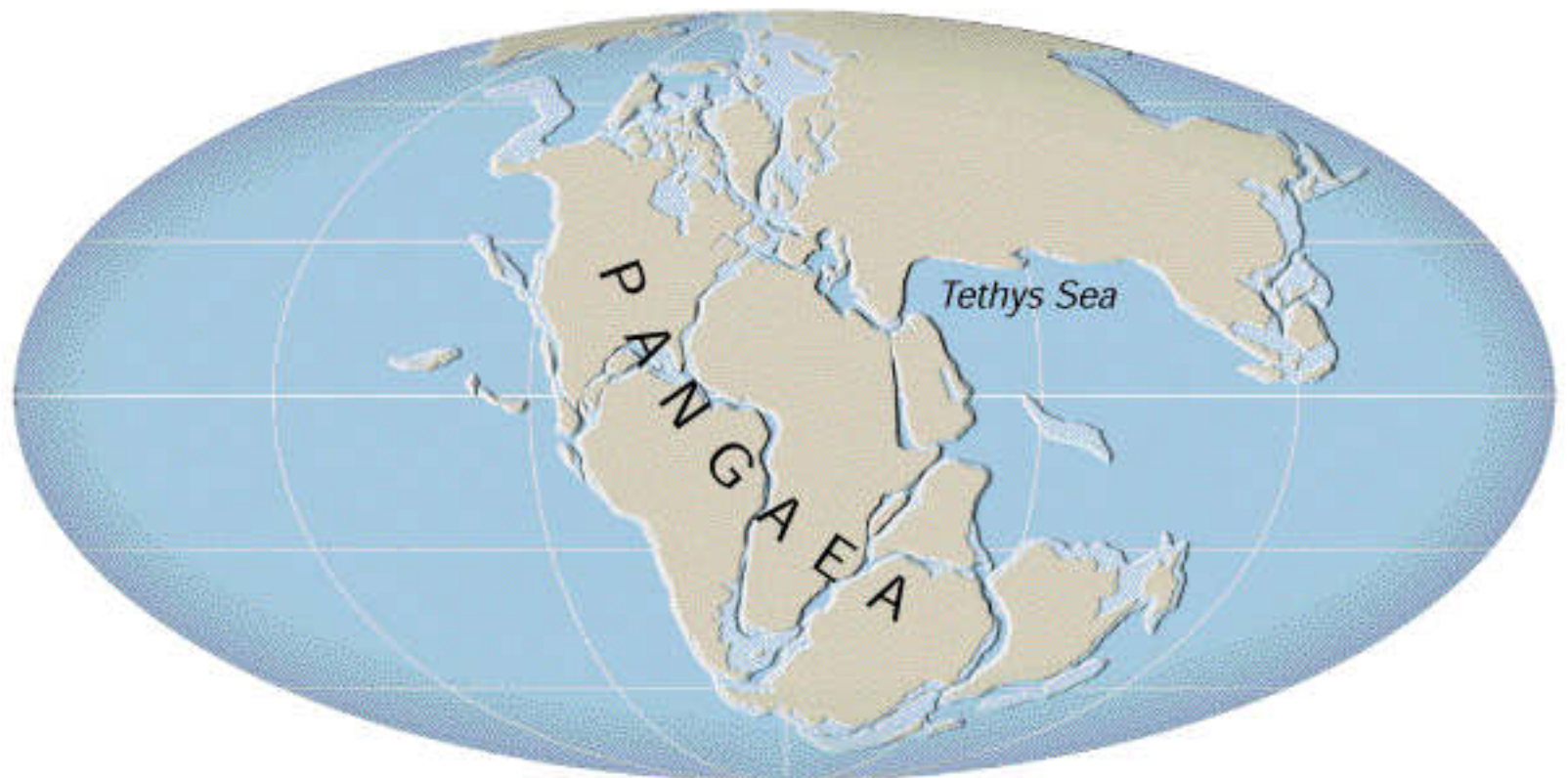


# Continental Drift

Looking at a map of the Earth, it appears that the continents could fit together like a jigsaw puzzle.

Alfred Wegener (1915) proposed the idea of "continental drift."

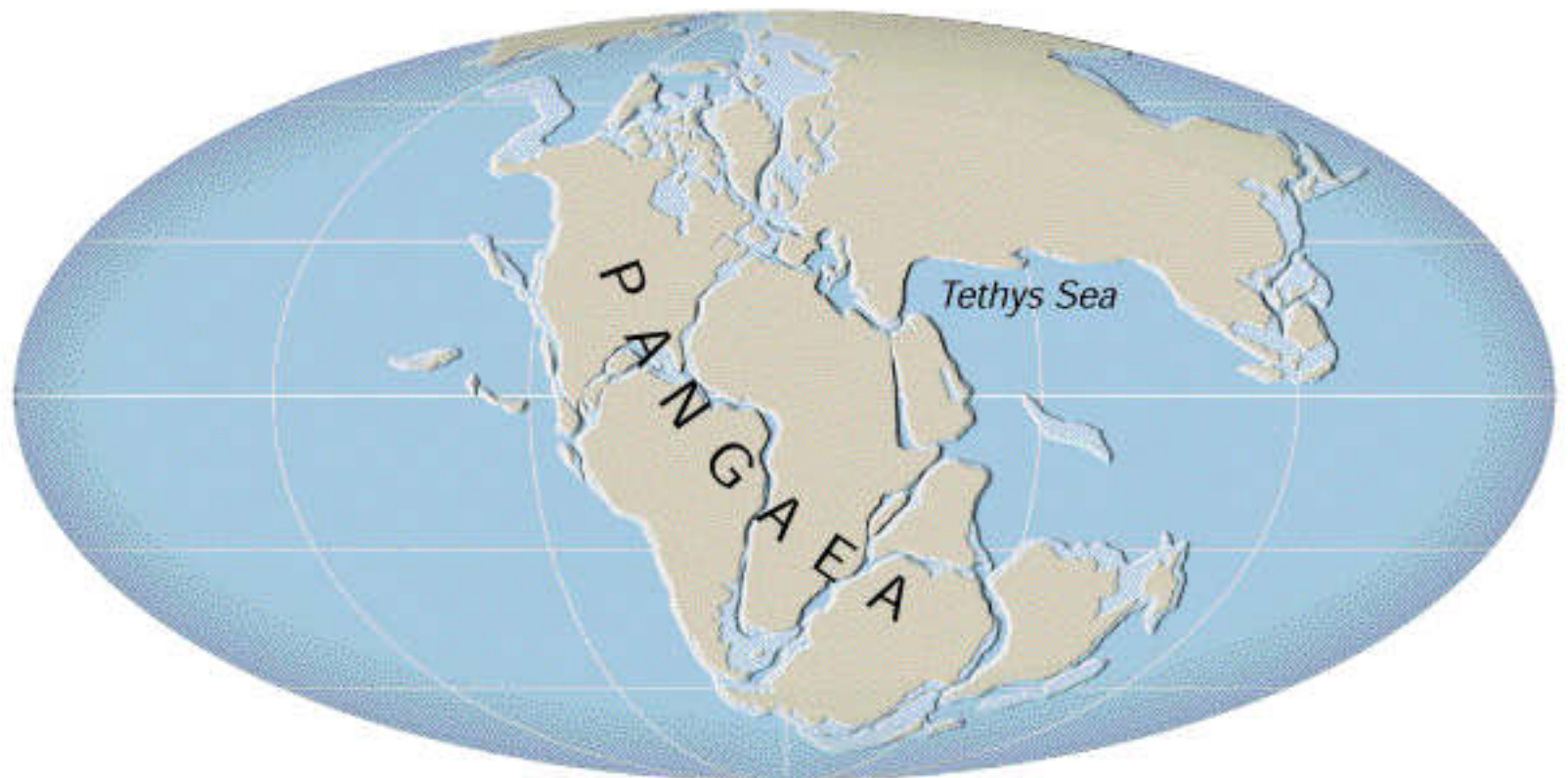
Wegener suggested that a single "supercontinent" called Pangaea once existed in the past.



# Continental Drift

Wegener developed his idea based upon 4 different types of evidence:

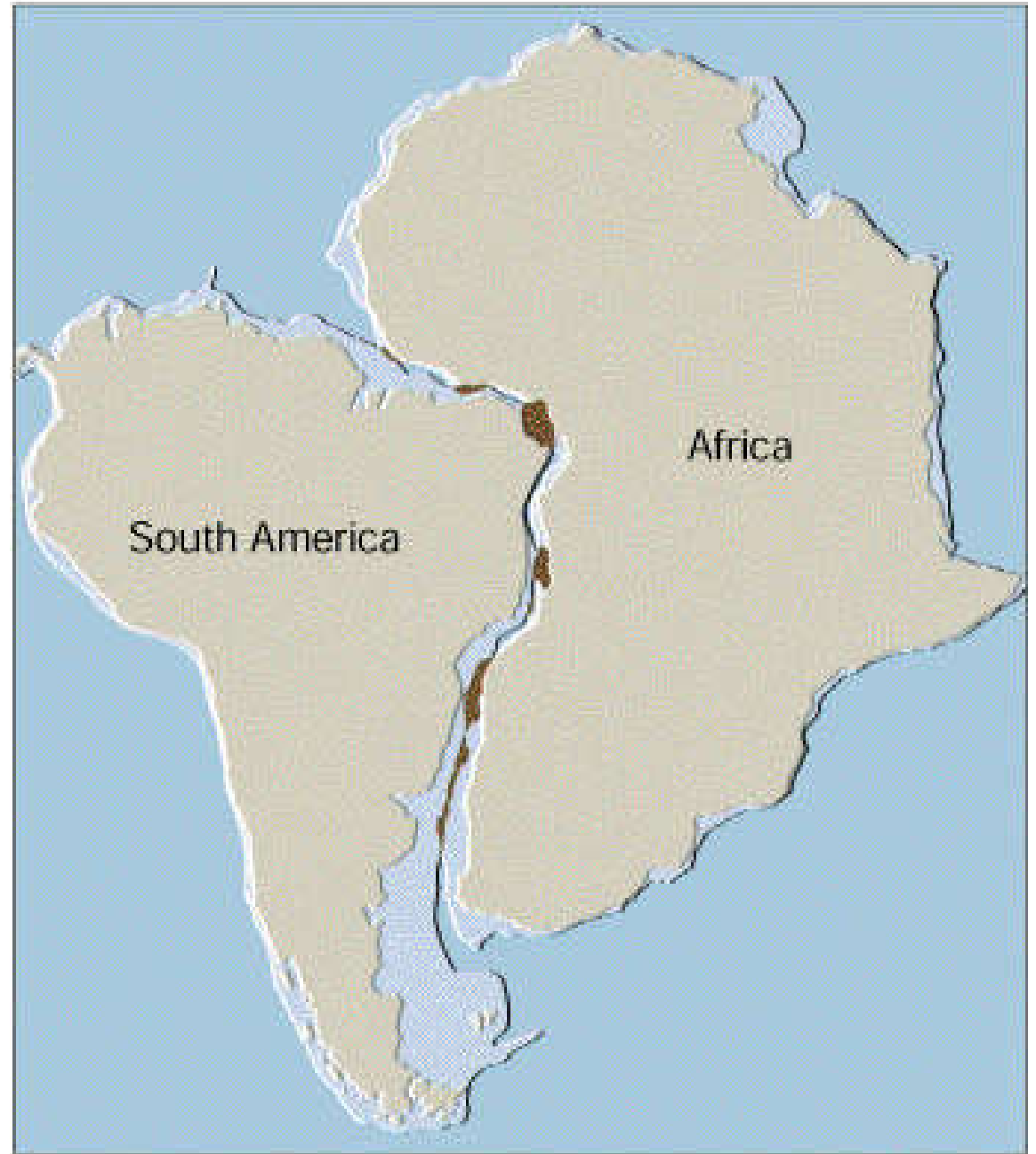
1. Fit of the Continents
2. Fossil Evidence
3. Rock Type and Structural Similarities
4. Paleoclimatic Evidence



## Evidence for Continental Drift: Fit of the Continents

It was the amazingly good fit of the continents that first suggested the idea of continental drift.

In the 1960's, it was recognized that the fit of the continents could be even further improved by fitting the continents at the edge of the continental slope — the actual extent of the continental crust.



# Evidence for Continental Drift:

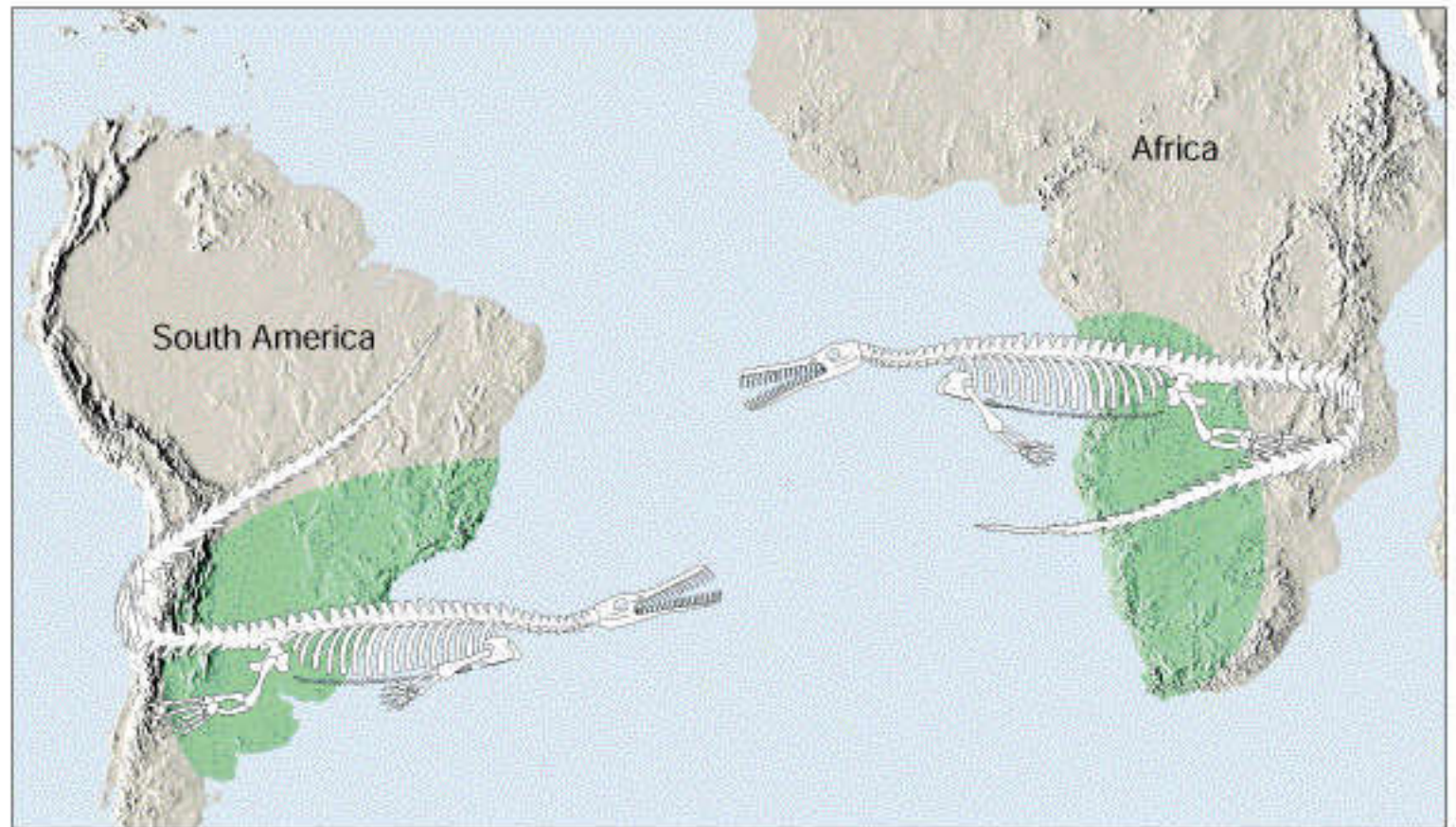
## Fossil Evidence

Wegener found that identical fossils were located directly opposite on widely separated continents.

This had been realized previously but the idea of "land bridges" was the most widely accepted solution.

Wegener found fossils to be convincing evidence that a supercontinent had existed in the past.

Example:  
Mesosaurus

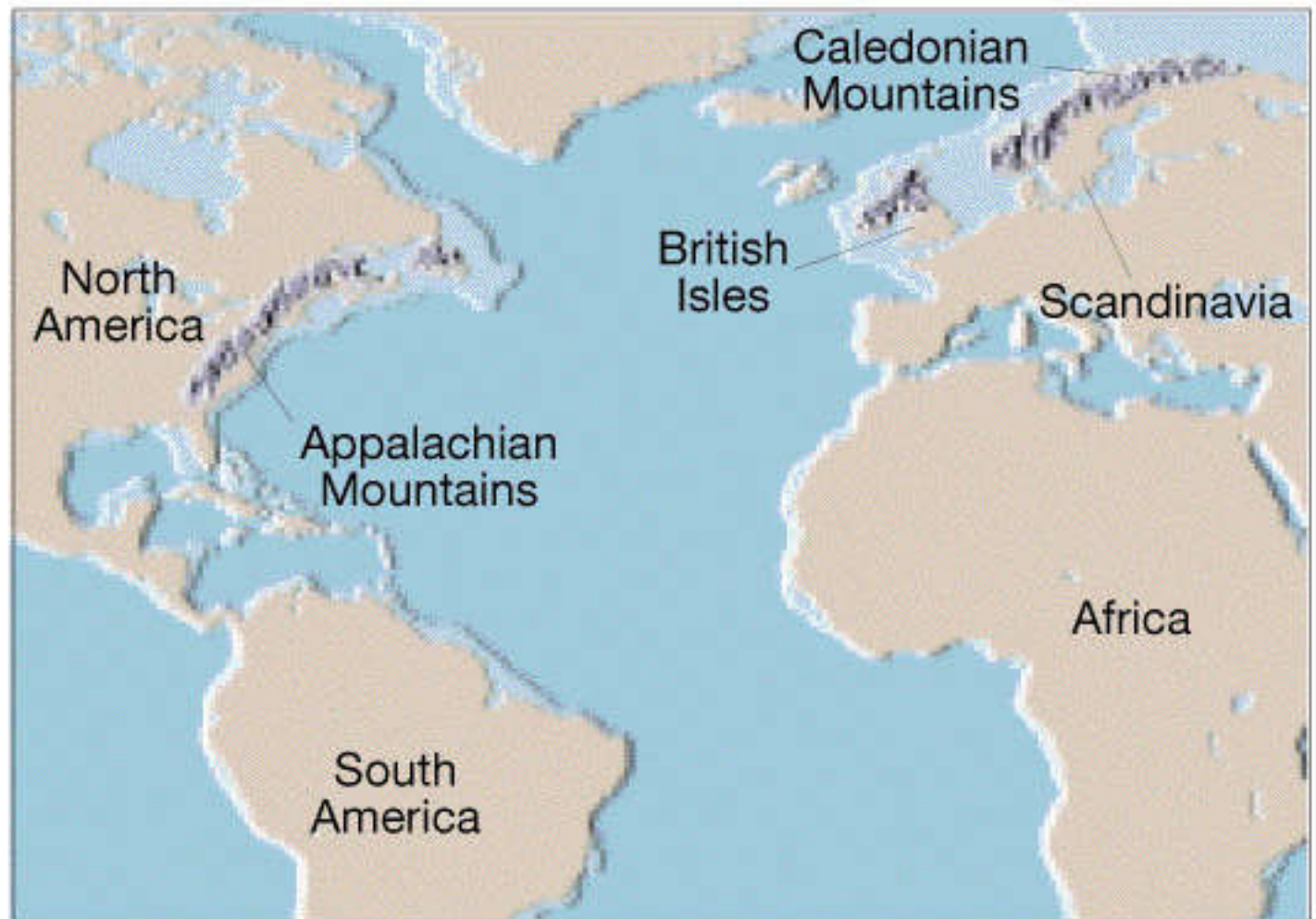


## Evidence for Continental Drift:

### Rock Type and Structural Similarities

We find similar rock types on continents on opposite sides of the Atlantic Ocean.

Similar, age, structure and rock types are found in the Appalachian Mtns. (N.A.) and mountains in Scotland and Scandinavia.



A.

## Evidence for Continental Drift: Rock Type and Structural Similarities

When the continents are reassembled, the mountain chains from a continuous belt — having the same rock types, structures and rock ages.



B.

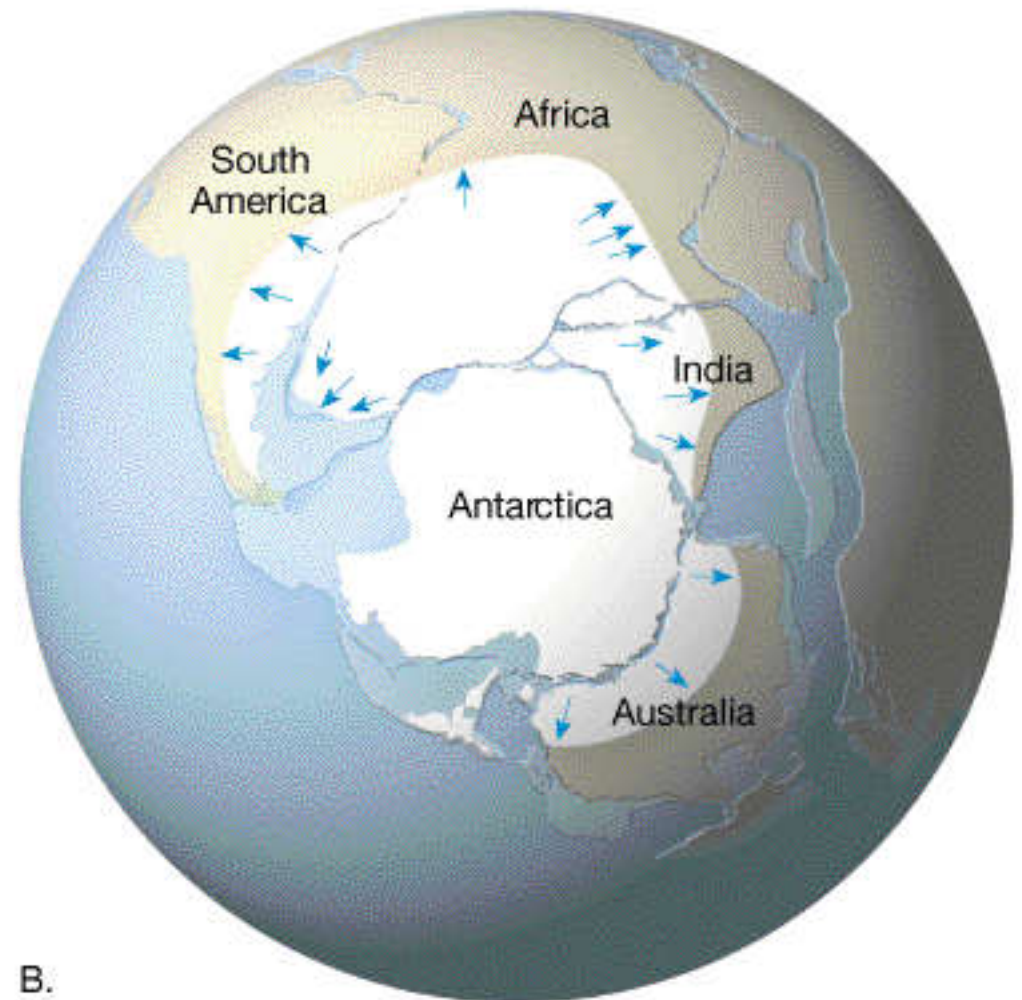
## Evidence for Continental Drift: Paleoclimatic Evidence

Glacial till of the same age is found in southern Africa, South America, India and Australia — areas that it would be very difficult to explain the occurrence of glaciation.

At the same time, large coal deposits were formed from tropical swamps in N. America and Europe.

Pangaea with S. Africa centered over the South Pole could account for the conditions necessary to generate glacial ice in the southern continents.

In addition, the areas with extensive coal deposits from the same time period occur in regions that would have been equatorial.



Science is based on more than mere empirical observation — we strive to understand the mechanisms.

We must develop a theory to explain our observations.

Wegener's idea of continental drift was not generally accepted because no one could come up with a reasonable mechanism for the movement of the continents.

It was not until the 1960's that further data led to the development of a the theory of plate tectonics that could explain the movement of continents.

# Paleomagnetism

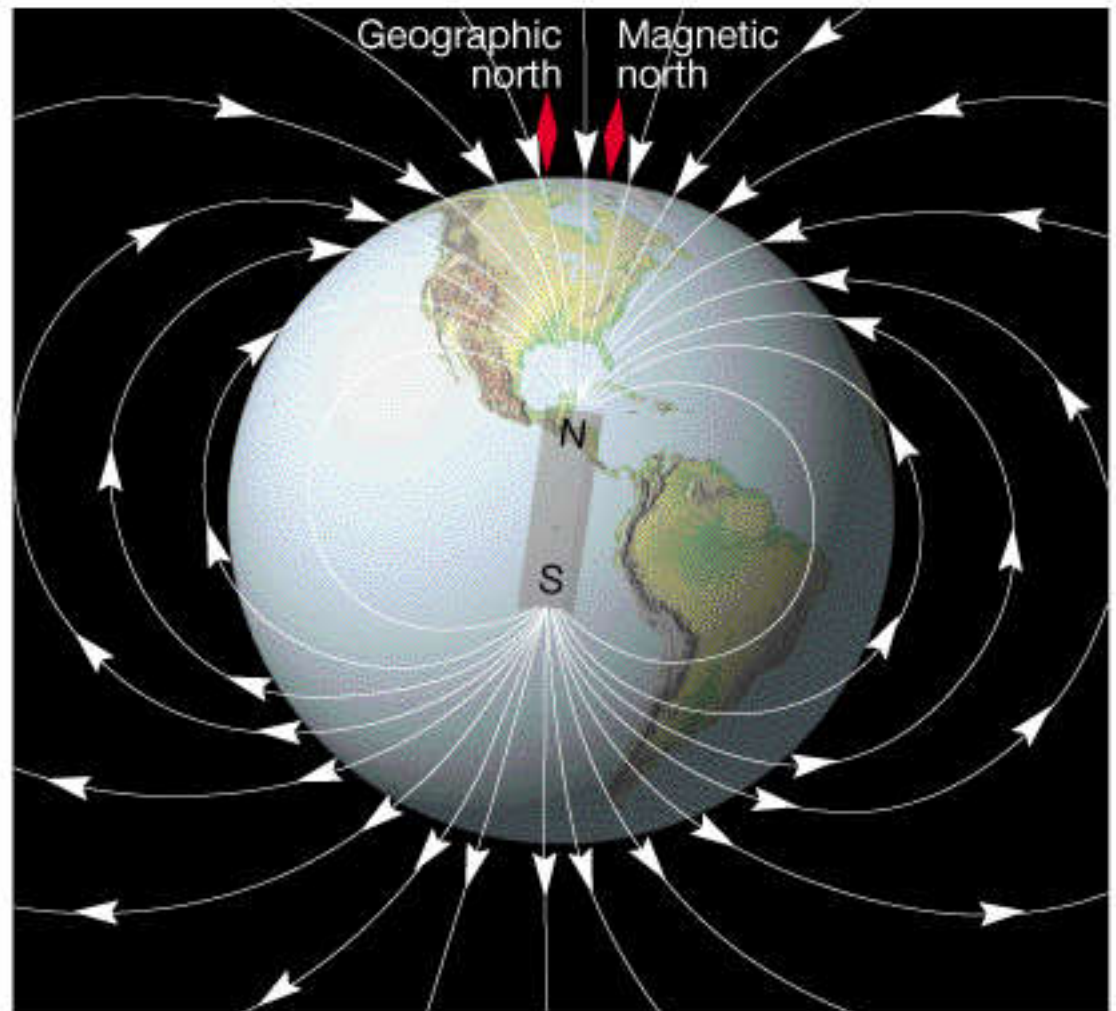
The Earth's magnetic field produces invisible lines of force that extend from one pole to the other.

A compass needle aligns itself with these lines of force — points toward the magnetic poles.

When igneous rocks containing magnetic minerals crystallize, the crystals align themselves with the Earth's magnetic field.

The magnetic field of the rock then points toward the magnetic pole that existed when the rock formed.

If the rock is moved, its magnetic field will act as a "fossil compass."



# Paleomagnetism

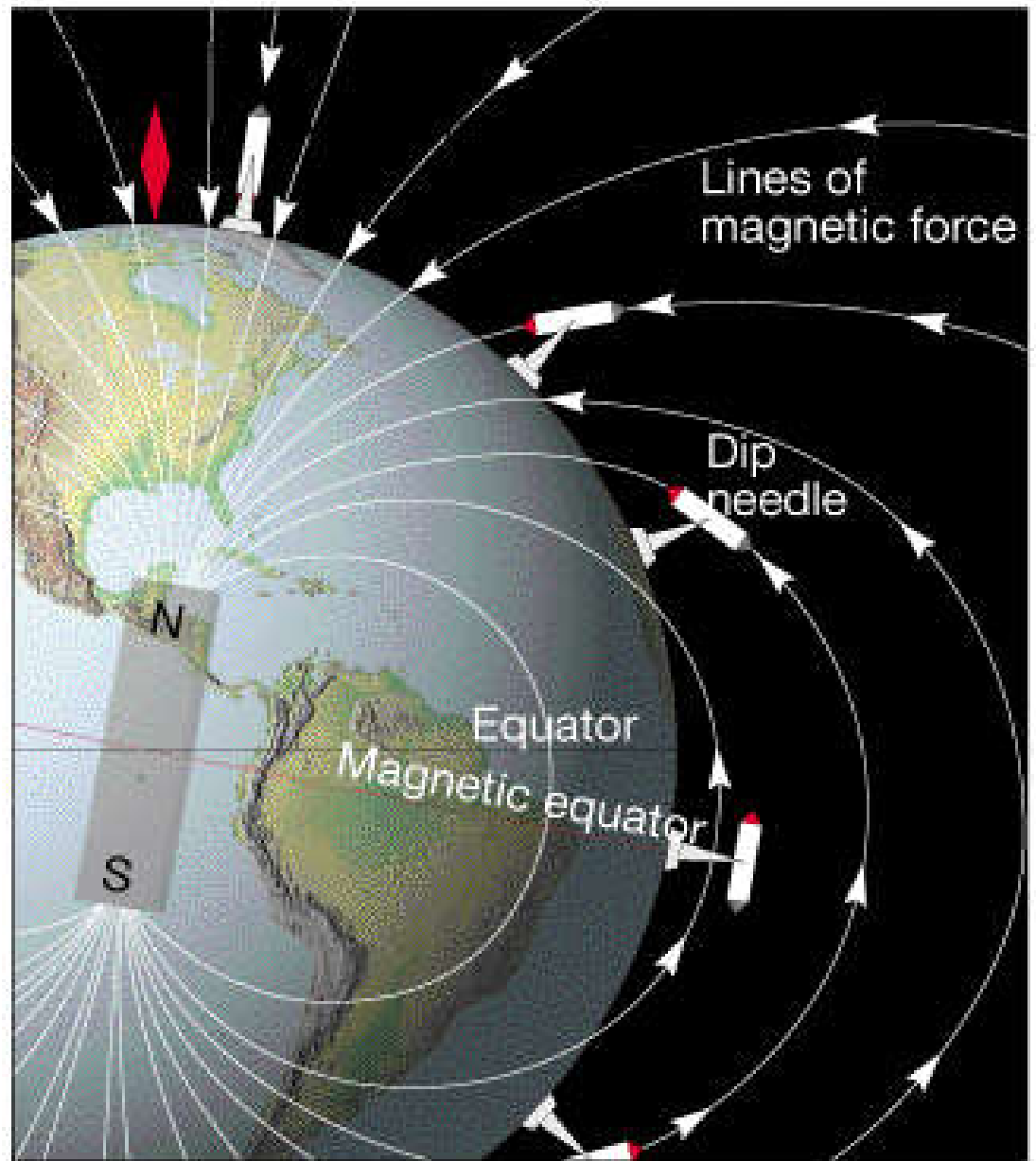
Magnetized minerals can also be used to determine the latitude of their origin.

The Earth's magnetic field is curved, and the inclination of the magnetic grains gives an estimate of the paleolatitude.

Equator: horizontal

Mid-latitude: high angle

Pole: straight up

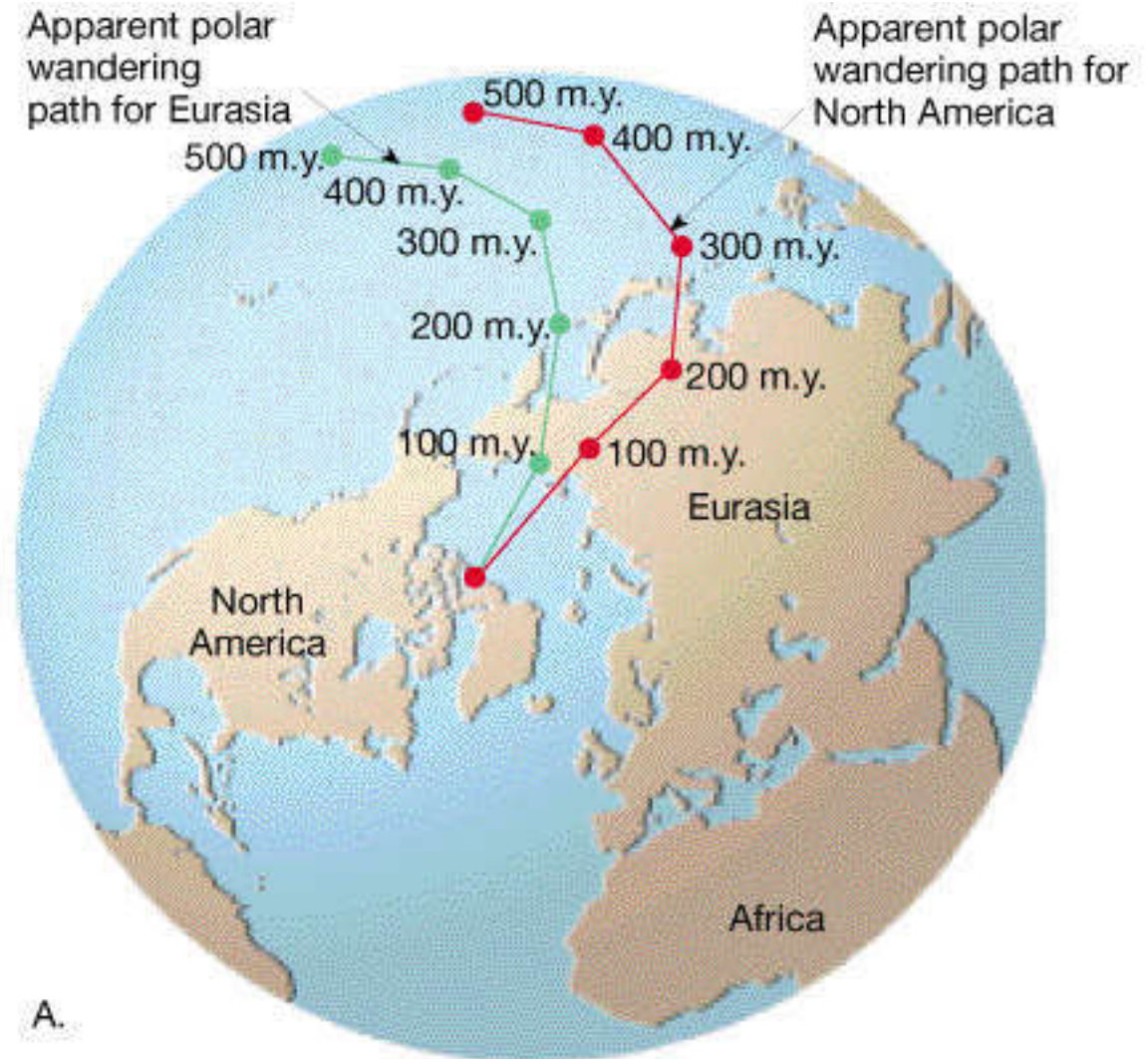


# Pole Wandering

Looking at igneous rocks, the apparent position of the North Pole was determined from the paleomagnetism of the rock.

Assuming that the magnetic poles are approximately coincident with the pole of rotation, the apparent movement of the poles must be due to movement of the continents.

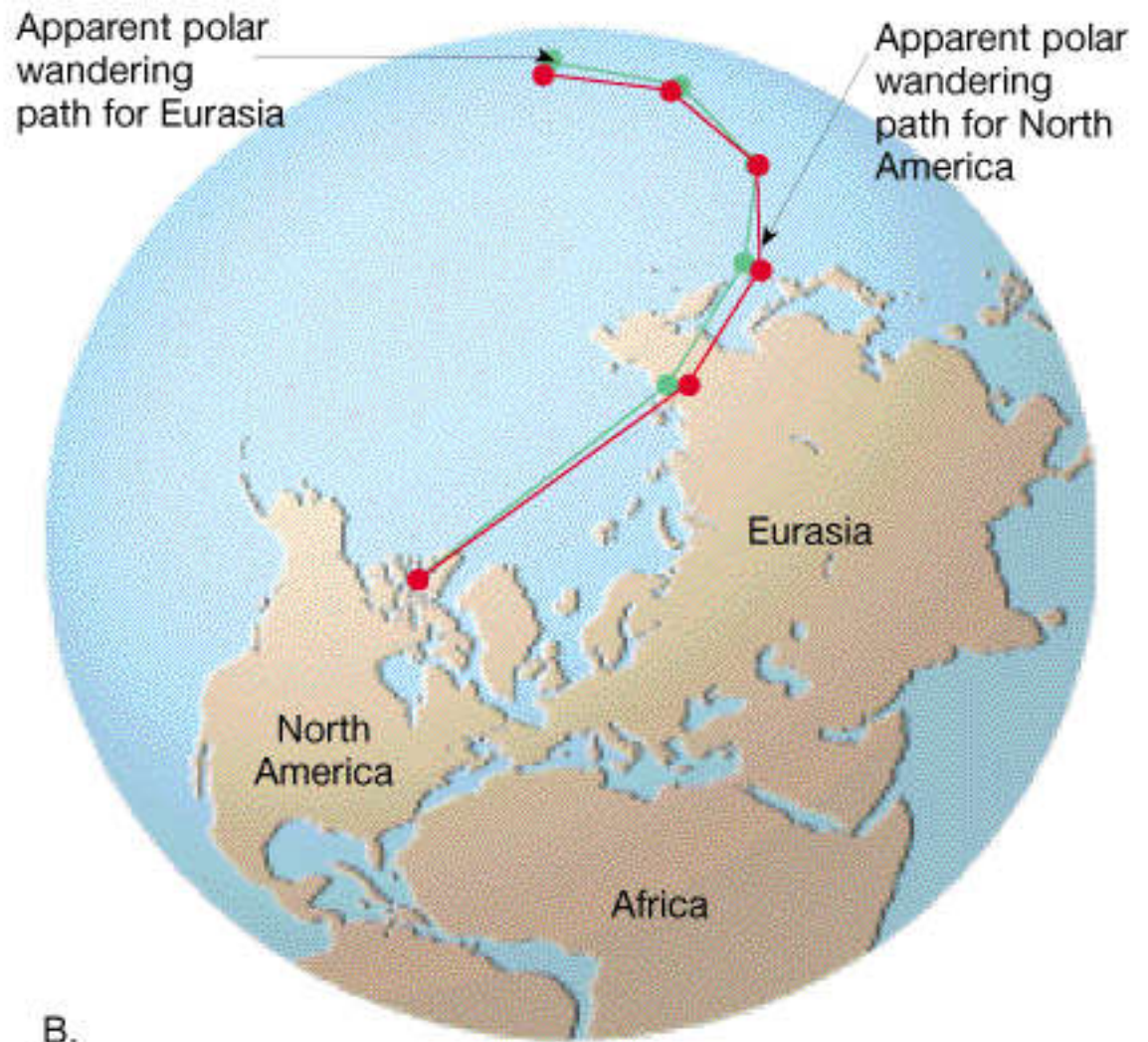
Curves are similar shape for N. America & Europe except that they were offset by  $\sim 24^\circ$  of longitude.



# Pole Wandering

If the two continents are placed next to one another to how we believe they fit in Pangaea, the apparent pole wandering paths coincide.

This would represent the time before the opening of the Atlantic Ocean

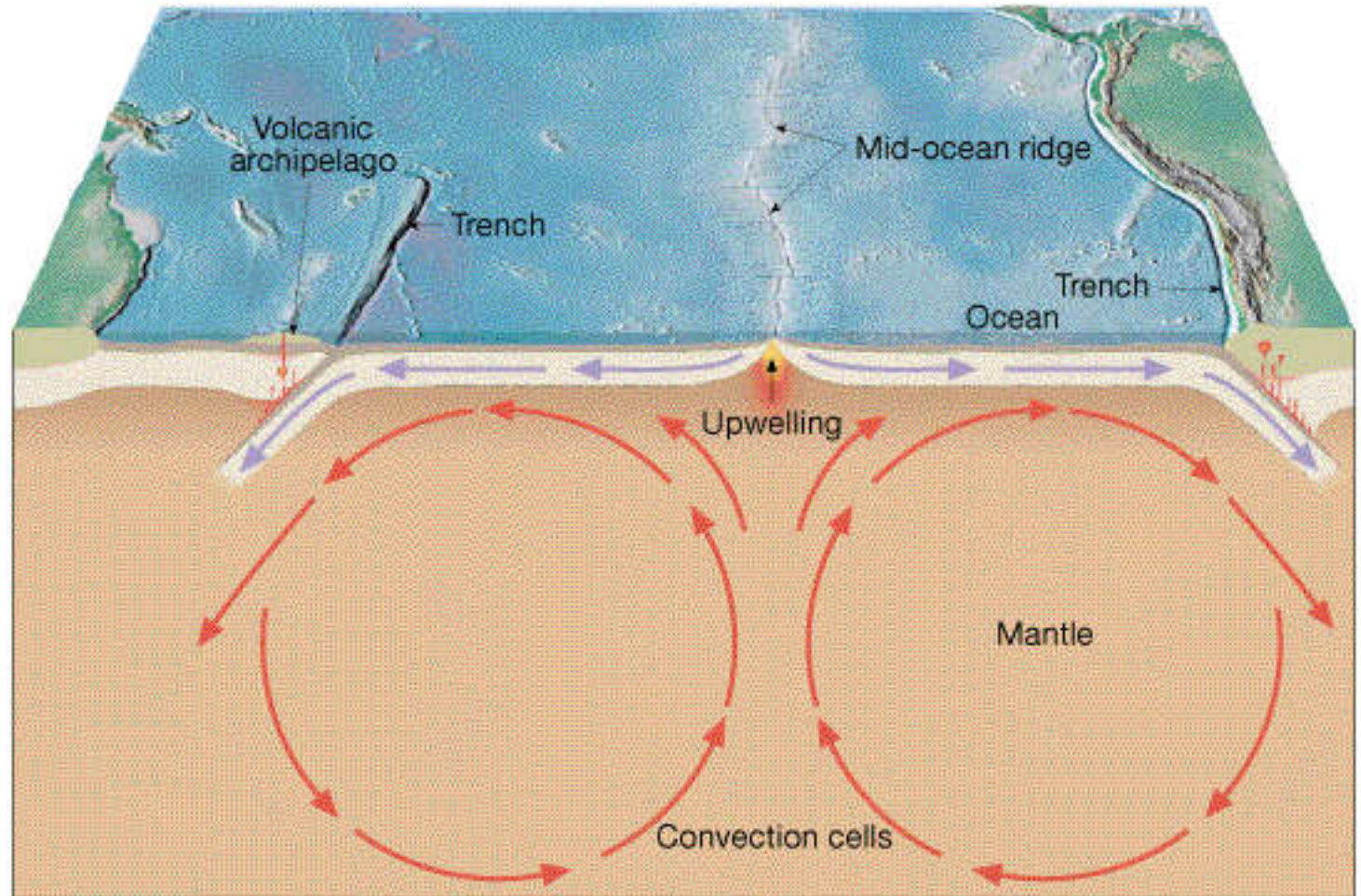


# Seafloor Spreading

Harry Hess (1960's) proposed the theory of seafloor spreading based upon this evidence and newly published maps of the seafloor topography indicating the existence of a world-wide mid-ocean ridge system.

He proposed that ridges are located above zones of upwelling in the mantle — resulting in the creation of seafloor.

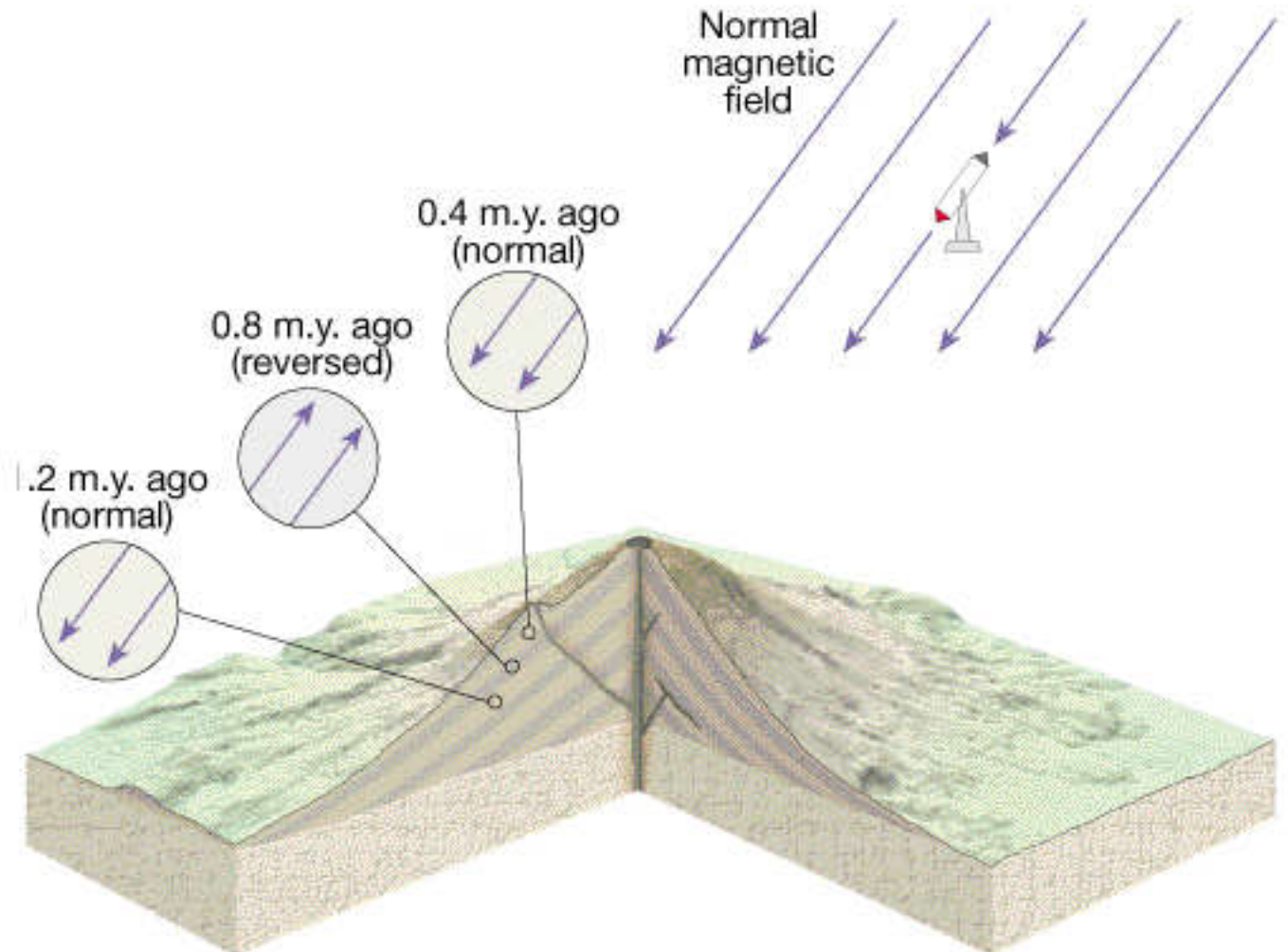
He also proposed subduction as a mechanism for recycling of the seafloor.



# Geomagnetic Reversals

Earth's magnetic field periodically reverses polarity — the north and south poles switch.

Rocks crystallizing during one of these periods of magnetic reversal will be magnetized with a polarity opposite of rocks that crystallize today.



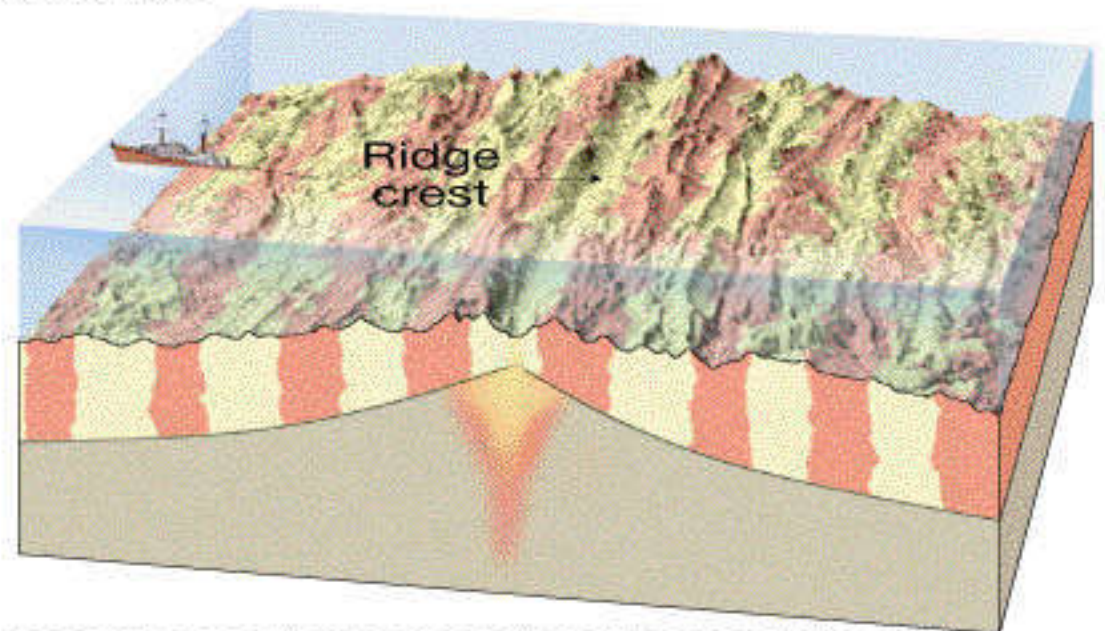
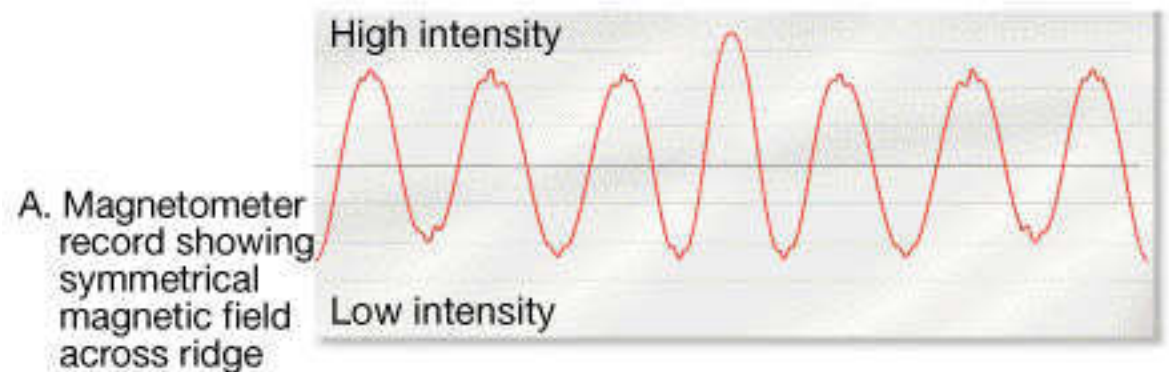
## Geomagnetic Reversals — Seafloor

Using a magnetometer, oceanographers discovered that the seafloor has regions of low- and high-intensity magnetism.

It was further found that these zones occur as stripes parallel to the ridge crest.

High-intensity zones correspond to seafloor formed during a period of normal magnetic polarity (2 fields add together).

Low intensity zones correspond to seafloor formed during a period of reversed magnetic polarity (2 fields cancel each other out).



B. Research vessel towing magnetometer across ridge crest

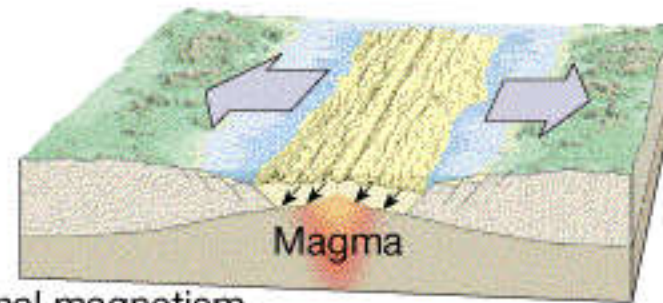
# Geomagnetic Reversals — Seafloor

As new seafloor is created at the ridge, it is added in equal amounts to both trailing edges of the spreading seafloor.

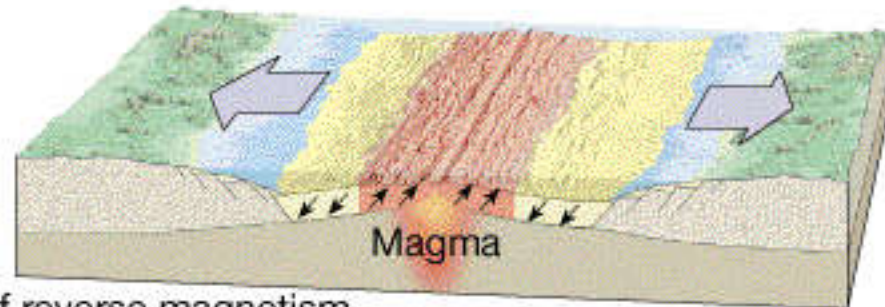
We would expect to see the pattern of stripes as mirror images on both sides of the ridge — strongest evidence for seafloor spreading.

In the Pacific, the stripes are much wider — indicating a faster rate of spreading (or creation of new seafloor).

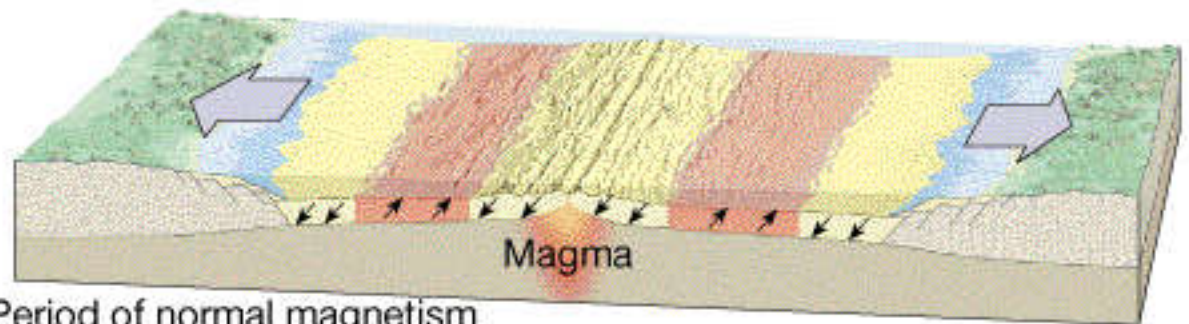
In the Atlantic, the stripes are much more narrow — indicating a relatively slow rate of spreading.



A. Period of normal magnetism



B. Period of reverse magnetism



C. Period of normal magnetism

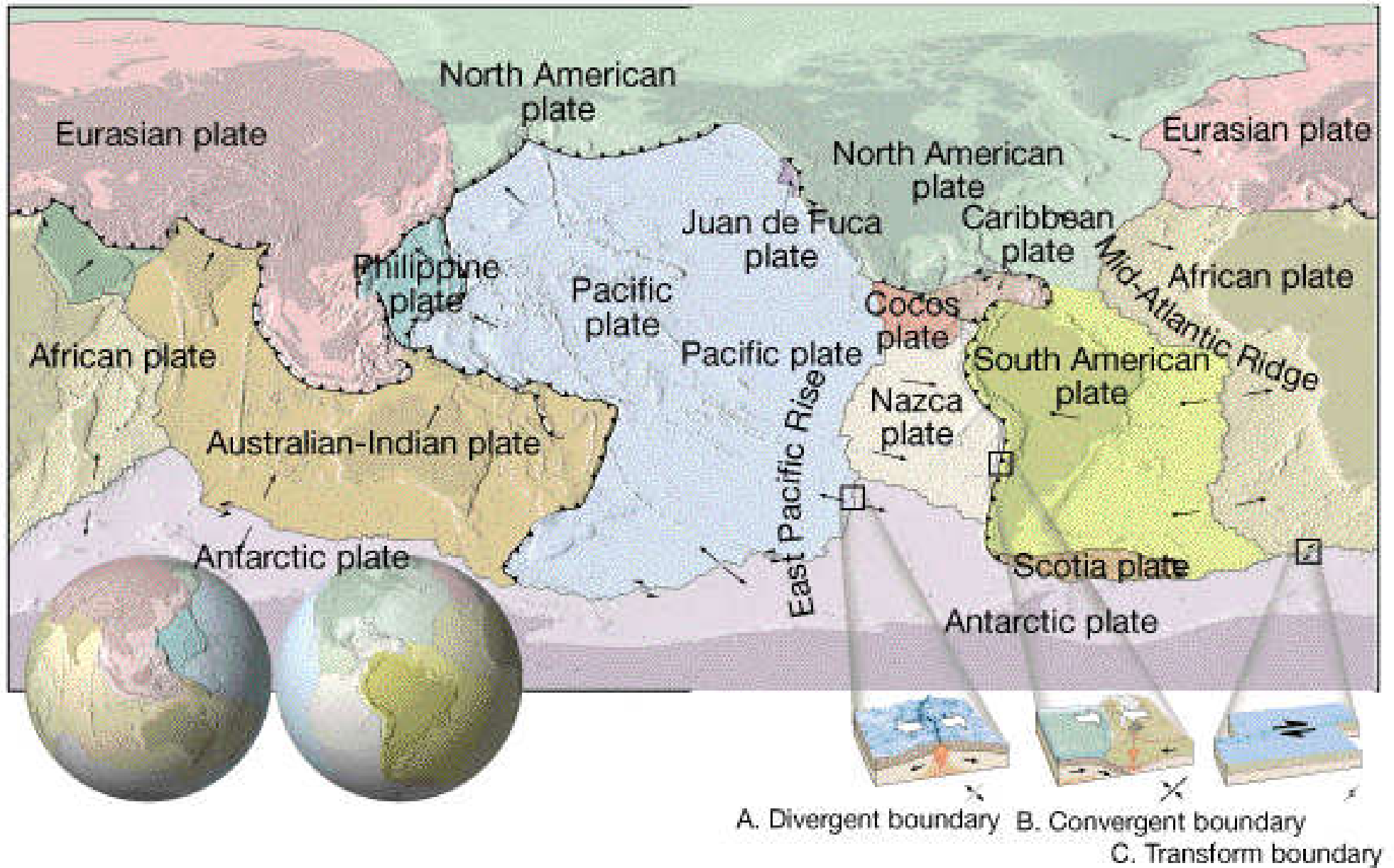
# Theory of Plate Tectonics

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

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

The Earth's surface is composed of rigid plates known as the lithosphere. These plates overlie a weaker region of the mantle known as the asthenosphere.

There are 7 major plates and over a dozen smaller plates. Plates move slowly but continuously on the order of a few cm/year.



# Plate Boundaries

There are 3 distinct types of boundaries:

1. divergent — plates move away from one another
2. convergent — plates move into one another (collision)
3. transform — plate grind past one another

Each plate is bounded by a variety of plate boundaries.

New plates can be created by forces that split plates apart such as at the East African Rift Valleys.

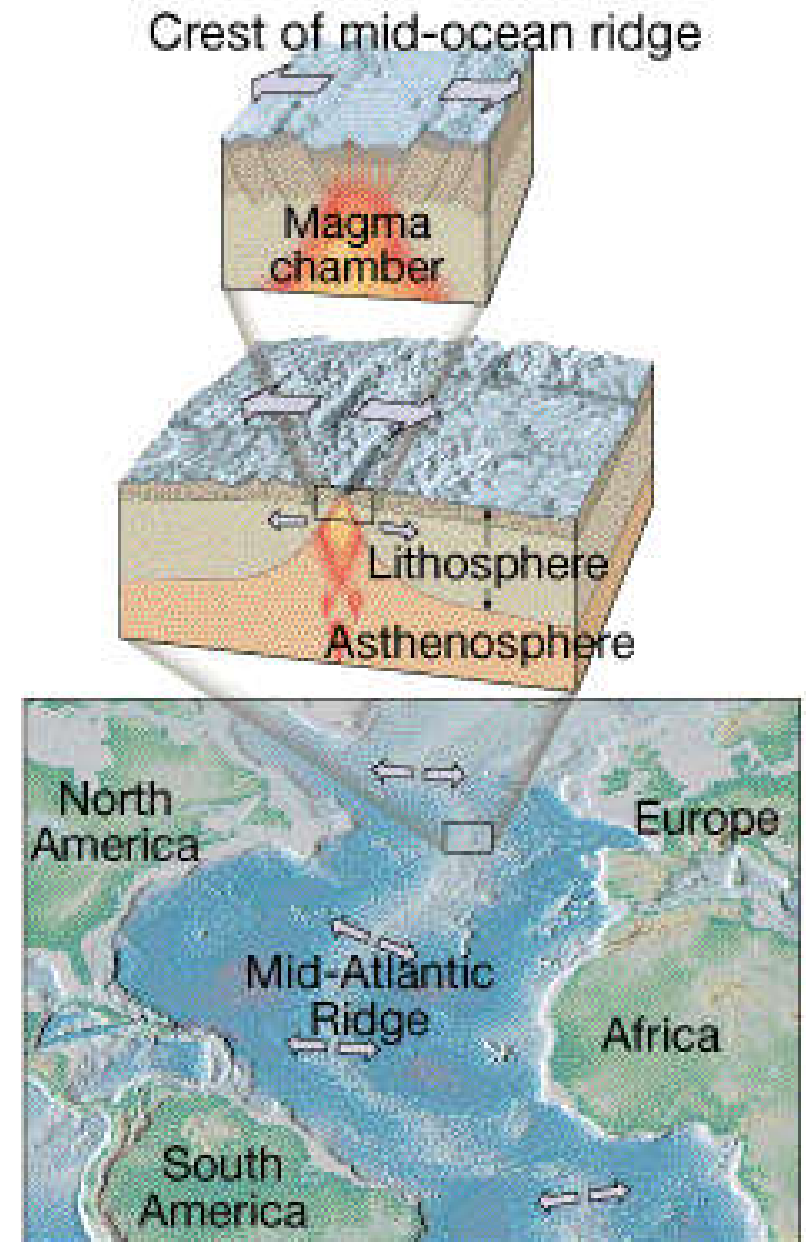
Two plates may suture together to form one plate such as may happen with the Himalayans.

# Plate Boundaries — Divergent Boundaries

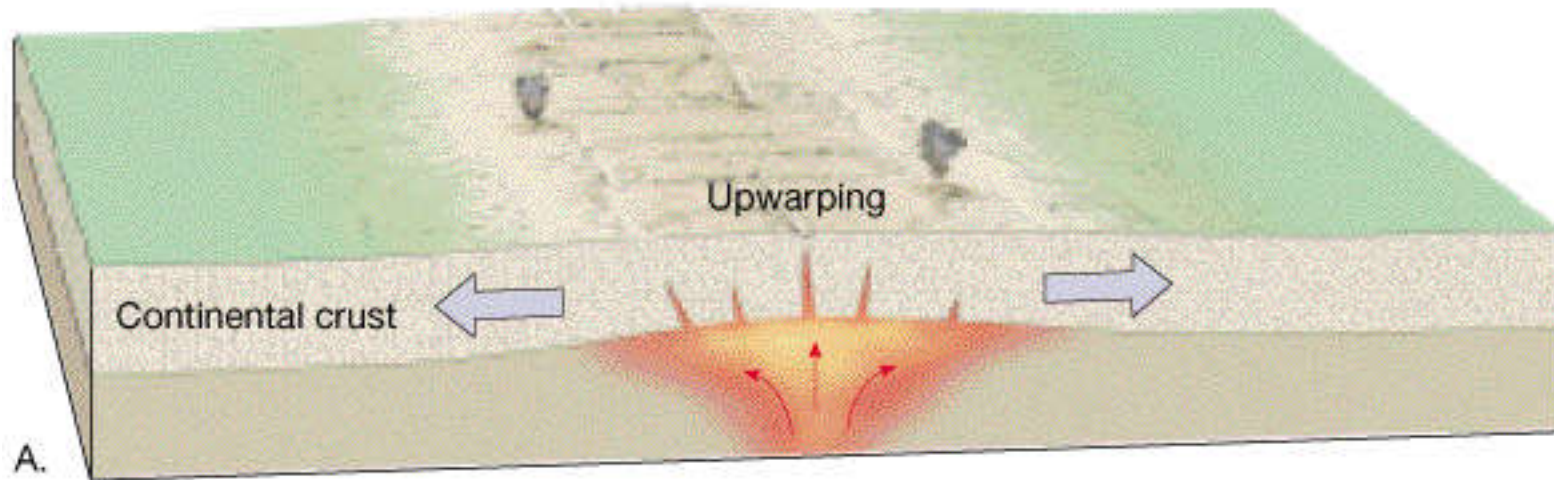
Most situated along the crests of the mid-ocean ridges.

Typical spreading rates are ~5 cm/year, however, range from 2 to 20 cm/year.

Red Sea and Gulf of California — new spreading ridges developing



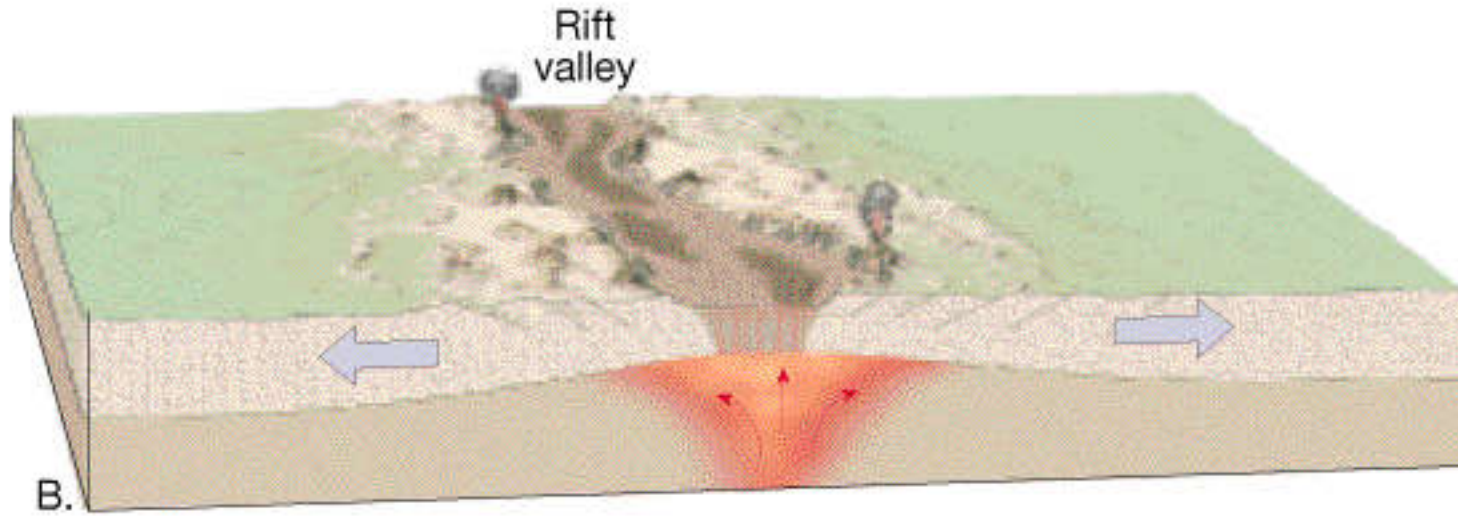
## Plate Boundaries — Divergent Boundaries



Continental crust can begin to rift from upward movement of hot rock from mantle.

Uplift results in extension that stretches the crust.

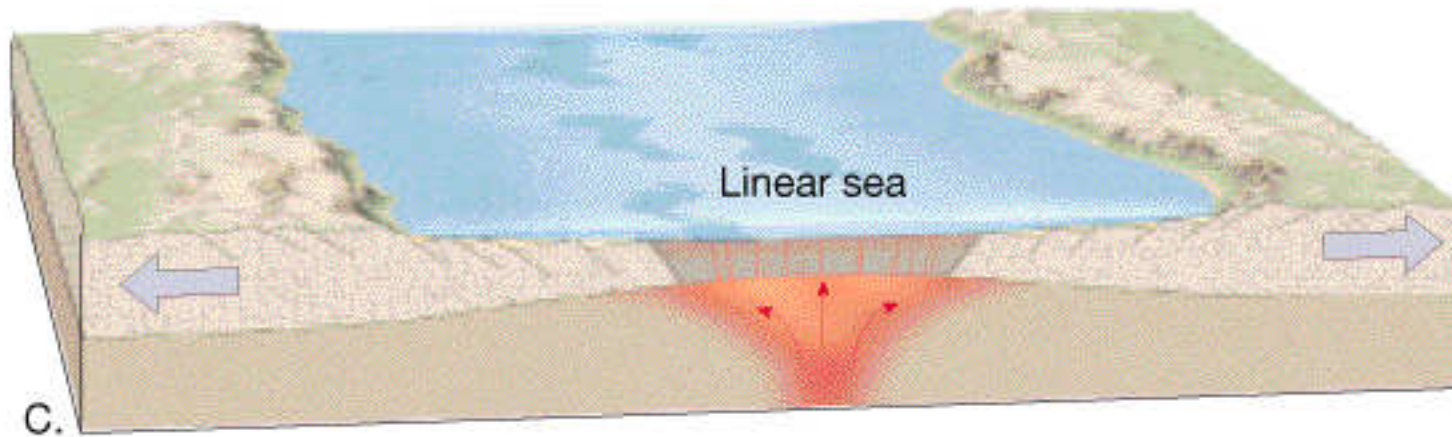
# Plate Boundaries — Divergent Boundaries



Extension of the crust is accompanied by episodes of faulting and volcanism.

This results in rift valley like the East African Rift Valleys.

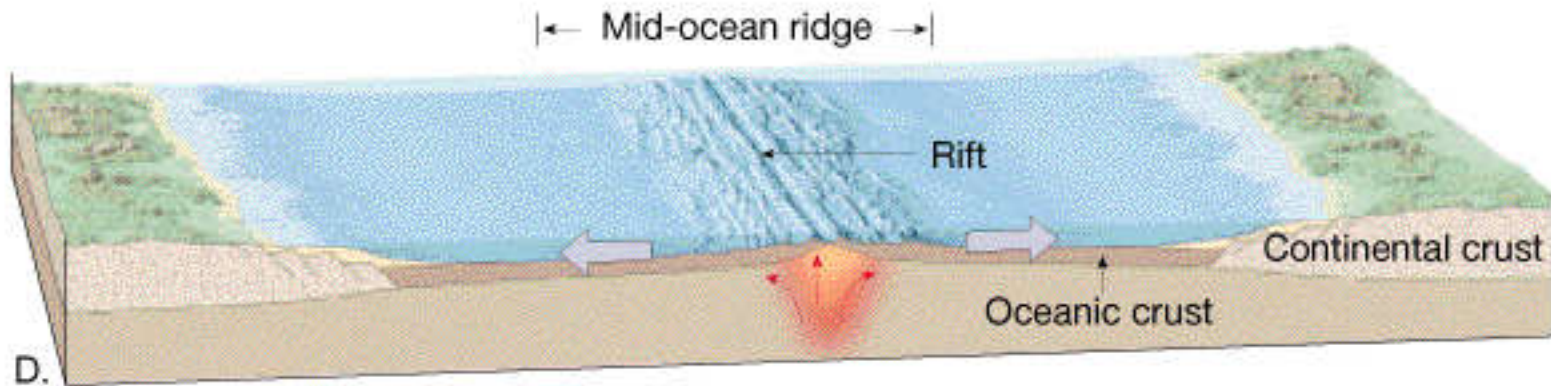
## Plate Boundaries — Divergent Boundaries



As the spreading continues, the rift valley will widen and deepen, extending out to the sea.

The valley then becomes a narrow linear sea — Red Sea, Gulf of California.

# Plate Boundaries — Divergent Boundaries



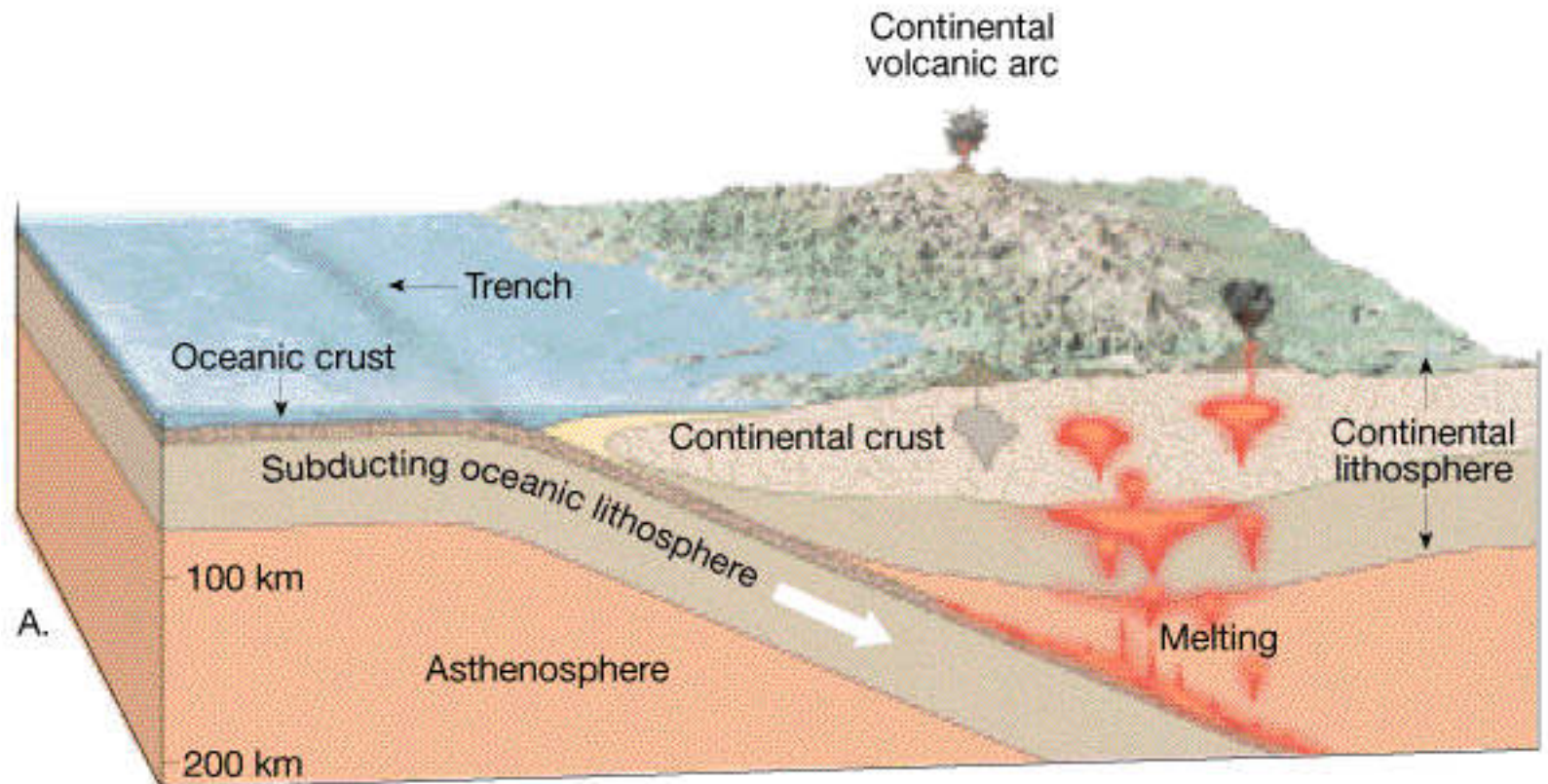
The rifting will continue until a full blown ridge system is created forming a large ocean basin — ex. Atlantic Ocean.

# Convergent Boundaries — Ocean-Continent Collisions

Denser oceanic crust is subducted — trench, accretionary wedge, volcanism.

Examples: Andes, Cascade Range

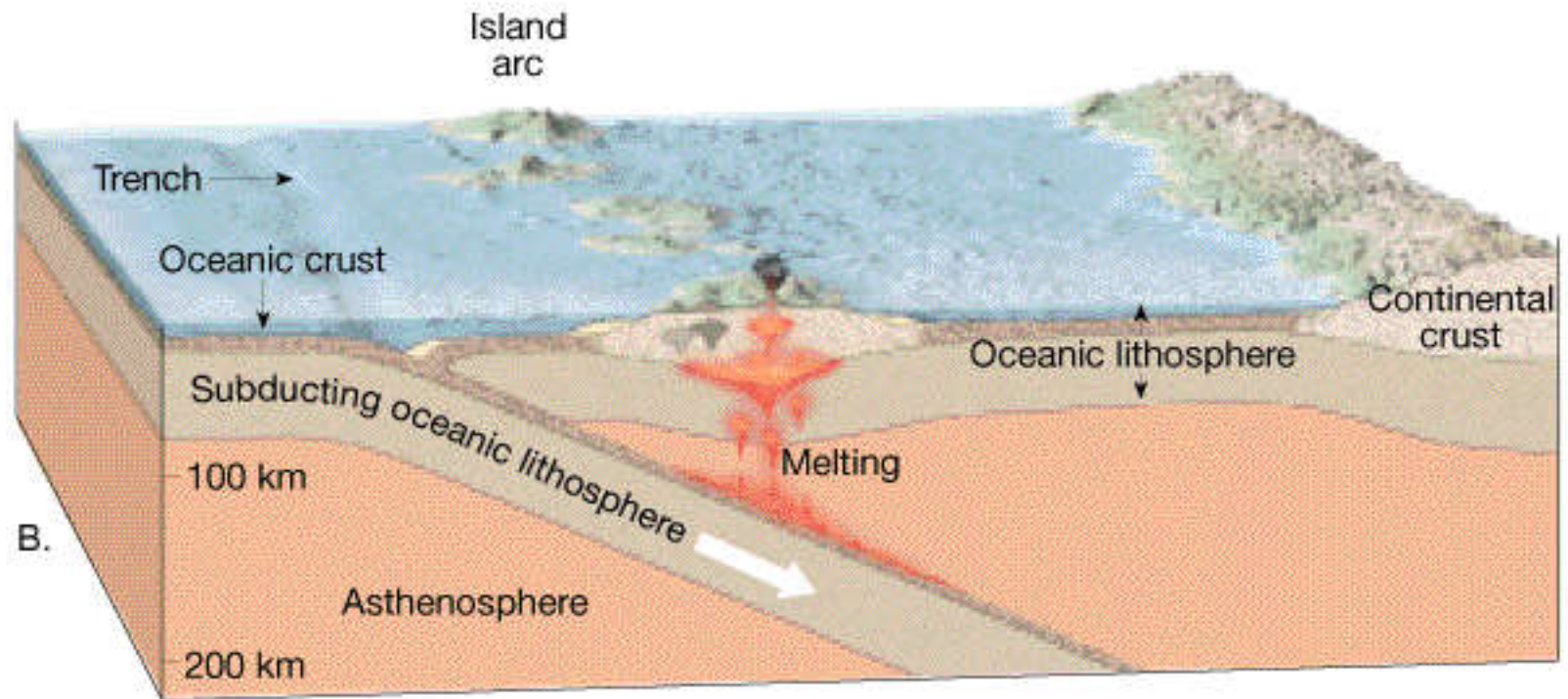
Sierra Nevada represents an inactive continental arc.



# Convergent Boundaries — Ocean-Ocean Collisions

Similar to ocean-continent collision except that volcanoes can form islands — volcanic island arc.

Ex. Aleutian Islands, Mariana, Tonga Islands.

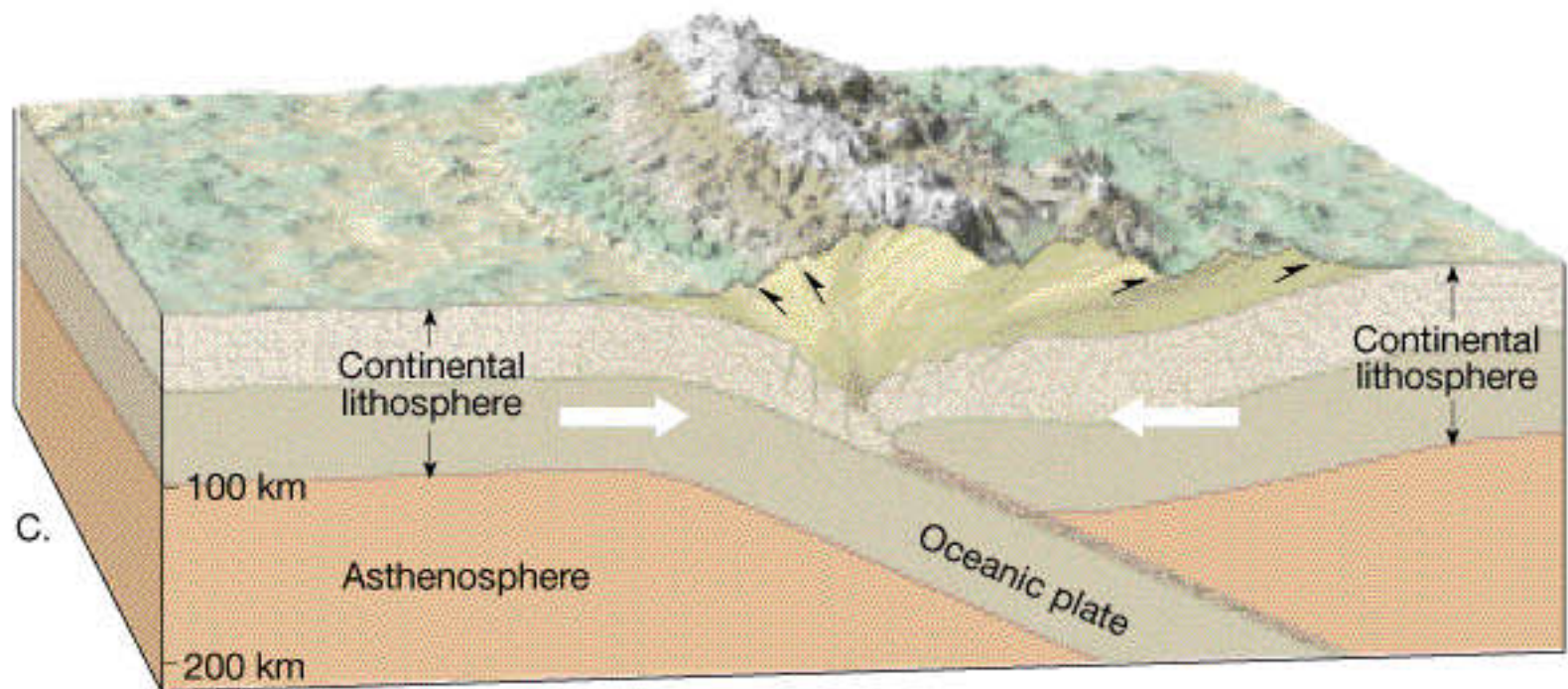


# Convergent Boundaries — Continent-Continent Collisions

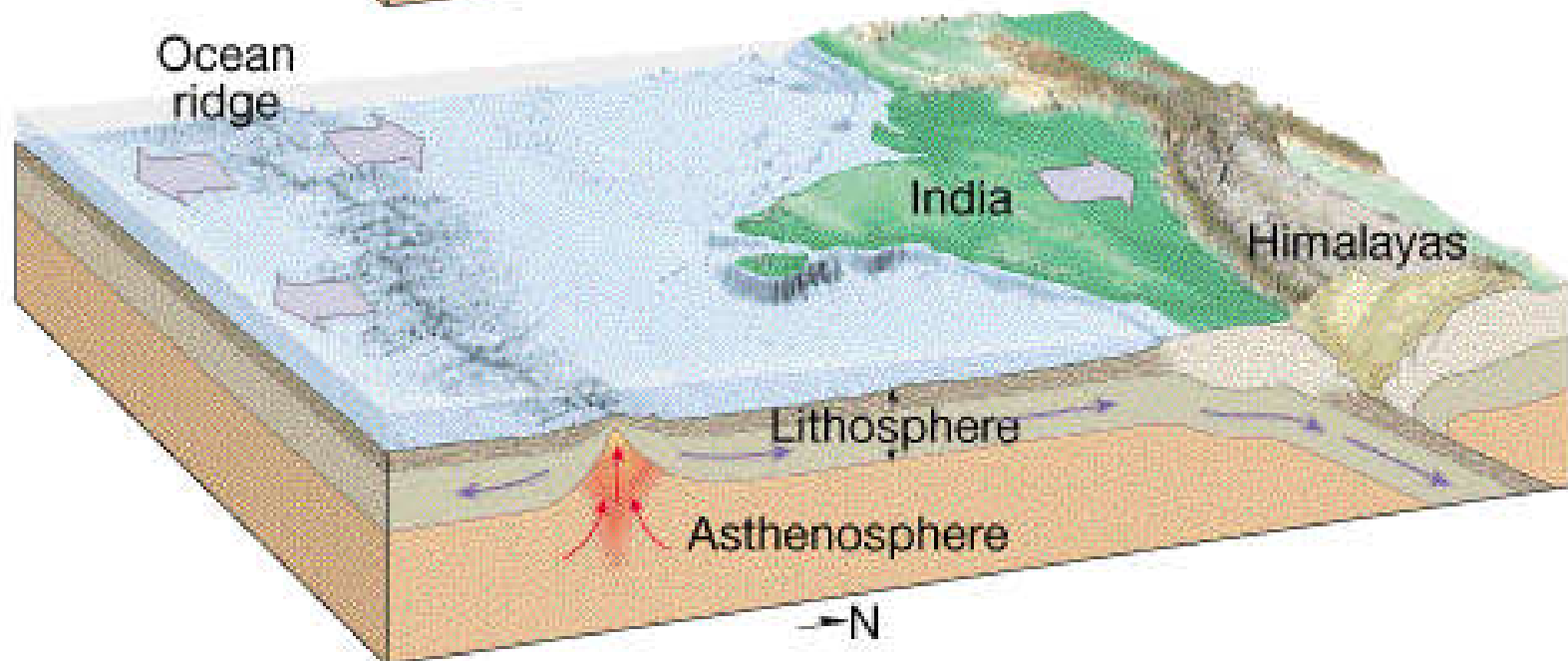
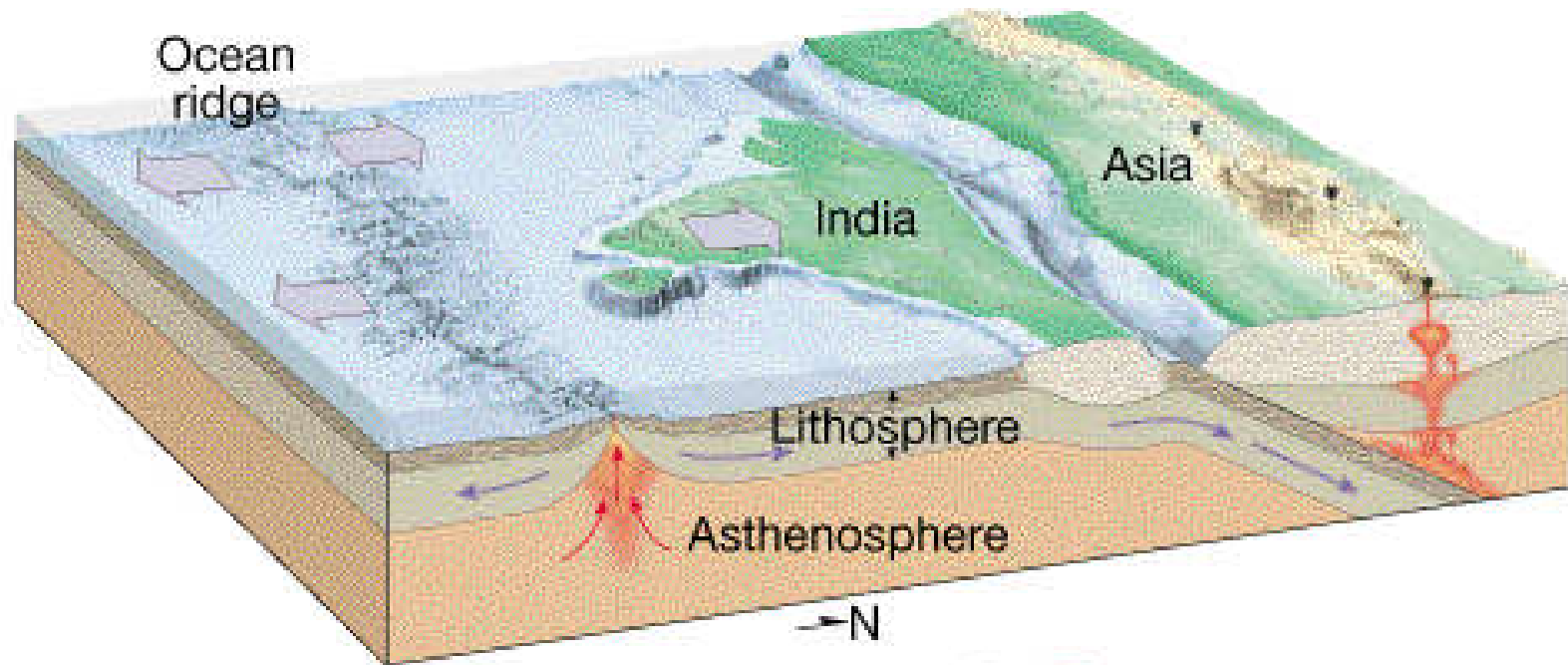
Usually preceded by subduction until continents smash into one another.

Results in thickening of crust and jumbled mess of many rock types superimposed on one another.

Example: Himalayan Mtns.

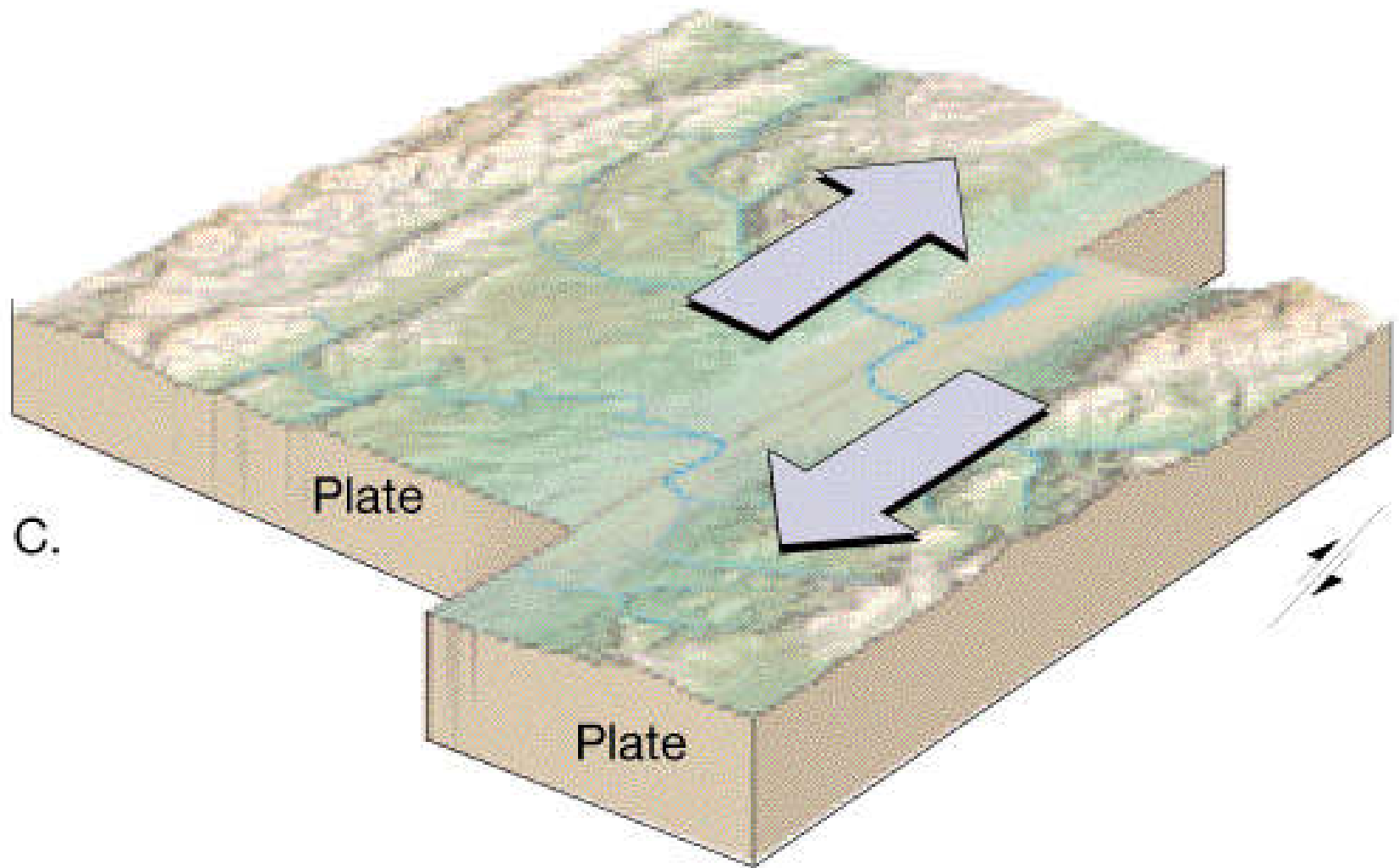


# Himalayan mountains as an example of continent-continent collision



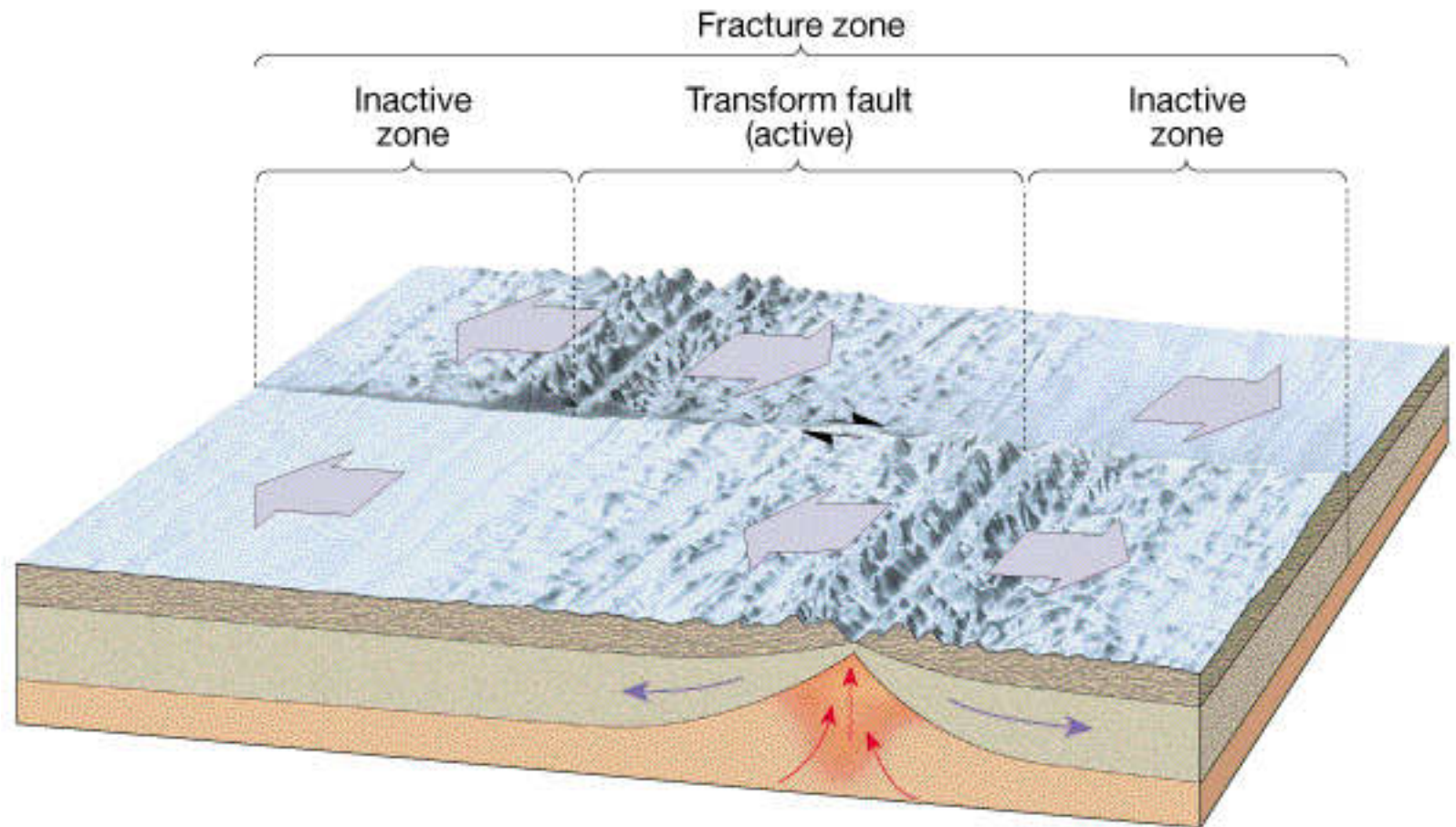
# Transform Plate Boundaries

Characterized by strike-slip motion — two plates grind past one another.  
Example: California



# Transform Plate Boundaries

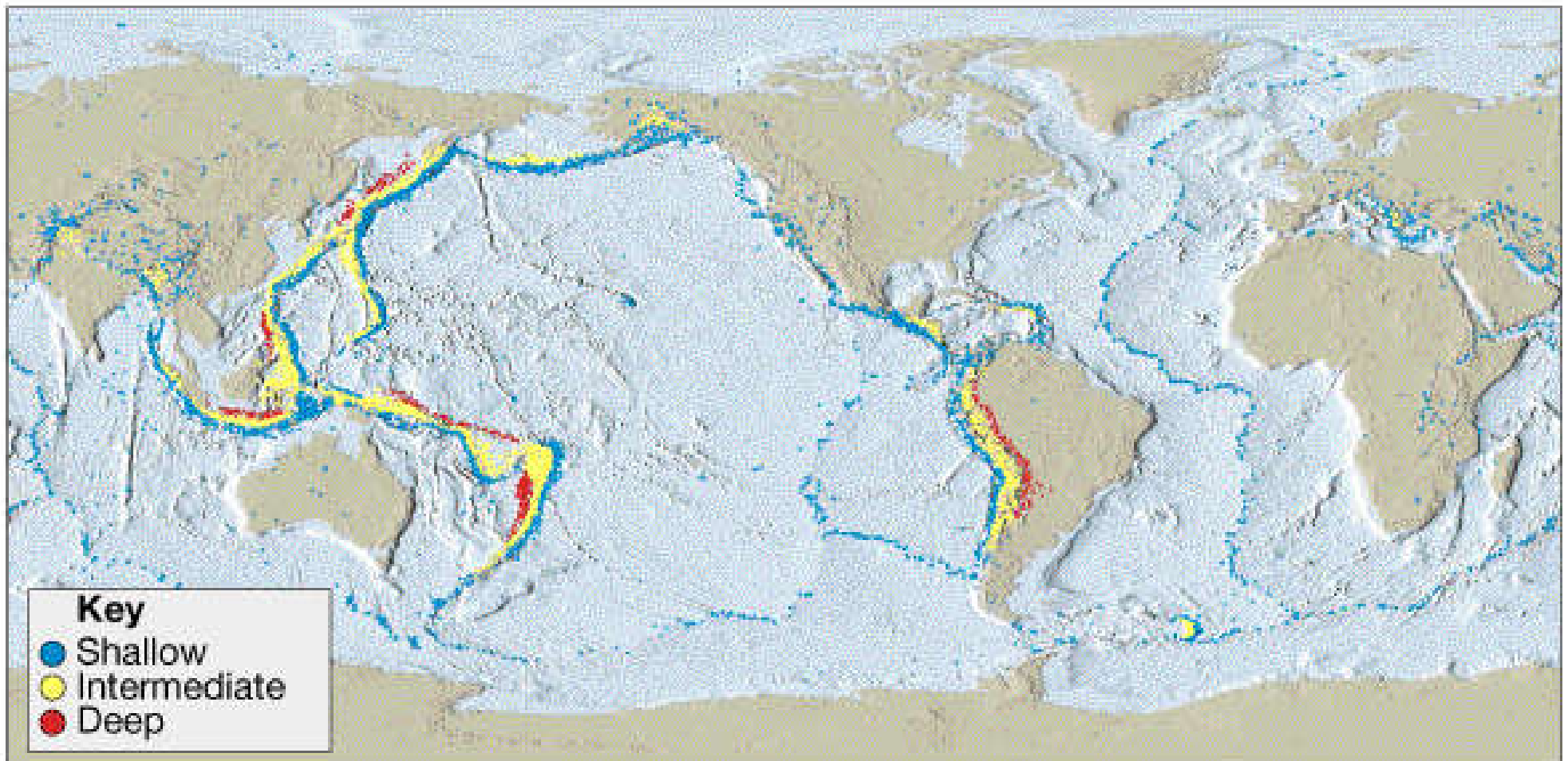
Most transform boundaries occur in association with mid-ocean ridge systems — forming fracture zones which include the transform fault and their inactive extensions into the plate interior. These transform fault occur about every 100 km along a ridge and offset the ridge crest.



# Plate Tectonics and Earthquakes

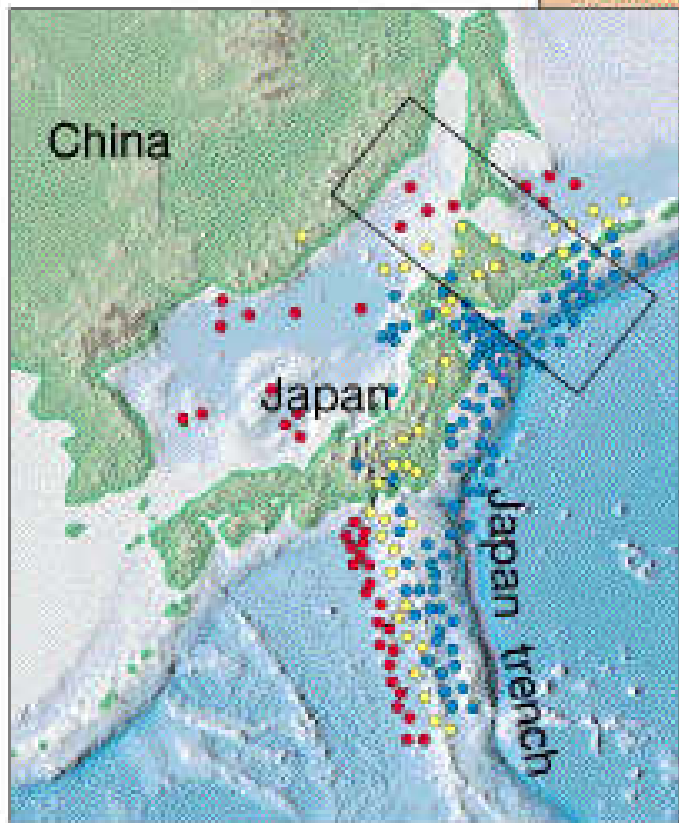
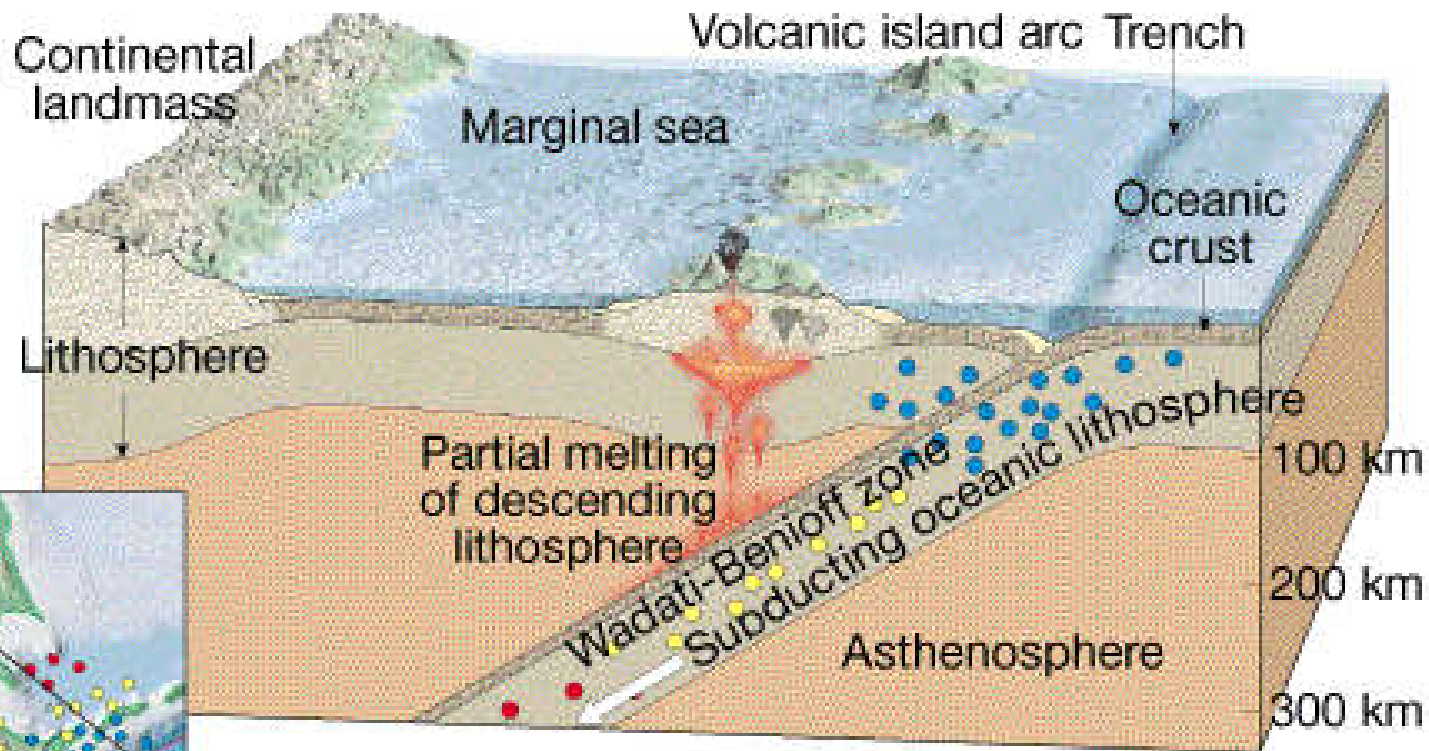
Most earthquakes are coincident with plate boundaries — due to movement along boundaries.

Divergent and transform boundaries usually result in shallow earthquakes.



# Plate Tectonics and Earthquakes

Subduction zones result in a range of depths of earthquakes — Benioff zone.



Key	
●	Shallow
●	Intermediate
●	Deep

# Hotspots

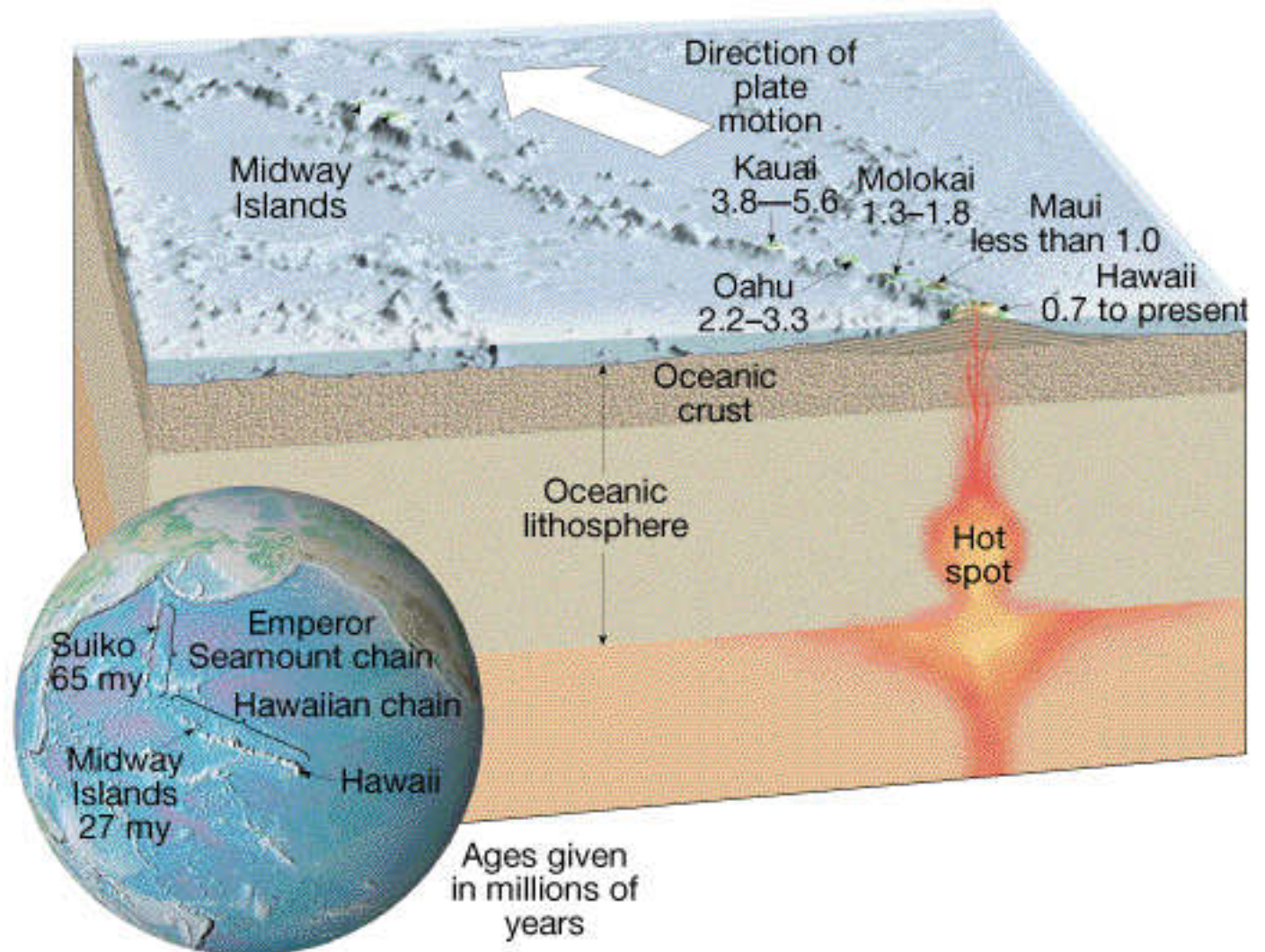
Most volcanic activity is associated with plate boundaries — MOR, subduction, etc.

Some "intraplate" volcanoes are the result of a plate moving across a mantle hot spot.

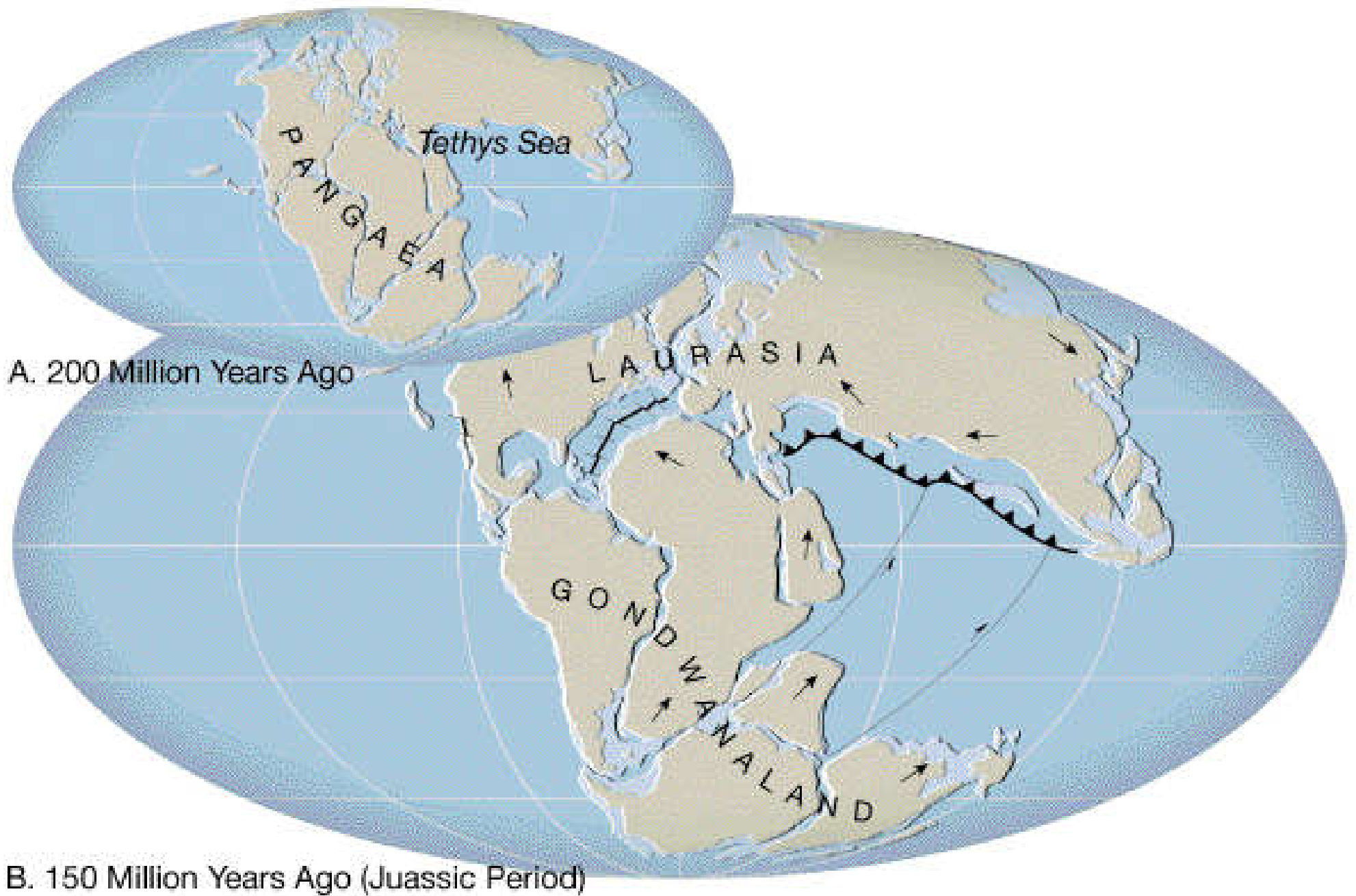
Examples:

Hawaii

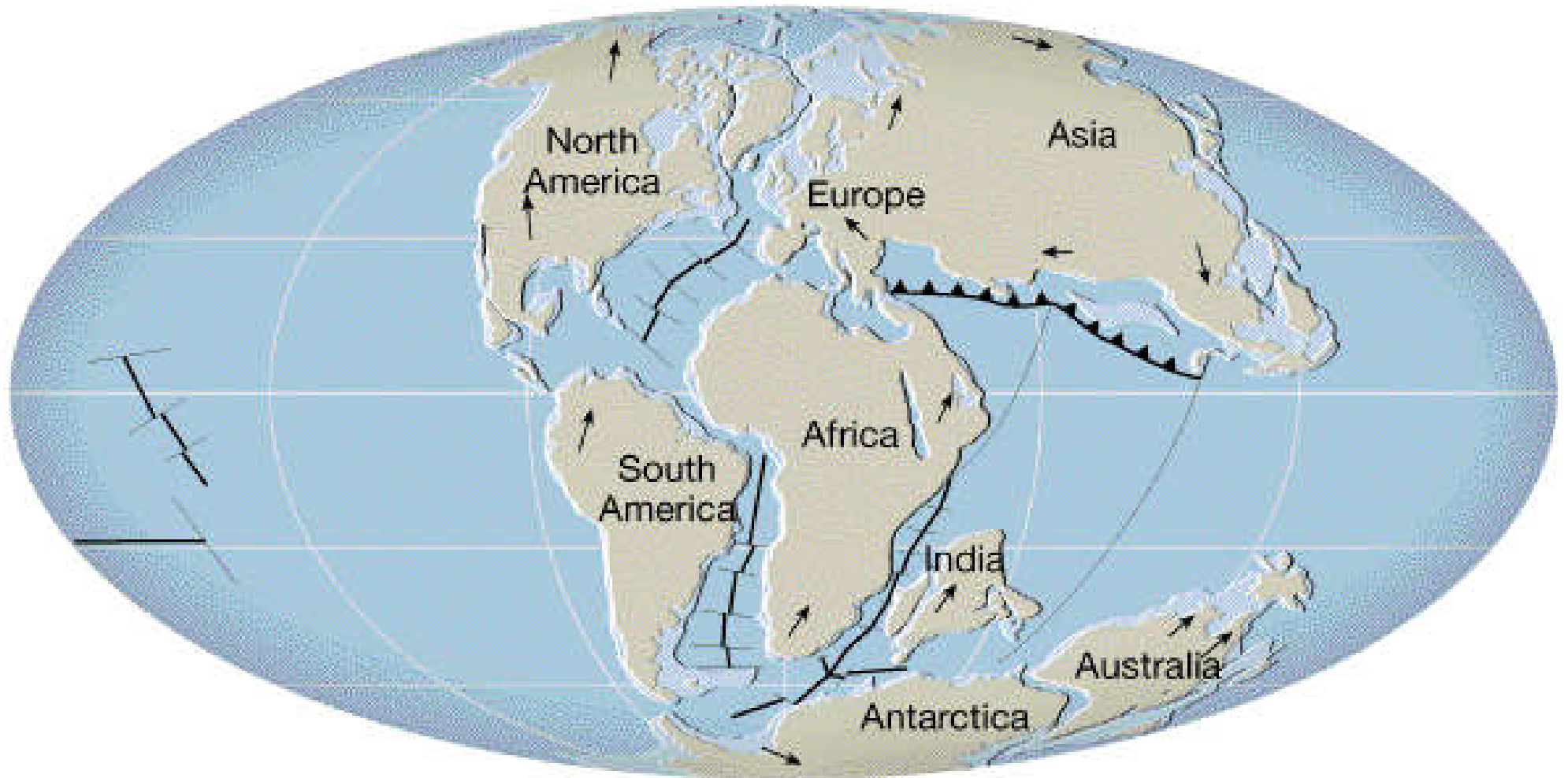
Yellowstone



# Breakup of Pangaea

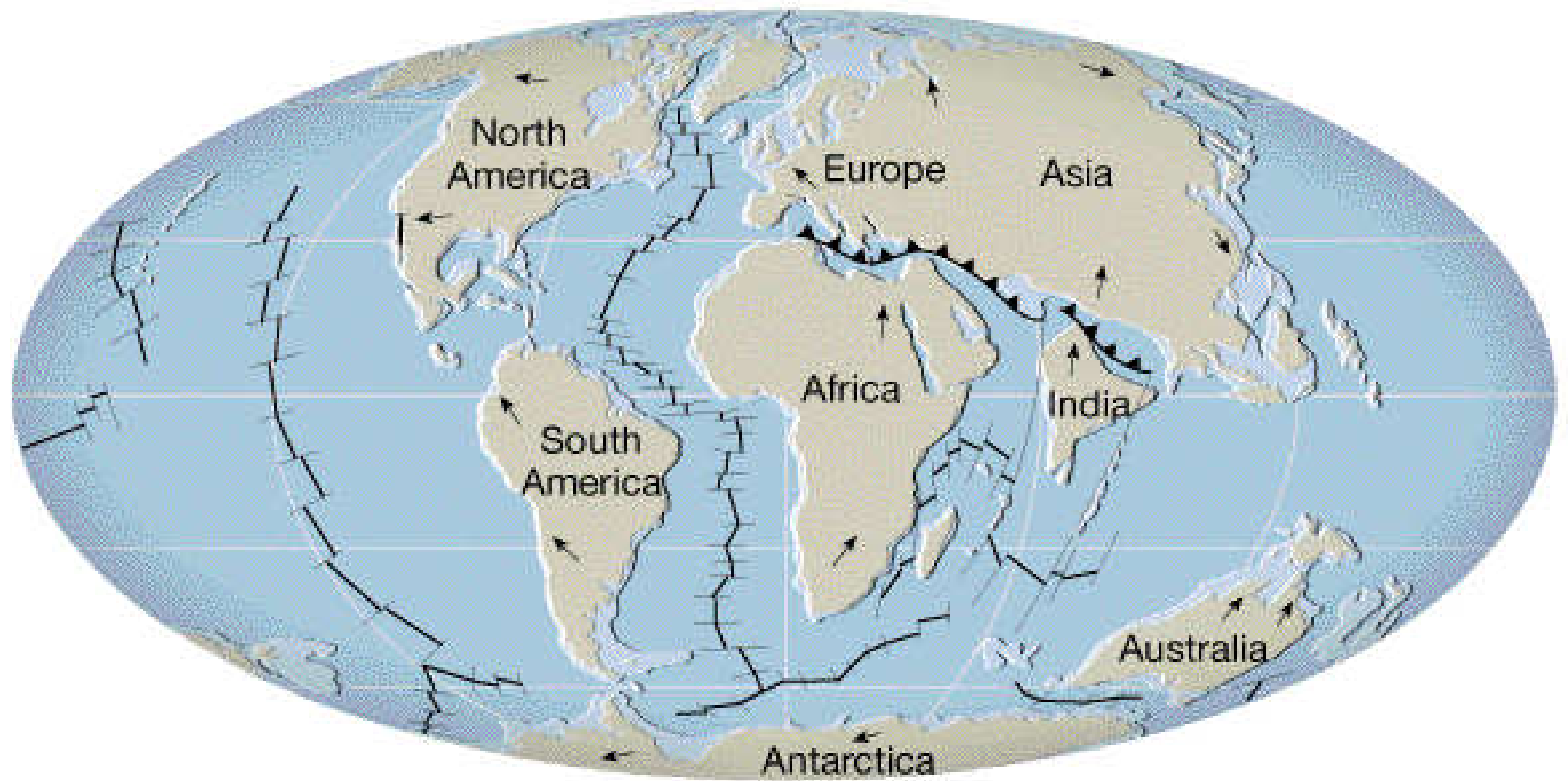


# Breakup of Pangaea



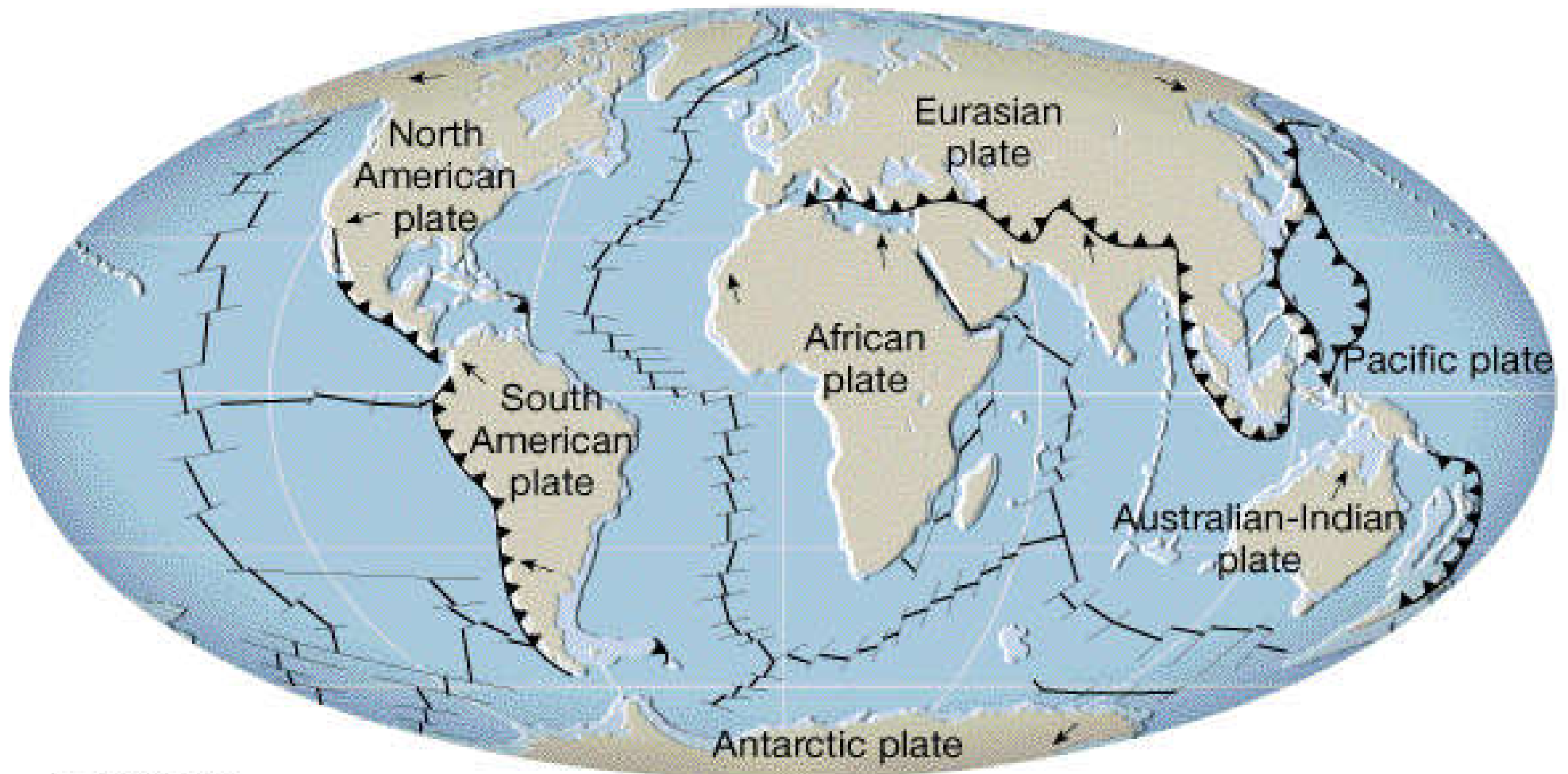
C. 100 Million Years Ago (Cretaceous Period)

# Breakup of Pangaea



D. 50 Million Years Ago (Early Cenozoic)

# Breakup of Pangaea



E. Present