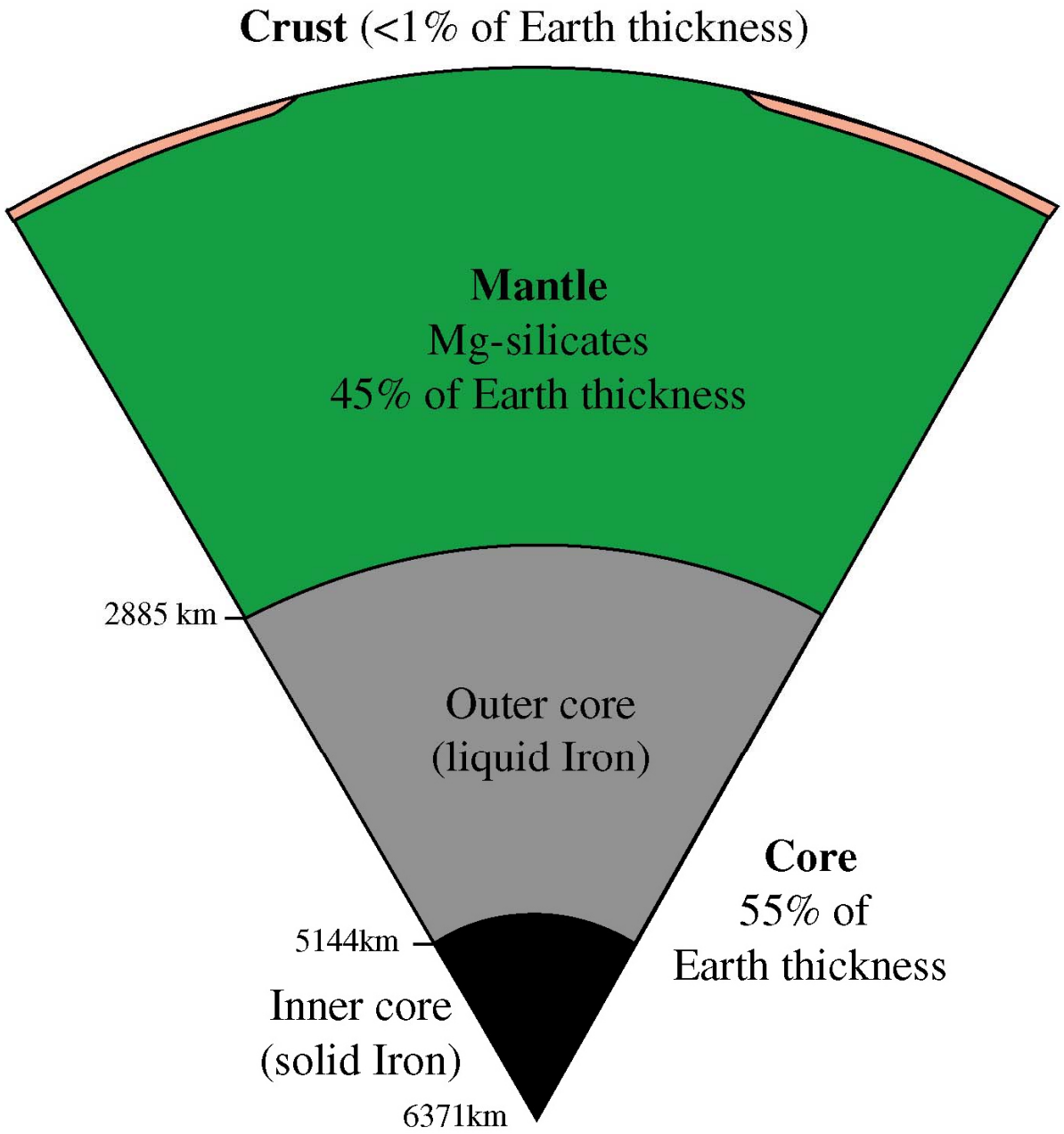
Geologic Evolution of Latin America

Plate Tectonics: General Concepts & Applications to Latin America

Structure of Earth: 3 major divisions of Core, Mantle, and Crust



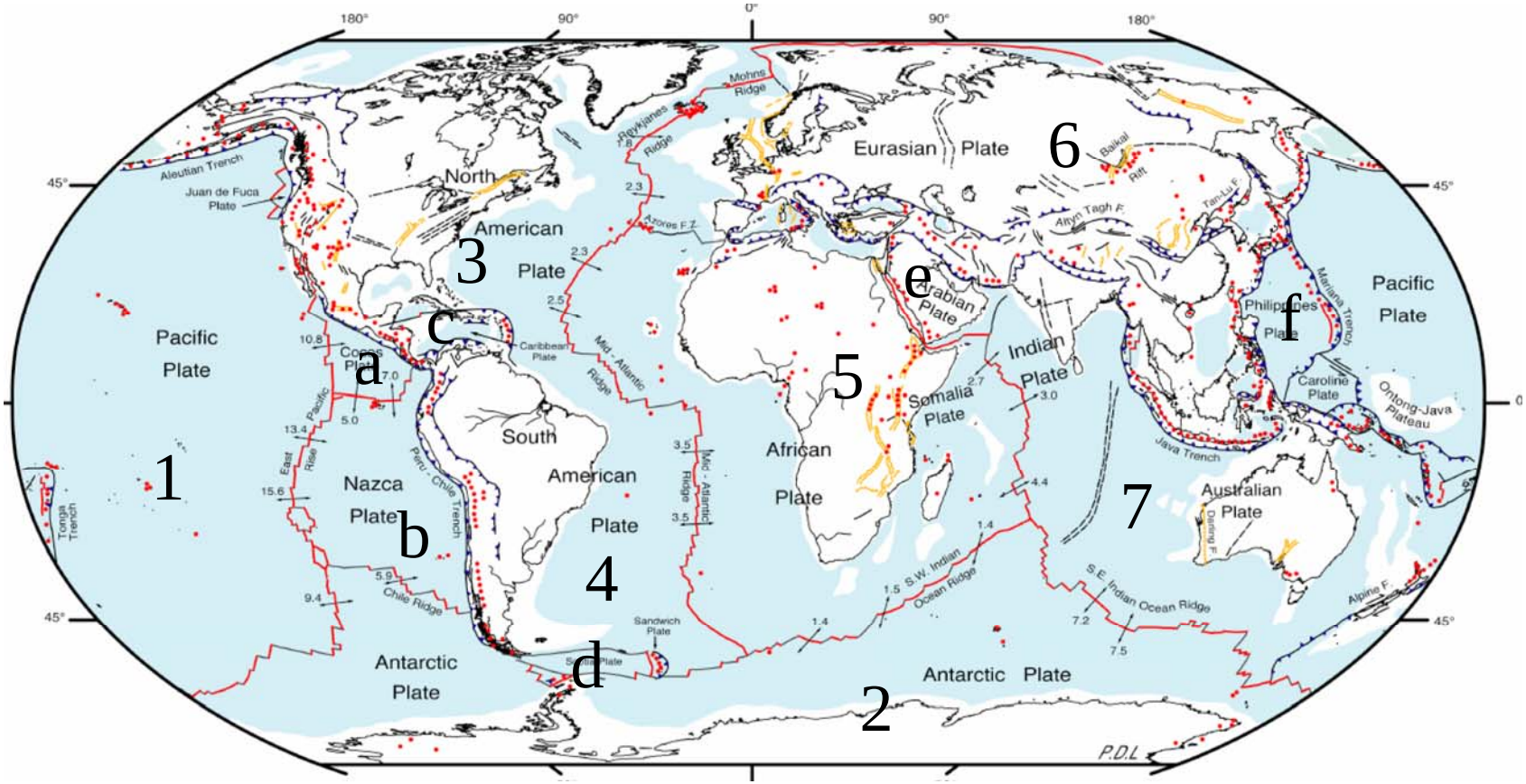
Upper mantle differs in the way that it transports heat

- Three ways to transport heat: radiation, convection,and conduction
- Uppermost 100-200 km of mantle is strong, cold, and transports heat by conduction
- Below this the mantle is hotter, weaker, and transports heat by convection

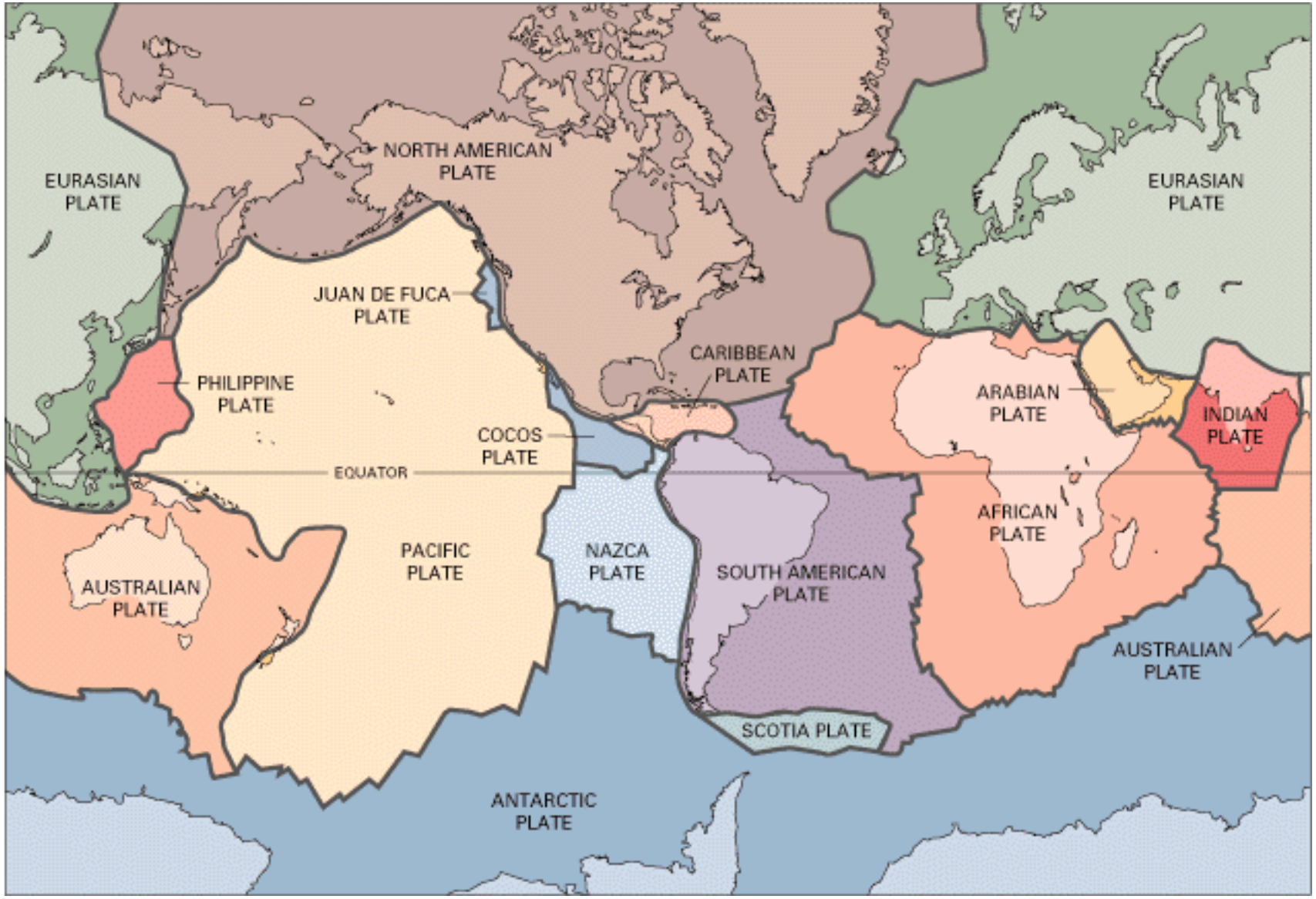
Lithosphere and Asthenosphere

- *Lithosphere*: strong upper mantle
- *Asthenosphere*: Weaker mantle beneath lithosphere
- Lithosphere = plate of plate tectonics
  - -Oceanic lithosphere thickens as it ages and cools
- Asthenosphere = what allows plates to move

7 major and 6 minor plates



Latin America occupies parts of 3 plates: N. America, Caribbean, and S. America

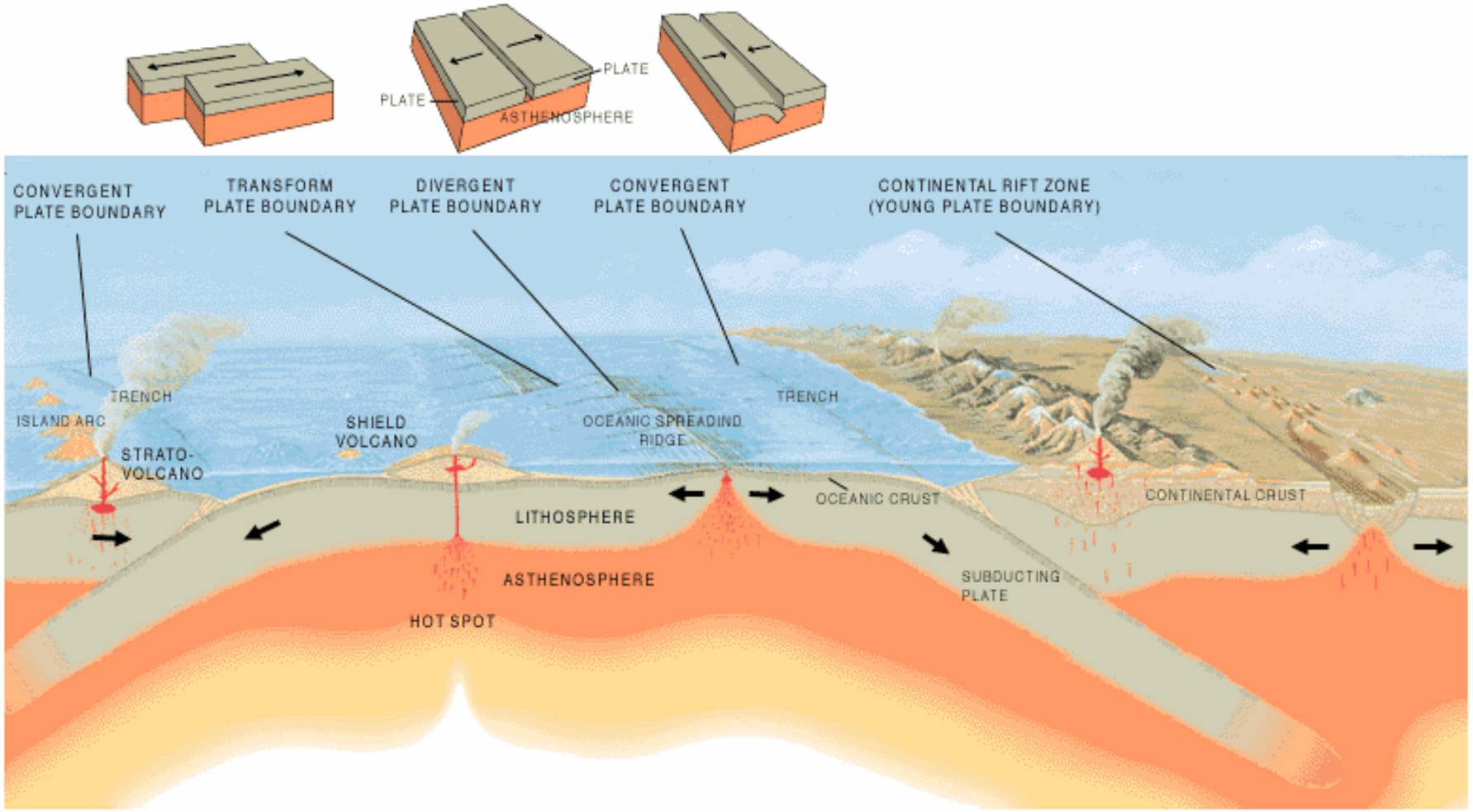


"This Dynamic Earth" http://pubs.usgs.gov/publications/text/slabs.html

Three types of Plate Boundaries

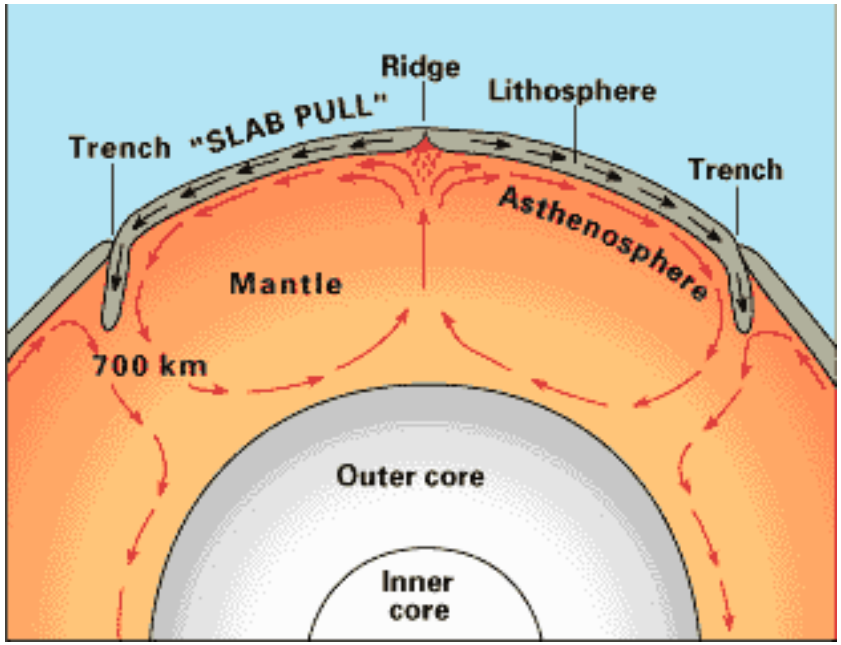
- Where lithosphere is created: *Divergent (Constructive) Plate Boundary*
- Where lithosphere is destroyed: *Convergent (Destructive) Plate Boundary*
- Where lithosphere is neither created nor destroyed: *Transform Plate Boundary*

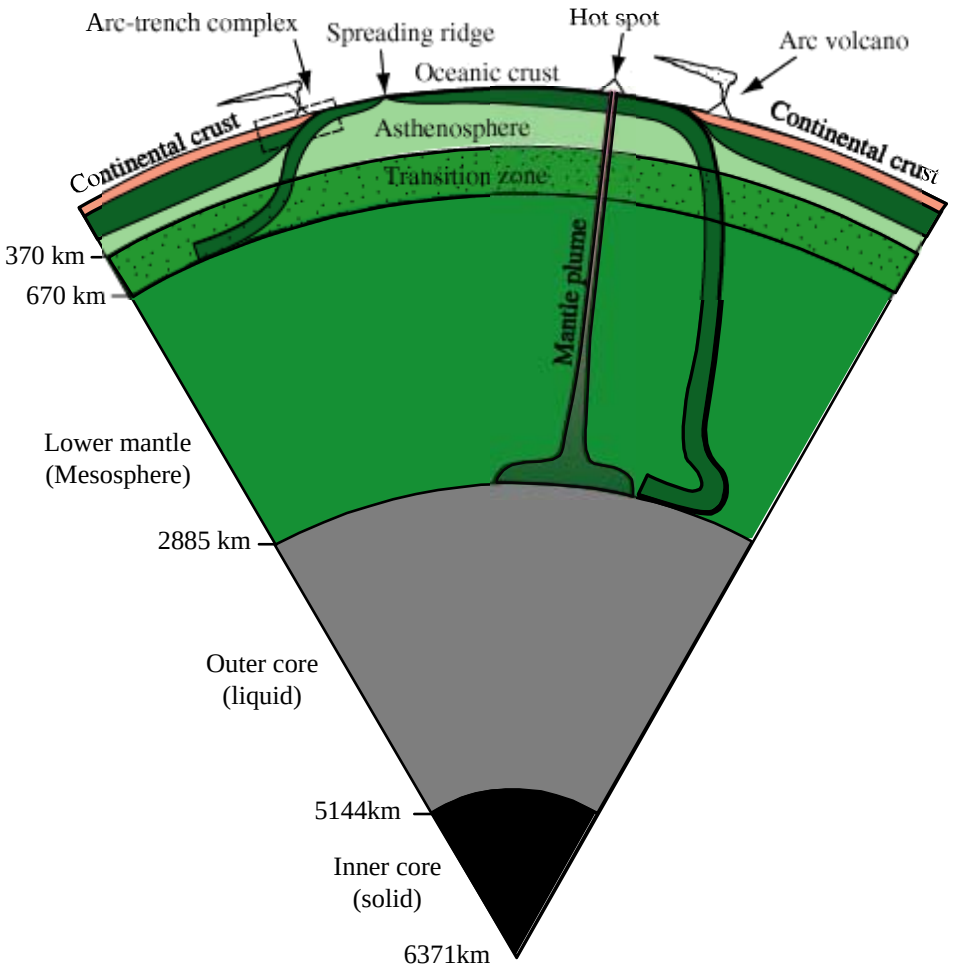
Plate Tectonics



"This Dynamic Earth" http://pubs.usgs.gov/publications/text/Vigil.html

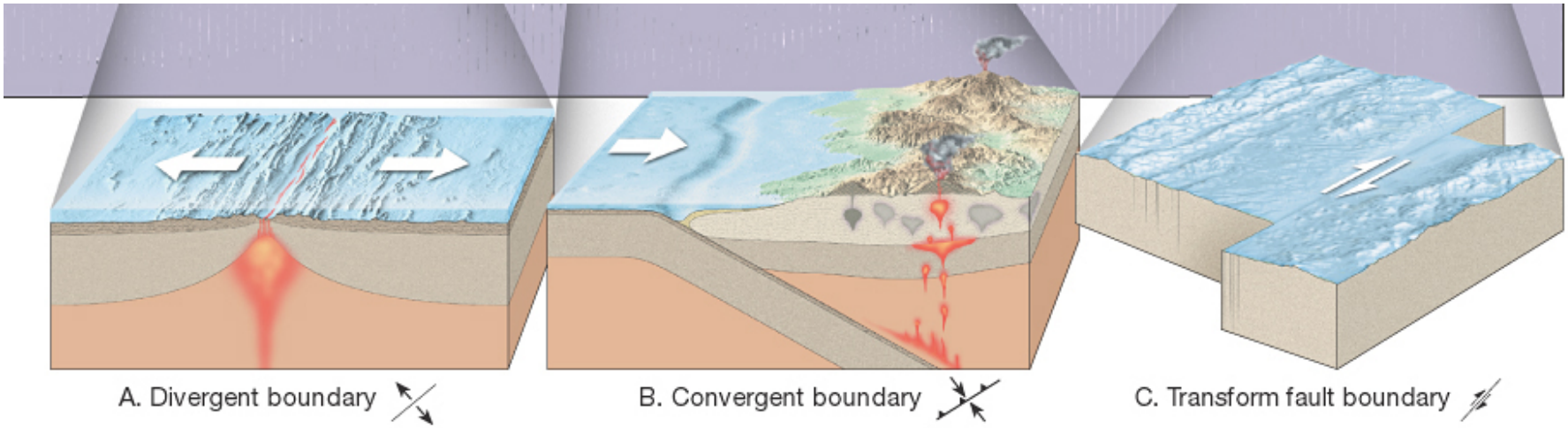
Mantle convection





Sinking of dense lithosphere in Subduction Zones drives plate motions

Plate boundaries

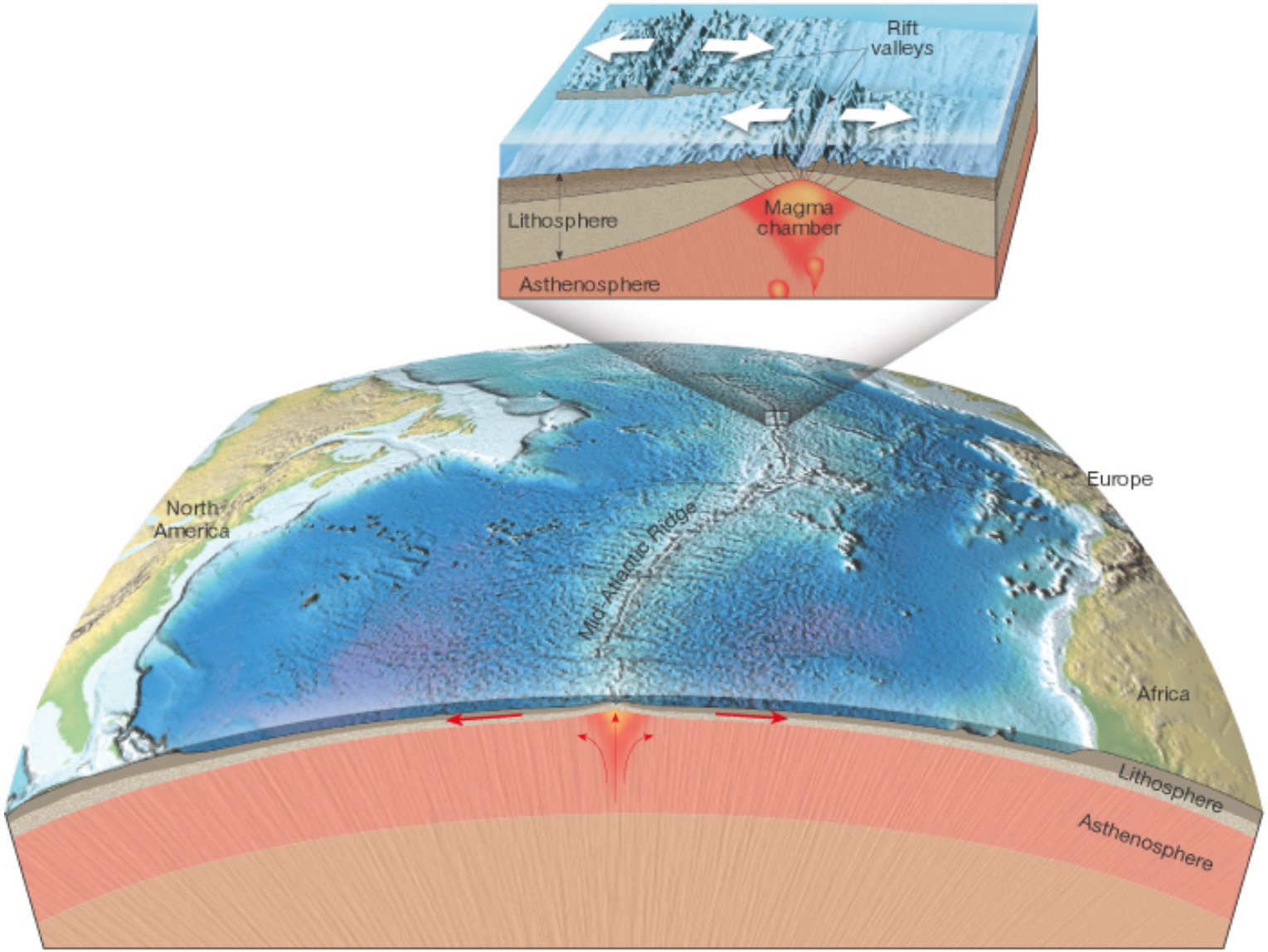


Divergent = Mid-Ocean Ridge Spreading
Convergent = Subduction Zone
Transform = plates slide past each other

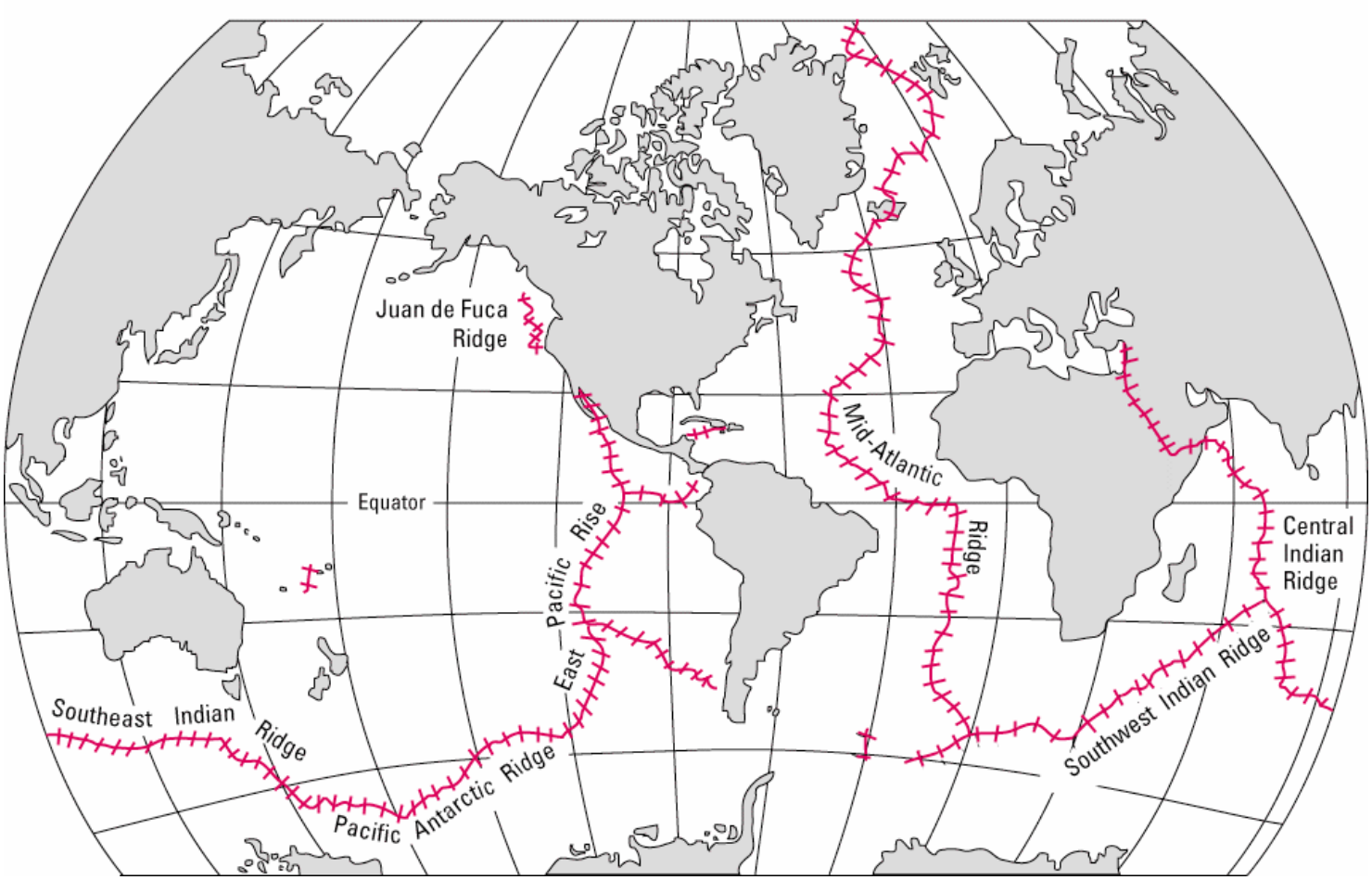
TASA Graphics

Divergent or Constructive Plate Boundaries
= Mid-Ocean Ridges – Spreading Centers

Constructive Plate boundary = Mid Ocean Ridge

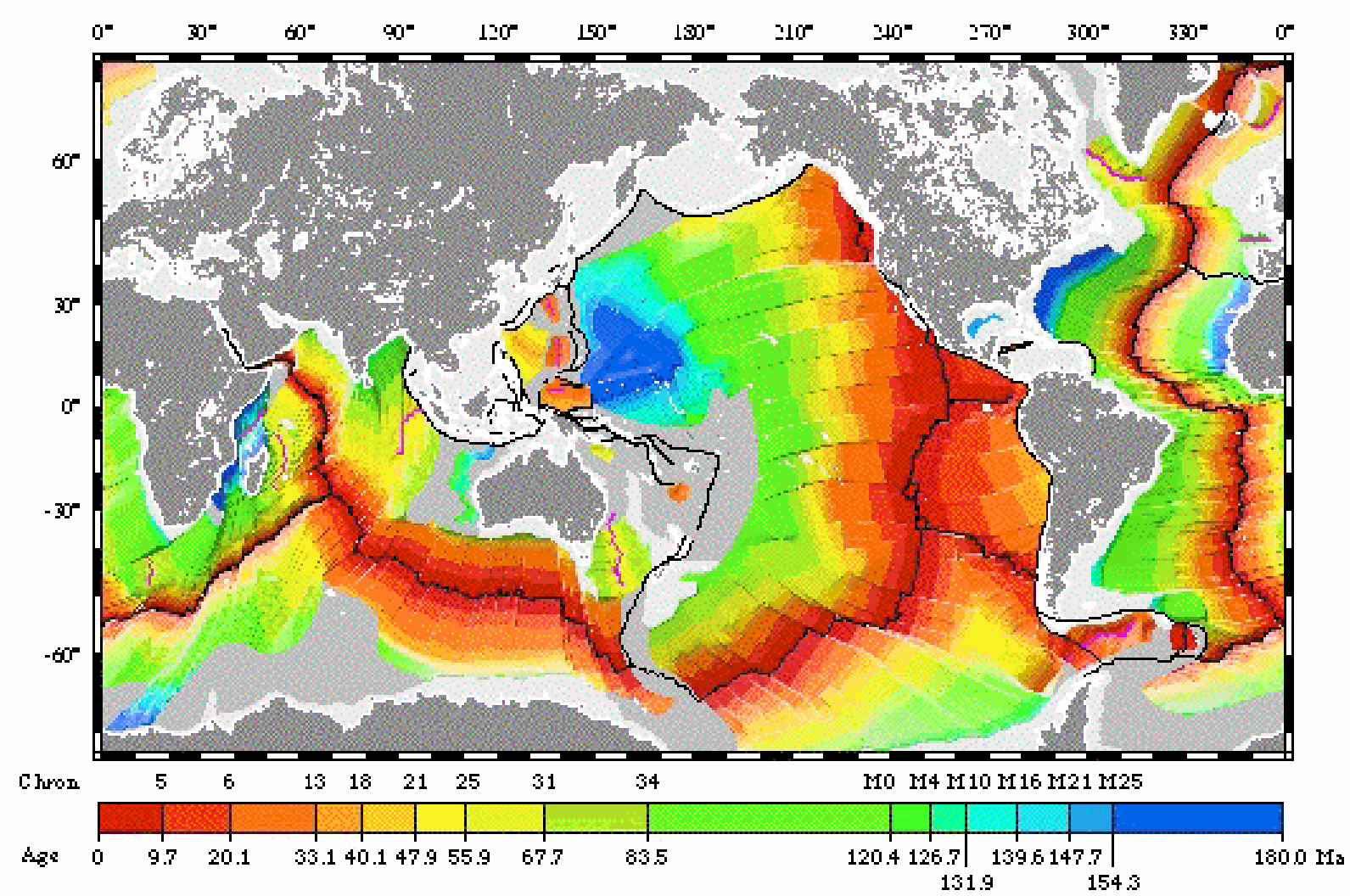


Mid-Ocean Ridge System (Constructive Plate Boundaries)

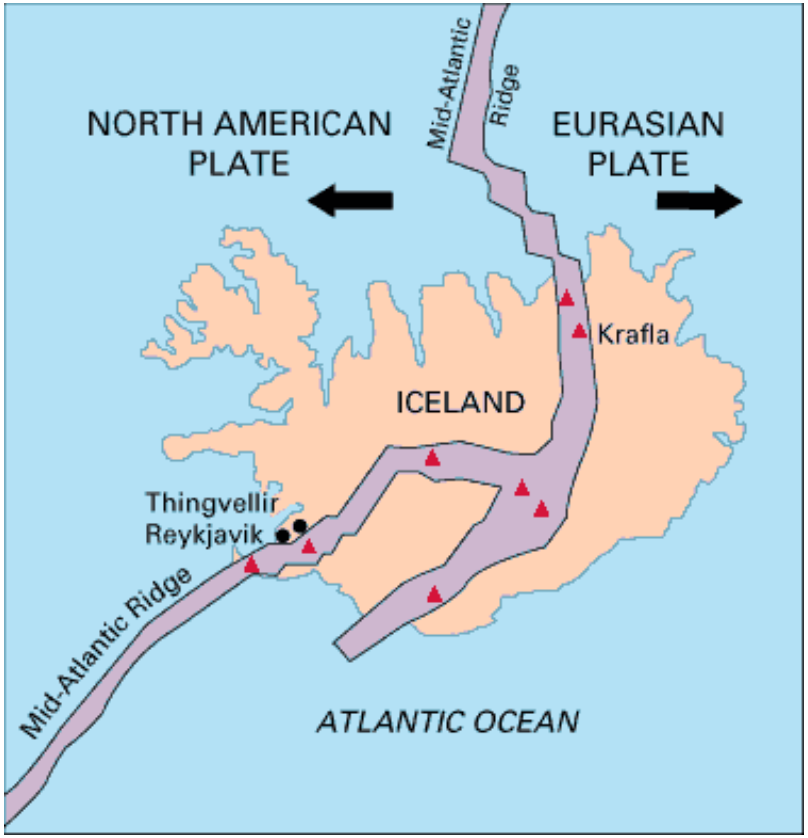


"This Dynamic Earth" http://pubs.usgs.gov/publications/text/baseball.html

Oceanic crust and lithosphere is created at Mid-Ocean ridges and gets older away from the ridge



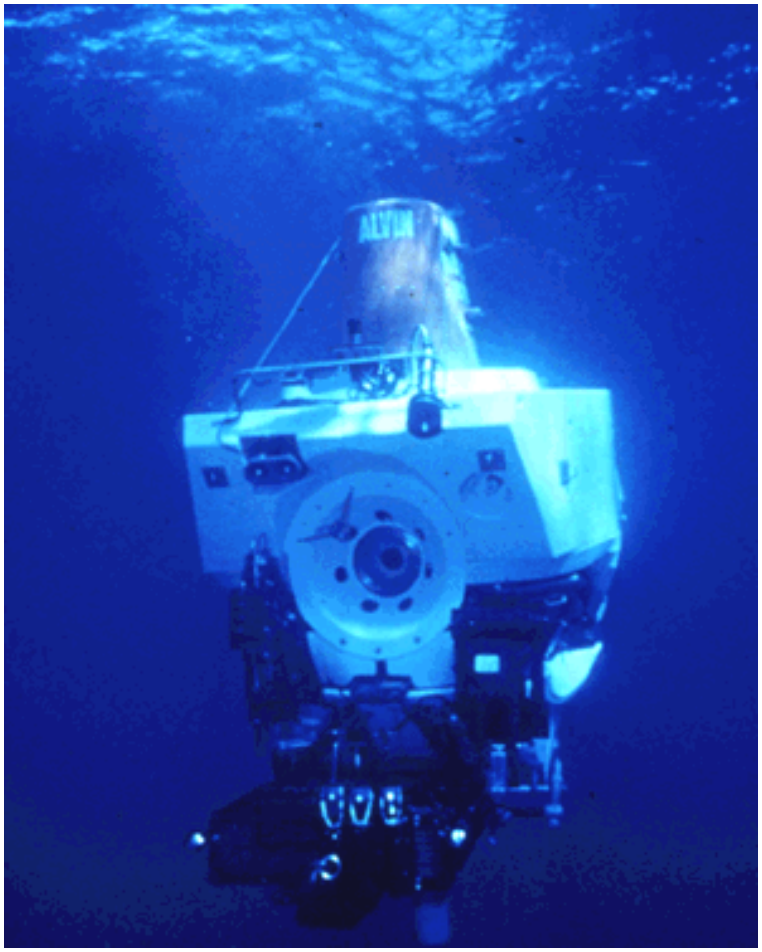
The Mid-Atlantic Ridge comes on shore in Iceland



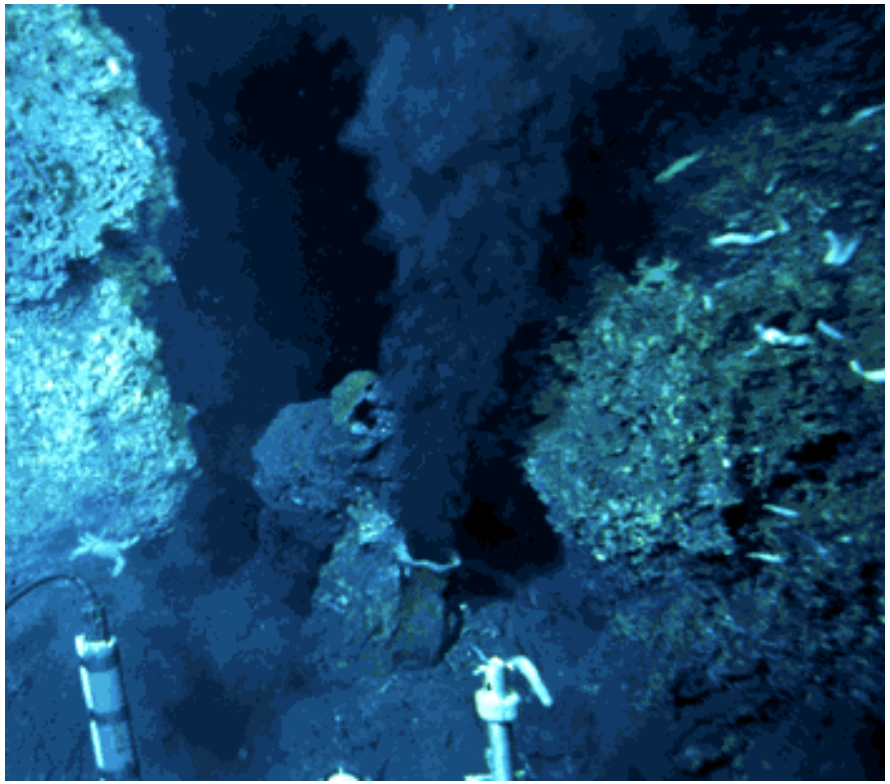
Krafla 1980

"This Dynamic Earth" http://pubs.usgs.gov/publications/text/Krafla.html

Mid-Ocean Ridges are mostly submarine



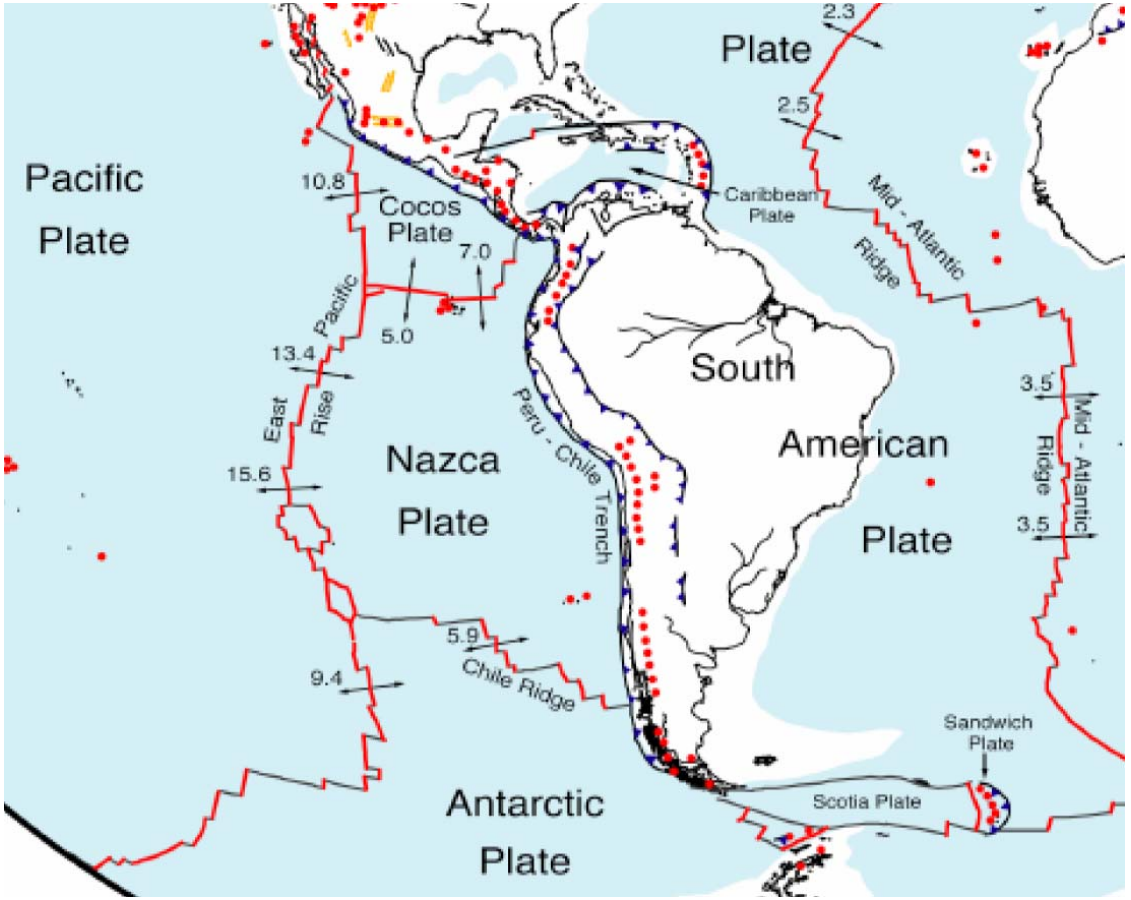
Research submarine “ALVIN”



Hydrothermal vent “Black smoker”

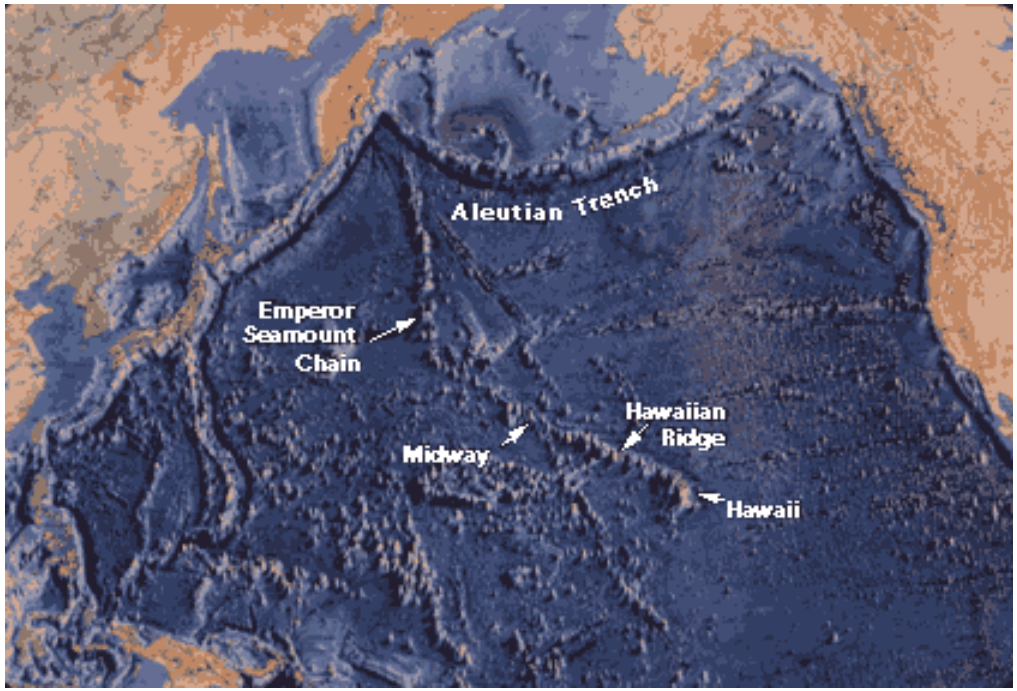
Several Mid-Ocean Ridges around LA

- Mid-Atlantic Ridge
- S. Sandwich
- East Pacific Rise
- Chile Ridge
- Cocos Ridge
- Cayman Trough



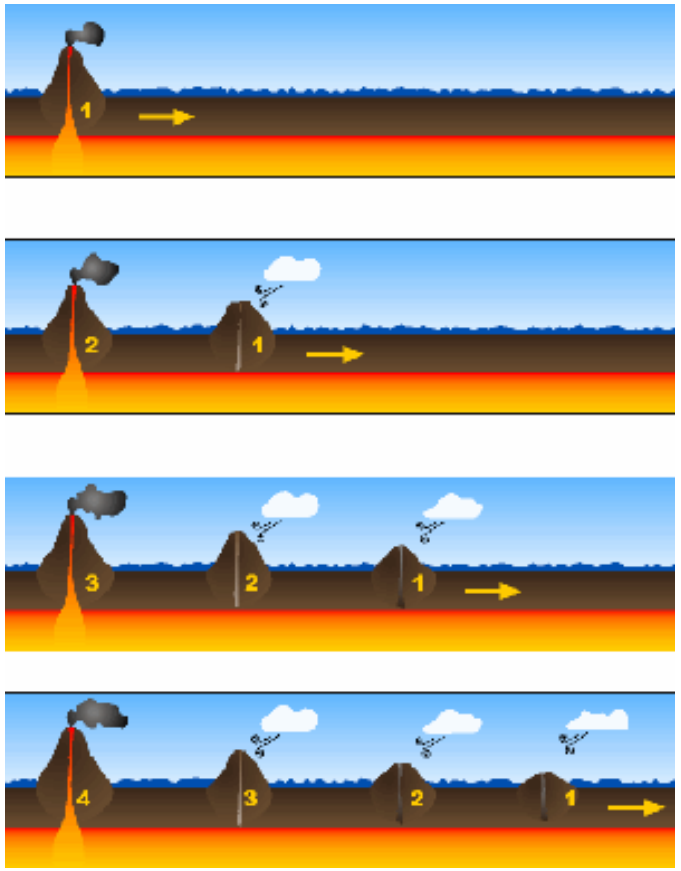
Mantle Plumes and Hot Spot Volcanoes

- Can occur anywhere within a plate or along a divergent plate boundary
- Caused by upwelling material from deep in the mantle
- Produce chains of volcanic islands or seamounts

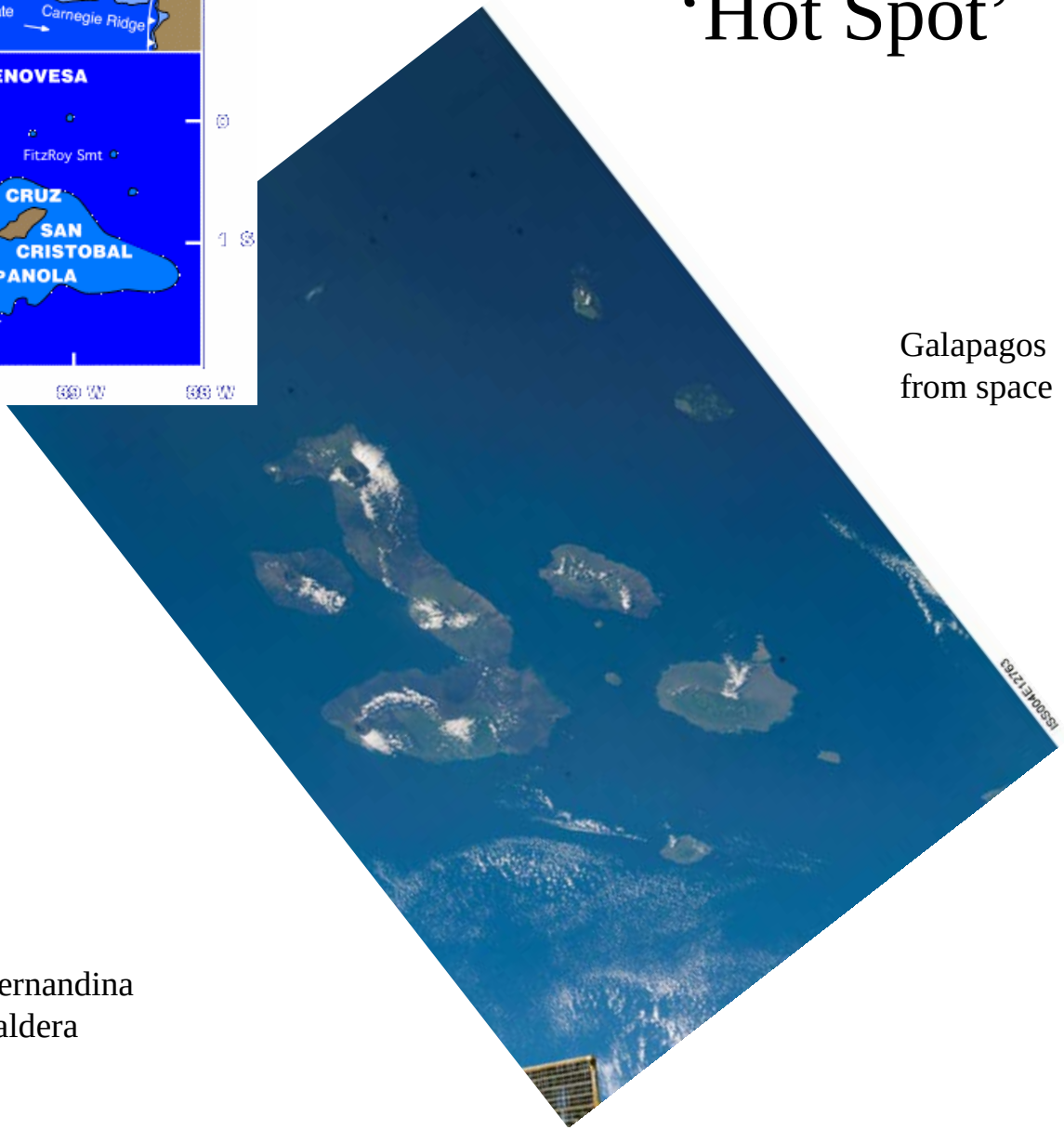


Moving plate over mantle plume

‘Hot Spot’ chains



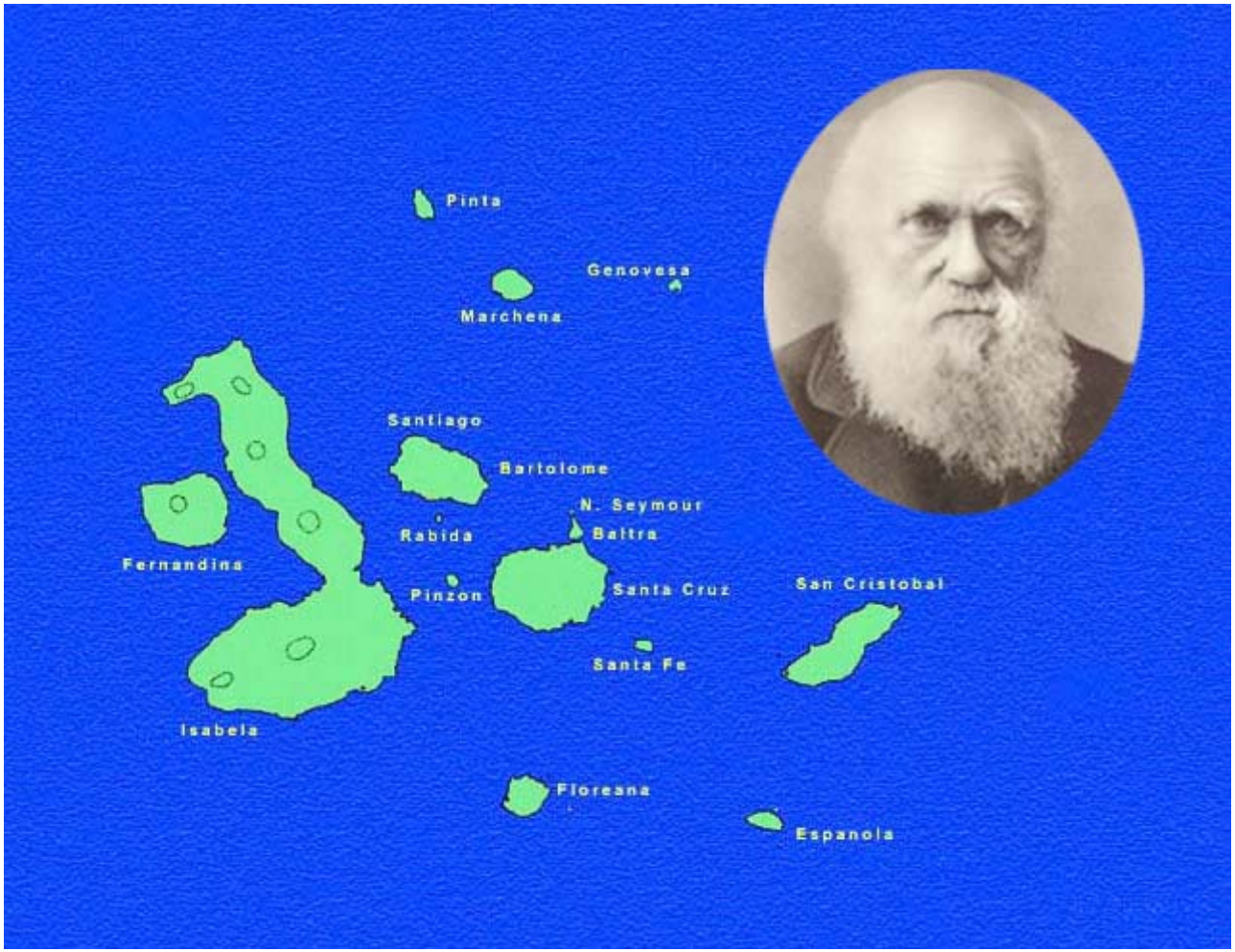
Galapagos ‘Hot Spot’



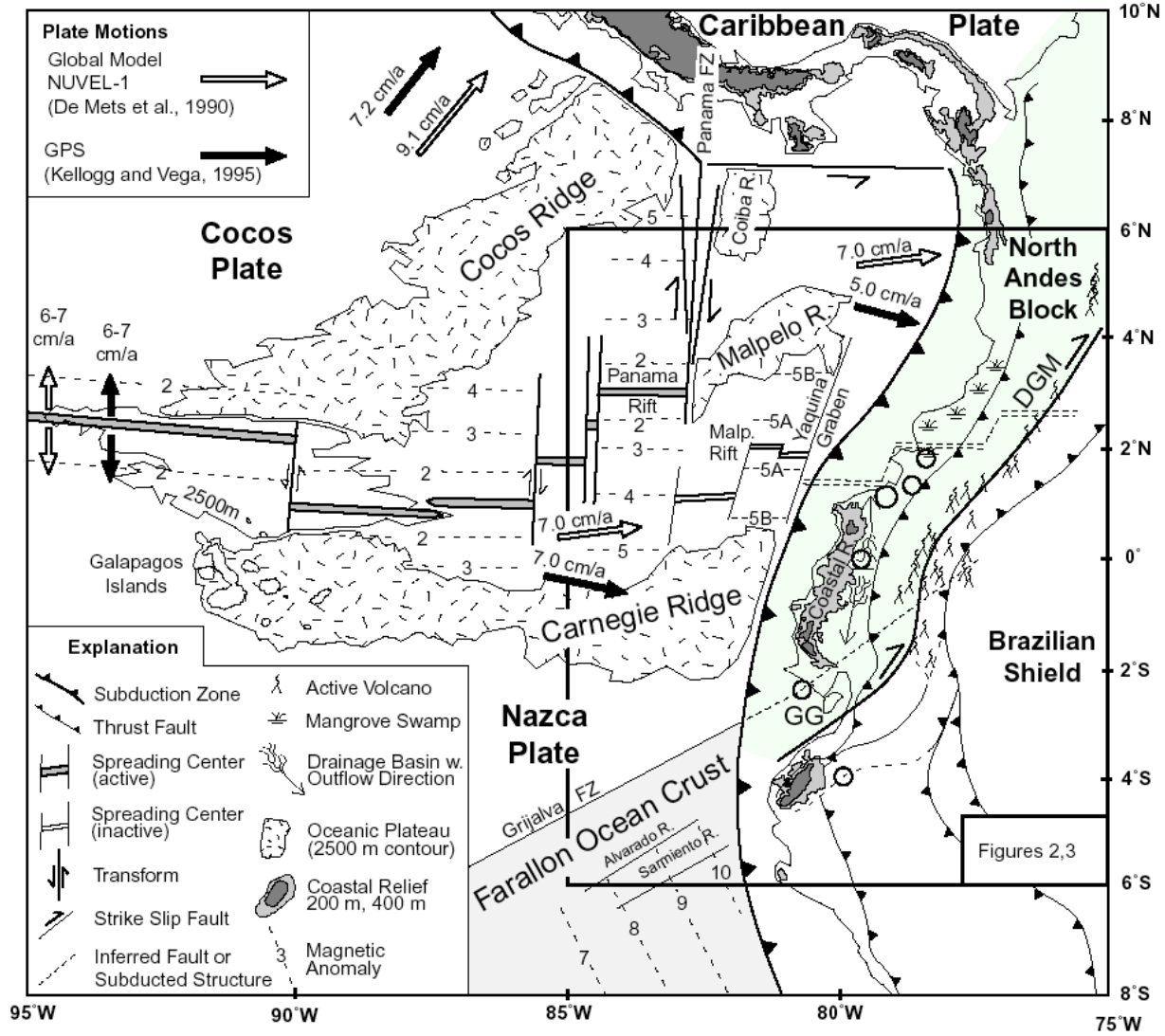
Galapagos from space

Fernandina caldera

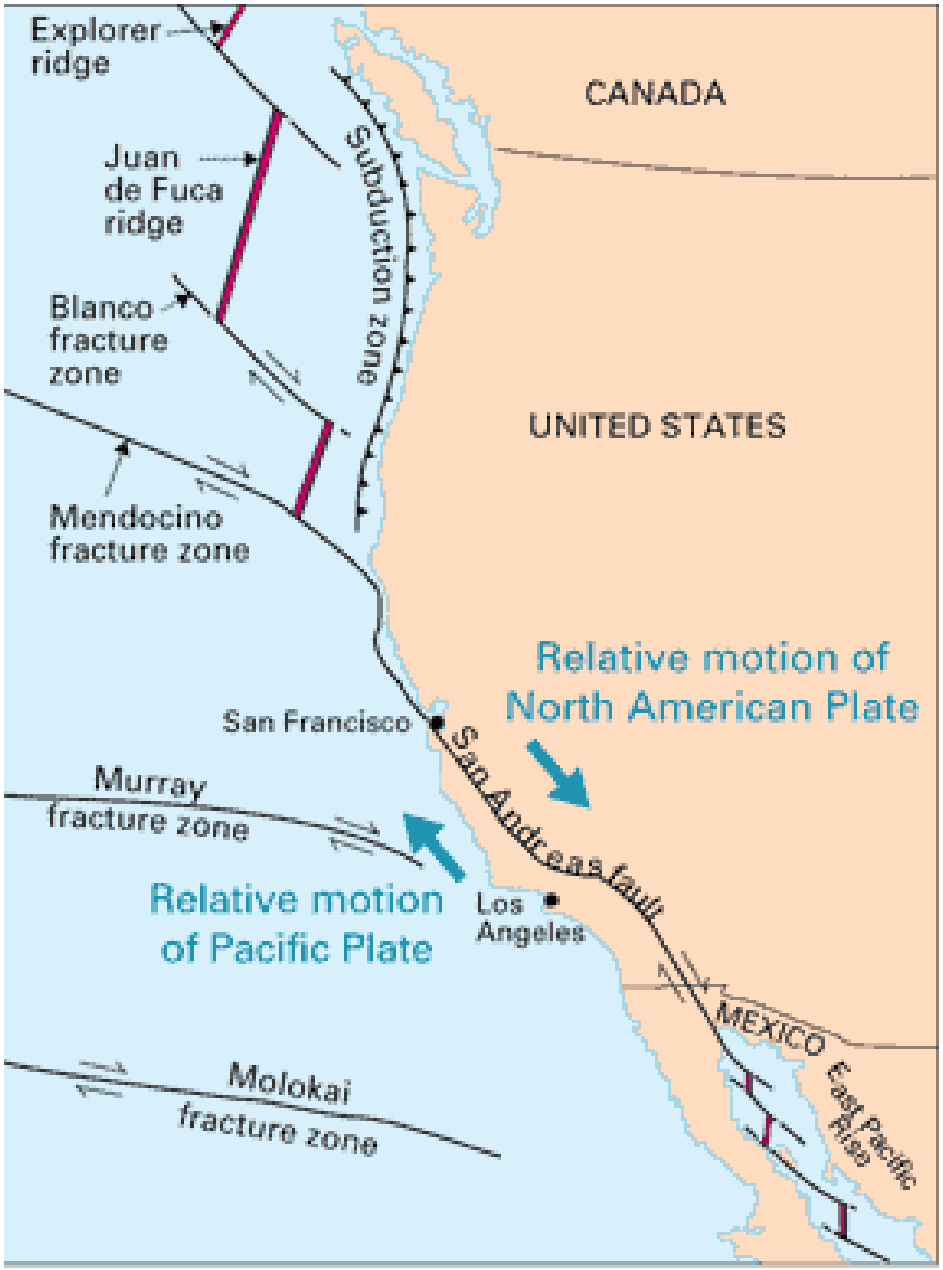
Galapagos & Darwin's Theory of Evolution



Galapagos Hot Spot trail



Gutscher et al. Earth and Planetary Science Letters 168 (1999) 255–270



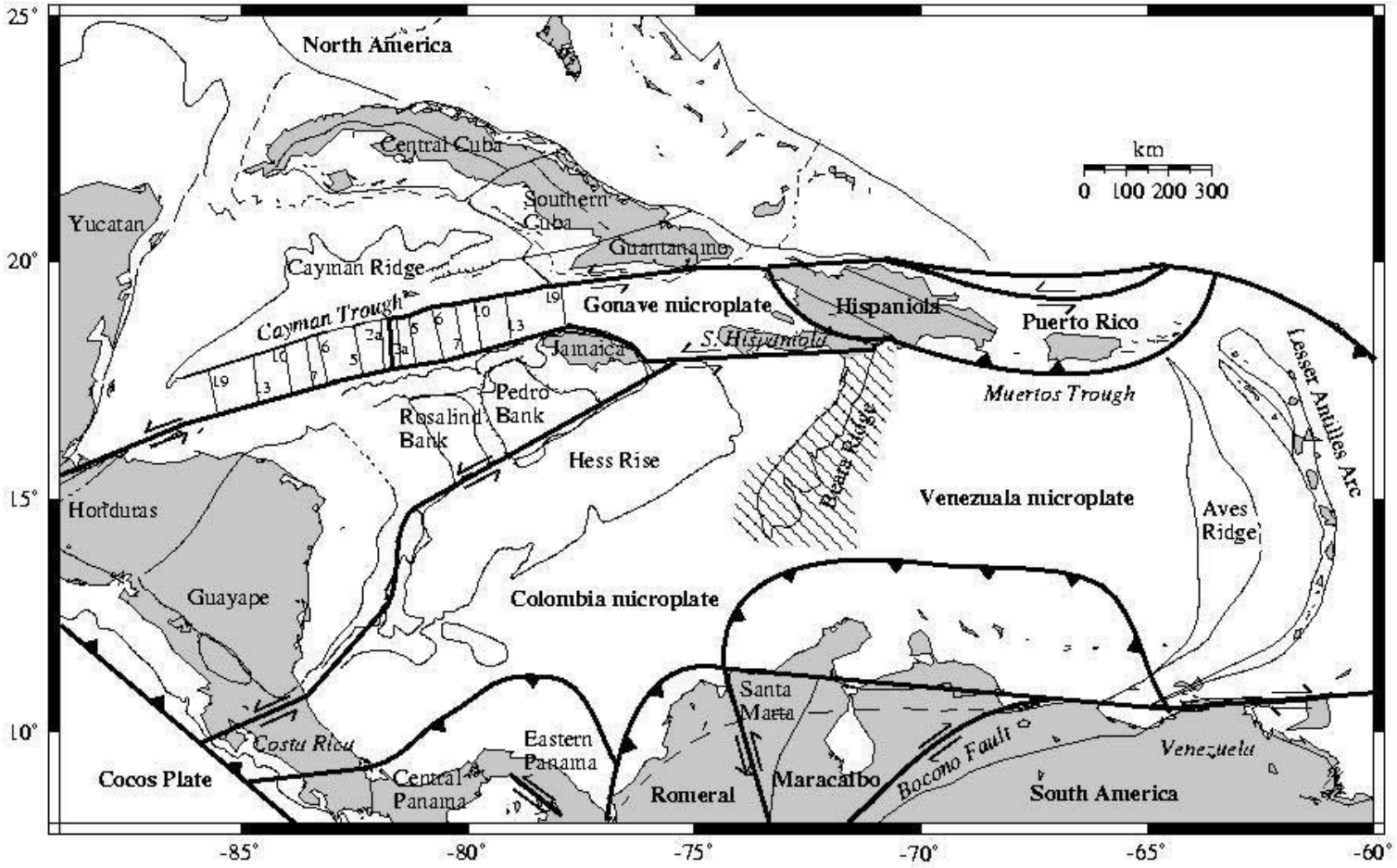
Transform Plate Boundaries

Plates slide past each other

Example: San Andreas fault of California

http://pubs.usgs.gov/publications/text/dynamic.html

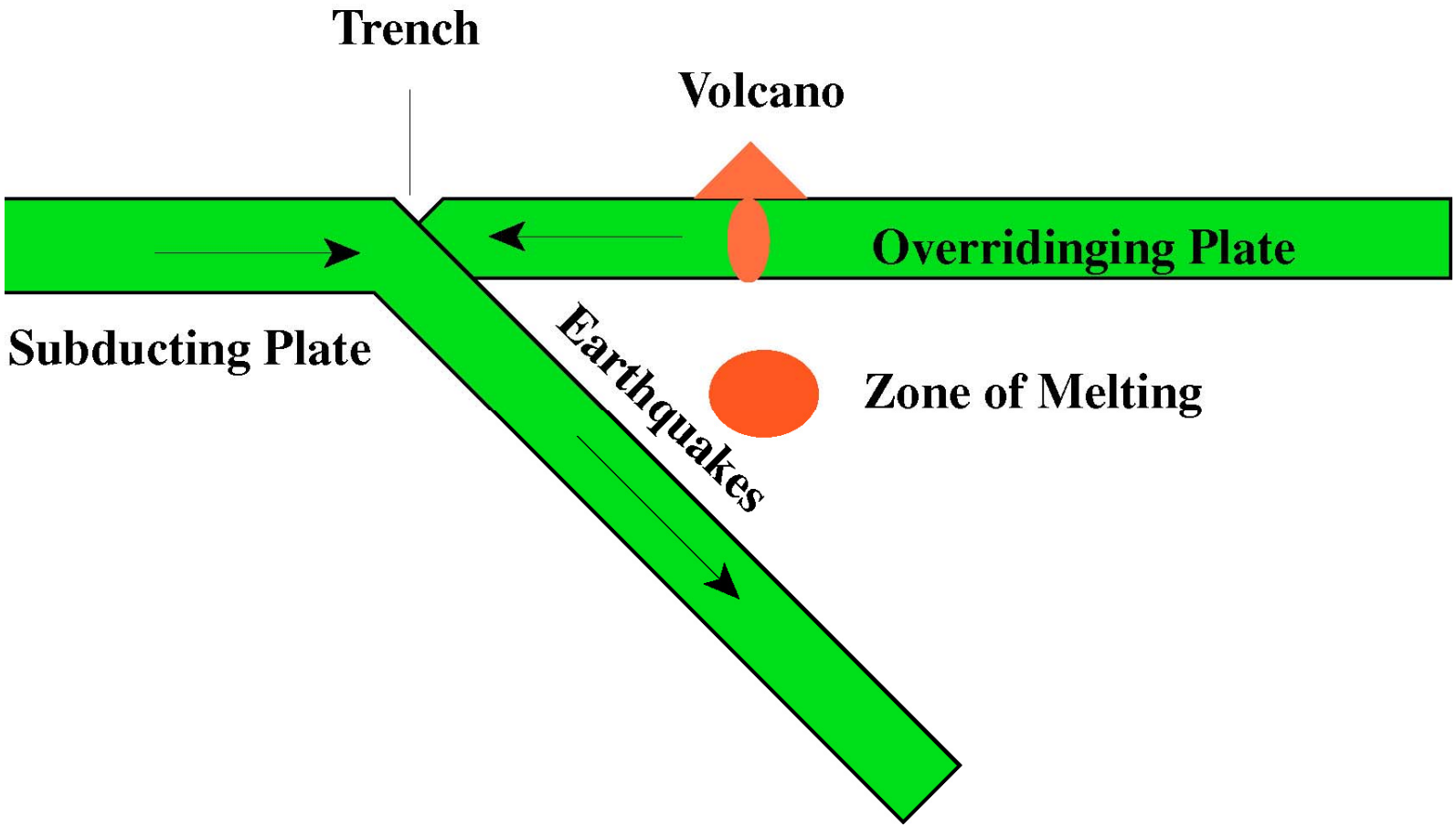
Latin American Transform Plate Boundaries are in the Caribbean



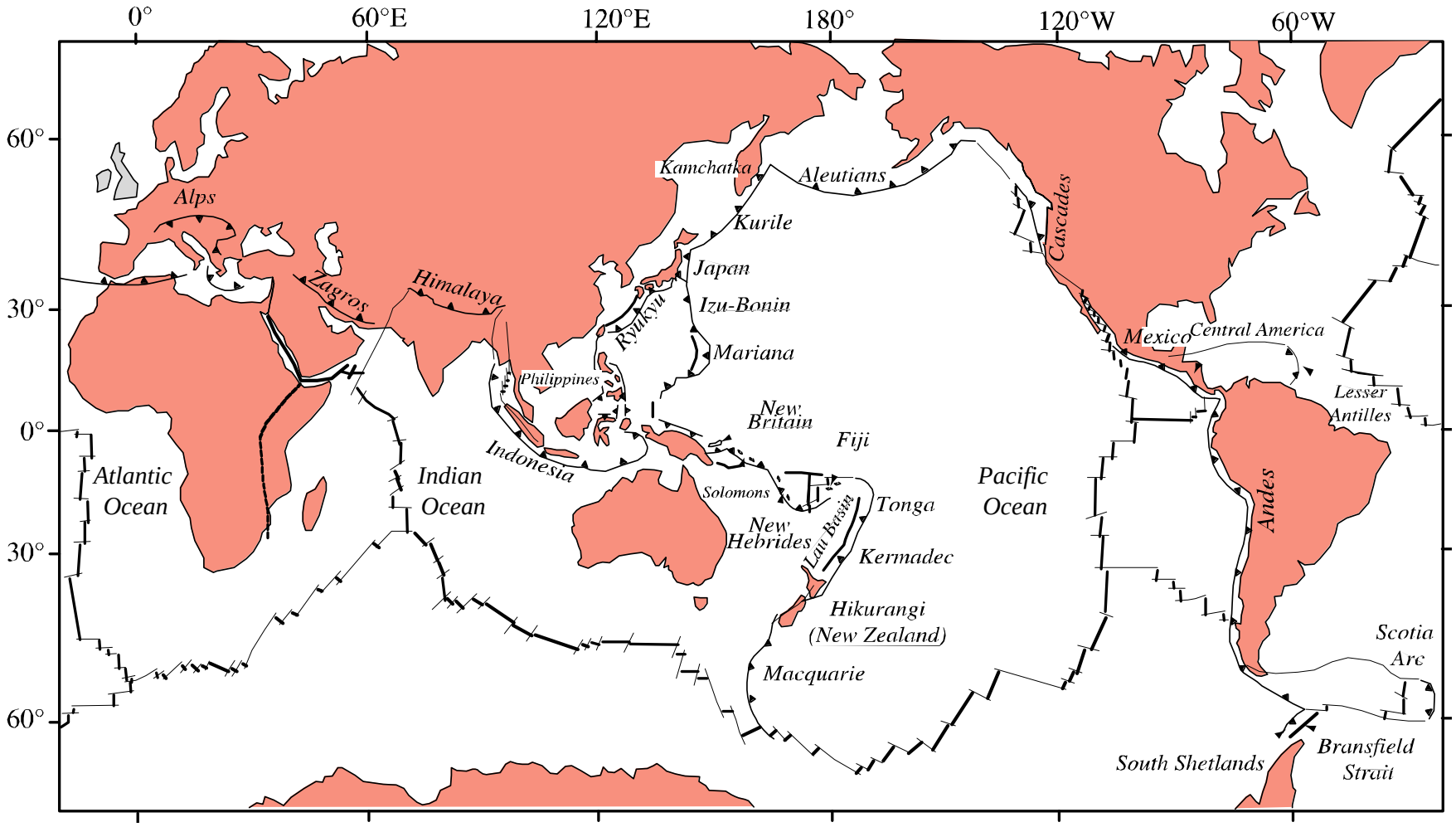
Convergent Plate Margins

- Subduction Zones
- Trenches
- Wadati-Benioff Zones
- Volcanic arcs

Convergent Margins, Subduction Zones: Trenches, Earthquakes, and Volcanoes



55,000 km of Convergent Plate Margins; Lallemand 1999



Trenches around Latin America

Puerto Rico Trench (<8605m)

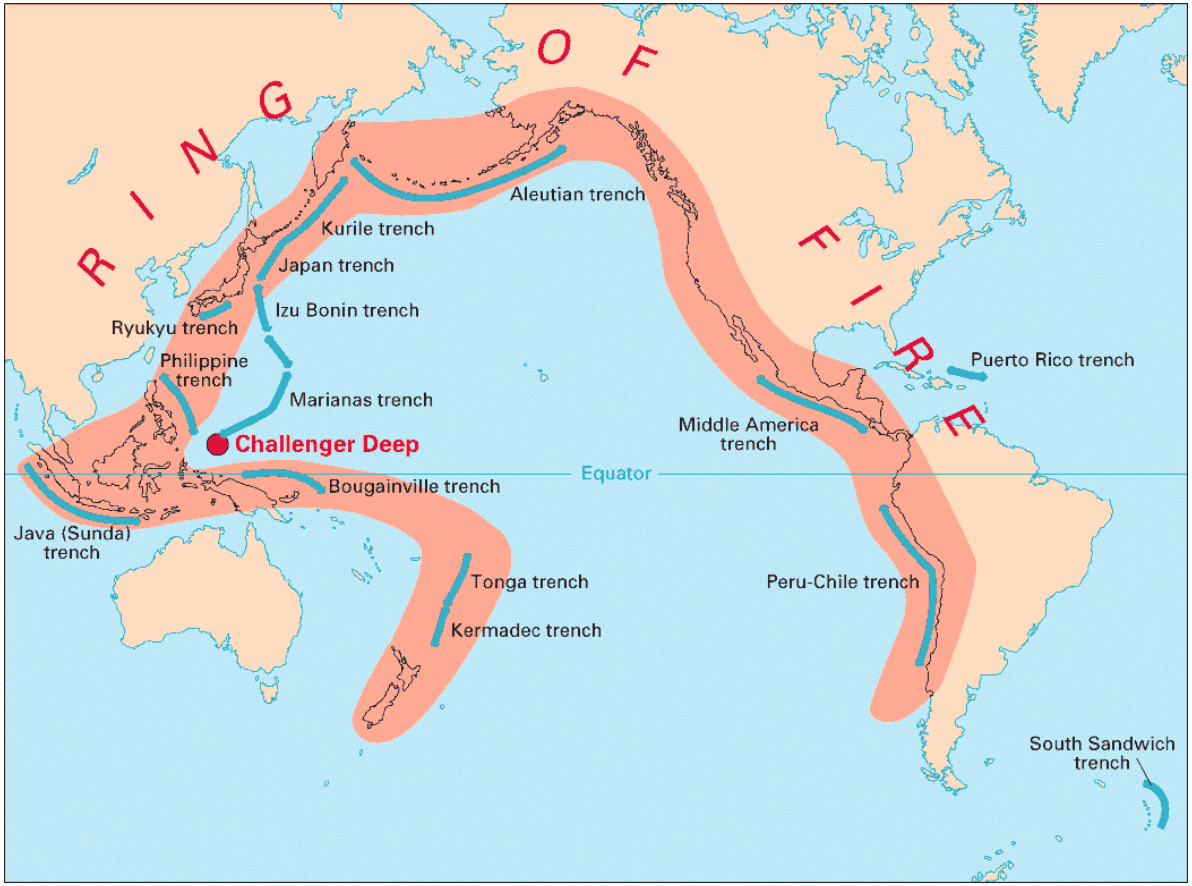
Middle America Trench (<6600m)

Peru-Chile Trench (<8170m)

South Sandwich Trench (<8325m)

Challenger Deep in W. Pacific = 10,920 m (Deepest point on Earth's surface)

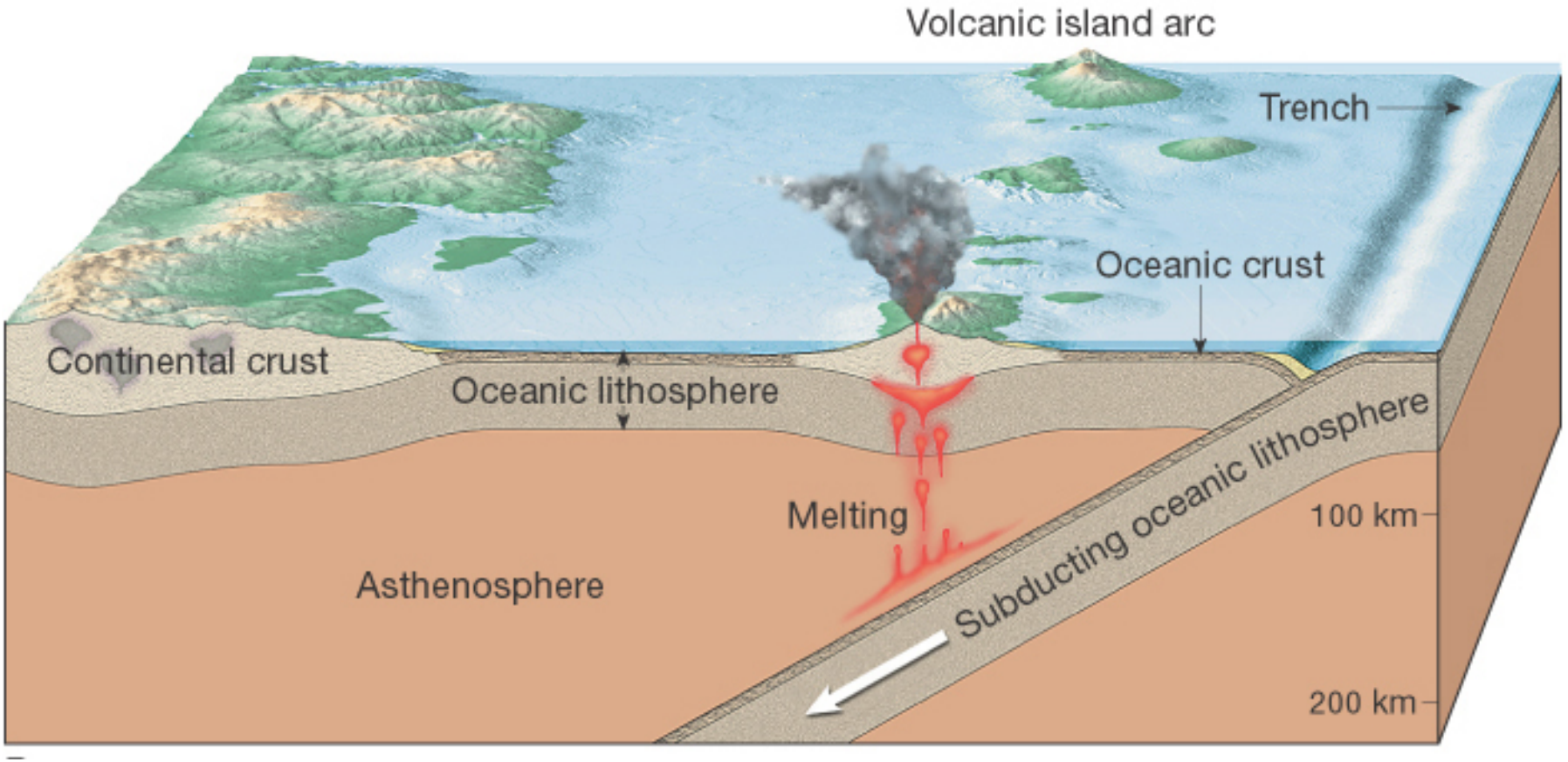
Circum-Pacific “Ring of Fire”



*Volcanic arcs and oceanic trenches partly encircling the Pacific Basin form the so-called **Ring of Fire**, a zone of frequent earthquakes and volcanic eruptions. The trenches are shown in blue-green. The volcanic arcs, although not labelled, are parallel to, and always landward of, the trenches. For example, the Andes volcanic arc is associated with the Peru-Chile Trench.*

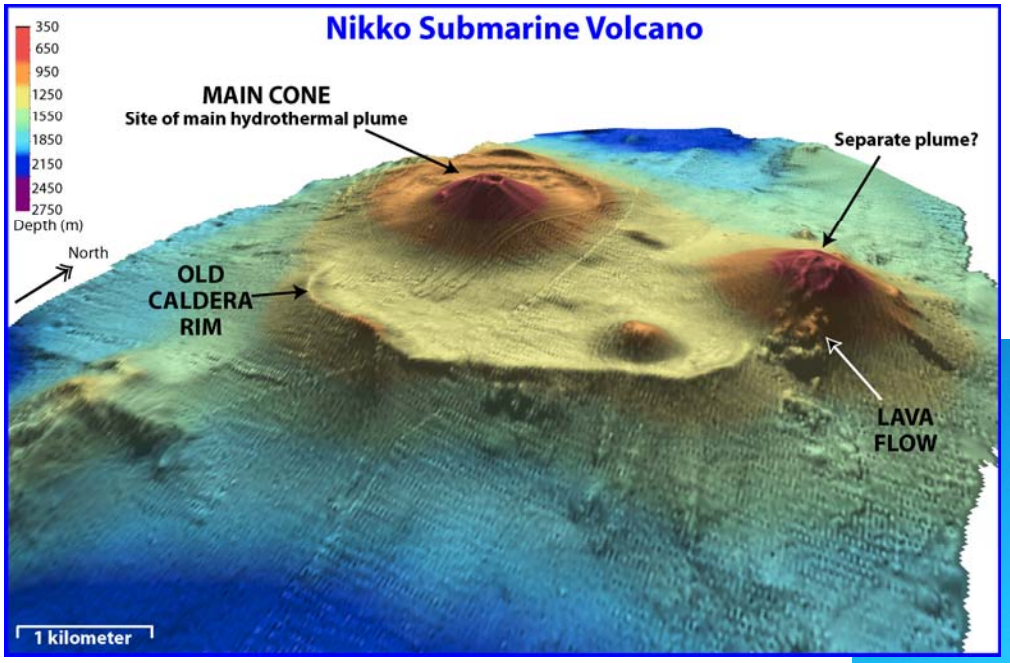
“This Dynamic Earth” http://pubs.usgs.gov/publications/text/fire.html

Oceanic Arc: Common in Western Pacific



TASA Graphics

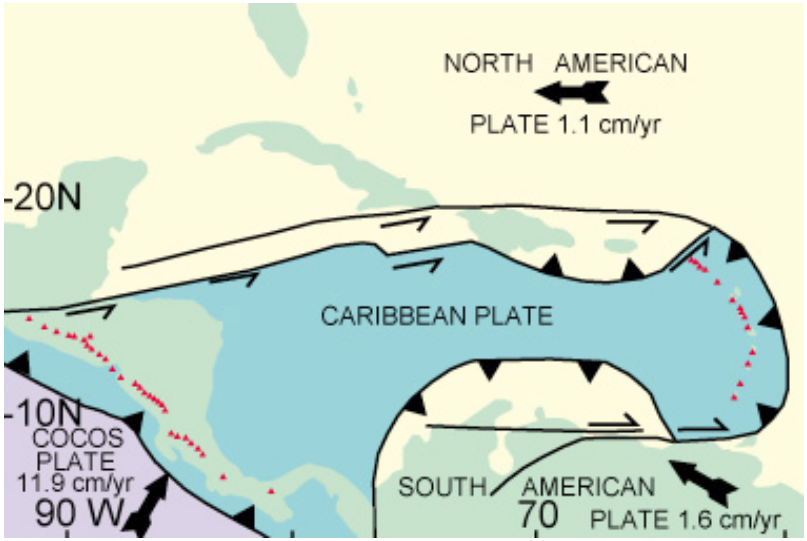
‘Island’ Arc Volcanoes

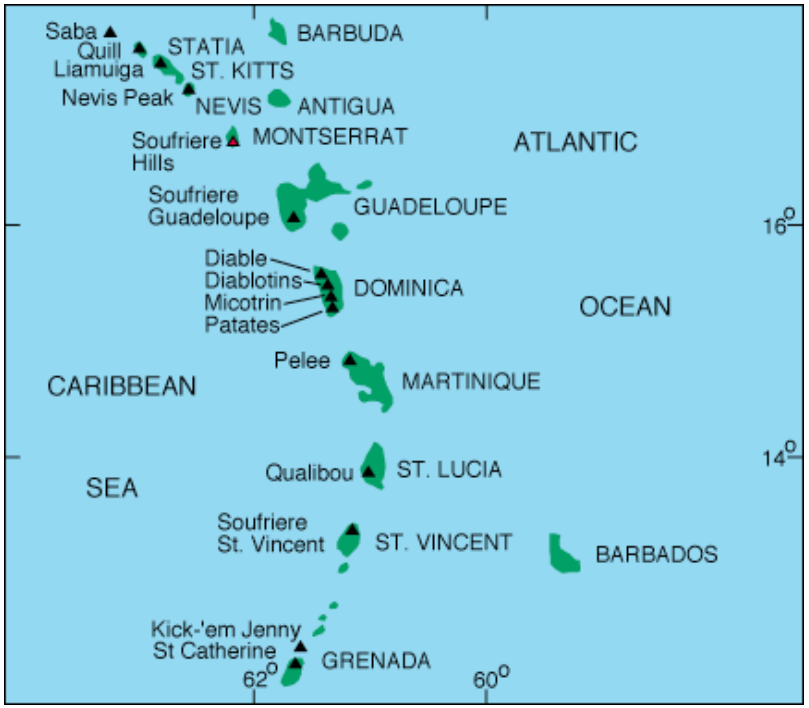


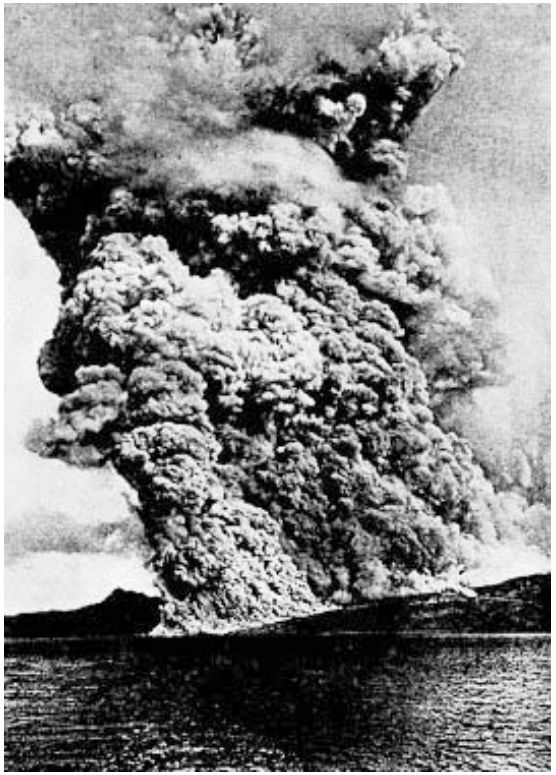
Some are not even islands!

Anatahan, Marianas 5/03

Lesser Antilles Island Arc



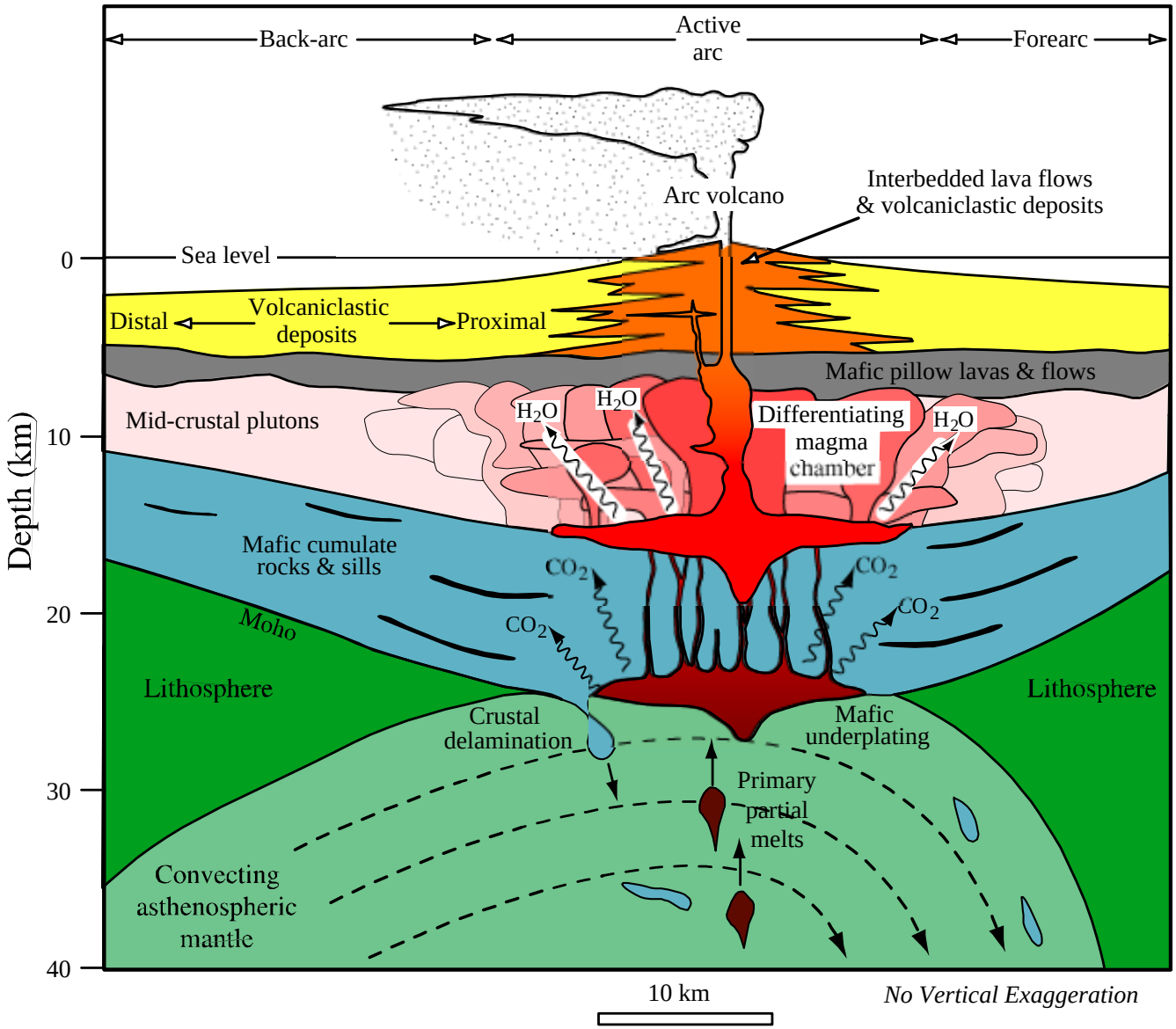




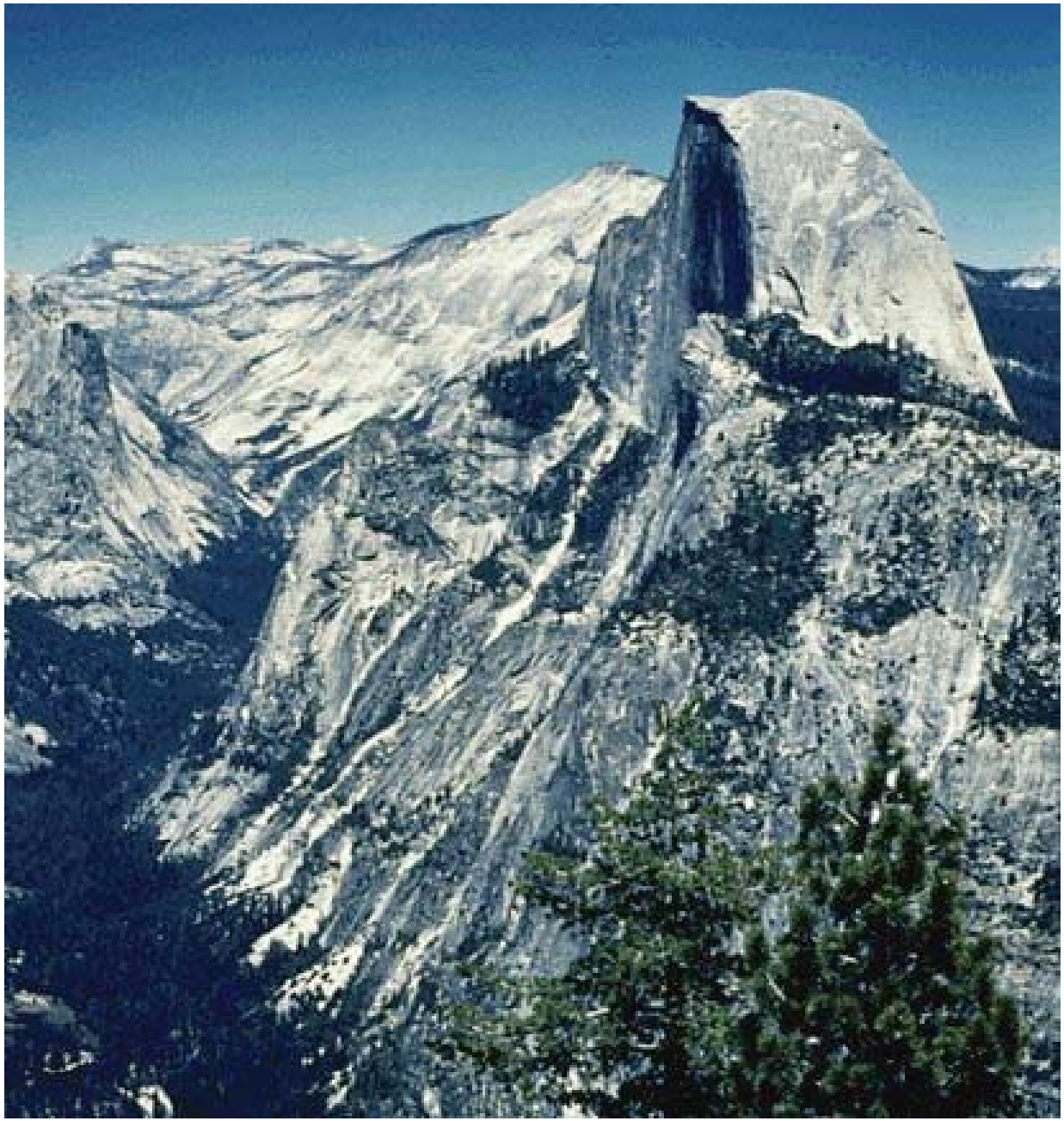
Pelee, Martinique 1902: 29,000 killed

"Volcano World' http://volcano.und.edu

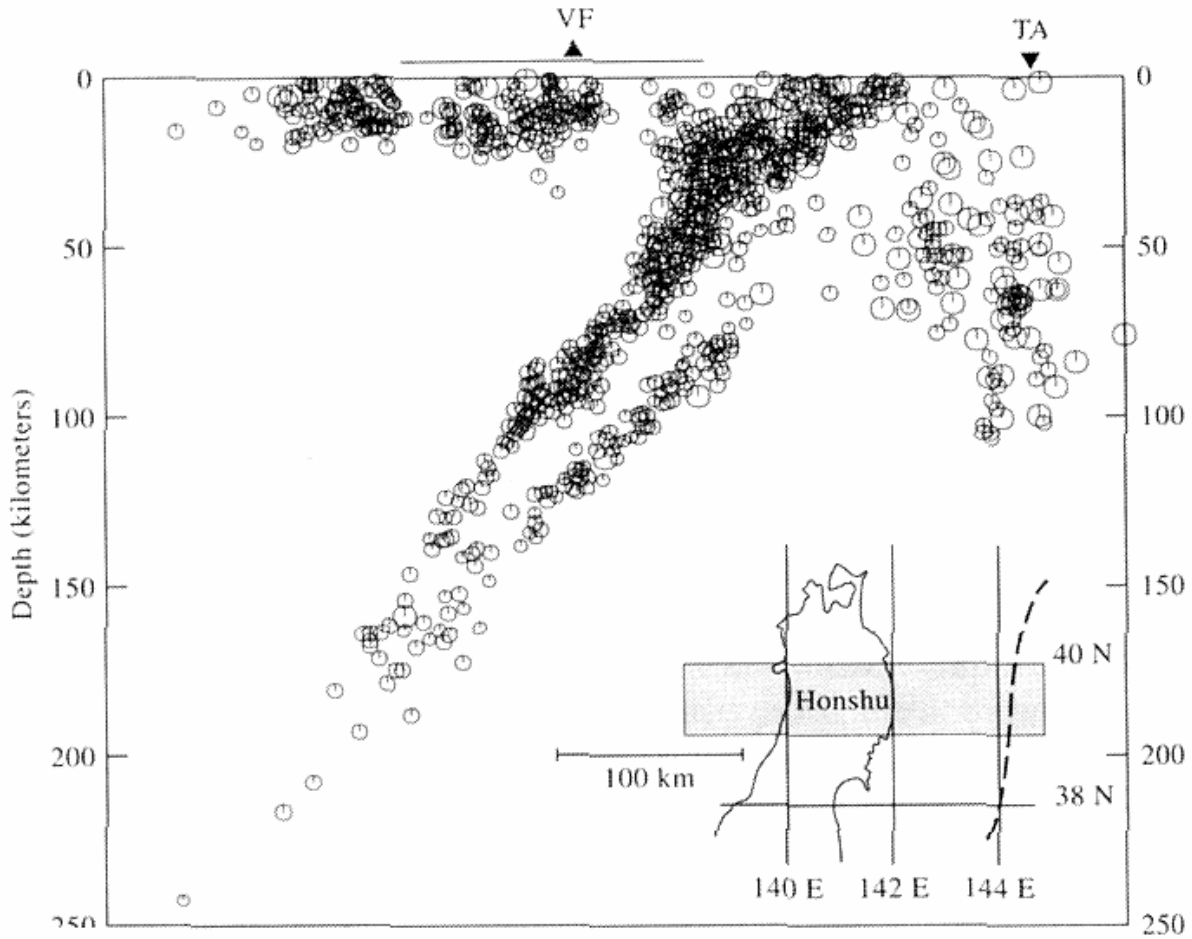
Arc volcanoes overly igneous intrusions in the crust



Half Dome, Yosemite (California): A good example of an ancient igneous intrusion

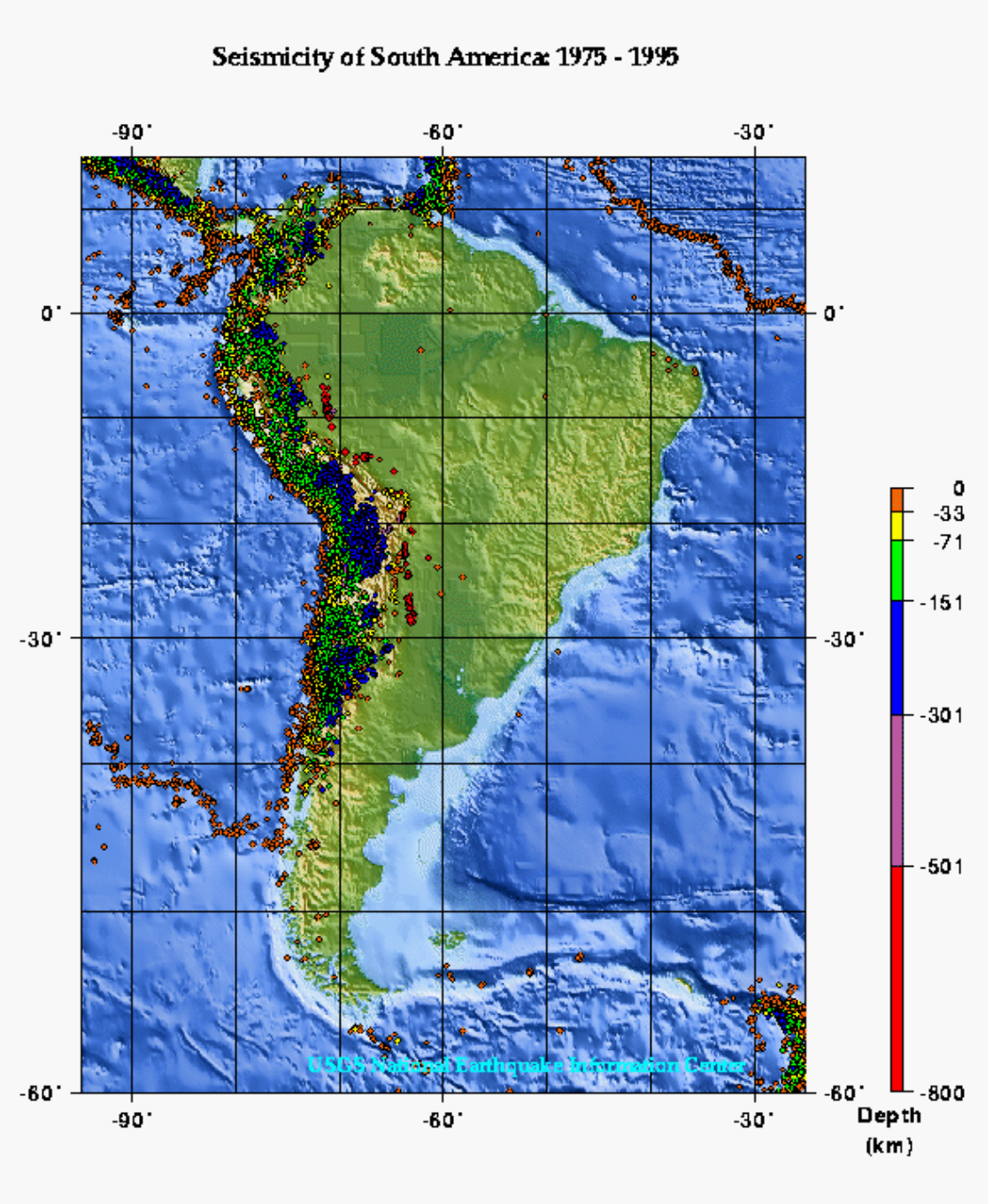


Subduction Zones are associated with inclined earthquake zones *(Wadati-Benioff Zones)*

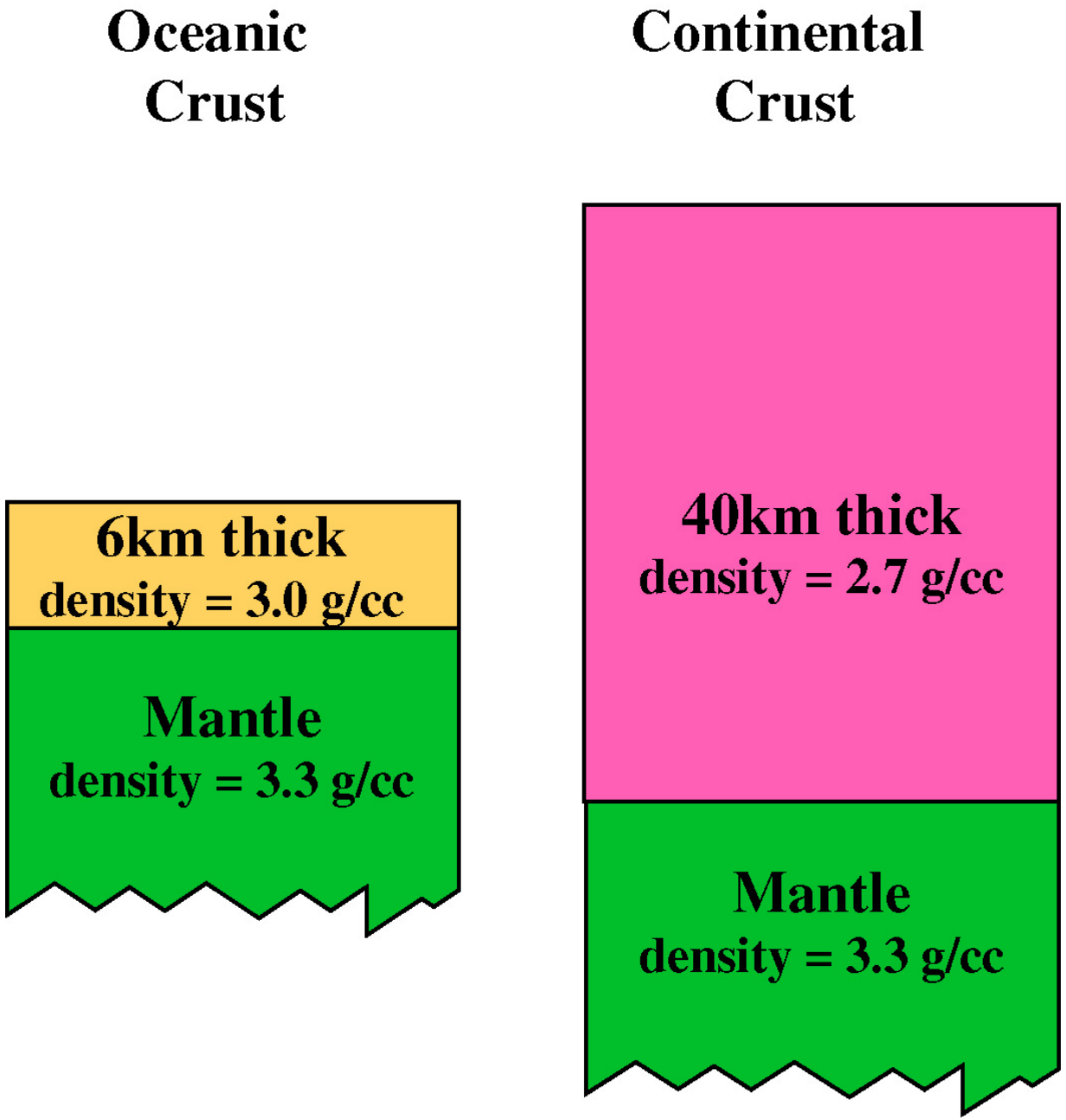


Earthquakes beneath Japan

Earthquakes in Latin America



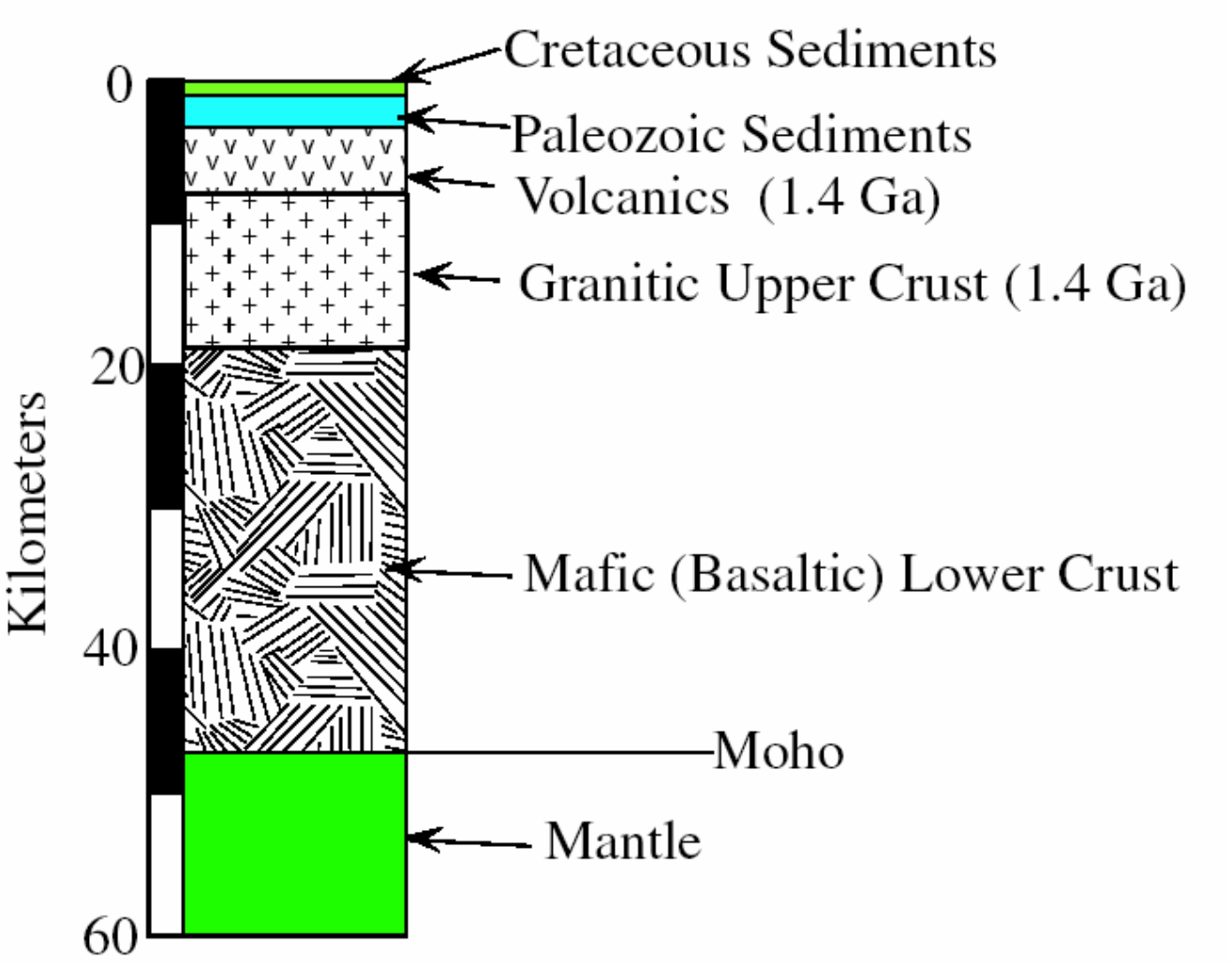
Oceanic vs. Continental Crust



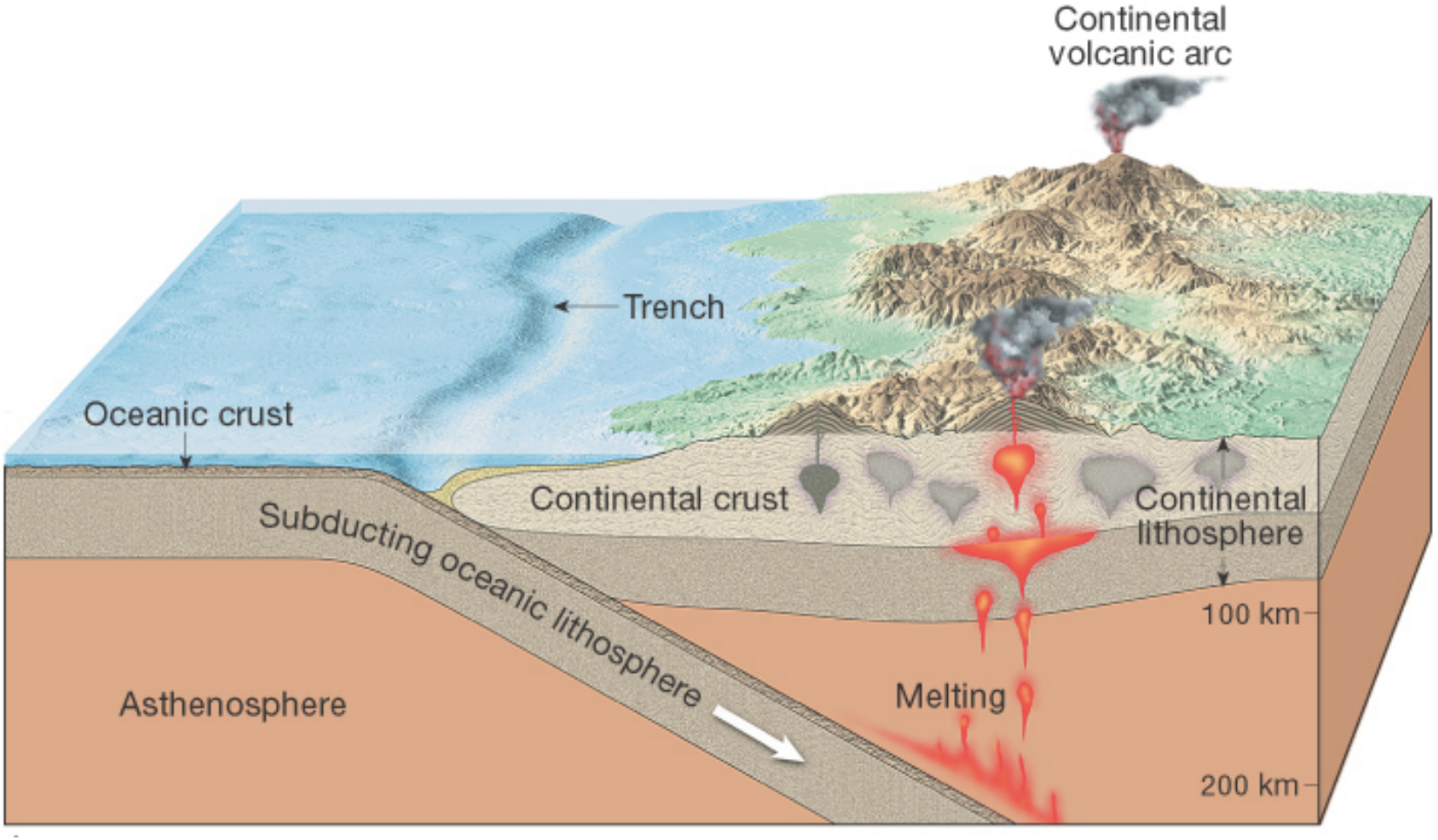
Two kinds of crust: Oceanic & Continental

	Ocean Basins	Continents
Thickness	6±1 km	~40 km
Composition	Basalt (~50% SiO_2)	Andesite (~50% SiO_2)
Max. Age	170 Ma	4000 Ma = 4.0 Ga
Origin	Seafloor spreading	Arc magmatism & accretion
Elevation	=f(age)	=f(tectonics)
Demise	Subducted	Immortal
Humans	No	Yes

Continental Crust beneath Dallas (Texas)



Arcs built on continental crust are “Andean-type” arcs

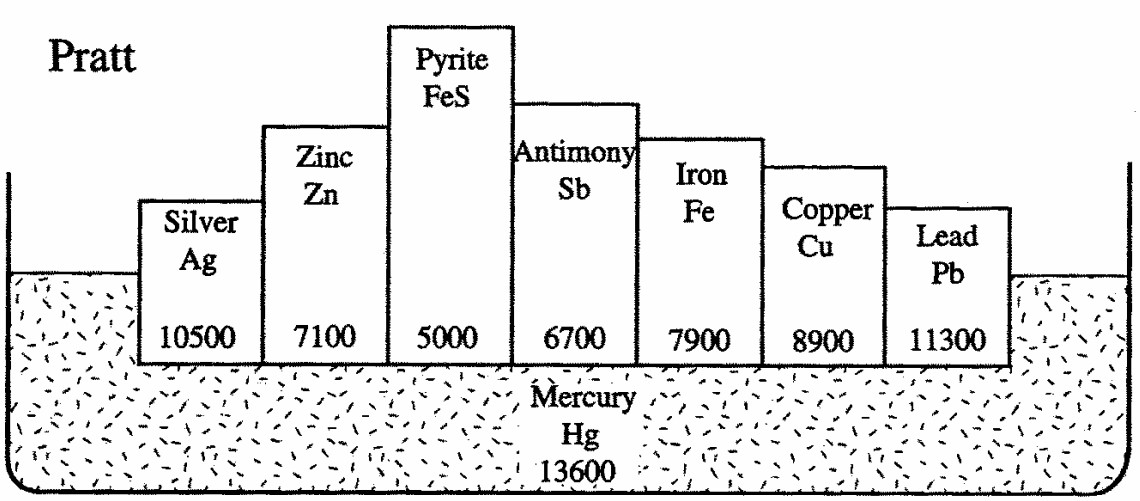


Tasa Graphics

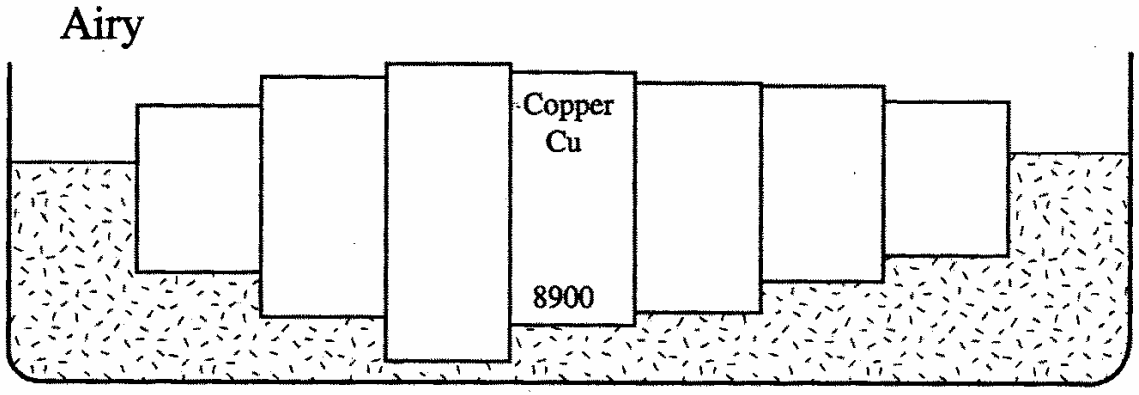
Isostasy

- Greek for “Equal standing”
- Indicates that masses must be equivalent above a ‘compensation depth’ (~asthenosphere)
- How can there be different elevations of Earth’s solid surface?

Pratt vs. Airy models of Isostasy

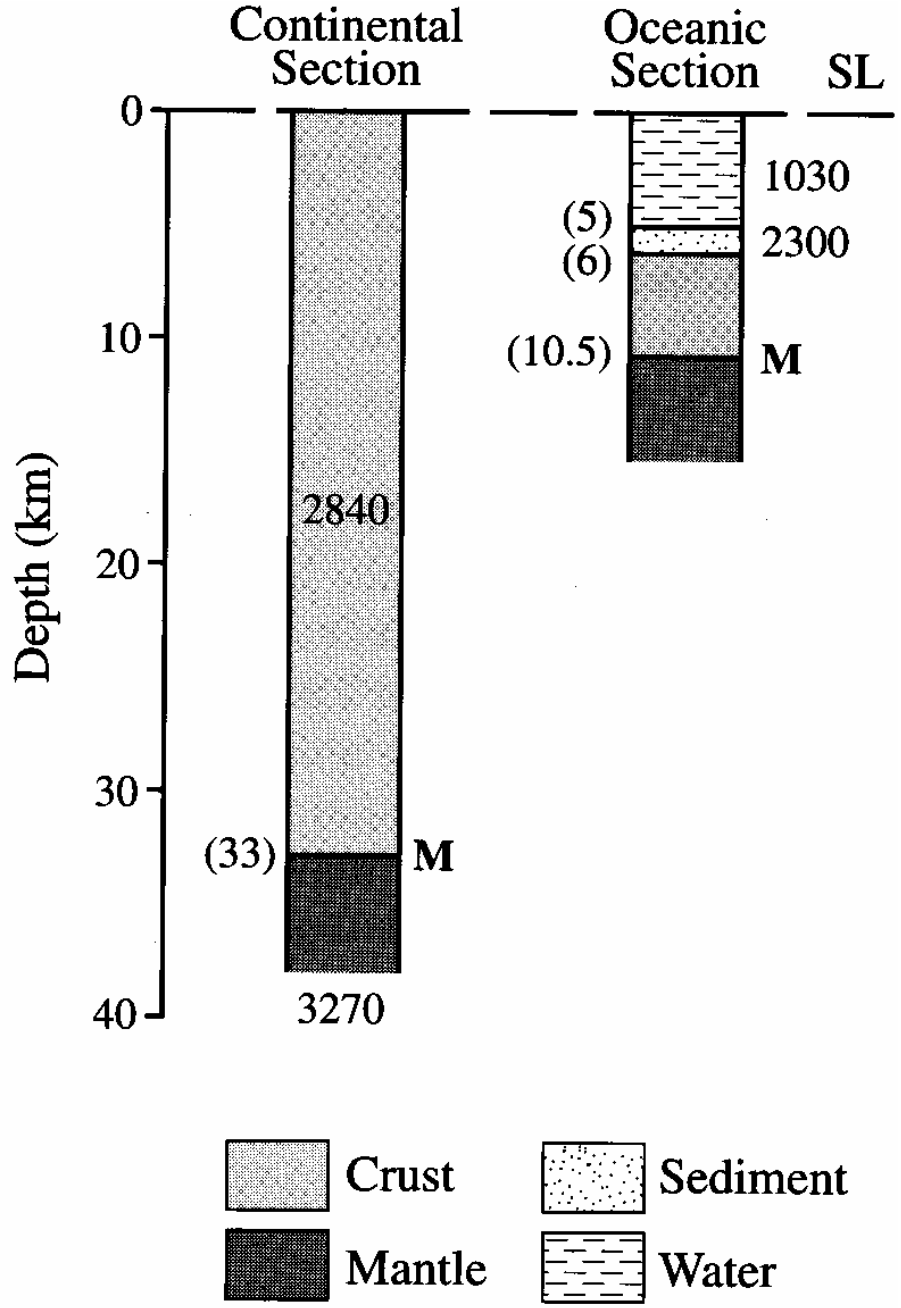


Different columns have different densities but reach the same depth



Different columns have the same density but different heights and depths

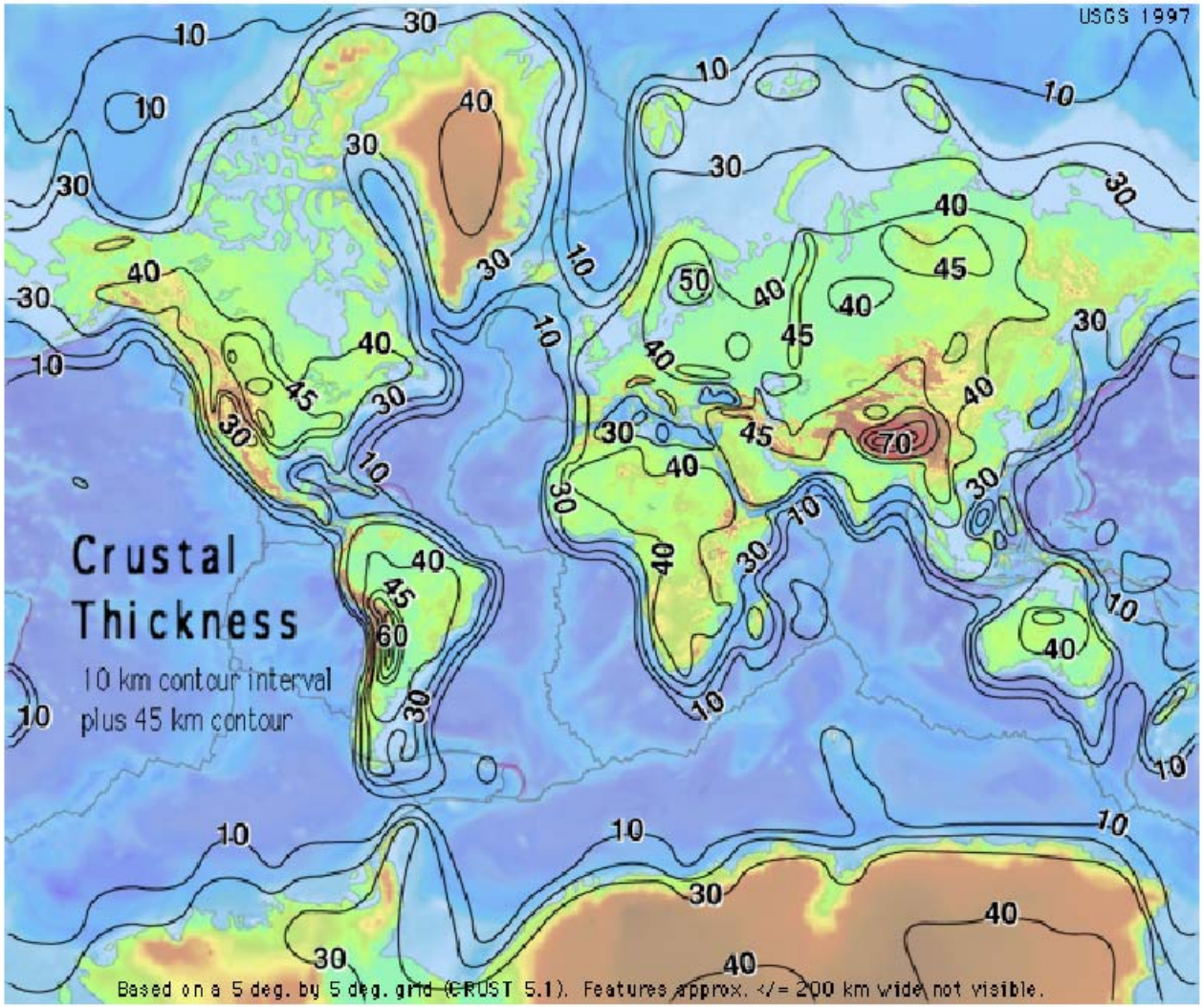
Watts 2001



Oceanic vs. Continental crust

Watts 2001

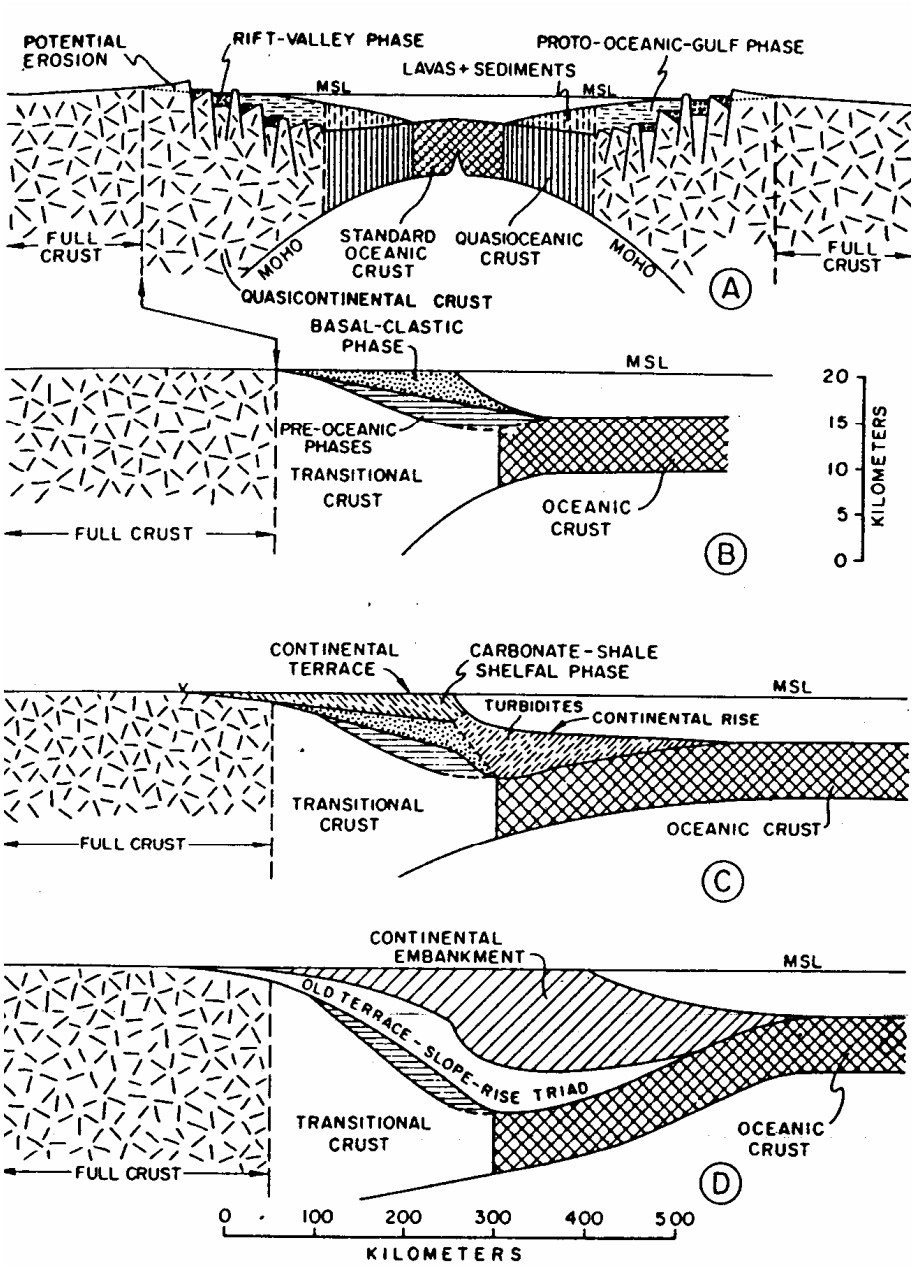
Thick crust of Central Andes



http://quake.wr.usgs.gov/research/structure/CrustalStructure/

Why are the Andes so high?

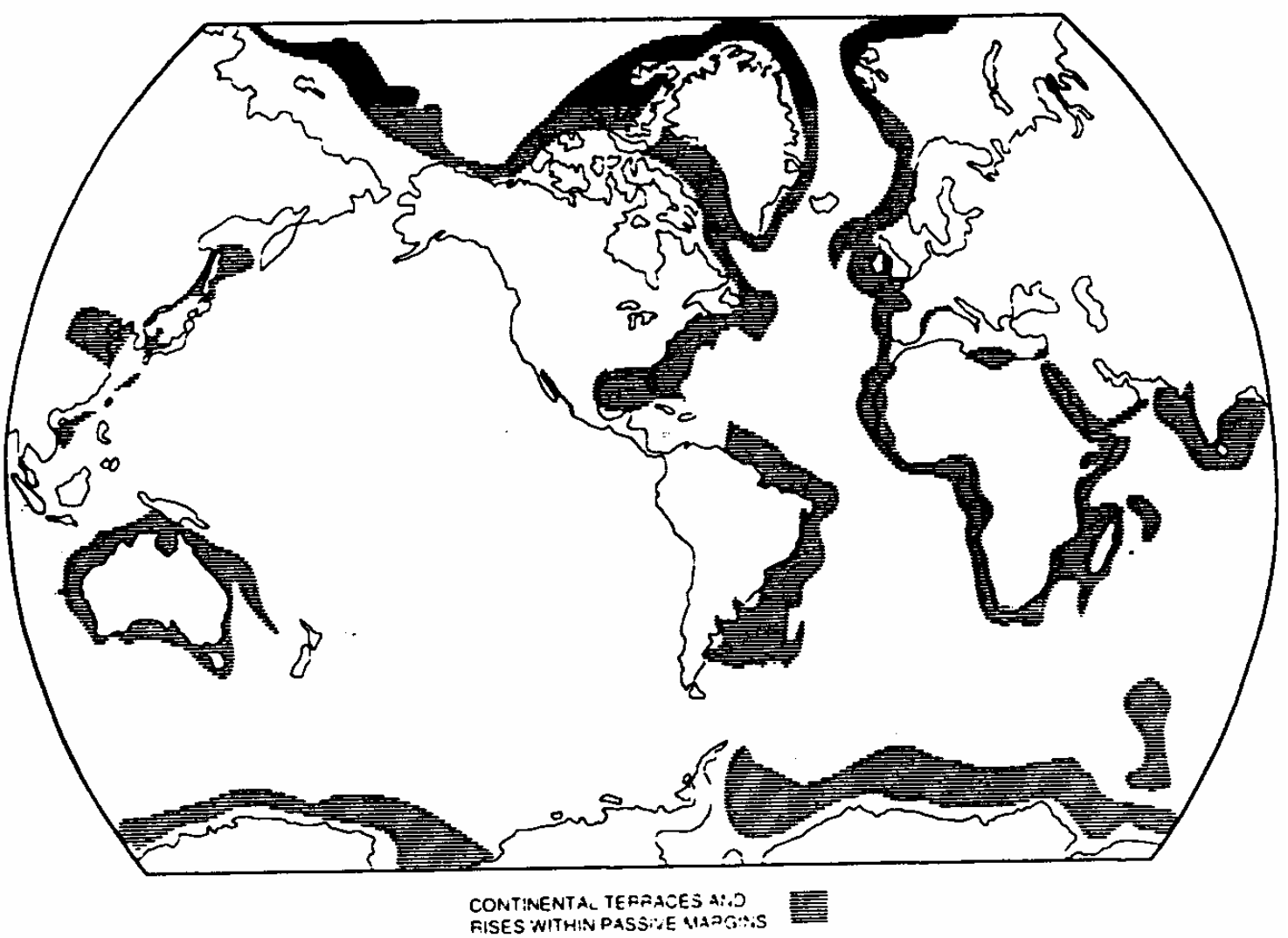
- Mountains of the Central Andes are the second highest range in the world (Himalayas are the highest with 100 peaks >8300m tall; Andes have 84 peaks over 6000m tall)
- Crust of Central Andes is the second thickest in the world (crust beneath the Himalayas and Tibet is the thickest)
- Isostasy! Thicker crust stands higher.



Passive margins

- Passive Margins are equivalent to continental shelves
- Crustal boundary between continental and oceanic crust
- These are not plate margins but are important because they are where thick accumulations of sediment occur

Passive Margins of the World



Moores & Twiss 1995