

Lecture-2: Plate Tectonics: Kinematic Earth

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Lecture Schedule

Date	Day	Time	L/R	Broad Topic(s)
Module 1: Earth Structure and Plate Tectonics				
				Internal structure of the Earth
			L1	Plate Tectonics: kinematic Earth, analyzing plate boundaries
			L2	Tectonics on a sphere: Geometry of Plate Tectonics
			L3	Triple Junction of plates: stability and significance
			L4	Absolute plate motion and plate driving forces

Earthquakes / Faults

P-wave (Longitudinal elastic waves)

Crust-Mantle

Mohorovicic Discontinuity (Moho)

Geotherm: 1-Dimensional $T(z)$ model

Lithosphere = Plate

Asthenosphere

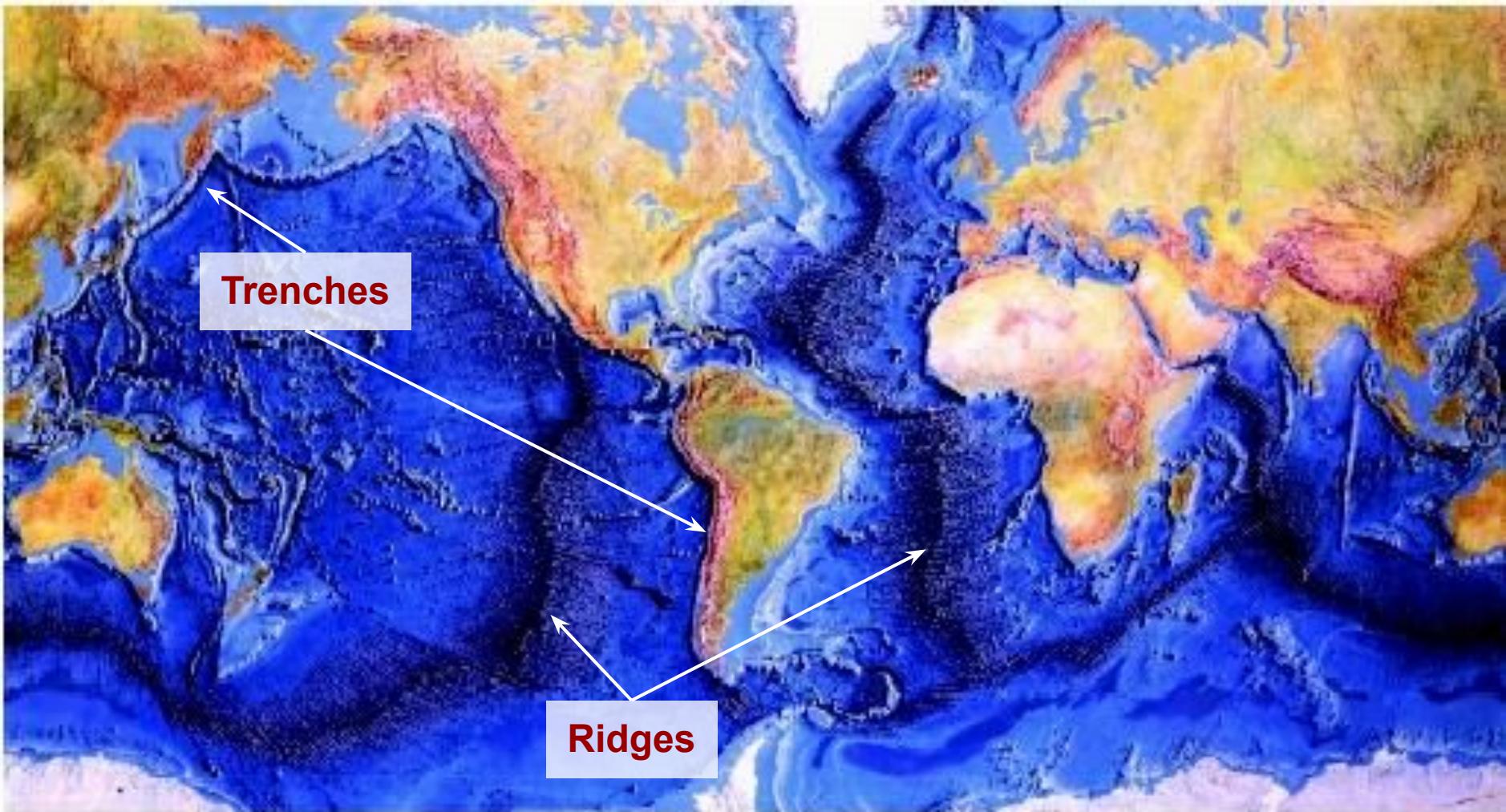
1915 – **Theory of Continental Drift** by Alfred Lothar Wegener (German Meteorologist)
The Origin of Continents and Oceans



Wegner stated: Continents simply plowed through the ocean floor and reached their present configuration.

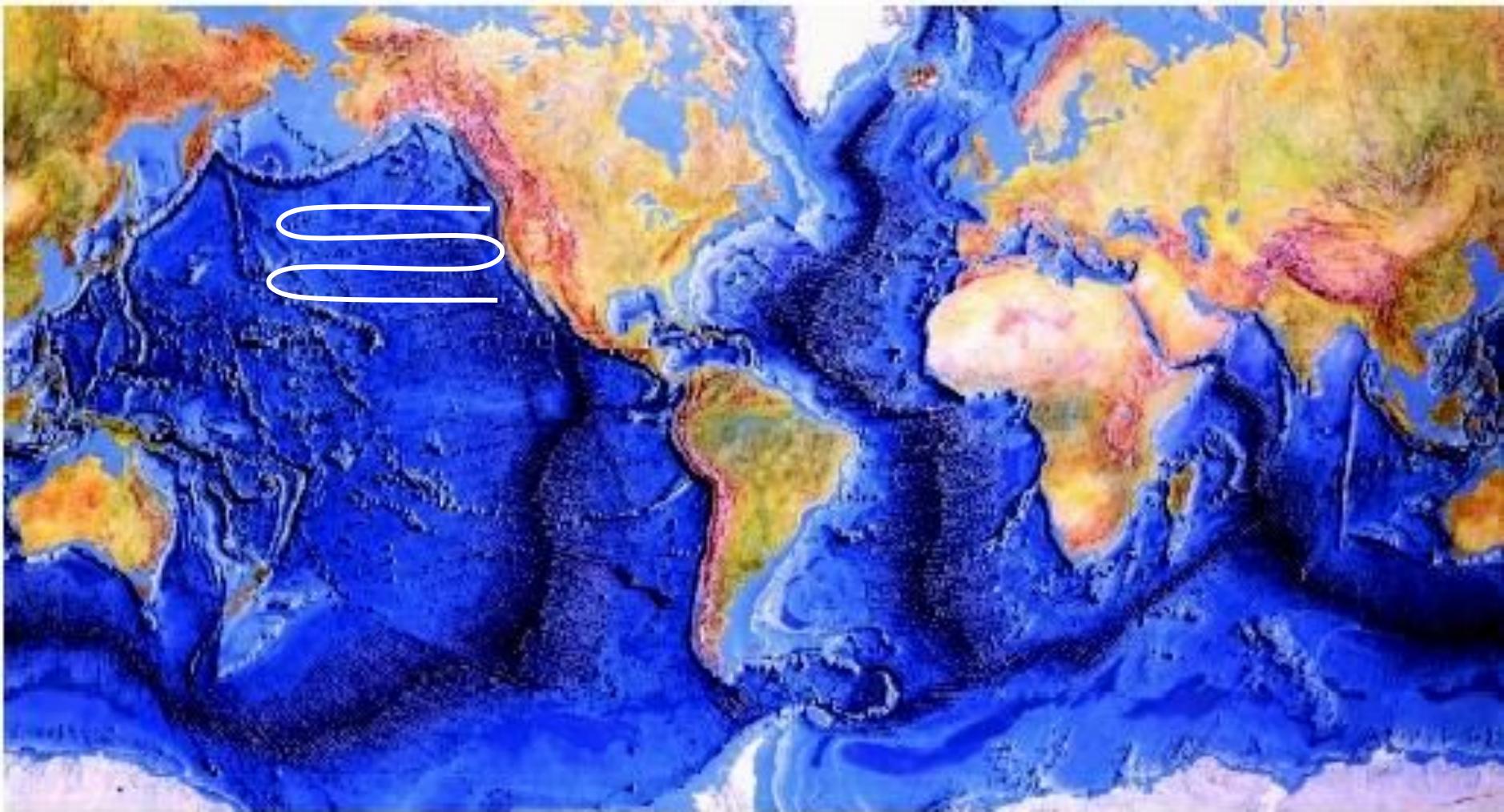


Exploration of the Ocean Floor



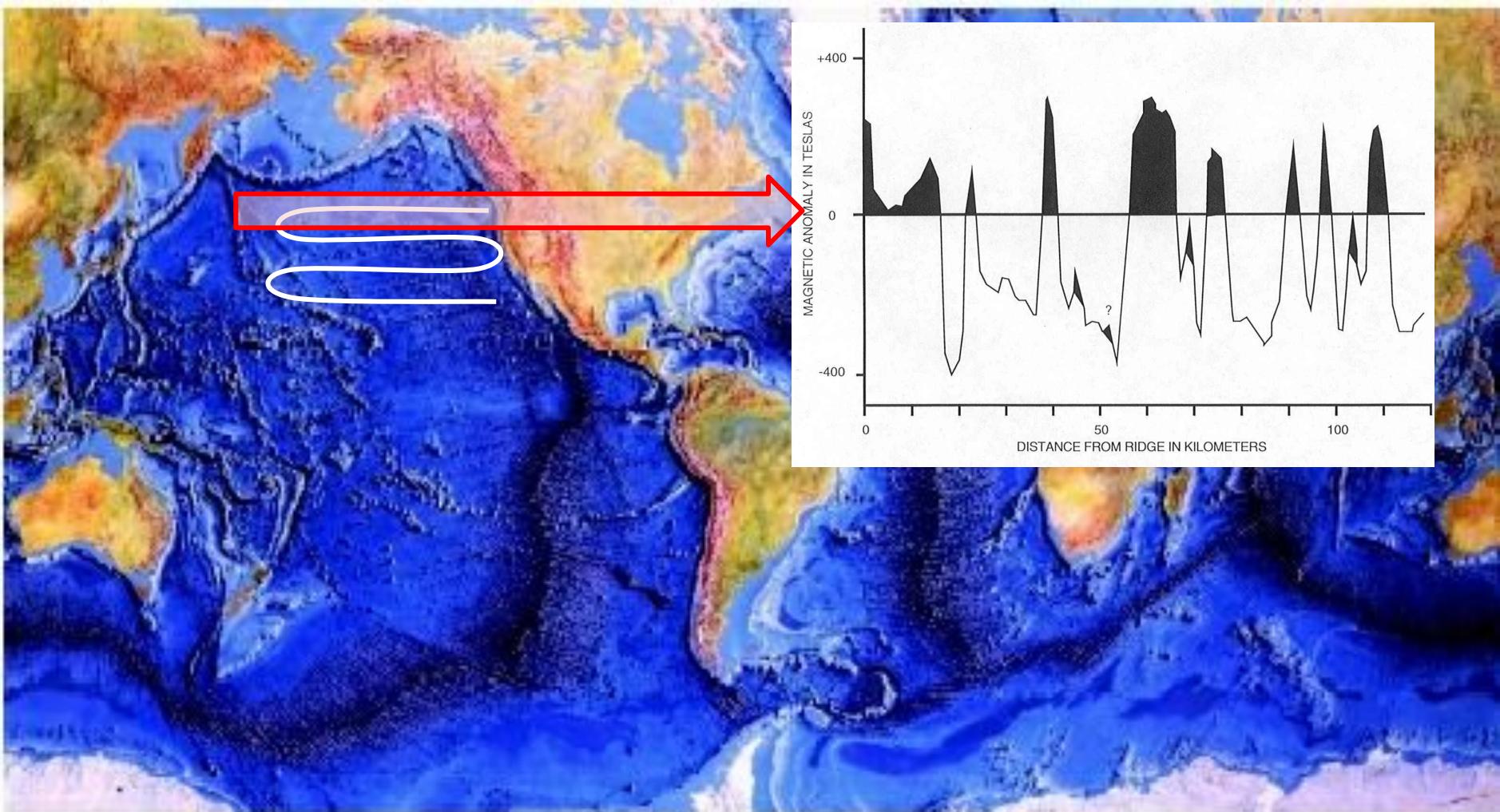
Bathymetry

Exploration of the Ocean Floor



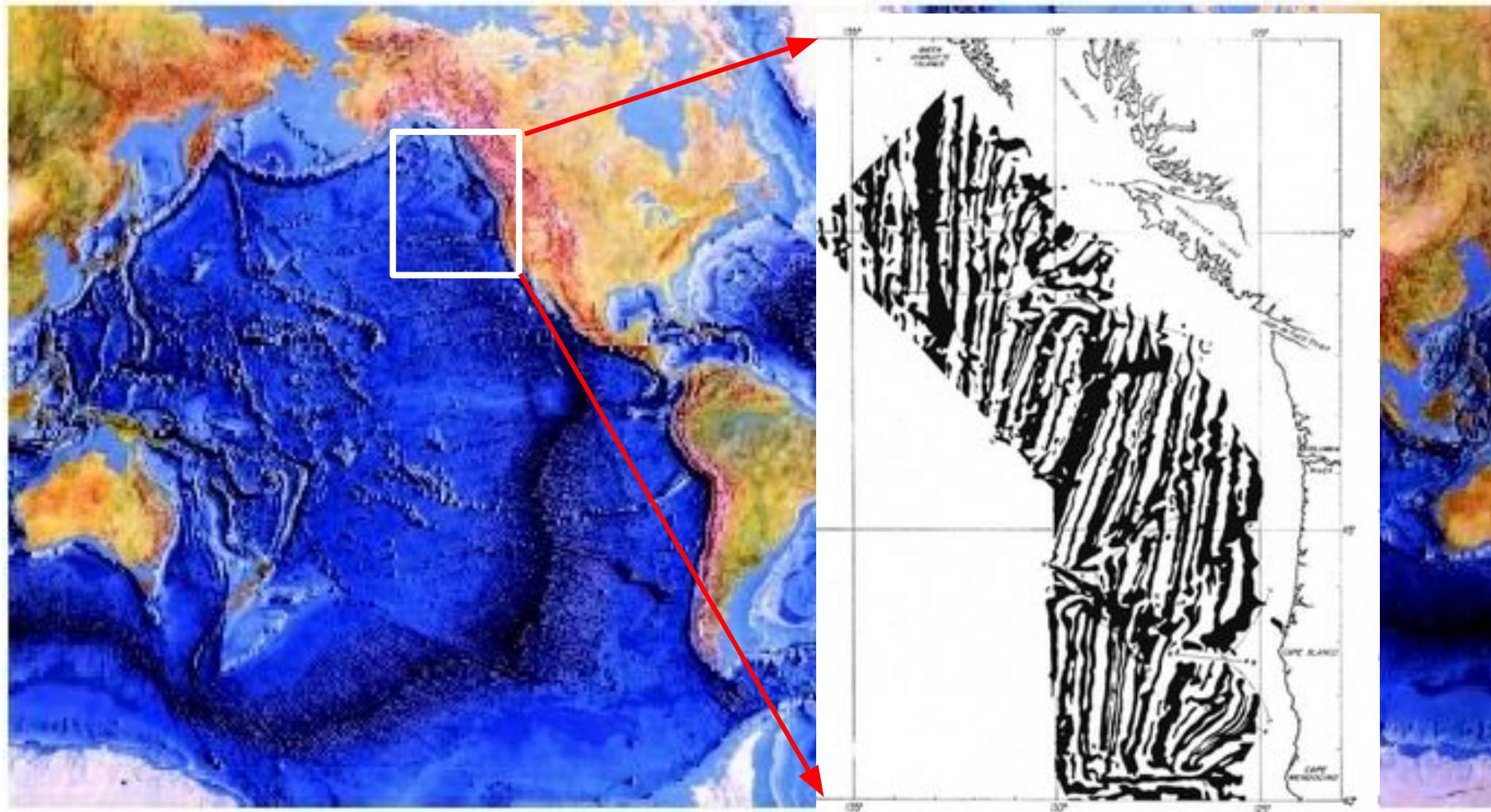
Bathymetry

Exploration of the Ocean Floor



Magnetization of the Ocean Floor

Exploration of the Ocean Floor



Magnetic Anomalies

Exploration of the Ocean Floor

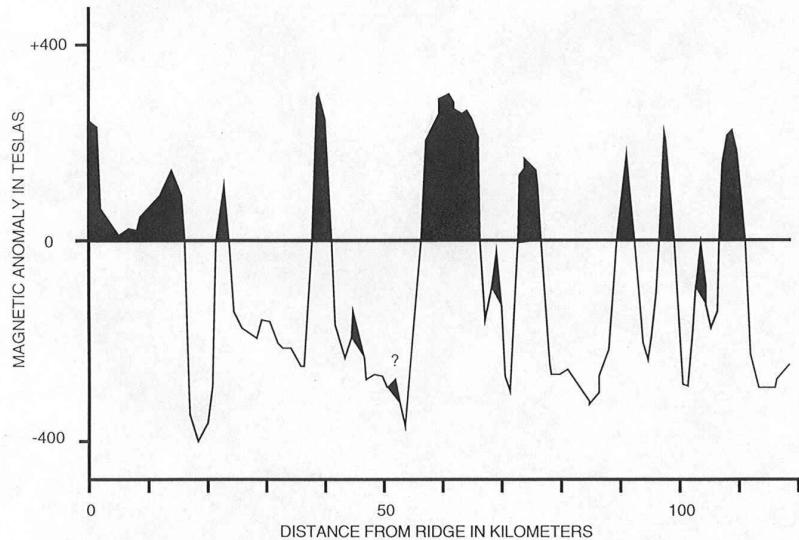


Figure 2. Magnetic anomalies measured over the South Atlantic Ocean along 0° latitude.



Alternating magnetic stripes of high and low magnitude on the seafloor

Magnetic Anomalies

Continental Lava Flows

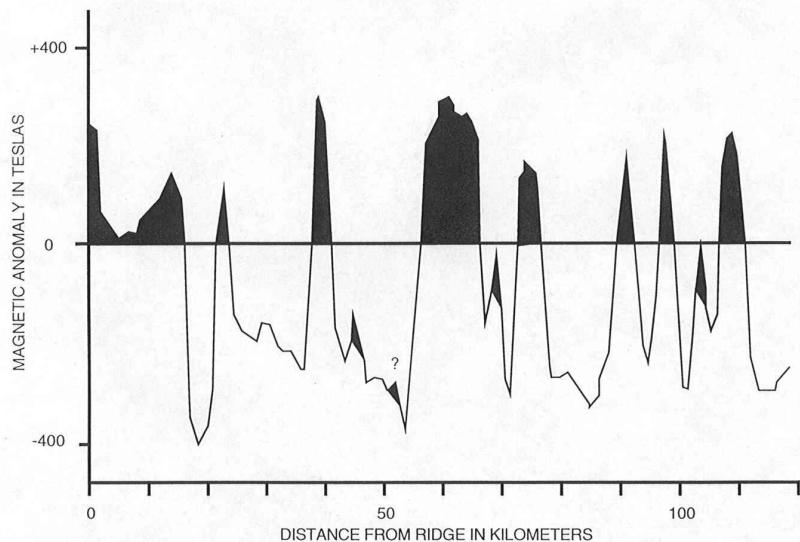
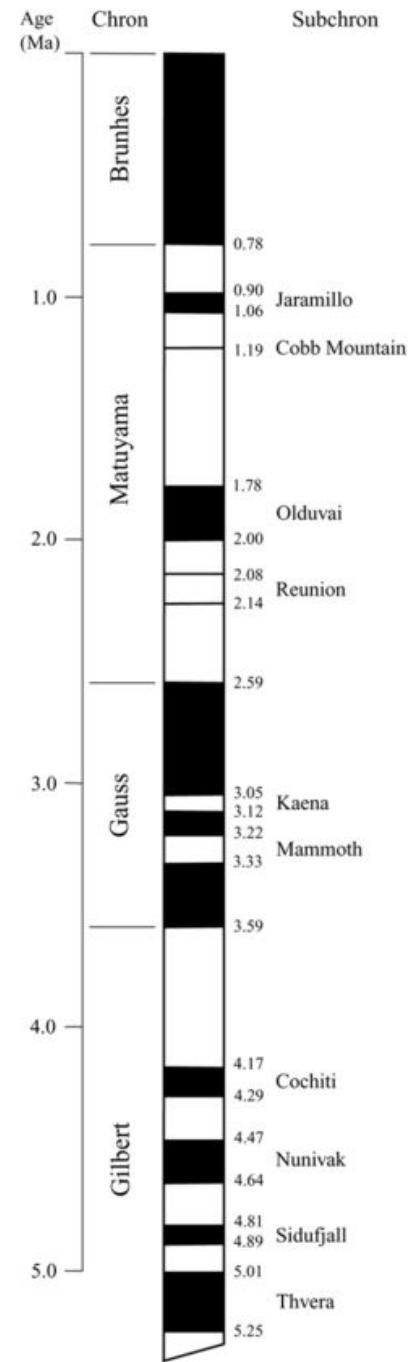


Figure 2. Magnetic anomalies measured over the South Atlantic Ocean along 0° latitude.

**Alternating magnetic stripes of
Normal and Reverse Polarities**

Paleo-magnetic Scale

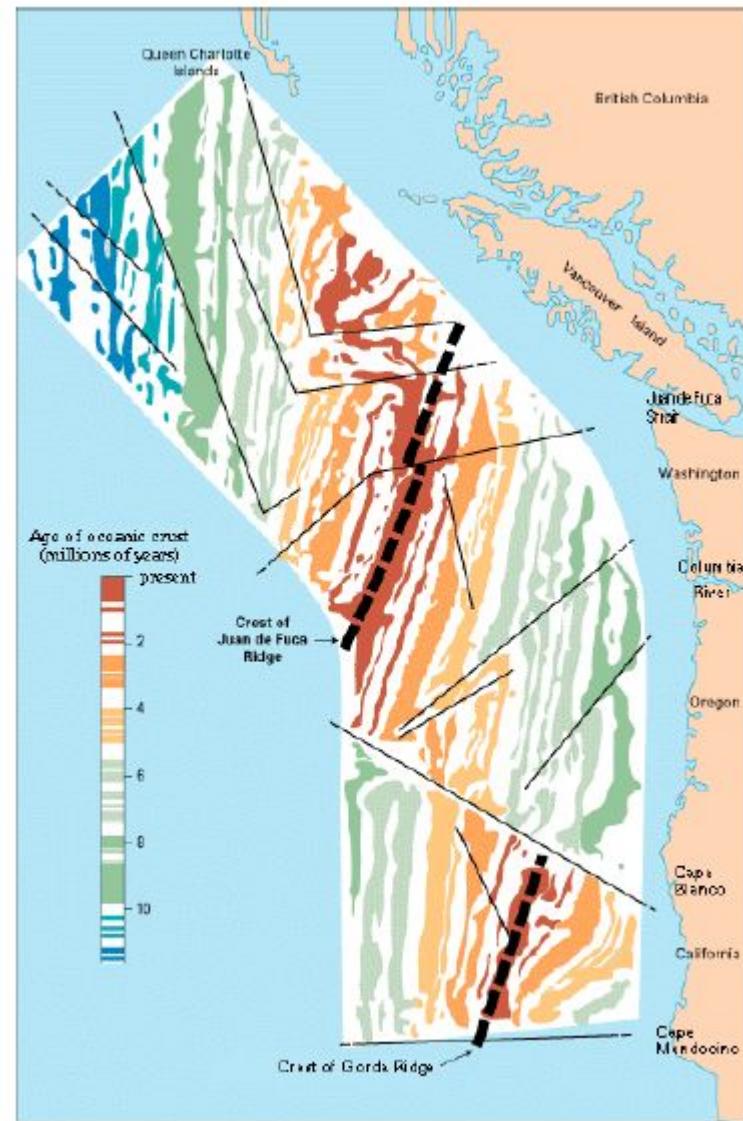


Bathymetry + Magnetic Anomalies

- Alternating magnetic stripes of Normal and reversed polarity on the seafloor
- Symmetric around the underwater chain of mountains that was discovered



Vine and Matthews (1963)



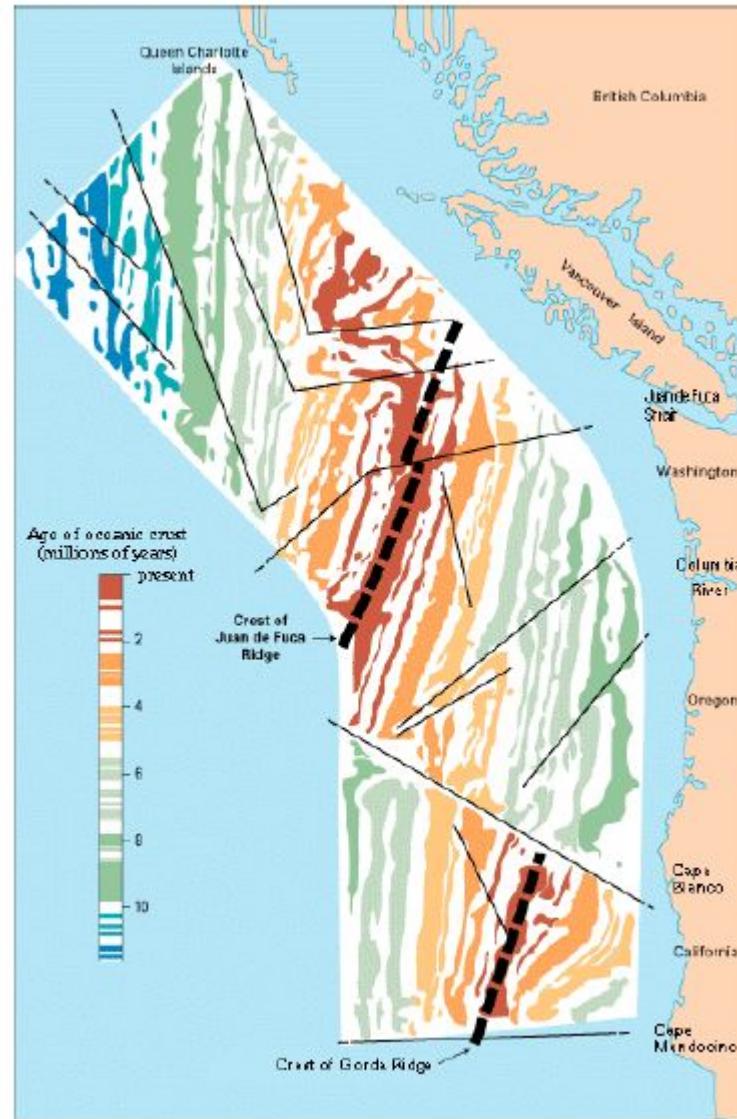
Bathymetry + Magnetic Anomalies

- Alternating magnetic stripes of Normal and reversed polarity on the seafloor
- Symmetric around the underwater chain of mountains that was discovered

Magnetic stripes prompted more questions:

- 1 How does the magnetic striping pattern form?
- 2 Why are these stripes symmetrical around the crest of MOR?

These could not be answered without knowing the significance of the ridges



Dating the Ocean Floor

- Rocks from the ocean floor are different from continents
- Youngest rock at Mid-Ocean Ridges
- Becomes older away from the MOR



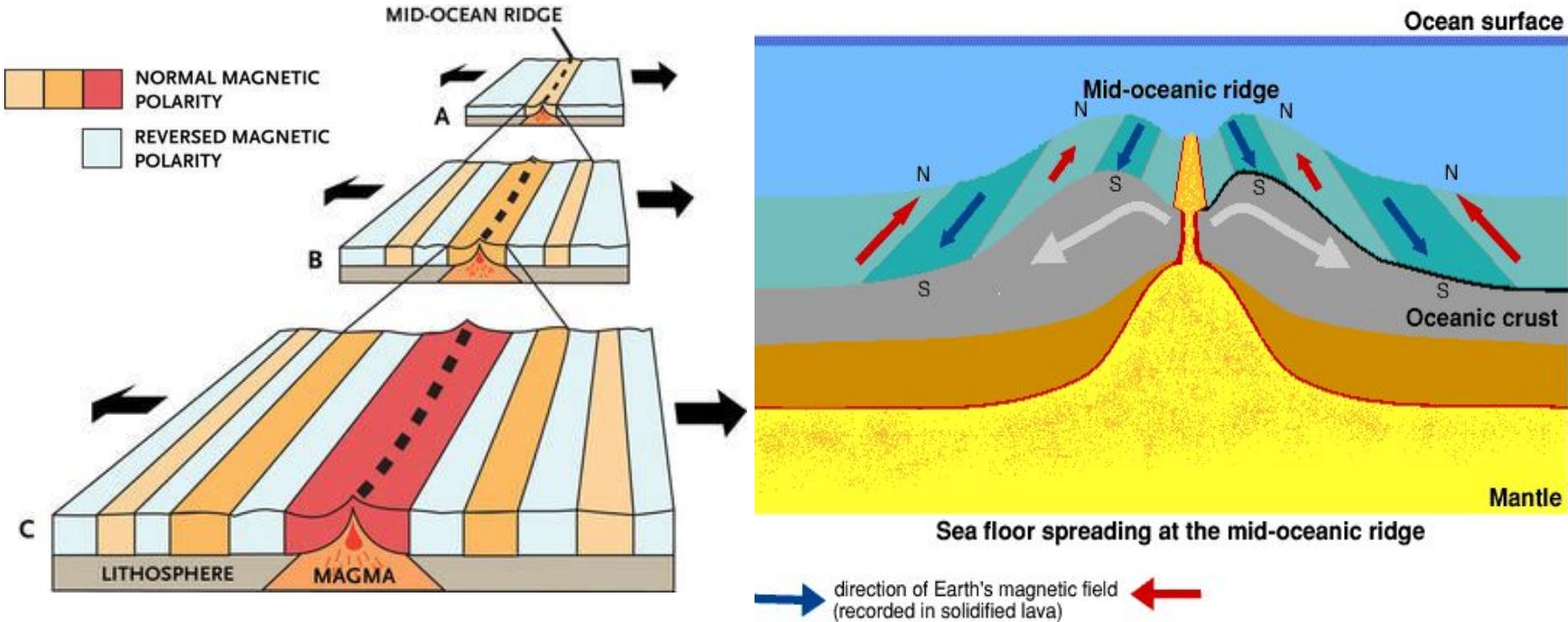
Ocean Floor



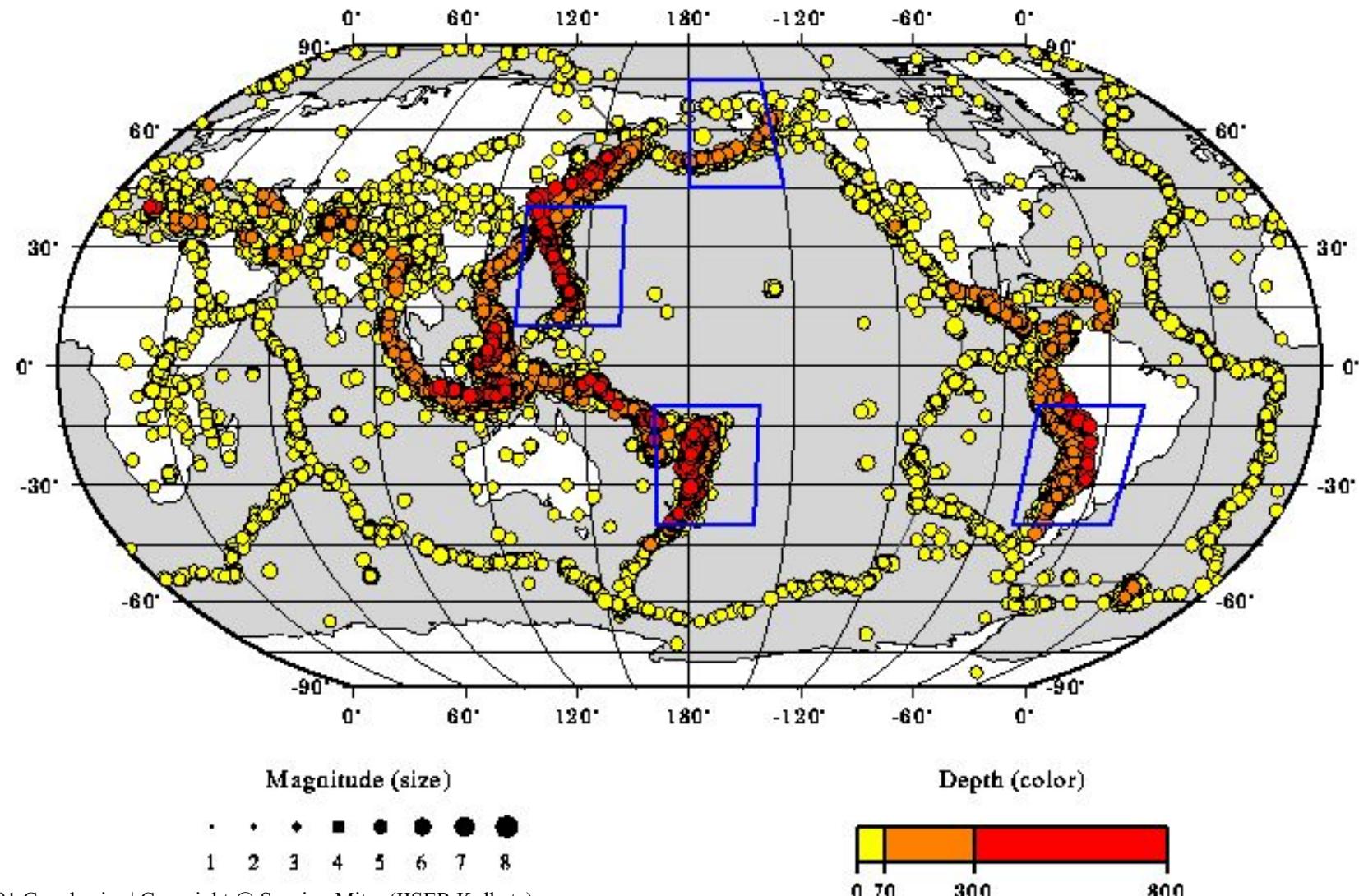
Continent

Mid-Ocean Ridges and Magnetization of Ocean Floor

1. MOR marked structurally weak zones
2. Ocean floor was being ripped apart lengthwise along the ridge crest
3. New magma from deep within the earth rises through these weak zones
4. Eventually erupts along crest of the ridge to create new oceanic crust
5. New ocean floor magnetized in the direction of the Earth's magnetic field



Significance of depth distribution of Earthquakes



Advancements (1950s and early 60s)

1. **Bathymetry** of the Ocean Floor: Mid-Ocean Ridges & Trenches
2. **Magnetic Anomaly** Patterns on the Ocean Floor: Alternating high and low (positive & negative) stripes
3. **Continental (Paleo) Magnetization**: Repeated reversals of the Earth's Magnetic Field
4. **Seafloor Spreading Hypothesis** (Harry Hess)
5. **Magnetic Anomalies + Seafloor Spreading**: Symmetric about MOR - Pattern & Age (youngest rocks at the Ridge with present day [Normal] polarity) - provided Seafloor Spreading rate!
6. **World Wide Standard Seismic Network (WWSSN)** - Defined Plate Boundaries, Marked zones of plate deformation along the boundaries (earthquakes) and revealed rigid plate interiors

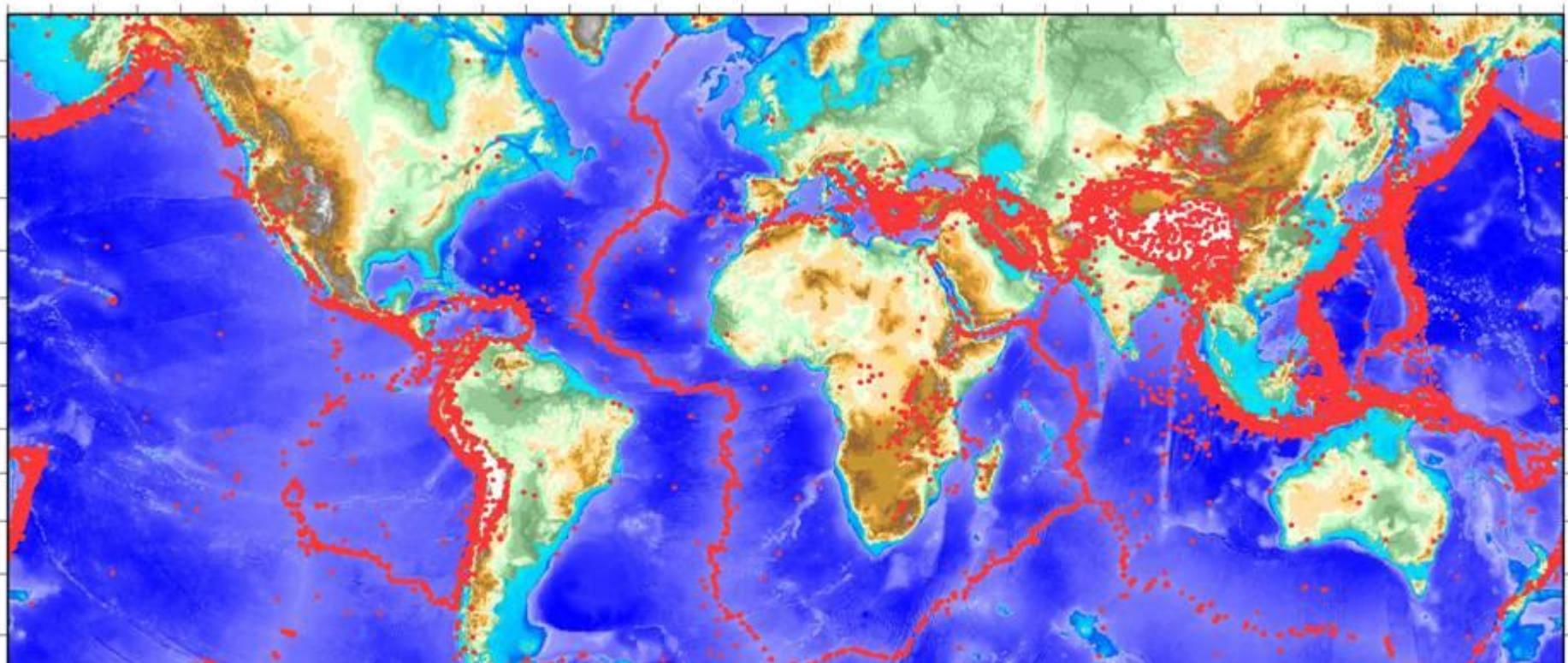
The unifying theory: Plate Tectonics

- The outermost layer of the Earth called the lithosphere is divided into small number of nearly rigid **plates** moving over the asthenosphere.



The unifying theory: Plate Tectonics

- Most of the deformation which results from plate motions (earthquakes) takes place along the edge, or *boundary*, of a plates. Deformation inside the boundary is not significant.



This is a **kinematic Theory**

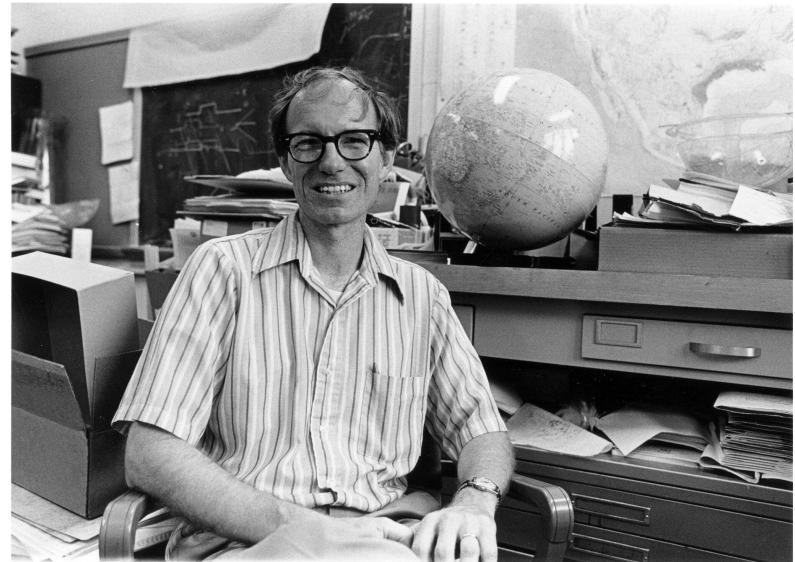
It is not concerned with the forces that maintain the motions.

Plate Tectonics



Dan Peter McKenzie

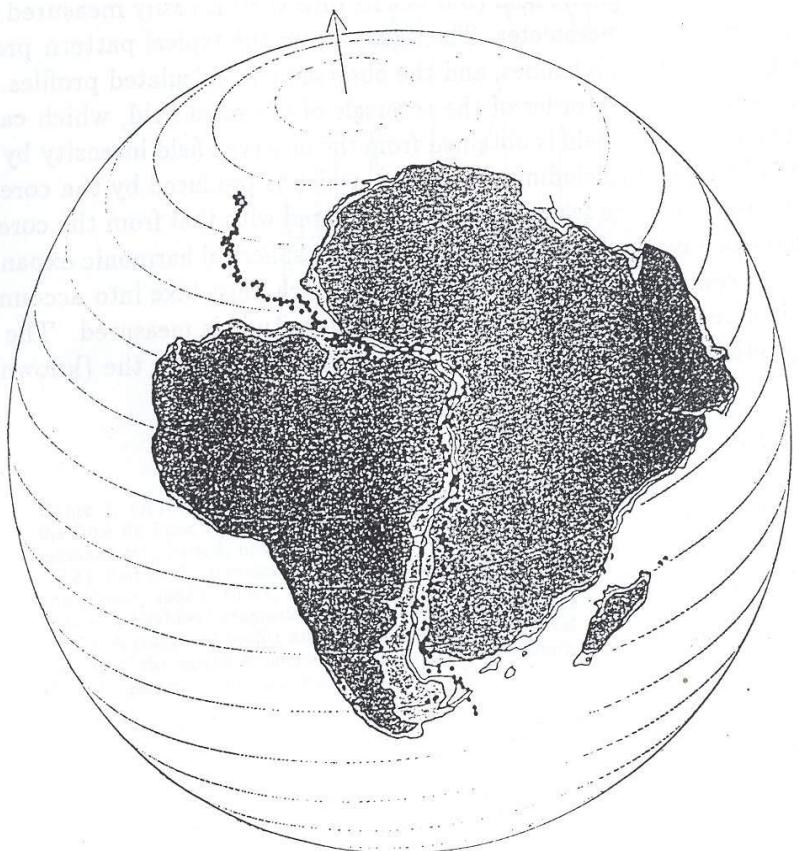
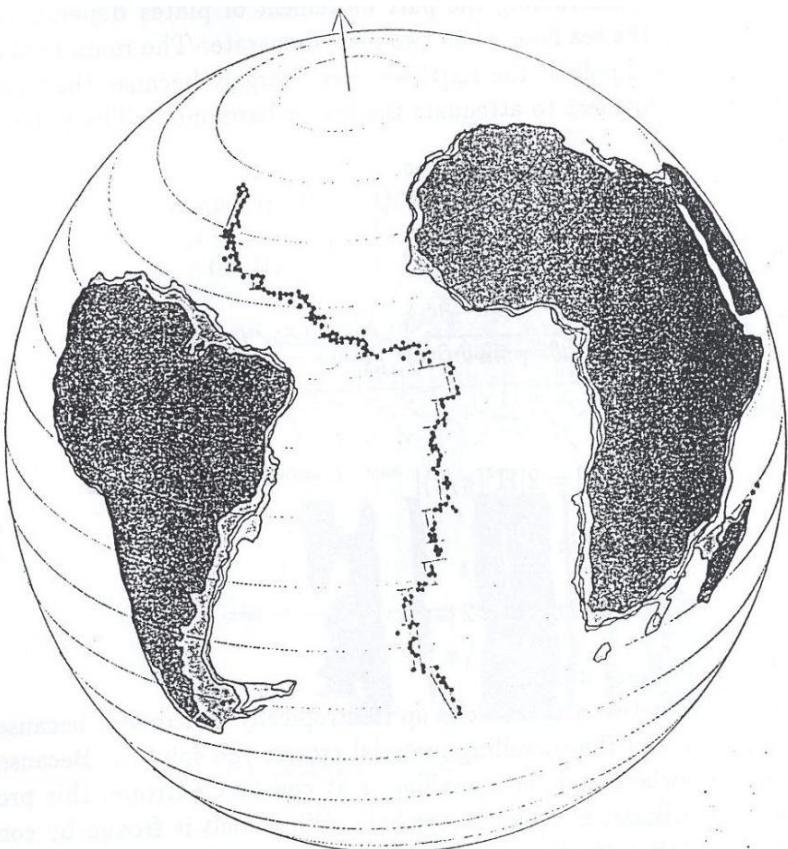
"The reaction was astonishing. I went from being an unknown graduate student to somebody who was one of the people everybody invited to their conference – and paid their way – within a year. ...I reckoned scientists didn't get this sort of opportunity very often, perhaps once in their life, so I should really work hard and get on with it, and see how far this all went. So I was too busy to be conceited and absolutely went hell for leather; I knew it was going to be competitive."



W. Jason Morgan

Inexplicable Observations!

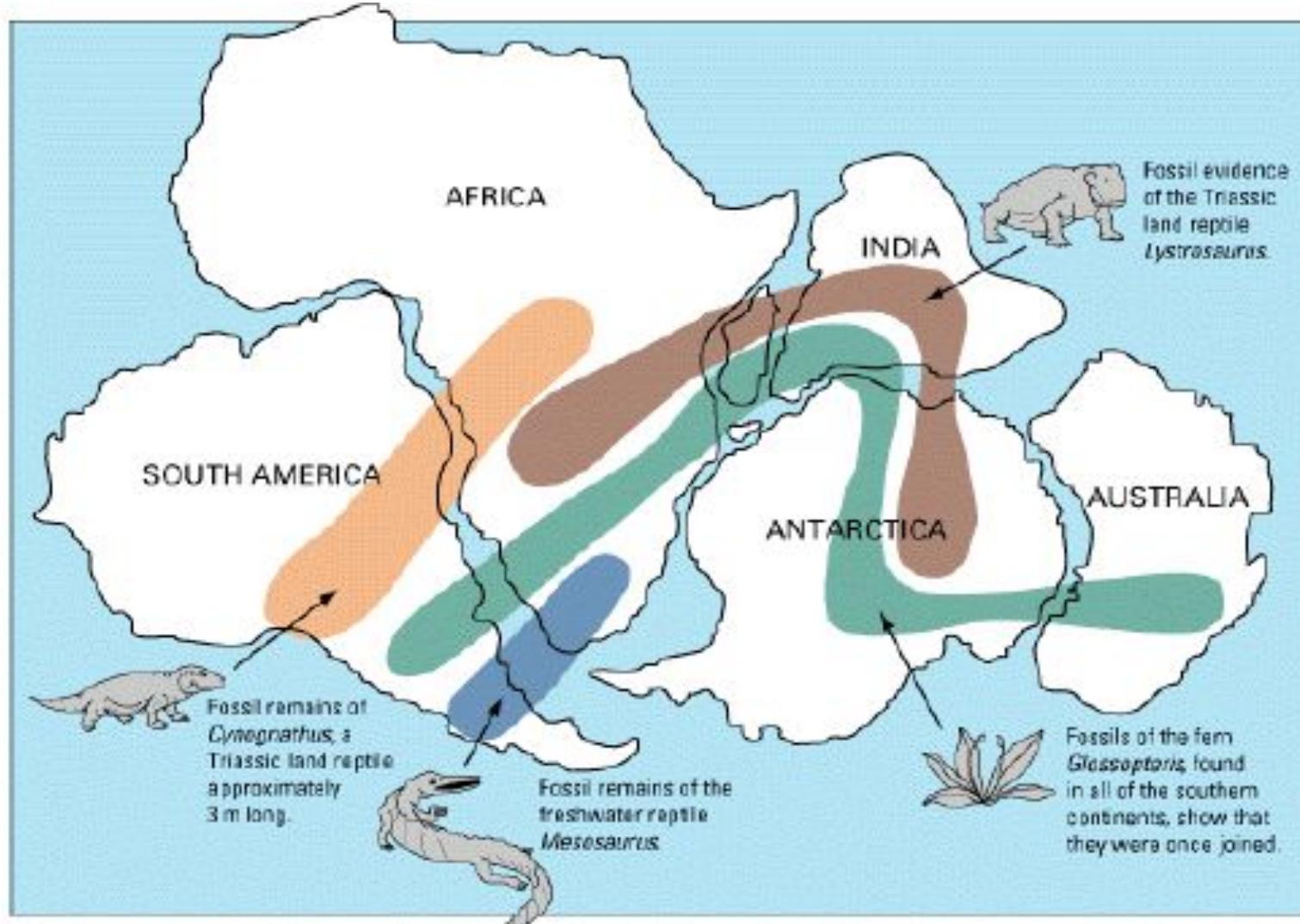
Remarkable fit of South American and African continents



Edward Bullard

Inexplicable Observations!

Occurrences of unusual geological structures and plant and animal fossils found on matching coastlines, now widely separated by the Oceans.

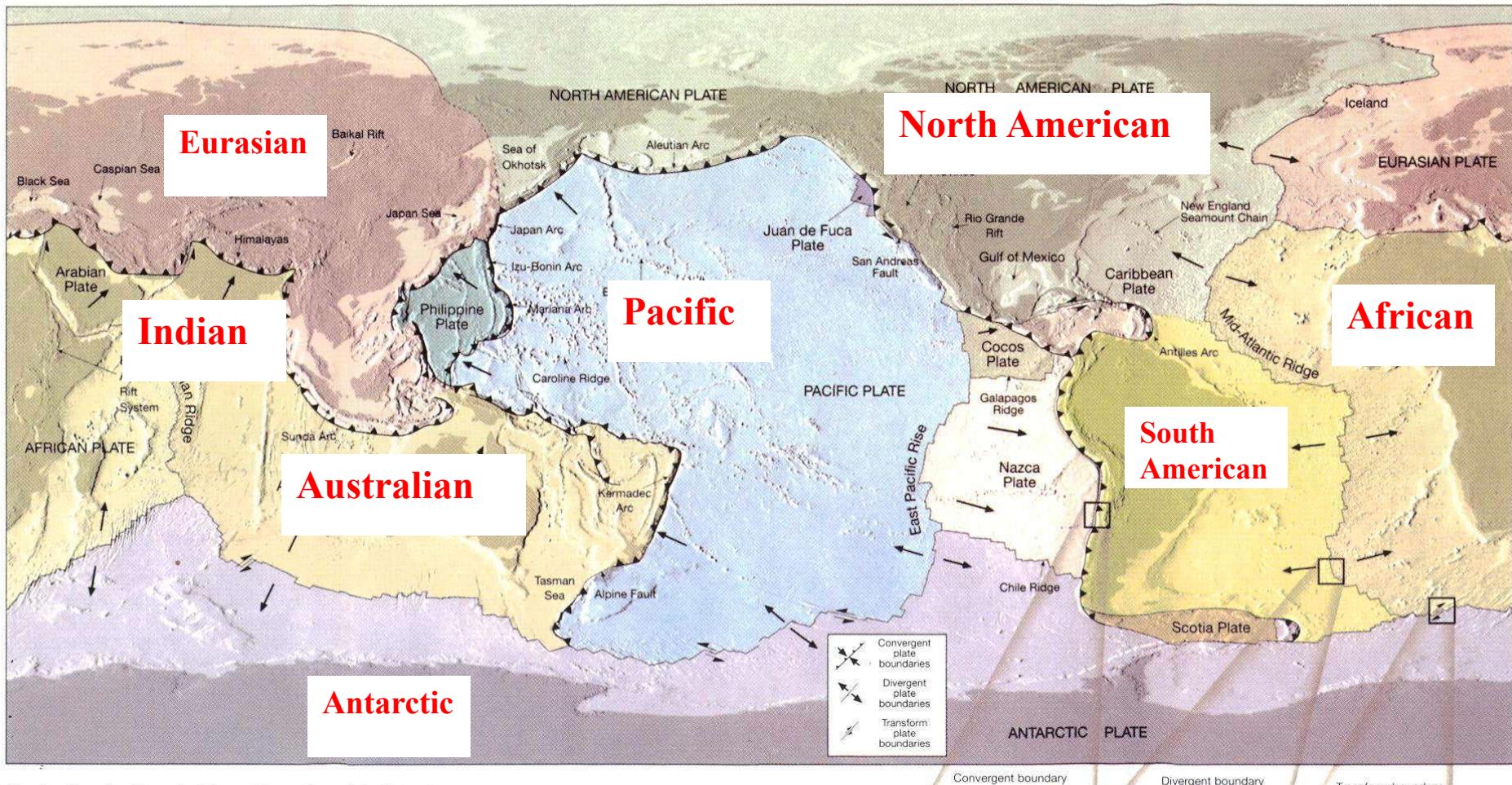


Important assumptions

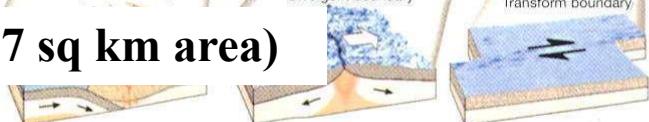
- The generation of new plate material occurs by **seafloor spreading**: that is, new oceanic lithosphere is generated along the active Mid Ocean Ridges.
- The new oceanic lithosphere, once created, forms part of a rigid plate, this plate may or may not include continental material.
- The earth's surface area remains **constant**; therefore seafloor spreading must be balanced by consumption of plate elsewhere.
- The lithospheric plates are capable of transmitting stresses over great horizontal distances without buckling; in other words, **the relative motion between plates is taken up only along plate boundaries**.

Analysing Plate Boundaries

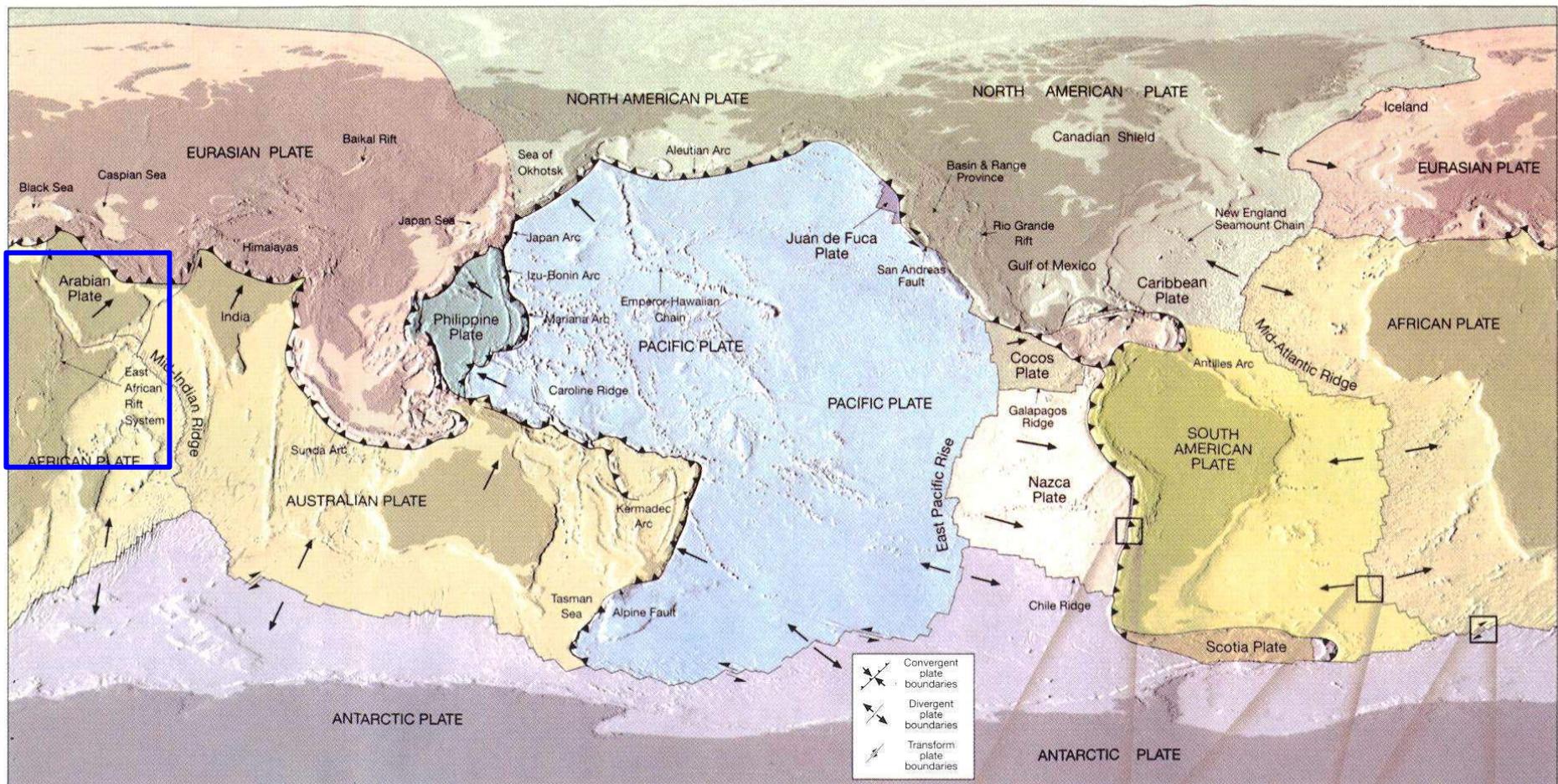
Eight Major Plates (10^7 to over 10^8 sq km area)



Several intermediate and smaller size plates (10^5 to 10^7 sq km area)

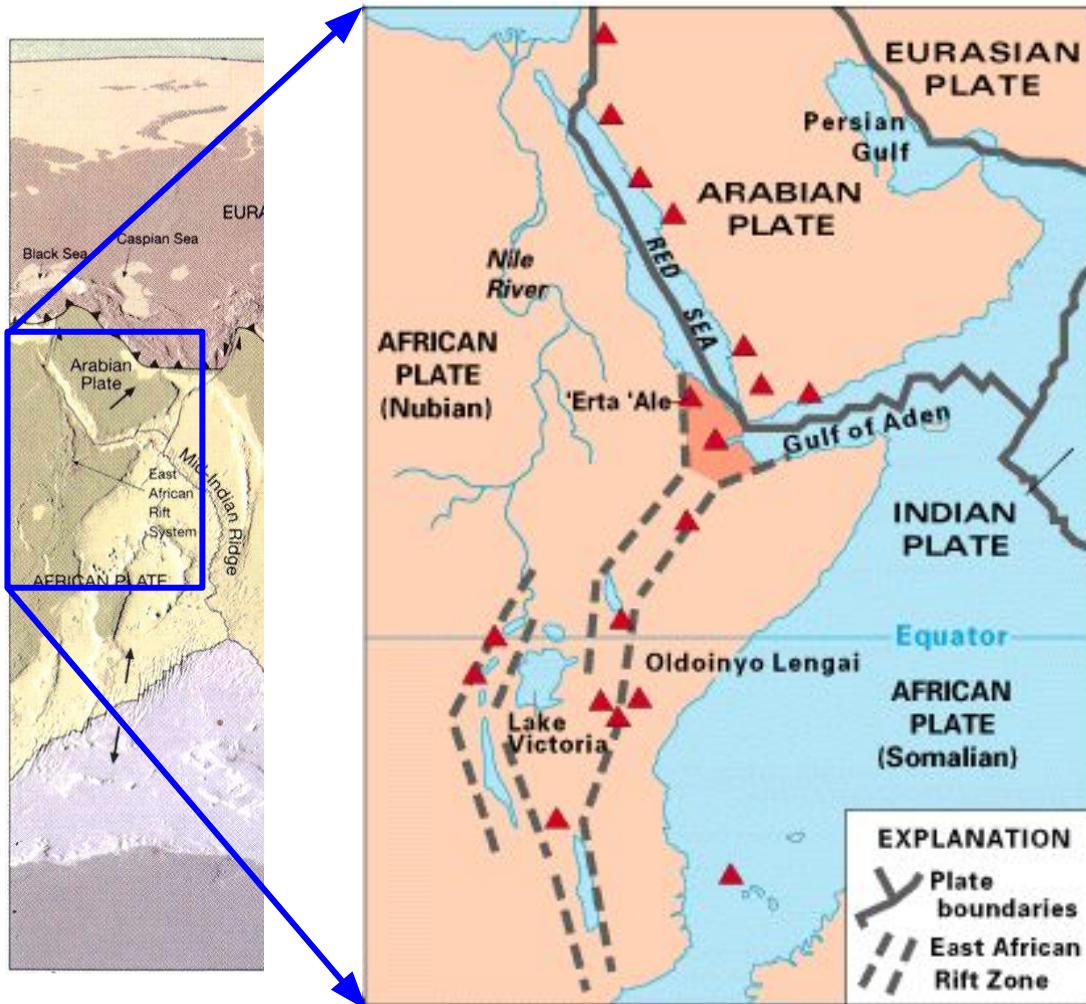


Divergent Plate Boundary

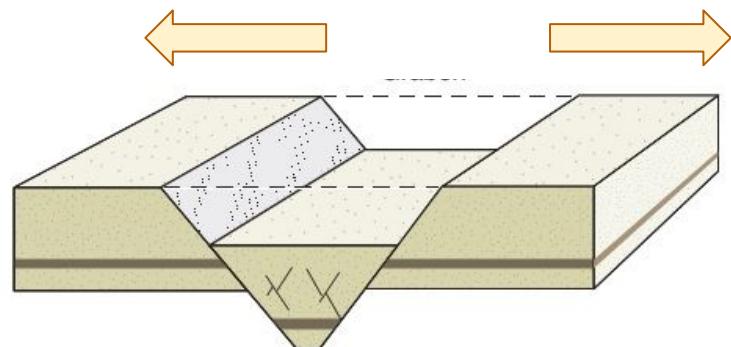


Divergent Plate Boundary

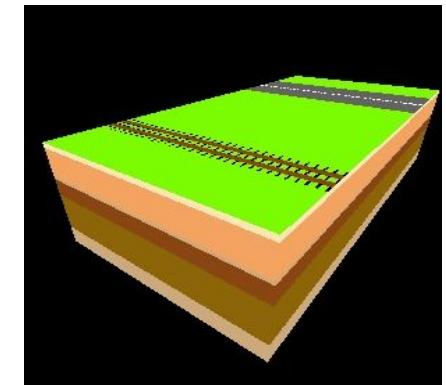
Accreting /
Constructive
plate boundary



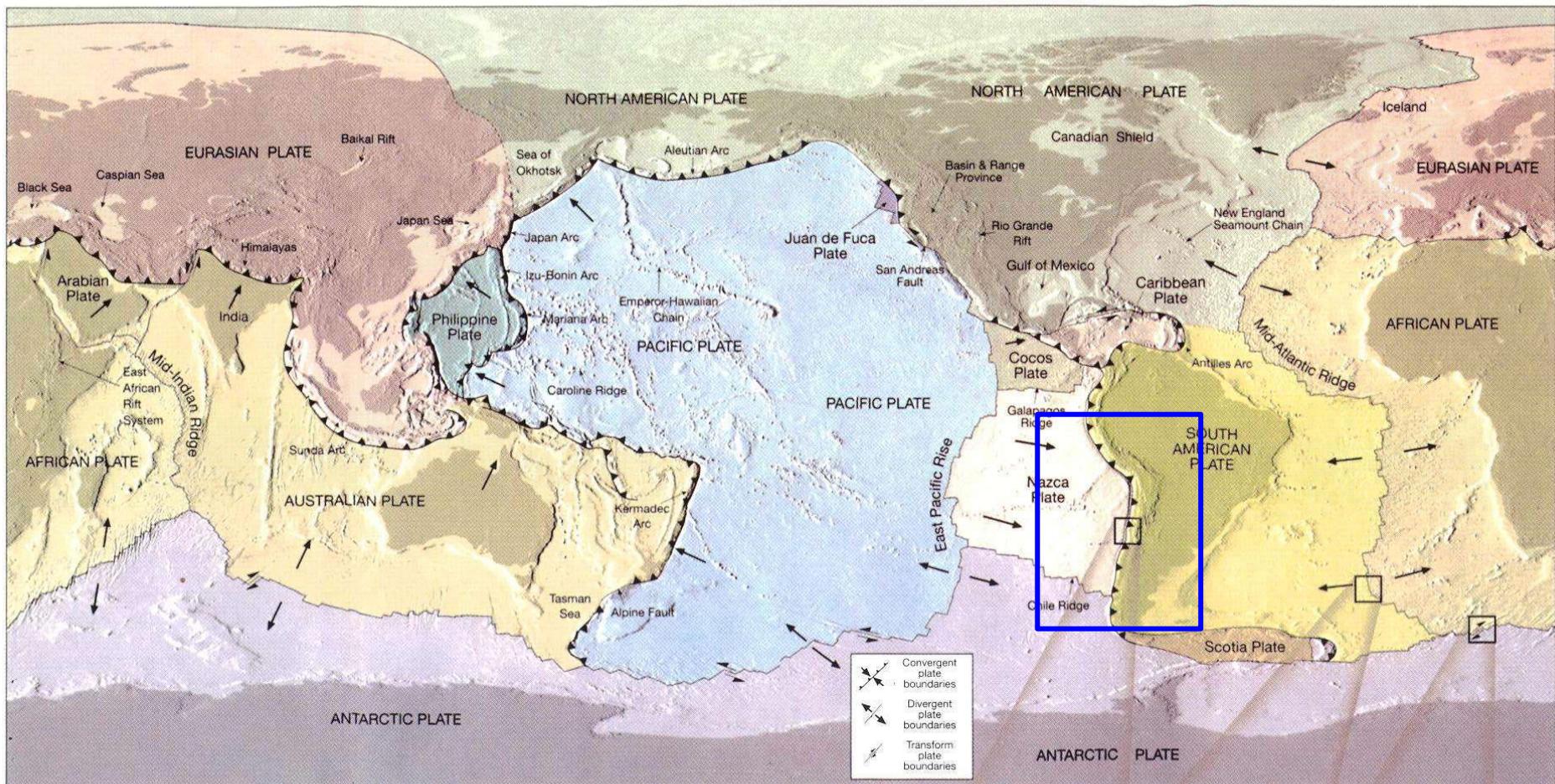
East African Rift Zone: Red Sea



Two African Plates: Nubian & Somalian Plates



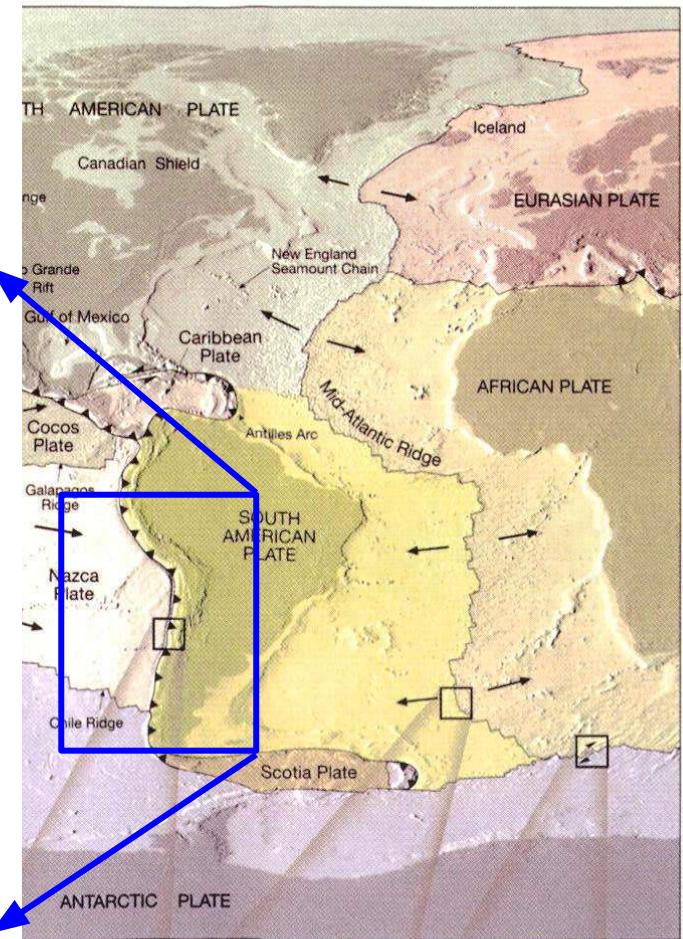
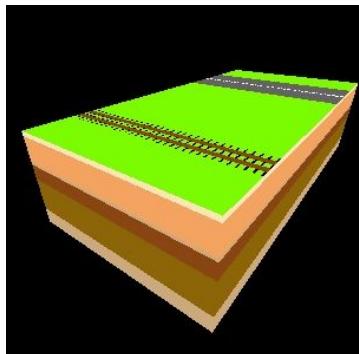
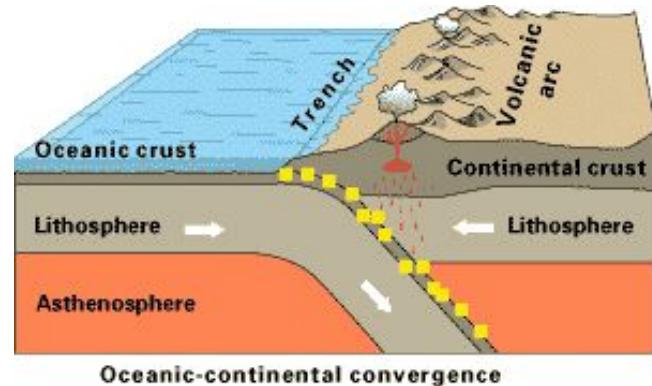
Convergent Plate Boundary



Convergent Plate Boundary

Consuming /
Destructive
plate boundary

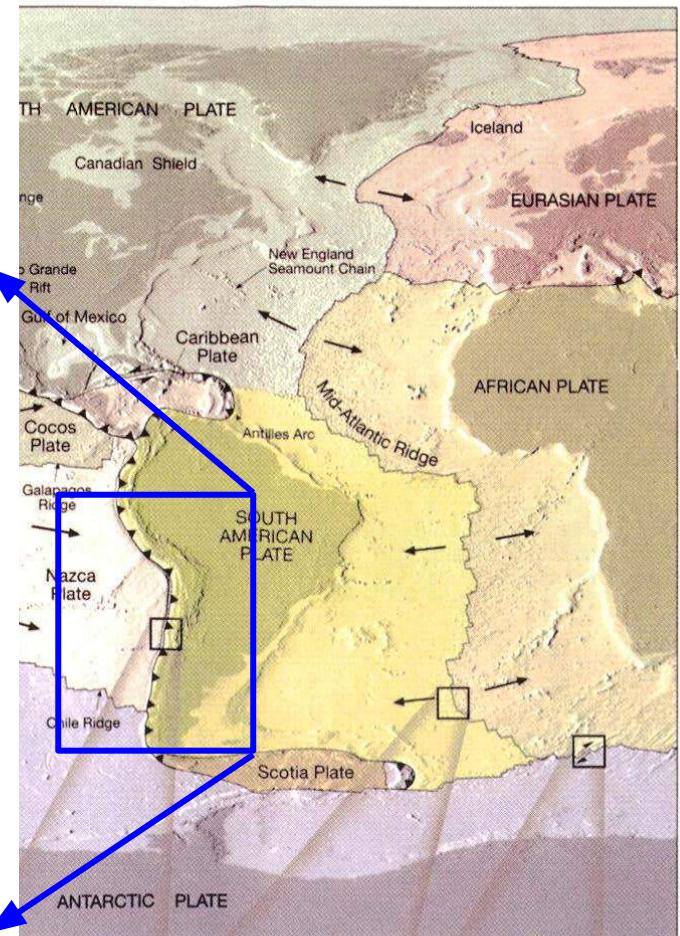
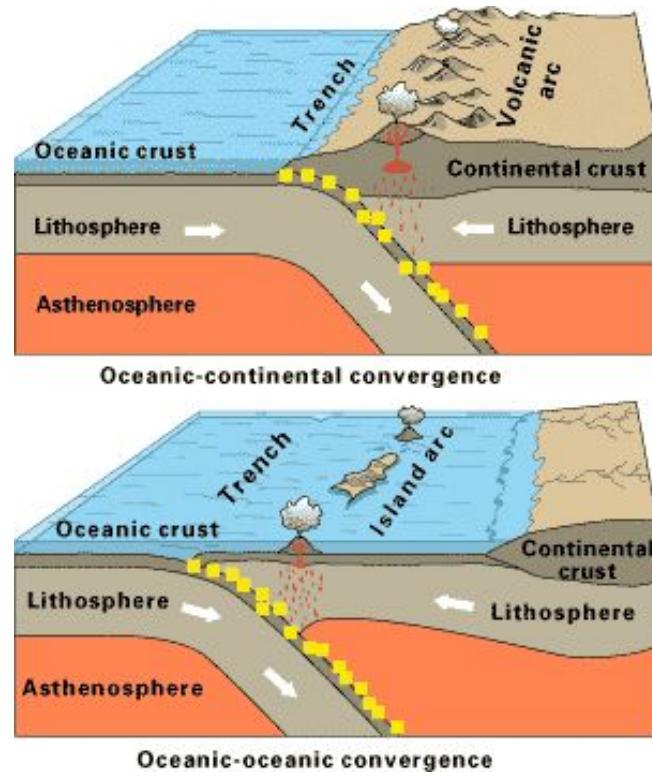
Peru-Chile trench: Off the coast of South America



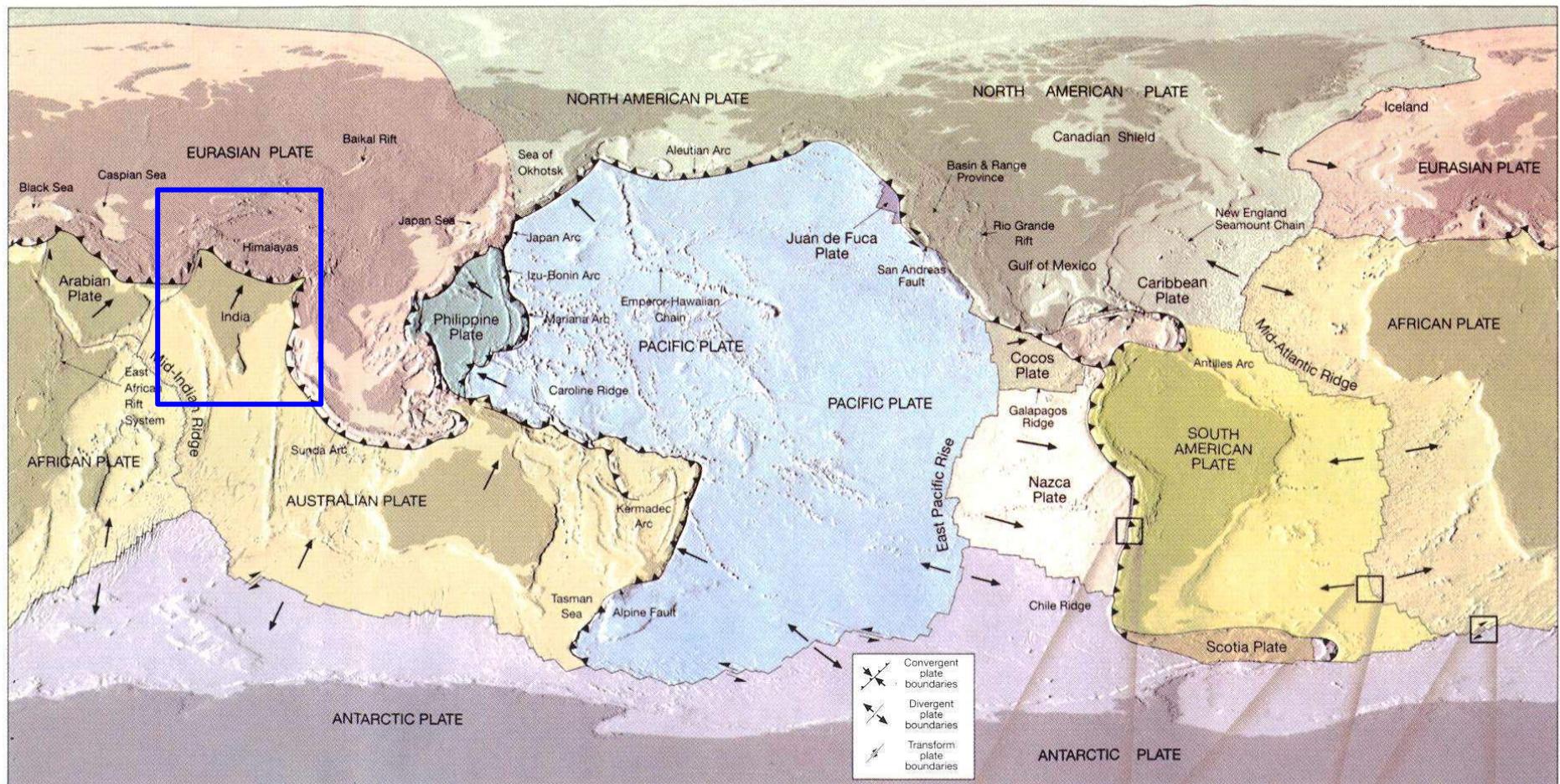
Oceanic Nazca Plate is subducted under the continental part of the South American Plate

Convergent Plate Boundary

Consuming /
Destructive
plate boundary

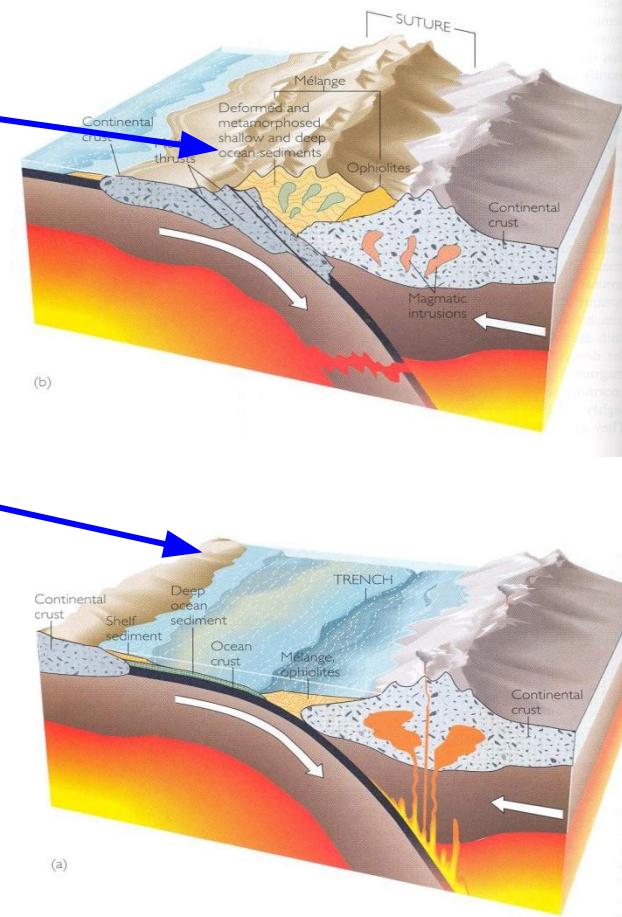
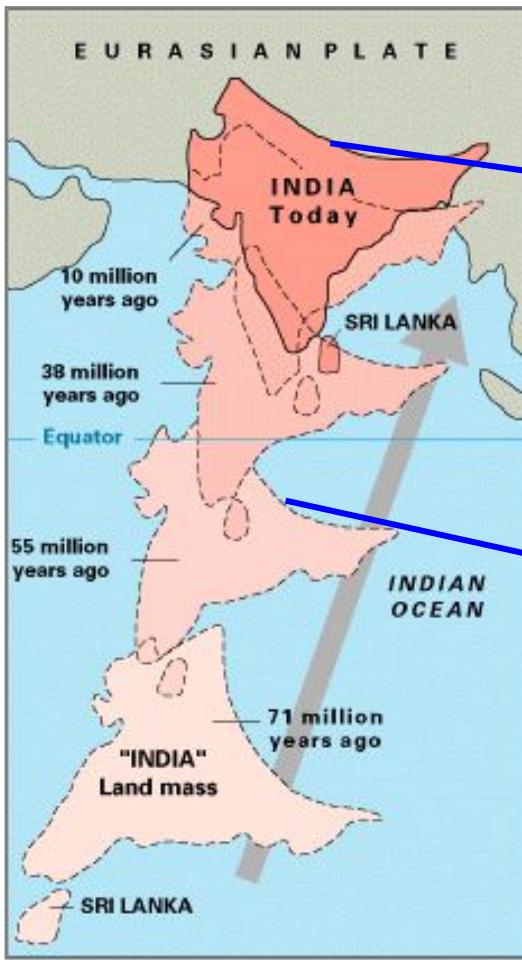
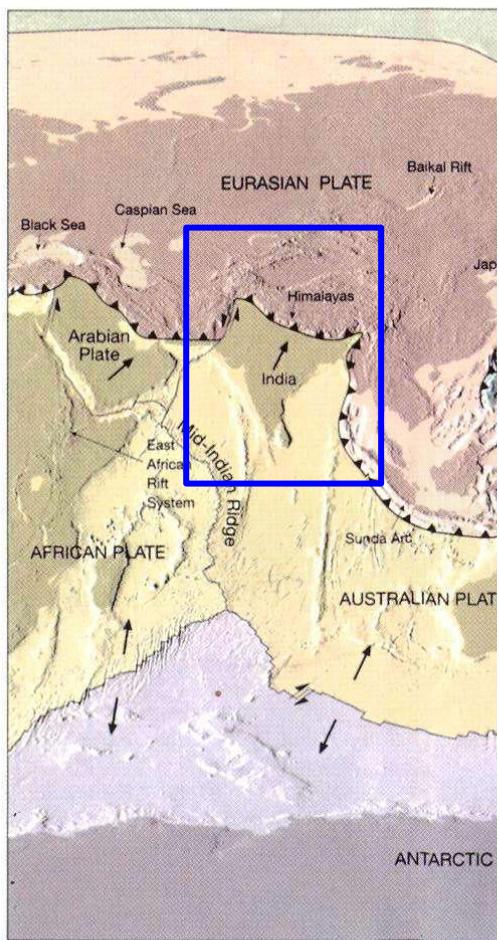


Collisional Plate Boundary



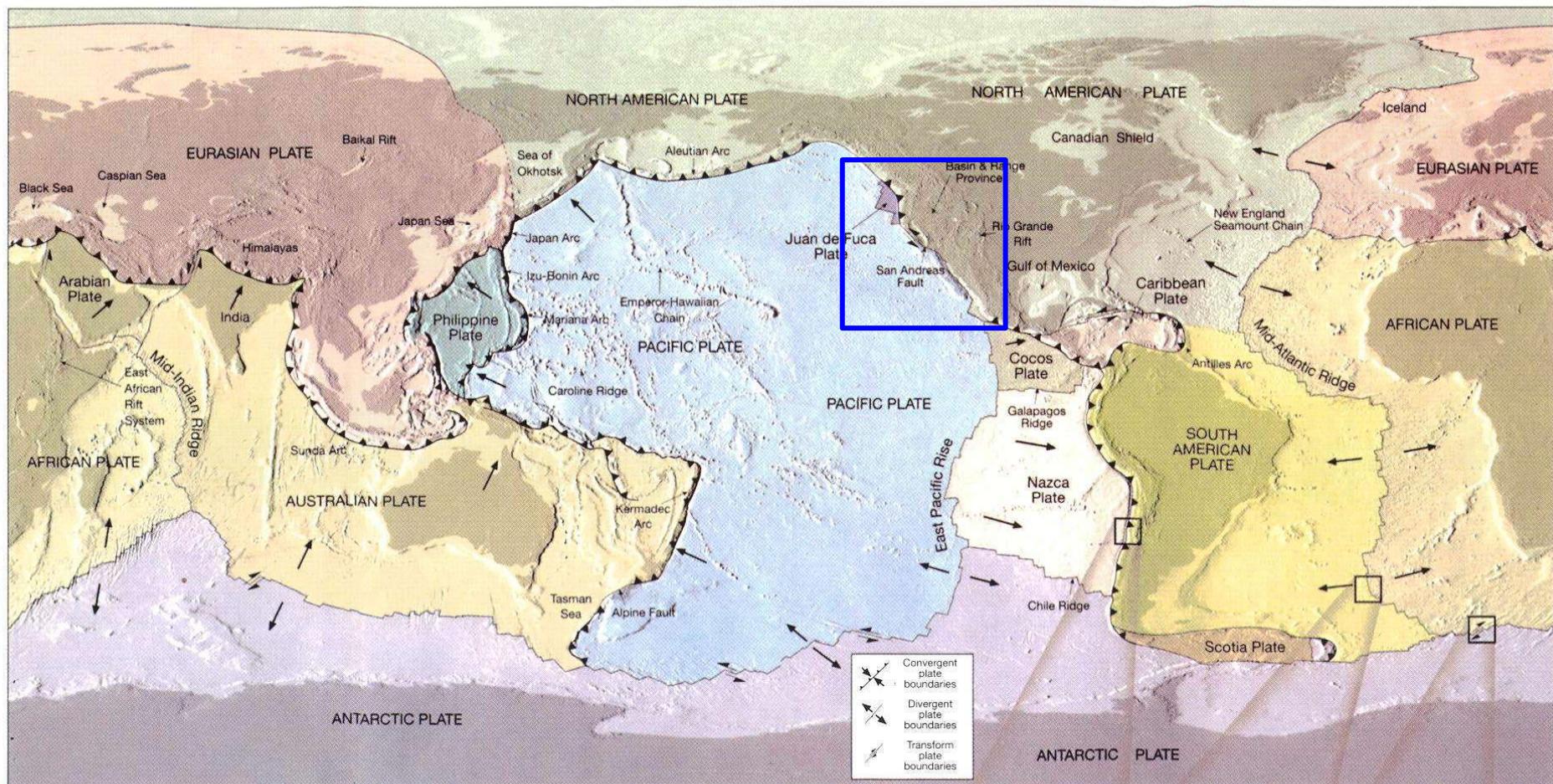
Collisional Plate Boundary

Himalayan Mountains



Continental Indian Plate in collision with Eurasian Plate

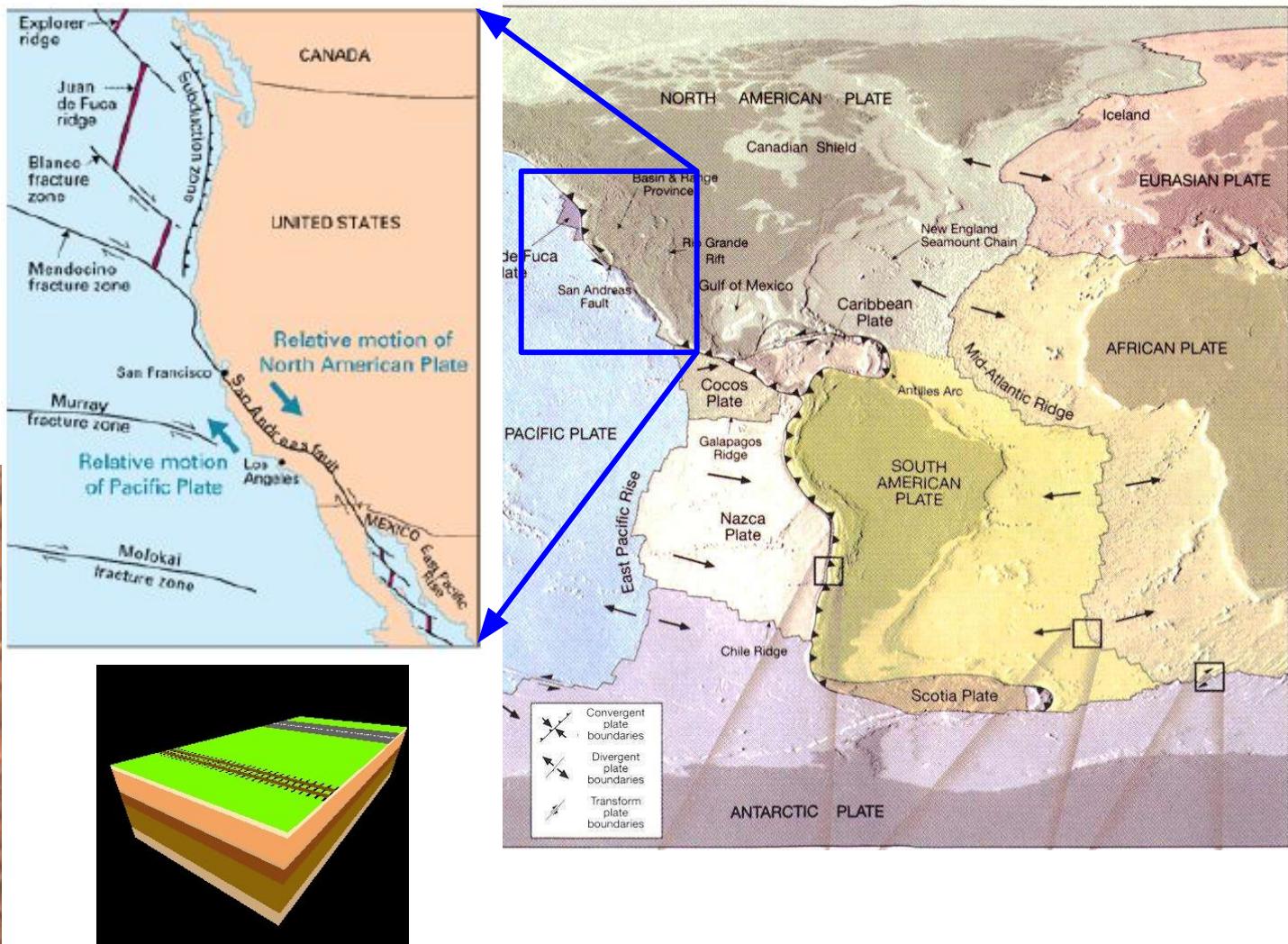
Conservative Plate Boundary



Conservative Plate Boundary

Transform Fault

The San Andreas Fault



Oceanic Pacific Plate goes past the continental North American Plate

The Global Picture

