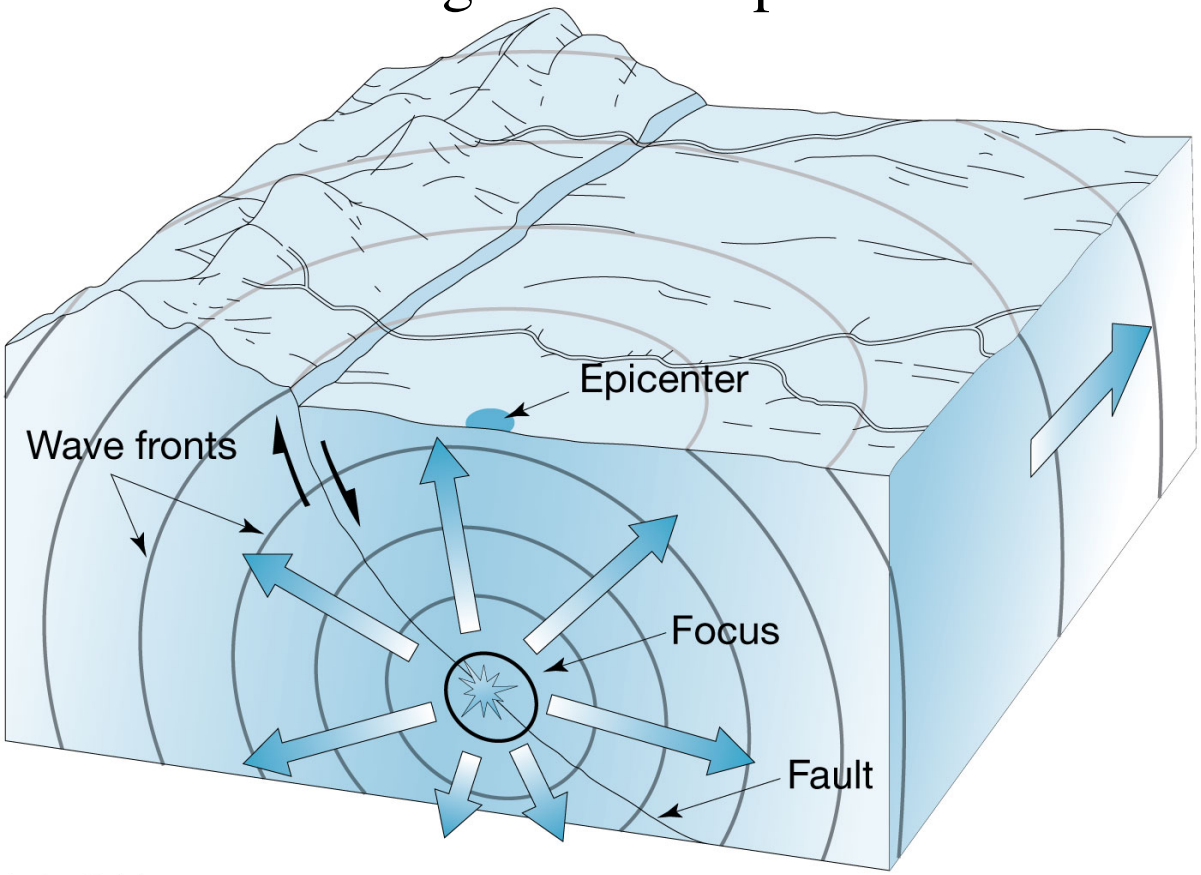
Chapter 7: Earth Circulation

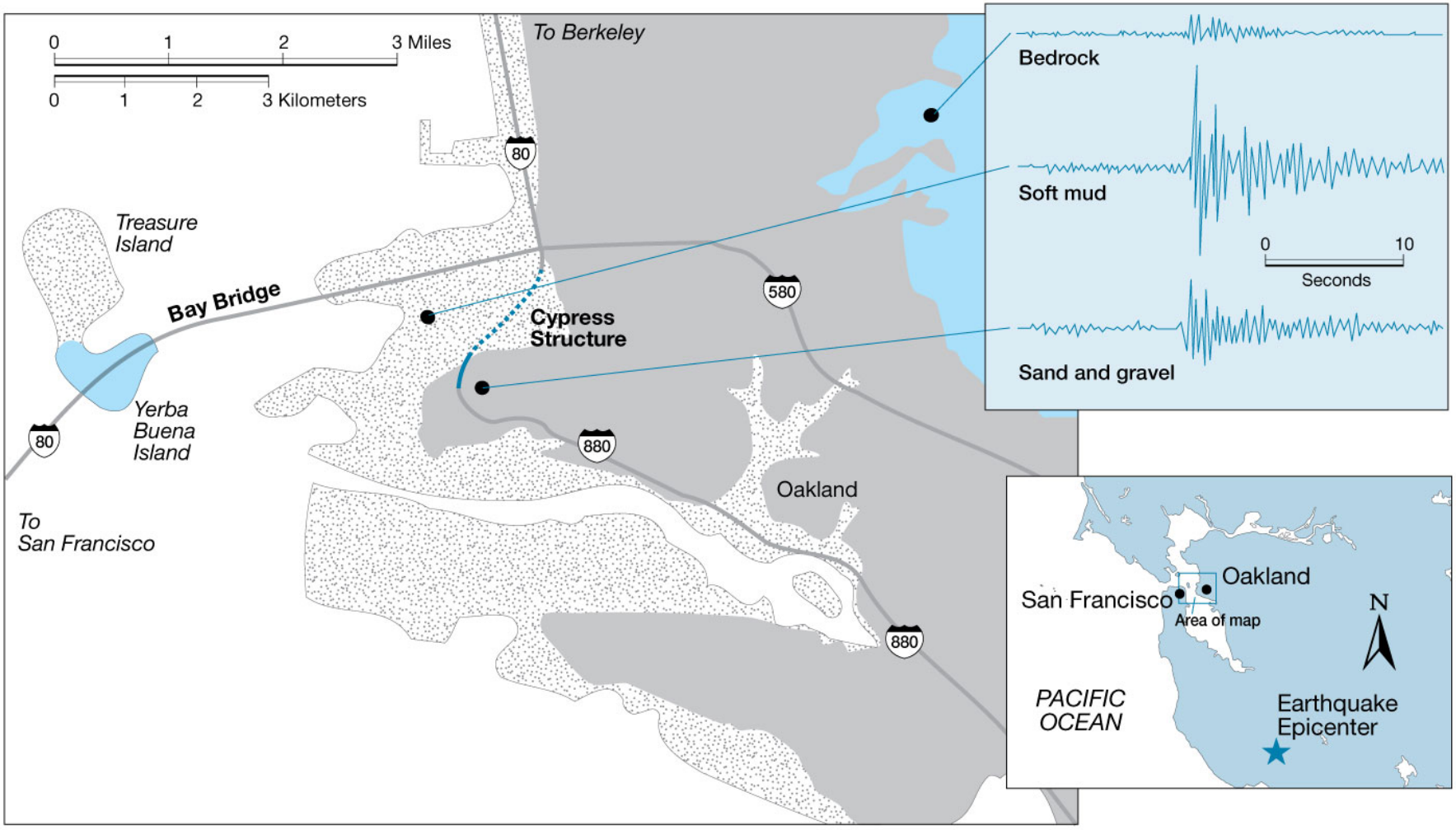
Circulation in the Solid Earth:

1. Structure of Earth
2. Origins of plate tectonic theory
3. Plates and plate boundaries
4. Driving forces for plate tectonics

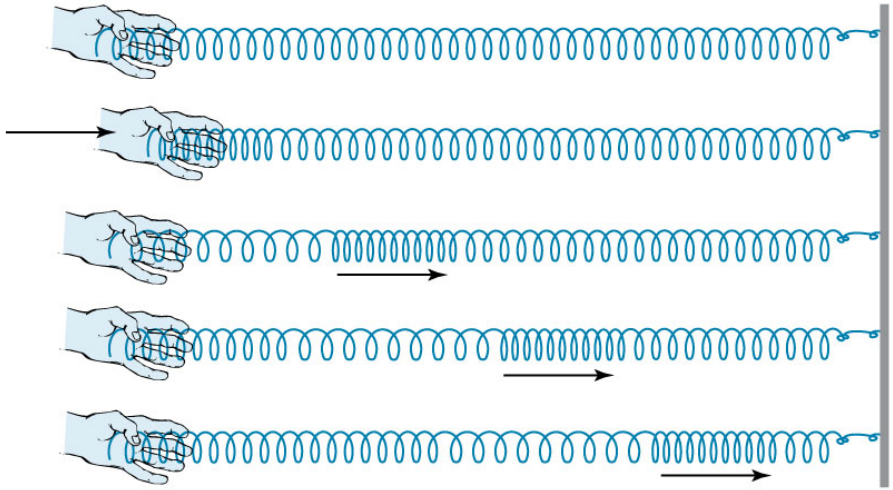


Earthquakes provide information about the Earth's structure


ROAD
CLOSED
89 10 28

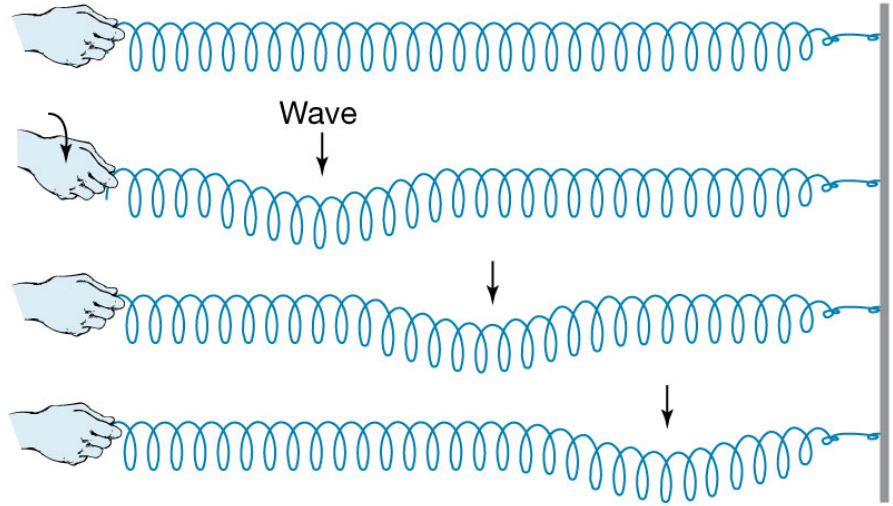


(b)



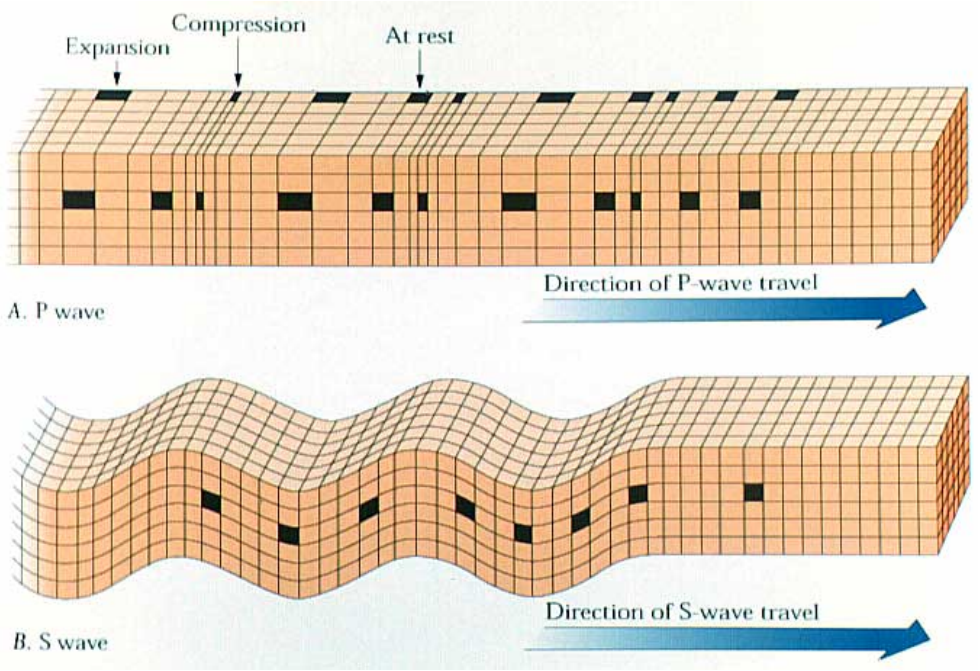
(a)

p-waves



(b)

s-waves



Body waves: (faster than surface waves)

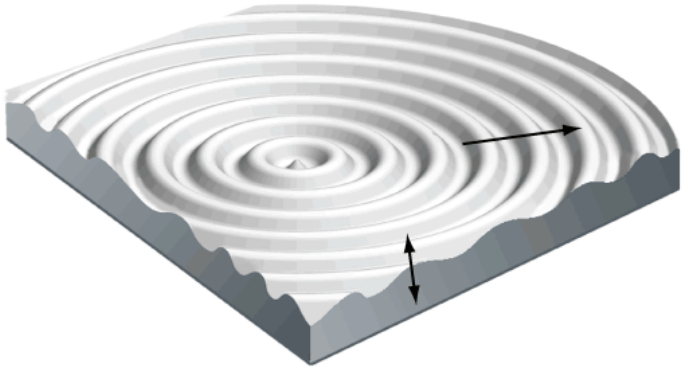
P waves compressional

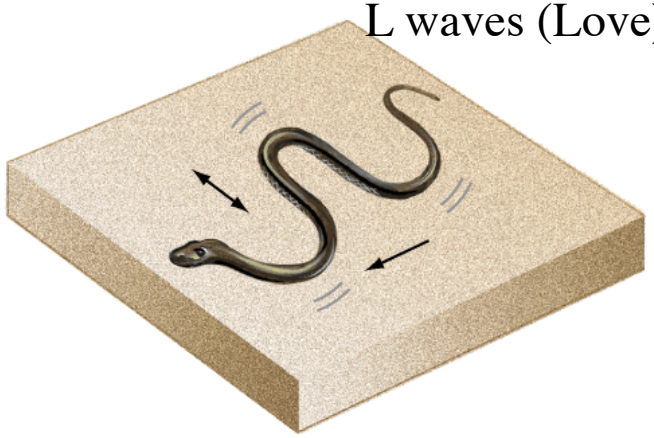
S waves = sine-wave shape

Surface waves: (slower than body waves)

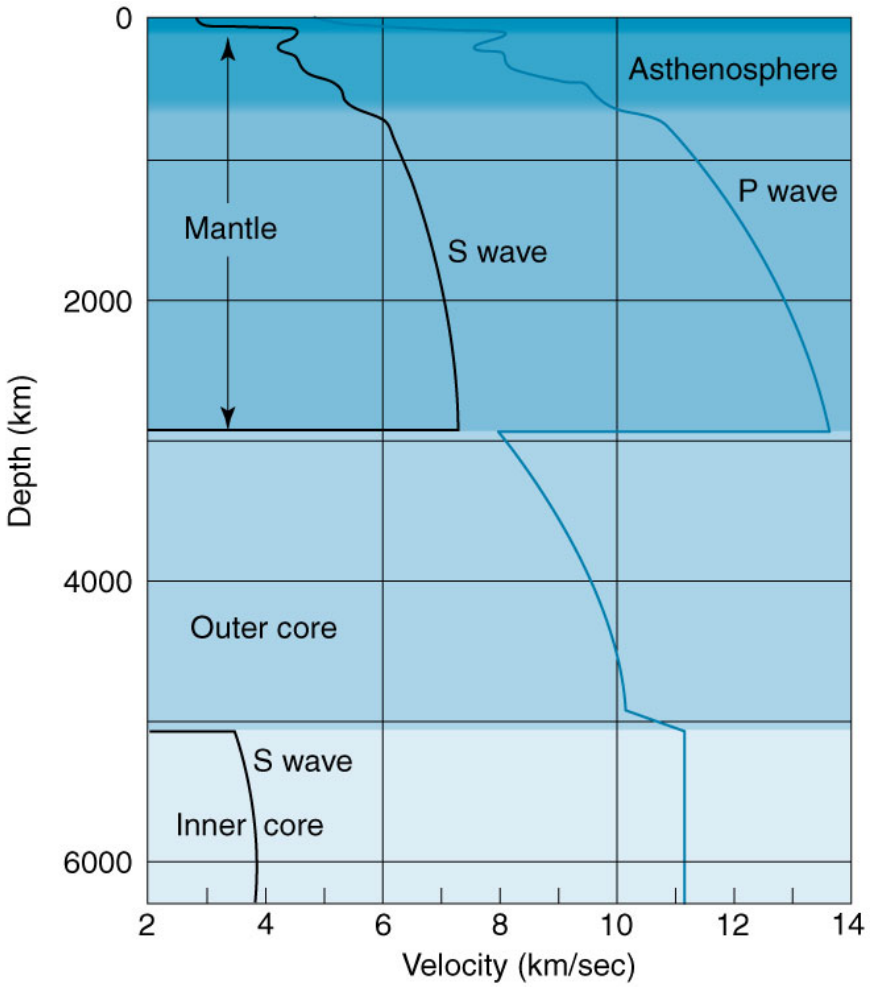
R waves (Rayleigh)ripples

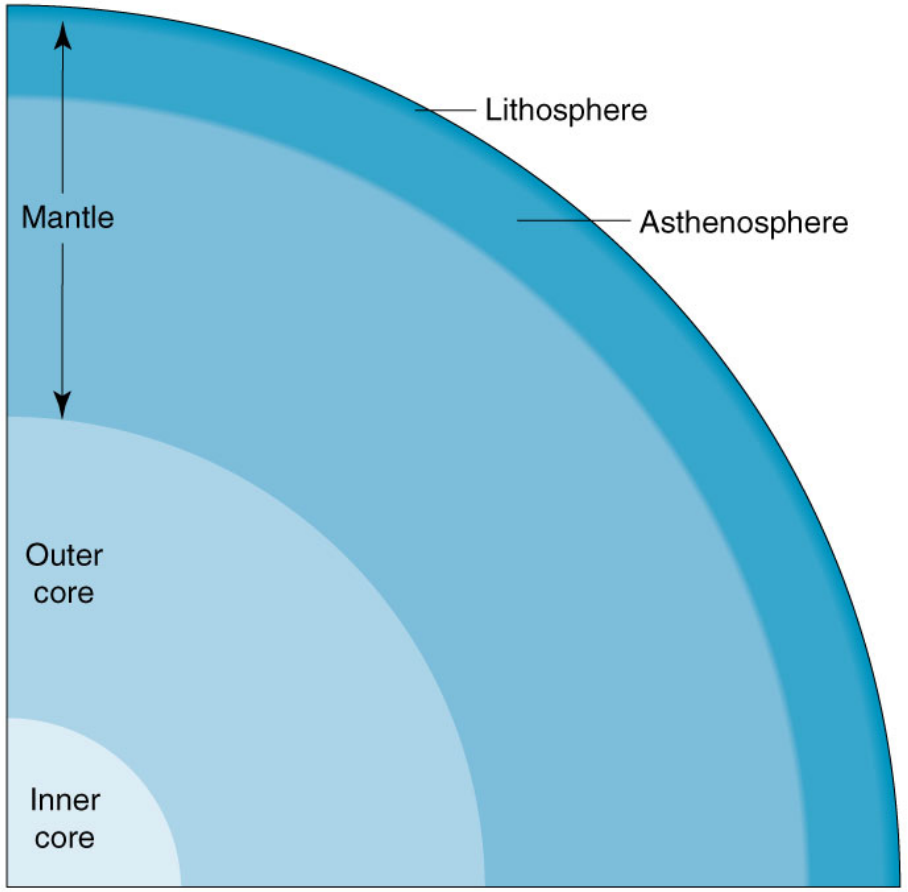
L waves (Love) snake-like motion





Interior structure of the Earth:





Information from earthquake energy:

Wave velocity gets faster deep in the earth

Fast rocks = dense minerals

<u>Crust</u>

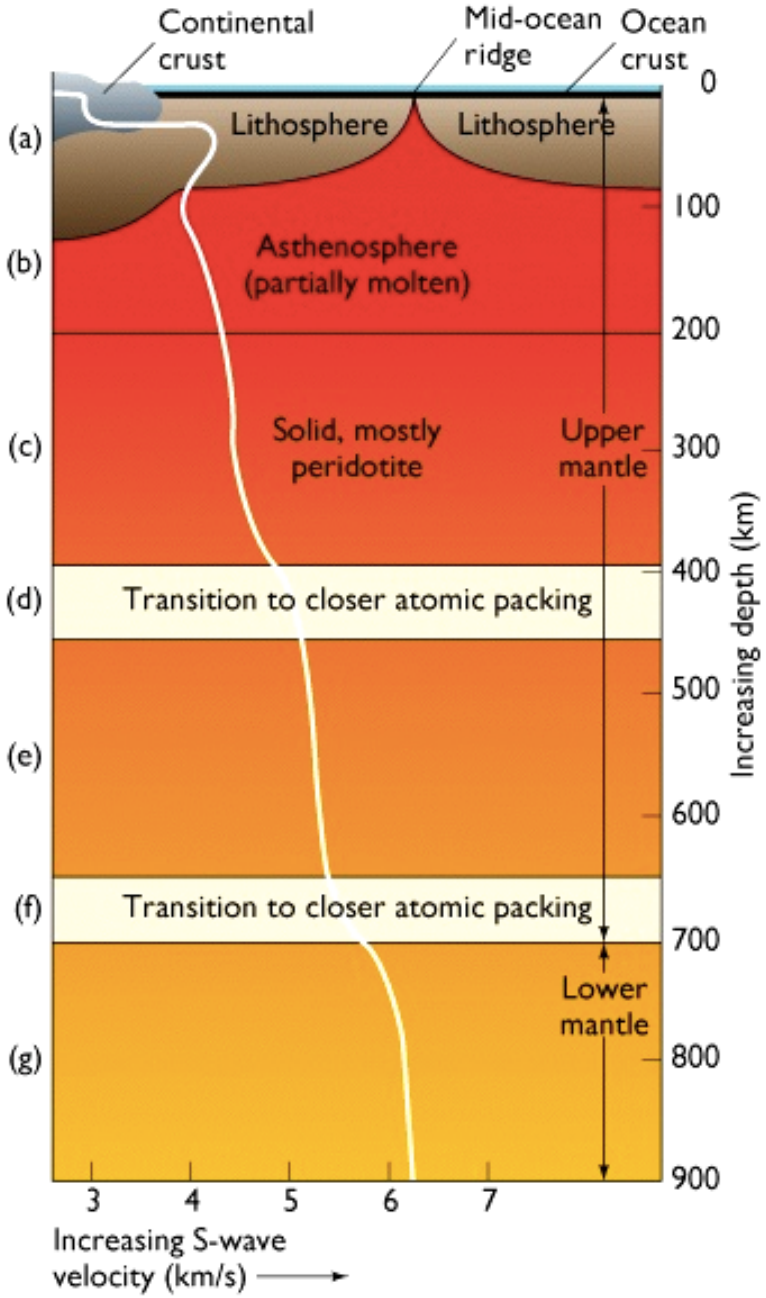
Slow velocity=low density (2.8 to 3 g/cc) = quartz, mica, feldspar

<u>Mantle</u>

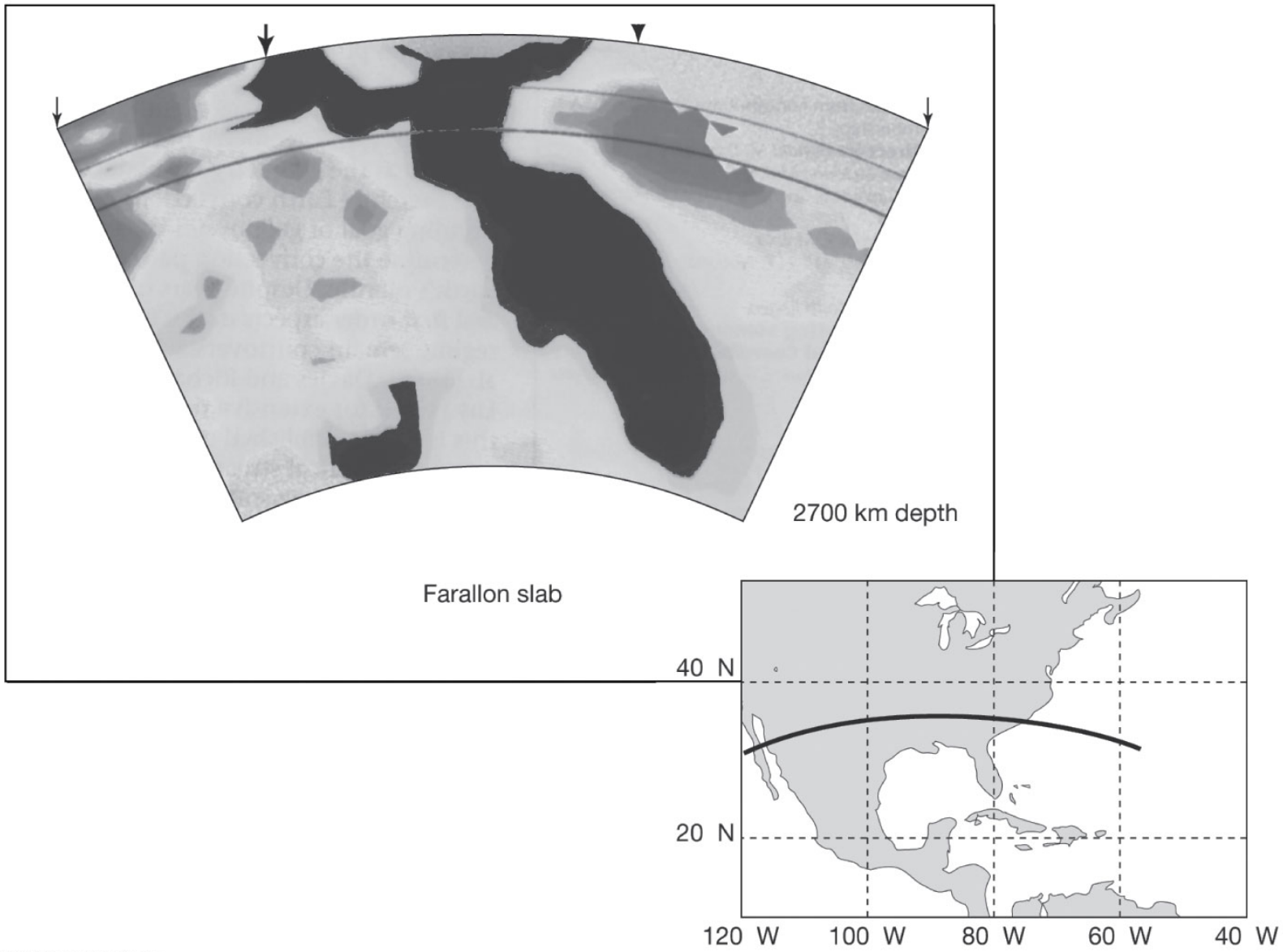
Fast velocity = high density (3 to 5 g/cc) = olivine, pyroxene

<u>Core</u>

Mostly iron metal, + 6%Ni + 8-10% light elements, an electrically conducting convecting fluid

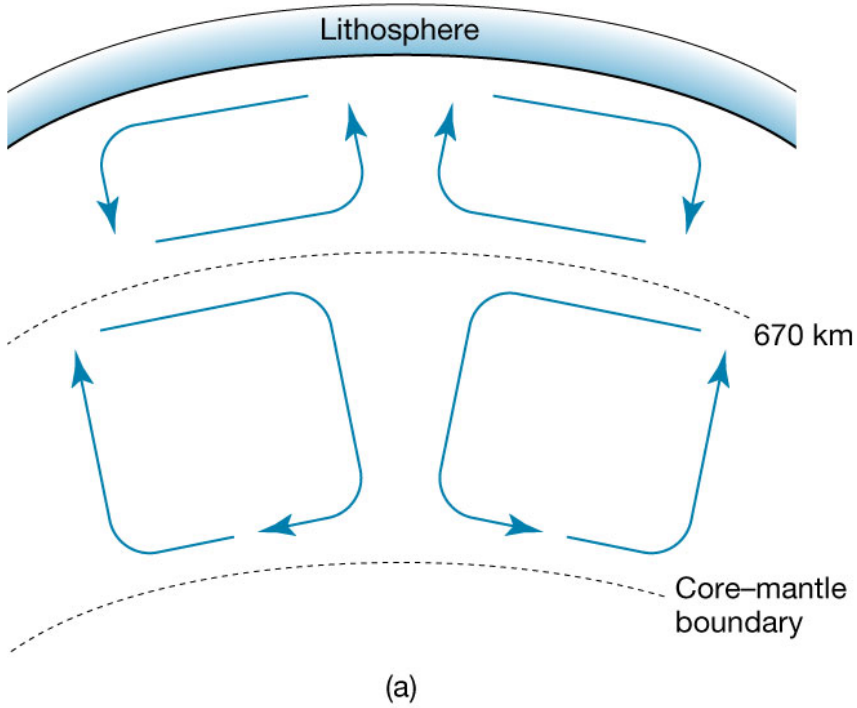


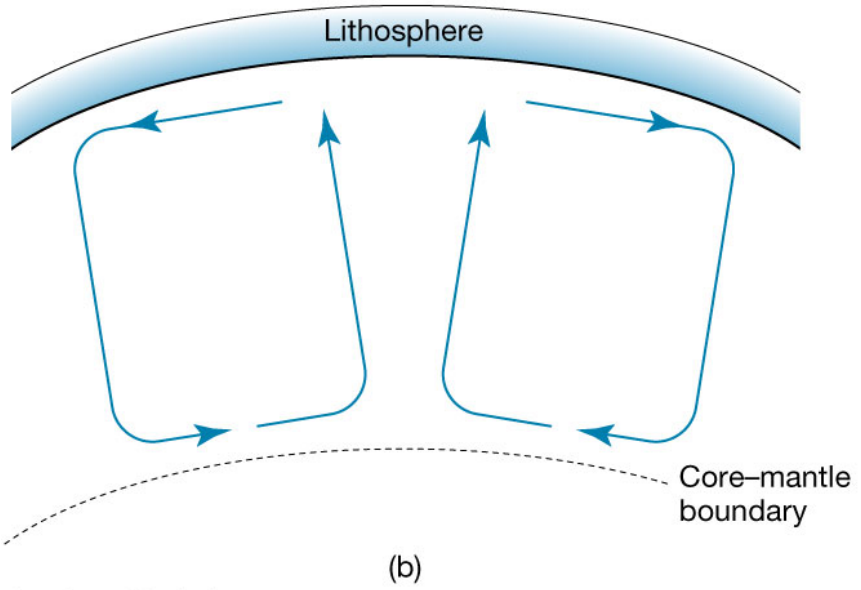
Velocity correlates with temperature, rising and sinking material:

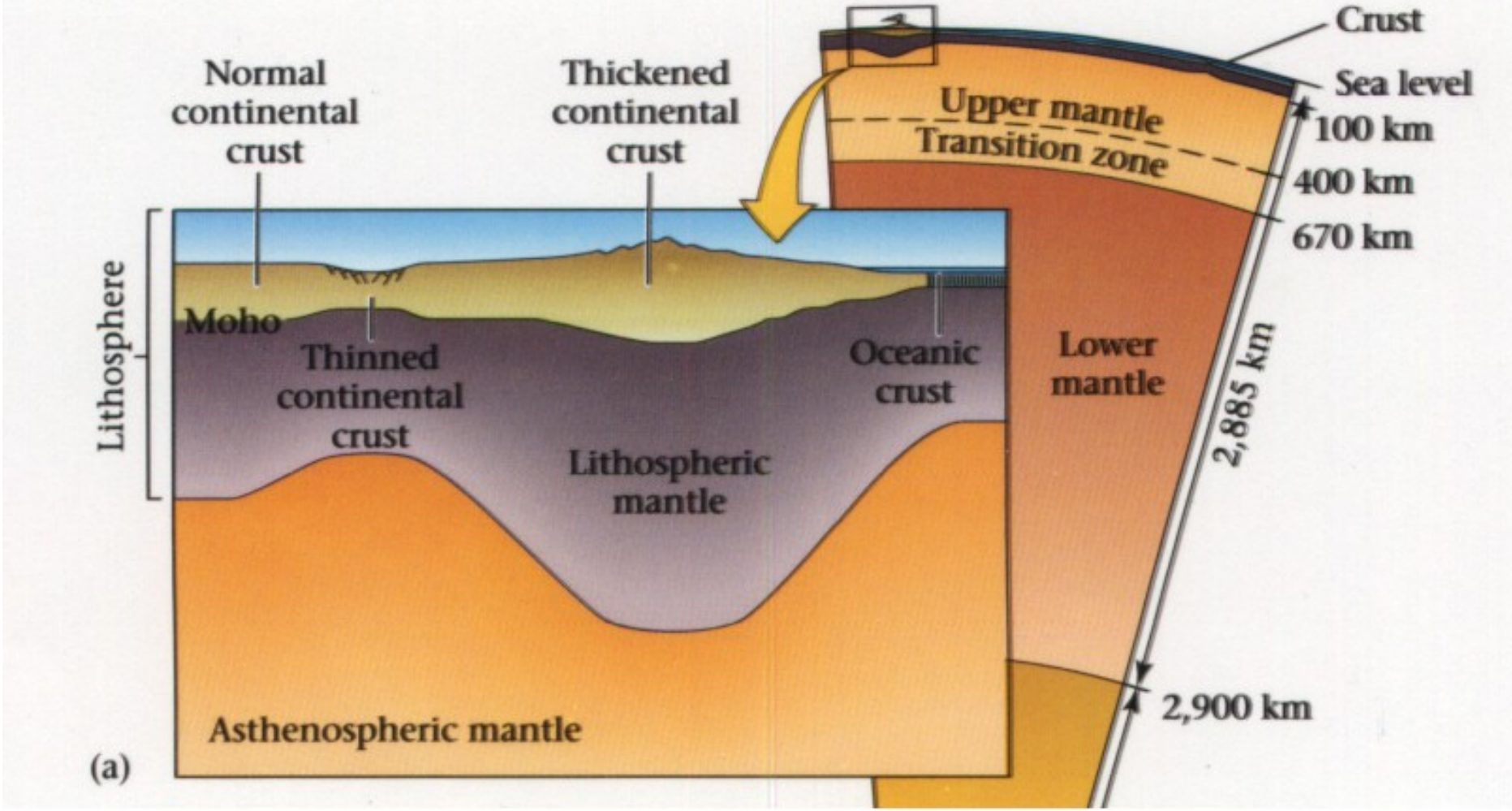


The density differences between the upper and lower mantle have been interpreted in terms of separate convection cells in upper and lower mantles. This would be required if the density differences represent compositional differences like they do at the crust/mantle boundary.

If they represent mineralogical structure differences that take place quickly, then whole-mantle convection is possible.







2 ways of defining layers:

1. By seismic velocity

crust, mantle, core

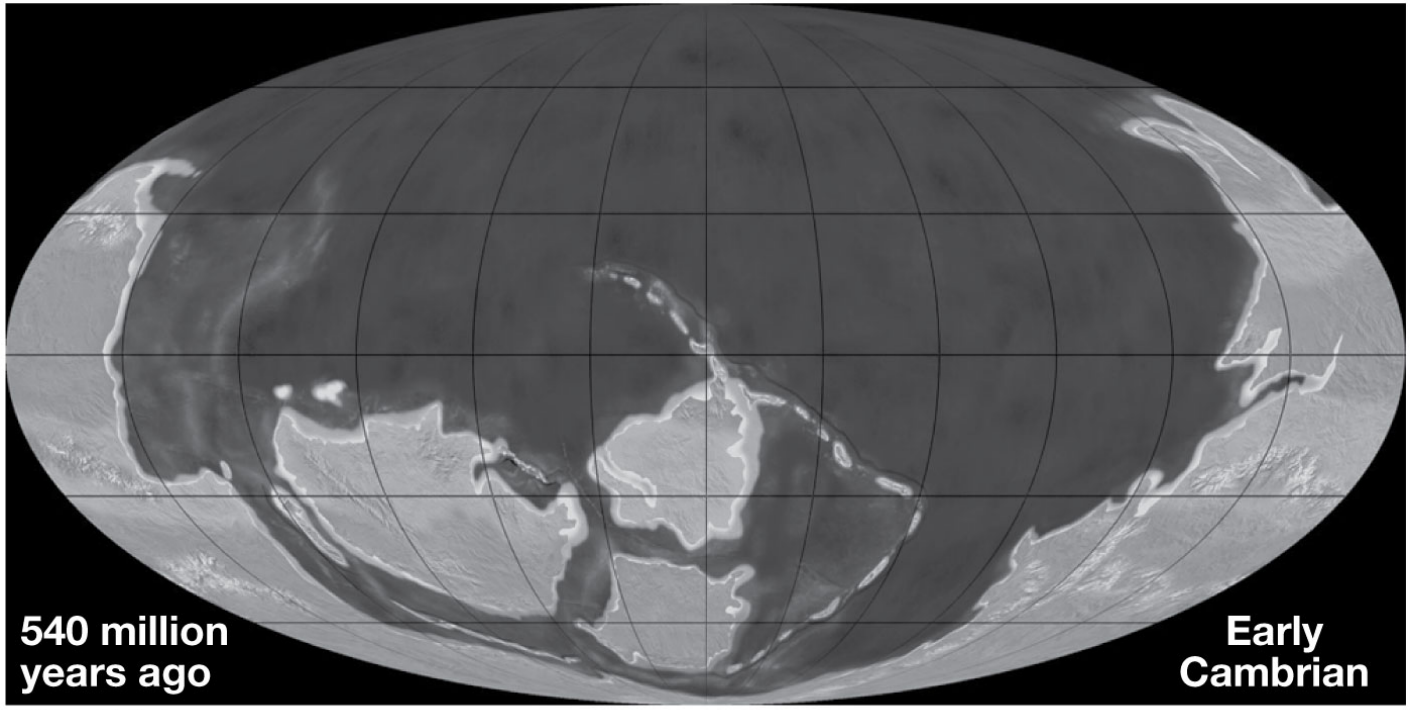
2. By flow characteristics

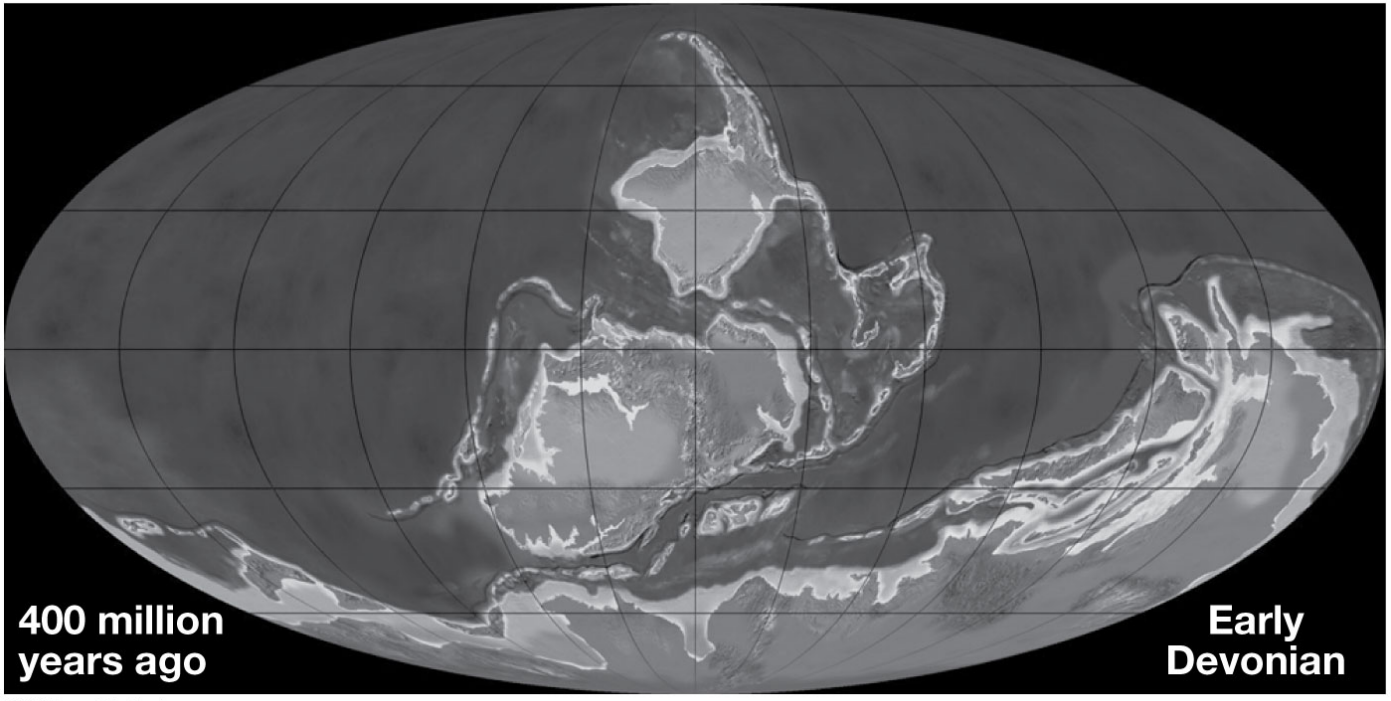
lithosphere, asthenosphere

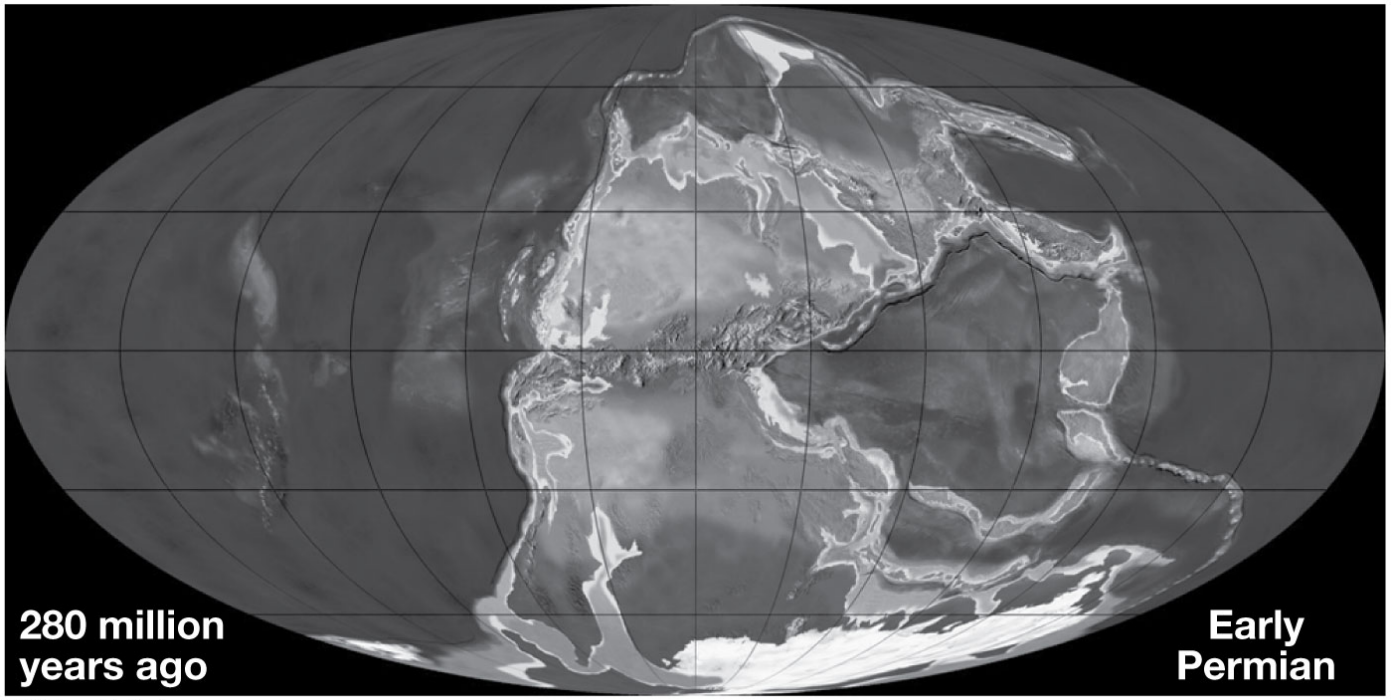
Plate Tectonics

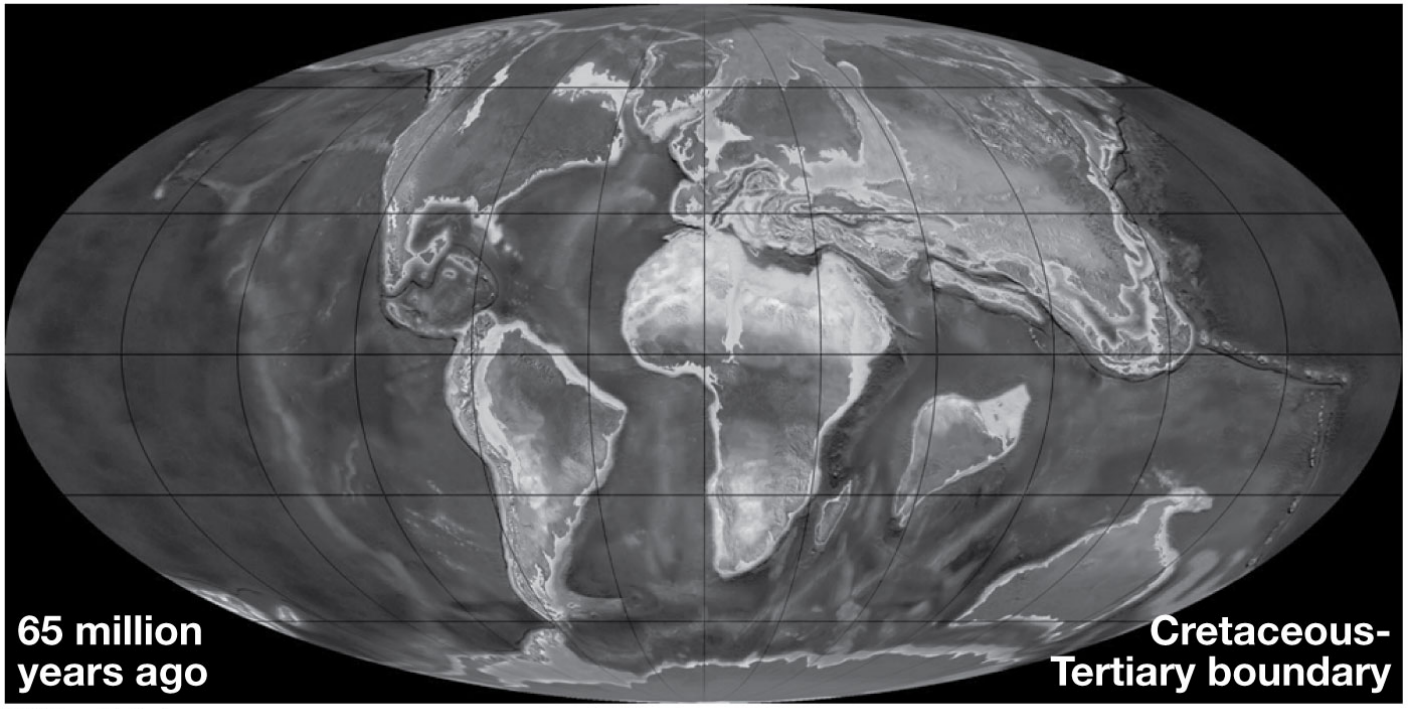
Origins of theory: Wegener's evidence for continental drift

- Fit of continents
- Locations of past glaciations
- Distribution of fossils
- Matching geology

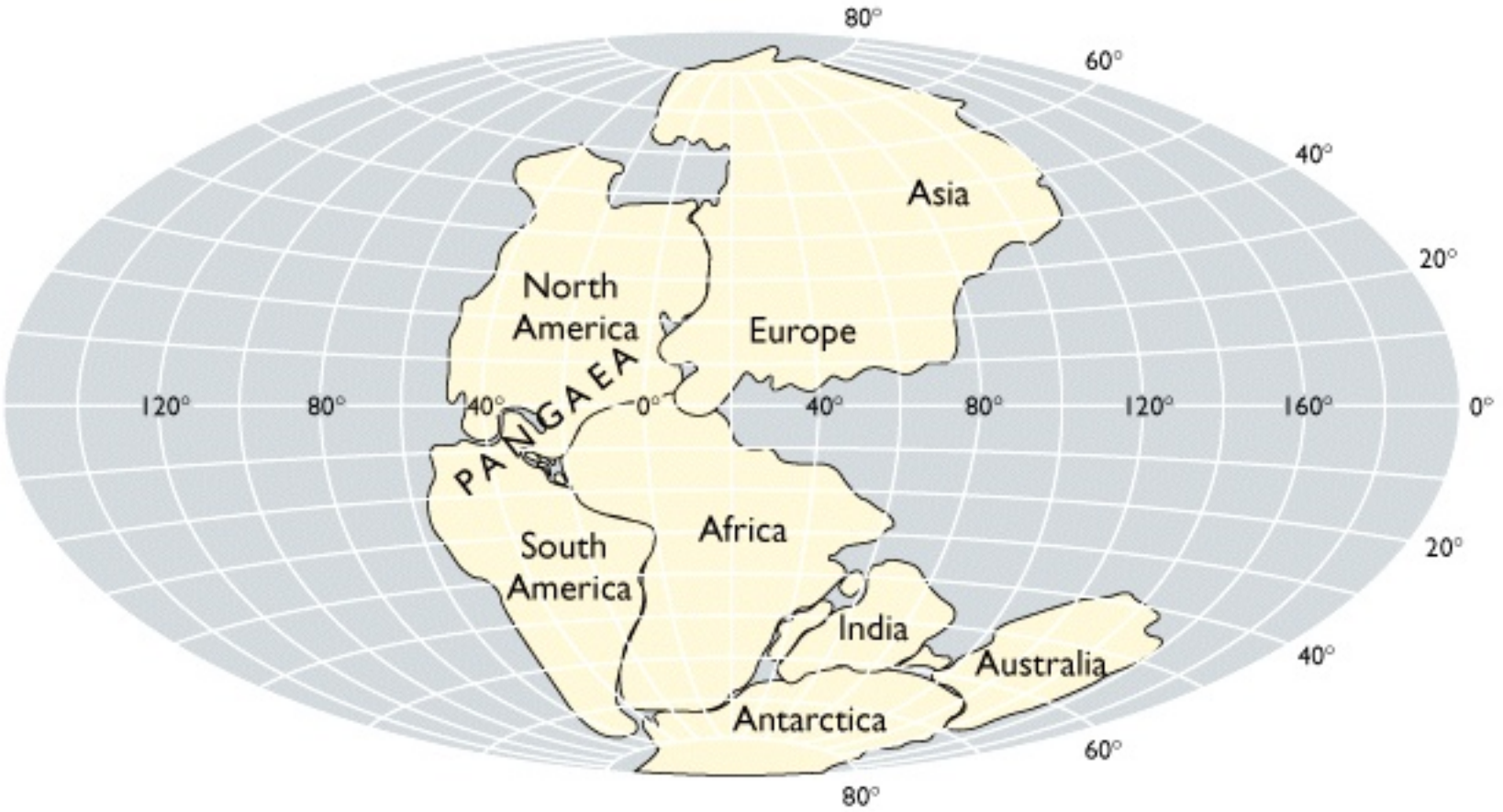






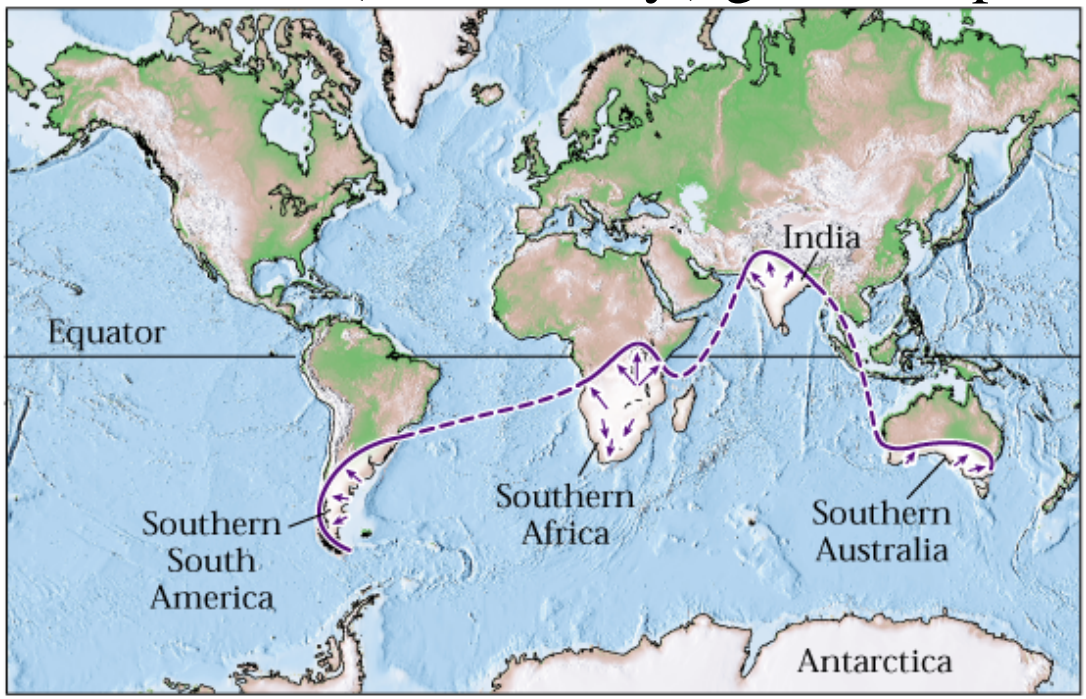


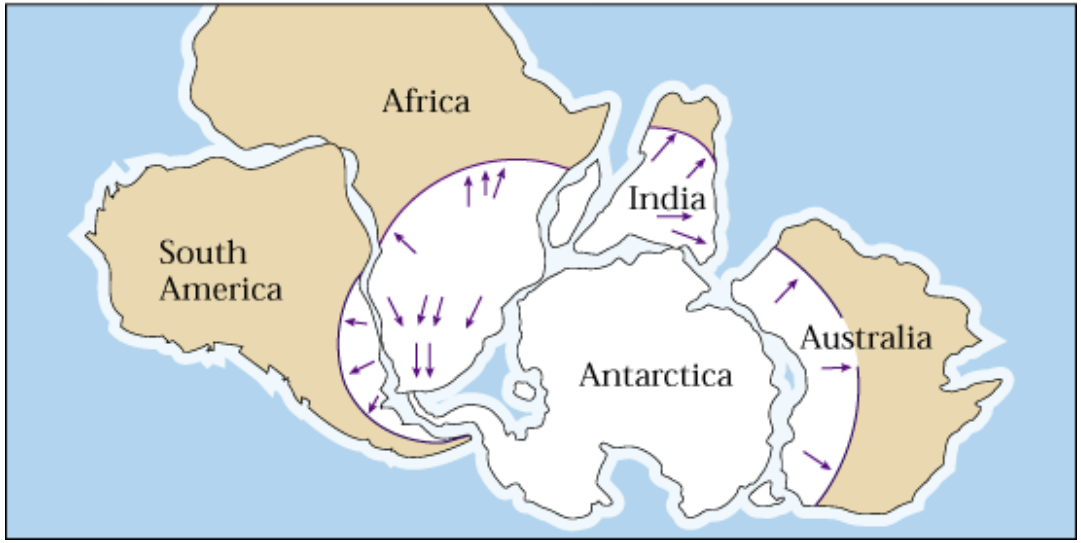
1. Fit of continents. Wegener proposed supercontinent Pangea existed during Mesozoic era (245-65 m.y. ago).



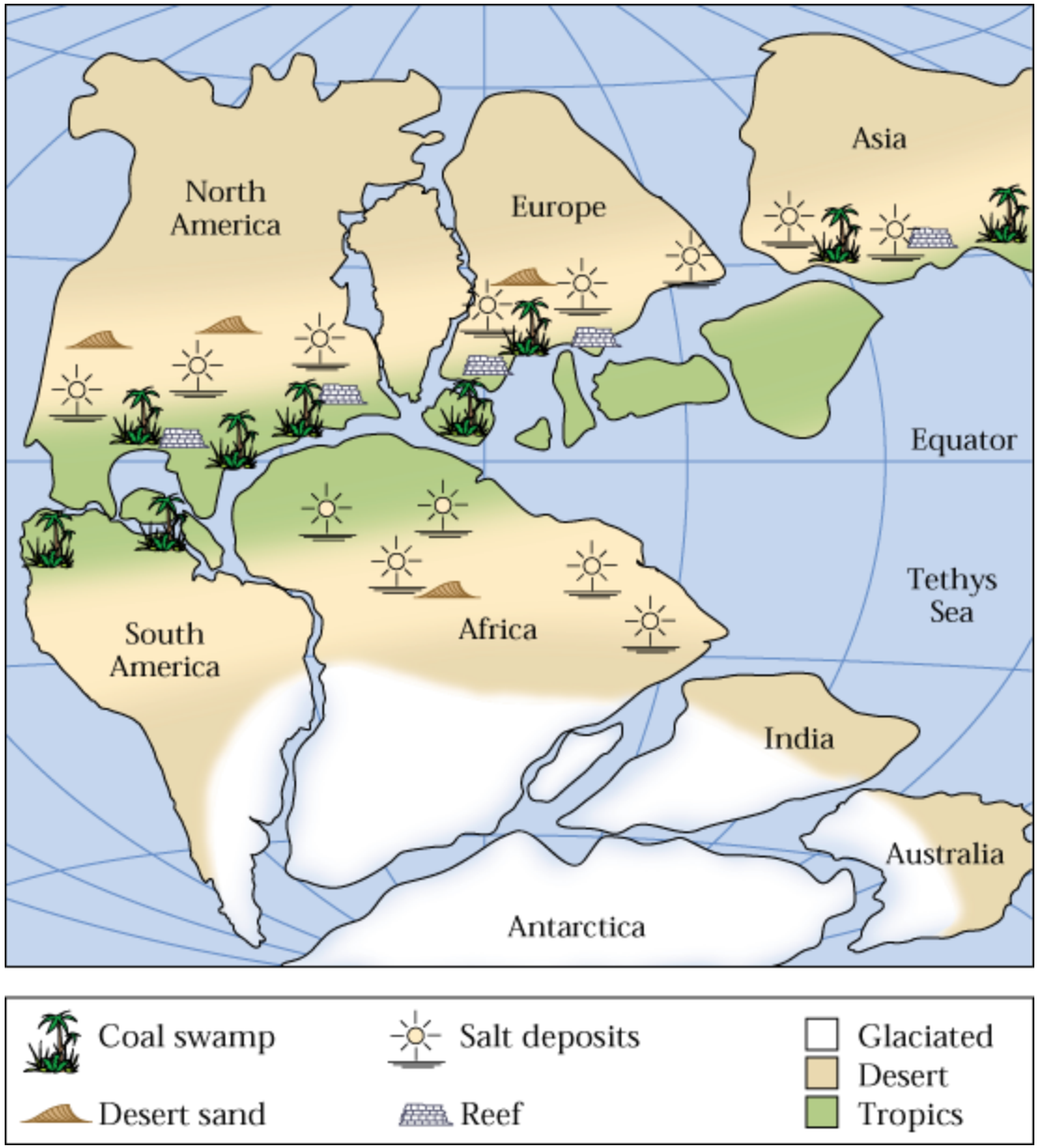
Pangea idea came from well-known fit of Atlantic coastlines

Late Paleozoic (260-280 my.) glacial deposits

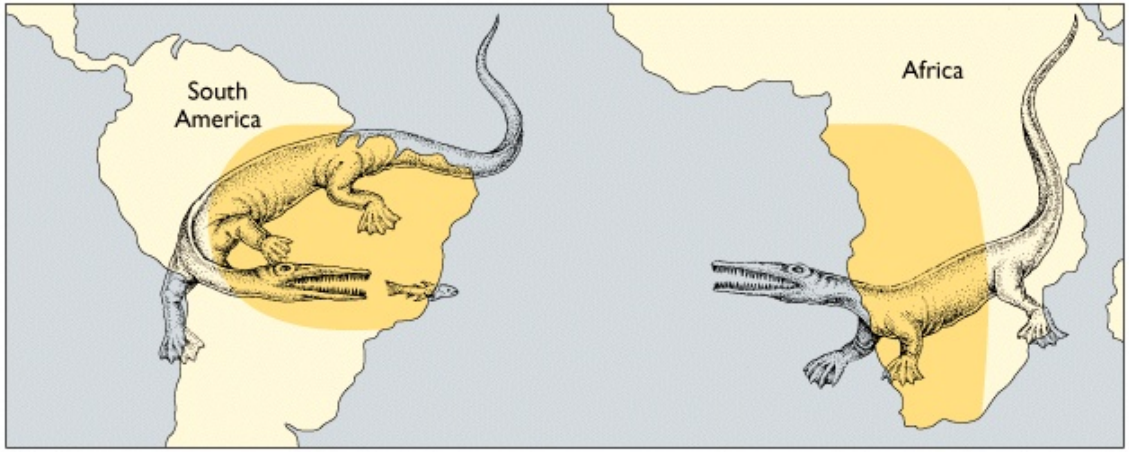




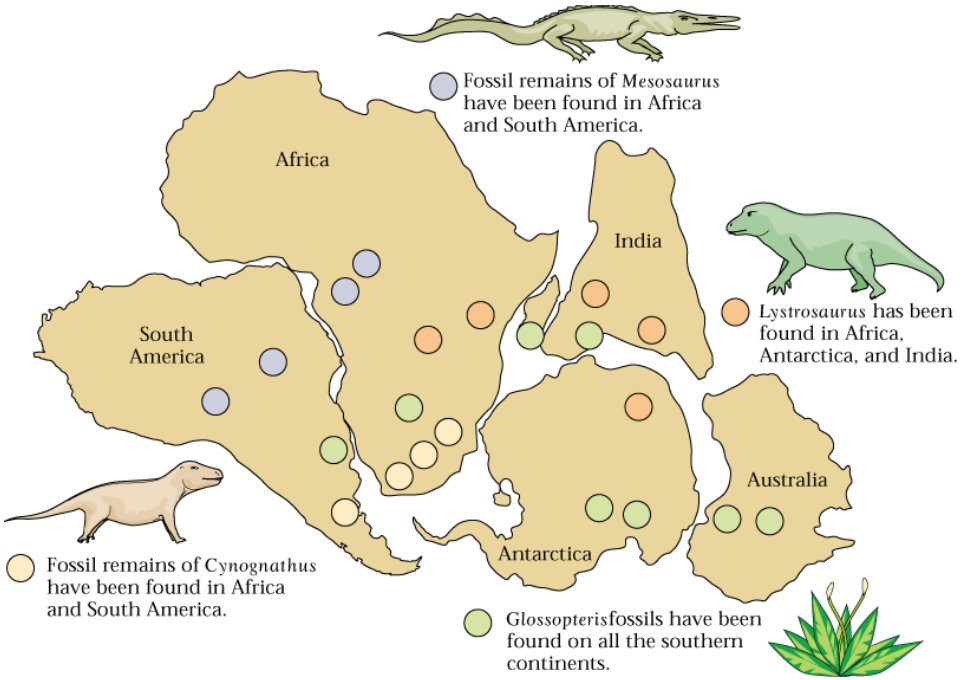
3. Distribution of Late Paleozoic tropical and subtropical deposits



4. Distribution of fossils

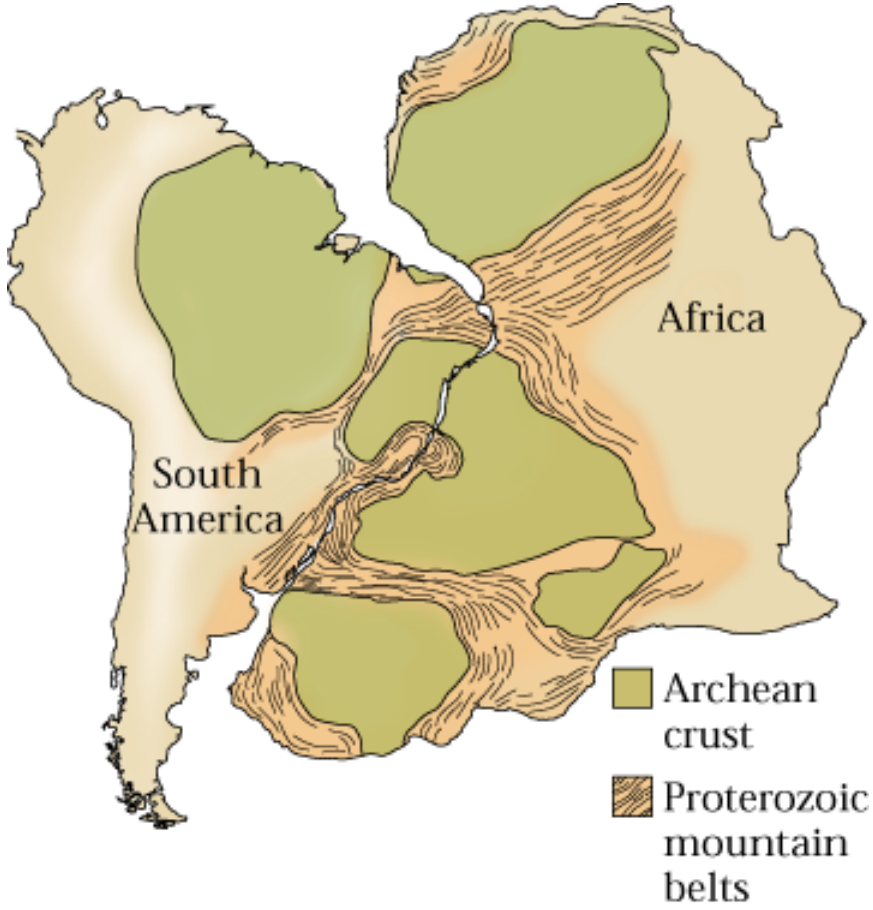


Mesosaurus fossils are found only in S. America and Africa. If *Mesosaurus* could swim across the Atlantic, it should have crossed other oceans and should be found more widely.



Lystrosaurus was a mammal-like reptile that ate plants and traveled in herds.

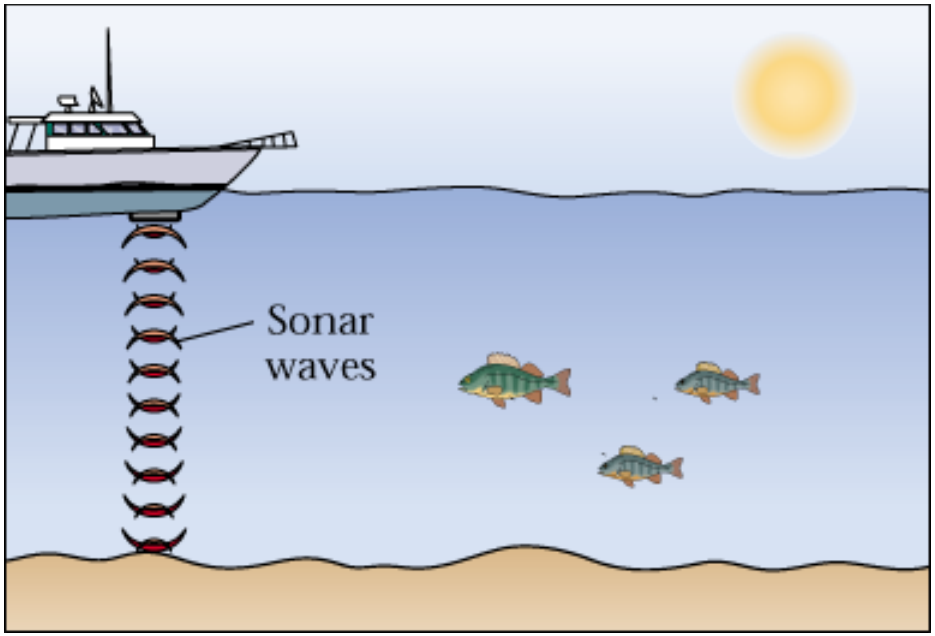
5. Matching geology: old crust and mountain belts

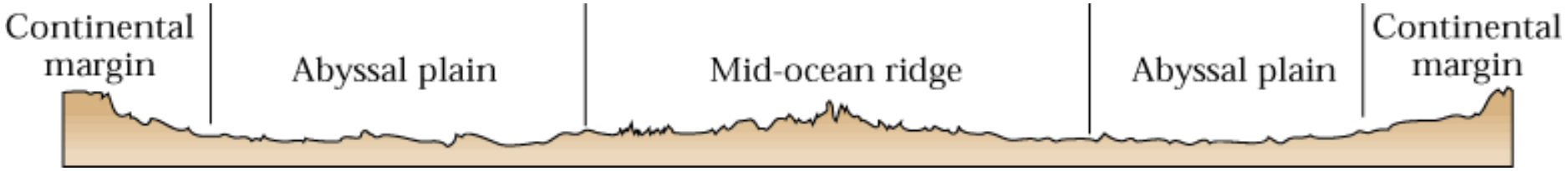


Criticism of continental drift

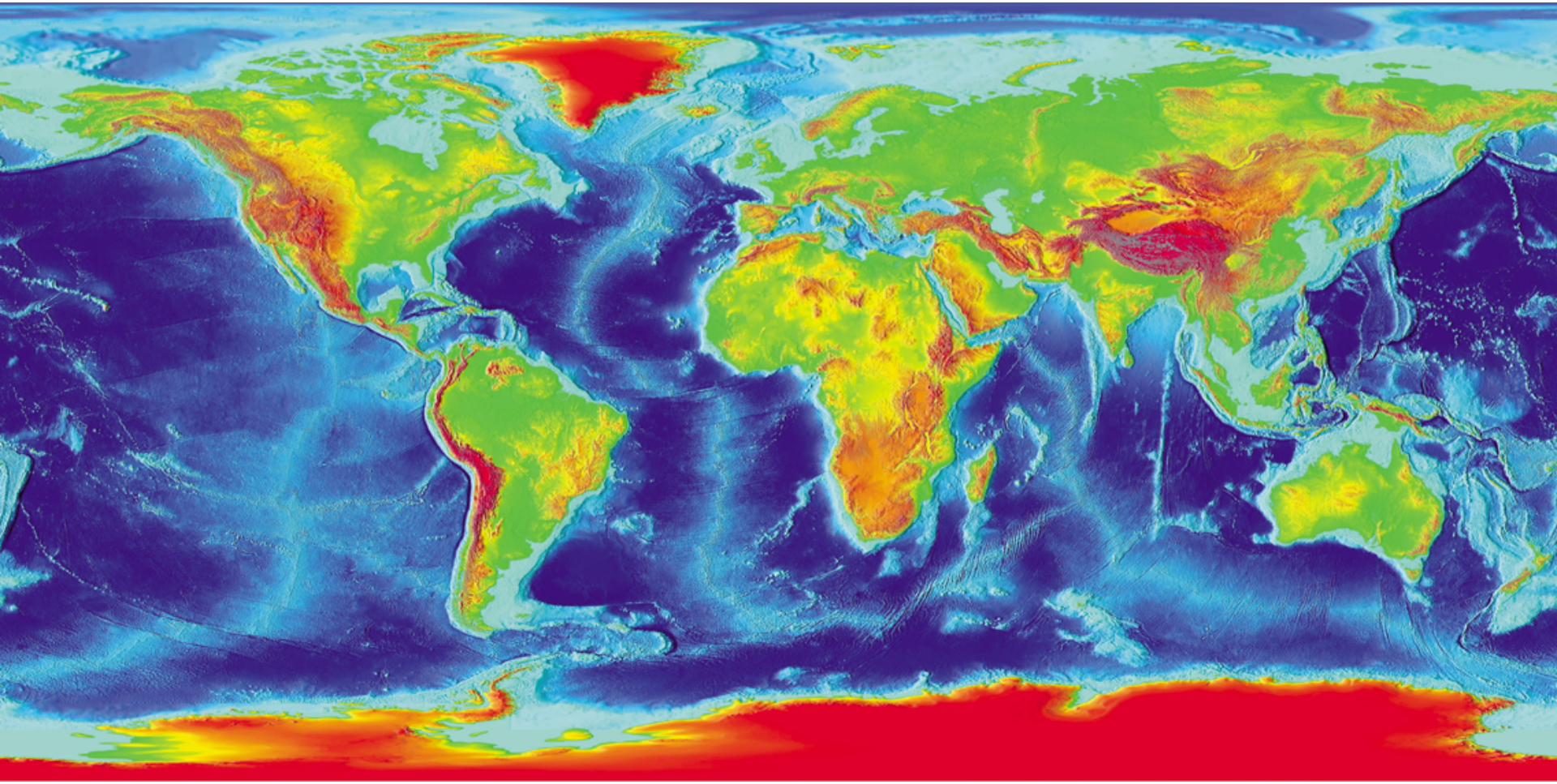
- What is **proof** that continents have moved?
- What was the **mechanism** that moved continents?
  - Centrifugal force?
  - Convective flow of the mantle?

Evidence from the seafloor
(prior to WWII very poorly known)



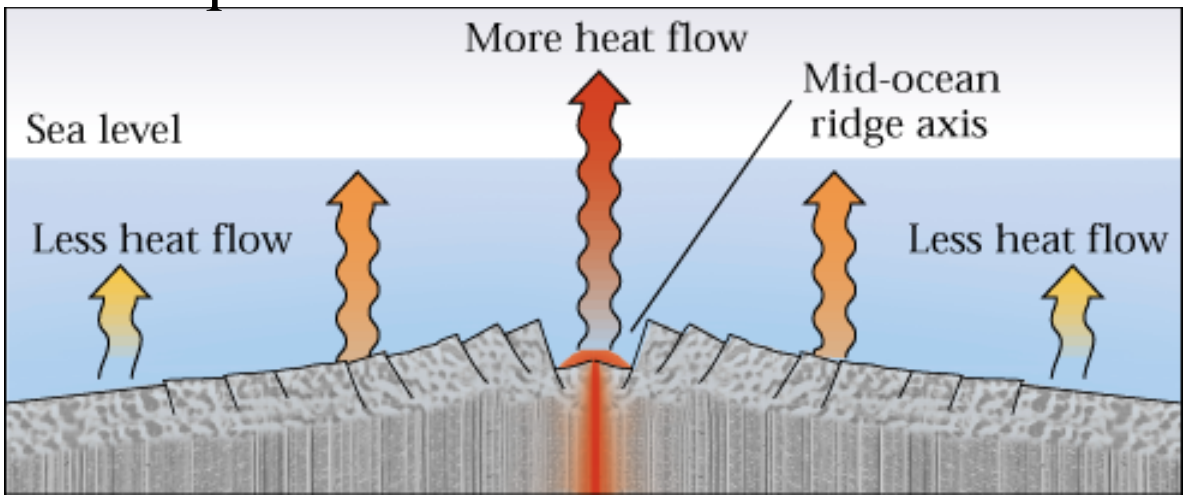


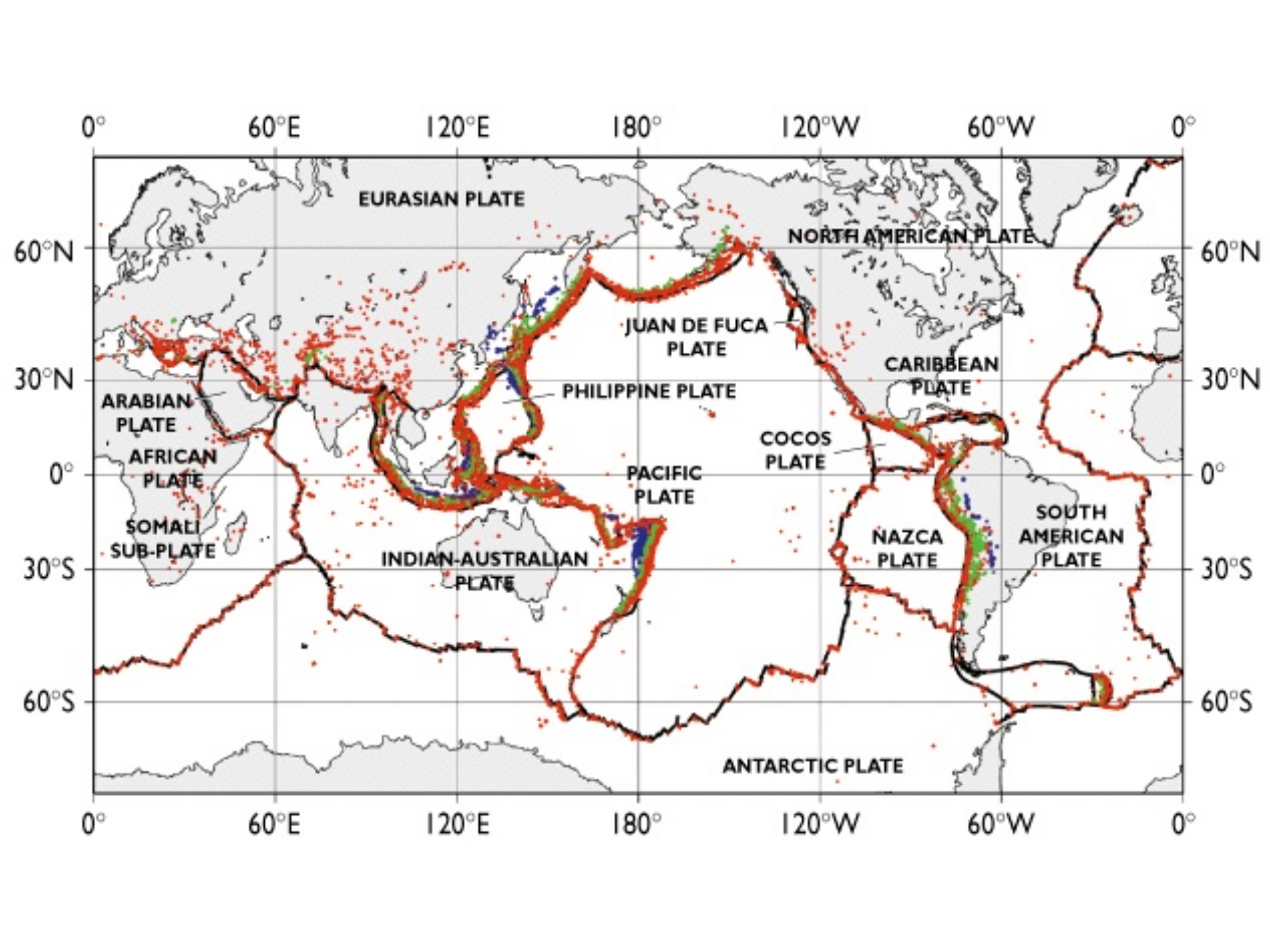
Seafloor has abyssal plains, mid-ocean ridges, trenches, seamounts, volcanoes, and fracture zones.



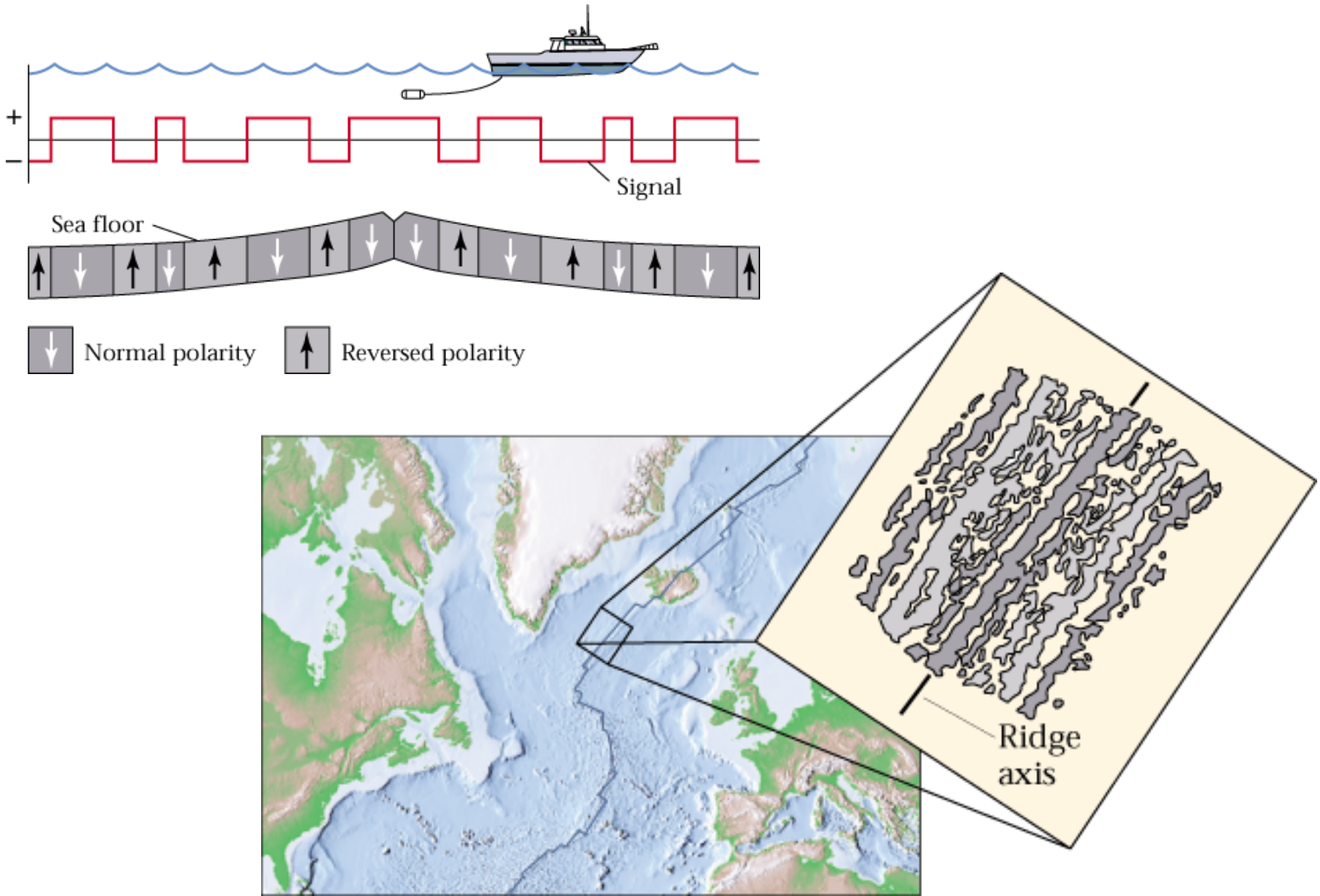
Characteristics of the seafloor:

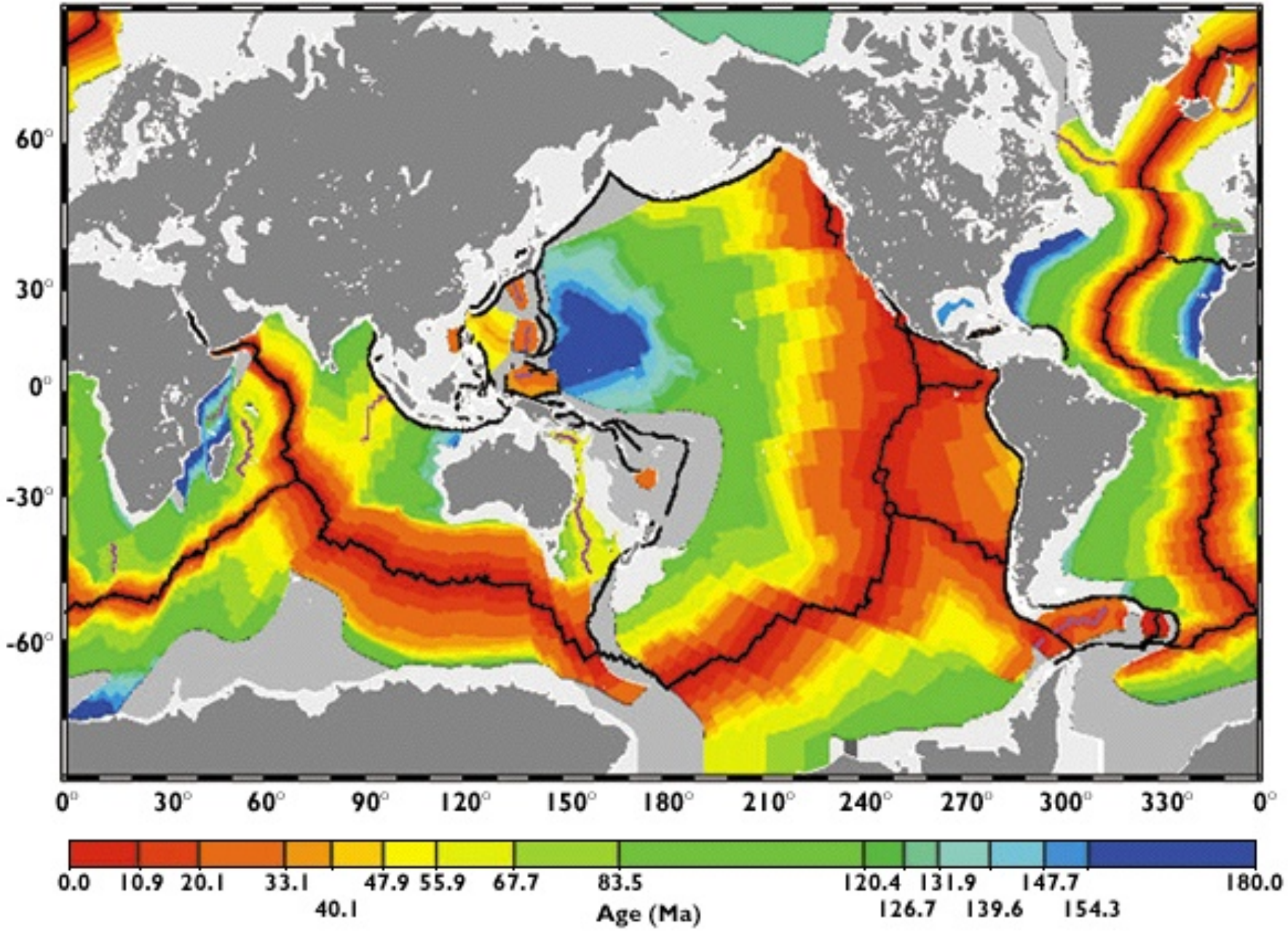
1. Sediment is absent at mid-ocean ridges, and gets thicker towards ocean margins
2. Ocean crust is made of basalt and gets deeper away from ridges
3. More heat rises beneath mid-ocean ridges than elsewhere
4. Earthquake locations are not random

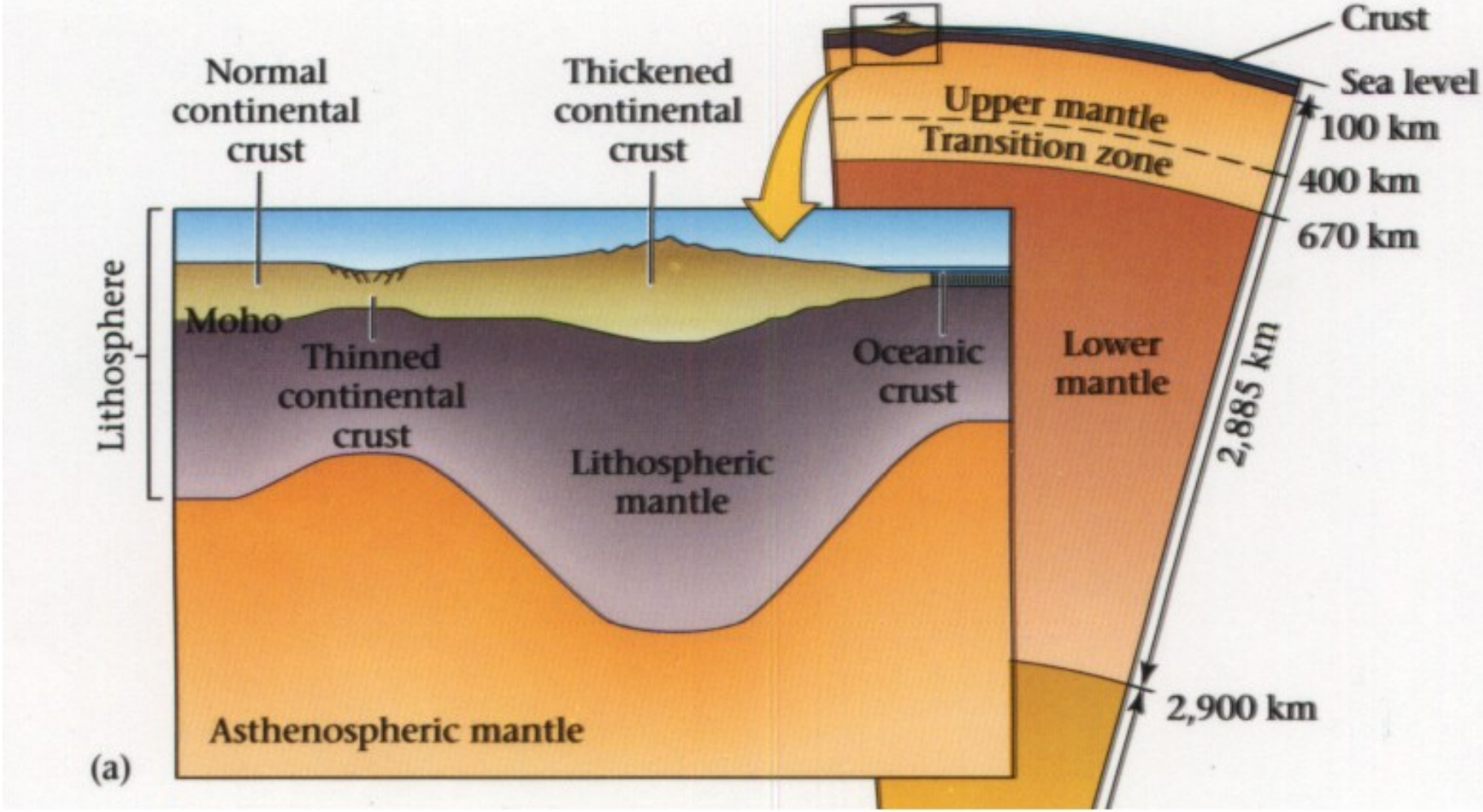



0°
60°E
120°E
180°
120°W
60°W
0°
60°N
30°N
0°
30°S
60°S
EURASIAN PLATE
NORTH AMERICAN PLATE
JUAN DE FUCA PLATE
CARIBBEAN PLATE
PHILIPPINE PLATE
ARABIAN PLATE
AFRICAN PLATE
COCOS PLATE
PACIFIC PLATE
SOMALI SUB-PLATE
INDIAN-AUSTRALIAN PLATE
NAZCA PLATE
SOUTH AMERICAN PLATE
ANTARCTIC PLATE

Magnetic anomalies on the seafloor run parallel to mid-ocean ridges.




60°
30°
0°
-30°
-60°
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
0°
0.0
10.9
20.1
33.1
40.1
47.9
55.9
67.7
83.5
120.4
126.7
131.9
139.6
147.7
154.3
180.0
Age (Ma)



2 ways of defining layers:

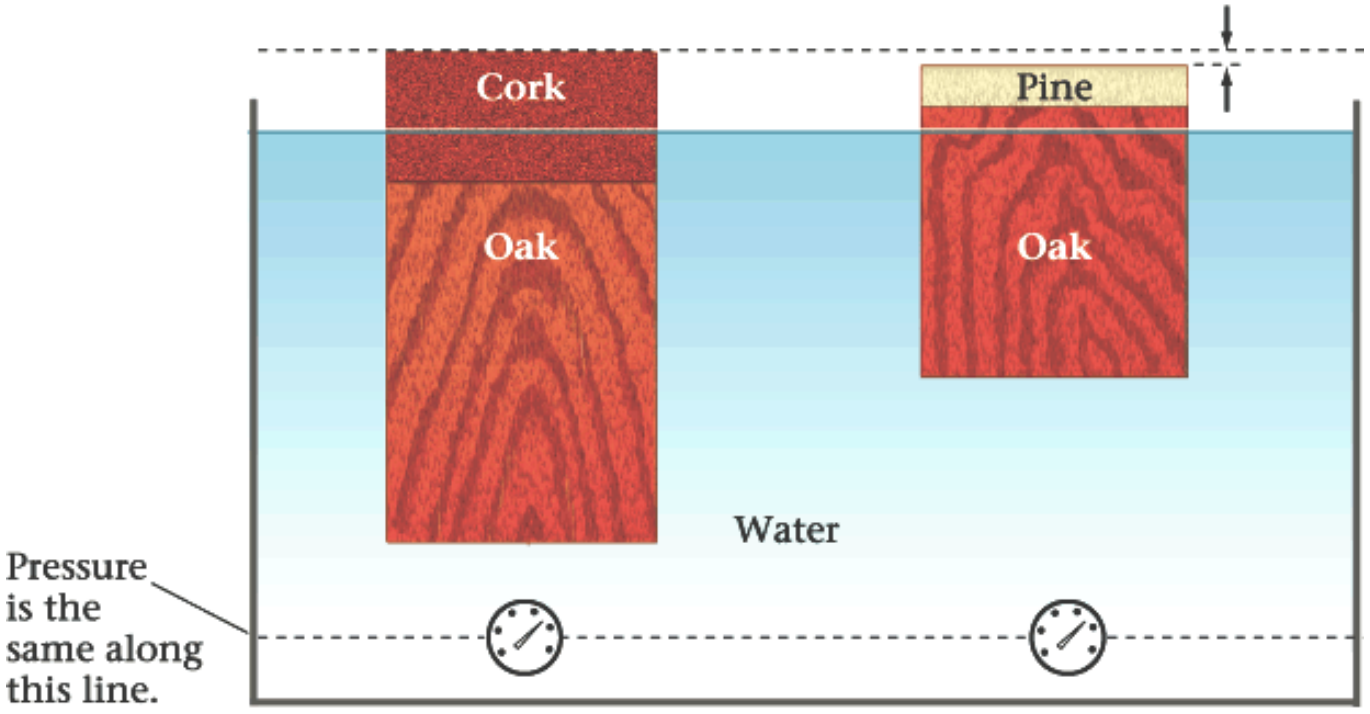
1. By seismic velocity

crust, mantle, core

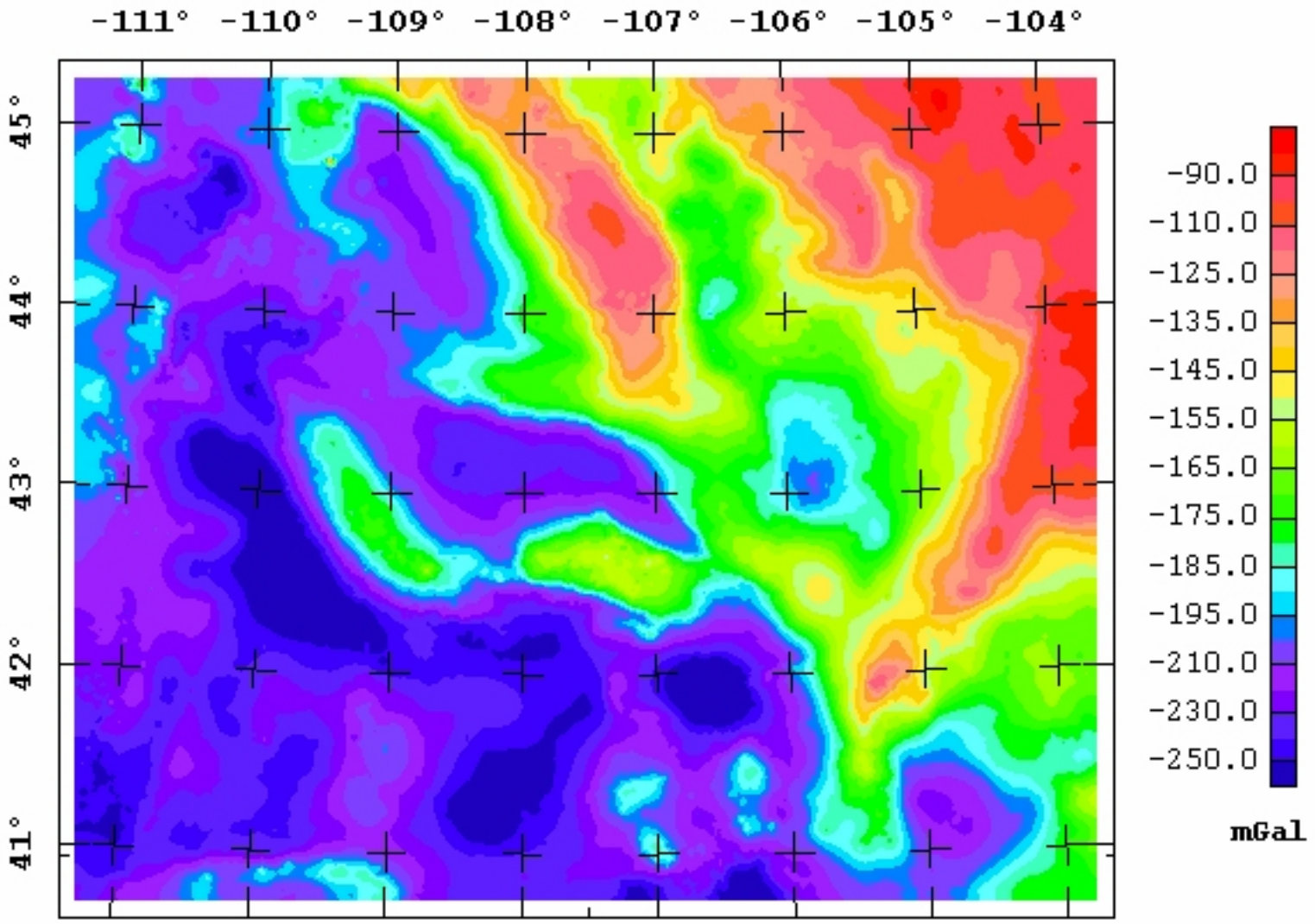
2. By flow characteristics

Plates: *lithosphere, asthenosphere*

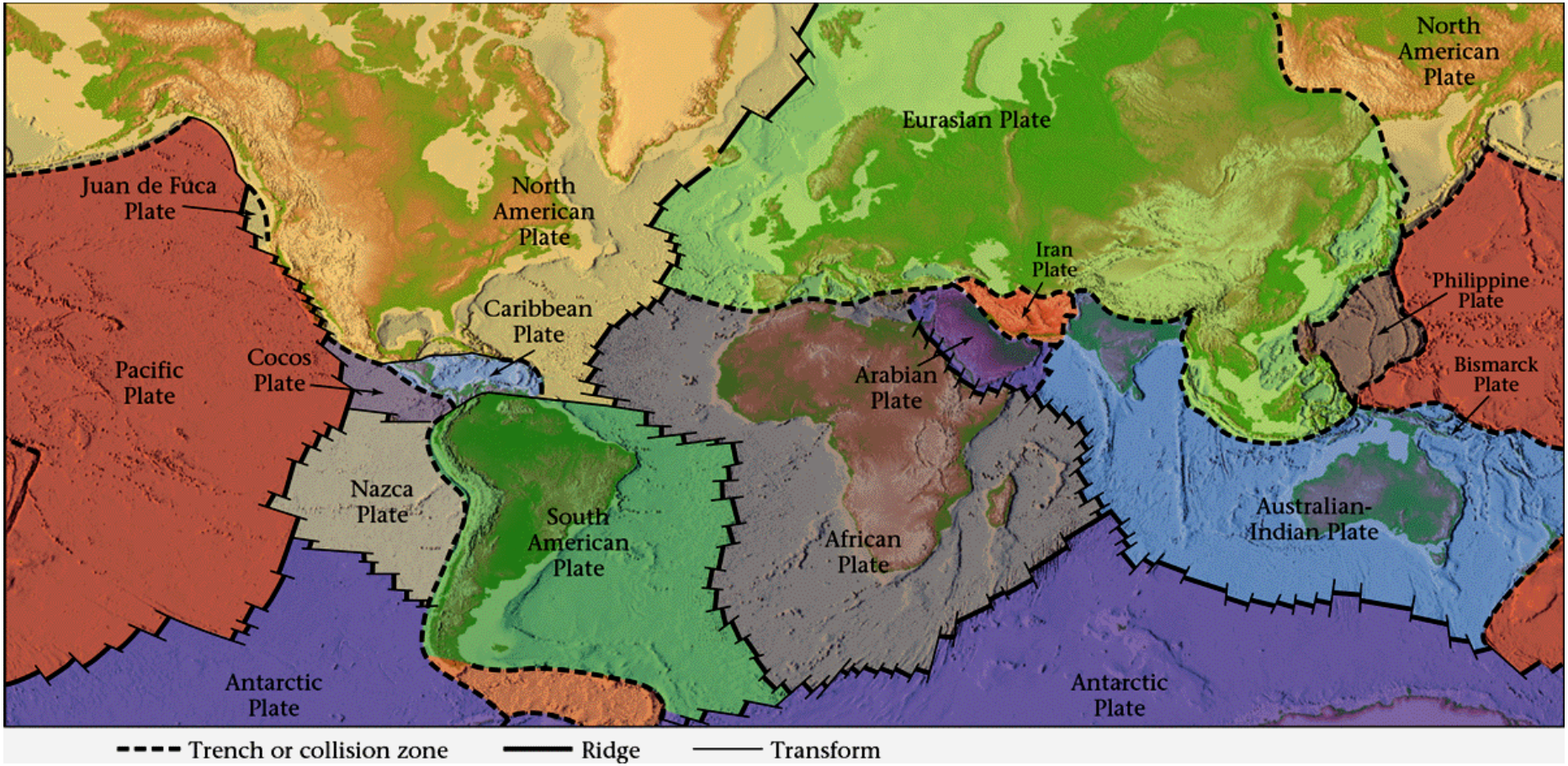
Plates are made of lithosphere, they float on asthenosphere.
Continental lithosphere is thicker but less dense than
oceanic lithosphere.
Continents thus are topographically higher than oceans.



Information from gravity



All other things equal, Bouguer gravity maps crustal thickness variations.So the SW 'half' of the state has thicker crust (lower Bouguer gravity) wrt to the NE 'half'. In general this is consistent with a decrease in regional elevation (with mountain ranges removed) towards the NE.

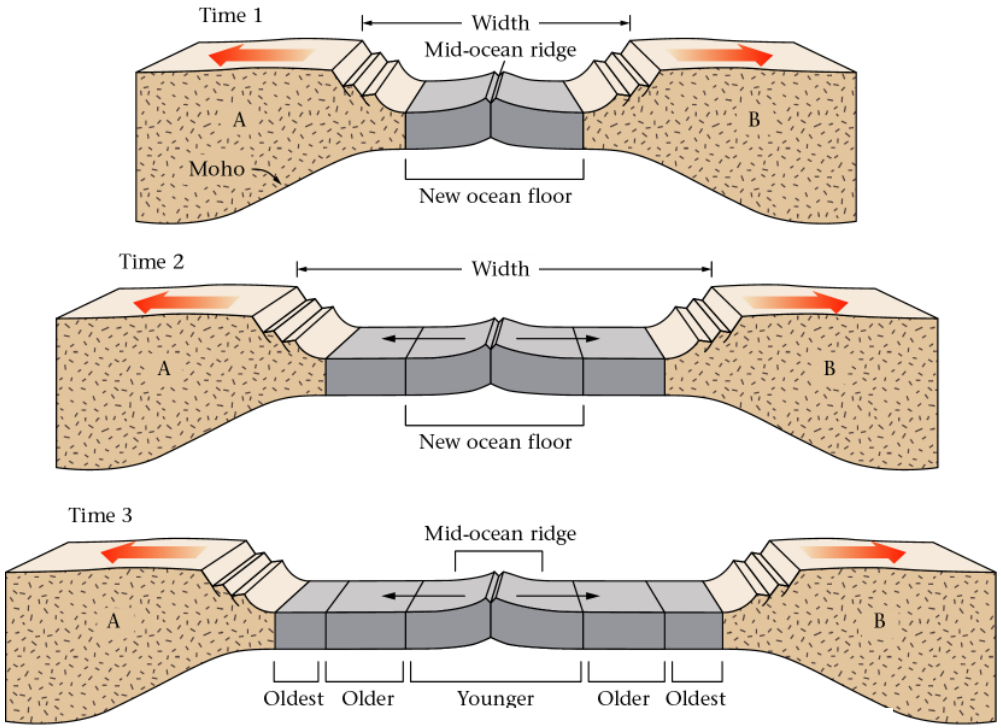


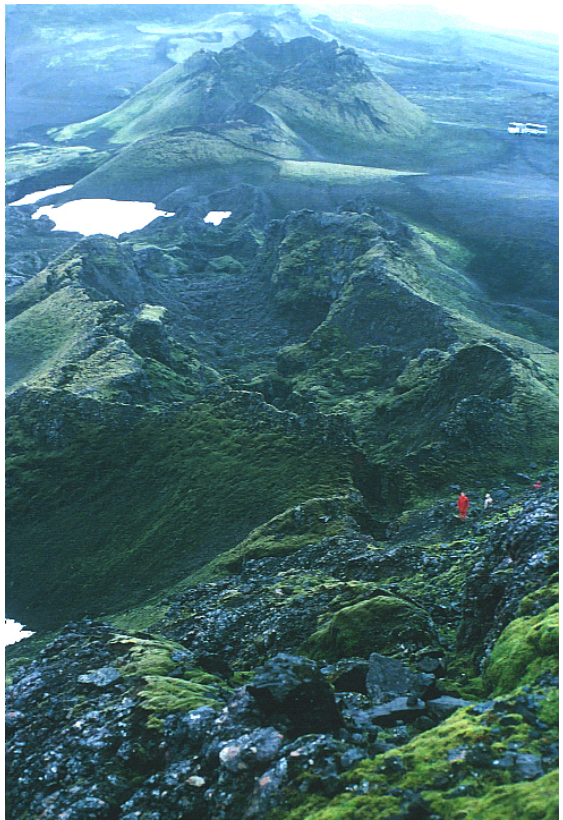
8 large plates, many smaller ones, some all oceanic, some not

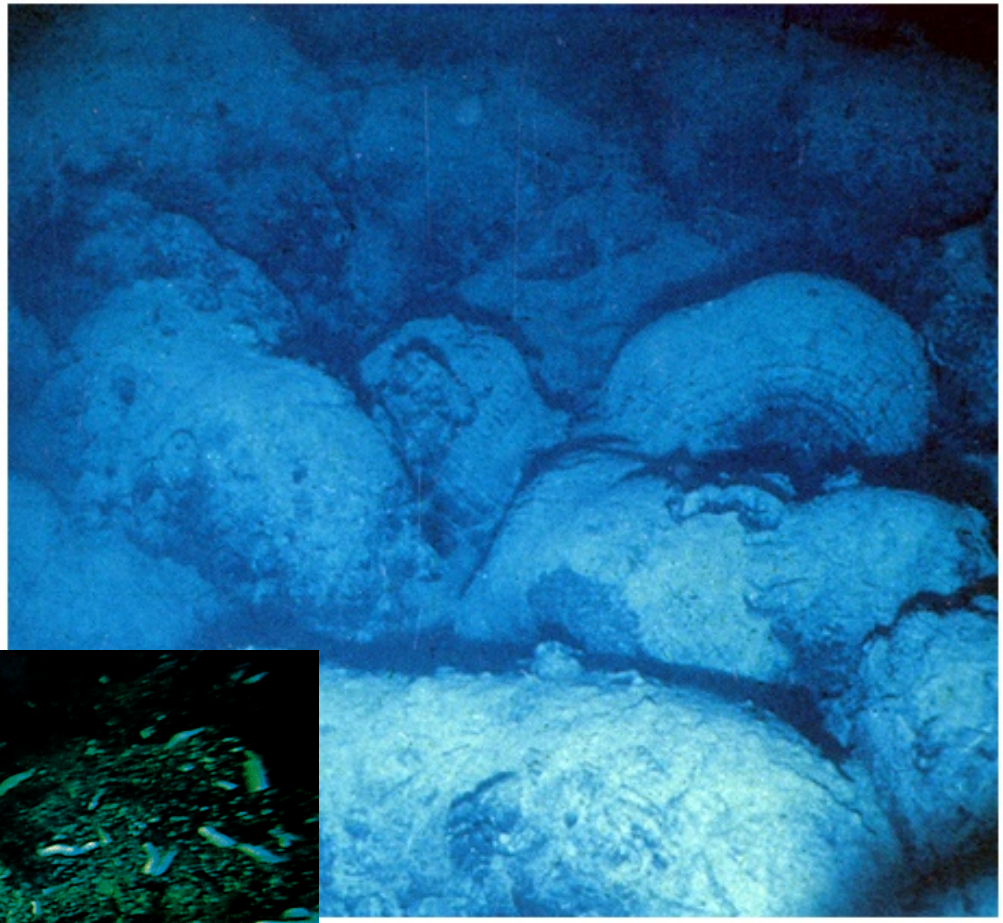
Plate boundaries at continental margins = active margins

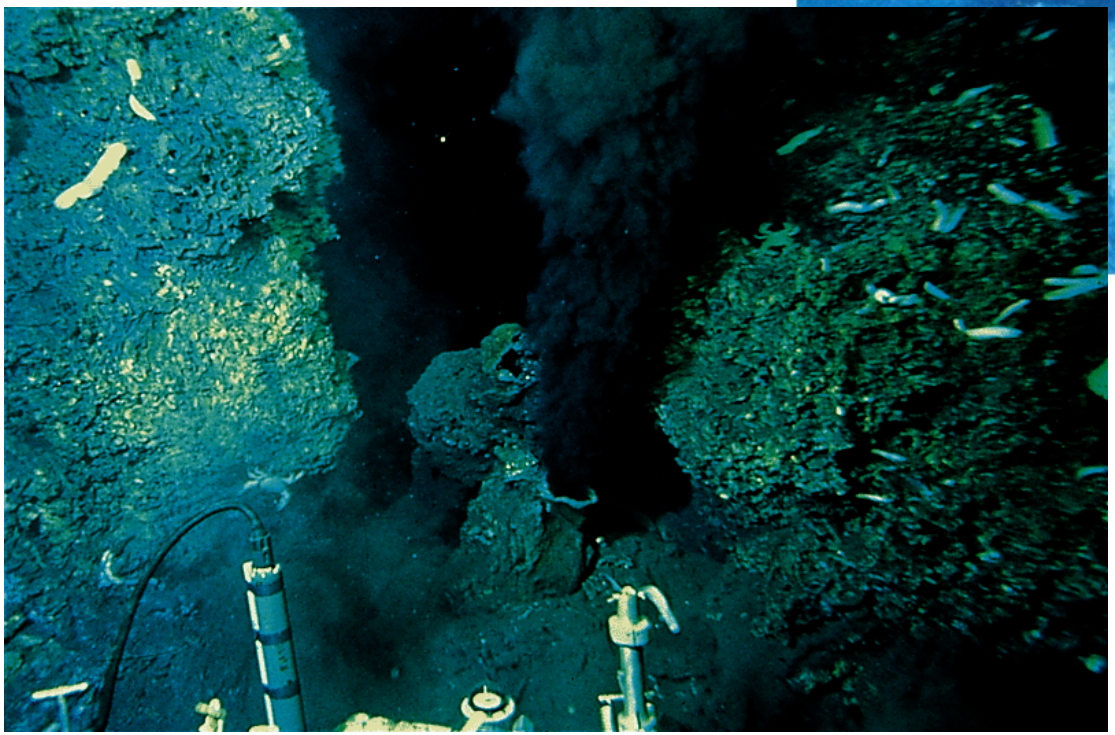
Continental margins not at plate boundaries = passive margins

1. Divergent, or spreading boundaries

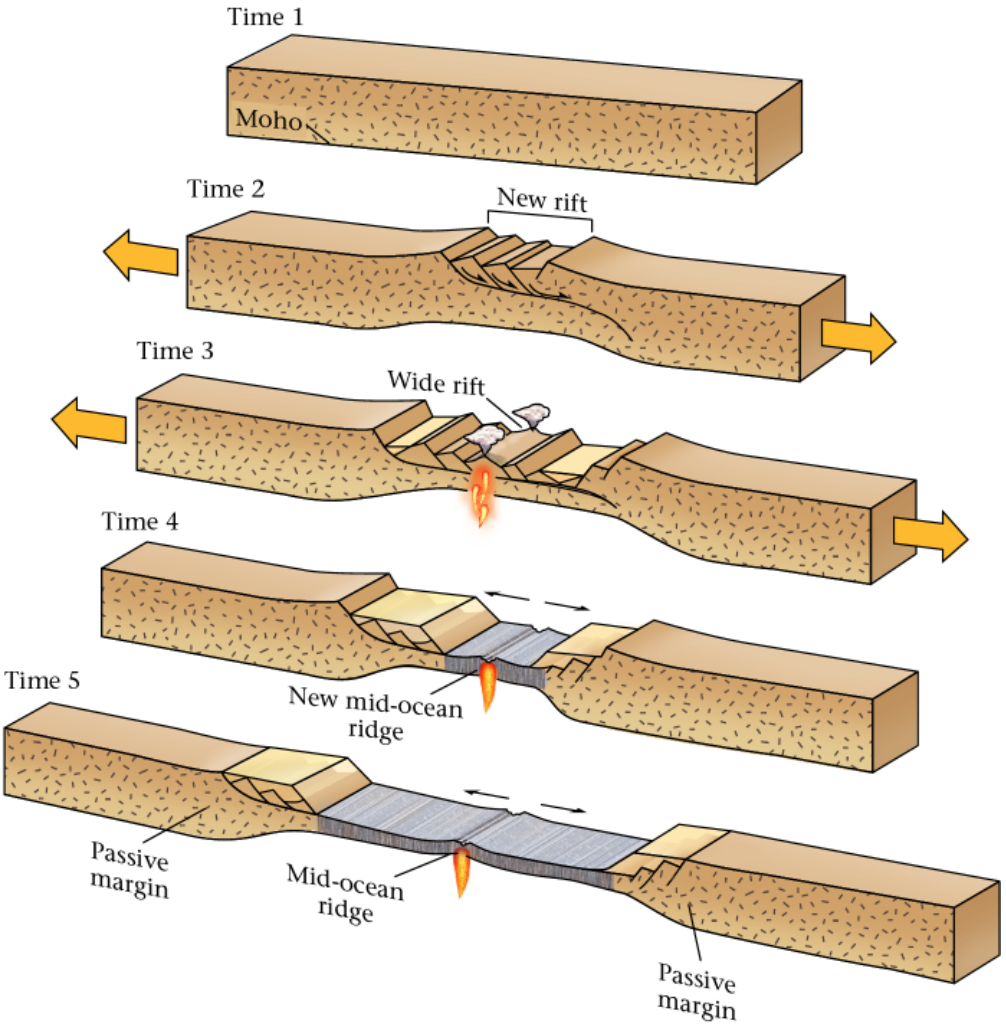


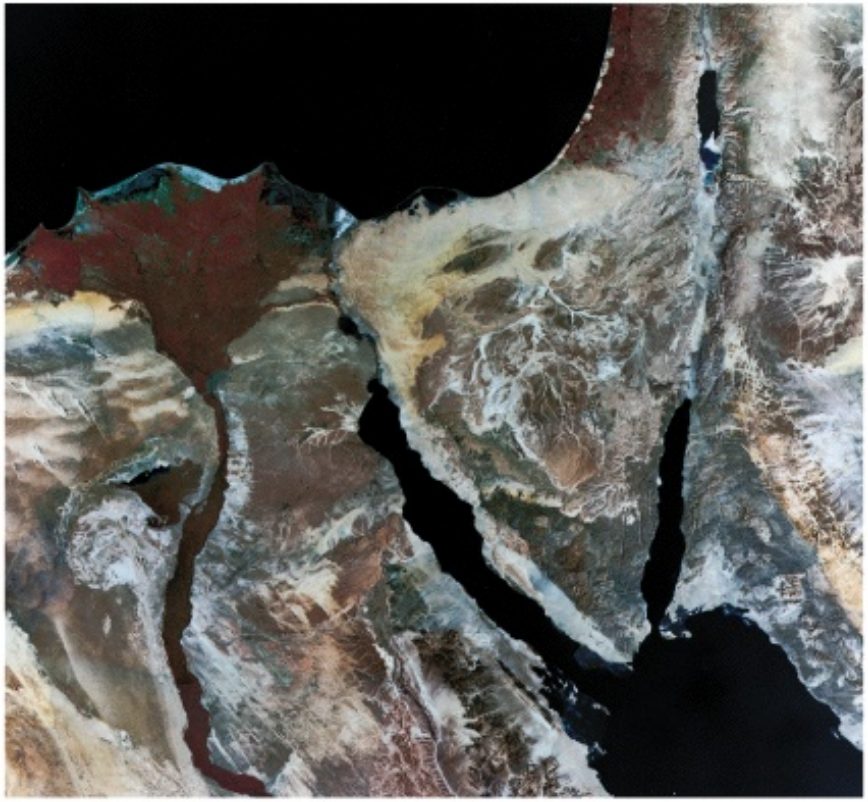






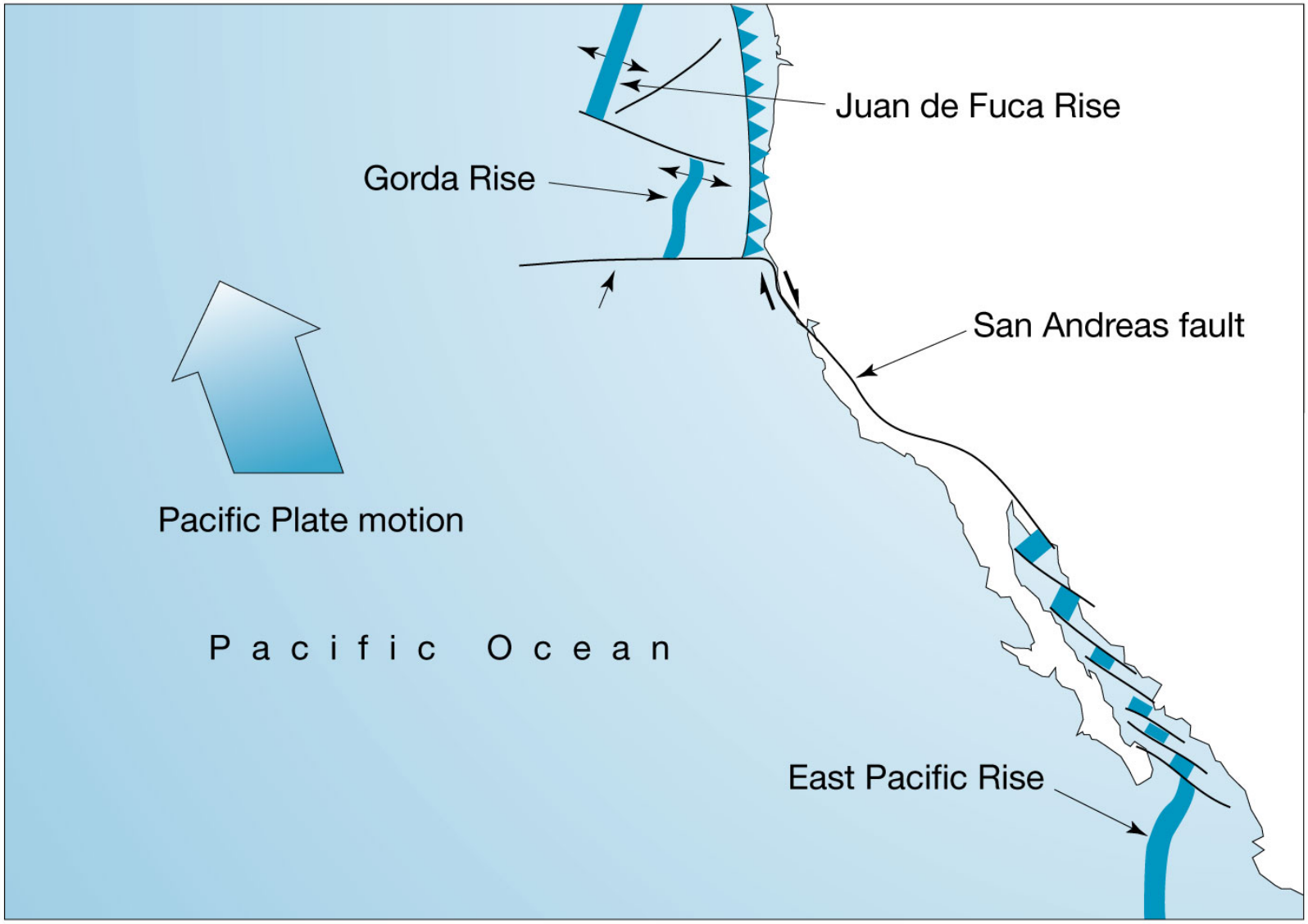
Continental rifts: birthplace of divergent margins



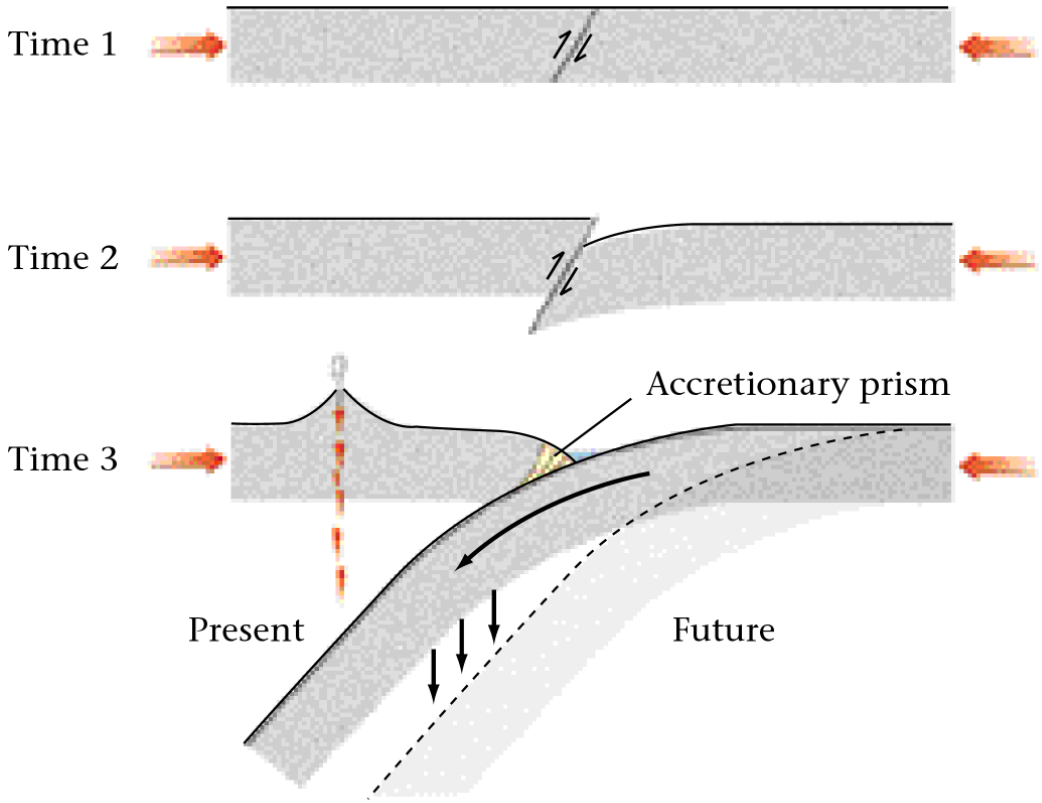


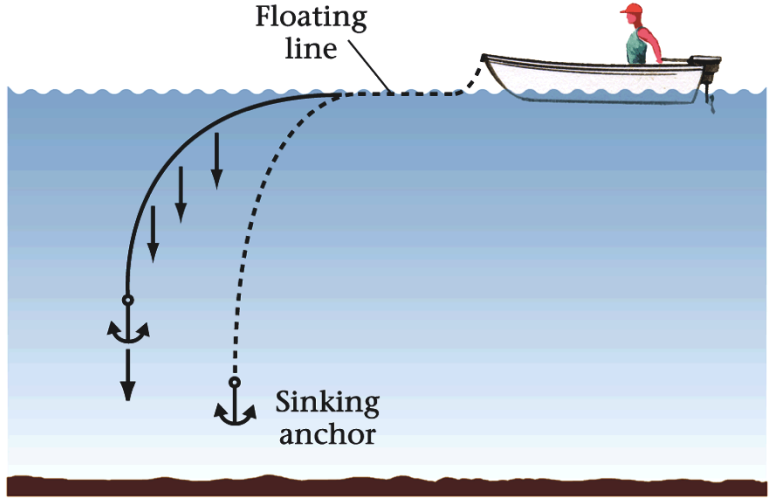
(a)

(b)



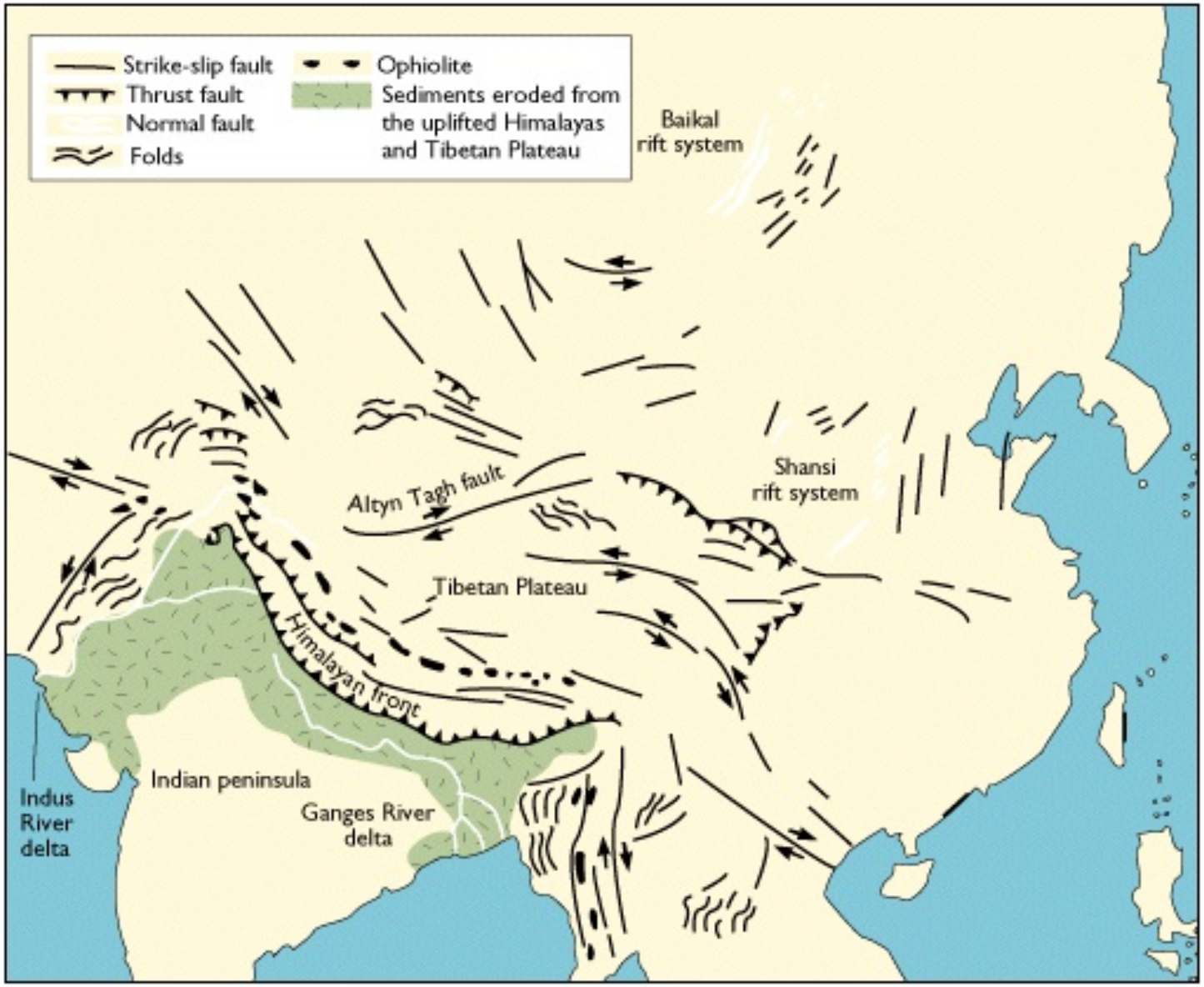
Convergence zones:





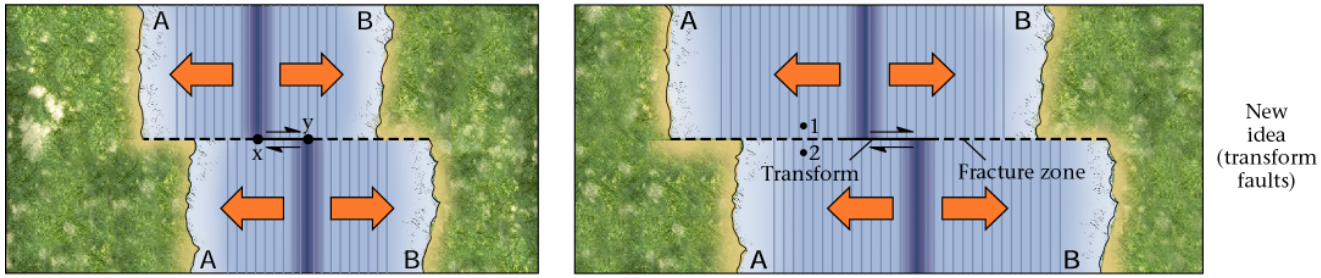
Continent-ocean collision: volcanic arc, accretionary prism, trench, EQ

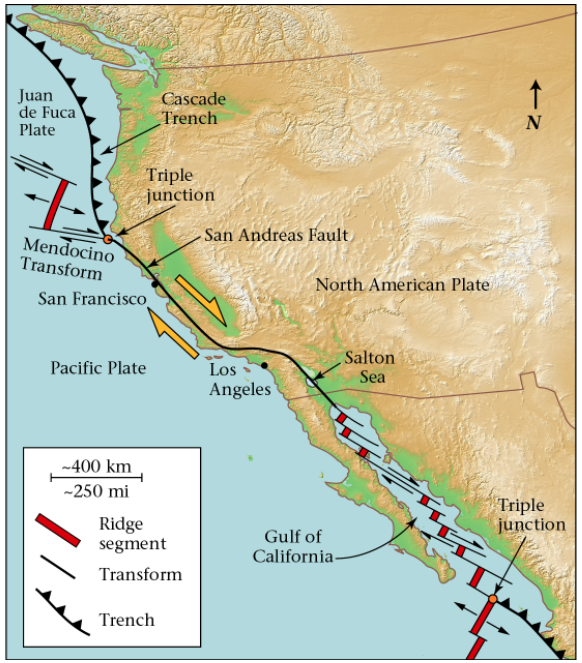
Continent-continent collision: crust is compressed, stacked, extruded because neither plate subducts easily. EQ

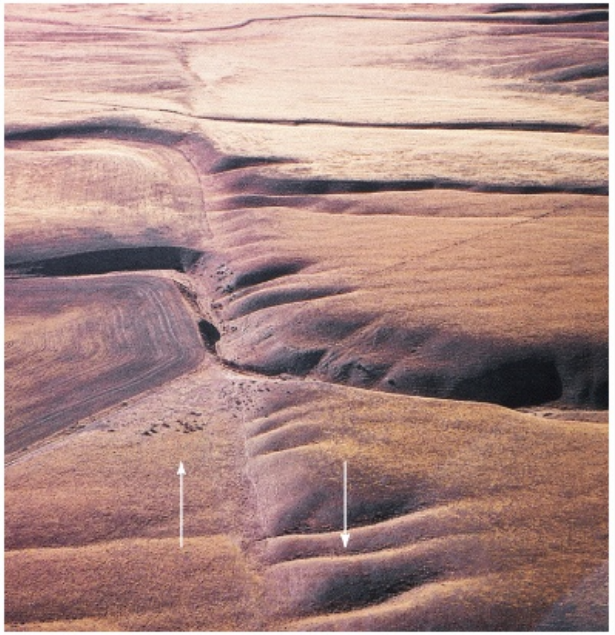


Transform plate boundaries: 2 plates slide past each other

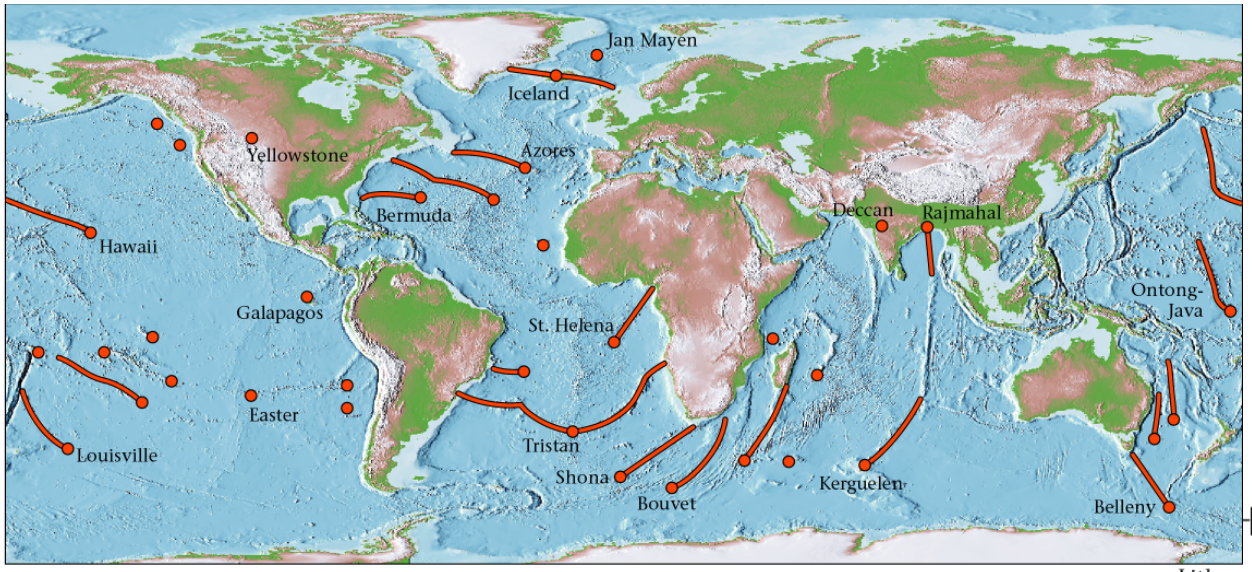
Transform fault lies between 2 ridge segments
Fracture zone beyond transform does not slip

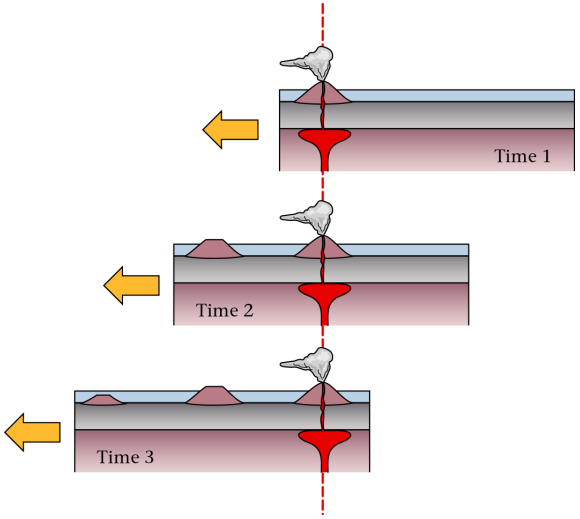


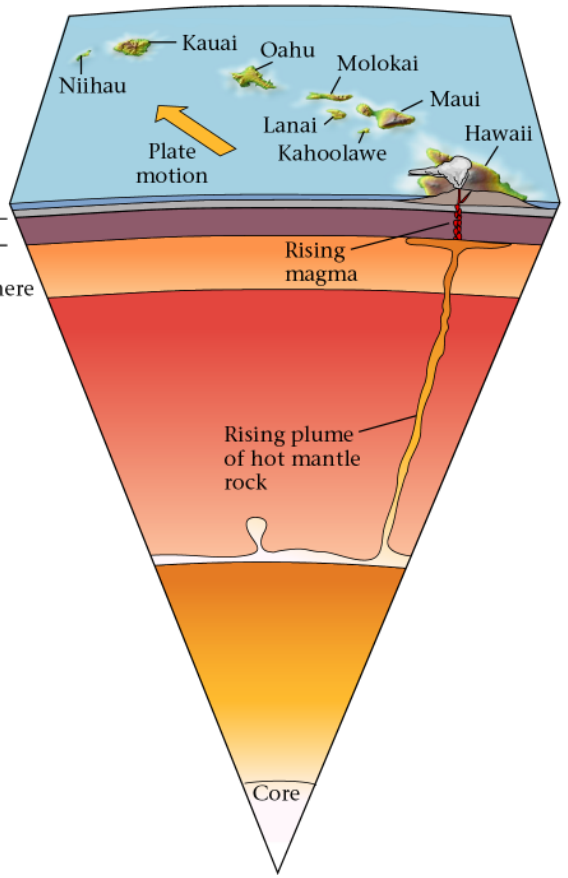


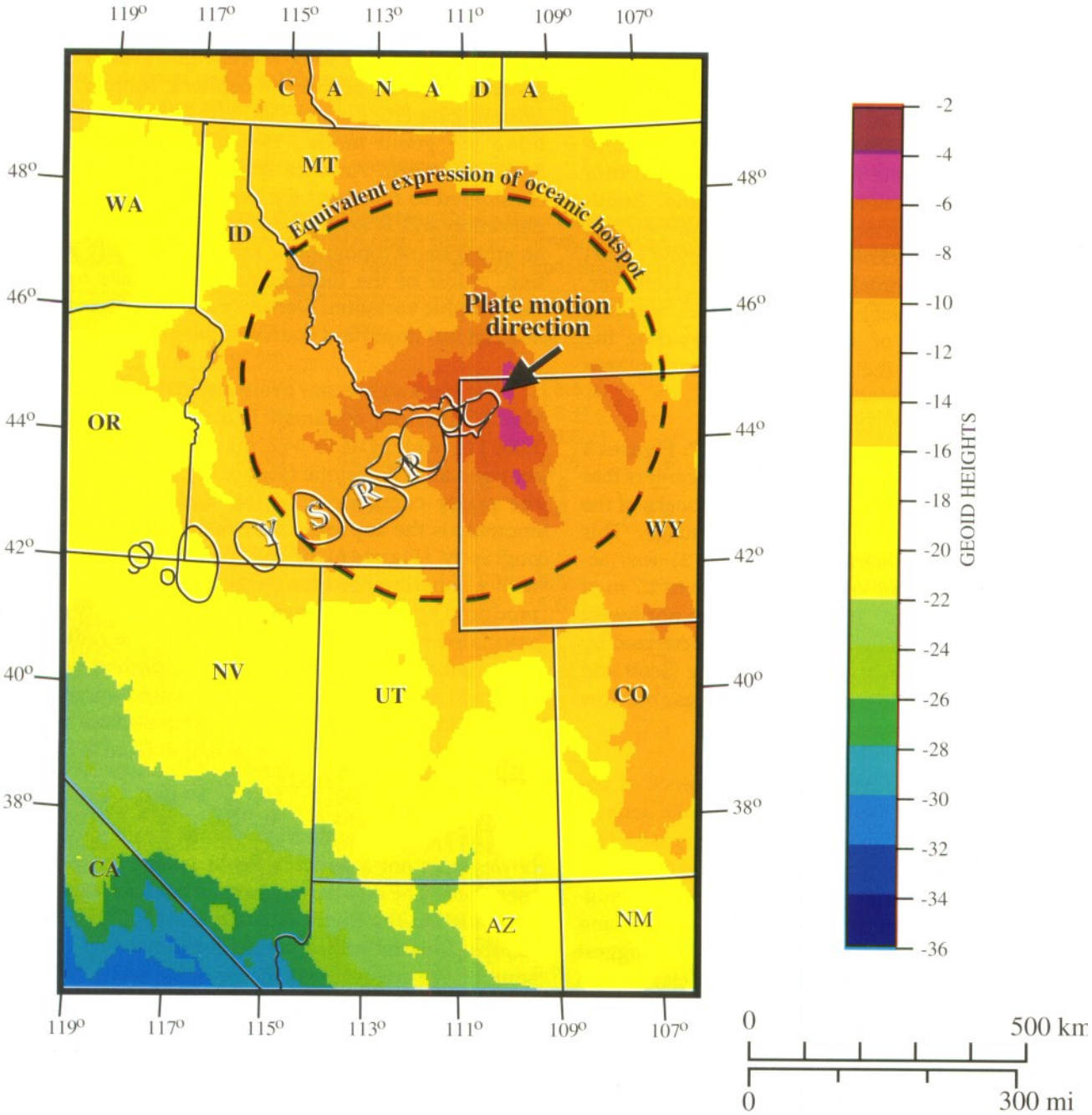


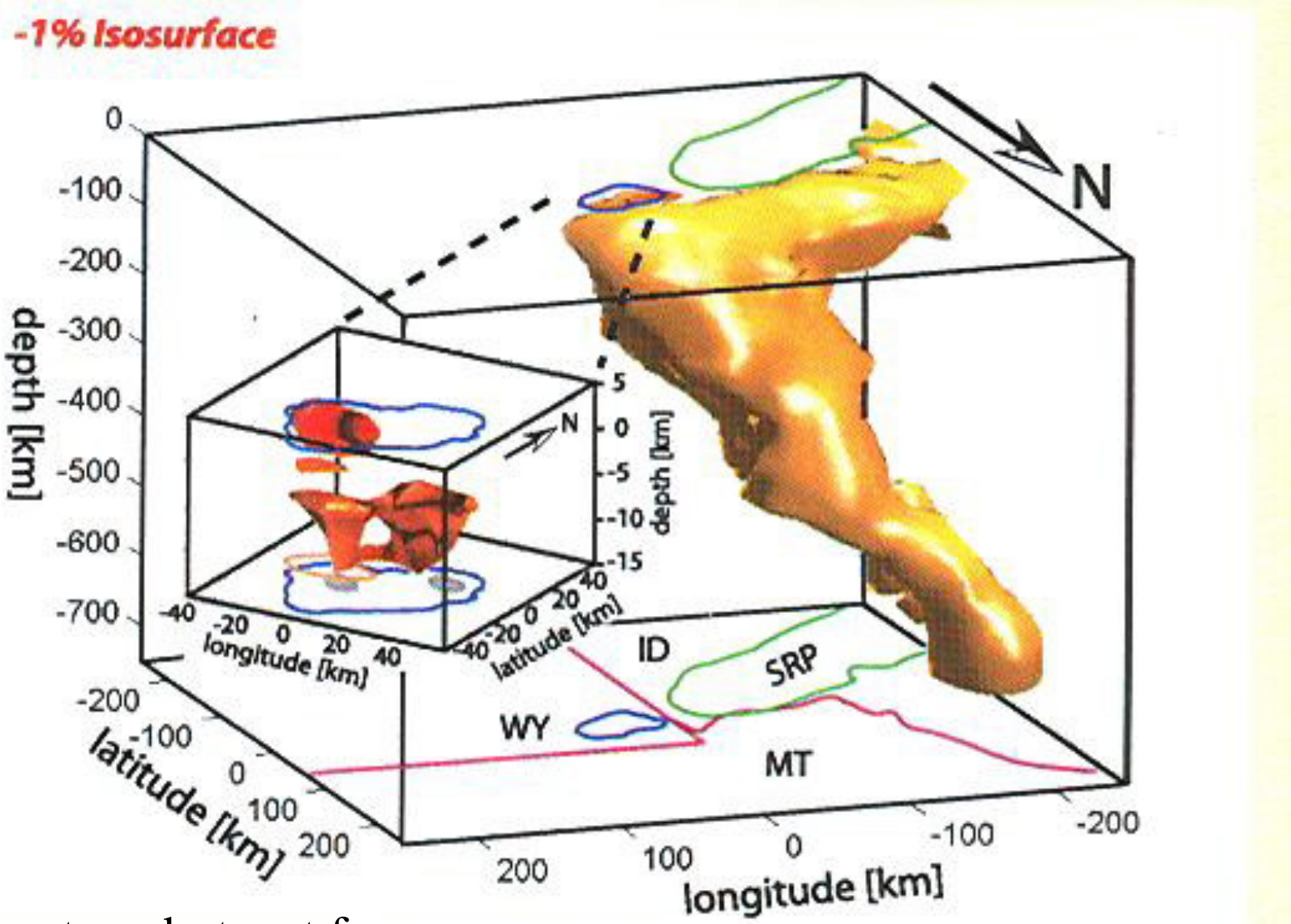
Hot spots: volcanoes NOT at plate boundaries





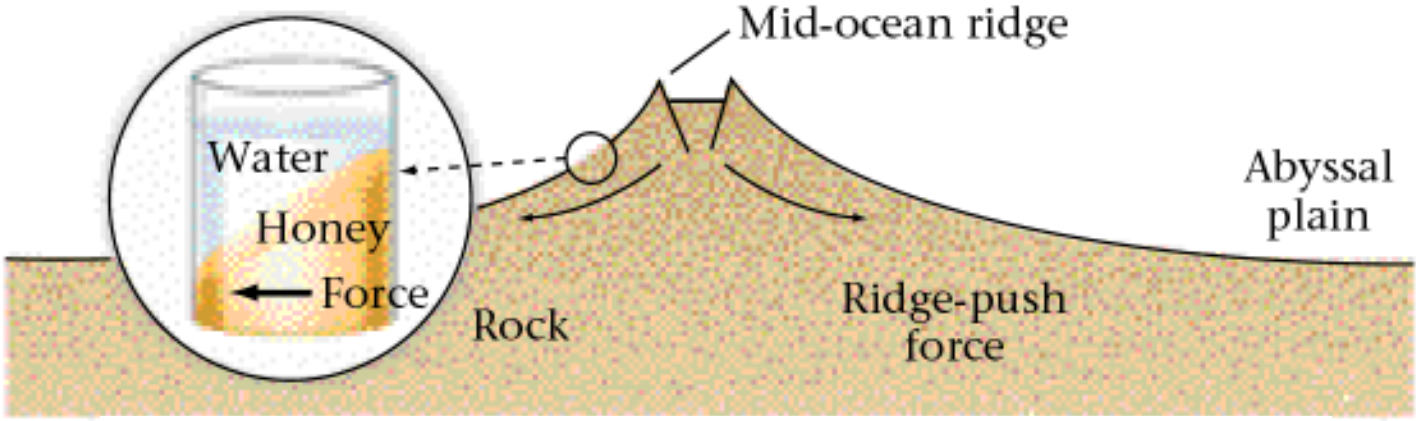



119°
117°
115°
113°
111°
109°
107°
48°
46°
44°
42°
40°
38°
C A N A D A
MT
WA
ID
OR
WY
NV
UT
CO
CA
AZ
NM
Equivalent expression of oceanic hotspot
Plate motion direction
Y S R R
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
-32
-34
-36
GEOID HEIGHTS
0
500 km
0
300 mi

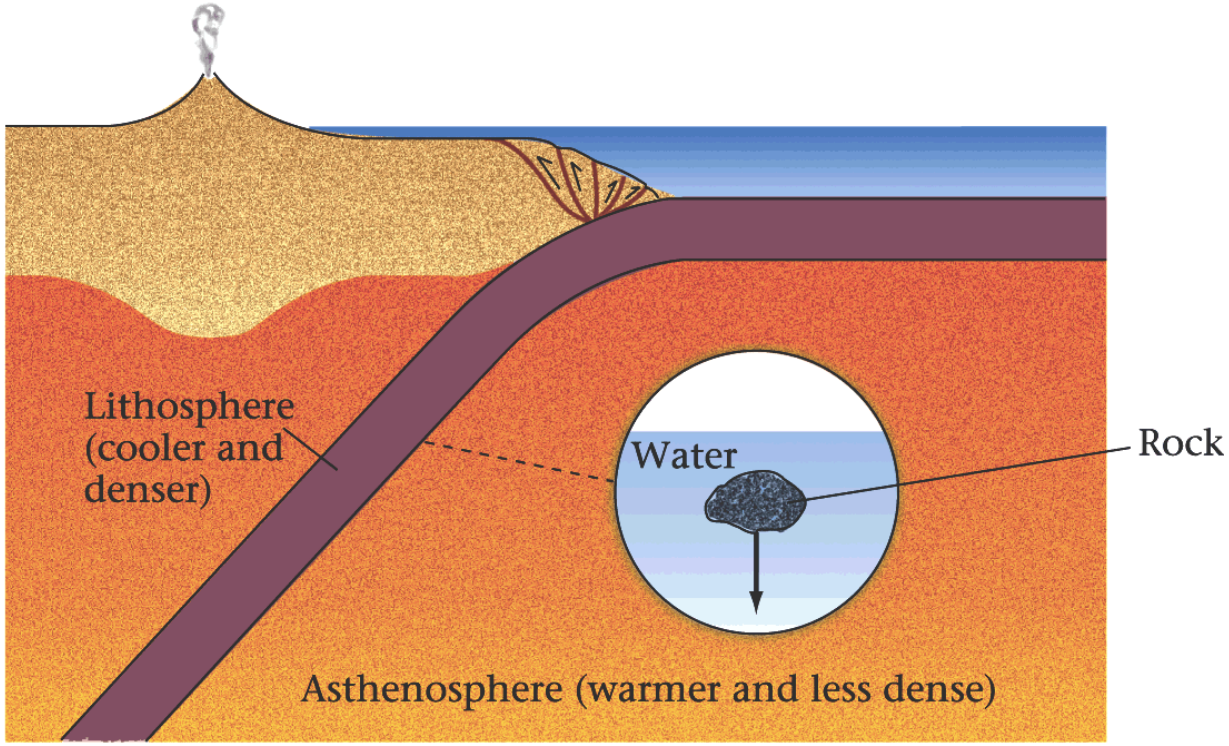


Yellowstone hotspot from
mantle tomography (Dueker, 2005)

What drives plate motions? 2 most important:

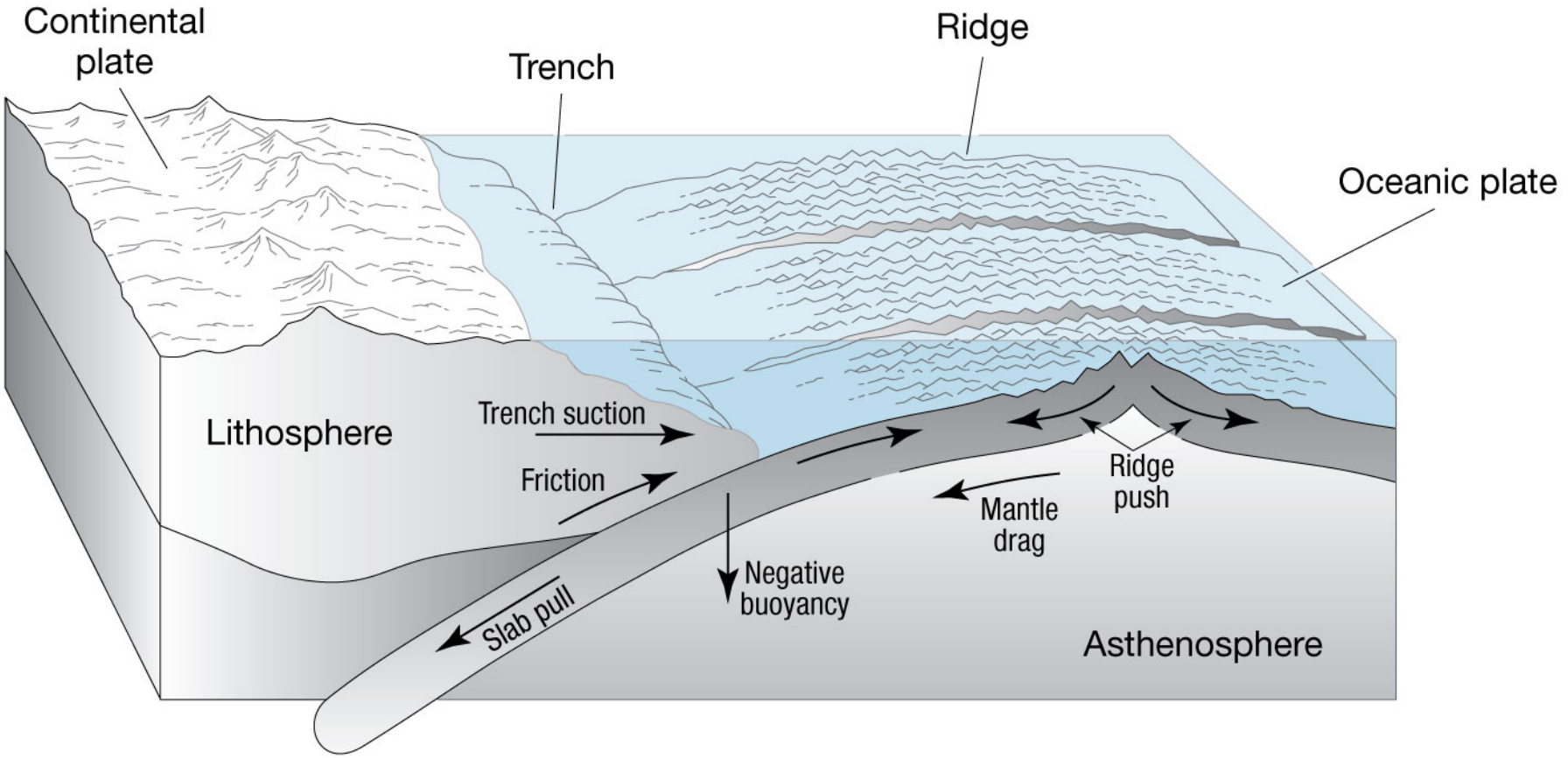


Ridge-push



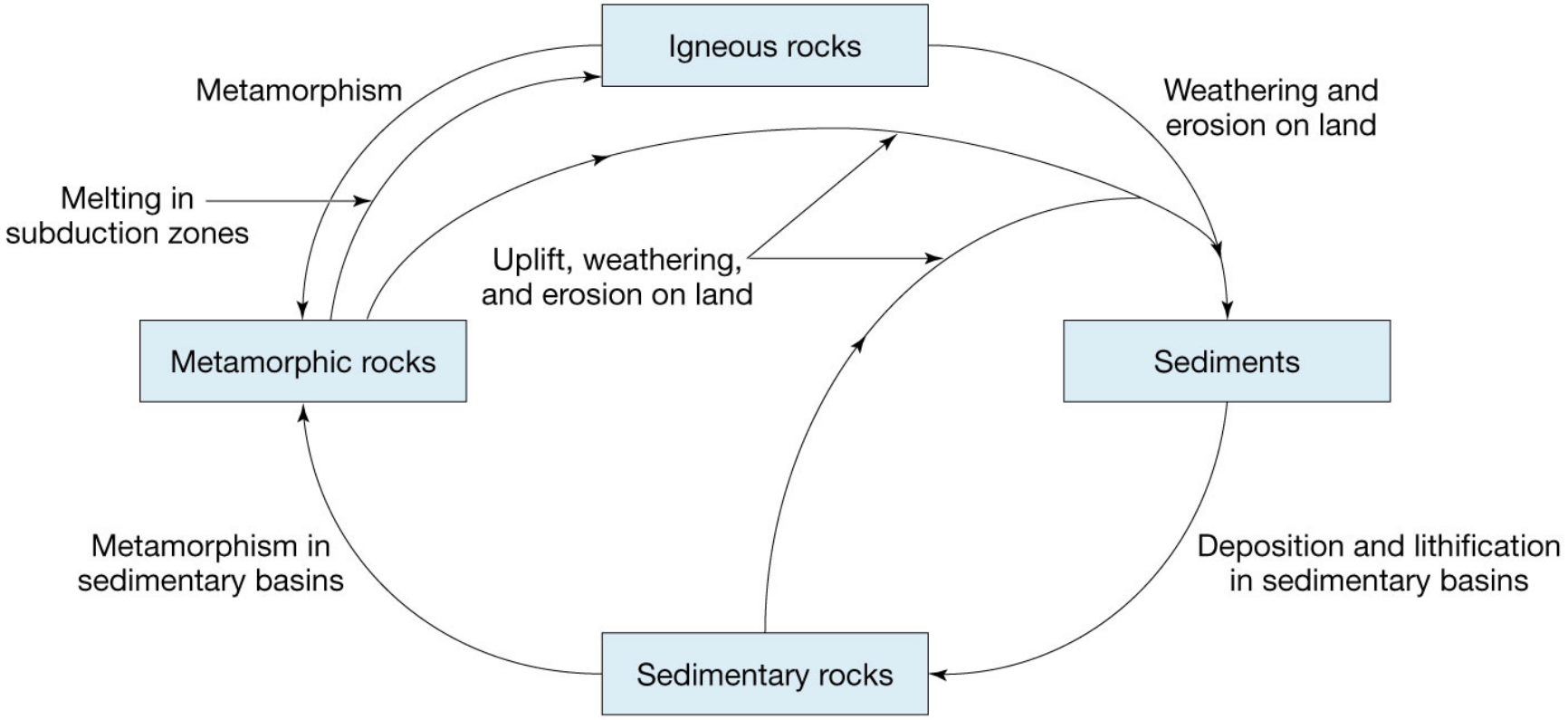
Slab-pull

F4 = elastic resistance to bending
F5 = extension in overlying plate
F6 = friction
F7 = density



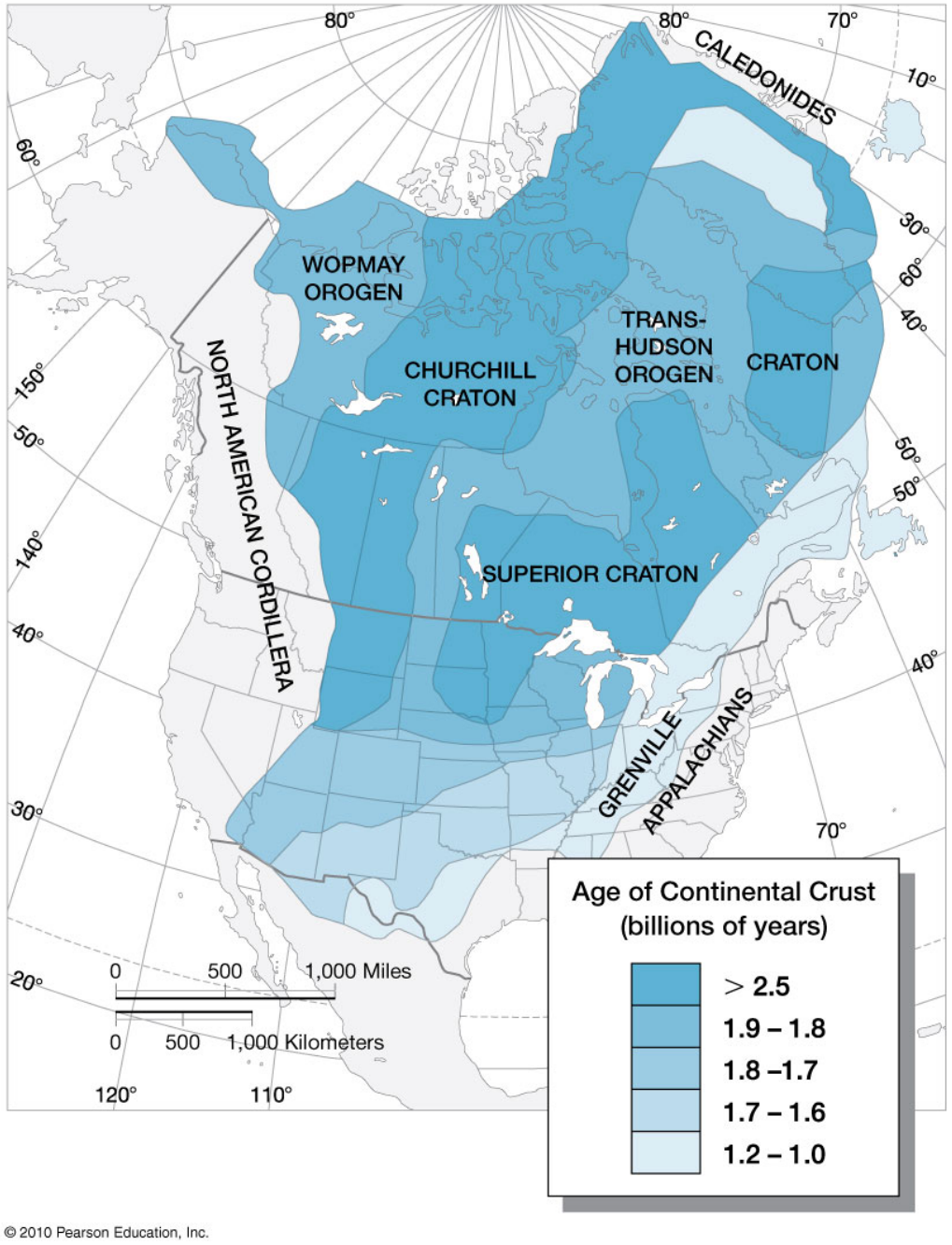
Forces acting on plate margins

The Rock Cycle



Evidence of continental "assembly"

…a series of accretion complexes of different ages



Wilson cycle: ~~500 Ma