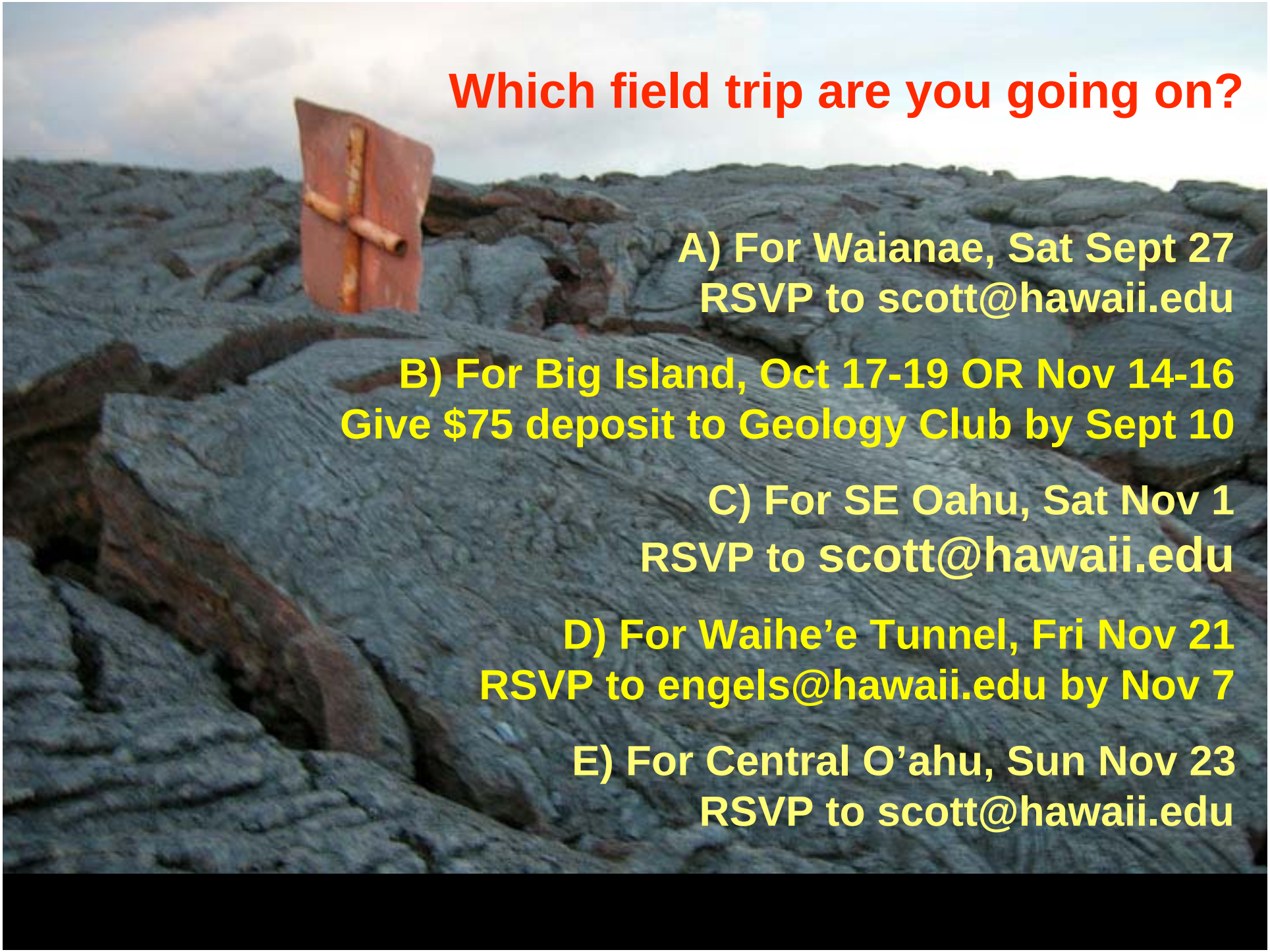


Which field trip are you going on?

A) For Waianae, Sat Sept 27
RSVP to scott@hawaii.edu

B) For Big Island, Oct 17-19 OR Nov 14-16
Give $75 deposit to Geology Club by Sept 10

C) For SE Oahu, Sat Nov 1
RSVP to scott@hawaii.edu

D) For Waihe'e Tunnel, Fri Nov 21
RSVP to engels@hawaii.edu by Nov 7

E) For Central O'ahu, Sun Nov 23
RSVP to scott@hawaii.edu



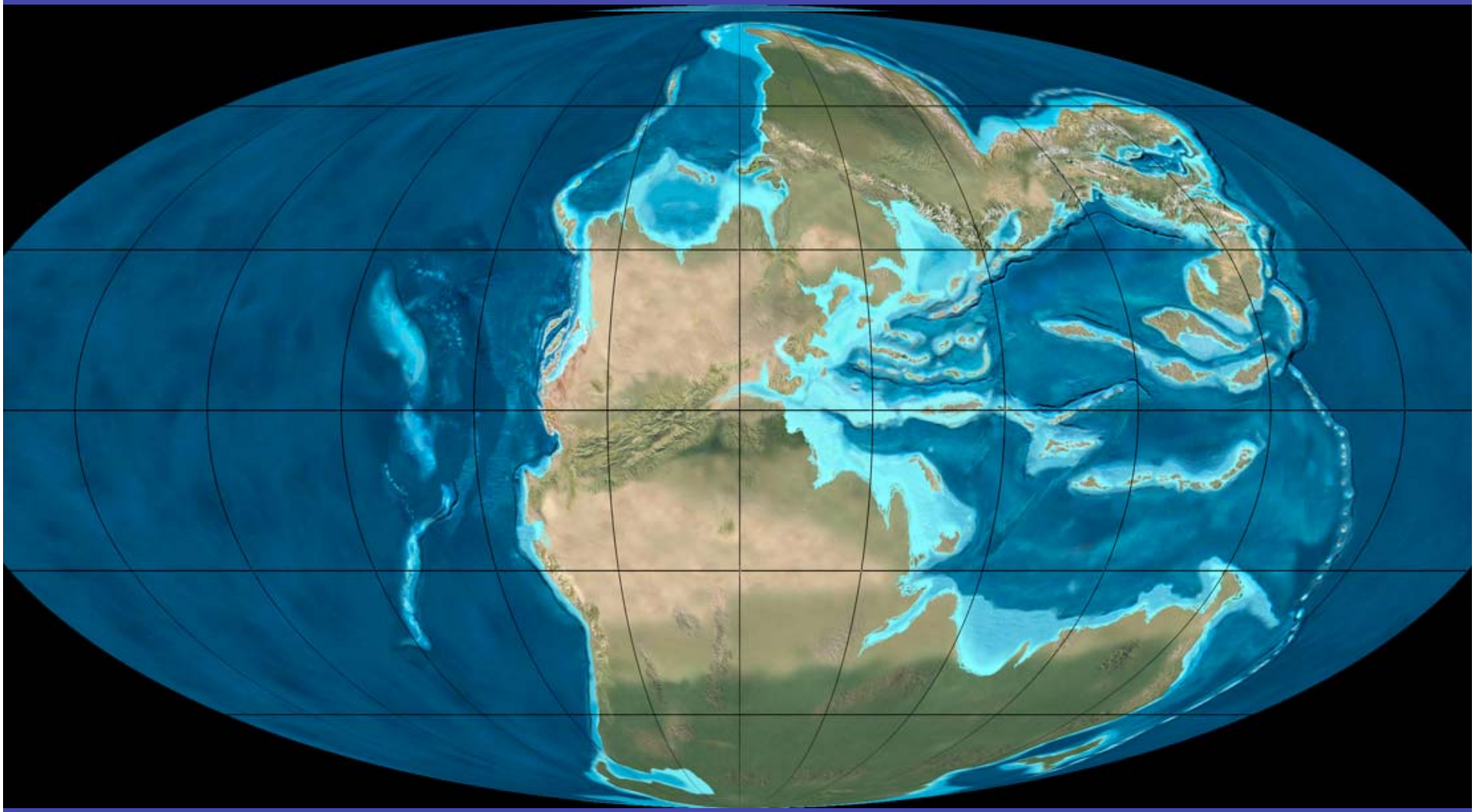
Alfred Wegener
Meteorologist

The Origins of Continents and Oceans
1915

“Continental drift”

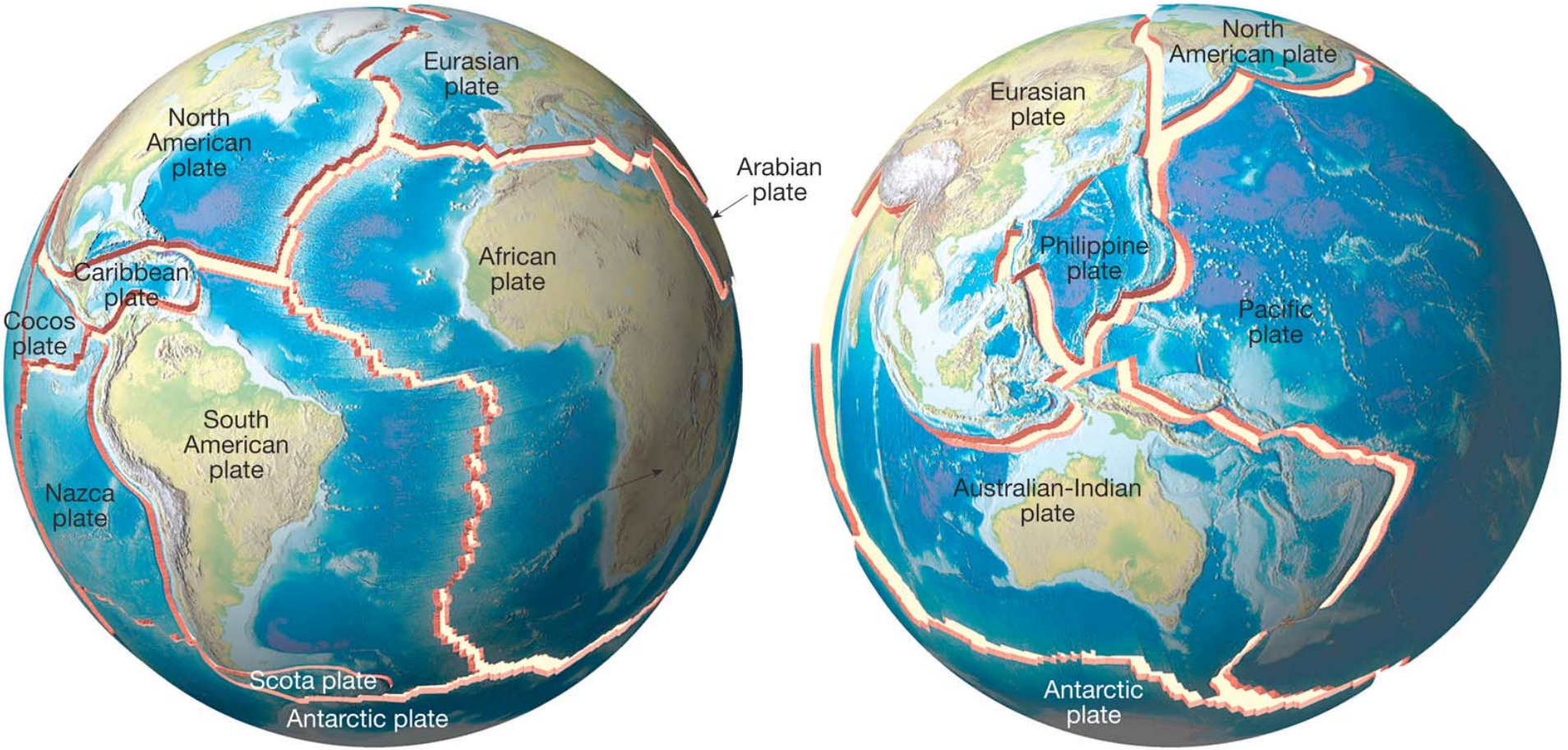
Modern Earth

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

=

26+ plates total

How should we test this idea?



Evidence 1: Continental Jigsaw Puzzle

South America

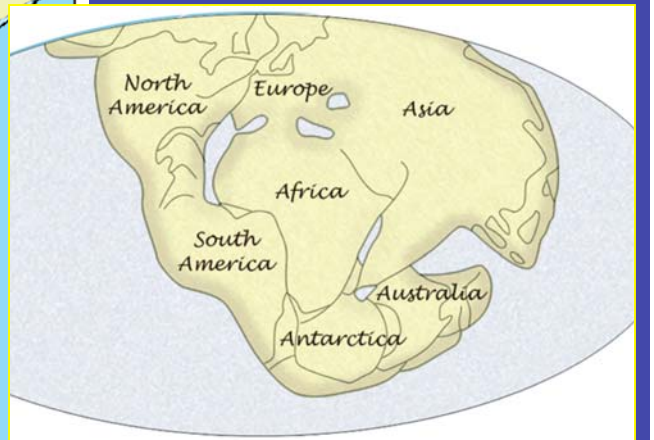
Africa

Overlap

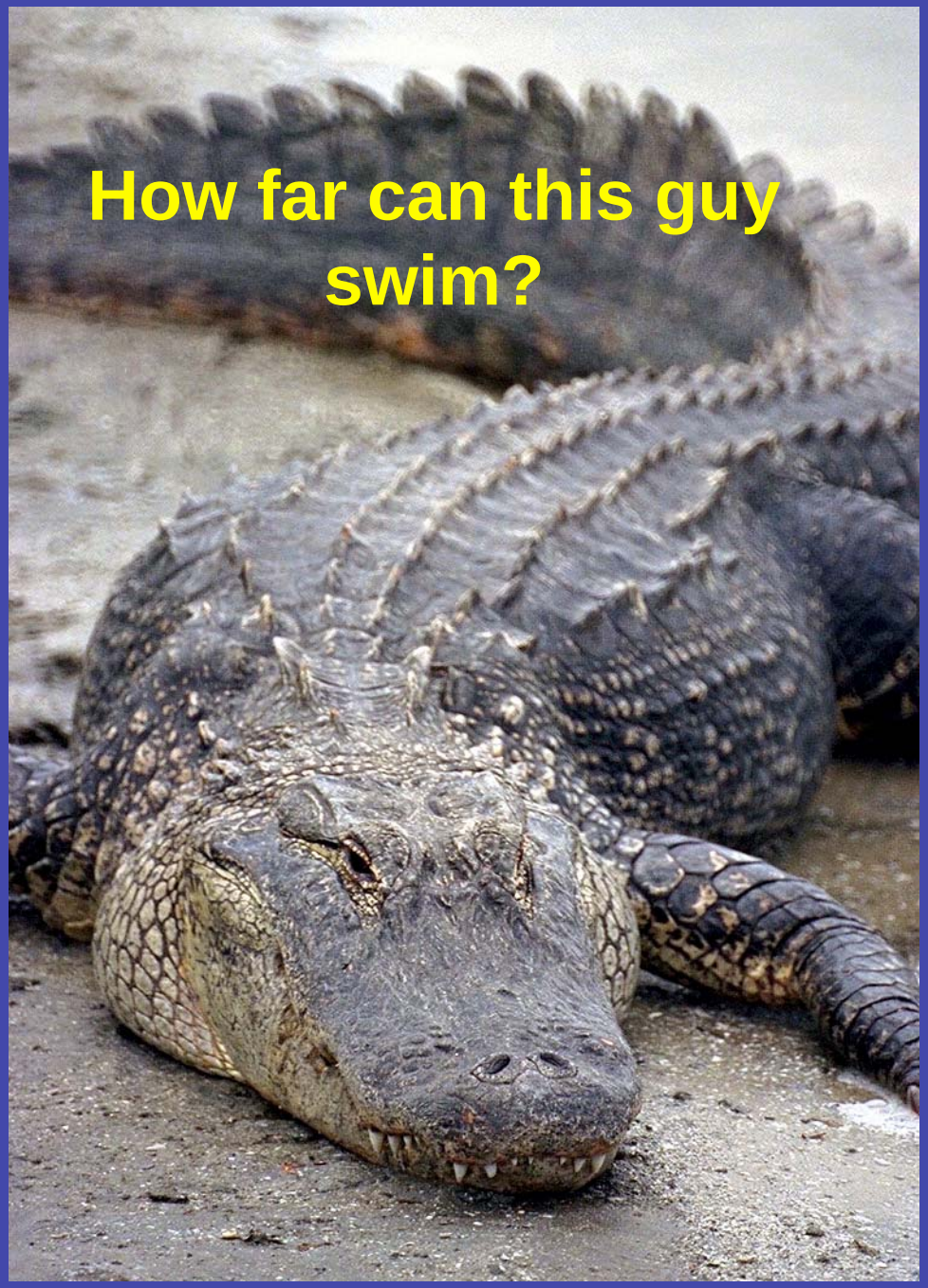
Gap



A. Modern reconstruction of Pangaea

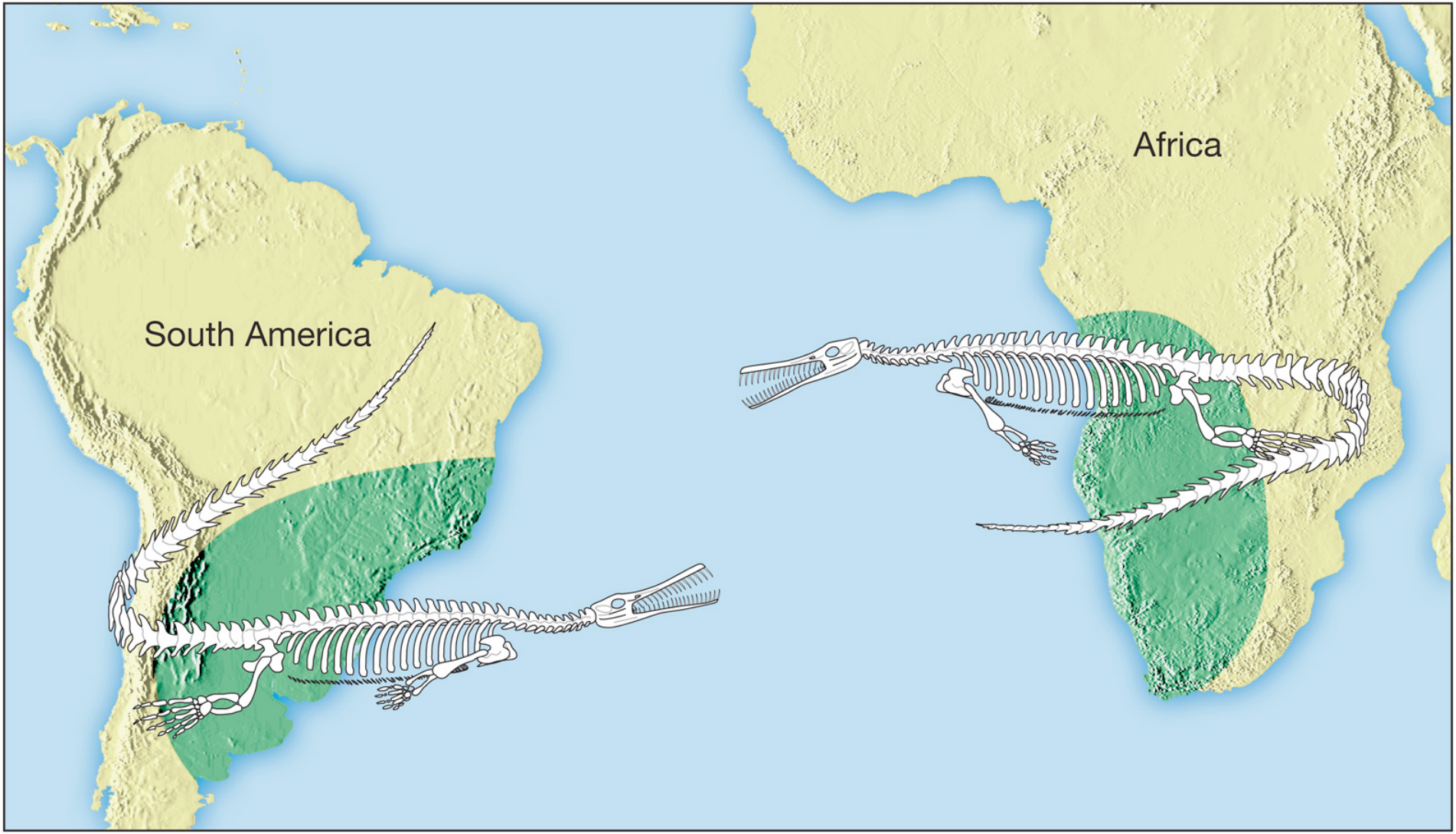


B. Wegener's Pangaea


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?

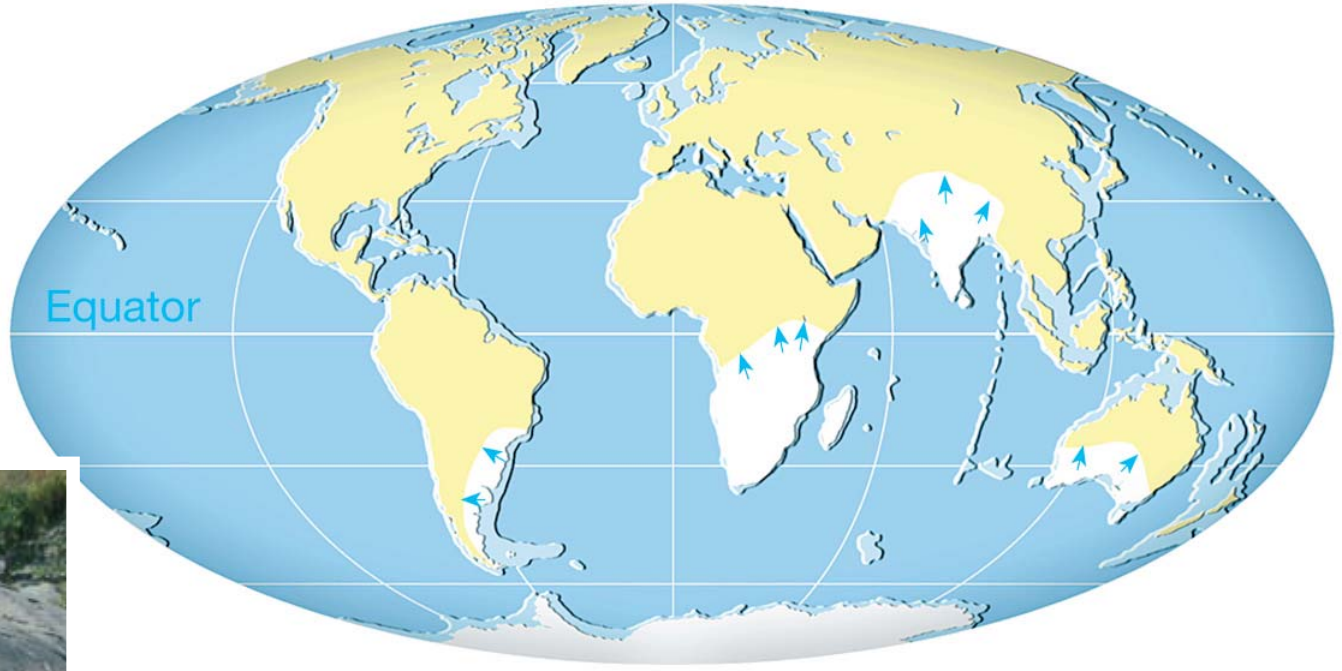


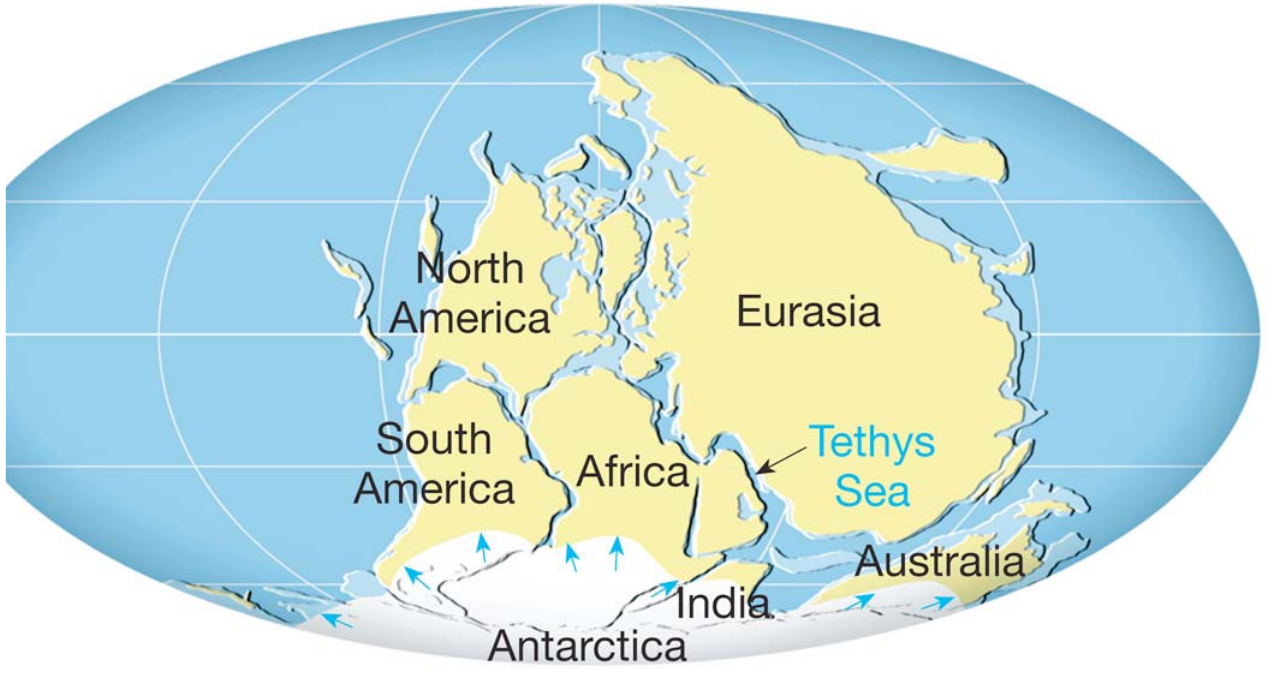
Would glacial striations form in an environment like this?



Evidence 4: Ancient climates







“Utter, damned rot!”

President of the prestigious American Philosophical Society

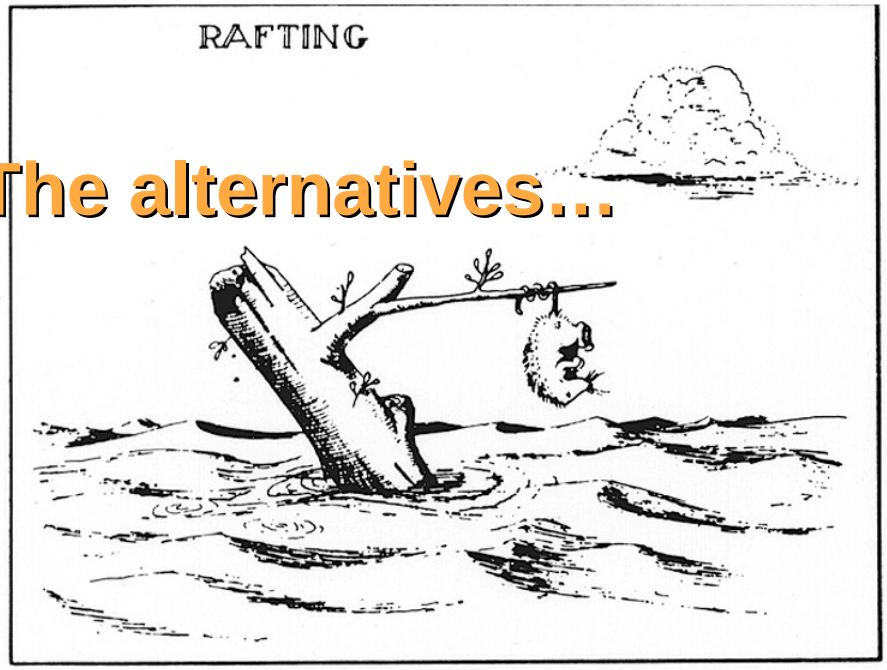
“If we are to believe this hypothesis, we must forget everything we have learned in the past 70 years and start all over again”

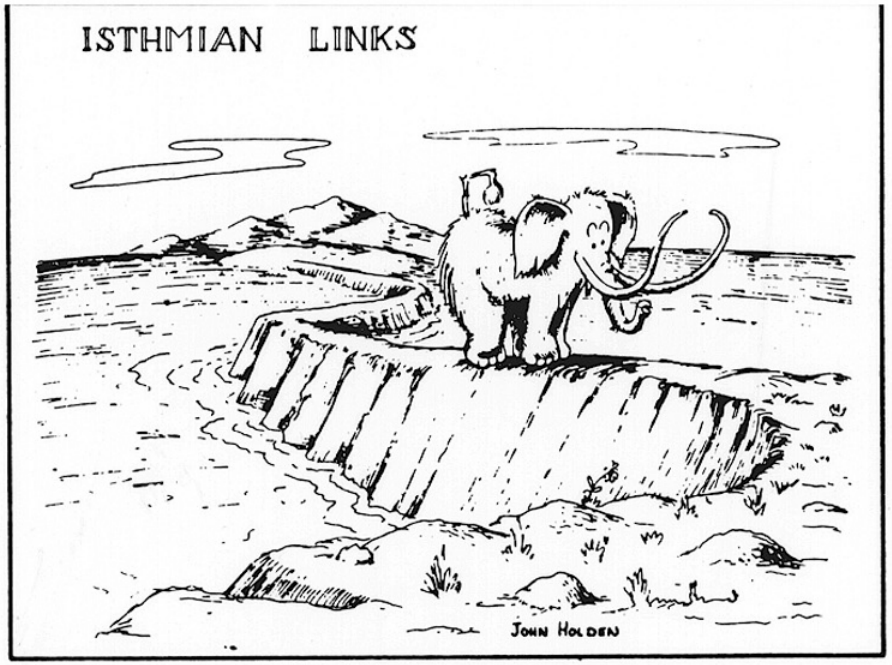
American scientist

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

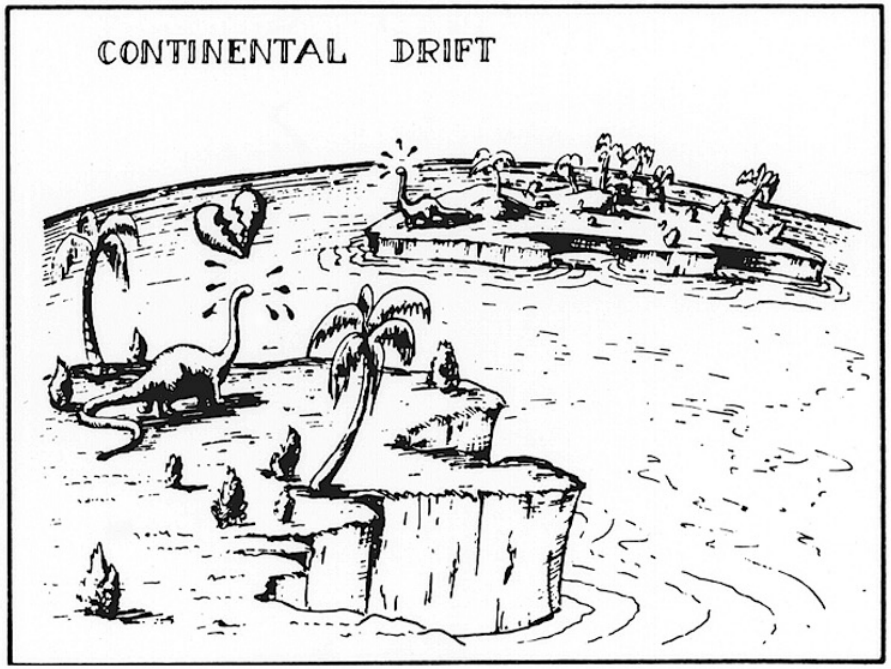
British geologist

The alternatives…











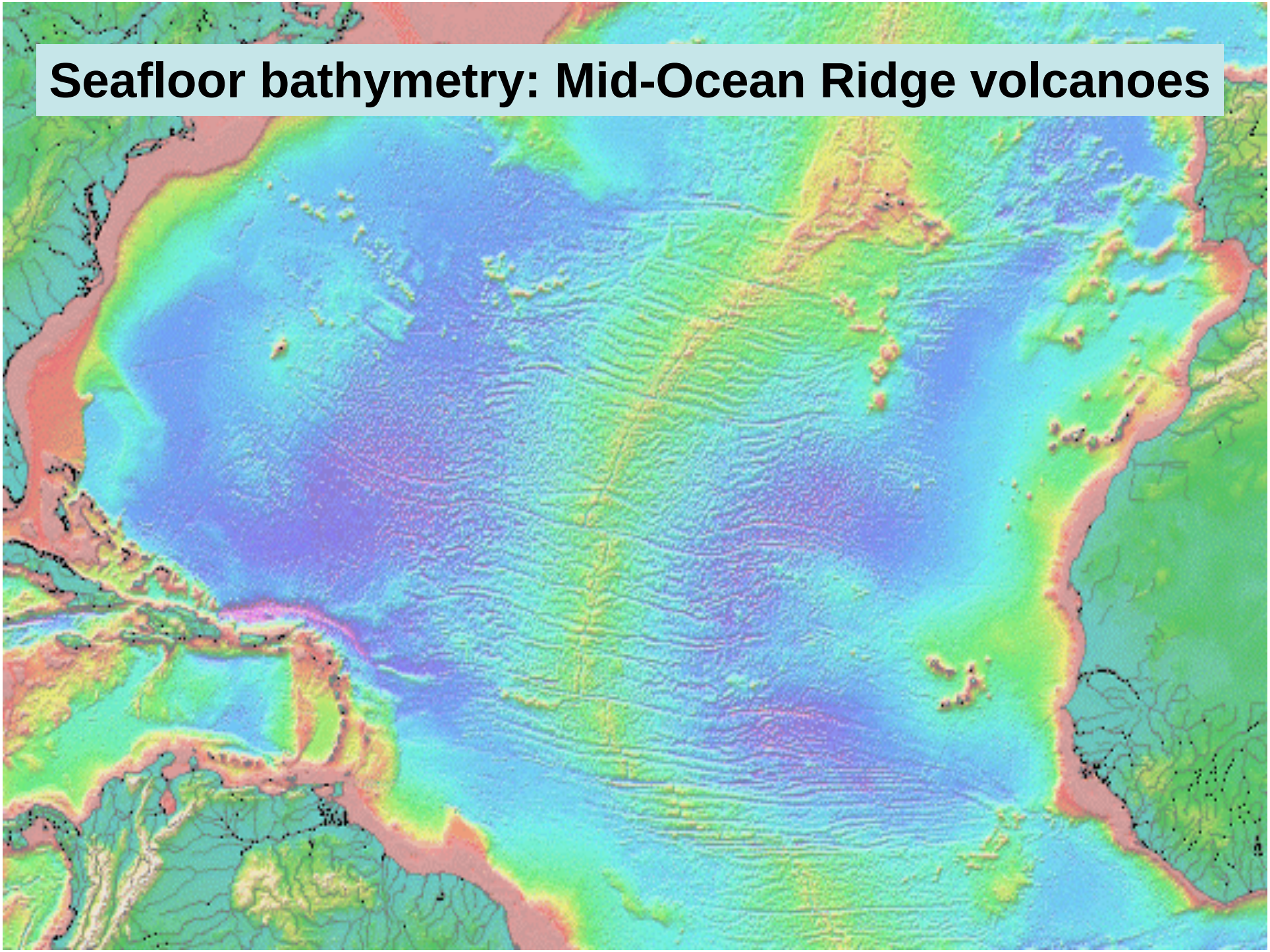




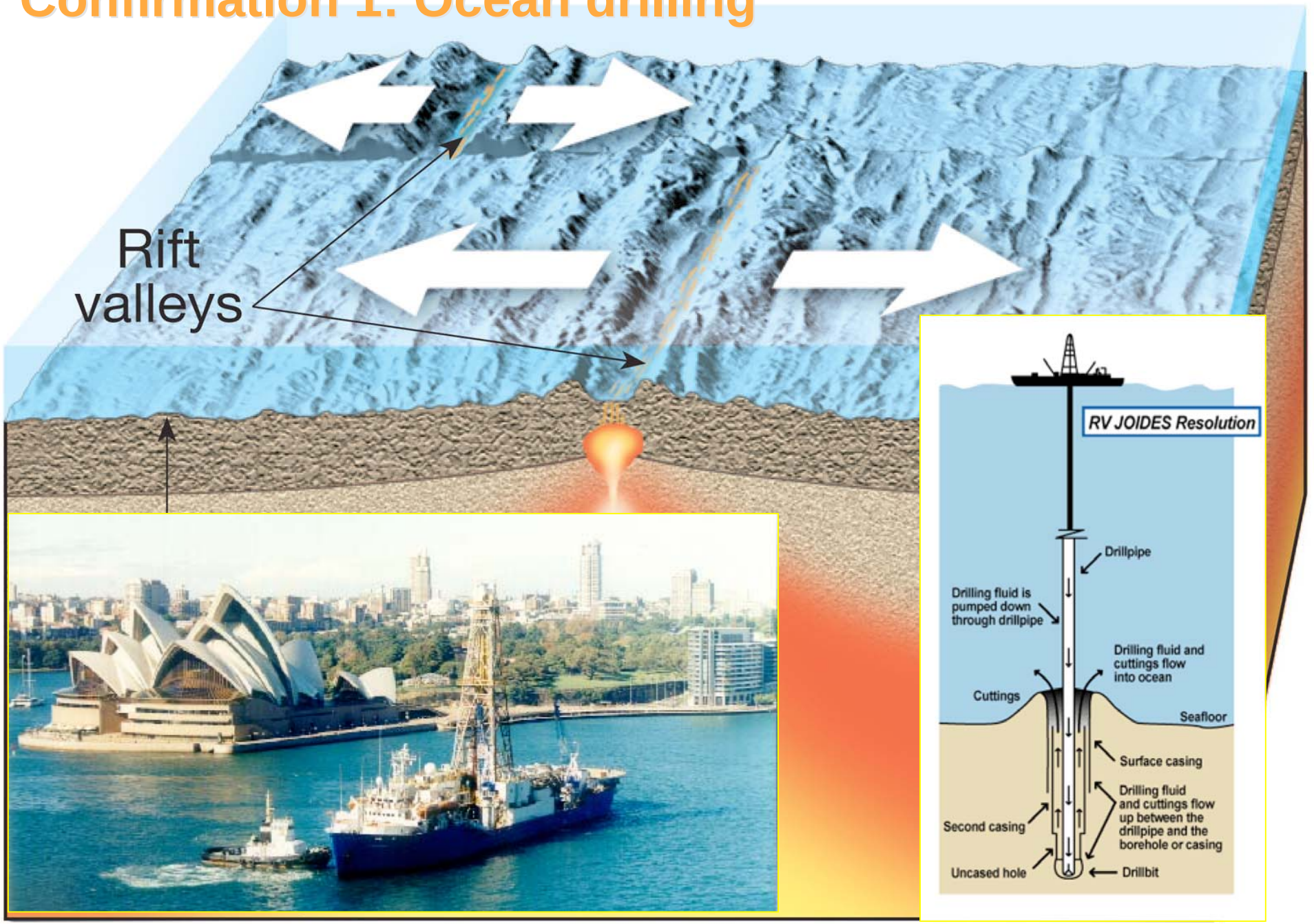
1950s-1960s

Post-WWII Military Industrial Complex

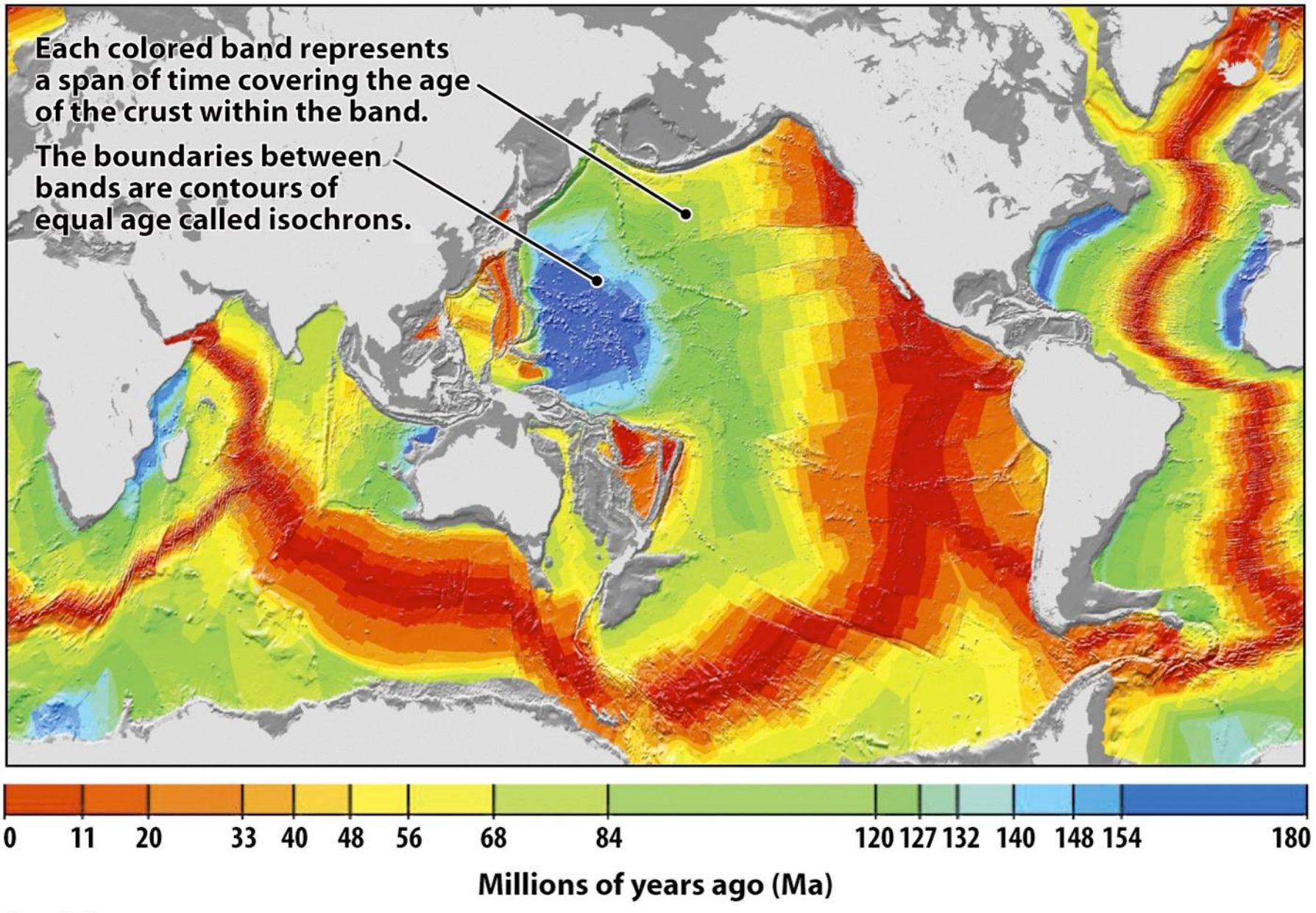
Seafloor bathymetry: Mid-Ocean Ridge volcanoes



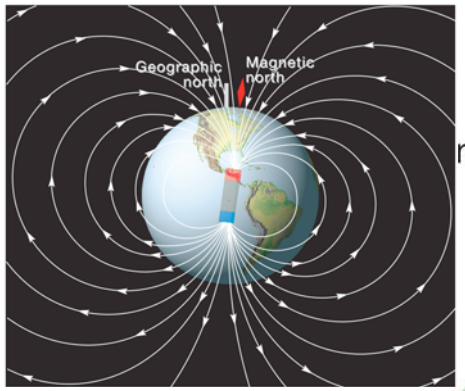
Confirmation 1: Ocean drilling

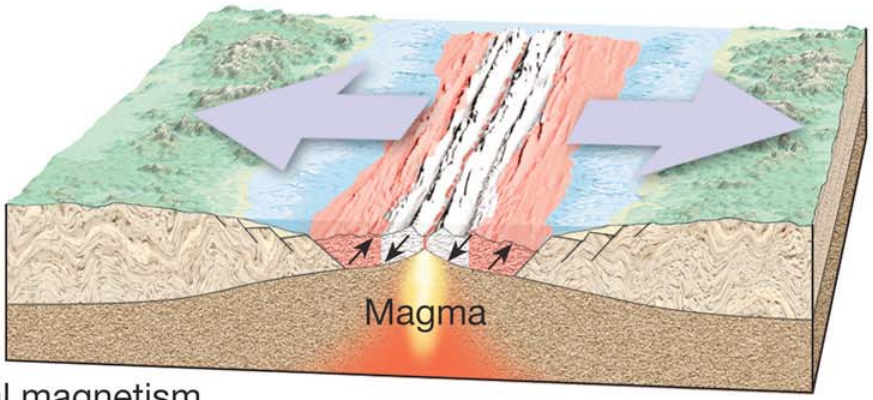


What is moving fastest, A) wide red bands, B) narrow red bands?

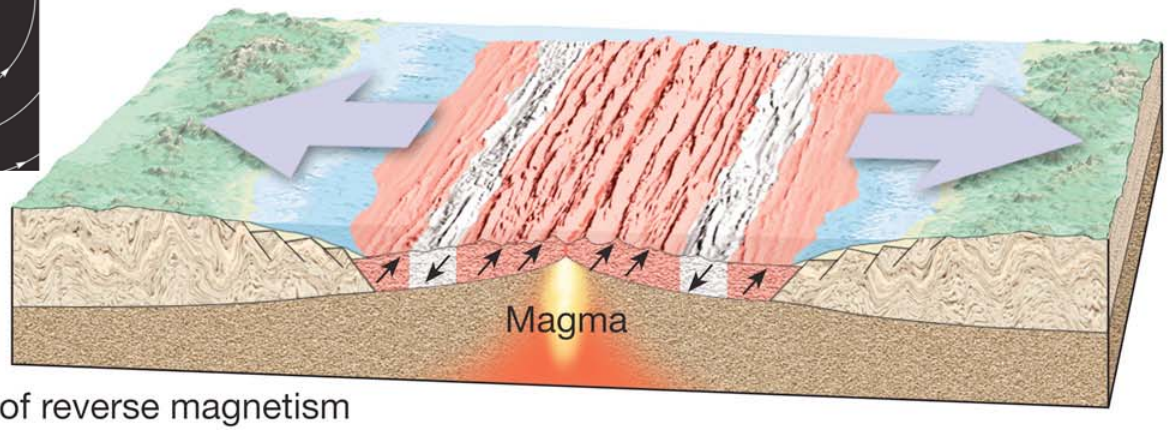


Confirmation 2: Paleomagnetism

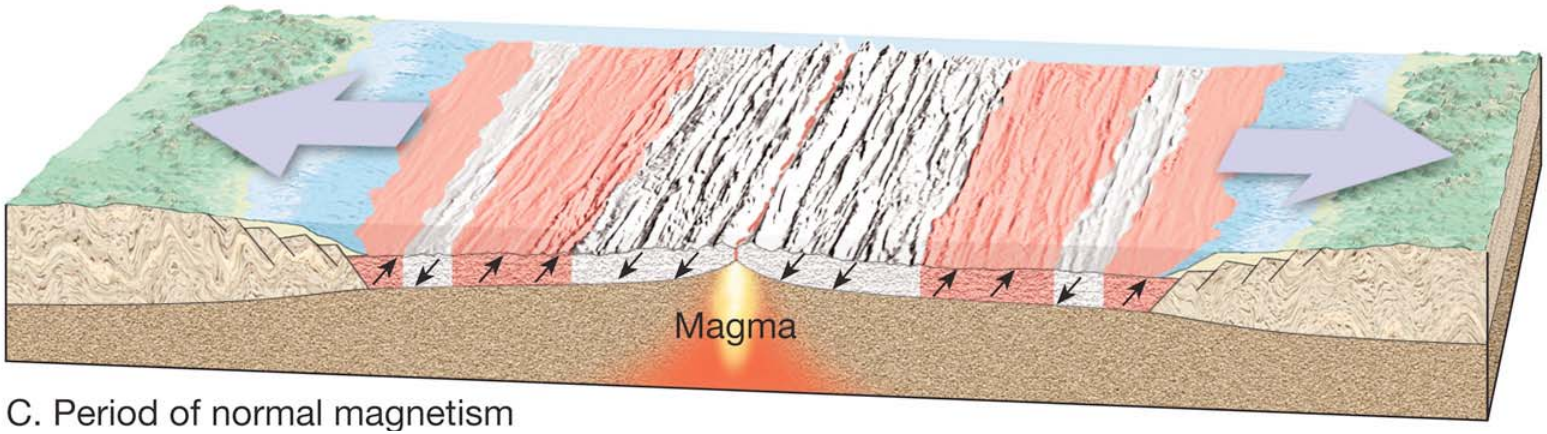




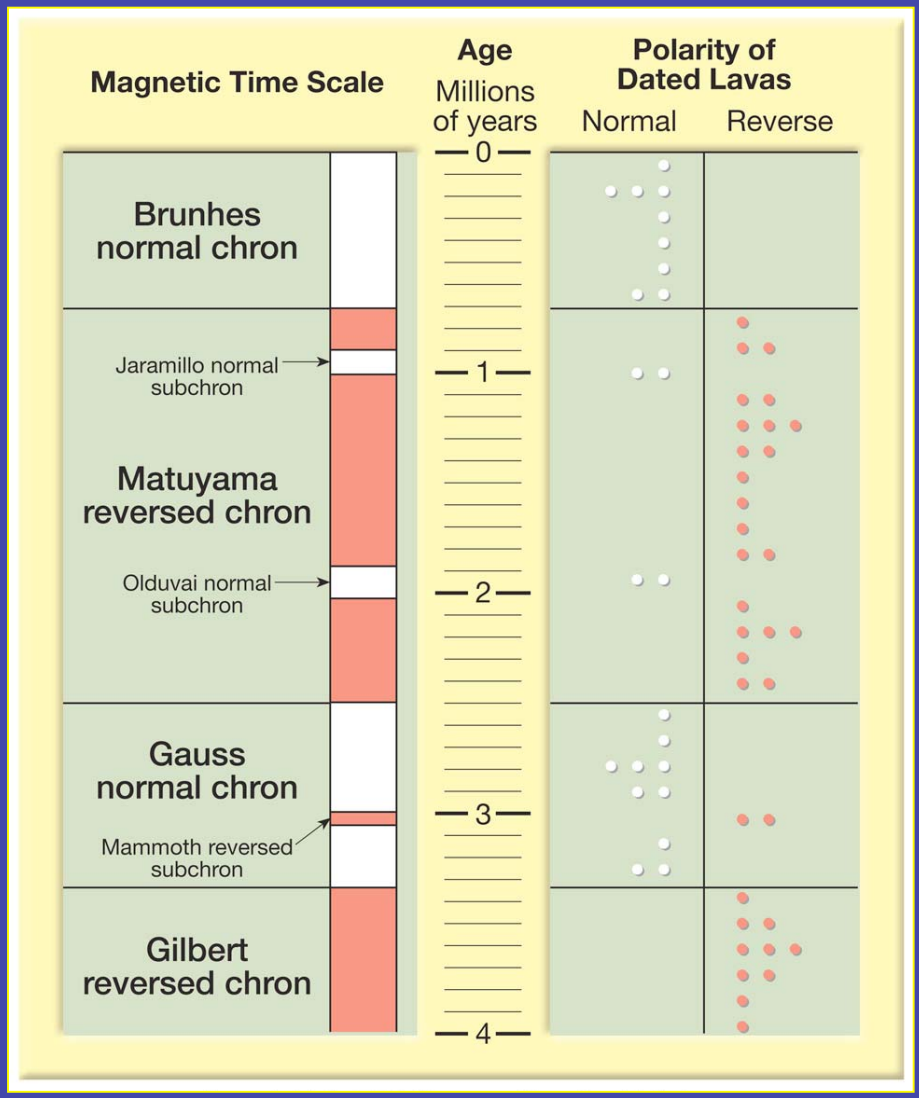
normal magnetism



B. Period of reverse magnetism



C. Period of normal magnetism

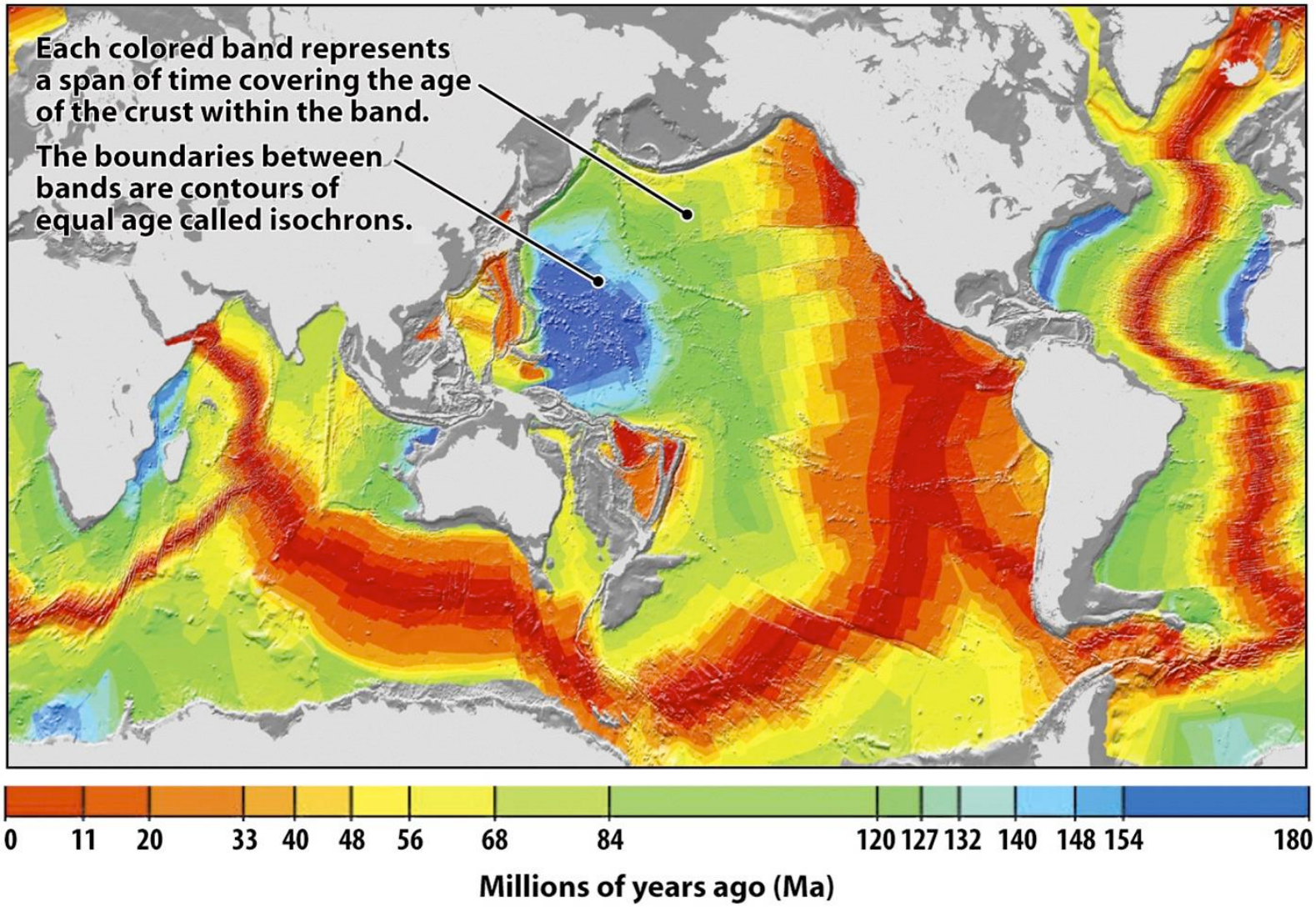


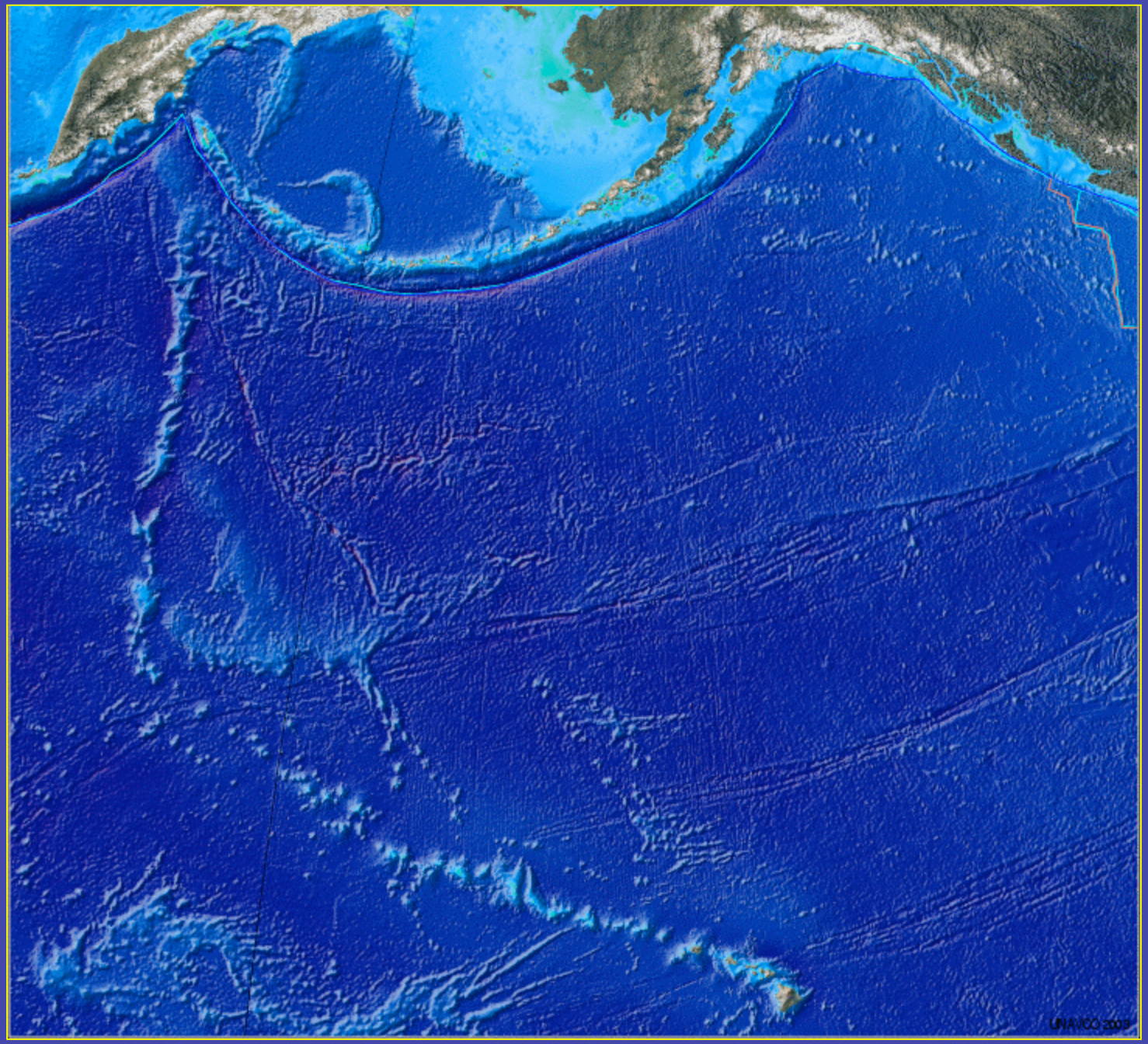


Magnetism of seafloor matches time scale of Earth's magnetic field

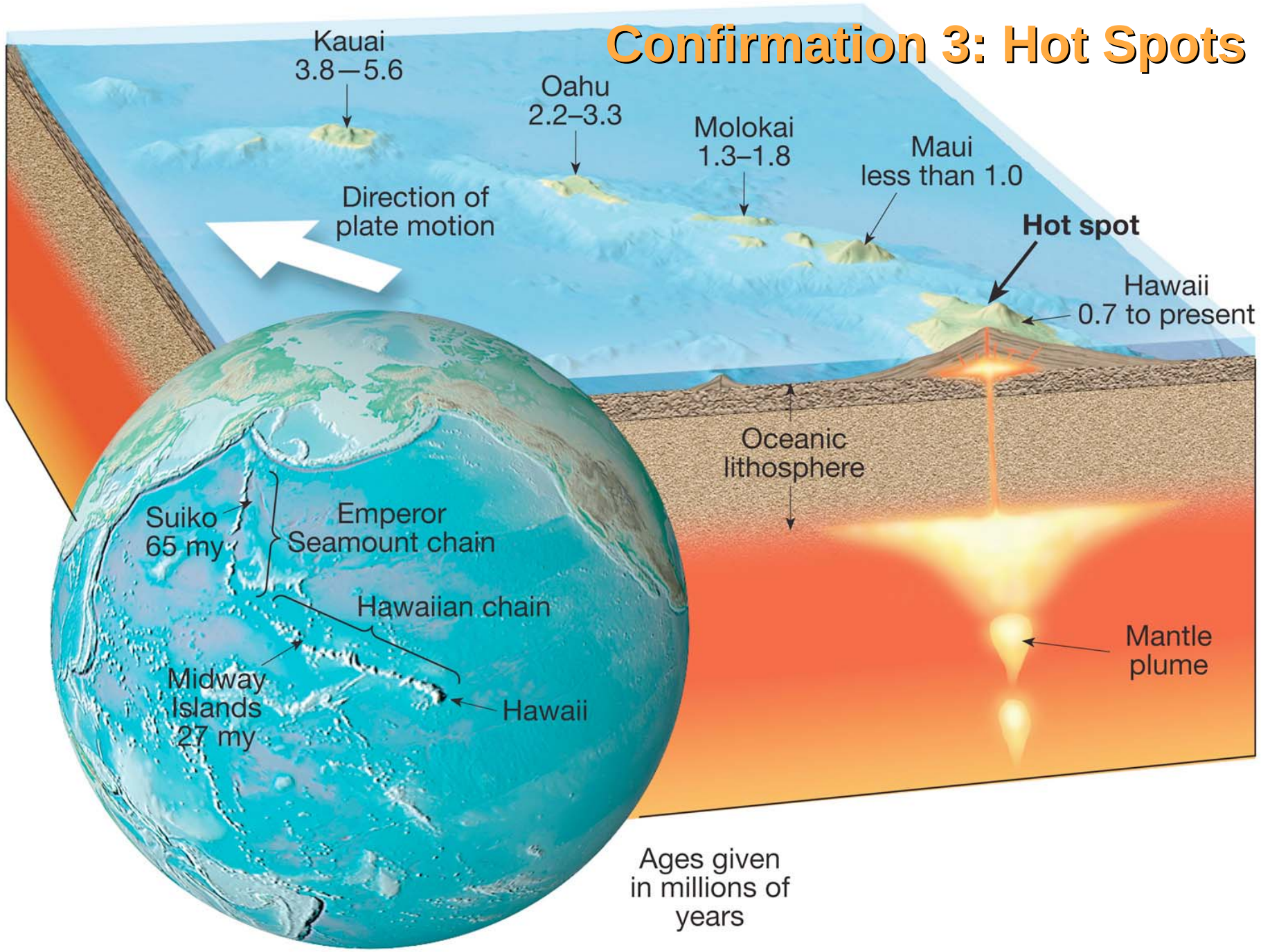
What does this map tell us about plate tectonics?

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




UNAVCO 2003

Confirmation 3: Hot Spots



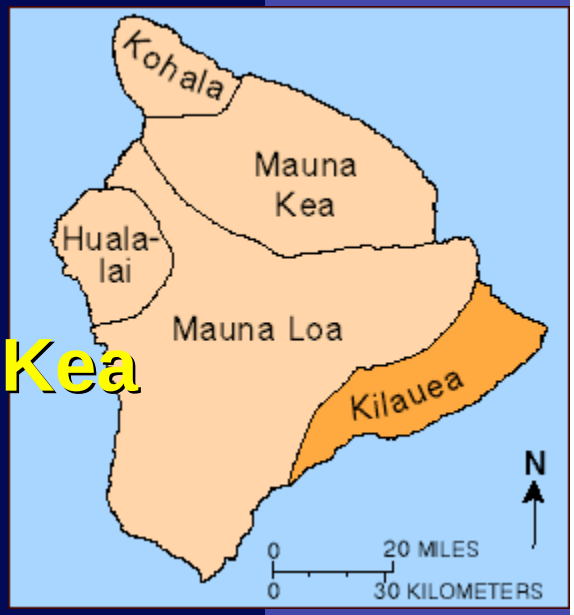
A) Kohala

B) Hualalai

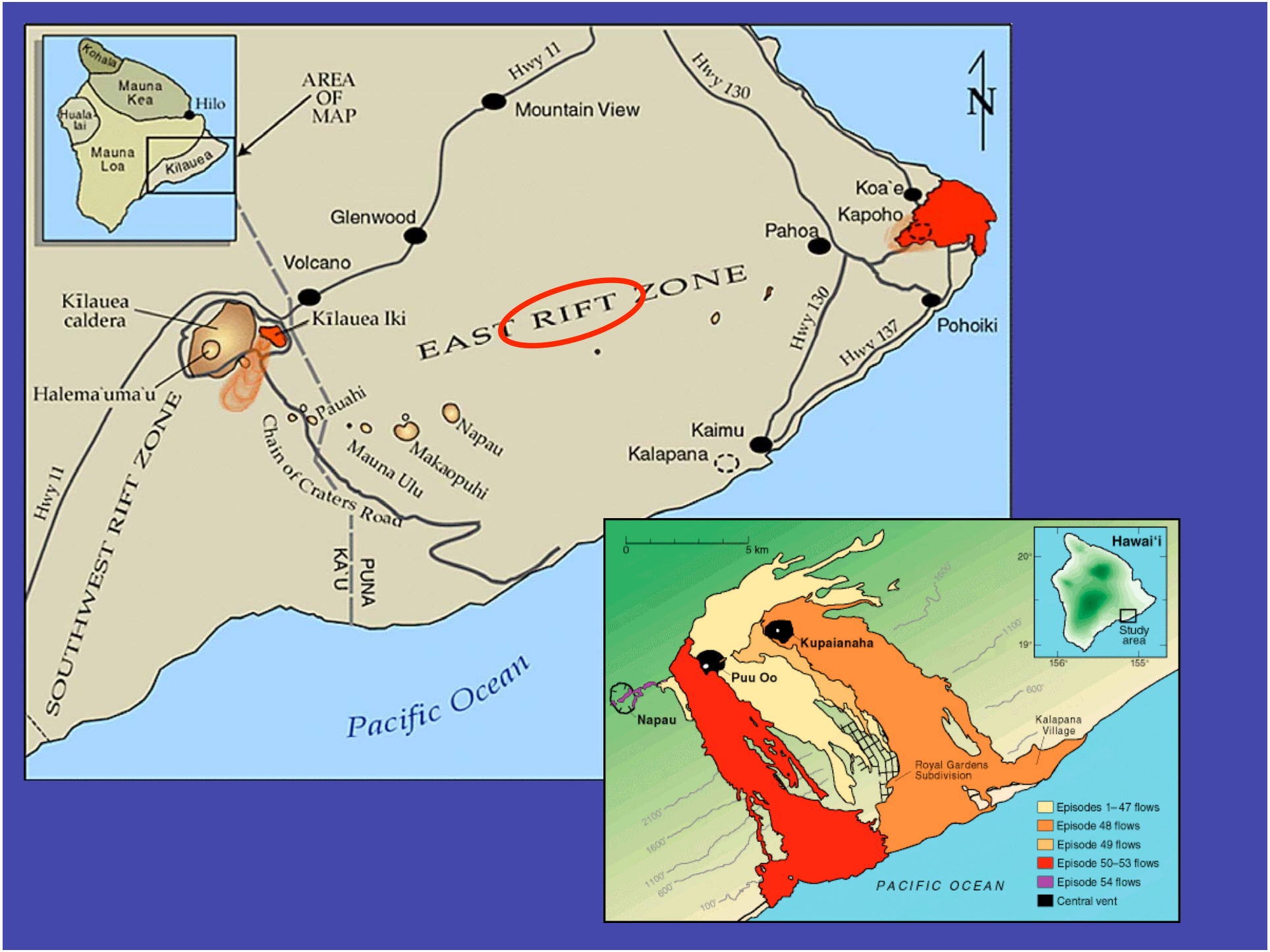
C) Mauna Kea

D) Mauna Loa

E) Kilauea



Which is <u>oldest</u> volcano?


Kohala
Mauna Kea
Hilo
Hualalai
Mauna Loa
Kilauea
AREA OF MAP
Hwy 11
Mountain View
Hwy 130
N
Koa`e
Kapoho
Glenwood
Pahoa
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
Hwy 11
SOUTHWEST RIFT ZONE
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

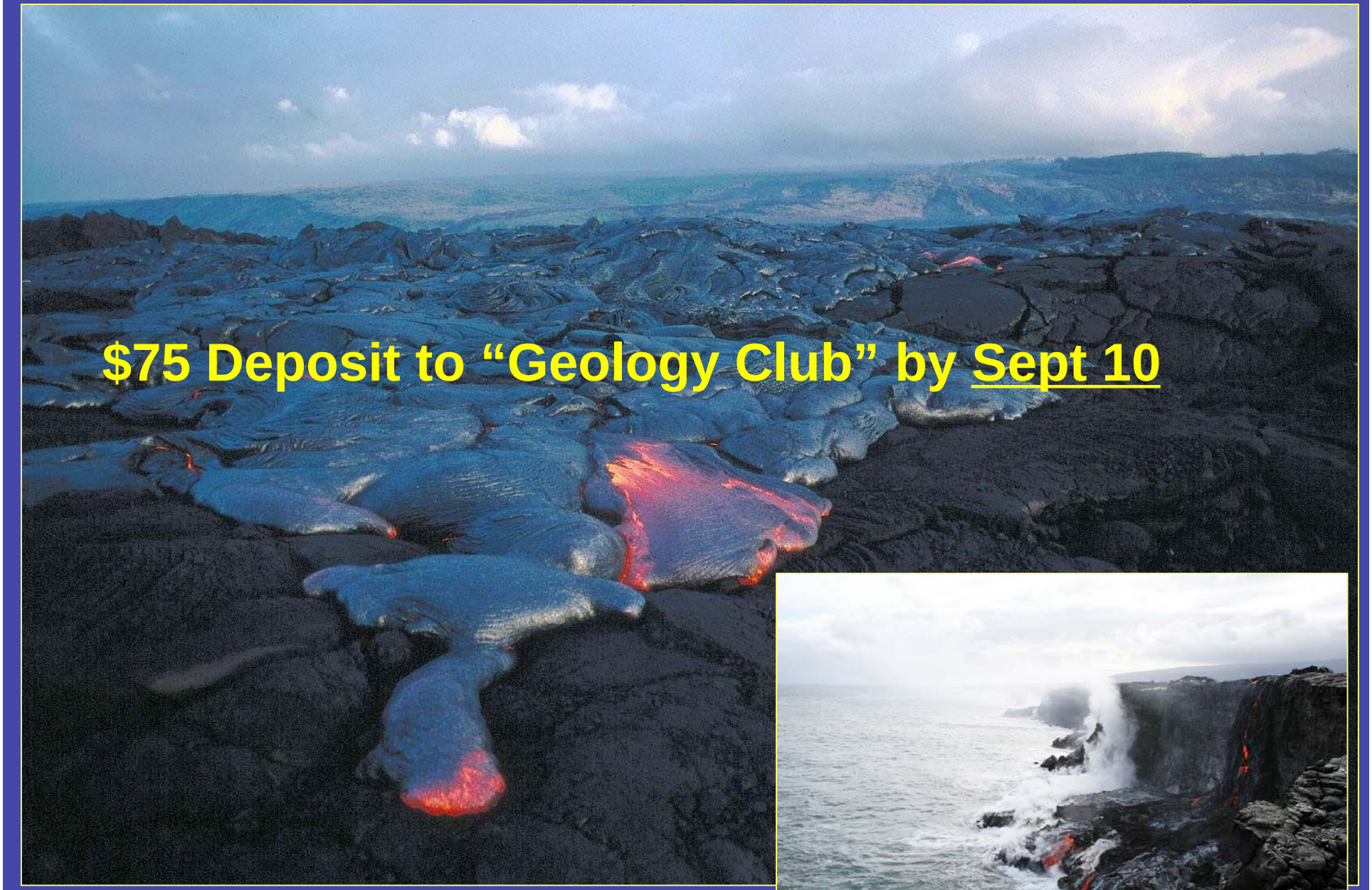
Kilauea

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

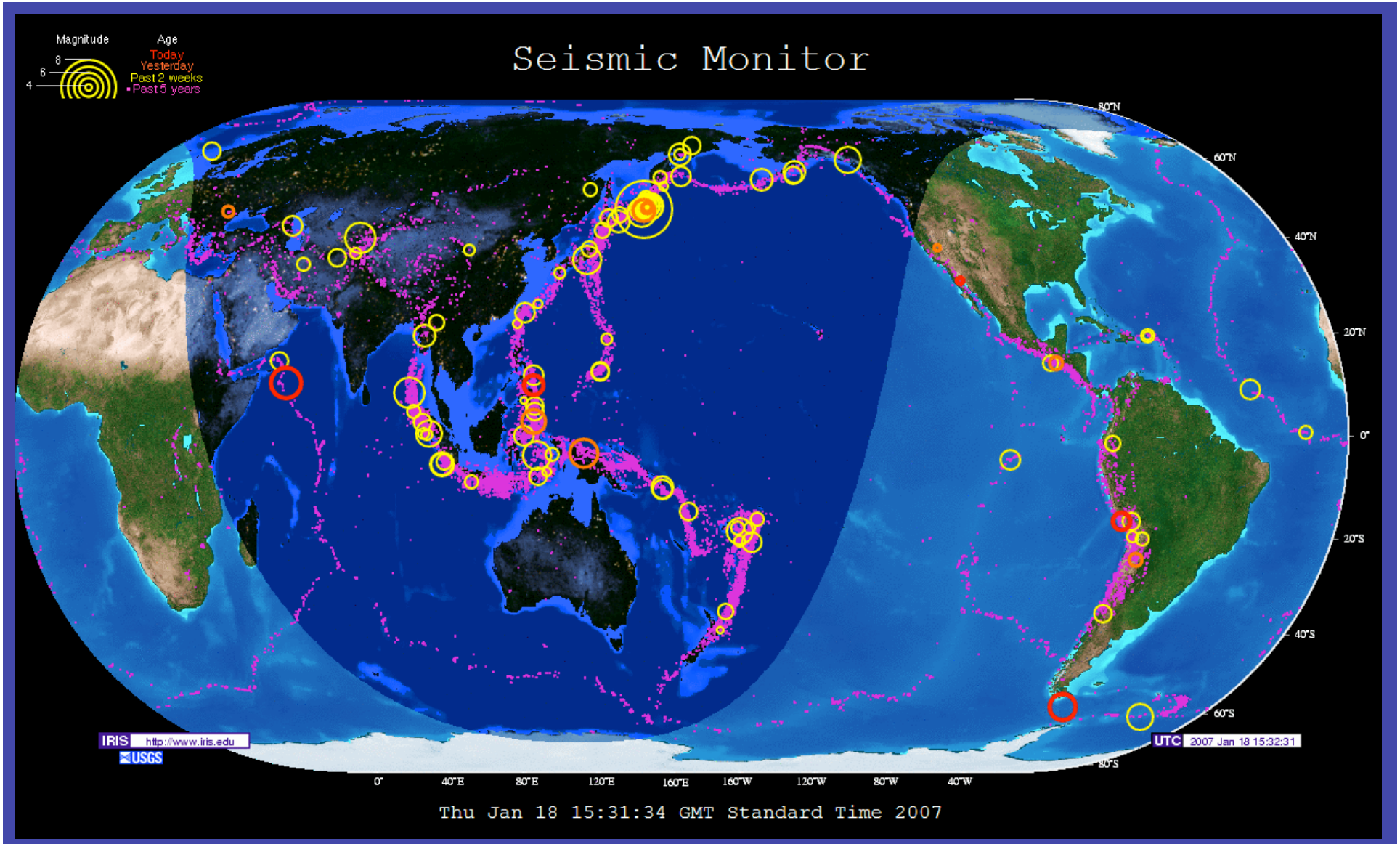
Live panorama of Pu`u `O`o vent, Kilauea Volcano

Last Image Update: 2006-09-11 11:58:03 (HST)



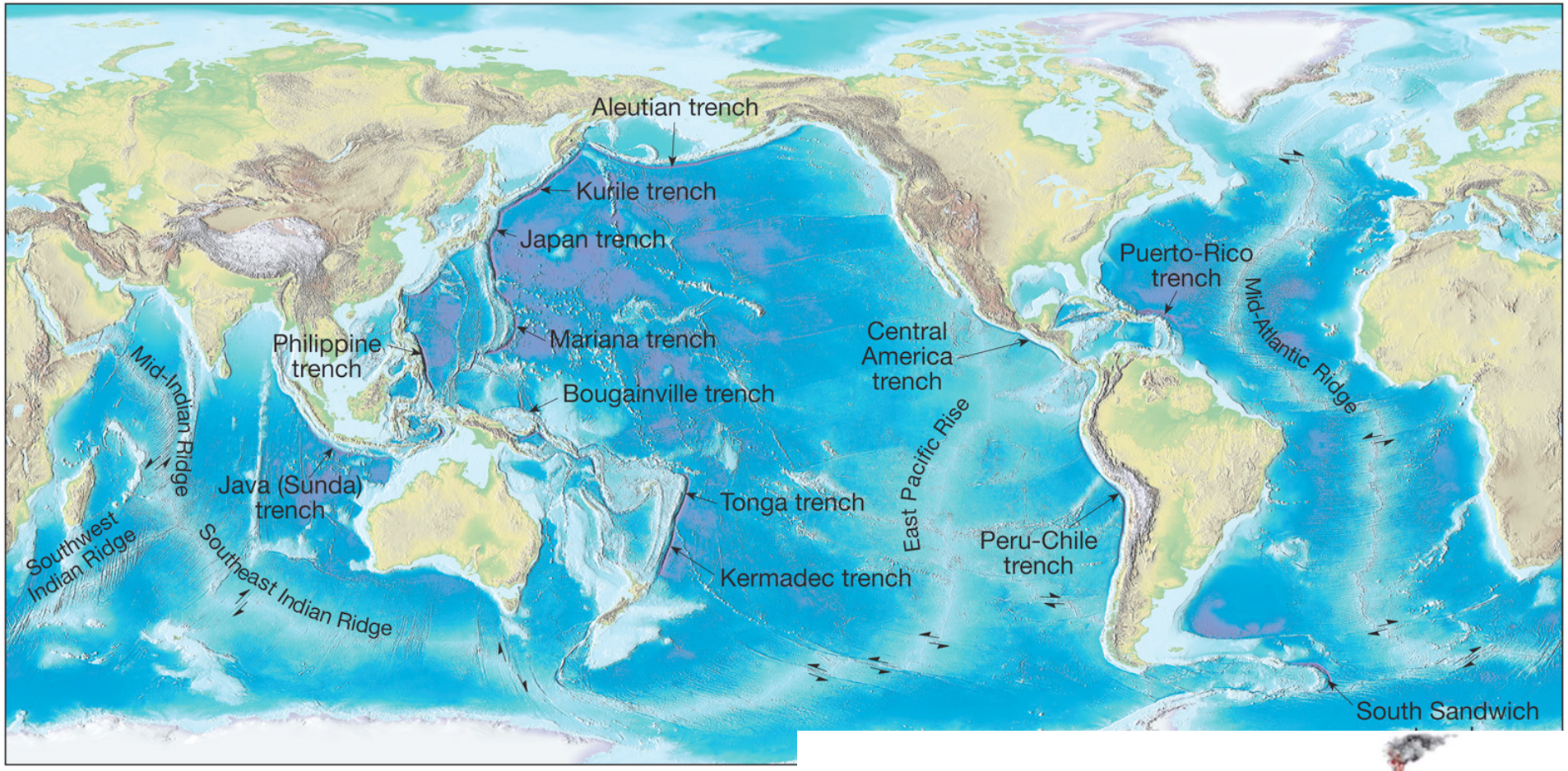


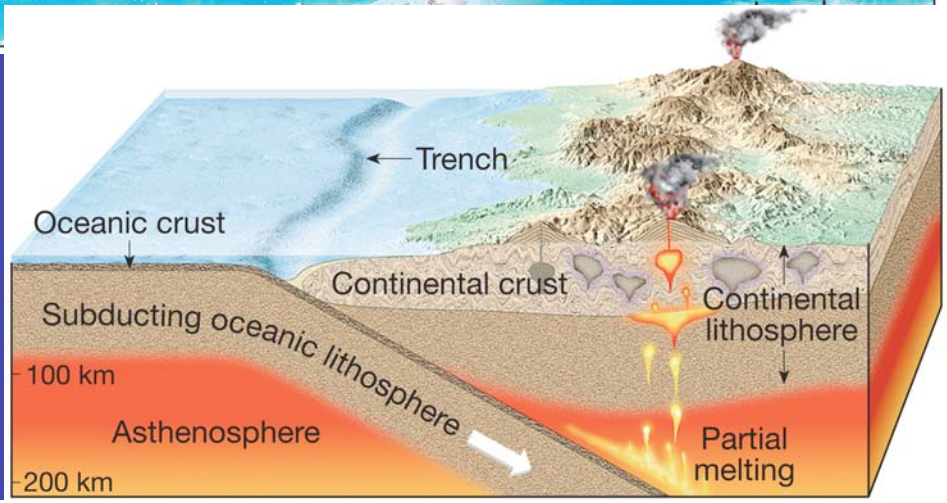
$75 Deposit to "Geology Club" by Sept 10

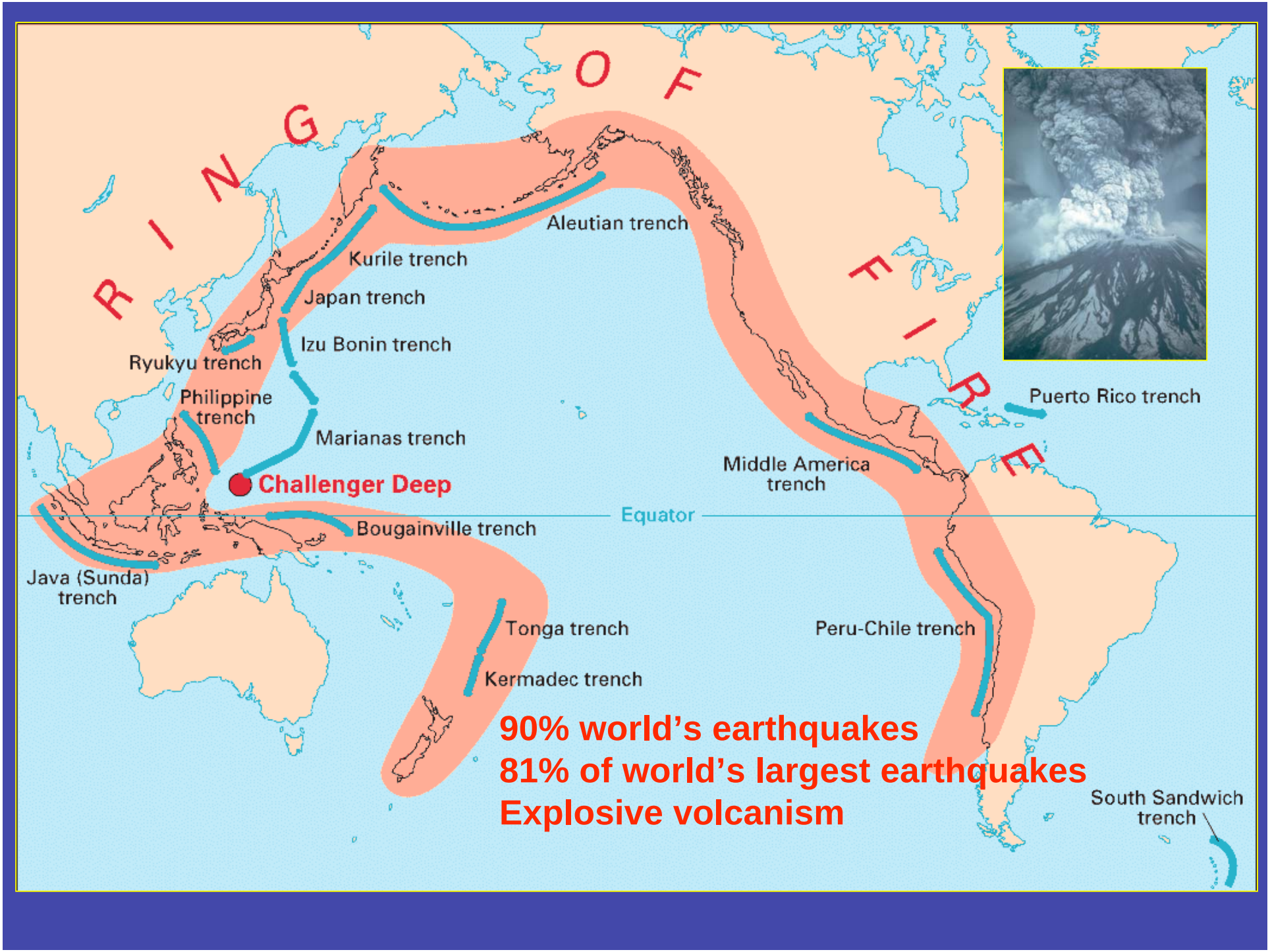


Where are the world's earthquakes?

Oceanic Trenches



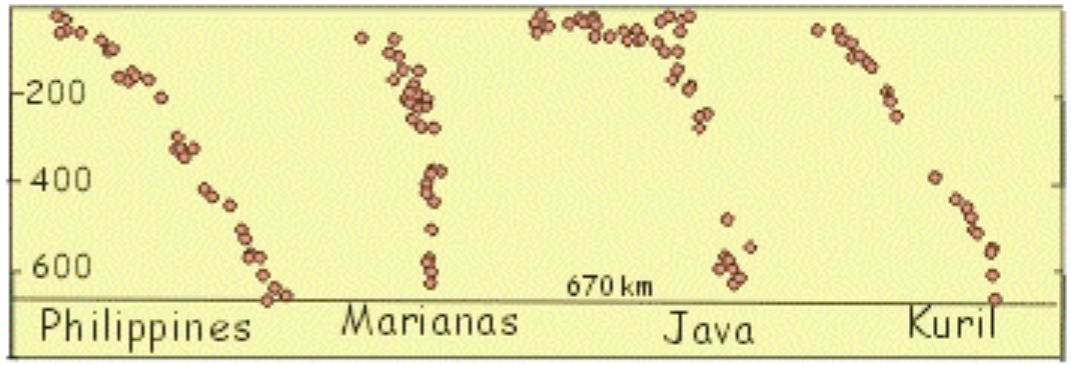


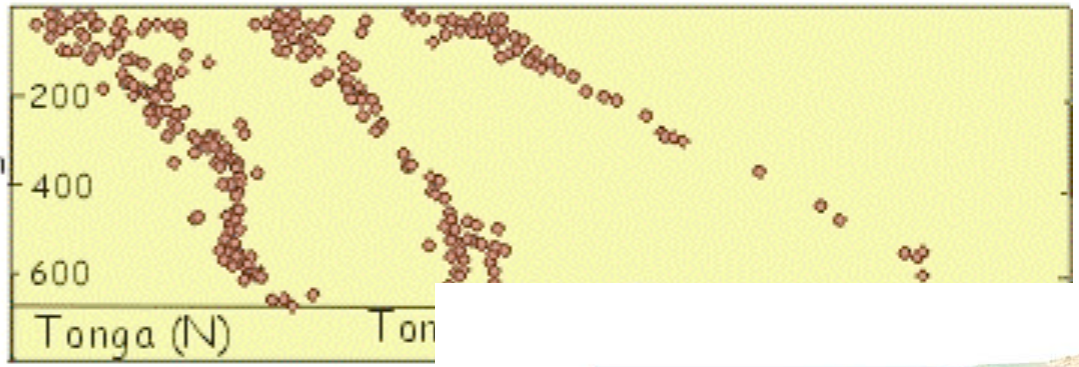

RING OF FIRE
Aleutian trench
Kurile trench
Japan trench
Izu Bonin trench
Ryukyu trench
Philippine trench
Marianas trench
Challenger Deep
Bougainville trench
Java (Sunda) trench
Tonga trench
Kermadec trench
Middle America trench
Puerto Rico trench
Equator
Peru-Chile trench
South Sandwich trench
90% world's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

Confirmation 4: Wadati-Benioff zones

Earthquakes and the dip of Wadati-Benioff seismic zones

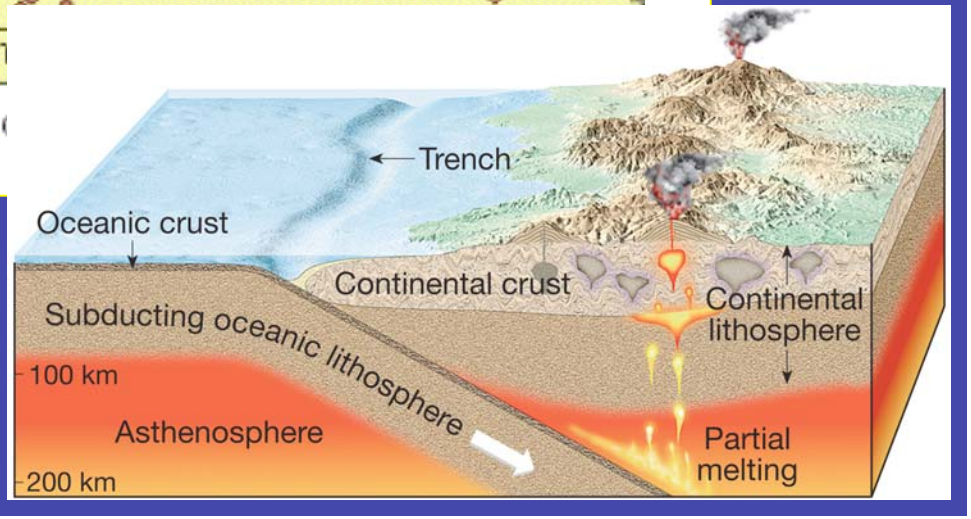






vertical an

Sinking oceanic crust

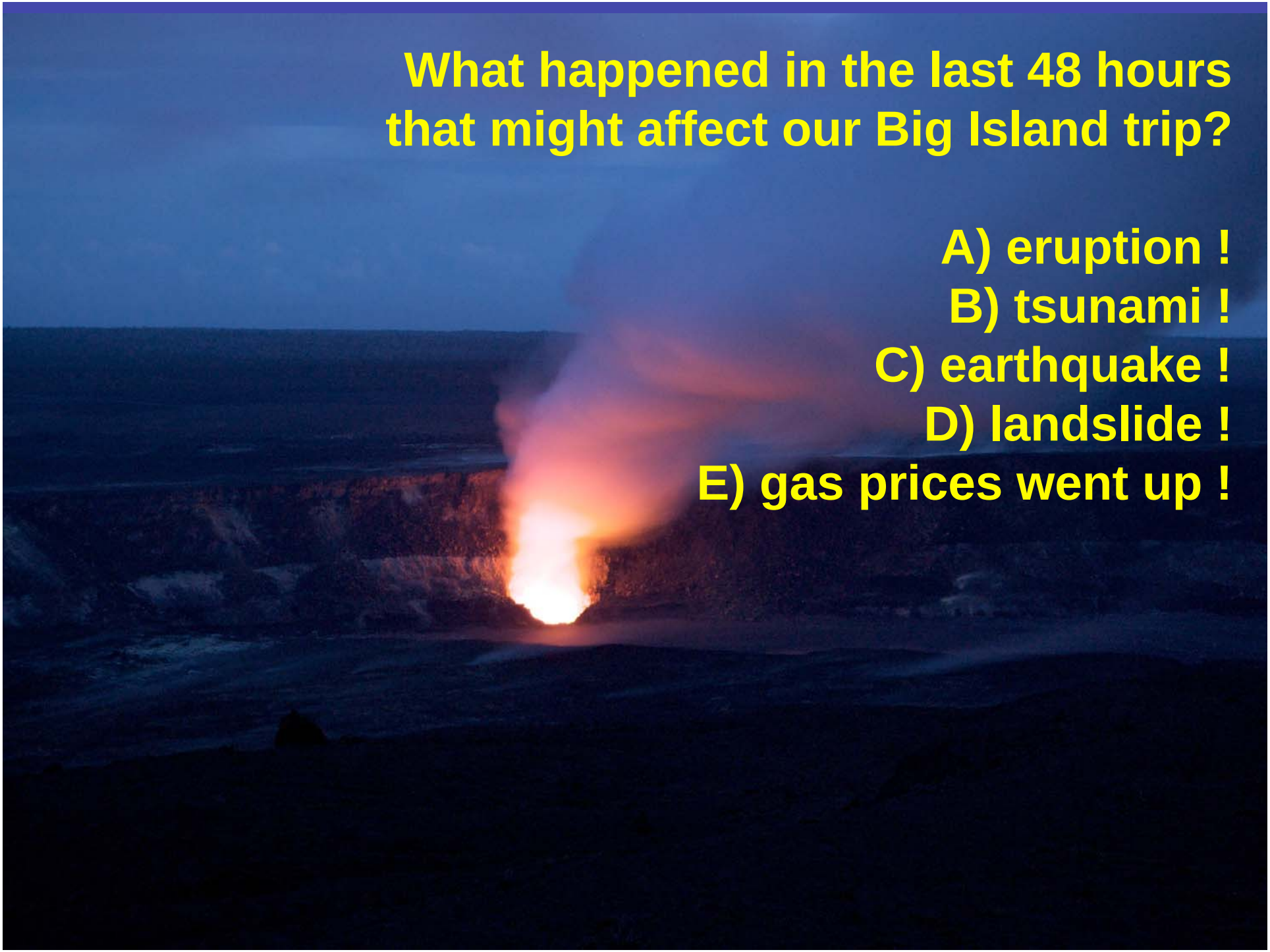


Support for plate tectonic model



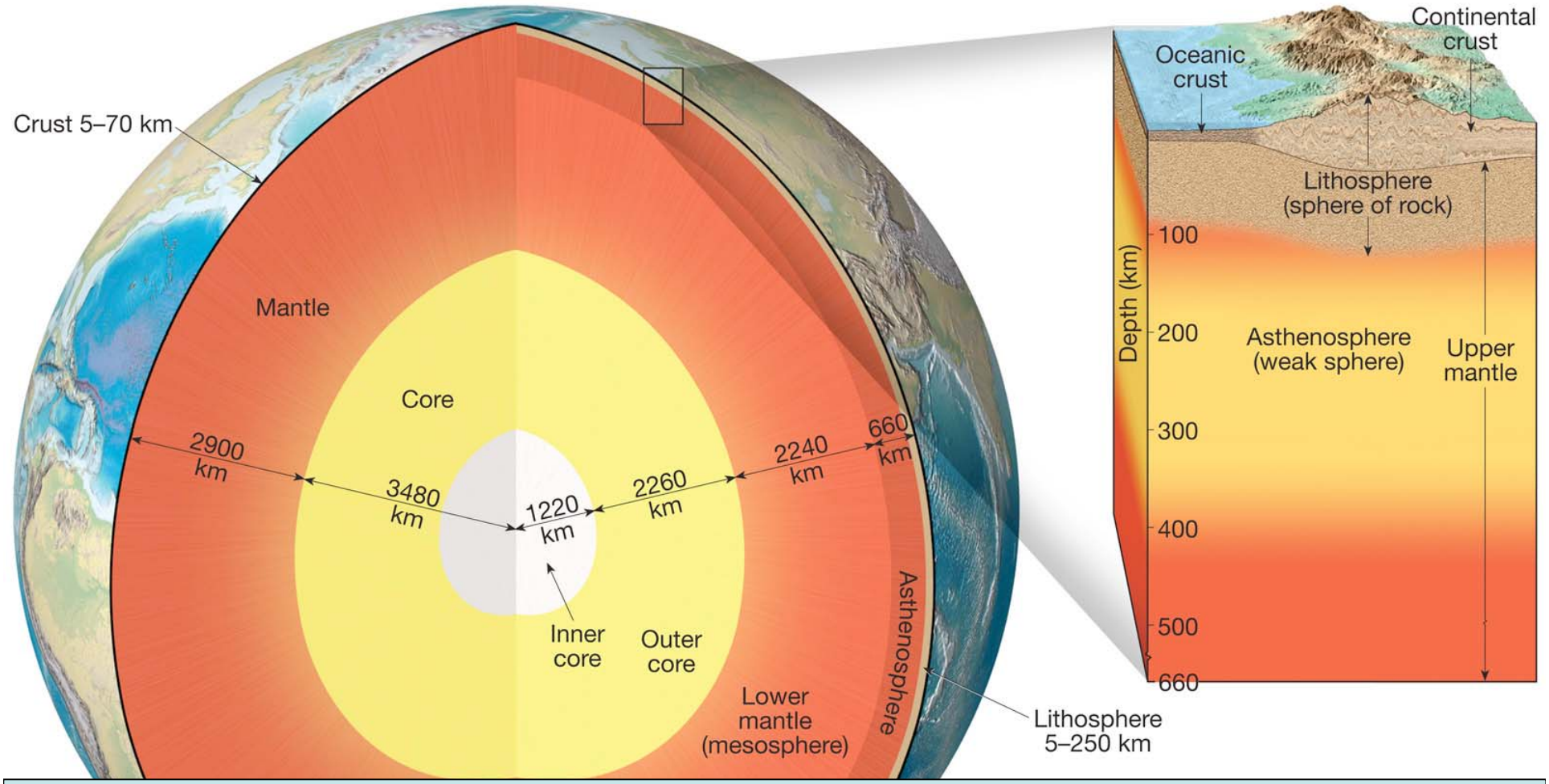
1. Continental jigsaw puzzle
2. Fossils match across Atlantic
3. Rock types/structures match across Atlantic
4. Ancient climates (i.e. glaciers in Africa)

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



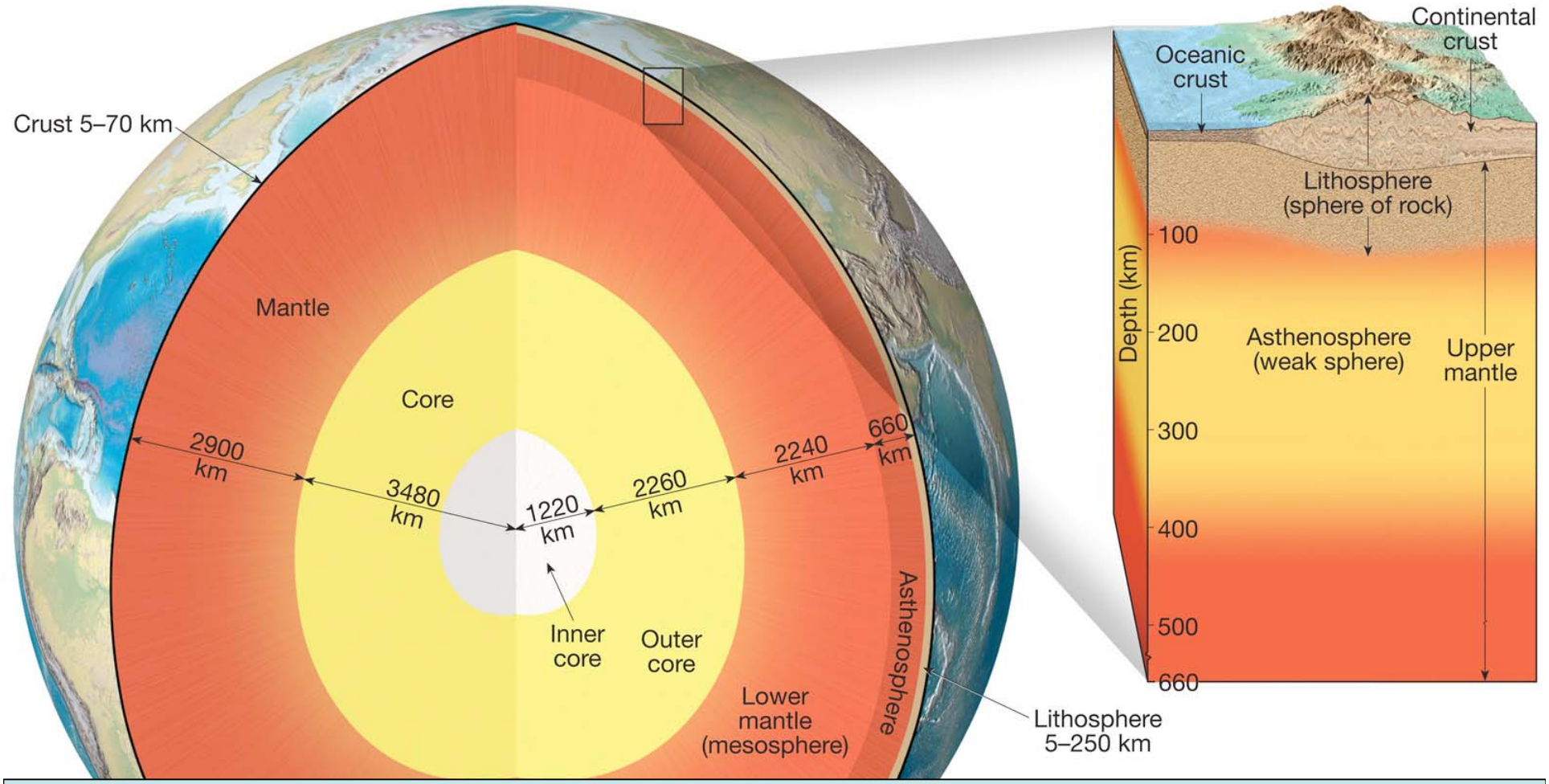
What happened in the last 48 hours that might affect our Big Island trip?

A) eruption !
B) tsunami !
C) earthquake !
D) landslide !
E) gas prices went up !



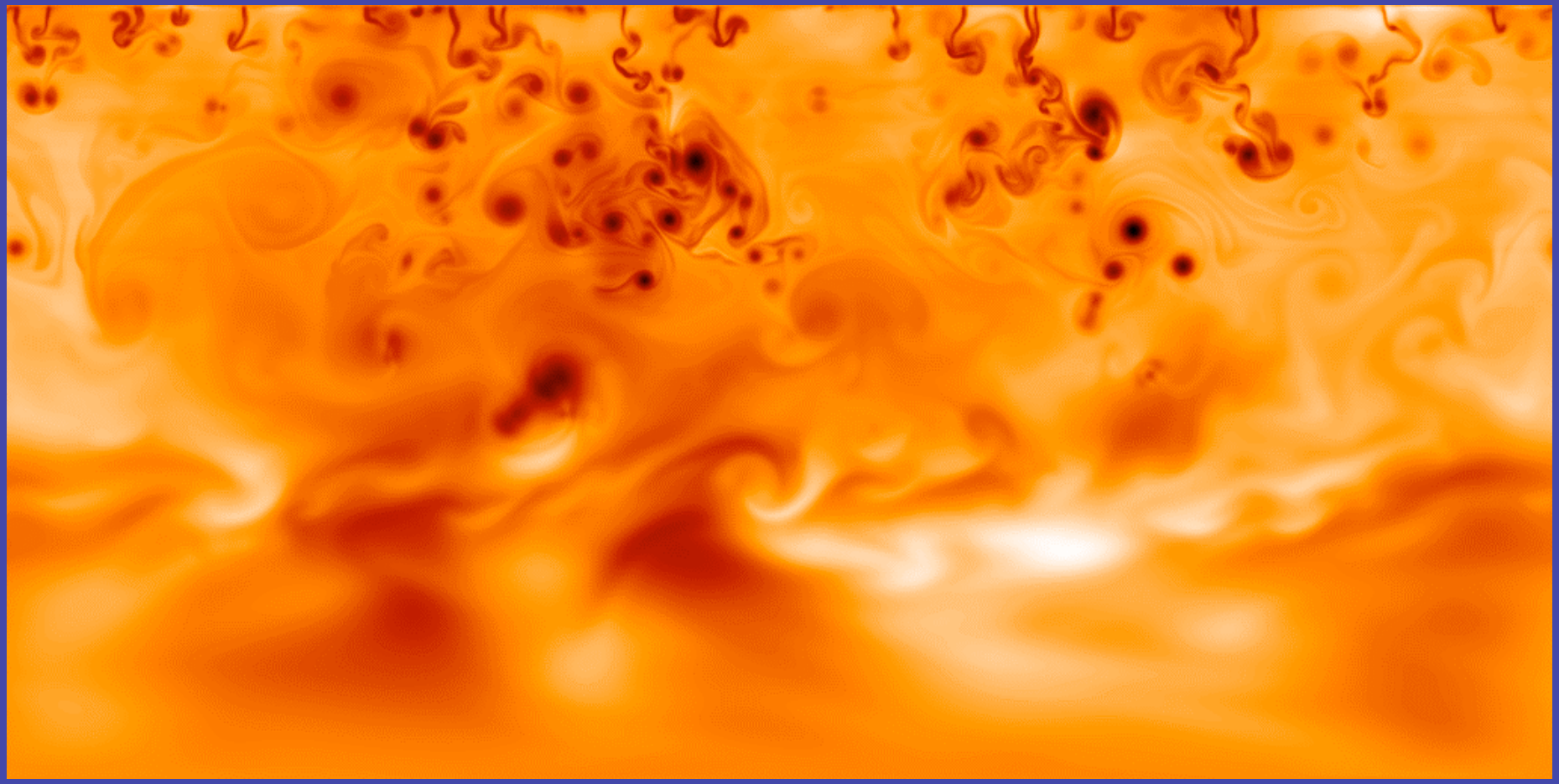
EARTH'S INTERNAL STRUCTURE — **PHASE** — **DENSITY(pressure)?**

- **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**

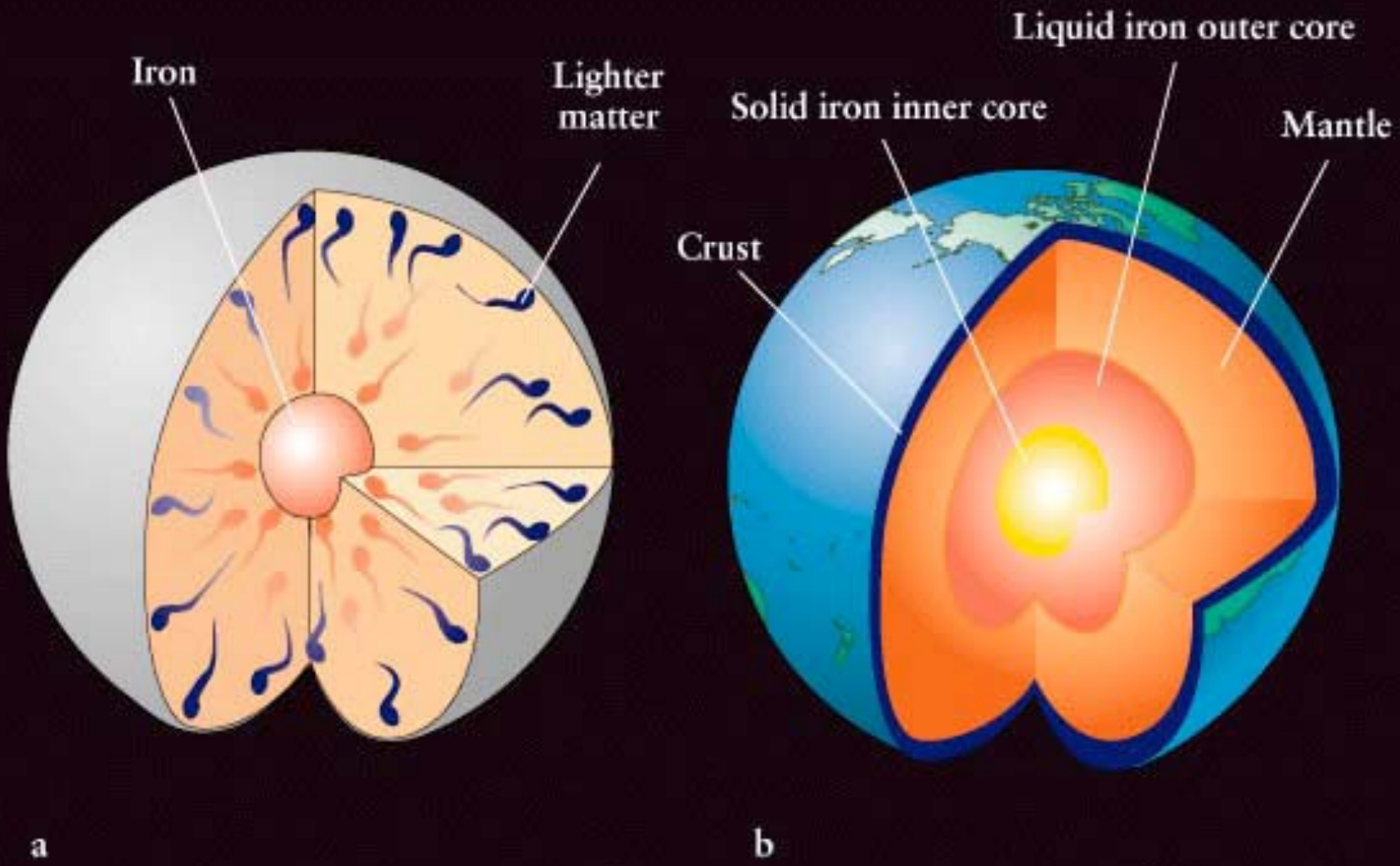
- **Crust – Fe/Mg/Si/O** — **solid** — **low**
  - **Continental crust – Si/O/Na**
  - **Oceanic crust – Fe/Mg/Ca**
- **Mantle – Fe/Mg** — **solid, but capable of flow**
- **Outer core – Fe/Ni/Mg** — **liquid**
- **Inner core – Fe/Ni** — **solid** — **high**



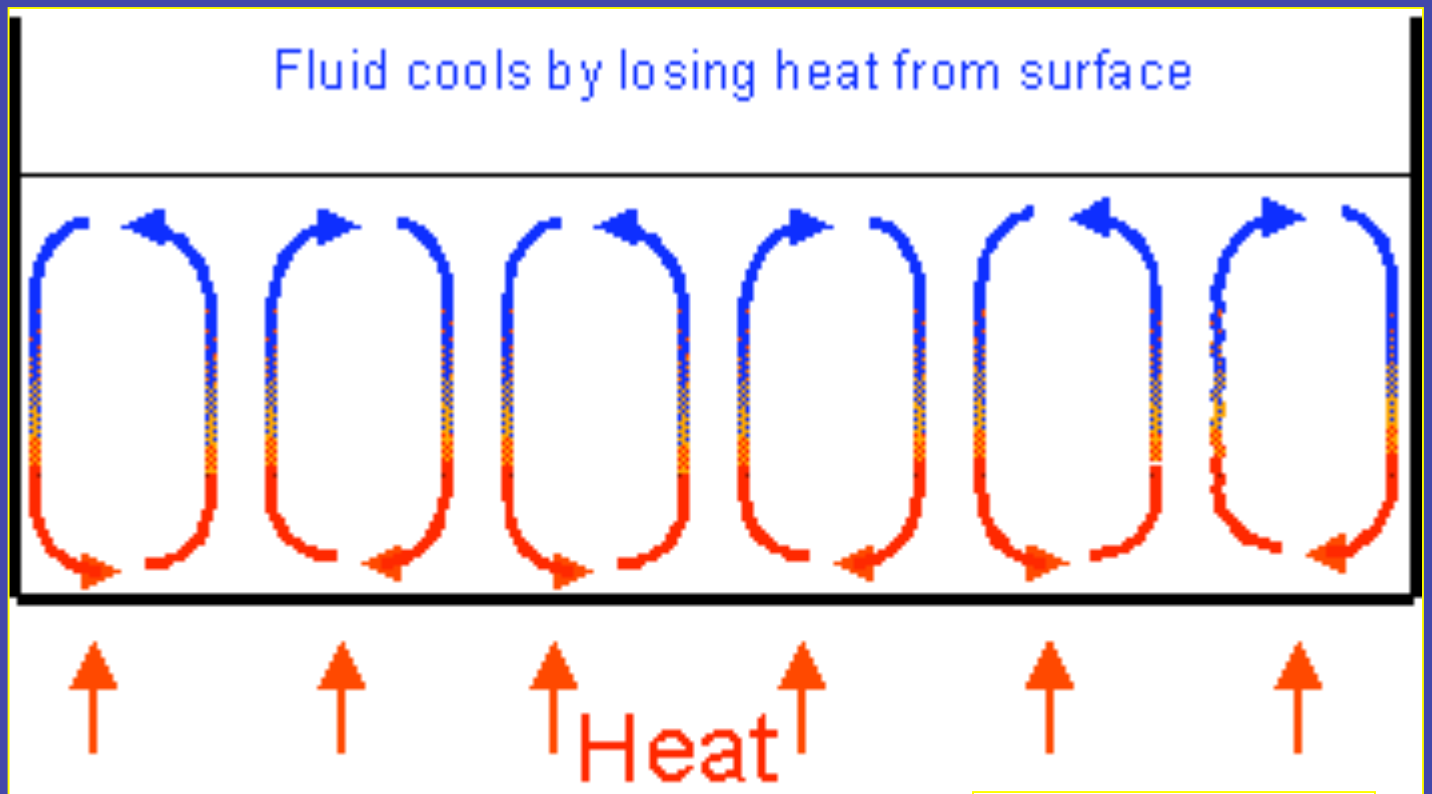
What's happening here?

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

"Iron Catastrophe"



Density stratification: core → atmosphere

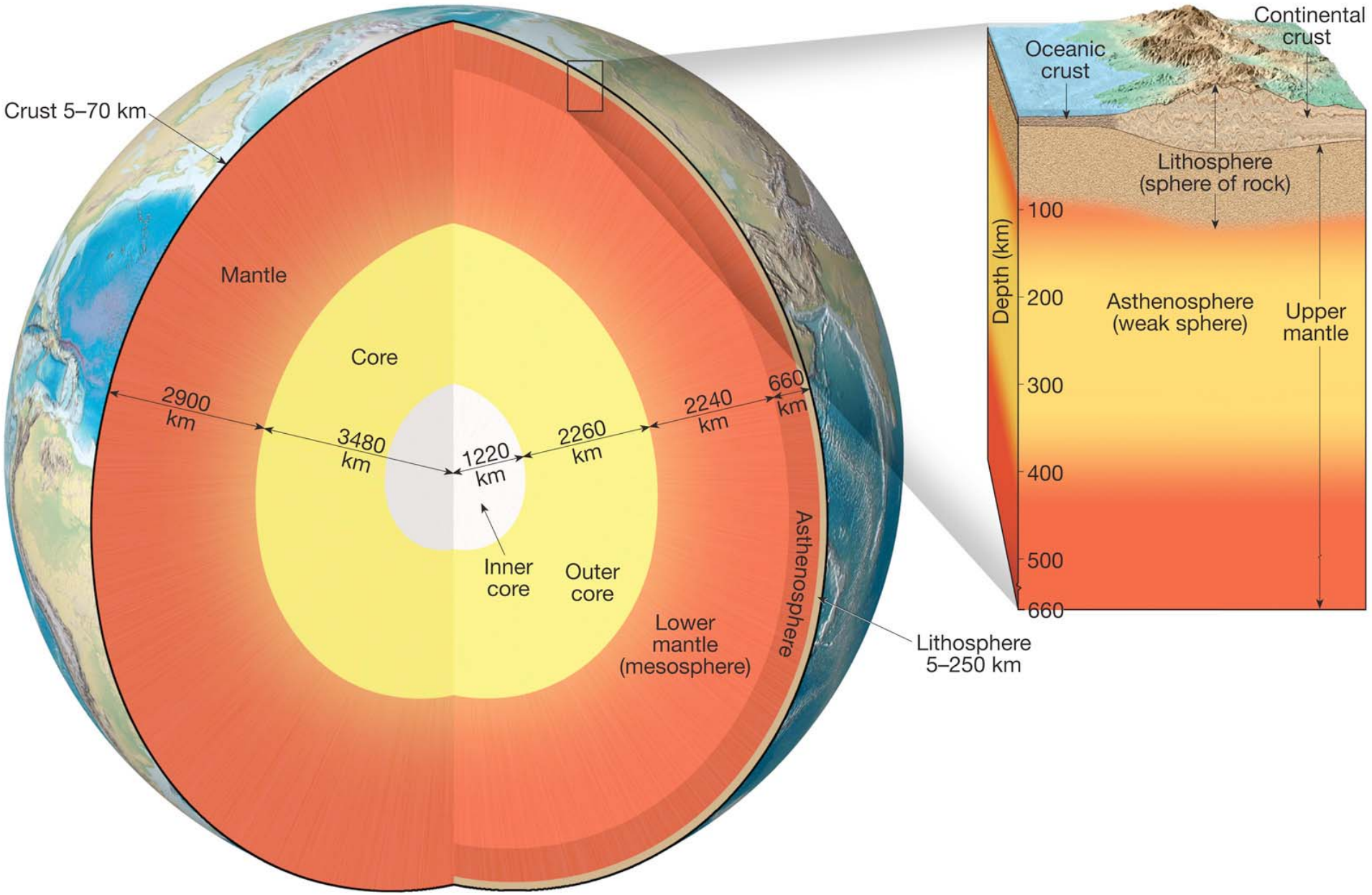


Convection cell

Warm, low density fluid rises

Cool, high density fluid sinks





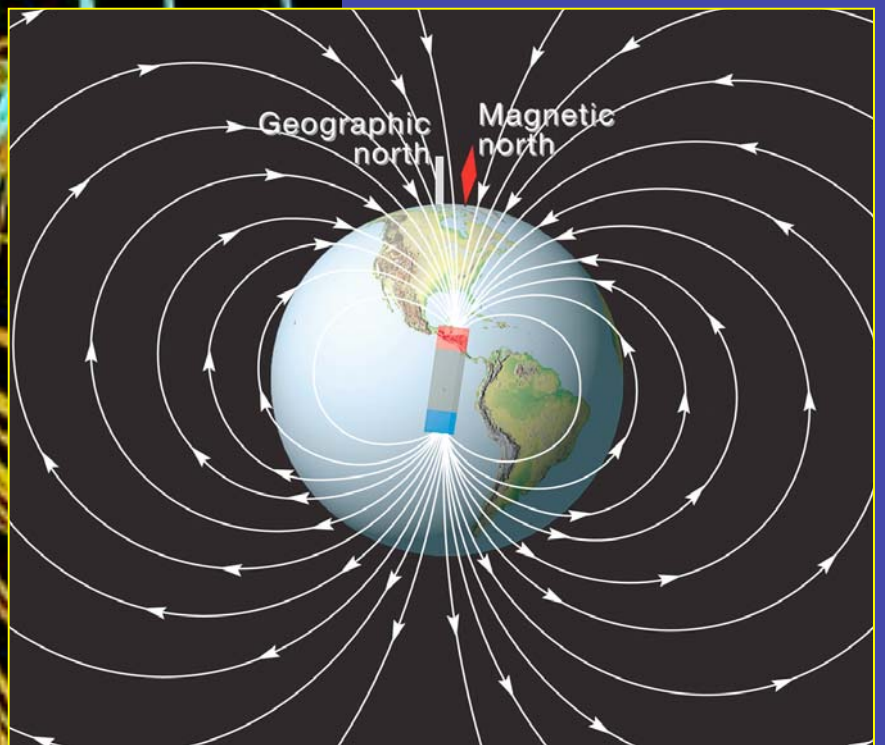
Where does convection occur?

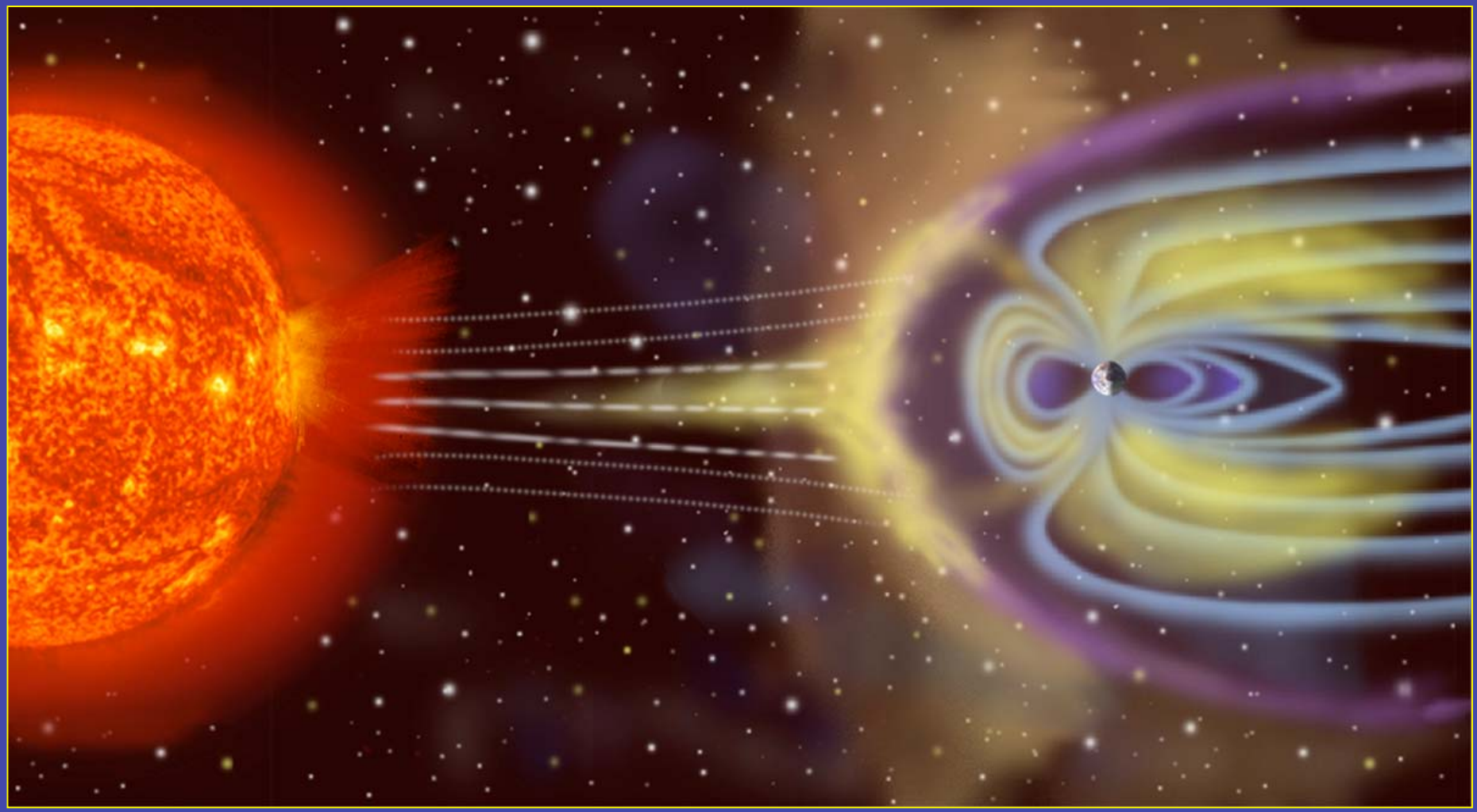
1) OUTER CORE

Magnetosphere
Magnetism gained from early nebula is magnified by:

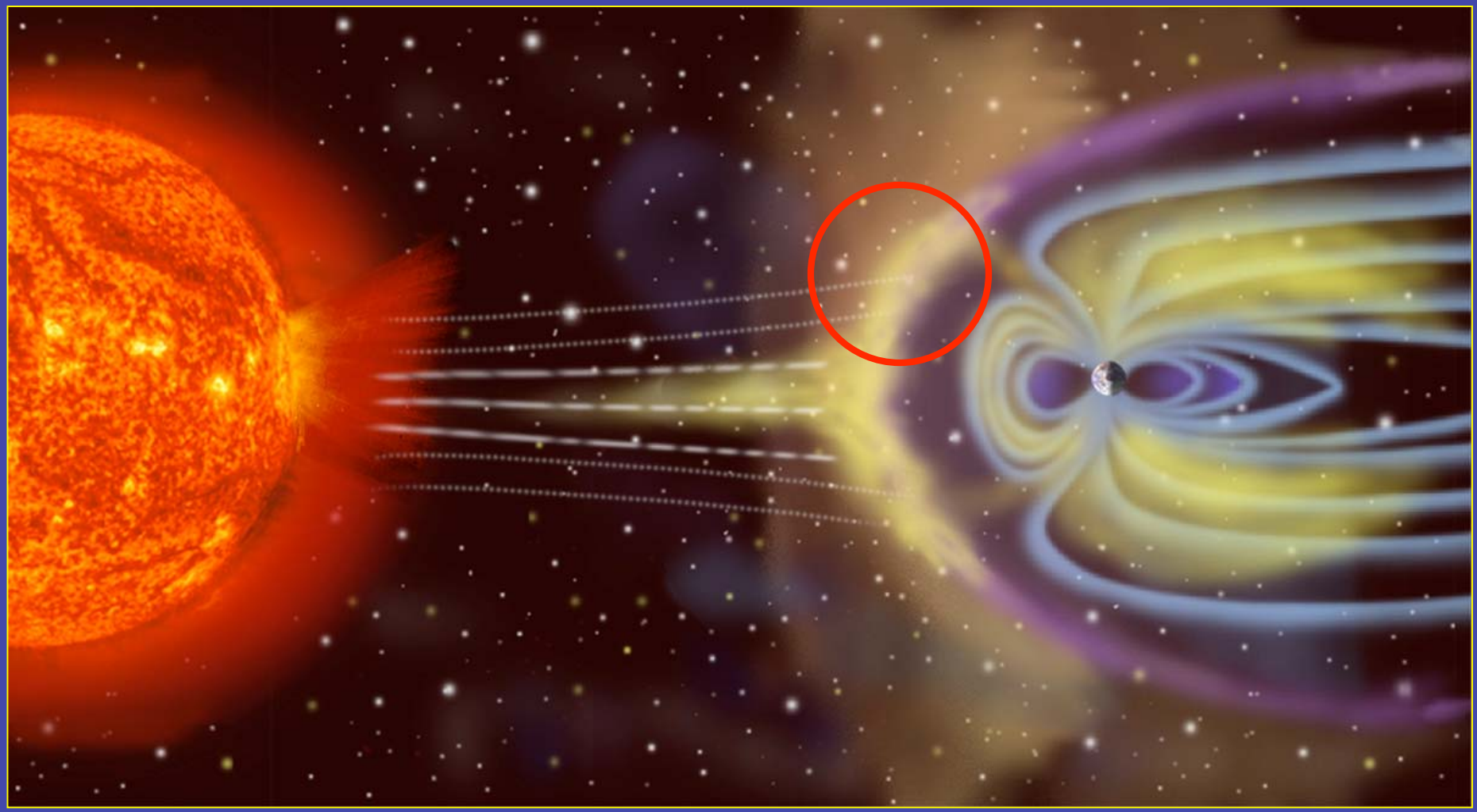
1) Turbulent iron/nickel fluid of outer core

2) Earth's rotation





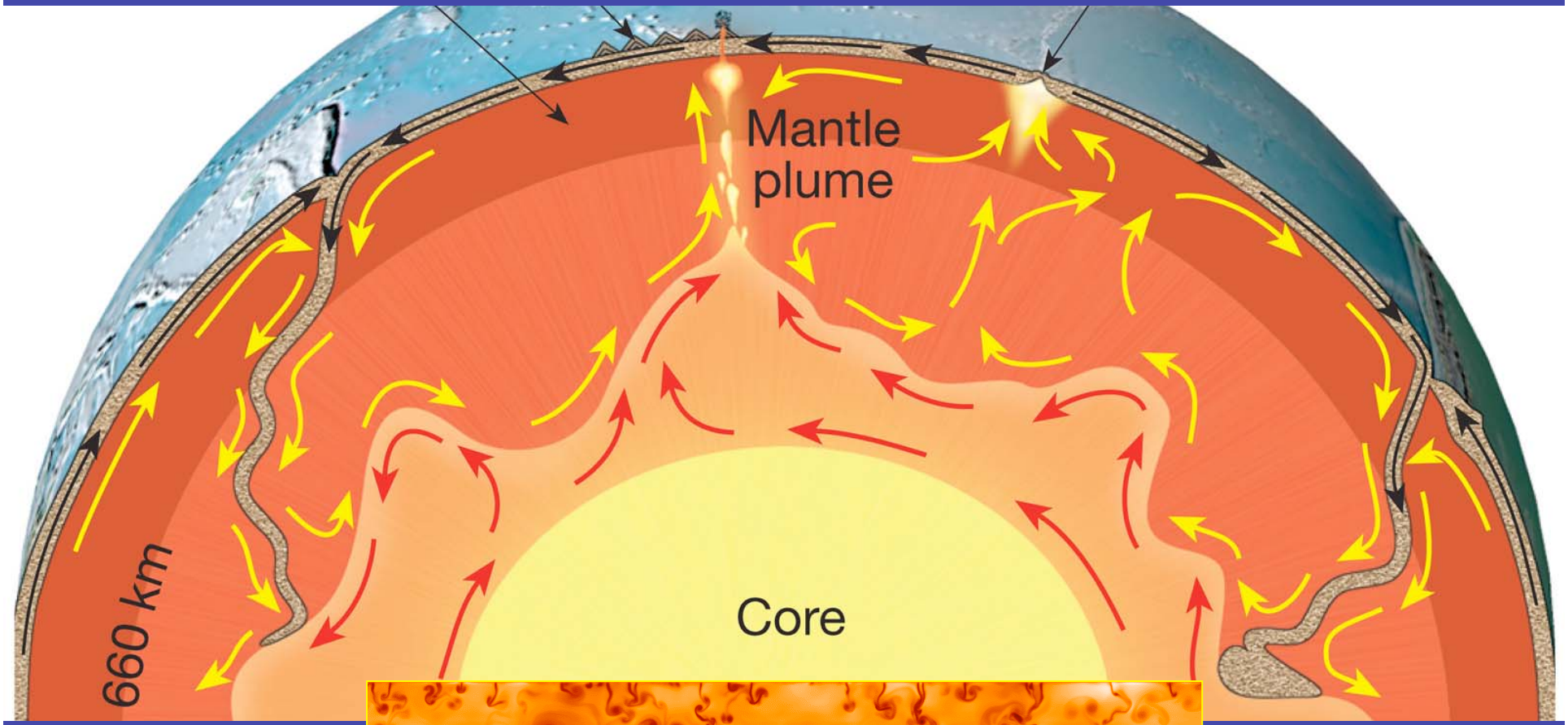
Earth’s magnetic field protects us from solar flares

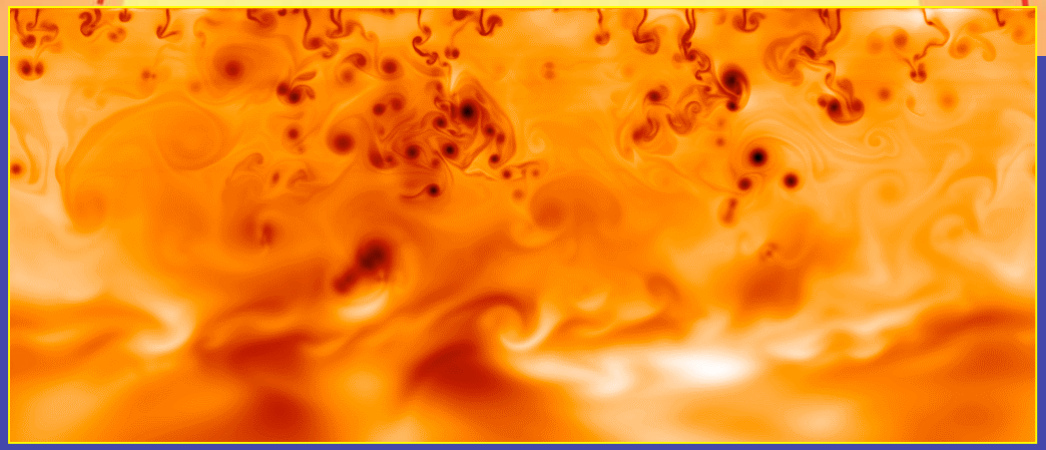


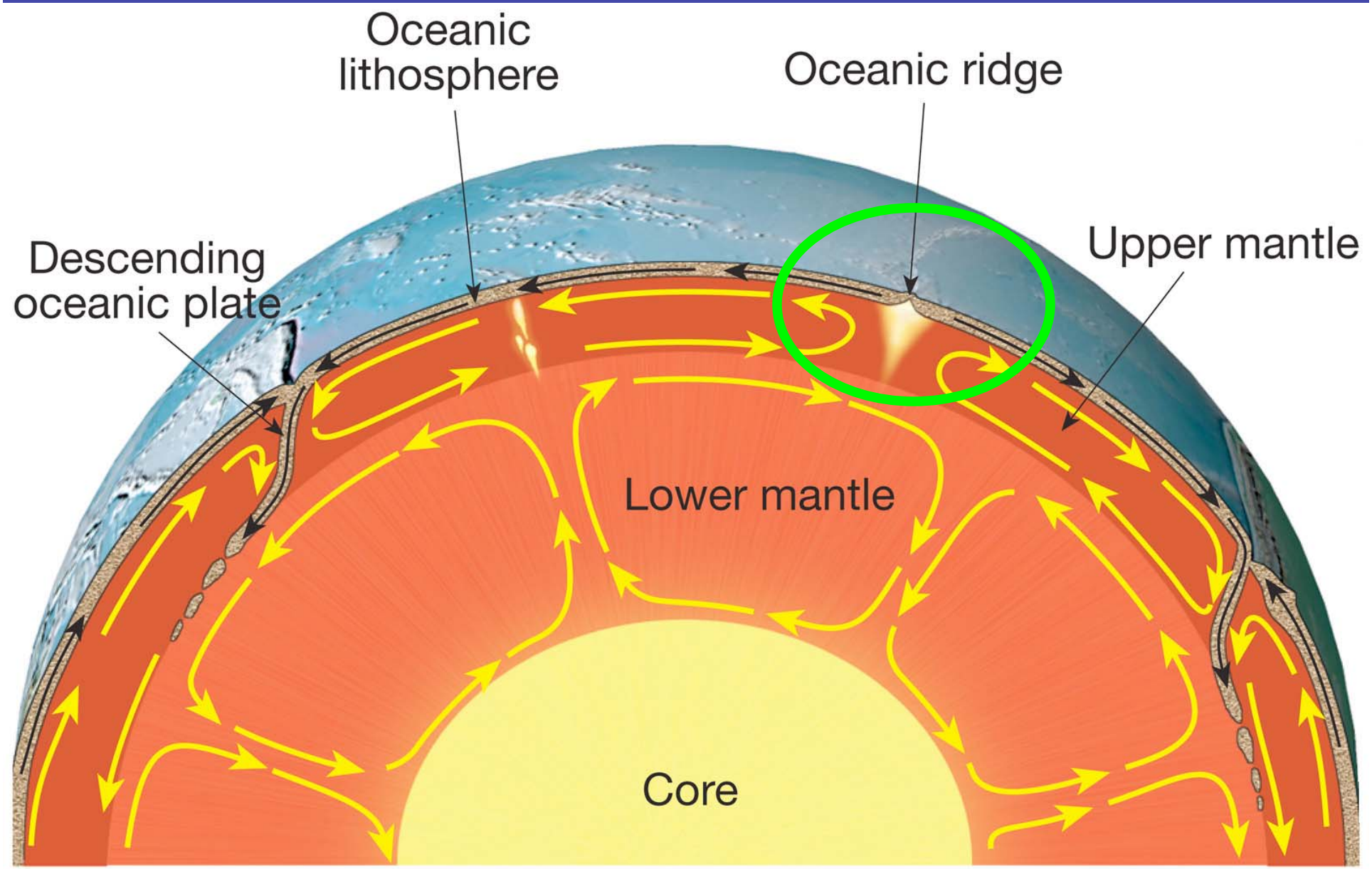
Earth's magnetic field + solar flares create Aurora (Borealis, Australis – Northern, Southern lights)



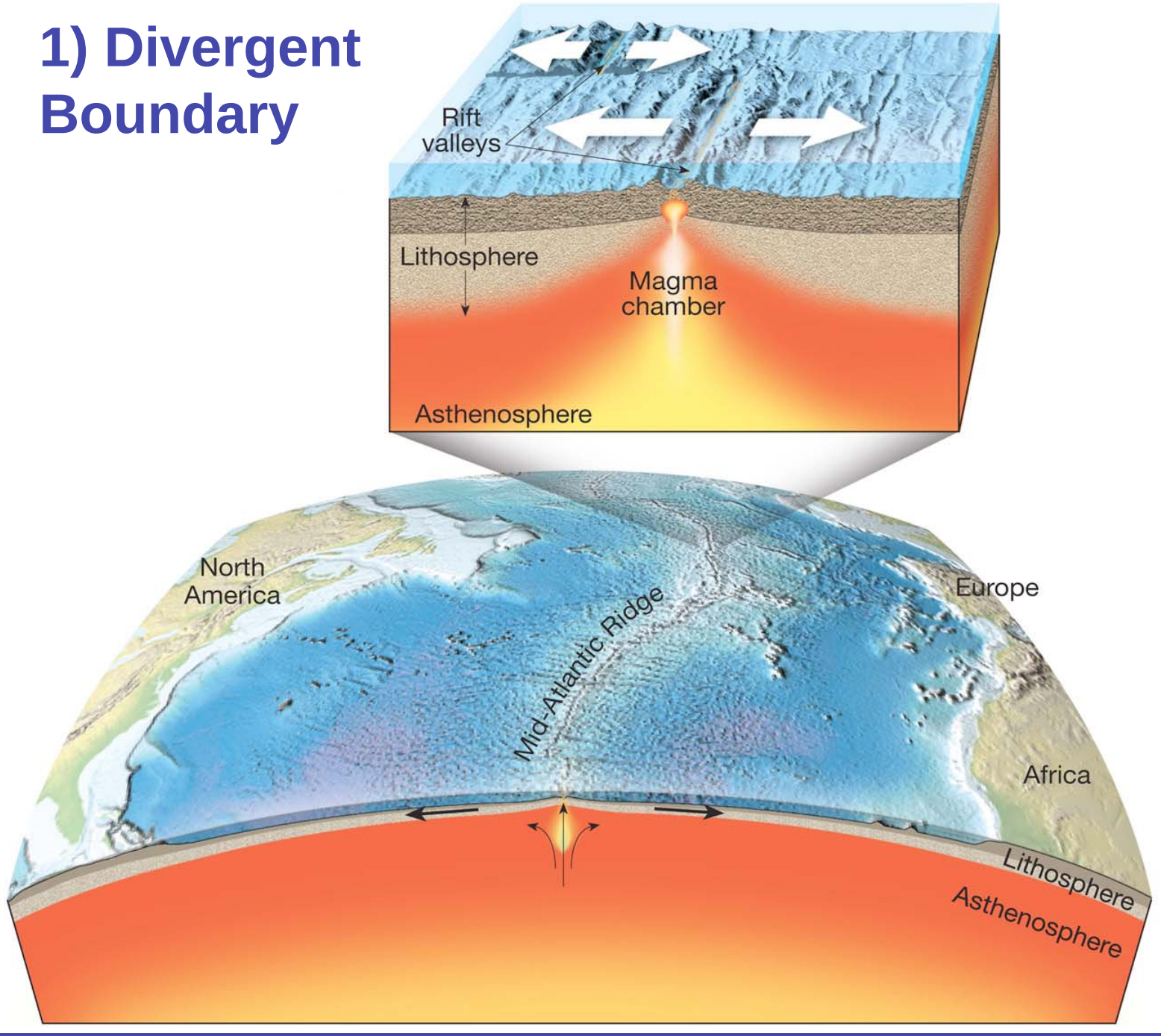
2) MANTLE CONVECTION – drives Plate Tectonics

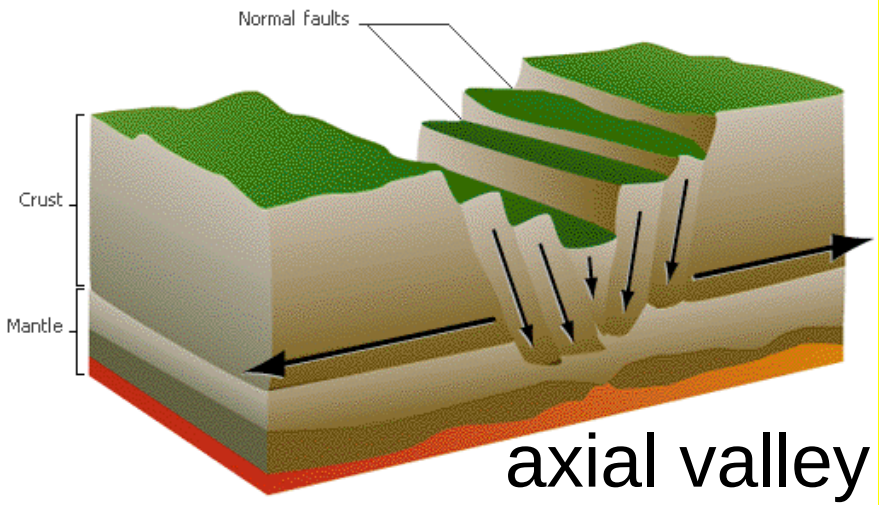





Oceanic lithosphere
Oceanic ridge
Descending oceanic plate
Upper mantle
Lower mantle
Core

1) Divergent Boundary





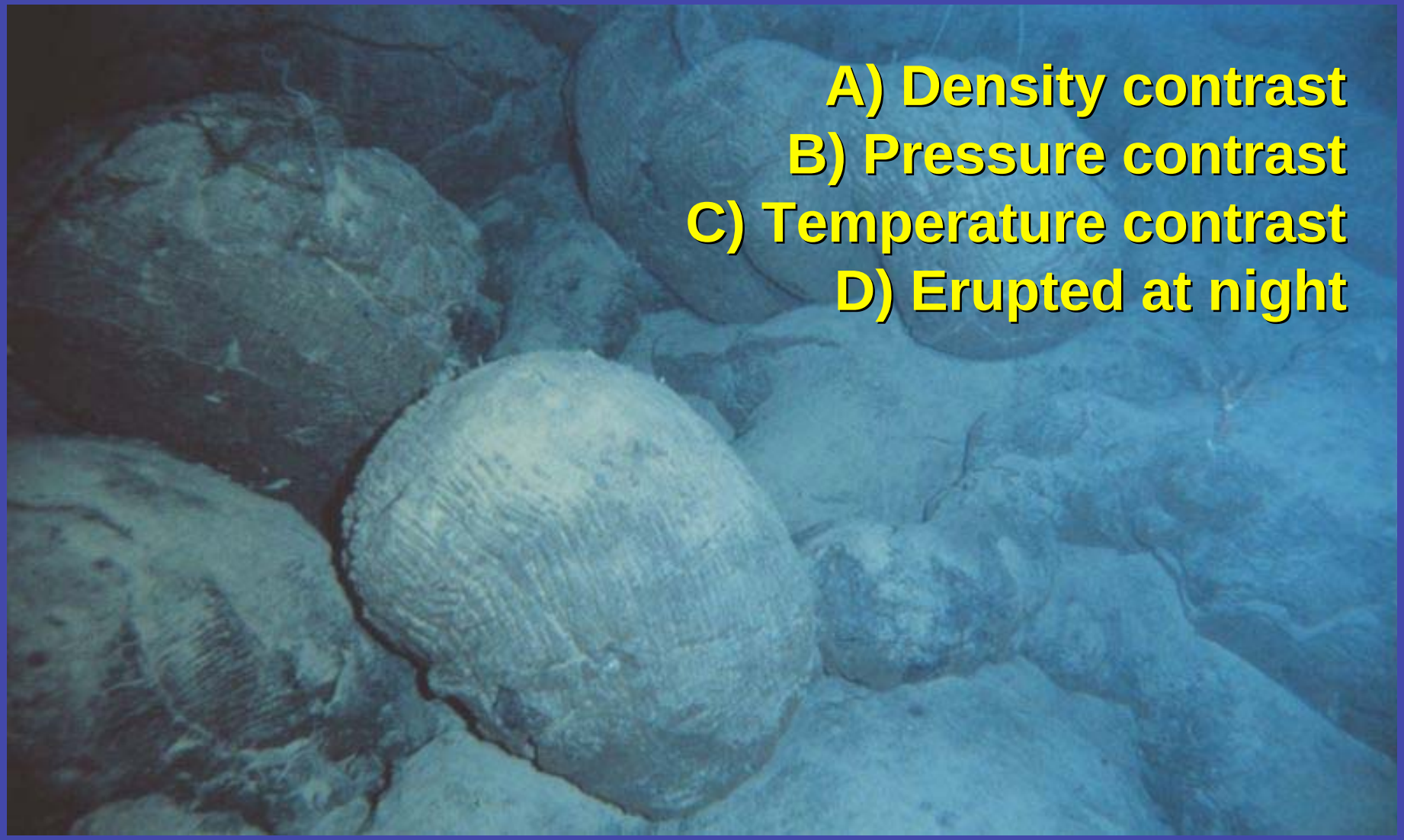
axial valley

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

Divergent boundary
oceanic example – East Pacific Rise

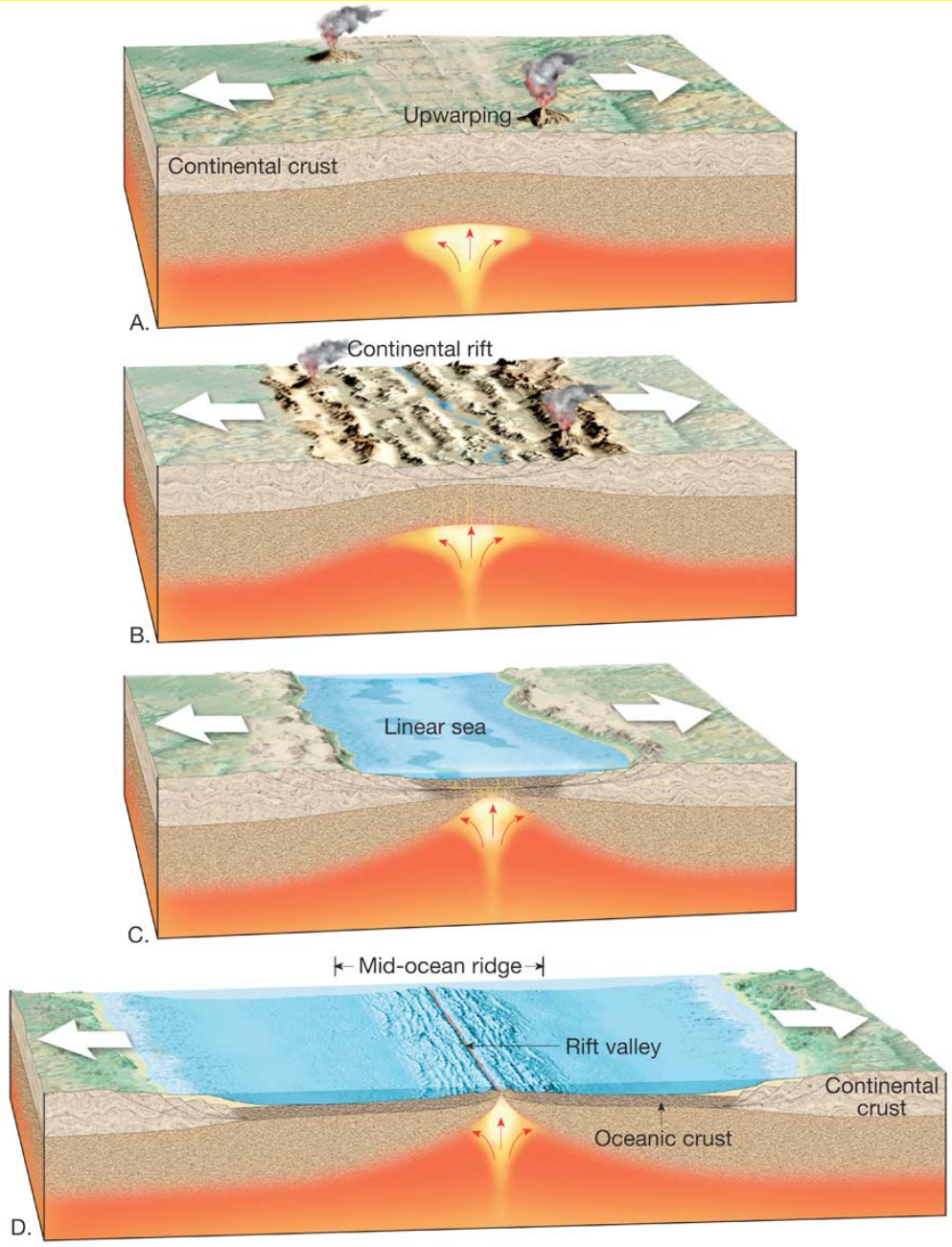


What causes the “pillow” shape of these lavas?



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

Divergent boundary – continental example



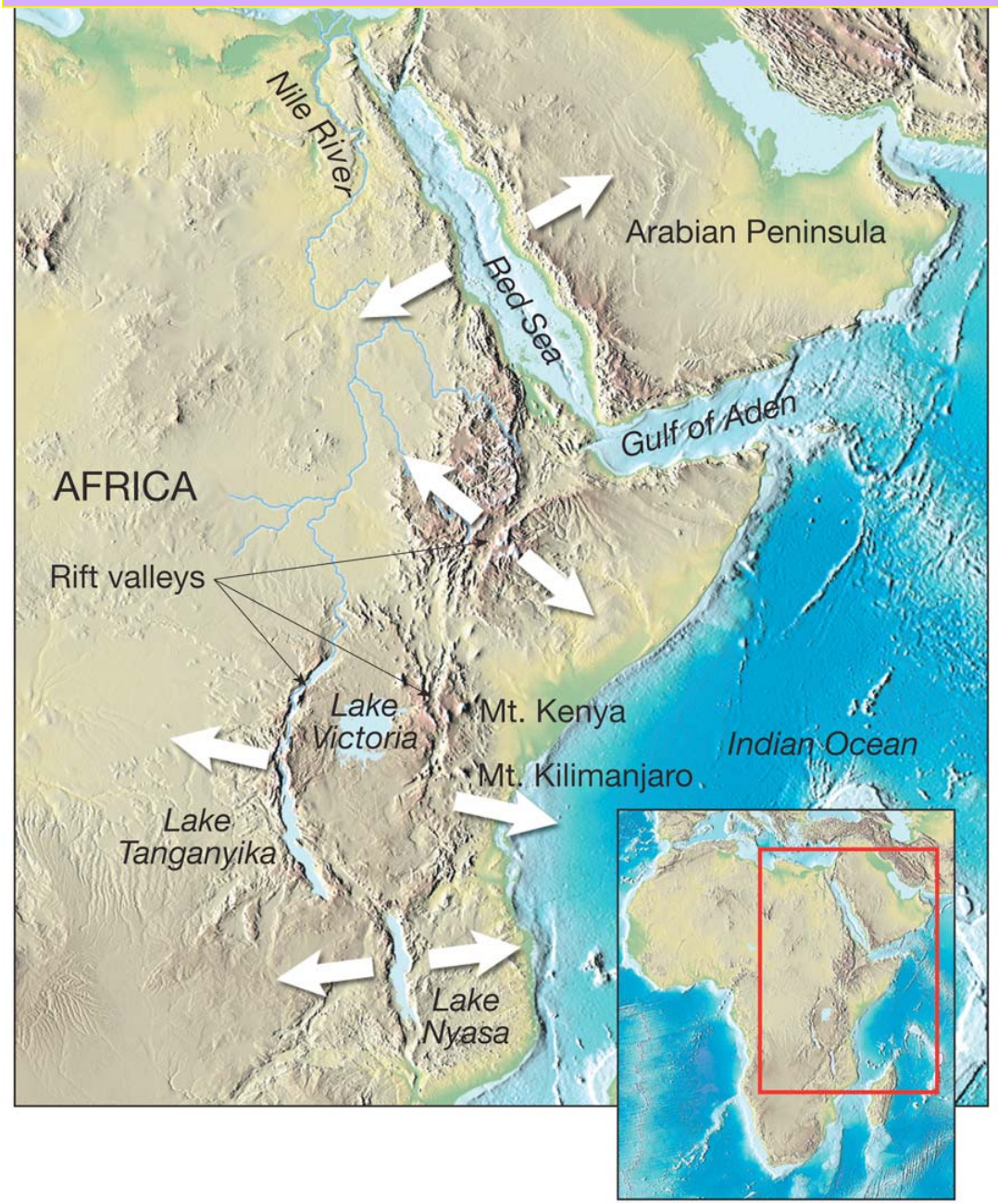
Upwarping, volcanism

Elongated rift valley

Narrow, linear sea

Seafloor spreading

Divergent boundary – East African Rift Valley

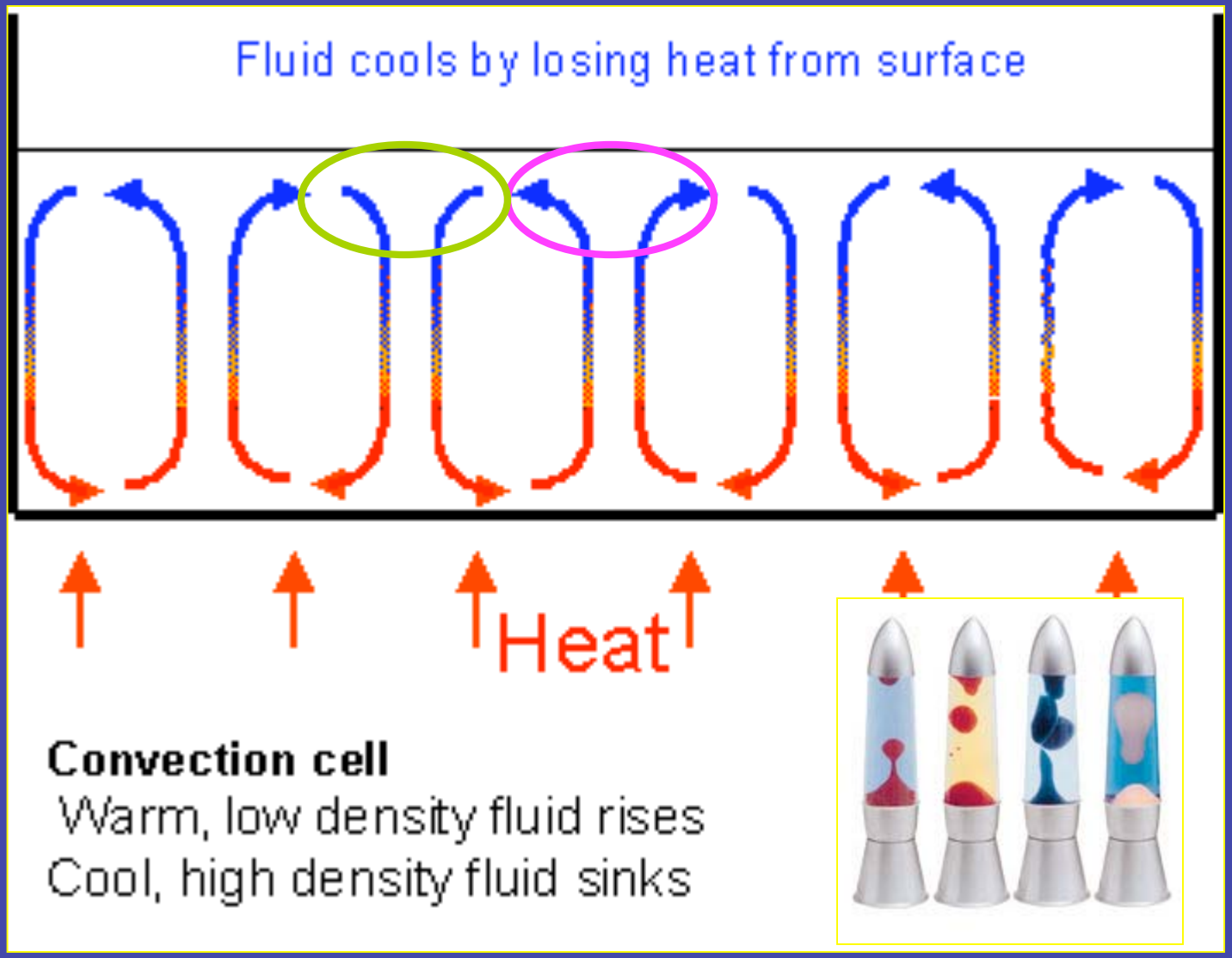




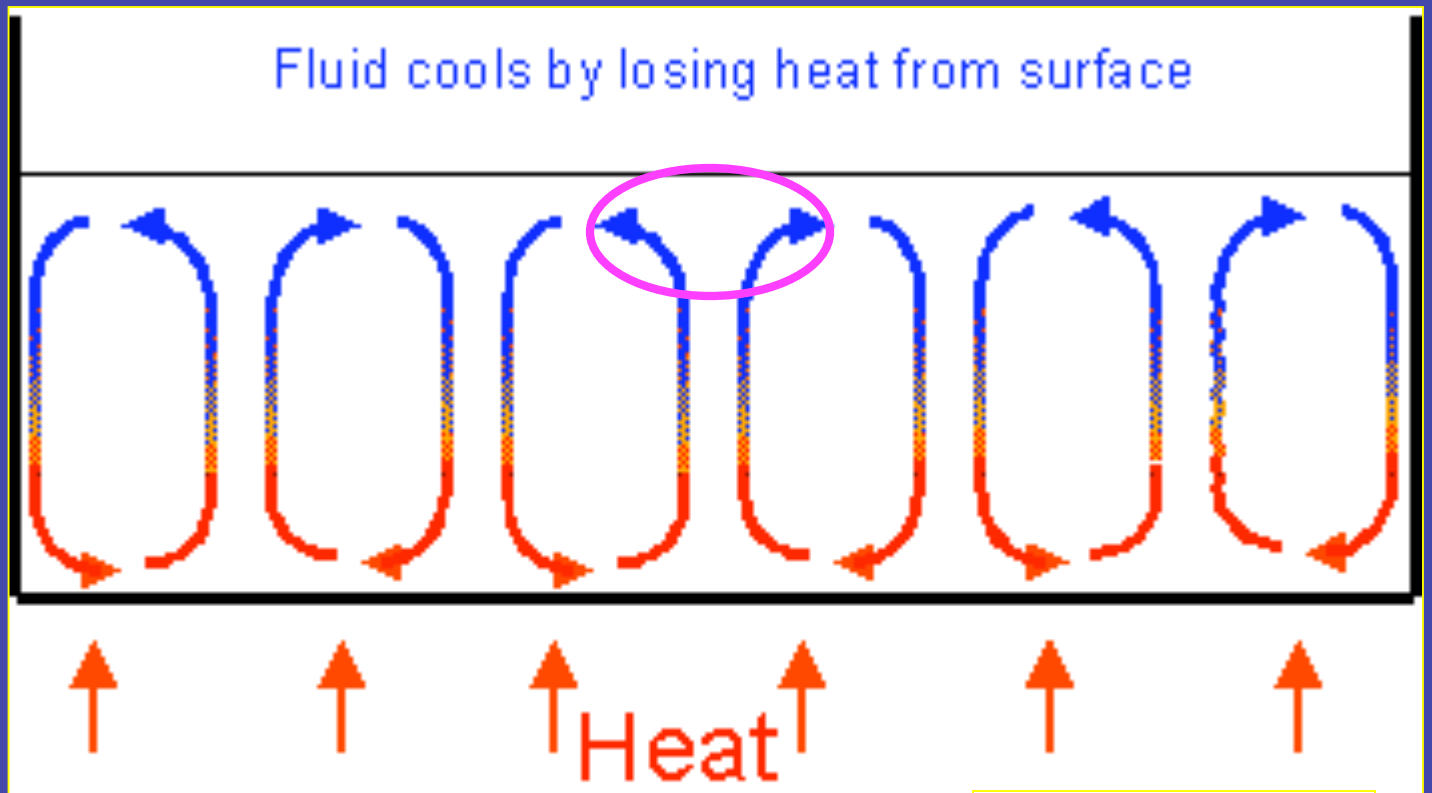








What does DIVERGENCE correspond to, A) or B) ?



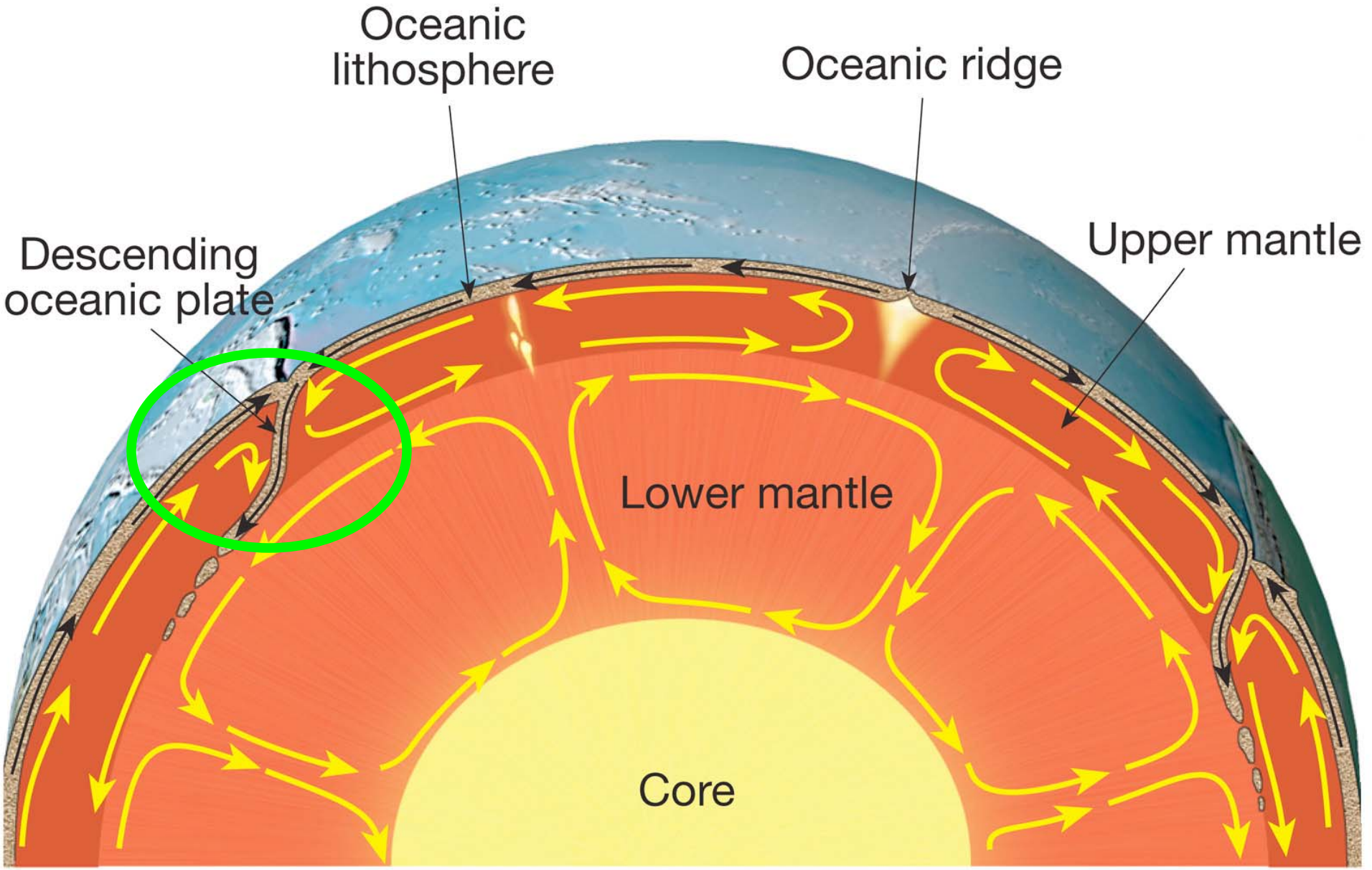
Convection cell

Warm, low density fluid rises

Cool, high density fluid sinks



DIVERGENCE

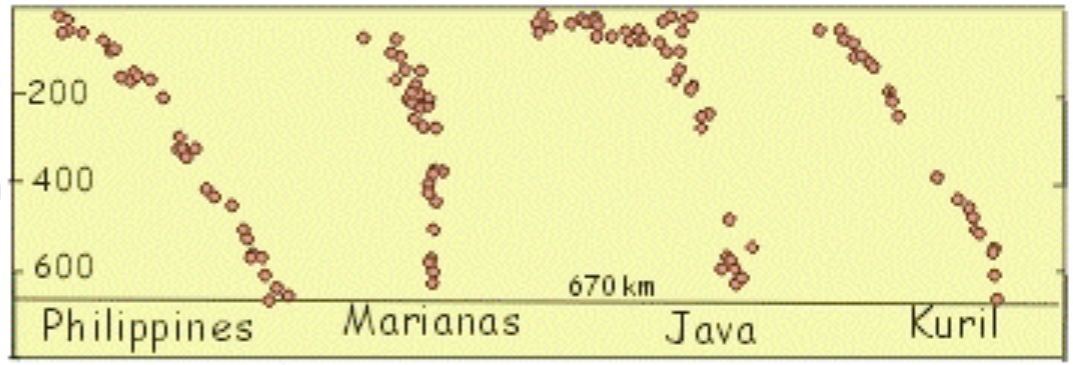


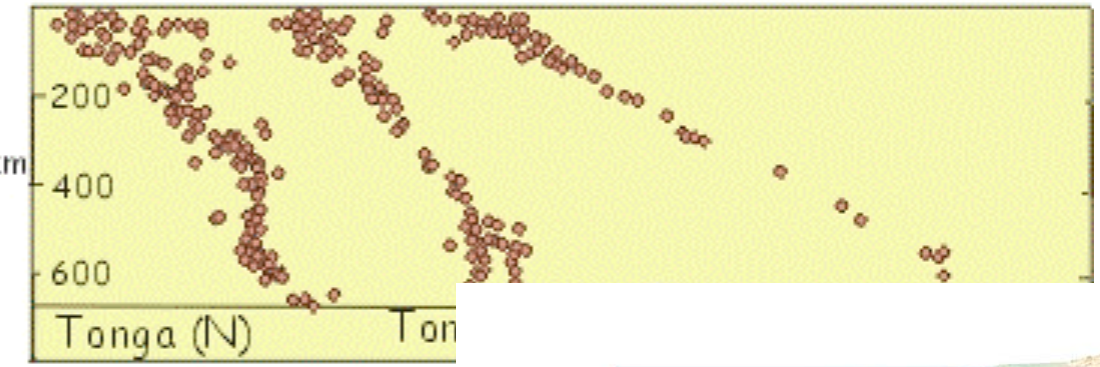
How do we know where these are?

Convergent boundary – Wadati-Benioff zones

Earthquakes and the dip of Wadati-Benioff seismic zones

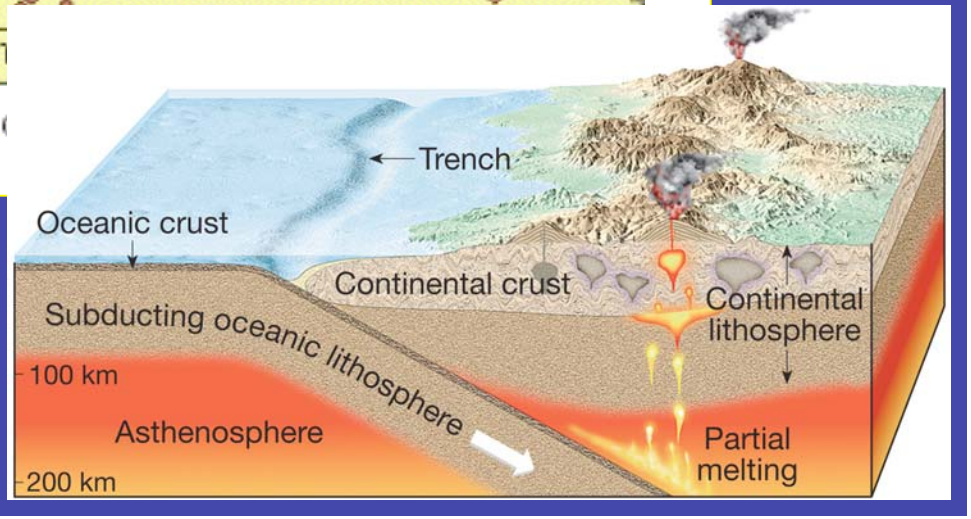




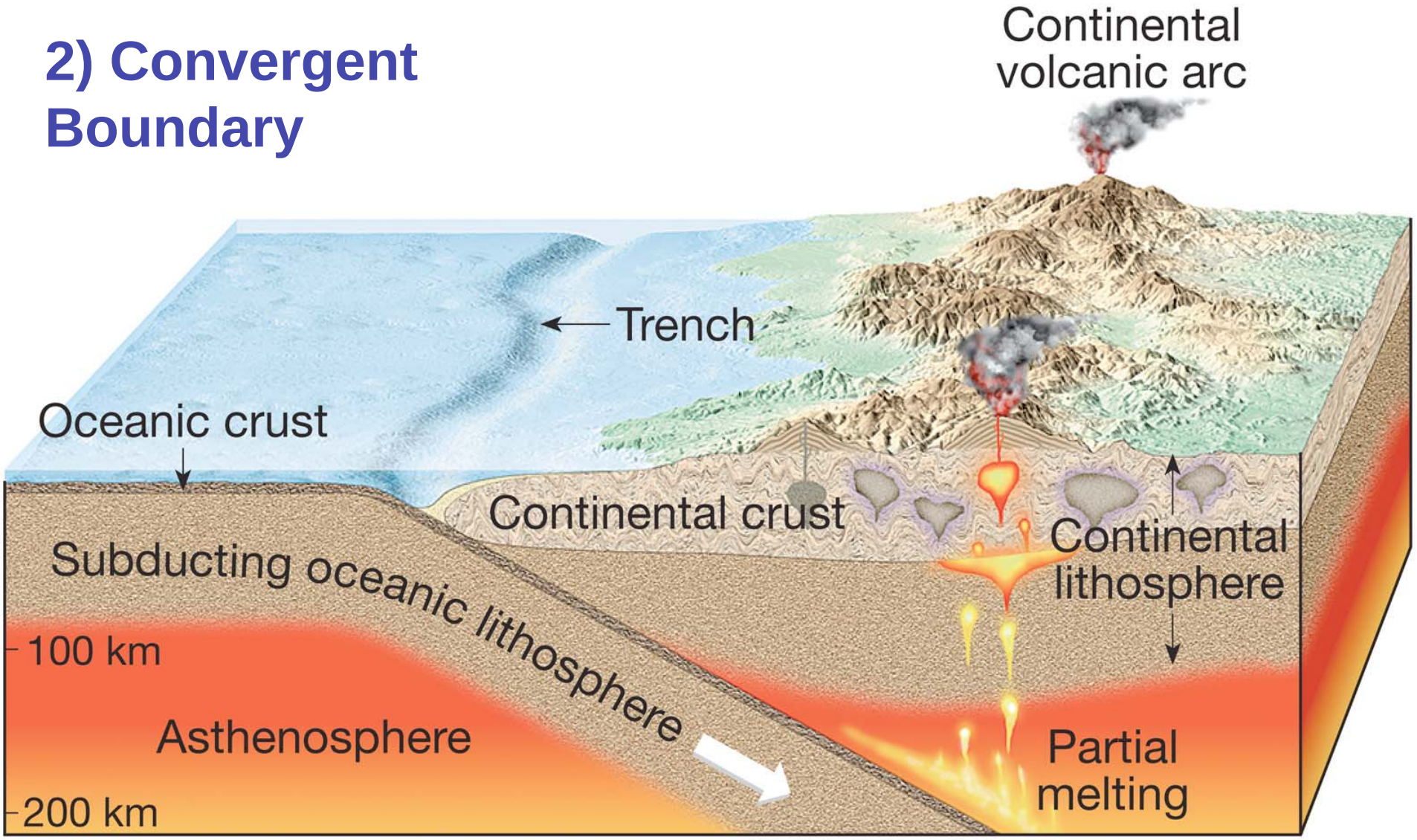


vertical an

Subducting oceanic crust



2) Convergent Boundary



Oceanic Trench

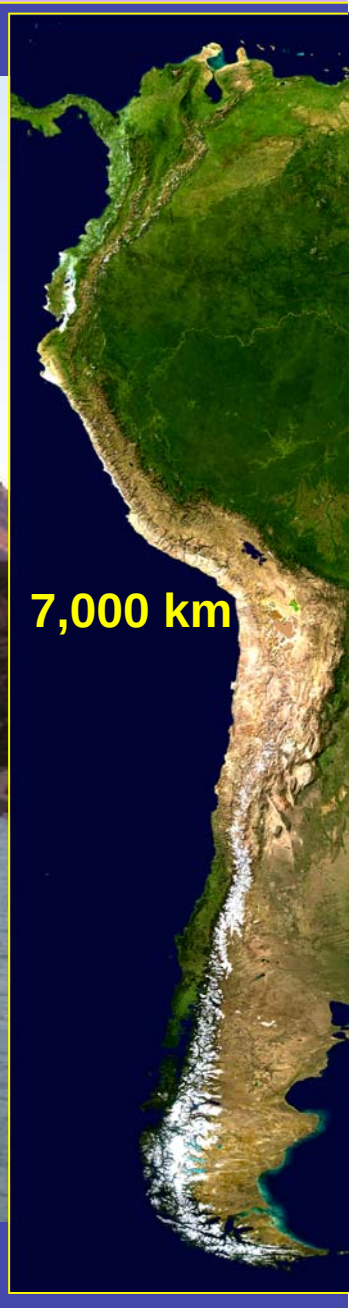
Why does one side sink and the other float?

Convergent boundary – oceanic-continental

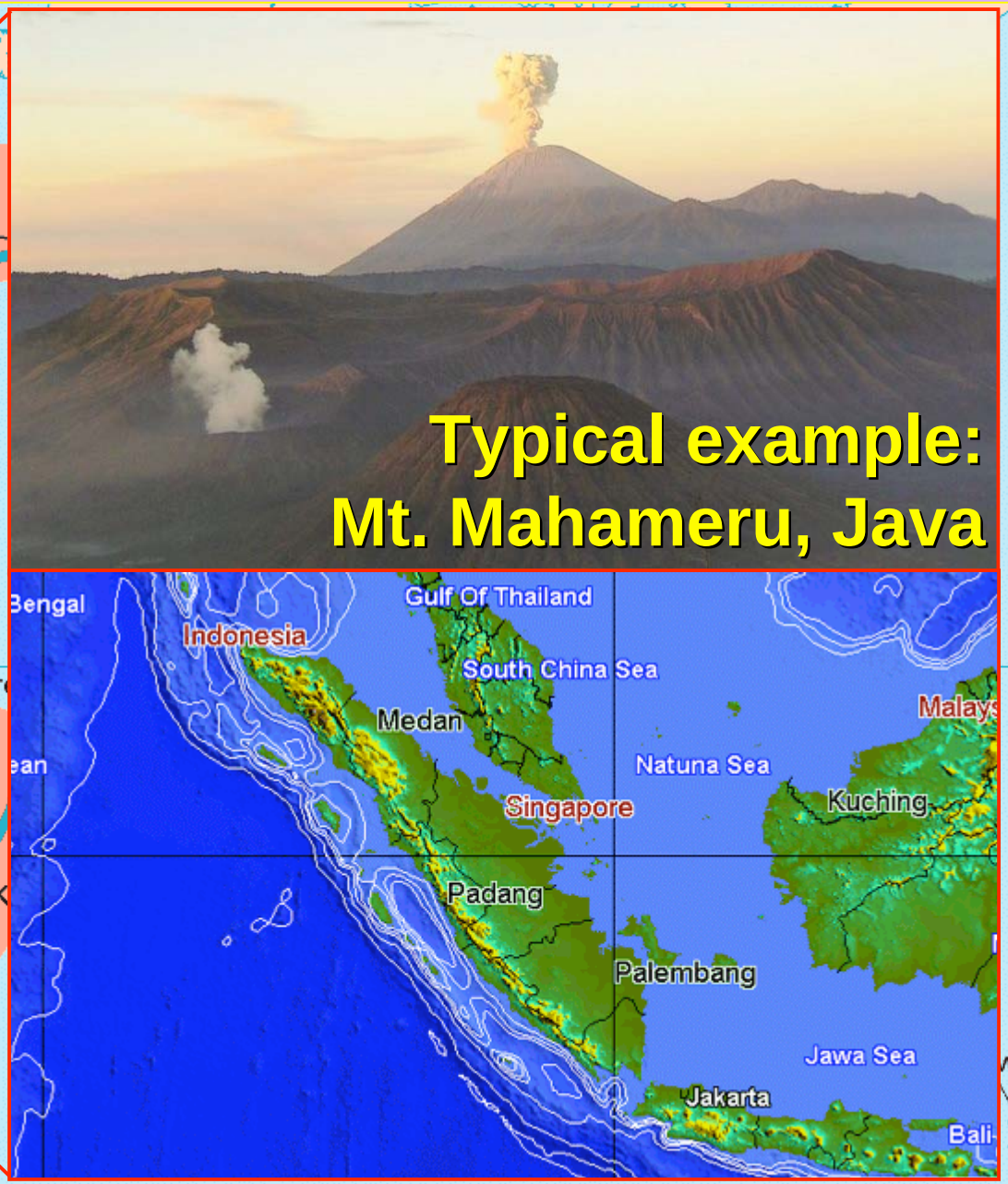


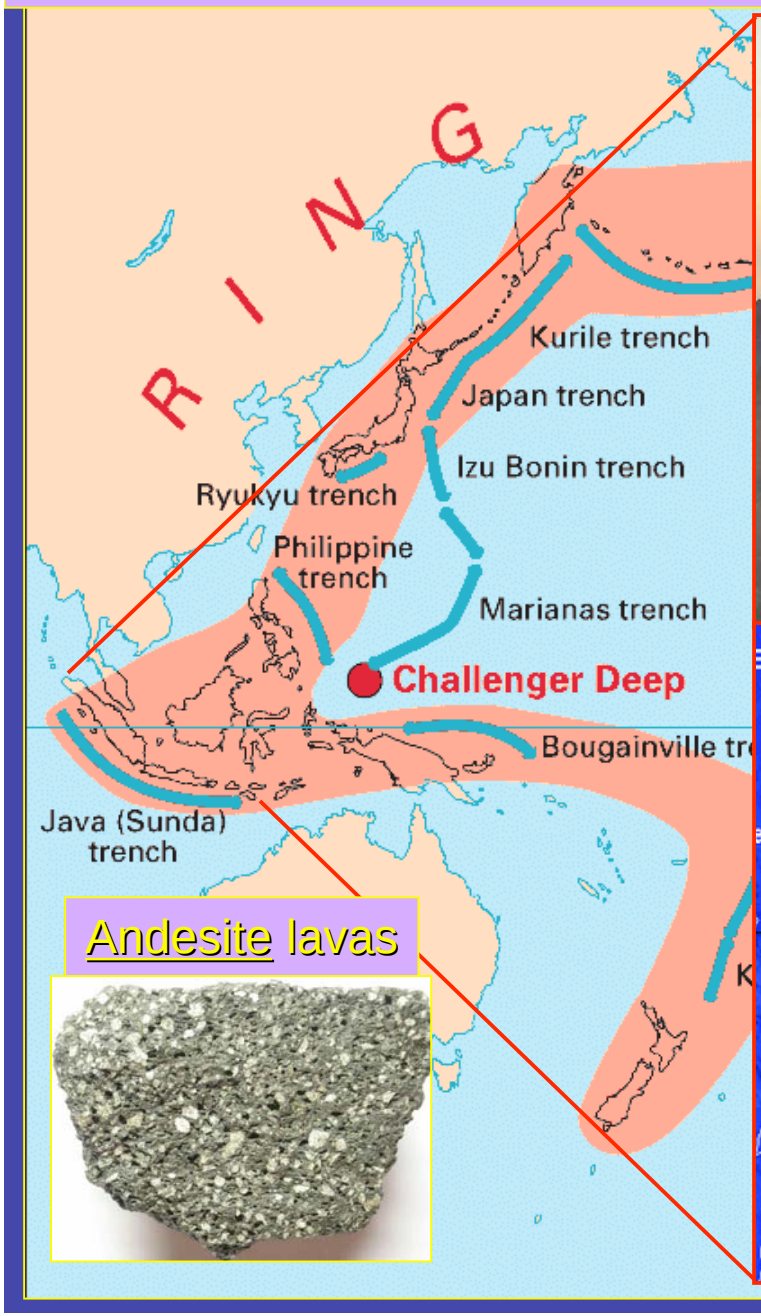
Typical Example –
Andes mountain range

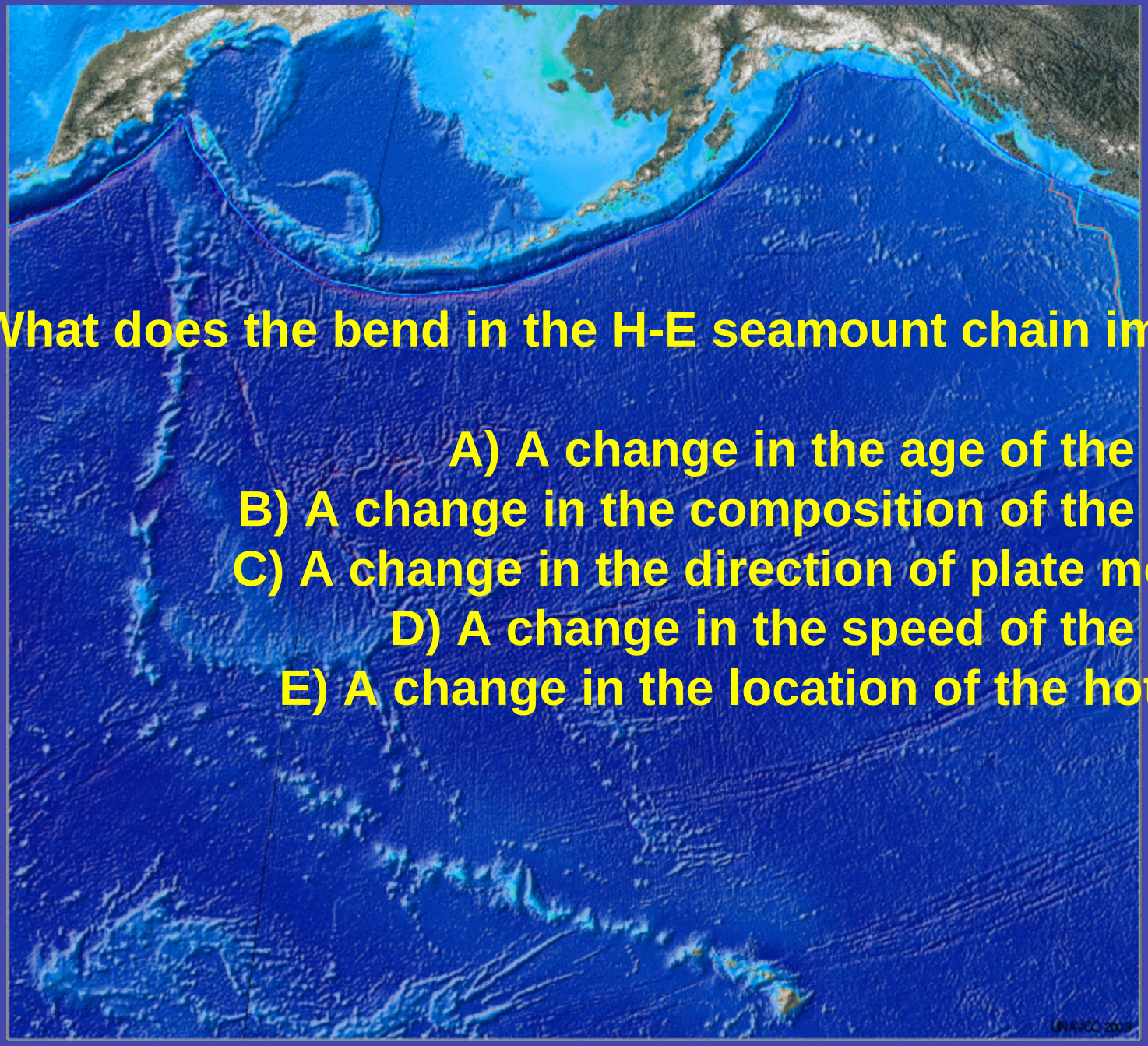
Andesite lavas



Convergent boundary – oceanic-oceanic

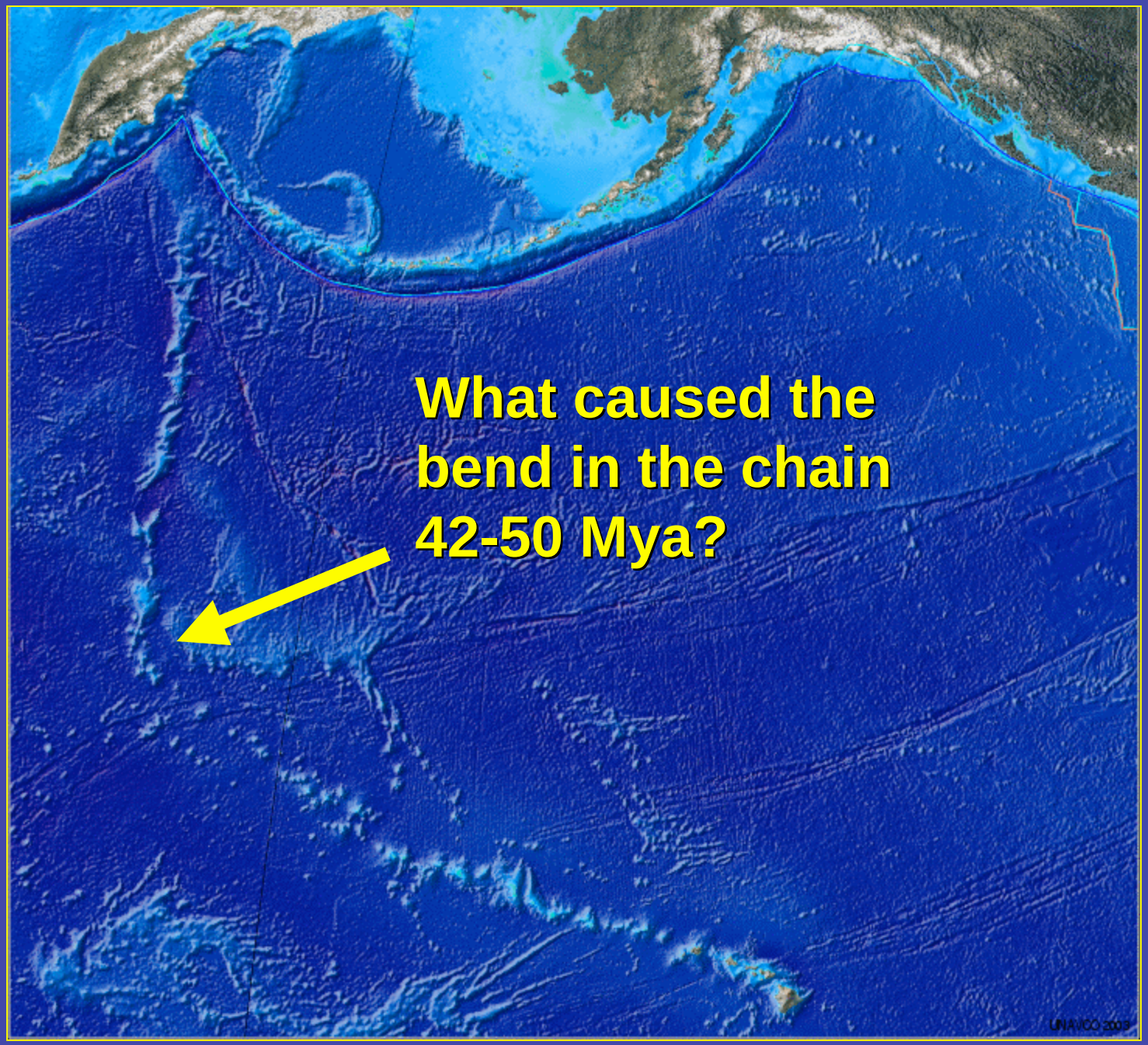




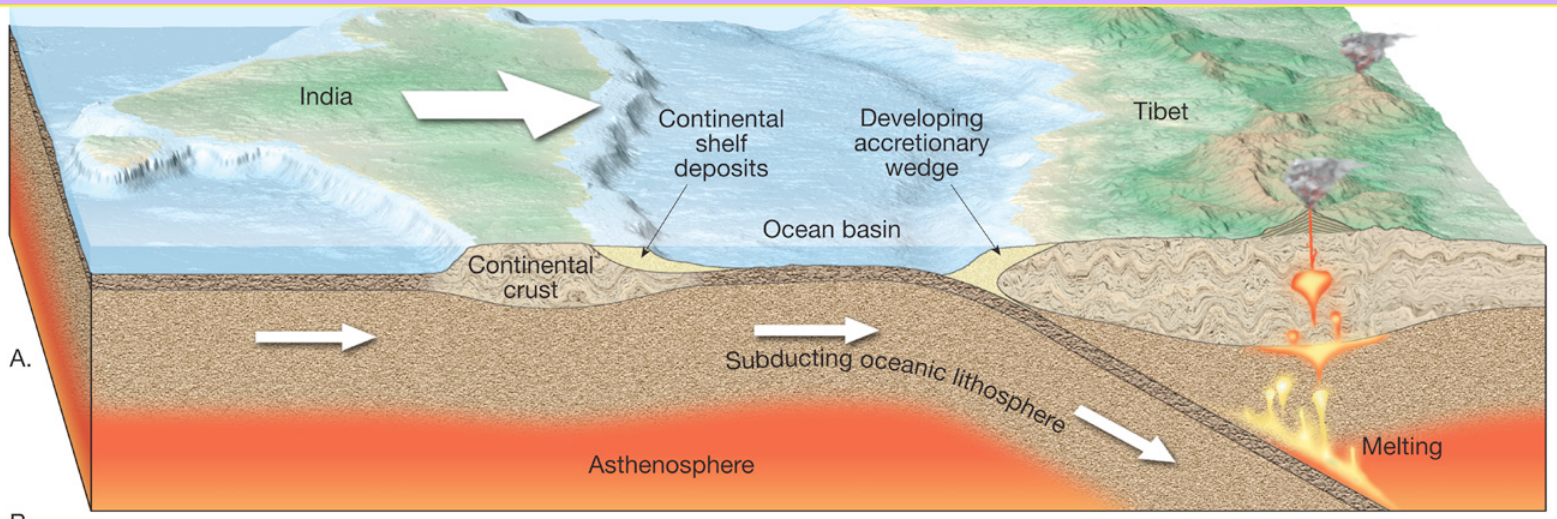


What does the bend in the H-E seamount chain imply?

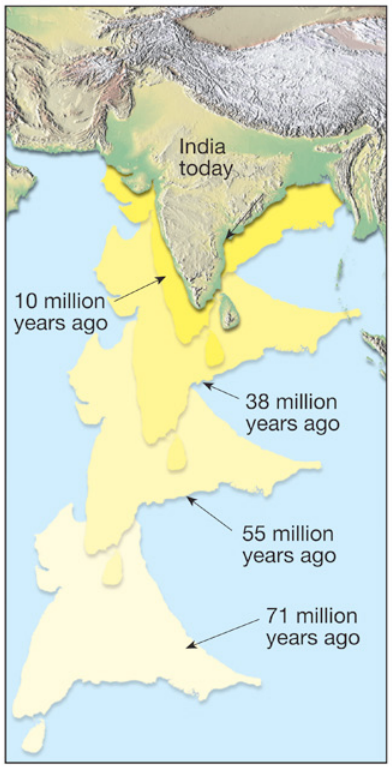
A) A change in the age of the plate
B) A change in the composition of the plate
C) A change in the direction of plate motion
D) A change in the speed of the plate
E) A change in the location of the hotspot

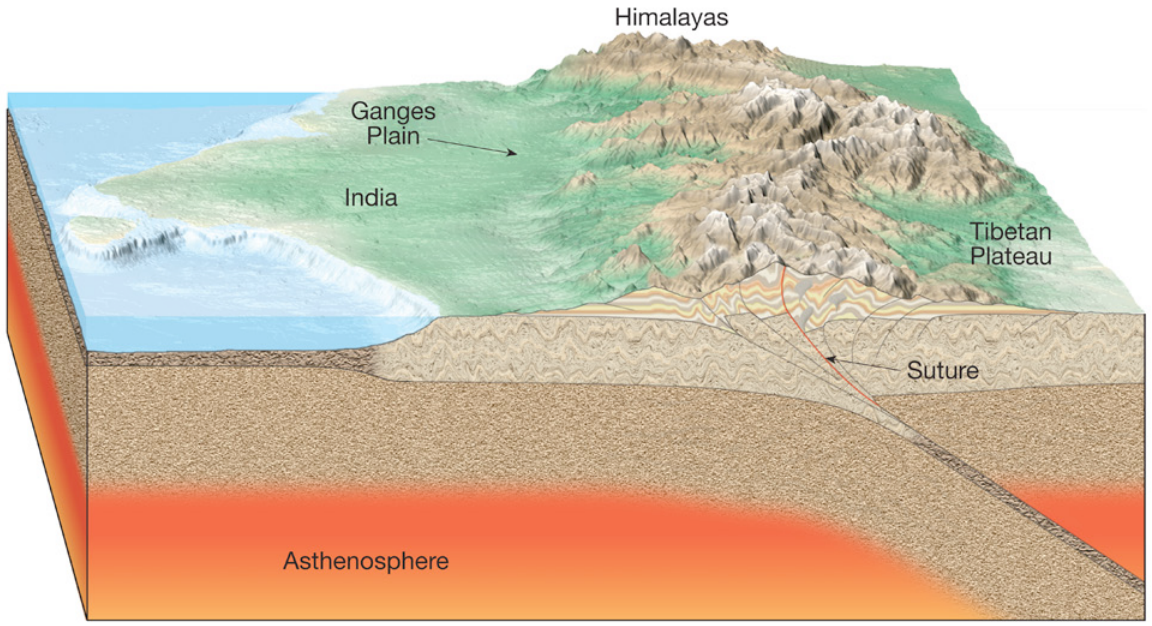

What caused the bend in the chain 42-50 Mya?

Convergent boundary – continental-continental



B.





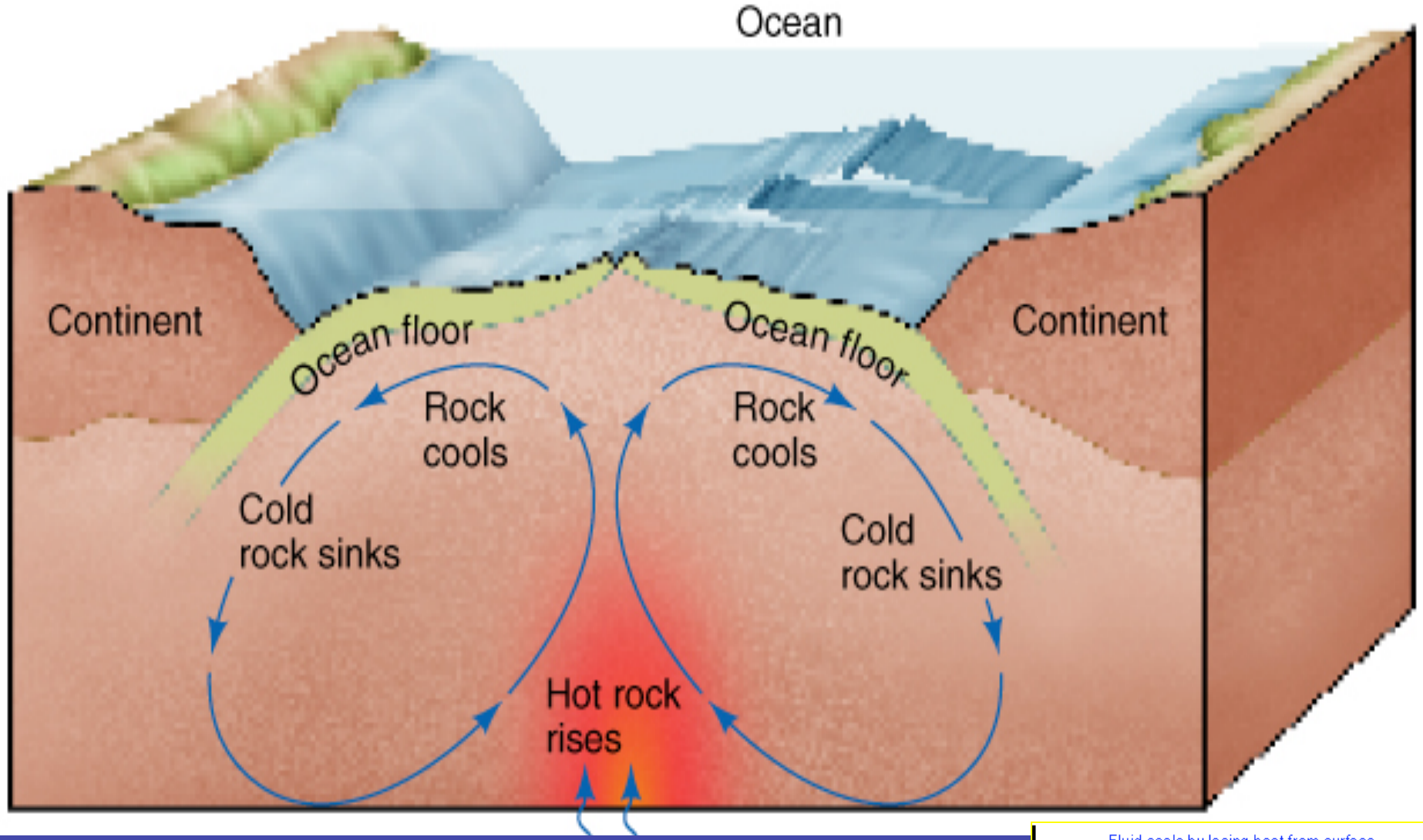
C.

Convergent boundary – continental-continental

Gneiss - metamorphic



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



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

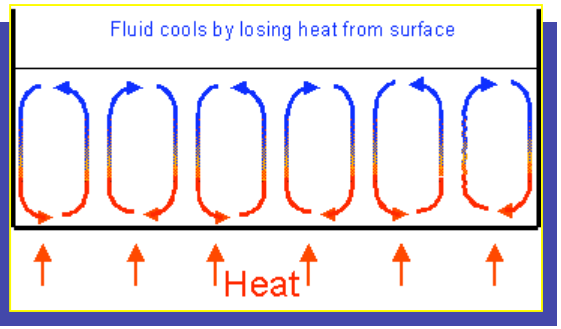
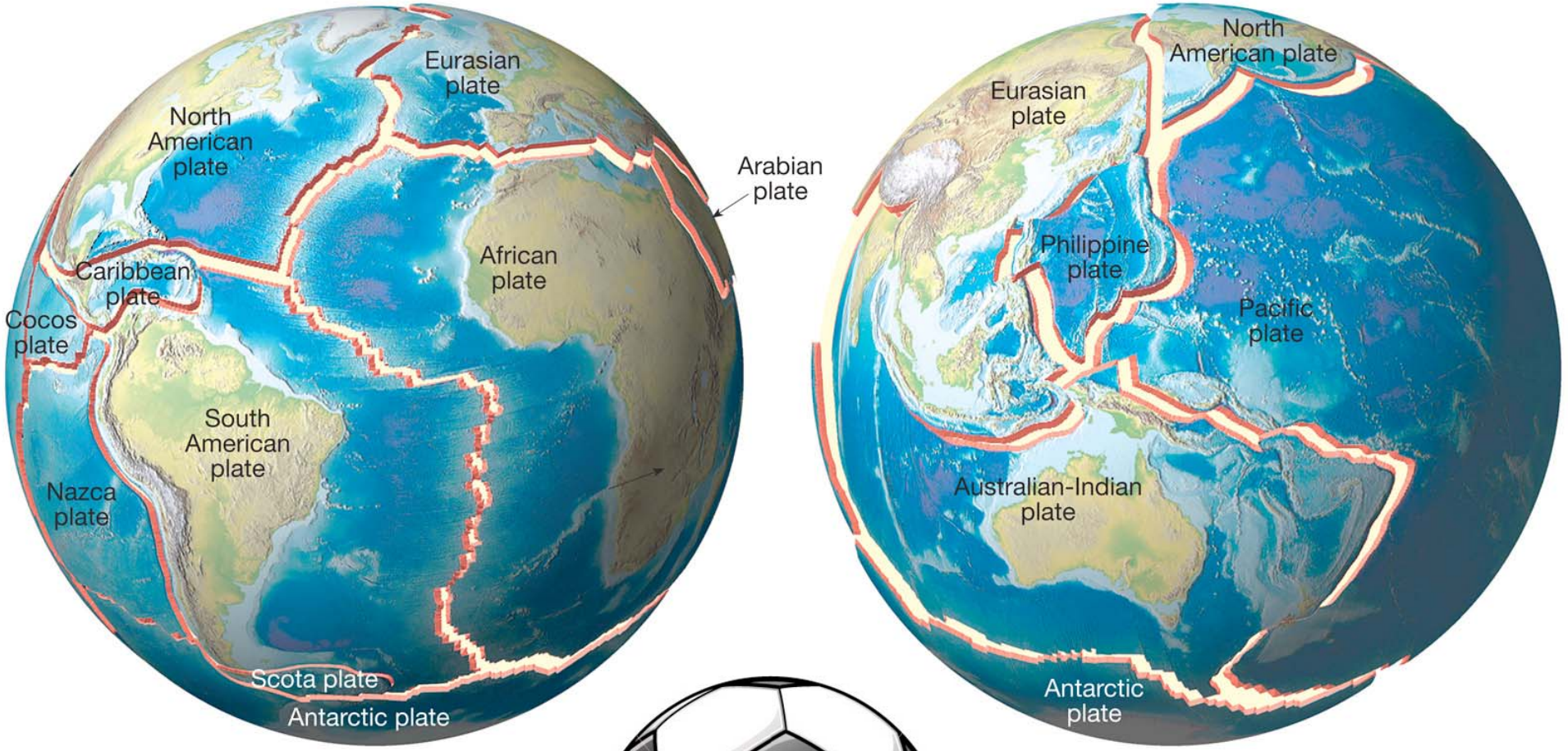
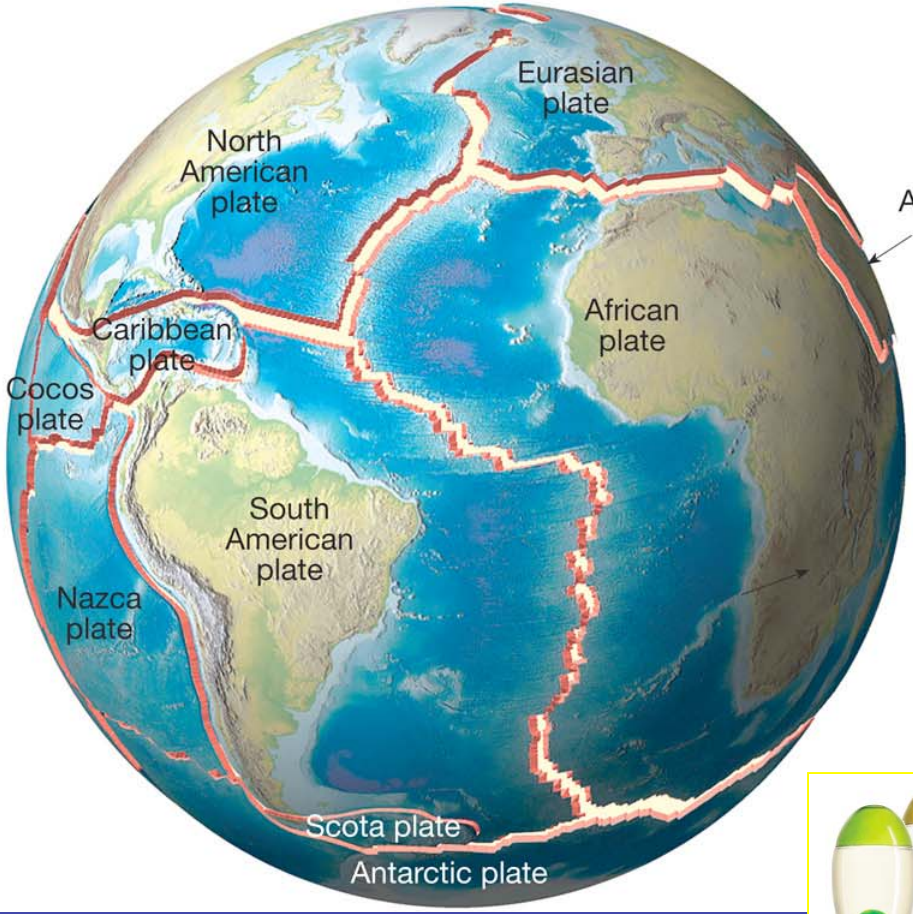


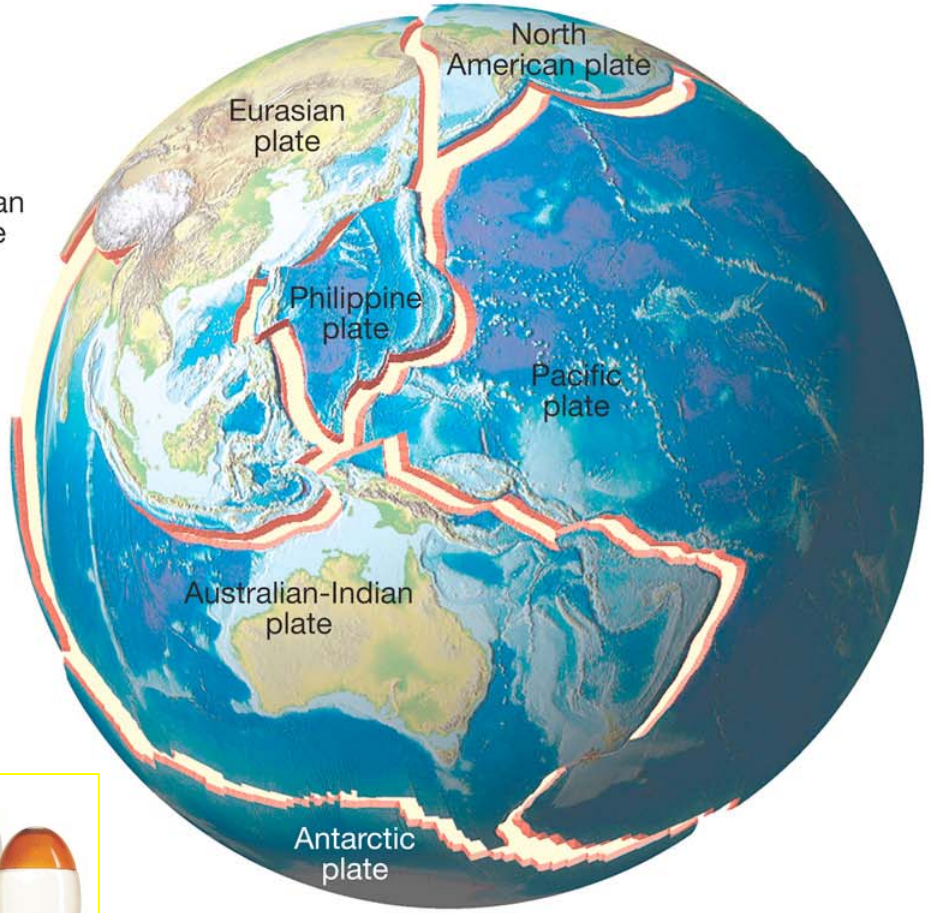
Plate boundaries: 1) ridges, 2) trenches, and 3)…?





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



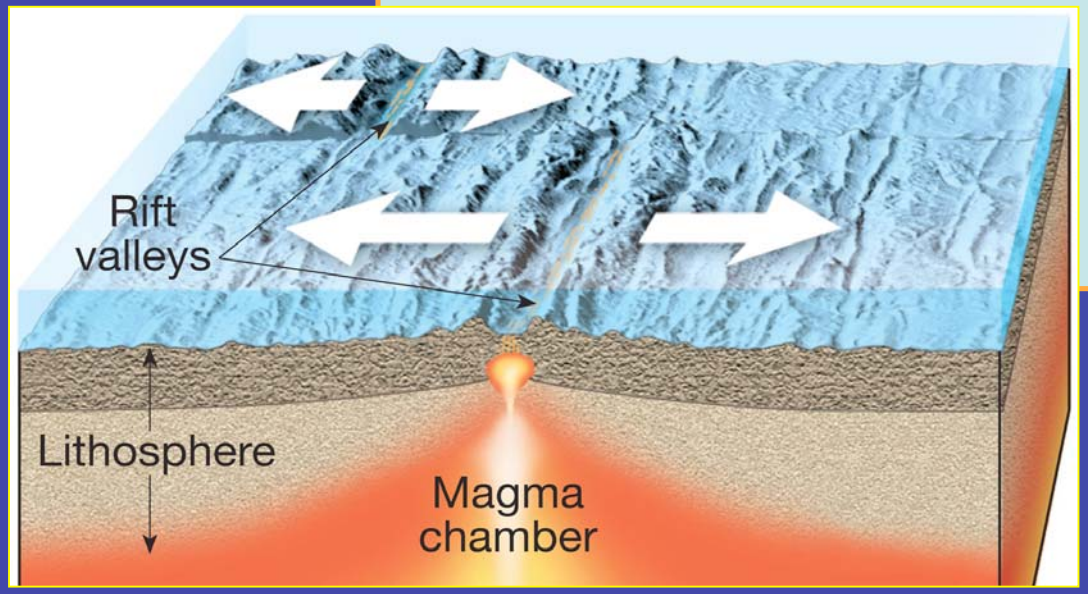




Transform faults are not directly related to mantle convection

…necessary for doing geometry on a sphere

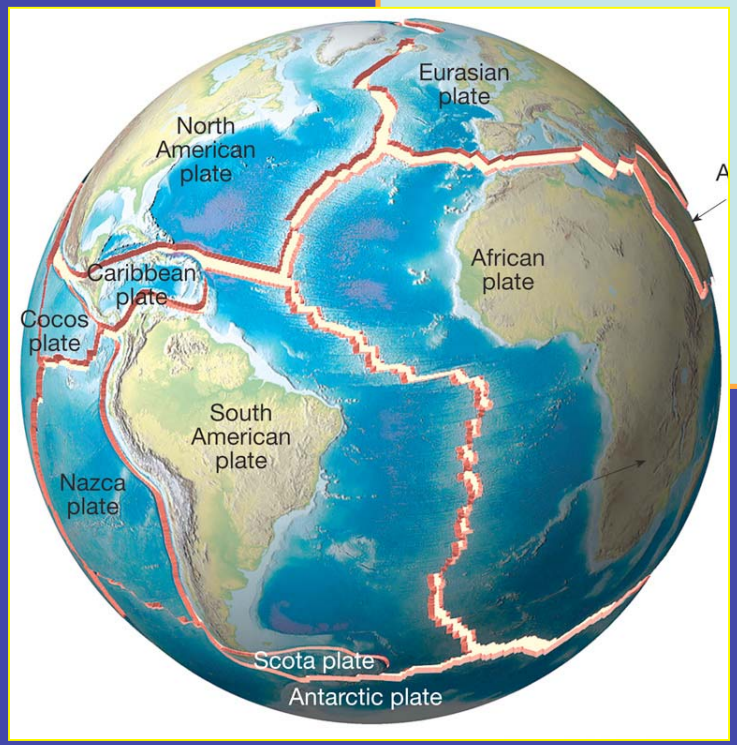
Transform fault boundary – oceanic



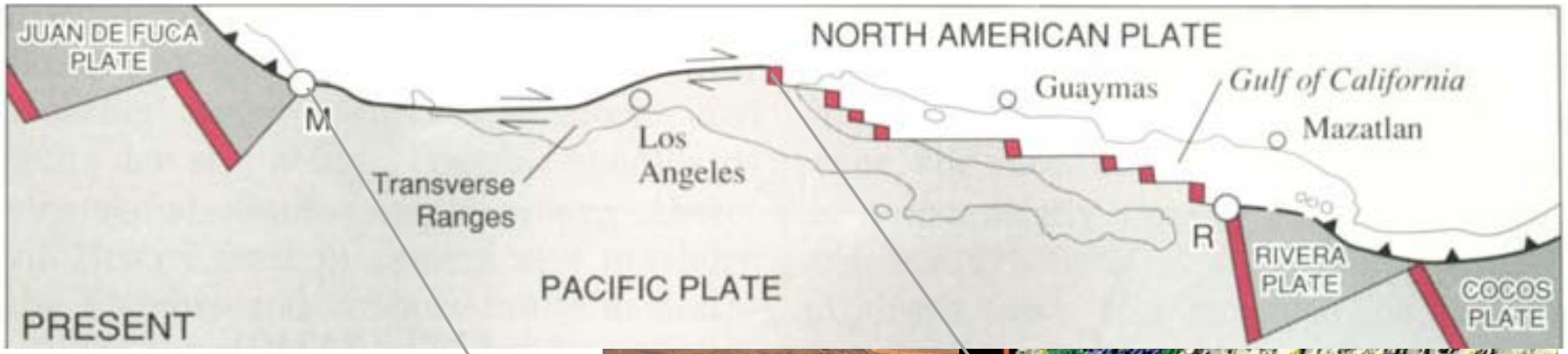
Spreading
ridges

Transform fault
vs. seafloor lineation

Accommodates transverse spreading geometry



Allows continents to split into irregular shapes

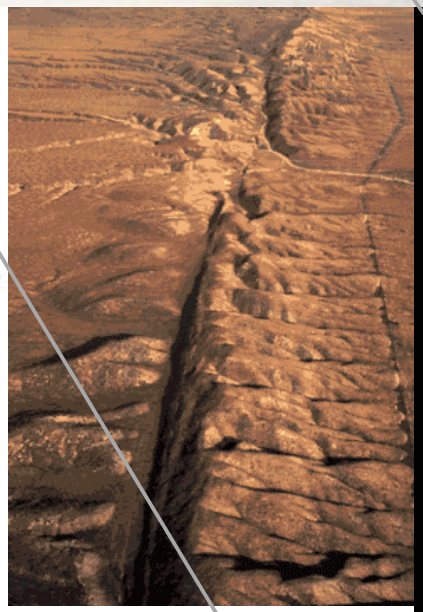


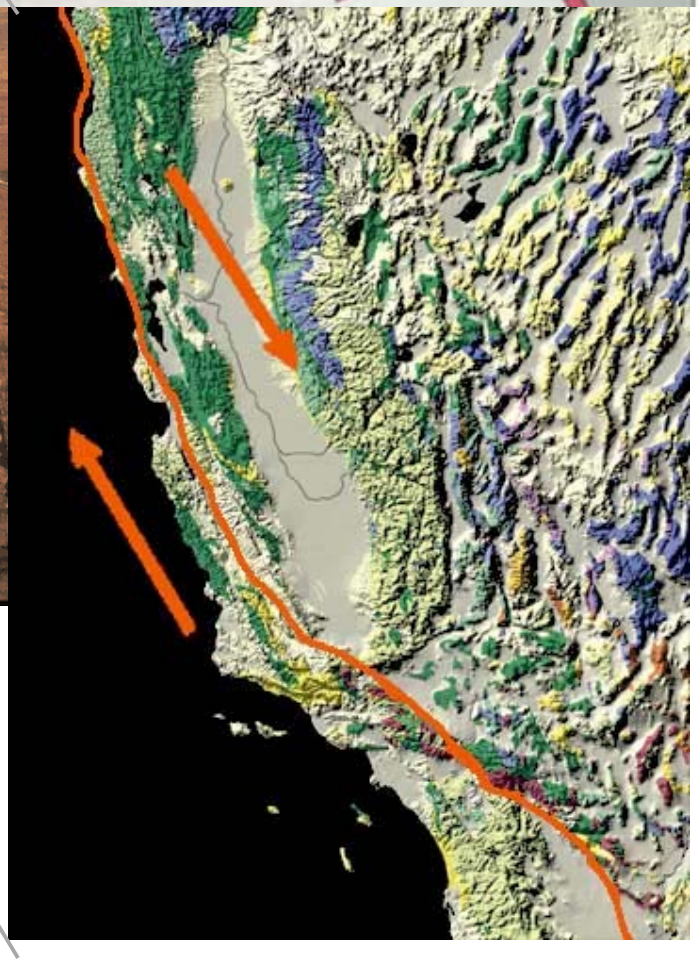
EXPLANATION

Spreading center

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

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

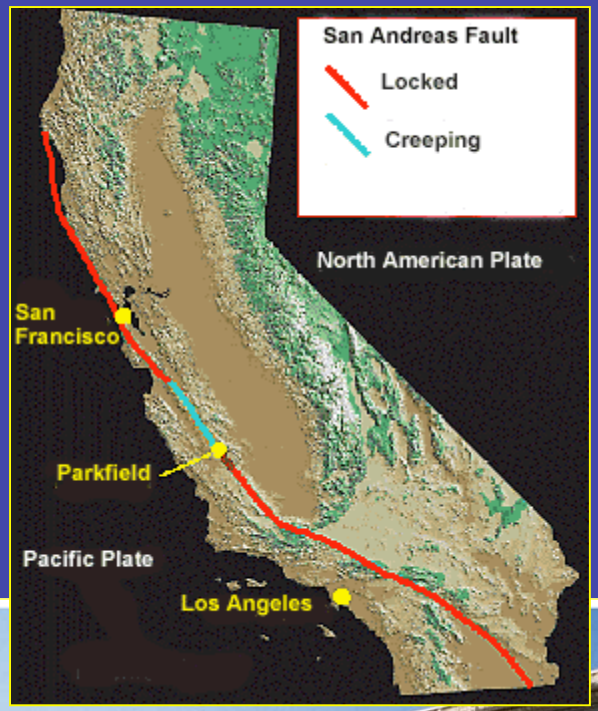


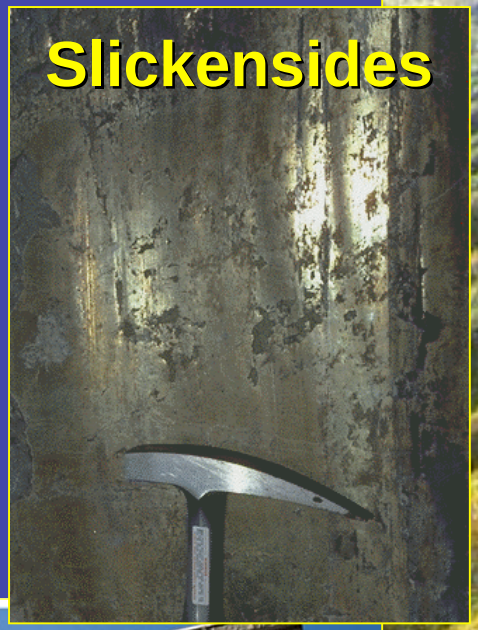


Transform faults can also occur on land

San Andreas separates Pacific and North American Plates

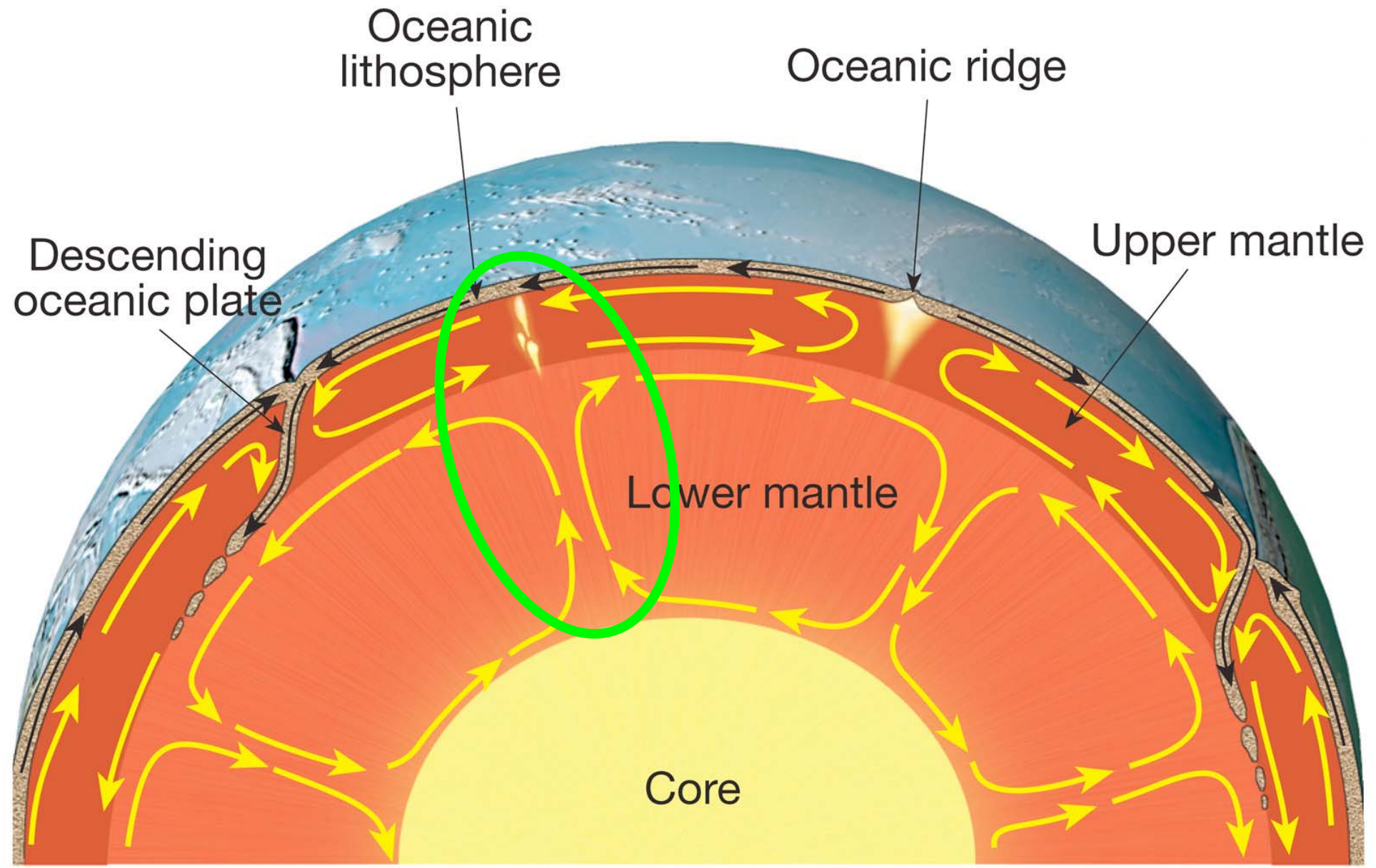
Transform fault boundary – continental

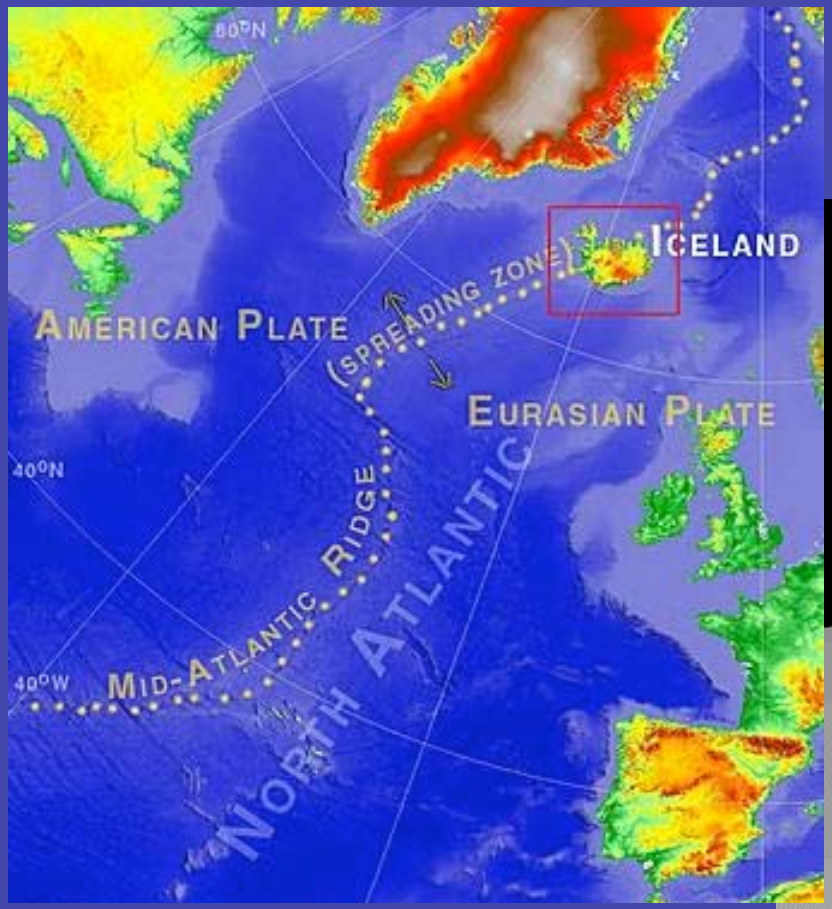




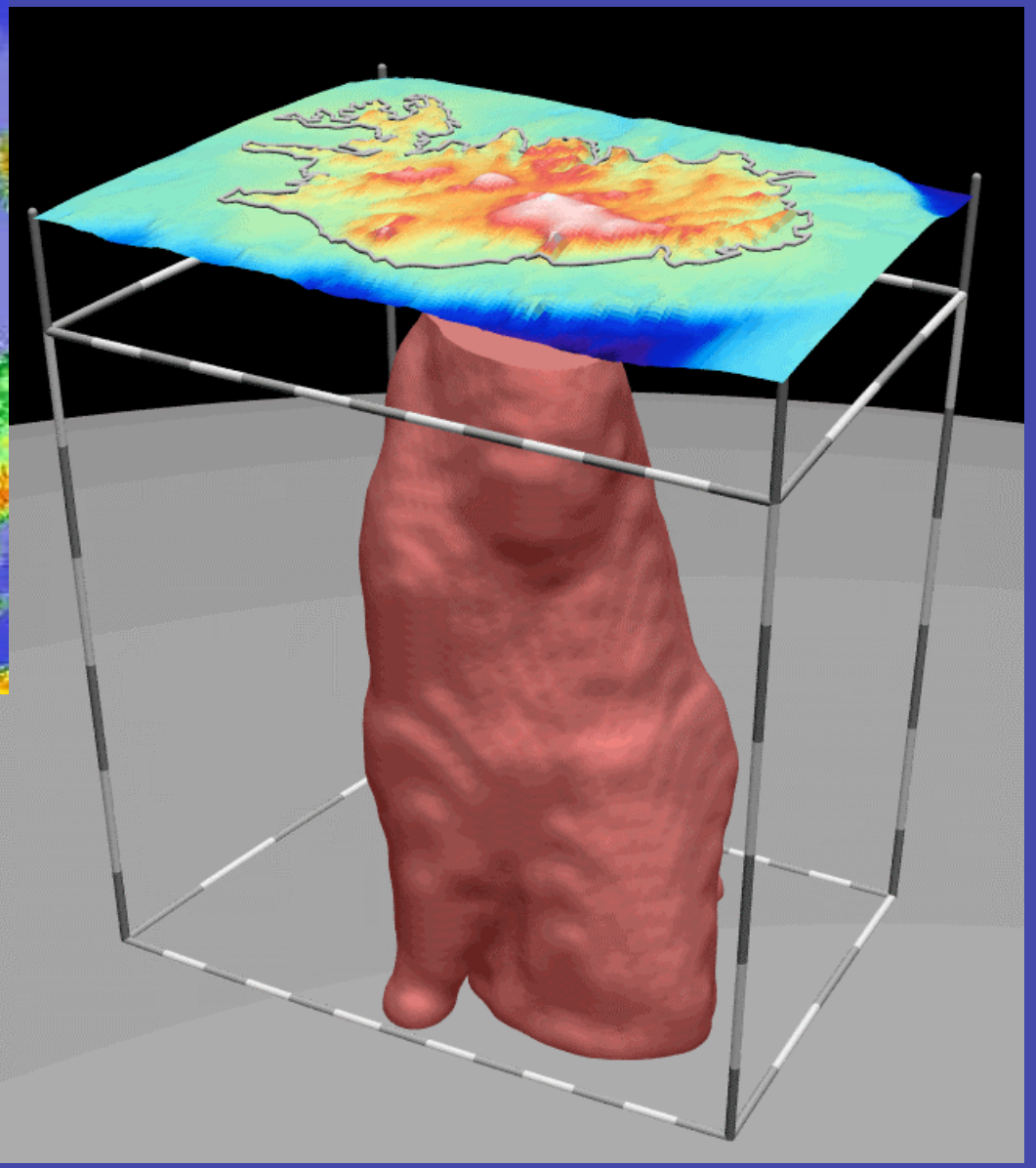





Oceanic lithosphere
Oceanic ridge
Descending oceanic plate
Upper mantle
Lower mantle
Core



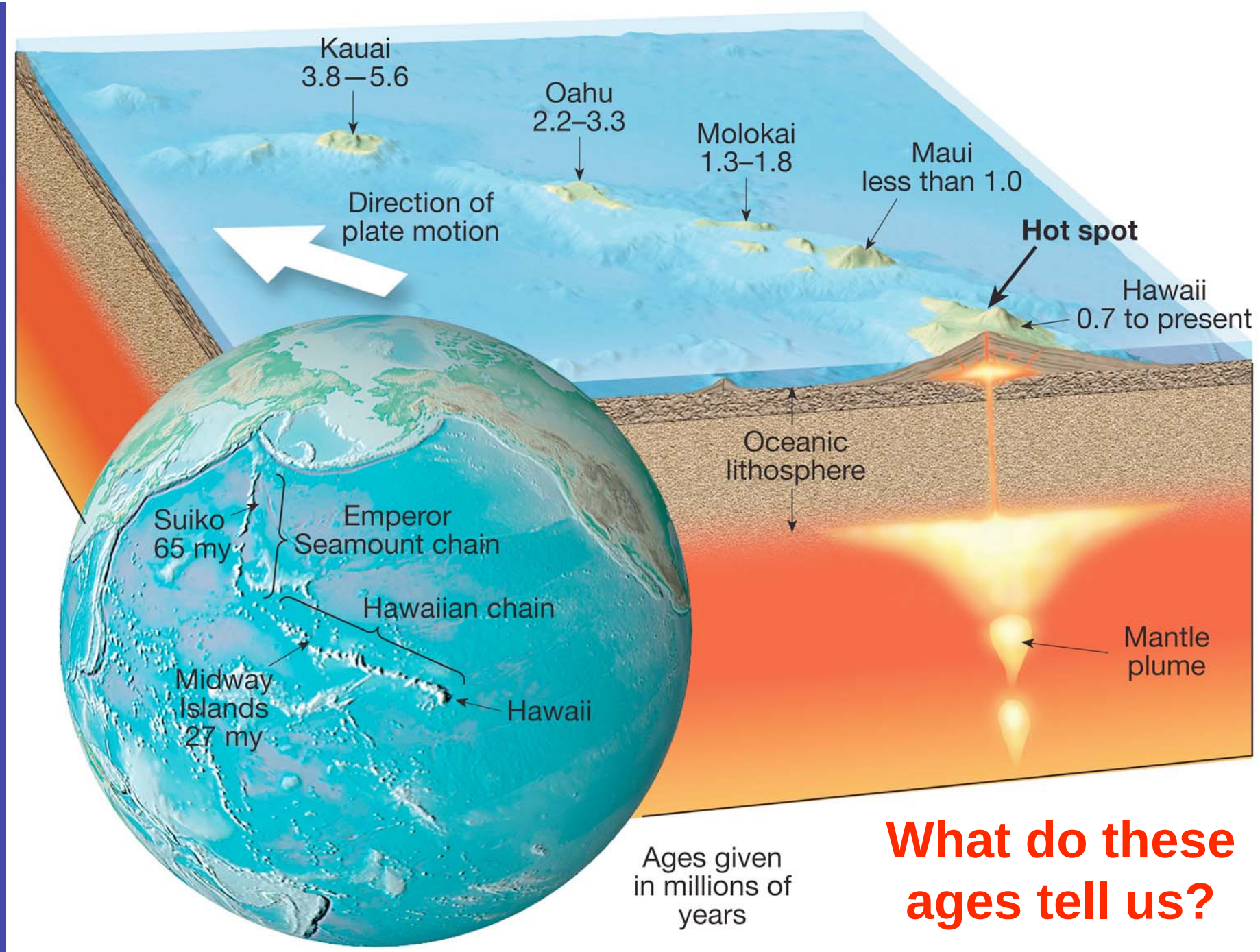
Iceland

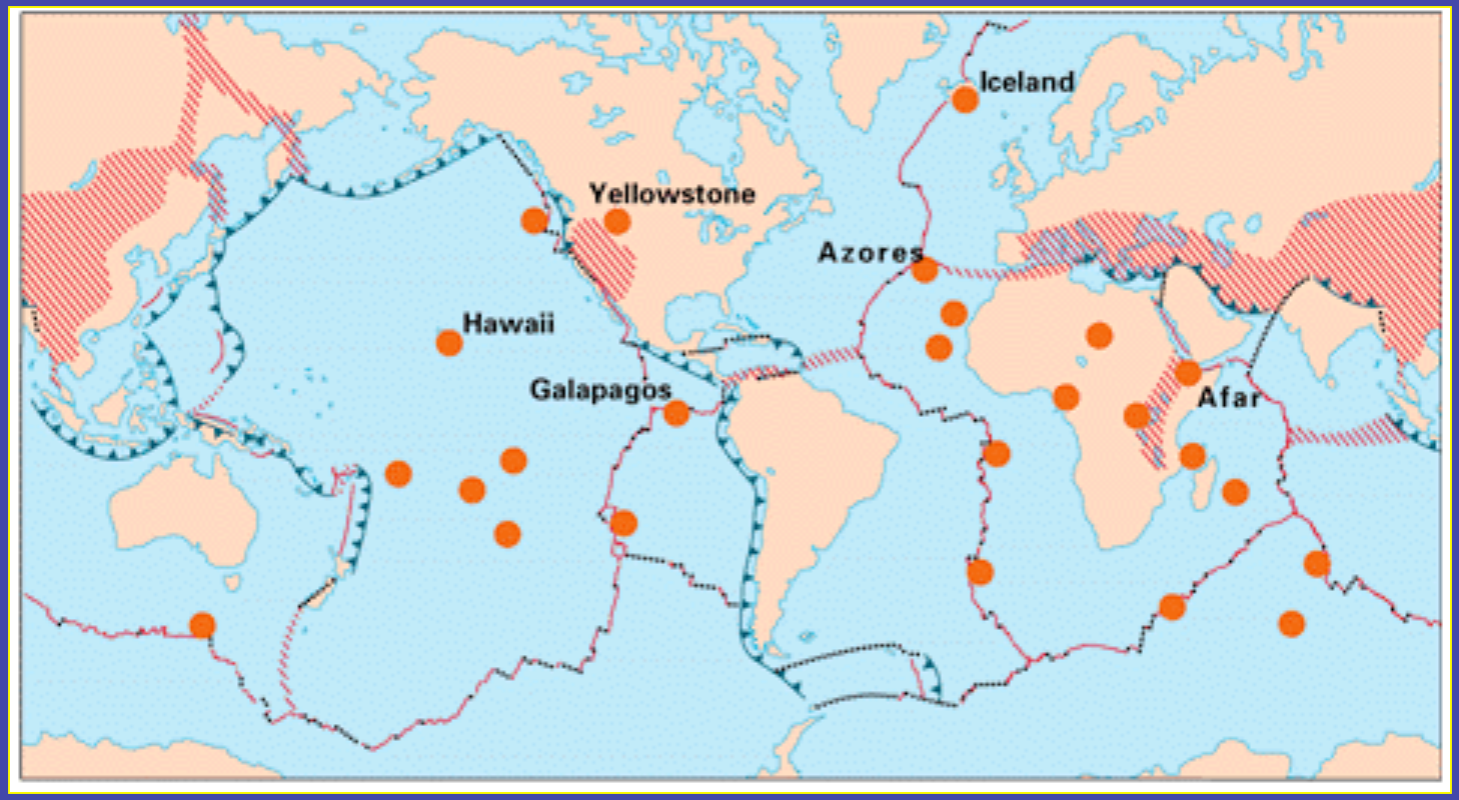


Divergent boundary

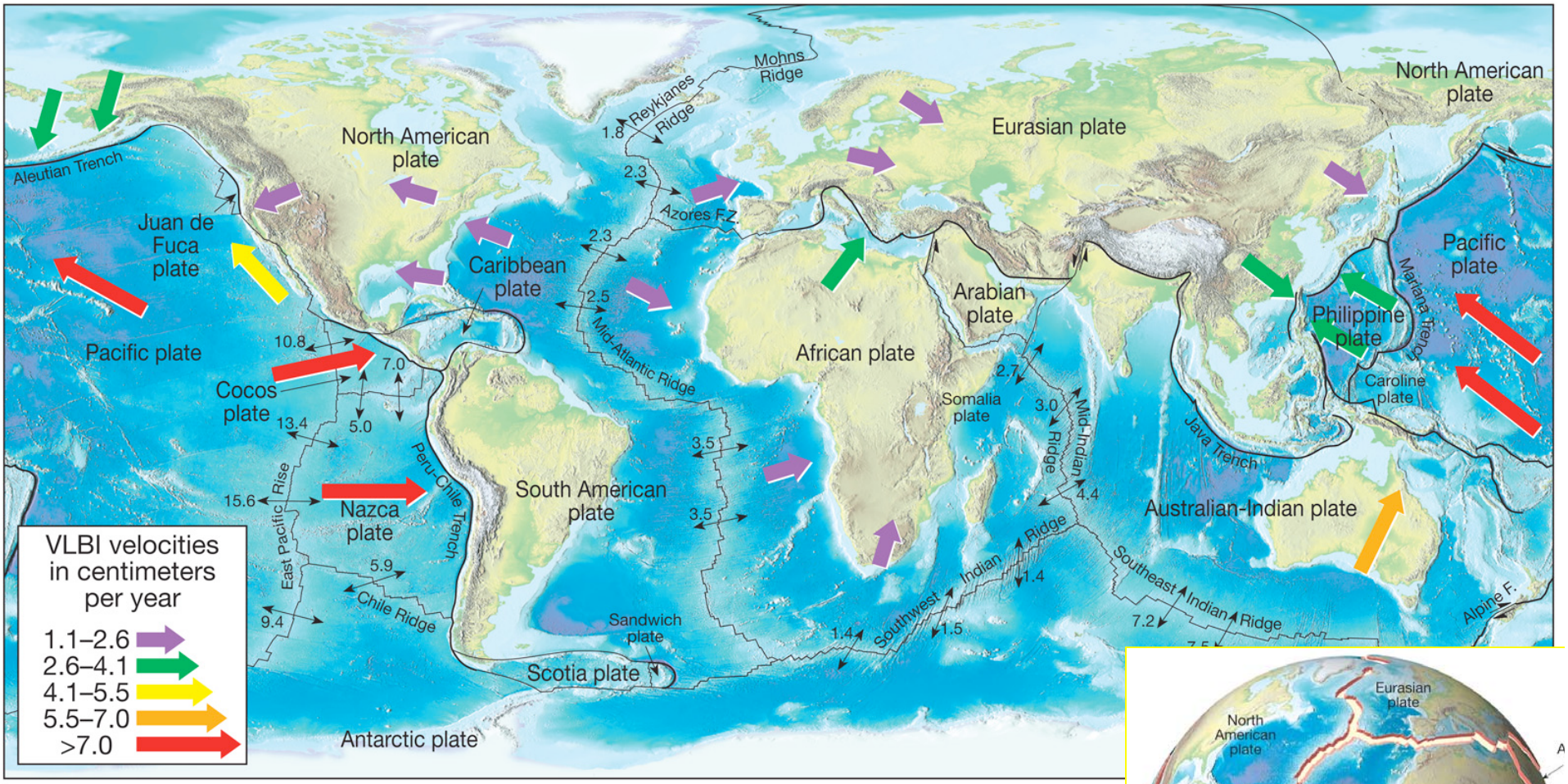
AND

Hot spot!

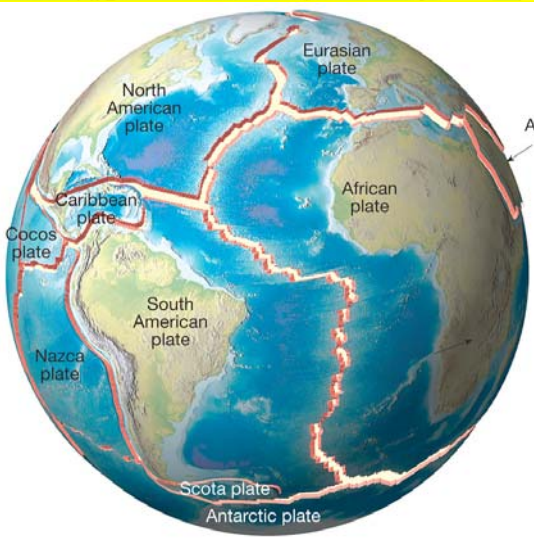

Kauai
3.8—5.6
Oahu
2.2–3.3
Molokai
1.3–1.8
Maui
less than 1.0
Direction of
plate motion
Hot spot
Hawaii
0.7 to present
Oceanic
lithosphere
Suiko
65 my
Emperor
Seamount chain
Hawaiian chain
Midway
Islands
27 my
Hawaii
Mantle
plume
Ages given
in millions of
years
What do these ages tell us?



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	----