

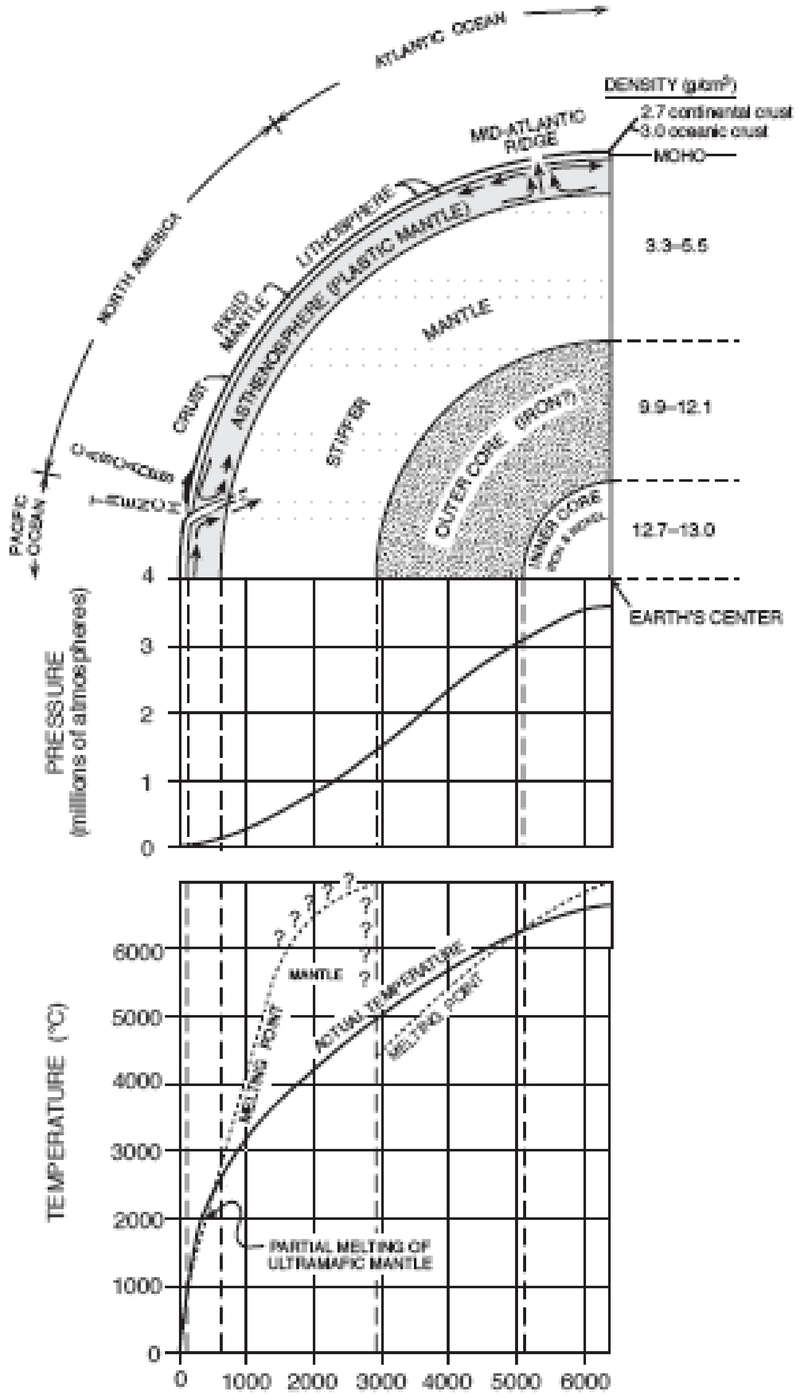

Dynamic Crust

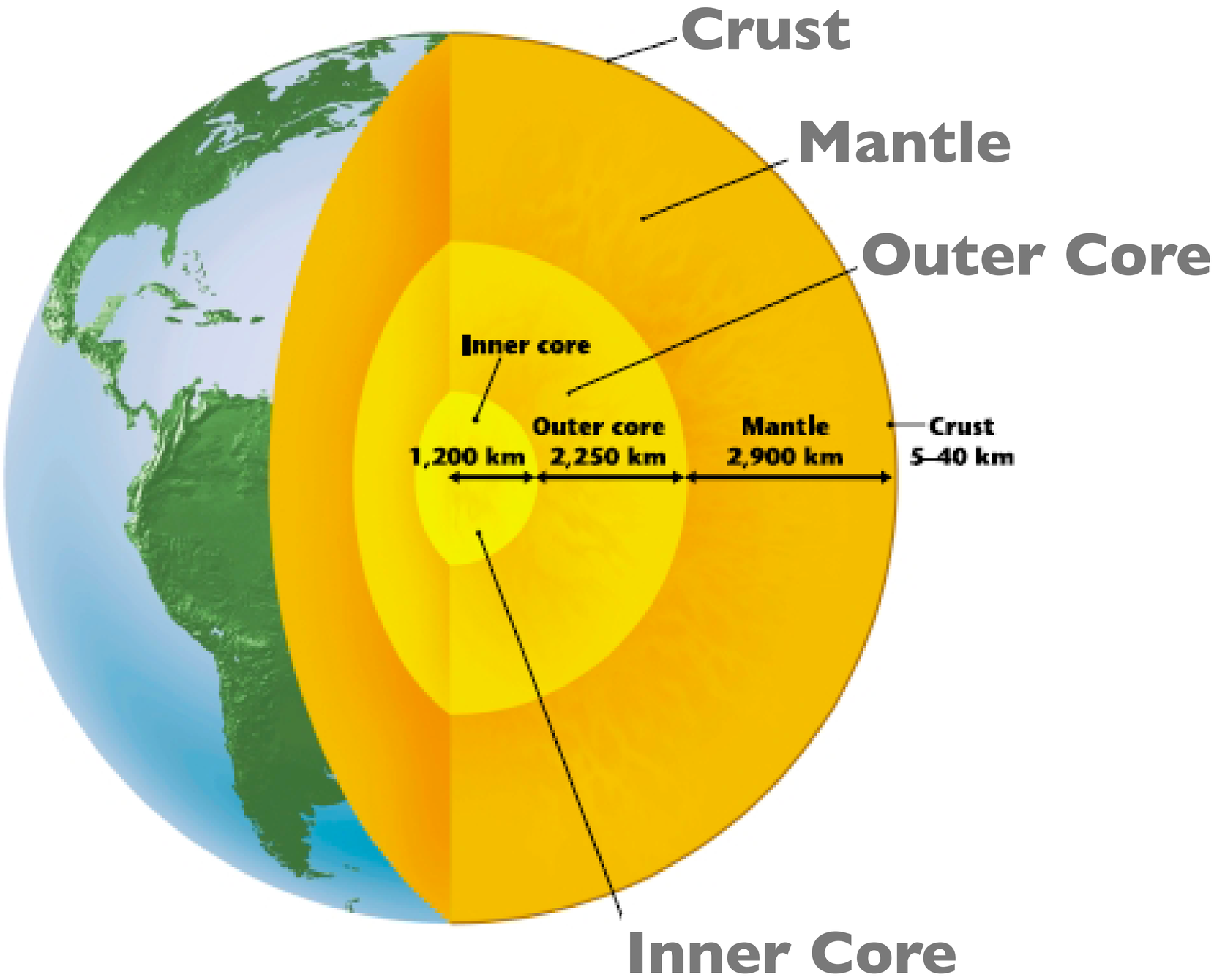
What is "The Dynamic Crust?"

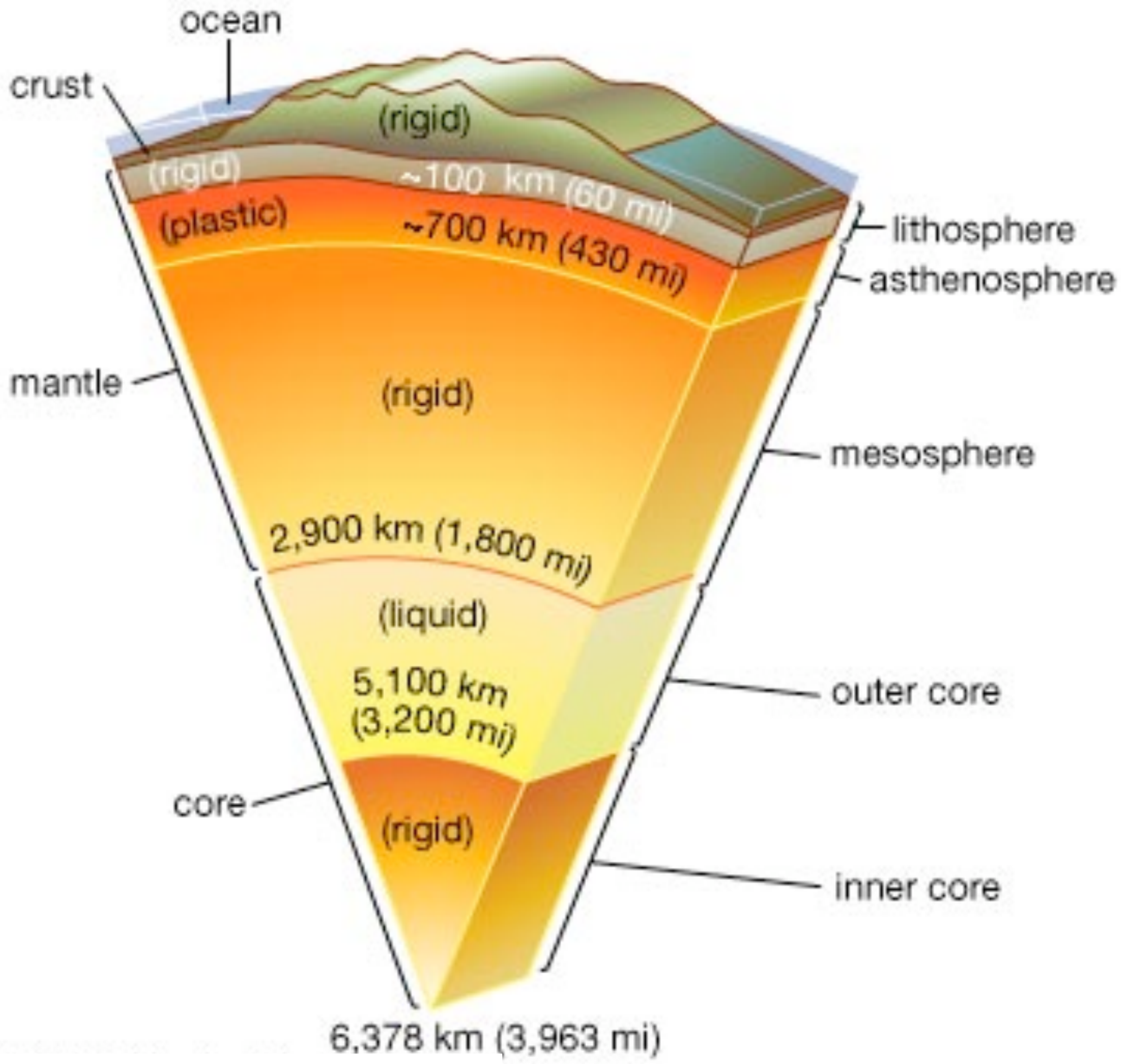
- Dynamic means constantly changing
- Crust is the outer portion of the earth
- Dynamic Crust is the term given to how the Earth's Crust is ever changing and evolving through plate tectonics

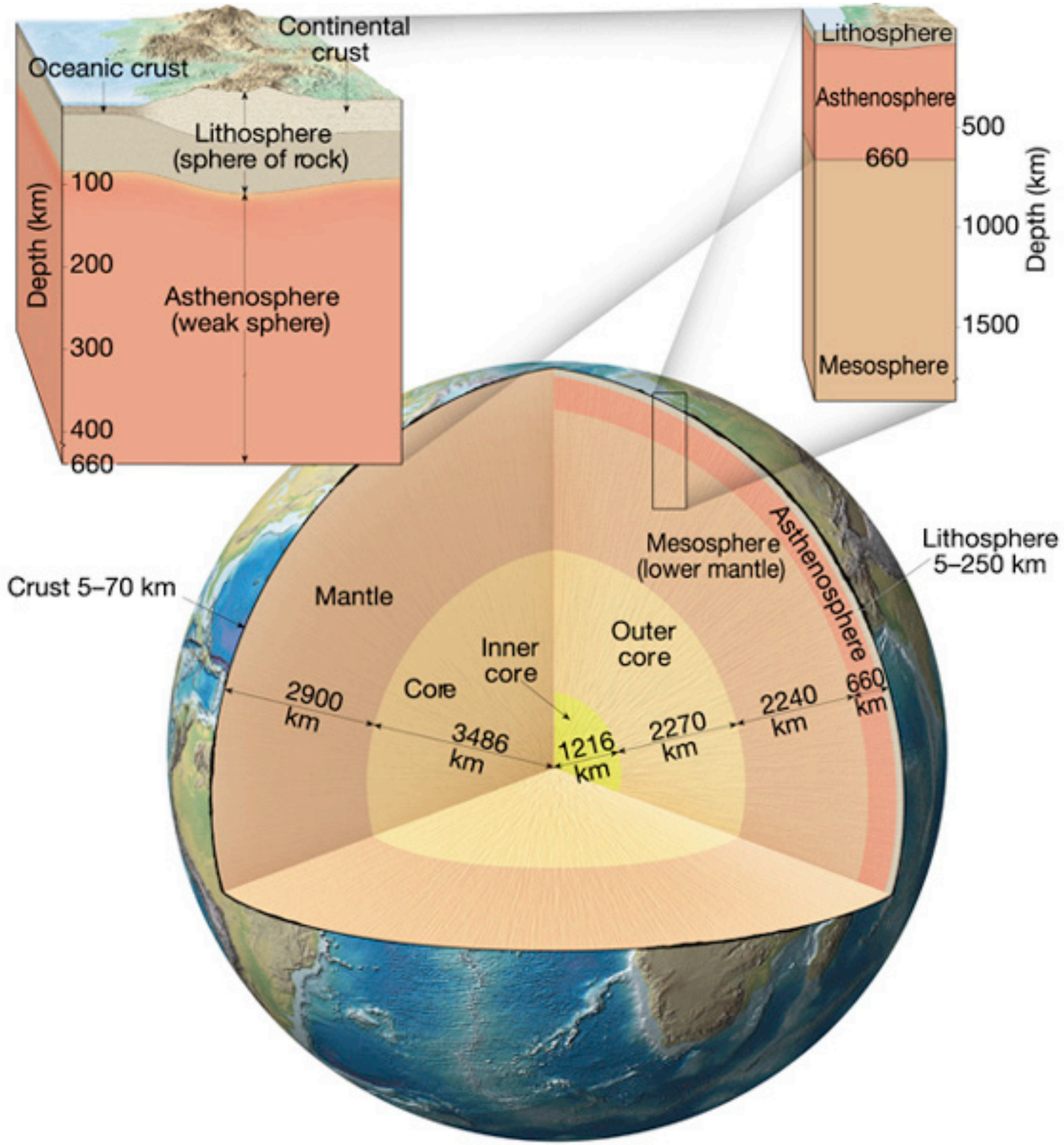
Inferred Properties of Earth's Interior

Page 10 of the ESRT



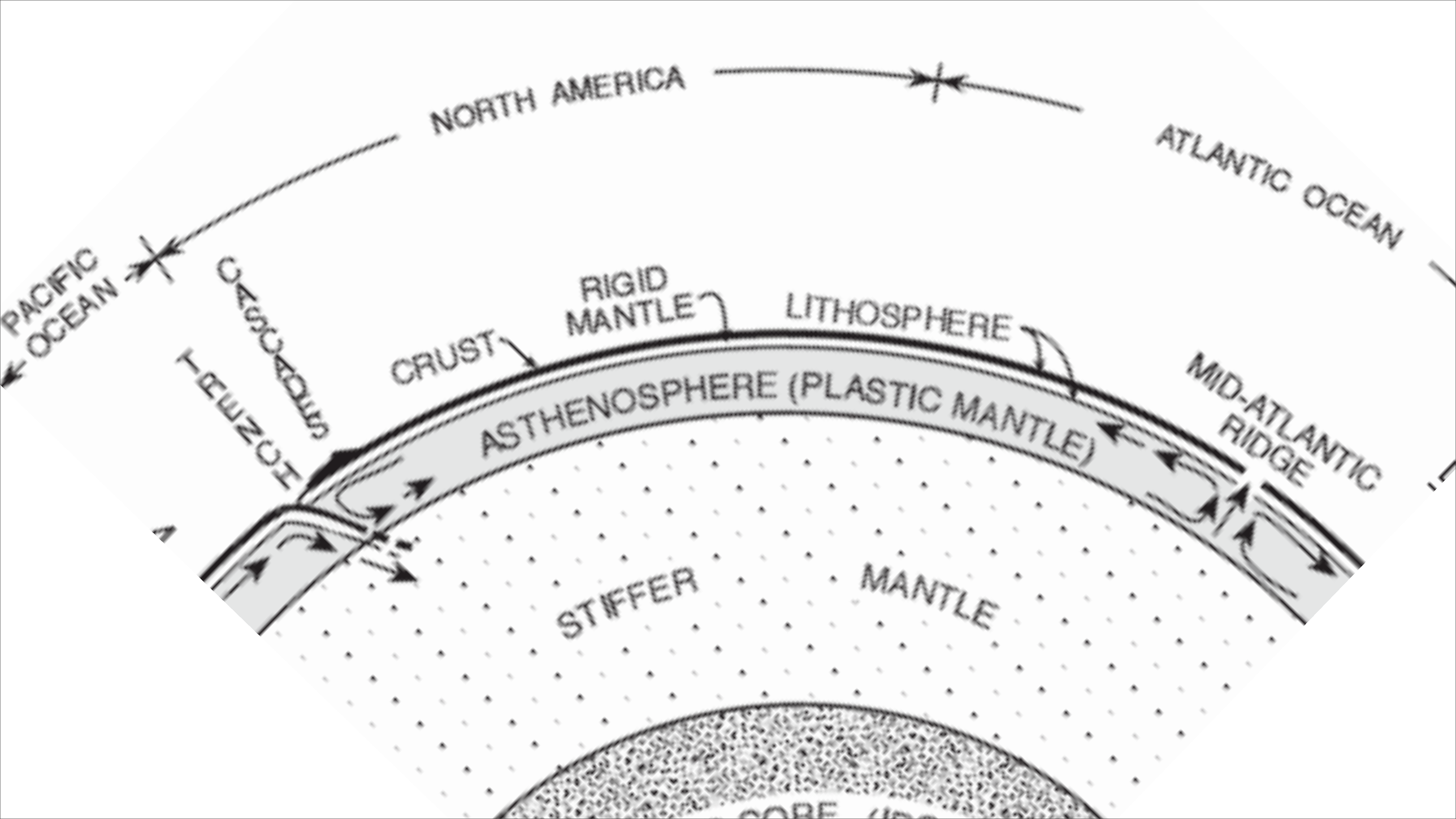

Crust
Mantle
Outer Core
Inner core
Outer core
1,200 km
2,250 km
Mantle
2,900 km
Crust
5–40 km
Inner Core

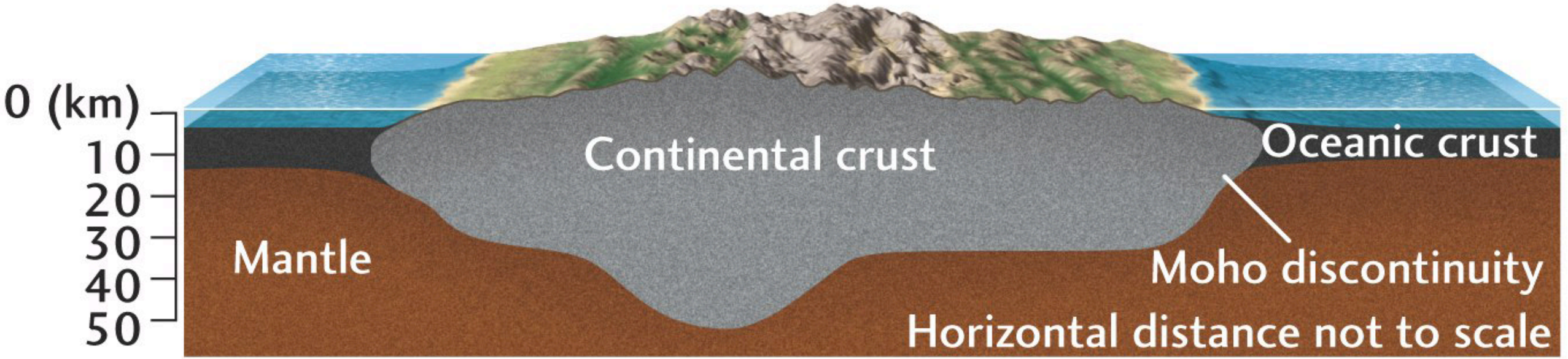

ocean
crust
(rigid)
(rigid)
~100 km (60 mi)
(plastic)
~700 km (430 mi)
lithosphere
asthenosphere
mantle
(rigid)
mesosphere
2,900 km (1,800 mi)
(liquid)
5,100 km
(3,200 mi)
outer core
core
(rigid)
inner core
6,378 km (3,963 mi)



The ***lithosphere*** = the **crust** and the outermost part of the mantle (the ***rigid mantle)***. It is solid rock.

The ***asthenosphere***= plastic (partially melted) layer beneath the lithosphere. This is where convection occurs.


NORTH AMERICA
ATLANTIC OCEAN
PACIFIC OCEAN
CRUST
RIGID MANTLE
LITHOSPHERE
ASTHENOSPHERE (PLASTIC MANTLE)
MID-ATLANTIC RIDGE
STIFFER MANTLE

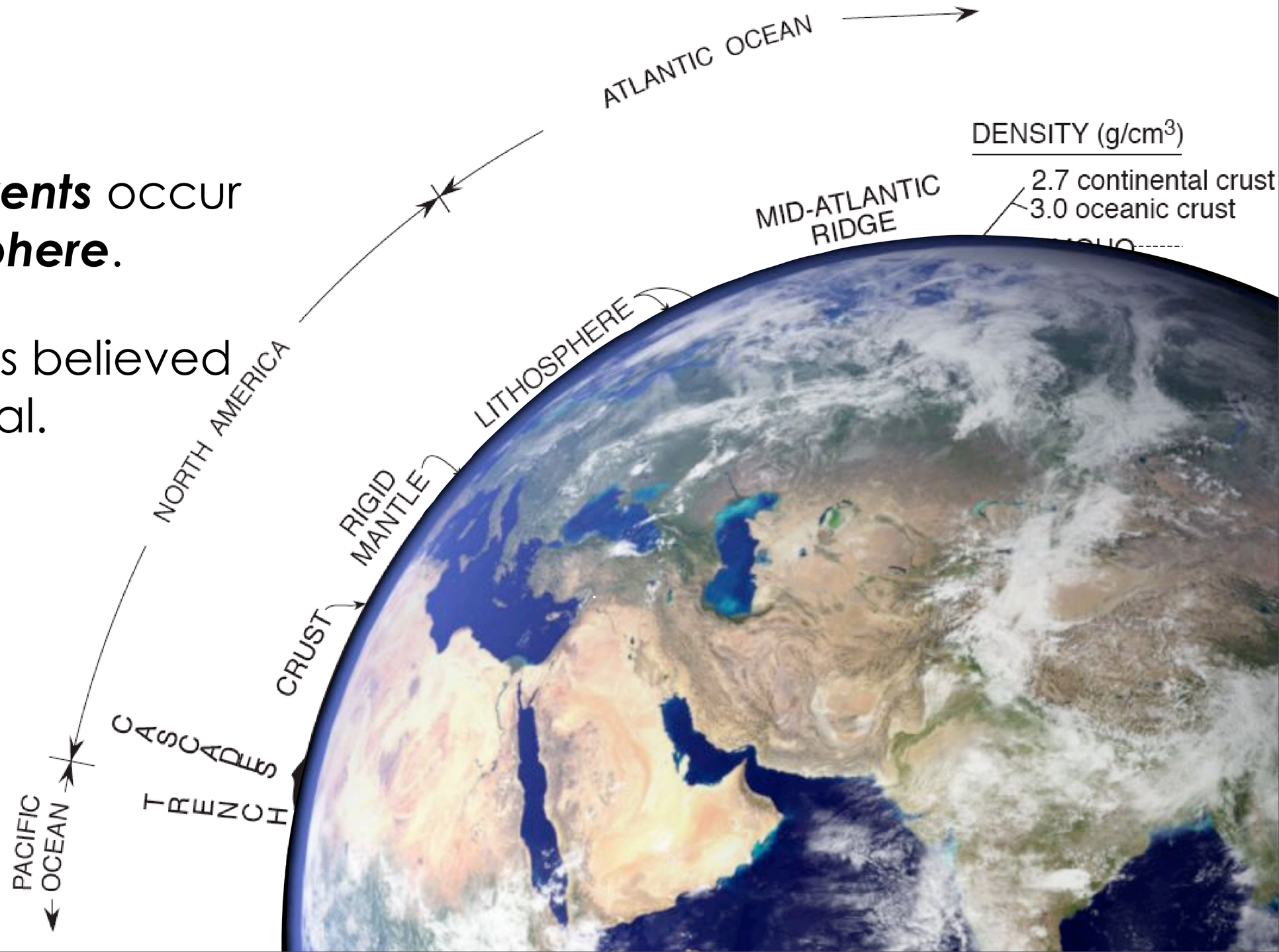


- **Continental Crust**
  - **Granite**
  - **Thick**
  - **Less dense**

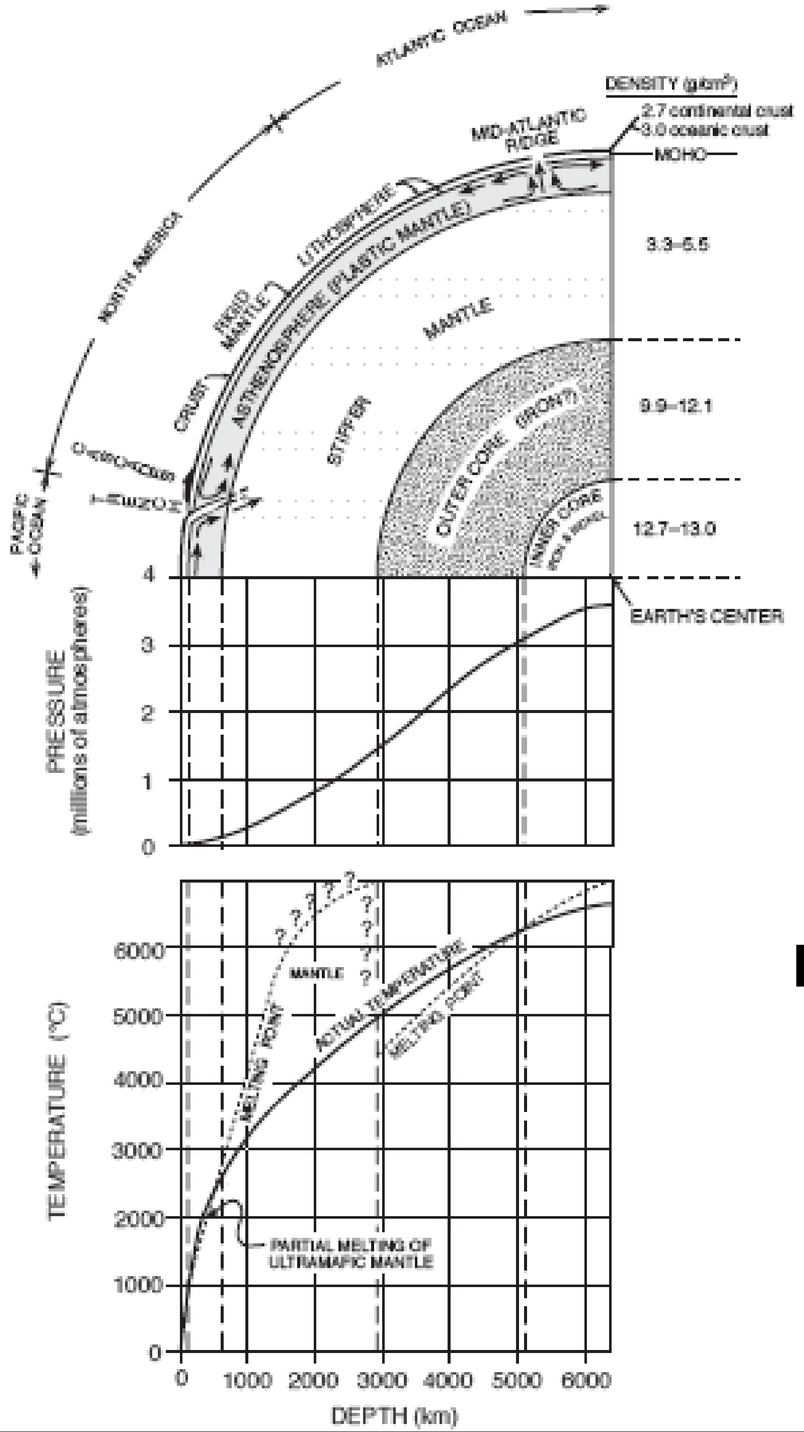
- **Oceanic Crust**
  - **Basalt**
  - **Thin**
  - **Dense**

- The ***Moho*** is the boundary between the crust and mantle

- ***Convection currents*** occur in the ***asthenosphere***.
- The ***Outer Core*** is believed to be liquid metal.

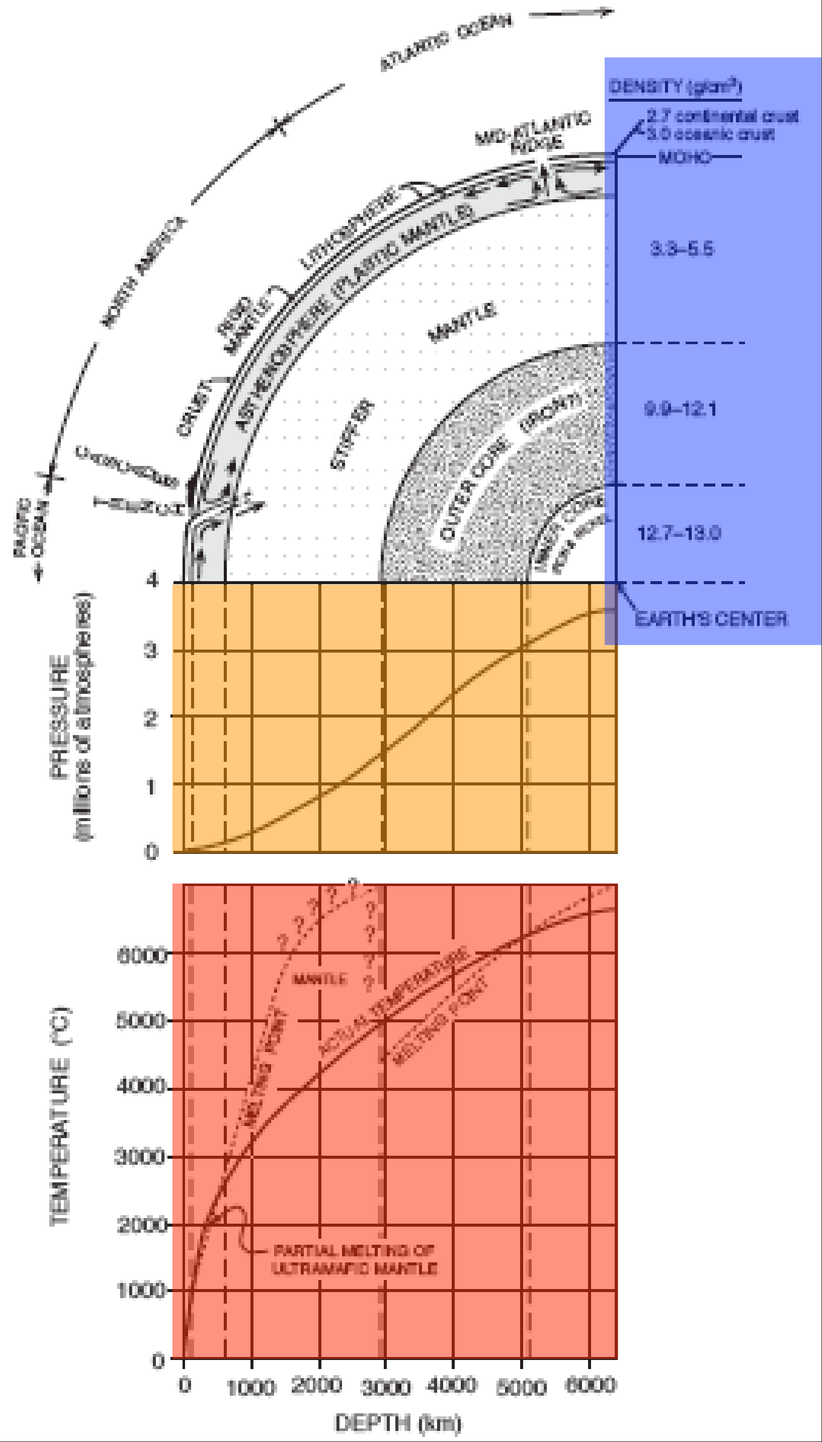


Inferred Properties of Earth's Interior



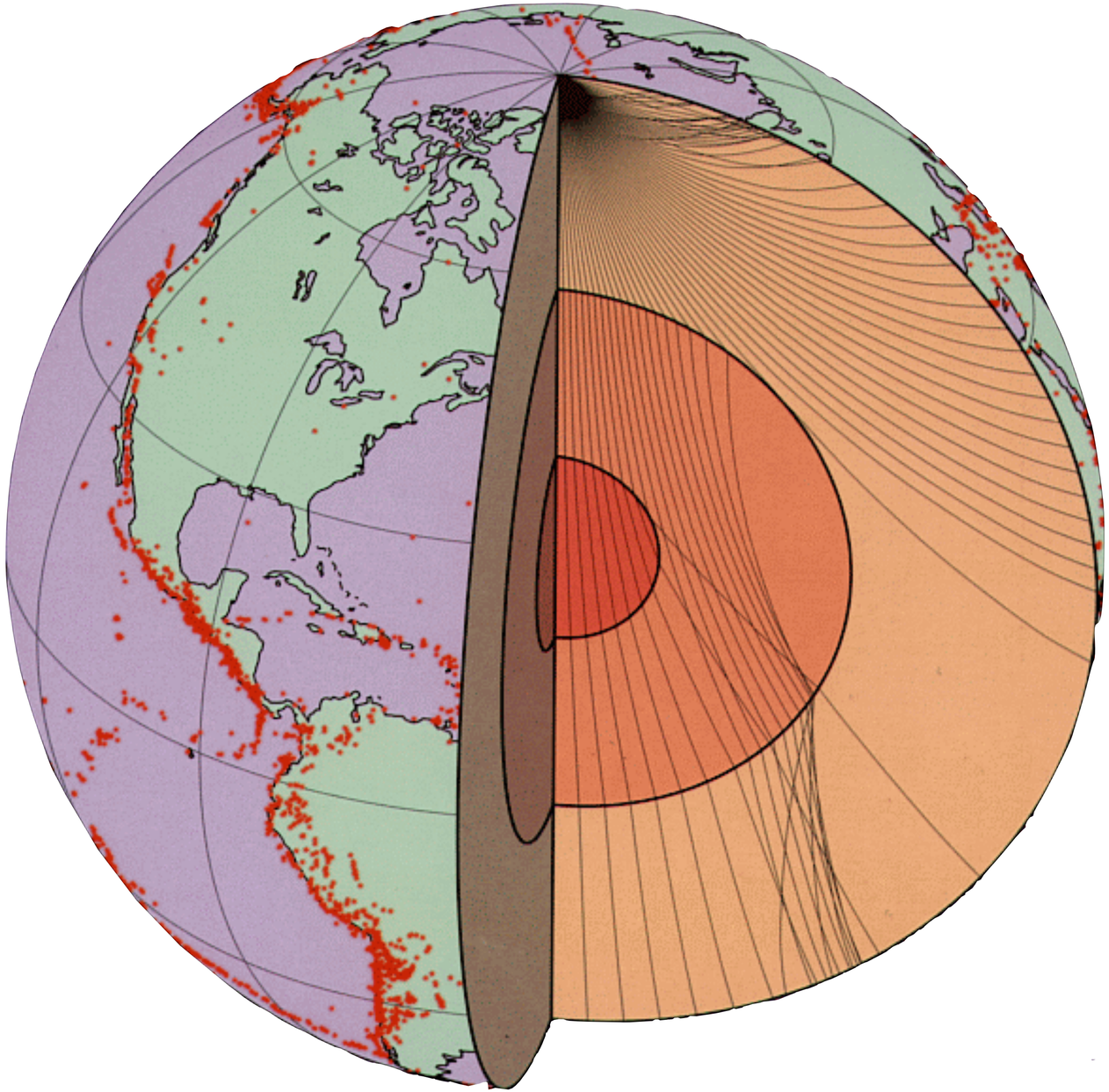
Model is based on the study of seismic (earthquake) waves

- As ***depth*** increases, ***pressure*** increases.
- As ***depth*** increases, ***temperature*** increases.
- When the ***actual temperature*** is greater than the ***melting point***, the layer is in liquid phase.
- As ***depth*** increases, ***density*** increases.





Our model of the Earth's interior is based entirely on the study of seismic waves.





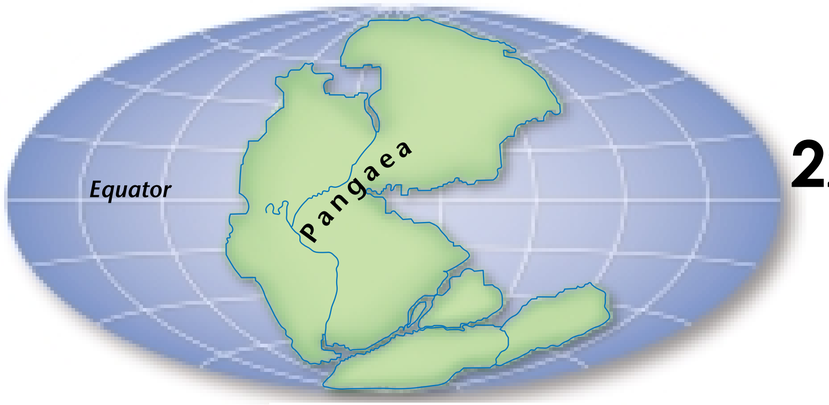
Continental Drift

- The theory that the continents have been moving across the Earth's surface throughout history



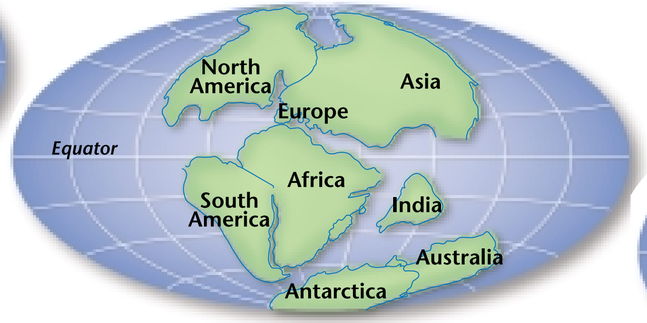
Pangea

- The Supercontinent that existed about 250 million years ago.



225 million years ago

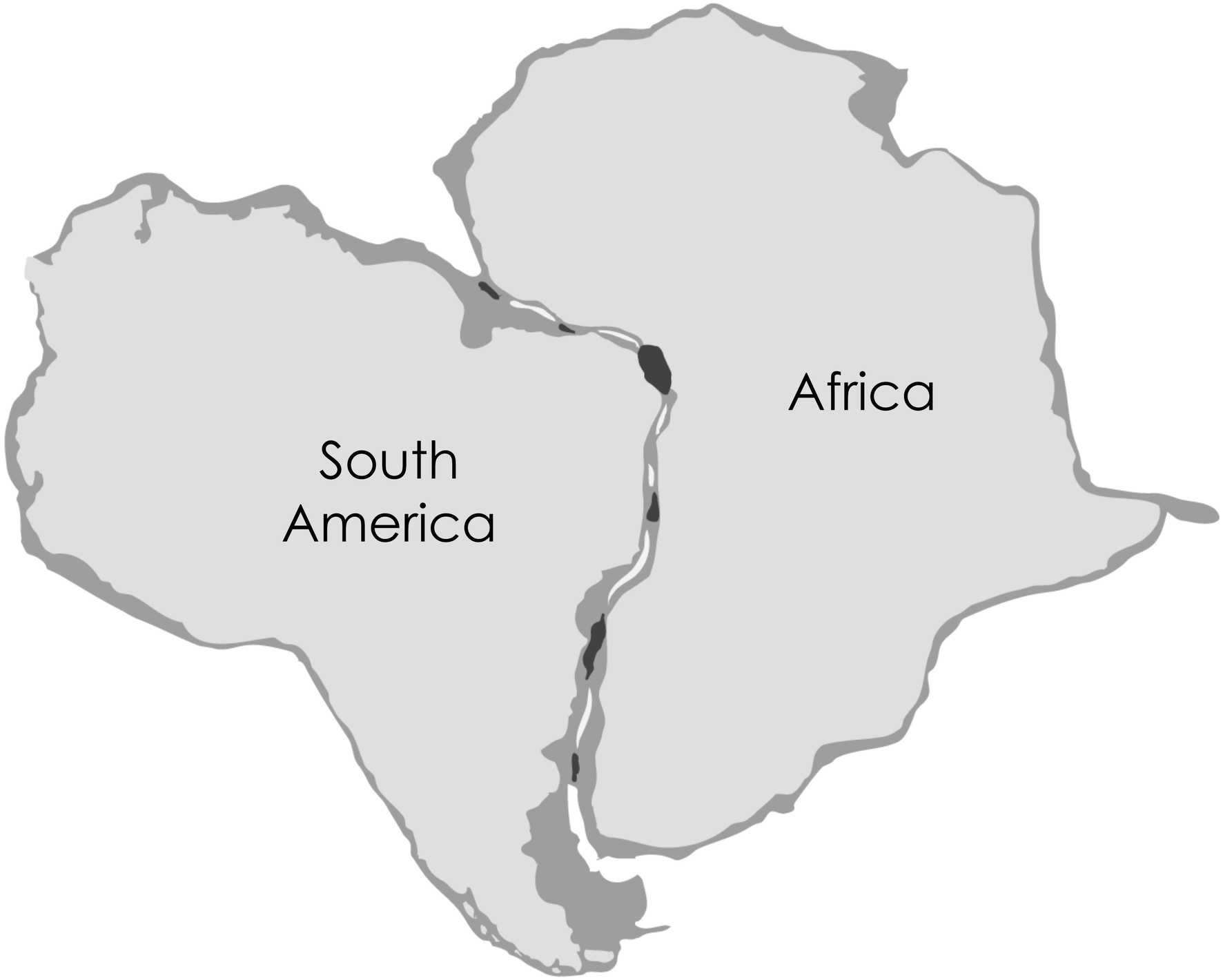


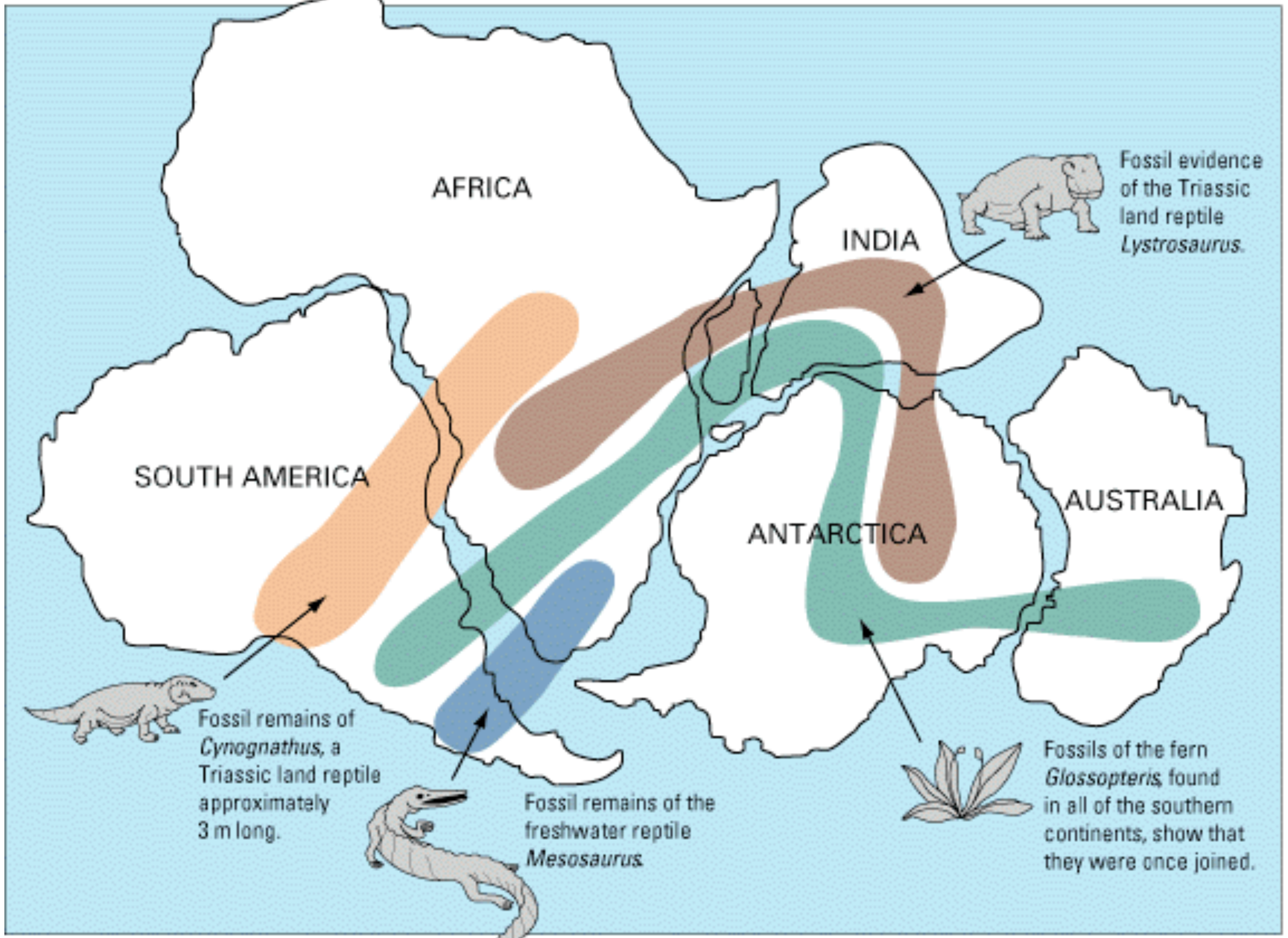




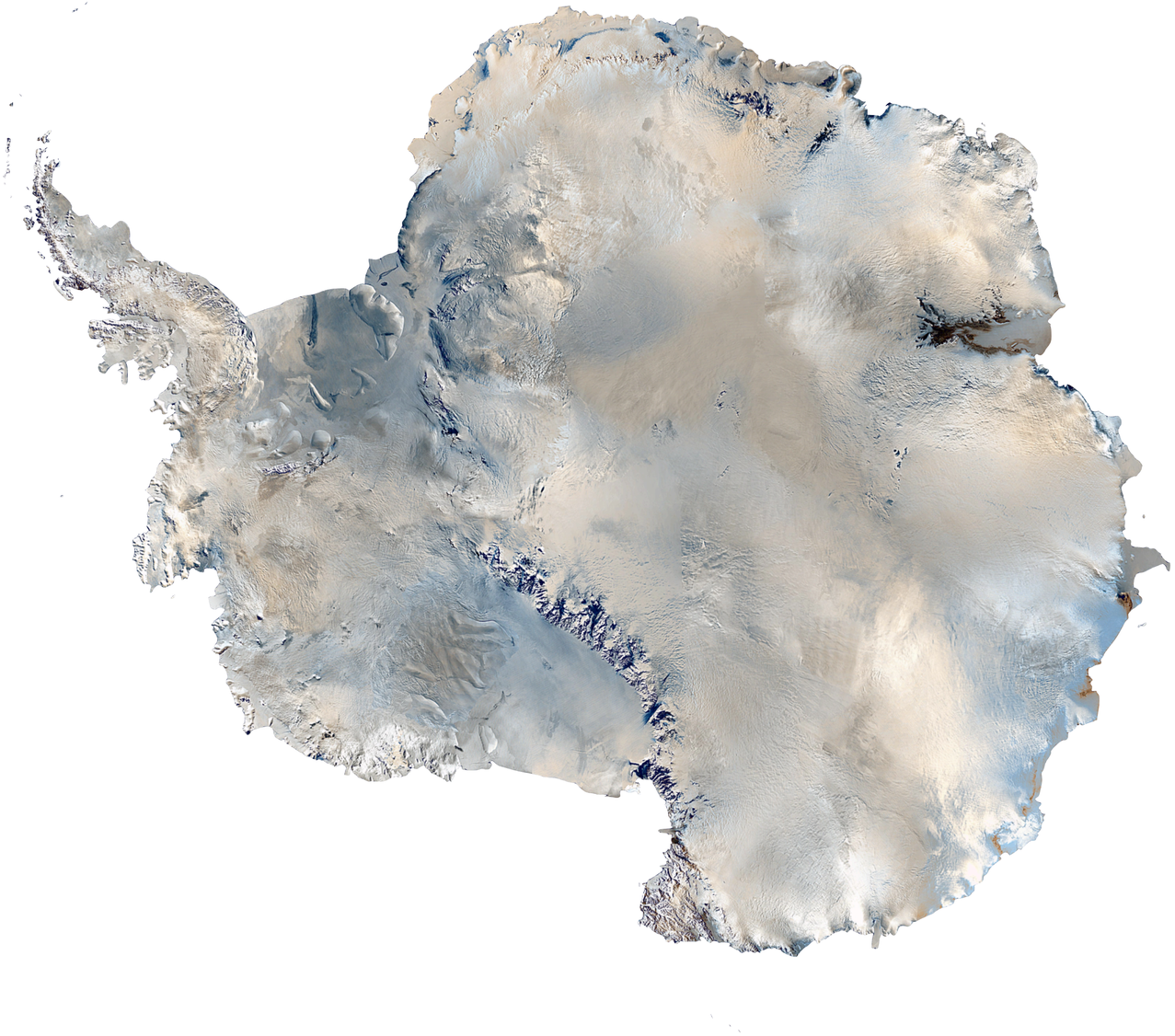
today




South America
Africa


AFRICA
INDIA
SOUTH AMERICA
ANTARCTICA
AUSTRALIA
Fossil evidence of the Triassic land reptile *Lystrosaurus*.
Fossil remains of *Cynognathus*, a Triassic land reptile approximately 3 m long.
Fossil remains of the freshwater reptile *Mesosaurus*.
Fossils of the fern *Glossopteris*, found in all of the southern continents, show that they were once joined.


Caledonian Mountains
British Isles
Scandinavia
North America
Appalachian Mountains
Africa
South America





Evidence for Continental Drift



Pangaea



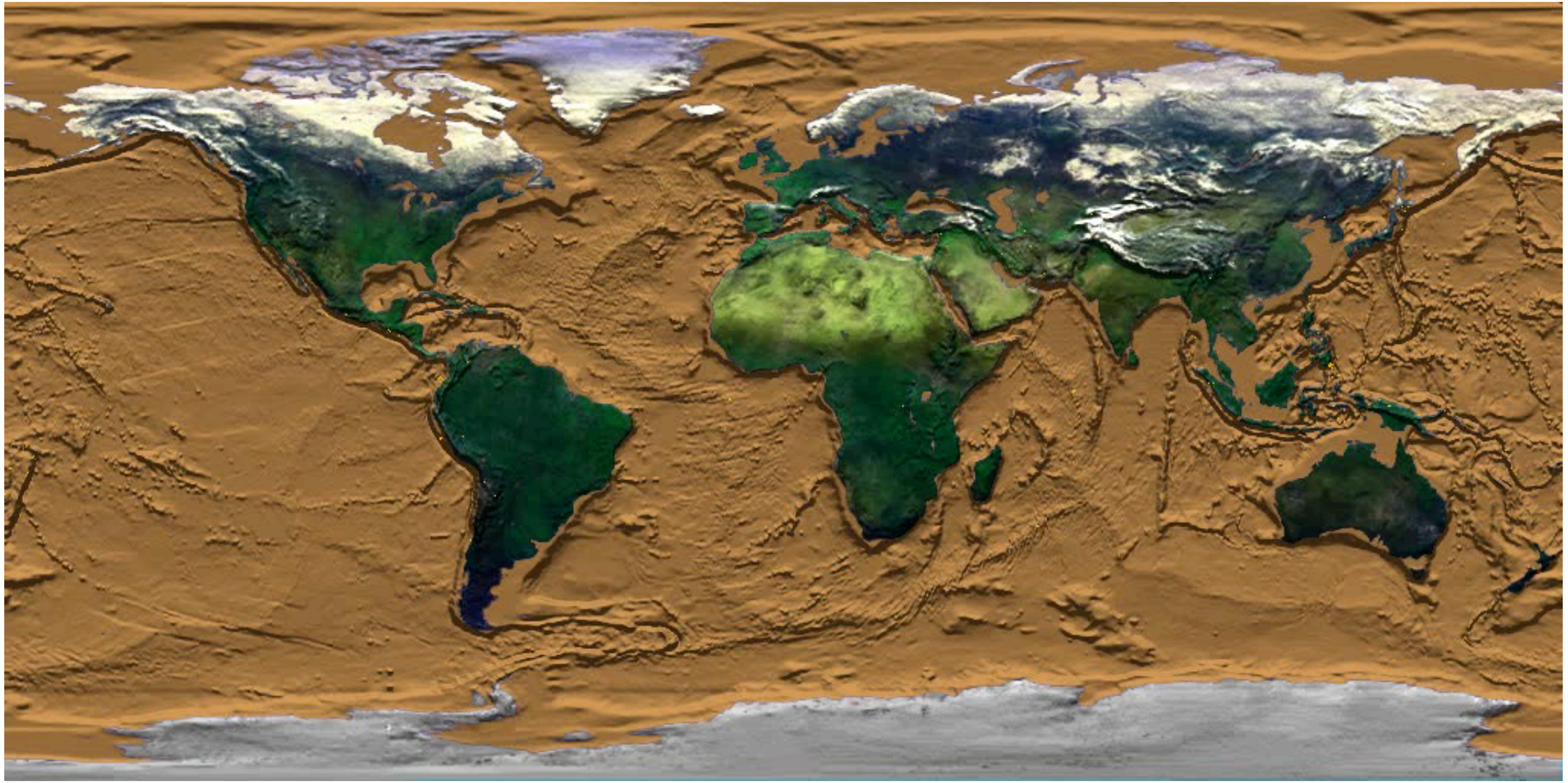
KEY

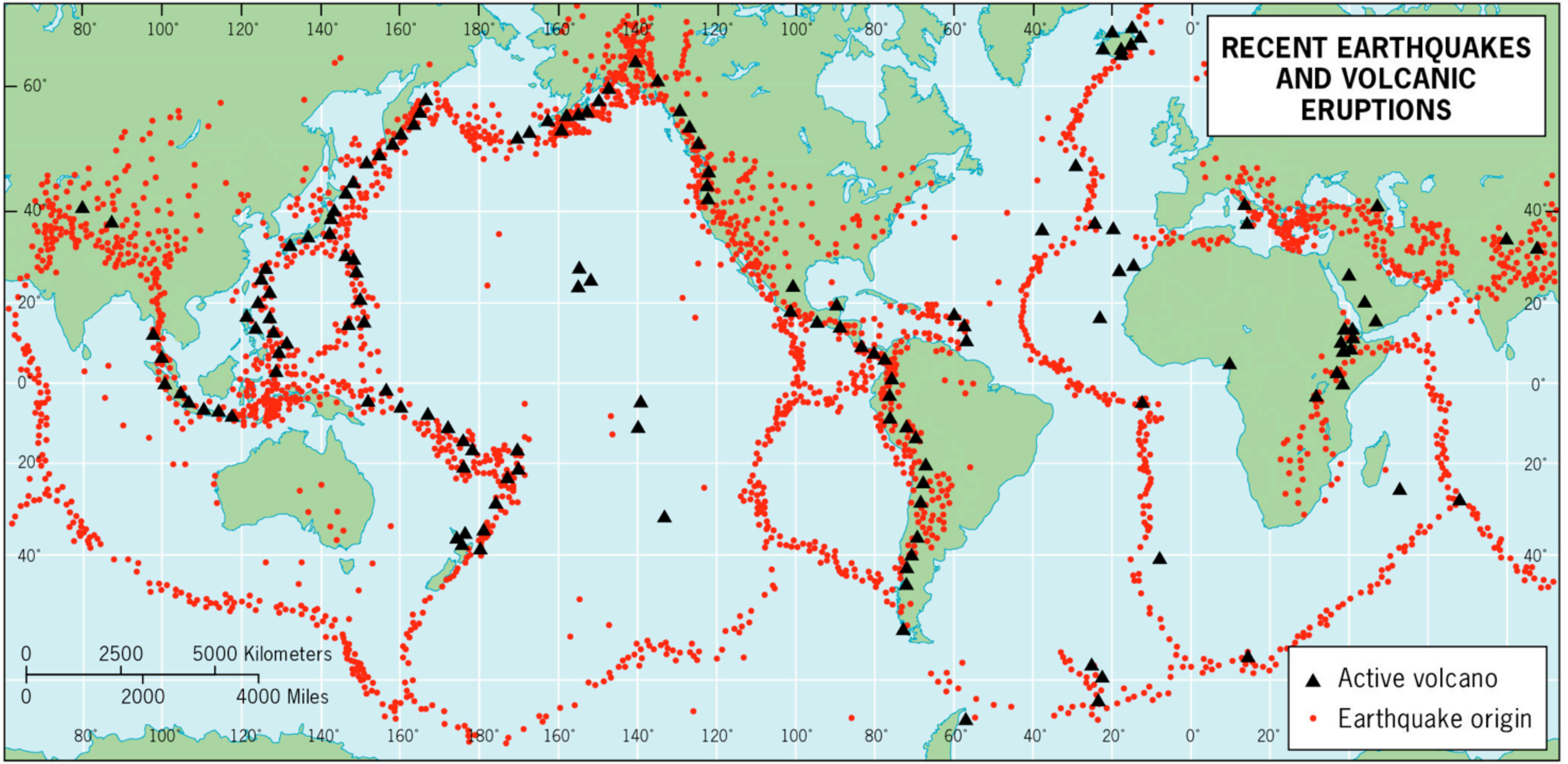
- Glossopteris fossils
- Folded mountains
- Glacial deposits
- Coal beds



Evidence Supporting Continental Drift
1. The Apparent Fit of the Continents
2. Fossil Correlation
3. Rock/Mountain Correlation
4. Past Climate Data

Wegener's theory was not accepted because he offered no mechanism for the motion of the continents.




RECENT EARTHQUAKES AND VOLCANIC ERUPTIONS
80° 100° 120° 140° 160° 180° 160° 140° 120° 100° 80° 60° 40° 0°
60°
40°
20°
0°
20°
40°
0 2500 5000 Kilometers
0 2000 4000 Miles
Active volcano
Earthquake origin



All seismic activity occurs along plate boundaries (except for hotspots).

The lithosphere is broken into plates

These plates “float” on the plastic asthenosphere

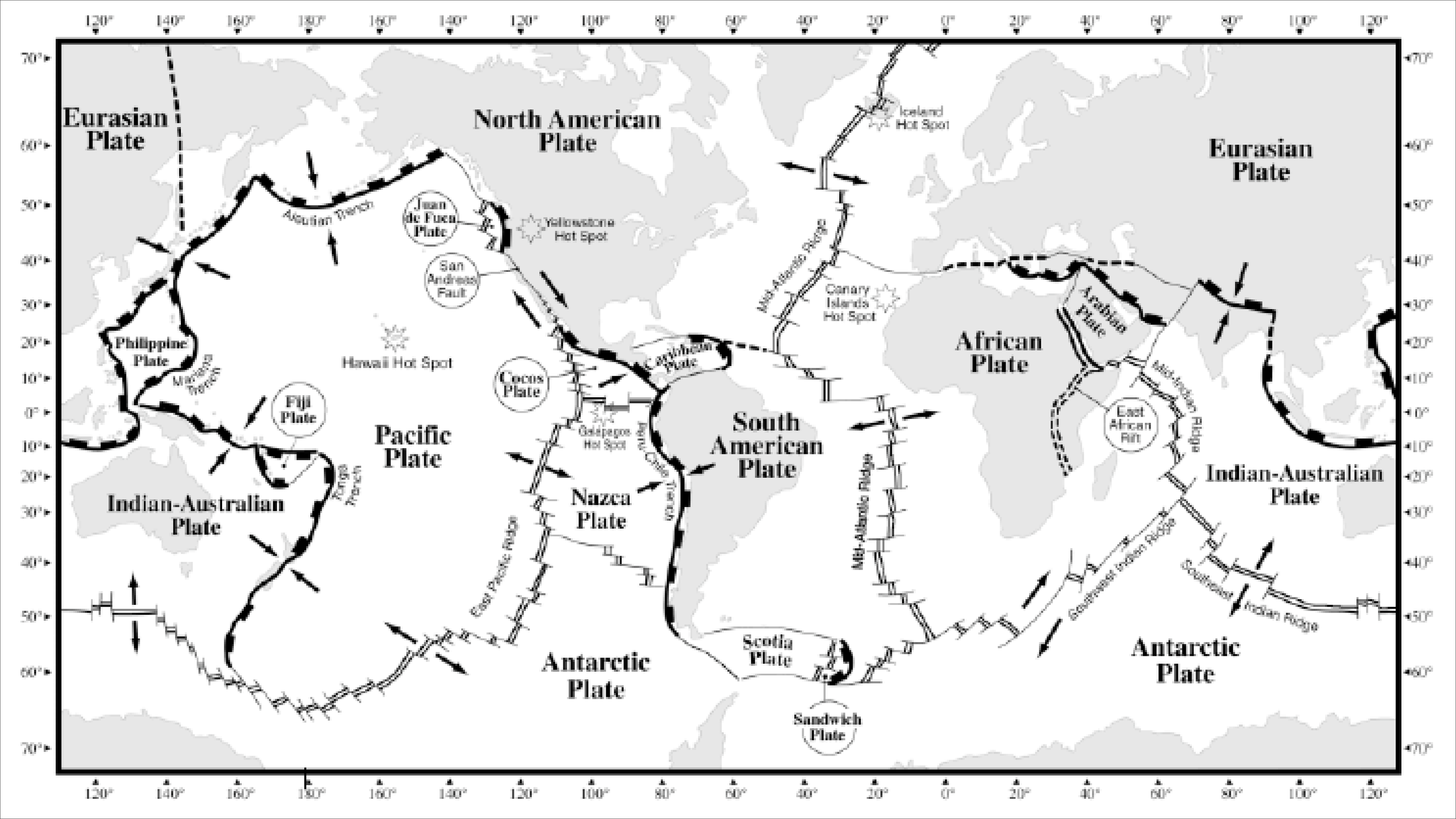
The Theory of Plate Tectonics is born

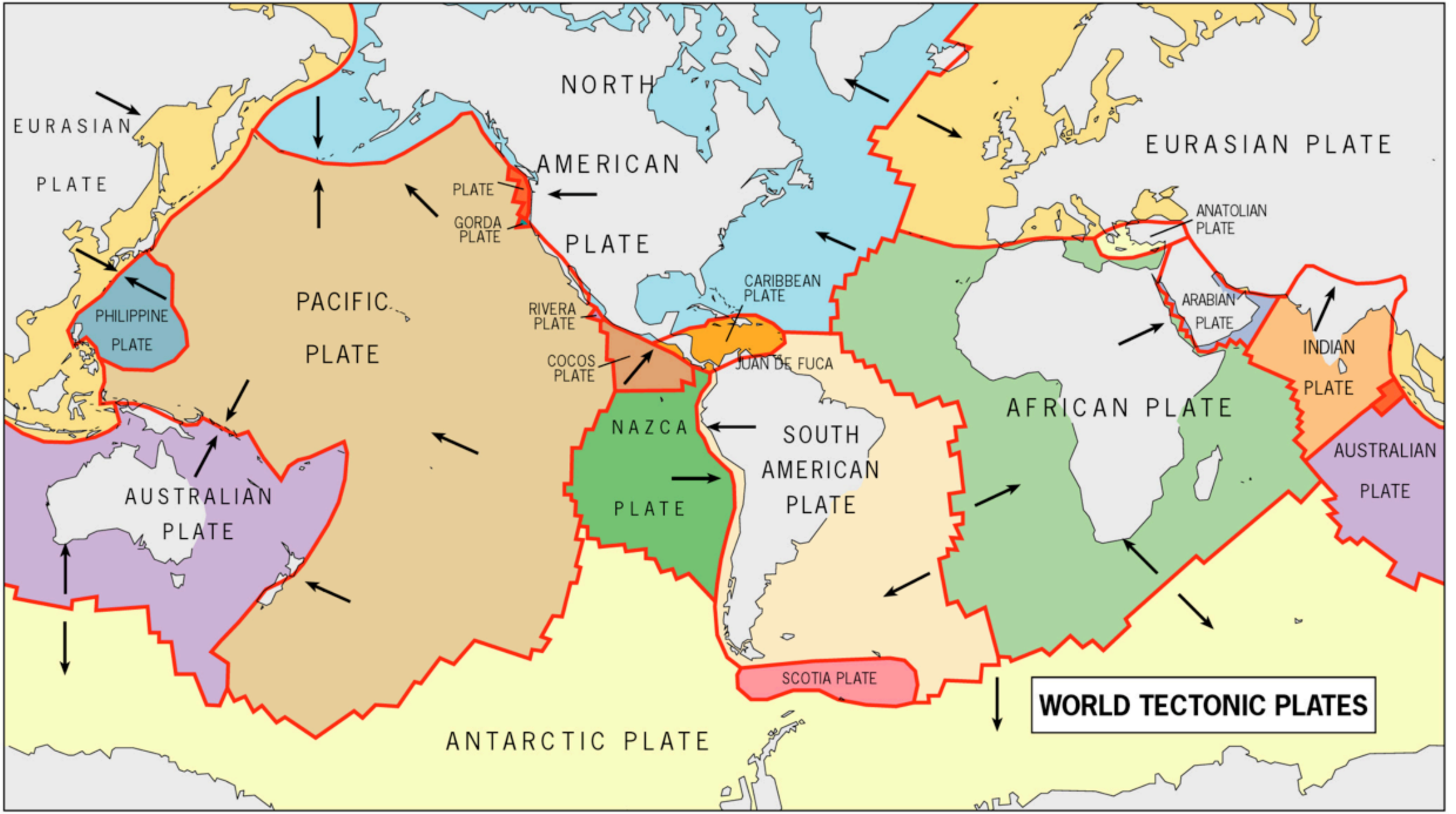
All seismic activity is found along plate boundaries

Plate motion is driven by mantle convection

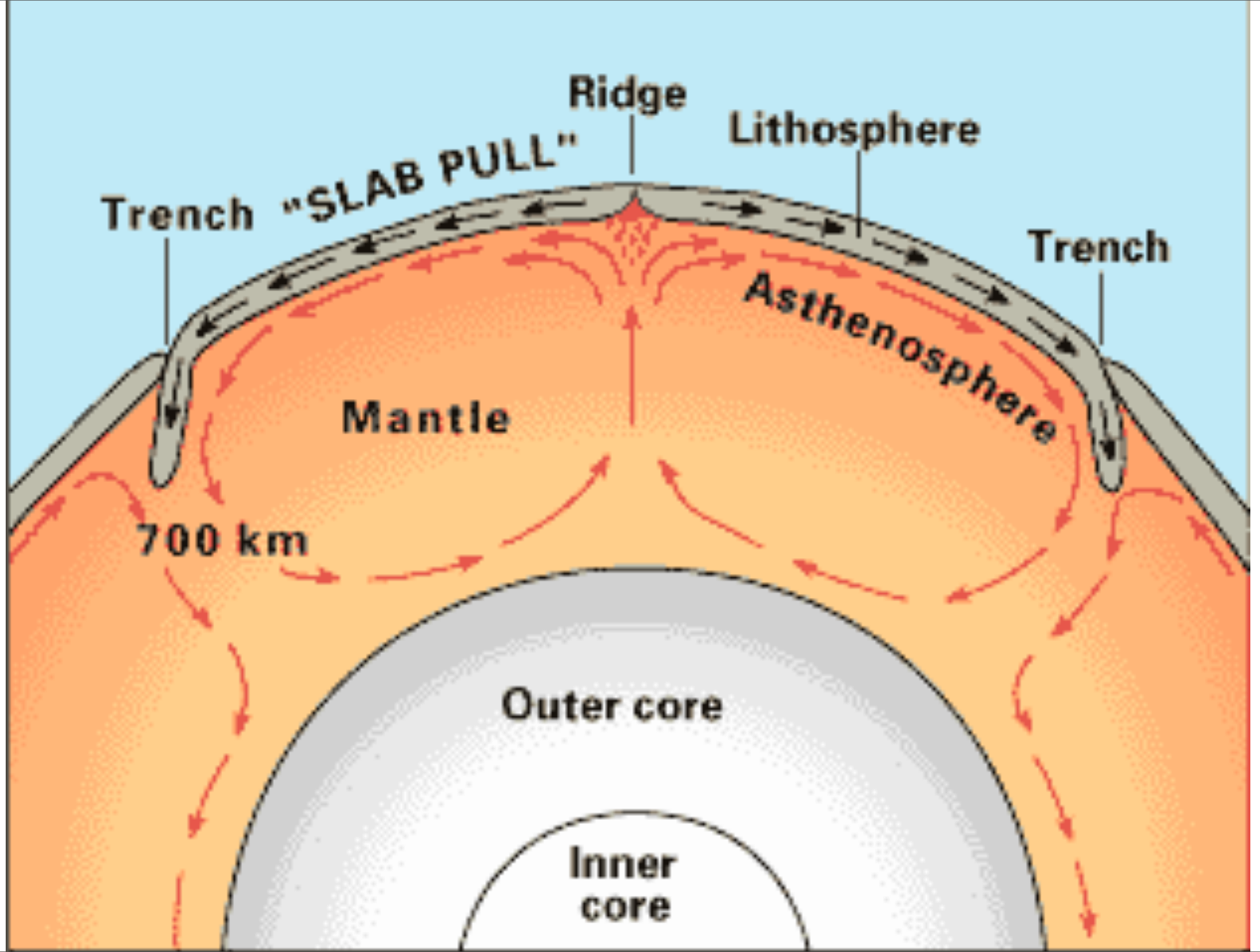
PLATE TECTONICS

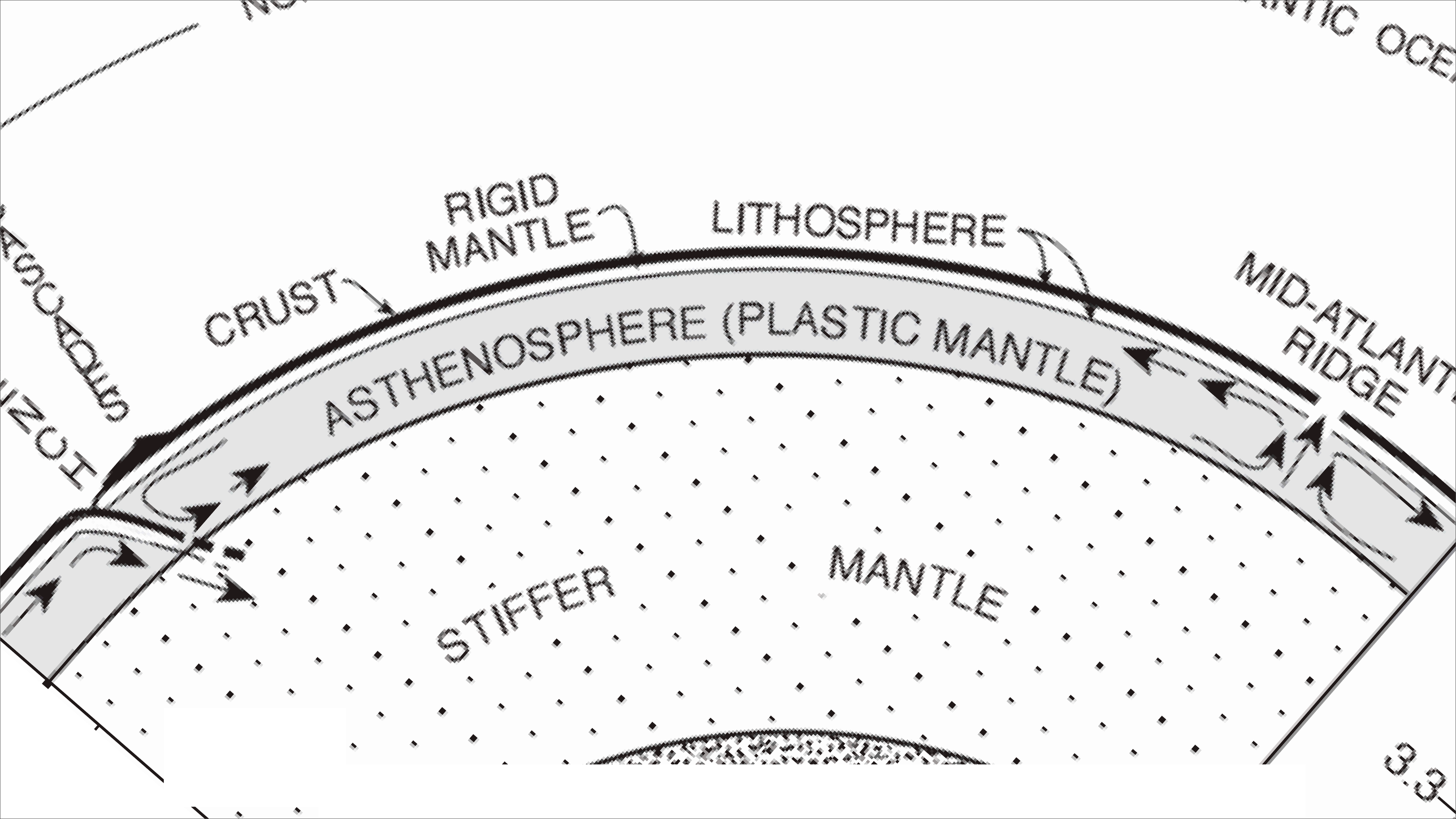
- The lithosphere is broken into plates
- These plates “float” on the plastic asthenosphere
- Along plate boundaries, the plates interact
- All seismic activity is found along plate boundaries
- Plate motion is driven by mantle convection


Eurasian Plate
North American Plate
Eurasian Plate
Iceland Hot Spot
Aleutian Trench
Juan de Fuca Plate
Yellowstone Hot Spot
San Andreas Fault
Mid-Atlantic Ridge
Canary Islands Hot Spot
Arabian Plate
African Plate
Philippine Plate
Mariana Trench
Hawaii Hot Spot
Cocos Plate
Caribbean Plate
Mid-Indian Ridge
East African Rift
Fiji Plate
Pacific Plate
Galapagos Hot Spot
Peru-Chile Trench
South American Plate
Indian-Australian Plate
Tonga Trench
Nazca Plate
Mid-Atlantic Ridge
Indian-Australian Plate
East Pacific Ridge
Southwest Indian Ridge
Southeast Indian Ridge
Scotia Plate
Antarctic Plate
Antarctic Plate
Sandwich Plate
120° 140° 160° 180° 160° 140° 120° 100° 80° 60° 40° 20° 0° 20° 40° 60° 80° 100° 120°
70° 60° 50° 40° 30° 20° 10° 0° 10° 20° 30° 40° 50° 60° 70°


EURASIAN
PLATE
NORTH
AMERICAN
PLATE
PLATE
GORDA
PLATE
EURASIAN PLATE
ANATOLIAN
PLATE
PHILIPPINE
PLATE
PACIFIC
PLATE
RIVERA
PLATE
CARIBBEAN
PLATE
ARABIAN
PLATE
INDIAN
PLATE
COCOS
PLATE
JUAN DE FUCA
AFRICAN PLATE
NAZCA
PLATE
SOUTH
AMERICAN
PLATE
AUSTRALIAN
PLATE
AUSTRALIAN
PLATE
SCOTIA PLATE
ANTARCTIC PLATE
WORLD TECTONIC PLATES

- The driving force behind plate tectonics, the force moving the lithospheric plates
- Heat lowers density causing a substance to rise where it cools, becomes more dense and sinks
- Occurs in the asthenosphere and moves the overlying plates around


Ridge
Lithosphere
Trench
"SLAB PULL"
Trench
Asthenosphere
Mantle
700 km
Outer core
Inner
core

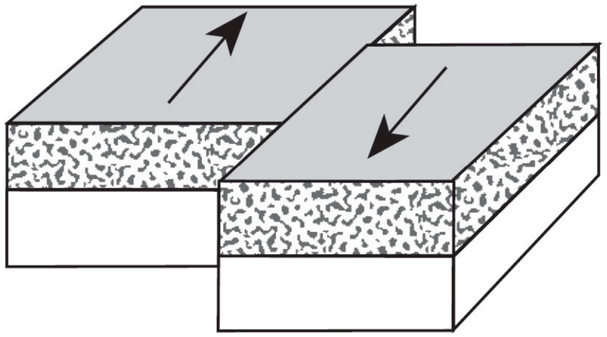

RIGID
MANTLE
LITHOSPHERE
CRUST
ASTHENOSPHERE (PLASTIC MANTLE)
MID-ATLANTIC
RIDGE
STIFFER
MANTLE



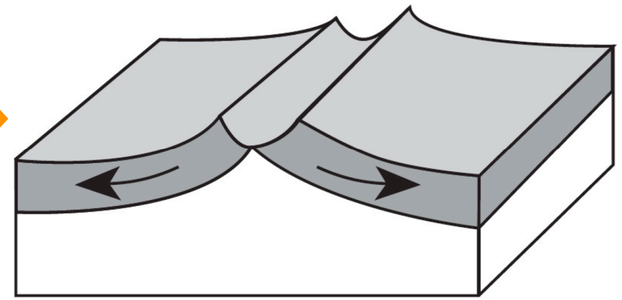


Mantle convection currents drive plate motion.

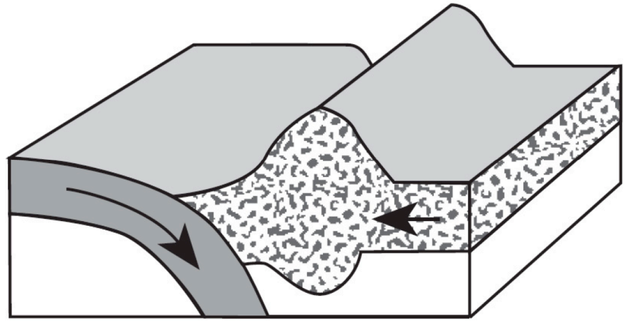
Plate Boundaries



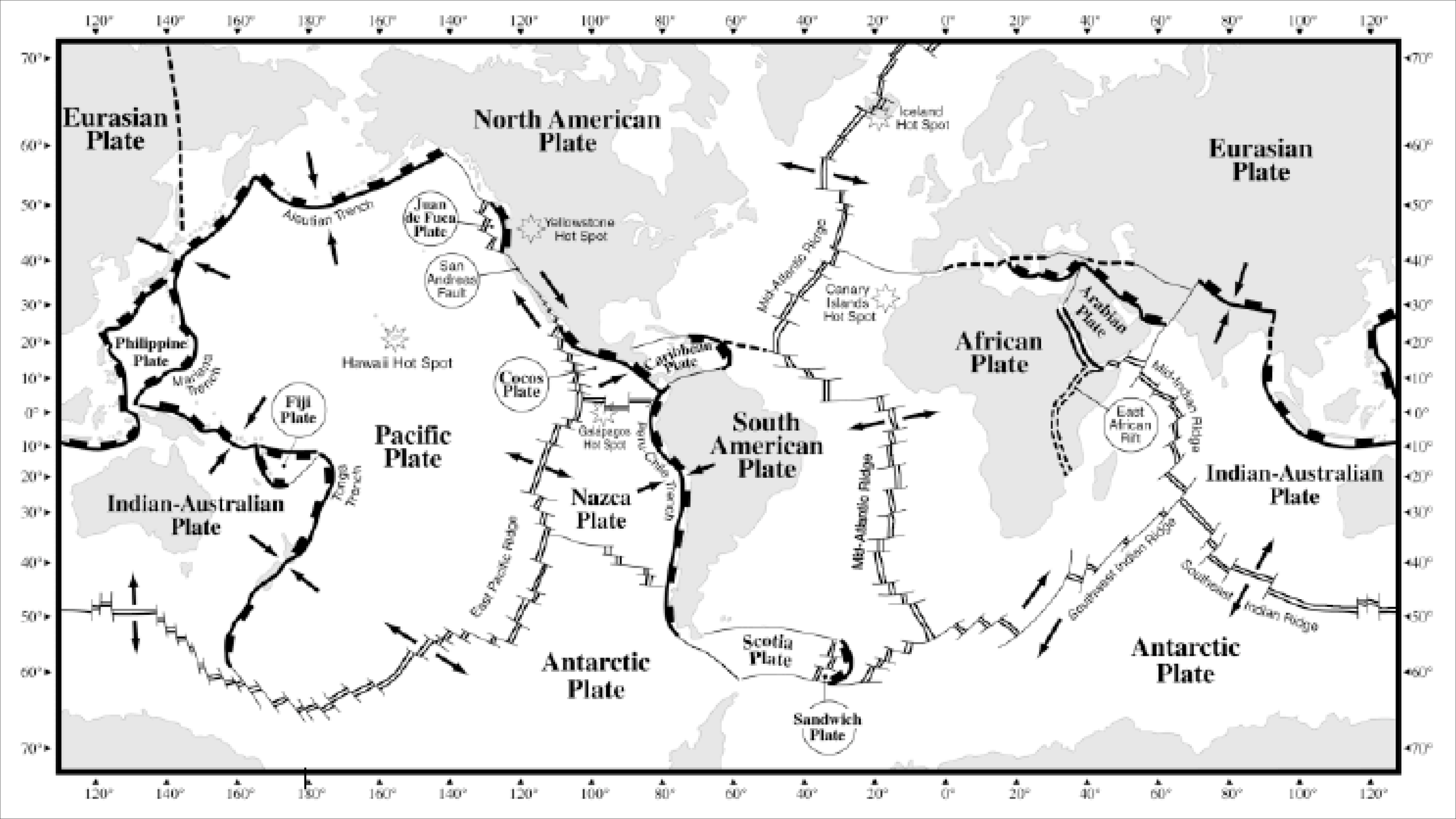
Transform



Divergent

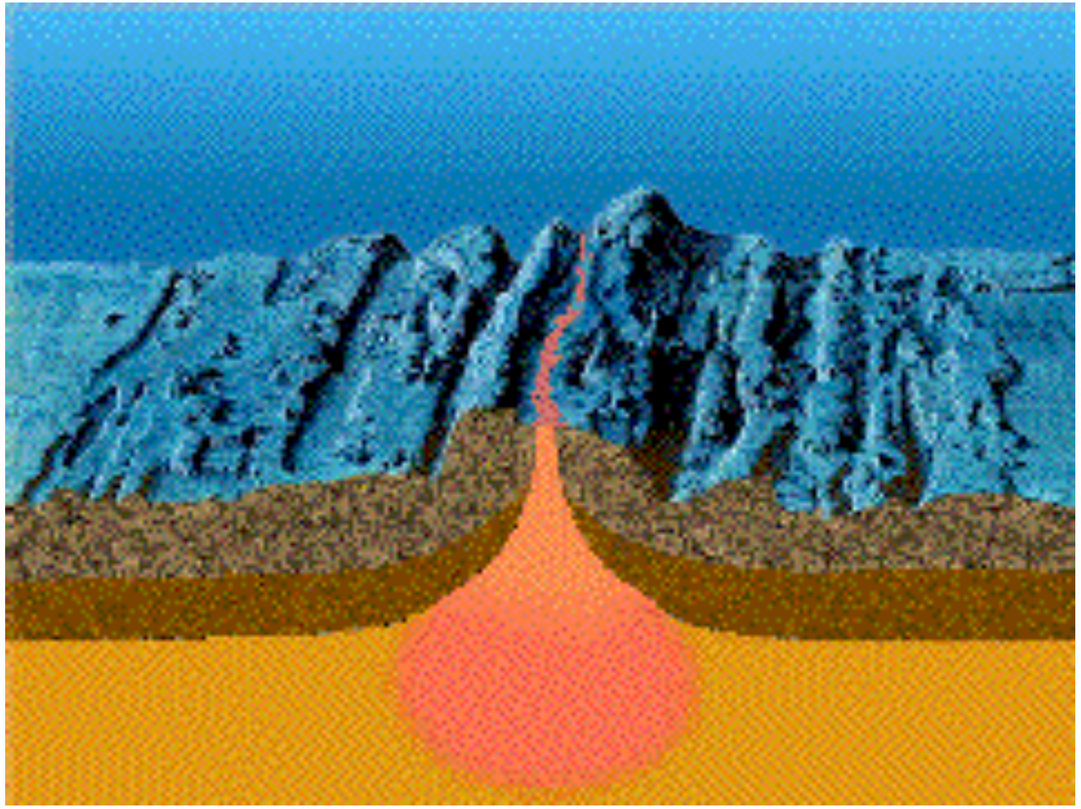


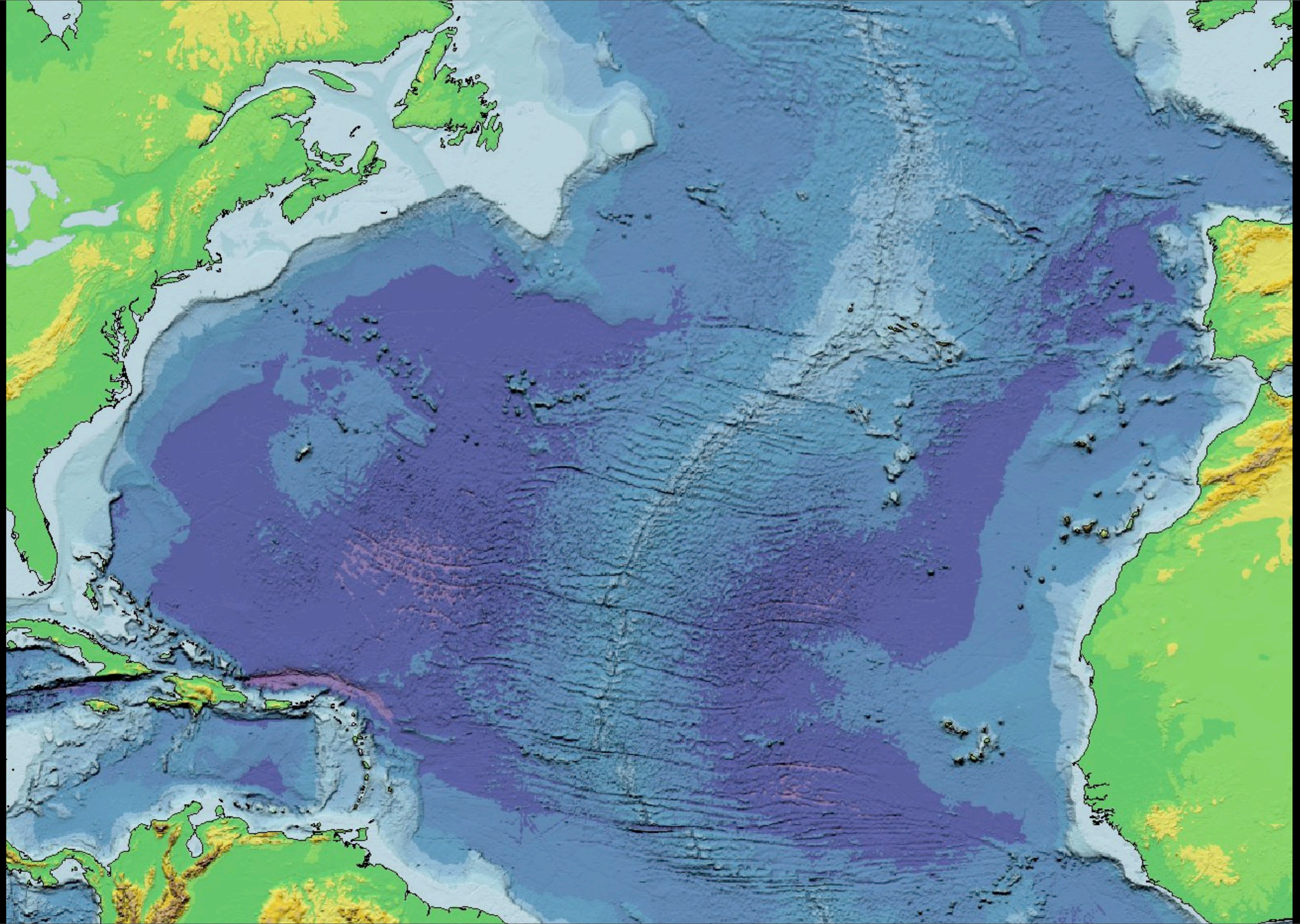
Convergent


Eurasian Plate
North American Plate
Eurasian Plate
Iceland Hot Spot
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Juan de Fuca Plate
Yellowstone Hot Spot
San Andreas Fault
Mid-Atlantic Ridge
Canary Islands Hot Spot
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Mariana Trench
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Caribbean Plate
Mid-Indian Ridge
East African Rift
Fiji Plate
Pacific Plate
Galapagos Hot Spot
Peru-Chile Trench
South American Plate
Indian-Australian Plate
Tonga Trench
Nazca Plate
Mid-Atlantic Ridge
Indian-Australian Plate
East Pacific Ridge
Southwest Indian Ridge
Southeast Indian Ridge
Scotia Plate
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120° 140° 160° 180° 160° 140° 120° 100° 80° 60° 40° 20° 0° 20° 40° 60° 80° 100° 120°
70° 60° 50° 40° 30° 20° 10° 0° 10° 20° 30° 40° 50° 60° 70°

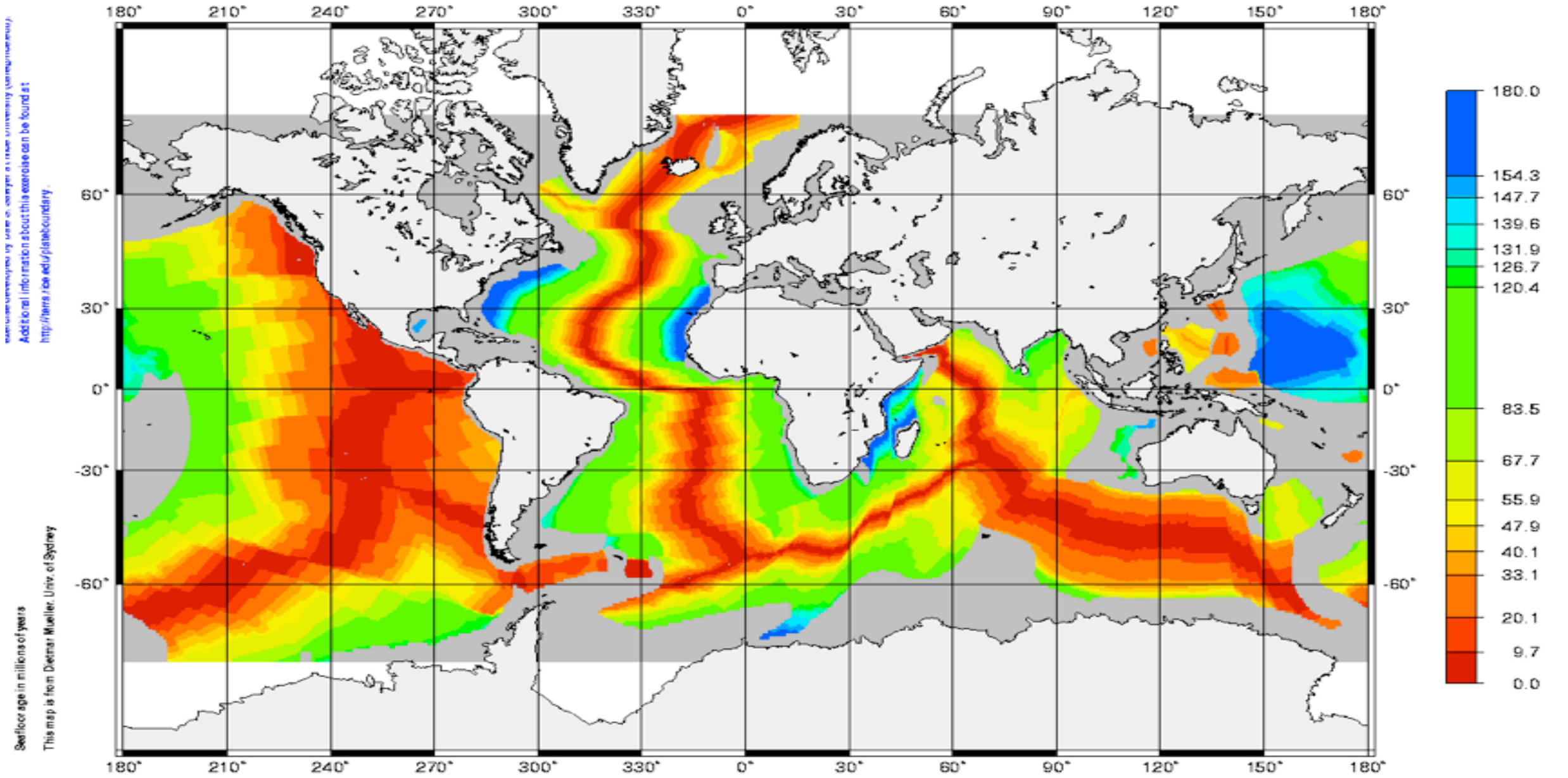
Divergent Plate Boundaries

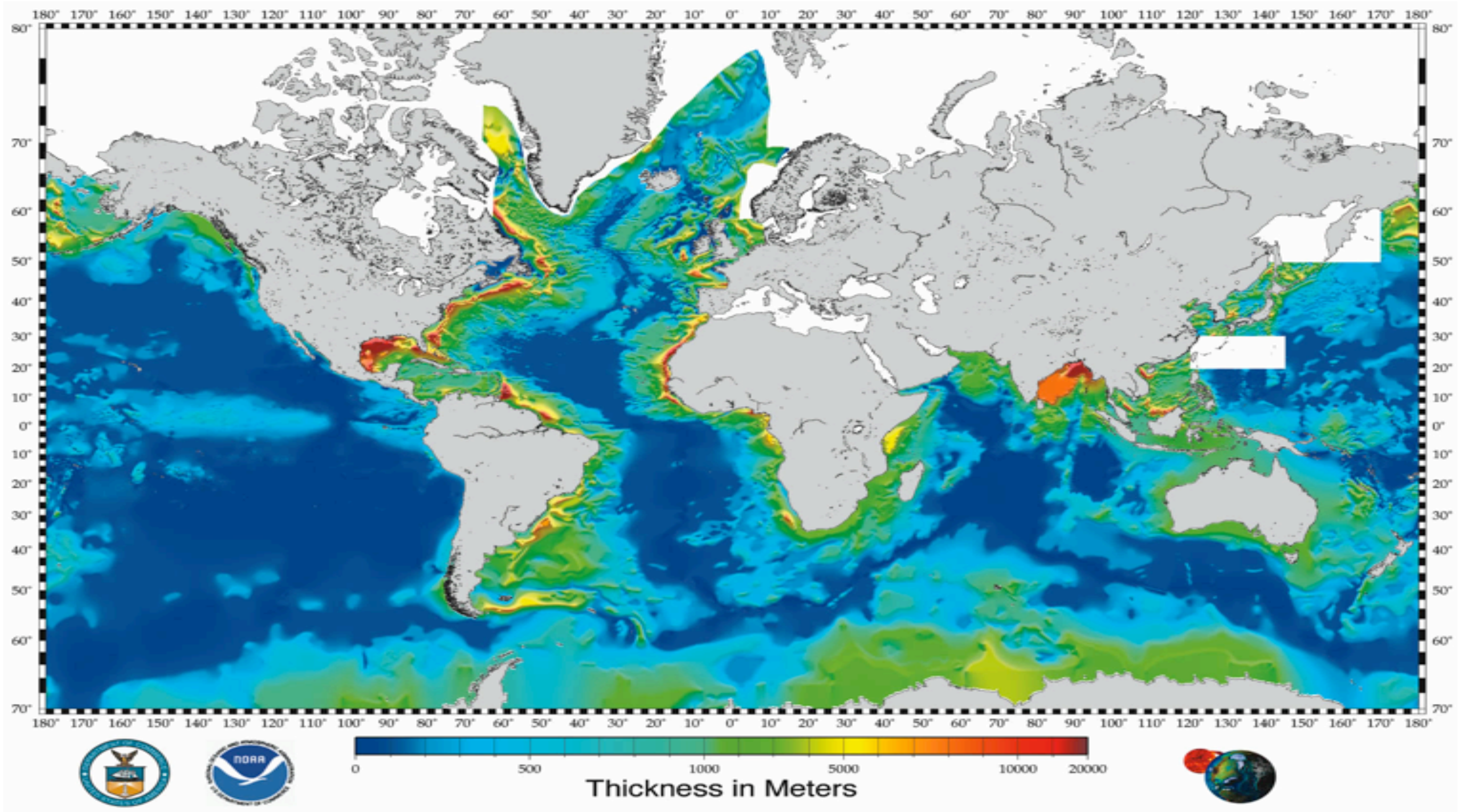
- Plates move apart
- Magma rises and cools forming new sea-floor
- Youngest rock is near the ridge, it gets older as you move away
- The earth's magnetic field is recorded in the rock as it forms. We have a record of the earth's magnetic reversals on either side of the ridge.





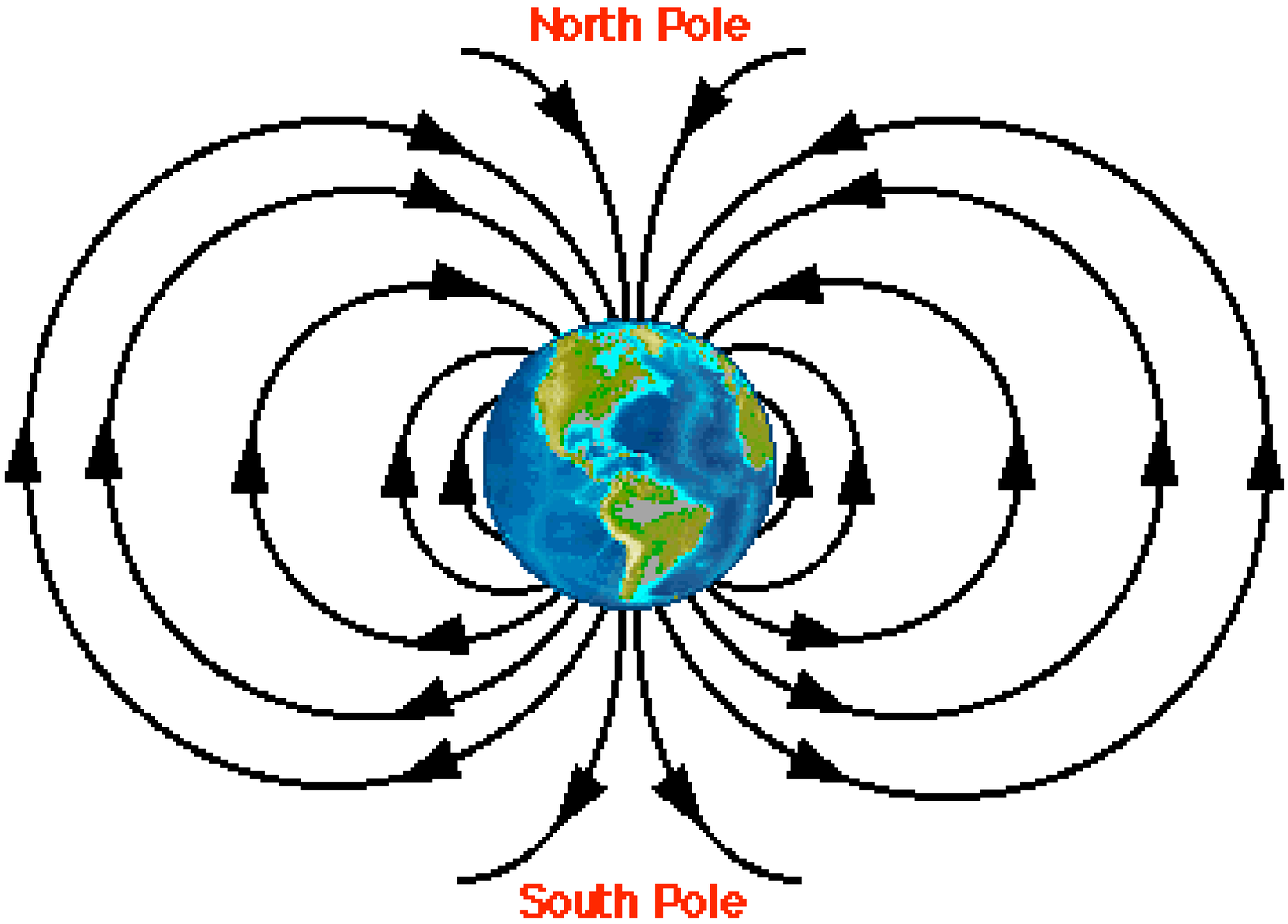
AGE OF SEA FLOOR

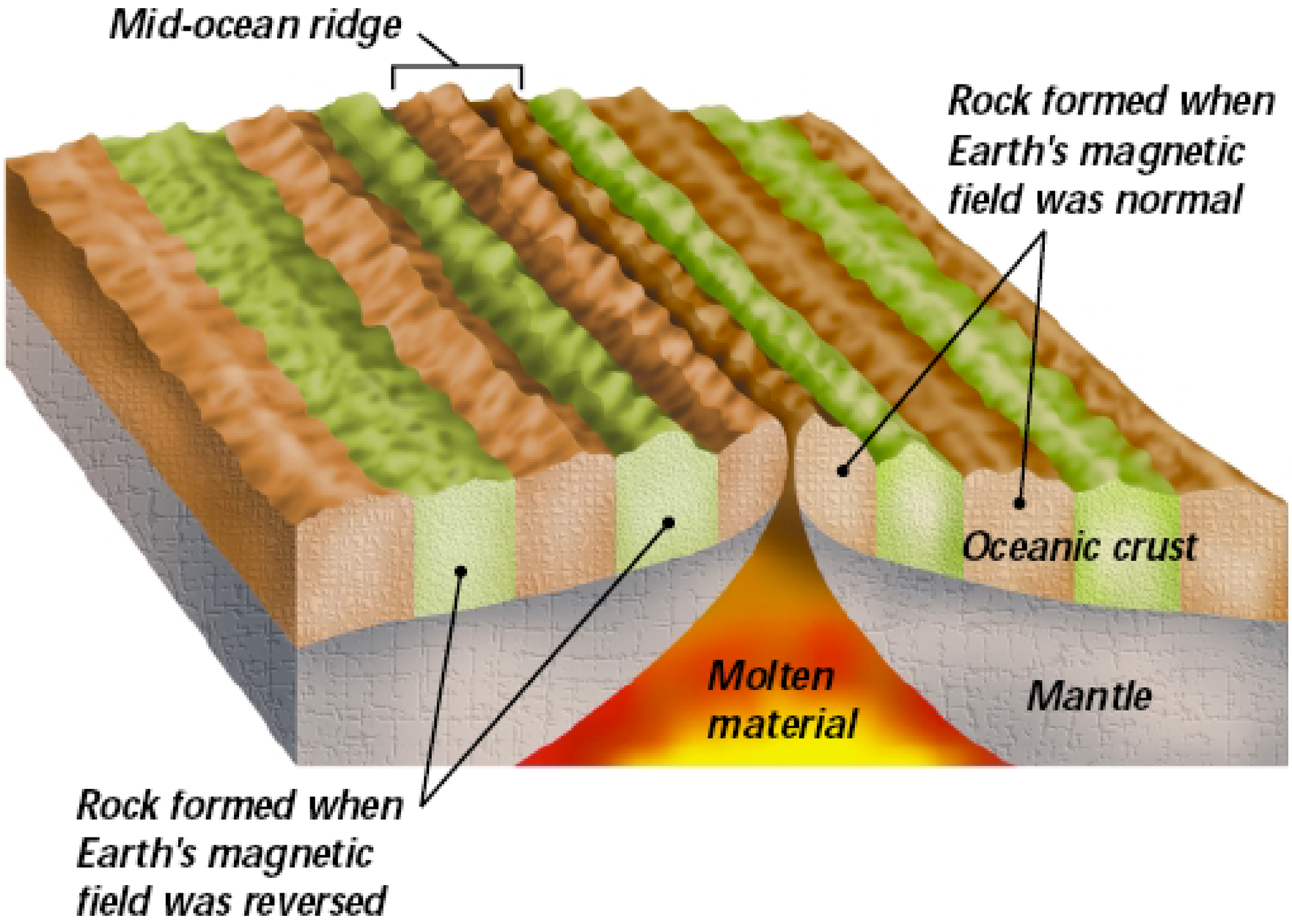



180° 170° 160° 150° 140° 130° 120° 110° 100° 90° 80° 70° 60° 50° 40° 30° 20° 10° 0° 10° 20° 30° 40° 50° 60° 70° 80° 90° 100° 110° 120° 130° 140° 150° 160° 170° 180°
80°
70°
60°
50°
40°
30°
20°
10°
0°
10°
20°
30°
40°
50°
60°
70°
NOAA
0
500
1000
5000
10000
20000
Thickness in Meters

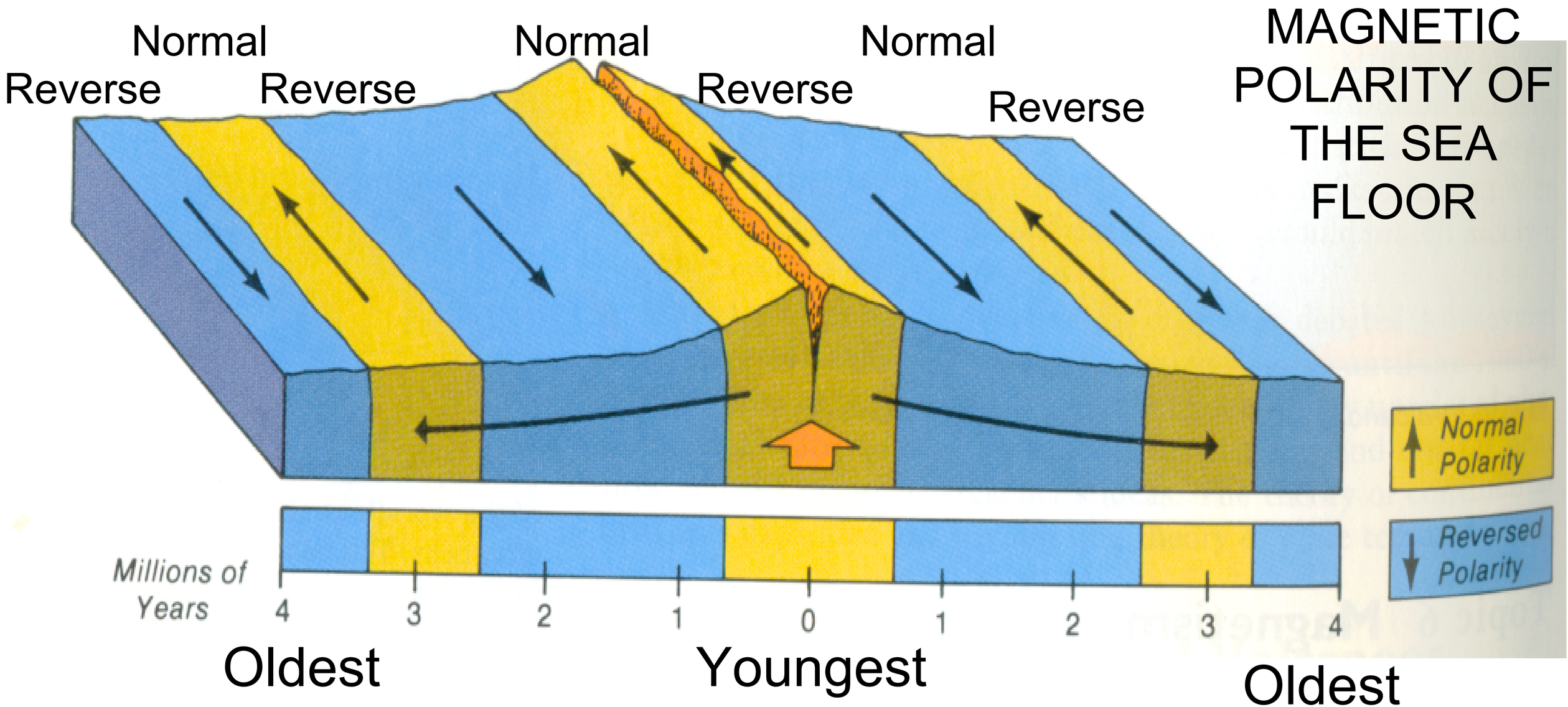


As distance from the ridge increases, the age of the sea-floor increases.


North Pole
South Pole


Mid-ocean ridge
Rock formed when Earth's magnetic field was normal
Oceanic crust
Molten material
Mantle
Rock formed when Earth's magnetic field was reversed

Evidence of Sea Floor Spreading

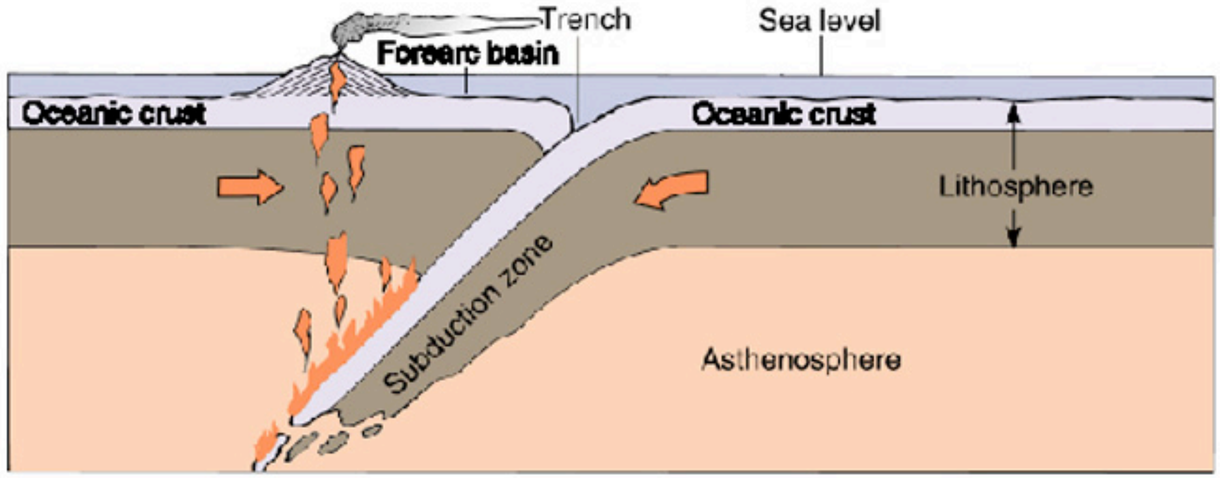


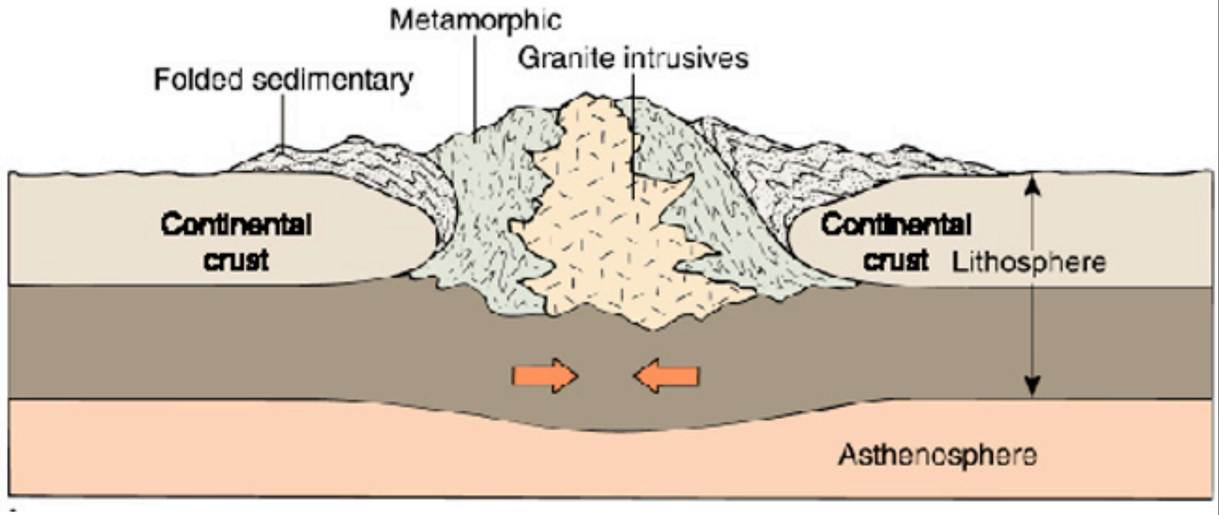


The pattern of magnetism in the sea-floor matches on either side of the ridge. This proves sea-floor spreading.

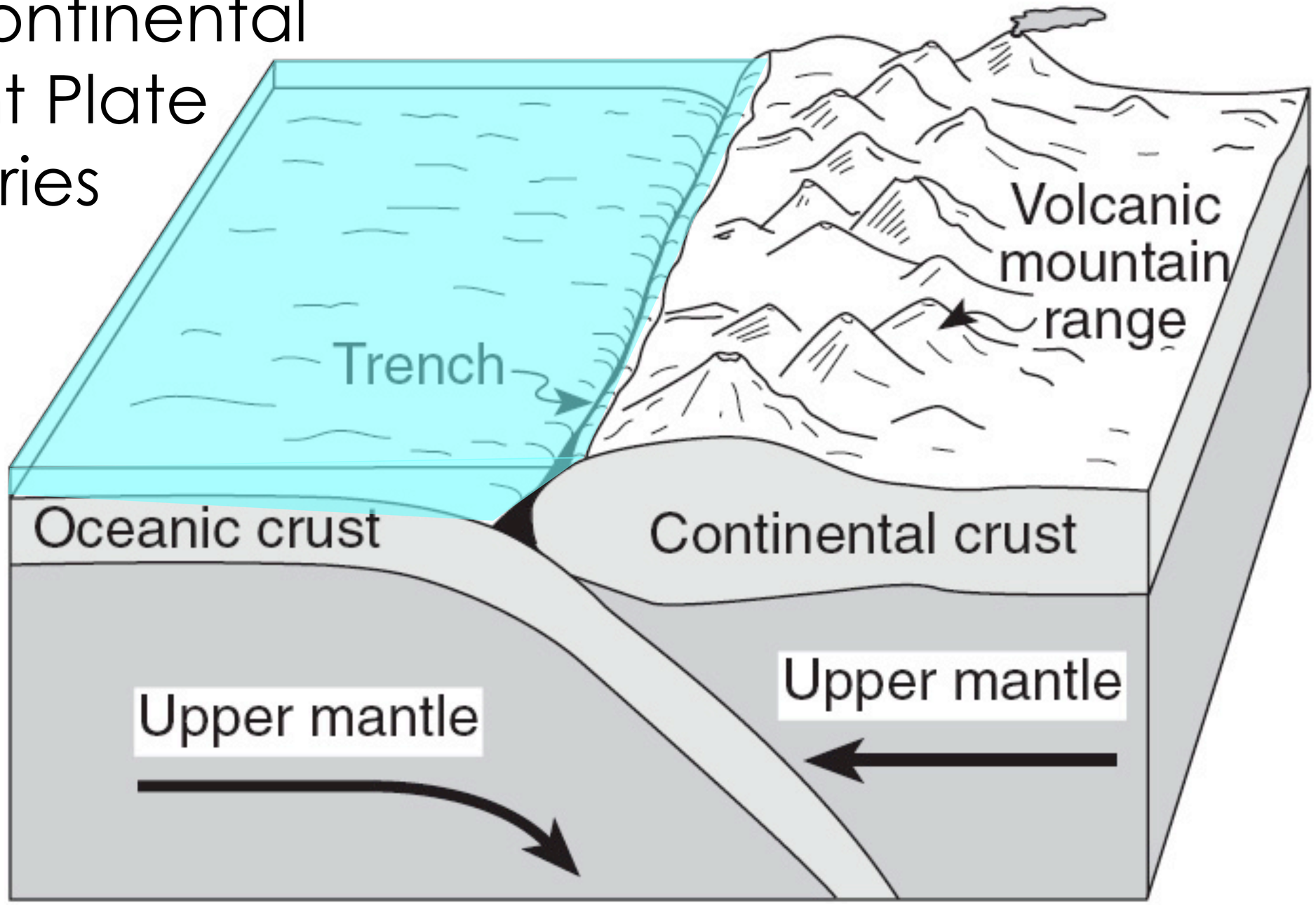
Convergent Plate Boundaries

- Plates move together
- Three types depending on crust involved:
  - Subduction zone (oceanic/ continental)
  - Island arc (oceanic/oceanic)
  - Collision zone (continental/ continental)
- Earthquakes and volcanoes are common

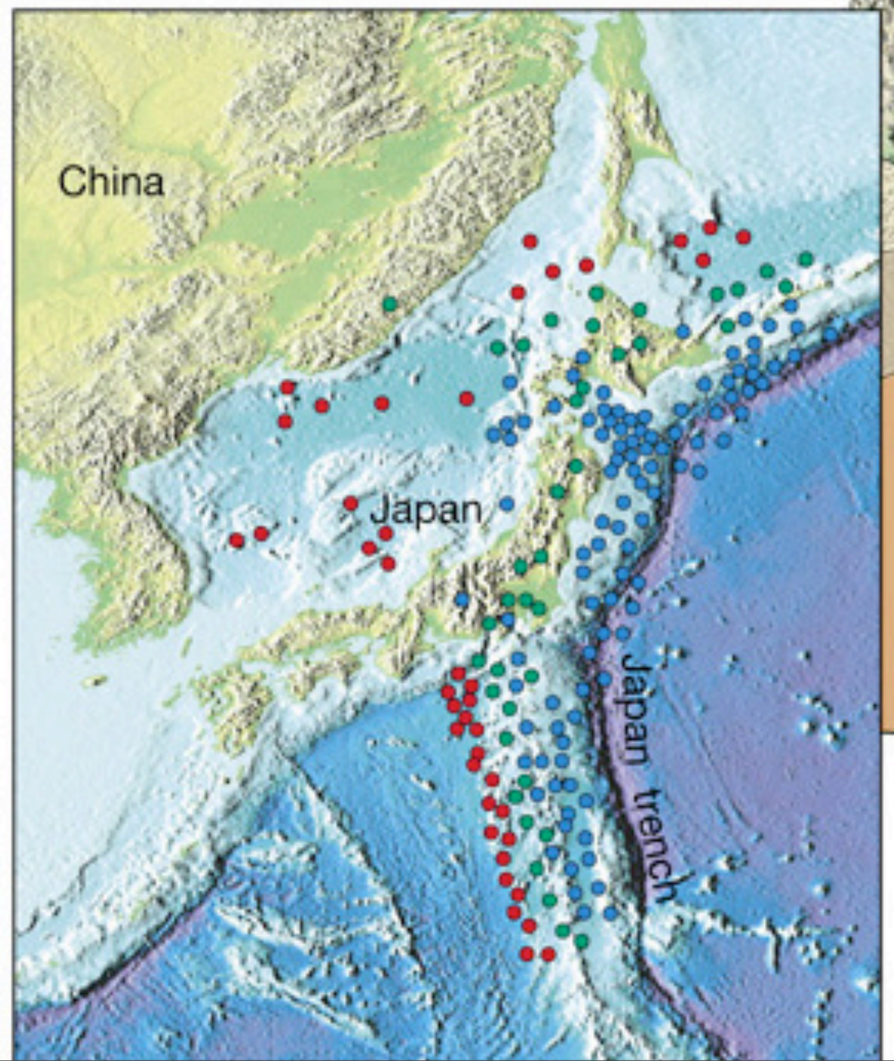


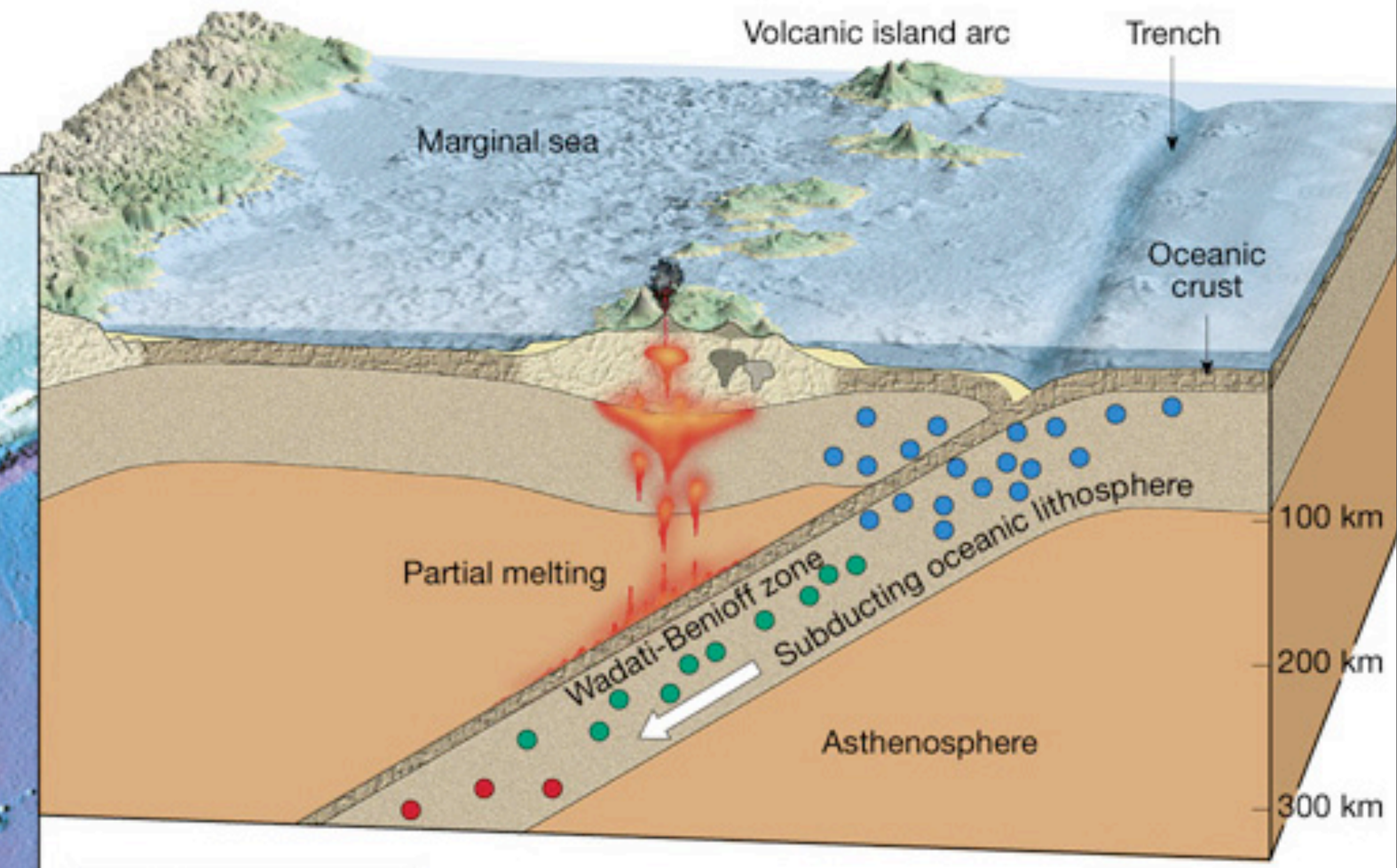


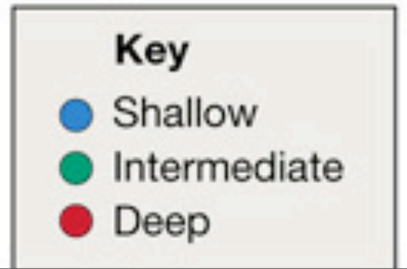
Oceanic to Continental Convergent Plate Boundaries



Oceanic to Oceanic Convergent Plate Boundaries



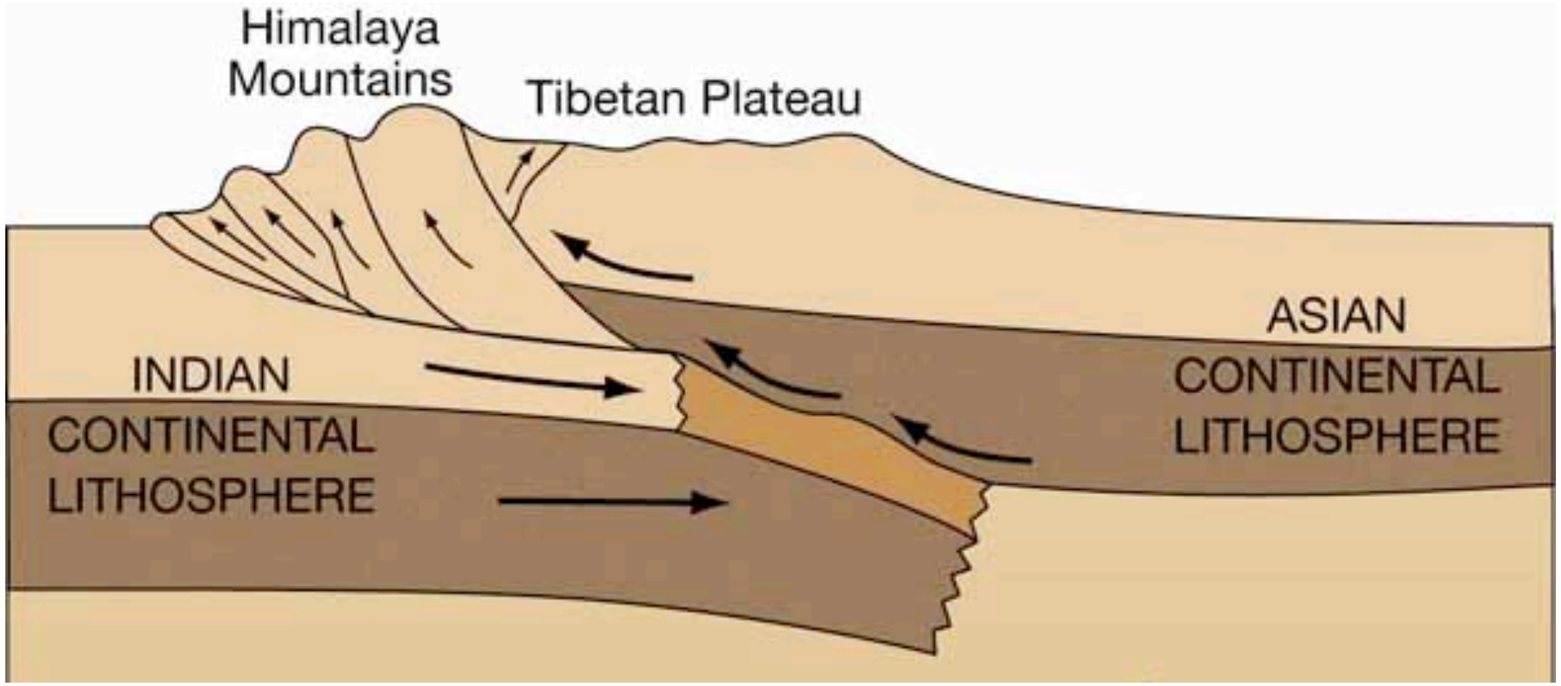


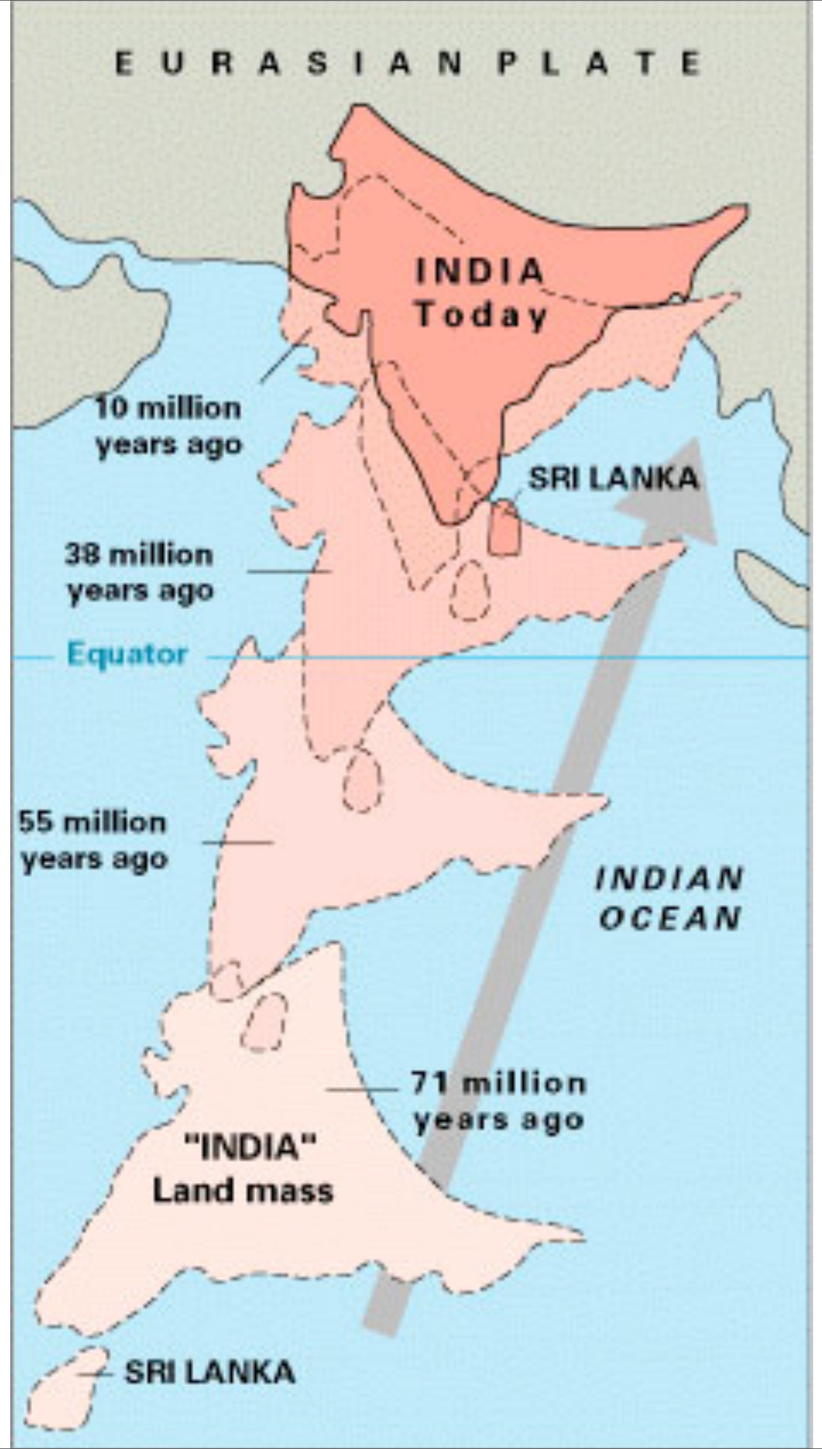




The depth of earthquakes increases as you travel over the subducting plate.

Continental to Continental Convergent Plate Boundaries

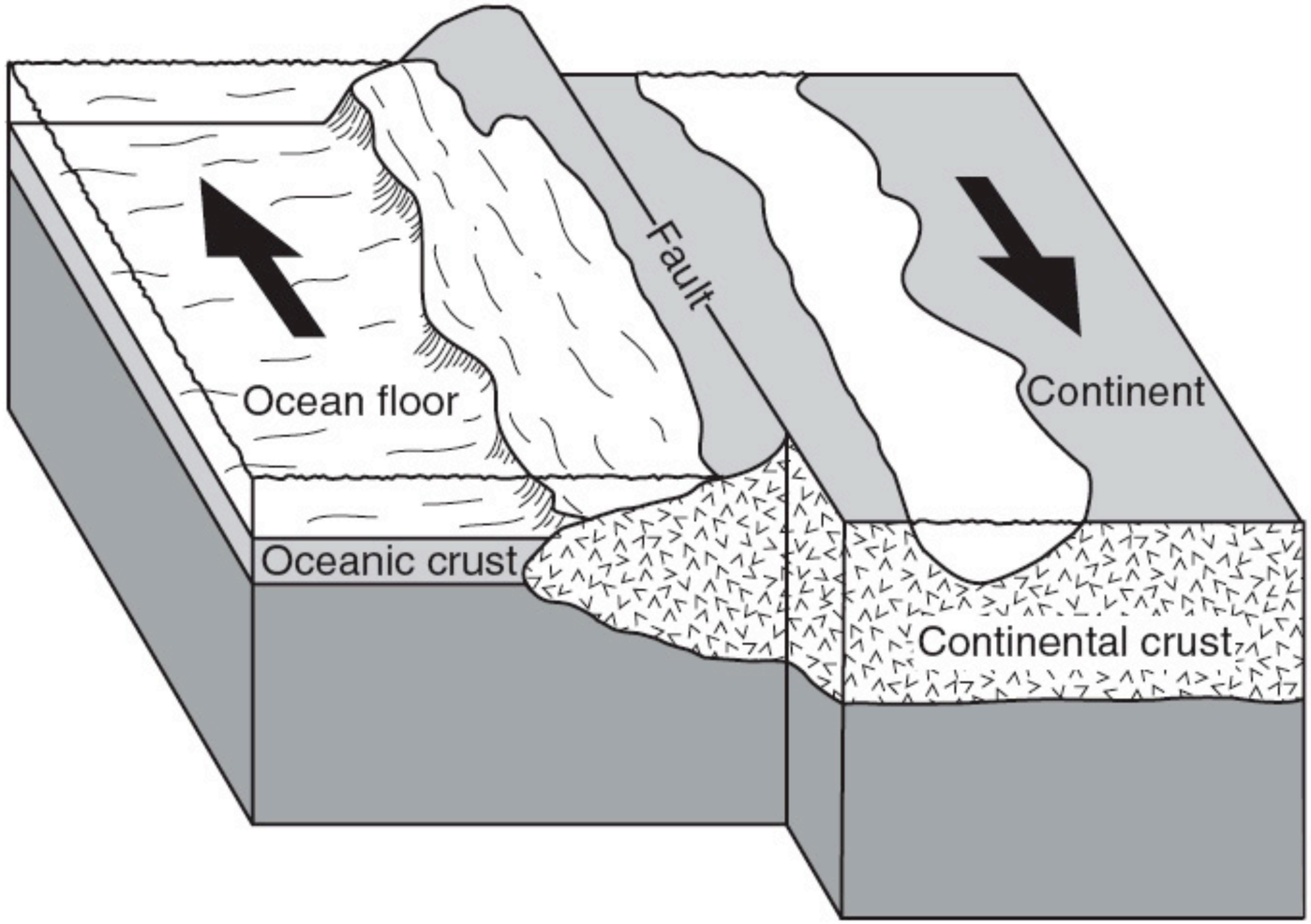






Transform Plate Boundaries

- Plates slide past one another
- Earthquakes are common
- Common Example: San Andreas Fault



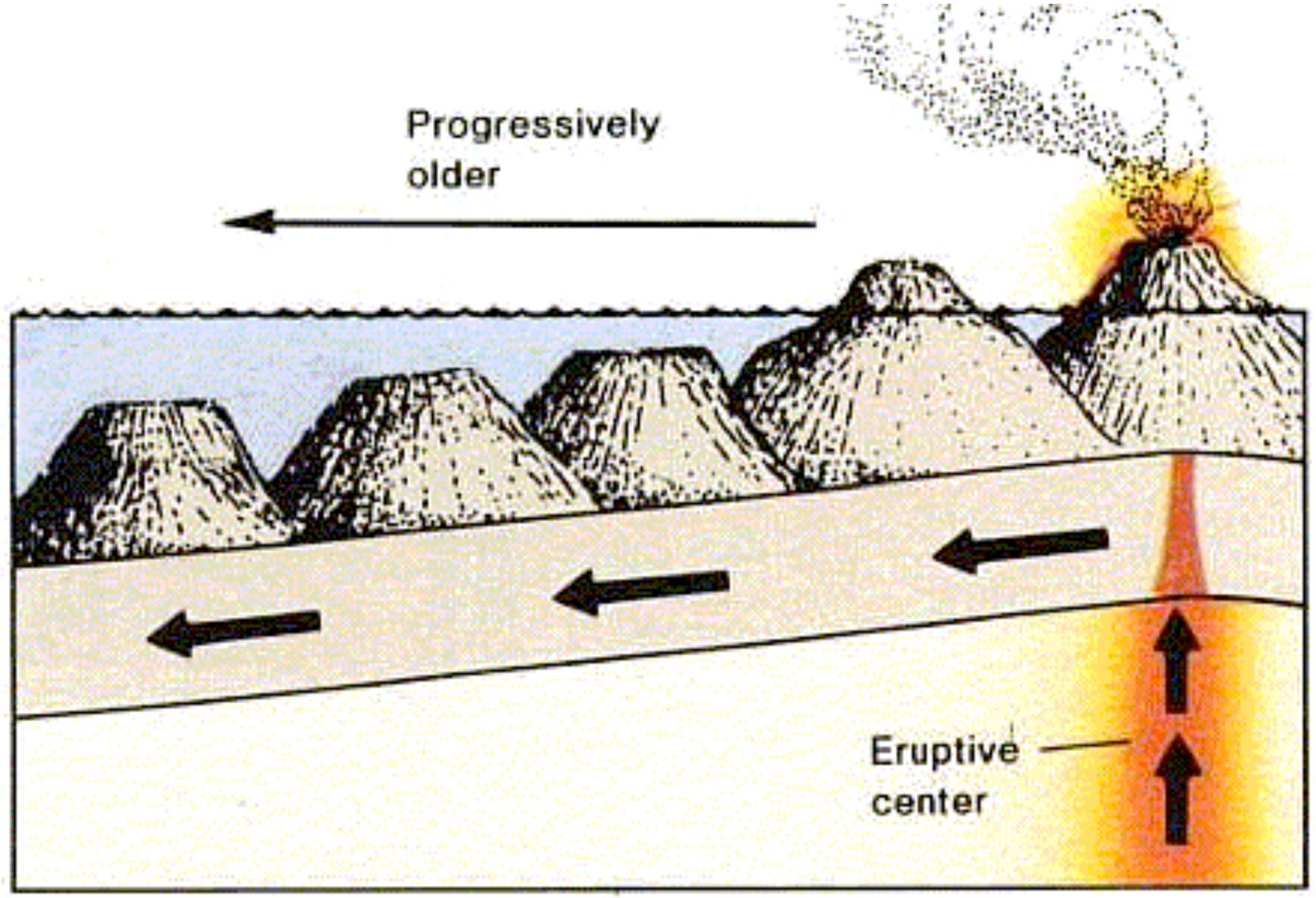


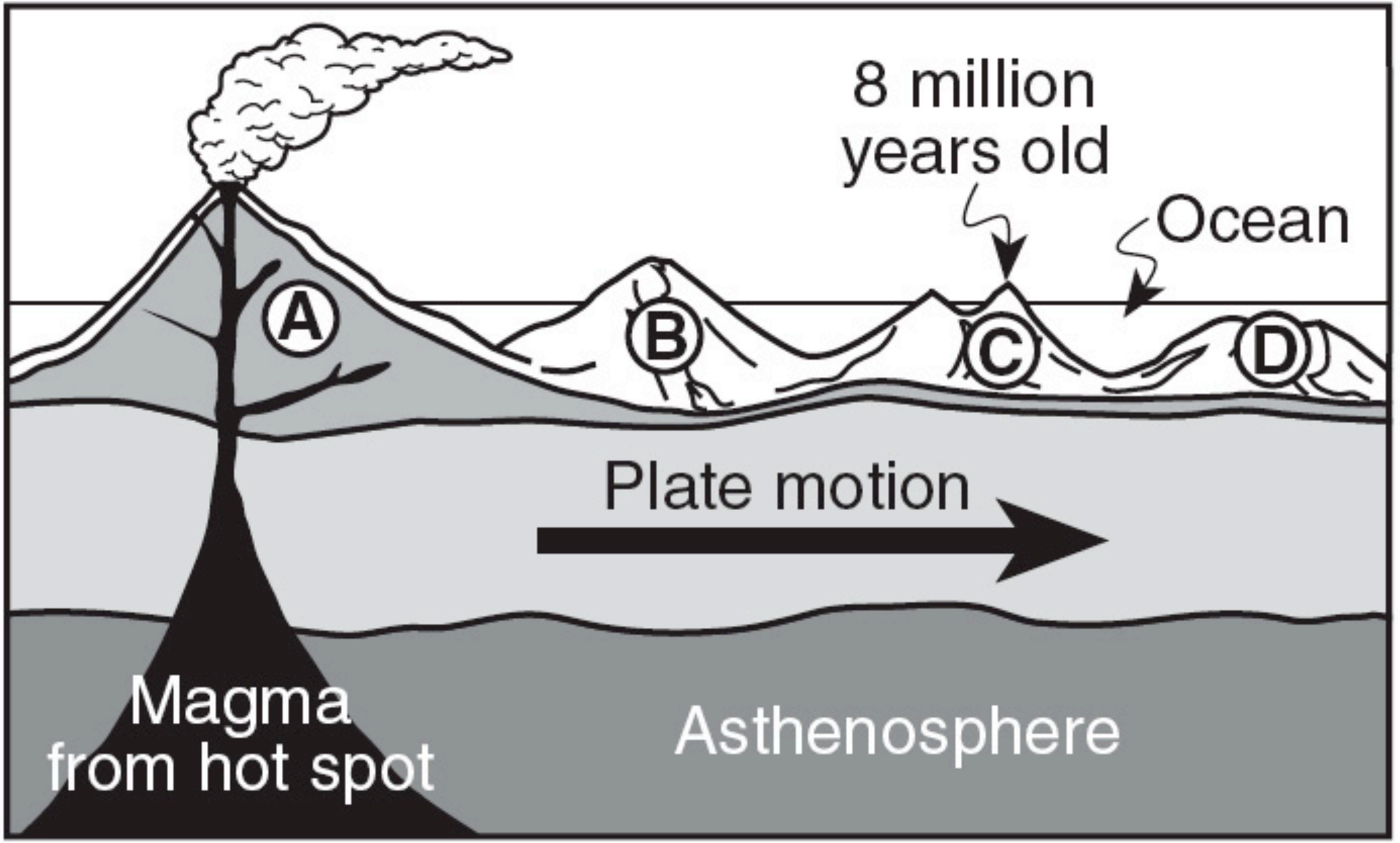
San Andreas Fault

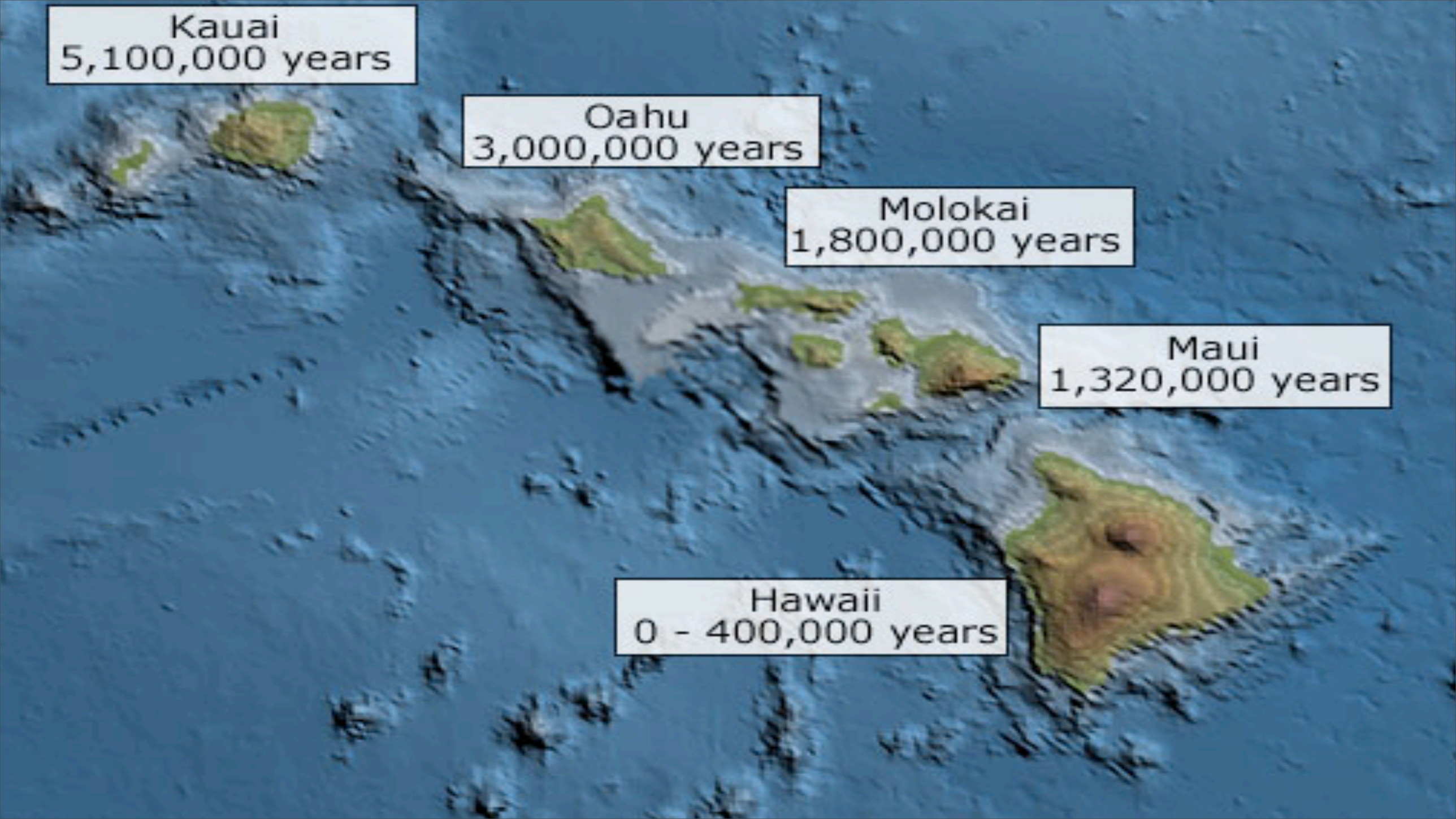
California, USA

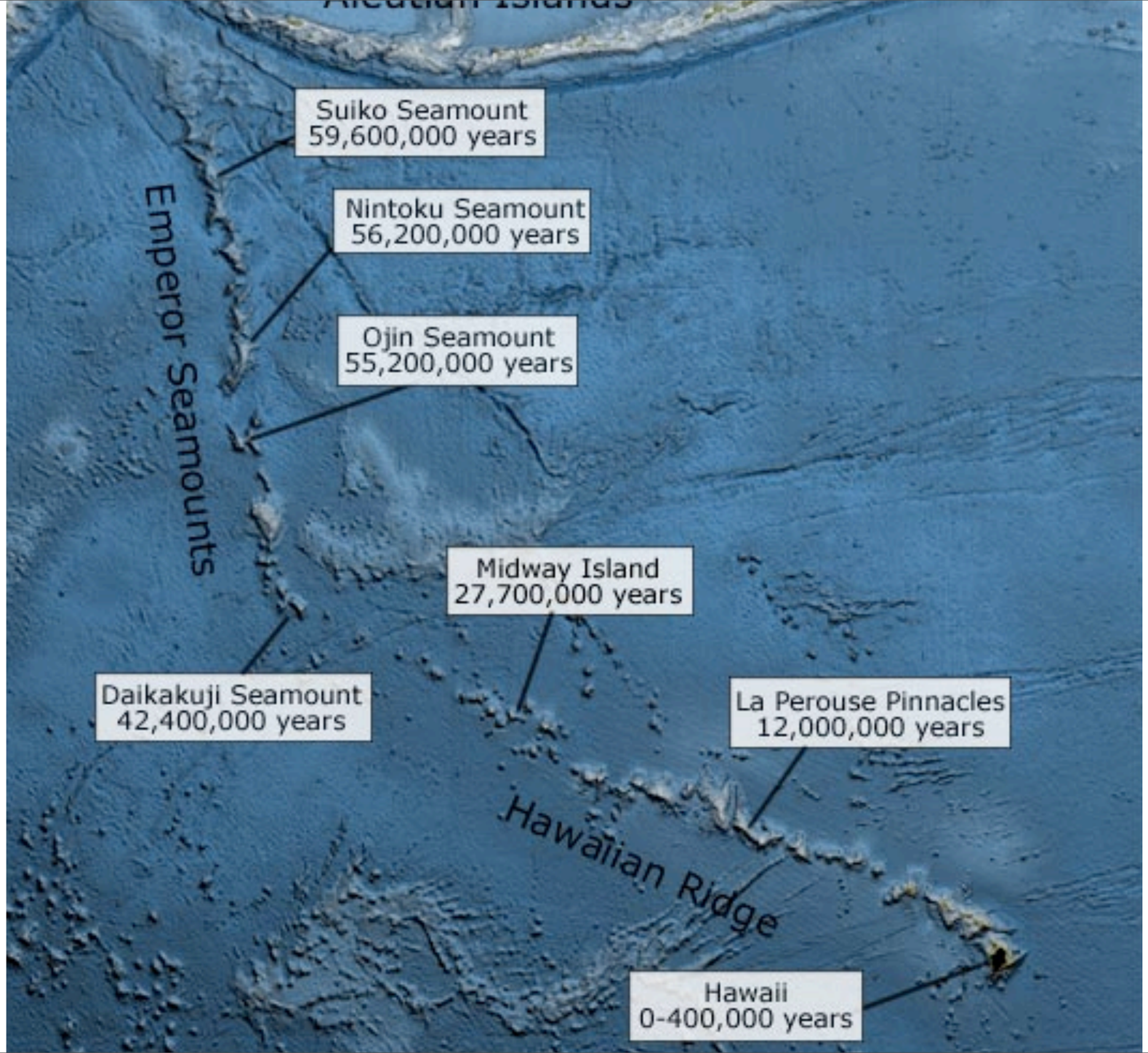
Hot Spots

- Volcanism away from a plate boundary
- Magma rises through the mantle forming an active volcano
- The plate moves over this spot forming a chain of islands with the active volcano being the one over the hot spot



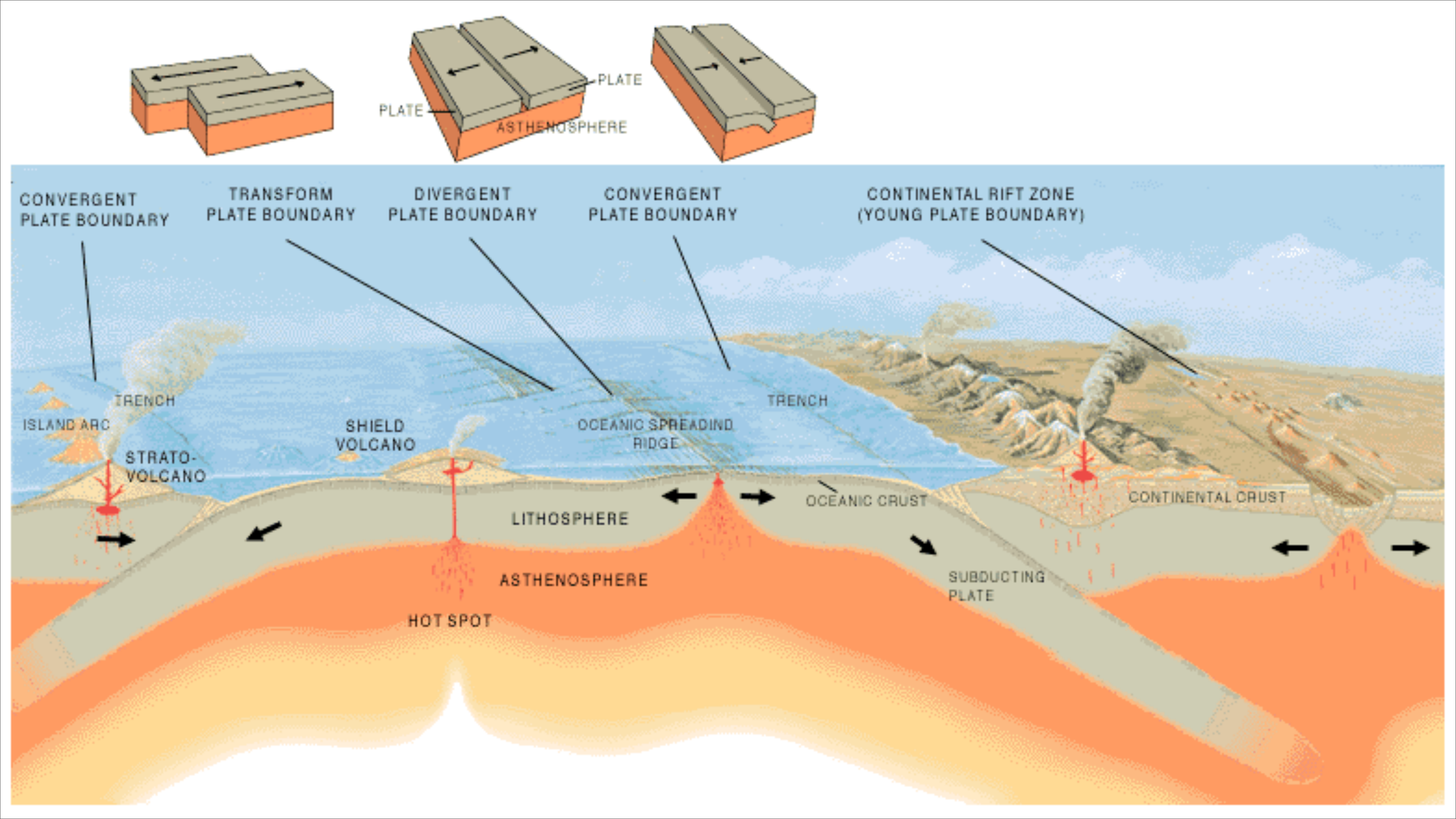

8 million
years old
Ocean
A
B
C
D
Plate motion
Magma
from hot spot
Asthenosphere


Kauai
5,100,000 years
Oahu
3,000,000 years
Molokai
1,800,000 years
Maui
1,320,000 years
Hawaii
0 - 400,000 years


Aleutian Islands
Suiko Seamount
59,600,000 years
Nintoku Seamount
56,200,000 years
Ojin Seamount
55,200,000 years
Emperor Seamounts
Midway Island
27,700,000 years
Daikakuji Seamount
42,400,000 years
La Perouse Pinnacles
12,000,000 years
Hawaiian Ridge
Hawaii
0-400,000 years

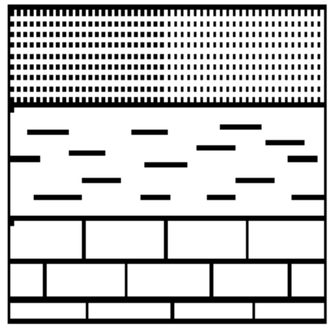


The active volcano, over the hot spot, is the youngest. Age increases as you get farther from the hot spot.

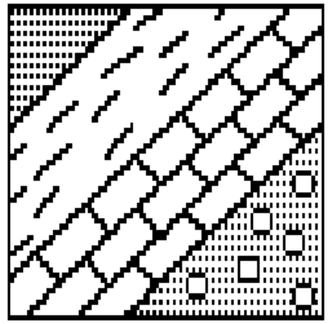

PLATE
PLATE
ASTHENOSPHERE
CONVERGENT PLATE BOUNDARY
TRANSFORM PLATE BOUNDARY
DIVERGENT PLATE BOUNDARY
CONVERGENT PLATE BOUNDARY
CONTINENTAL RIFT ZONE (YOUNG PLATE BOUNDARY)
TRENCH
ISLAND ARC
STRATO-VOLCANO
SHIELD VOLCANO
OCEANIC SPREADING RIDGE
TRENCH
LITHOSPHERE
OCEANIC CRUST
CONTINENTAL CRUST
ASTHENOSPHERE
SUBDUCTING PLATE
HOT SPOT

Crustal Deformation

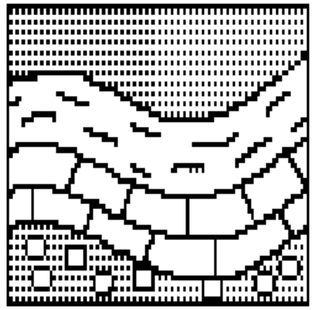
- Changes in rocks caused by crustal movements
  - Folds
  - Faults
  - Tilts
  - Uplift
  - Subsidence



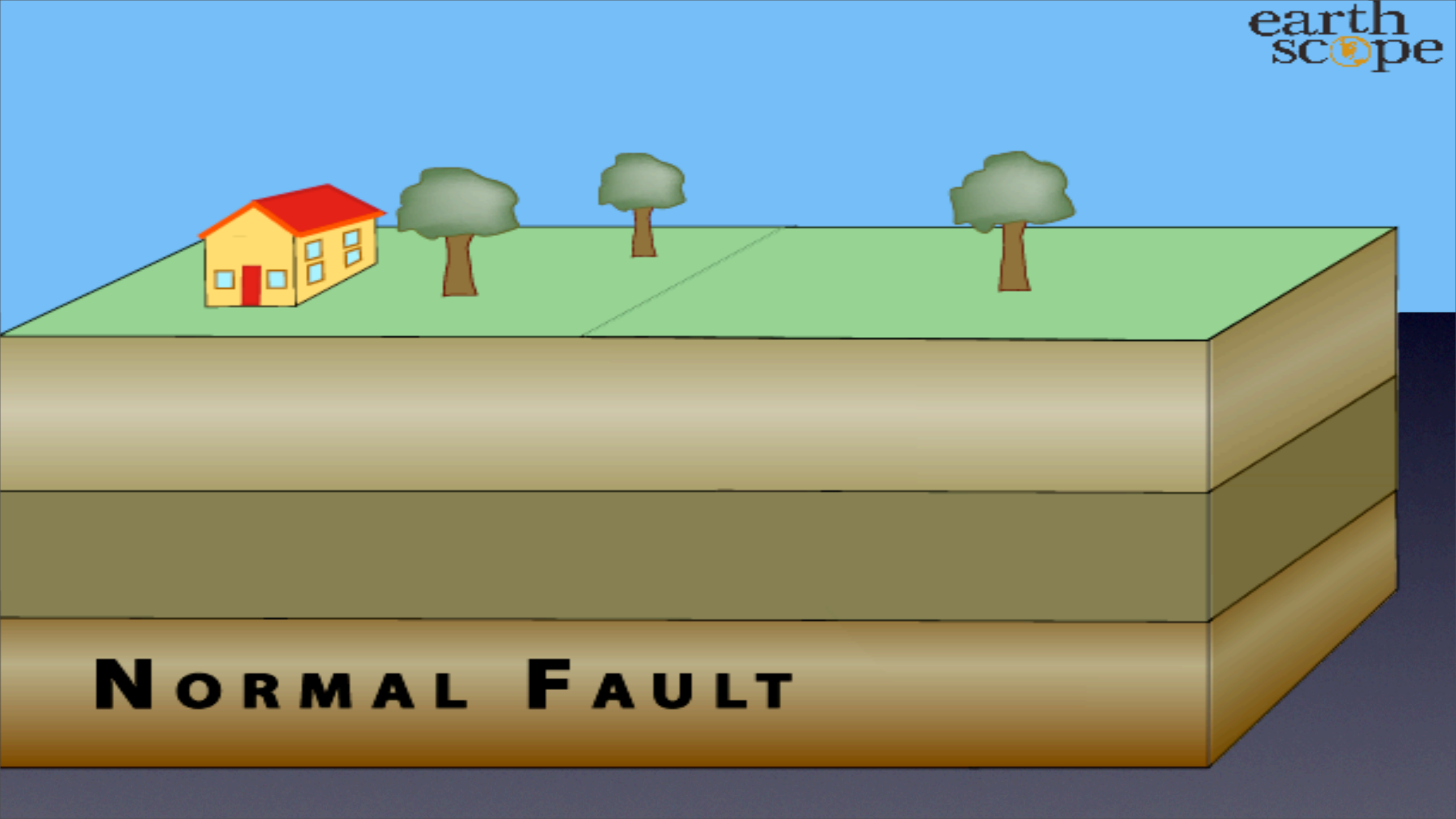
Undeformed Layers

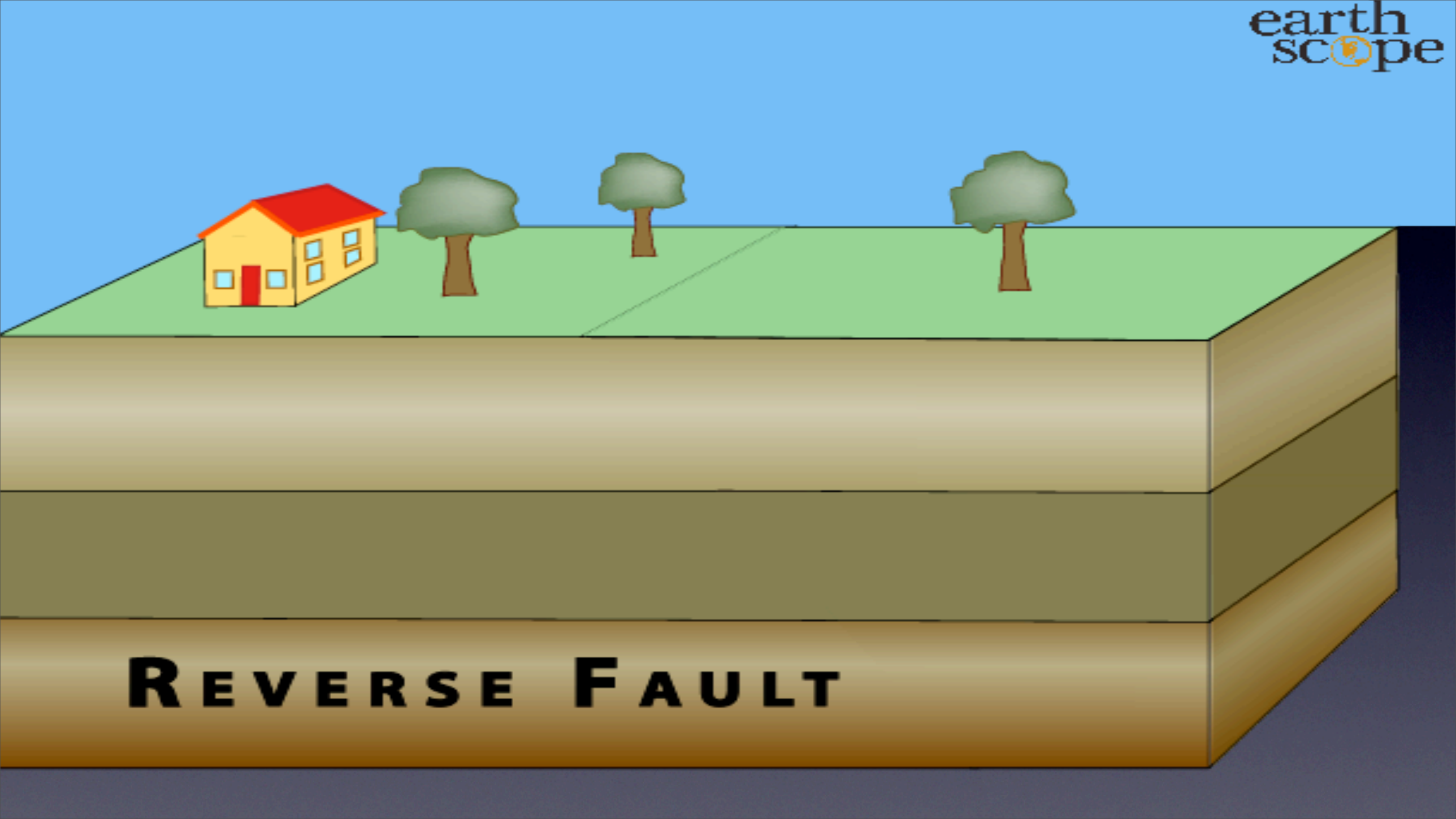


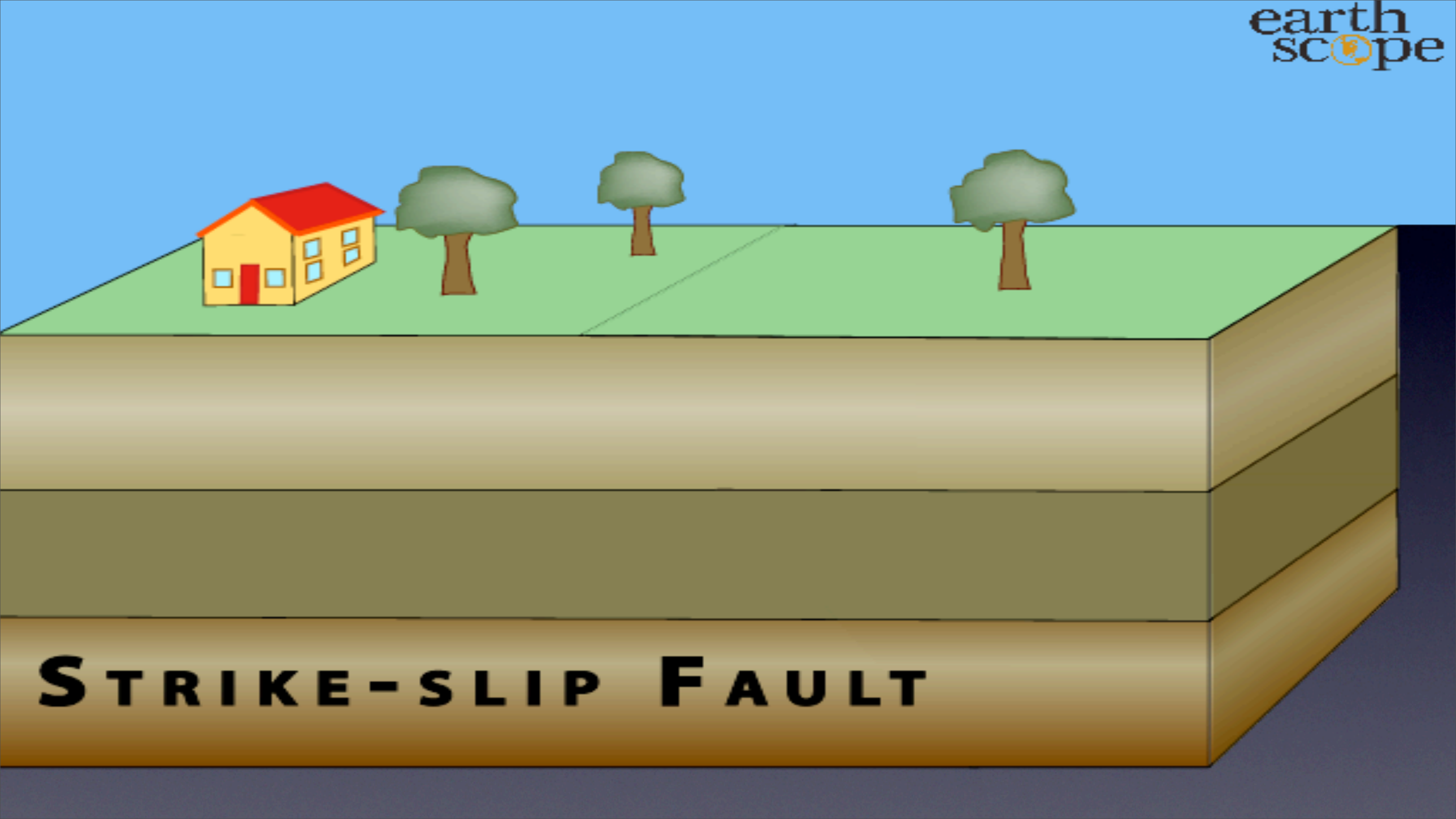
Tilted Layers

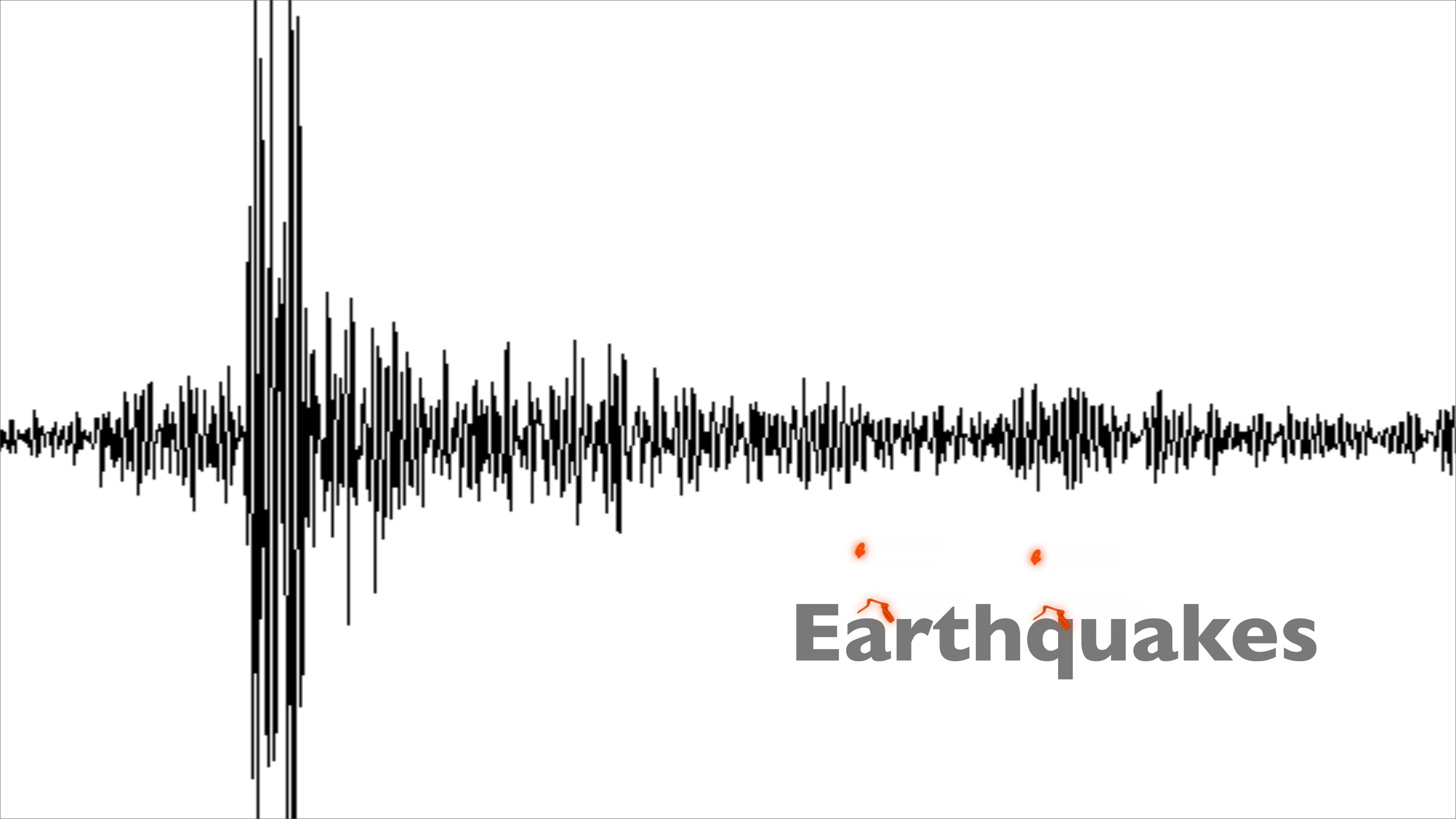


Folded Layers


earth scope
NORMAL FAULT


earth scope
REVERSE FAULT


earth scope
STRIKE-SLIP FAULT

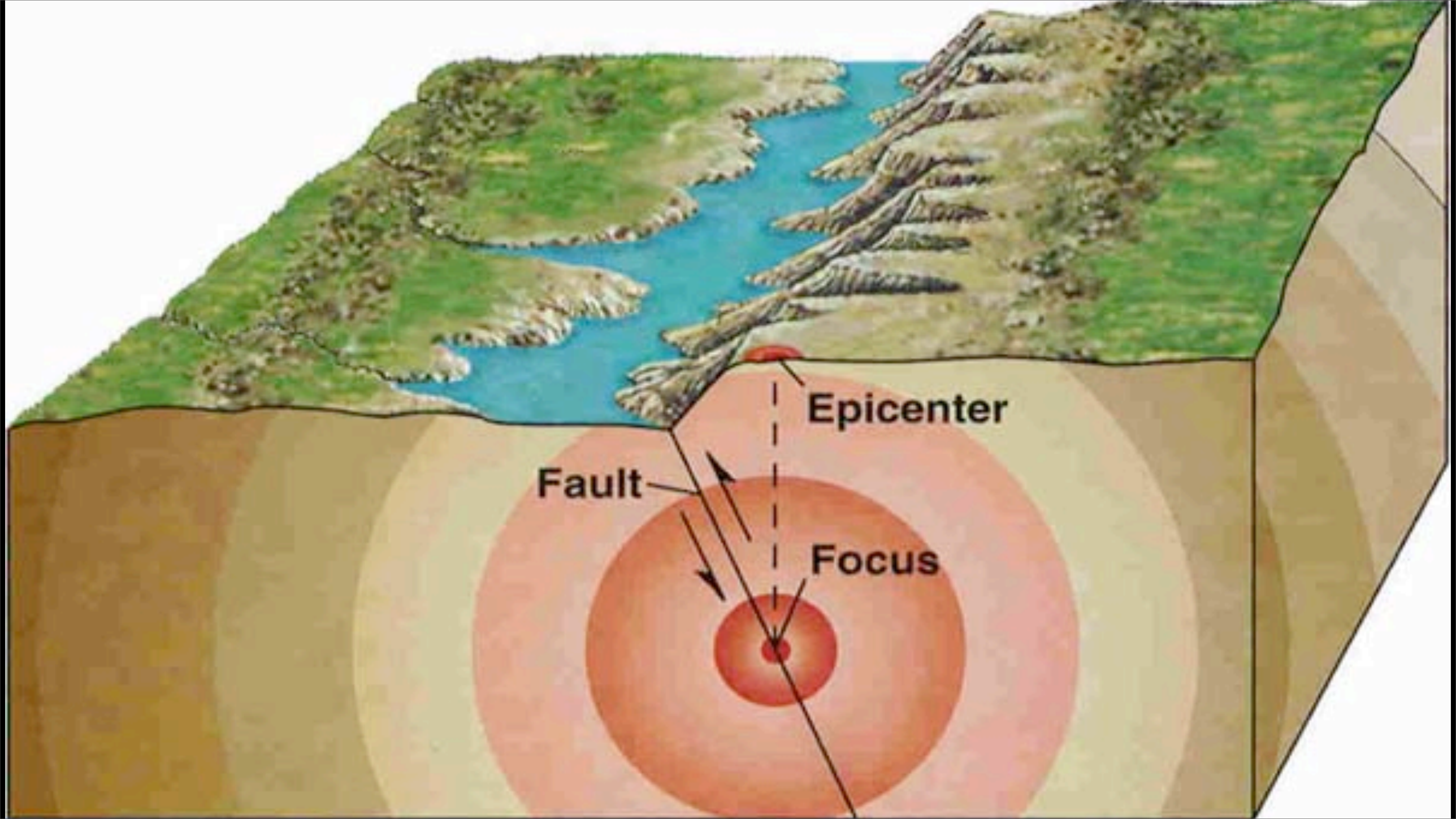


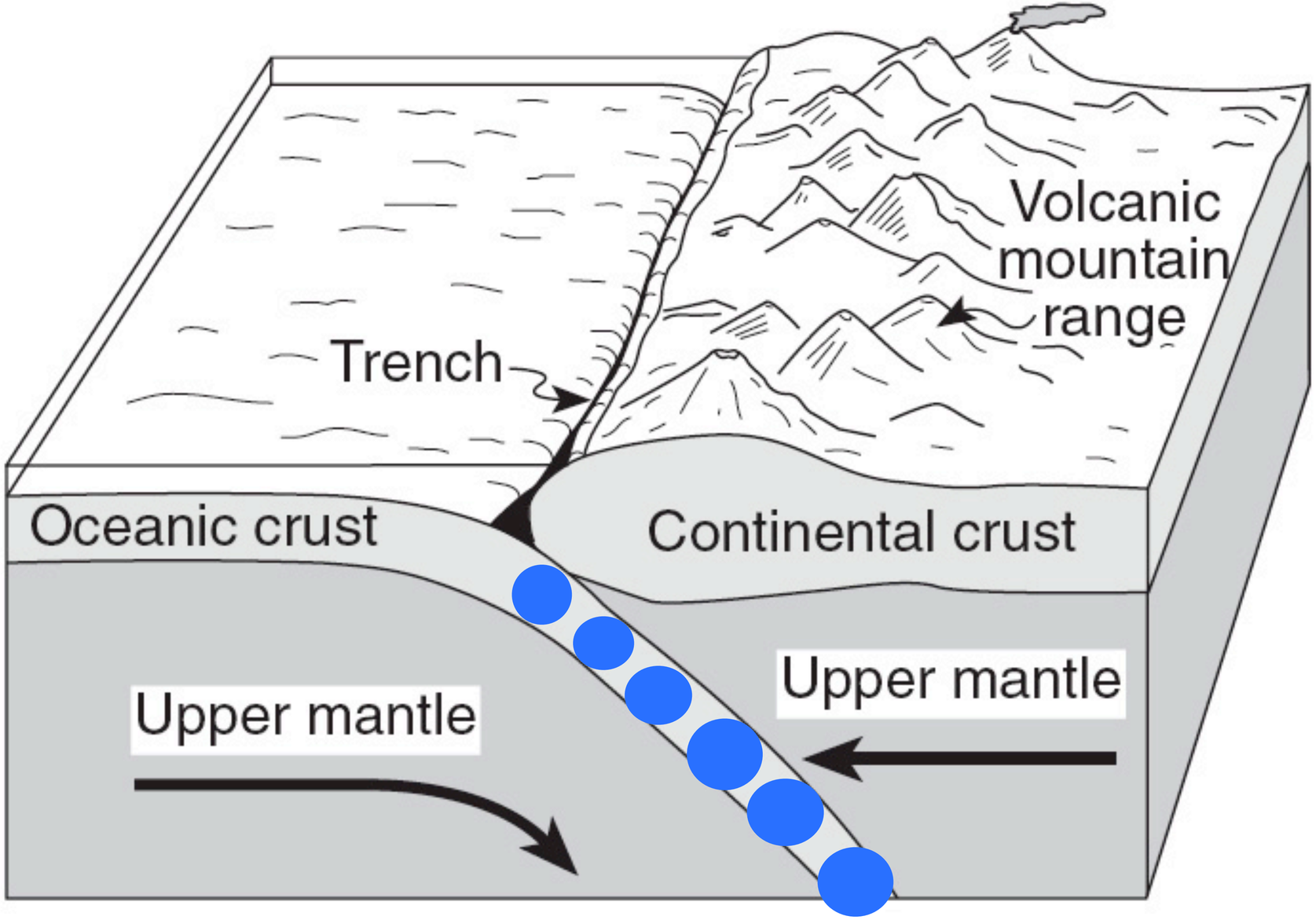
Earthquakes



Parts of an Earthquake

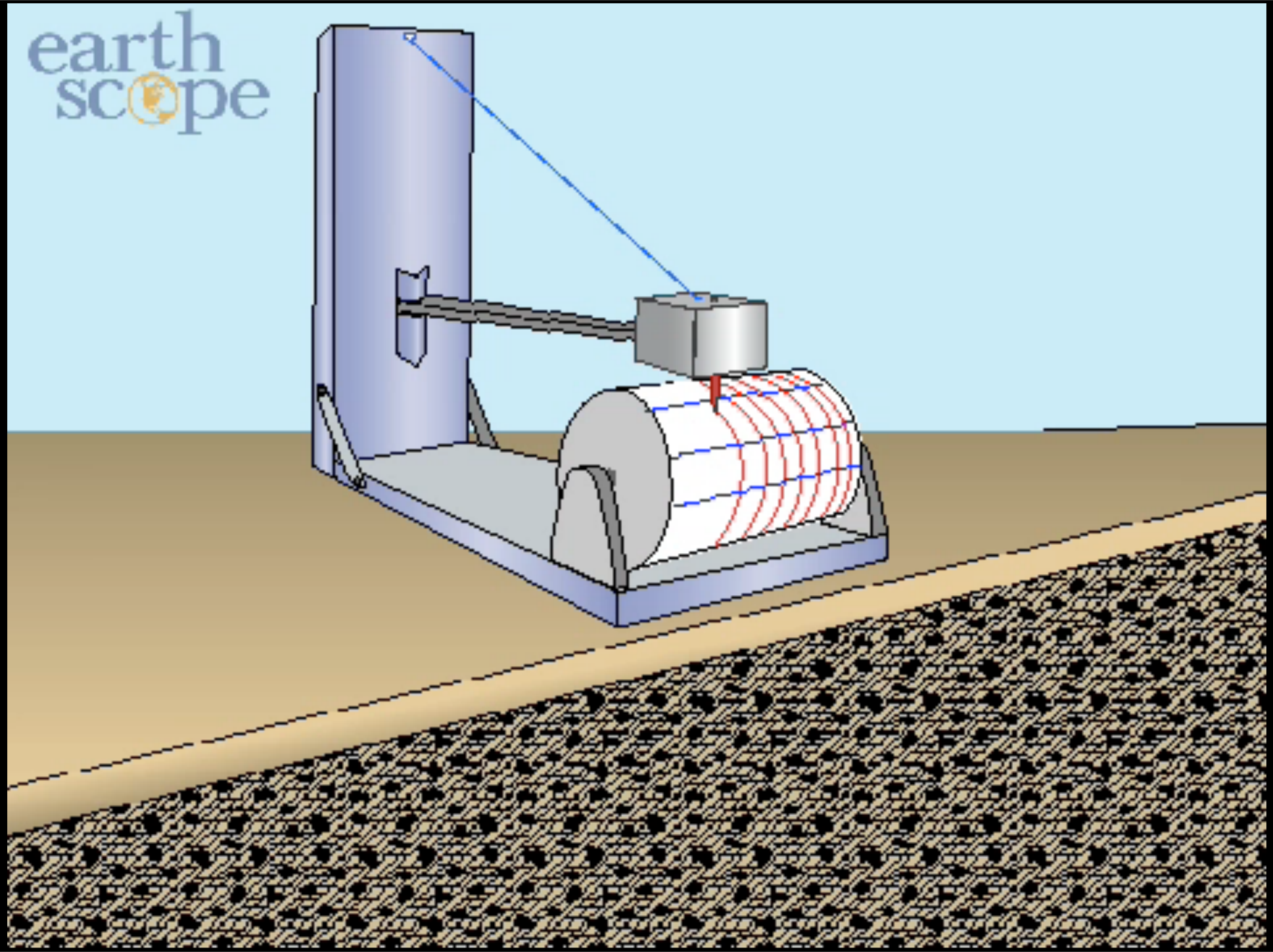
- Focus is where the Earthquake actually occurs inside the Earth
- Deeper the Focus, the stronger the earthquake. Think about a subduction zone!!!!!! (Focal Depth)
- Epicenter is the location at the surface of crust just above the Focus.
- Seismic Waves are the different waves (vibrations) that are sent throughout the planet from the earthquake
  - P- Waves
  - S-Waves

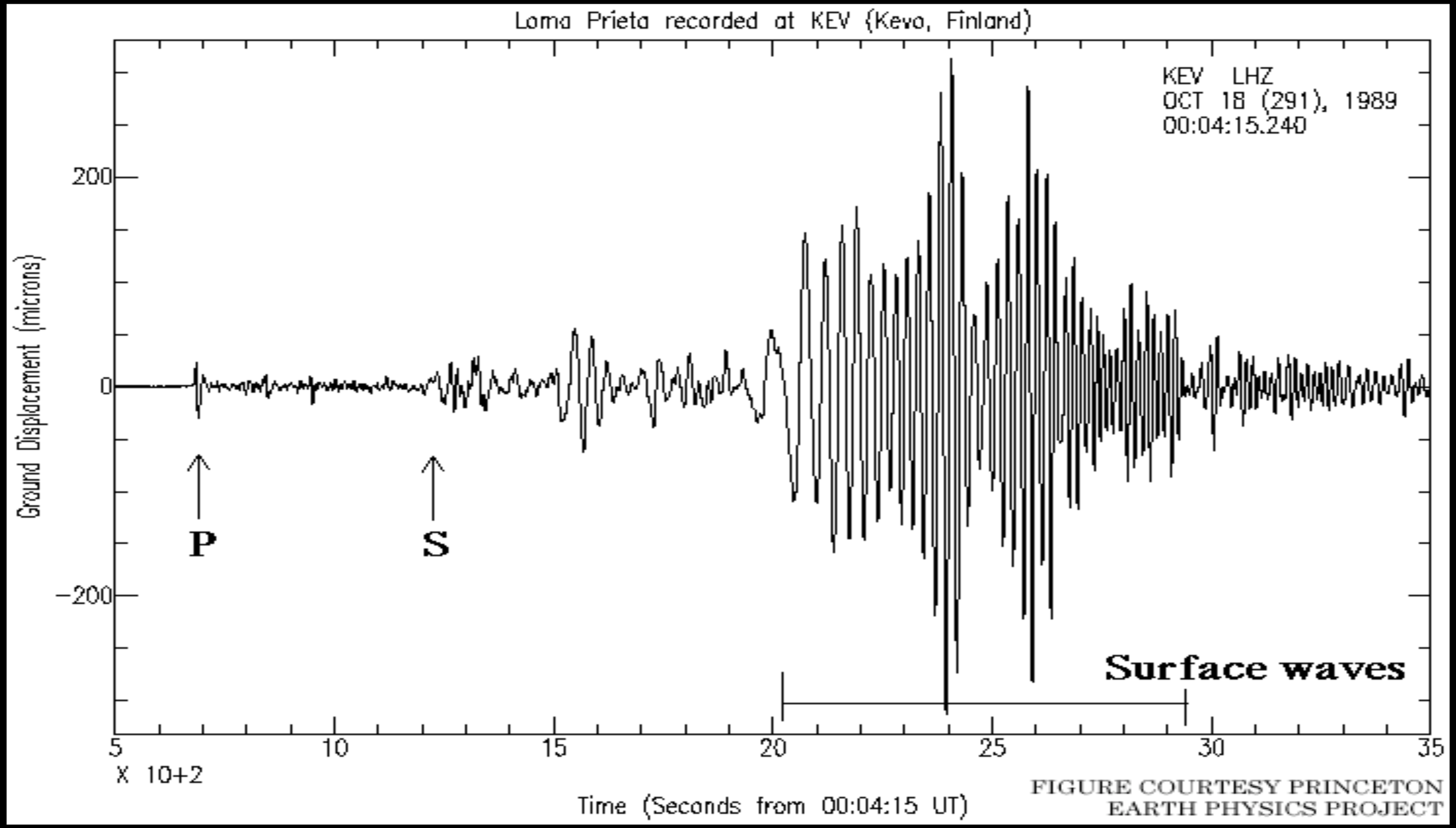

Epicenter
Fault
Focus


Volcanic
mountain
range
Trench
Oceanic crust
Continental crust
Upper mantle
Upper mantle

“SEIS”=Earthquake

- Seismologist-Someone who studies earthquakes
- Seismograph-Machine that picks up vibrations on the ground
- Seismogram-Printout of the vibrations
- Vibrations are measured by how big the “zig-zag” pattern is (Amplitude of Waves)
  - Bigger they are....stronger the earthquake...closer
  - Smaller they are....weaker the earthquake...farther


earth
scope


Loma Prieta recorded at KEV (Kevo, Finland)
KEV LHZ
OCT 18 (291), 1989
00:04:15.240
200
0
−200
Ground Displacement (microns)
P
S
Surface waves
5
10
15
20
25
30
35
X 10+2
Time (Seconds from 00:04:15 UT)
FIGURE COURTESY PRINCETON
EARTH PHYSICS PROJECT

Modified Mercalli Intensity Scale

I	Not felt
II	Felt only by persons at rest
III–IV	Felt by persons indoors only
V–VI	Felt by all; some damage to plaster, chimneys
VII	People run outdoors, damage to poorly built structures
VIII	Well-built structures slightly damaged; poorly built structures suffer major damage
IX	Buildings shifted off foundations
X	Some well-built structures destroyed
XI	Few masonry structures remain standing; bridges destroyed
XII	Damage total; waves seen on ground; objects thrown into air

Guiseppe Mercalli



Magnitude = Strength

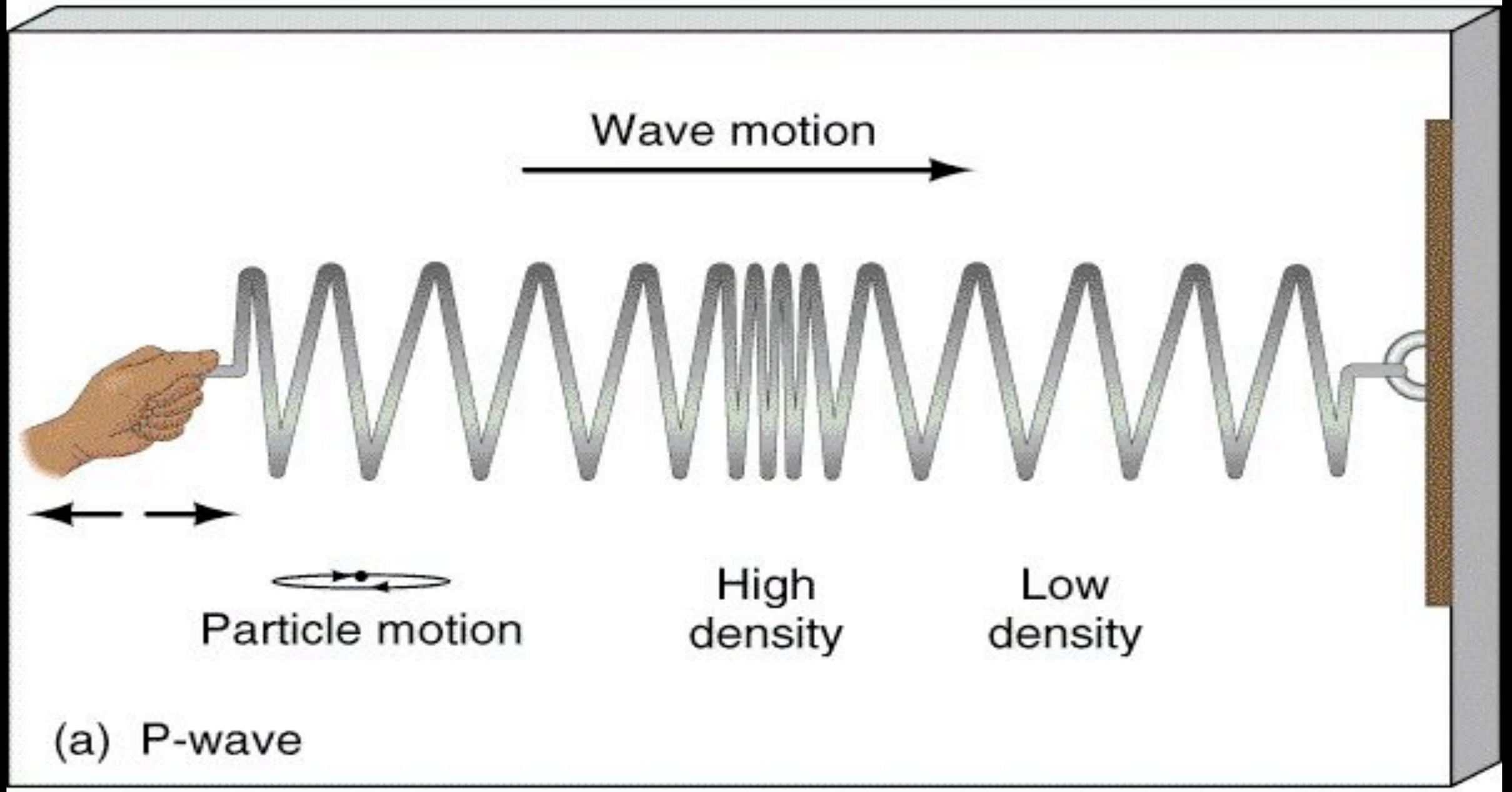
Richter Magnitude	TNT Equivalent	
1.0	6 ounces	
1.5	2 pounds	
2.0	13 pounds	
2.5	63 pounds	
3.0	397 pounds	
3.5	1,000 pounds	
4.0	6 tons	Small atomic bomb
4.5	32 tons	Average tornado
5.0	199 tons	
5.5	500 tons	
6.0	6,270 tons	
6.5	31,550 tons	
7.0	199,000 tons	San Francisco (7.1) 1989
7.5	1,000,000 tons	Los Angeles (7.4) 1992
8.0	6,270,000 tons	San Francisco (8.3) 1906
8.5	31,550,000 tons	Anchorage, Alaska 1964
9.0	199,999,000 tons	

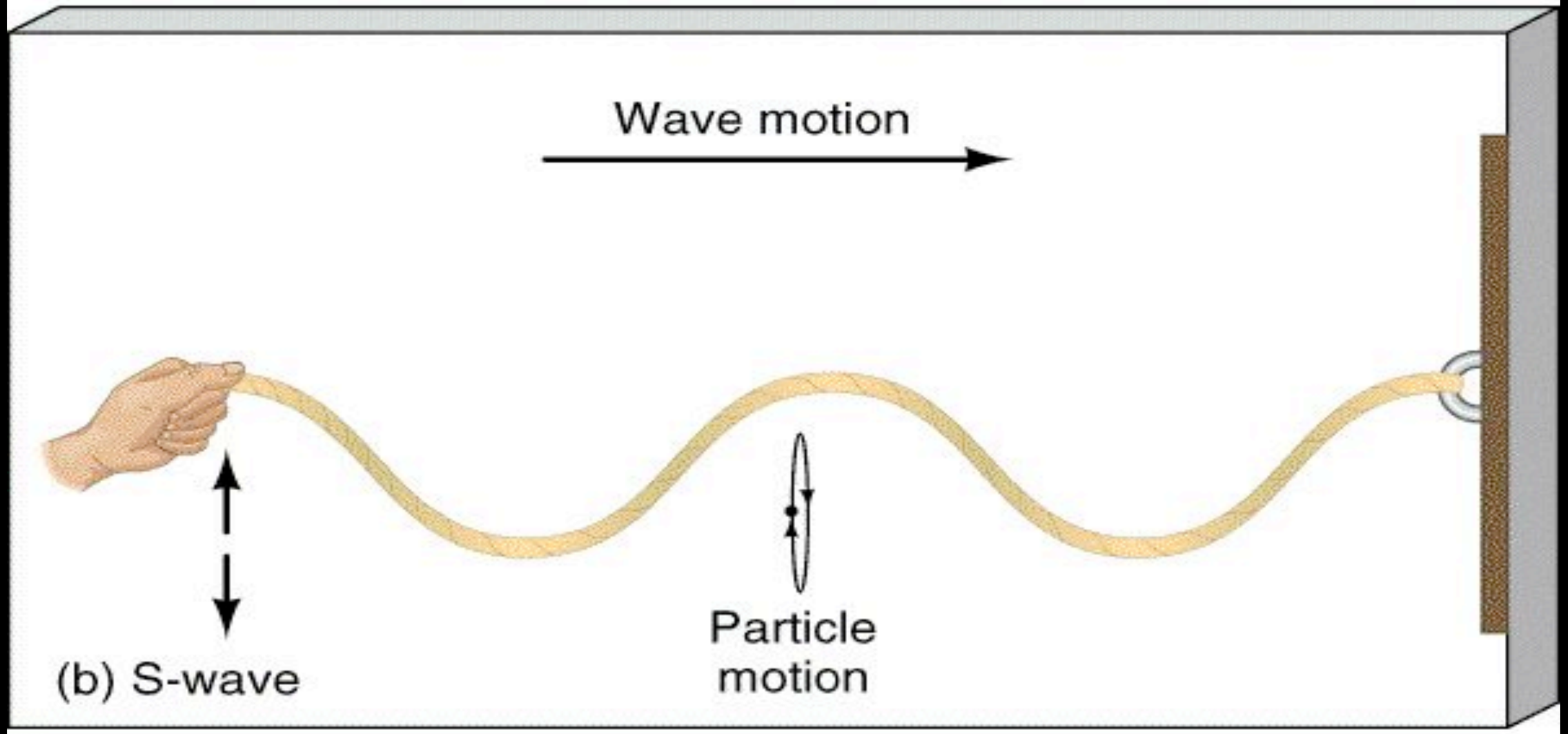


Charles Richter

Earthquake Magnitudes and Expected World Incidence

Moment Magnitudes	Effects Near Epicenter	Estimated Number per Year
< 2.0	Generally not felt, but can be recorded	> 600,000
2.0–2.9	Potentially perceptible	> 300,000
3.0–3.9	Rarely felt	> 100,000
4.0–4.9	Can be strongly felt	13,500
5.0–5.9	Can be damaging shocks	1,400
6.0–6.9	Destructive in populous regions	110
7.0–7.9	Major earthquakes; inflict serious damage	12
8.0 and above	Great earthquakes; destroy communities near epicenter	0–1


Wave motion
Particle motion
High
density
Low
density
(a) P-wave


Wave motion
Particle
motion
(b) S-wave

Easy way to remember the waves

P- Waves/Compression

- **P**rimary Waves
- **P**hirst to seismic station
- **P**haster than S wave
- **P**ush-**P**ull
- **P**ass through solids,liquids and gases
- **P**orsche

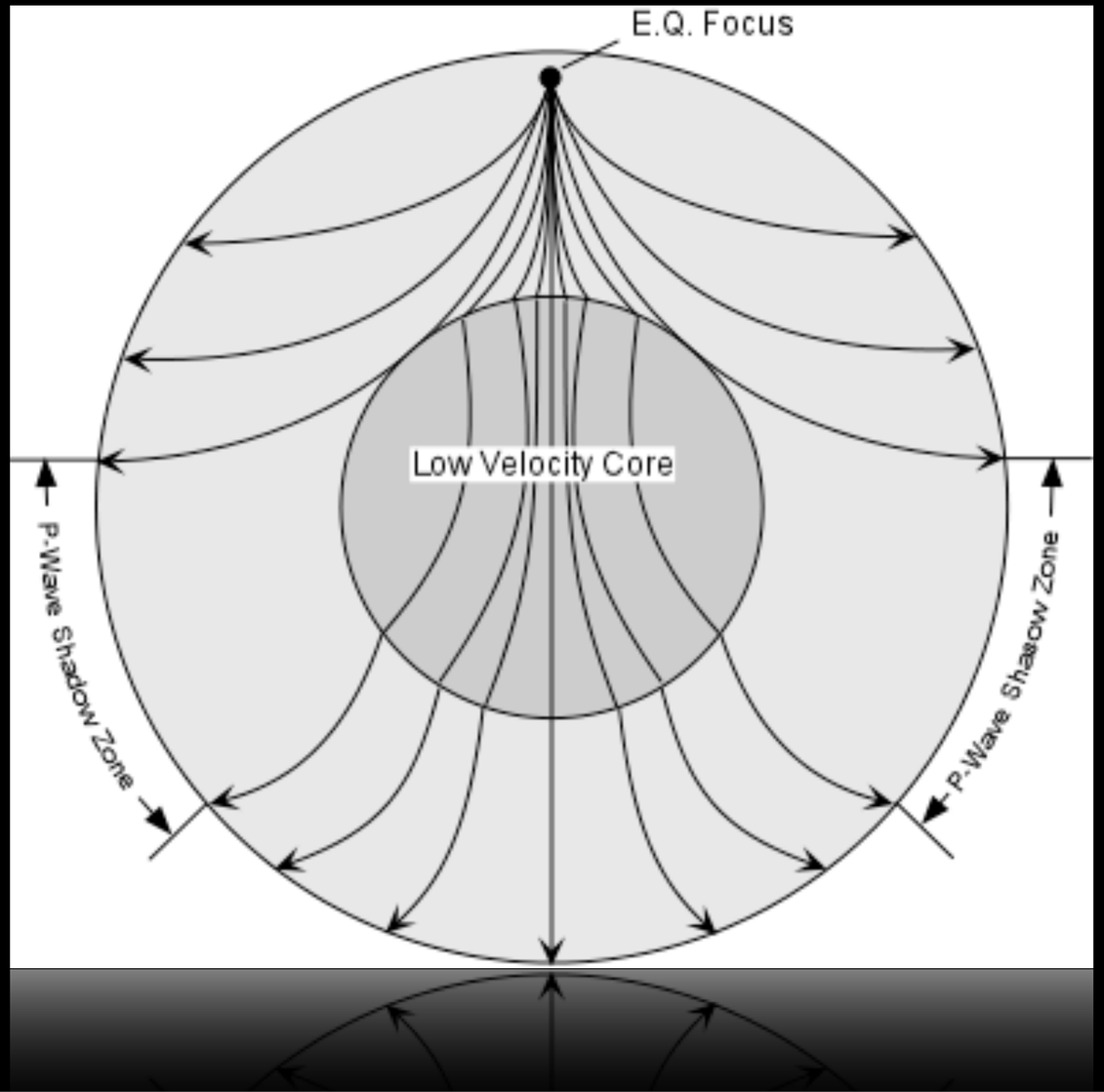


S-Waves/Shear

- **S**econdary Waves
- **S**econd to seismic station
- **S**lower than P wave
- Travels in an "**S**"-like pattern (**S**ide to **S**ide)
- **S**olids Only!!
- **s**aturn

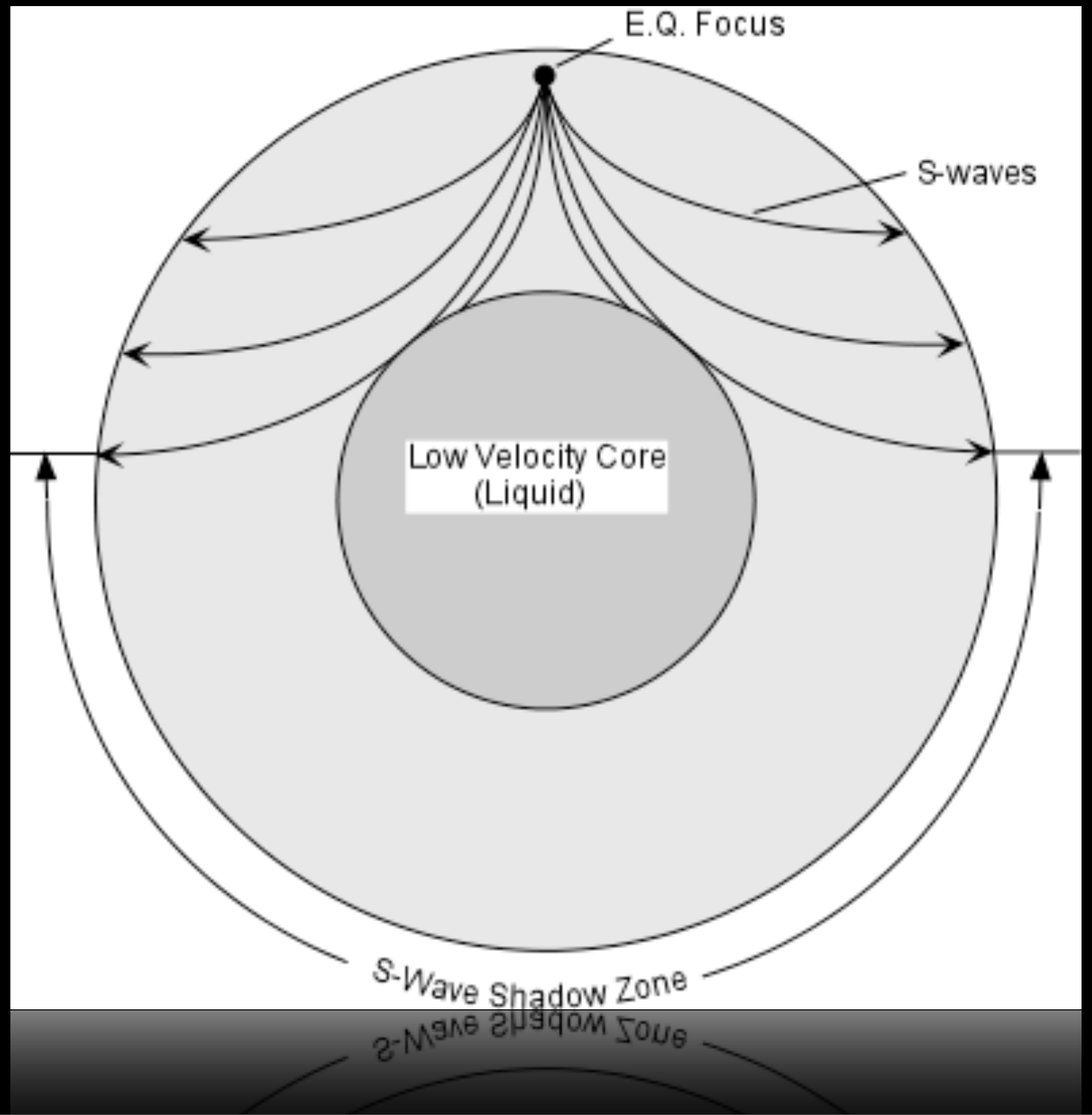


P -Wave Shadow Zone



- Caused by density differences between mantle and outer core
- P-Waves bend (Refrect)
- Area Between 103-142 degrees away from epicenter do not receive P-Waves
- Area not receiving P-Waves is in the Shadow Zone

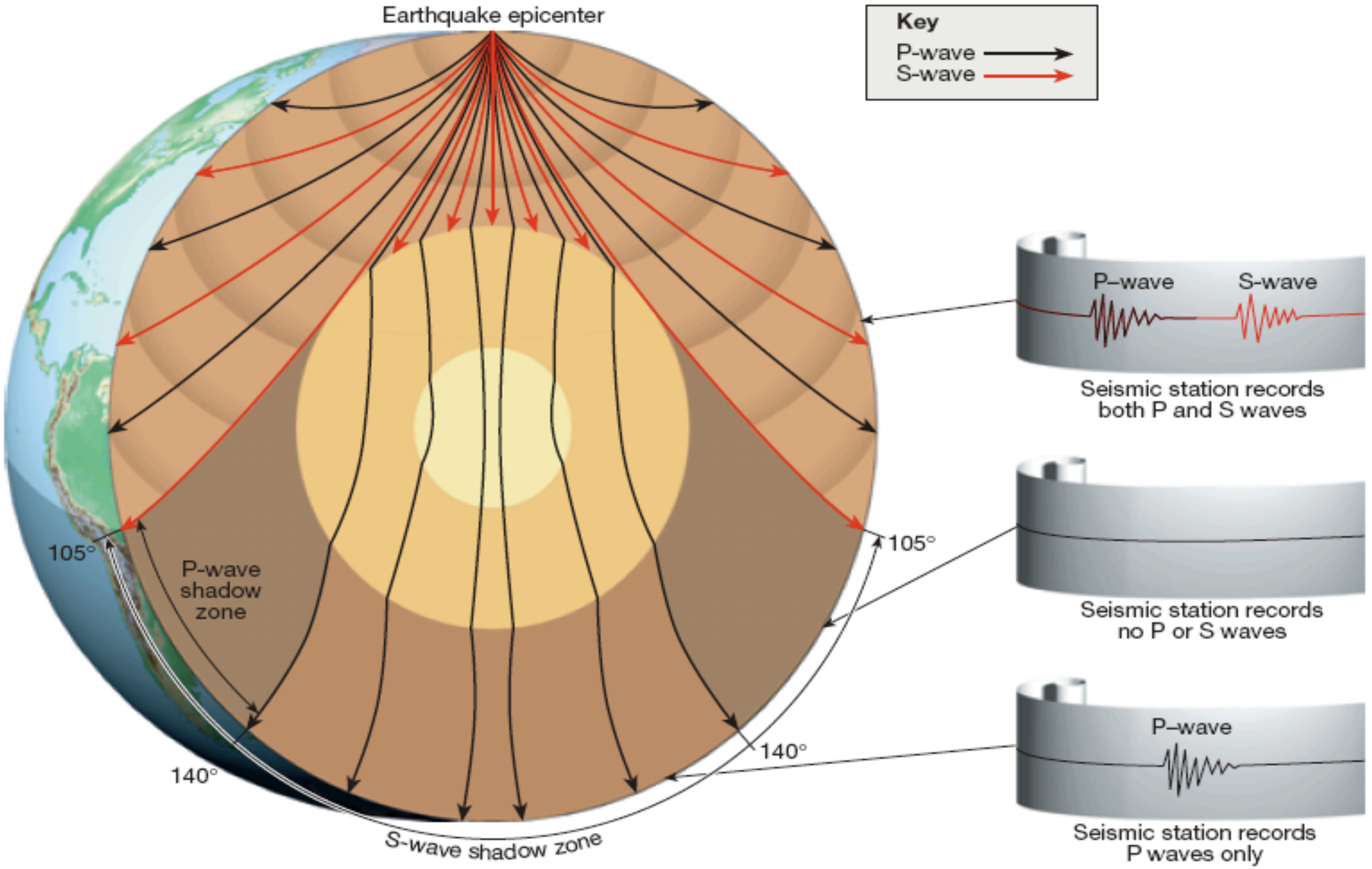
S-Wave Shadow Zone



- Caused by S-Waves not being able to pass through the liquid outer core

S-Waves get absorbed by the liquid outer core

Area 103 degrees in all directions from epicenter do not receive S-Waves


Earthquake epicenter
Key
P-wave
S-wave
105°
P-wave shadow zone
140°
S-wave shadow zone
105°
140°
P–wave
S-wave
Seismic station records both P and S waves
Seismic station records no P or S waves
P–wave
Seismic station records P waves only

How to Determine Epicenter Location

- 1 Seismic Station only tells you epicenter distance, not location.
- 2 Seismic Stations take an infinite number of possible locations and narrows it down to 2 possible points for epicenter location.
- 3 Seismic Stations will let you know exactly where the epicenter is located.
- Look to see where all 3 circles intersect (TRIANGULATION)
- The closer a seismic station is to the epicenter, the smaller the circle.
- The farther a seismic station is to the epicenter, the larger the circle.

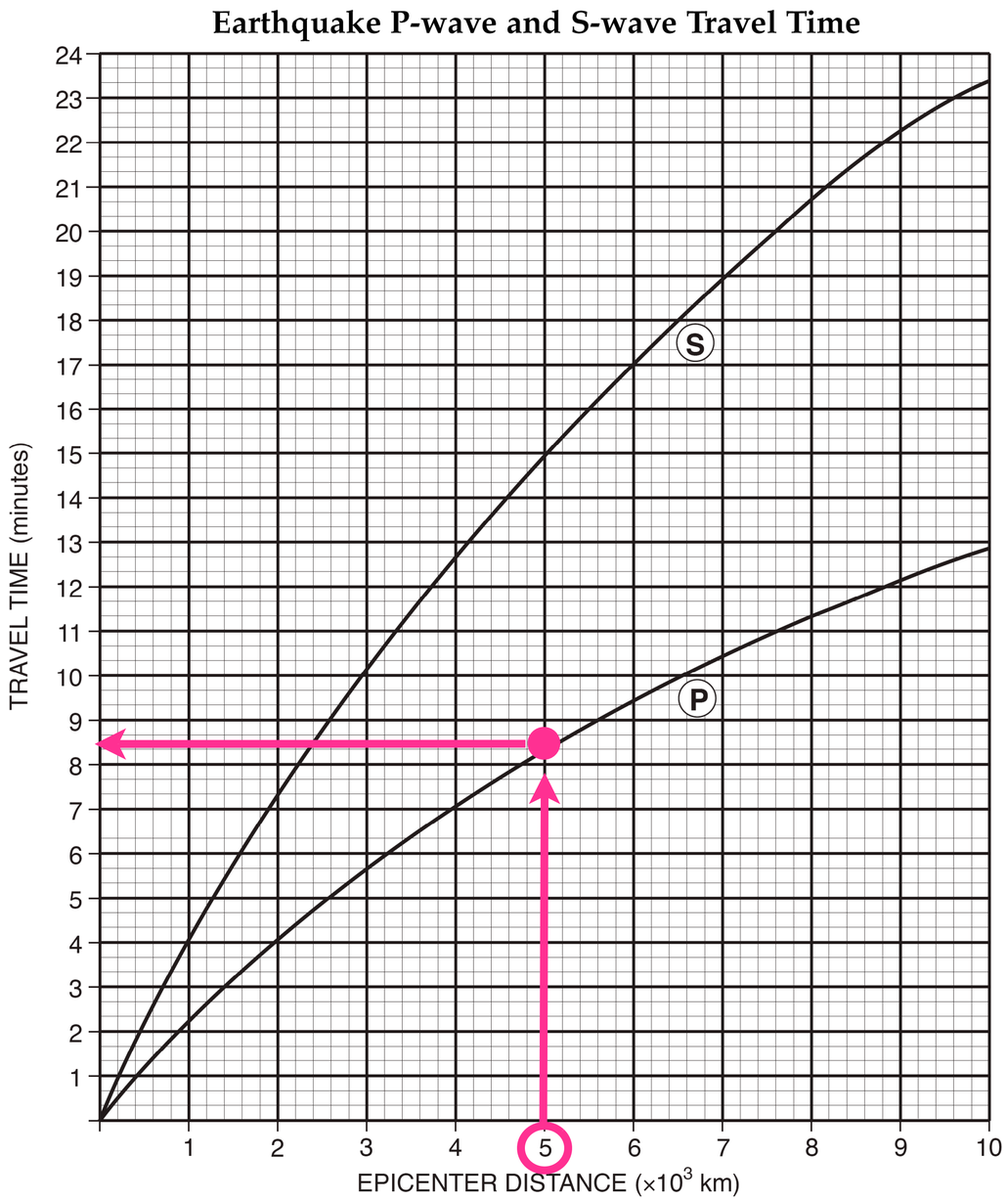

Montréal
Paris
8400 km
6700 km
Epicenter
5500 km
São Paulo

Things to think about.....

- Travel Time - Amount of time it takes for a P wave or S wave to travel a specific distance (Use Chart Directly!!).
- Arrival Time - The time a P wave or S wave arrives at a seismic station (Subtract P wave and S wave time and use weggie method).
- Lag Time-Difference between P-Wave and S-Wave Arrival Times.
- Origin Time - When the earthquake started.
- Bigger the difference between arrival times, the farther away the epicenter is.
- The smaller the difference between arrival times, the closer the epicenter is.

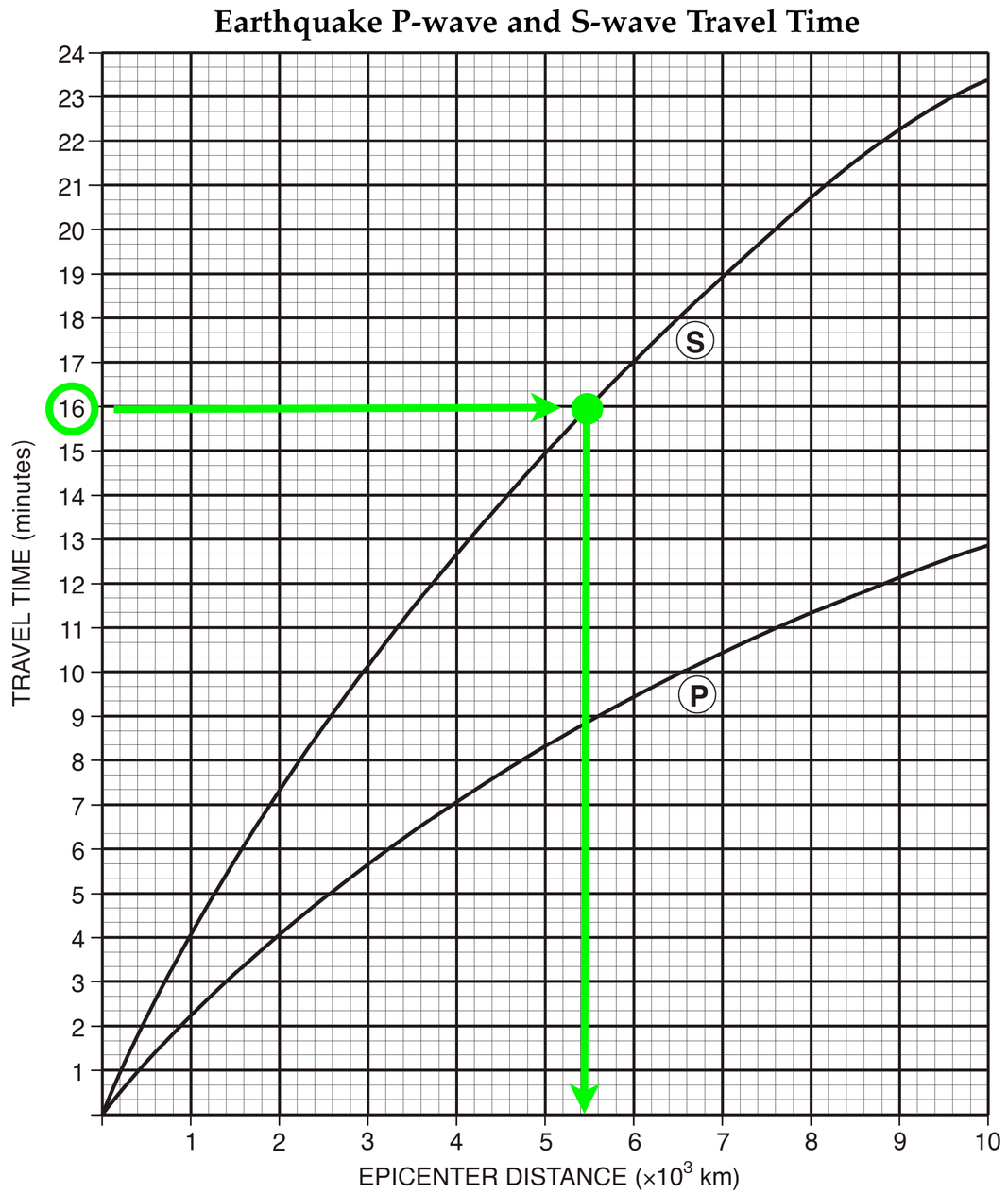
Things we need to be able to determine...

- ✓ P-wave travel time (P_{tt})
- ✓ P-wave arrival time (P_{arr})
- ✓ S-wave travel time (S_{tt})
- ✓ S-wave arrival time (S_{arr})
- ✓ Lag time ($S_{arr} - P_{arr}$)
- ✓ Epicenter distance (E_{dis})
- ✓ Epicenter location



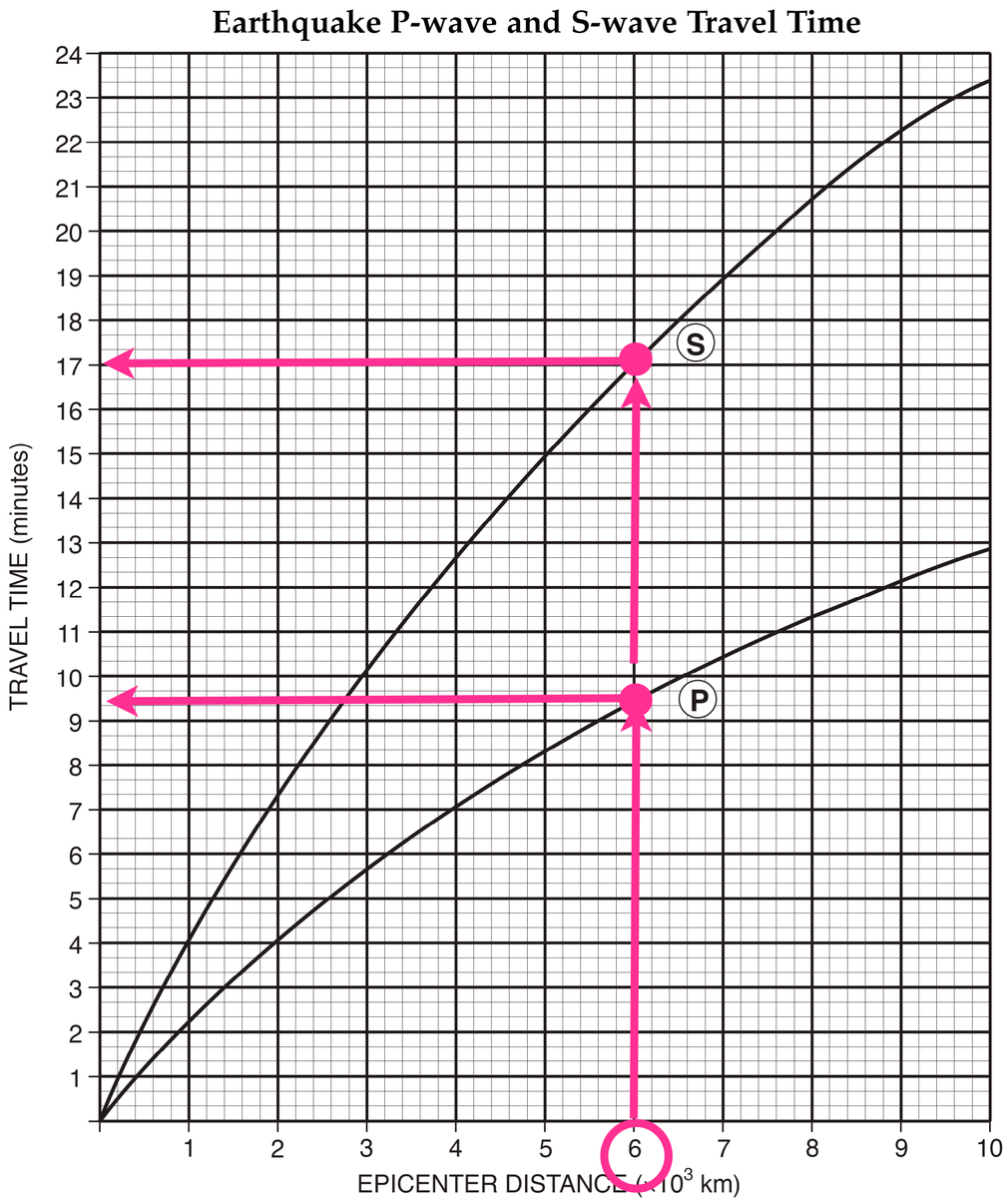
How long does it take a P-wave to travel 5,000 km?

8 minutes
20 seconds



How far does an S-wave travel in 16 minutes?

5,400 km



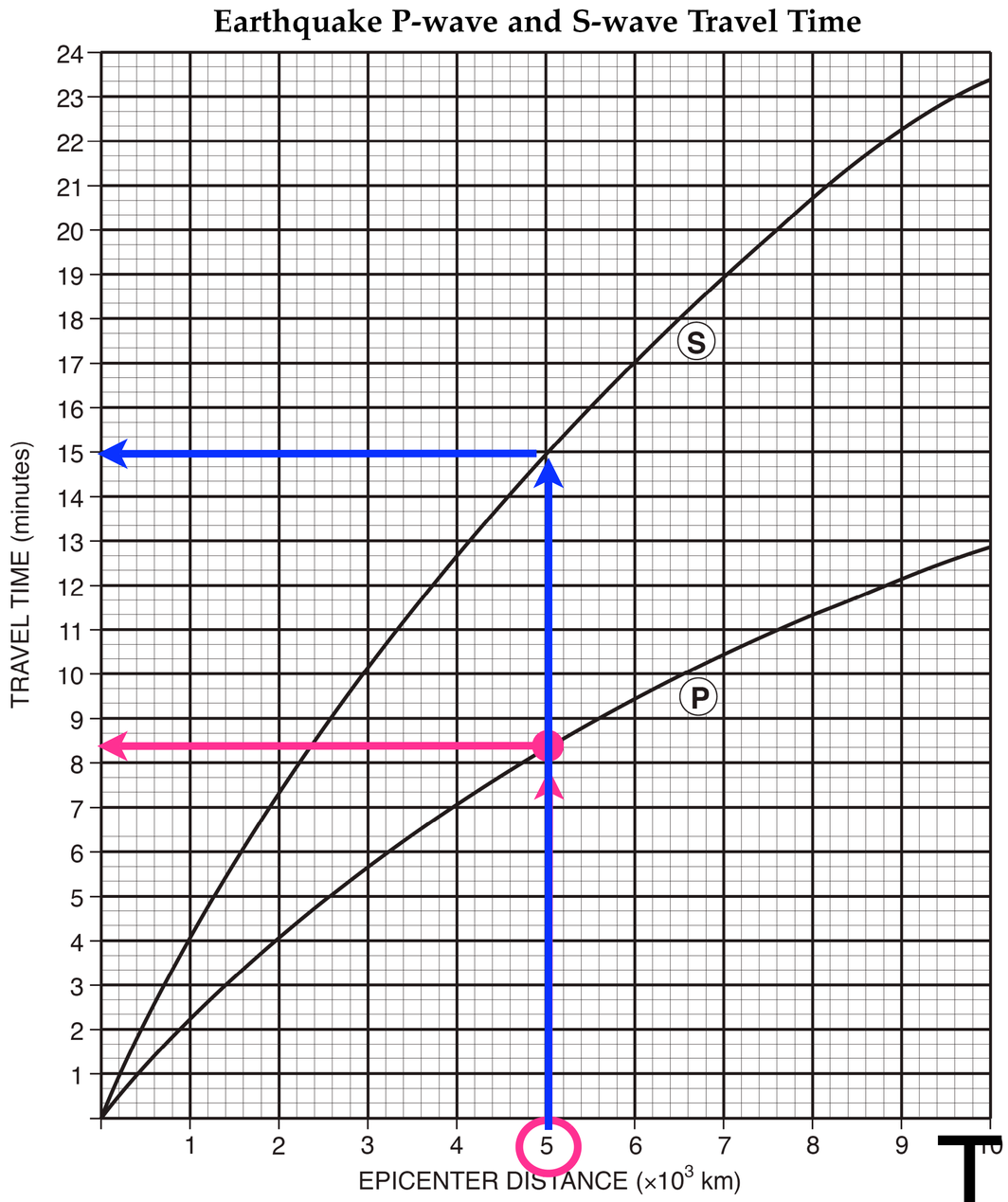
If an Earthquakes P-Wave arrives at 12:00 pm and travels 6000 km, what time will the S-Wave arrive?

P-Wave Travel Time: 00:09:20

S-Wave Travel Time: 00:17:00

Difference: 00:07:40

Time of Arrival: 12:07:40 pm



If an Earthquakes S-Wave travels 5000 km and arrives at a seismic station at 11:46:40 am, What is the origin time of the Earthquake?

8 min 20 sec Minute Travel Time

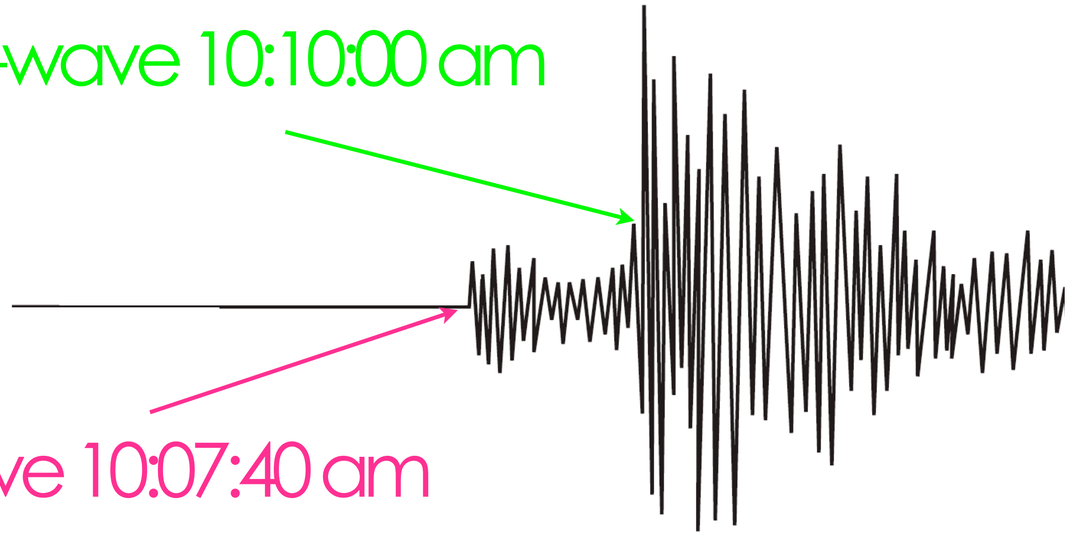
15 min Minute Travel Time

Origin Time-11:31:40 am

Origin Time-11:31:40 am

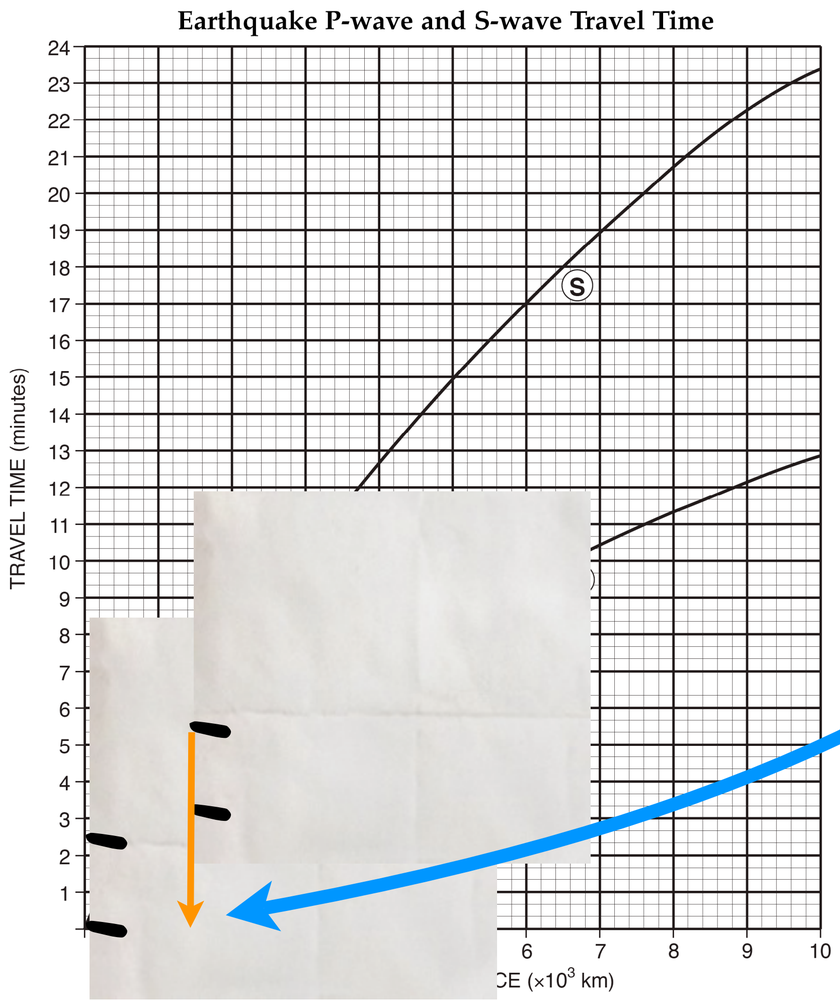
THEY ARE THE SAME!

arrival of S-wave 10:10:00 am



arrival of P-wave 10:07:40 am

- ✓ P_{arr} = 10:07:40
- ✓ S_{arr} = 10:10:00
- ✓ Lag time (S_{arr} - P_{arr}) = 00:02:20
- ✓ Epicenter distance?



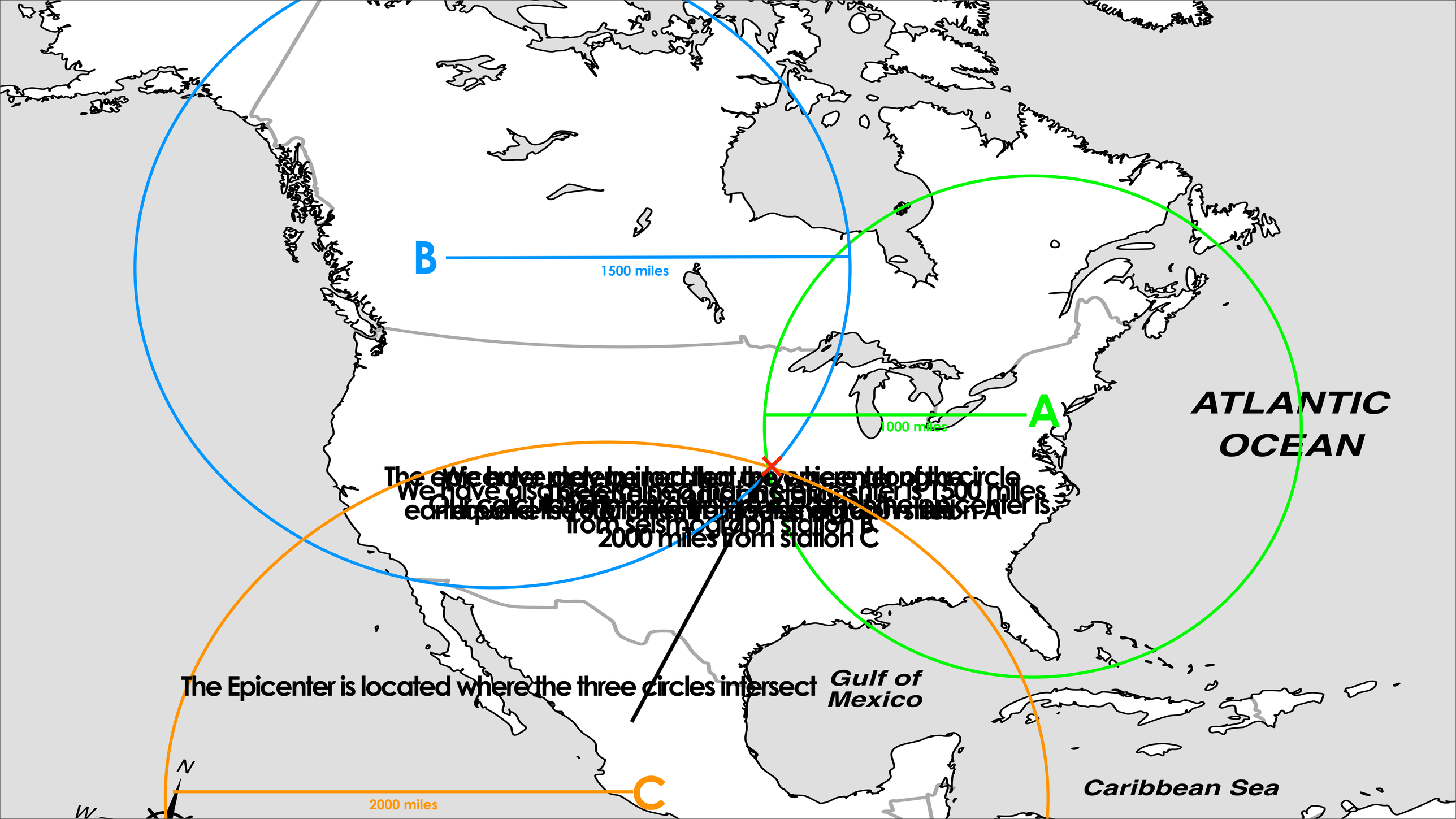
✓ S_{arr} = 10:10:00

✓ P_{arr} = 10:07:40

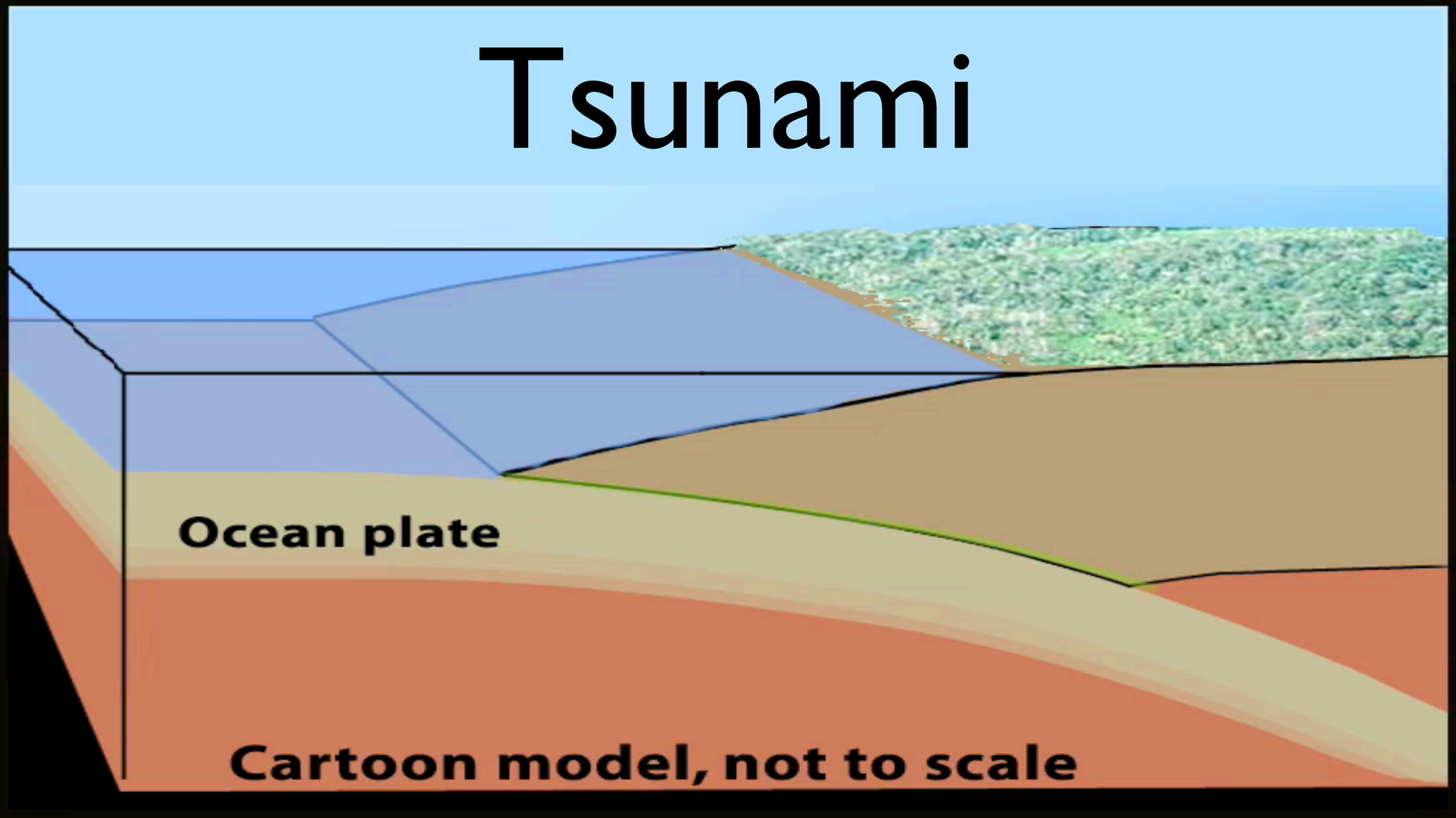
✓ Lag time = 00:02:20

✓ Epicenter distance?

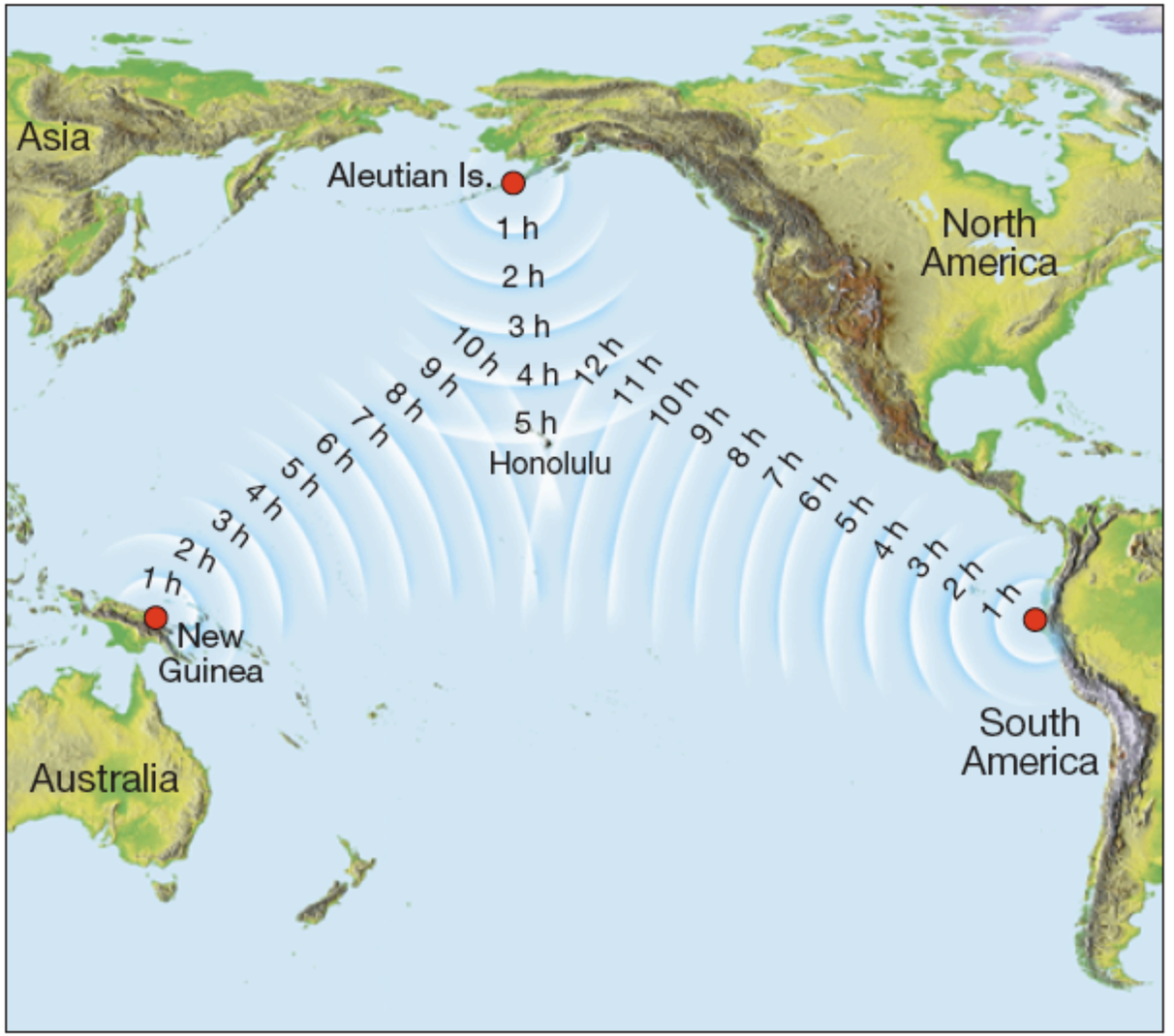
Epicenter distance = 1,400 km


B
1500 miles
A
1000 miles
ATLANTIC
OCEAN
The epicenter is located where the three circles intersect
Gulf of
Mexico
Caribbean Sea
N
W
C
2000 miles

Tsunami






Asia
Aleutian Is.
North America
1 h
2 h
3 h
4 h
5 h
Honolulu
6 h
7 h
8 h
9 h
10 h
11 h
12 h
New Guinea
Australia
South America