

Which field trip are you going on?

A) For SE O'ahu, Sat March 1
RSVP to scott@soest.hawaii.edu

B) For Big Island, March 7-9
Give $75 deposit to Geology Club by January 31

C) For Maui, March 20-23
RSVP to sinton@hawaii.edu

D) For Waihe'e Tunnel, Wed April 16
RSVP to engels@hawaii.edu

E) For Central O'ahu, Sat April 19
RSVP to scott@soest.hawaii.edu



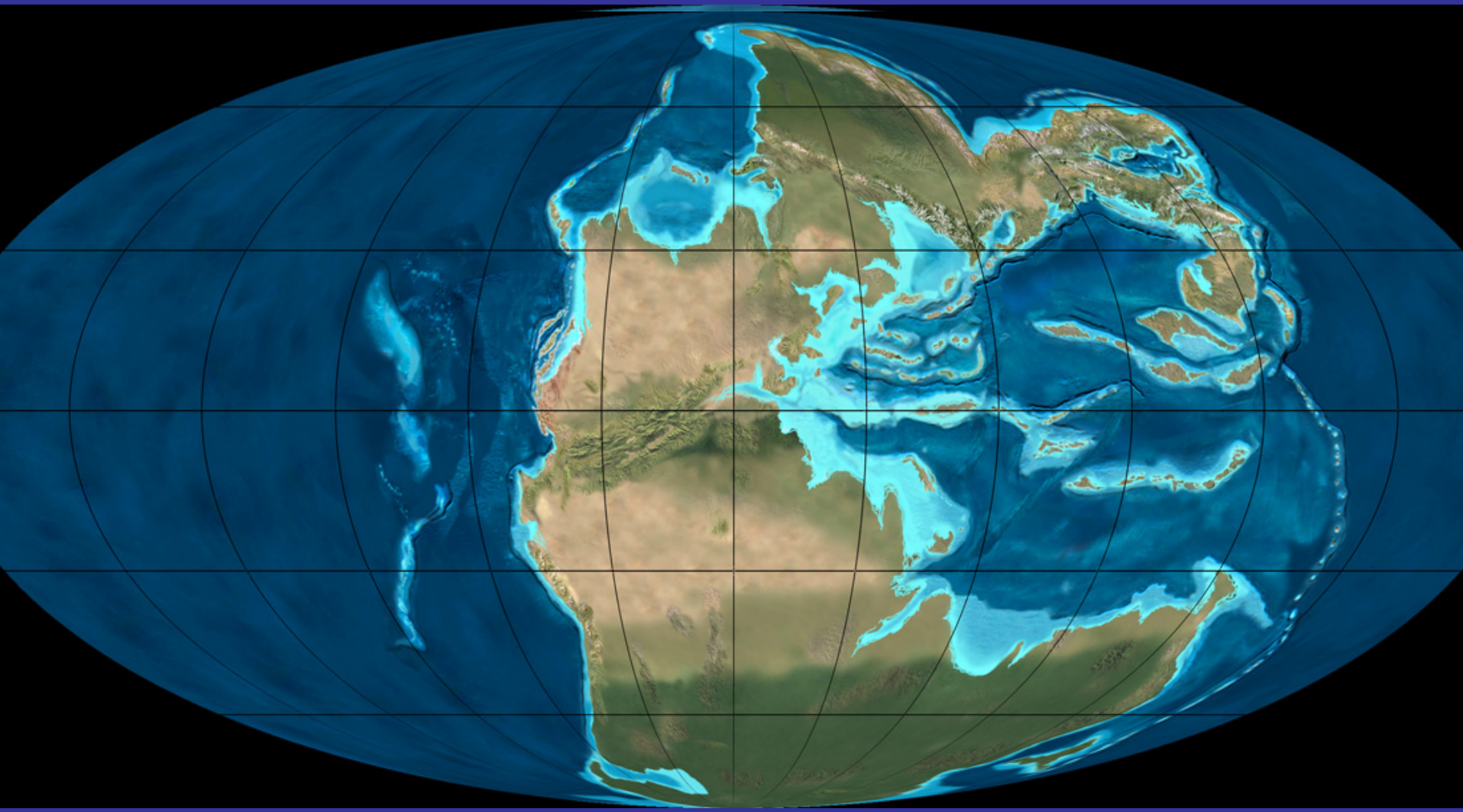
Alfred Wegener
Meteorologist

The Origins of Continents and Oceans
1915

“Continental drift”

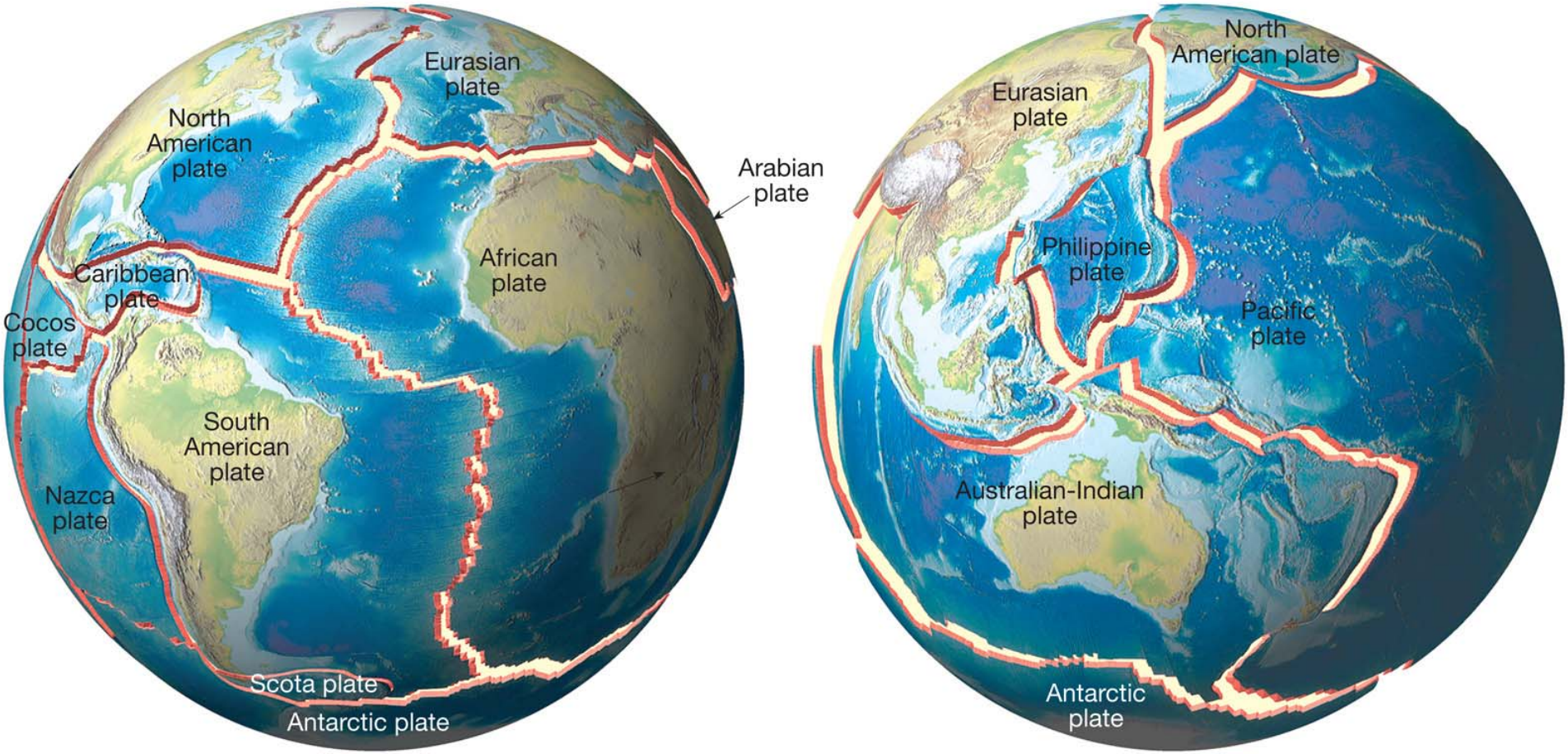
Modern Earth

Pangaea (240 Mya)



Pangaea


Eurasia
North America
Africa
South America
India
Antarctica
Australia



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

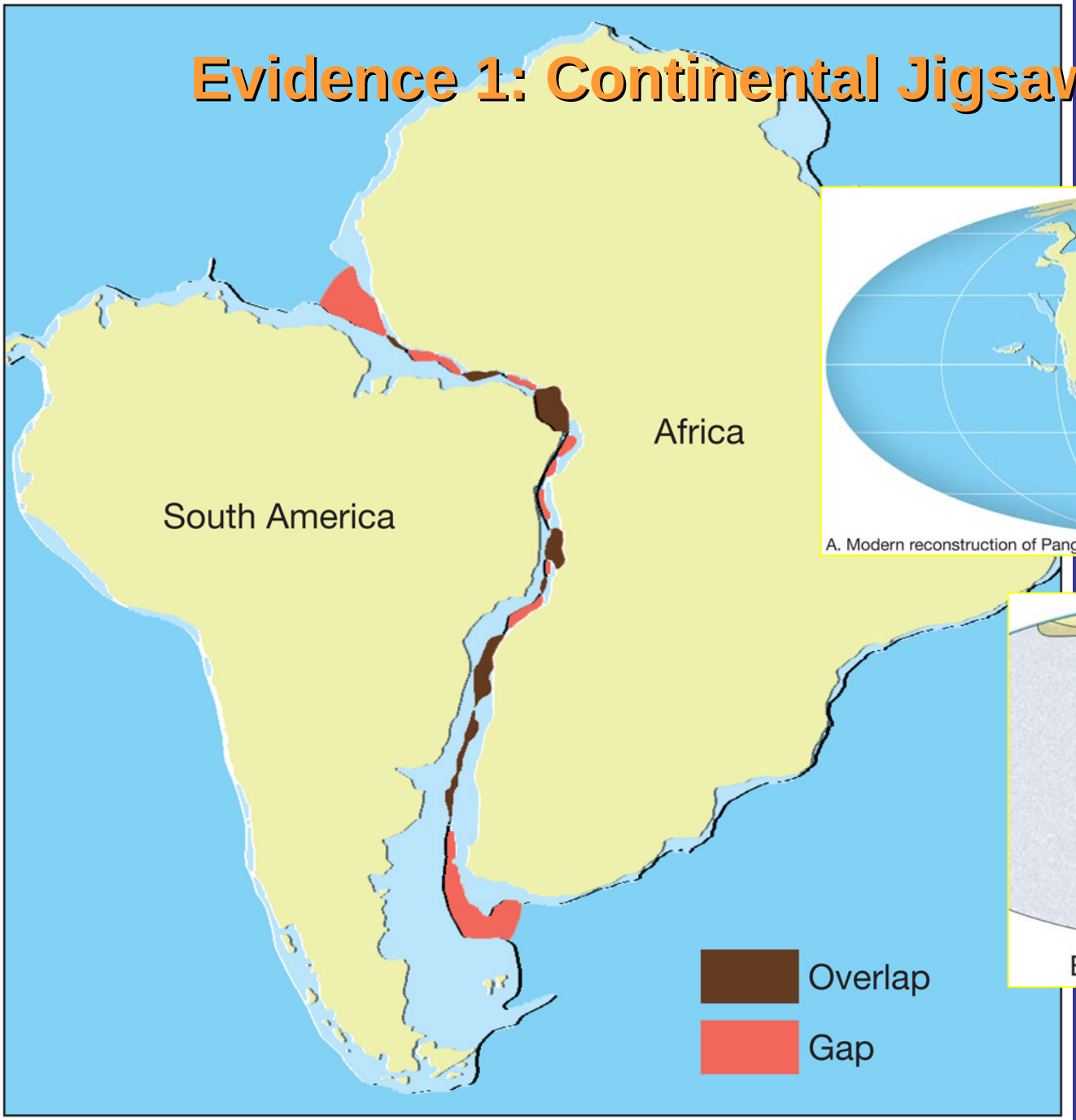
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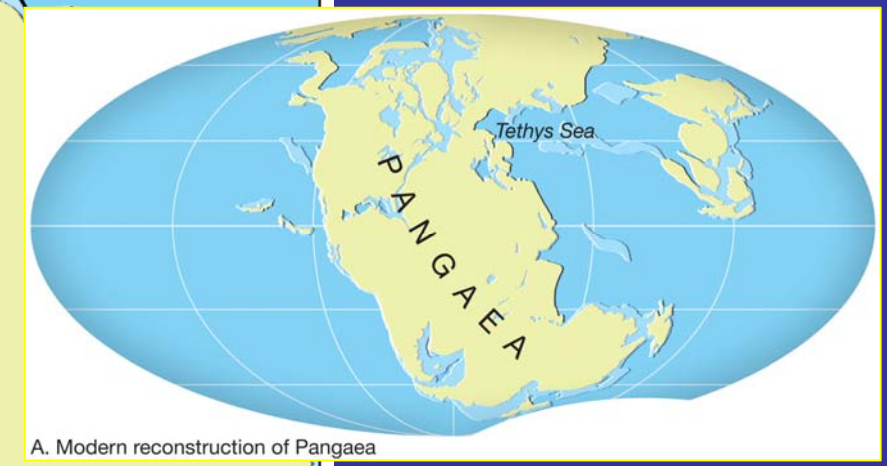
26+ plates total

How should we test this idea?

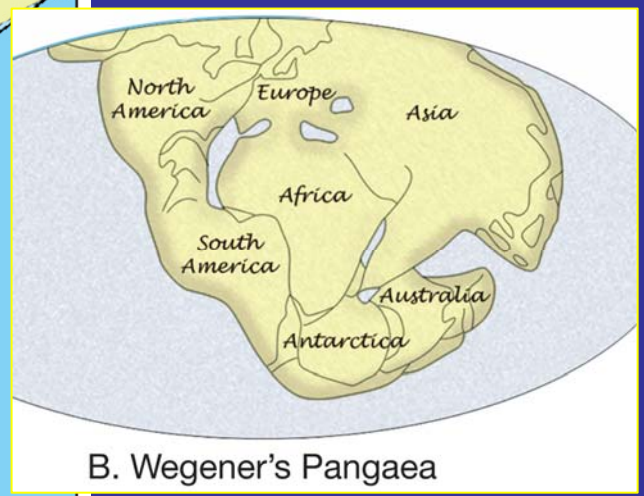


Evidence 1: Continental Jigsaw Puzzle





A. Modern reconstruction of Pangaea

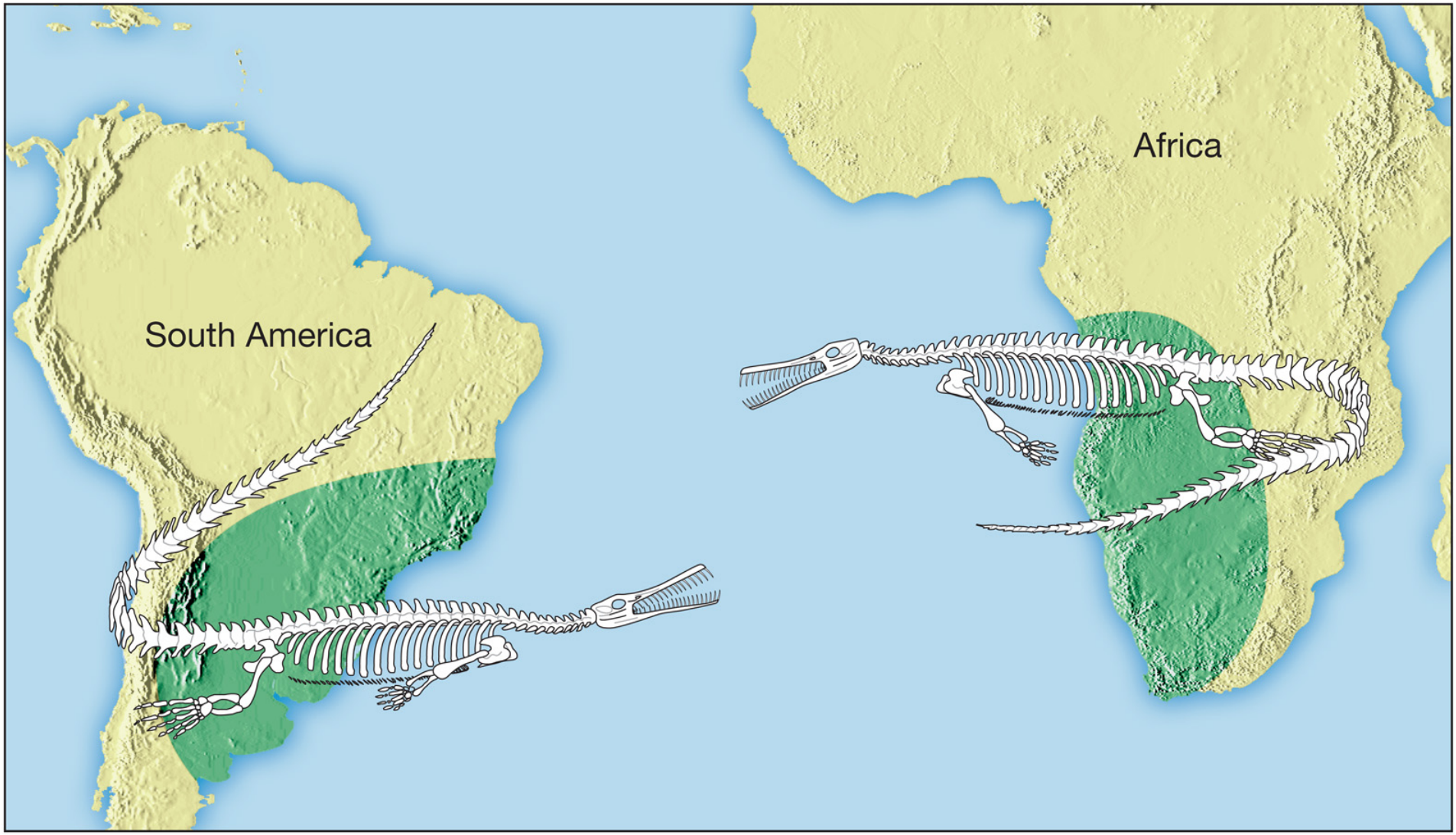


B. Wegener's Pangaea

How far can this guy swim?



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?

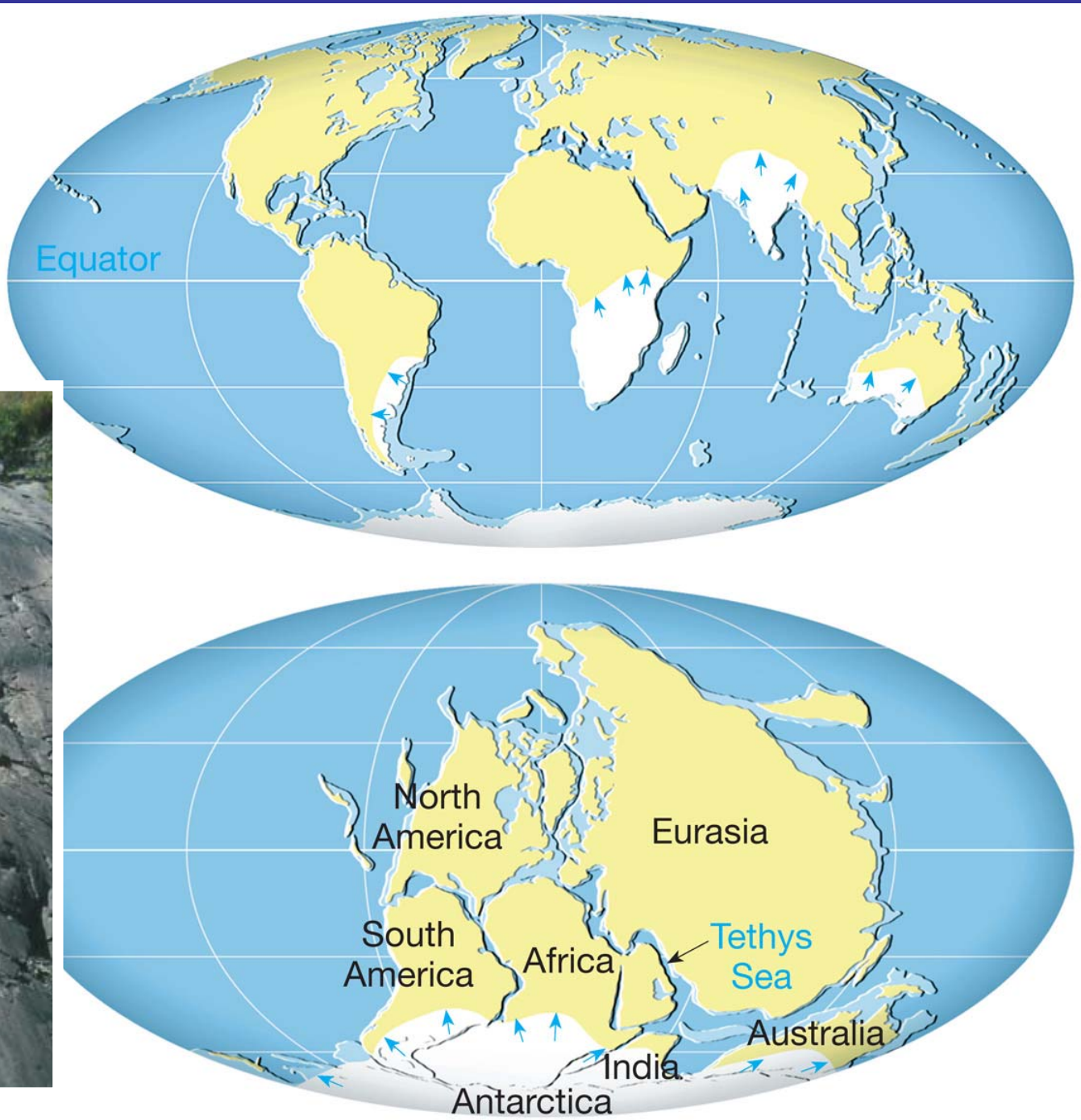


Would glacial striations form in an environment like this?



Evidence 4: Ancient climates





“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”

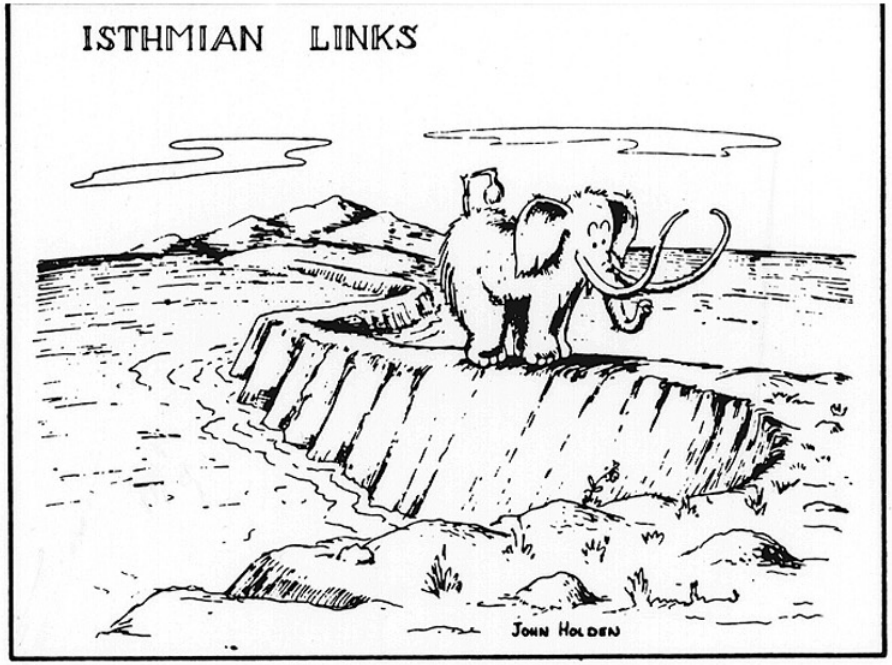
American scientist

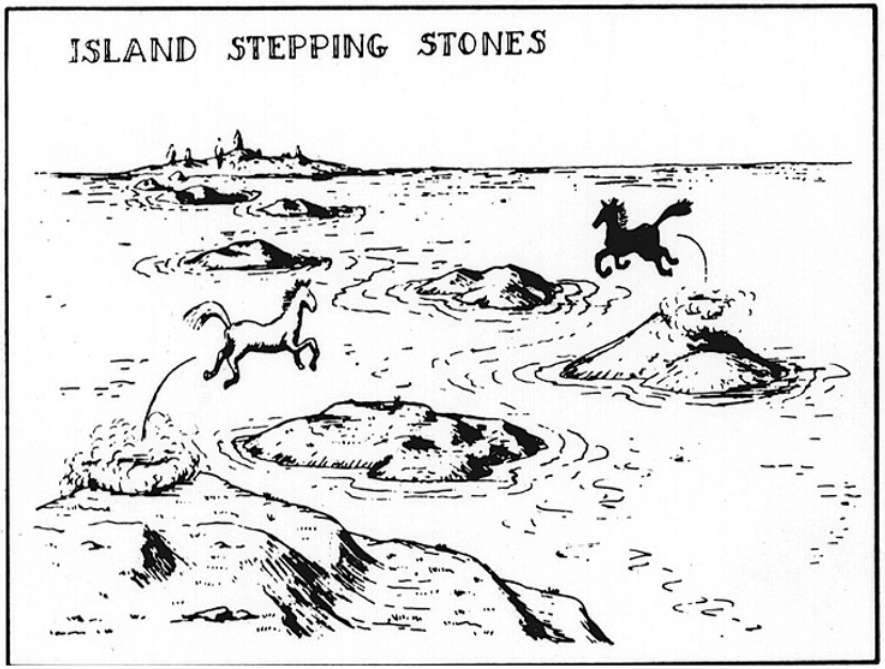
“Anyone who valued his reputation for scientific sanity would never dare support such a theory”

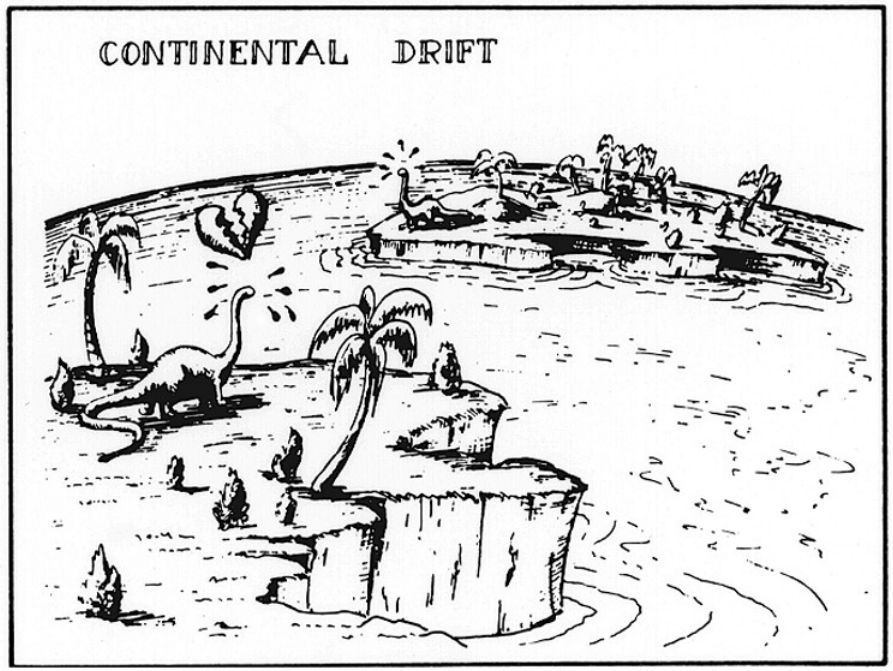
British geologist

The alternatives…











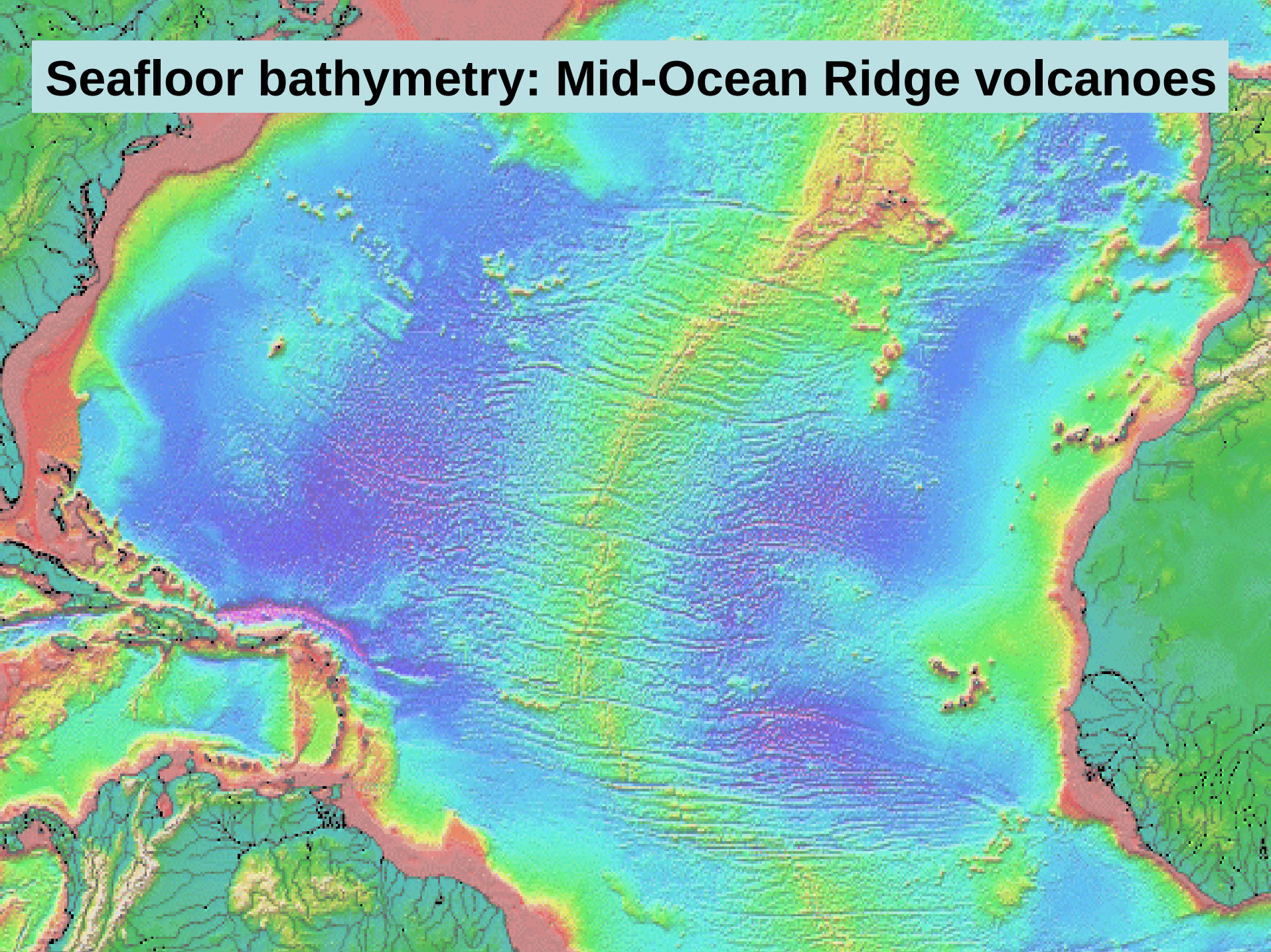




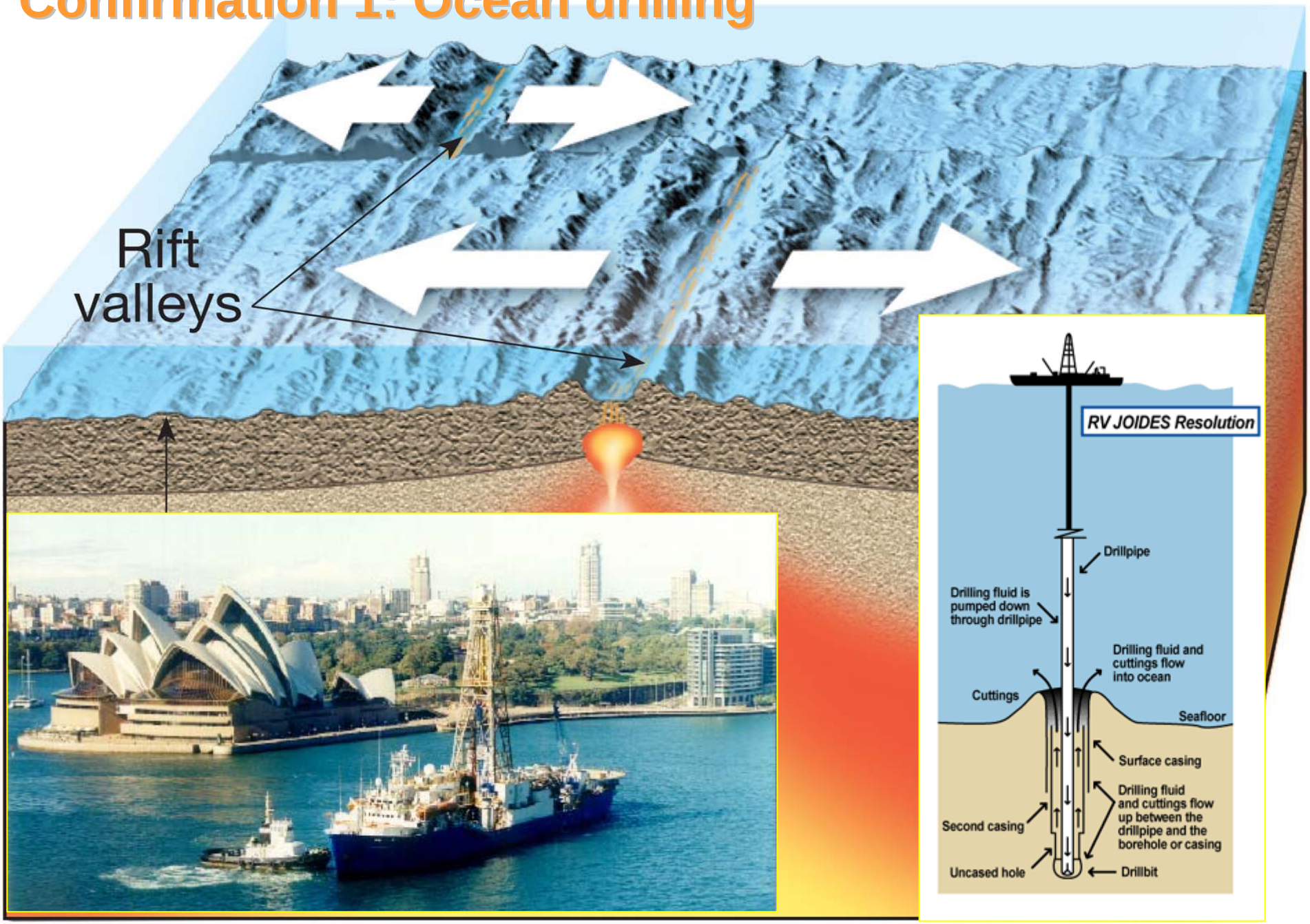
1950s-1960s

Post-WWII Military Industrial Complex

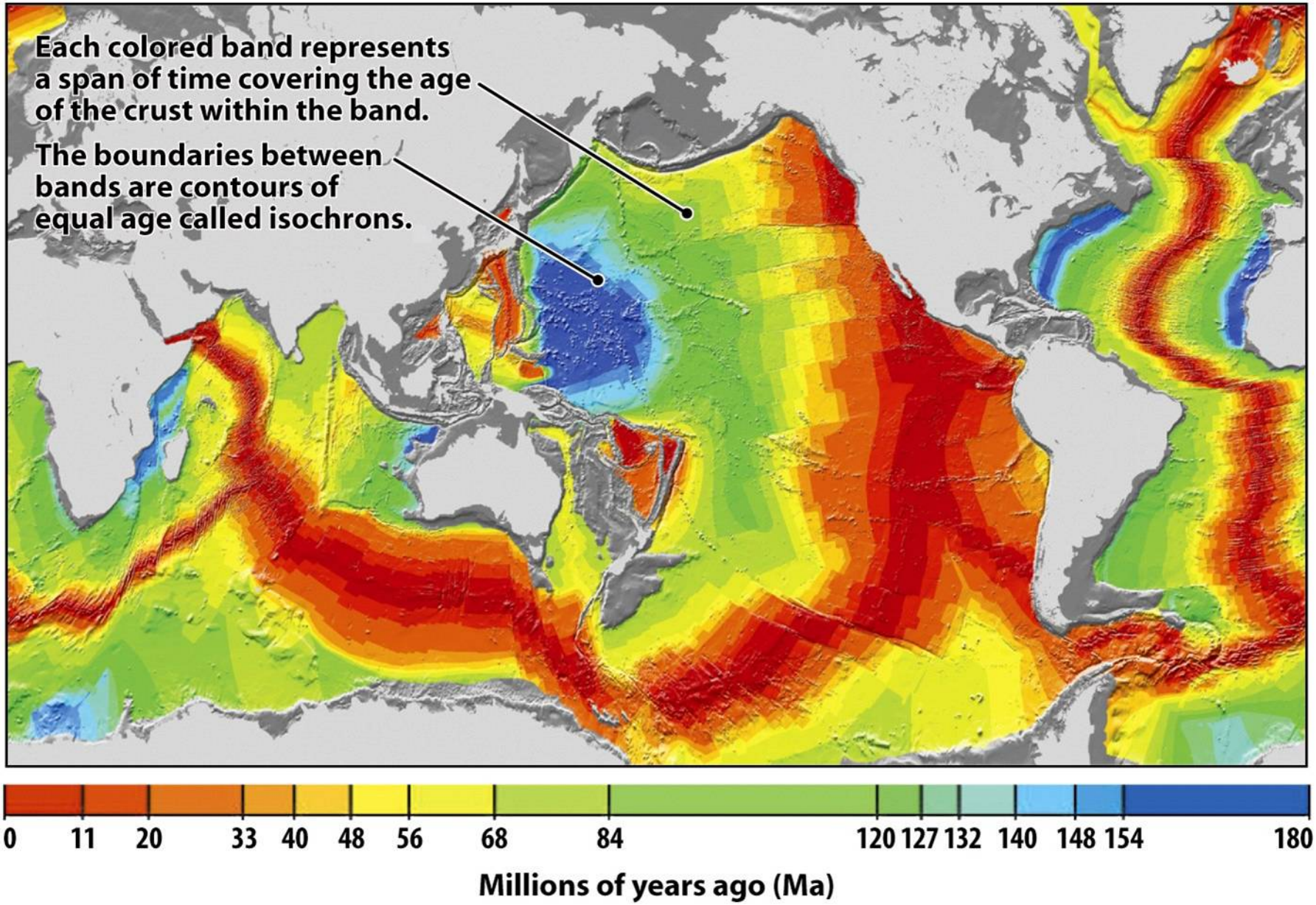
Seafloor bathymetry: Mid-Ocean Ridge volcanoes



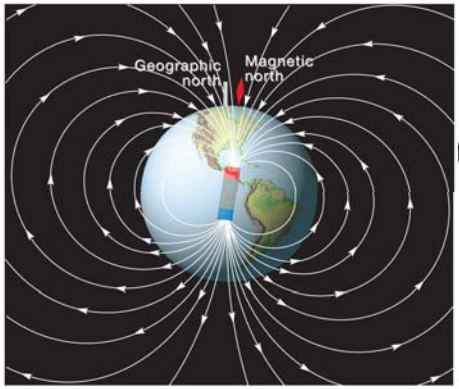
Confirmation 1: Ocean drilling

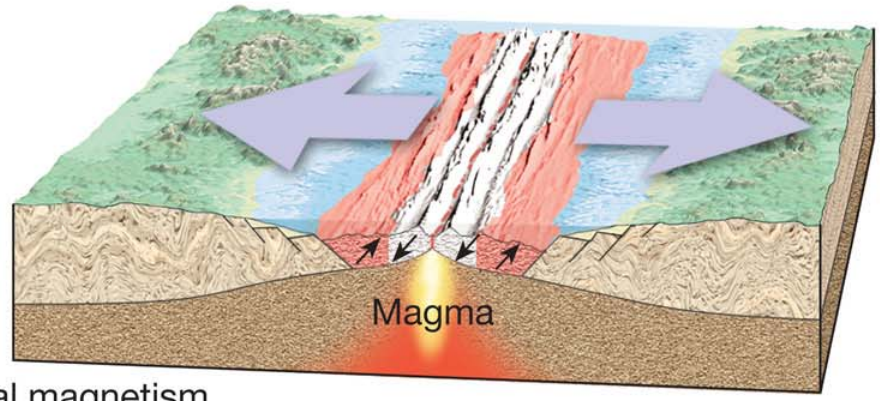


What is moving fastest, A) wide red bands, B) narrow red bands?

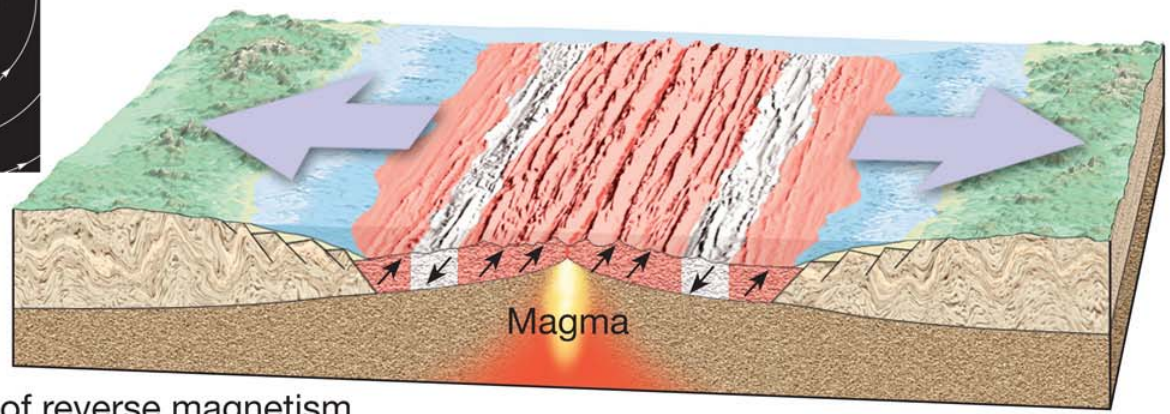


Confirmation 2: Paleomagnetism

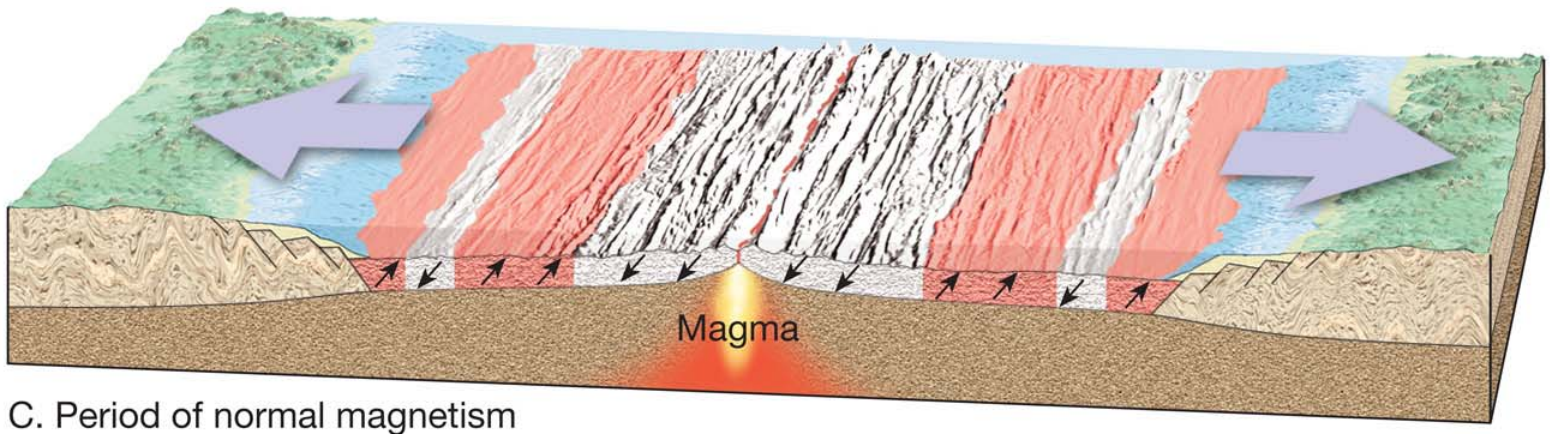




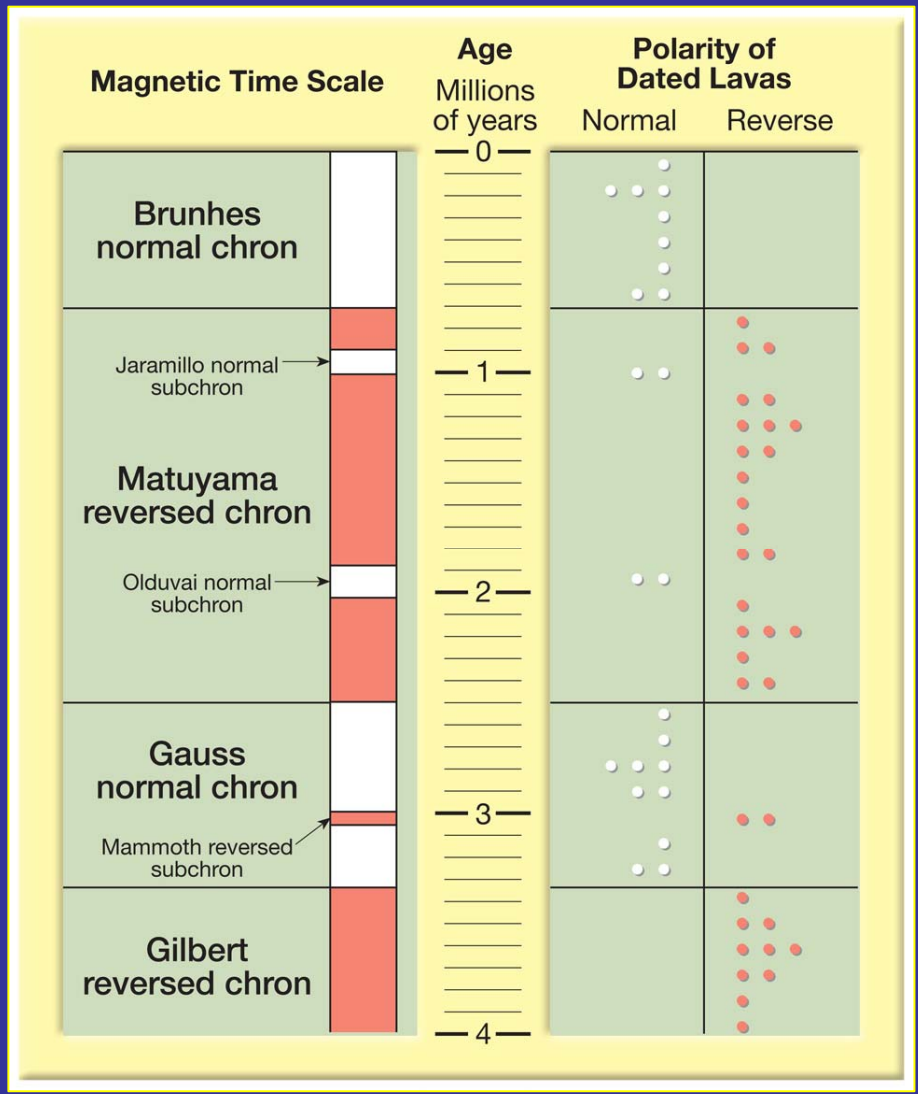
normal magnetism



B. Period of reverse magnetism



C. Period of normal magnetism

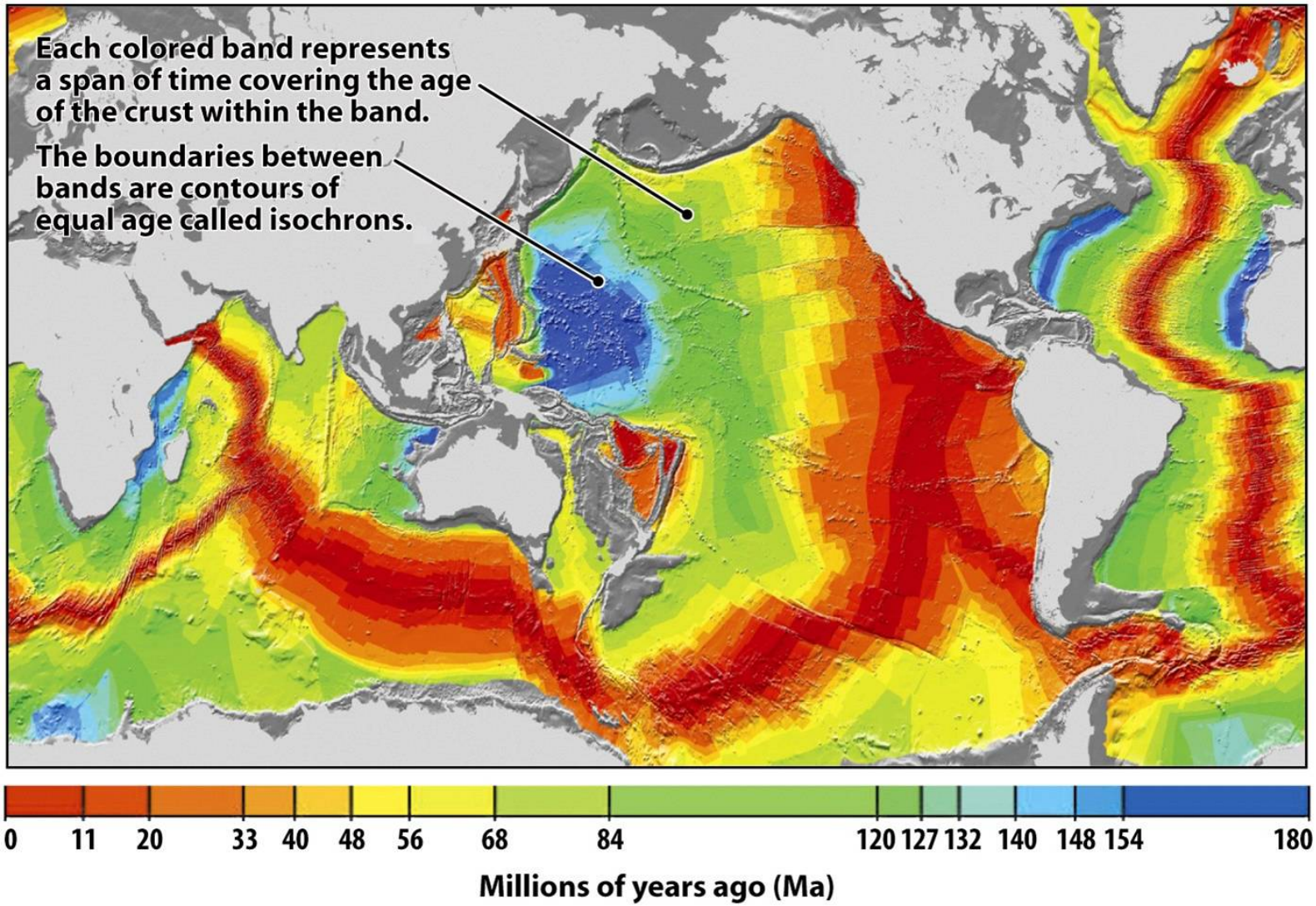


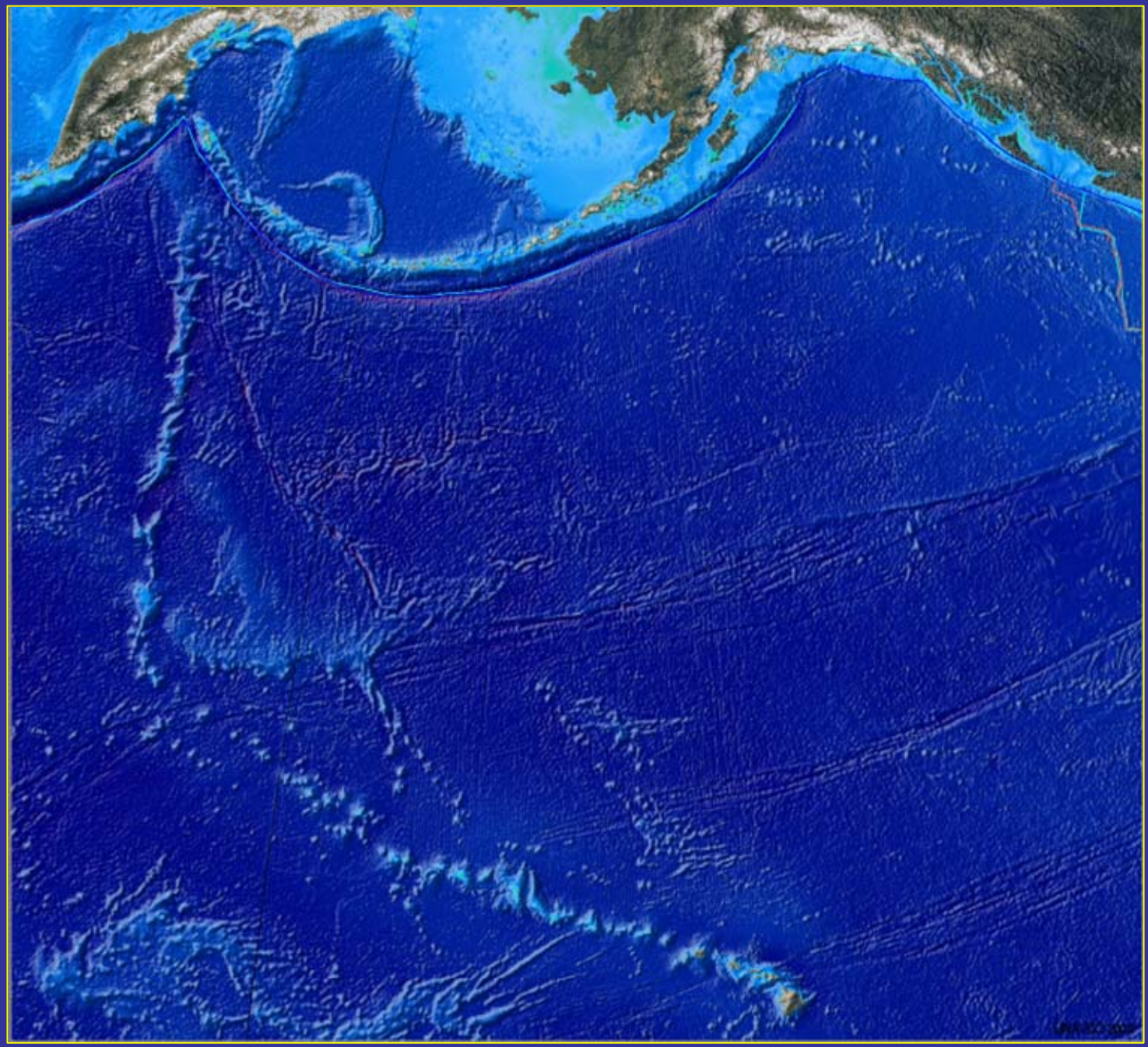


Magnetism of seafloor matches time scale of Earth's magnetic field

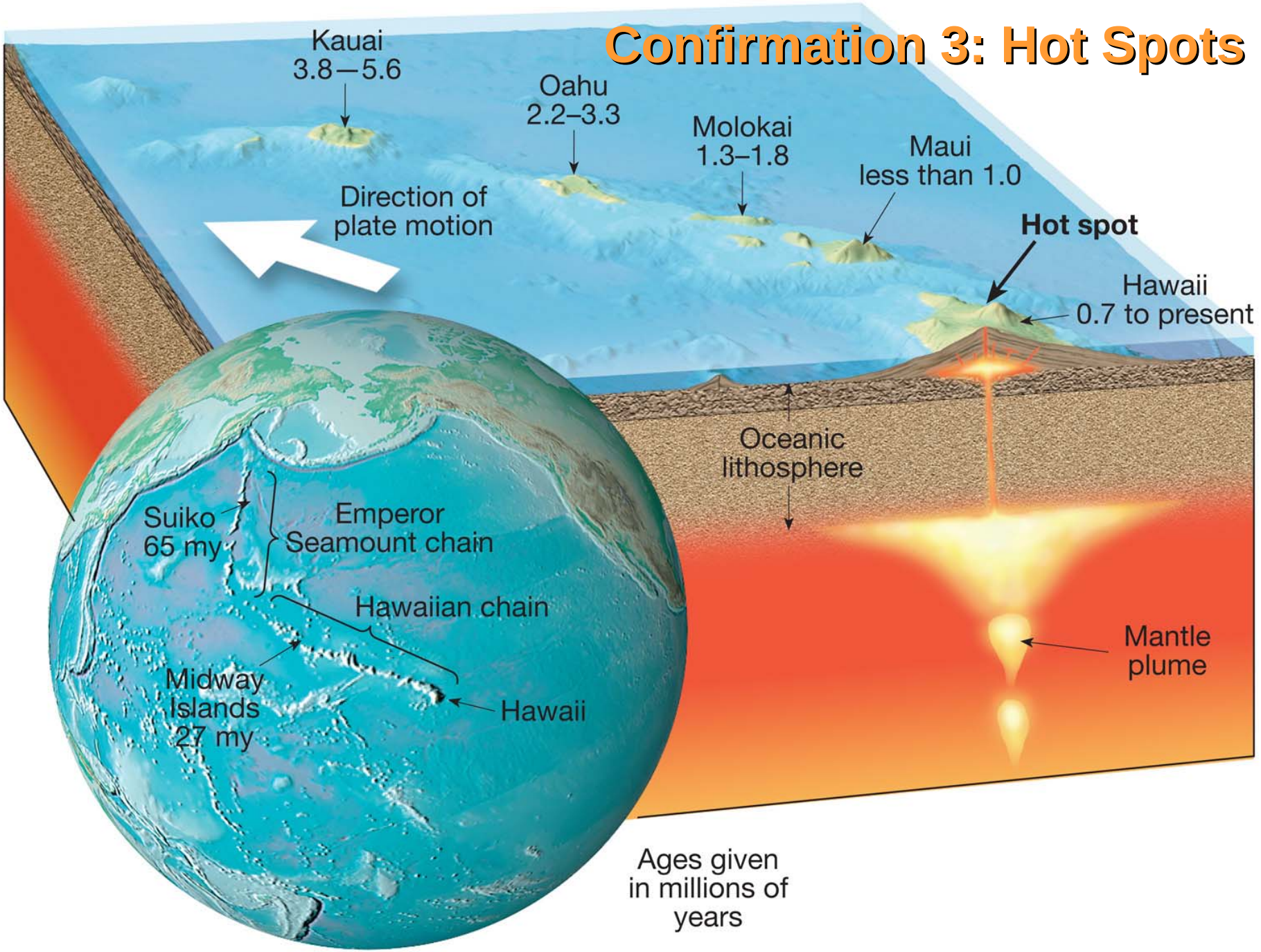
What does this map tell us about plate tectonics?

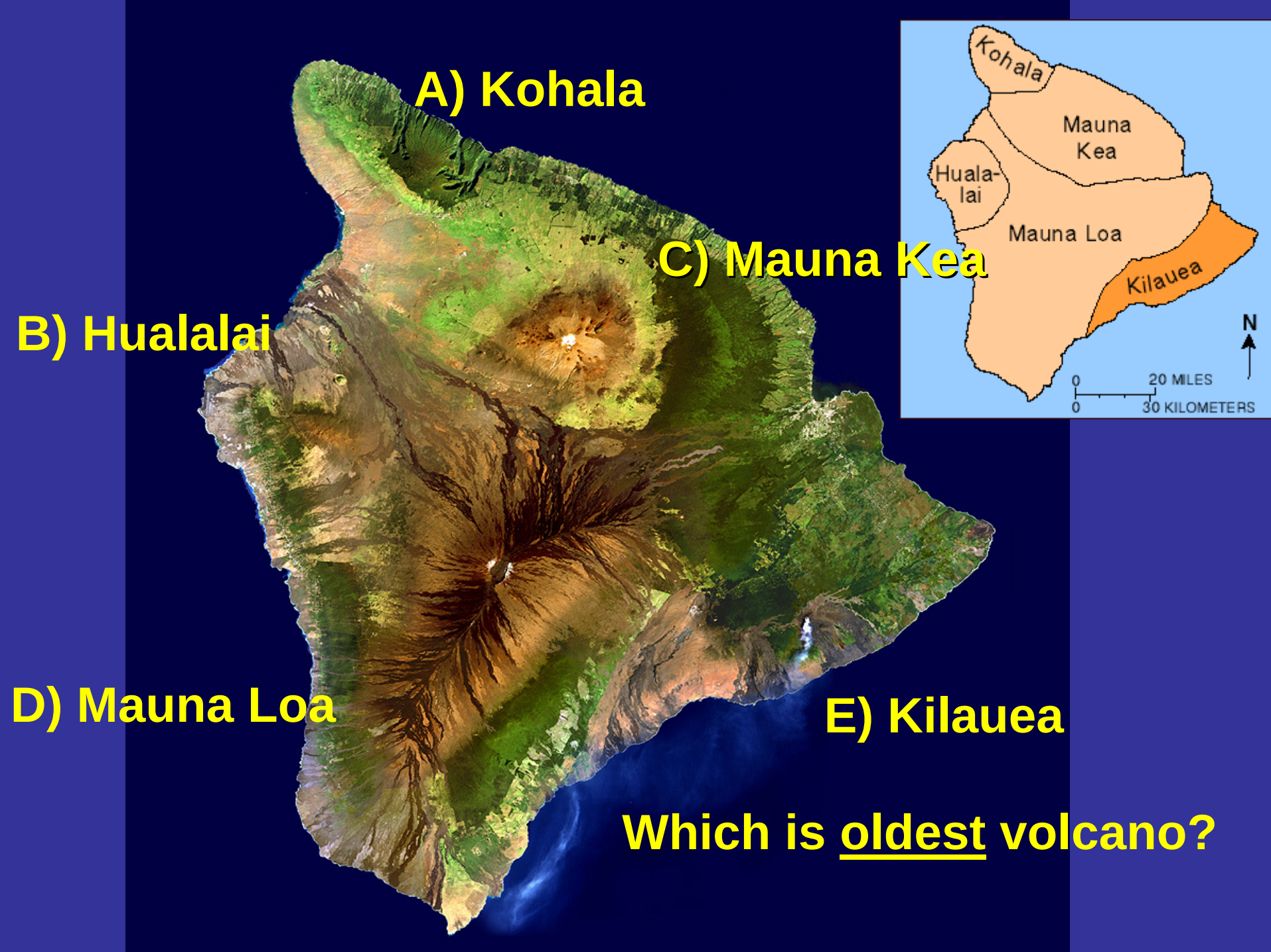
A) Earth is growing, B) oceans are growing, C) continents are growing
D) ocean floor grows at the same rate everywhere
E) there is new ocean floor and old ocean floor

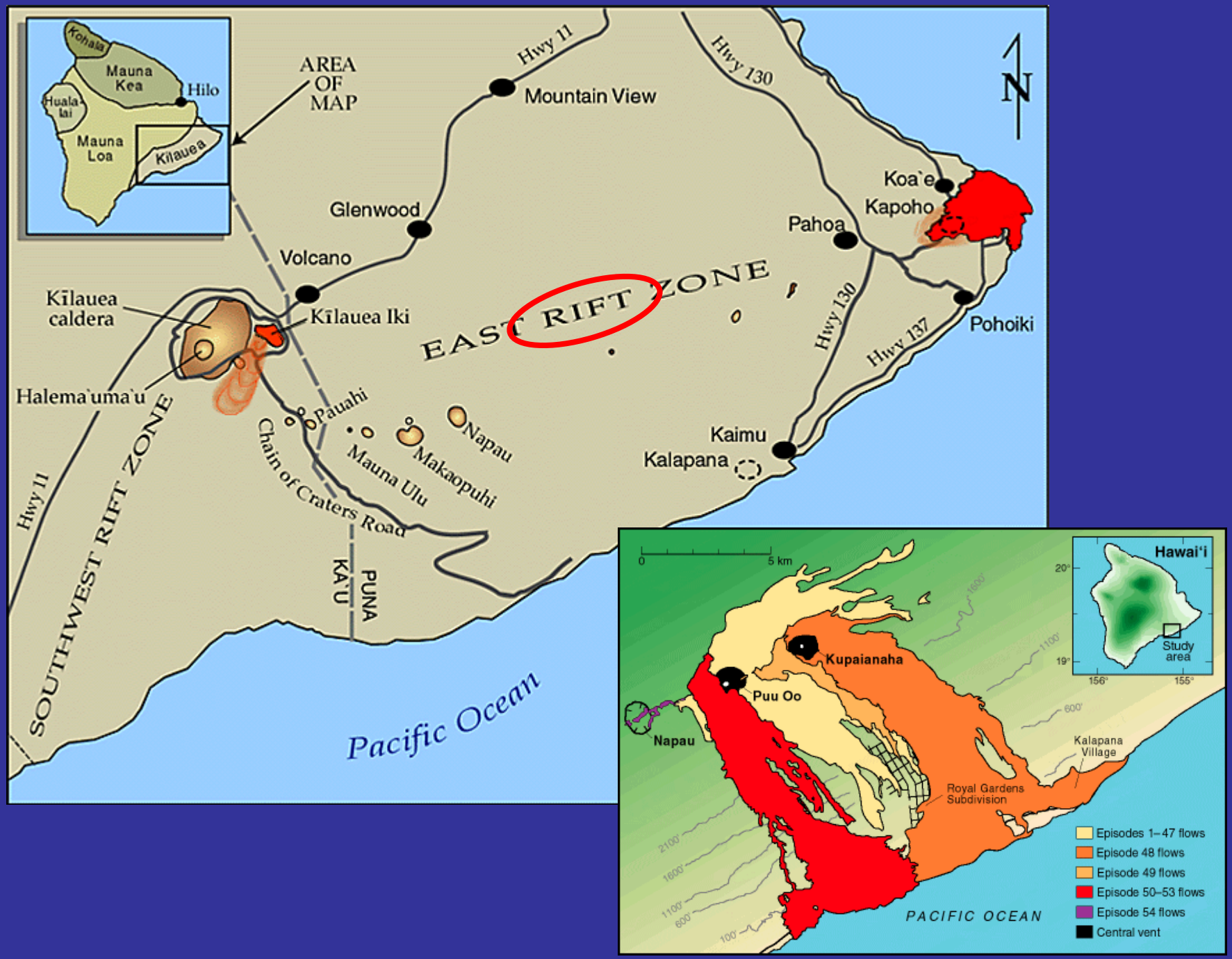




Confirmation 3: Hot Spots




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


Kohala
Mauna Kea
Hilo
Hualalai
Mauna Loa
Kīlauea
AREA OF MAP
Hwy 11
Mountain View
Hwy 130
N
Koa`e
Kapoho
Pahoa
Glenwood
Volcano
EAST RIFT ZONE
Kīlauea caldera
Kīlauea Iki
Hwy 130
Hwy 137
Pohoiki
Halema`uma`u
Pauahi
Napau
Makaopuhi
Mauna Ulu
Chain of Craters Road
Kaimu
Kalapana
SOUTHWEST RIFT ZONE
Hwy 11
KA`U
PUNA
Pacific Ocean
0
5 km
Hawai`i
Study area
20°
19°
156°
155°
Kupaianaha
Puu Oo
Napau
Kalapana Village
Royal Gardens Subdivision
2100'
1600'
1100'
600'
100'
PACIFIC OCEAN
Episodes 1–47 flows
Episode 48 flows
Episode 49 flows
Episode 50–53 flows
Episode 54 flows
Central vent

MOUNTAIN COTTAGES & RESORT

KILAUEA VOLCANO

Kilauea Military Camp (KMC)• A JOINT SERVICES RECREATION CENTER

About KMC | Kilauea Volcano | Accommodations | Amenities
Restaurants & Lounge | Tours & Wild Ginger Packages | Meetings & Conferences
Rates & Eligibility | Reservations | Contact Us



Kilauea Military Camp (KMC), a Joint Services Recreation Center, is surrounded by the dramatic beauty of Hawai'i Volcanoes National Park. Nearby is the world's most active volcano, Kilauea. The accommodations, amenities and tour packages offered by KMC let you capture all the mystery and wonder of the Big Island.

KMC is open to all active and retired military, Reserve and National Guard members, current and retired Department of Defense civilian employees, dependents and sponsored guests.

Check out our Current Events sheet.



On the Big Island of Hawai'i

KMC Home | About KMC | Kilauea Volcano | Accommodations | Amenities | Restaurants and Loun
Reservations | Co

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For problems with the web site, pleas

KMC at Kilauea Volcano, A Joint Services Recreation Center, Crater

Lectures | FieldTrips.ppt | Kilauea Military Camp ...



Night hike through lava tube



Hawaii Volcano Observatory

Kilauea Caldera

Halema'uma'u



Lava falls and rainforest hike





Lava hunting,
black sand beach, Rainbow Falls





http://hvo.wr.usgs.gov/kilauea/update/

USGS
science for a changing world
Hawaiian Volcano Observatory

Kilauea

| Pu`u `O`o crater activity | aerial photo | maps | disclaimer | eruption update |

Live panorama of Pu`u `O`o vent, Kilauea Volcano

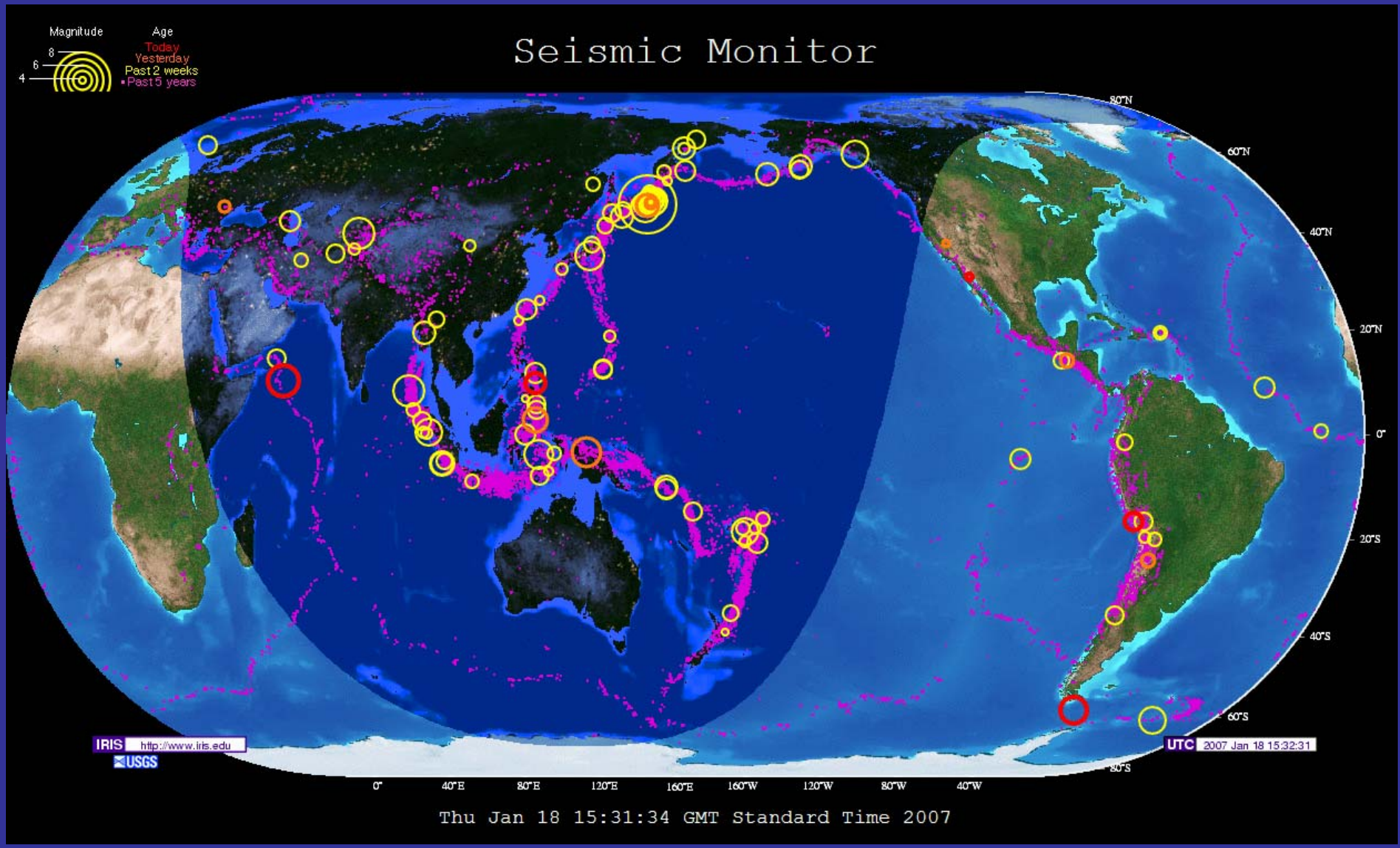
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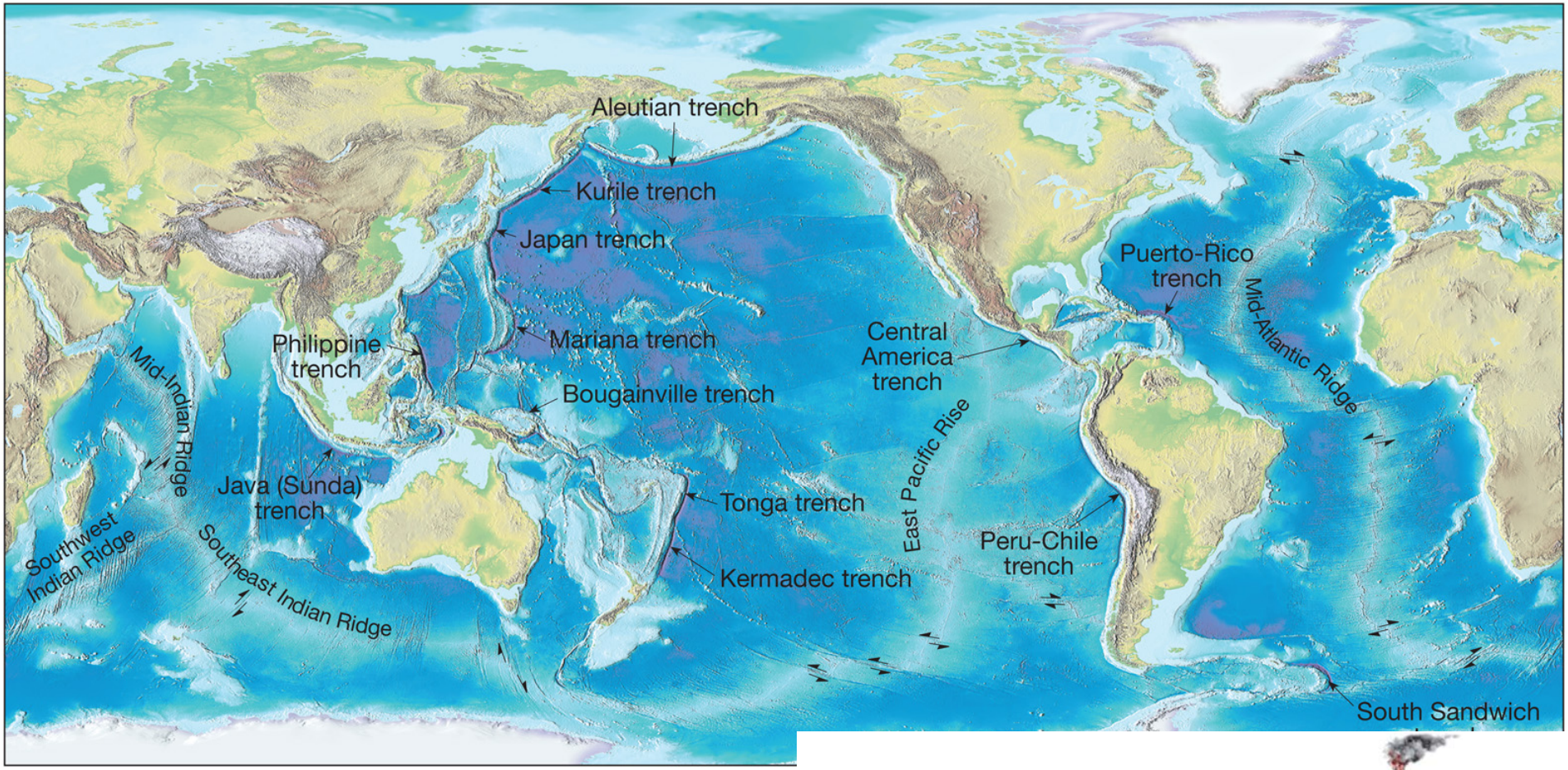
$75 Deposit to “Geology Club” by Thursday

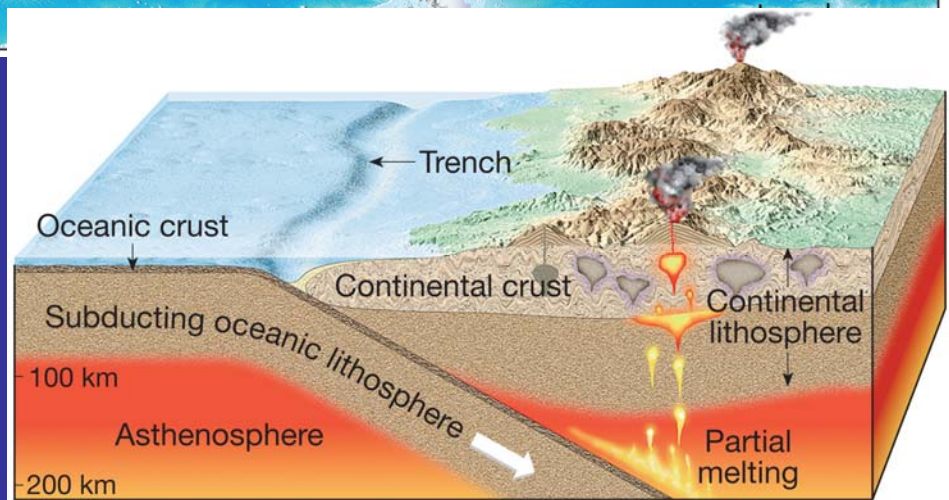


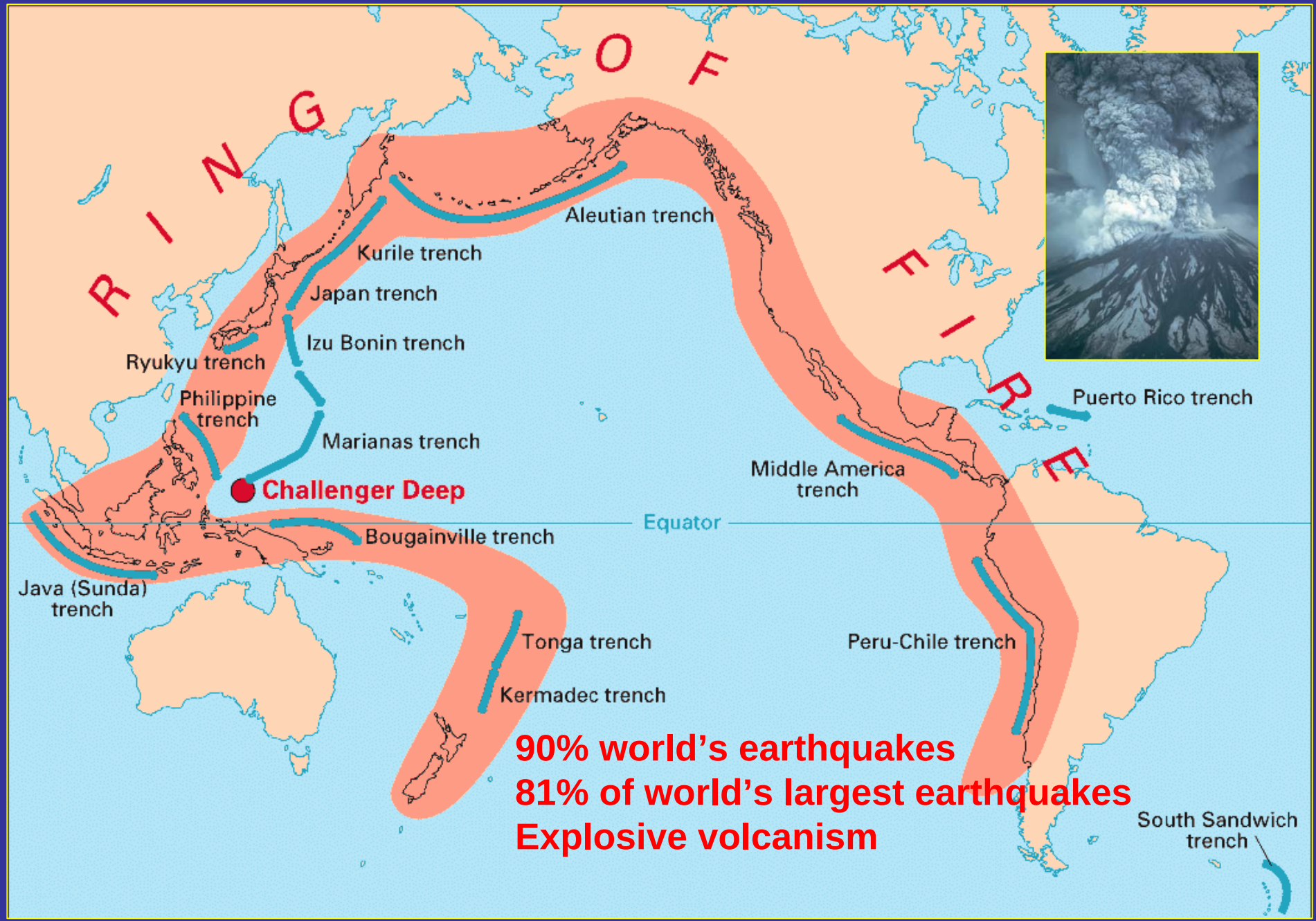


Where are the world's earthquakes?

Oceanic Trenches

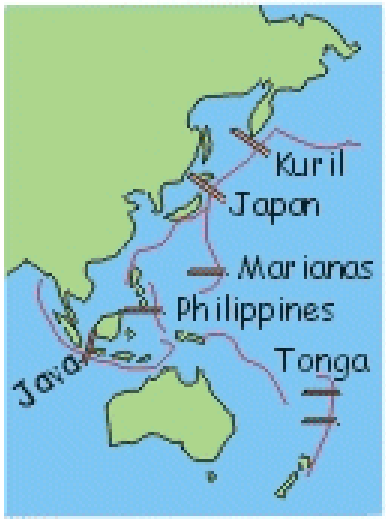


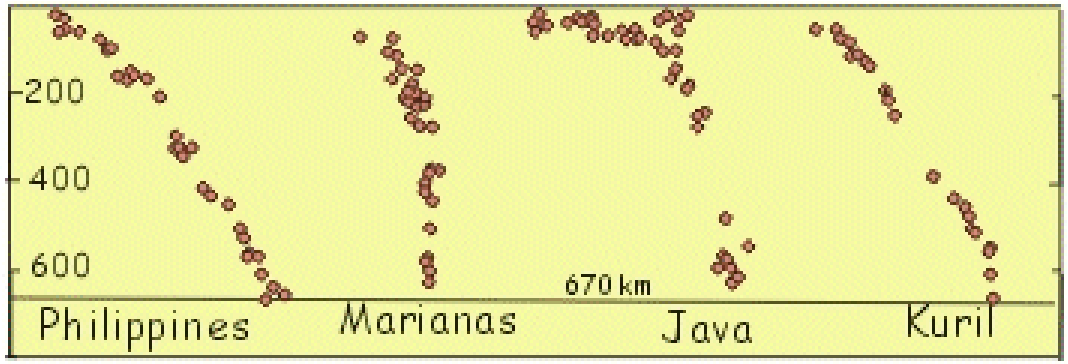


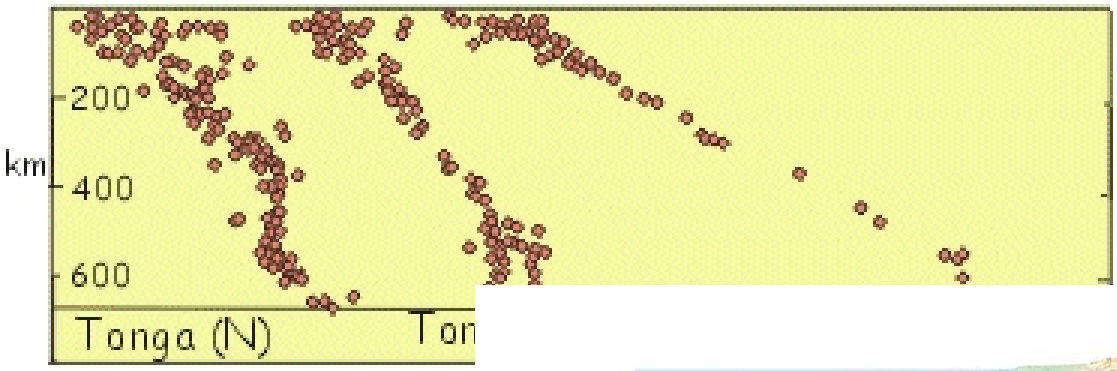

RING OF FIRE
Aleutian trench
Kurile trench
Japan trench
Izu Bonin trench
Ryukyu trench
Philippine trench
Marianas trench
Challenger Deep
Bougainville trench
Java (Sunda) trench
Tonga trench
Kermadec trench
Equator
Middle America trench
Puerto Rico trench
Peru-Chile trench
South Sandwich trench
90% world's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

Confirmation 4: Wadati-Benioff zones

Earthquakes and the dip of Wadati-Benioff seismic zones

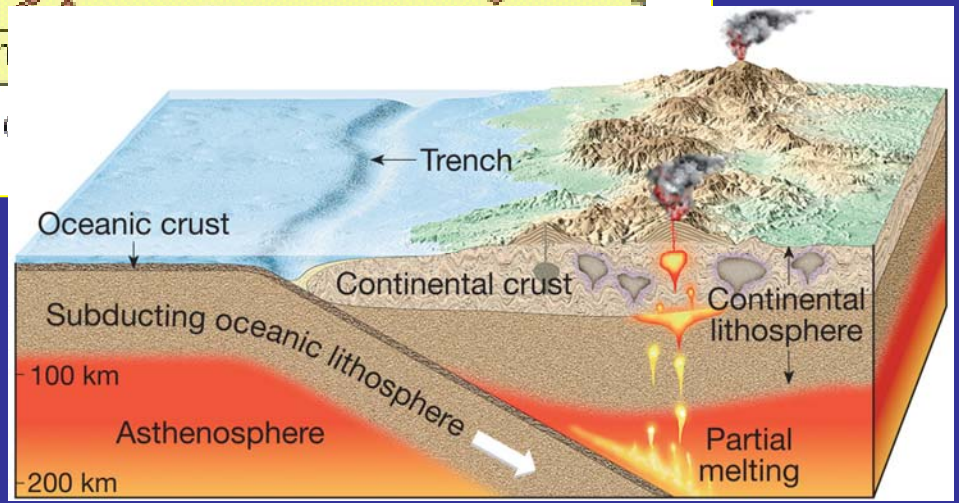






vertical an

Sinking oceanic crust

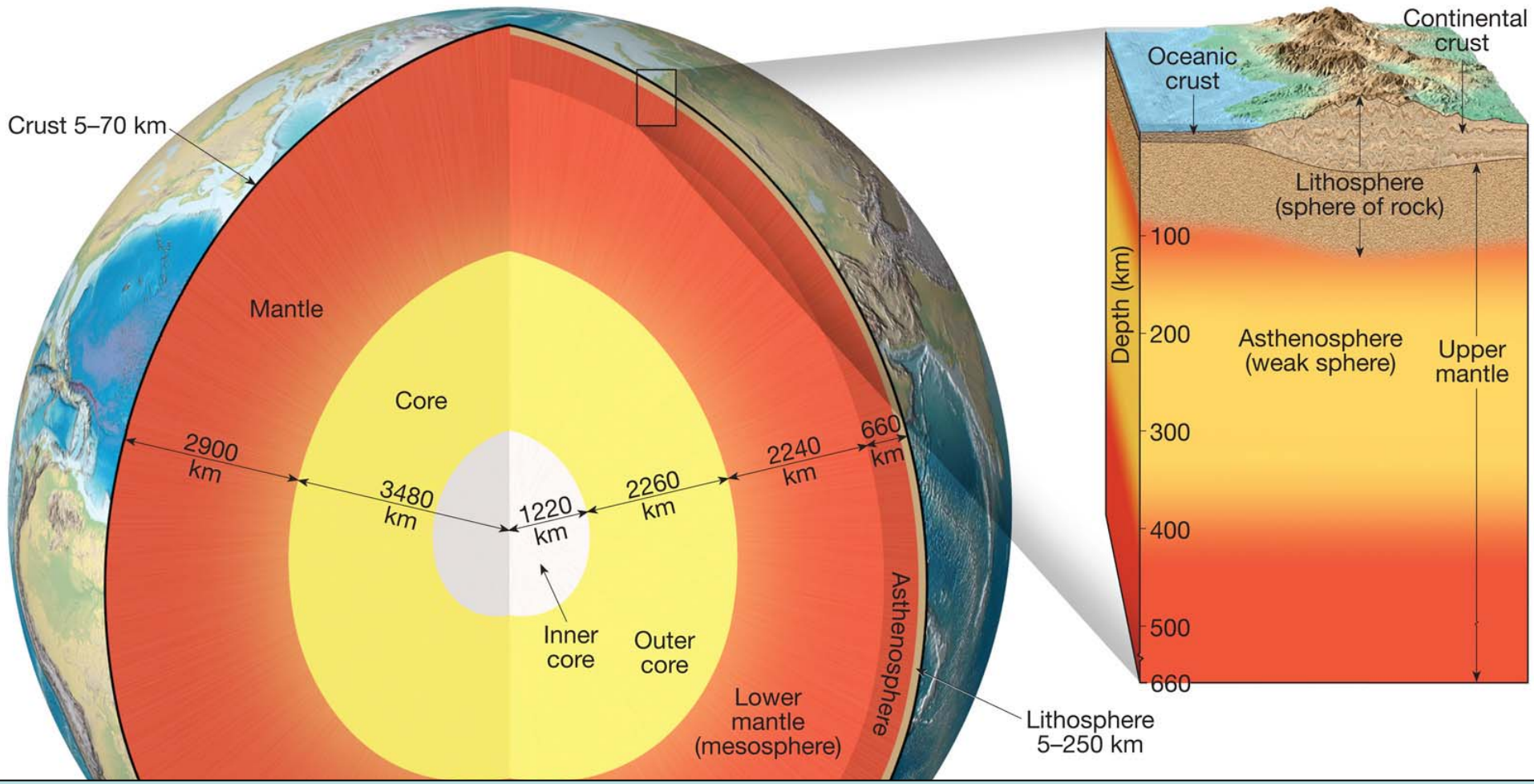


Support for plate tectonic model

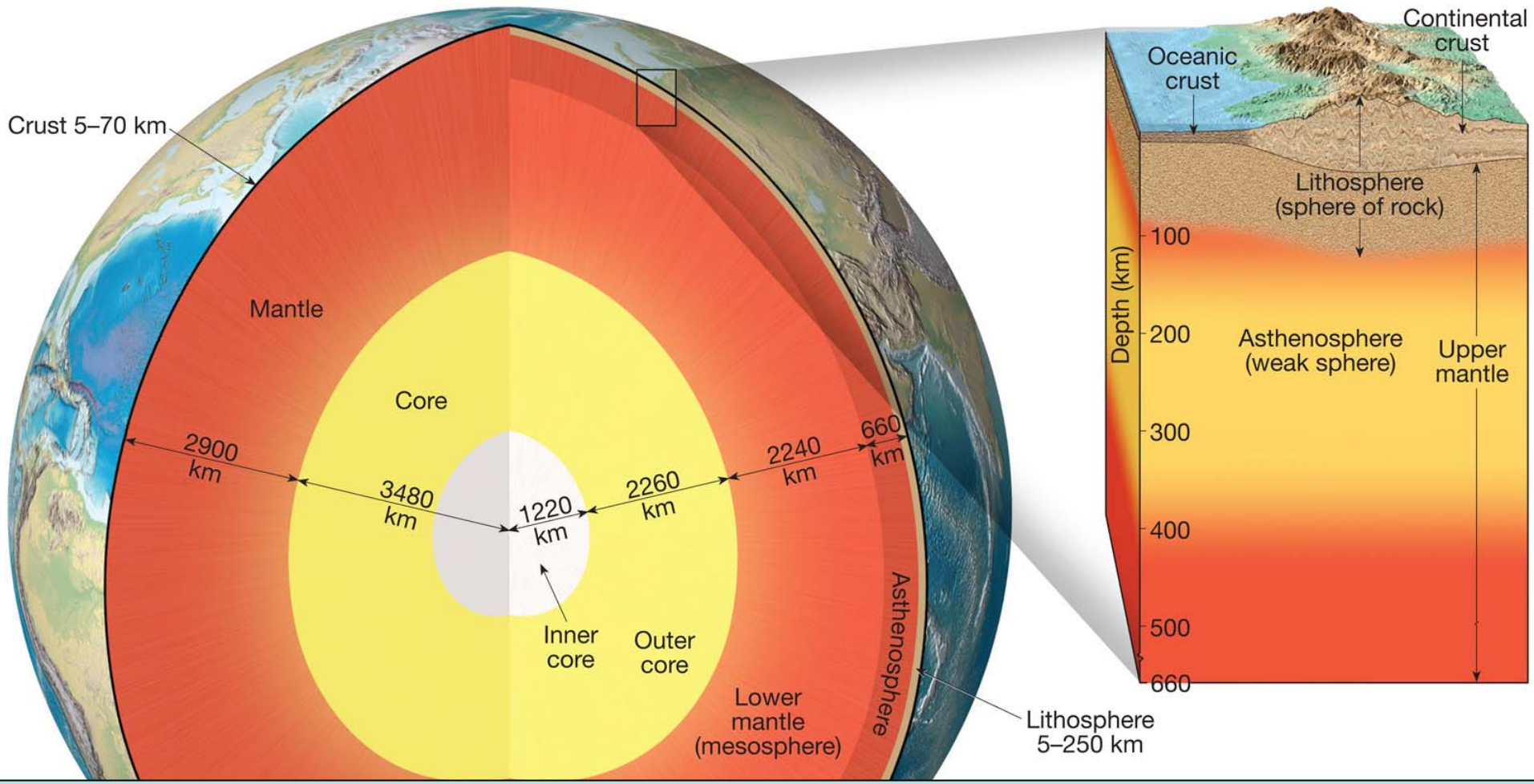


1. Continental jigsaw puzzle
2. Fossils match across Atlantic
3. Rock types/structures match across Atlantic
4. Ancient climates (i.e. glaciers in Africa)

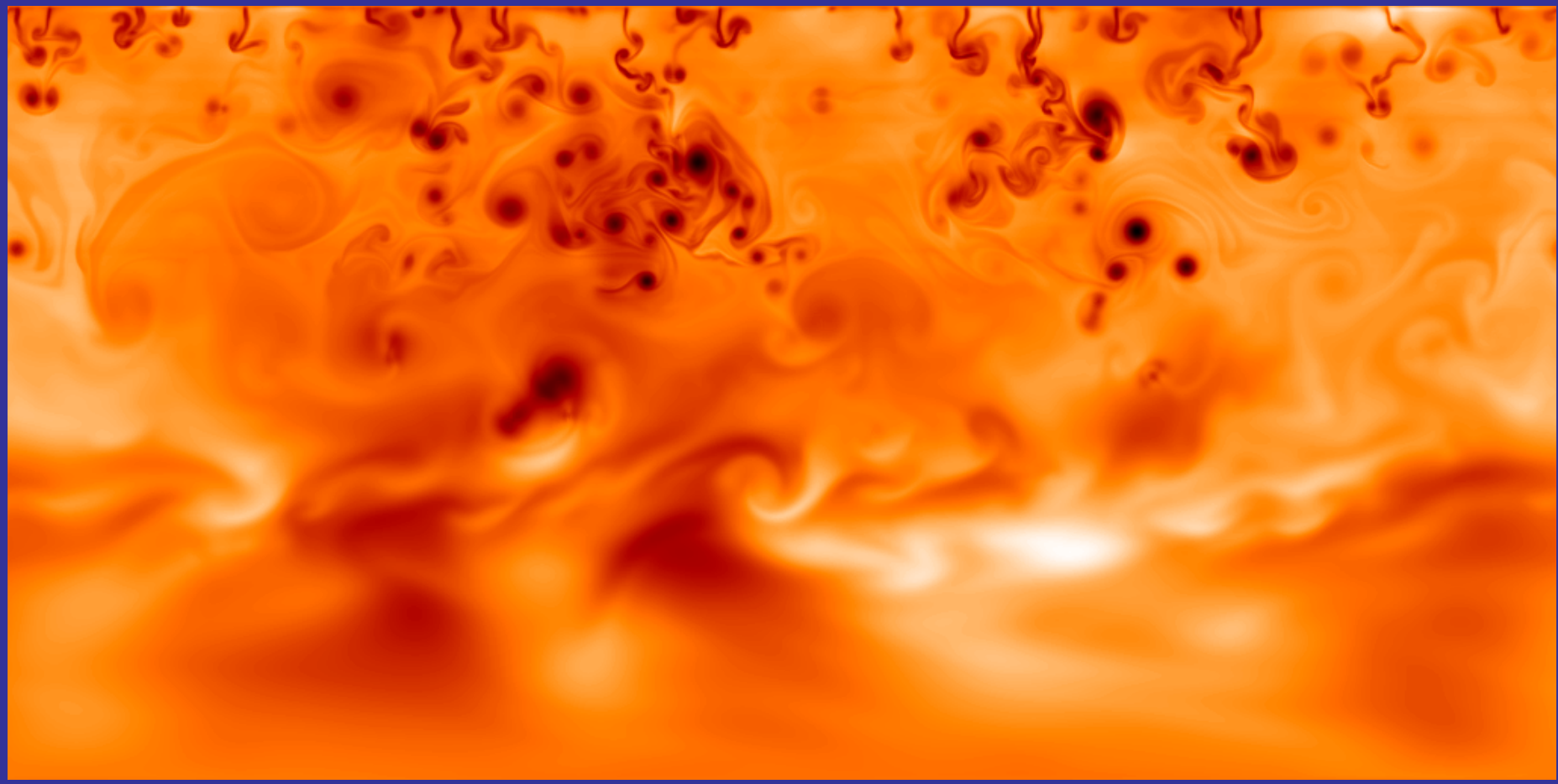
5. Ocean drilling confirms increasing seafloor age with distance from mid-ocean ridges
6. Paleomagnetism of lavas at ridges tracks formation of new seafloor
7. Hot spots track plate movement
8. Wadati-Benioff zones show descending plates



EARTH'S INTERNAL STRUCTURE	**PHASE**	**DENSITY(pressure)?**
• **Crust** – Fe/Mg/Si/O	**solid**	
◦ 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**	



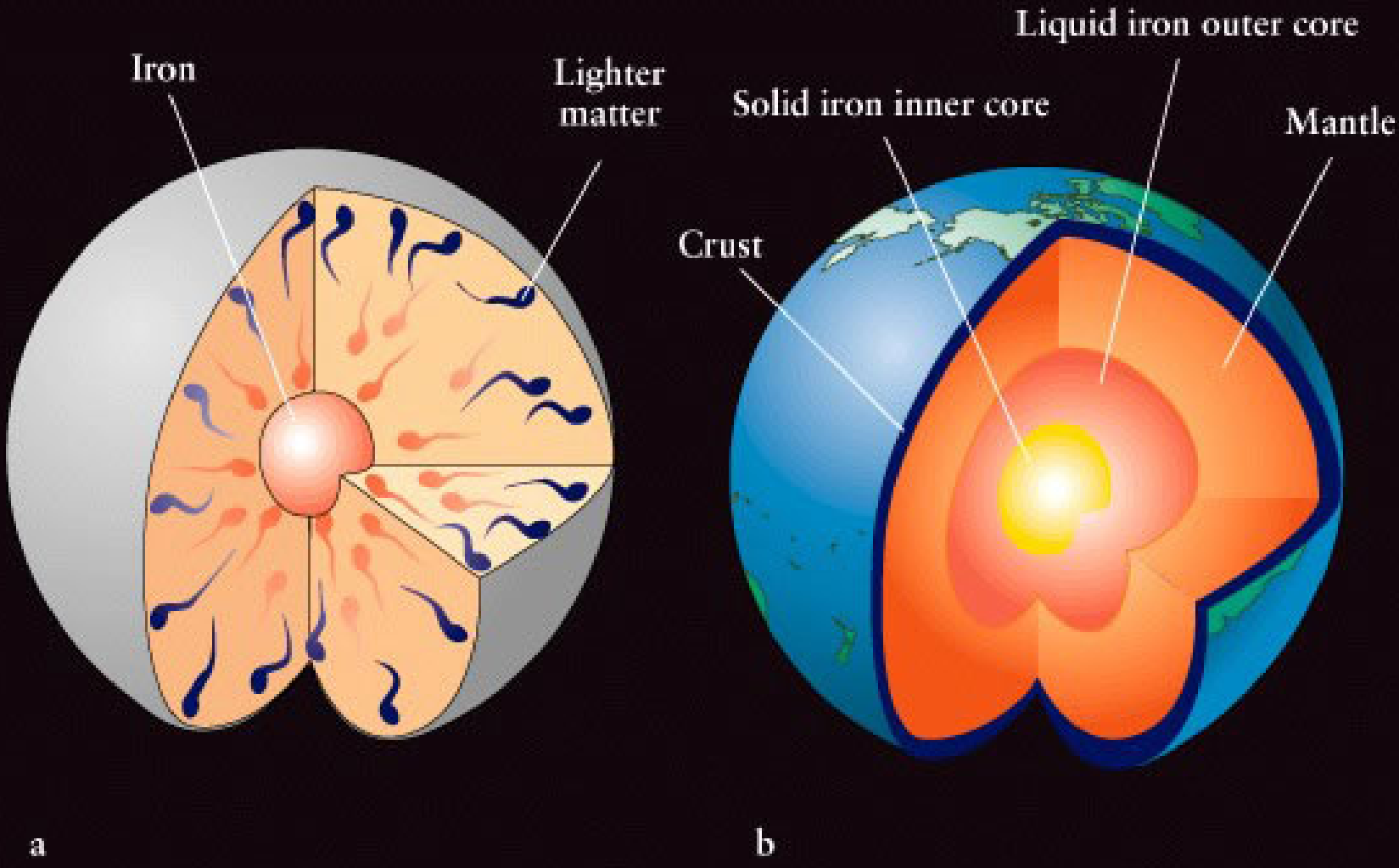
EARTH'S INTERNAL STRUCTURE	PHASE	(density)PRESSURE
• **Crust** – Fe/Mg/Si/O	solid	low
◦ Continental crust – Si/O/Na		
◦ Oceanic crust – Fe/Mg/Ca		
• **Mantle** – Fe/Mg	solid, but capable of flow	
• **Outer core** – Fe/Ni/Mg	liquid	
• **Inner core** – Fe/Ni	solid	high



What's happening here?

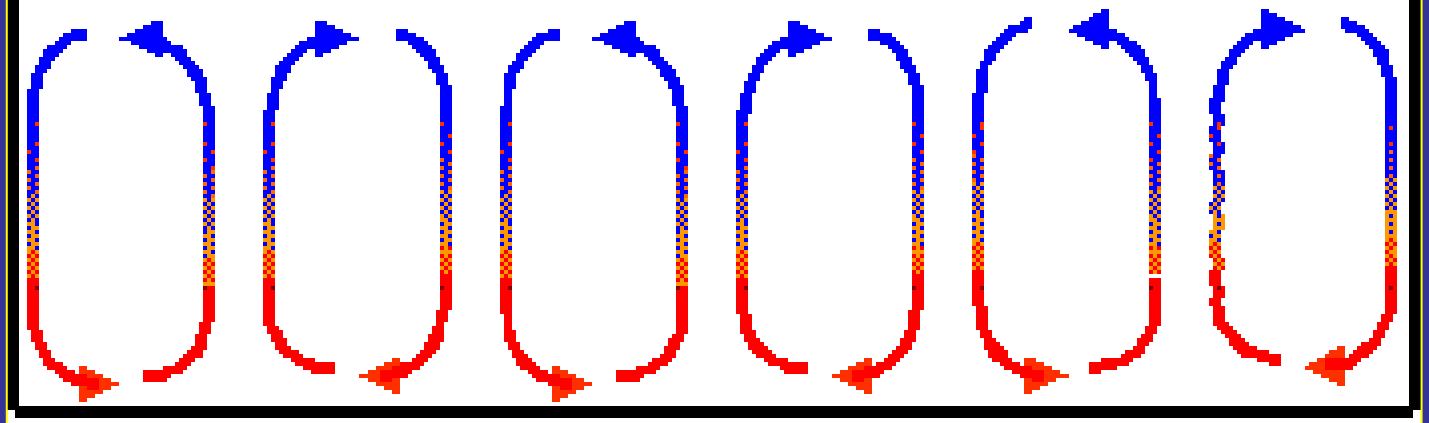
A) Density difference
B) Heat difference
C) Pressure difference

"Iron Catastrophe"



Density stratification: core → atmosphere

Fluid cools by losing heat from surface



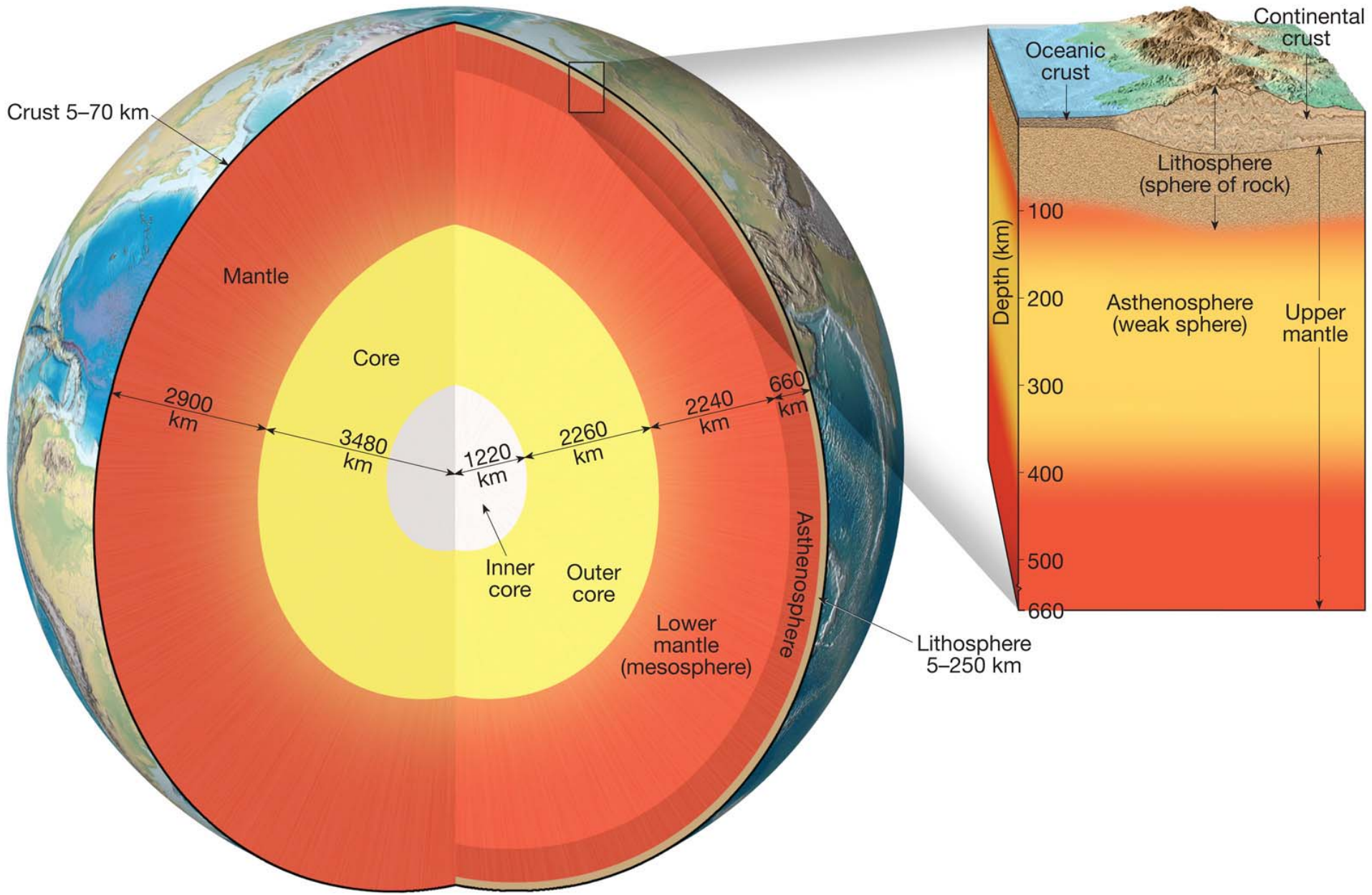


Convection cell

Warm, low density fluid rises

Cool, high density fluid sinks





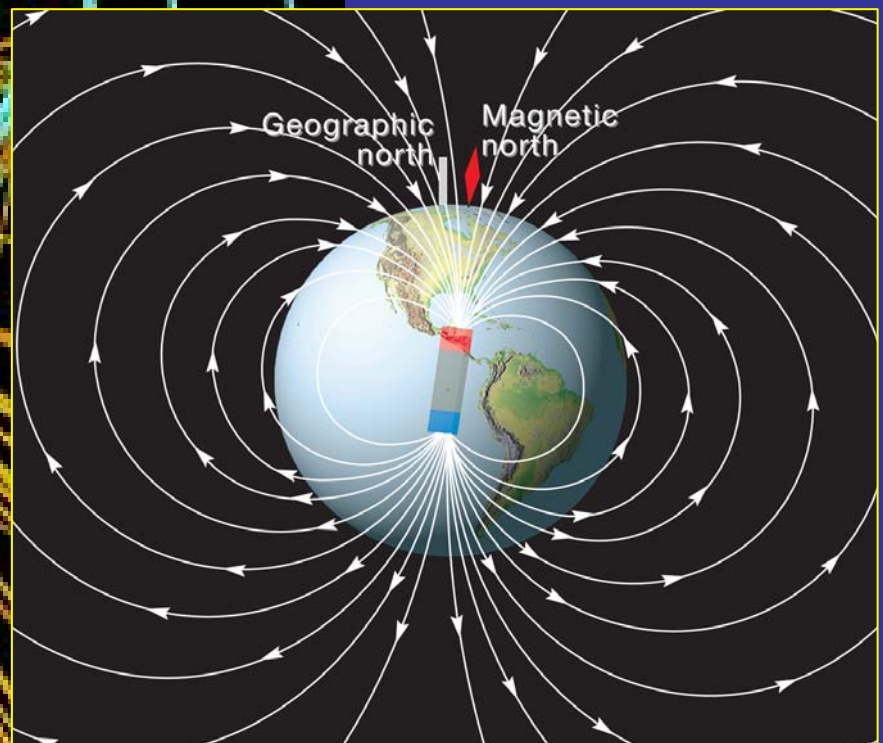
Where does convection occur?

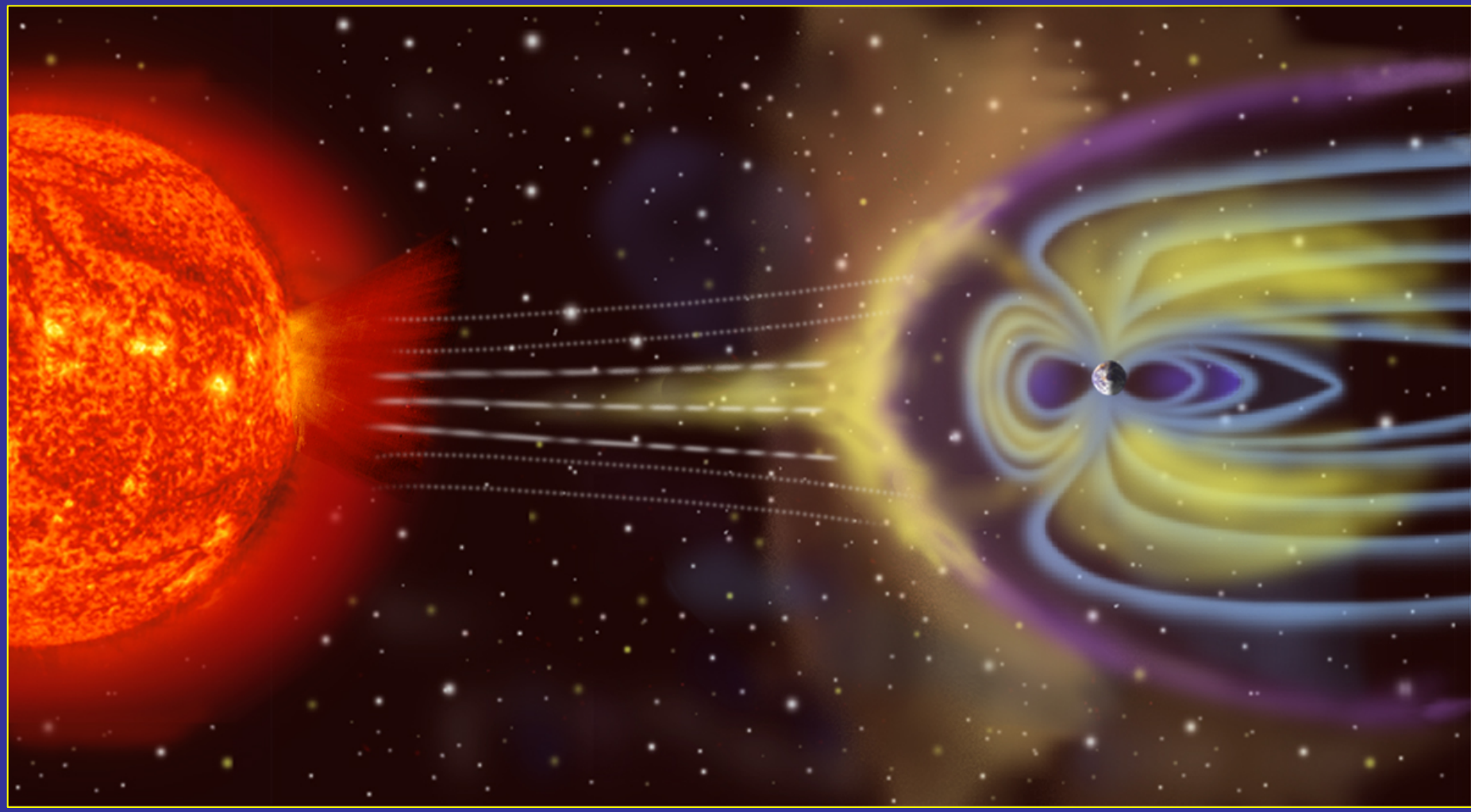
1) OUTER CORE

Magnetosphere
Magnetism gained from early nebula is magnified by:

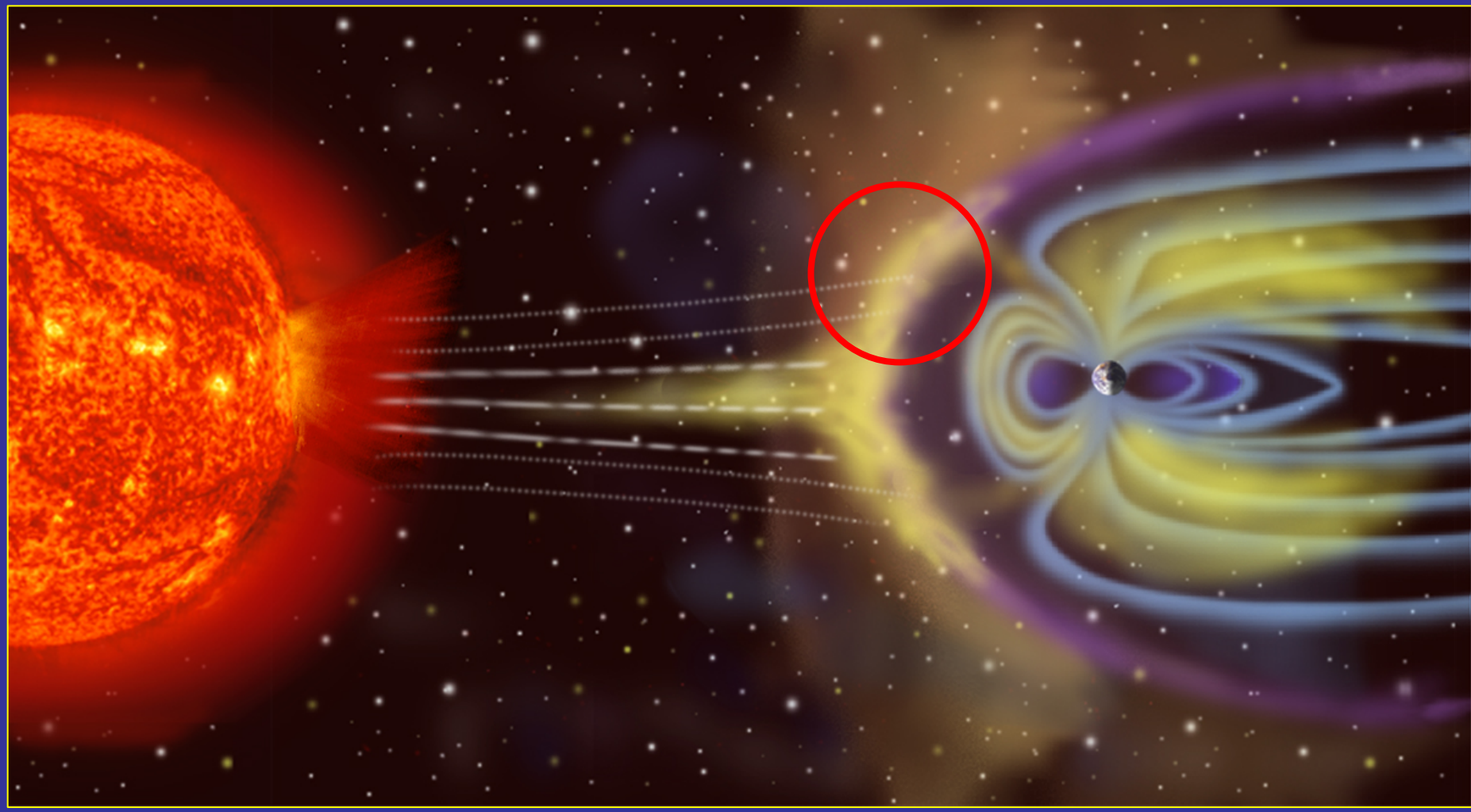
1) Turbulent iron/nickel fluid of outer core

2) Earth's rotation





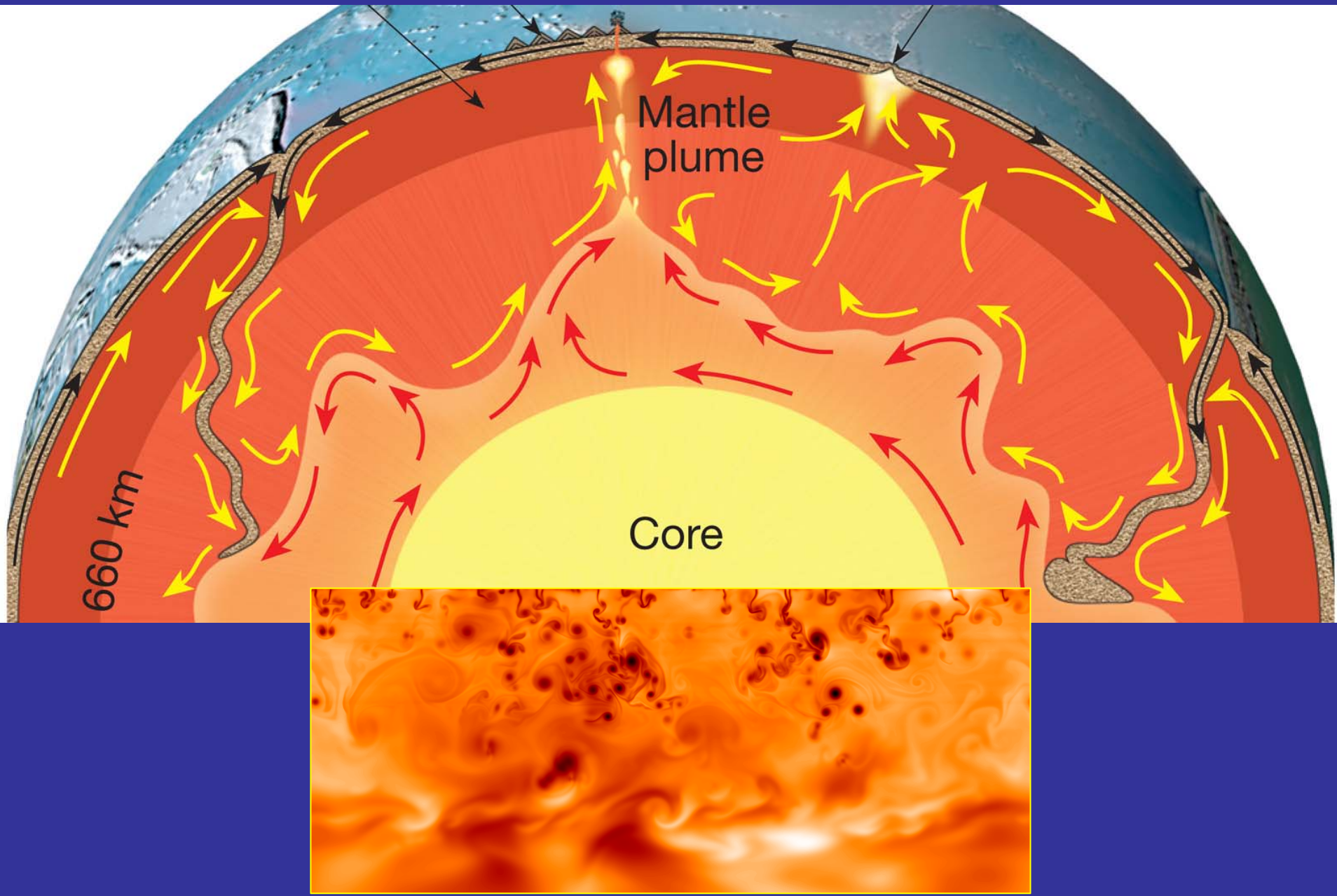
Earth’s magnetic field protects us from solar flares

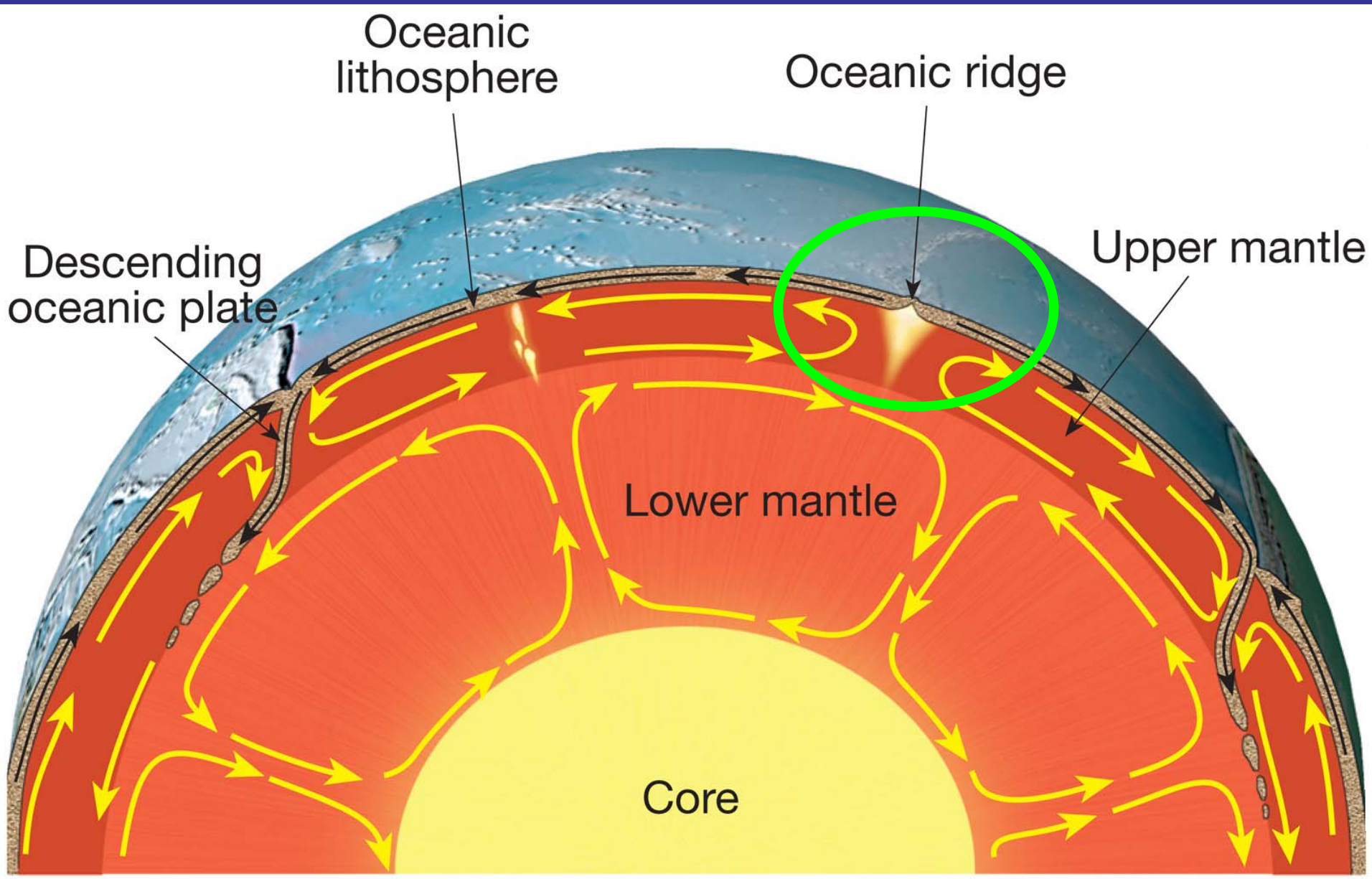


Earth’s magnetic field + solar flares create Aurora (Borealis, Australis – Northern, Southern lights)

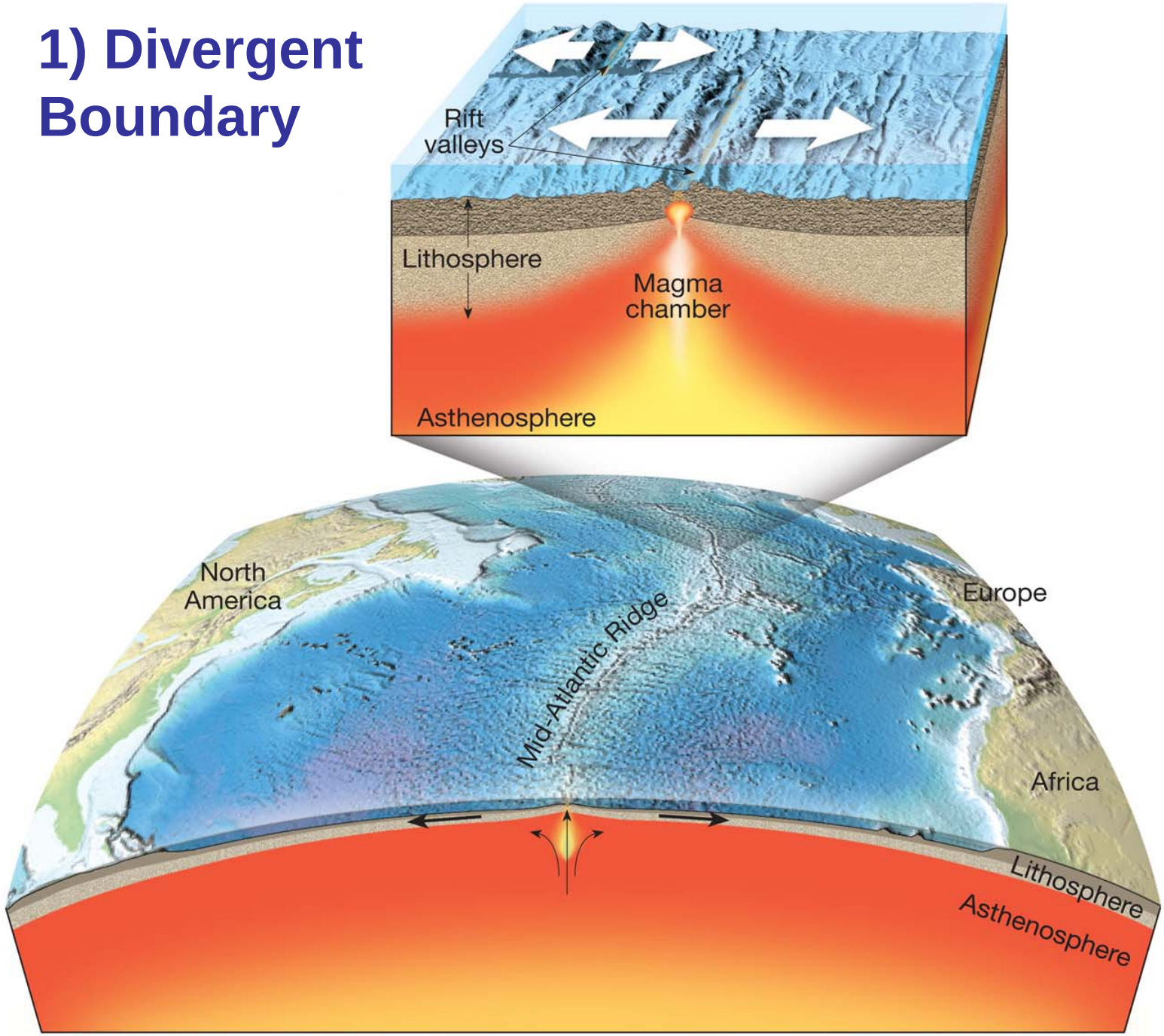


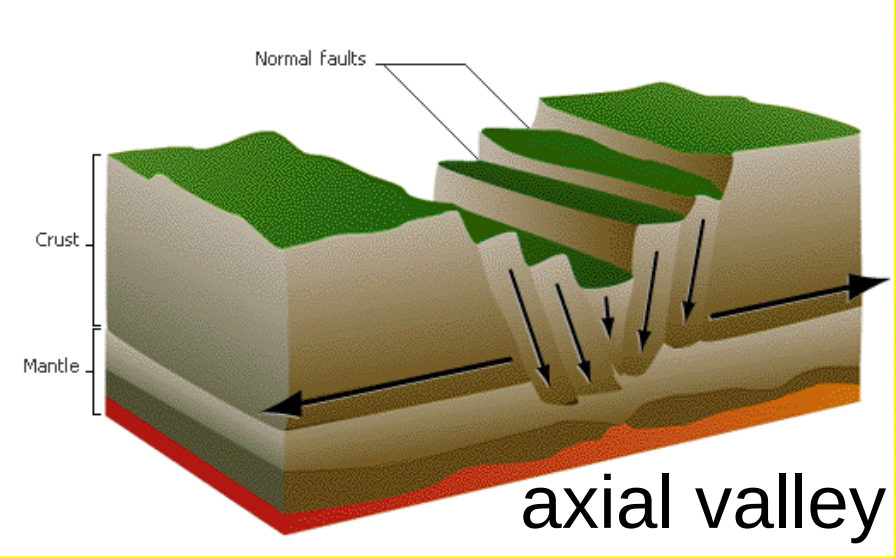
2) MANTLE CONVECTION – drives Plate Tectonics




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

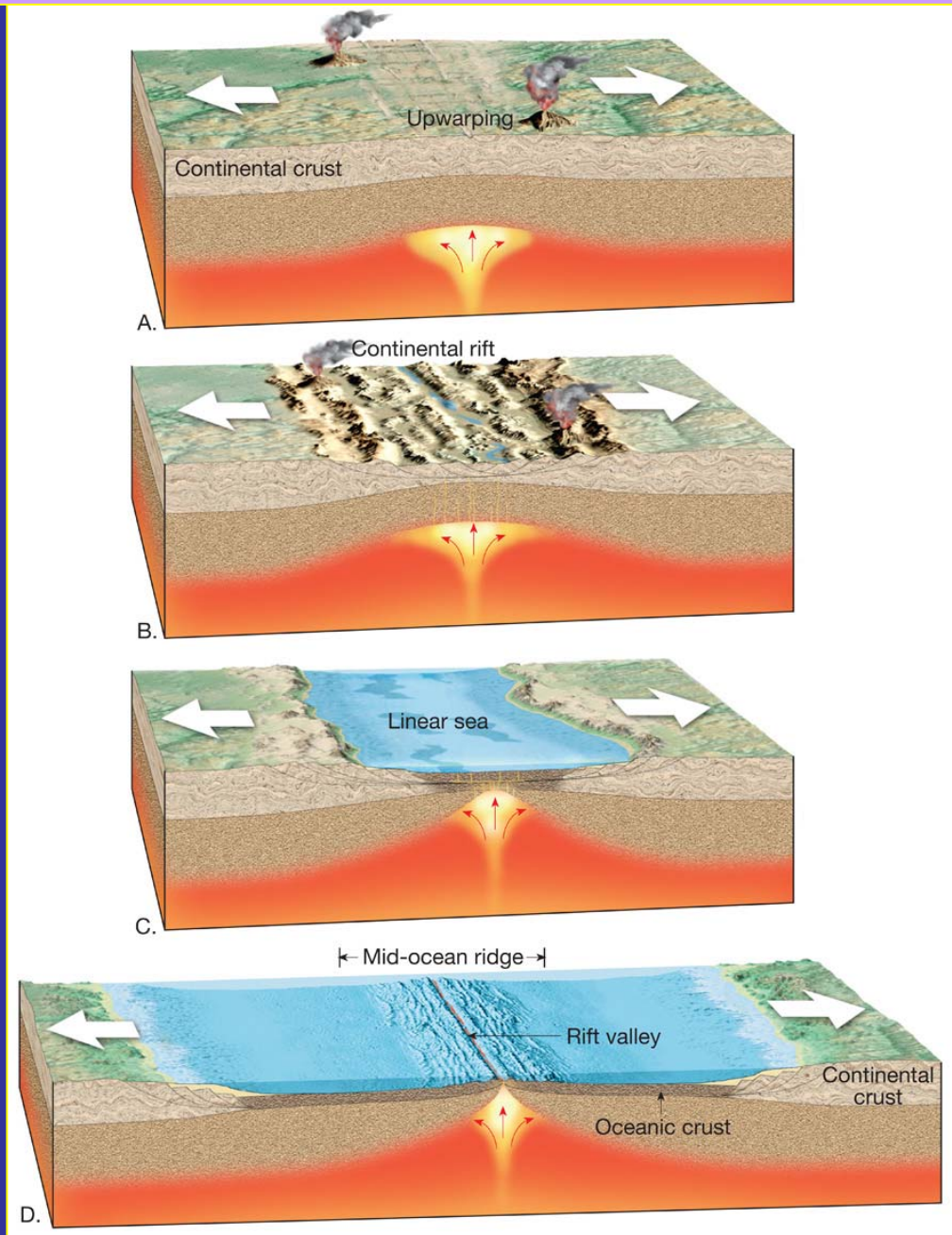


Cocos

Pacific

Nazca

Divergent boundary – continental example



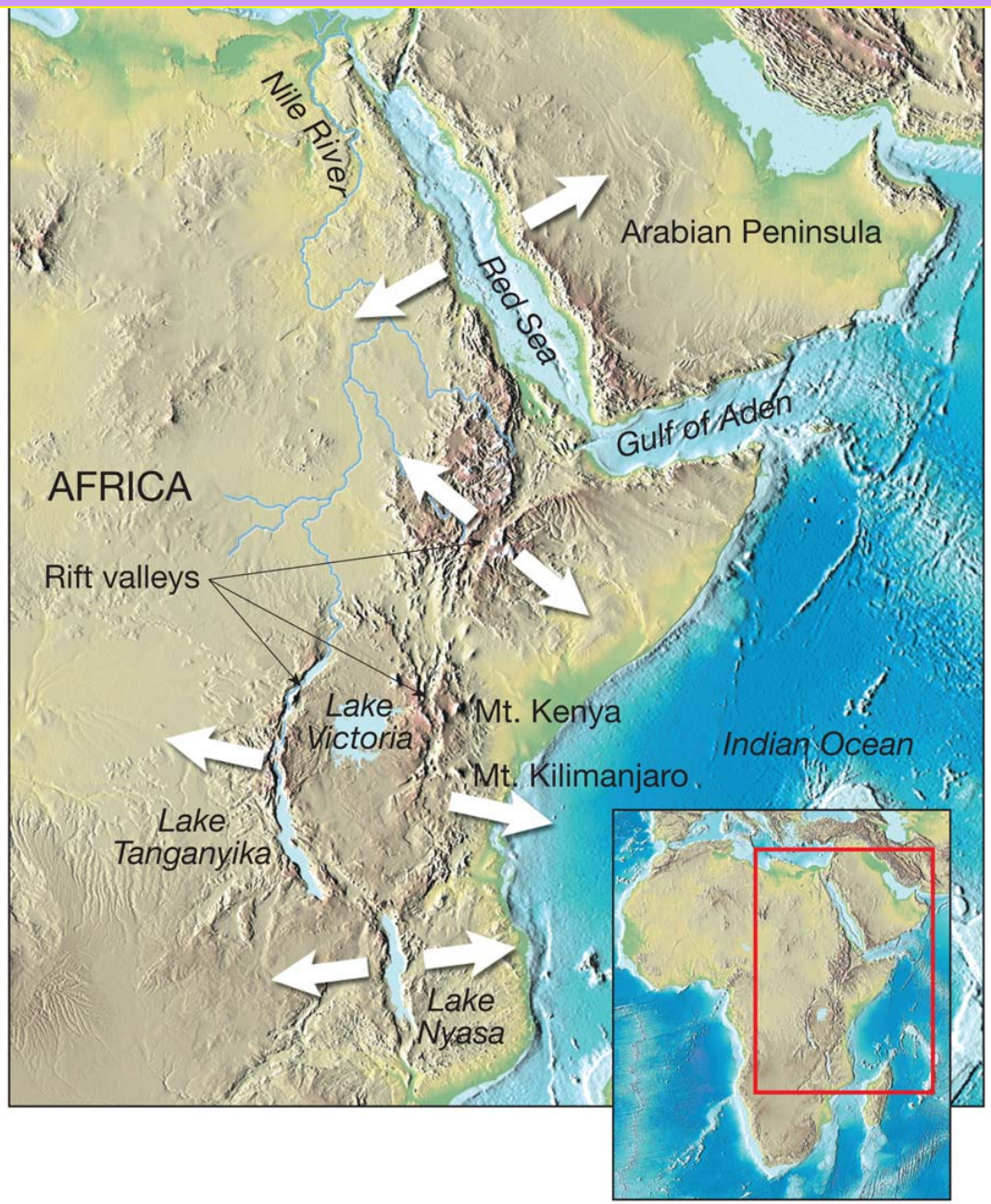
Upwarping, volcanism

Elongated rift valley

Narrow, linear sea

Seafloor spreading

Divergent boundary – East African Rift Valley

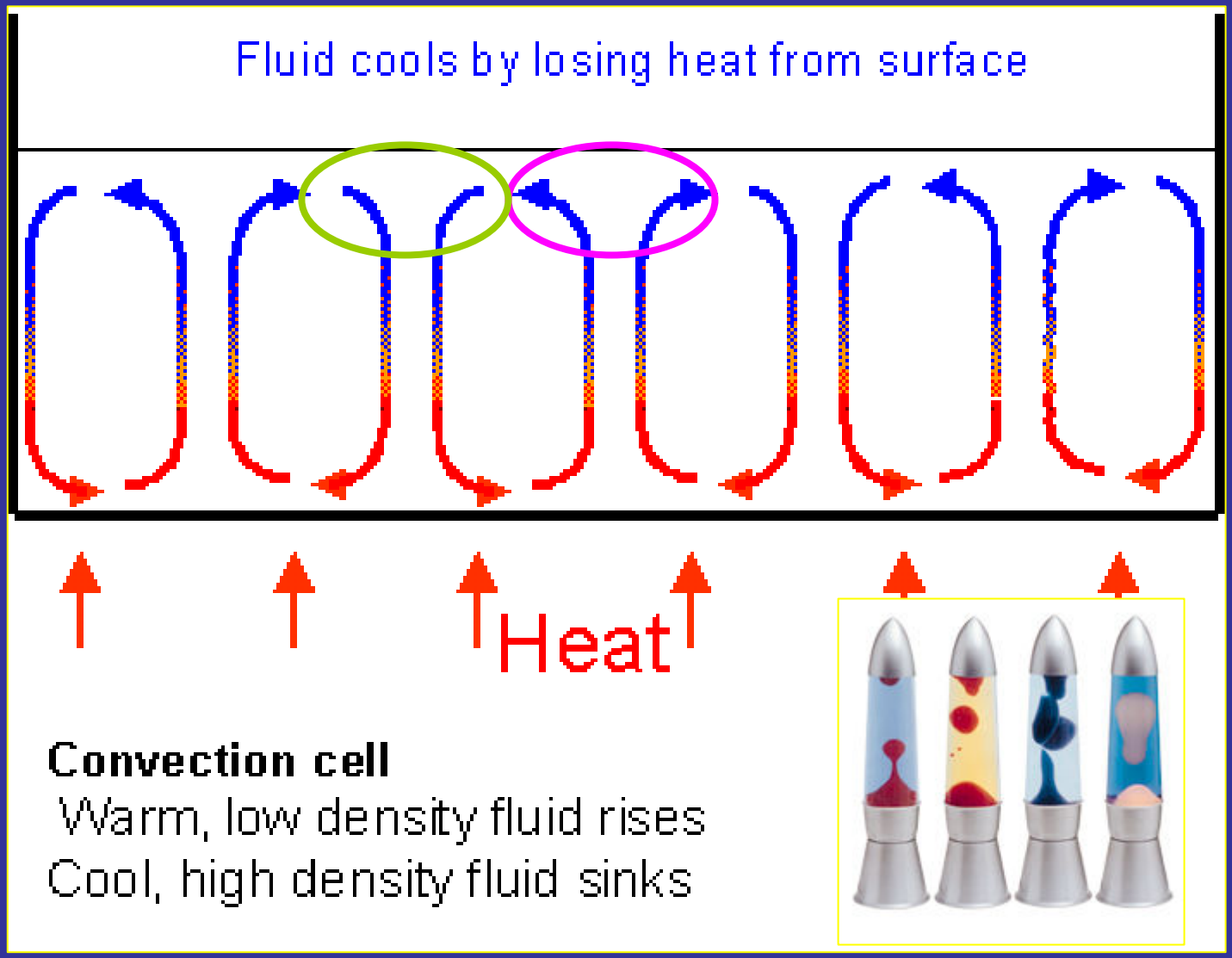






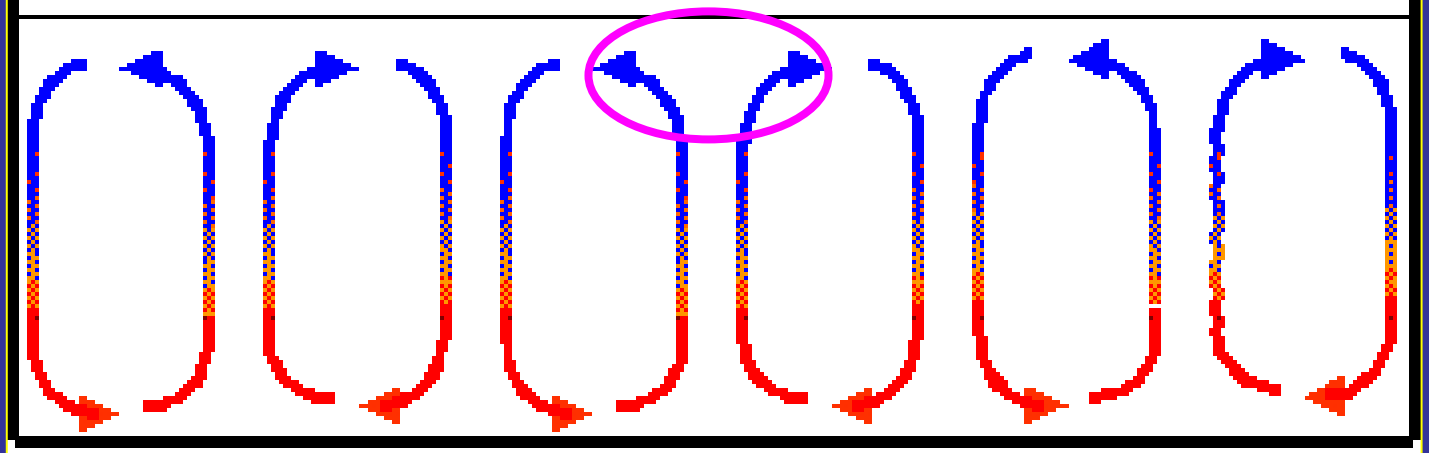






What does DIVERGENCE correspond to, A) or B) ?

Fluid cools by losing heat from surface



Heat

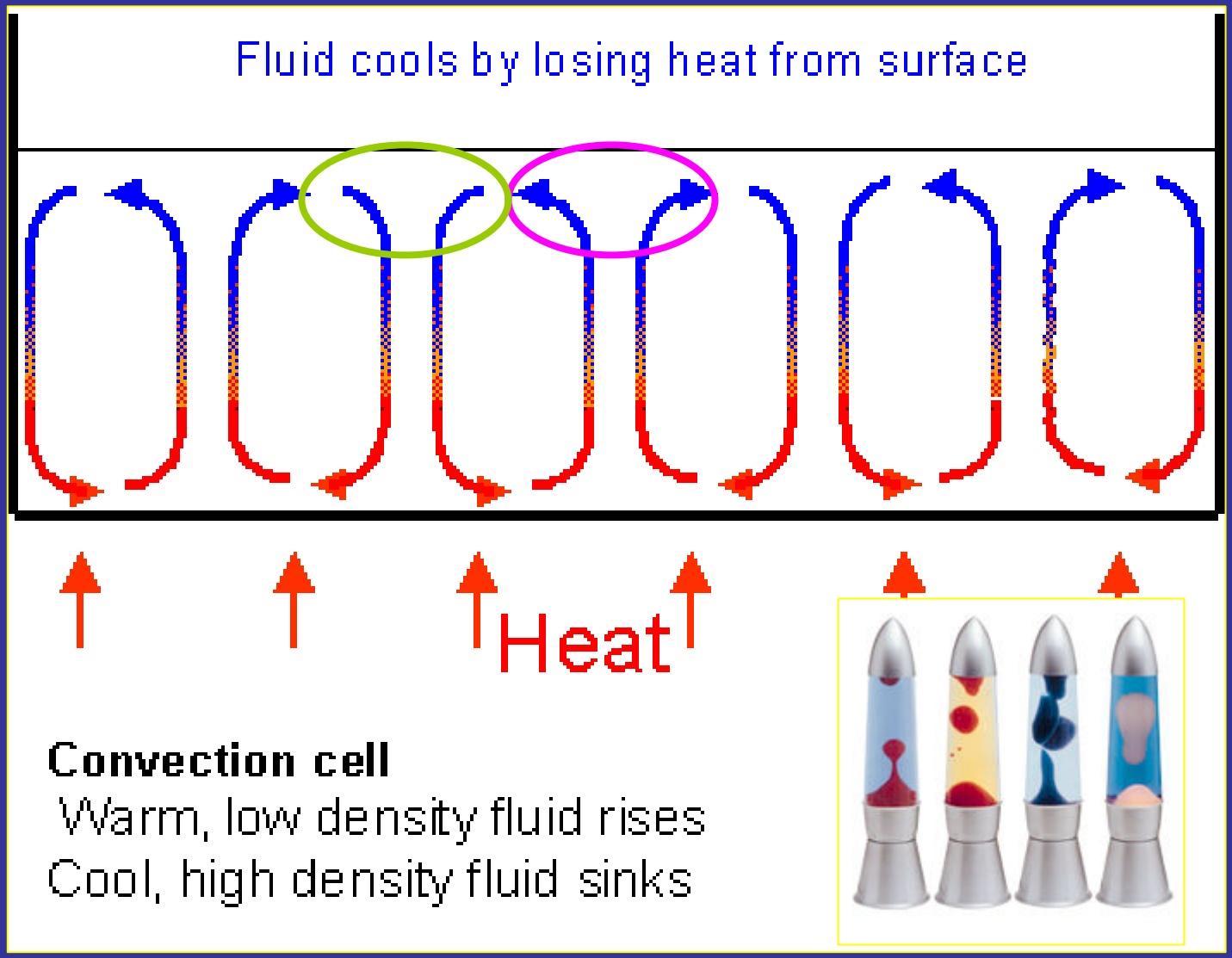
Convection cell

Warm, low density fluid rises

Cool, high density fluid sinks

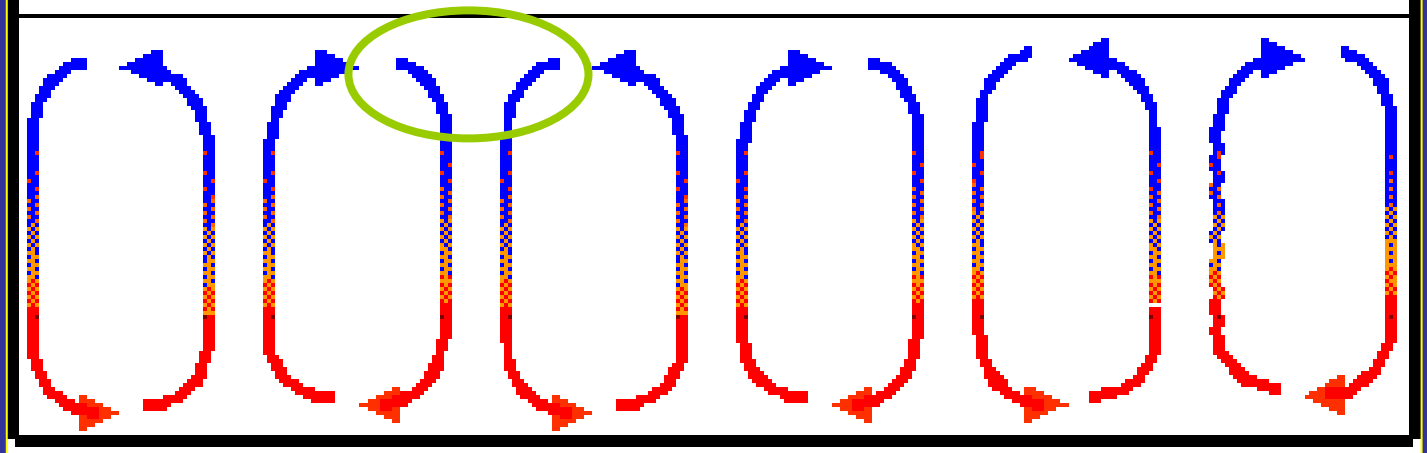


DIVERGENCE



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

Fluid cools by losing heat from surface





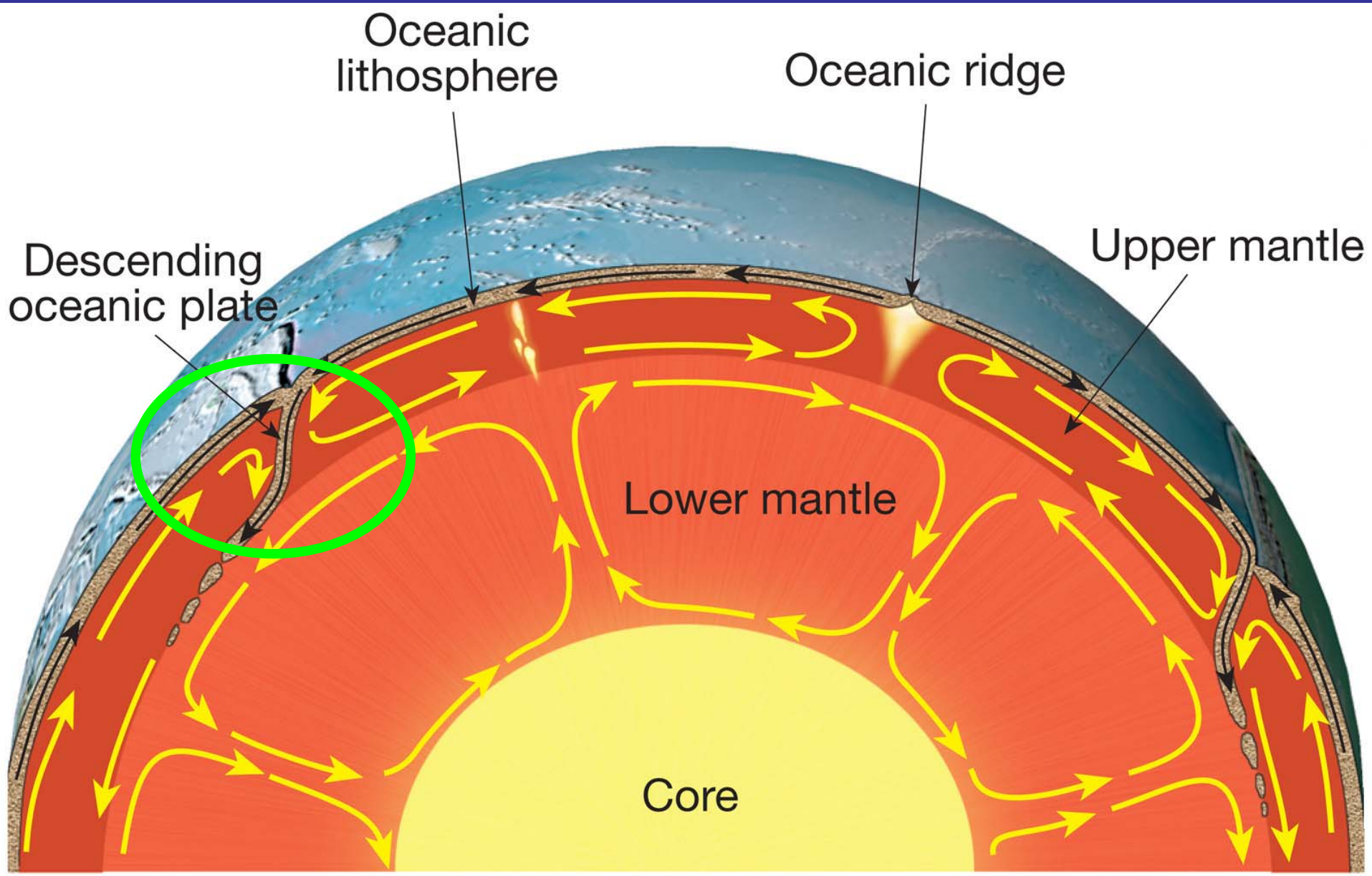
Convection cell

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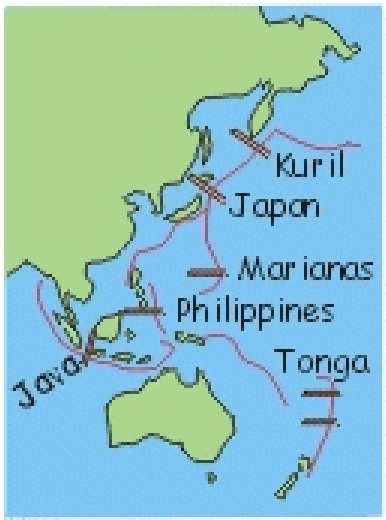
CONVERGENCE

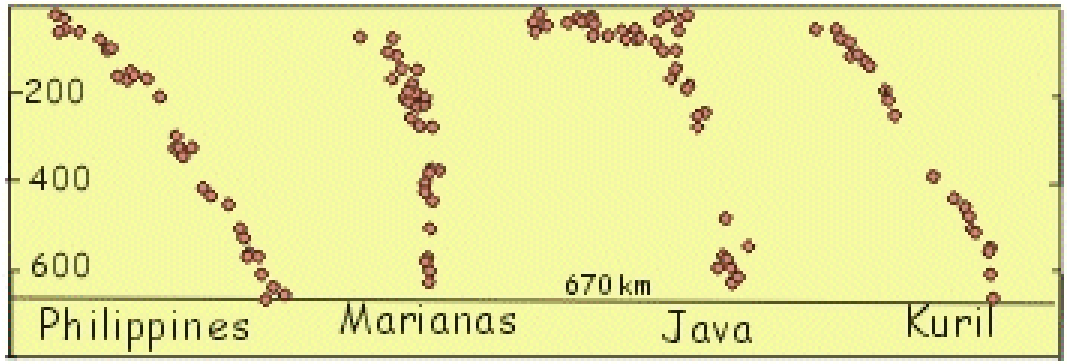


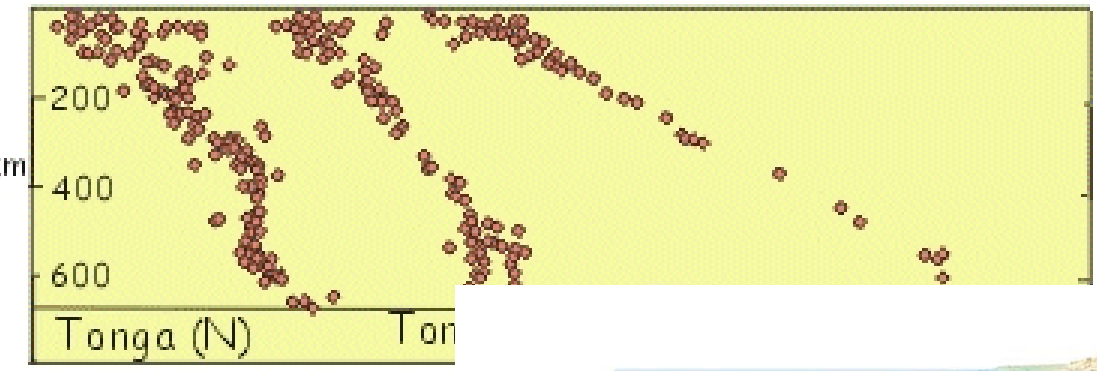
How do we know where these are?

Convergent boundary – Wadati-Benioff zones

Earthquakes and the dip of Wadati-Benioff seismic zones

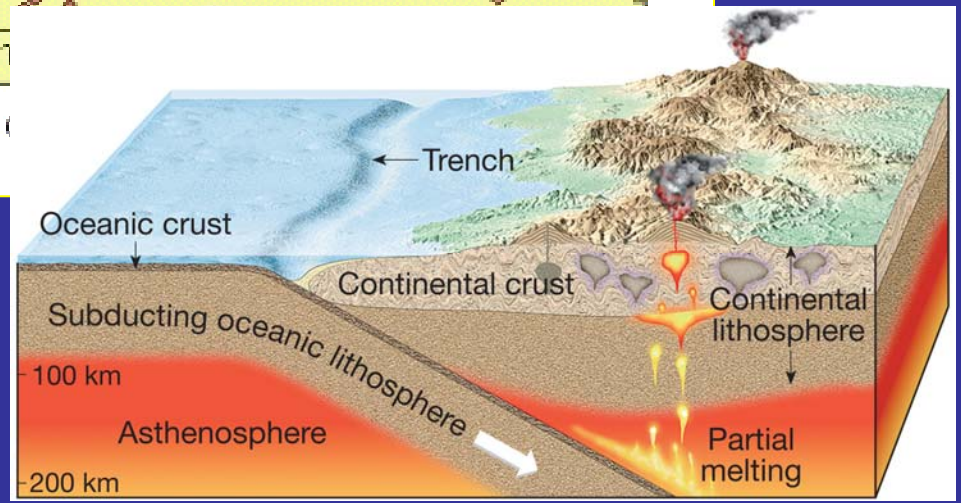




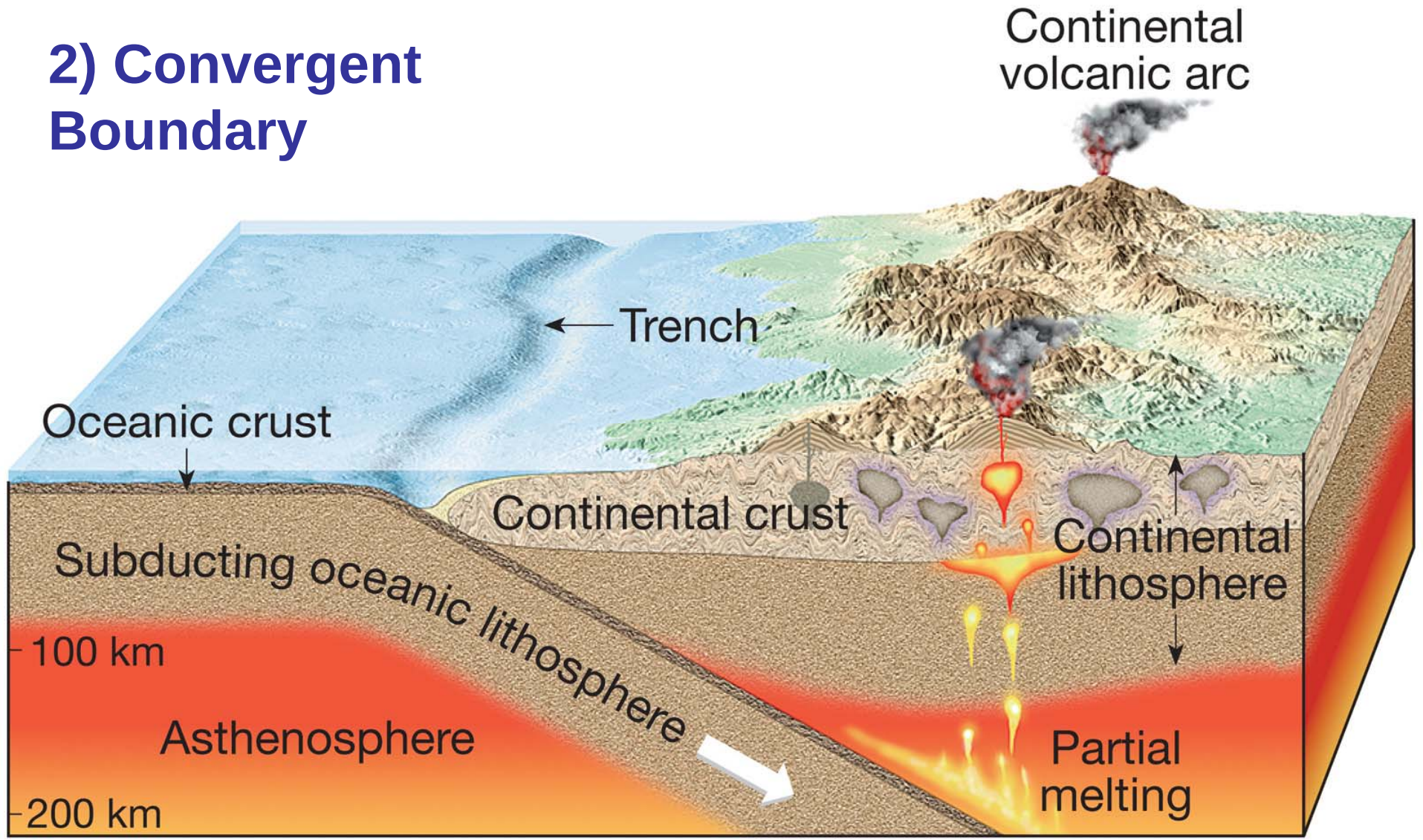


vertical an

Subducting oceanic crust



2) Convergent Boundary



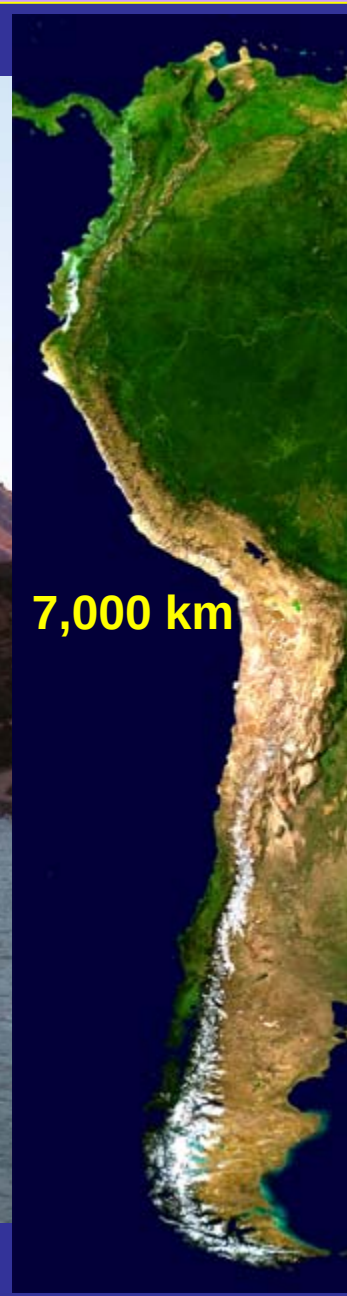
Oceanic Trench

Why does one side sink and the other float?

Convergent boundary – oceanic-continental

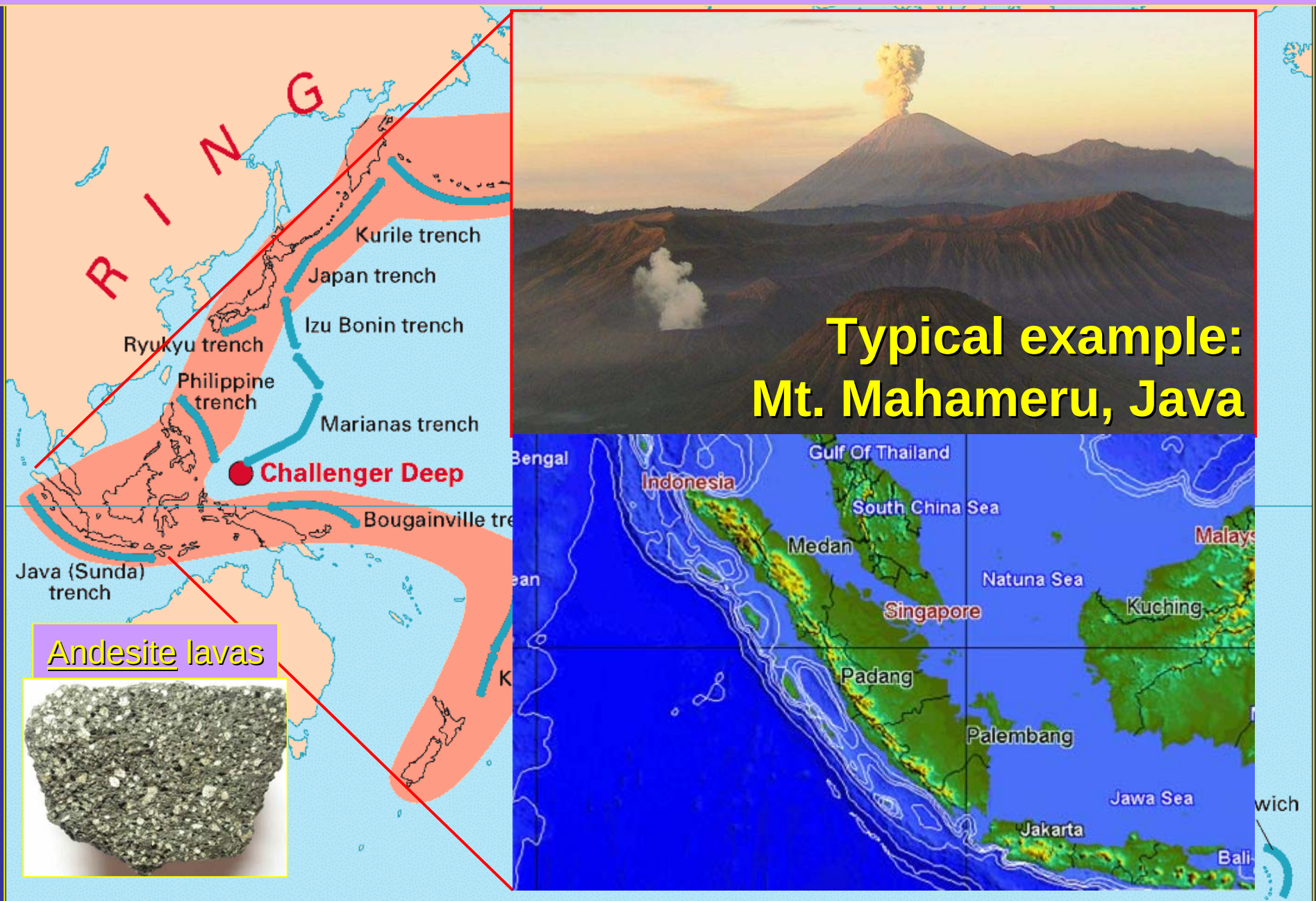


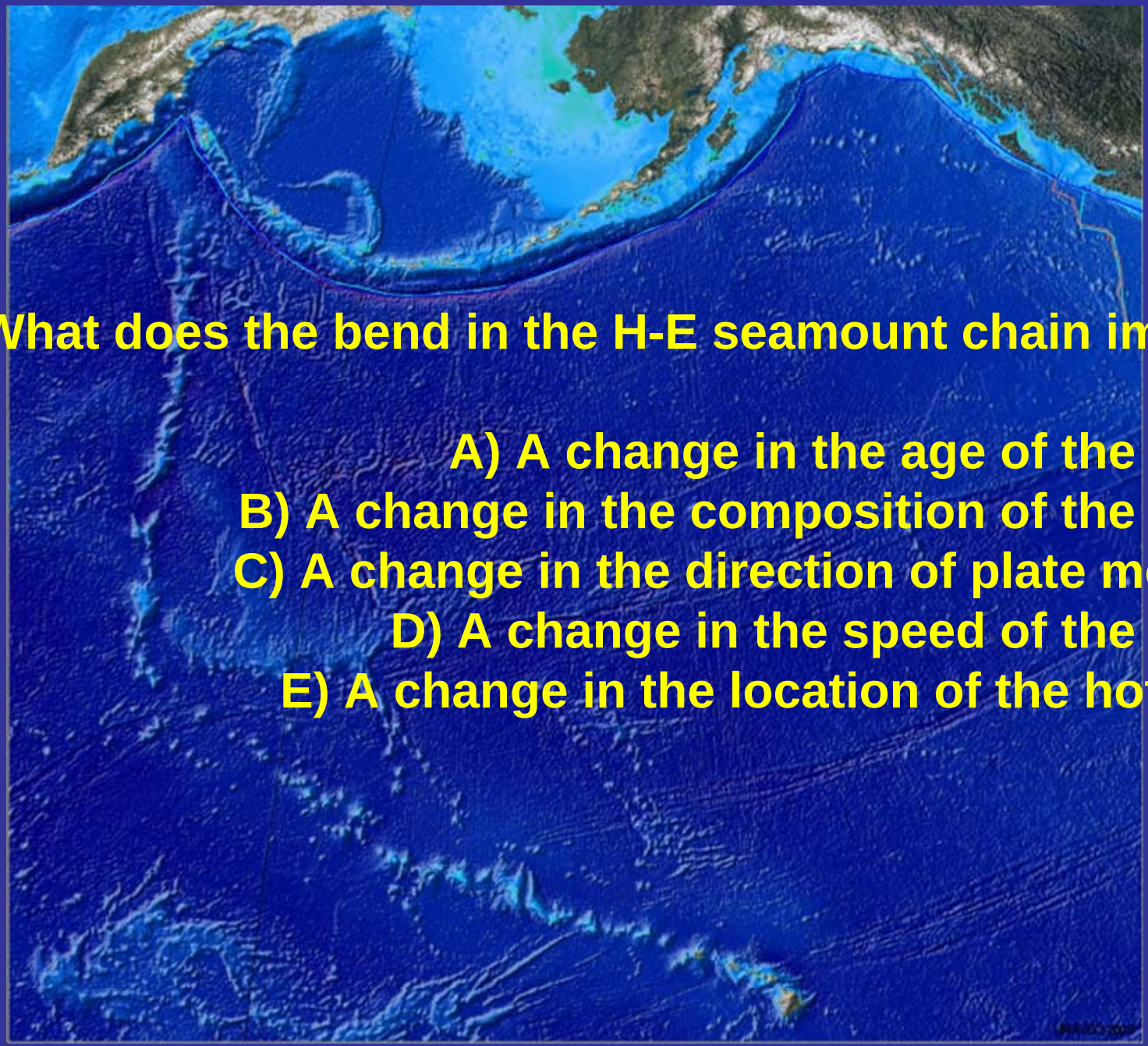
Typical Example –
Andes mountain range



Andesite lavas

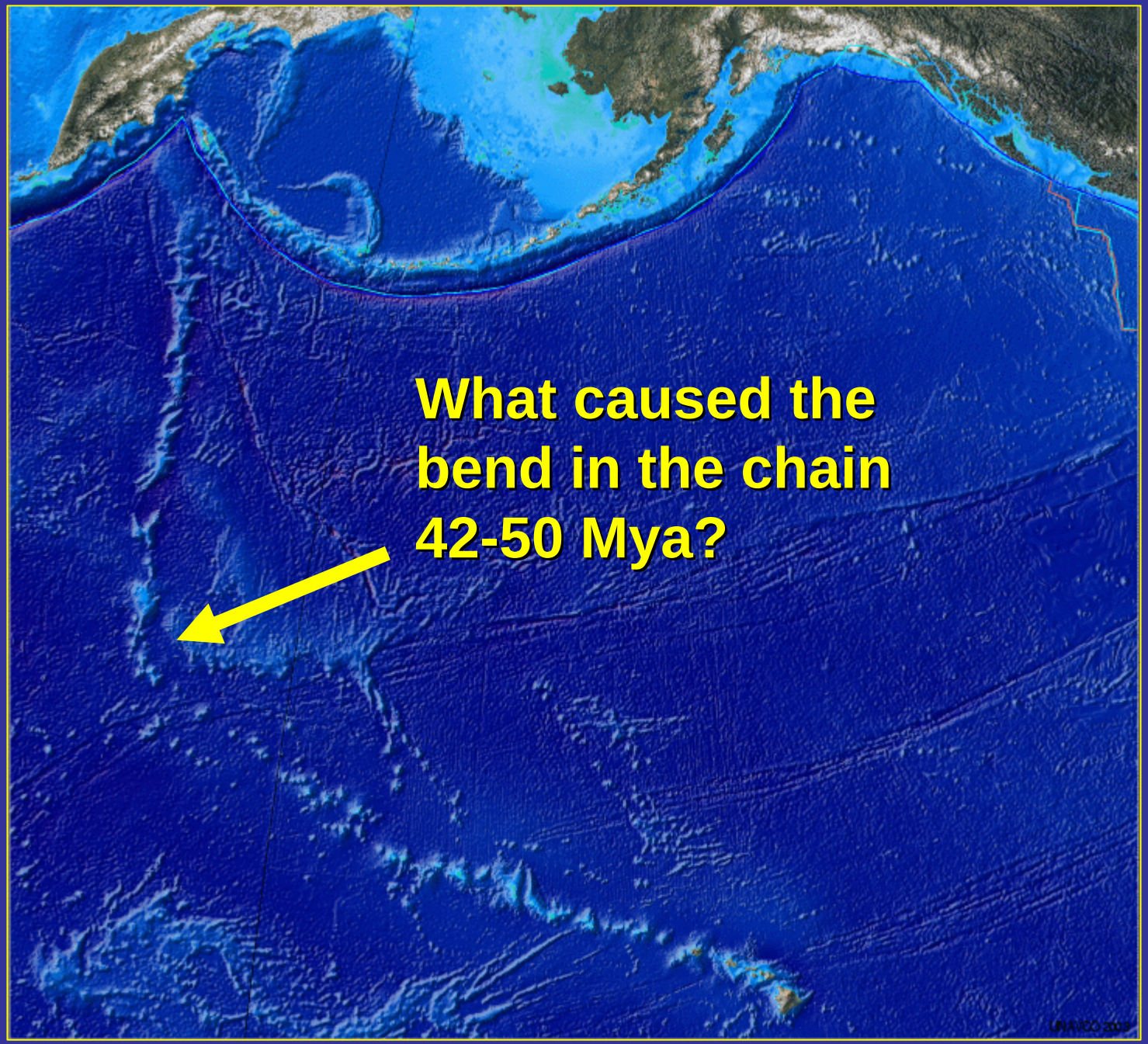
Convergent boundary – oceanic-oceanic



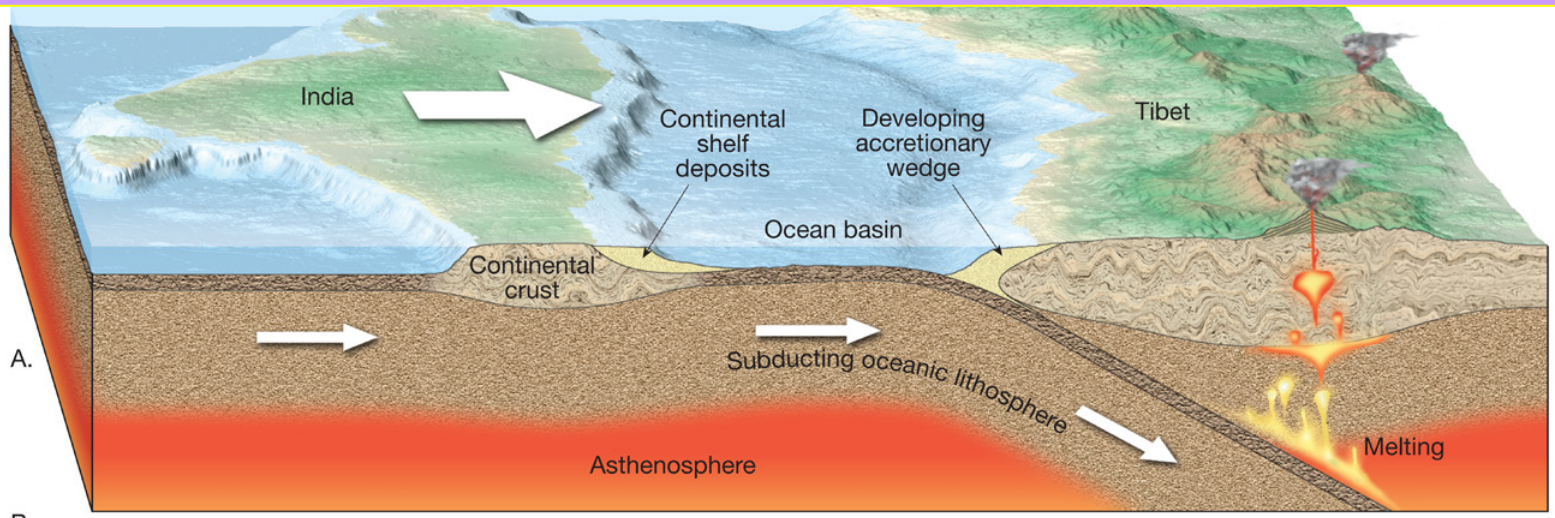


What does the bend in the H-E seamount chain imply?

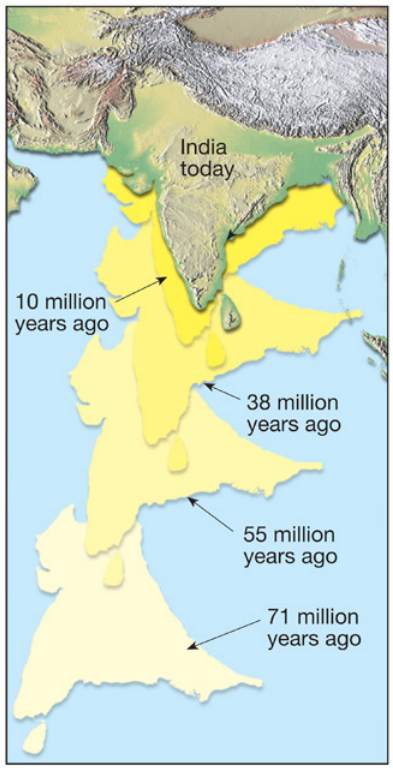
A) A change in the age of the plate
B) A change in the composition of the plate
C) A change in the direction of plate motion
D) A change in the speed of the plate
E) A change in the location of the hotspot

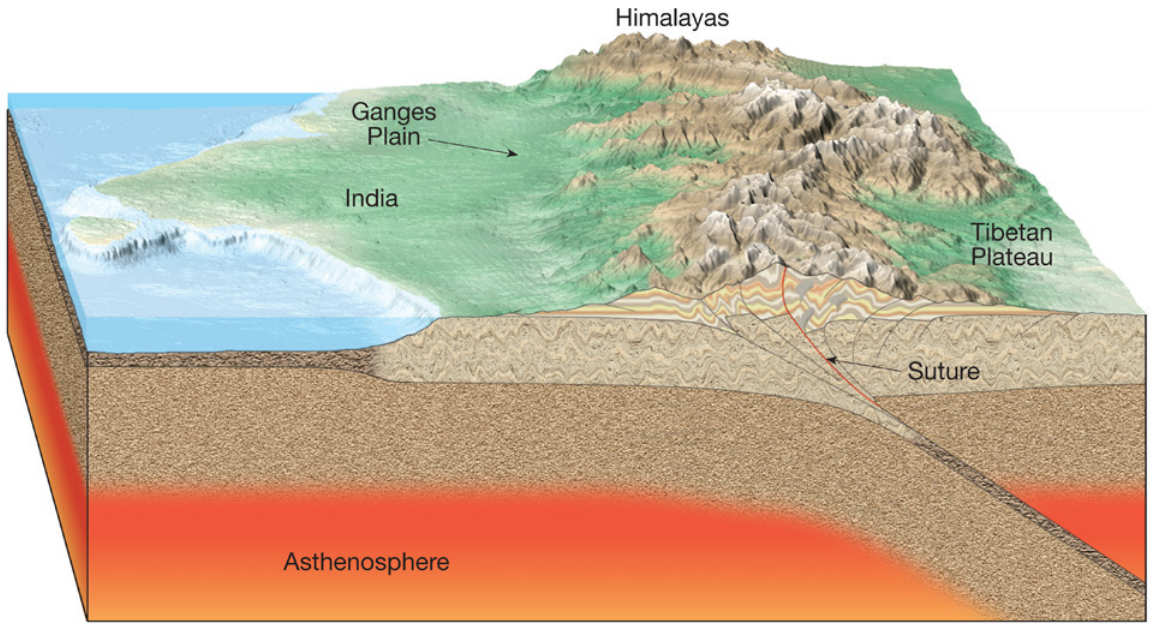

What caused the bend in the chain 42-50 Mya?

Convergent boundary – continental-continental



B.





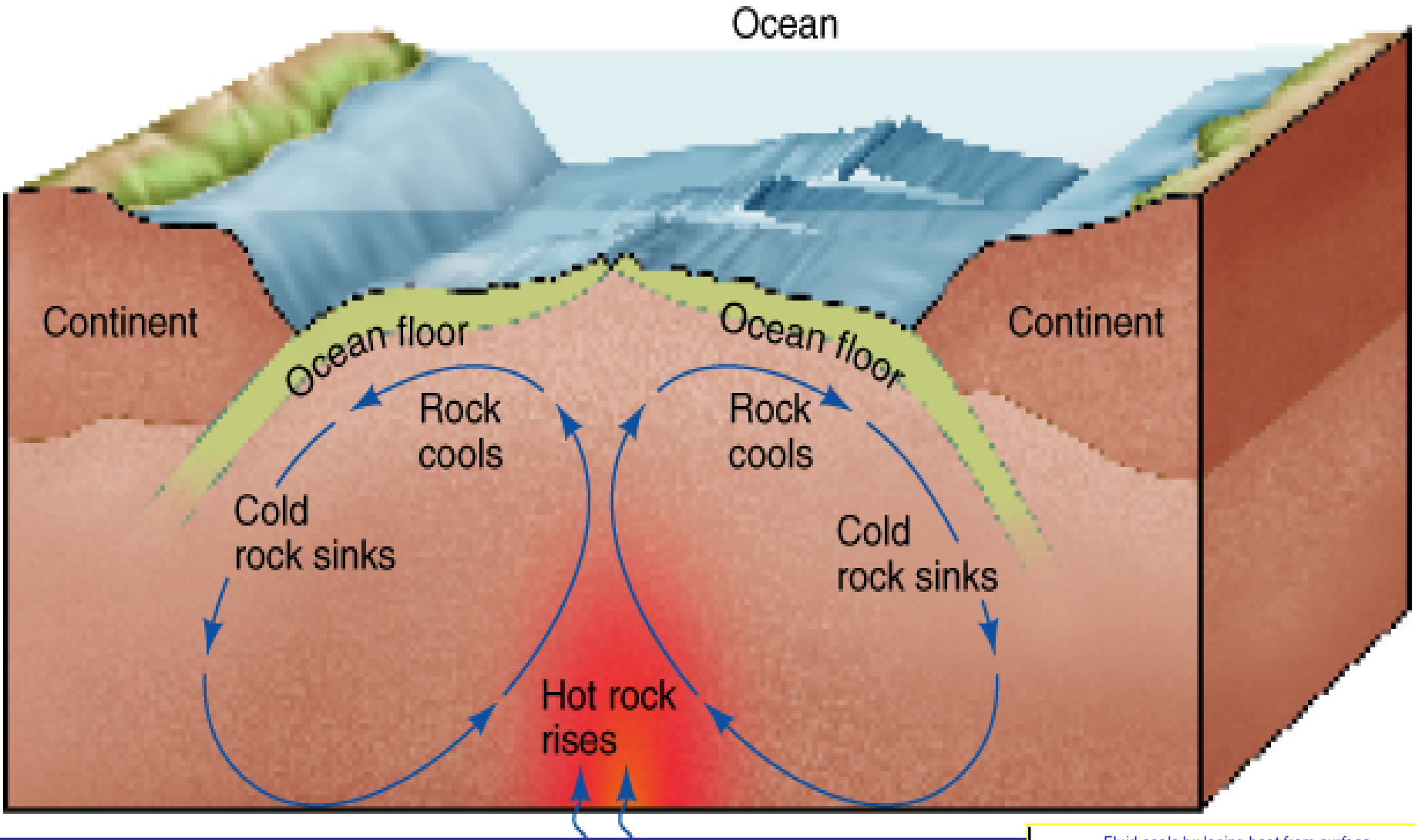
C.

Convergent boundary – continental-continental

Gneiss - metamorphic



Typical example - Mt. Everest, Nepal



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

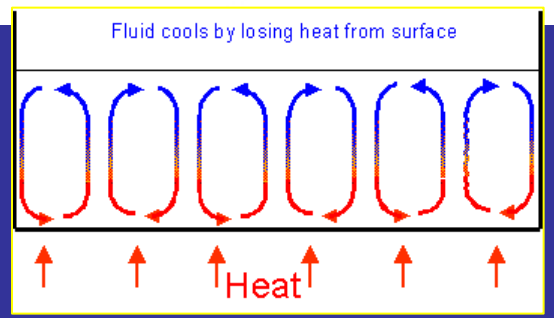
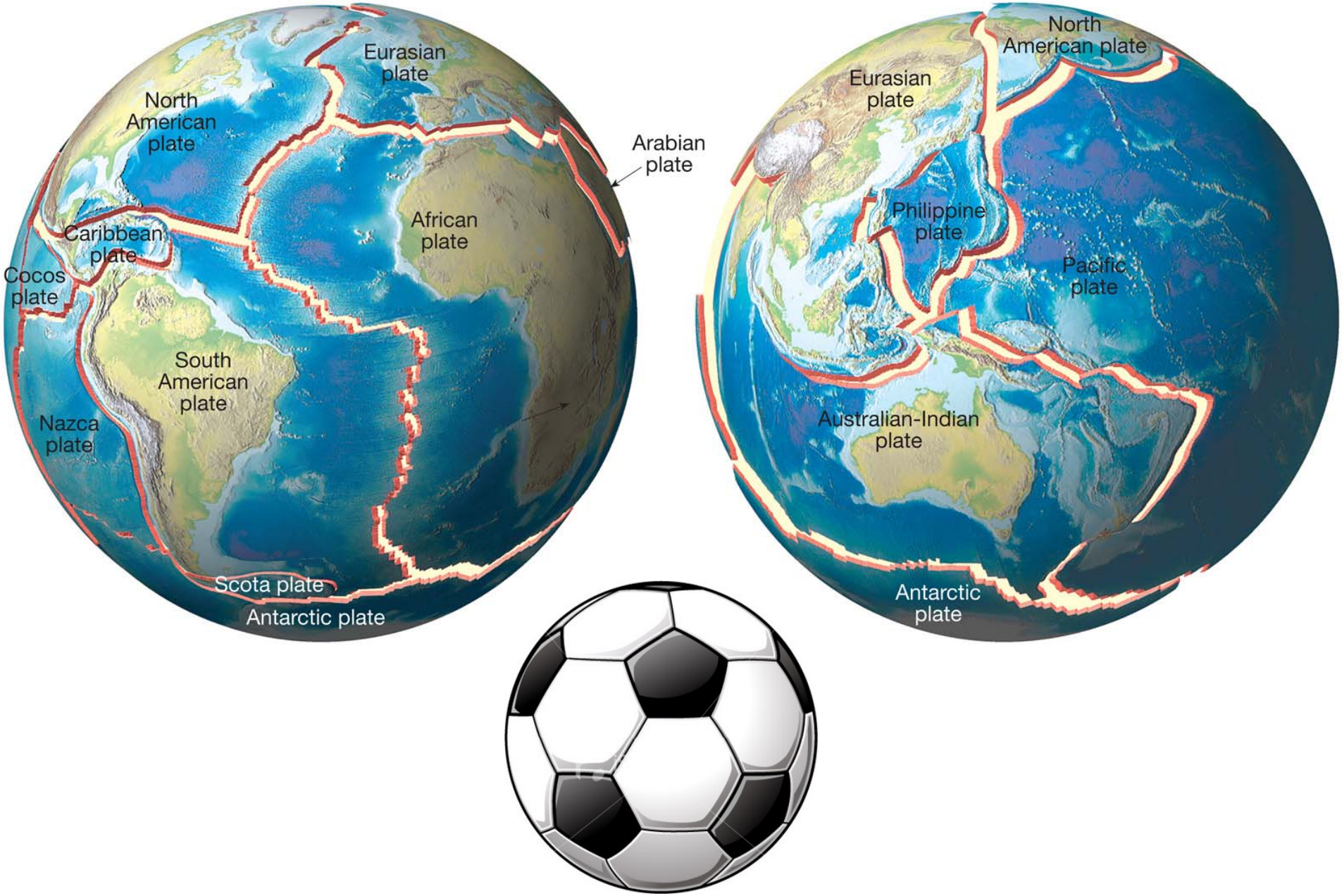
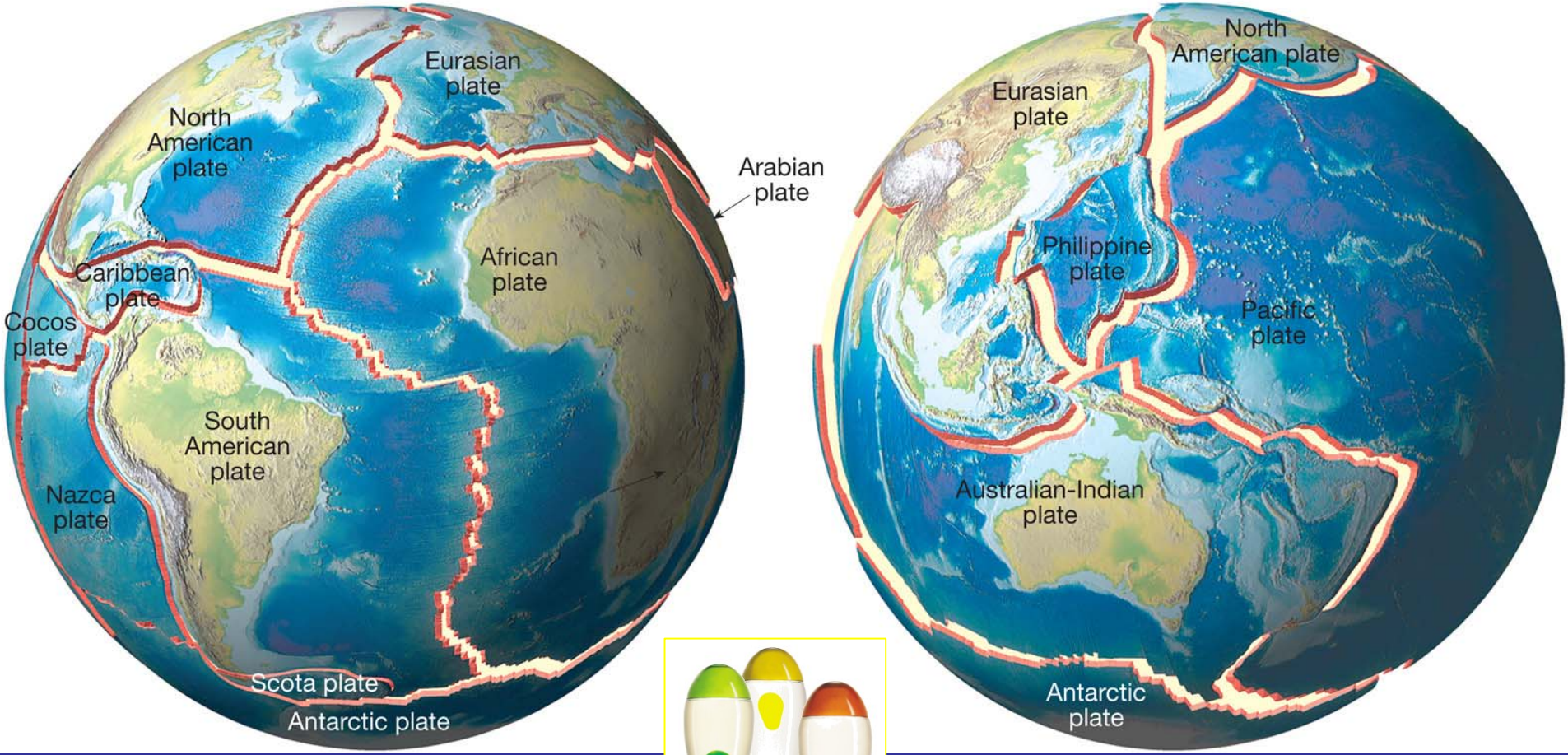


Plate boundaries: ridges, trenches, and…?



Ridges, trenches, and transform faults

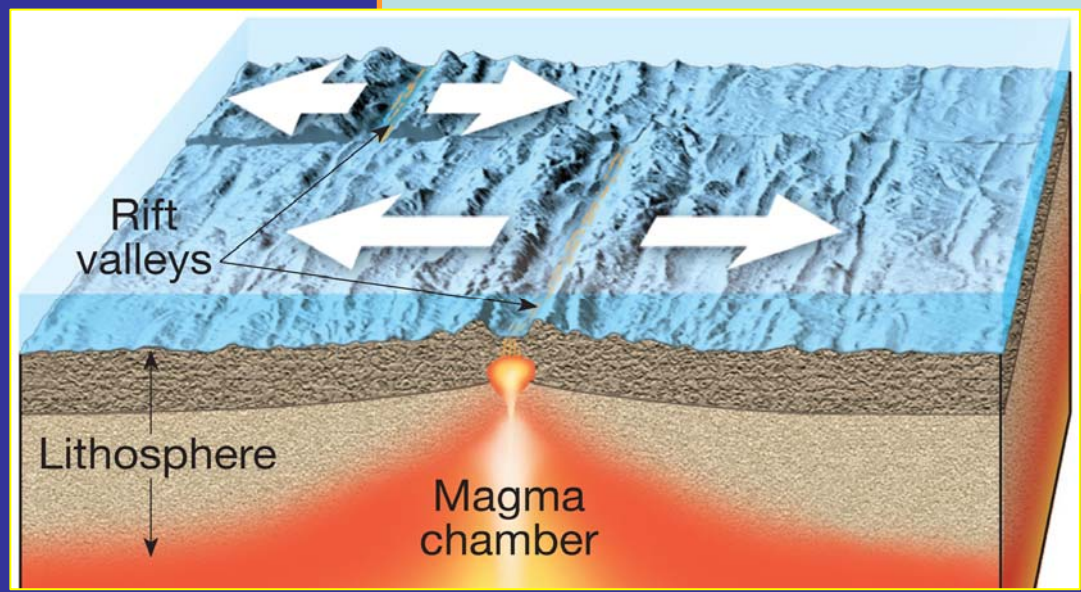


Transform faults are not directly related to mantle convection



…necessary for doing geometry on a sphere

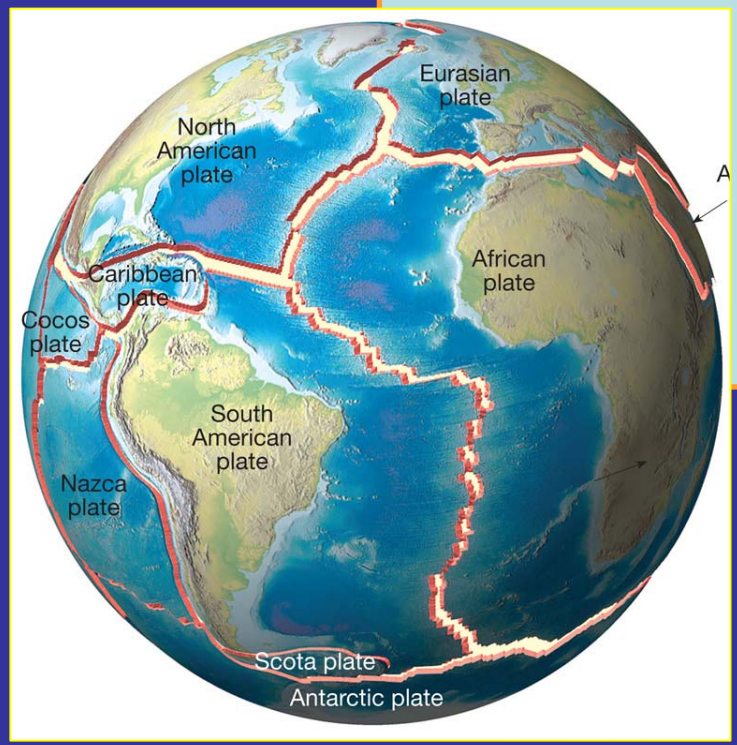
Transform fault boundary – oceanic



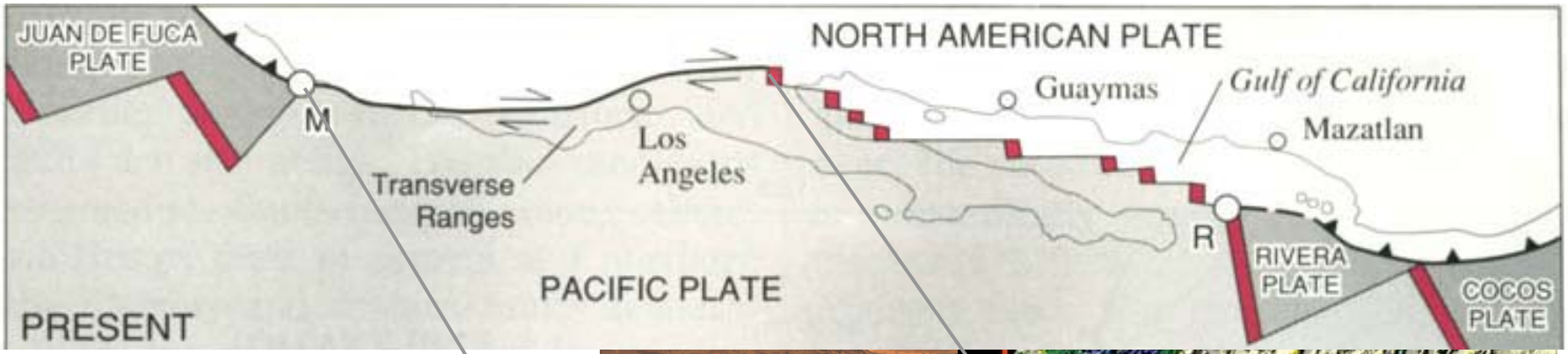
Spreading
ridges

Transform fault
vs. seafloor lineation

Accommodates transverse spreading geometry



Allows continents to split into irregular shapes

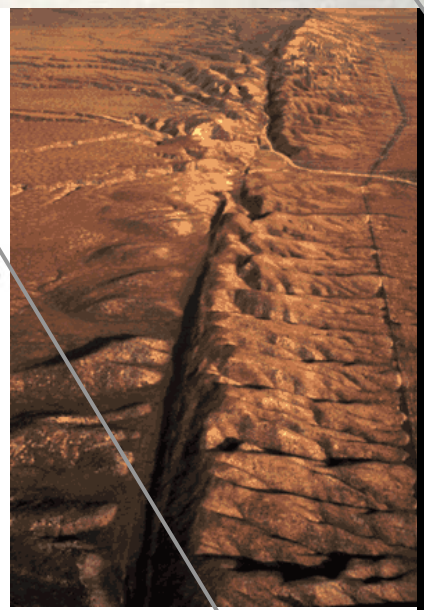


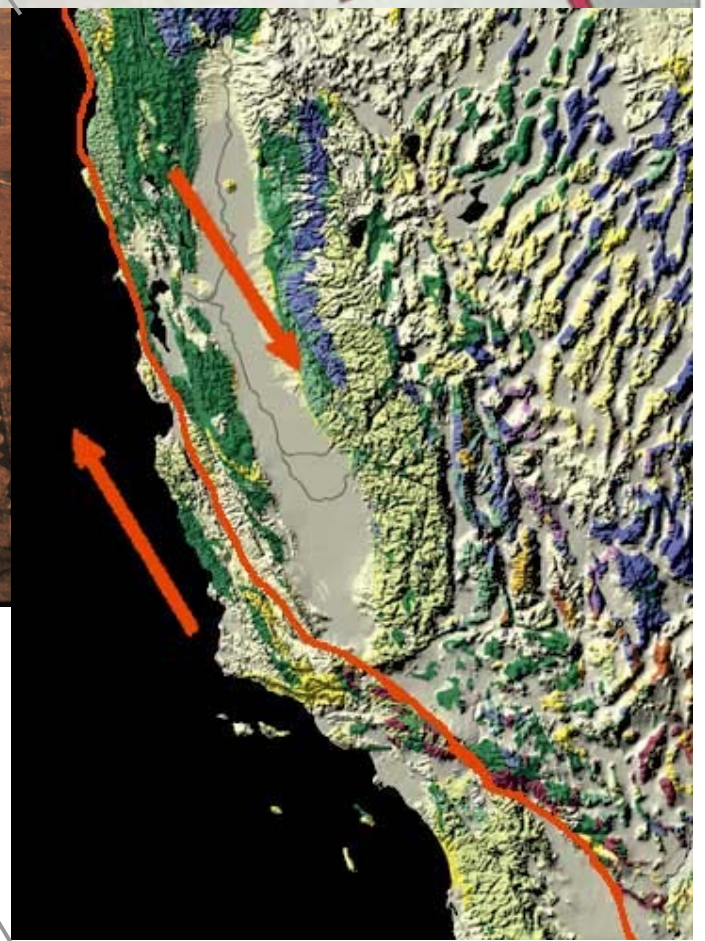
EXPLANATION

Spreading center

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

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

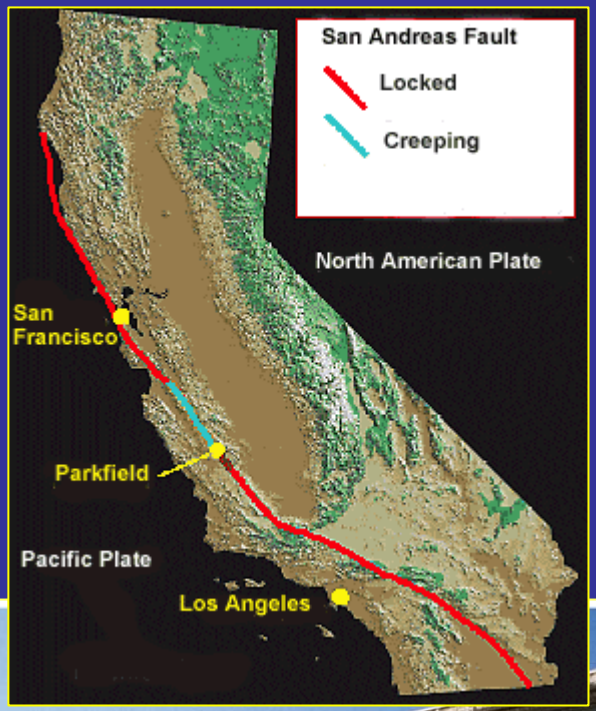


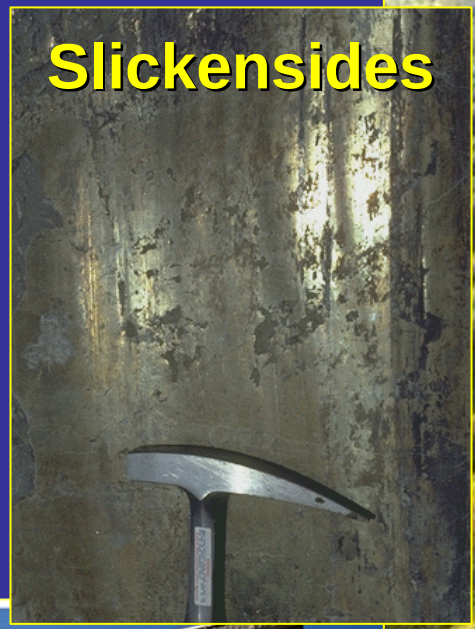


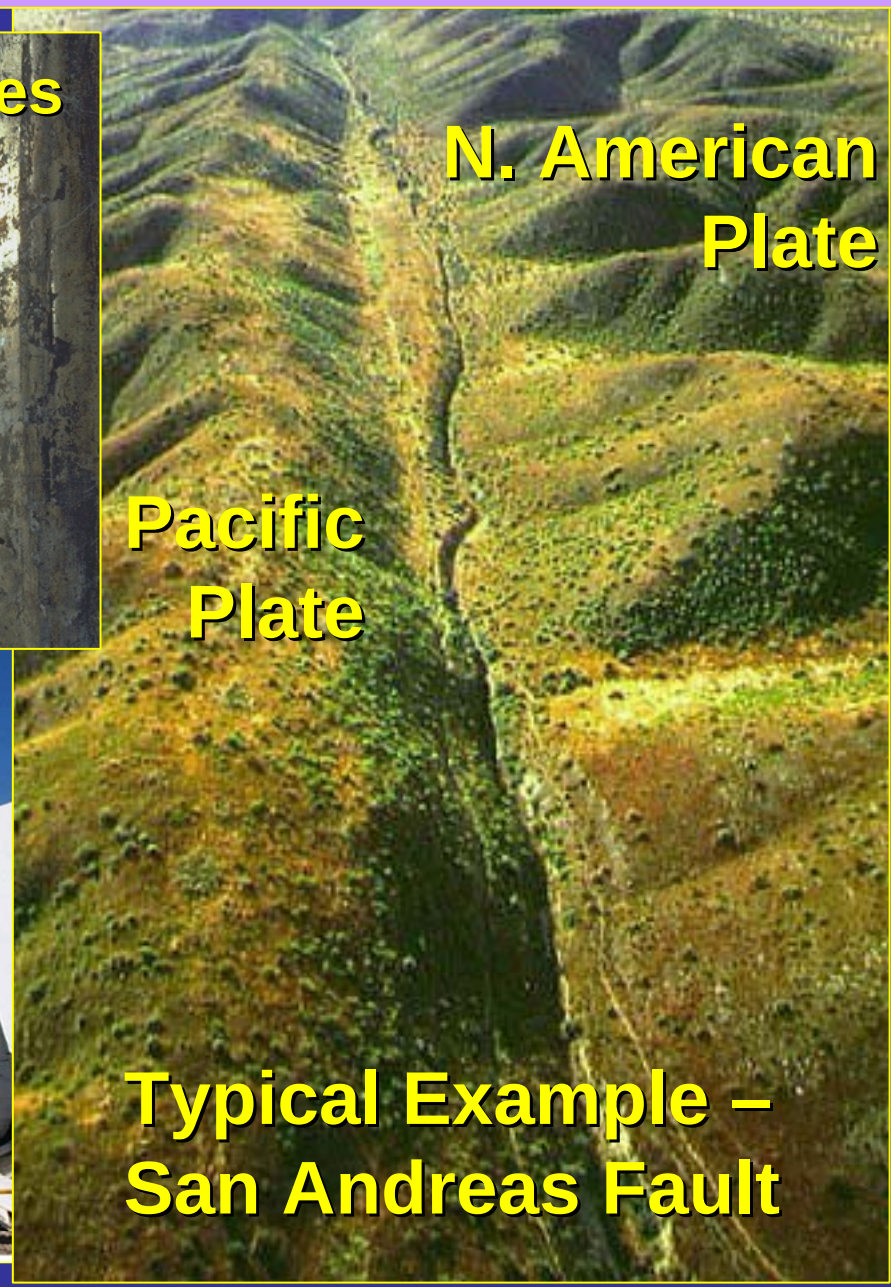
Transform faults can also occur on land

San Andreas separates Pacific and North American Plates

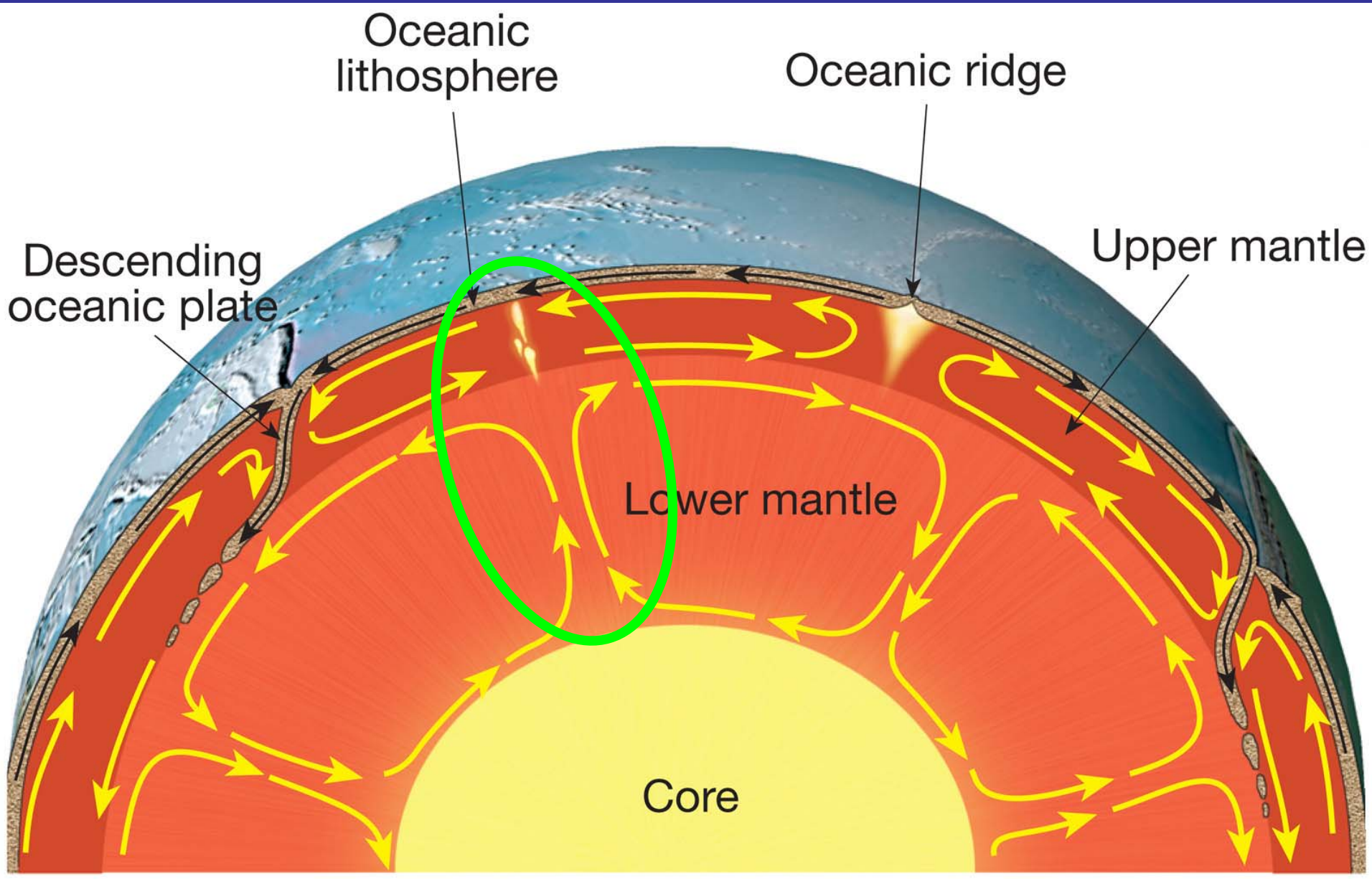
Transform fault boundary – continental



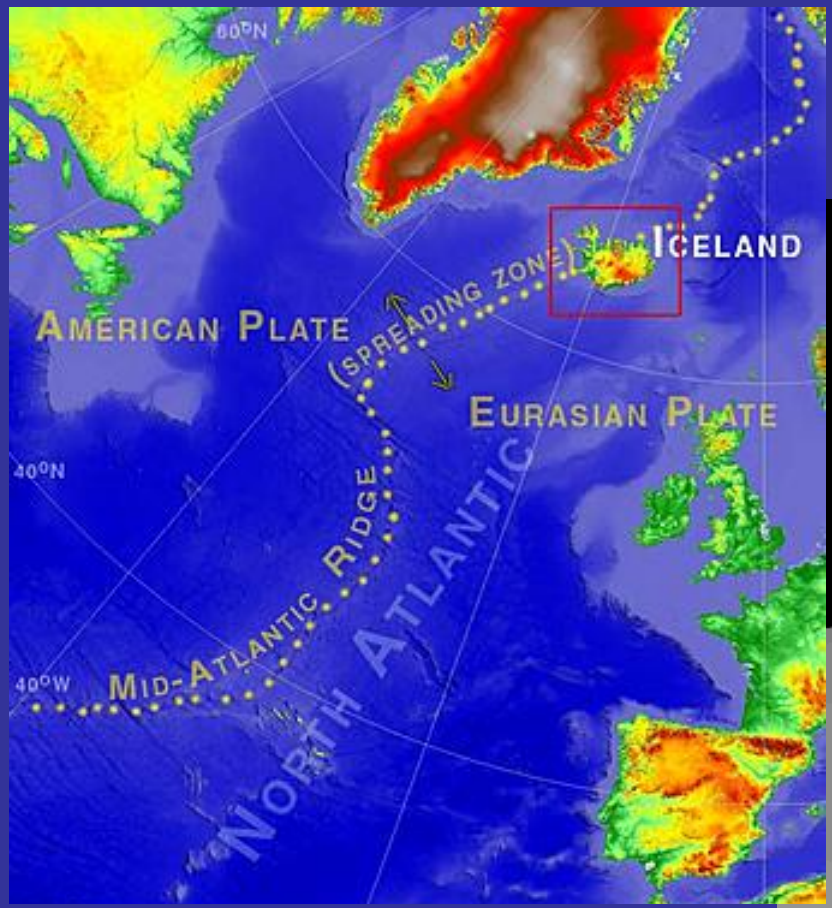


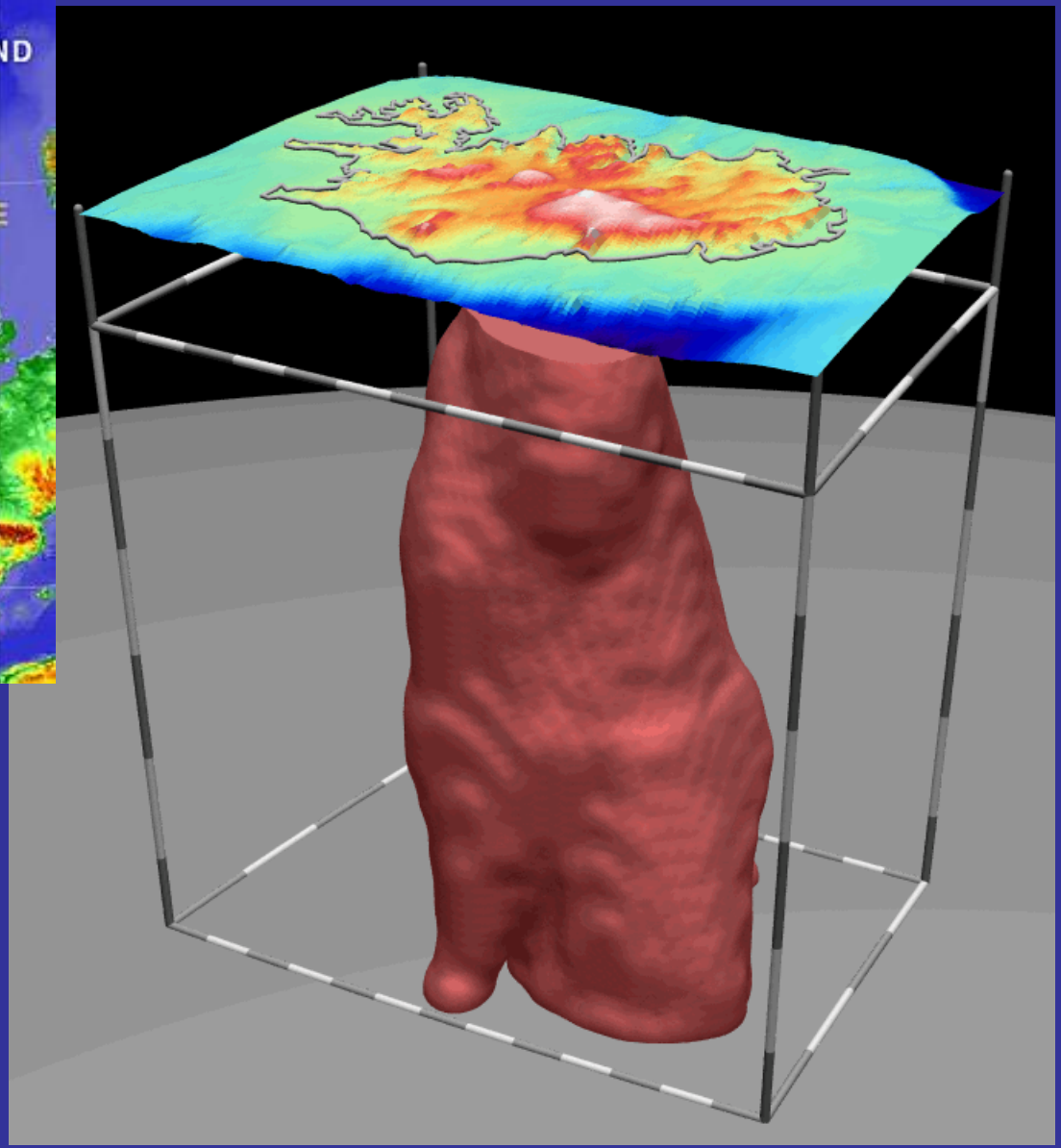





Oceanic lithosphere
Oceanic ridge
Descending oceanic plate
Upper mantle
Lower mantle
Core

Iceland

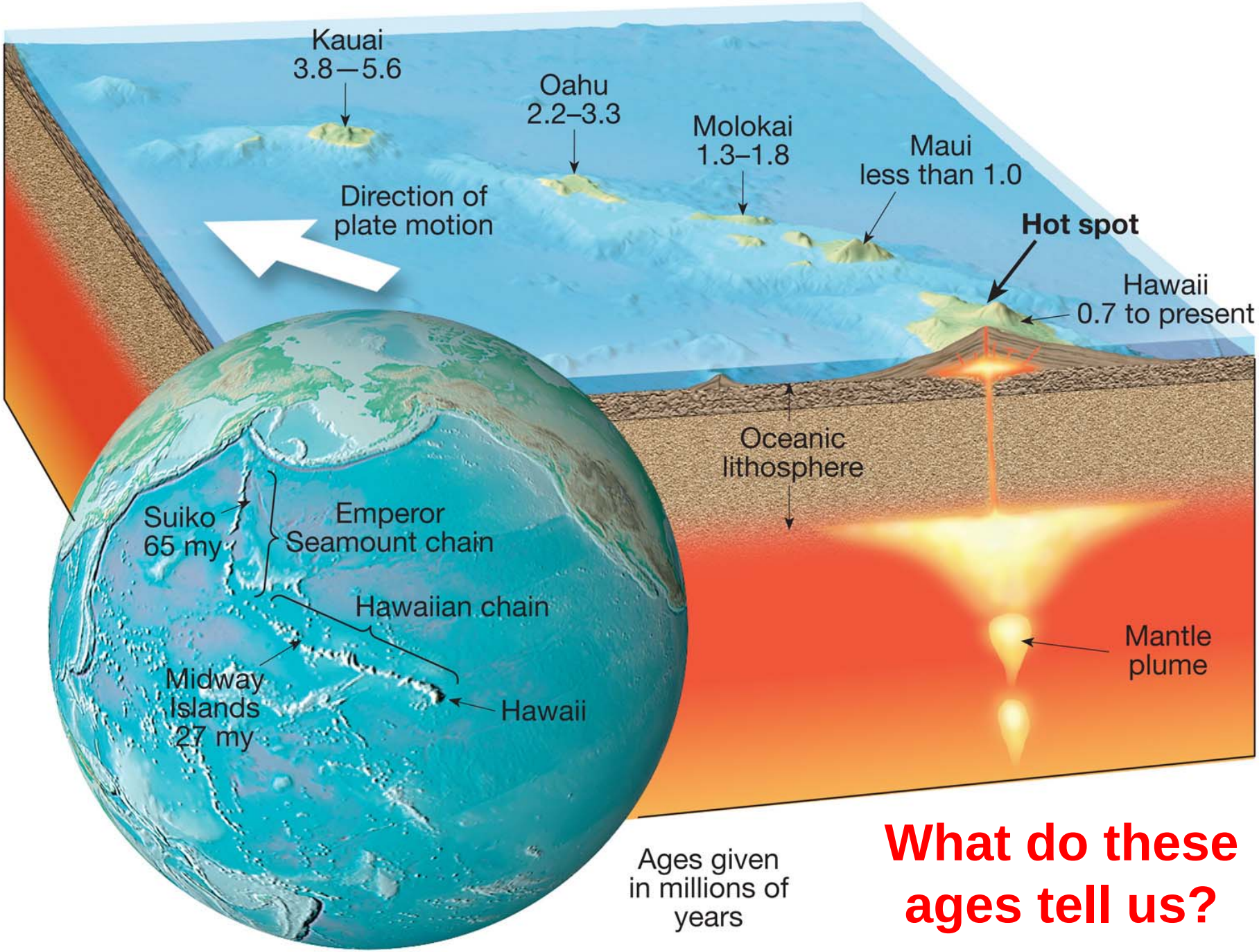




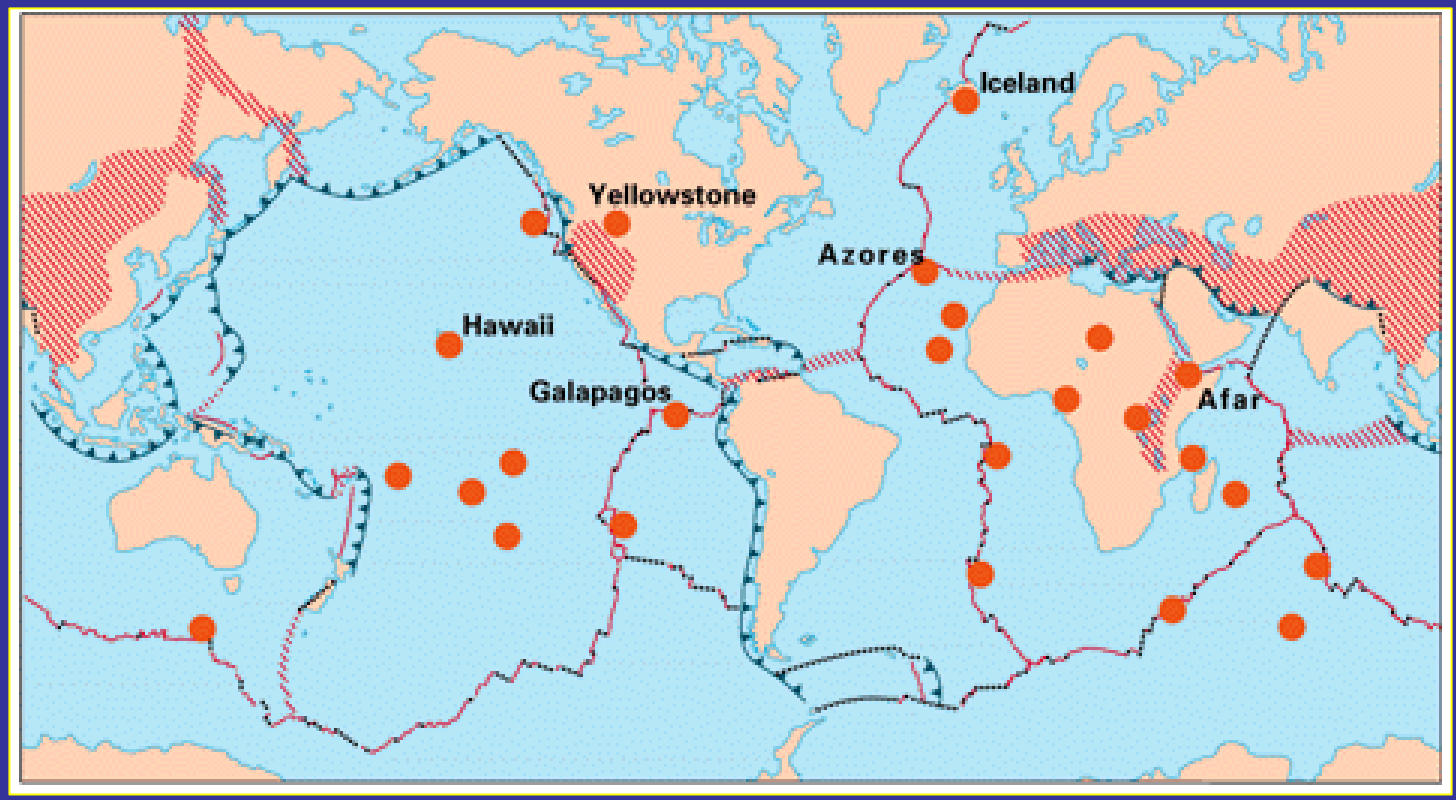
Divergent boundary

AND

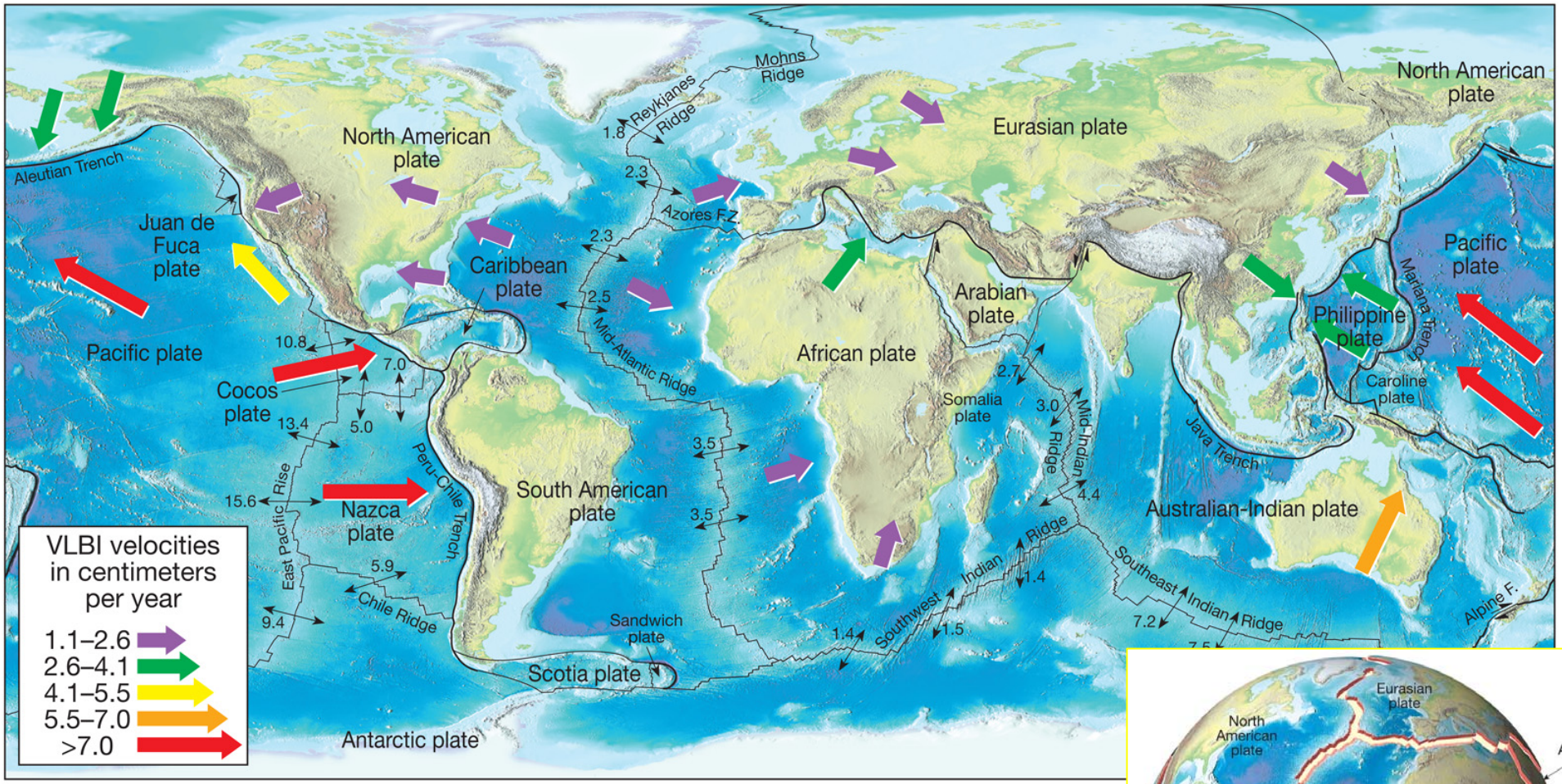
Hot spot!



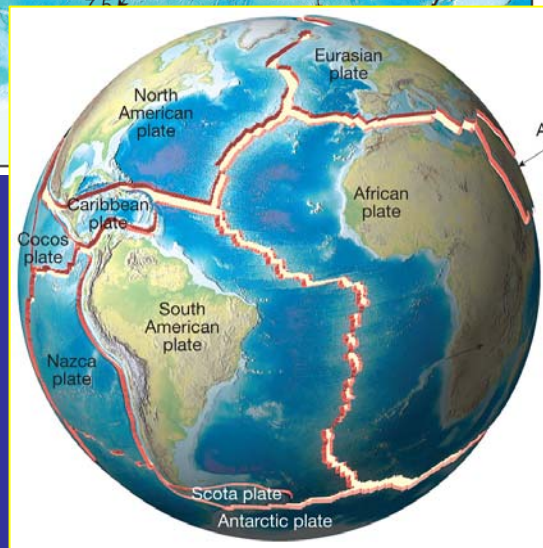
What do these ages tell us?



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	----