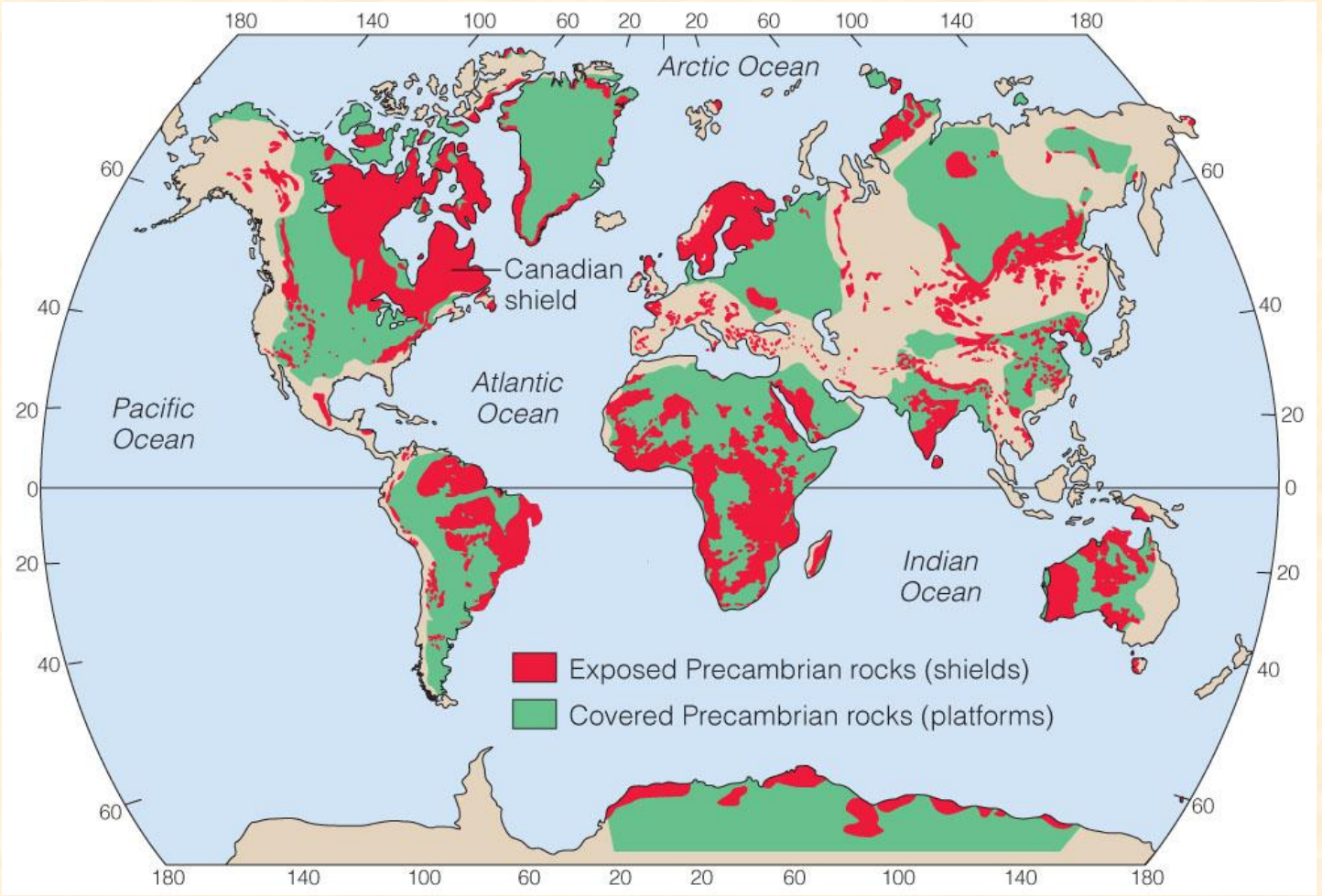
Craton: an old and stable part of the continental lithosphere.

Having often survived cycles of merging and rifting of continents, cratons are generally found in the interiors of tectonic plates.

They have a thick crust and deep lithospheric roots that extend as much as several hundred km into the mantle.

The term *craton* is used to distinguish the stable portion of the continental crust from regions that are more geologically active and unstable.





Cratons can be described as **Shields**, Precambrian crystalline rock that crops out at the surface and **Platforms**, in which the basement rock is overlaid by younger sediments and sedimentary rock. The age of these rocks is in all cases greater than 540 million years, and radiometric age dating has revealed some that are as old as 2 to 3 billion years

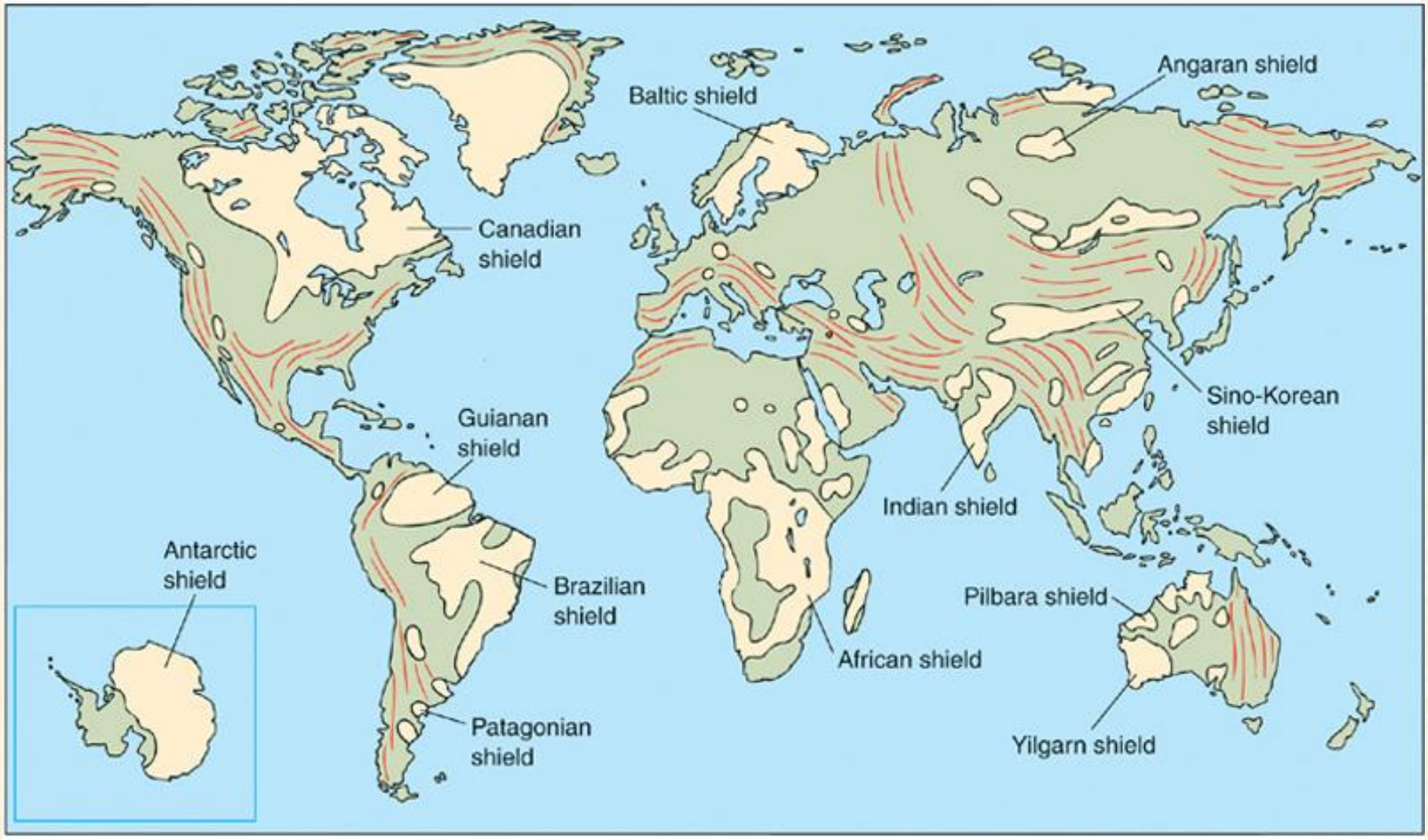
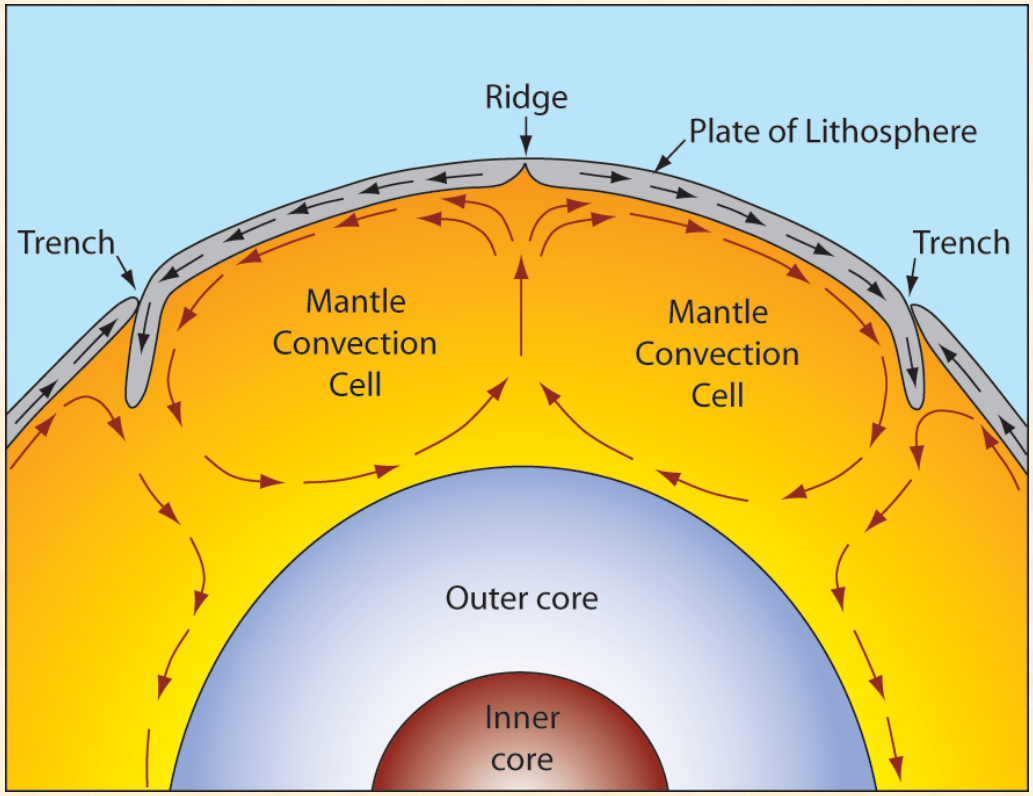

Baltic shield
Angaran shield
Canadian shield
Guianan shield
Sino-Korean shield
Indian shield
Antarctic shield
Brazilian shield
Pilbara shield
African shield
Patagonian shield
Yilgarn shield

Plate Movement

- “Plates” of lithosphere are moved around by the underlying hot mantle convection cells



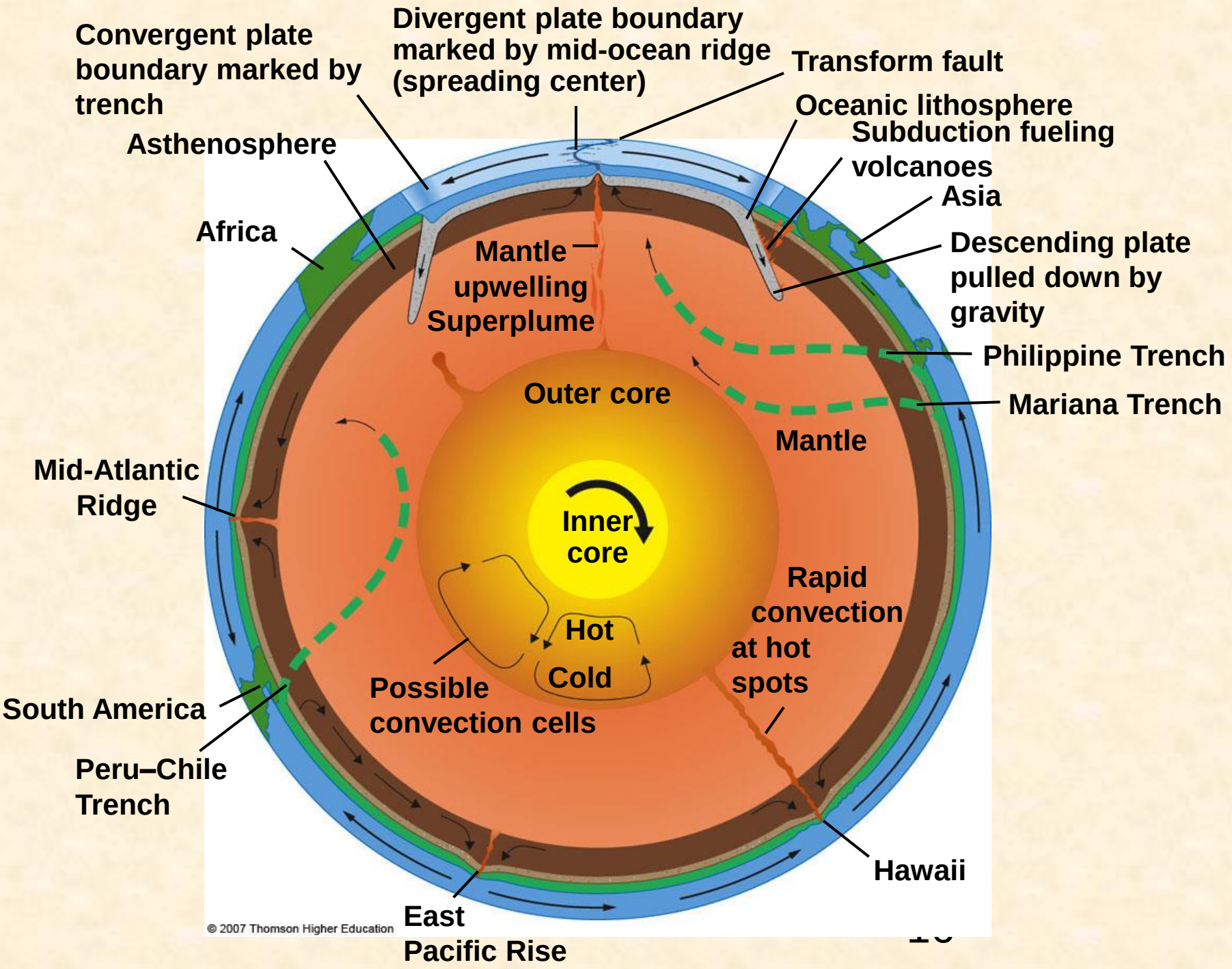

Convergent plate boundary marked by trench
Divergent plate boundary marked by mid-ocean ridge (spreading center)
Transform fault
Oceanic lithosphere
Subduction fueling volcanoes
Asthenosphere
Asia
Africa
Mantle upwelling Superplume
Descending plate pulled down by gravity
Philippine Trench
Outer core
Mariana Trench
Mantle
Mid-Atlantic Ridge
Inner core
Rapid convection at hot spots
Hot
Cold
Possible convection cells
South America
Peru–Chile Trench
Hawaii
East Pacific Rise
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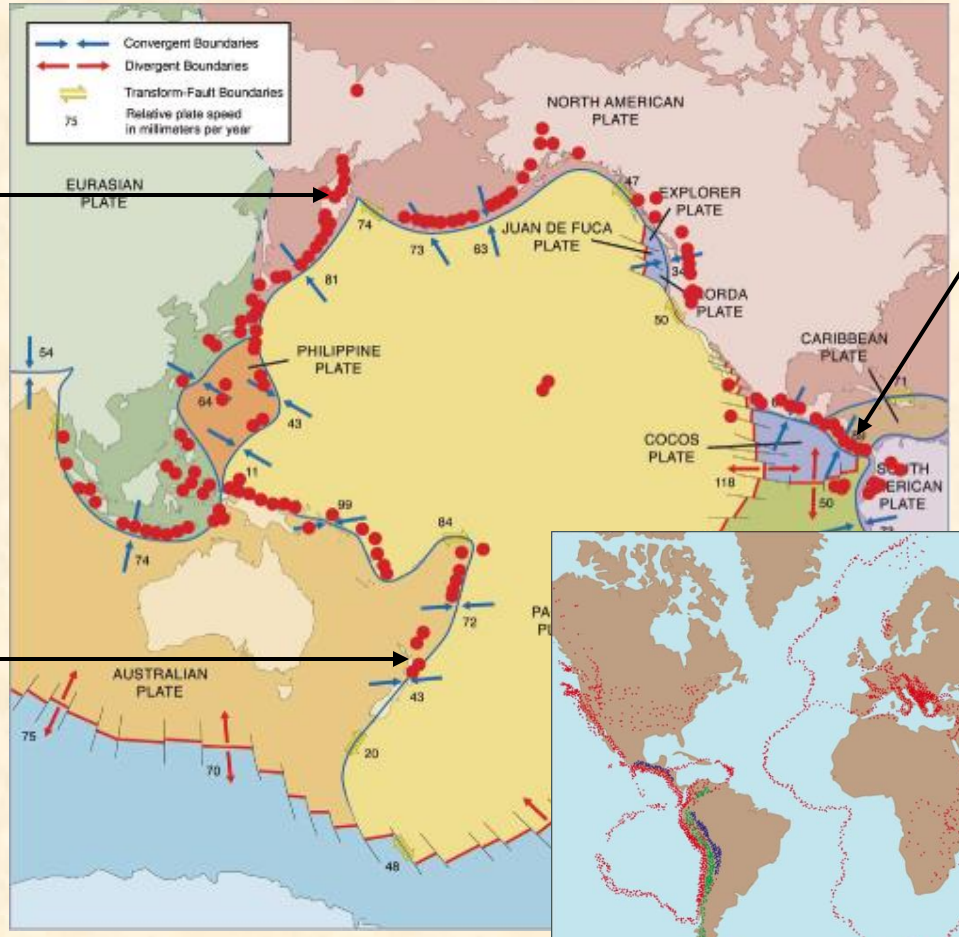
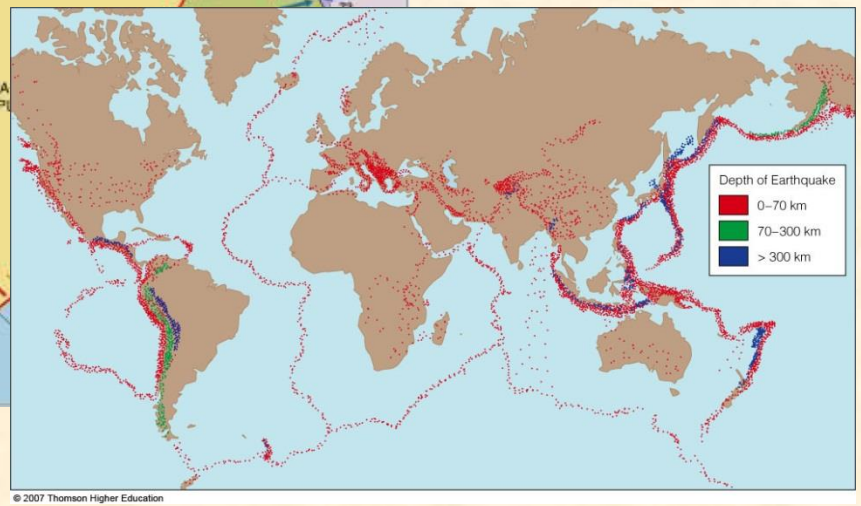
Plate Boundaries

Sites of significant geologic activity

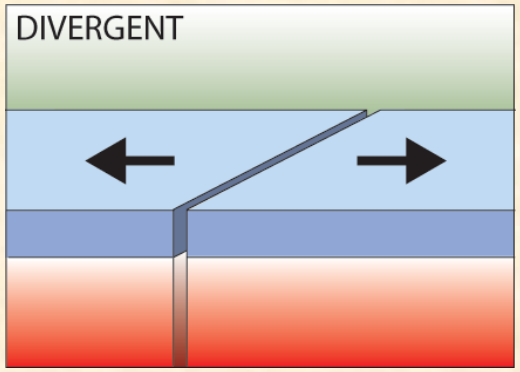
earthquakes, volcanism, orogenesis

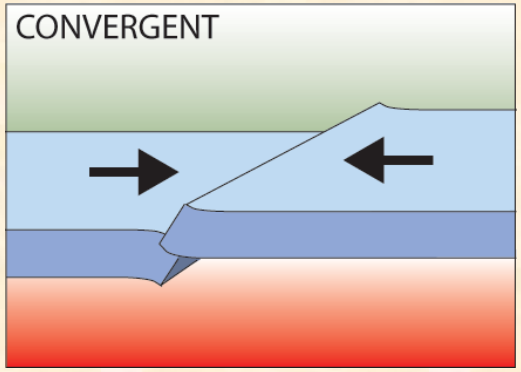


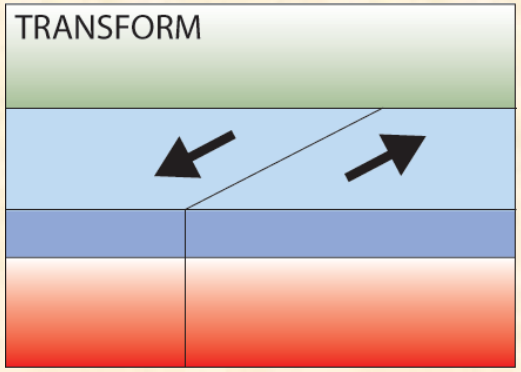


Three types of plate boundary

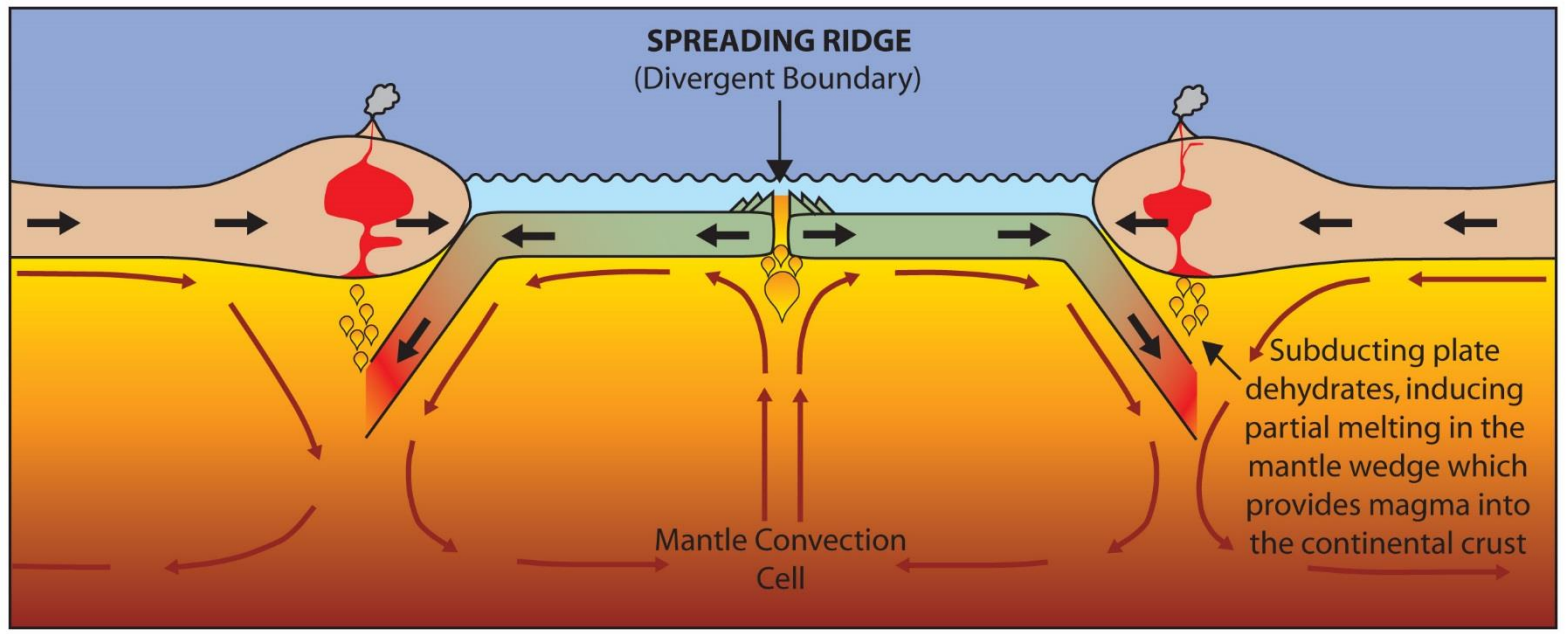
- Divergent
- Convergent
- Transform





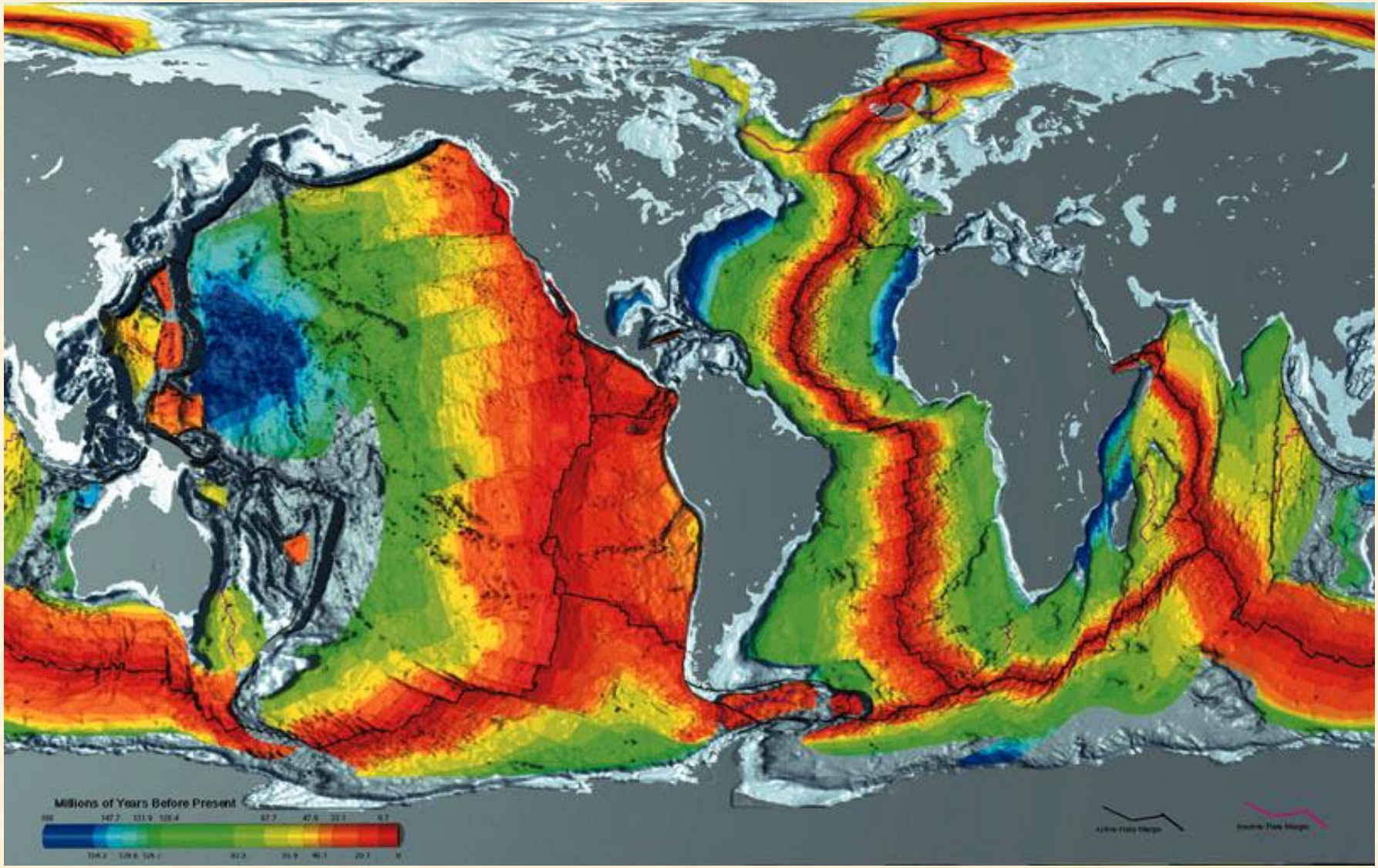


Divergent Boundaries



- Spreading ridges
  - As plates move apart new material is erupted to fill the gap

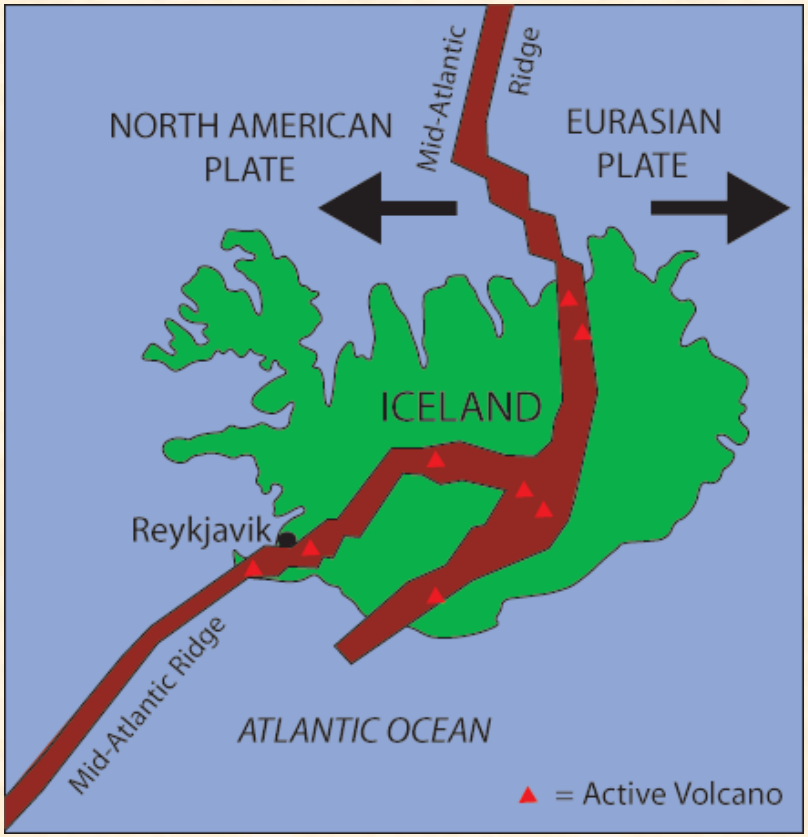
Age of Oceanic Crust

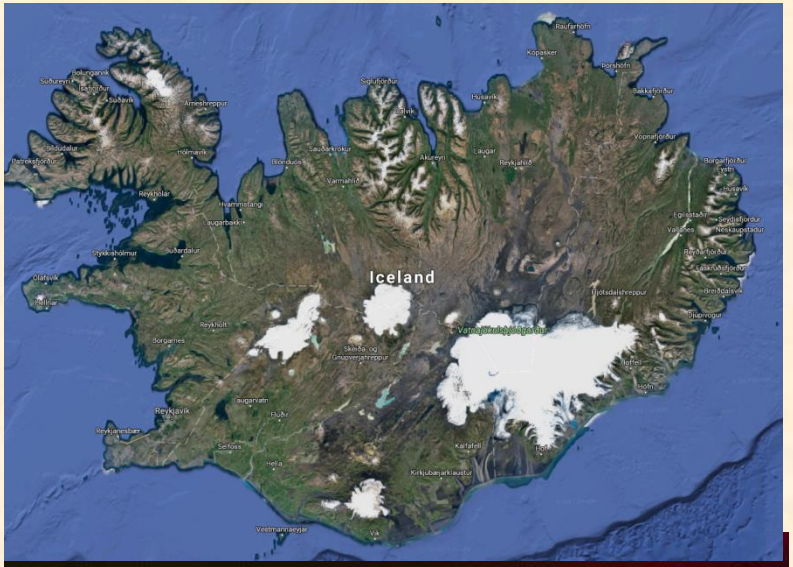


Courtesy of www.ngdc.noaa.gov

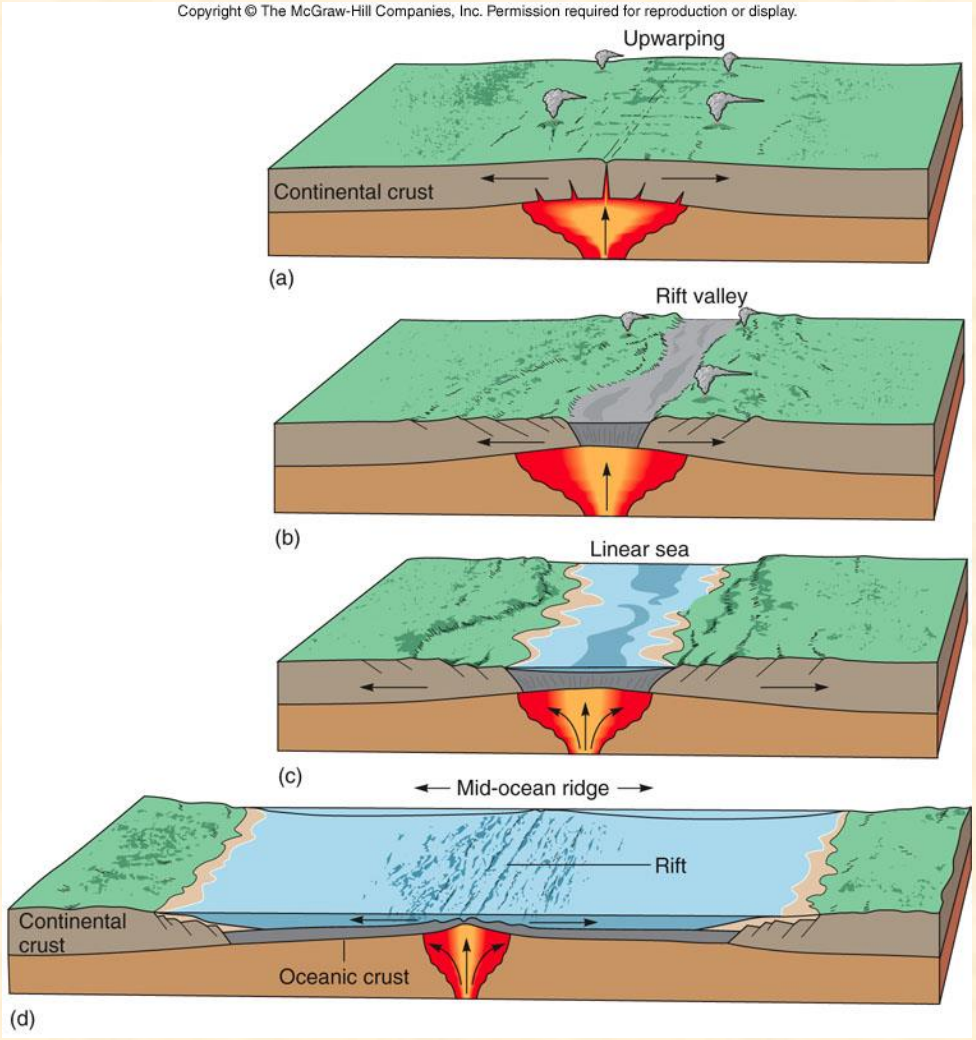
Iceland: An example of continental rifting

- Iceland has a divergent plate boundary running through its middle





Modern divergence
East African Rift System



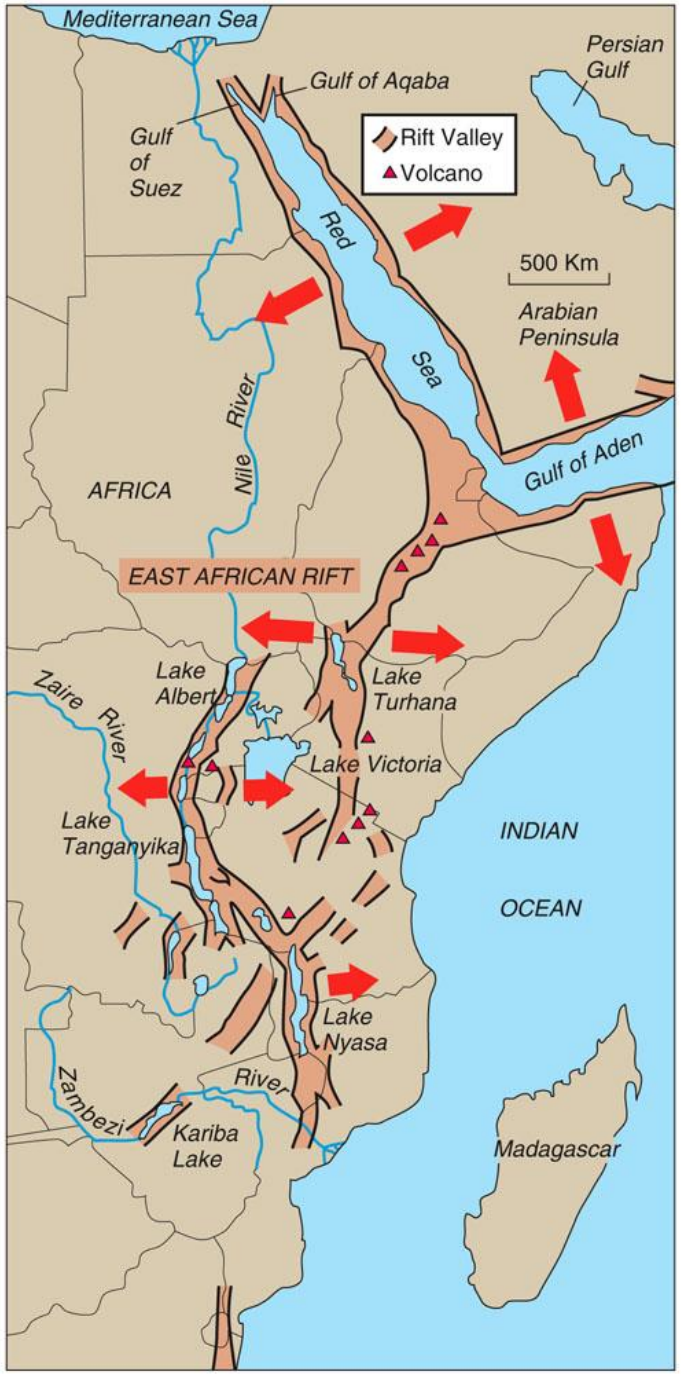
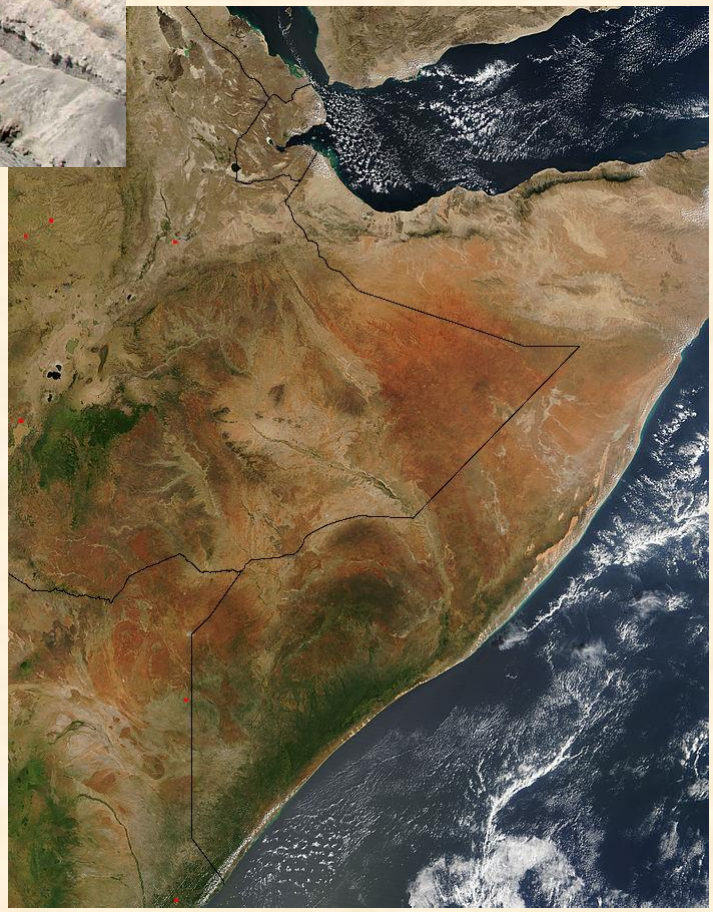
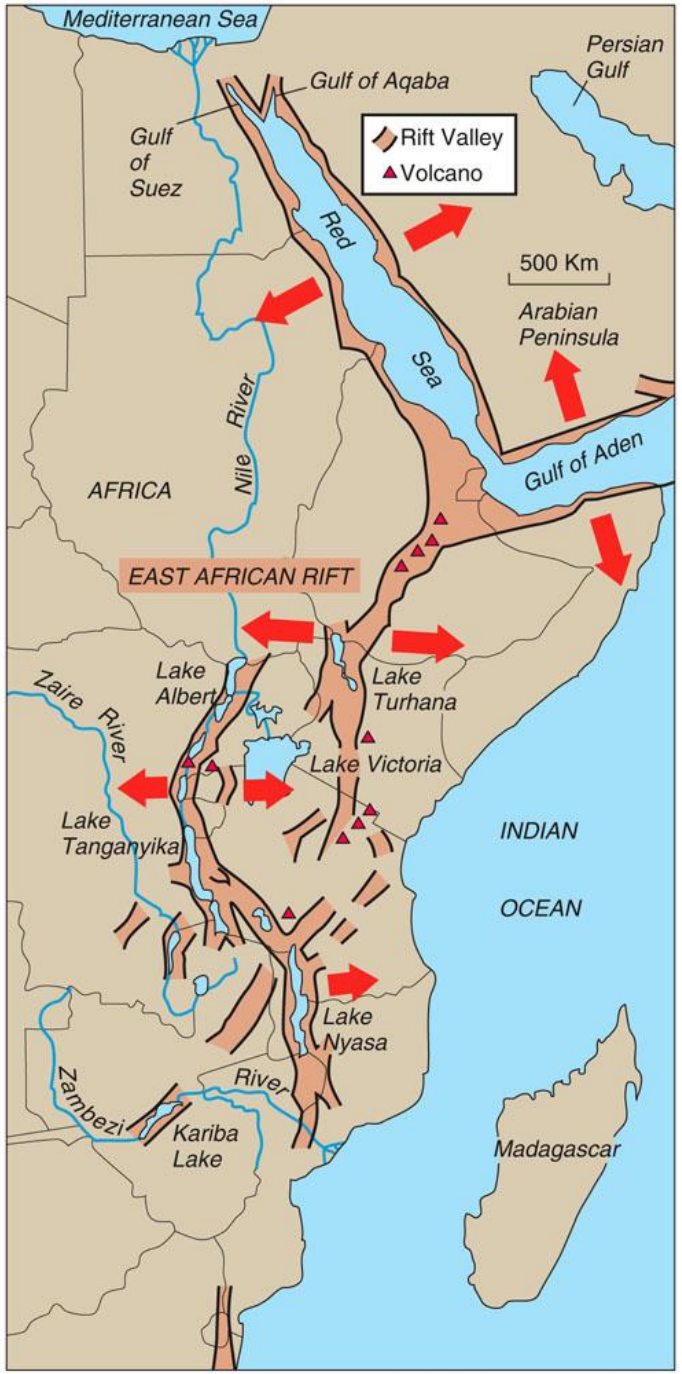


Figure 4.22 A hand-drawn map of a portion of the Atlantic Ocean floor showing some major oceanic features: mid-ocean ridge, transform faults, fracture zones, submarine canyons, seamounts, continental rises, trenches, and abyssal plains. Depths are in feet. The map is vertically exaggerated.

East African Rift System



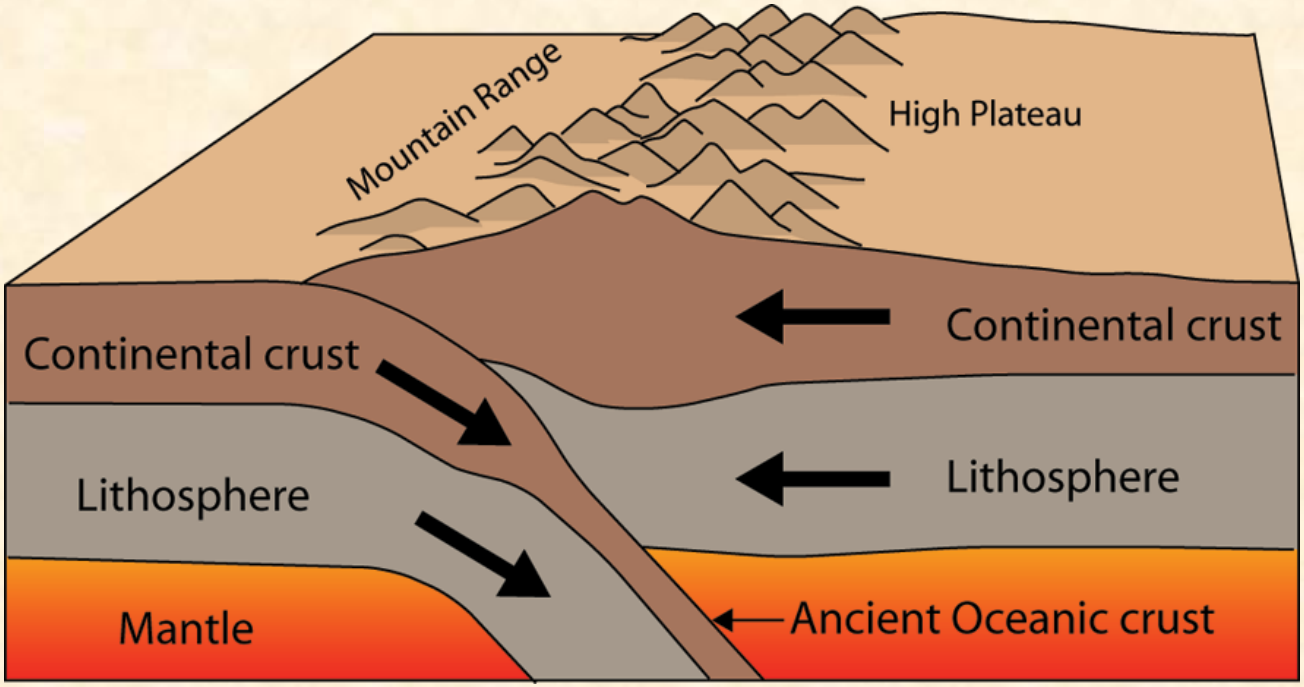


Convergent Boundaries

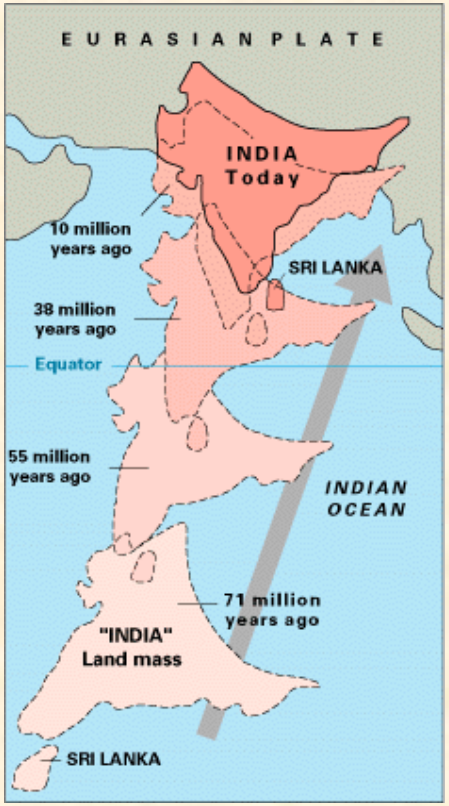
- There are three styles of convergent plate boundaries
  - Continent-continent collision
  - Continent-oceanic crust collision
  - Ocean-ocean collision

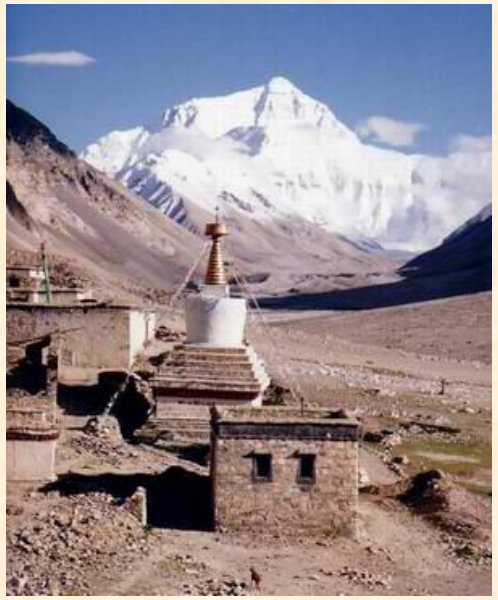
Continent-Continent Collision

- Forms mountains, e.g. European Alps, Himalayas



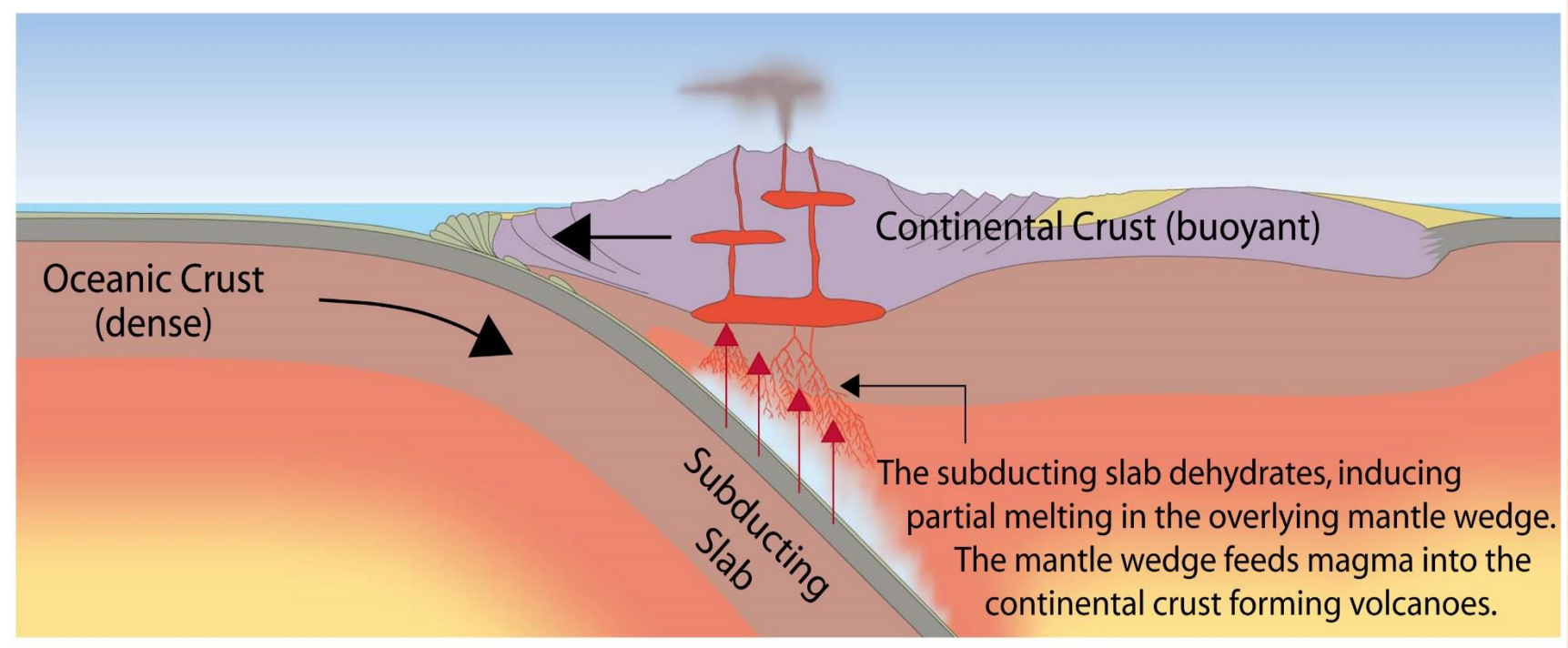
Himalayas


EURASIAN PLATE
INDIA
Today
10 million
years ago
SRI LANKA
38 million
years ago
Equator
55 million
years ago
INDIAN
OCEAN
71 million
years ago
"INDIA"
Land mass
SRI LANKA

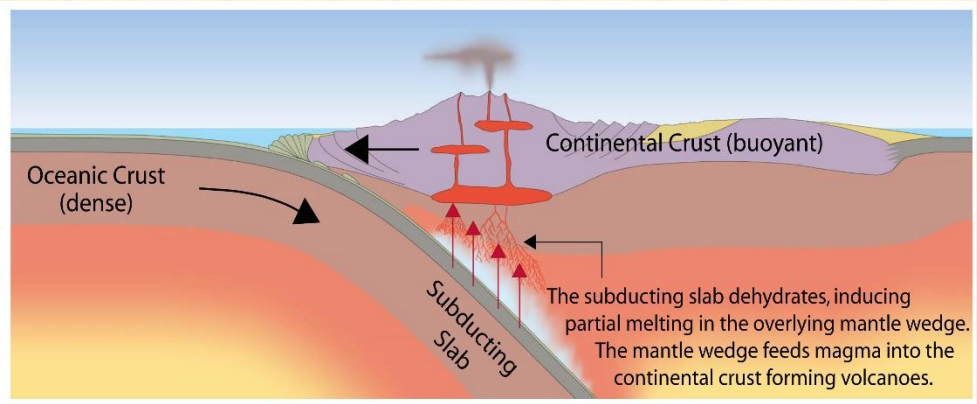


Continent-Oceanic Crust Collision

- Called SUBDUCTION



Subduction

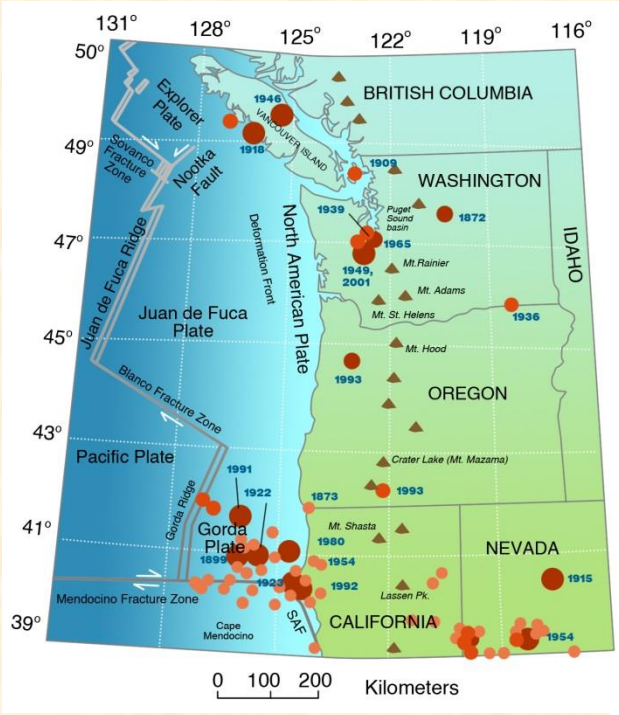


- Oceanic lithosphere subducts underneath the continental lithosphere
- Oceanic lithosphere heats and dehydrates as it subsides
- The melt rises resulting in volcanism
- E.g. The Andes

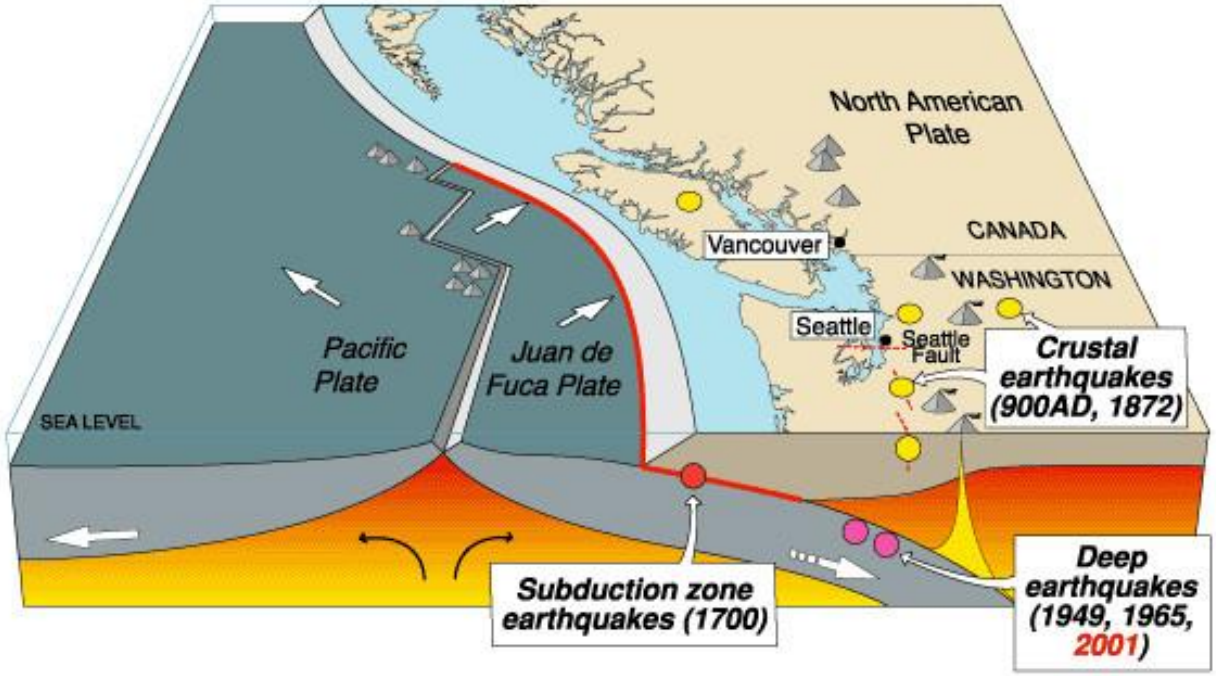

Continent – Ocean
West Coast of South America
© 2007 Europa Technologies
Image © 2007 NASA
Image © 2007 TerraMetrics
©2006 Google™
Pointer 19°13'31.68" S 76°23'04.10" W
Streaming 100%
Eye alt 5282.93 mi

- Continent – Ocean

- Mount St. Helens



Cascadia earthquake sources



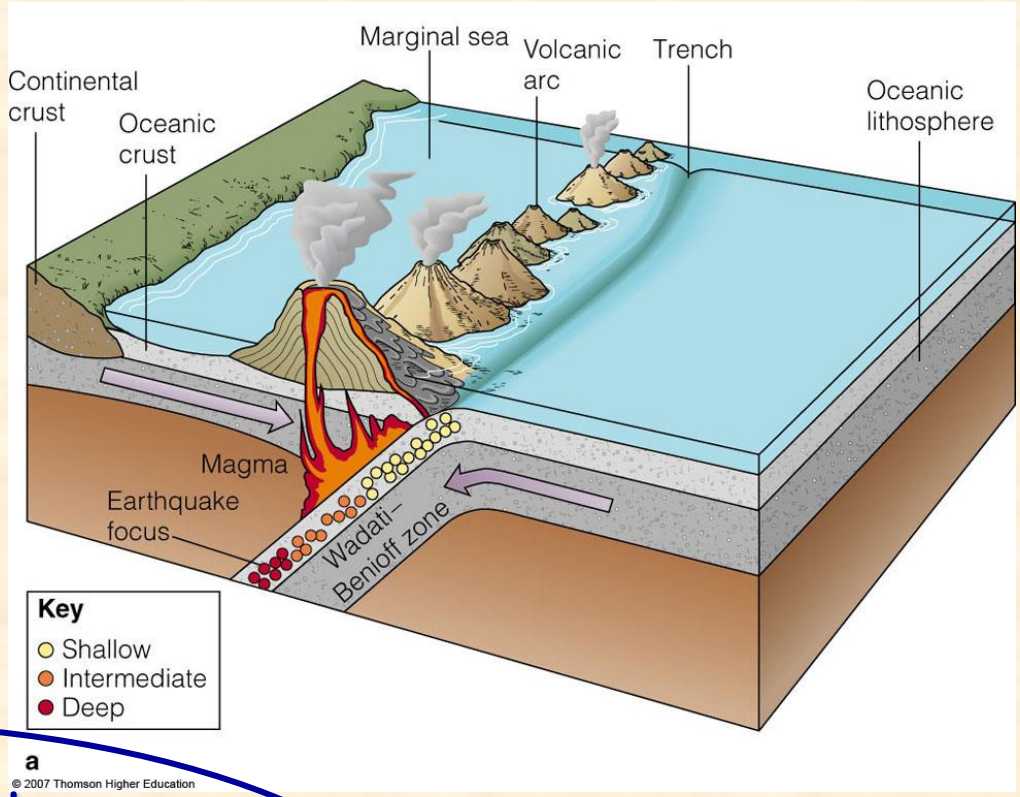
Source	Affected area	Max. Size	Recurrence
Subduction Zone	W.WA, OR, CA	M 9	500-600 yr
Deep Juan de Fuca plate	W.WA, OR,	M 7+	30-50 yr
Crustal faults	WA, OR, CA	M 7+	Hundreds of yr?

Ocean-Ocean Plate Collision

- When two oceanic plates collide, the older more dense slab will sink back into the mantle forming a **subduction zone**.
- The subducting plate is bent downward to form a very deep depression in the ocean floor called a **trench**.
- Trench systems occur for both continent-ocean and ocean-ocean boundaries
- The worlds deepest parts of the ocean are found along trenches.
  - E.g. The Mariana Trench is 11 km deep!

Island Arcs Form, Continents Collide, and Crust Recycles at Convergent Plate Boundaries

The formation of an island arc along a trench as two oceanic plates converge. The volcanic islands form as masses of magma reach the seafloor. The Japanese islands were formed in this way.



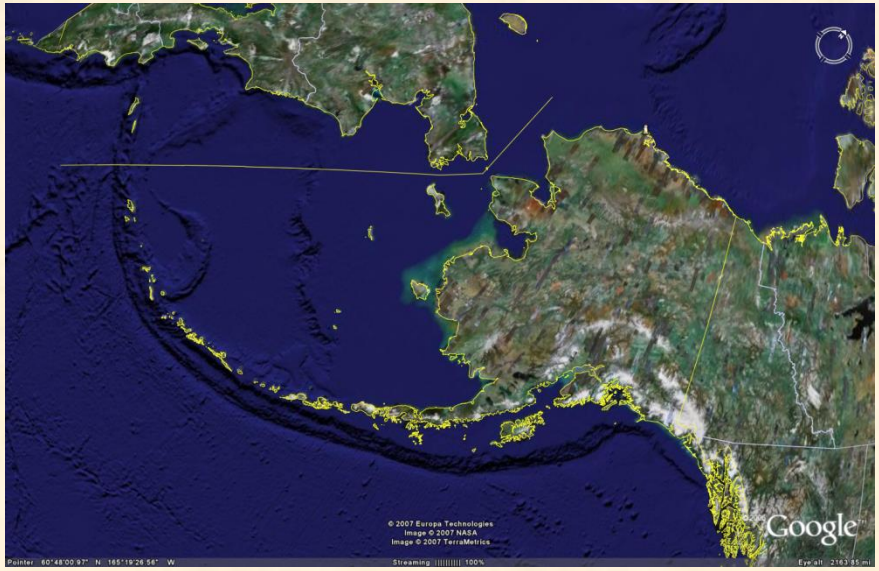
Motion of the plates:

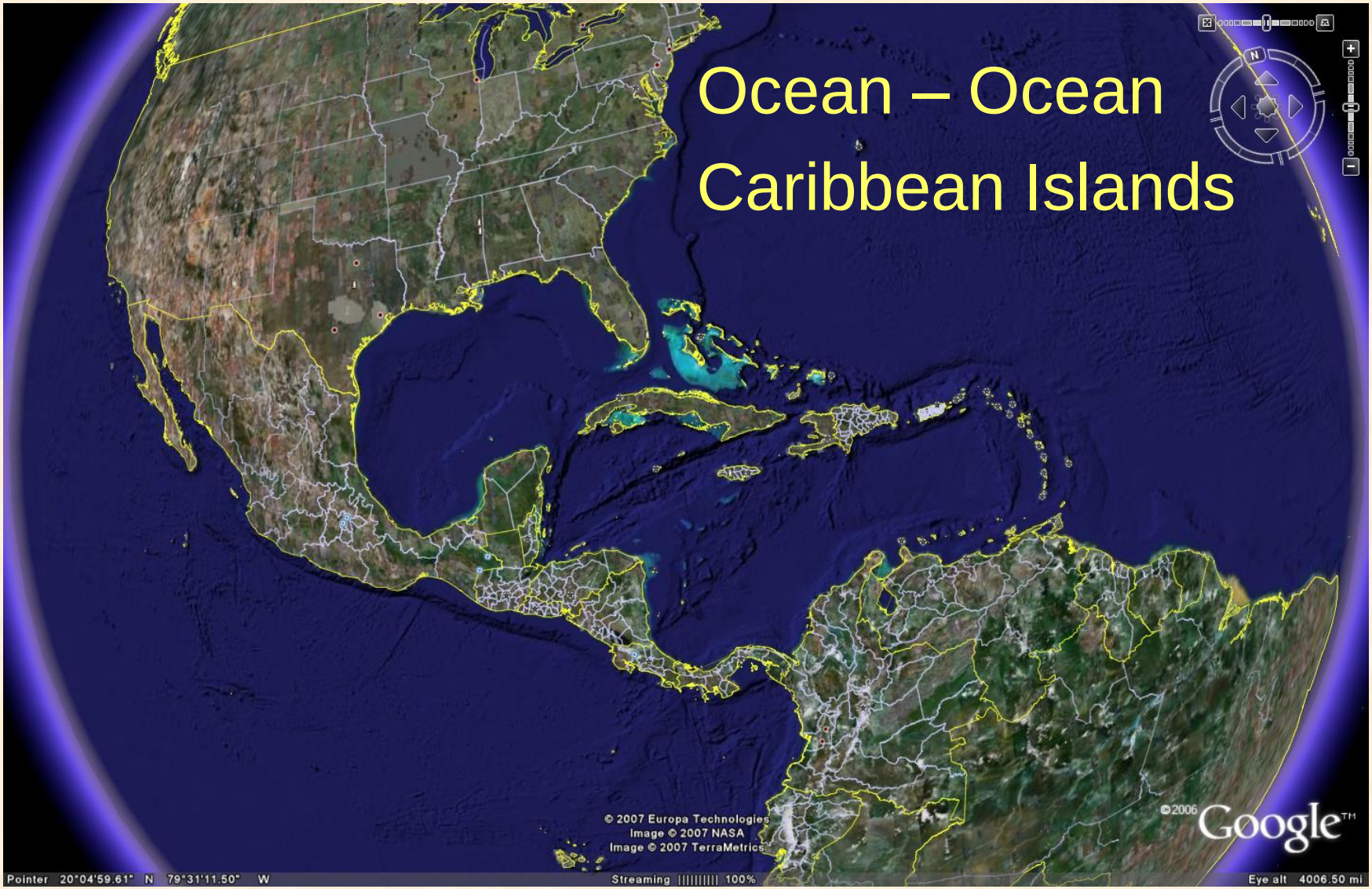
- ✓Rates: average 5 cm/year
- ✓ Mid-Atlantic Ridge = 2.5 – 3.0 cm/yr
- ✓ East-Pacific Rise = 8.0 – 13.0 cm/yr

Convergent Plate Boundaries

Ocean-Ocean

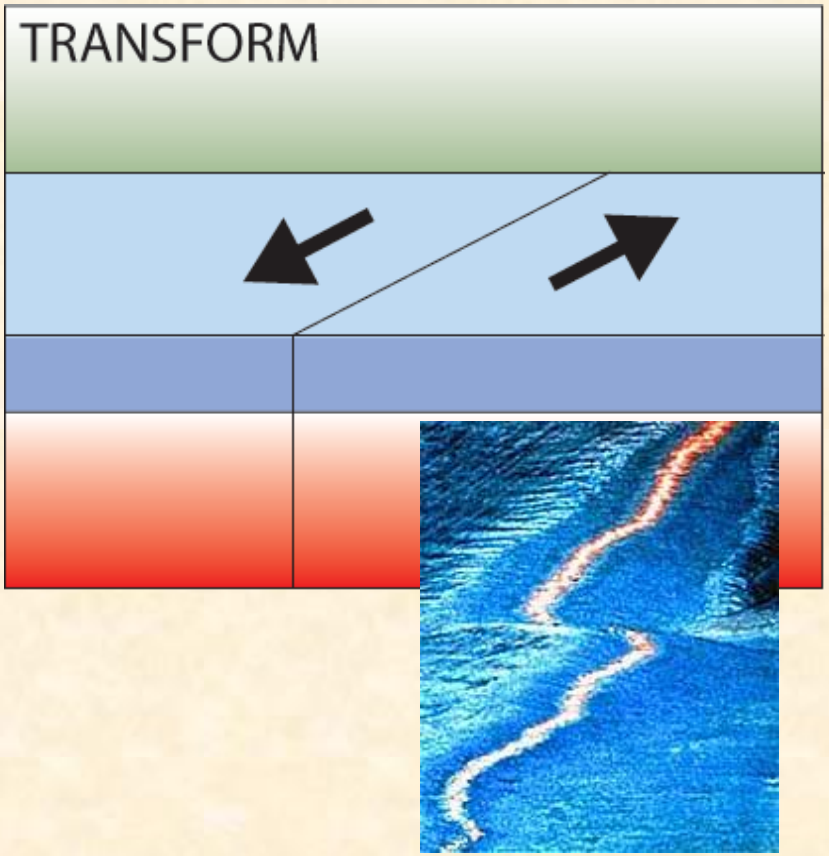
Aleutian Islands, Alaska

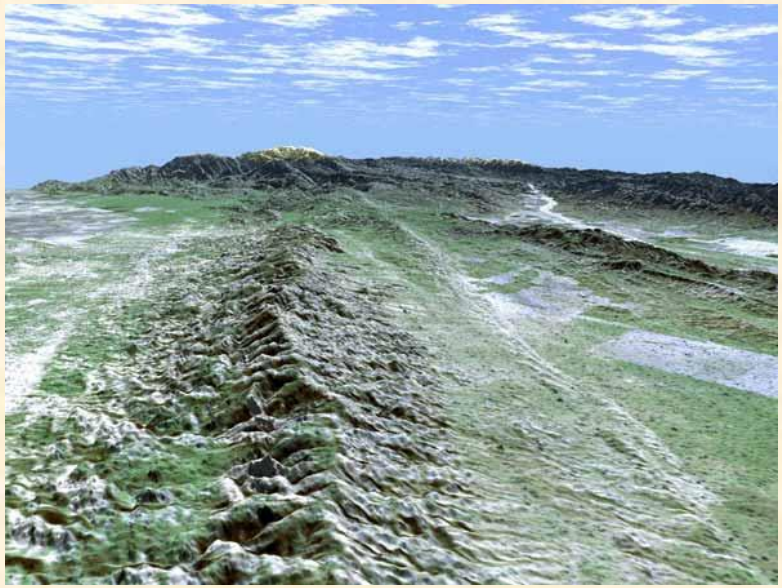



Ocean – Ocean
Caribbean Islands
© 2007 Europa Technologies
Image © 2007 NASA
Image © 2007 TerraMetrics
©2006 Google™
Pointer 20°04'59.61" N 79°31'11.50" W
Streaming 100%
Eye alt 4006.50 mi

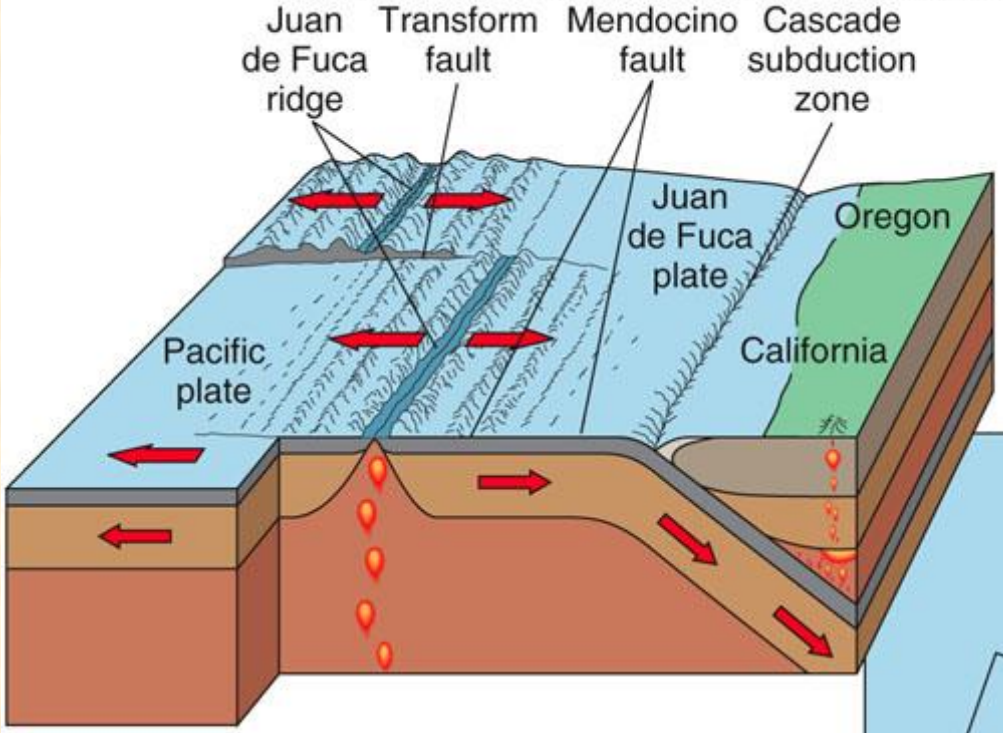
Transform Boundaries

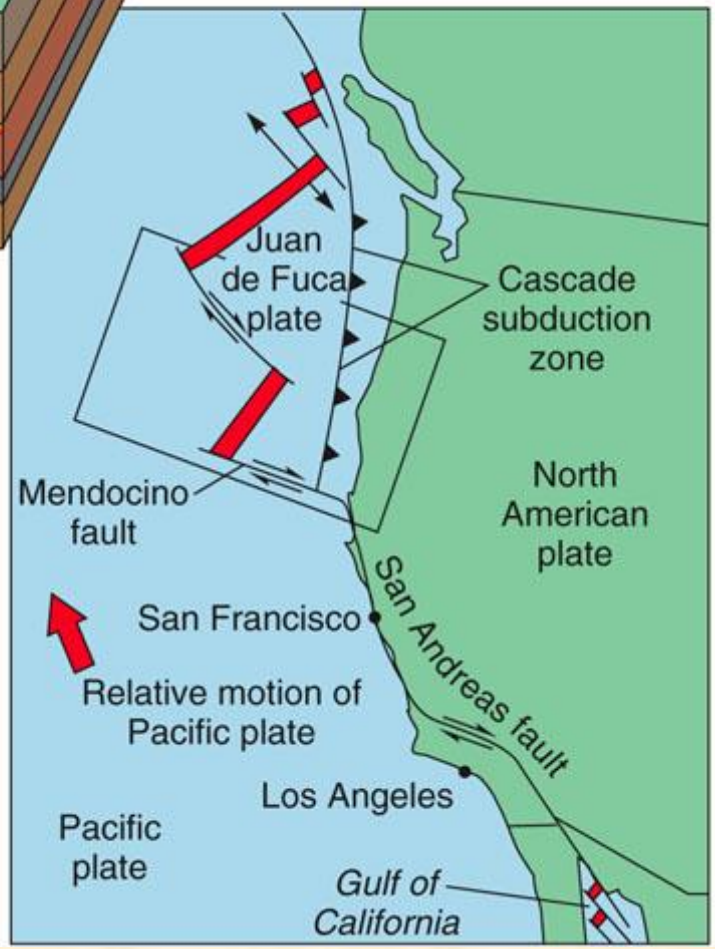
- Where plates slide past each other

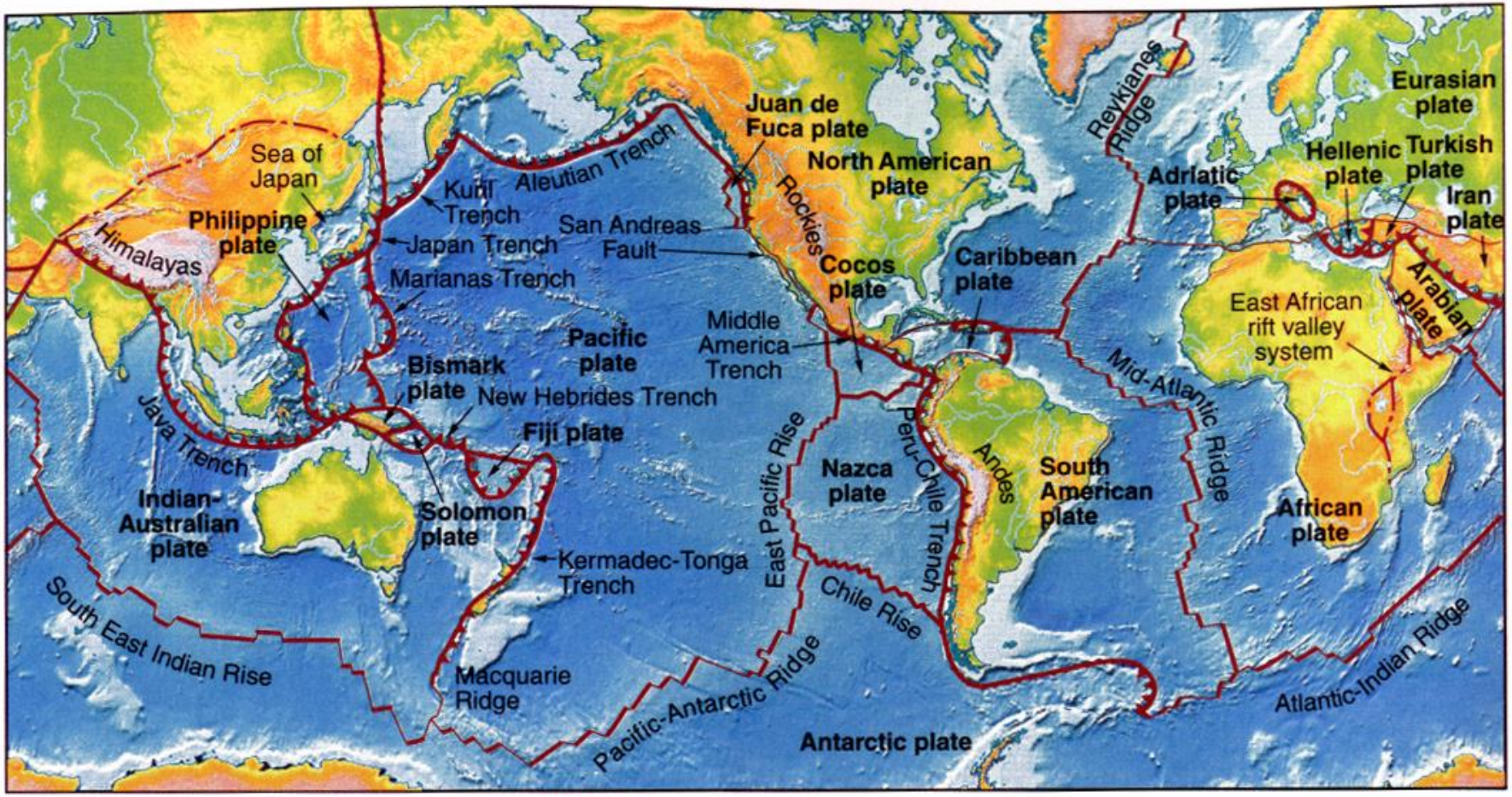




Above: View of the San Andreas transform fault

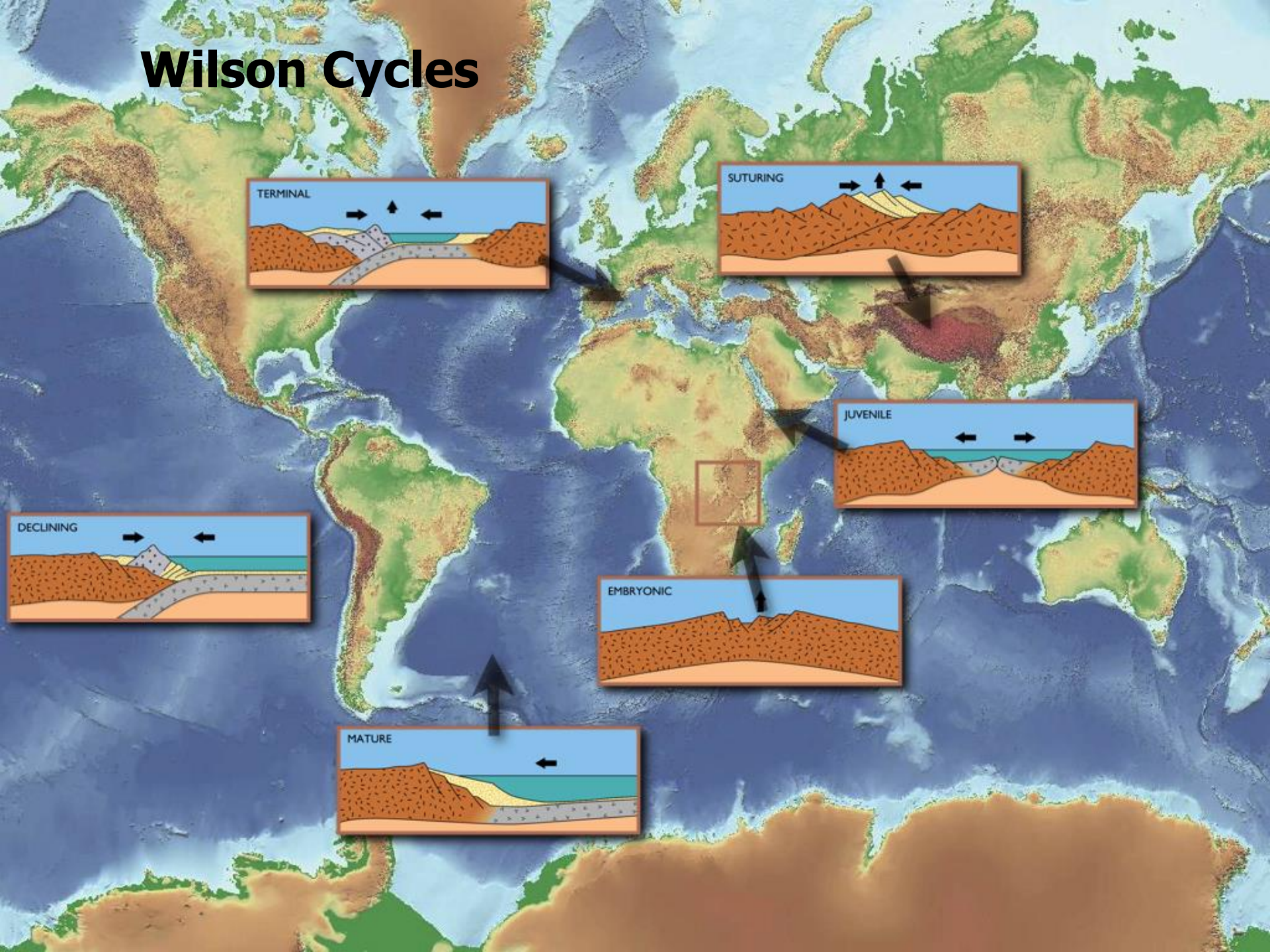





Sea of Japan
Philippine plate
Himalayas
Kuril Trench
Aleutian Trench
Japan Trench
Marianas Trench
Juan de Fuca plate
North American plate
Rockies
San Andreas Fault
Cocos plate
Caribbean plate
Reykjanes Ridge
Eurasian plate
Hellenic plate
Turkish plate
Adriatic plate
Iran plate
Arabian plate
East African rift valley system
Middle America Trench
Pacific plate
Bismark plate
New Hebrides Trench
Fiji plate
Java Trench
Indian-Australian plate
Solomon plate
Kermadec-Tonga Trench
East Pacific Rise
Nazca plate
Peru-Chile Trench
Andes
South American plate
Mid-Atlantic Ridge
African plate
Chile Rise
South East Indian Rise
Macquarie Ridge
Pacific-Antarctic Ridge
Antarctic plate
Atlantic-Indian Ridge
Ridge axis divergent boundary
Transform
Subduction zone Convergent boundary
Zones of Extension within continents
Uncertain plate boundary

Earth Plate

Wilson Cycles

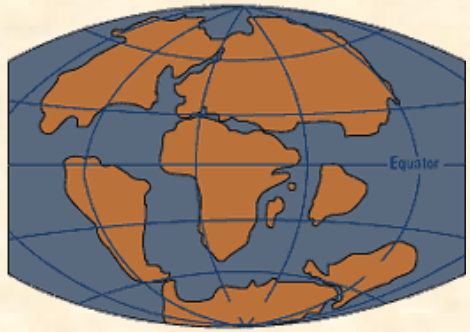


Supercontinent	Formation (Ma)	Breakup (Ma)	Mode Ref.
Pangaea	350	250	Atlantic (4)
Pannotia/Gondwanaland	650	550	Pacific (4, 5)
Rodinia	900	760	Pacific (4, 6, 39)
Nuna	1800	1500	Atlantic? (4)

Permian Period
225 million years ago

Triassic Period
200 million years ago

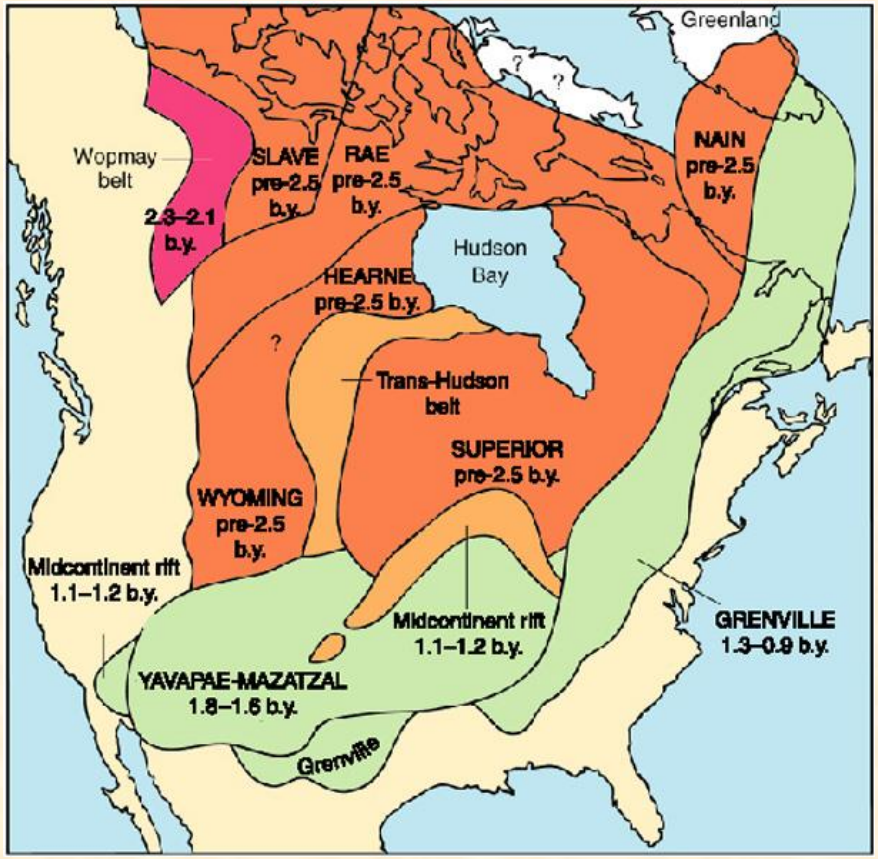
Jurassic Period
135 million years ago



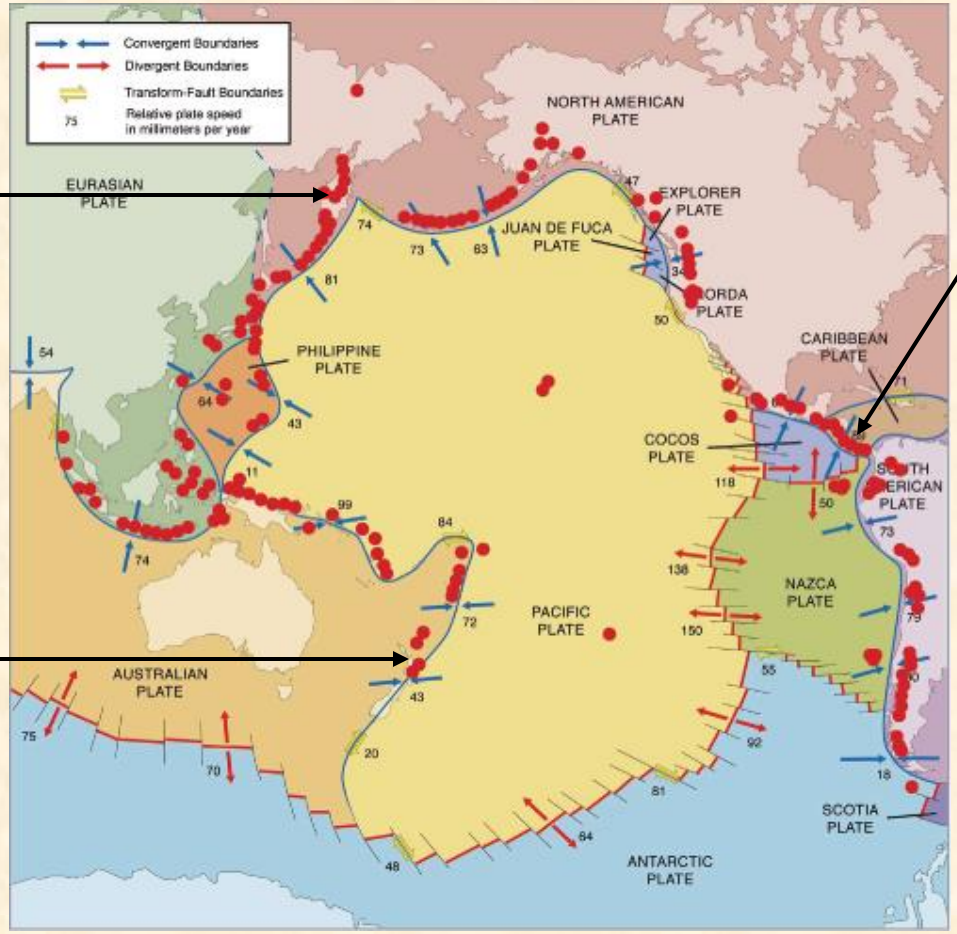
Cretaceous Period
65 million years ago

Present Day

Craton/Shields



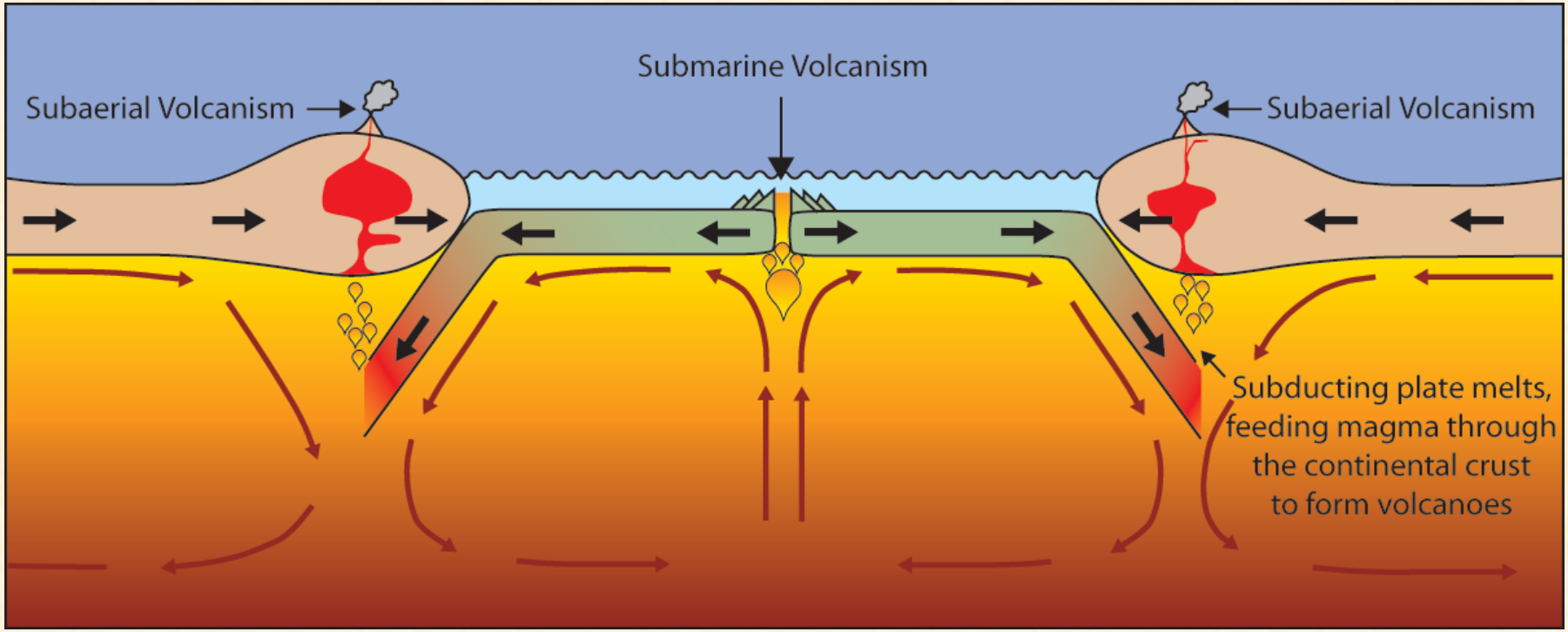
Volcanoes & Plate Tectonics
Pacific Ring of Fire



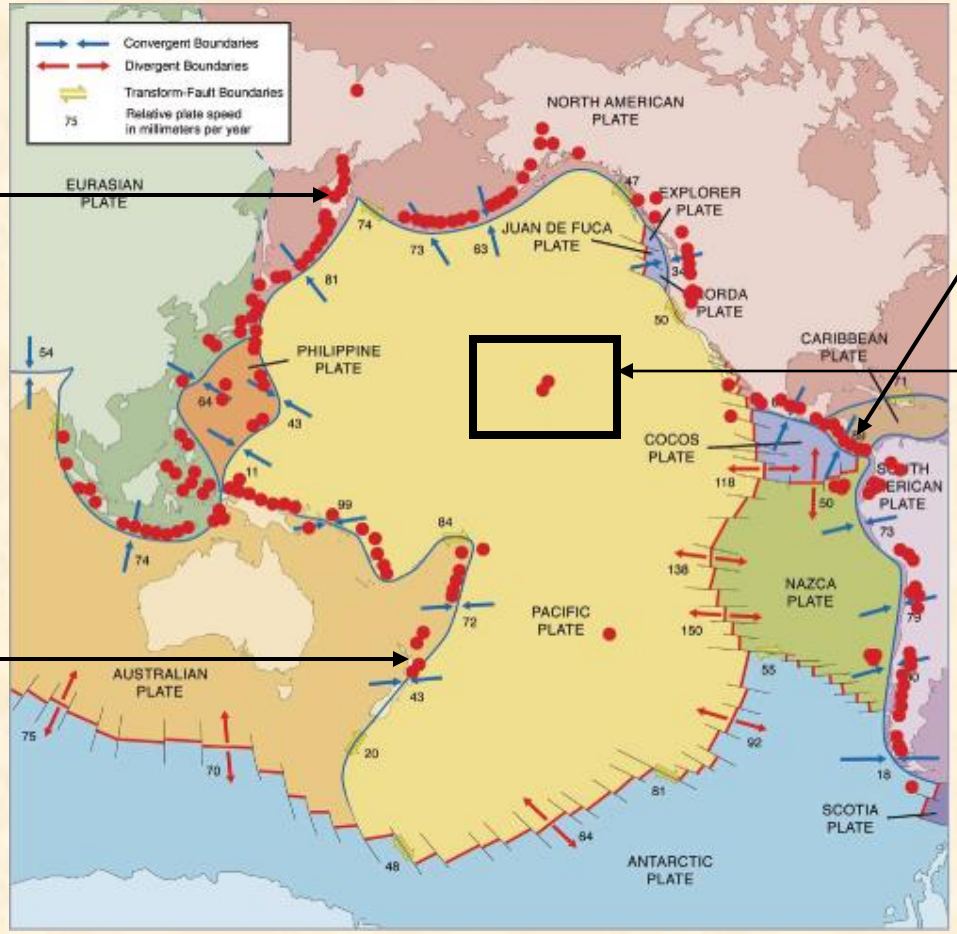
Volcanism is mostly focused at plate margins

Volcanoes are formed by:

- Subduction - Rifting - Hotspots



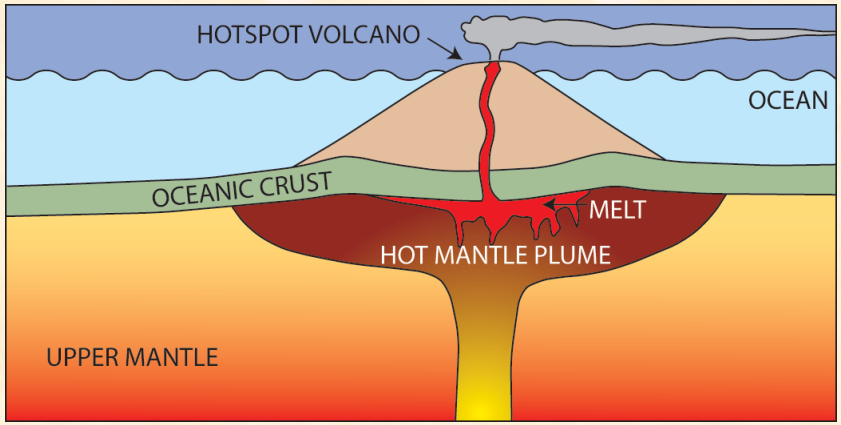
Pacific Ring of Fire



Hotspot volcanoes

What are Hotspot Volcanoes?

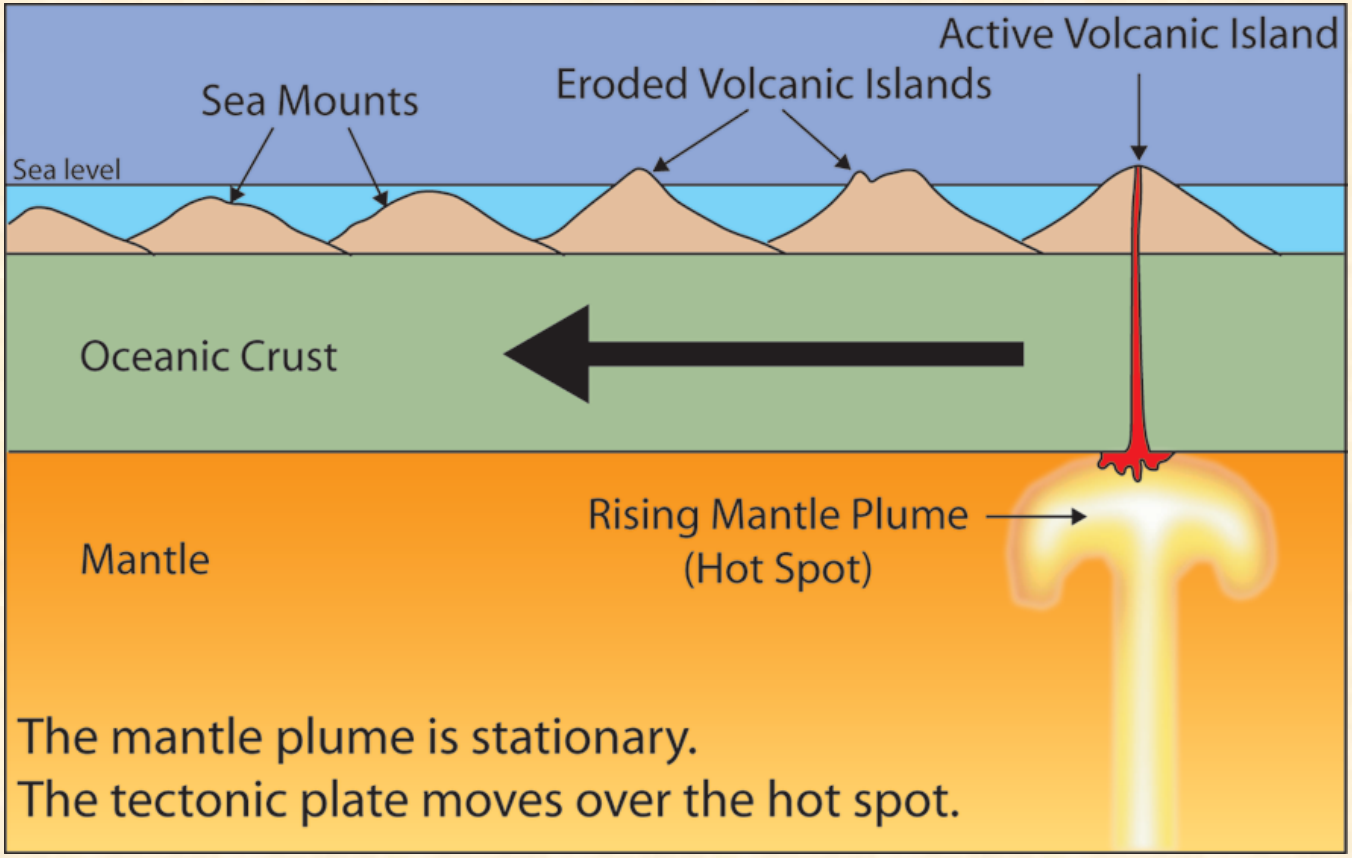
- Hot mantle plumes breaching the surface in the middle of a tectonic plate



The Hawaiian island chain are examples of hotspot volcanoes.

Photo: Tom Pfeiffer / www.volcanodiscovery.com

The tectonic plate moves over a fixed hotspot forming a chain of volcanoes.



The volcanoes get younger from one end to the other.

Plate Tectonics Summary

- The Earth is made up of 3 main layers (core, mantle, crust)
- On the surface of the Earth are tectonic plates that slowly move around the globe
- Plates are made of crust and upper mantle (lithosphere)
- There are 2 types of plate
- There are 3 types of plate boundaries
- Volcanoes and Earthquakes are closely linked to the margins of the tectonic plates