Engineering Seismology and Seismic Hazard – 2019

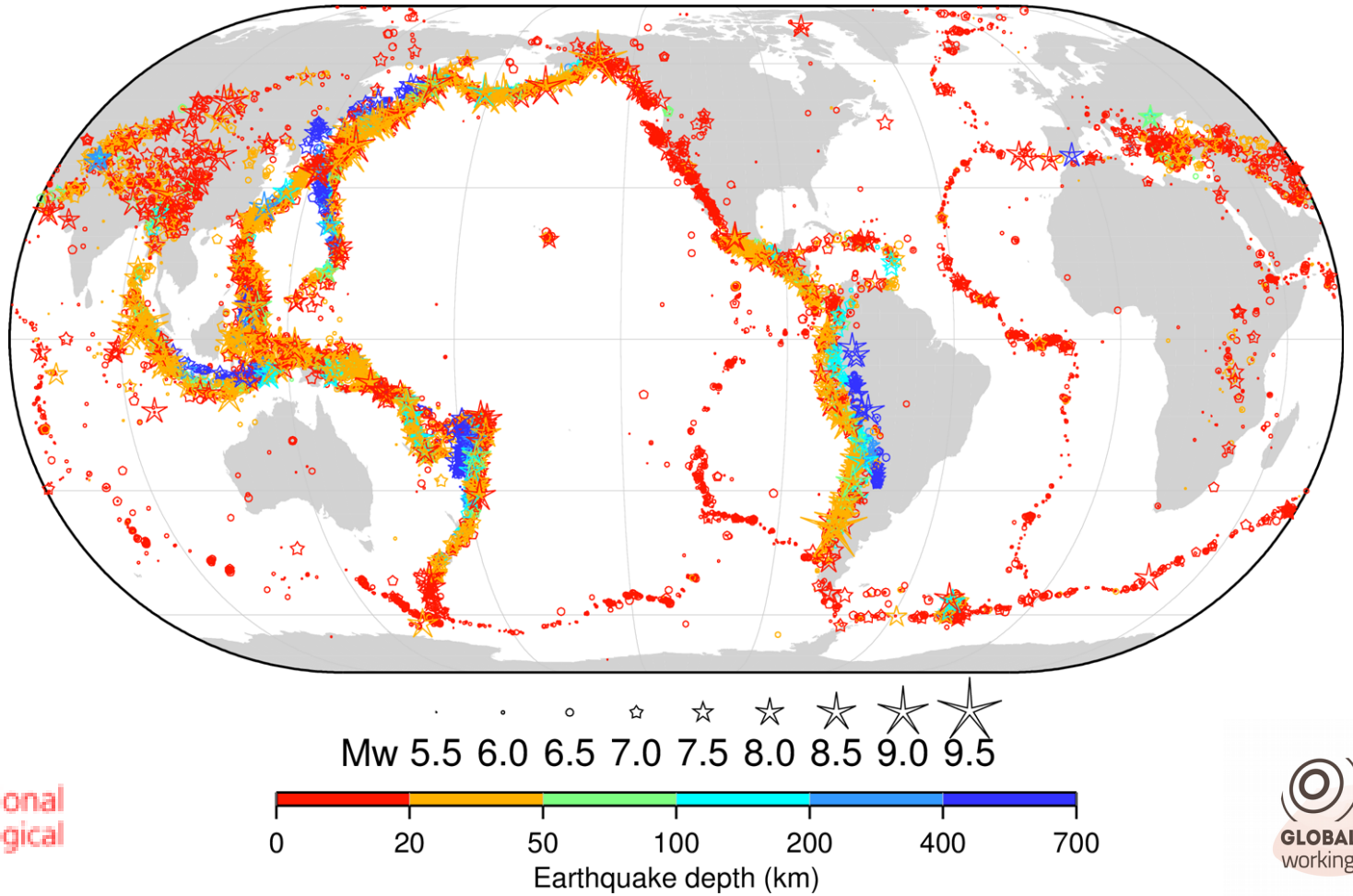
Lecture 4

Seismotectonics

Valerio Poggi
Seismological Research Center (CRS)
National Institute of Oceanography and Applied Geophysics (OGS)

World's Earthquake Activity

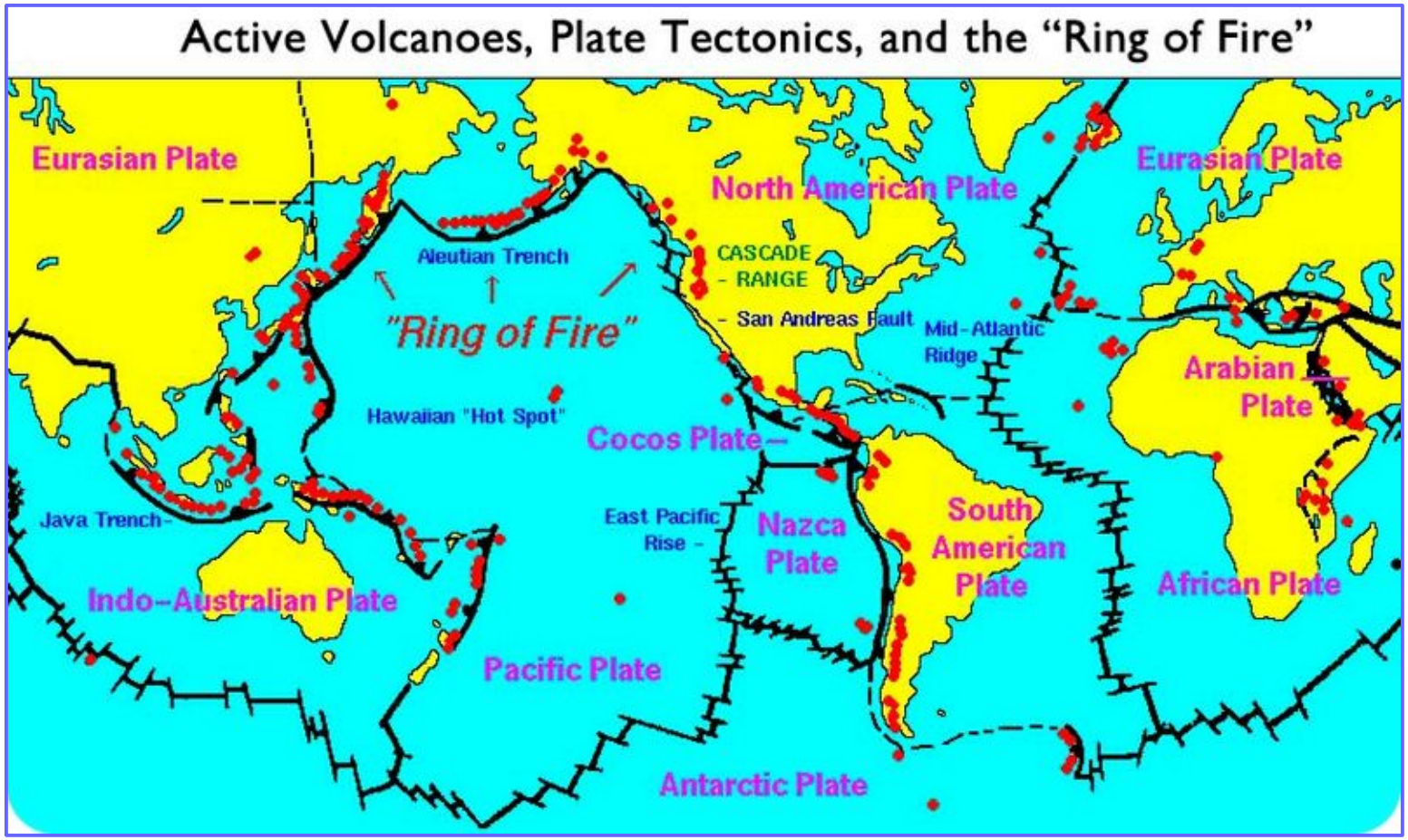
Earthquake activity is not distributed uniformly around the world.
It is mainly confined to relatively narrow bands of intense seismicity that enclose areas within which very few earthquakes occur.



International Seismological Centre

GEM GLOBAL EARTHQUAKE MODEL working together to assess risk

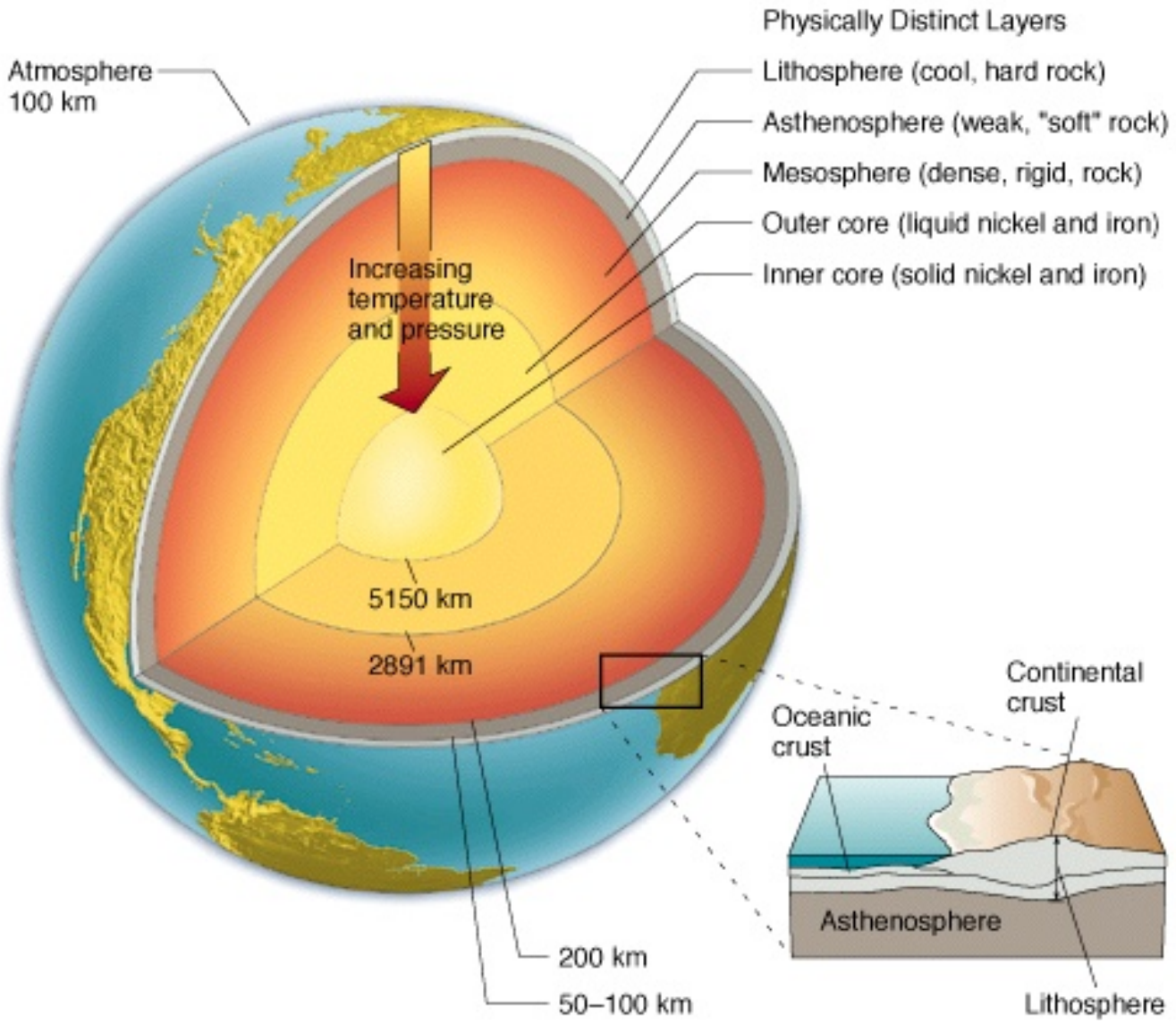
World's Earthquake Activity



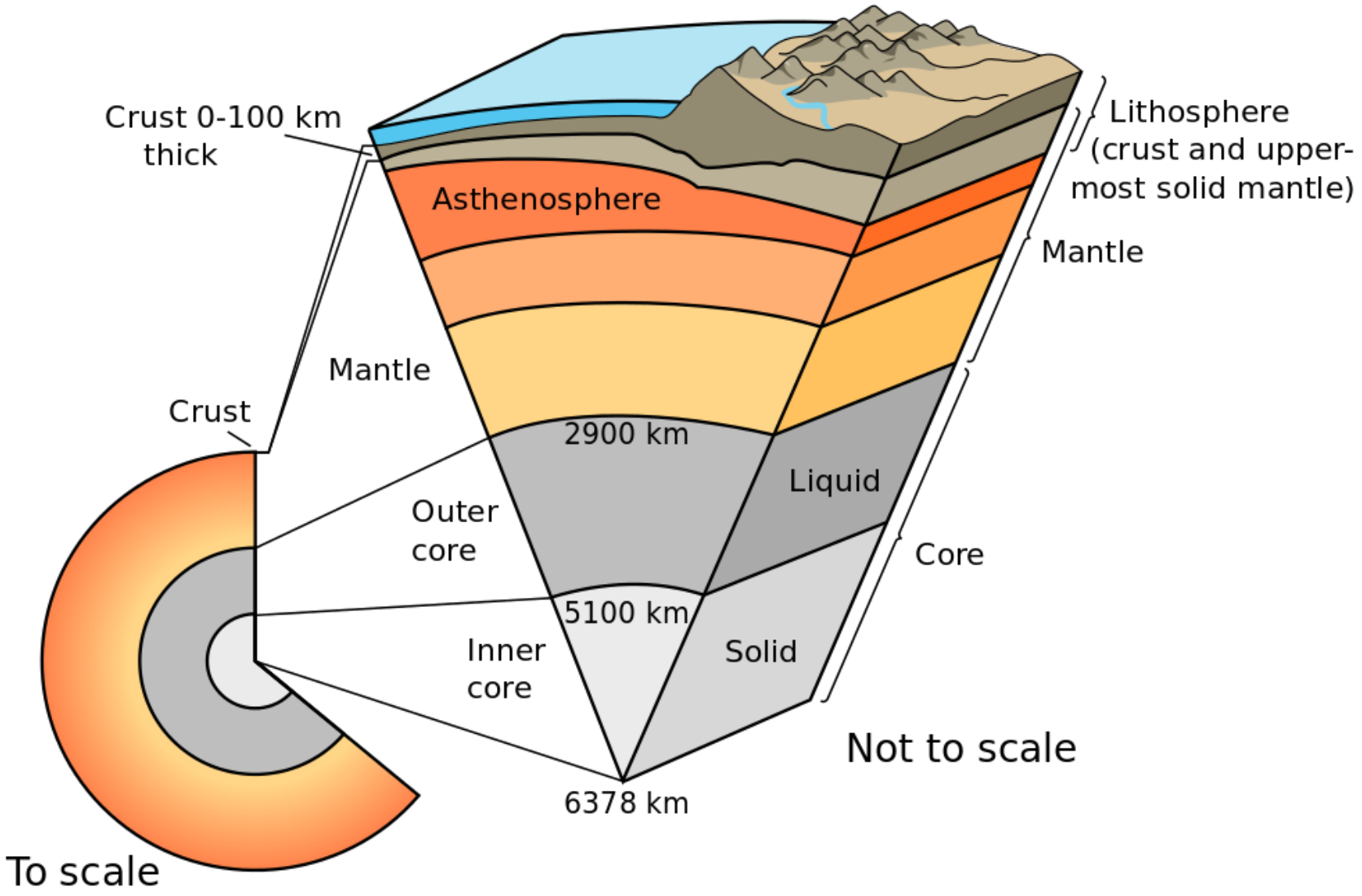
The majority of earthquakes occur at locations on or close to the boundaries between tectonic plates:

- about 75% on the circum–Pacific belt ("ring of fire")
- about 22% on the Alpine–Himalayan region
- less than 2% on the oceanic spreading ridges

The Earth Structure



Composition vs. Rheology



The Earth Core

16% in volume of the earth and 32% in mass. Divided in an outer part considered to be liquid (shear waves do not propagate within it) and the inner core (from 5200 km)

The boundary between the liquid outer core and the solid inner core occurs at a radius of about 1220 km – Lehman discontinuity, after Inge Lehman from Denmark.

The change in density across the core–mantle boundary is greater than that at the Earth's surface!

The Earth Mantle

Divided into the upper mantle (until 660 km) and lower mantle until the contact with the Core at about 2900 km depth – Gutenberg discontinuity

It is further subdivided into:

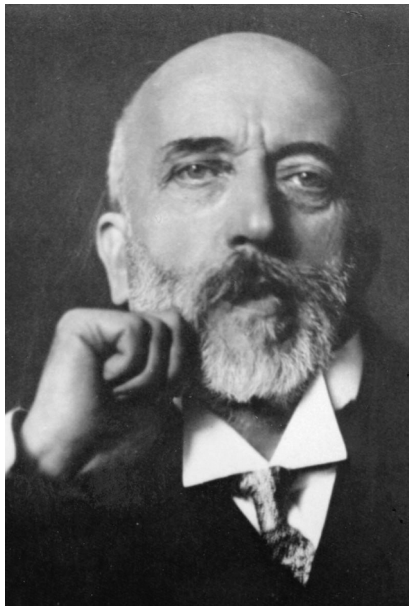
- The uppermost mantle (crust to 400 km depth)
- The transition zone (400 – 700 km depth)
- The mid-mantle (700 to ~2650 km depth)
- The lowermost mantle (~2650 – 2891 km depth)

The Earth Crust

Continental crust is made of 'light' rocks (mostly of granitic composition).

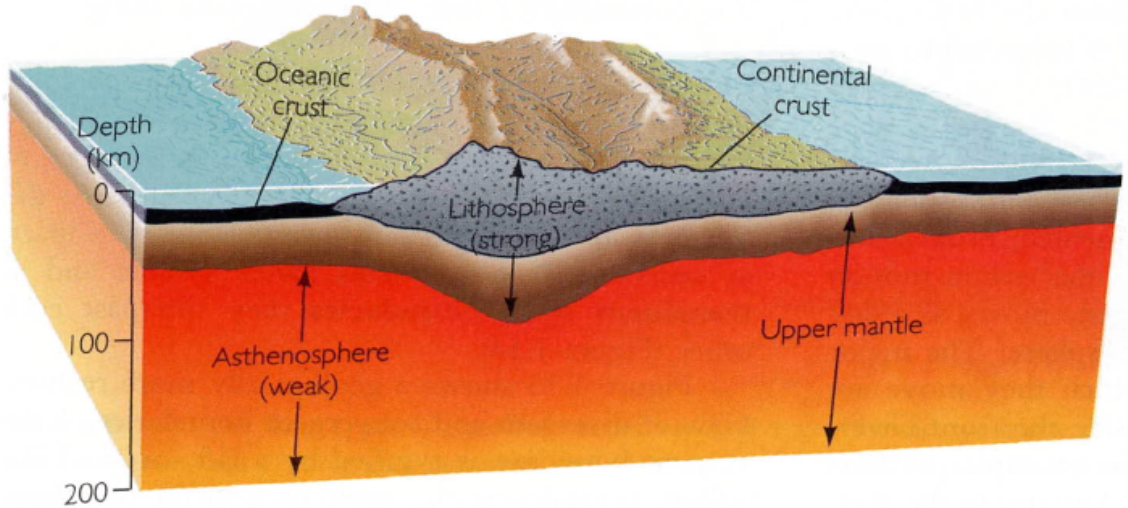
The boundary between the crust and the Uppermost Mantle is referred to as the"Moho" discontinuity

It was discovered in 1910 by the Croatian seismologist Andrija Mohorovičić.



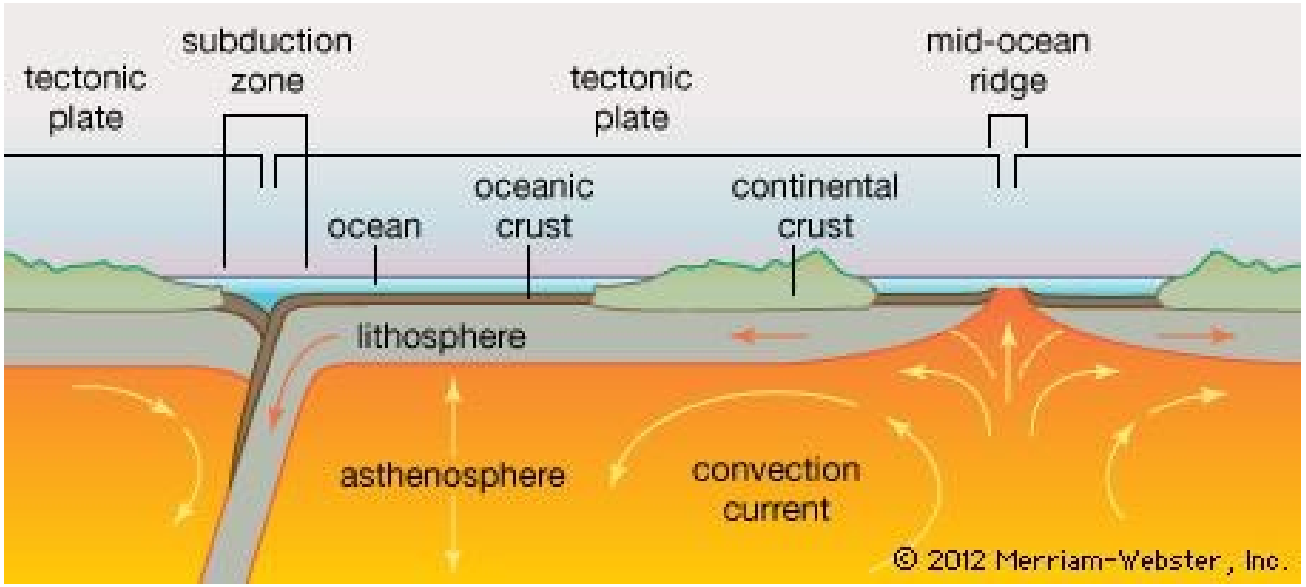
Asthenosphere

The asthenosphere exists between depths of 100–200 km.
It is the weakest part of the mantle.
It is a solid over short time scales, but behaves like a fluid over millions of years (viscoelastic solid).
The asthenosphere decouples the lithosphere (tectonic plates) from the rest of the mantle.
There is not a strict boundary between the lithosphere and the asthenosphere as there is between the crust and mantle.



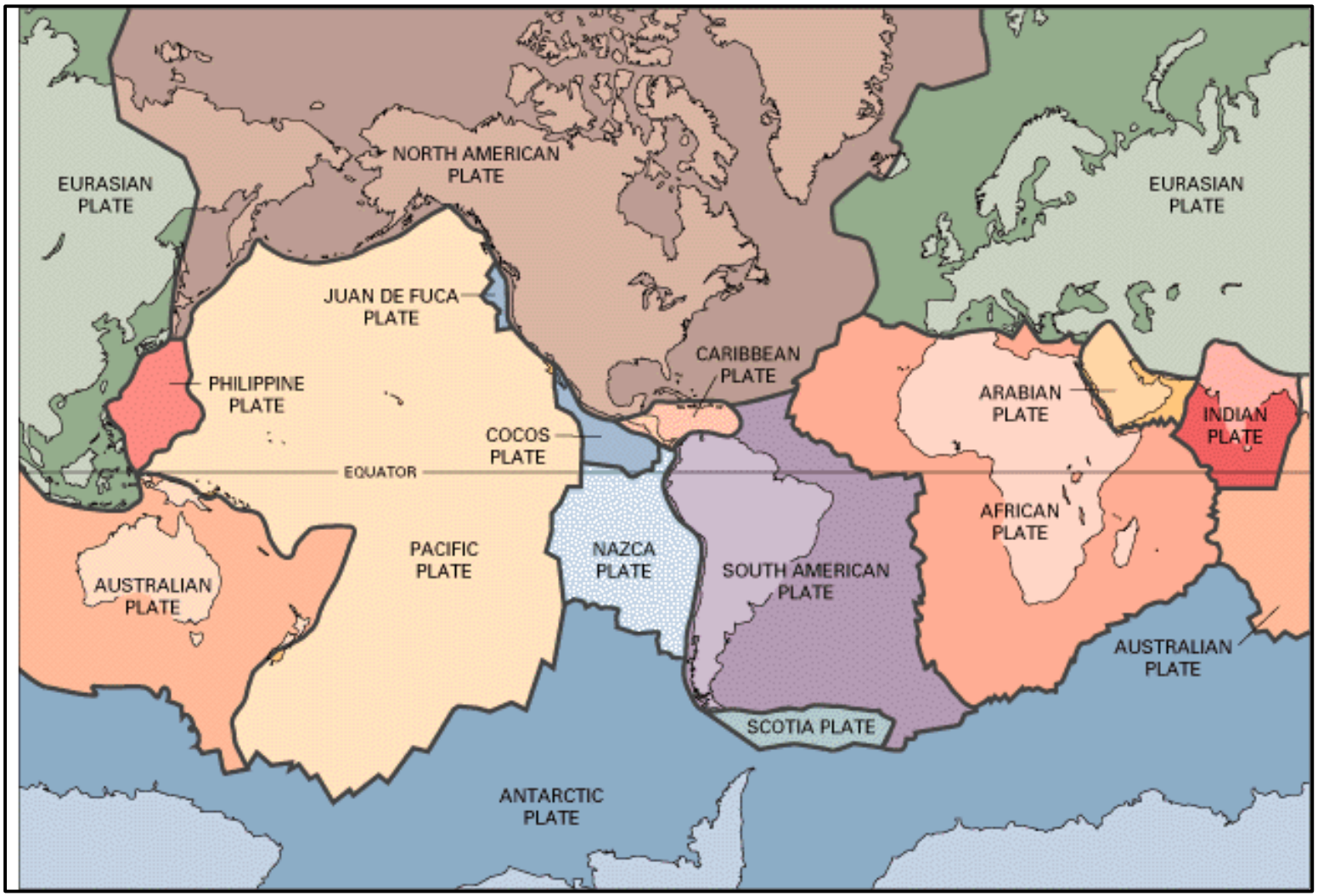
Lithosphere

Includes the crust and the upper part of the mantle. Its average thickness is about 80–100 km.
Below mountain chains it can reach a thickness of about 200 km.
For seismic hazard this is the most important 'layer' since it's the outer one and is also the one where a large portion of the earthquakes occurs.
Derived from GREEK word: Lithos = Rocky/Stone

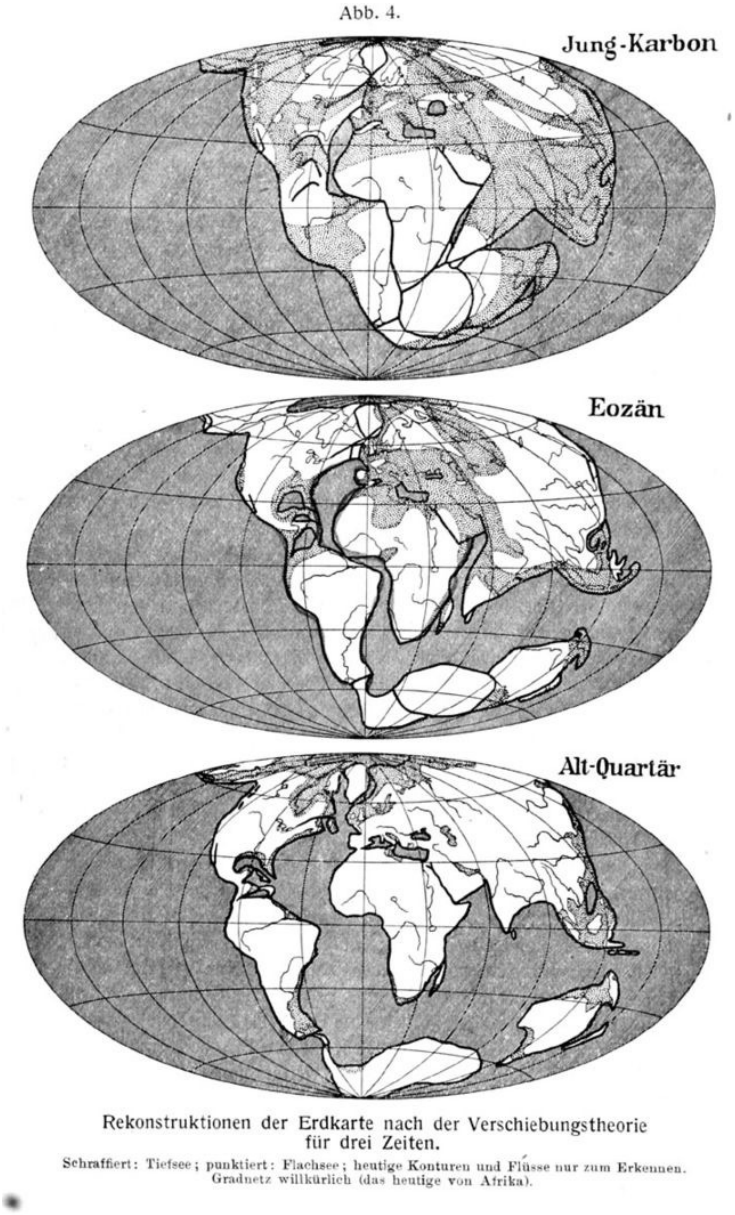


Tectonic Plates

Earth's lithosphere is divided in about 20 plates that move relative to each other



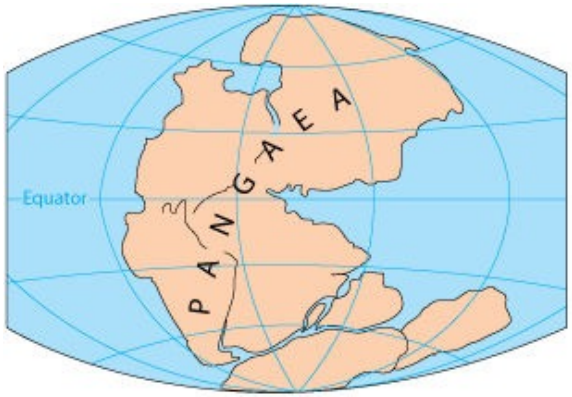
Continental Drift: Hypothesis



Alfred Wegener (1920)

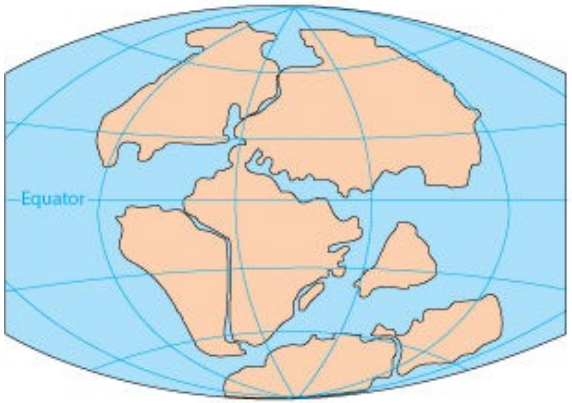
Wegener had compiled a strong circumstantial case for continental drift, but he could not adequately explain how or why contents drifted.

Continental Drift: Hypothesis

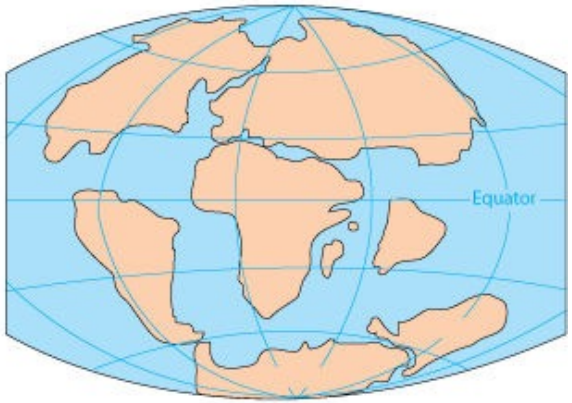


PERMIAN
250 million years ago

TRIASSIC
200 million years ago



JURASSIC
145 million years ago

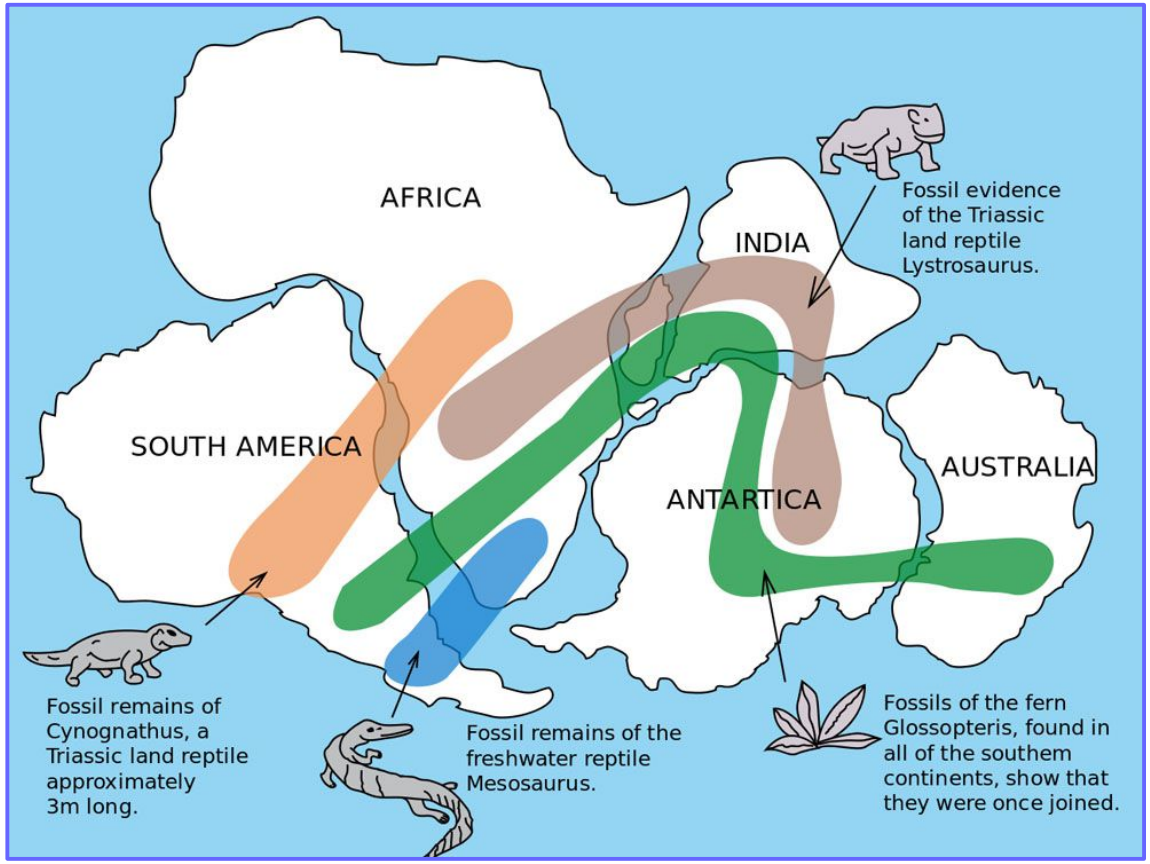


CRETACEOUS
65 million years ago

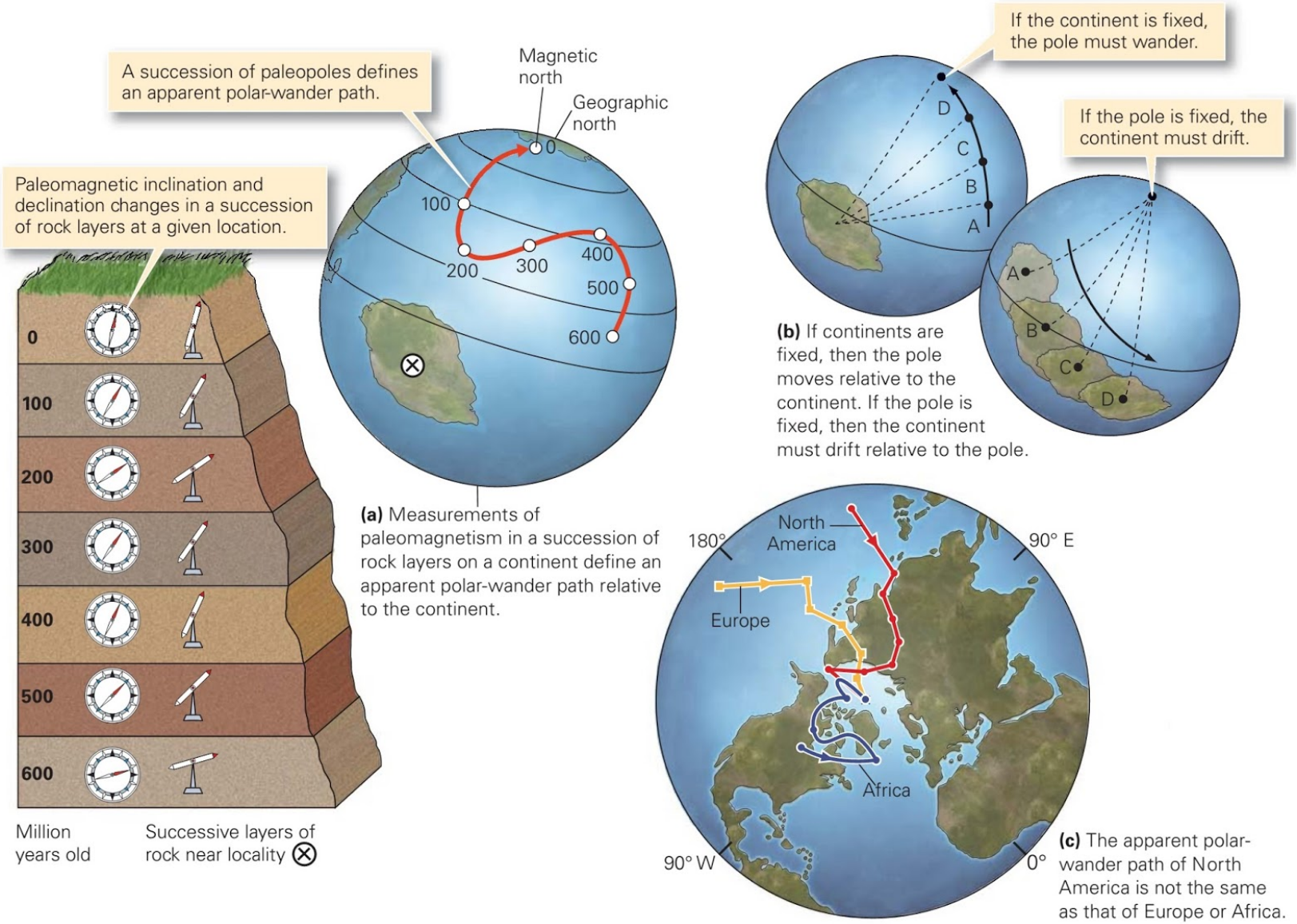
PRESENT DAY

Continental Drift: Evidences

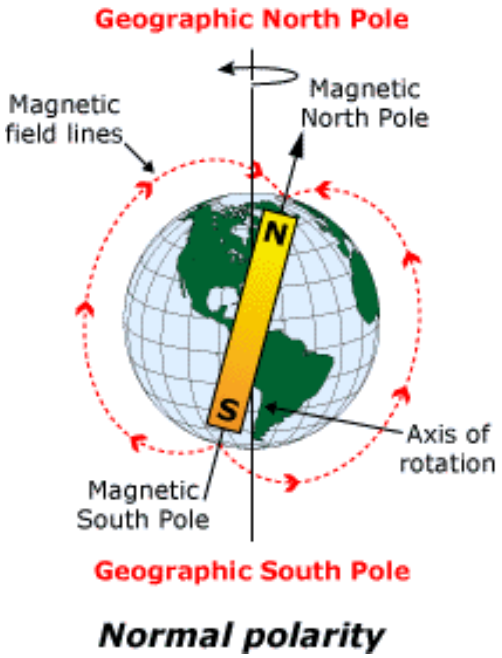
Empirical evidences:
1) Geometrical fit of continents
2) Similarities on distribution of fossils
3) Common Paleozoic glacial deposits
4) Continuity of pre-Cambrian mountain belts

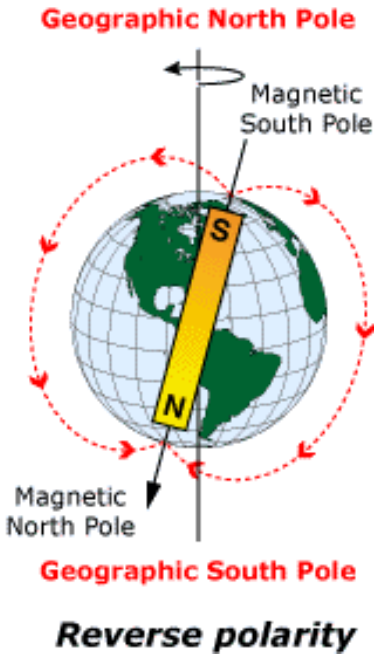


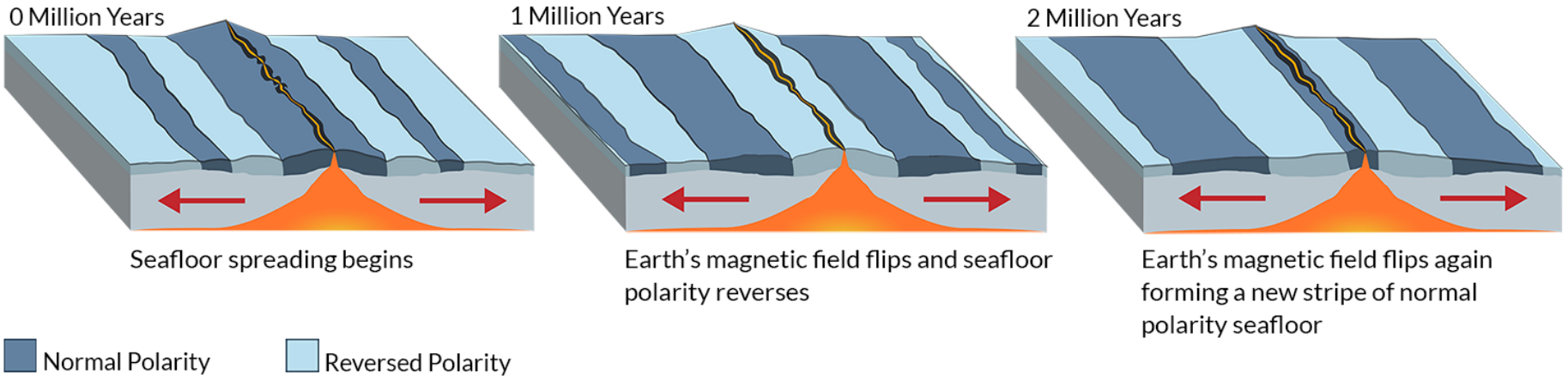
Proof: Paleomagnetism



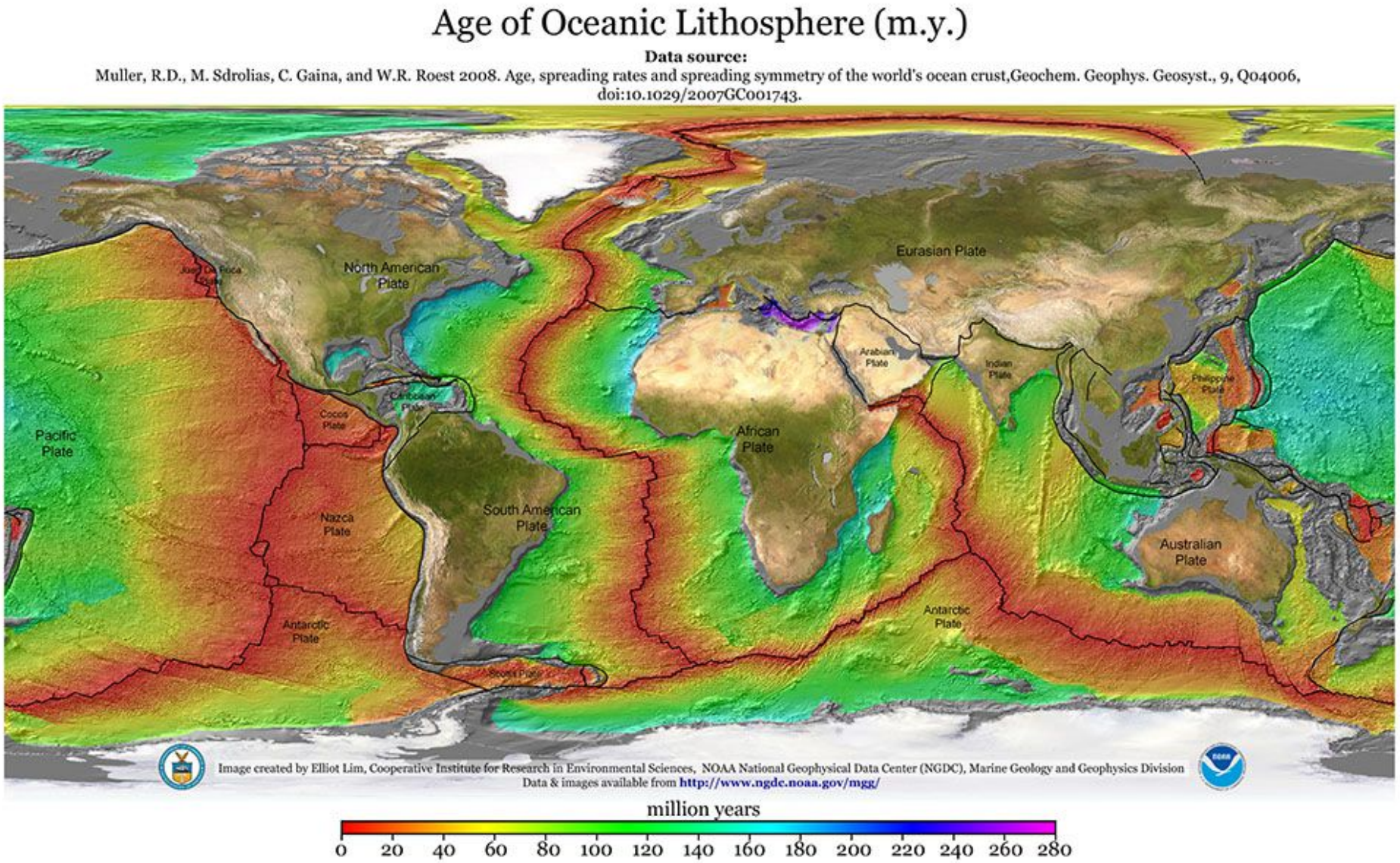
Proof: Paleomagnetism



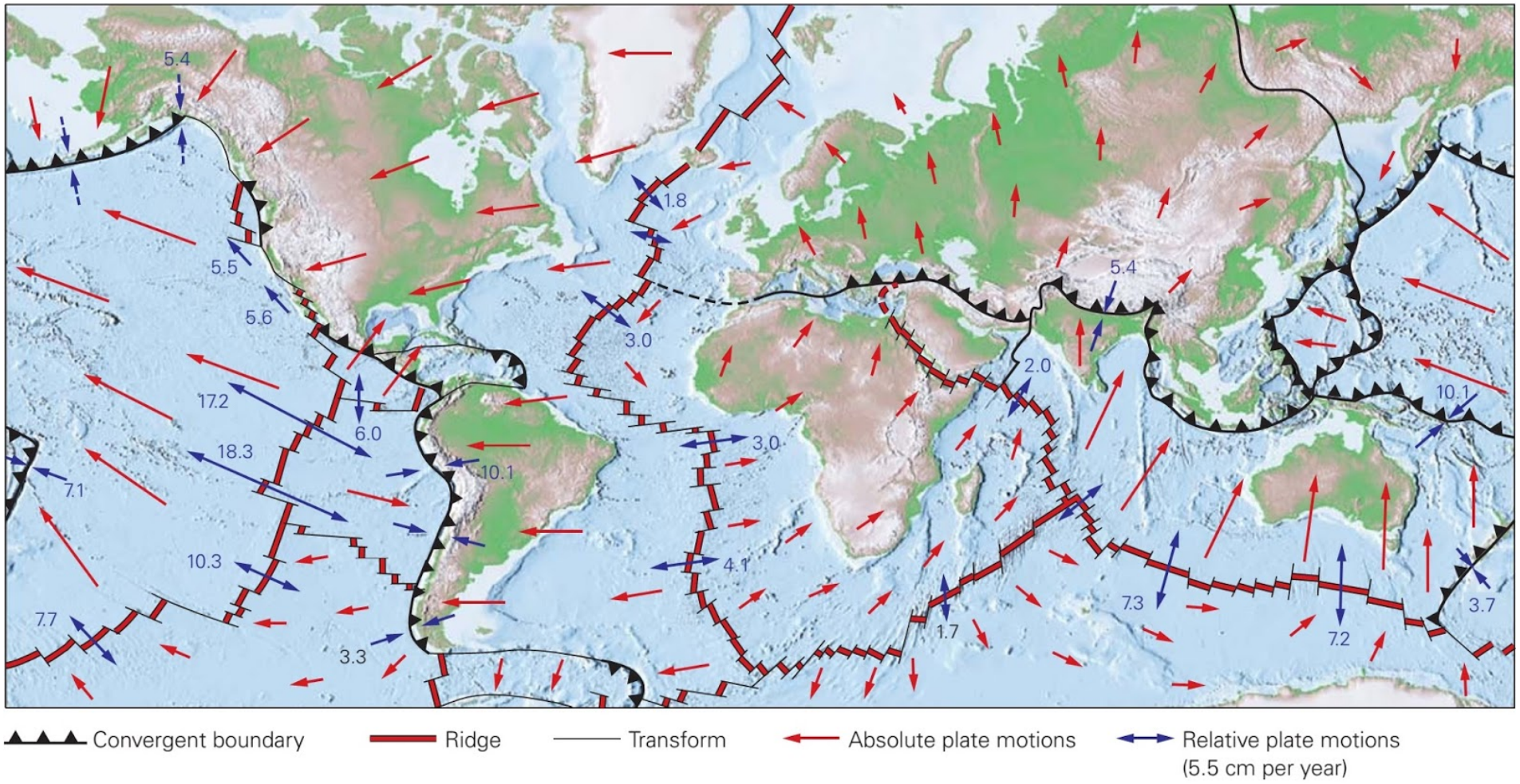




Proof: Geochronology

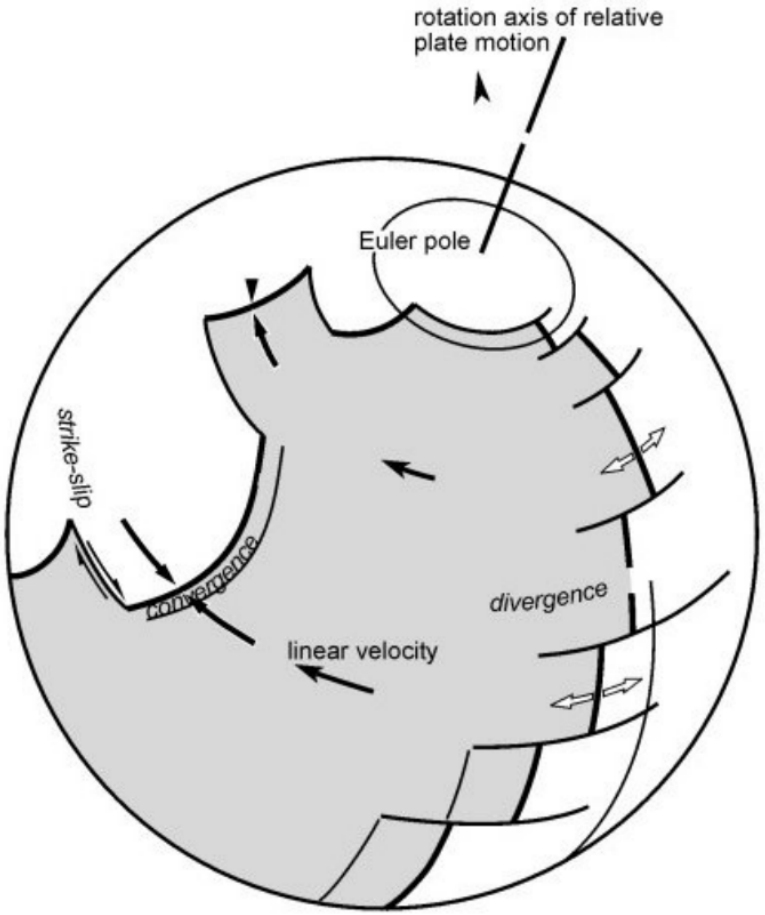


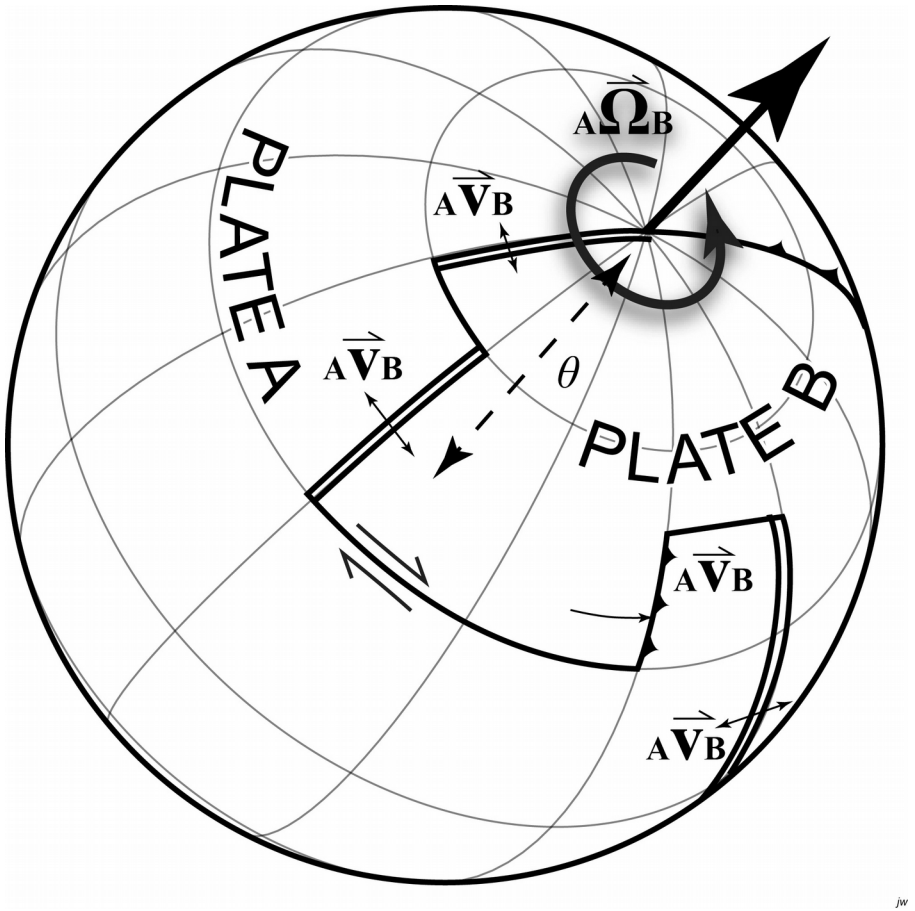
Proof: GPS velocities



Credits: Stephen Marshak (Essentials of Geology)

Plate Rotation: Euler's Poles

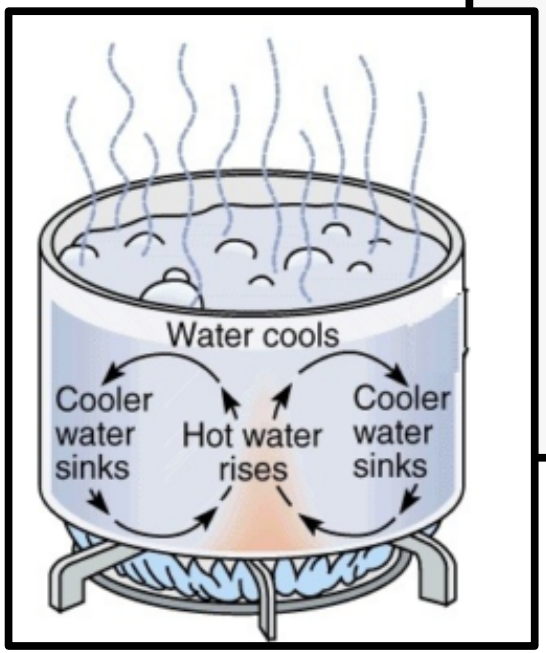




GEOPHYSICS AND GEOCHEMISTRY - Vol.I -Tectonic Processes - Jean-Pierre Burg

Mantle Convection

Mantle behaves over geological times as a viscous fluid. Heated by the decay of radiogenic elements, it flows in gigantic convection cells



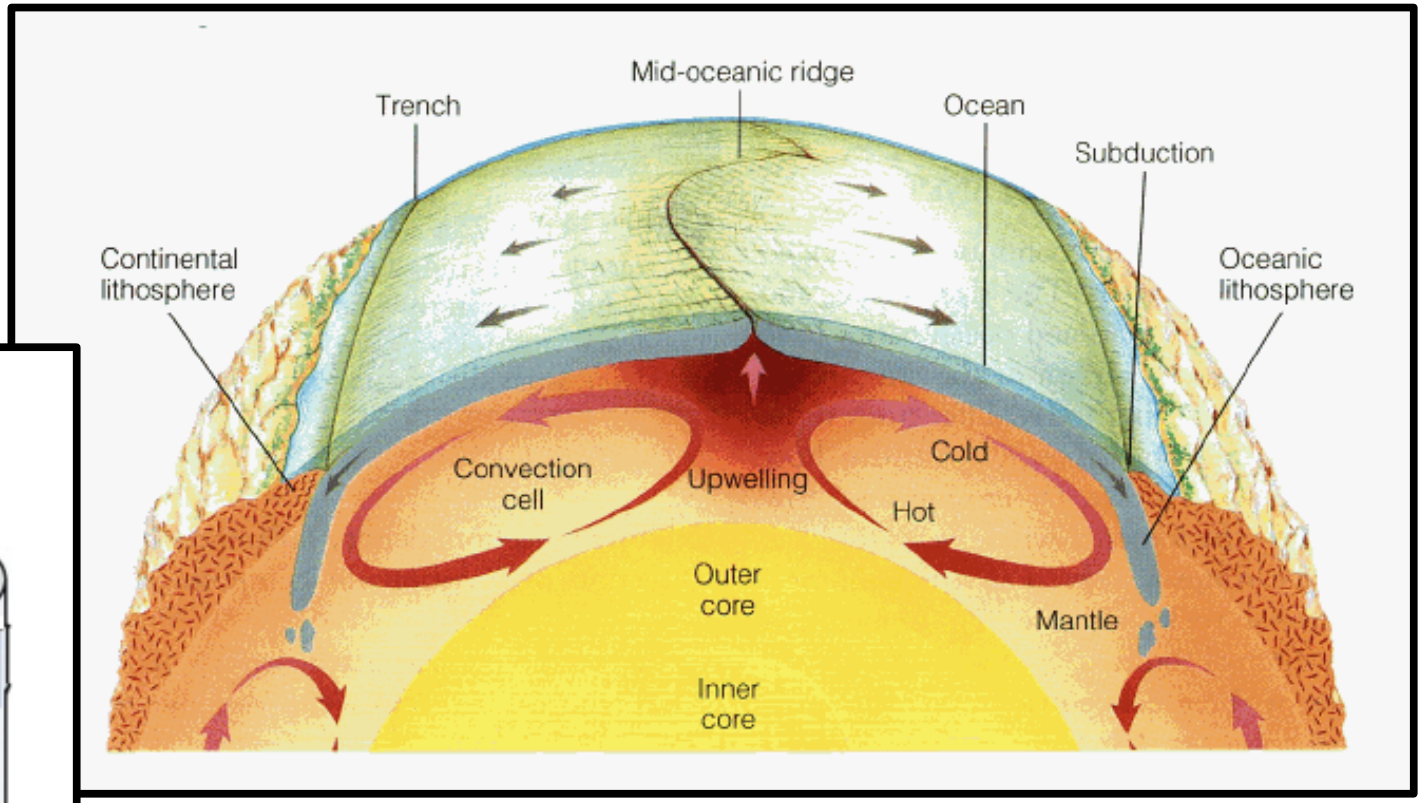
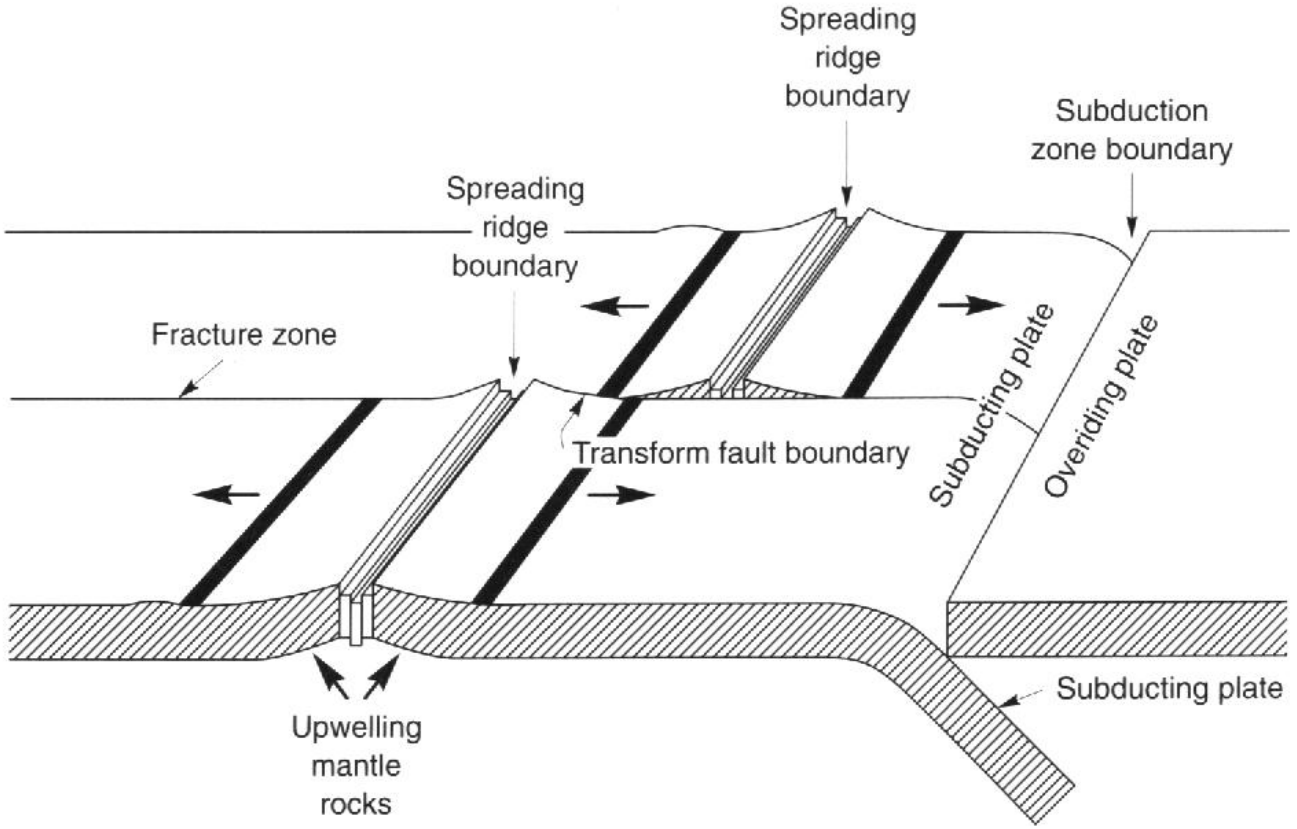


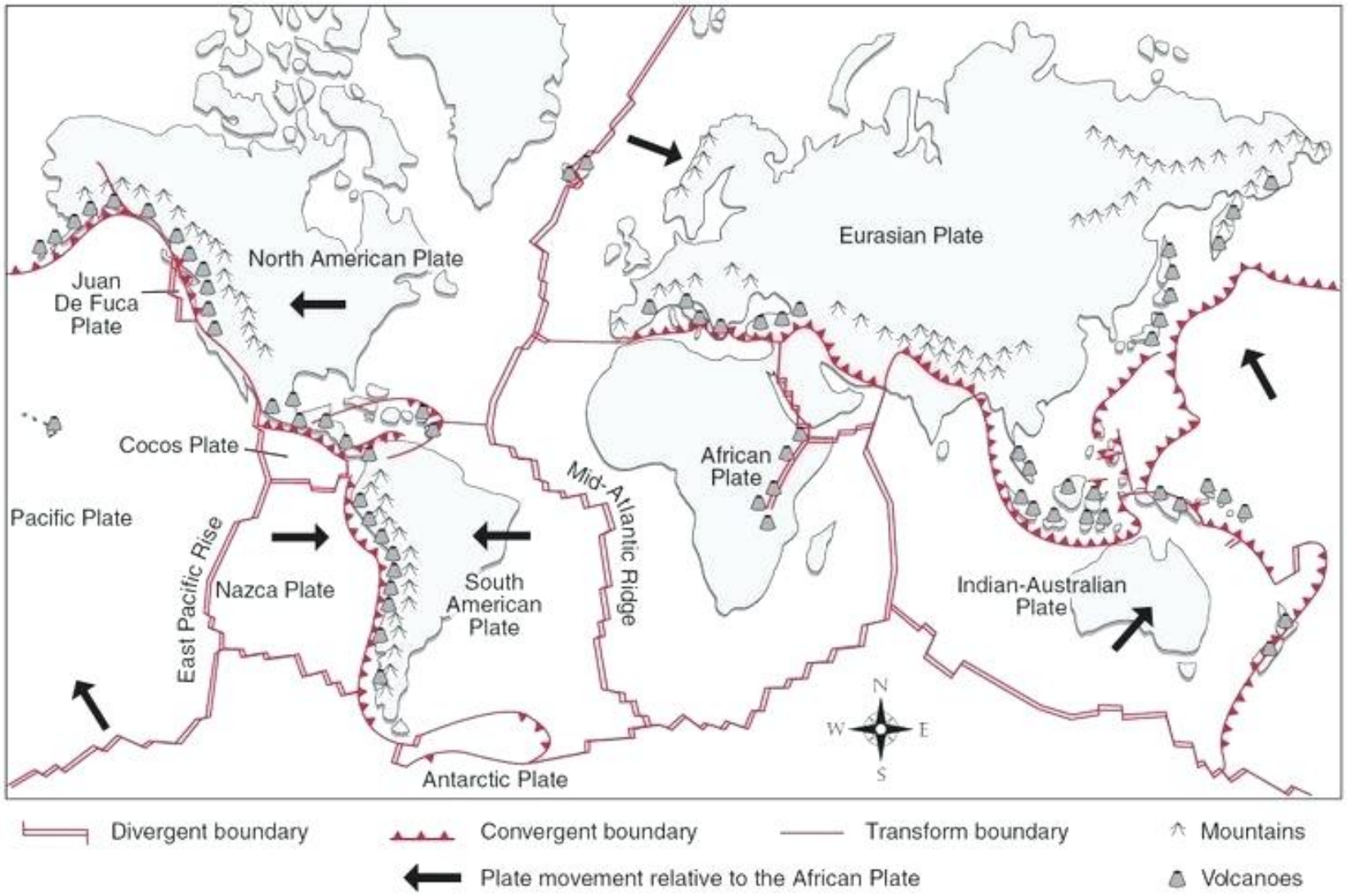
Plate Boundaries

Due to convective currents, the plates interact with one another in three basic ways:

1. They collide >> convergent boundaries
2. They move away from each other >> divergent boundaries
3. They slide one past another >> transform boundaries

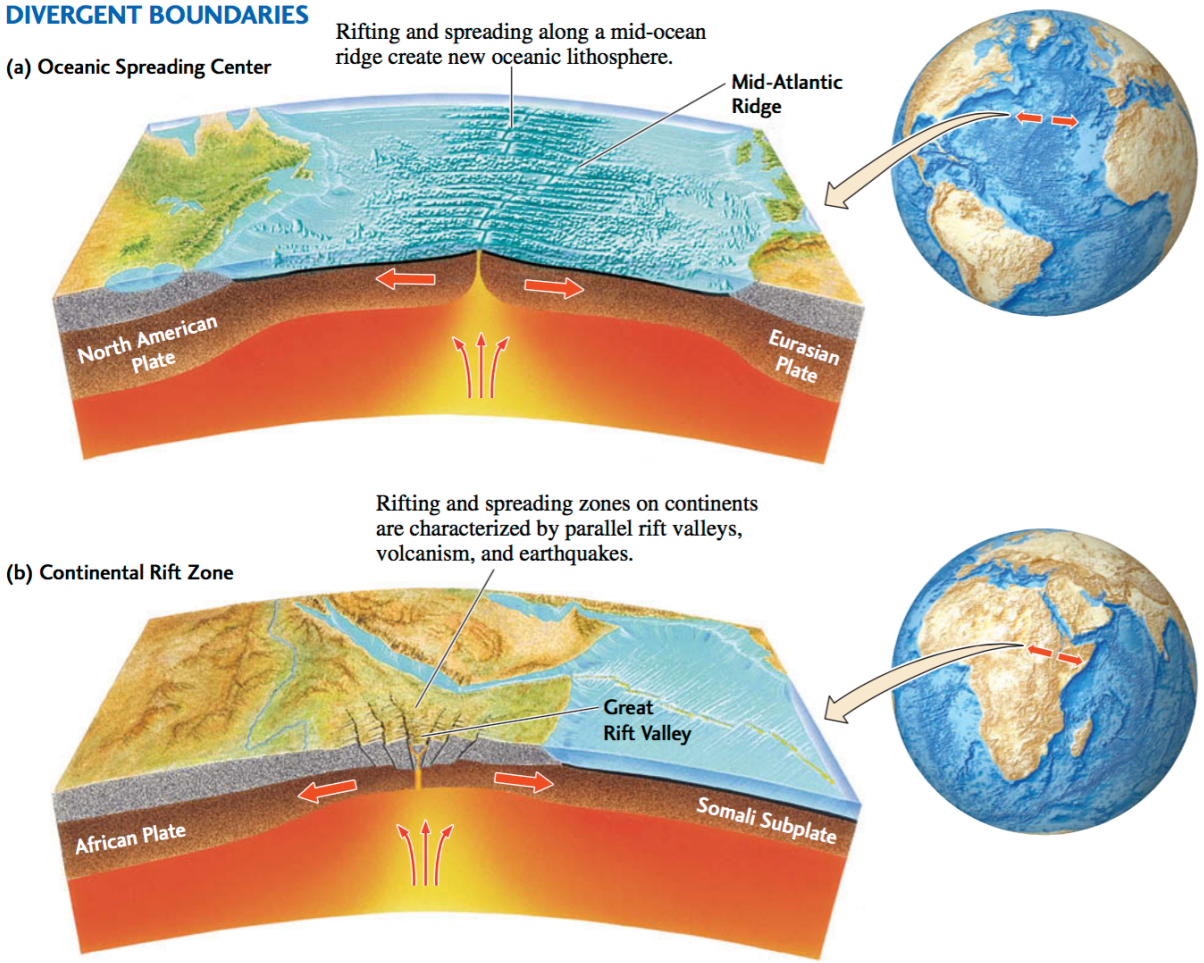


Boundary Distribution



Divergent Boundaries

New crust is generated as the plates pull apart. Occur at spreading ocean ridges and in continental rifts. Earthquakes are shallow and small.

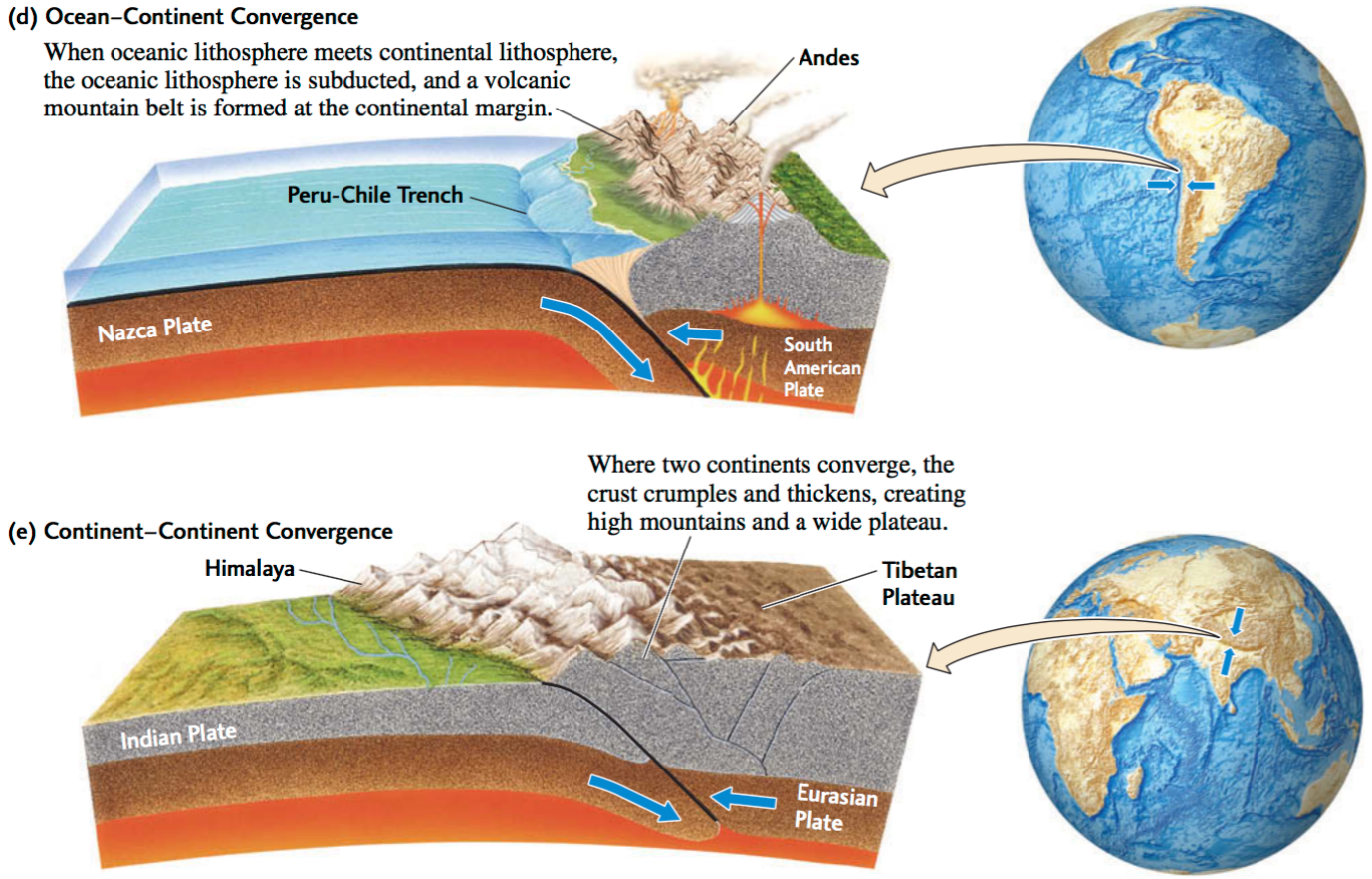


Example:
East Pacific Rise
(about 15 cm/year)

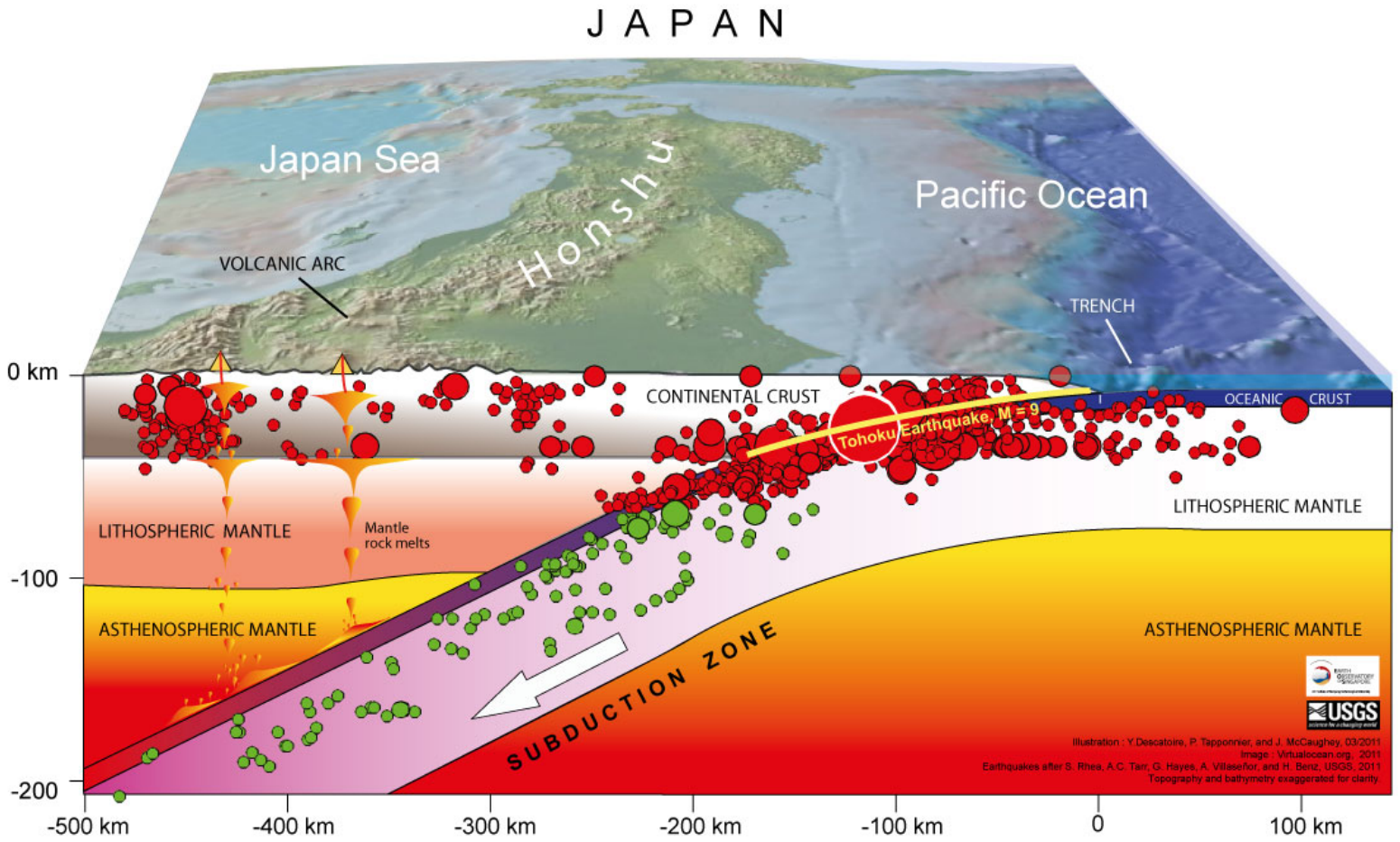
Examples:
African Rift Valley
Northern Red Sea
Basin and Range, USA

Convergent Boundaries

Plates push together and collide violently. The largest and deepest earthquakes in the world are generated. Two cases:
A) oceanic–continental crust >> the denser oceanic crust subducts
B) continental–continental crust >> creation of orogenic belts

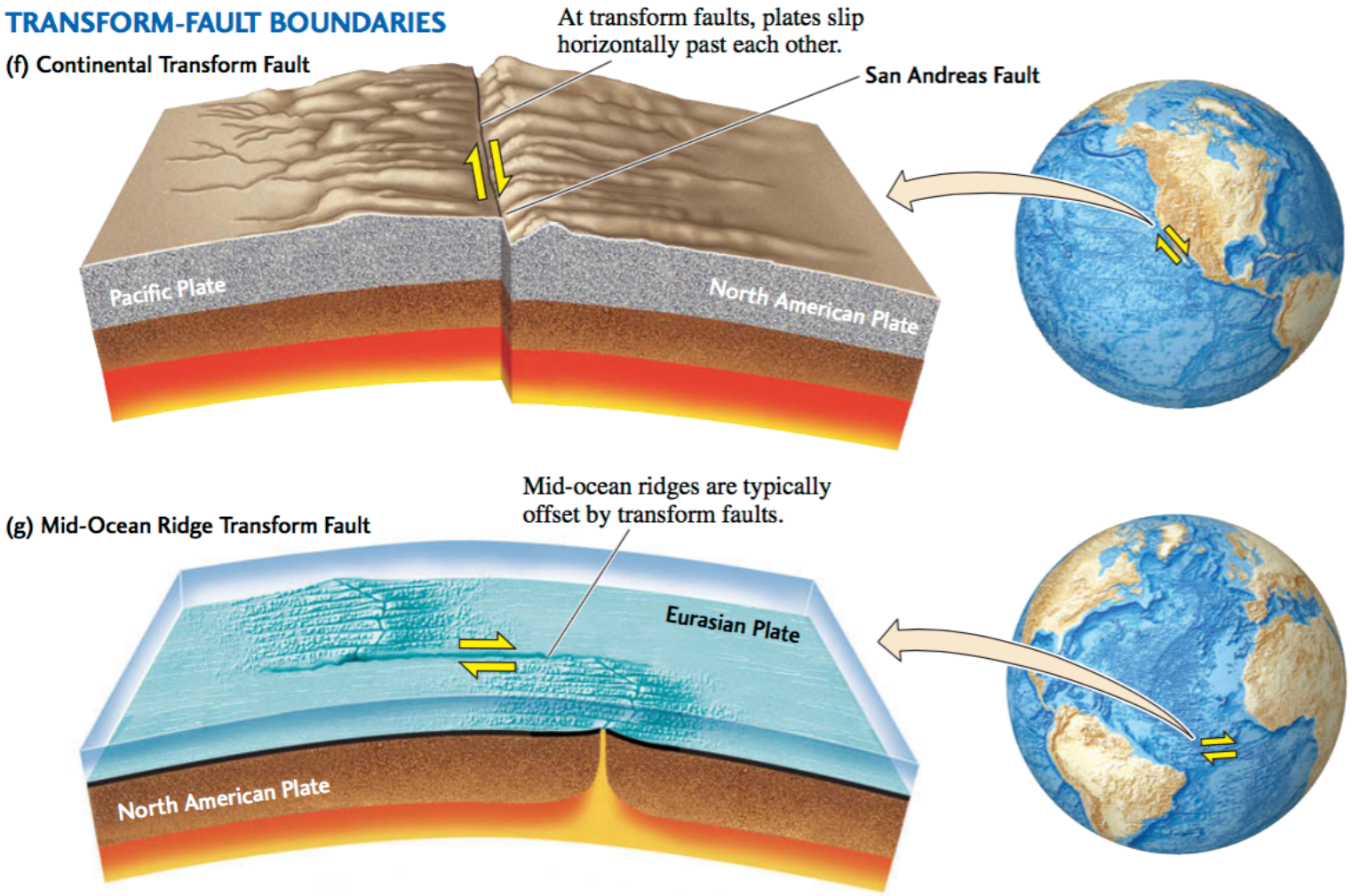


Convergent Boundaries



Transform Boundaries

Plates slides one other. Large but shallow earthquakes are generated.



Transform Boundaries

Hypocentral Depth Distribution