

Which field trip are you going on?

A) SE O'ahu, Saturday Jan. 31

B) North Shore, Saturday Feb. 28

C) *SE O'ahu, Sunday 1st half March

D) Waihe'e Tunnel, Friday Apr. 17

E) *Waianae, Saturday 2nd half April

RSVP to engels@hawaii.edu !



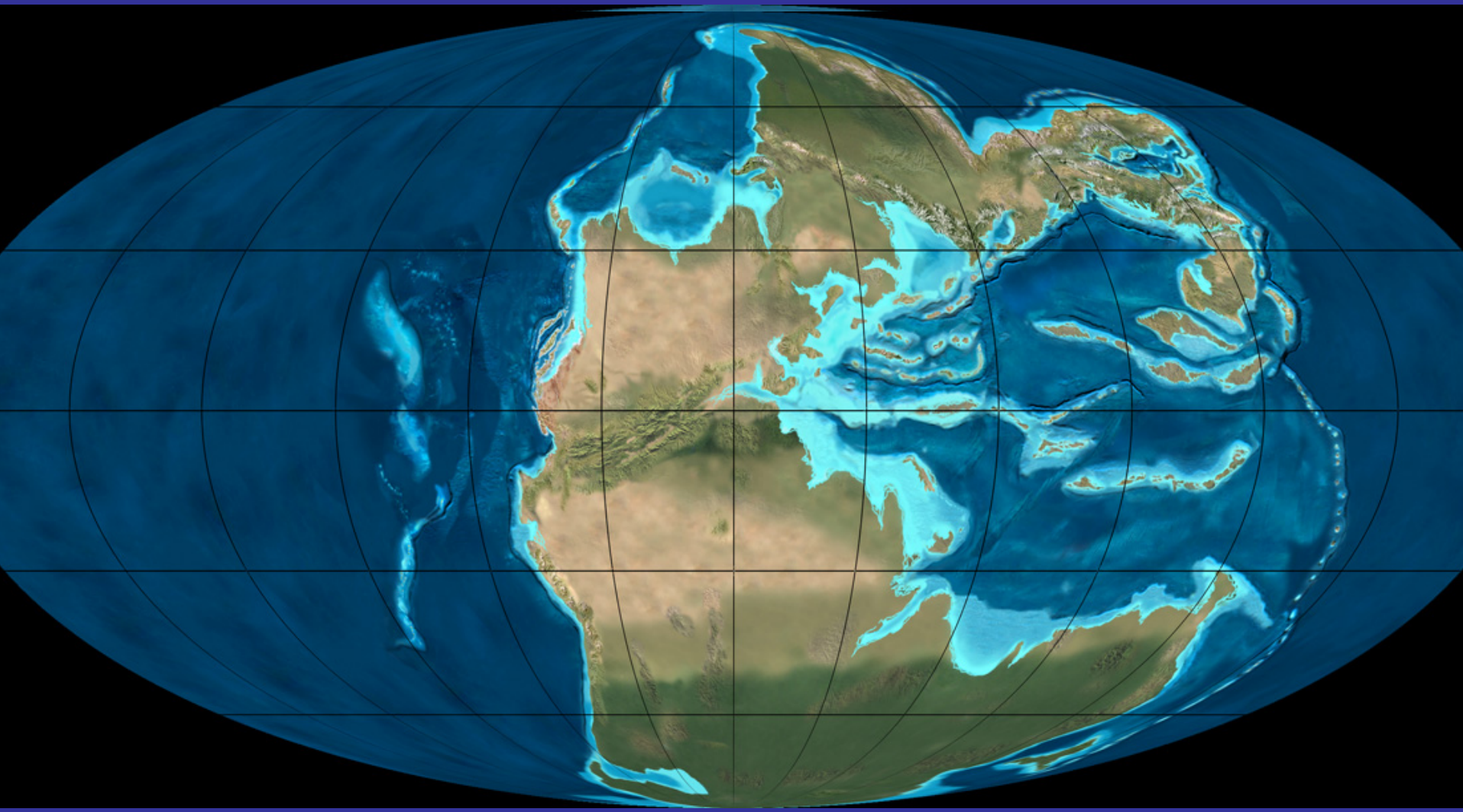
Alfred Wegener
Meteorologist

The Origins of Continents and Oceans
1915

“Continental drift”

Modern Earth

Pangaea (240 Mya)



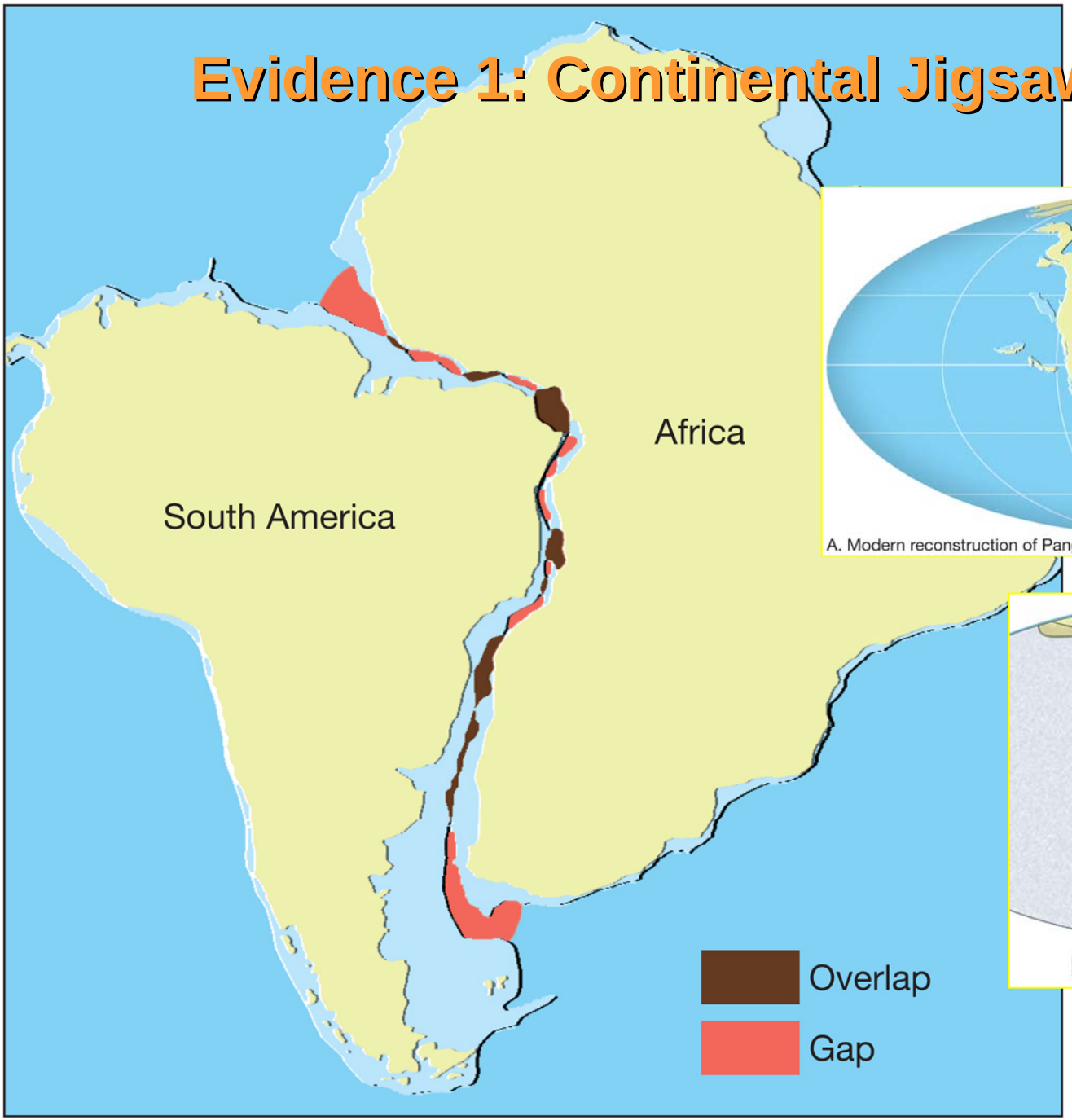
Pangaea

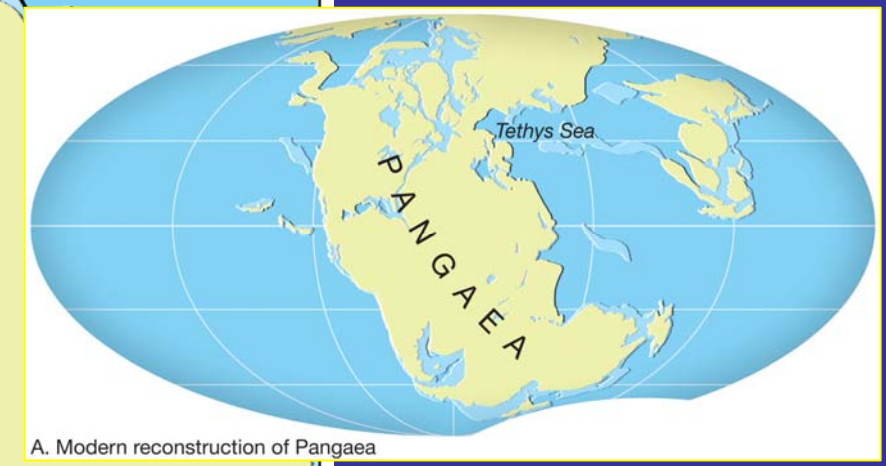

Eurasia
North America
Africa
South America
India
Antarctica
Australia

How should we test this idea?

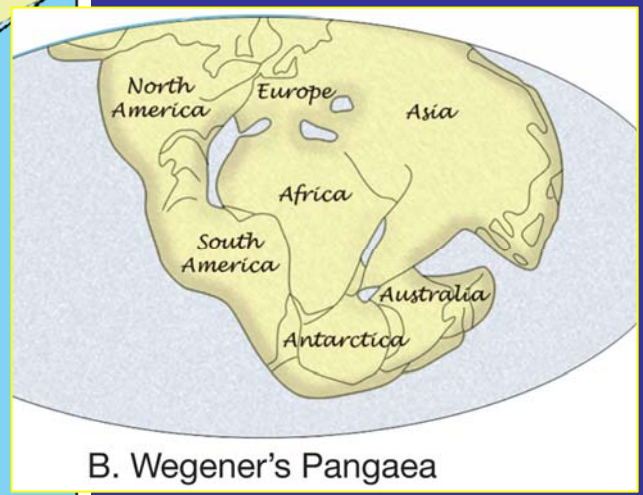


Evidence 1: Continental Jigsaw Puzzle





A. Modern reconstruction of Pangaea



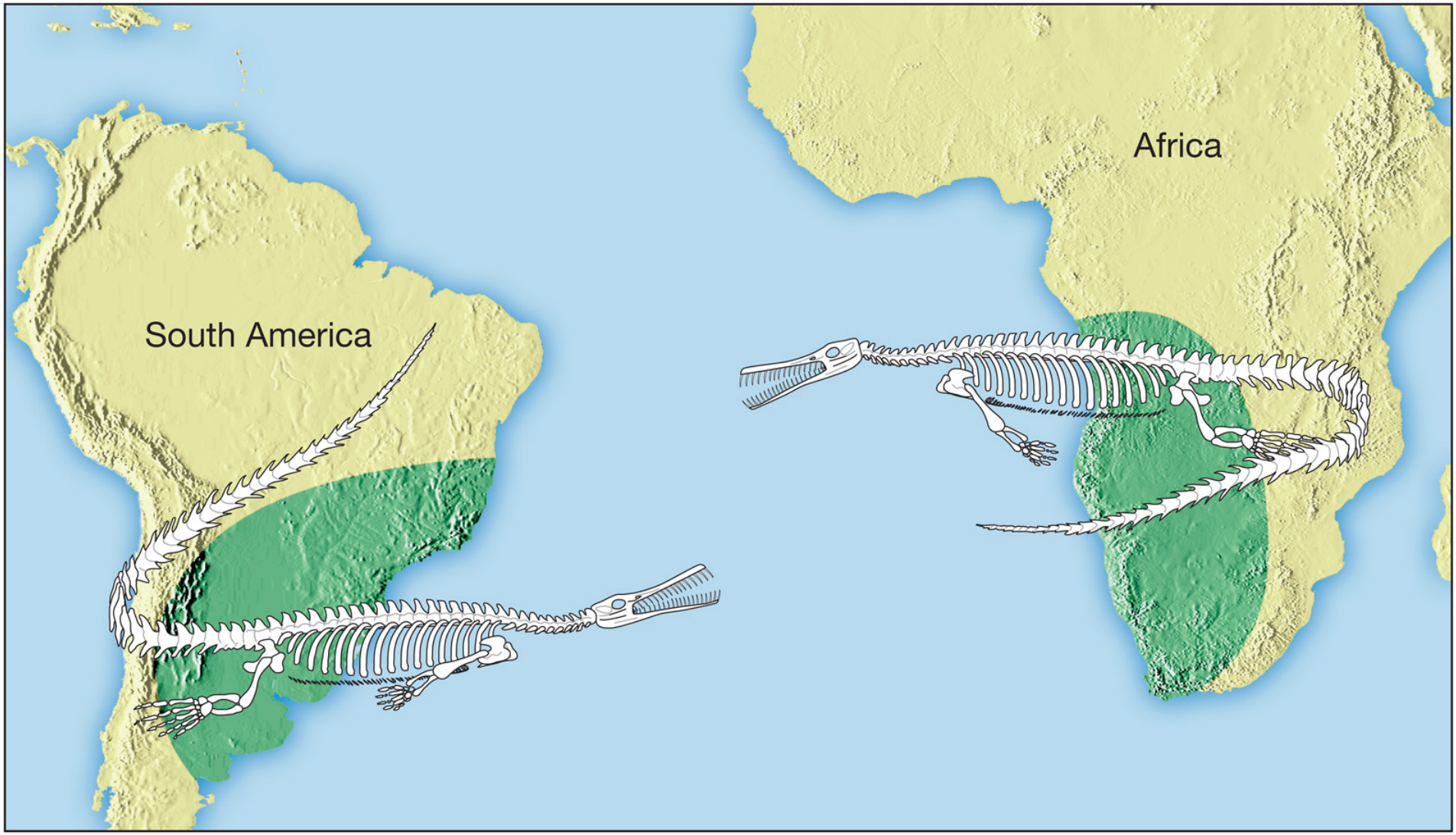
B. Wegener's Pangaea

How far can this guy swim?

A) 30m
B) 300m
C) 30km
D) 300km
E) 3,000km



Evidence 2: Fossils match across Atlantic



Mesosaurus (260 Mya)

Evidence 3: Rock types & structures match





U.S., Africa, Greenland, British Isles, Scandinavia



What do these striations result from?

A) Stream flow
B) Freeze/thaw cycles
C) A bulldozer
D) Lava flow
E) Glaciers



Would glacial striations form in environments like these?





Would glacial striations form in an environment like this?

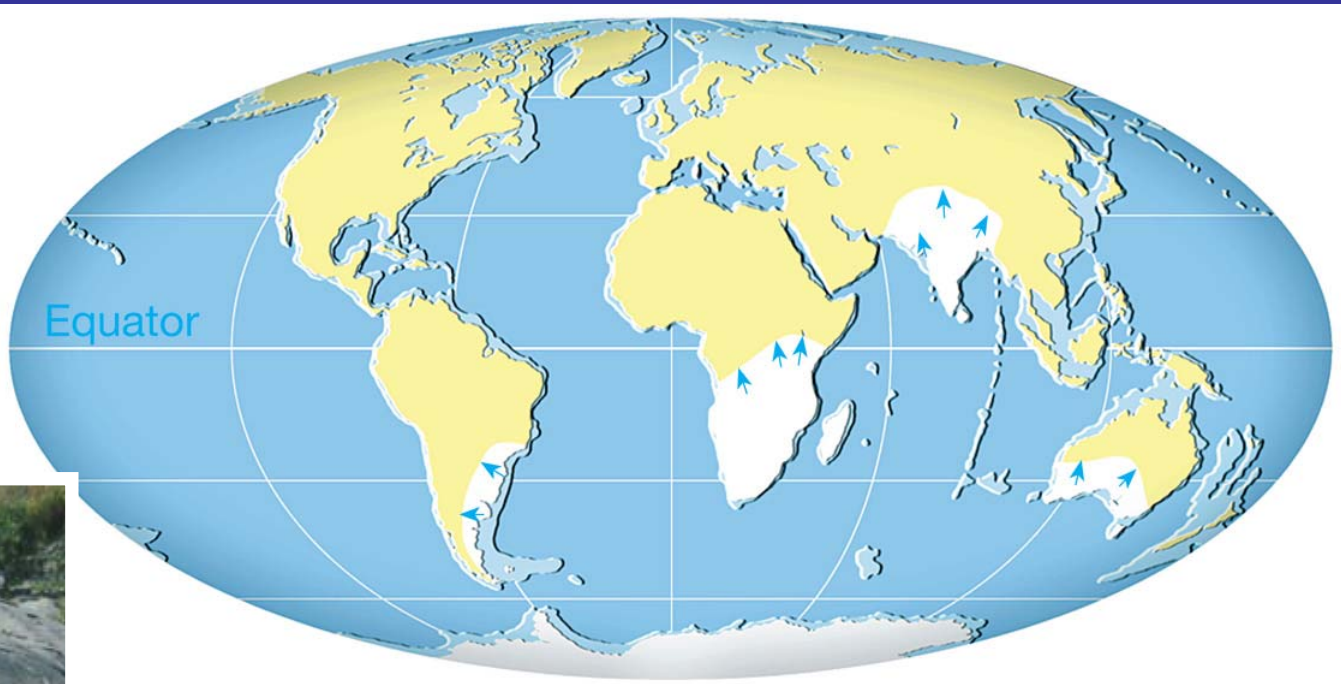


Would glacial striations form in an environment like this?



Evidence 4: Ancient climates

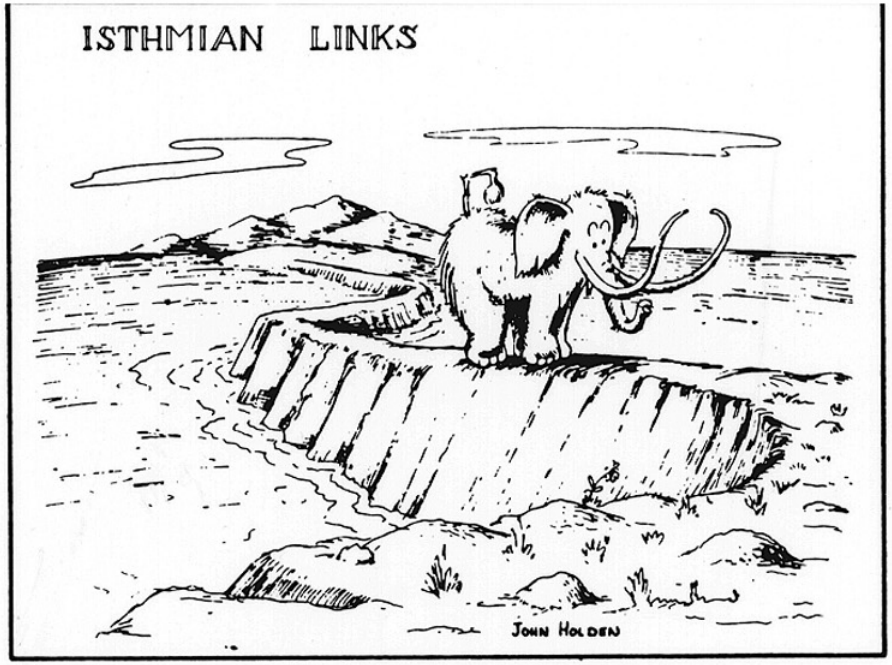


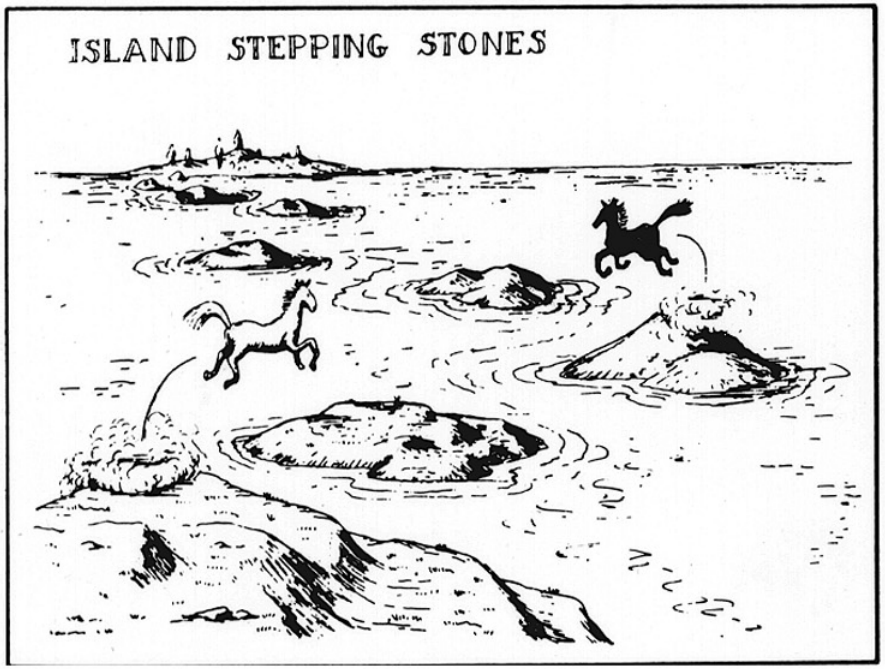


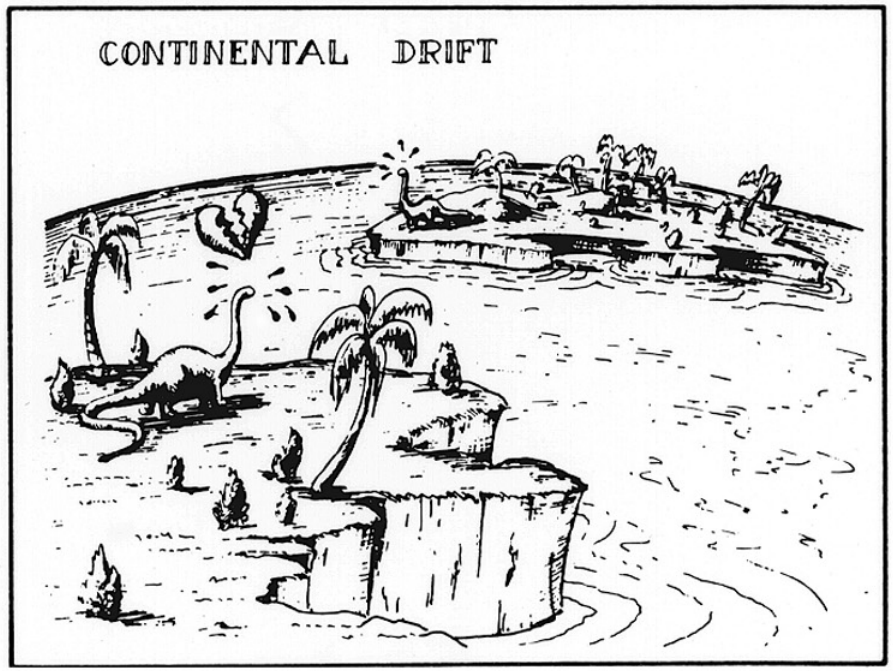


The alternatives…









“Utter, damned rot!”

President of the prestigious American Philosophical Society

“If we are to believe this hypothesis, we must forget everything we have learned in the past 70 years and start all over again”

American scientist

“Anyone who valued his reputation for scientific sanity would never dare support such a theory”

British geologist



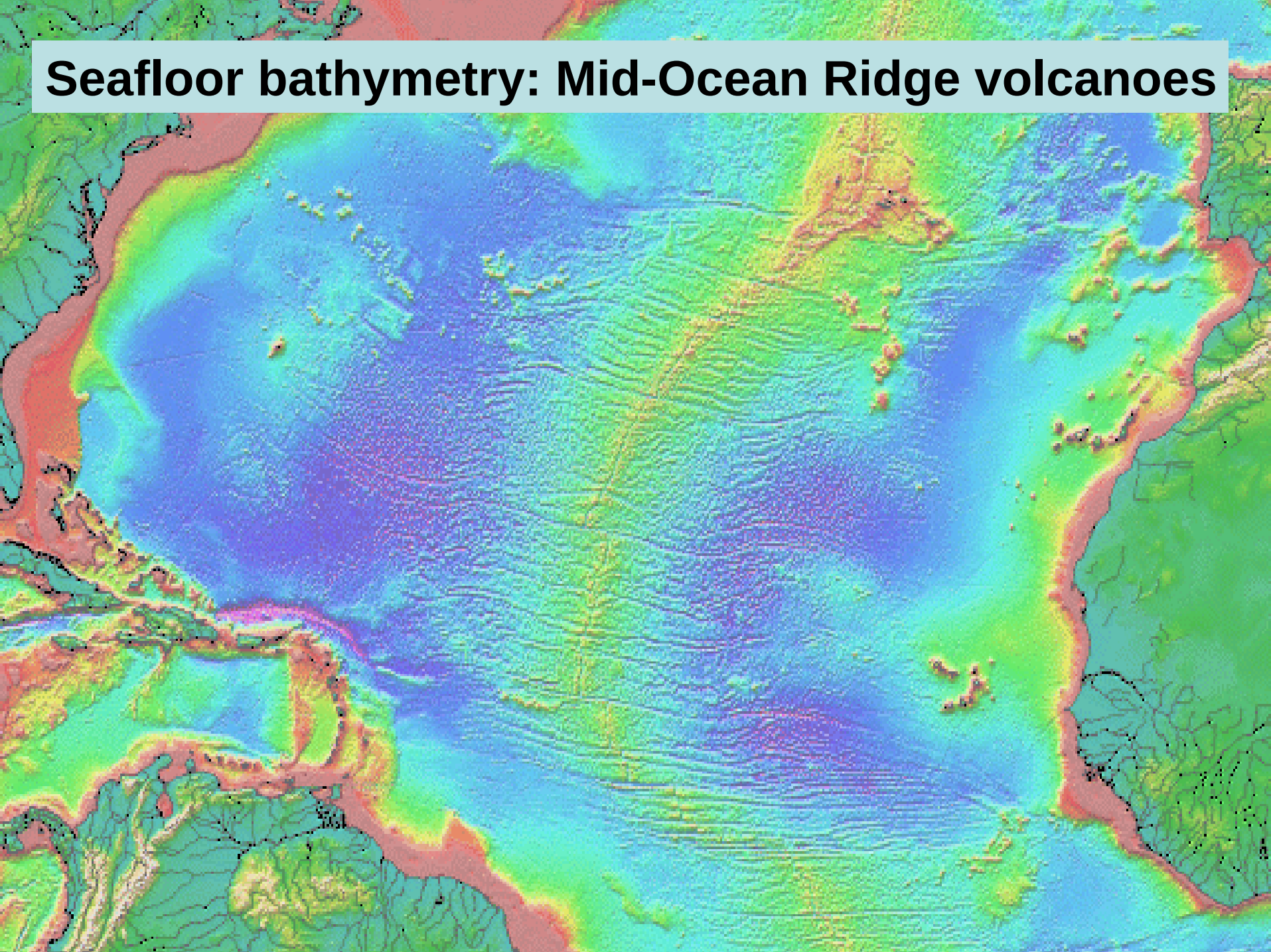




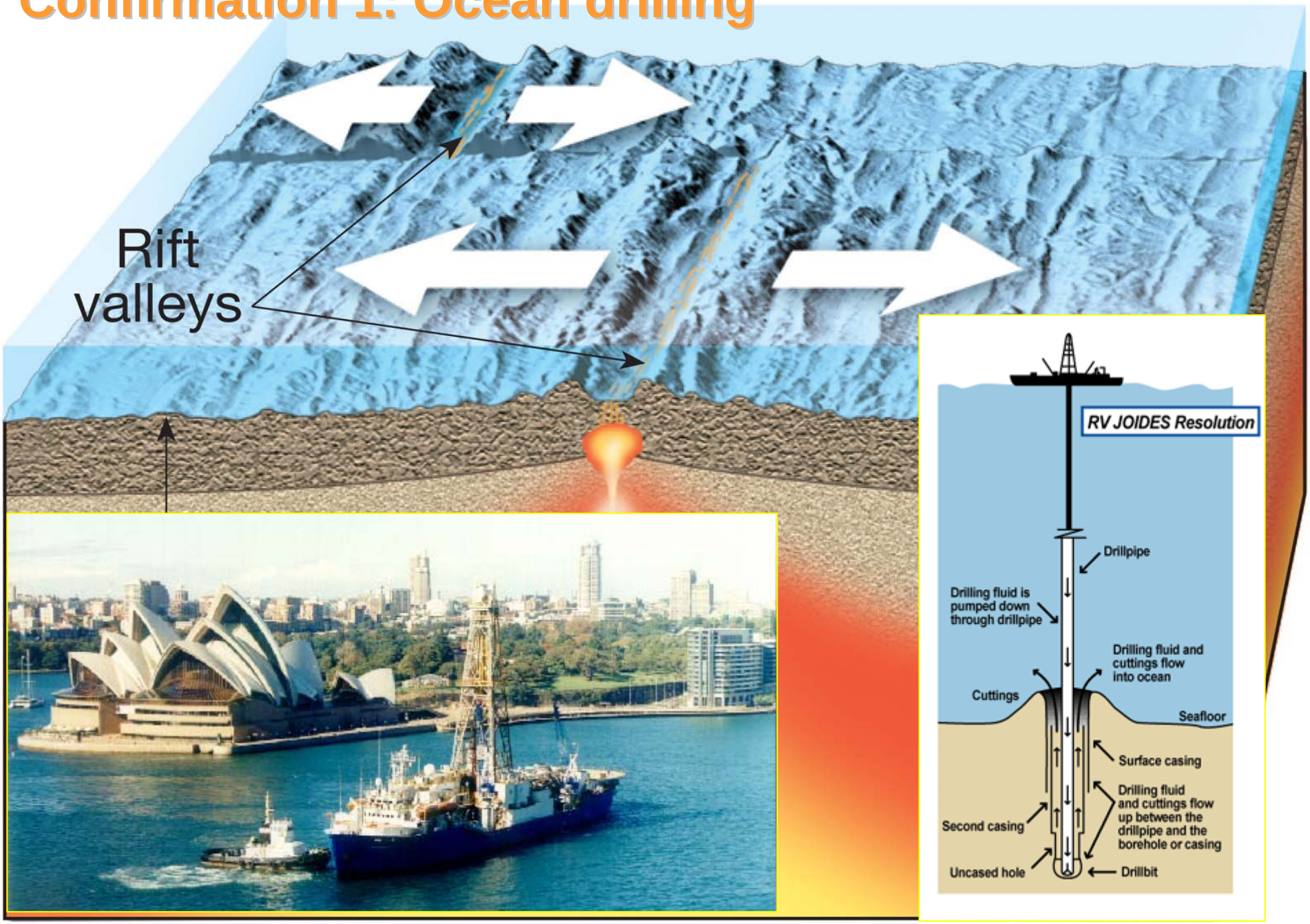
1950s-1960s

Post-WWII Military Industrial Complex

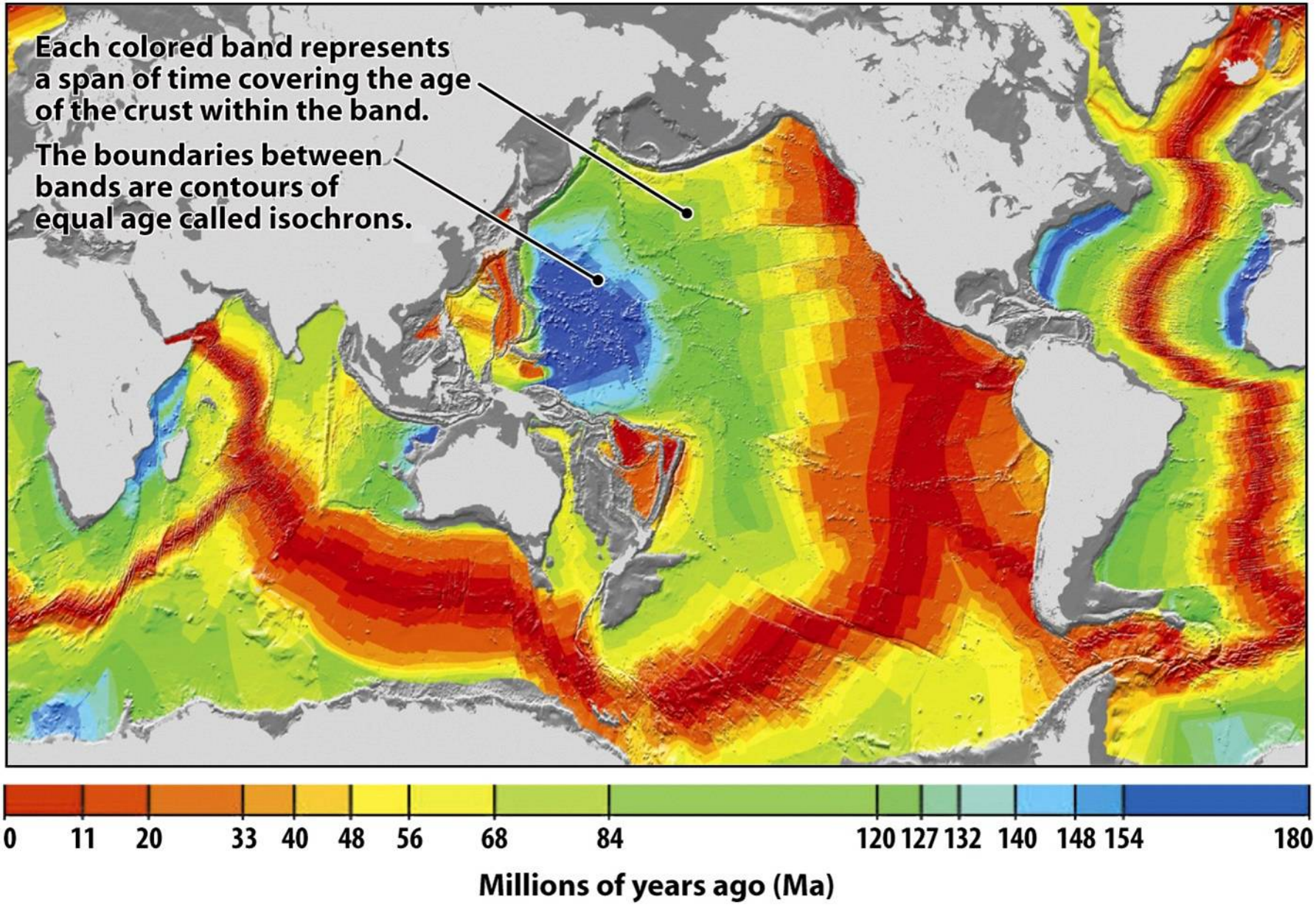
Seafloor bathymetry: Mid-Ocean Ridge volcanoes



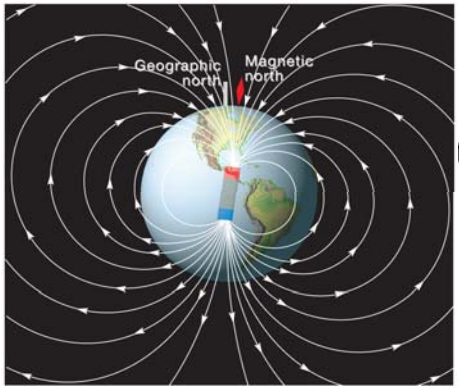
Confirmation 1: Ocean drilling

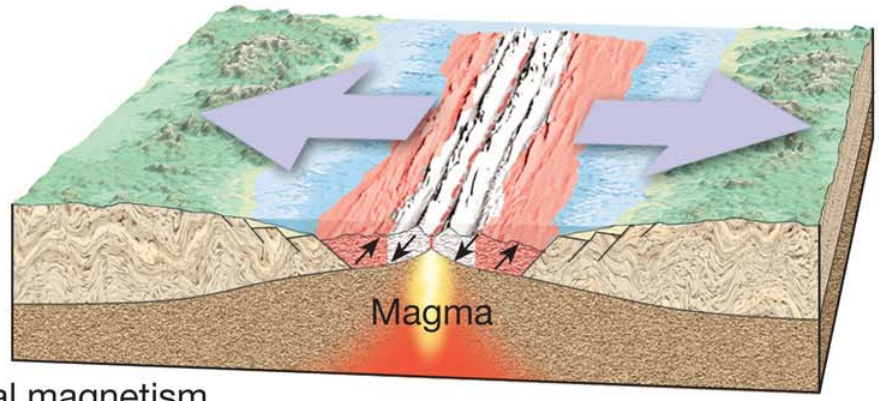


What is growing fastest, A) wide red bands, B) narrow red bands?

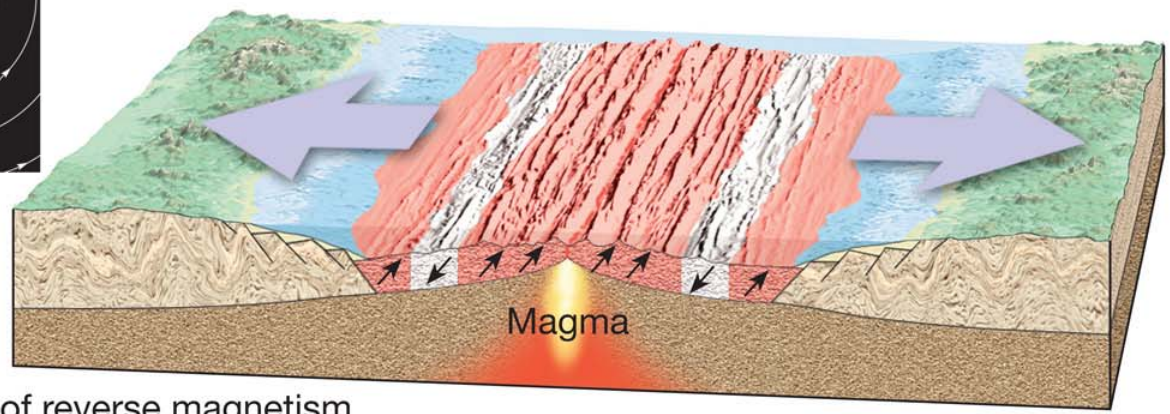


Confirmation 2: Paleomagnetism

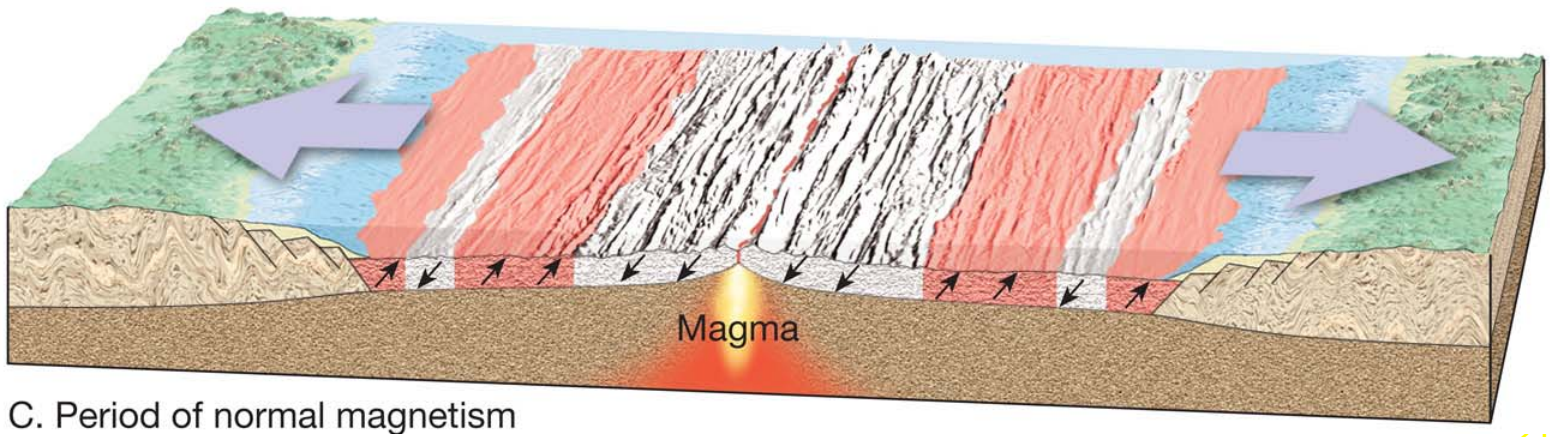




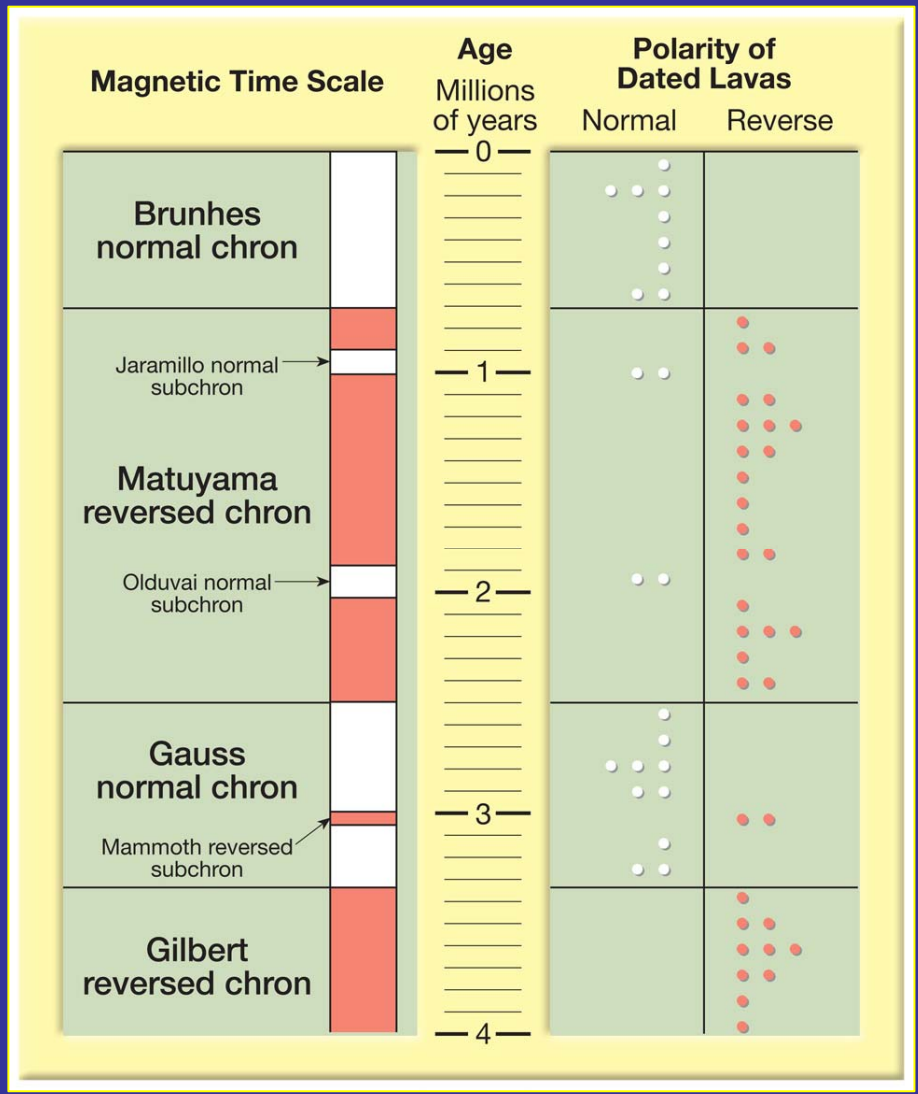
normal magnetism



B. Period of reverse magnetism

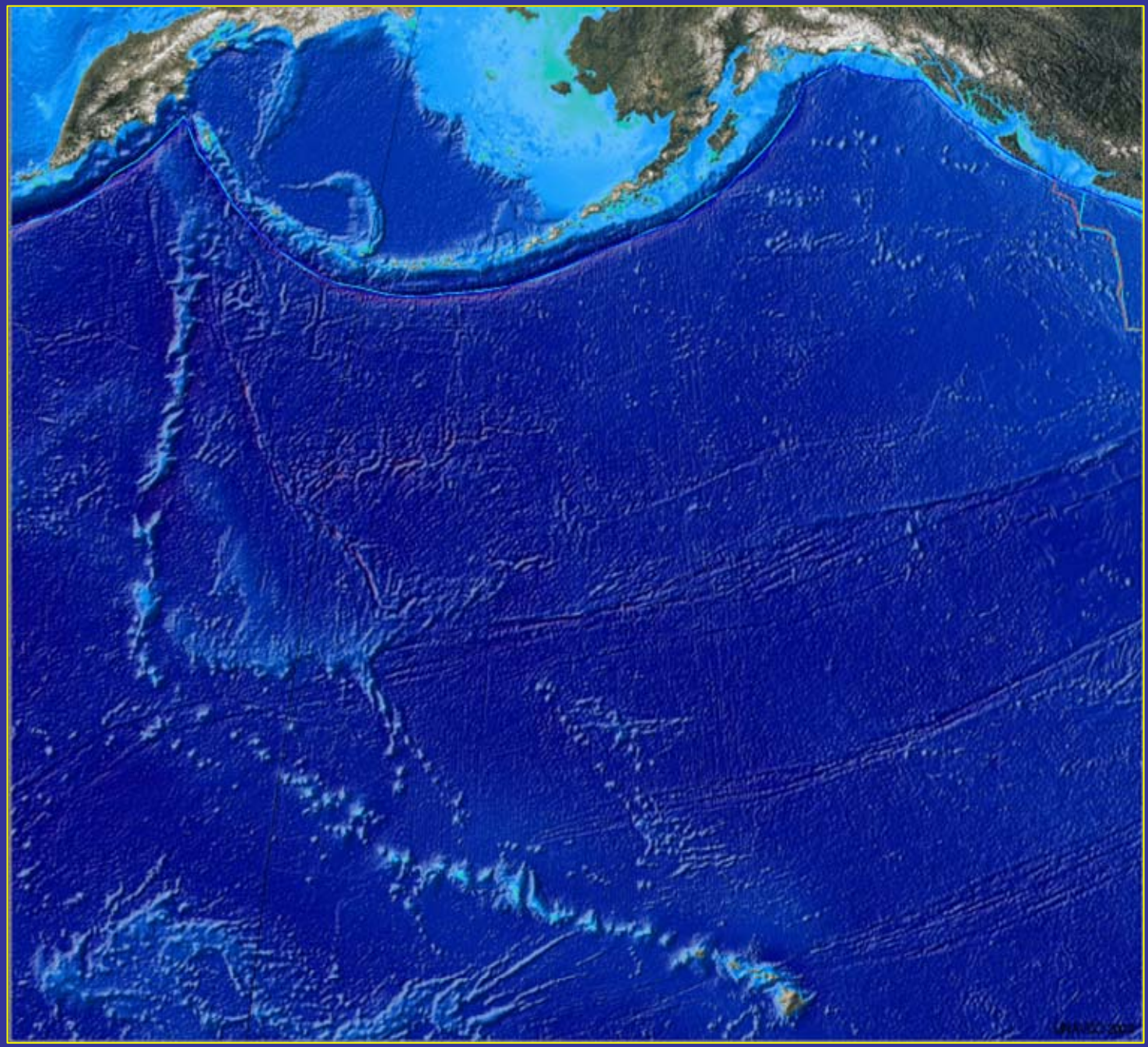


C. Period of normal magnetism

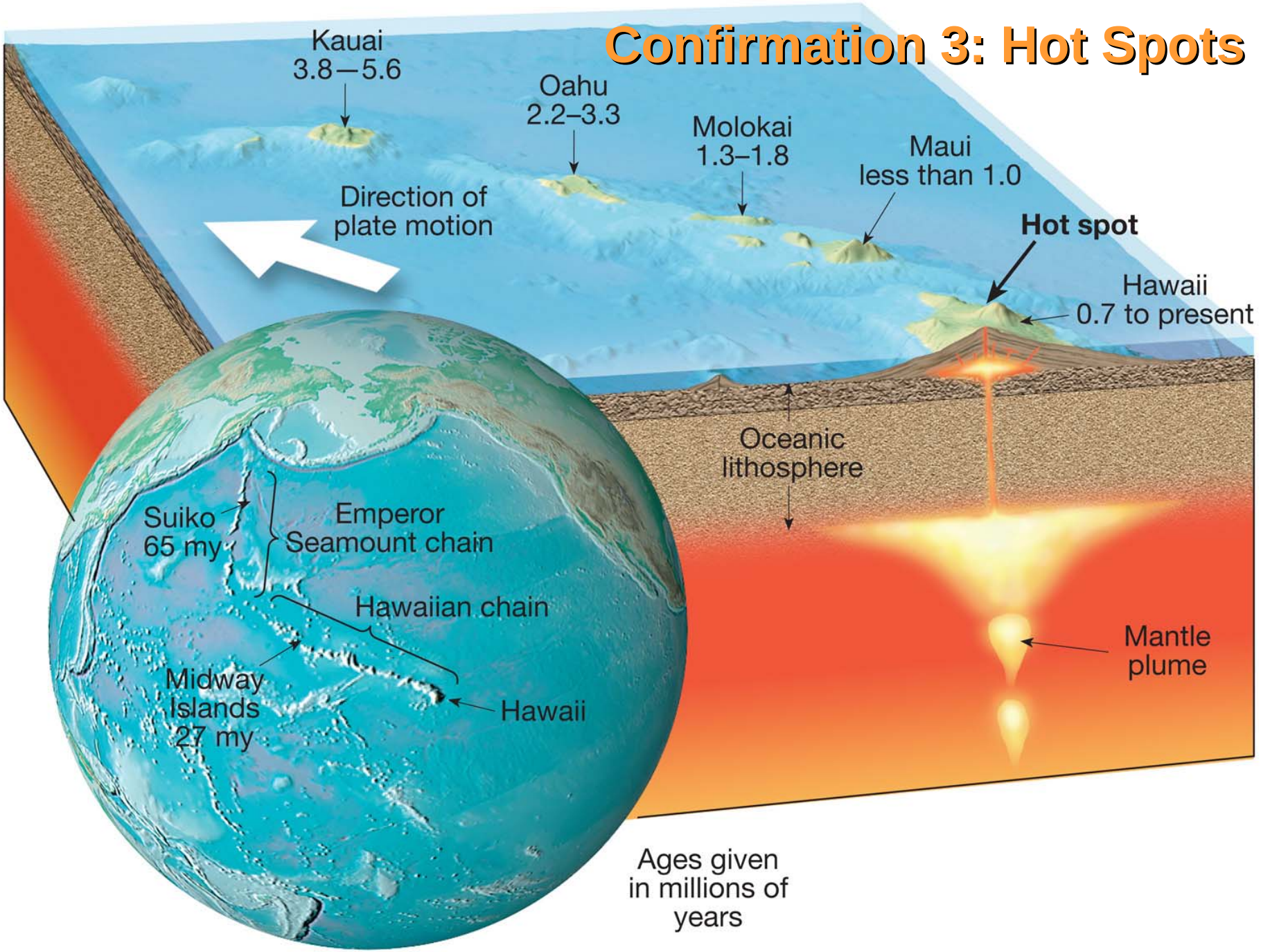


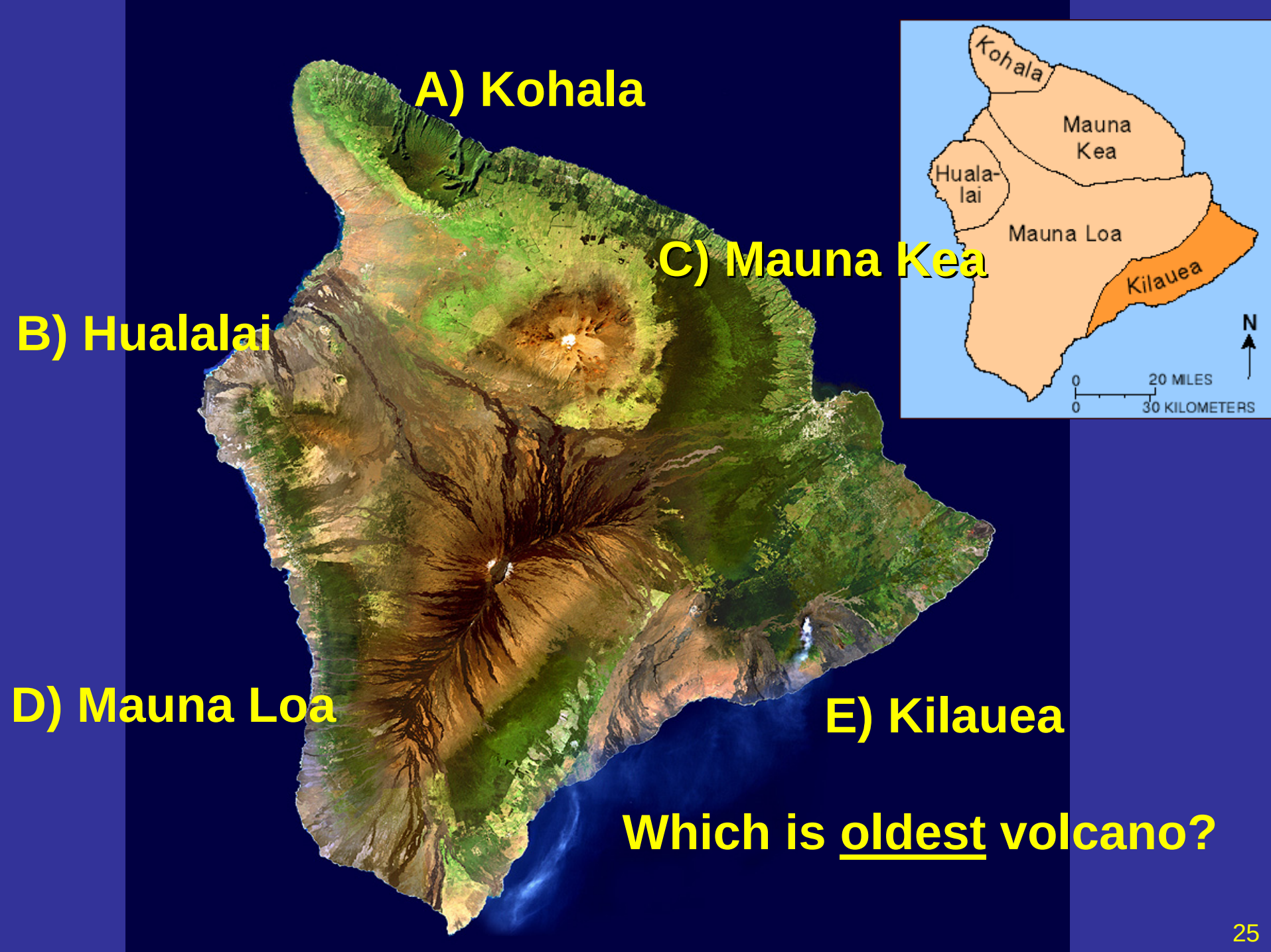


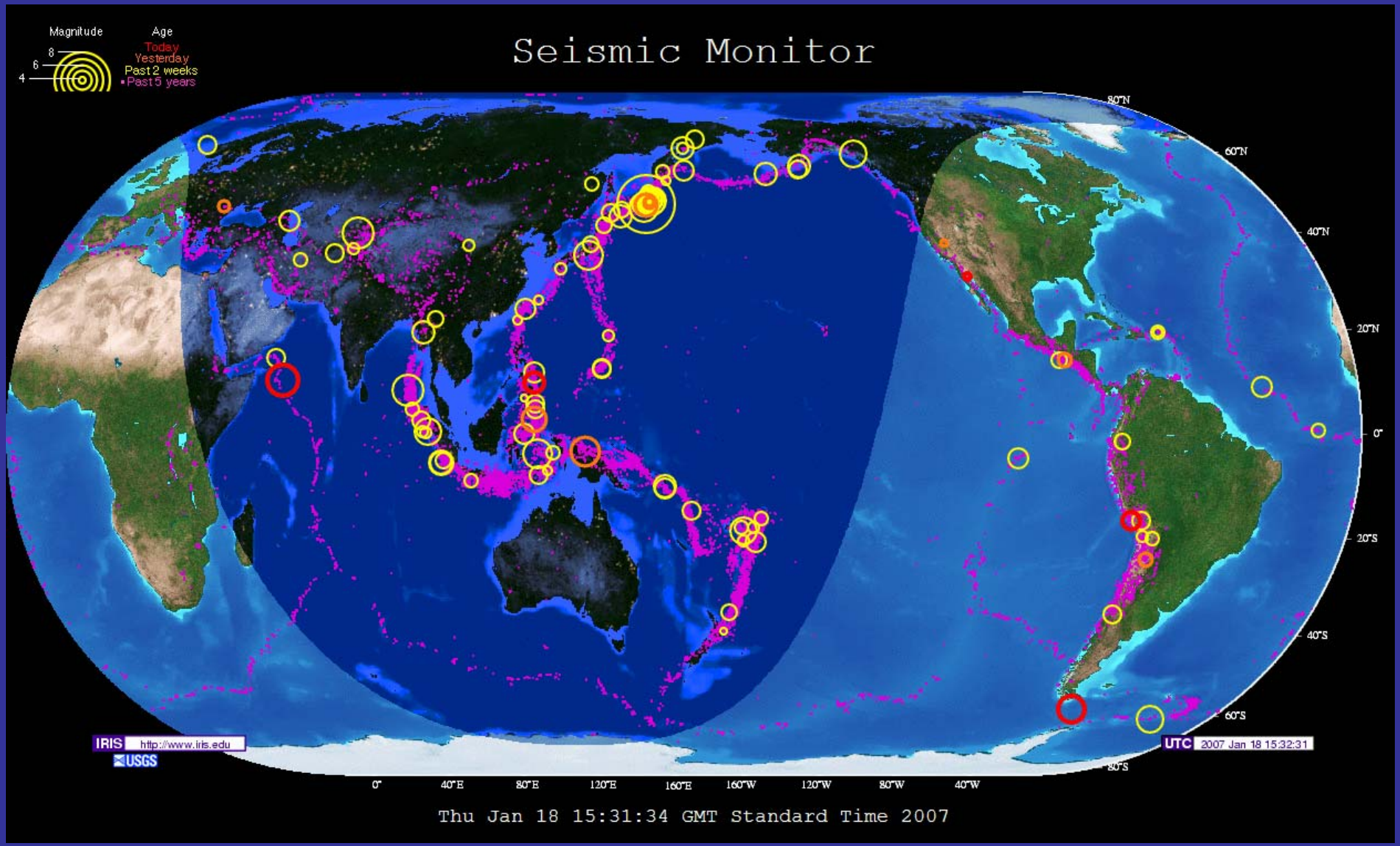
Magnetism of seafloor matches time scale of Earth's magnetic field



Confirmation 3: Hot Spots

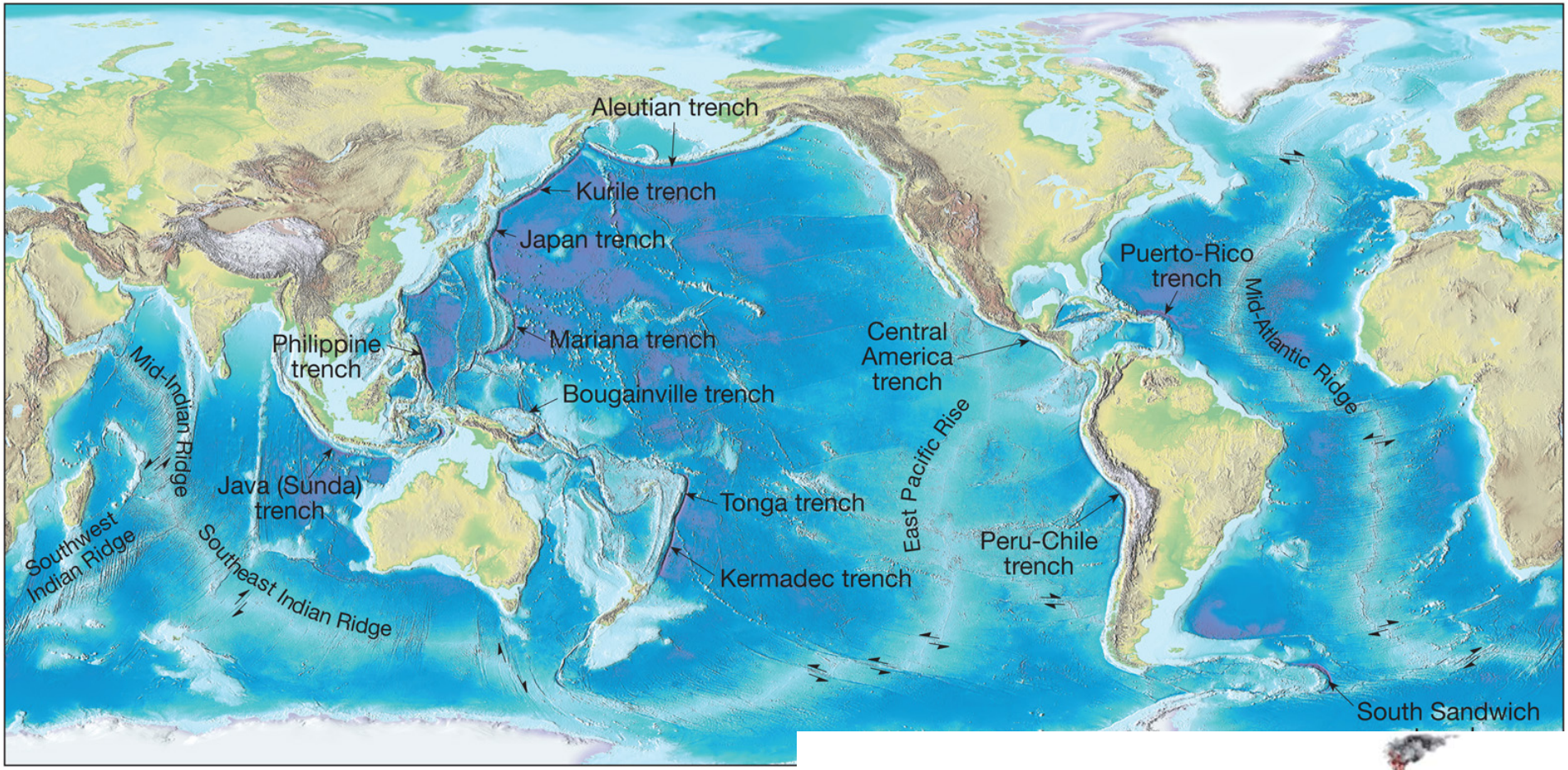


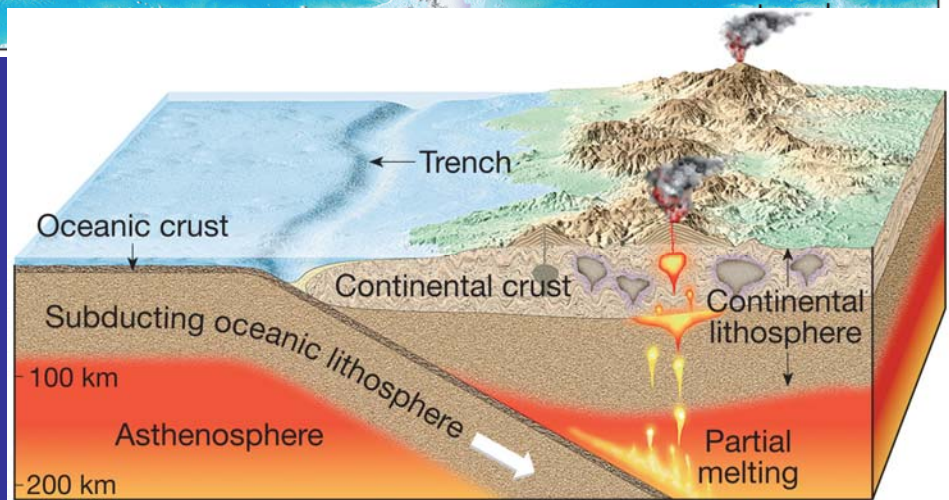

A) Kohala
C) Mauna Kea
B) Hualalai
D) Mauna Loa
E) Kilauea
Which is oldest volcano?
Kohala
Mauna Kea
Hualalai
Mauna Loa
Kilauea
N
0
20 MILES
0
30 KILOMETERS

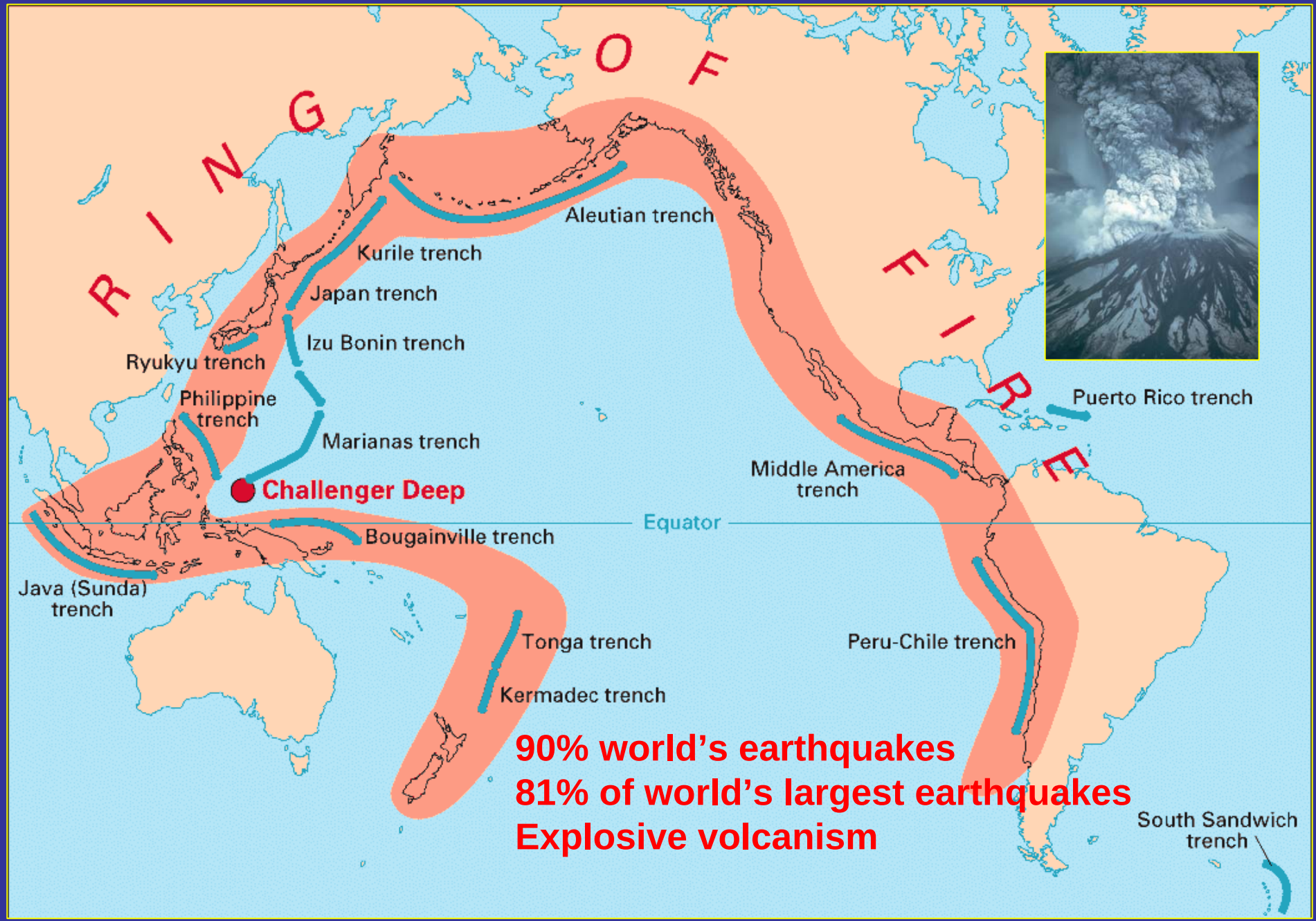


Where are the world's earthquakes?

Oceanic Trenches

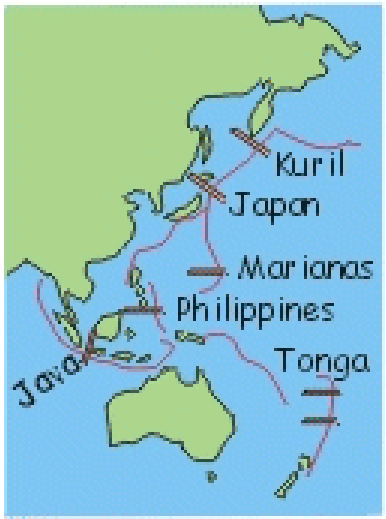


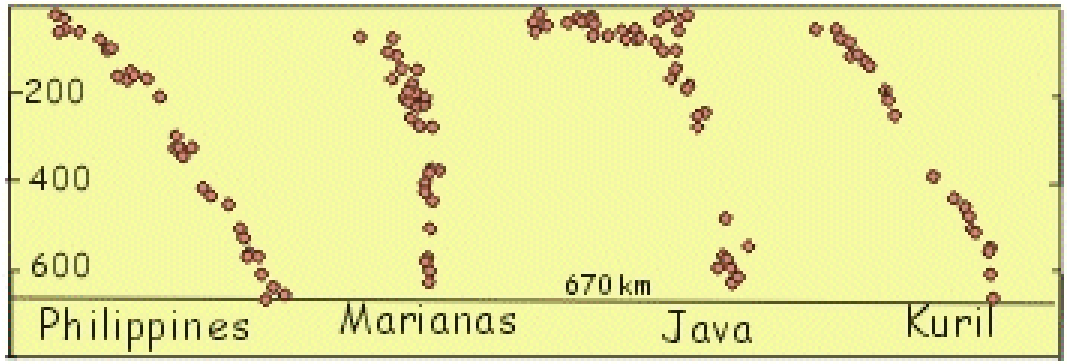


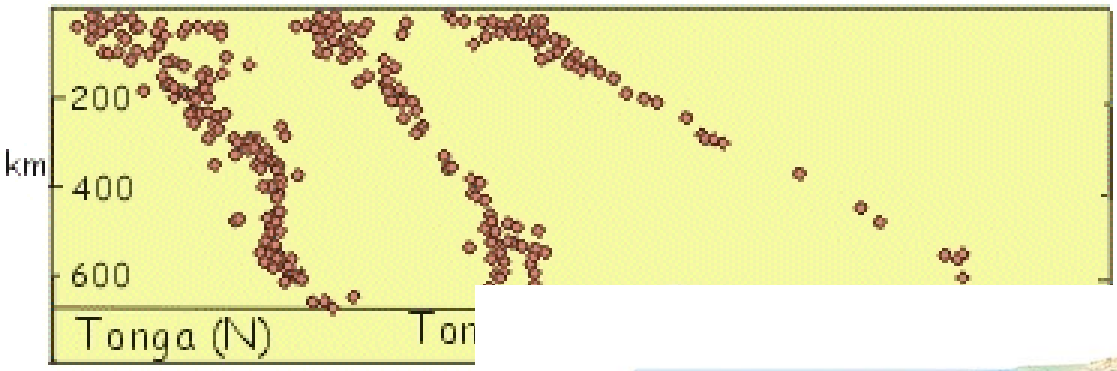

RING OF FIRE
Aleutian trench
Kurile trench
Japan trench
Izu Bonin trench
Ryukyu trench
Philippine trench
Marianas trench
Challenger Deep
Bougainville trench
Equator
Java (Sunda) trench
Tonga trench
Kermadec trench
Middle America trench
Puerto Rico trench
Peru-Chile trench
South Sandwich trench
90% world's earthquakes
81% of world's largest earthquakes
Explosive volcanism

Confirmation 4: Wadati-Benioff zones

Earthquakes and the dip of Wadati-Benioff seismic zones

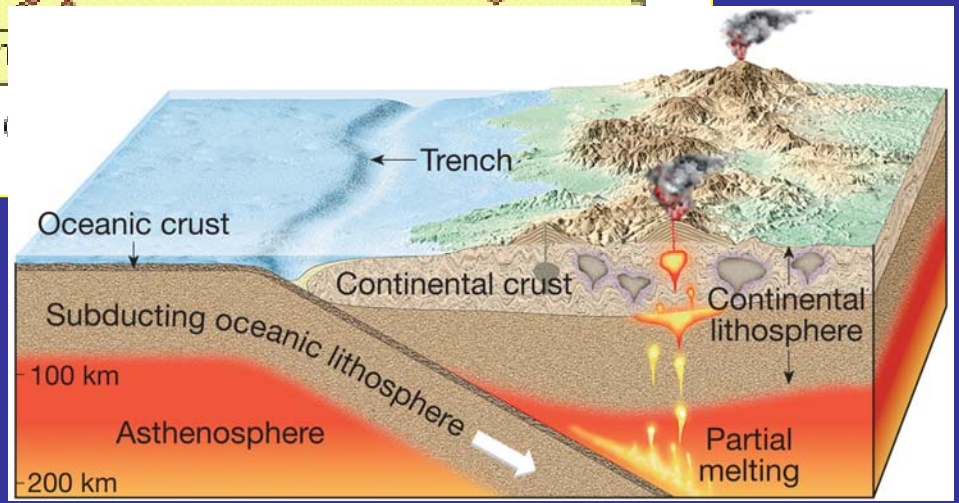


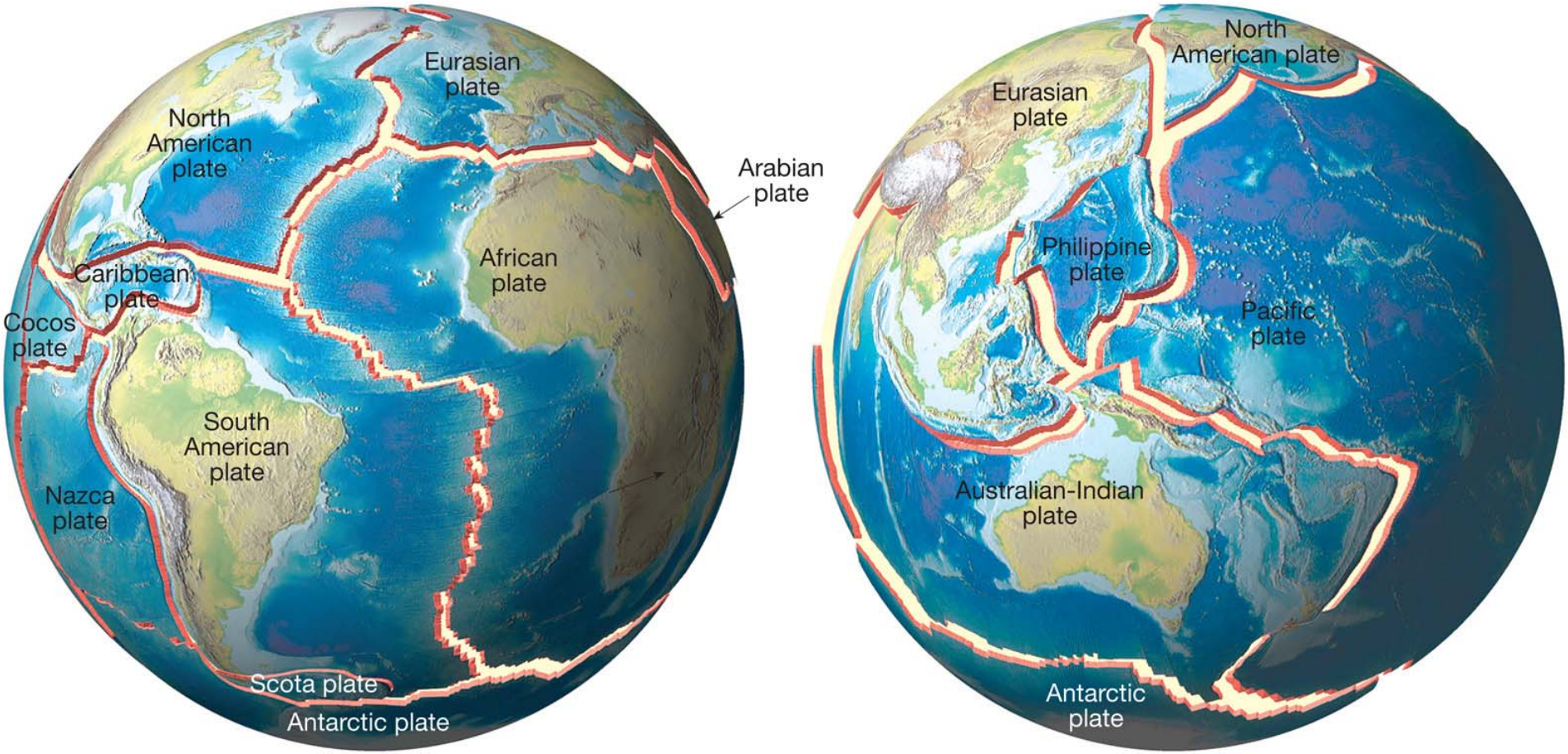




vertical an

Sinking oceanic crust





7 major plates:

N. American, S. American, Pacific, African, Eurasian, Australian-Indian, Antarctic

7 intermediate plates:

Caribbean, Nazca, Philippine,Arabian, Cocos, Scotia, Juan de Fuca

12+ minor plates

=

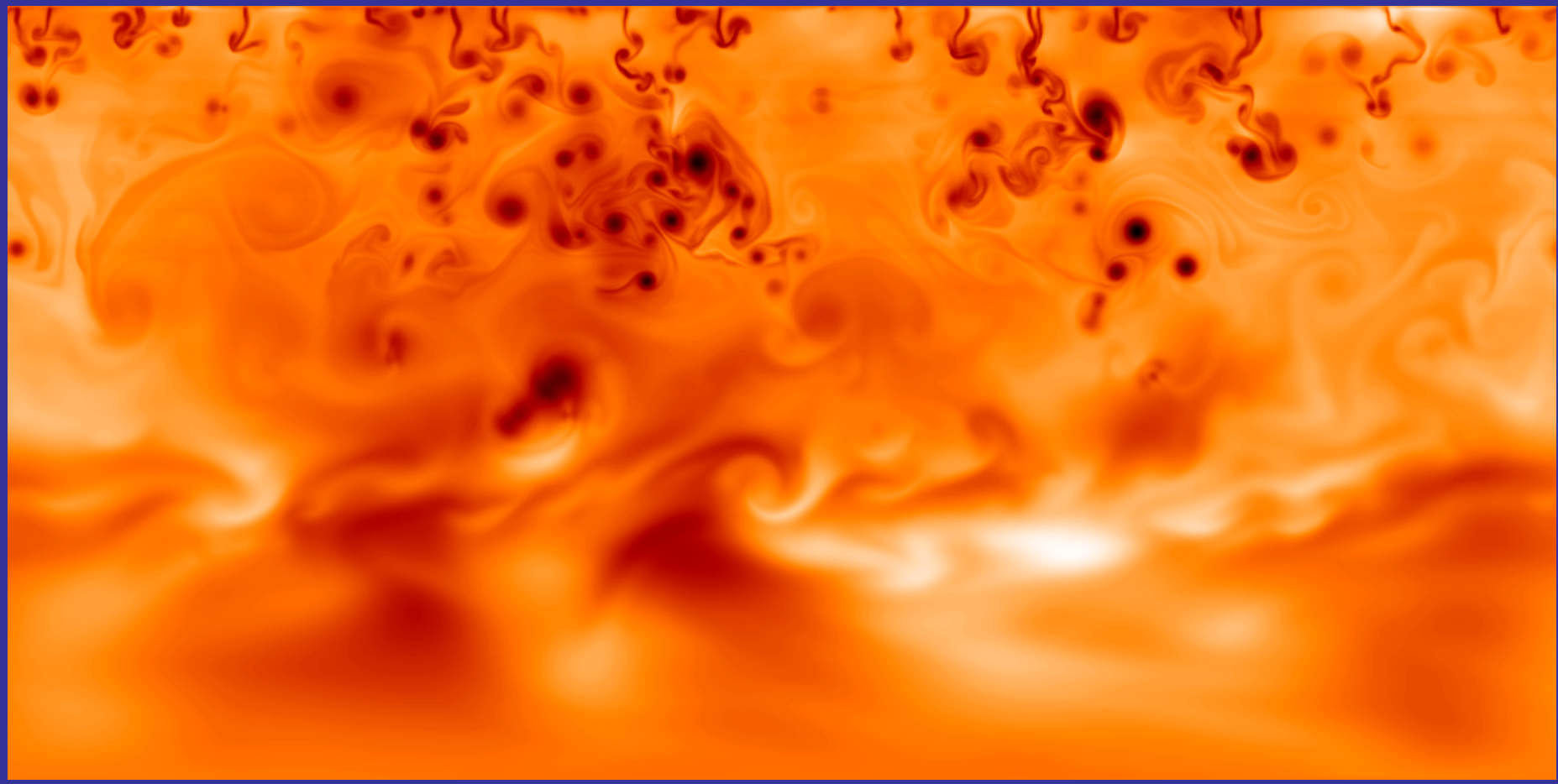
26+ plates total

Support for plate tectonic model



1. Continental jigsaw puzzle
2. Fossils match across Atlantic
3. Rock types/structures match across Atlantic
4. Ancient climates (i.e. glaciers in Africa)

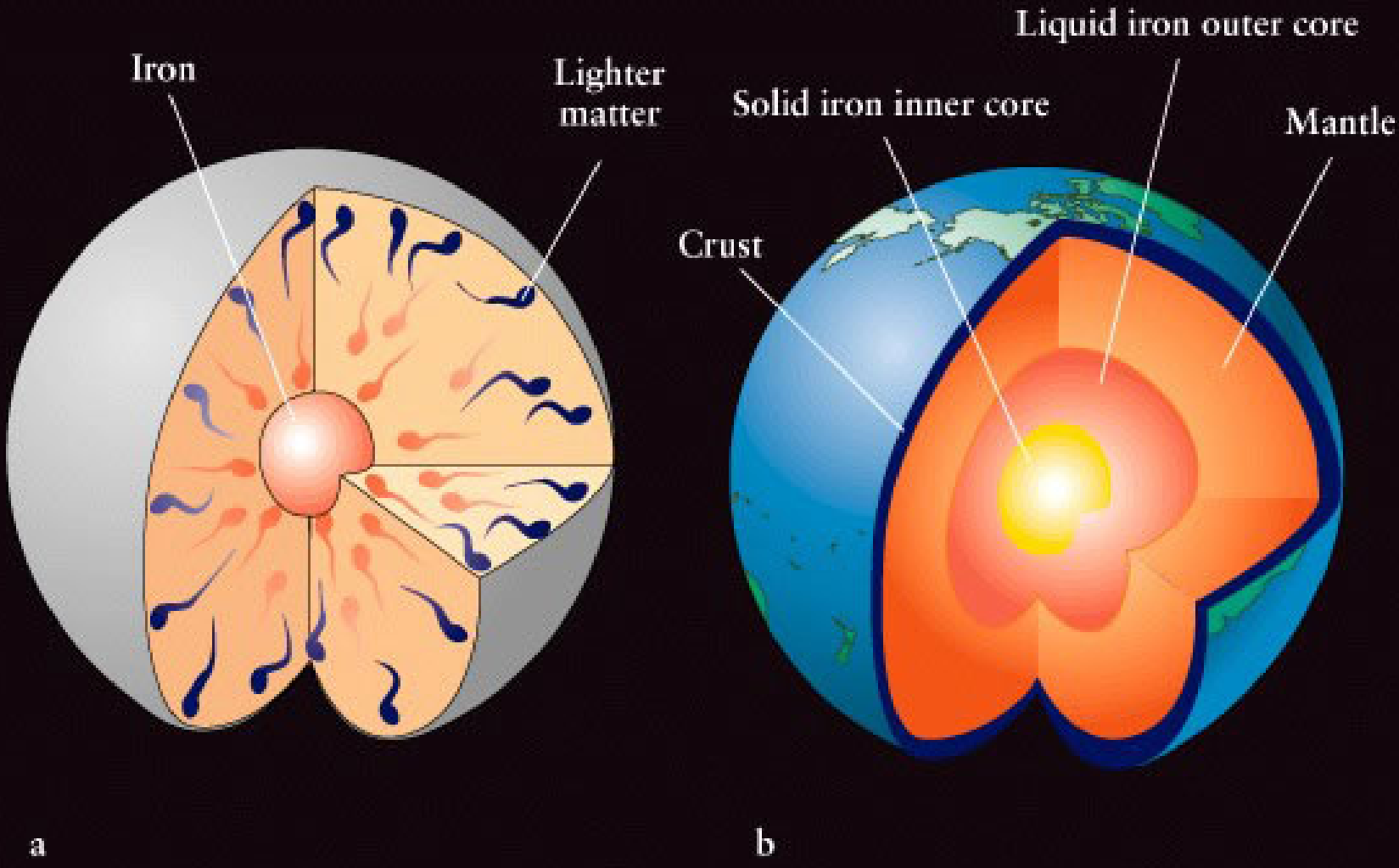
5. Ocean drilling confirms increasing seafloor age with distance from mid-ocean ridges
6. Paleomagnetism of lavas at ridges tracks formation of new seafloor
7. Hot spots track plate movement
8. Wadati-Benioff zones show descending plates



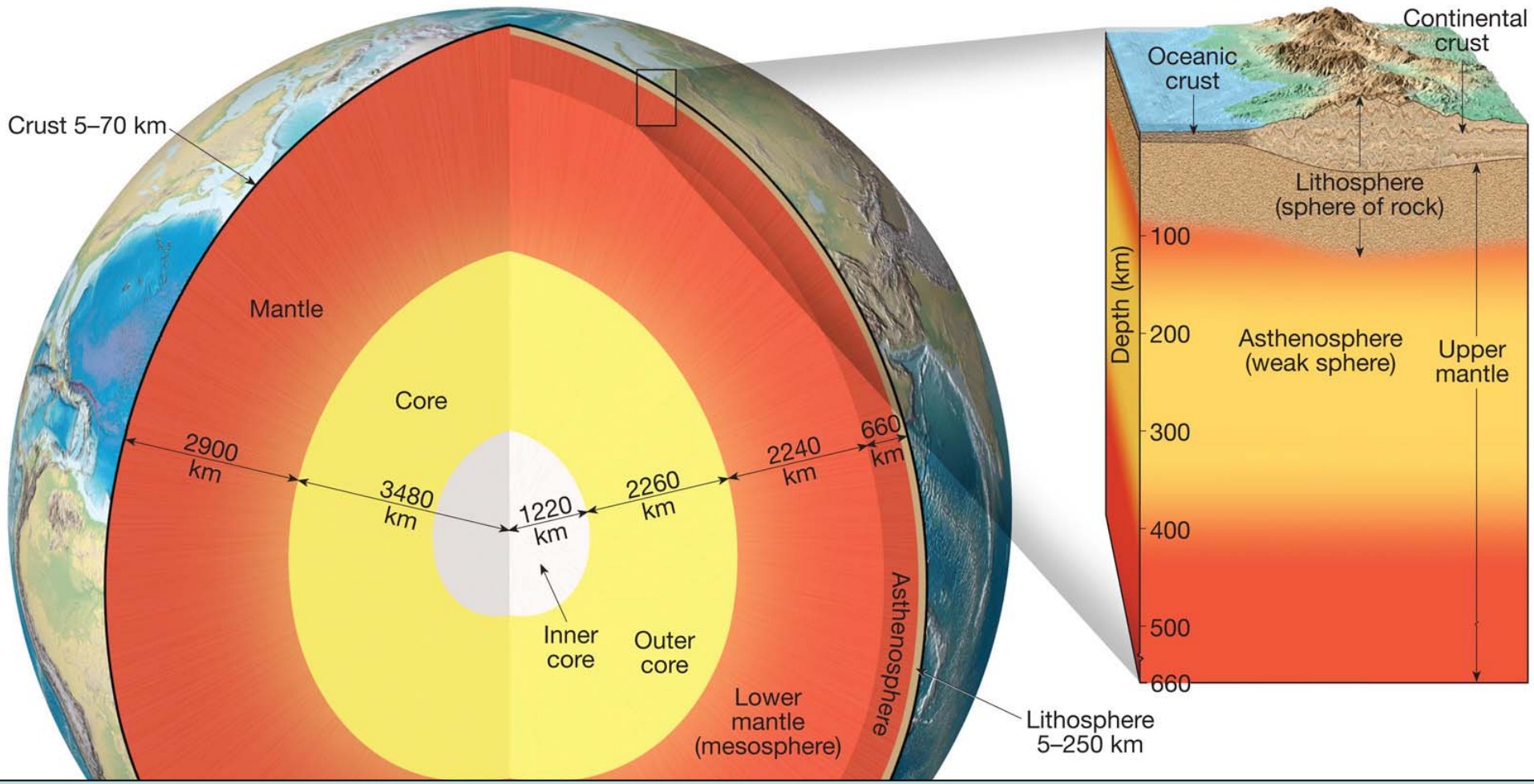
What's happening here?

A) Density difference
B) Heat difference
C) Pressure difference

"Iron Catastrophe"

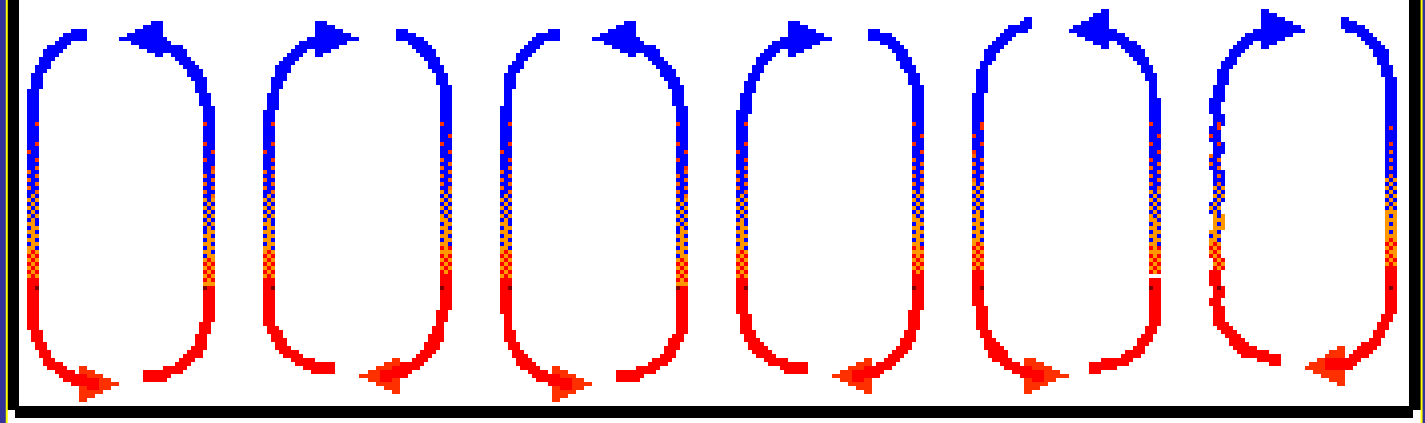


Density stratification: core → atmosphere



EARTH'S INTERNAL STRUCTURE	**PHASE**	**(density)PRESSURE**
• **Crust** – Fe/Mg/Si/O	**solid**	**low**
◦ **Continental crust – Si/O/Na**		
◦ **Oceanic crust – Fe/Mg/Ca**		
• **Mantle** – Fe/Mg	**solid, but capable of flow**	
• **Outer core** – Fe/Ni/Mg	**liquid**	
• **Inner core** – Fe/Ni	**solid**	**high**

Fluid cools by losing heat from surface



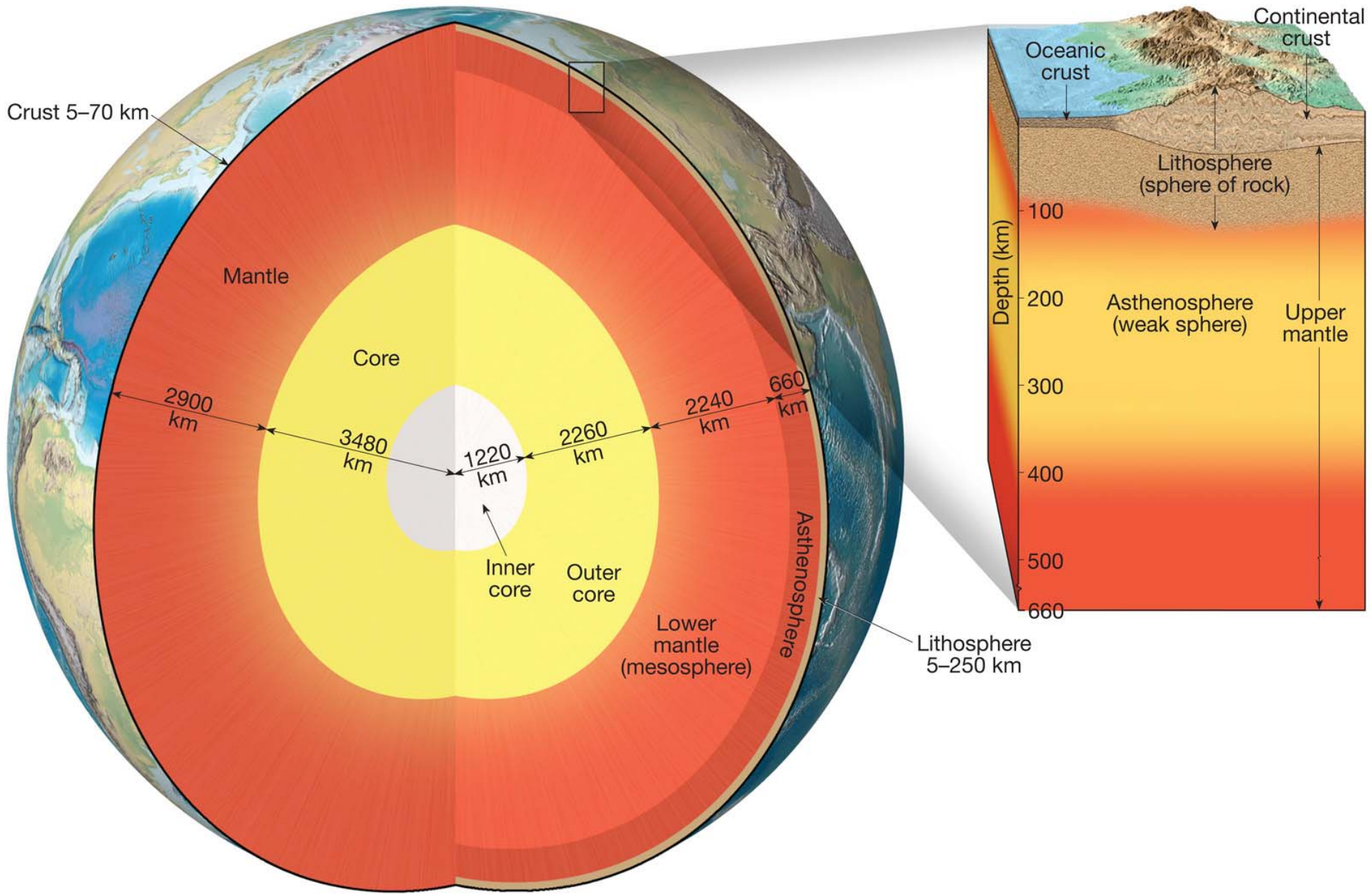


Convection cell

Warm, low density fluid rises

Cool, high density fluid sinks





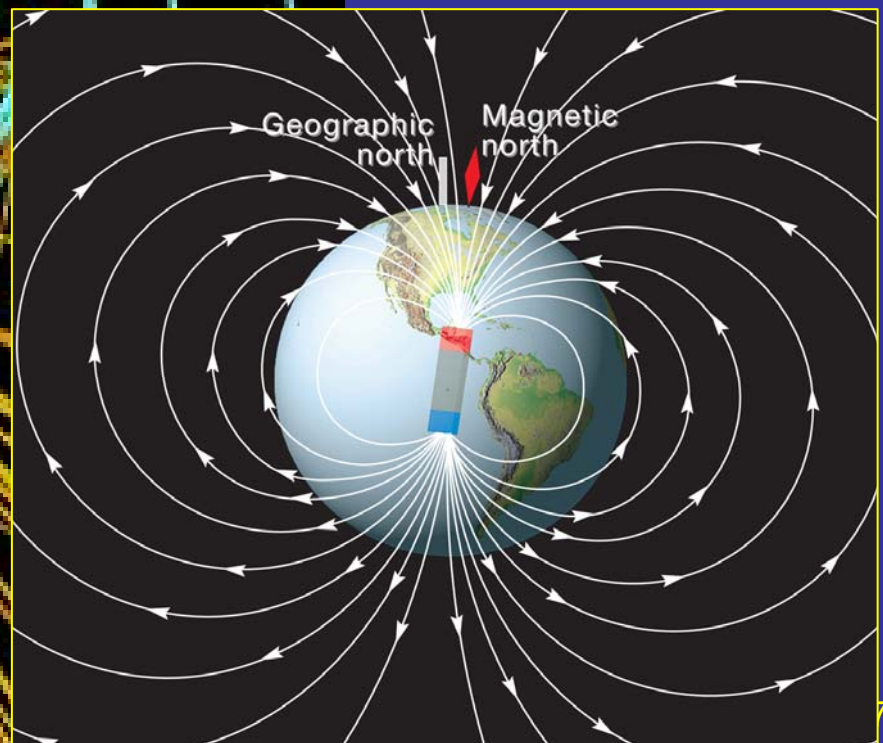
Where does convection occur?

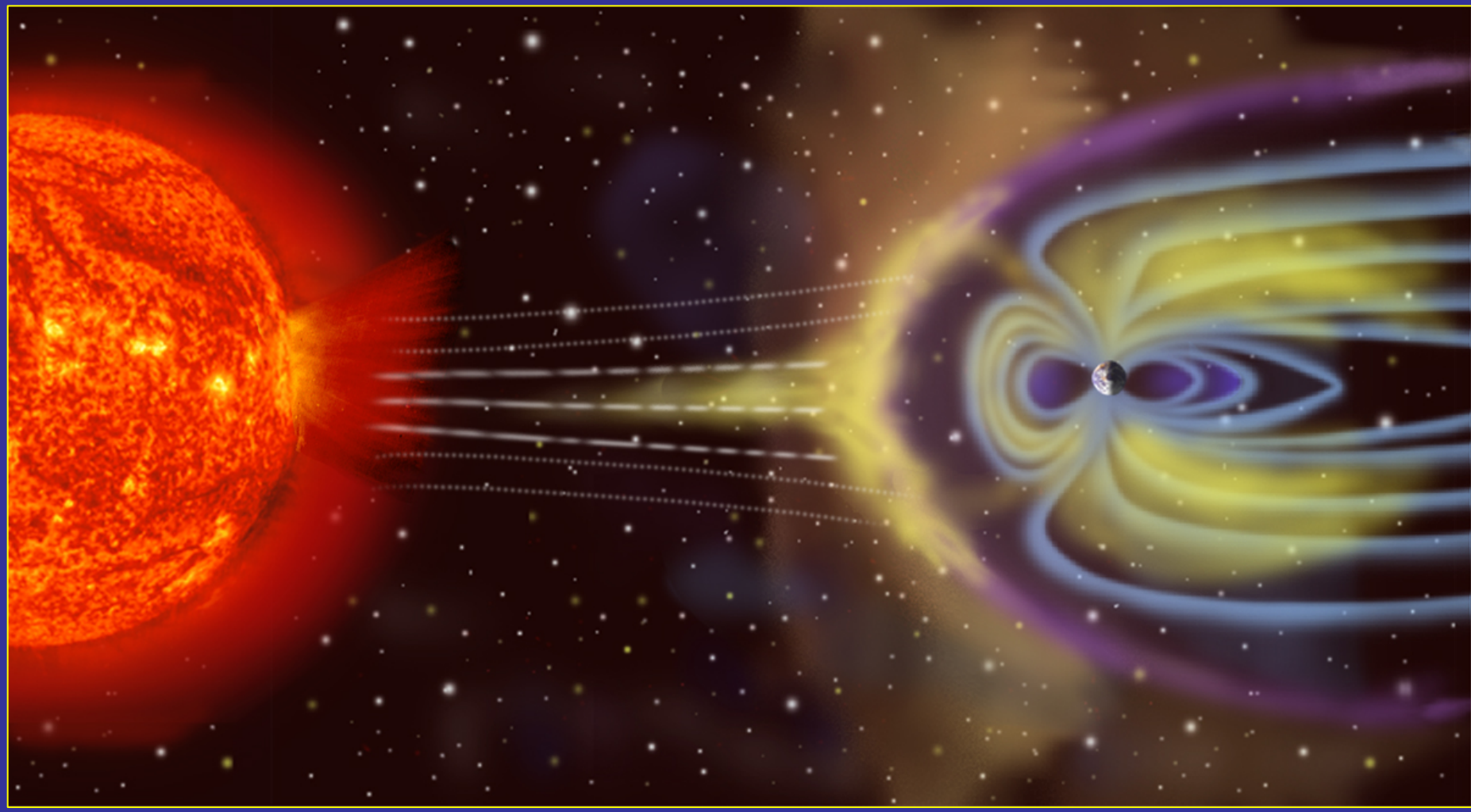
1) OUTER CORE

Magnetosphere
Magnetism gained from early nebula is magnified by:

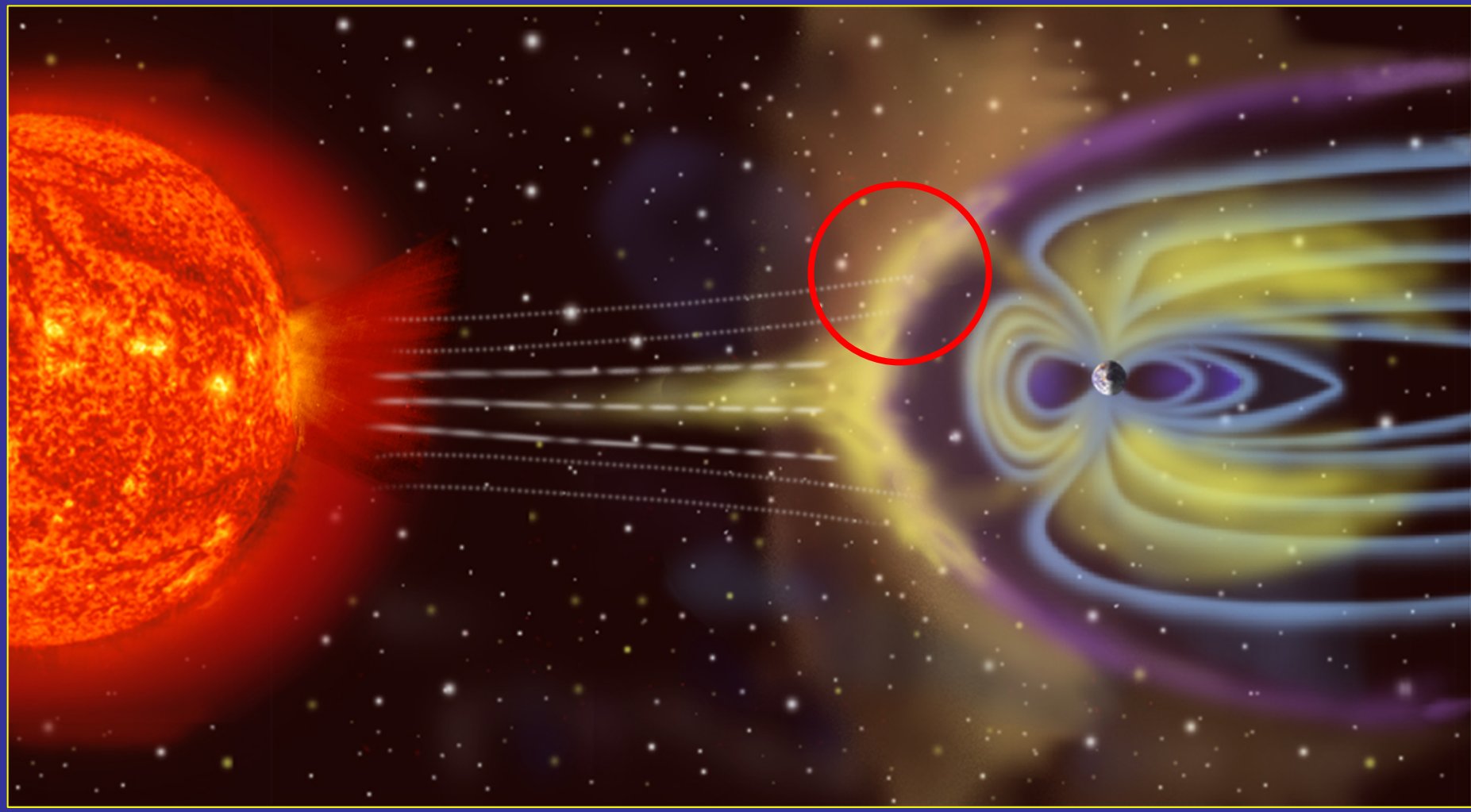
1)Turbulent iron/nickel fluid of outer core

2) Earth's rotation





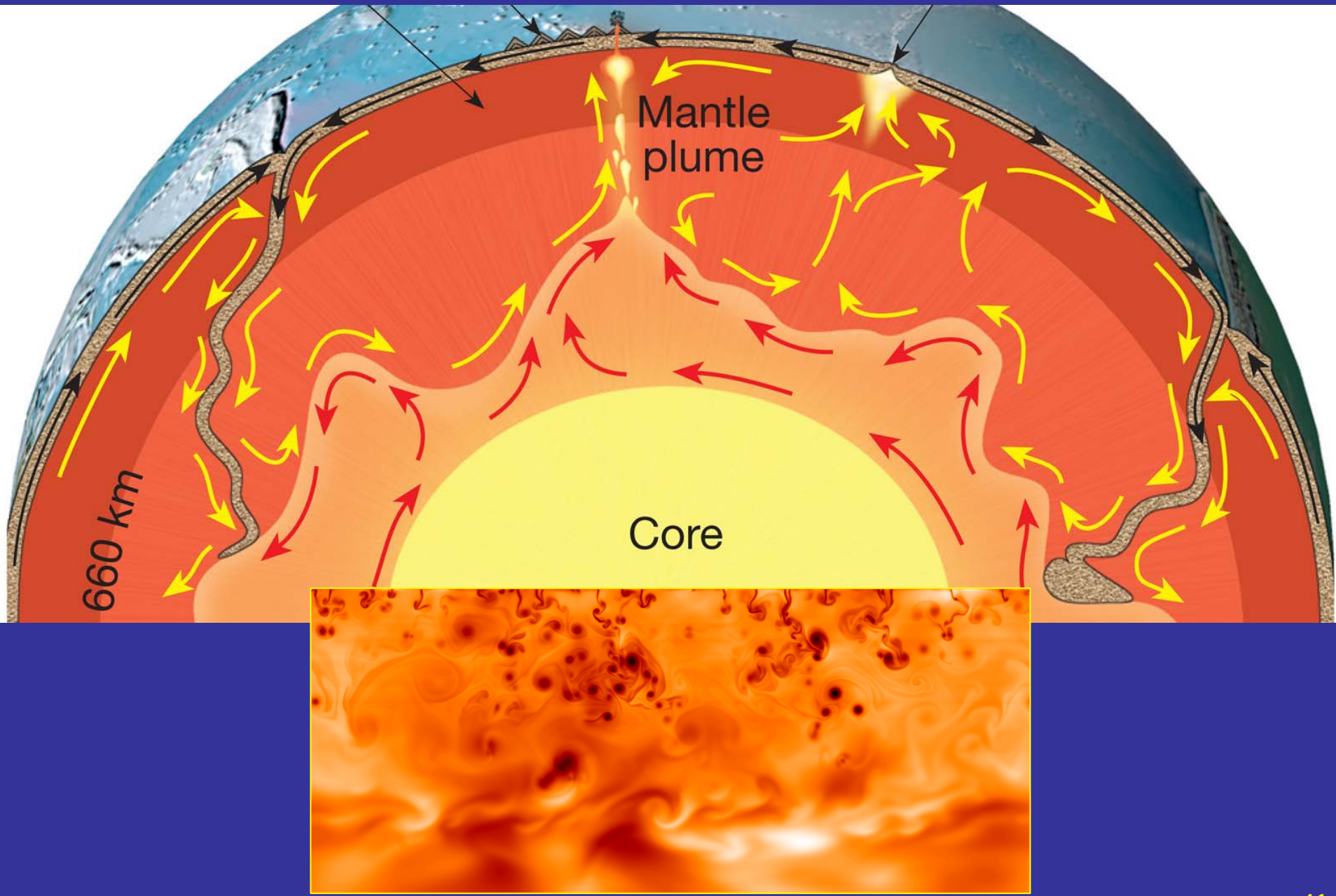
Earth’s magnetic field protects us from solar flares

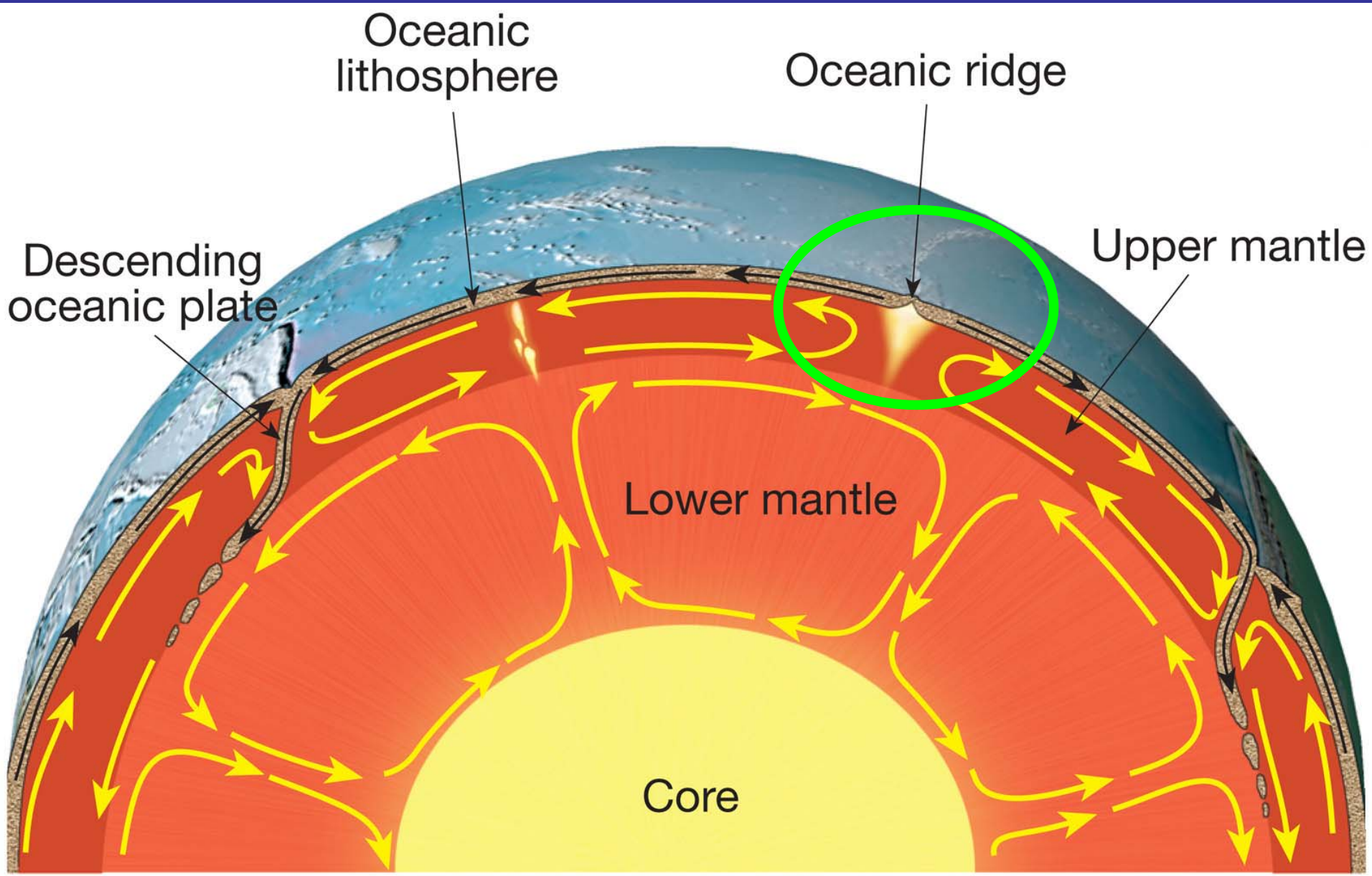


Earth’s magnetic field + solar flares create Aurora (Borealis, Australis – Northern, Southern lights)

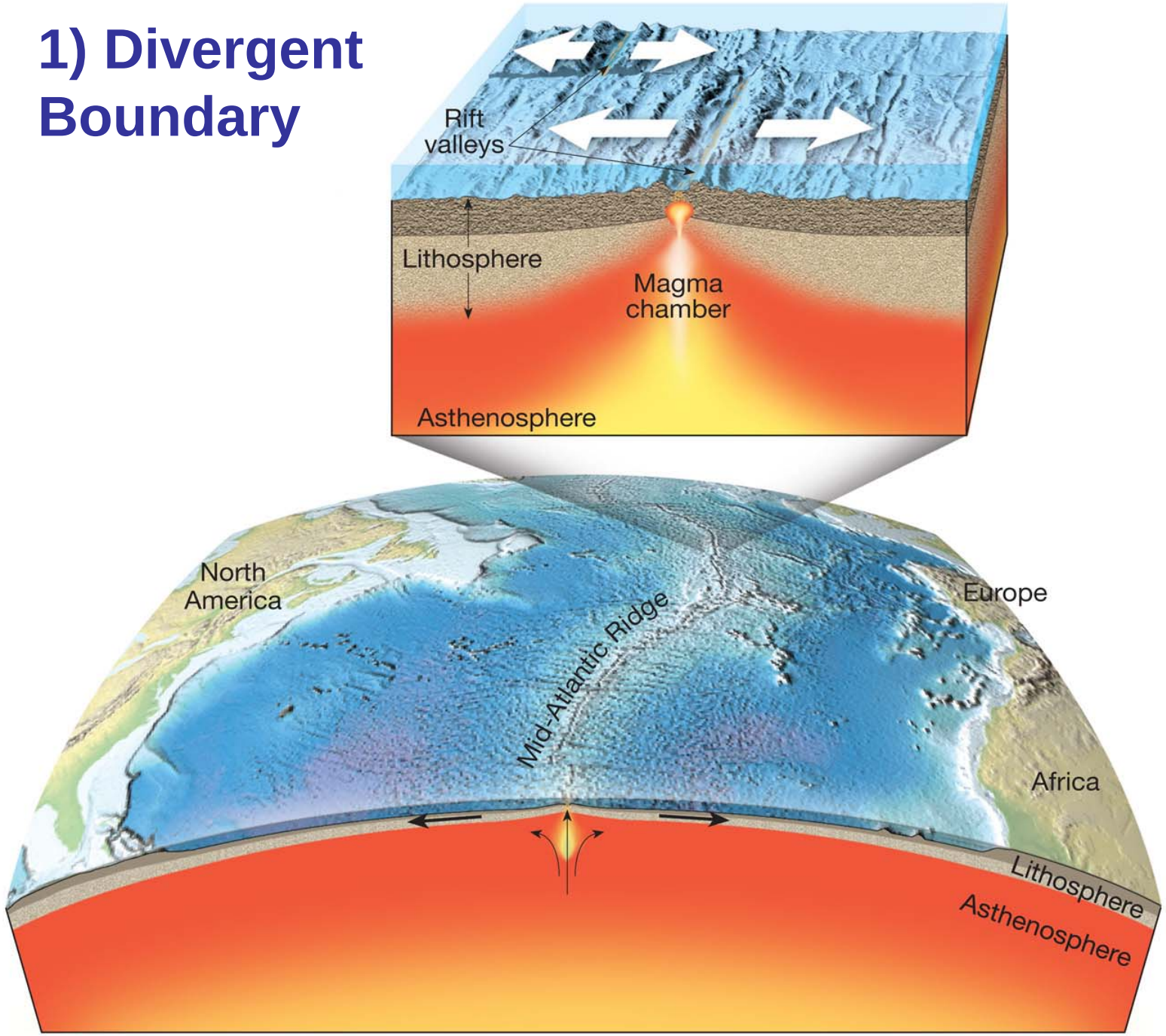


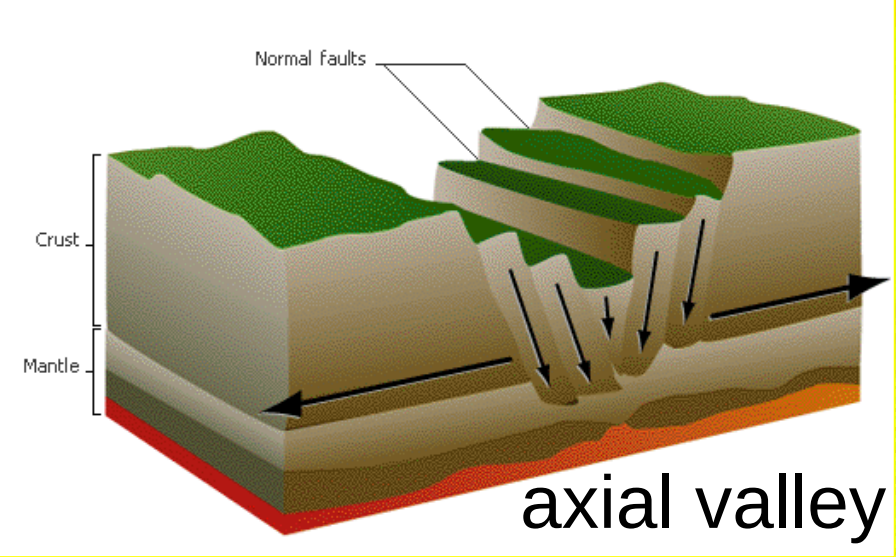
2) MANTLE CONVECTION – drives Plate Tectonics




Oceanic lithosphere
Oceanic ridge
Descending oceanic plate
Upper mantle
Lower mantle
Core

1) Divergent Boundary





axial valley

oceanic “ridge”
70,000 km long
broad inflation feature

Divergent boundary oceanic example – East Pacific Rise

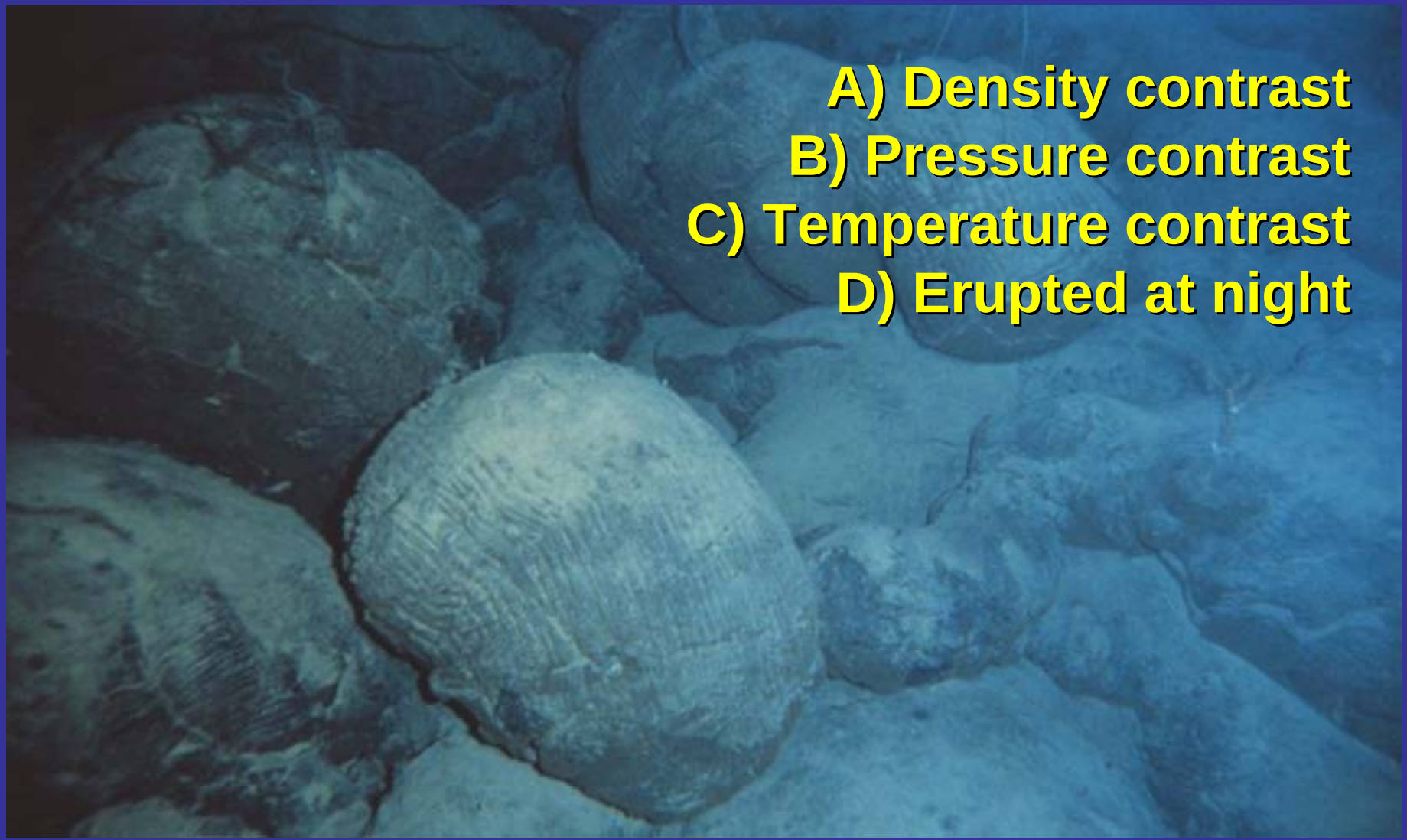


Cocos

Pacific

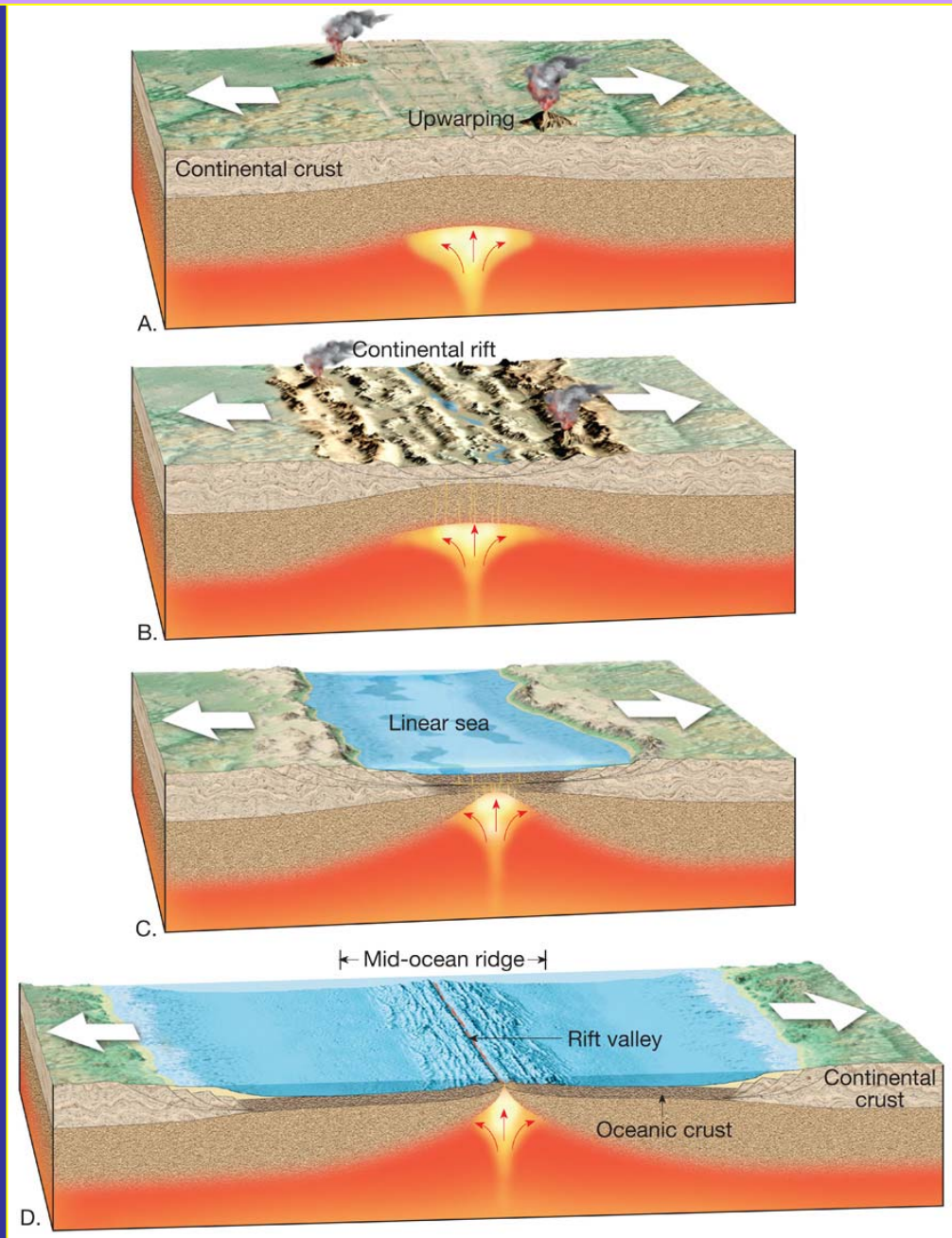
Nazca

What causes the “pillow” shape of these lavas?



A) Density contrast
B) Pressure contrast
C) Temperature contrast
D) Erupted at night

Divergent boundary – continental example



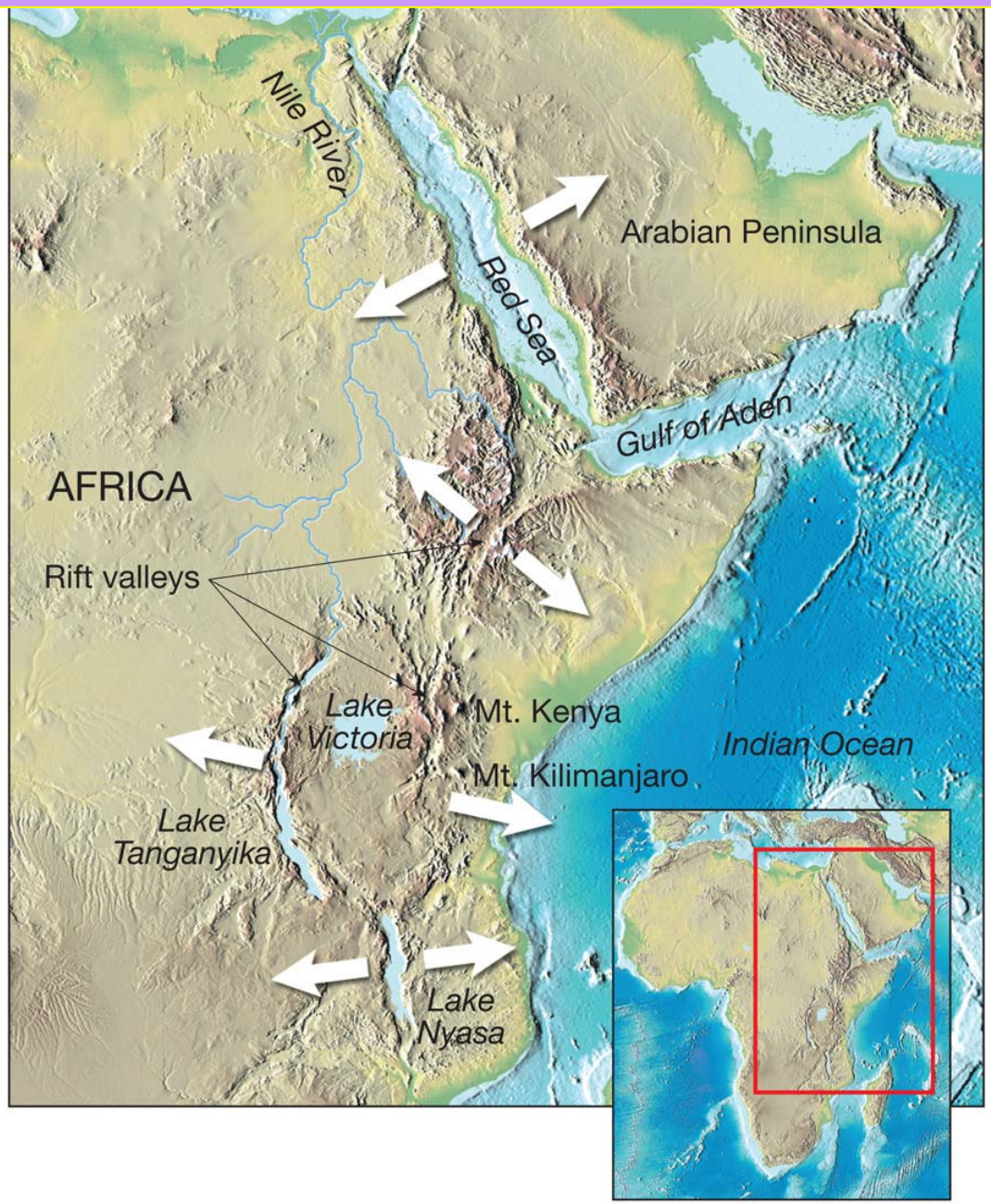
Upwarping, volcanism

Elongated rift valley

Narrow, linear sea

Seafloor spreading

Divergent boundary – East African Rift Valley

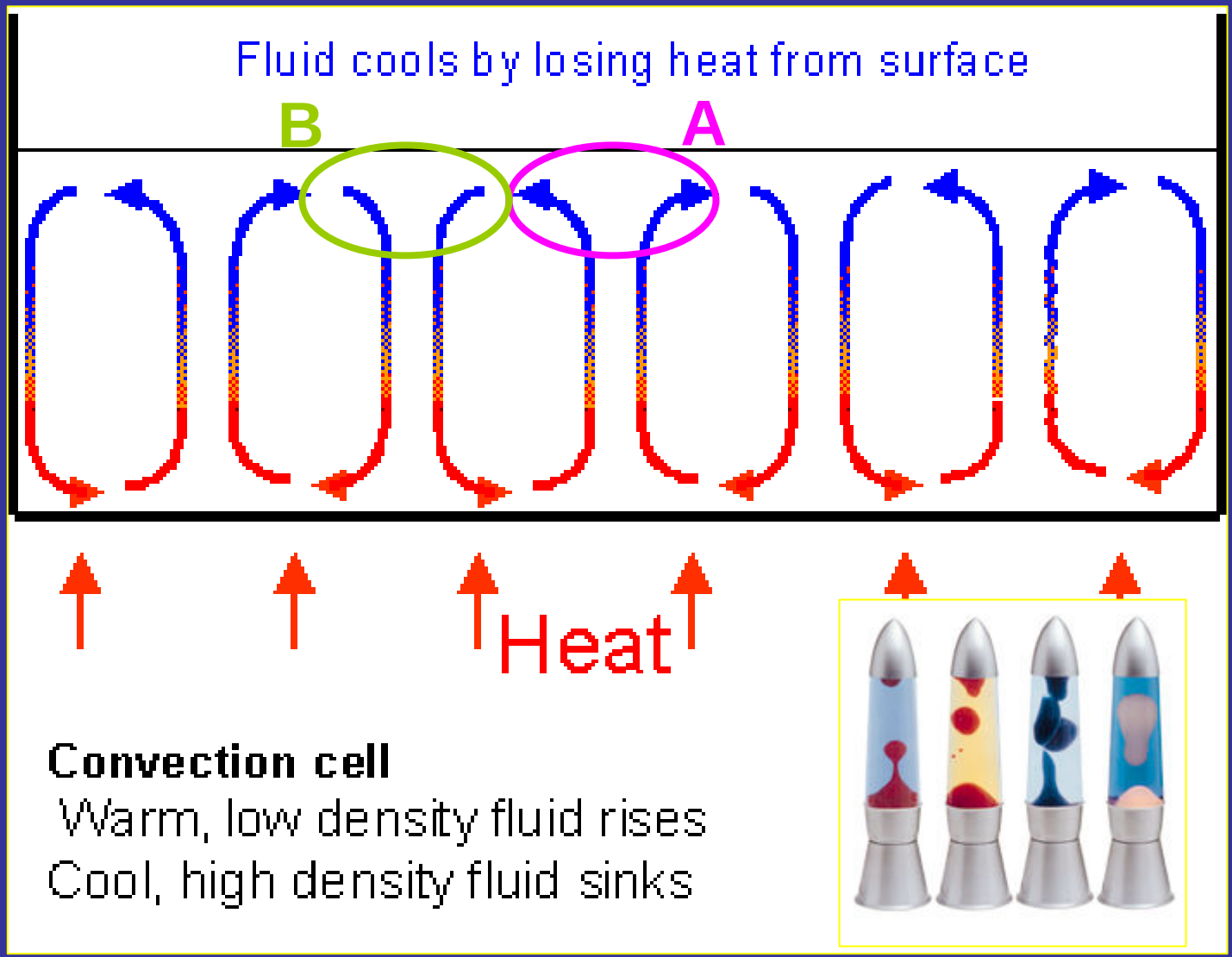




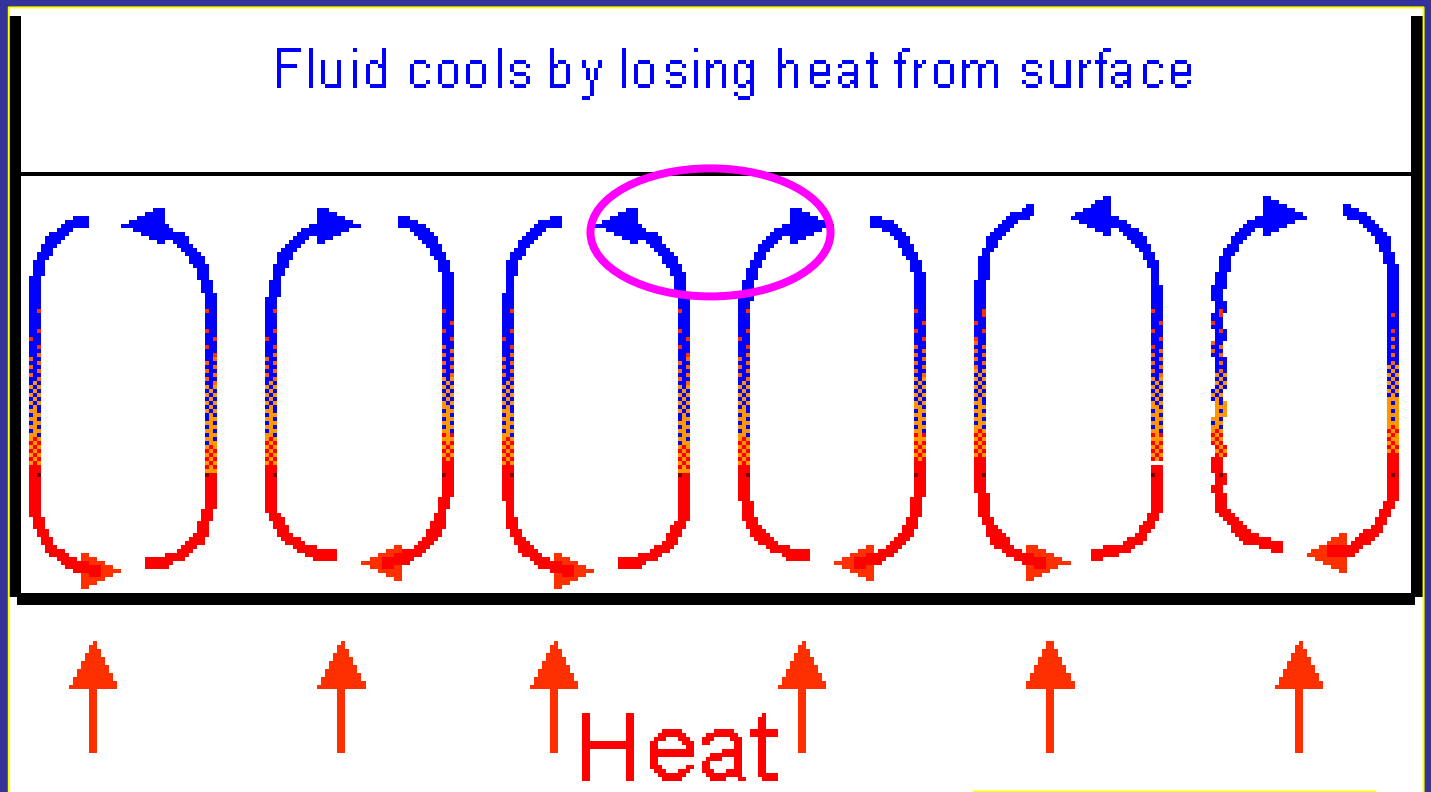








What does DIVERGENCE correspond to, A) or B) ?



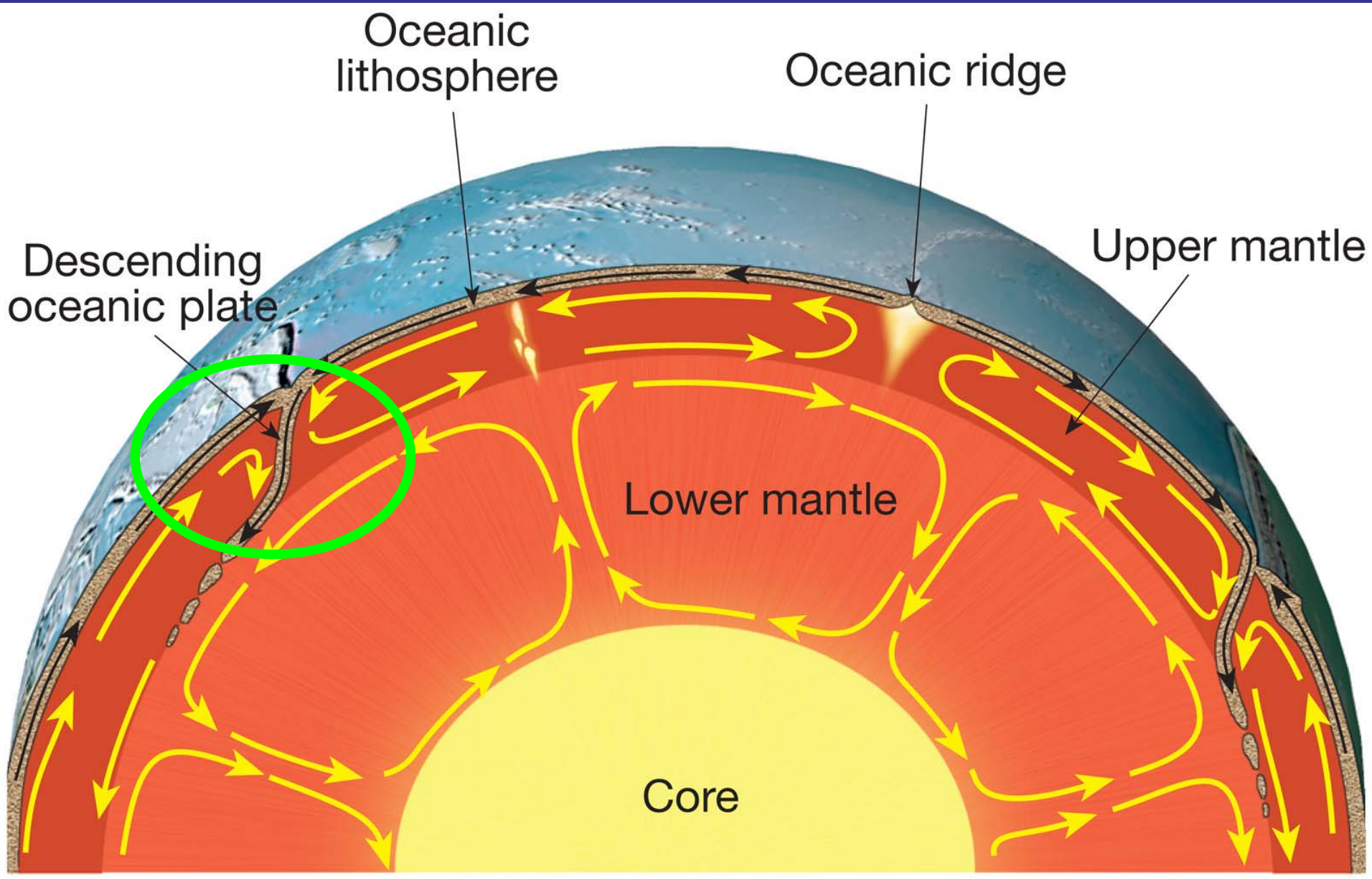
Convection cell

Warm, low density fluid rises

Cool, high density fluid sinks



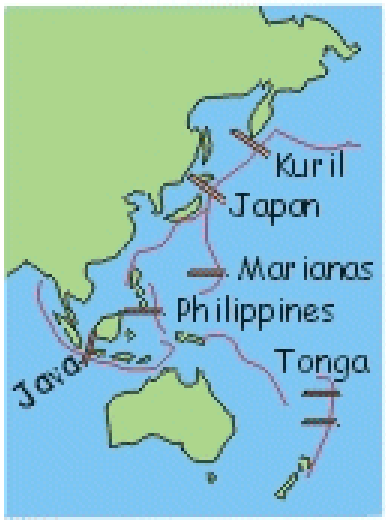
DIVERGENCE

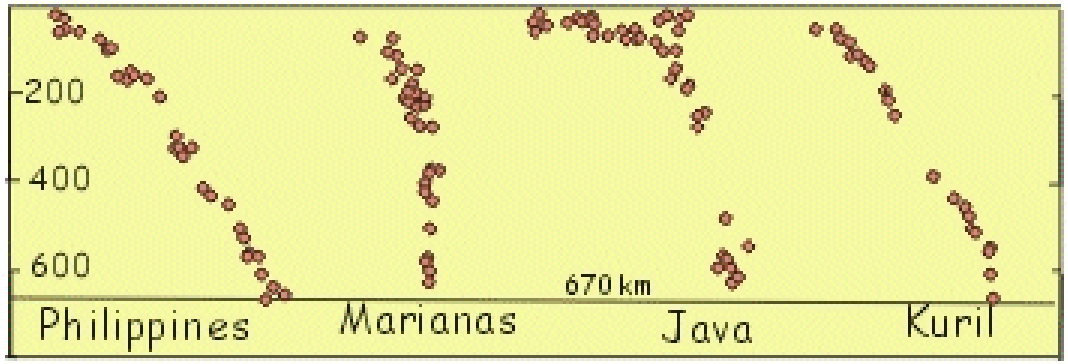


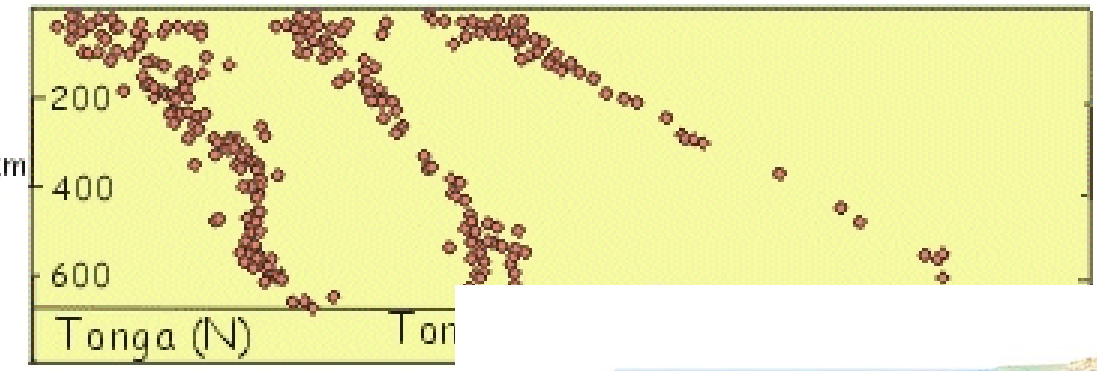
How do we know where these are?

Convergent boundary – Wadati-Benioff zones

Earthquakes and the dip of Wadati-Benioff seismic zones

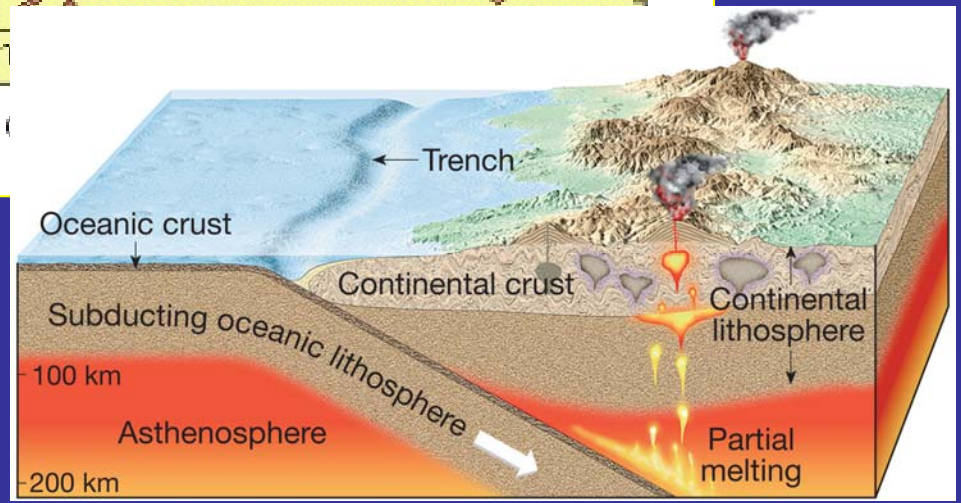




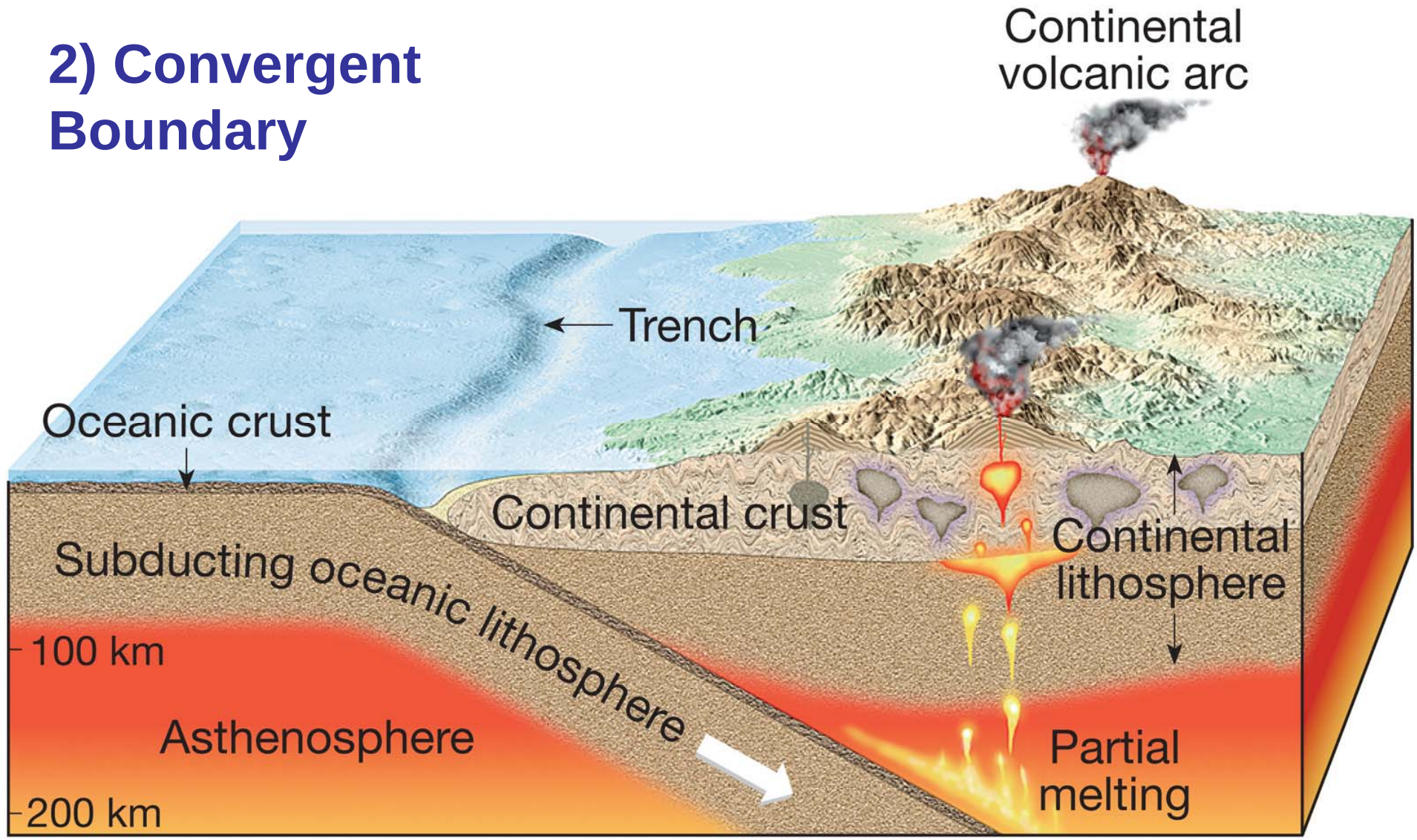


vertical an

Subducting oceanic crust



2) Convergent Boundary



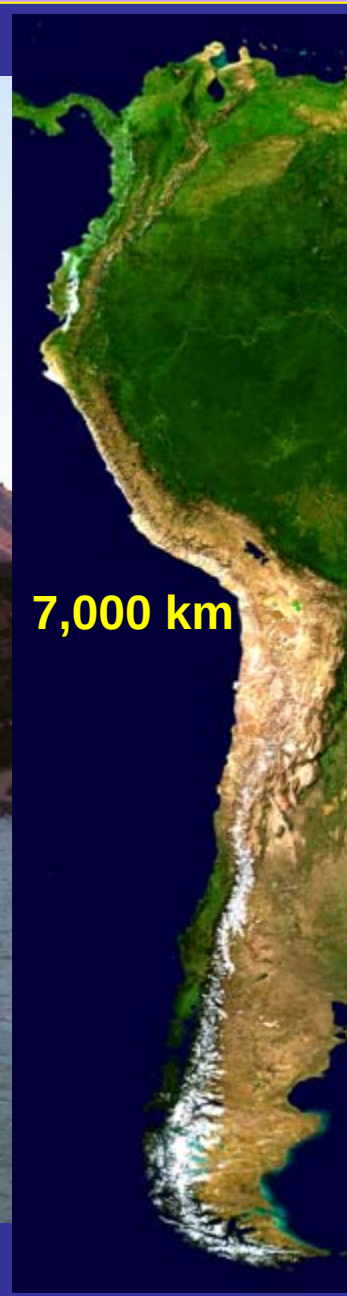
Oceanic Trench

Why does one side sink and the other float?

Convergent boundary – oceanic-continental

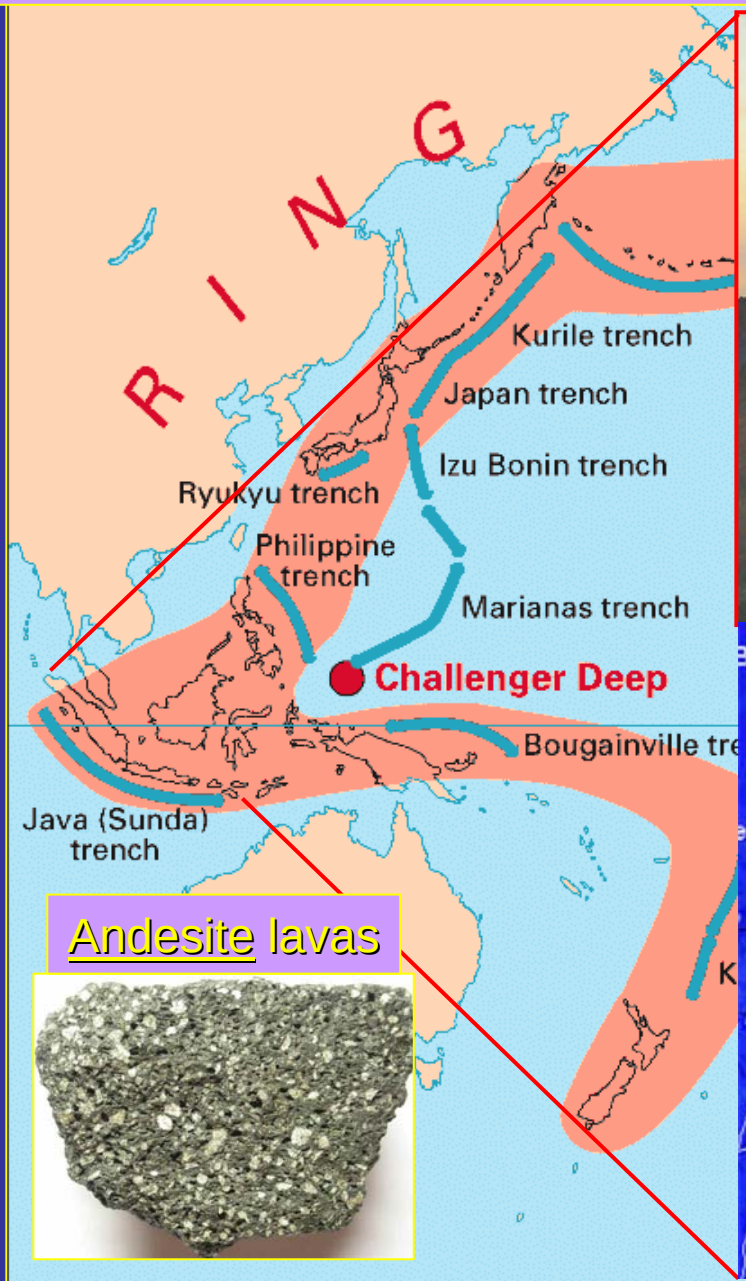


Typical Example –
Andes mountain range

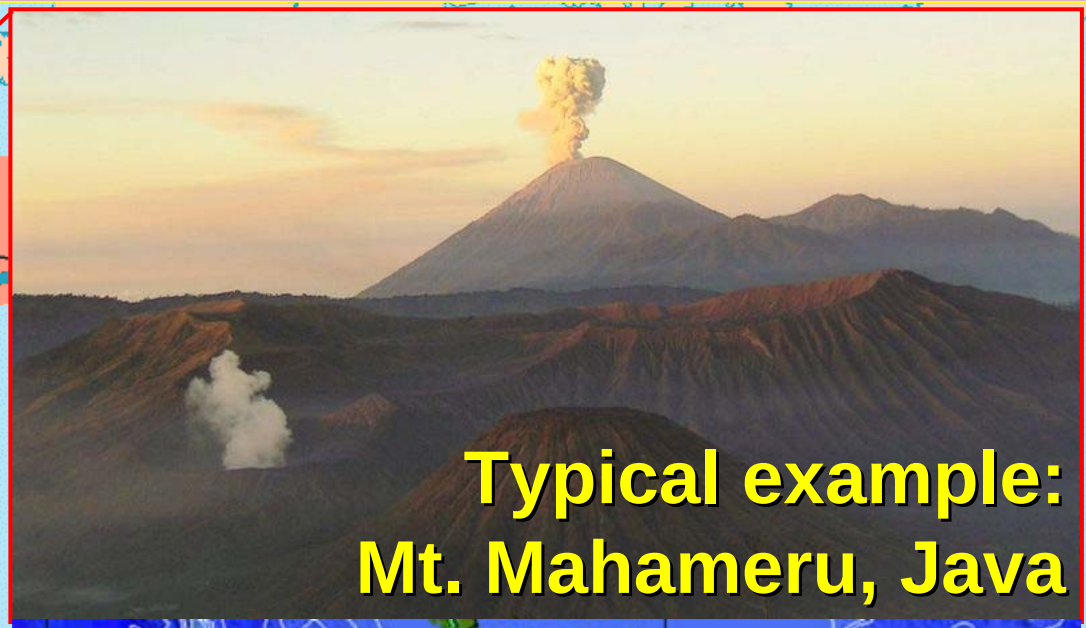


Andesite lavas

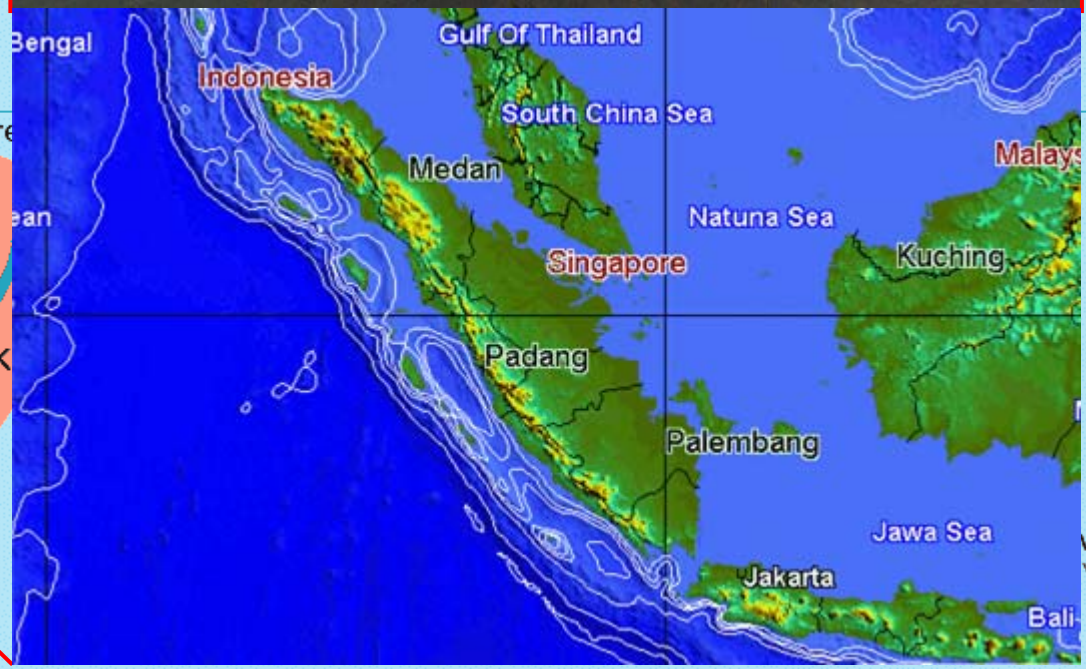
Convergent boundary – oceanic-oceanic

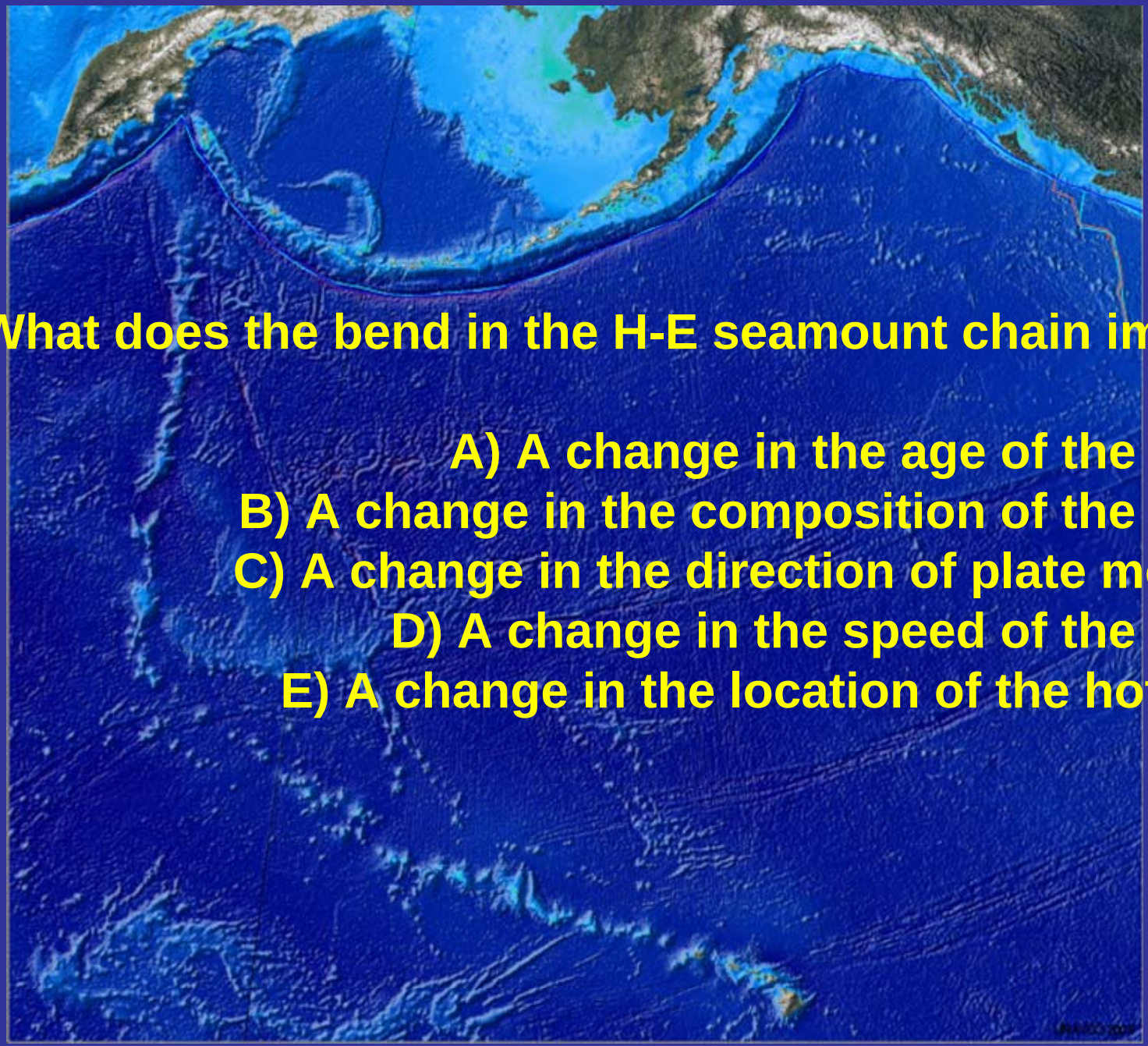


Andesite lavas



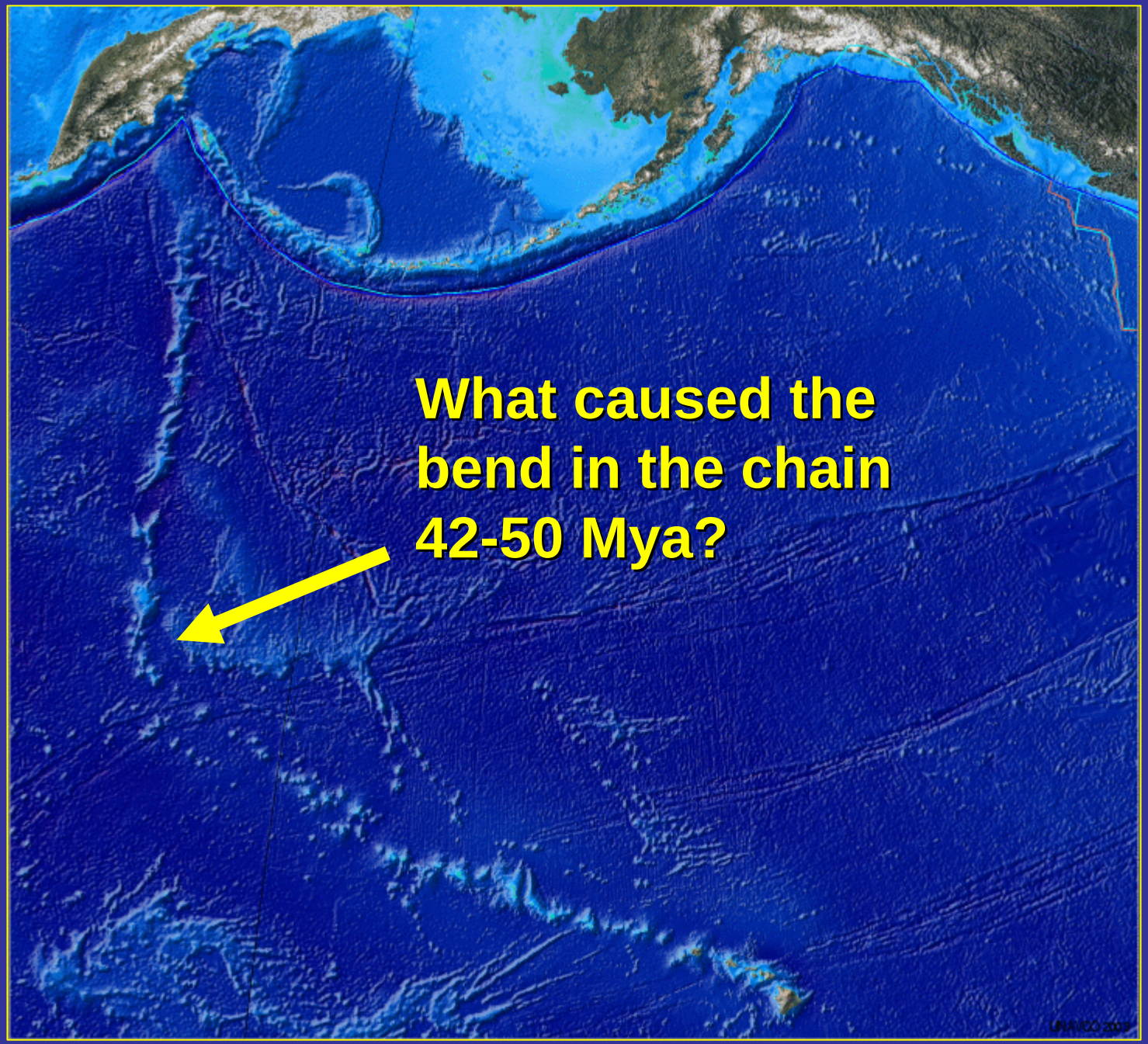
Typical example: Mt. Mahameru, Java



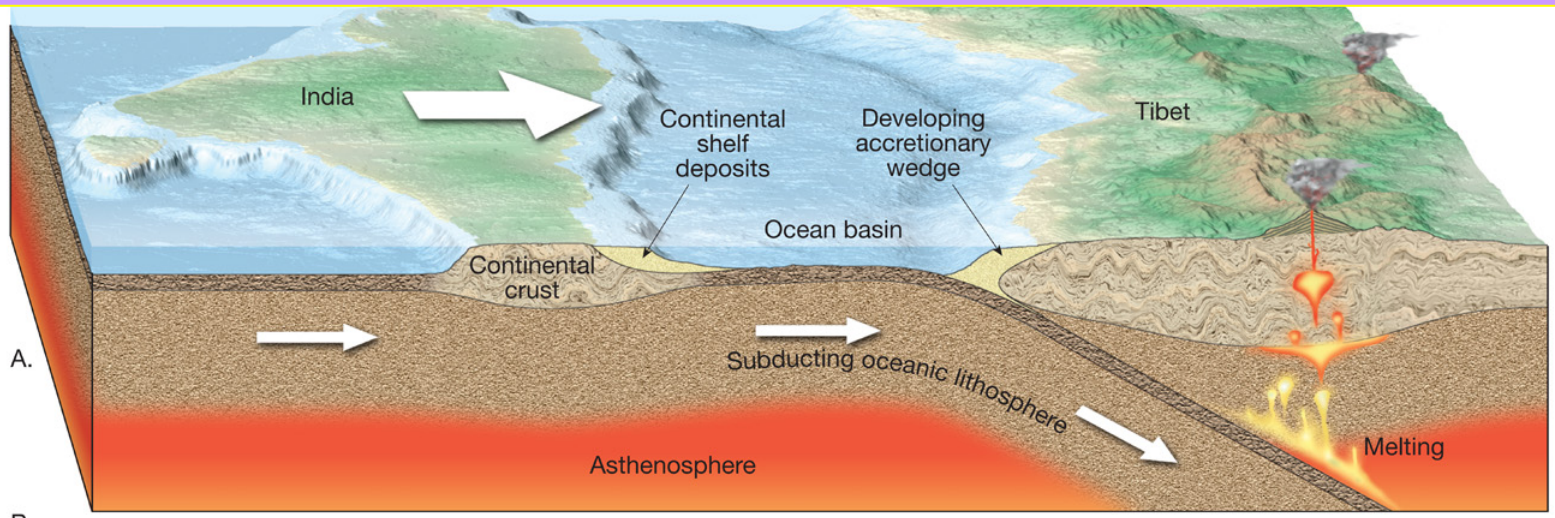


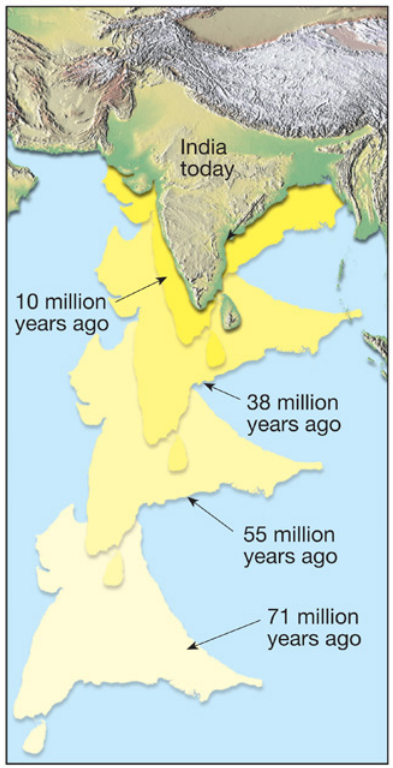
What does the bend in the H-E seamount chain imply?

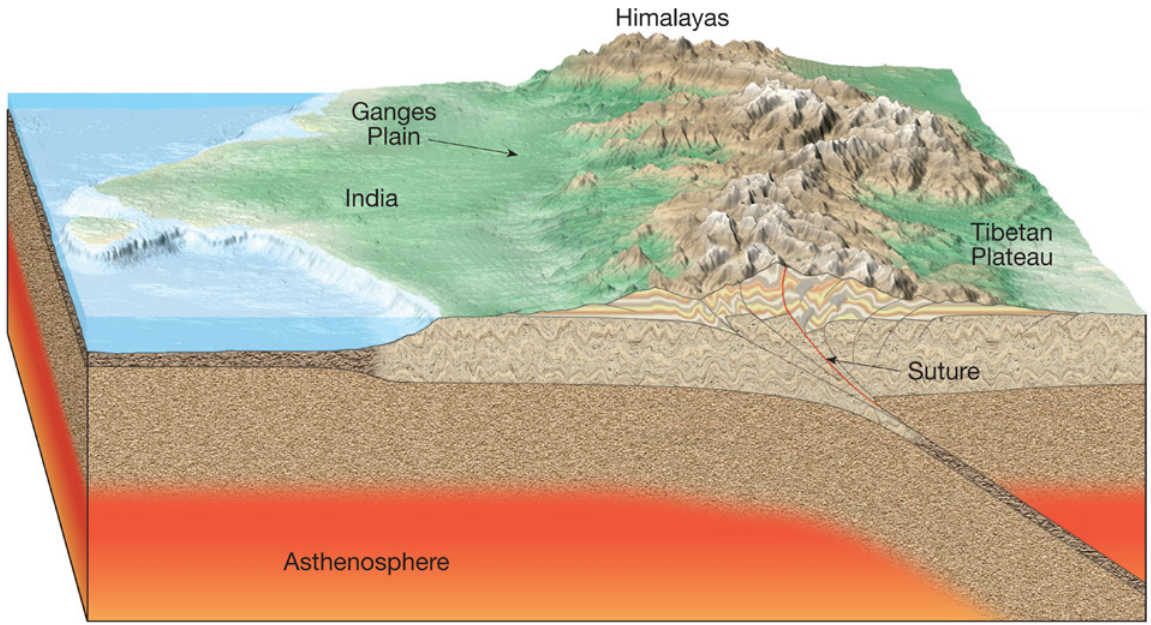
A) A change in the age of the plate
B) A change in the composition of the plate
C) A change in the direction of plate motion
D) A change in the speed of the plate
E) A change in the location of the hotspot


What caused the bend in the chain 42-50 Mya?

Convergent boundary – continental-continental





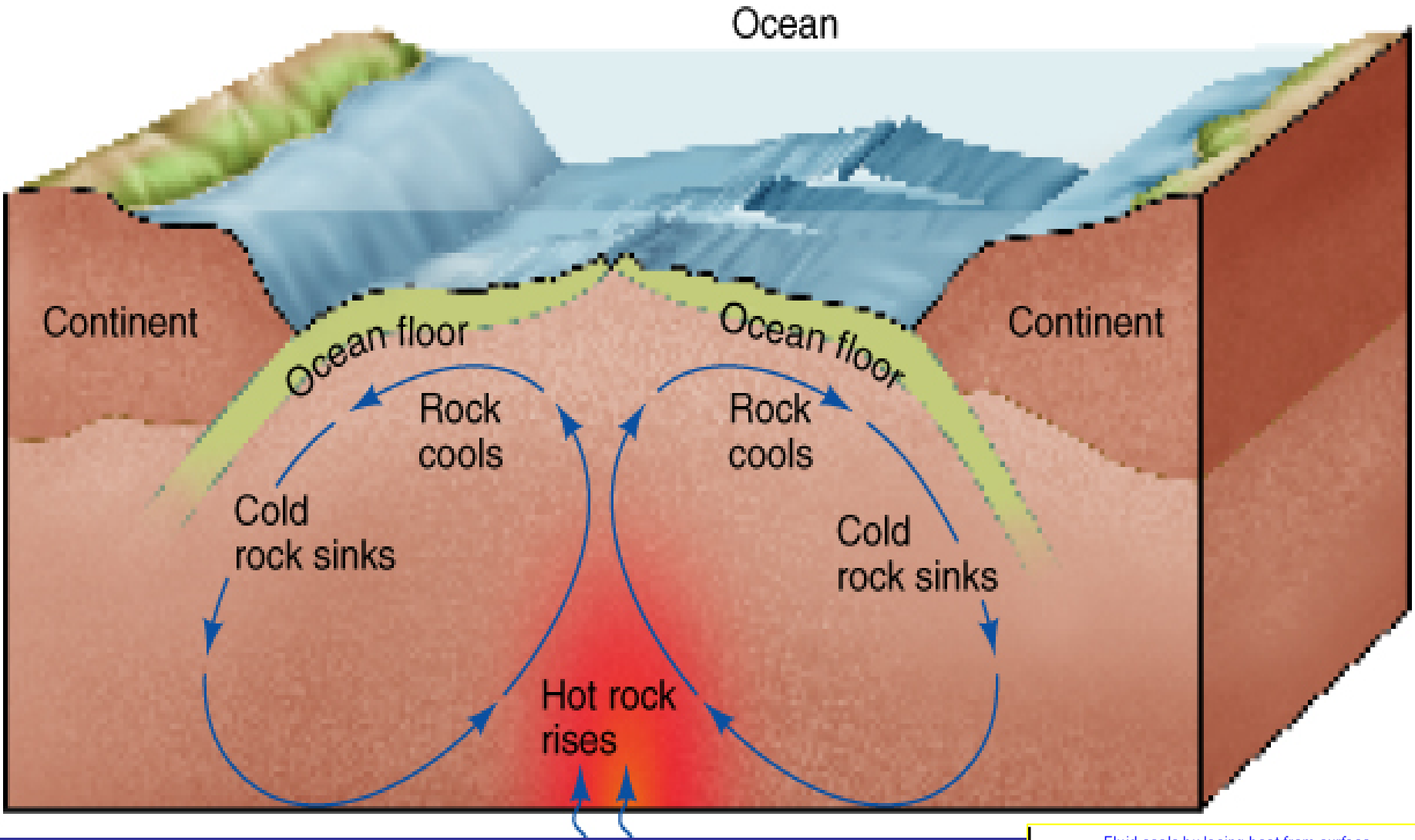


Convergent boundary – continental-continental

Gneiss - metamorphic



Typical example -
Mt. Everest, Nepal 8,848m 29,029ft



Spreading ridge and subduction trench form a <u>complete</u> convection cell

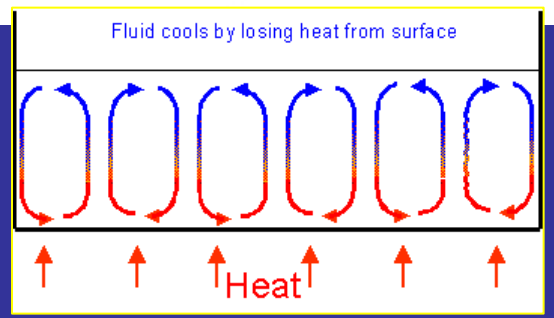
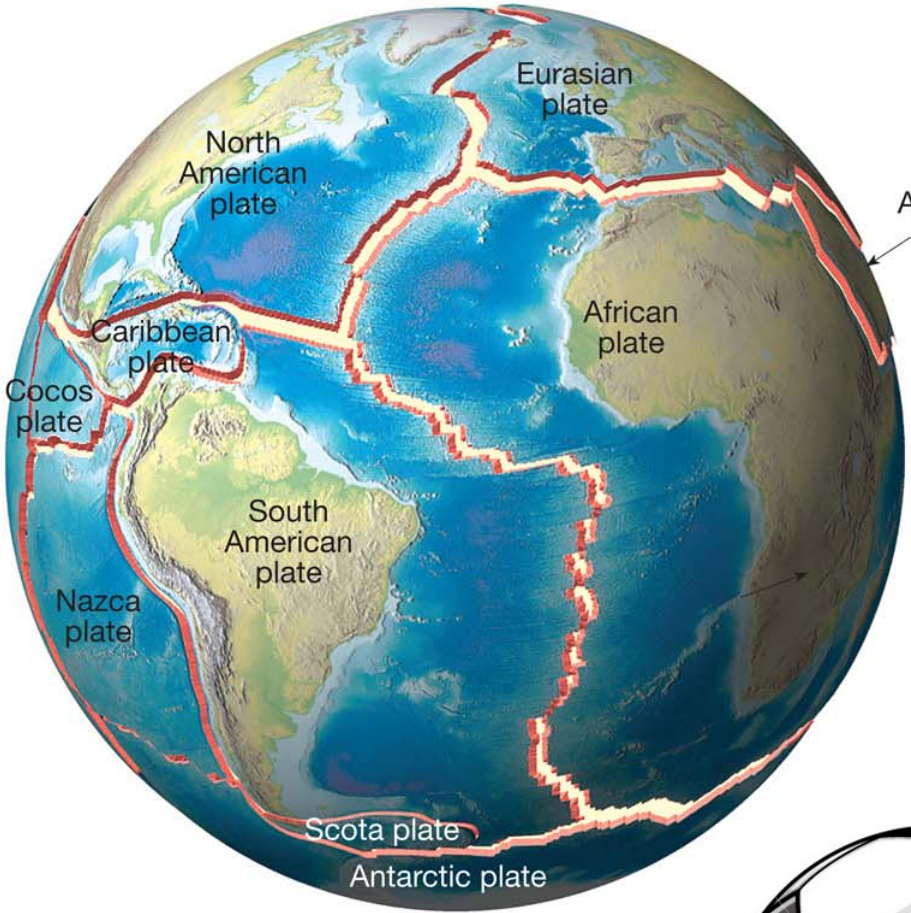
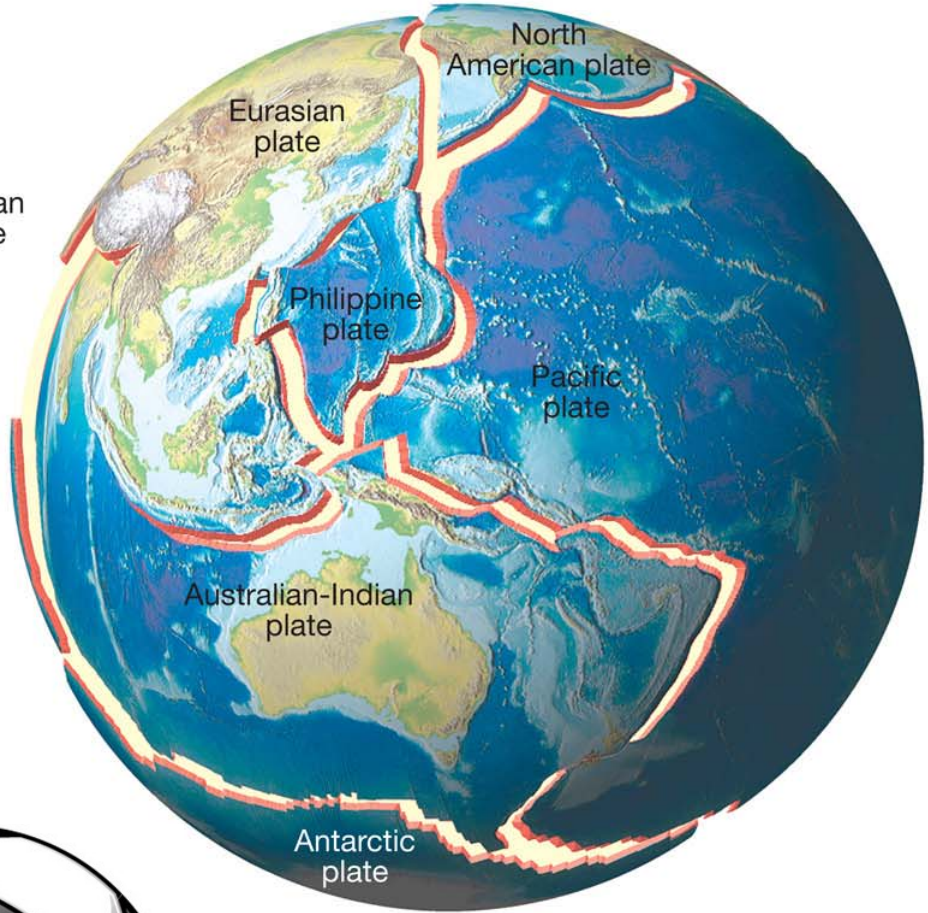


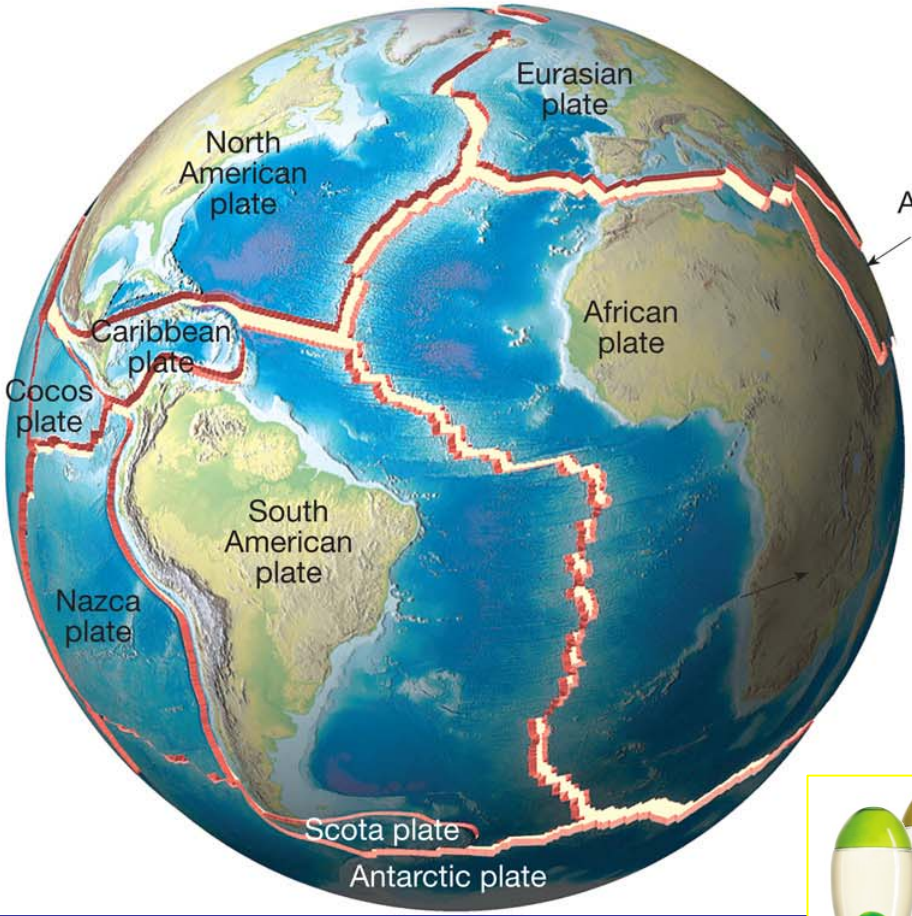
Plate boundaries: 1) ridges, 2) trenches, and 3)…?

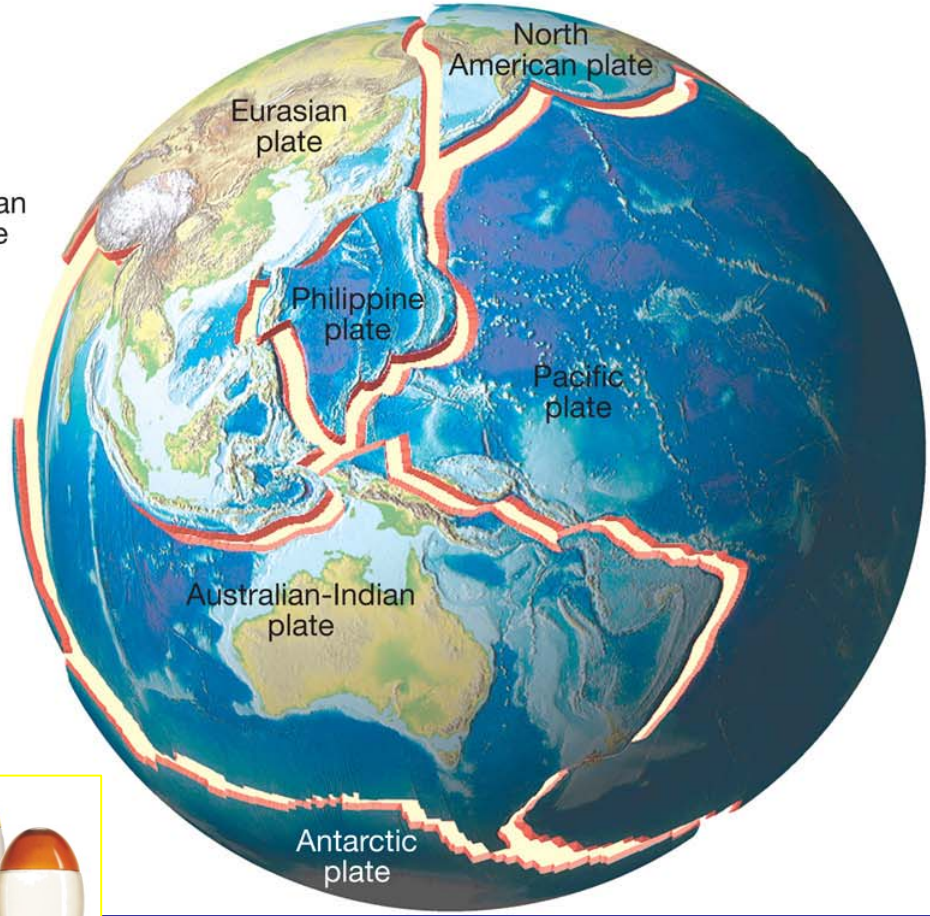






1) Ridges, 2) trenches, and 3) transform faults



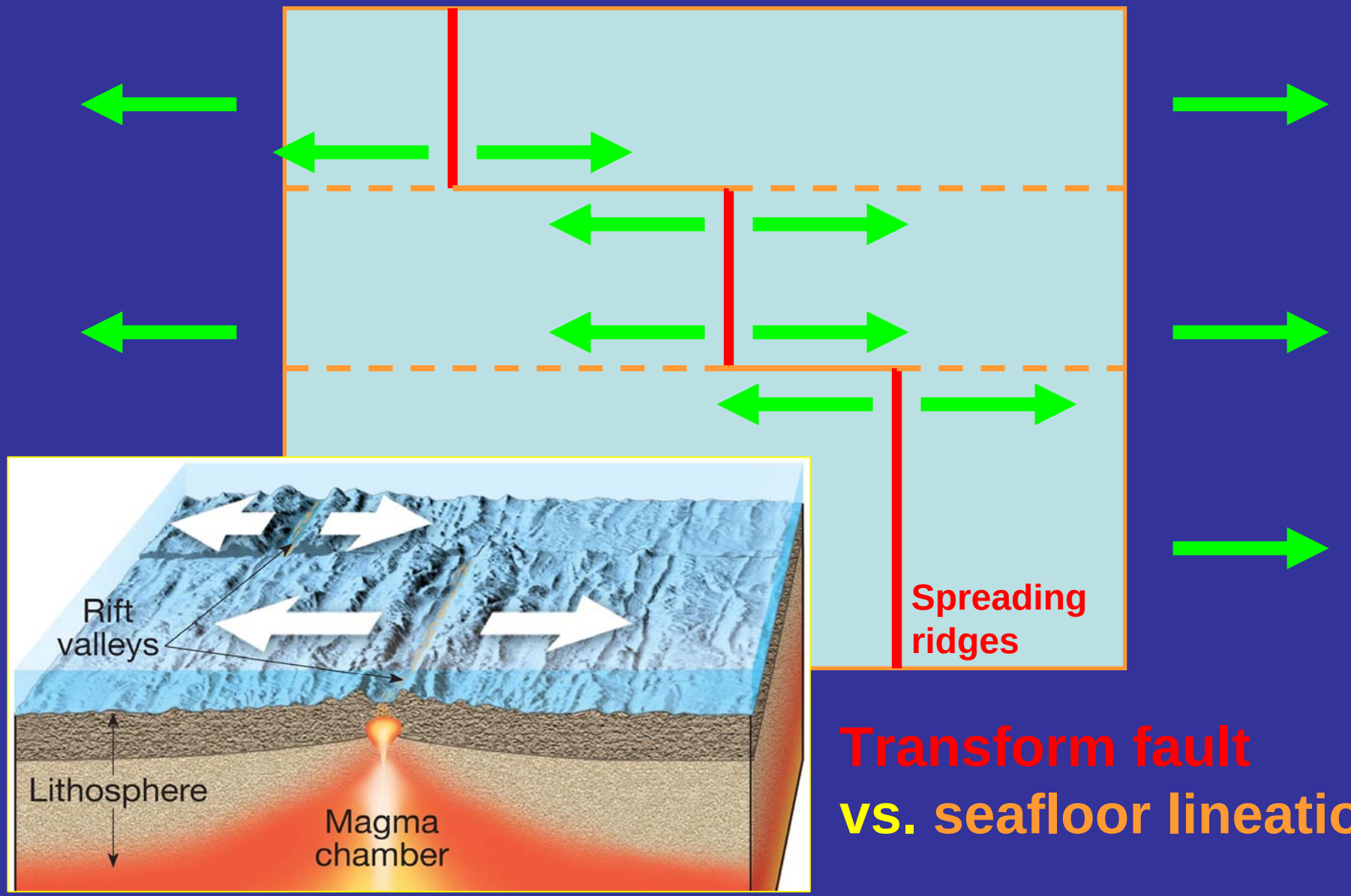


Transform faults are not <u>directly</u> related to mantle convection



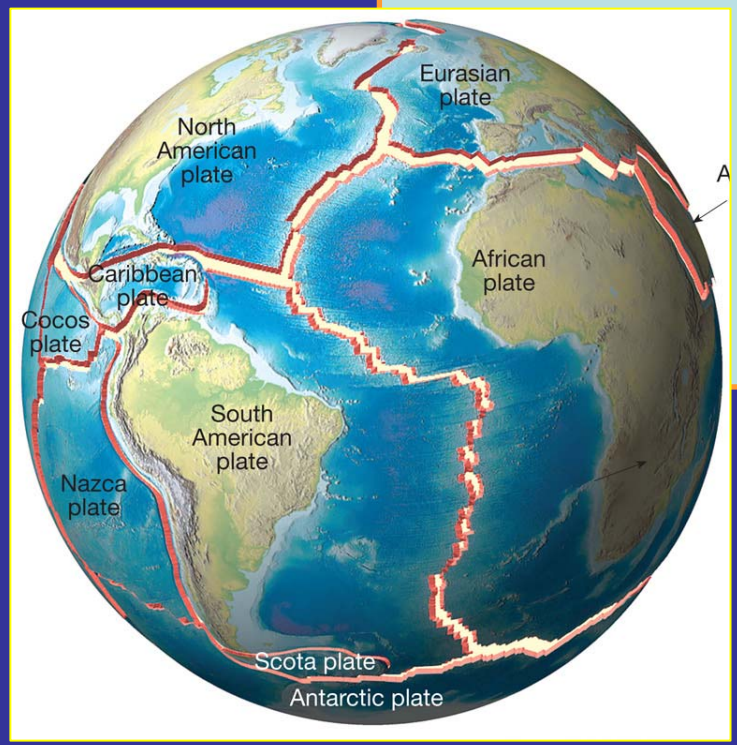
…necessary for doing geometry on a sphere

Transform fault boundary – oceanic

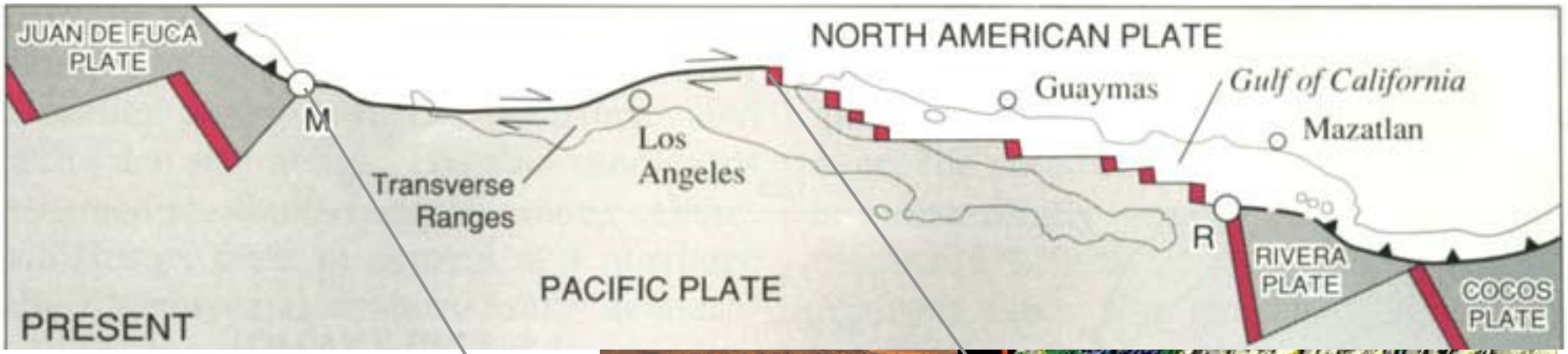


Transform fault vs. seafloor lineation

Accommodates transverse spreading geometry



Allows continents to split into irregular shapes

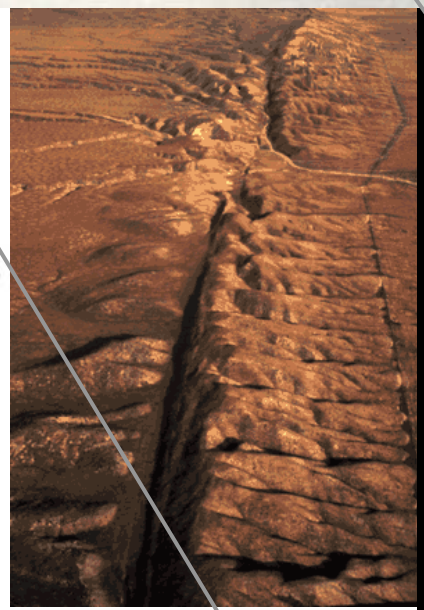


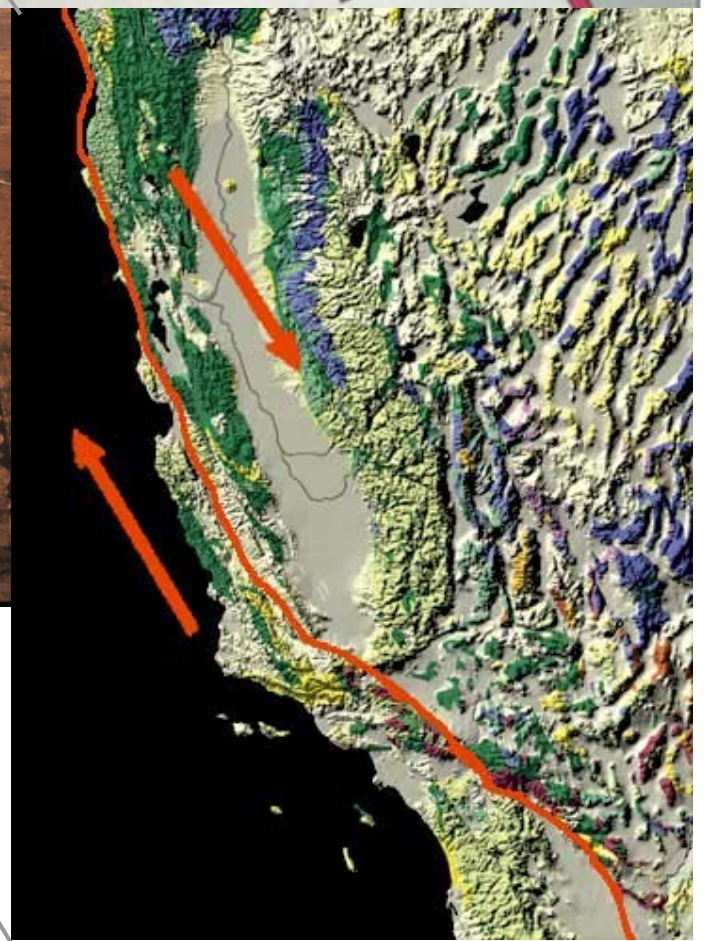
EXPLANATION

Spreading center

Subduction zone—Dashed where approximately located. Sawteeth on upper plate

Fault—Dashed where approximately located. Arrows indicate direction of relative movement



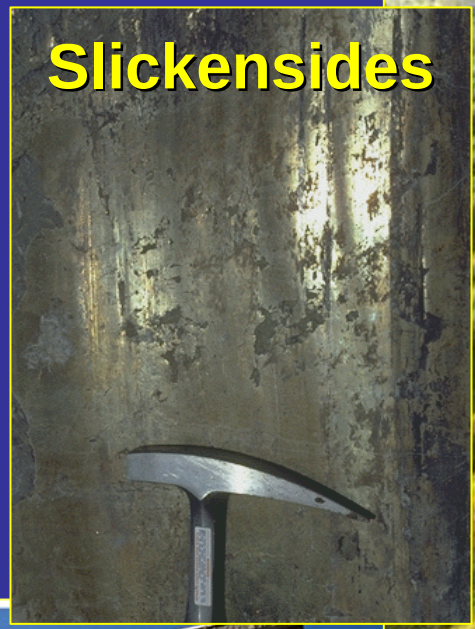


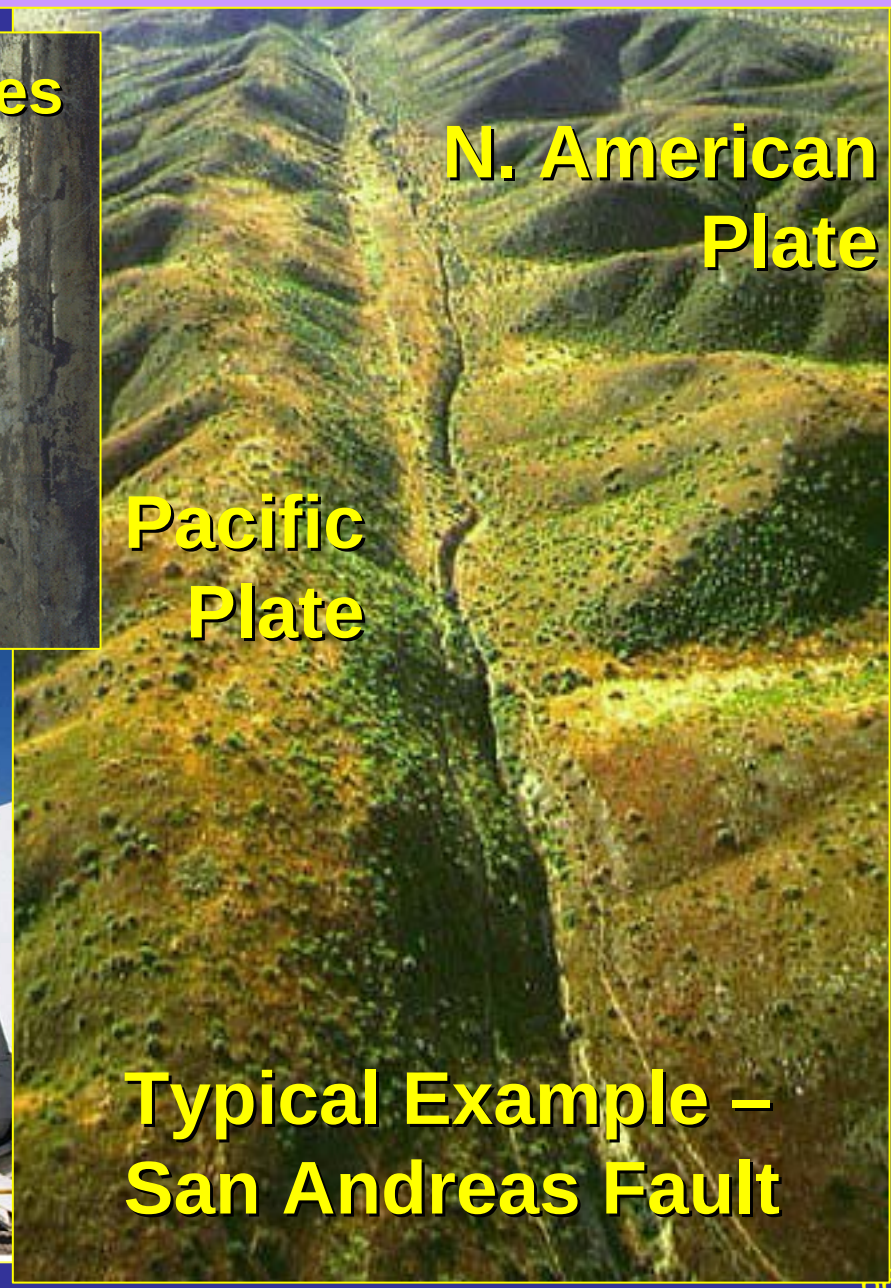
Transform faults can also occur on land

San Andreas separates Pacific and North American Plates

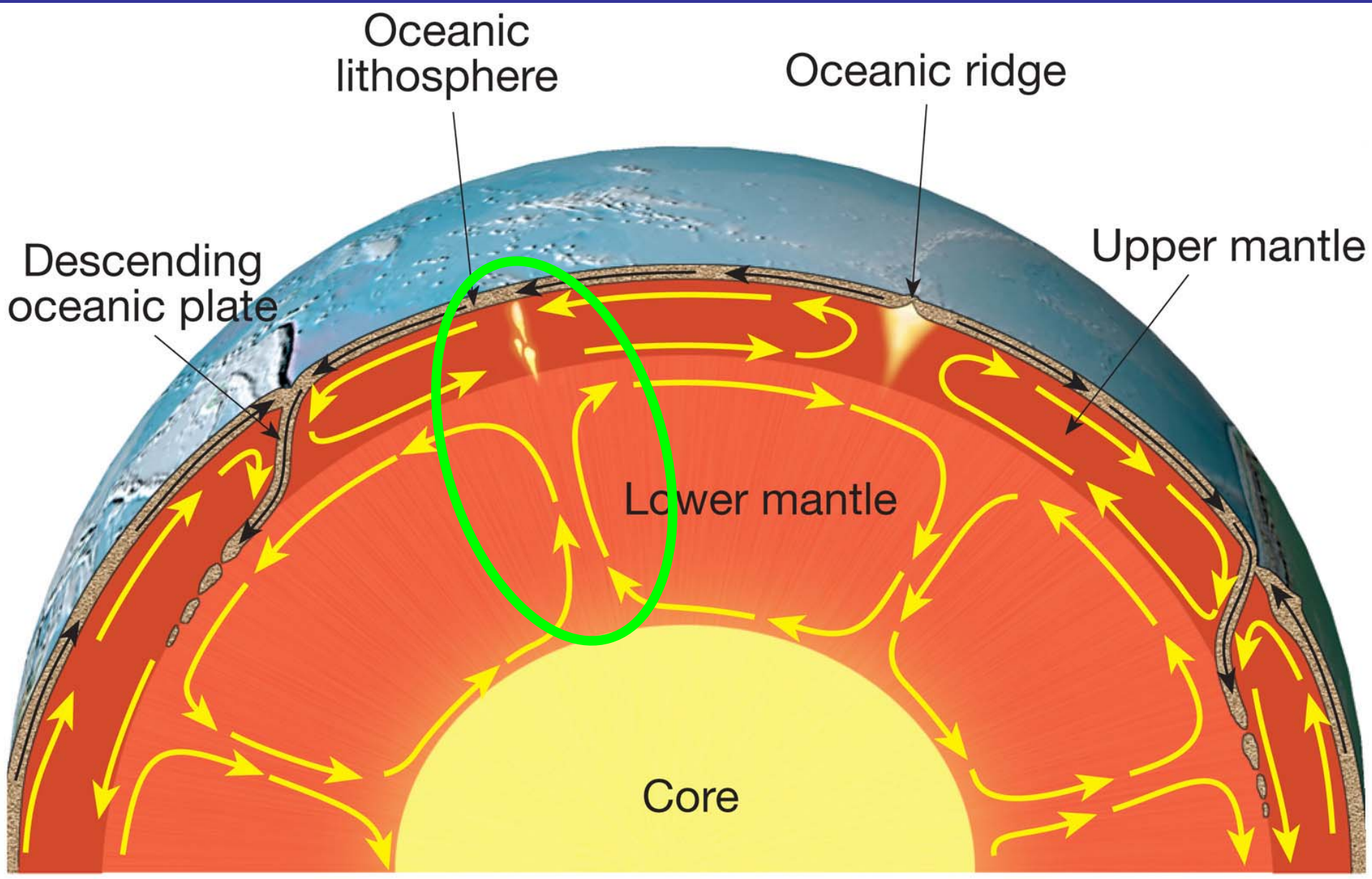
Transform fault boundary – continental



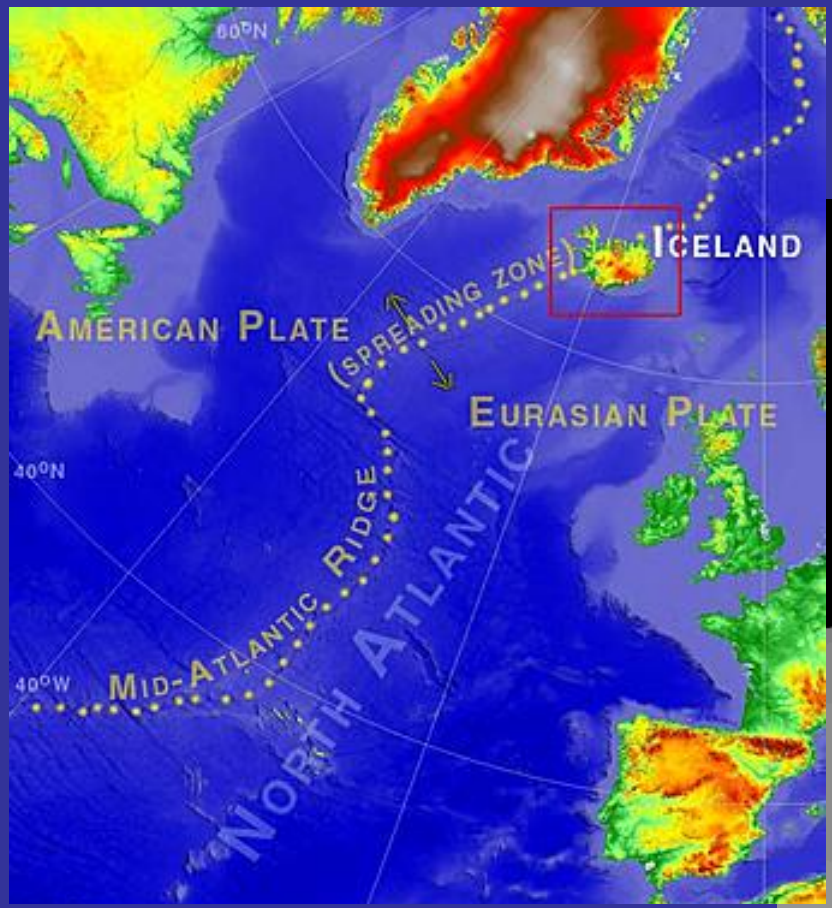


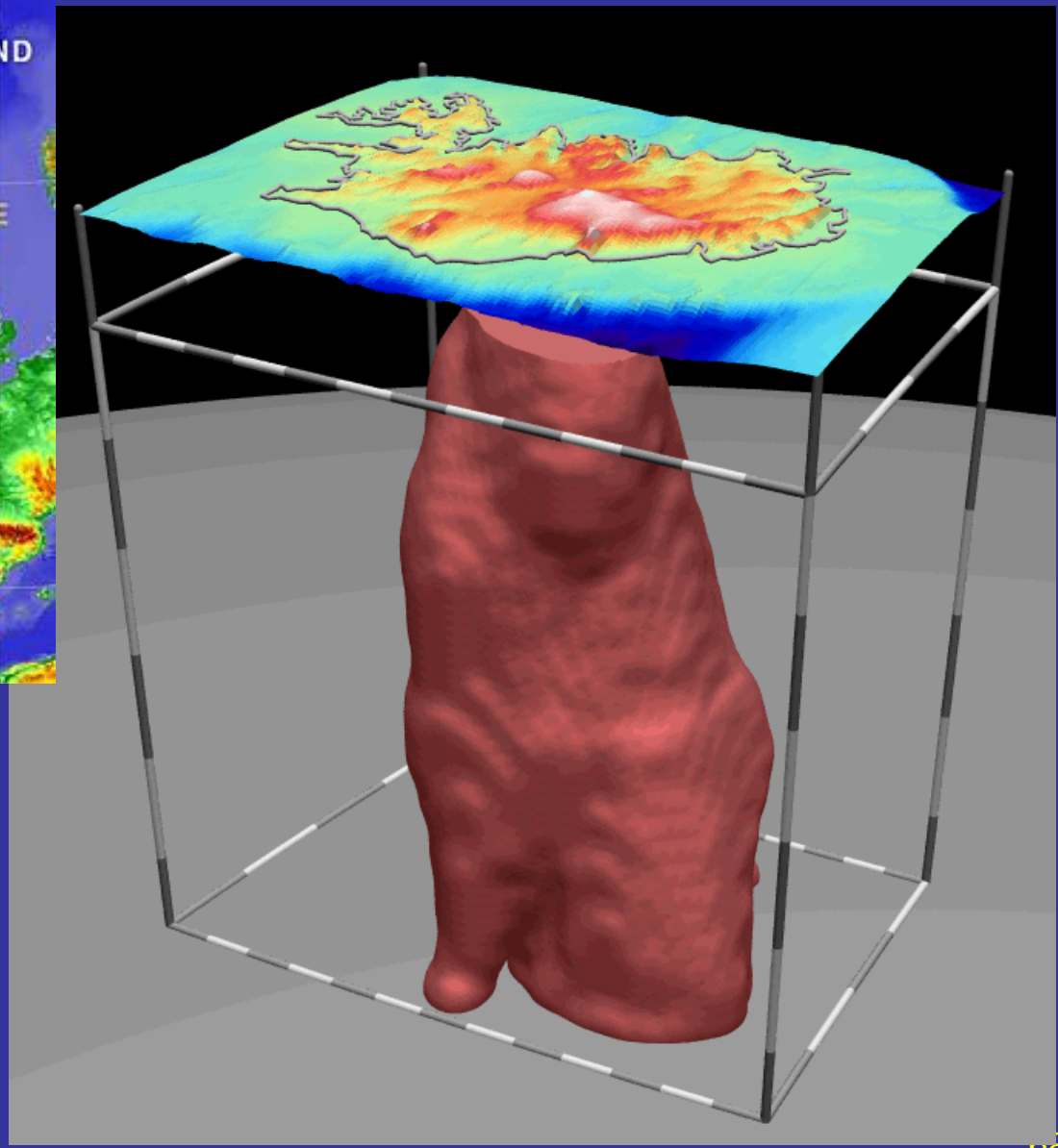





Oceanic lithosphere
Oceanic ridge
Descending oceanic plate
Upper mantle
Lower mantle
Core

Iceland

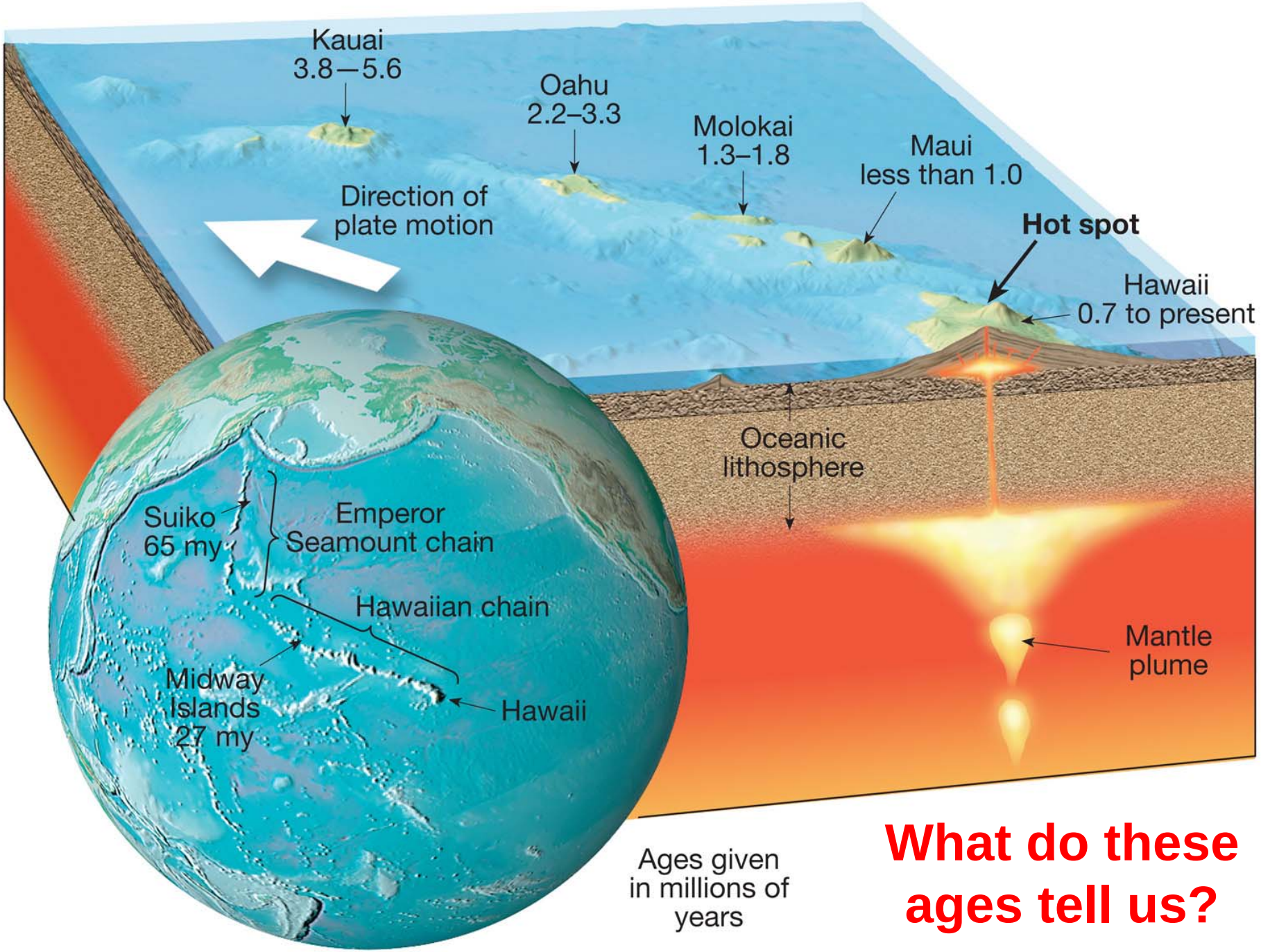




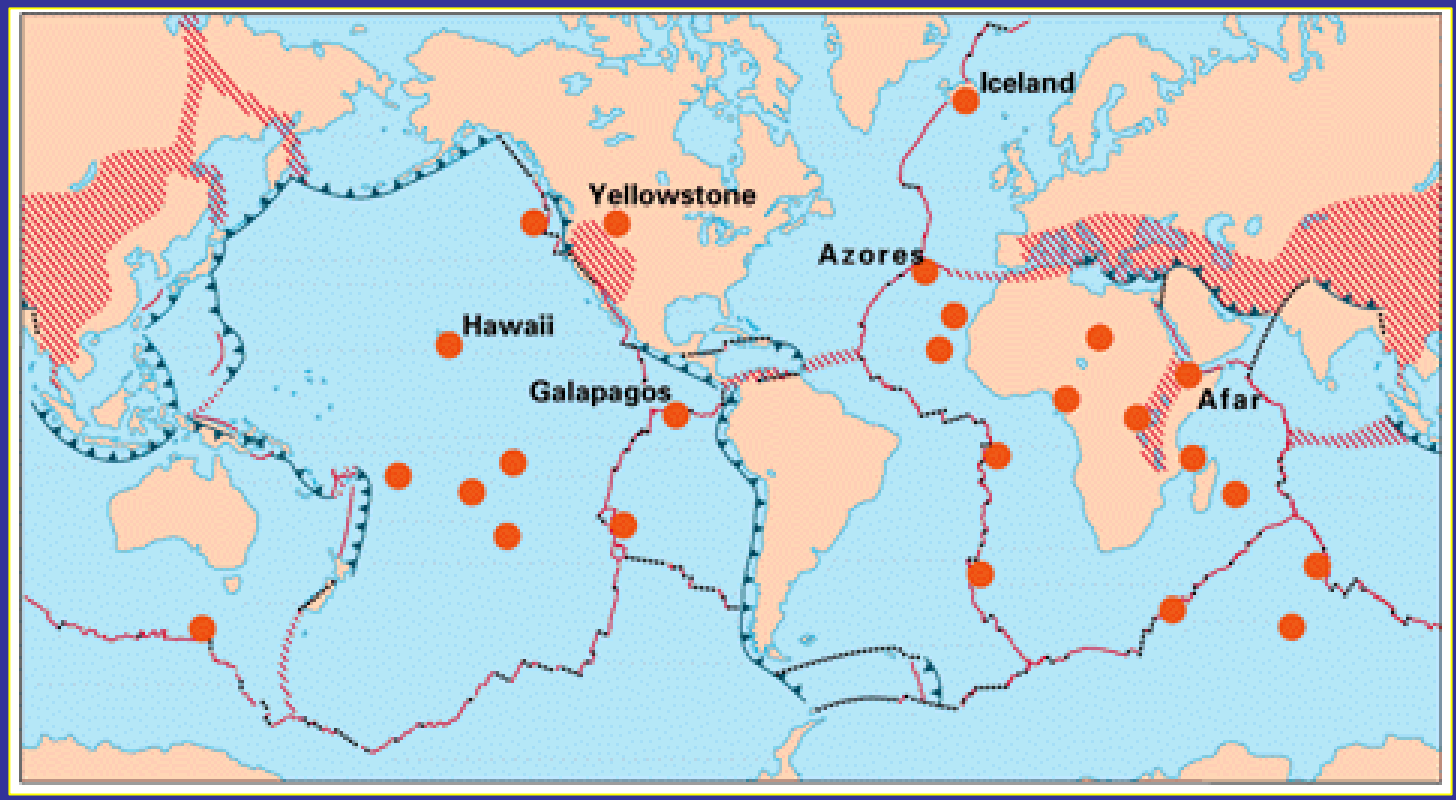
Divergent boundary

AND

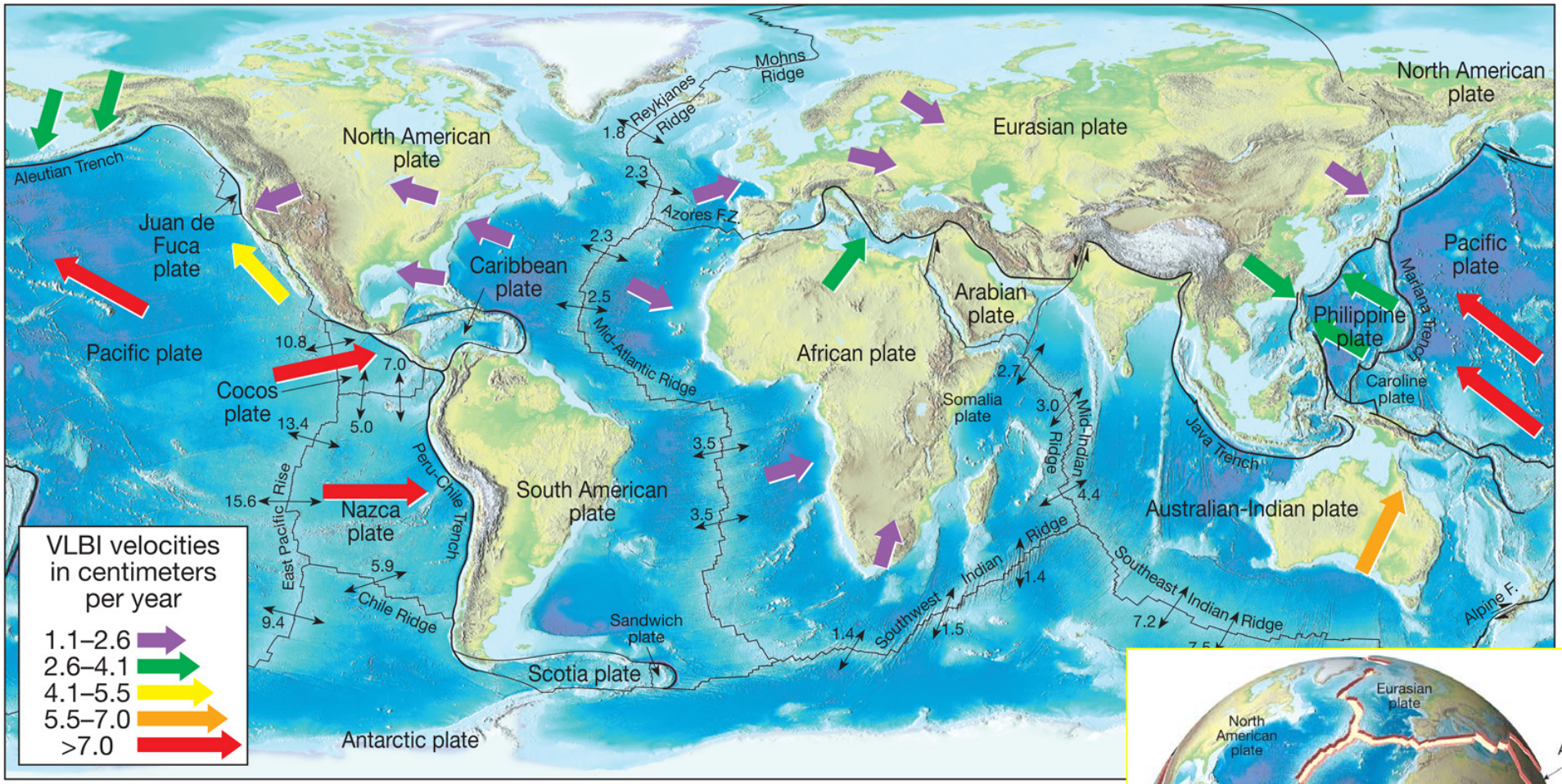
Hot spot!



What do these ages tell us?



Hot Spot locations



Absolute Plate Motion



Mantle convection / Plate tectonic summary

Convection	Landform	Boundary Type
1) Upwelling (hot)	Mid-ocean ridge	Divergent
2) Sinking (cool)	Ocean trench *(Subduction zone)*	Convergent
3) ----	Transform fault	Transform
4) Hot Spot (hot) *(Concentrated upwelling)*	Volcanoes	----