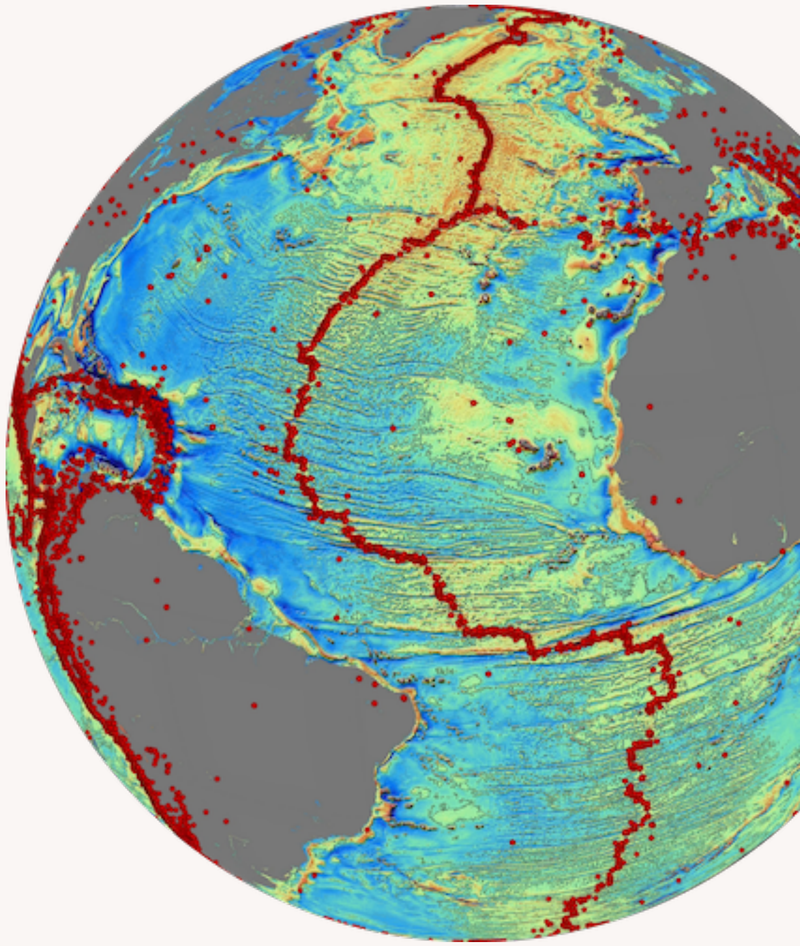
EAS 3610

Module 1: Plate Tectonics

Today's Objectives

1. Intro to Plate Tectonics
2. Continental drift theory & sea-floor spreading
3. Earth structure and division



What’s Plate Tectonics?

Tectonic plate boundaries, like the San Andreas Fault pictured here, can be the sites of mountain-building events, volcanoes, or valley or rift creation.

Plate Tectonics Theory

Definition:

Plate tectonics is a scientific theory that explains how major landforms are created as a result of Earth's **subterranean movements**

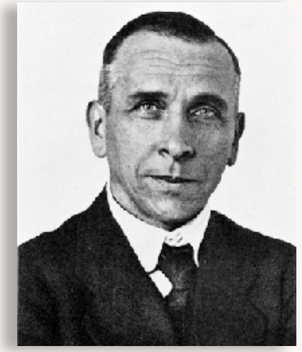
And helps explain phenomena, e.g.,

Continental Drift Theory (1912)

Alfred Wegener

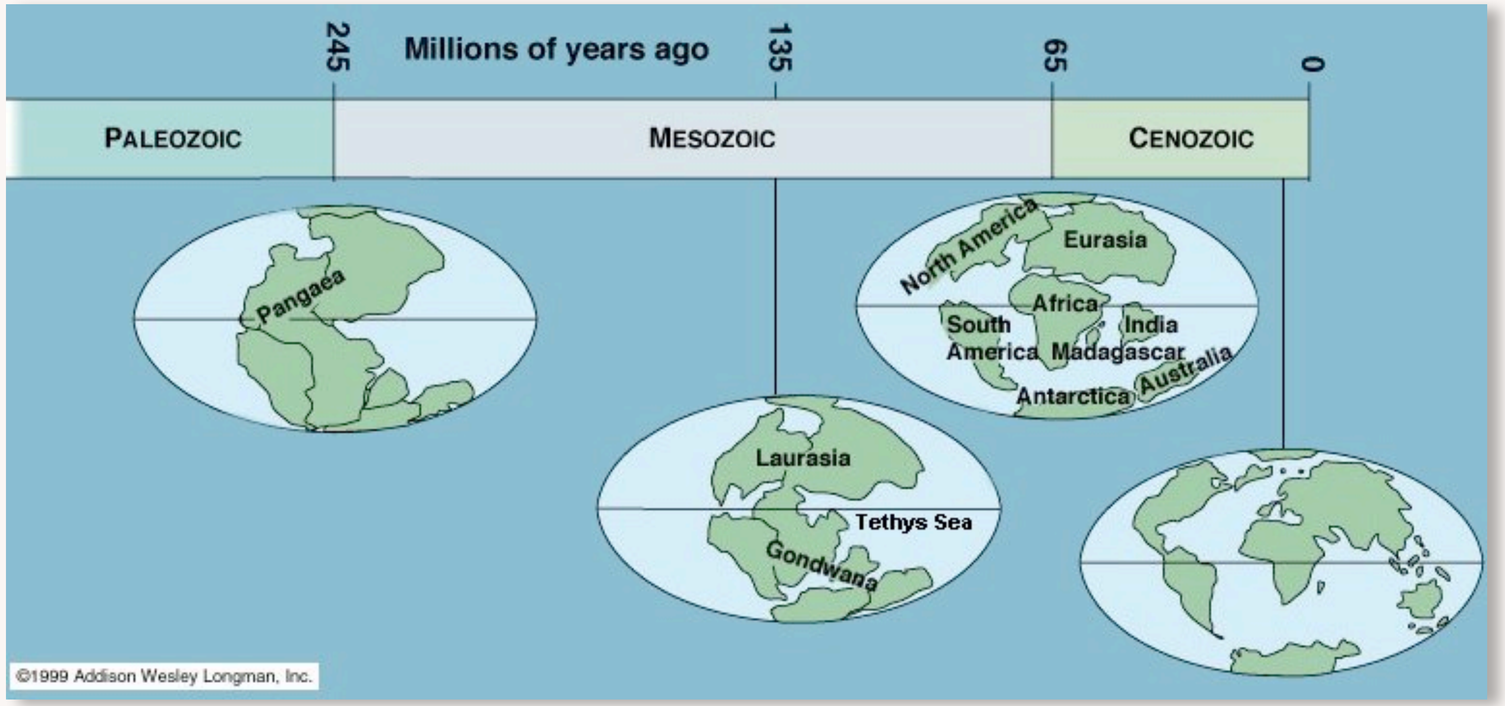
German climatologist

(1880 – 1930)



- The originator of **continental drift hypothesis**

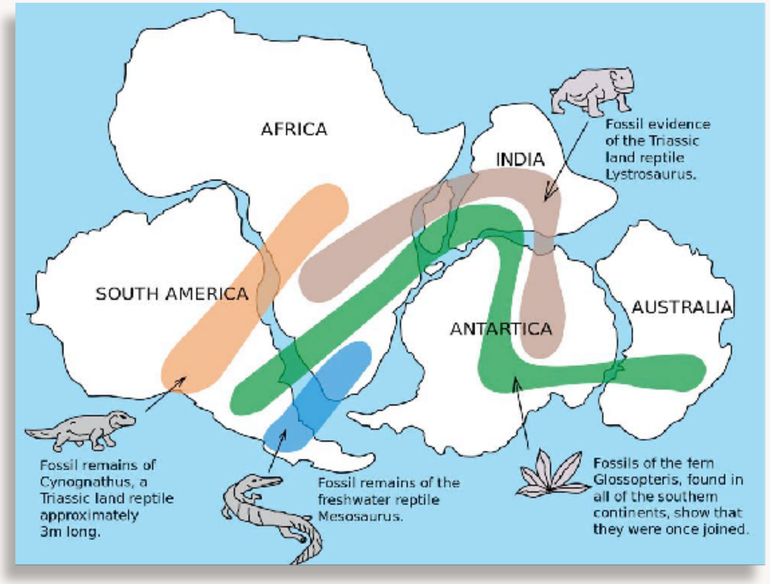
Continent drift suggests that the continents are slowly drifting around the Earth



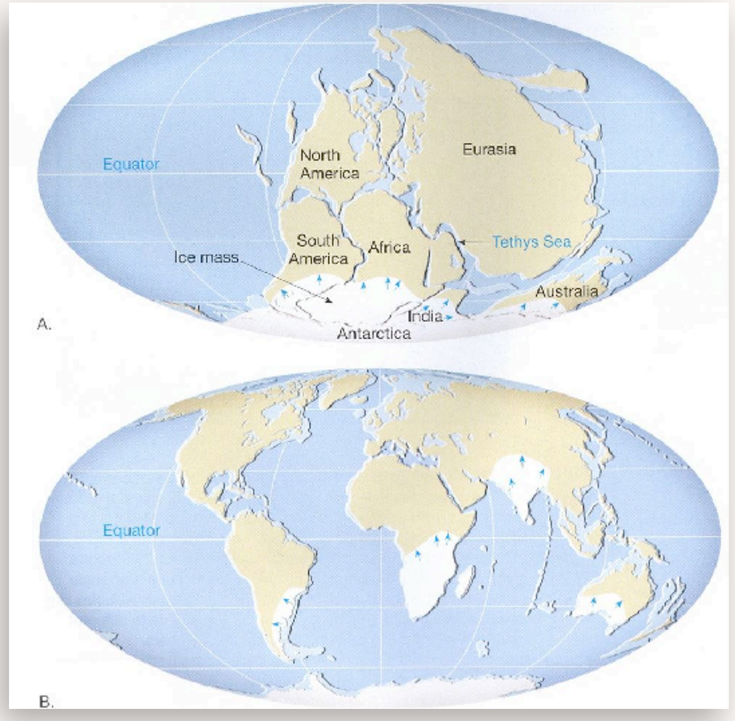
Evidence for Continental Drift

Matching continents' shape

Common fossils found in different continents



Evidence of glacial deposits in modern tropical places



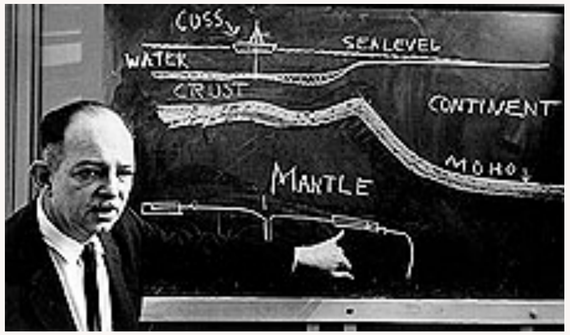
The Problem

Scientists did not accept Wegener's theory, mainly because it was missing the mechanism for how it works -

Why did the continents drift?

- Wegener suggested that perhaps the rotation of the Earth caused the continents to shift towards and apart from each other (which was wrong)

Sea-floor Spreading (1960)



Harry Hess (1906 - 1969) added a geologic mechanism: **sea-floor spreading**, to account for Wegener's moving continents

During WWII, he mapped the ocean floor using sonar technology

PETROLOGIC STUDIES: A VOLUME TO HONOR
A. F. BUDDINGTON
PP. 599-620 NOVEMBER 1962

History of Ocean Basins

H. H. HESS
Princeton University, Princeton, N. J.

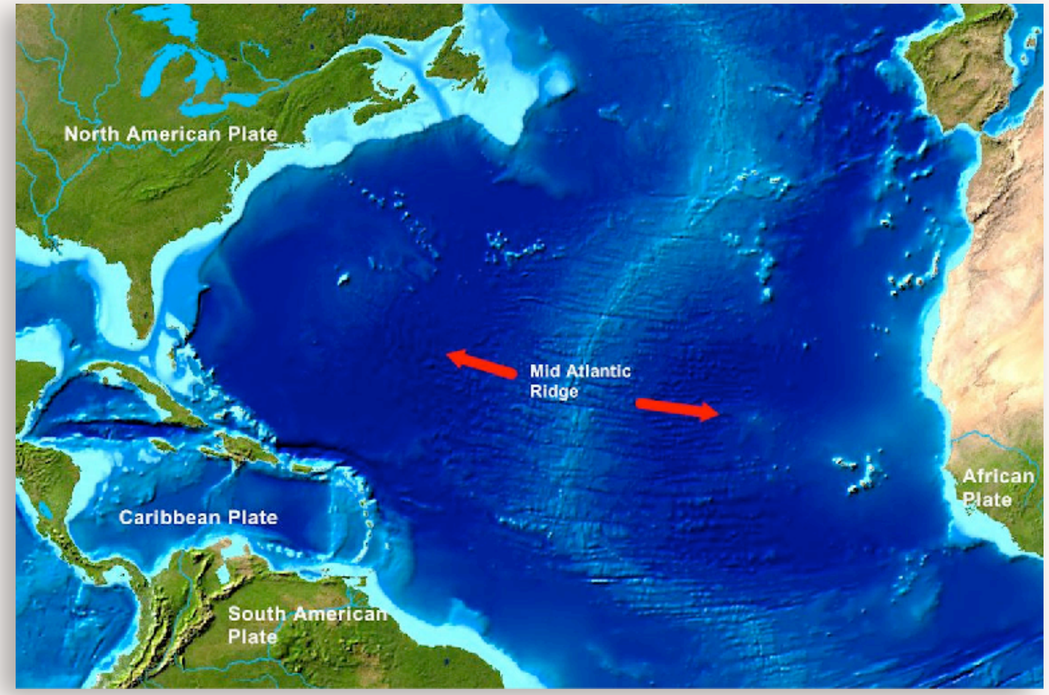
ABSTRACT

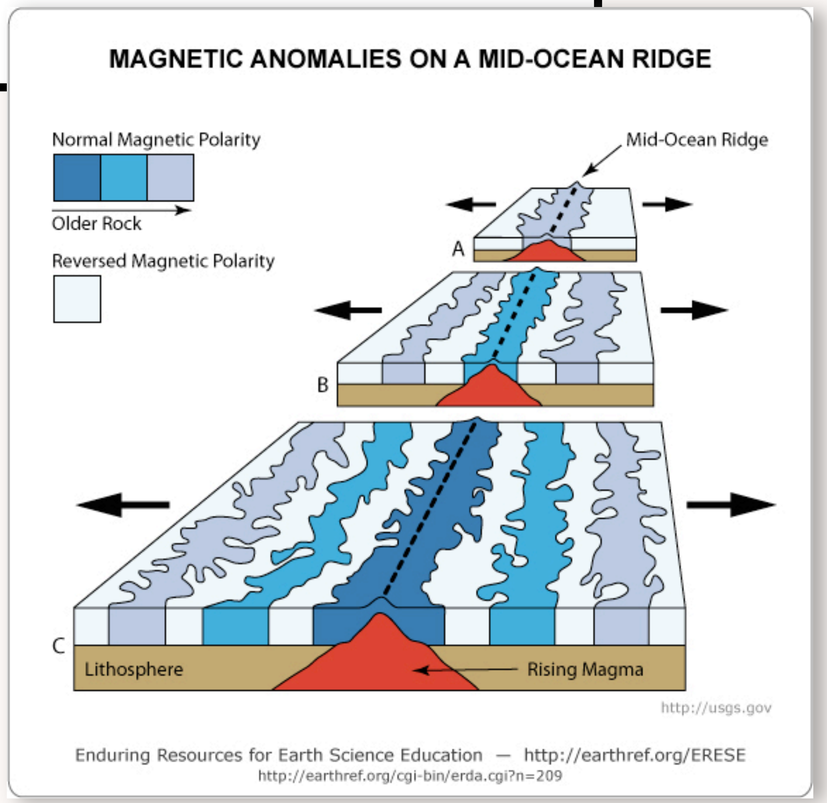
For purposes of discussion certain simplifying assumptions are made as to initial conditions on the Earth soon after its formation. It is postulated that it had little in the way of an atmosphere or oceans and that the constituents for these were derived by leakage from the interior of the Earth in the course of geologic time. Heating by short-lived radio nuclides caused partial melting and a single-cell convective overturn within the Earth which segregated an iron core, produced the primordial continents, and gave the Earth its bilateral asymmetry.

Mid-ocean ridges have high heat flow, and many of them have median rifts and show lower seismic velocities than do the common oceanic areas. They are interpreted as representing the rising limbs of mantle-convection cells. The topographic elevation is related to thermal expansion, and the lower seismic velocities both to higher than normal temperatures and microfracturing. Convective flow comes right through to the surface, and the oceanic crust is formed by hydration of mantle material starting at a level 5 km below the sea floor. The water to produce serpentine of the oceanic crust comes from the mantle at a rate consistent with a gradual evolution of ocean water over 4 aeons.

Sea-floor Spreading (1960)

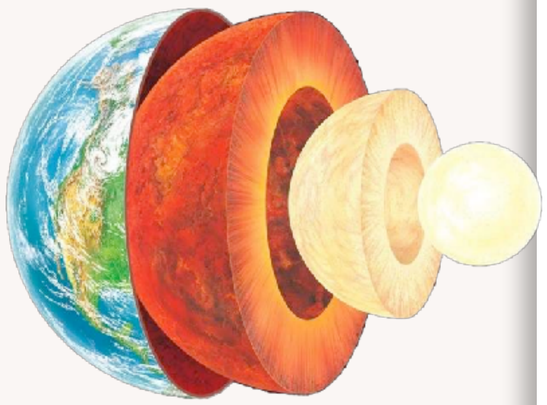
Sea-floor spreading occurs when two tectonic plates separate at a mid-ocean ridge, allowing molten material from the mantle to rise and form new oceanic crust.

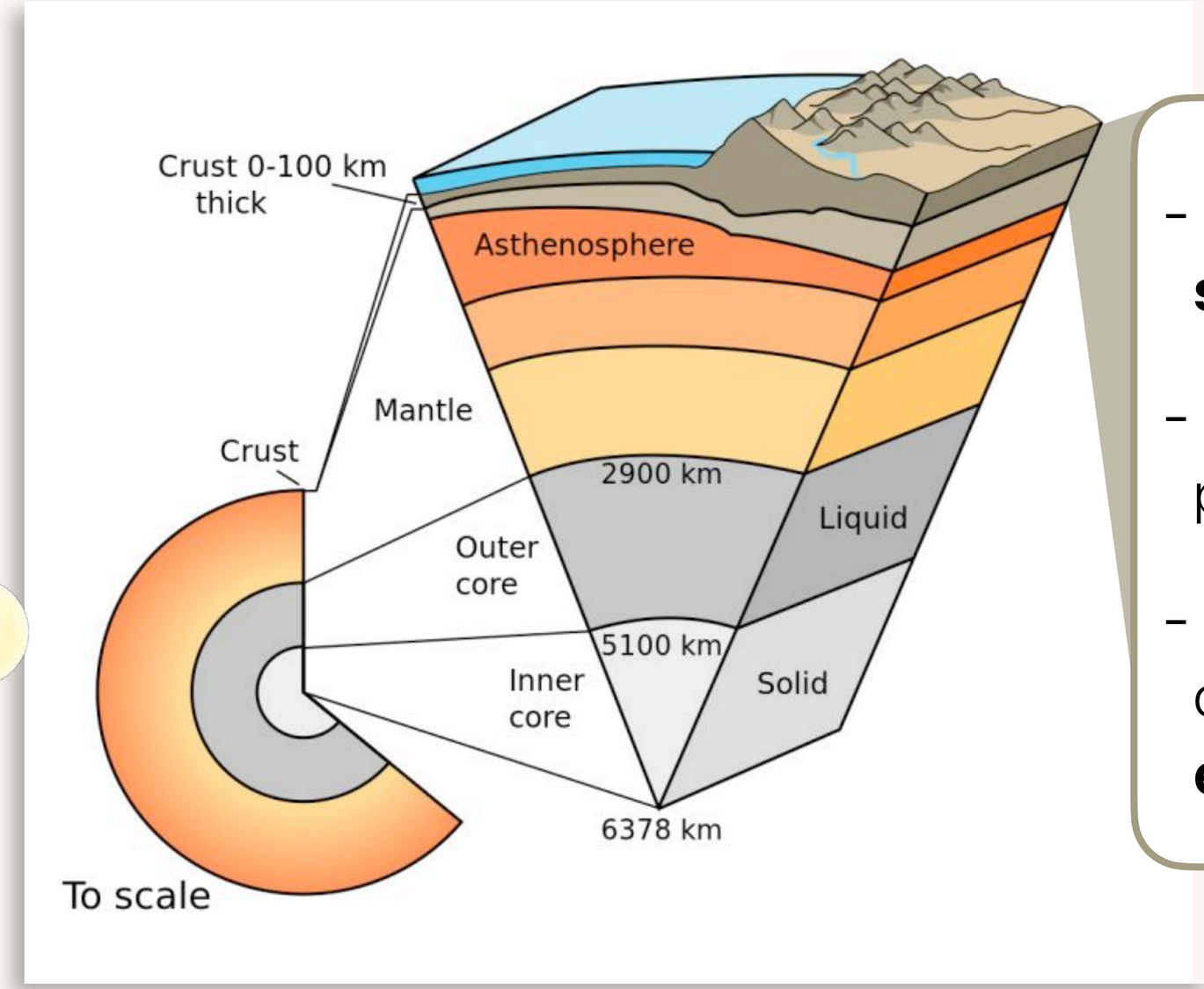




Modern Plate Tectonics Theory

Earth is composed of multiple layers

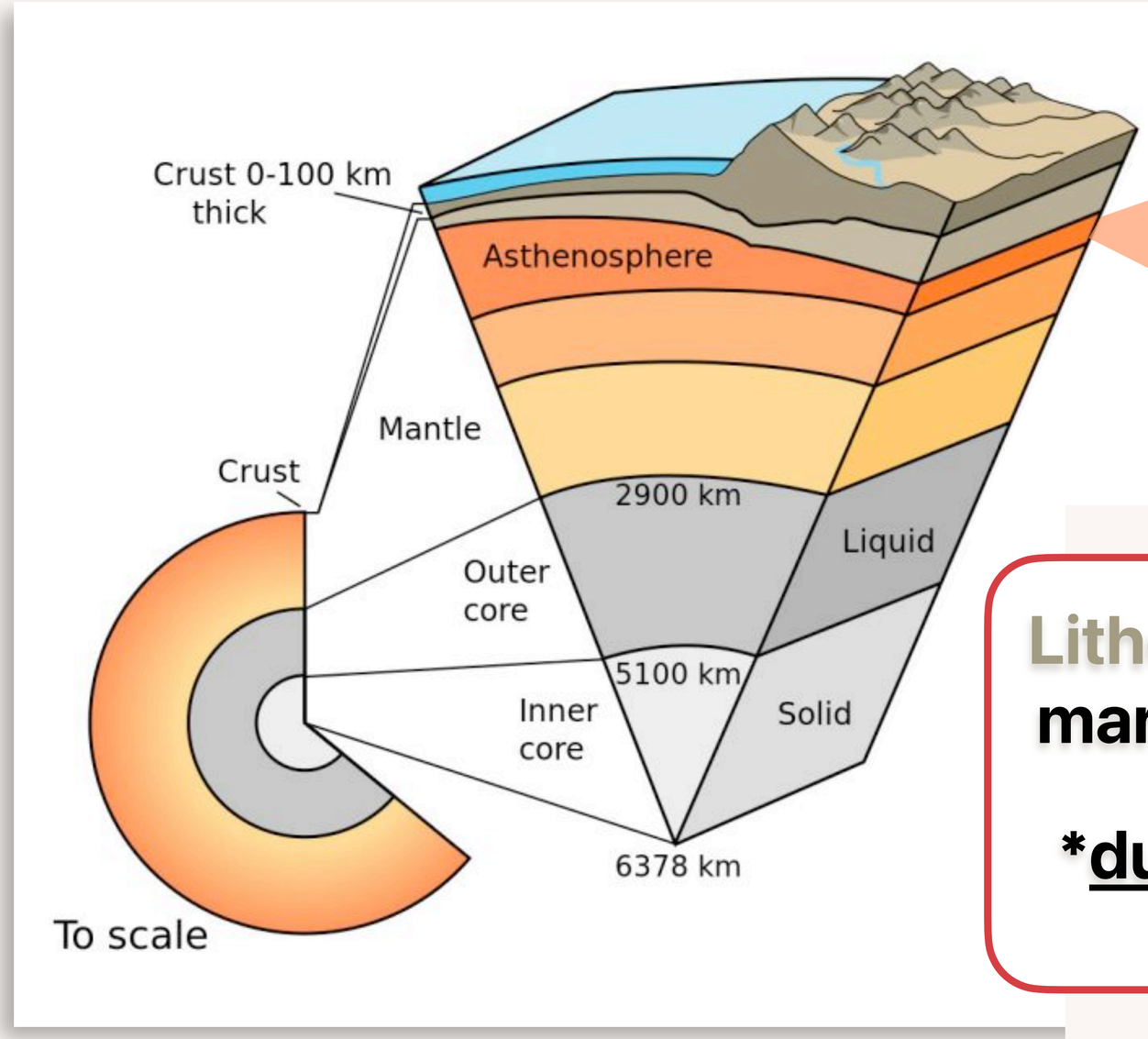




Lithosphere

- Brittle **crust** and **solid upper mantle**
- Coolest, most rigid part of the Earth
- Rock material is considered as **elastic**

Second layer: Asthenosphere



Asthenosphere

- Lower part of the **upper mantle**
- Rock material is considered as **viscous**

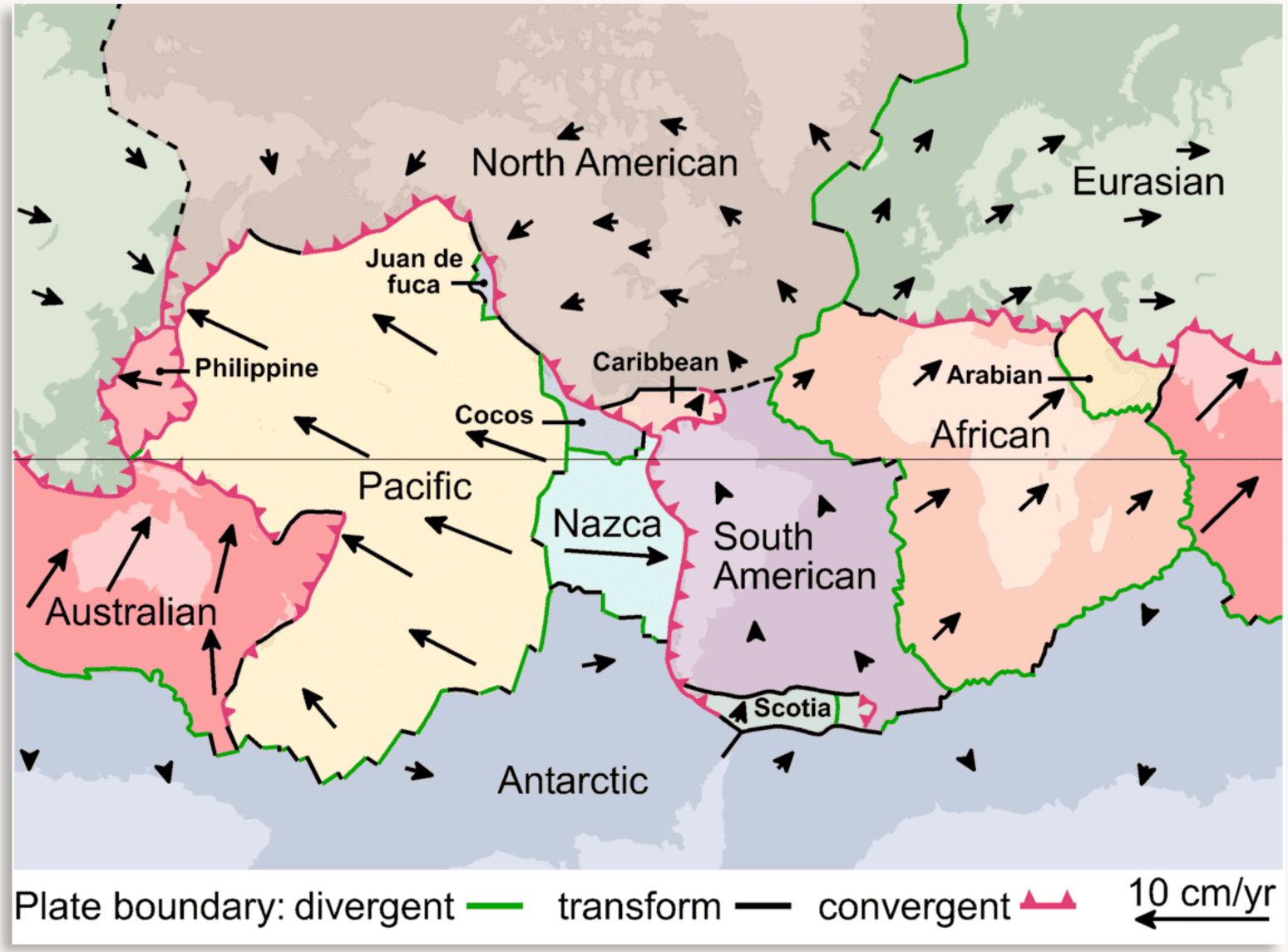
Lithosphere - Asthenosphere Boundary marks the ductility transition

***ductility = measures how a solid deform under stress**

Lithosphere divided into Tectonic Plates

7 major ones with other smaller tectonic plates

Tectonic Activities at Plate Boundaries



Most tectonic activity takes place at the plate boundaries

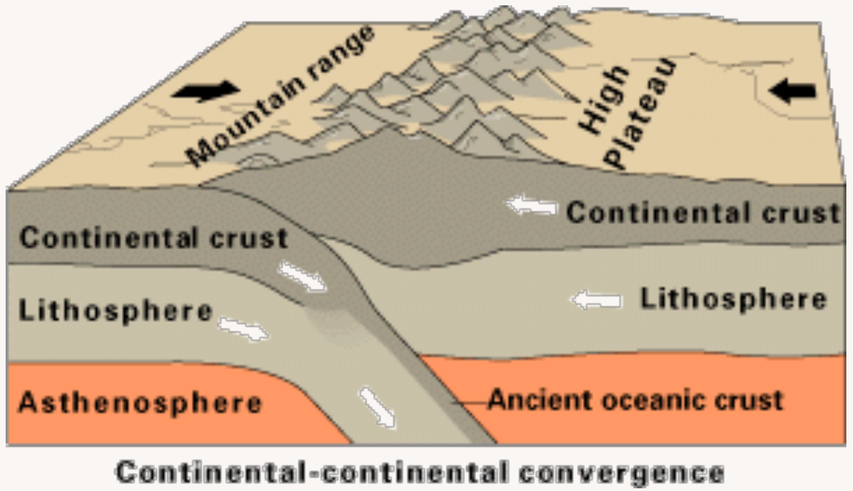
Classified plate boundaries into three types

1. Convergent Boundary

Definition:

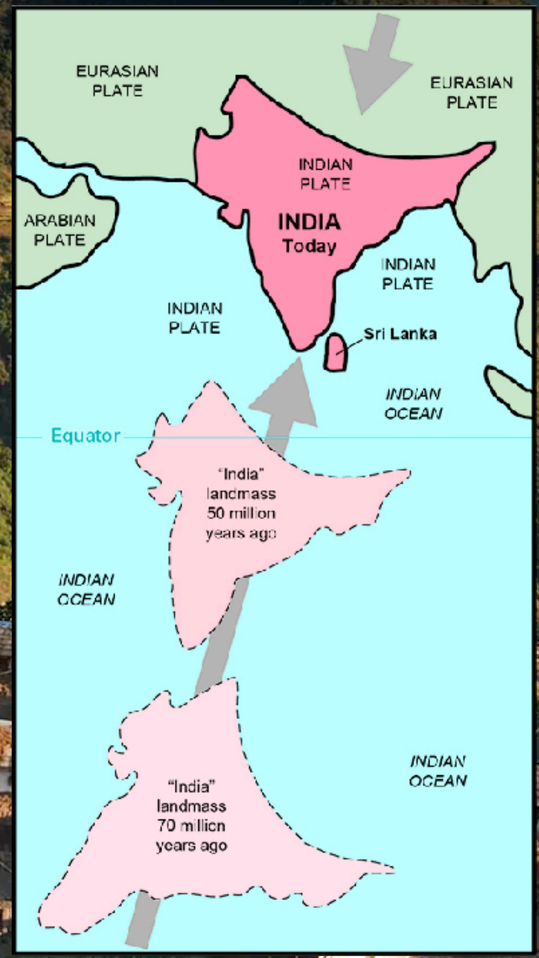
When two plates come together, it is known as a convergent boundary

typically represented as saw-tooth on maps

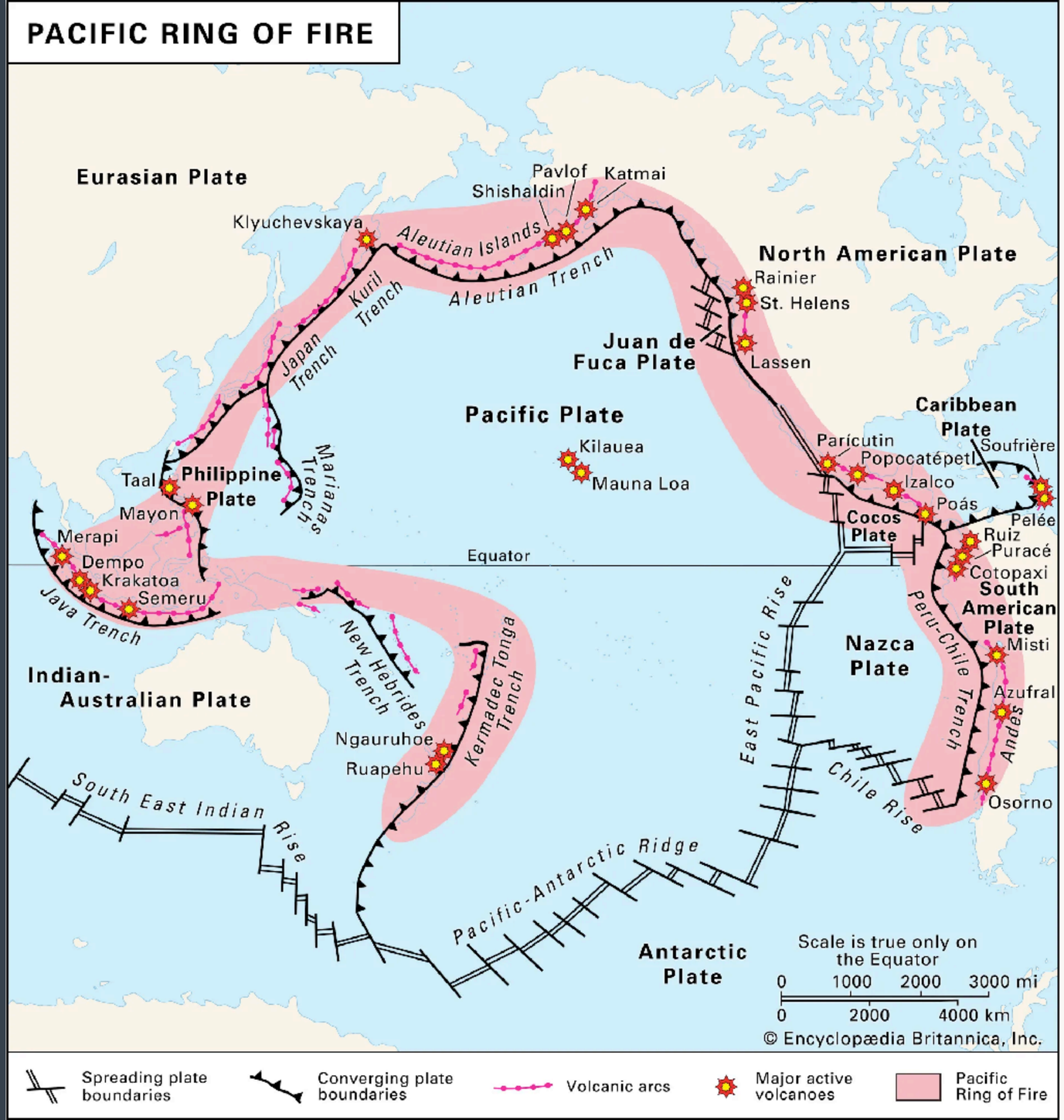


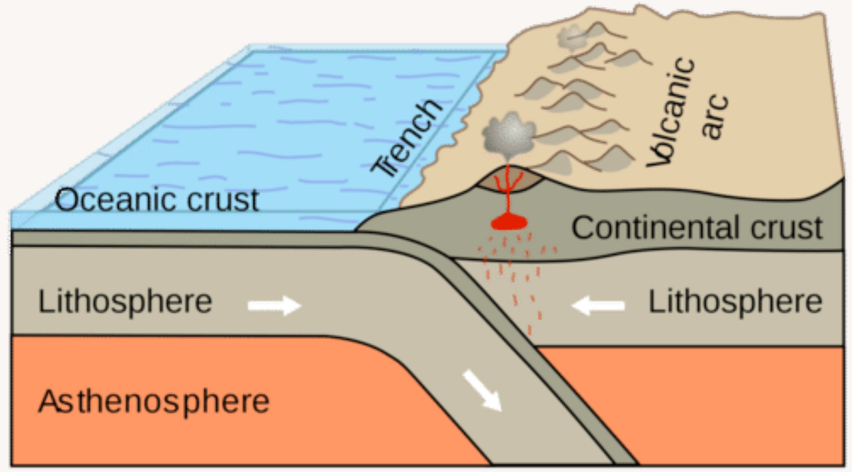
Continental-continental convergence

Himalayas mountain formed by the collision between Indian Plate and the Eurasian Plate



Other examples





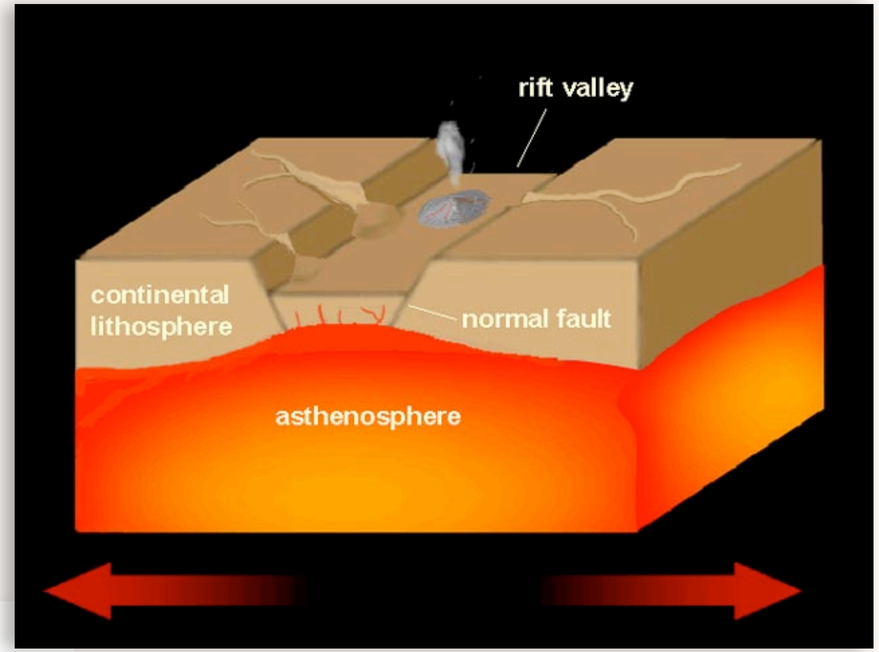
The Pacific Ring of Fire is due to oceanic-continental convergent

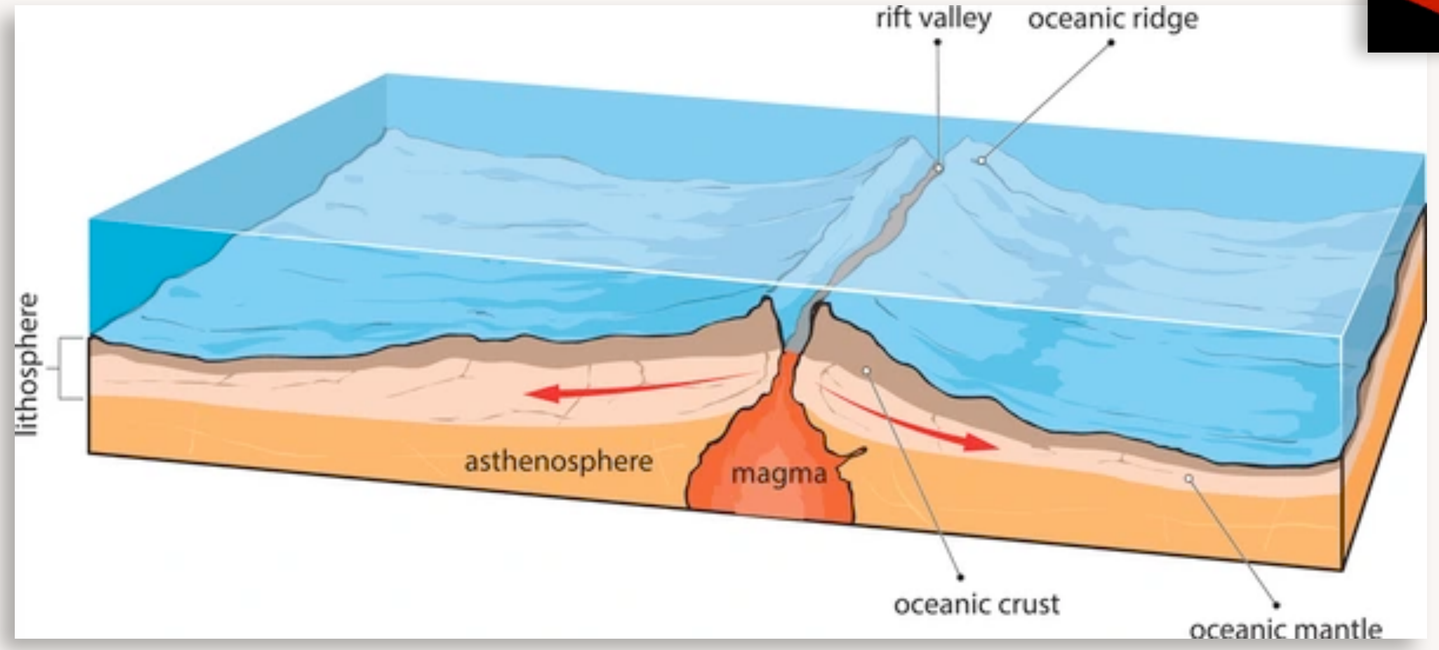
- where the Pacific plate **subducted** beneath the Eurasian & North American Plates

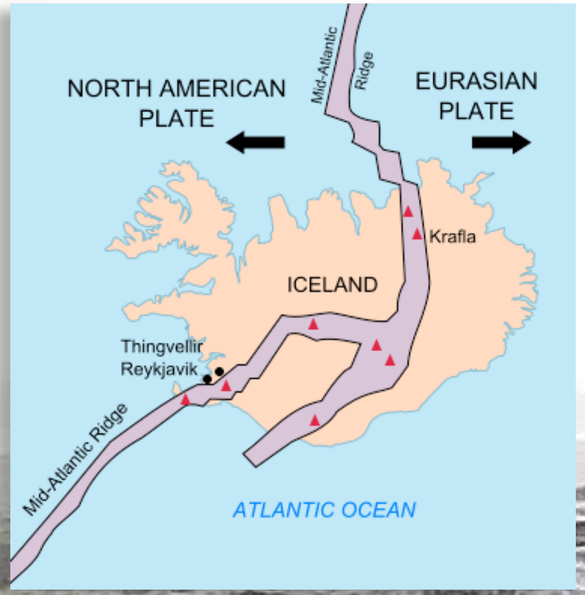
2. Divergent Boundary

Definition:

A **divergent boundary** occurs when two tectonic plates **move away** from each other

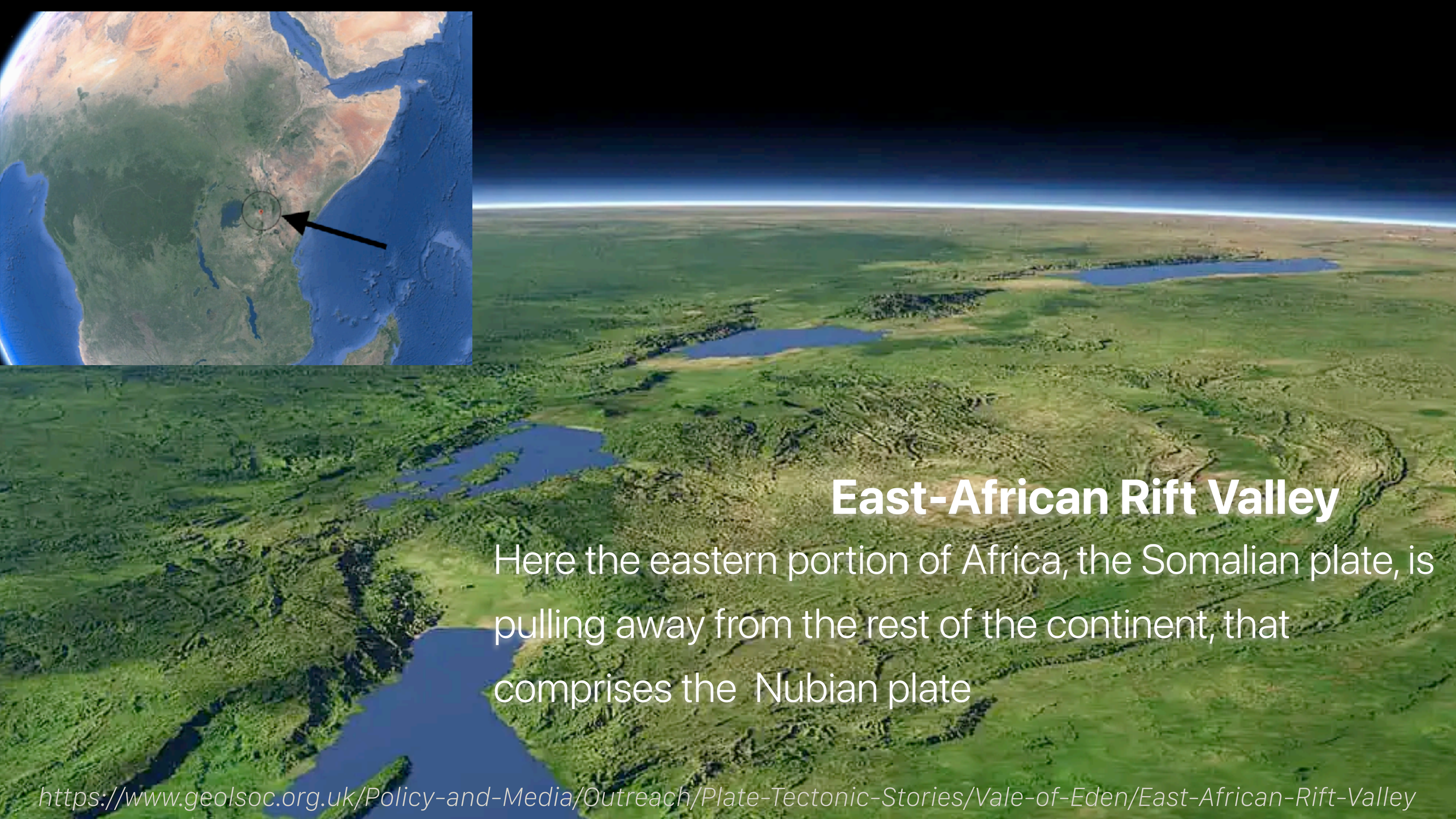






Mid-Atlantic Ridge

Bridge across the Álfagjá rift valley in southwest Iceland, that is part of the boundary between the Eurasian and North American continental plates



East-African Rift Valley

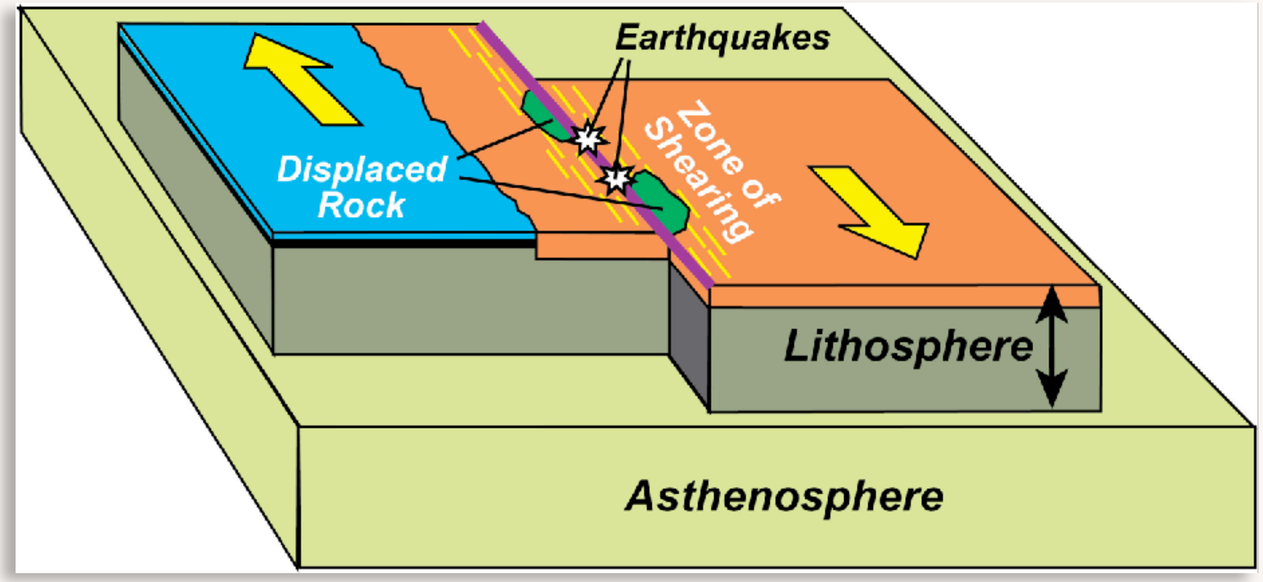
Here the eastern portion of Africa, the Somalian plate, is pulling away from the rest of the continent, that comprises the Nubian plate

https://www.geolsoc.org.uk/Policy-and-Media/Outreach/Plate-Tectonic-Stories/Vale-of-Eden/East-African-Rift-Valley

3. Transform Boundary

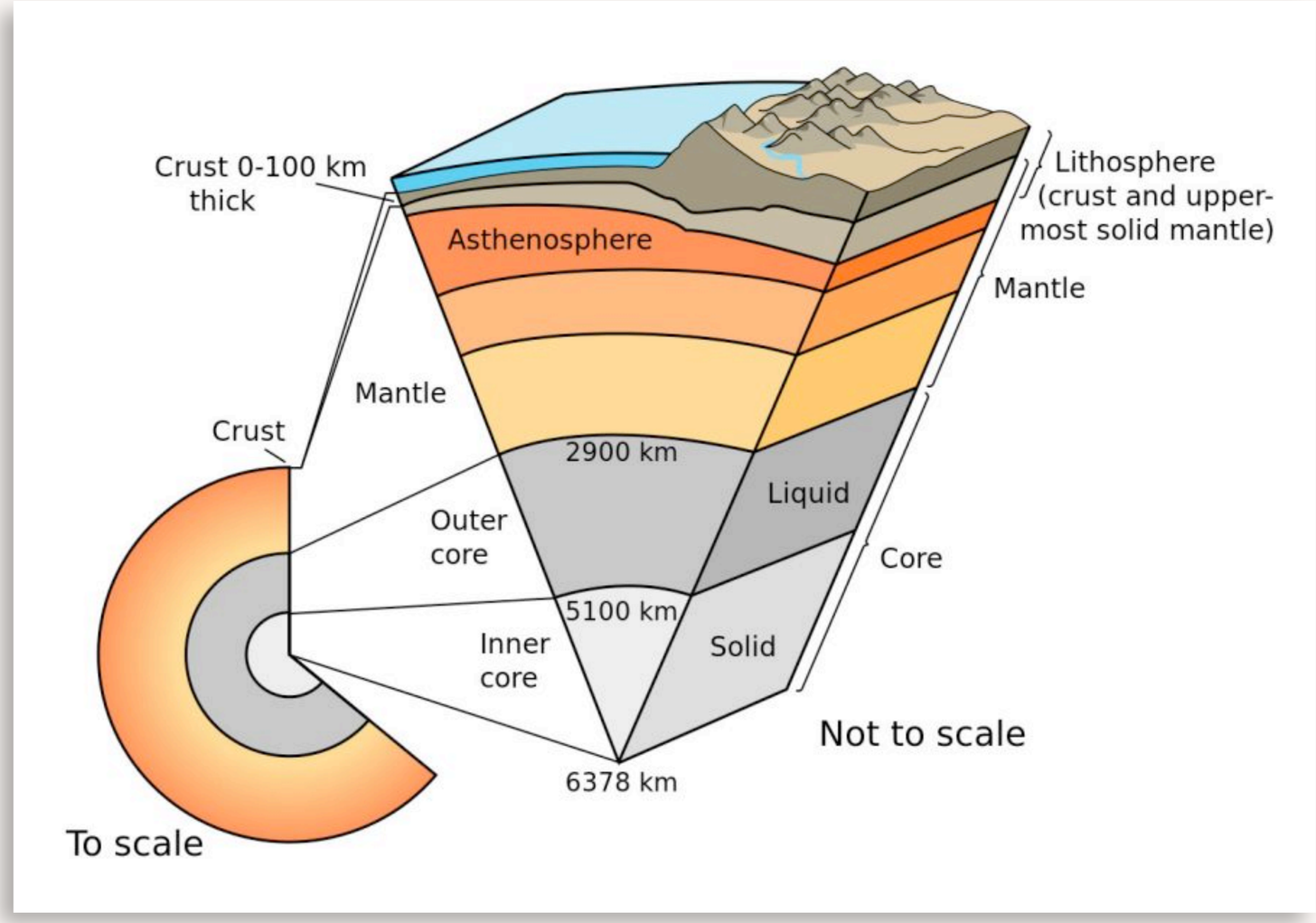
Definition:

Two plates sliding past each other forms a transform plate boundary



- In contrast to convergent and divergent boundaries, rocks along the transform boundaries are pulverized as the plates grind along, but they are **not created or destroyed**

Recap



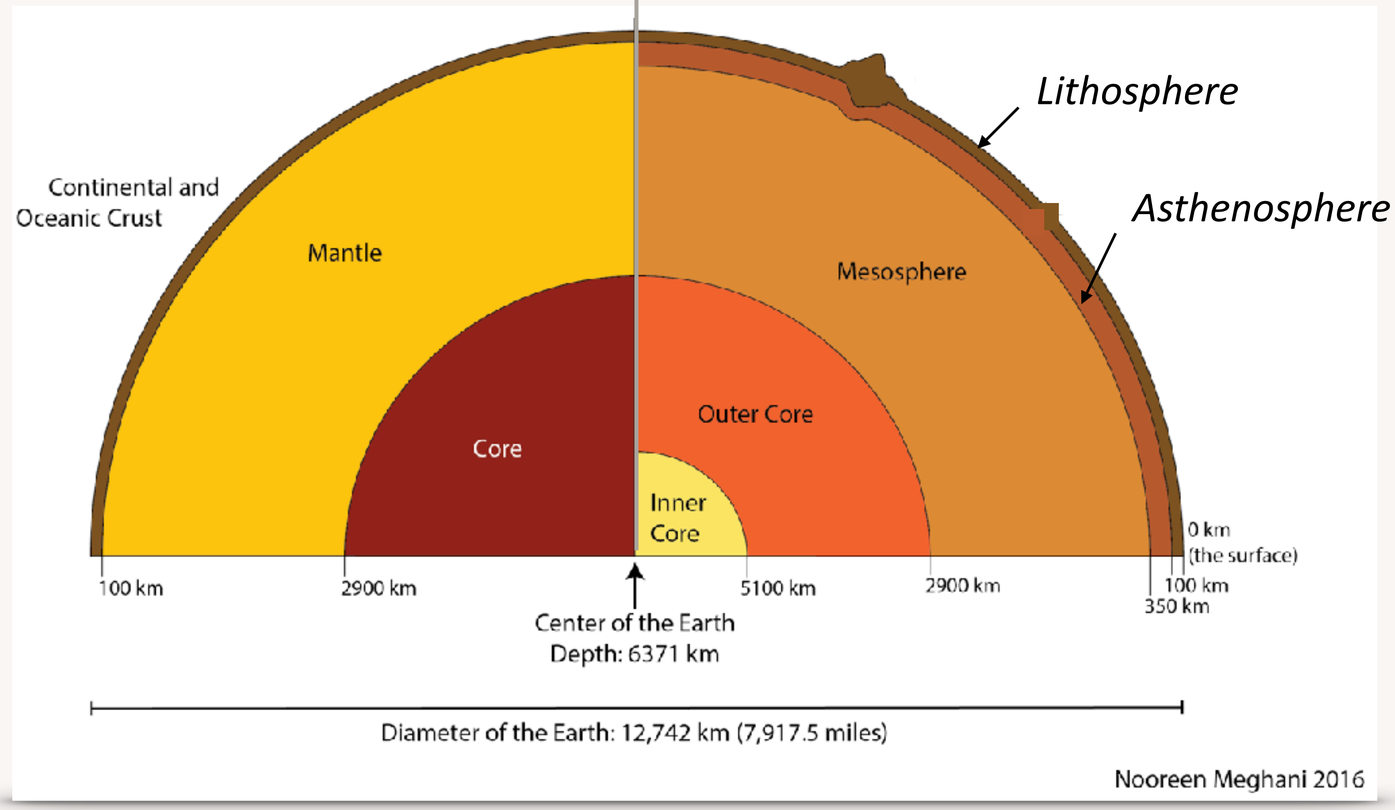
In plate tectonics, **lithosphere** is broken into tectonic plates

These plates gliding along a partially molten layer of rock called the **asthenosphere**

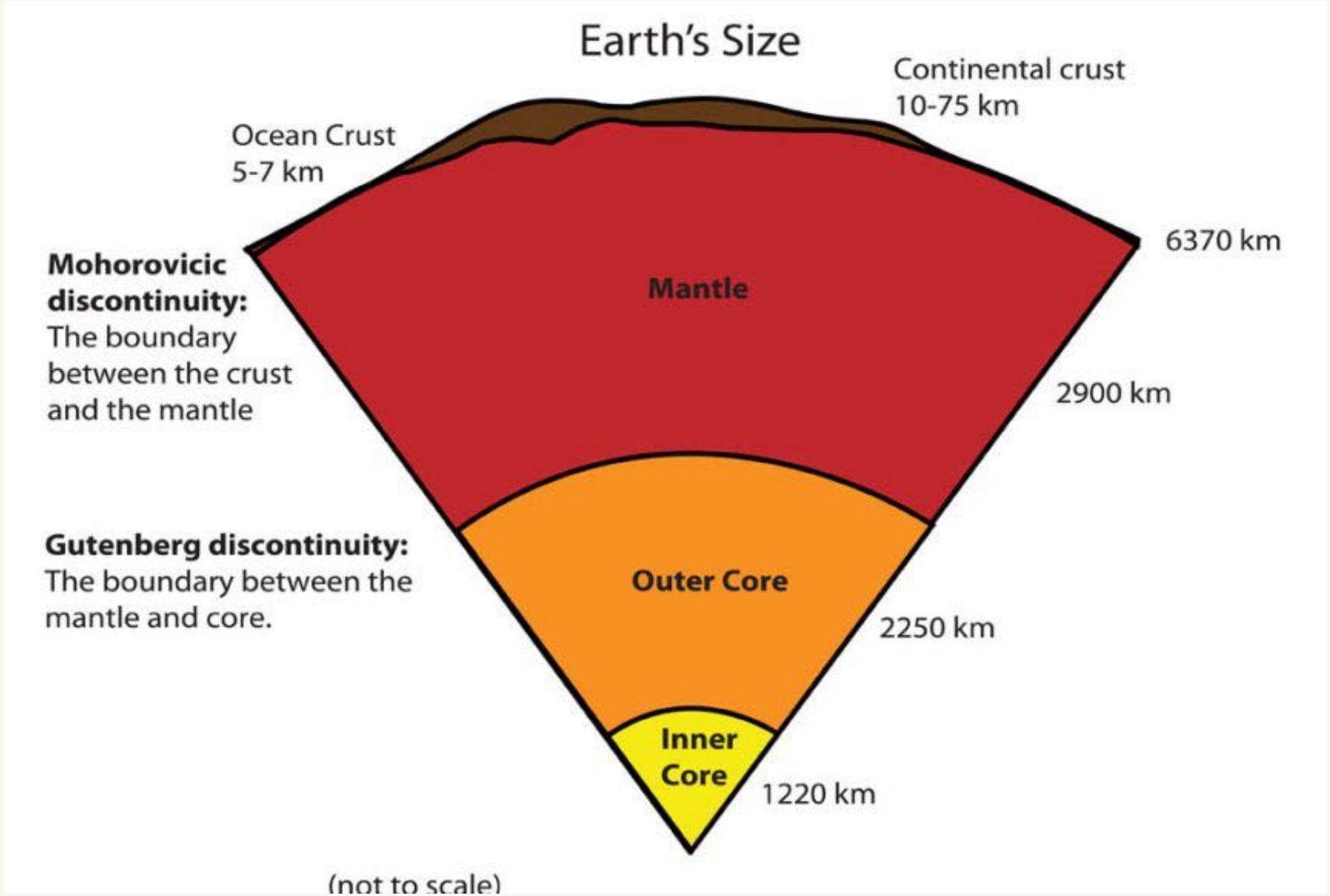
Major Division of the Earth

Two ways to divide Earth's interior into **multiple layers** based on:

a) by composition or **b) mechanical properties**



a) By composition



Four zones:

- Crust
- Mantle
- Outer Core
- Inner Core

Top Layer: Crust

Thickness: 0 - 100 km

- Thicker **Continental crust** (average: 40 km)
- **Oceanic crust** average thickness: 10 km

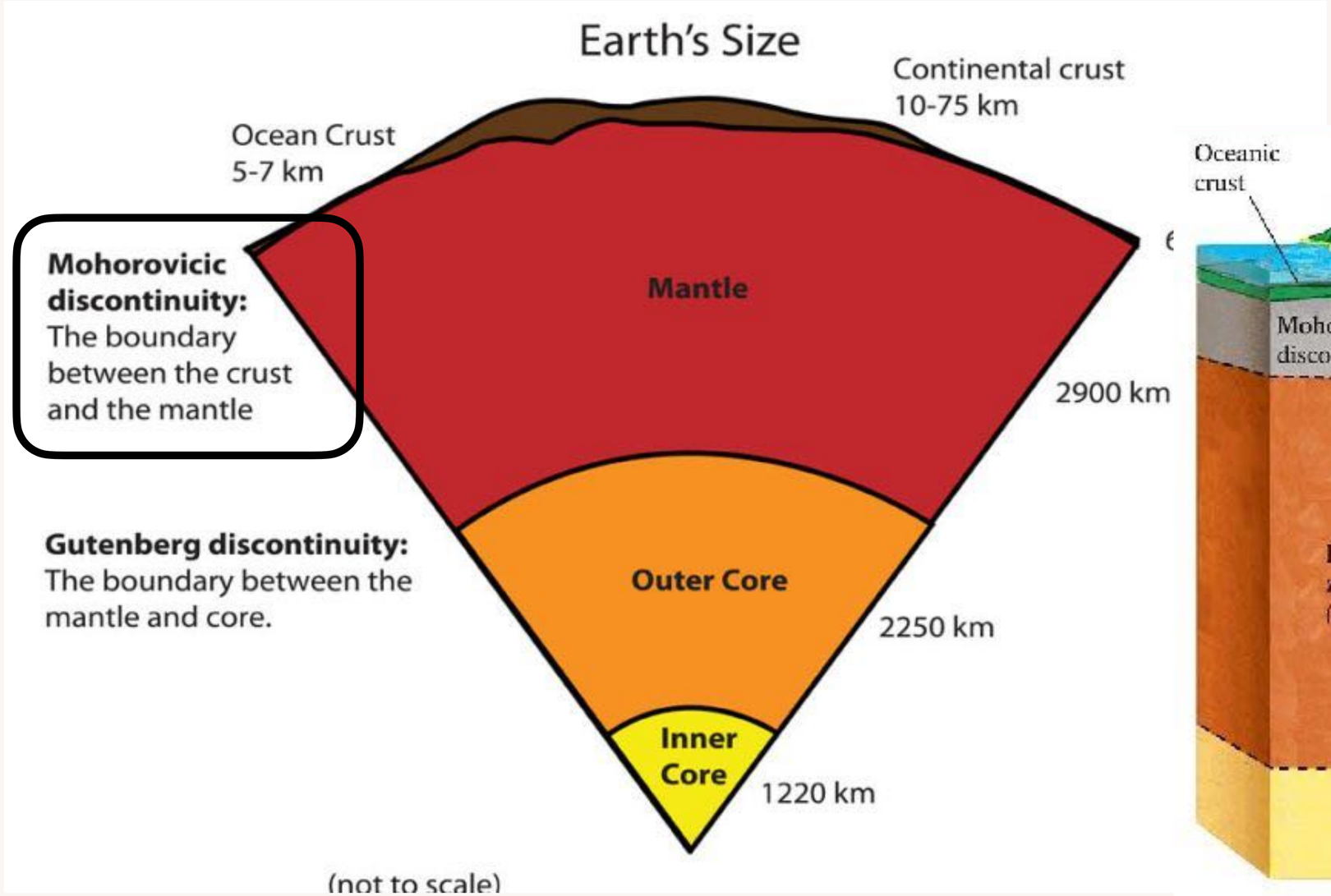
Least dense layer: 2 - 3 g/cm^3

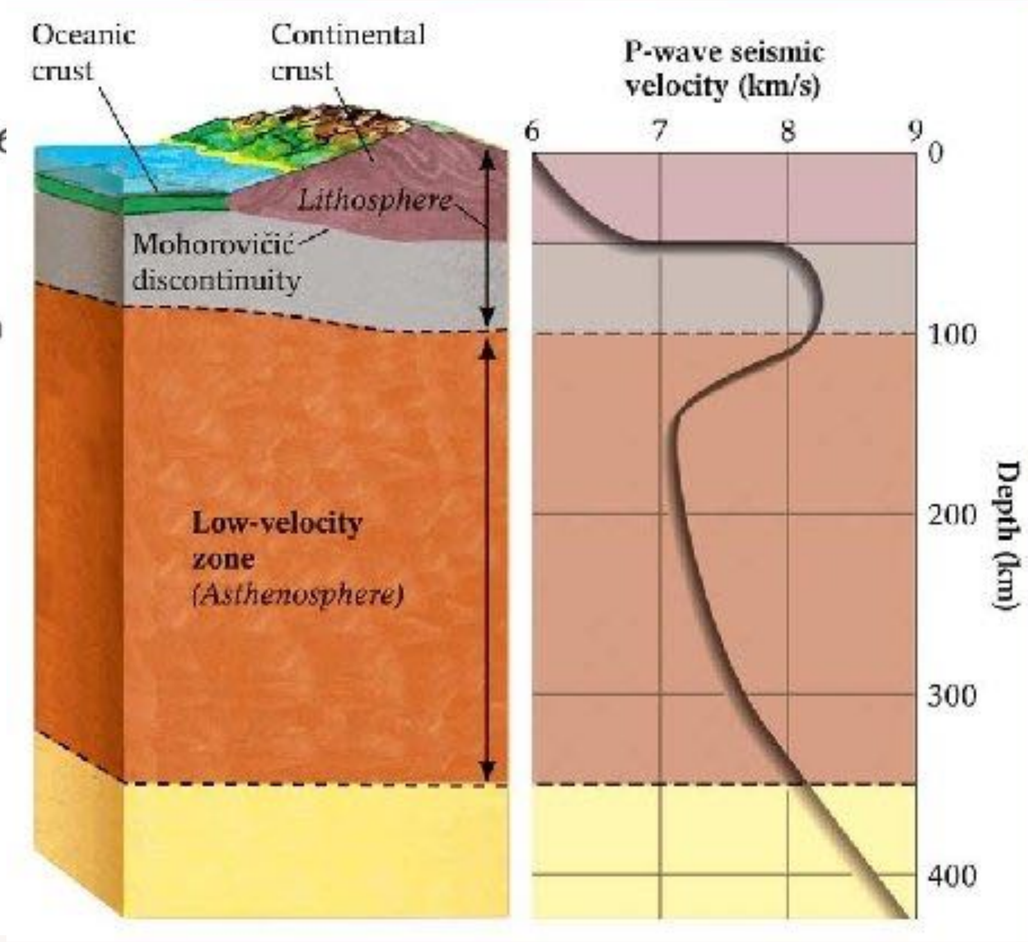
- **Oceanic crust is slightly denser** than continental crust

Composition:

- Continental crust: **granitic**
- Oceanic crust: **basaltic**
- Mostly oxygen (47%), Silicon (28%)

MOHO Marks the Boundary Between Crust & Mantle





2nd Layer: Mantle

Thickness: 100 - 2900 km

Denser than crust: 3 - 4 g/cm^3

Composition:

- Composed of **peridotite** rock
- Mostly oxygen (44%), Silicon (21%) Magnesium (22.8%)

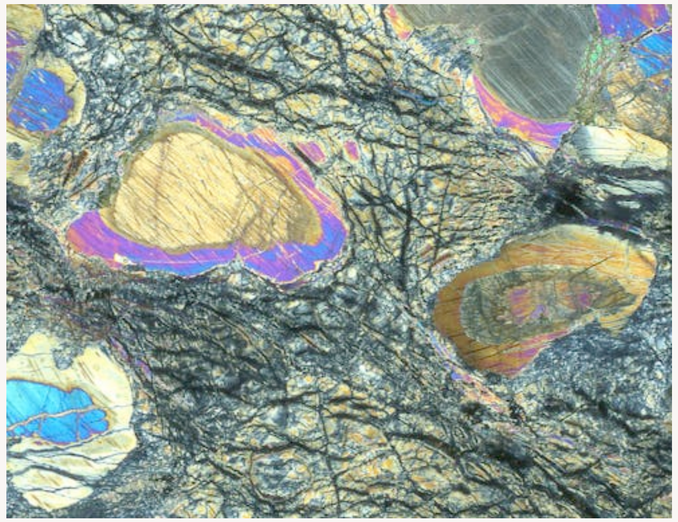
3rd & 4th: Outer & Inner Core

Thickness:
- Outer core: 2900 - 5100 km
- Inner core: 5100 - 6371 km

Mechanical property: - Outer core is liquid, while inner core is solid

Most dense layers: 9 - 12 g/cm^3

Composition: - Iron & nickel alloy



Deepest mantle sample at 1298 m containing core material fragments

Continued Next Lecture

Two ways to divide Earth's interior into **multiple layers** based on:

a) by composition or **b) mechanical properties**