

OLLI SG 492

Plate Tectonics

Session 3 - October 3, 2022

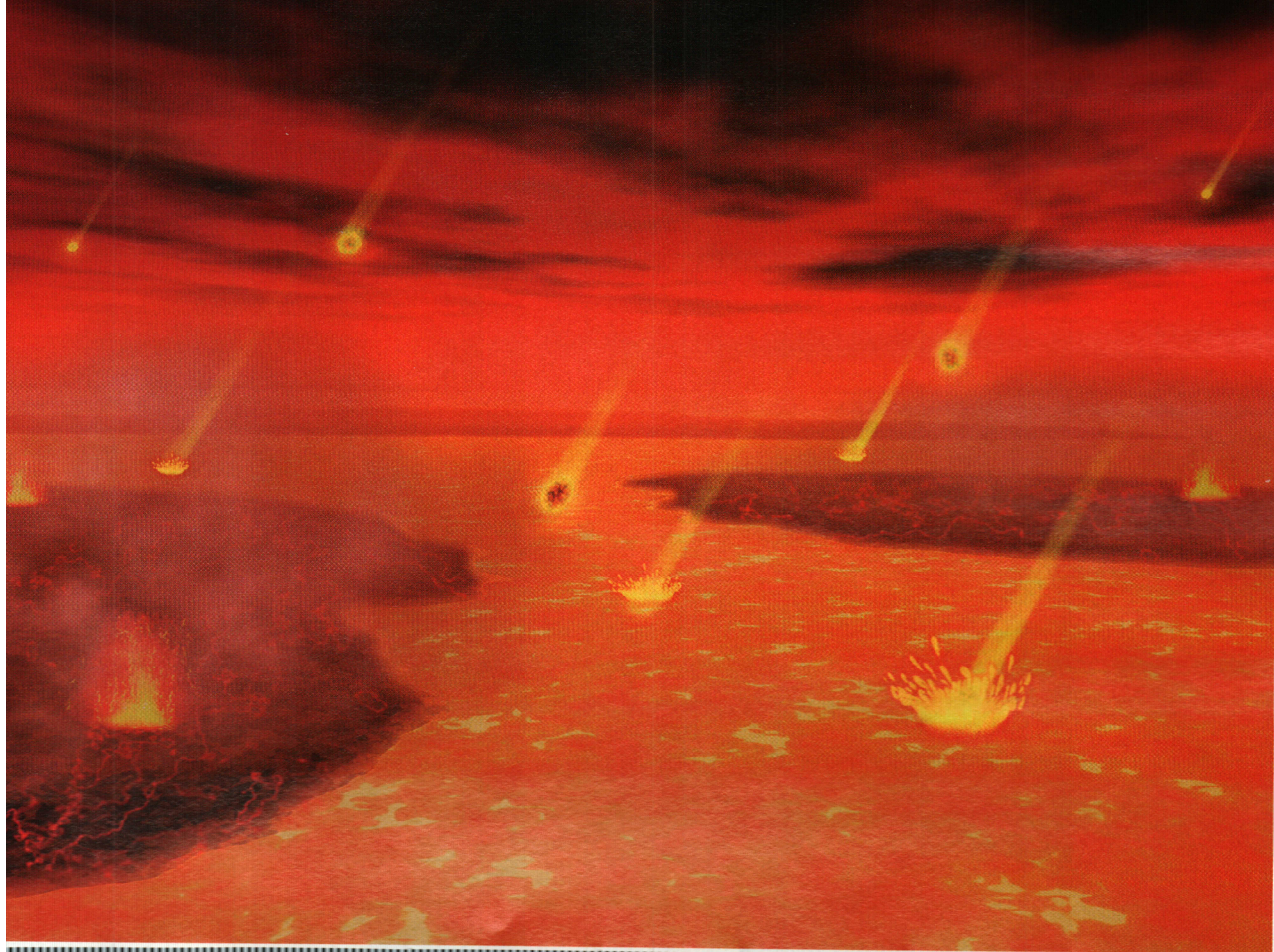
Today's Meeting

- Finish the picture of early Earth.
- Heat transport - convection in the Earth's mantle.
- High level view of plates and plate tectonics - What they explain.
- History of the theory of plate tectonics.
- The evidence for the truth of the theory.

Earth's Hadean Period

- Early Earth was continuously subject to impacts from asteroids and meteorites, keeping its temperature very high. Decay of radioactive elements also contributed to the heat.
- A magma ocean formed, several hundred kilometers deep.
- As molten rock on the surface of Earth cooled, a crust formed.

Hadean Earth



The Archaean Period - Cooling Earth

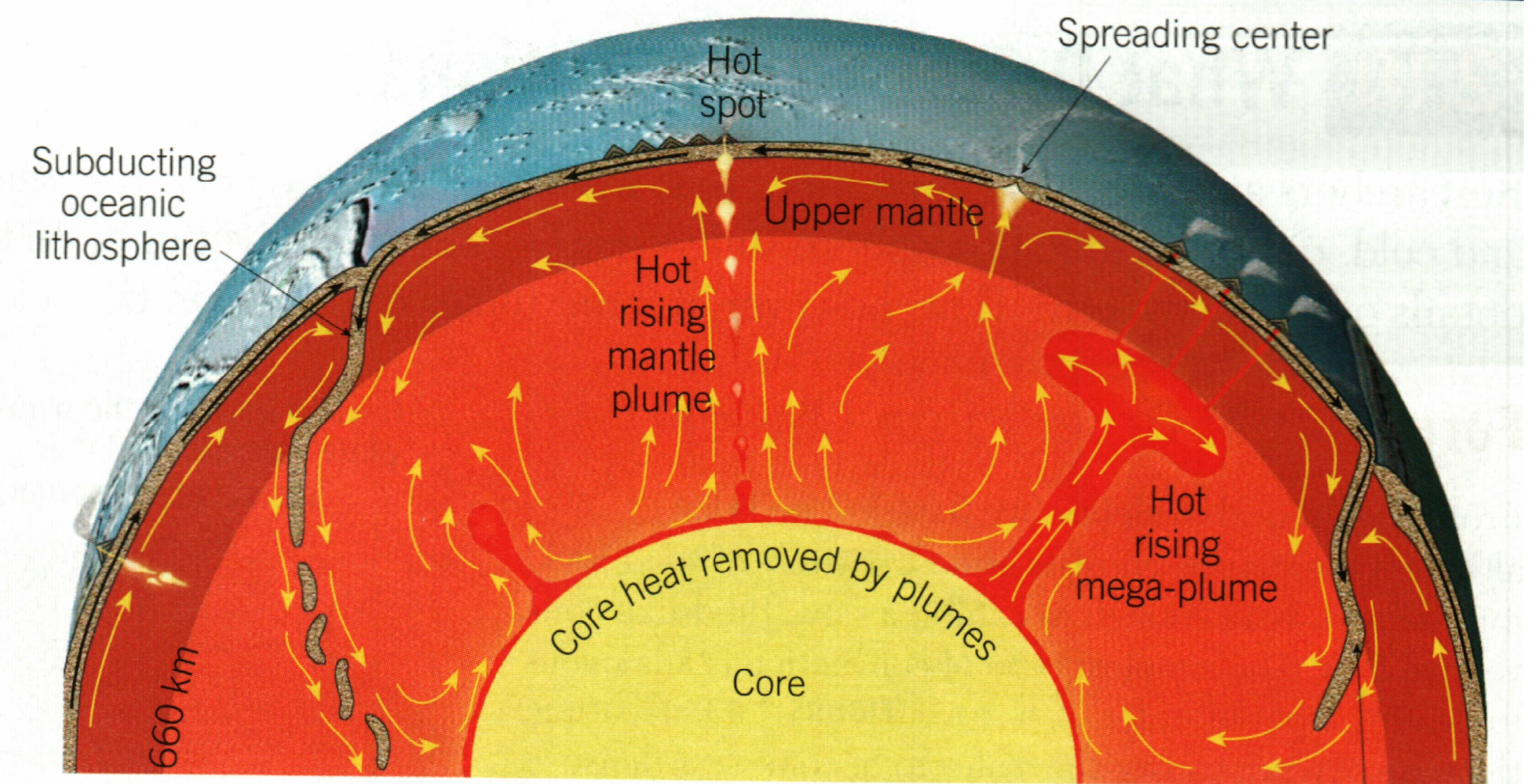
- No free oxygen in Earth's early atmosphere.
- Water, carbon dioxide, and other gases were out-gassed into the atmosphere from volcanoes. As Earth cooled, water vapor condensed into clouds.
- Torrential rainfalls filled low-lying areas with water, forming early, shallow oceans.
- By 4 billion years ago, 90% of the current volume of water collected into the developing oceans.

Heat Transport by Convection

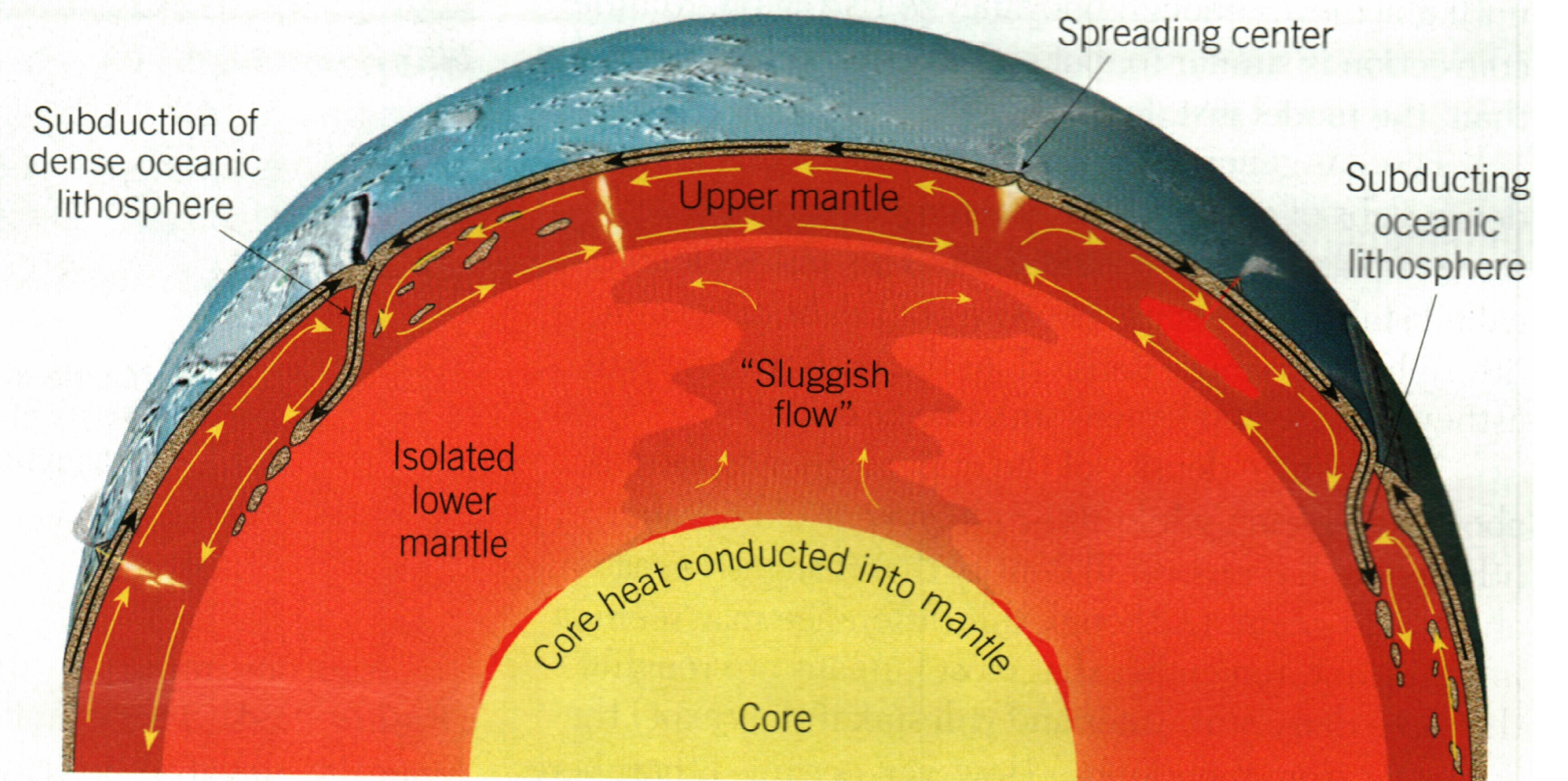
Two Models

FIGURE 2.35 Models of mantle convection

A. In the whole-mantle convection model, cold oceanic lithosphere descends into the lowermost mantle, while two types of hot mantle plumes transport heat toward the surface. **B.** The layer cake model consists of two convection layers—an upper dynamic convective layer overlying a sluggish layer below.



A. In the “whole mantle model”, sinking slabs of cold oceanic lithosphere are the downward limbs of convection cells, while rising mantle plumes carry hot material from the core-mantle boundary toward the surface.



B. The “layer cake model” has two largely disconnected convective layers. A dynamic upper layer driven by descending slabs of cold oceanic lithosphere and a sluggish lower layer that carries heat upward without appreciably mixing with the layer above.

Heat Transport Processes

- Three types of heat transport:
 - Conduction
 - Convection
 - Radiation
- Hazen on heat transport processes:
 - Video 18.1 - from 0:00 to 10:00

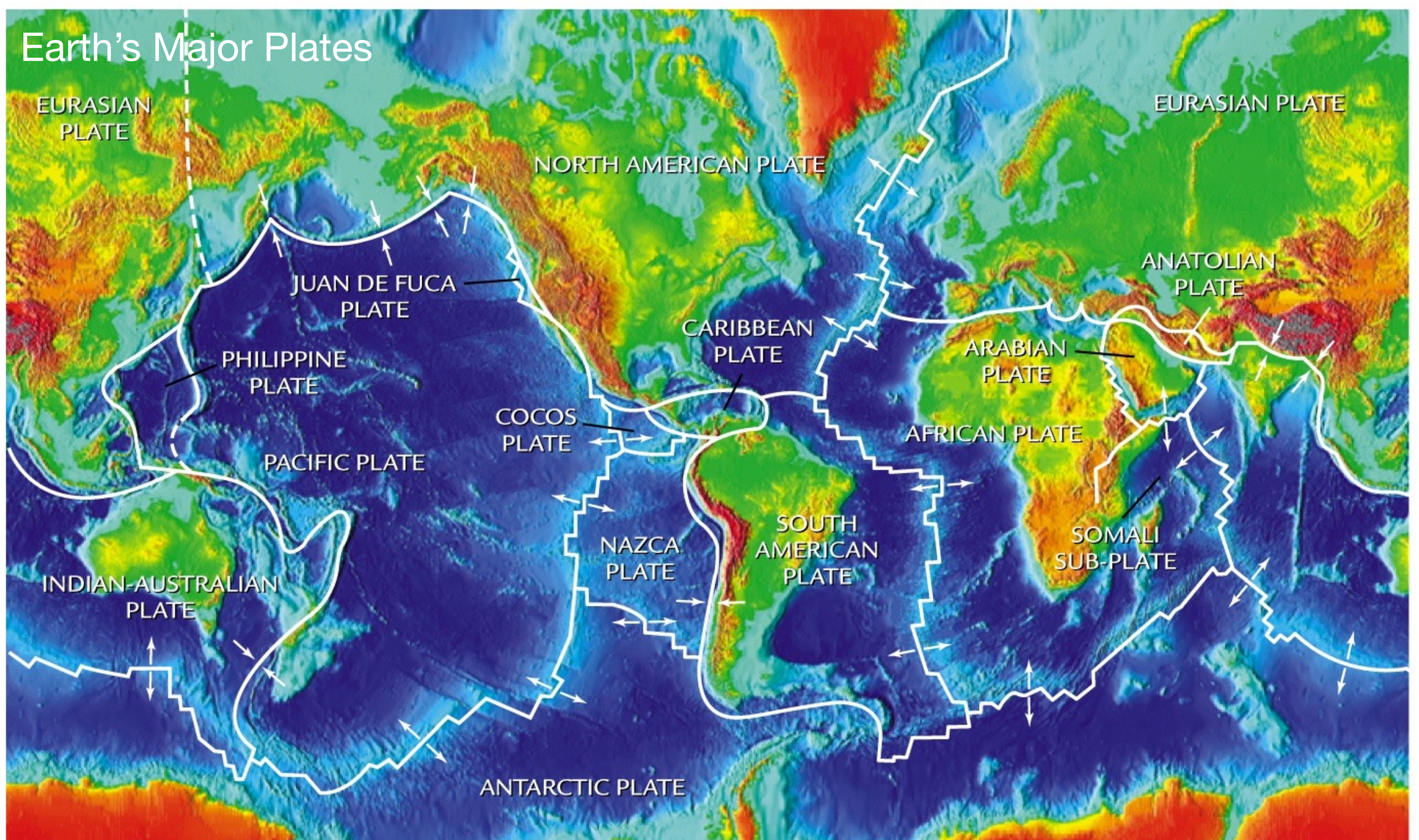
“For the first time, a unifying concept, plate tectonics, could reconcile and unify all phenomena in geoscience into a common synthesis.... The impact of the theory of plate tectonics cannot be overestimated - its importance to geoscience is as basic as Darwin’s theory of evolution is to the biological sciences.”

*Plate Tectonics: Continental Drift
and Mountain Building -
Wolfgang Frisch, Martin
Meschede, and Ronald Blakey*

“Plate tectonics remains the first and only global geodynamic theory which orchestrates all known tectonic phenomena including earthquake zones, mountain building, structural patterns, nature of sedimentary basins, magmatism, and metamorphism - plate tectonics is an elegant and comprehensive synthesis of Earth’s geodynamics.”

*Plate Tectonics: Continental Drift
and Mountain Building - Wolfgang
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Earth's Major Plates



Earth's Major Plates

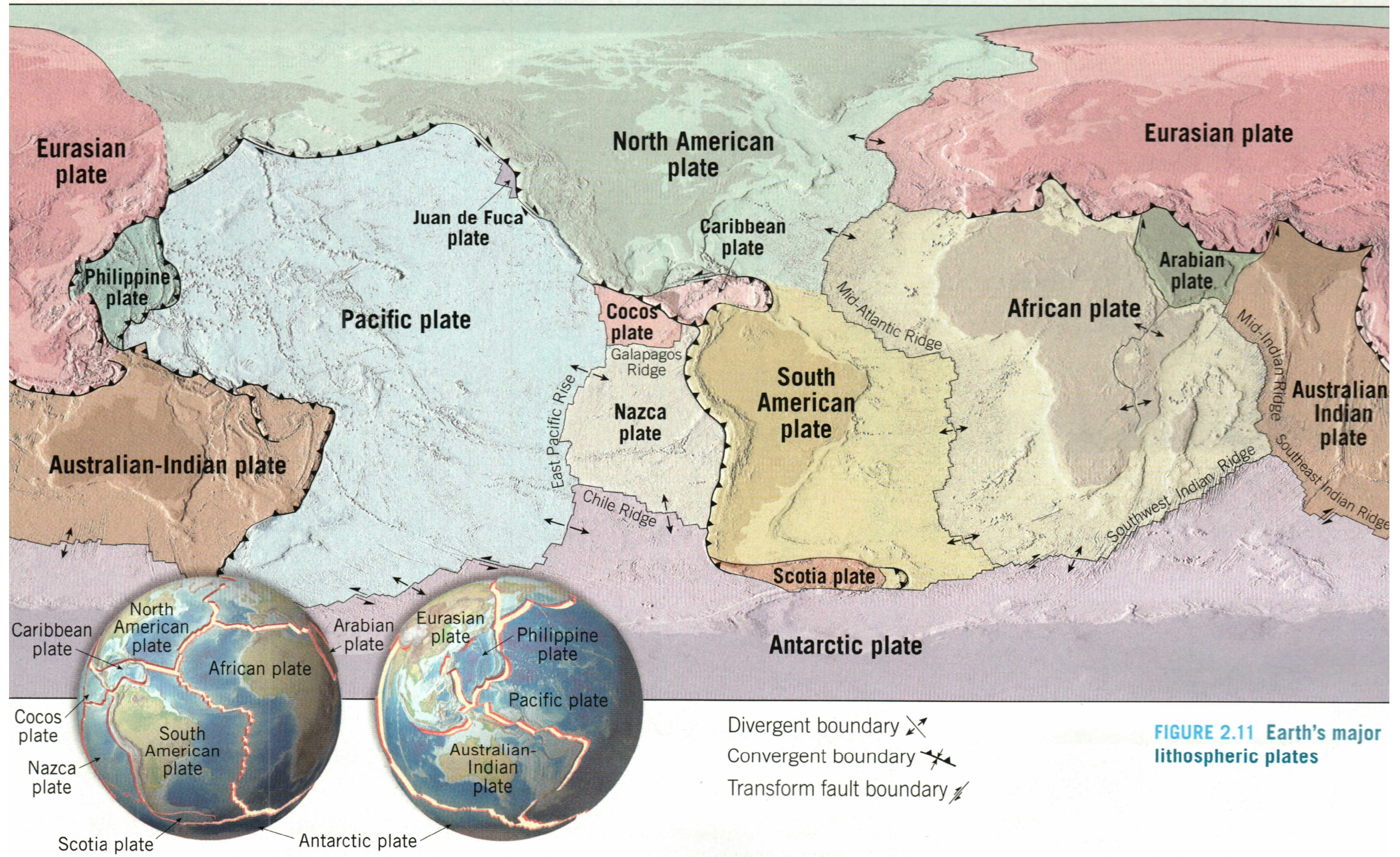


FIGURE 2.11 Earth's major lithospheric plates

North American Plate

Polar Perspective



Earth's Major Plates - Speed and Direction of Movement

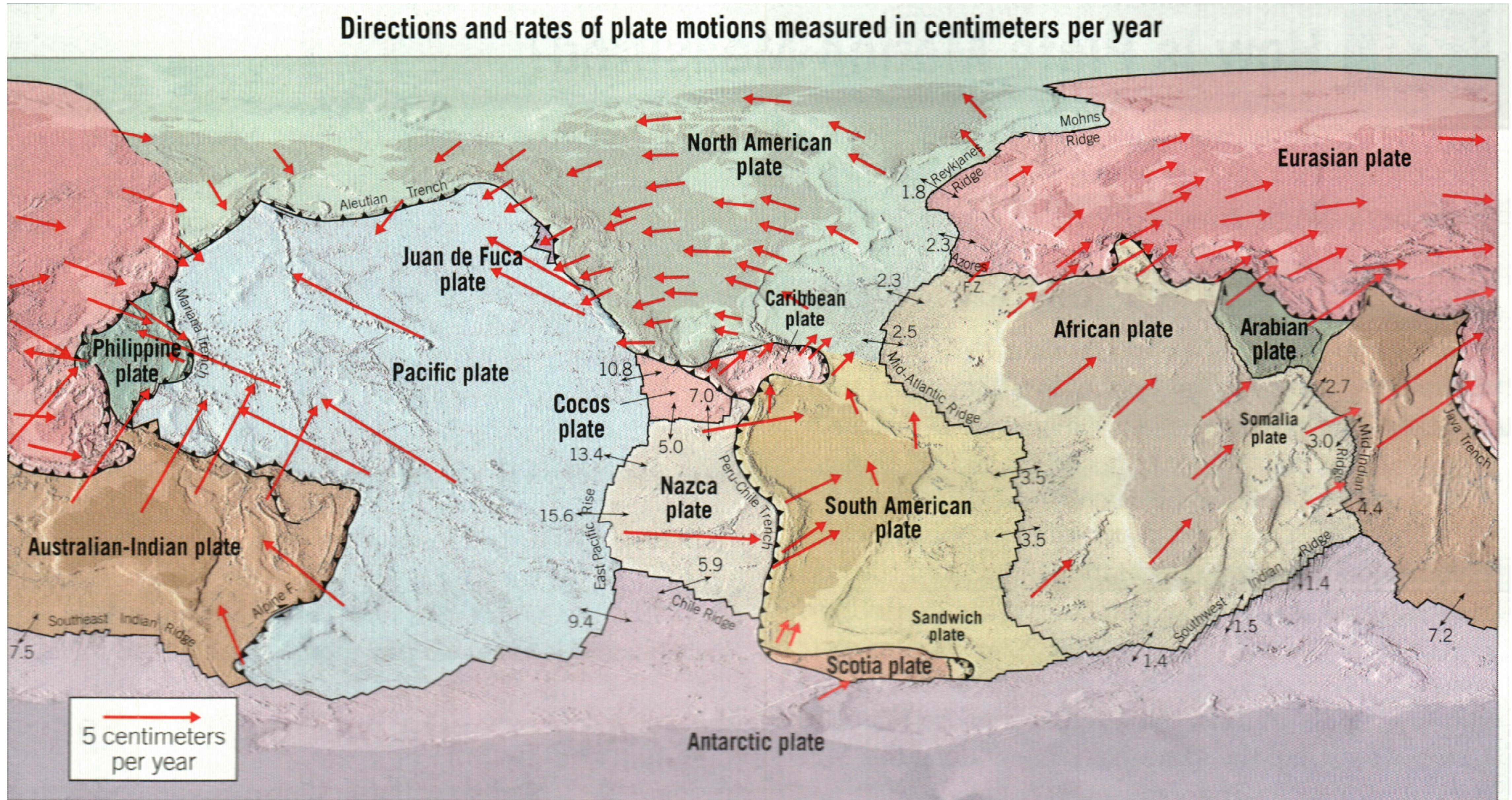


Plate Tectonics and Earthquakes

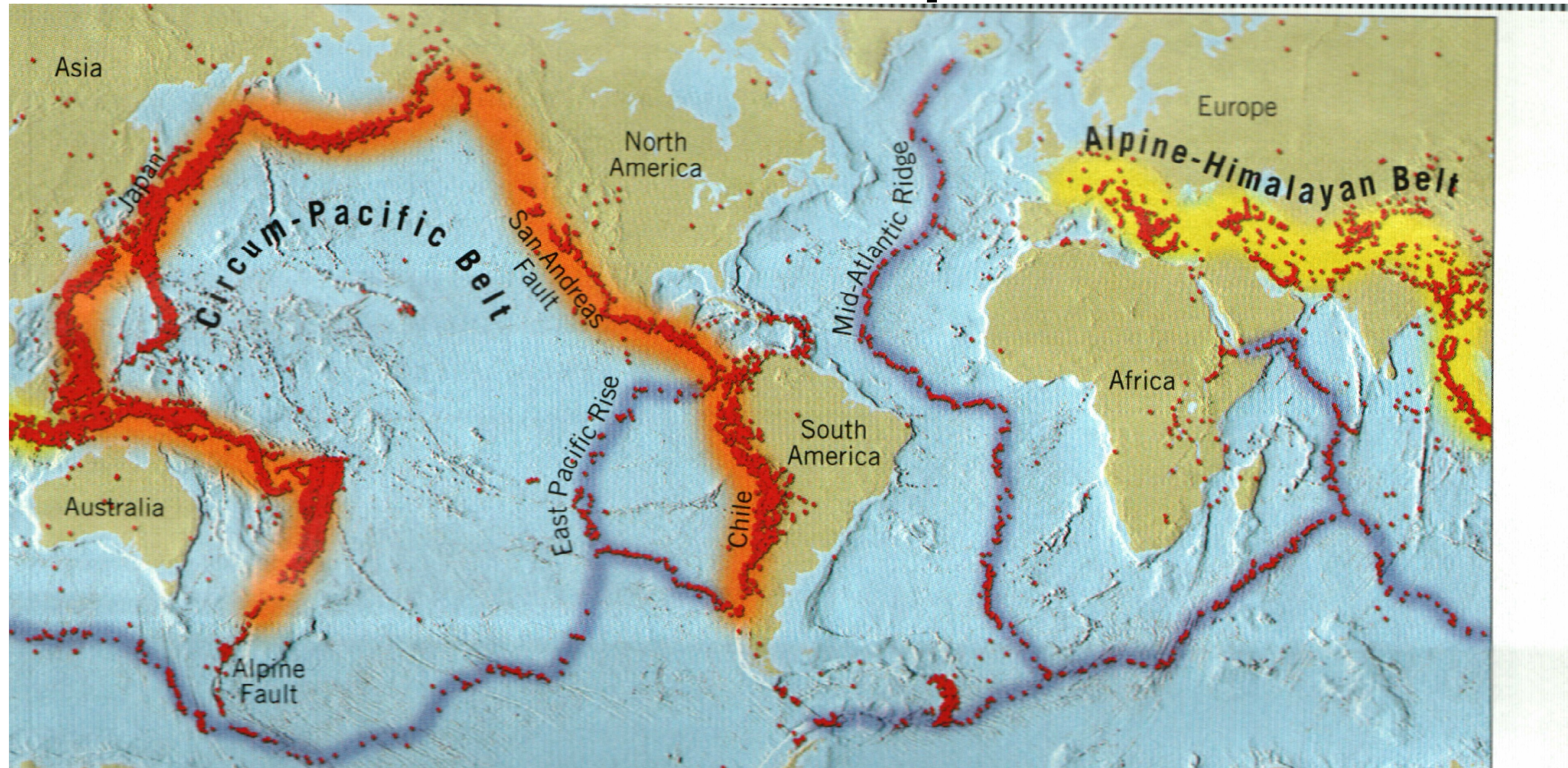


Plate Tectonics and Volcanos



History of the Theory

Pre-20th Century

- With the publication of accurate maps of North and South America in the 16th century, many naturalists noticed the “fit” between these continents and the continents of Africa and Europe. They proposed they were once joined, and subsequently drifted apart (e.g., Francis Bacon).
- Variants of this proposal were offered into the early 20th century, without much success.

History of the Theory

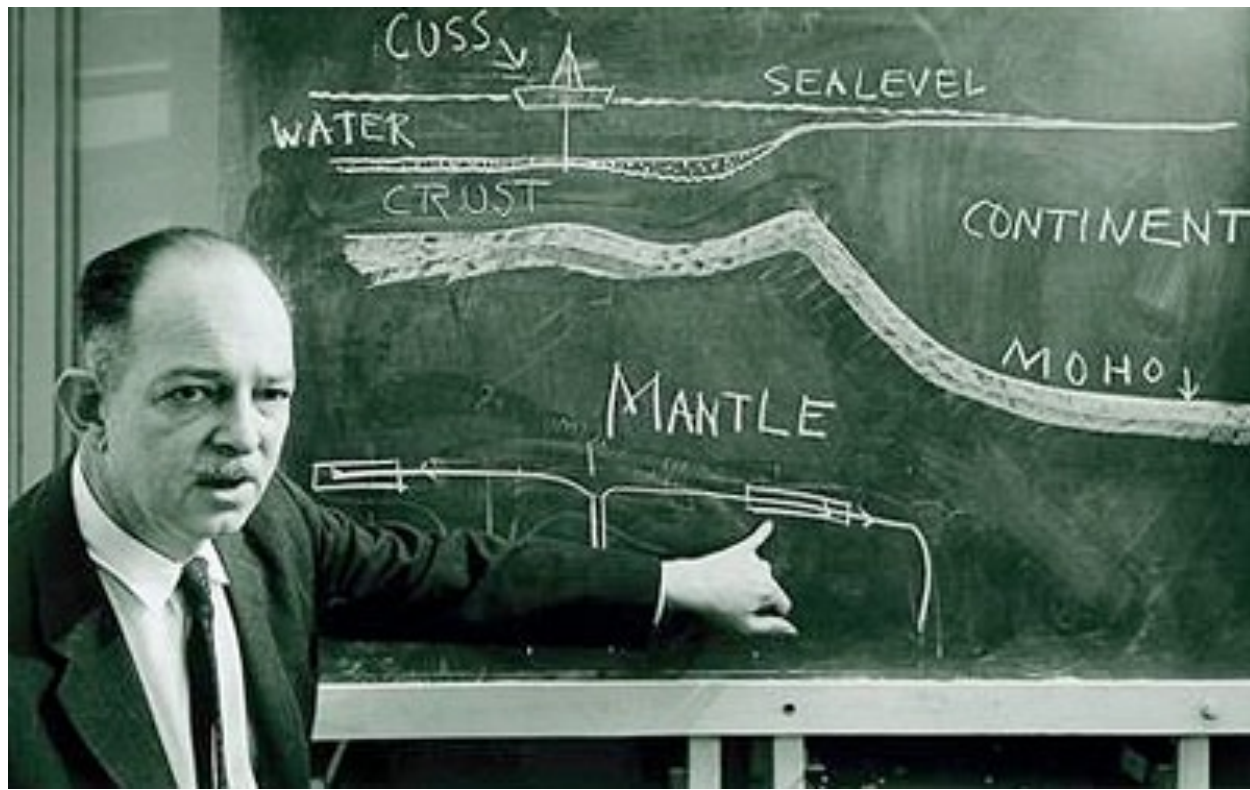
20th Century



- Alfred Wegener (1880-1930) - German Meteorologist and Geophysicist.
- Published “The Origin of Continents and Oceans” (1915)
- Proposed a supercontinent (“Urkontinent”) consisting of all landmasses - Pangaea.
- Continental Drift Hypothesis - Pangaea broke apart and current continents “drifted” to their current locations.
- Theory not accepted; ridiculed - no credible mechanism for continental drift.
- Wegener perished while on a research trip to Greenland to study the ice cap and climate.

History of the Theory

20th Century



- Harry Hess (1906-1969) - American Geologist; Professor of Geology, Chair of Geology Department, Princeton Univ.
- During WWII, he was Captain of an attack transport ship in the Pacific equipped with sonar. Rose to the rank of Rear Admiral in the Naval Reserve.
- While criss-crossing the Pacific, mapped underwater volcanos.
- In 1960, first proposed that the Earth's crust moved laterally away from volcanically active mid-ocean ridges.



History of the Theory

20th Century

- During the Cold War, naval submarine warfare planning led to extensive mapping of the seafloor.
- New and improved instruments, such as magnetometers, seismometers and advanced sonar, developed for the military, provided powerful new tools to geologists and oceanographers.
- Evidence grew overwhelming for sea floor spreading.
- After initial resistance, acceptance of the theory of plate tectonics accelerated among geologists.

Evidence for Plate Tectonics

Continental Fit



Evidence for Plate Tectonics

Fossil Distribution

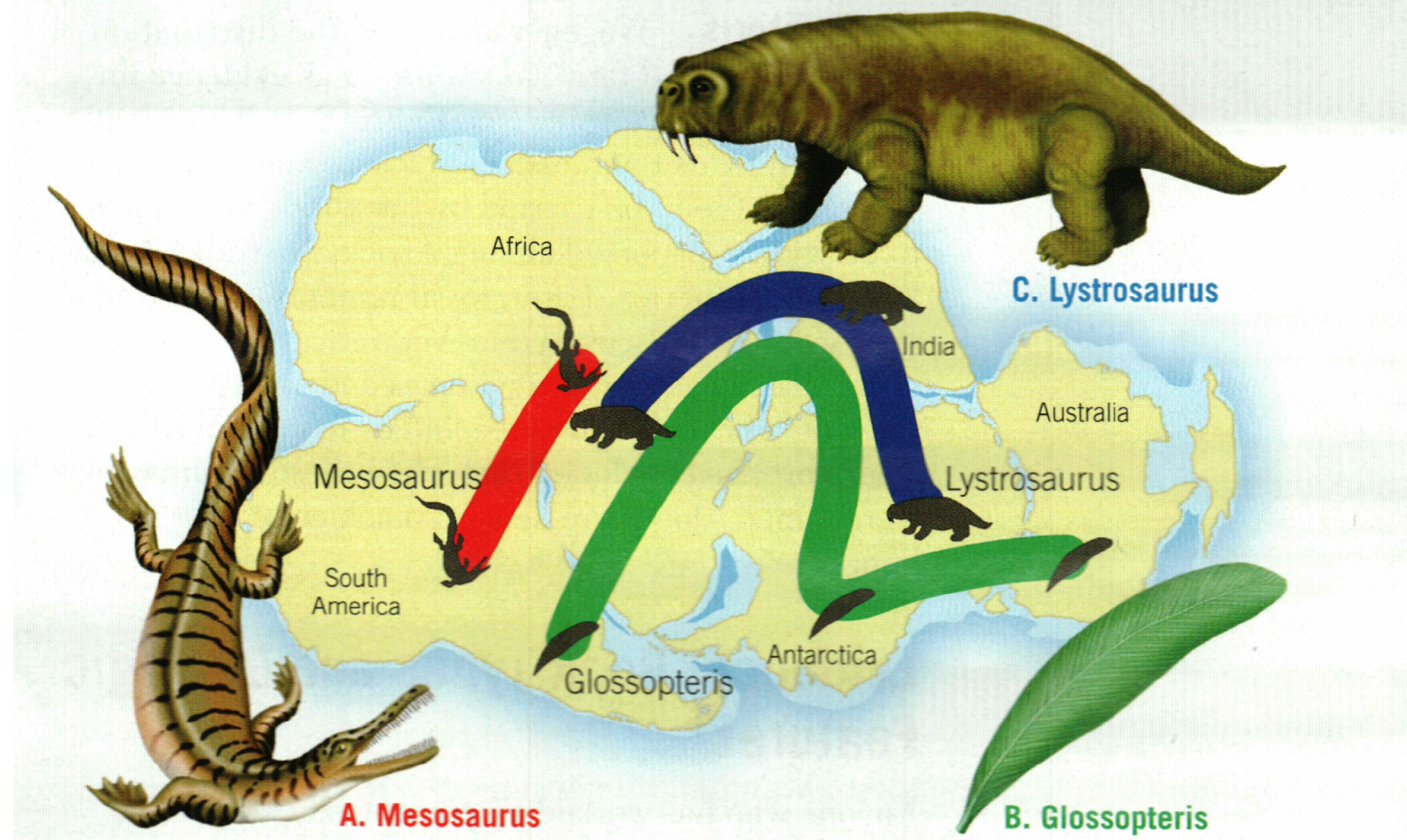


FIGURE 2.4 Fossil evidence supporting continental drift

Fossils of identical organisms have been discovered in rocks of similar age in Australia, Africa, South America, Antarctica, and India—continents that are currently widely separated by ocean barriers. Wegener accounted for these occurrences by placing these continents in their pre-drift locations.

Examples of Fossils

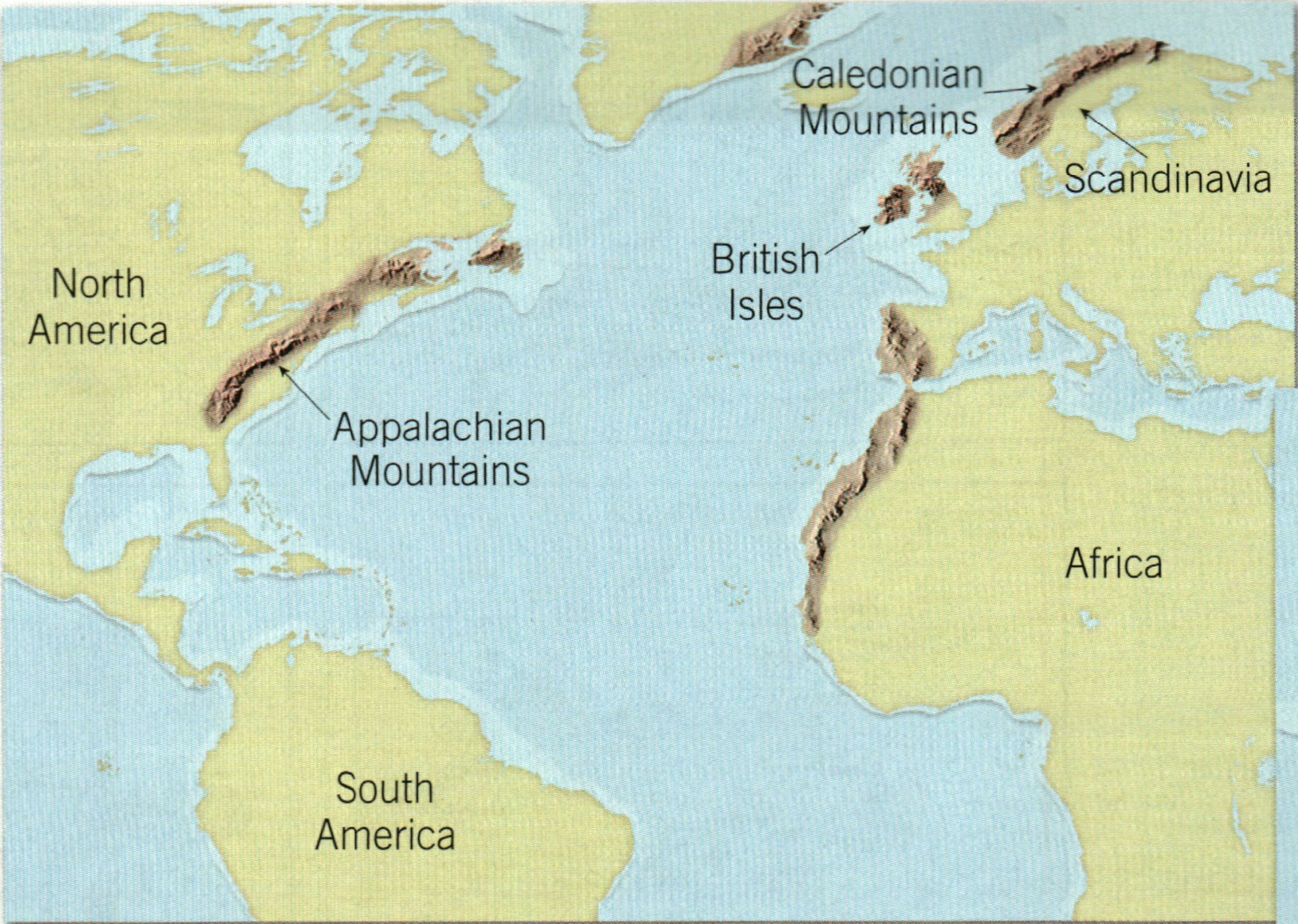


Glossopteris



Mesosaurus

FIGURE 2.6 Matching mountain ranges across the North Atlantic



A.



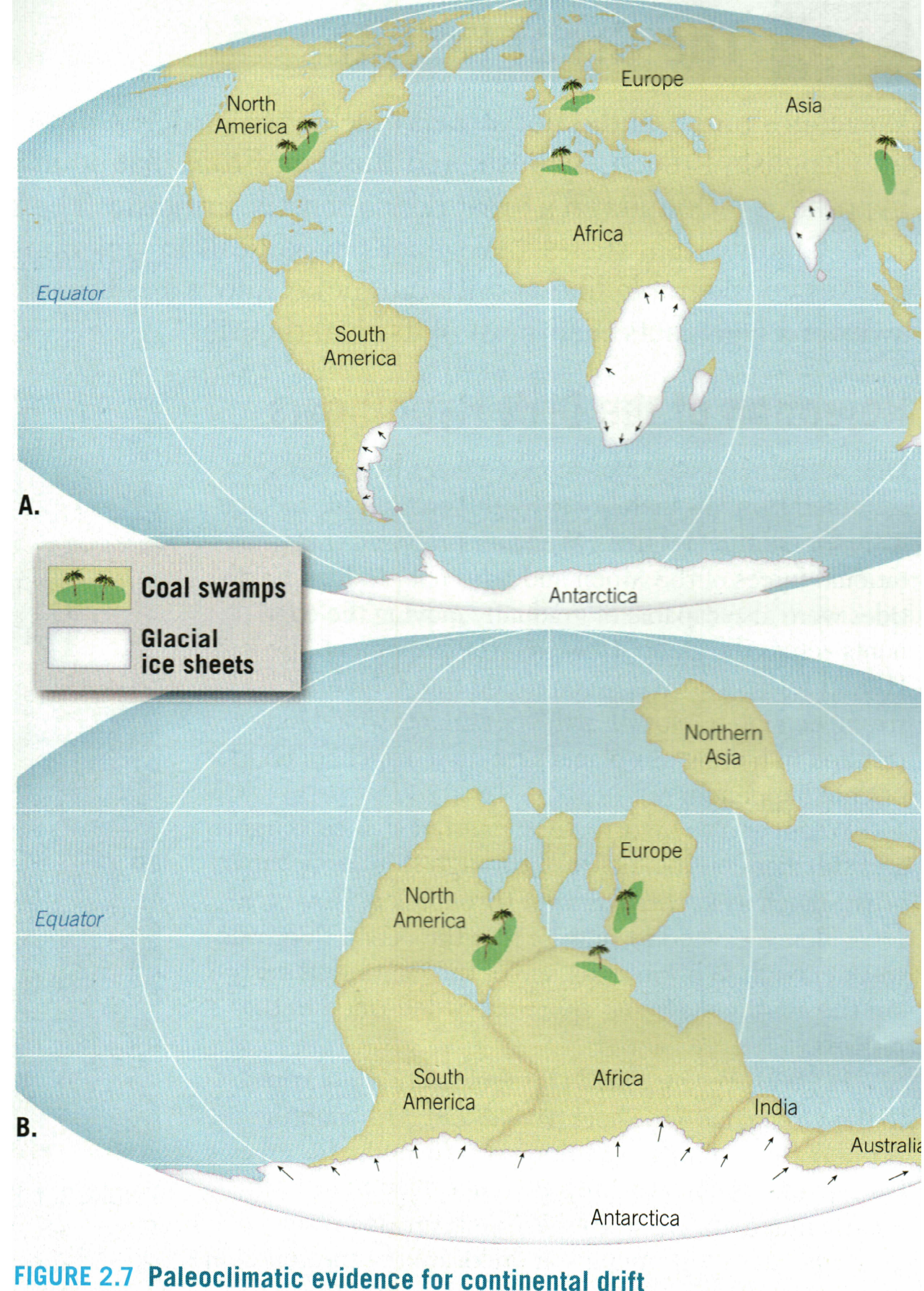
B.

Evidence for Plate Tectonics

Mountain Ranges

Evidence for Plate Tectonics

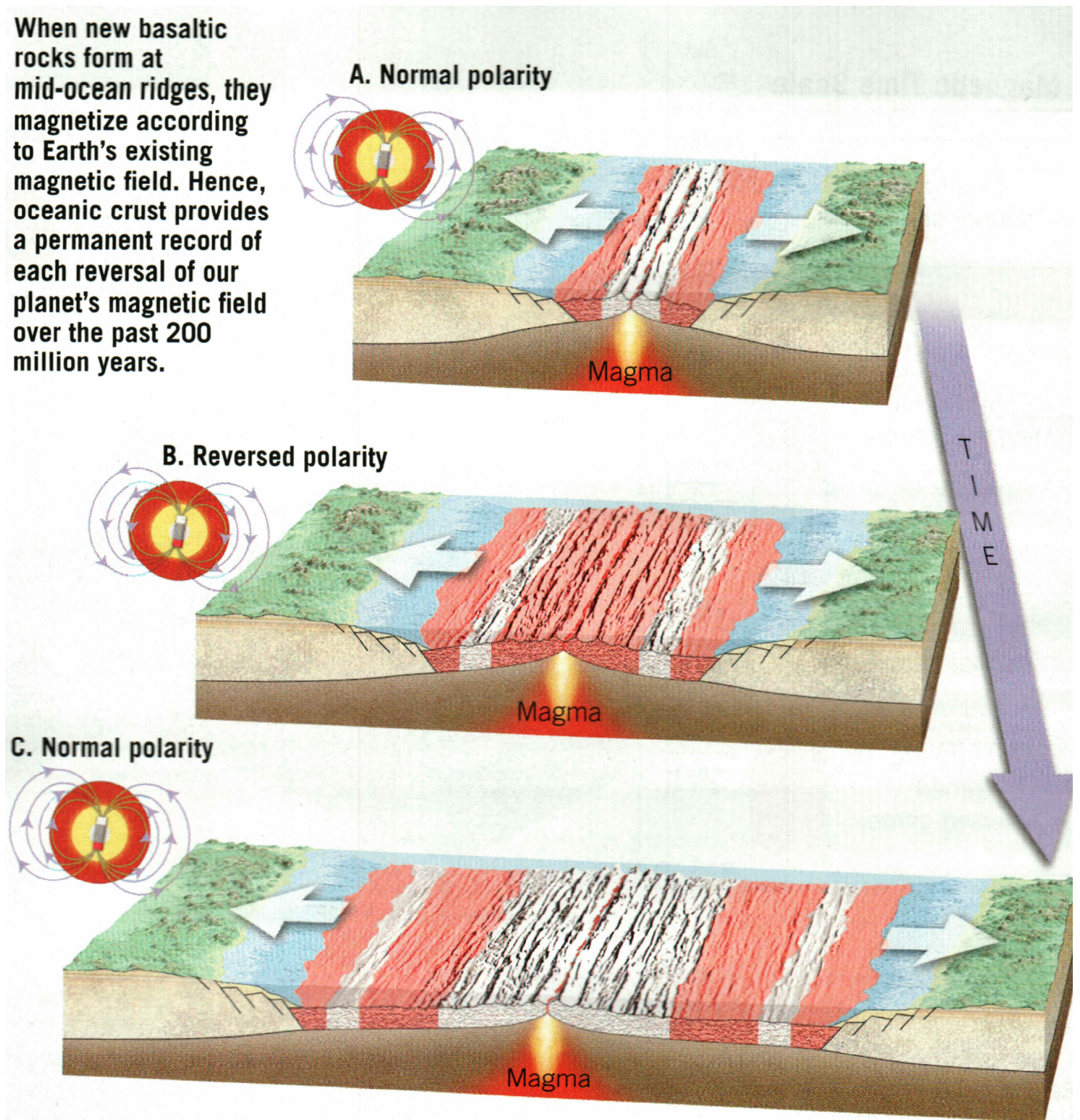
Paleoclimate



Evidence for Plate Tectonics

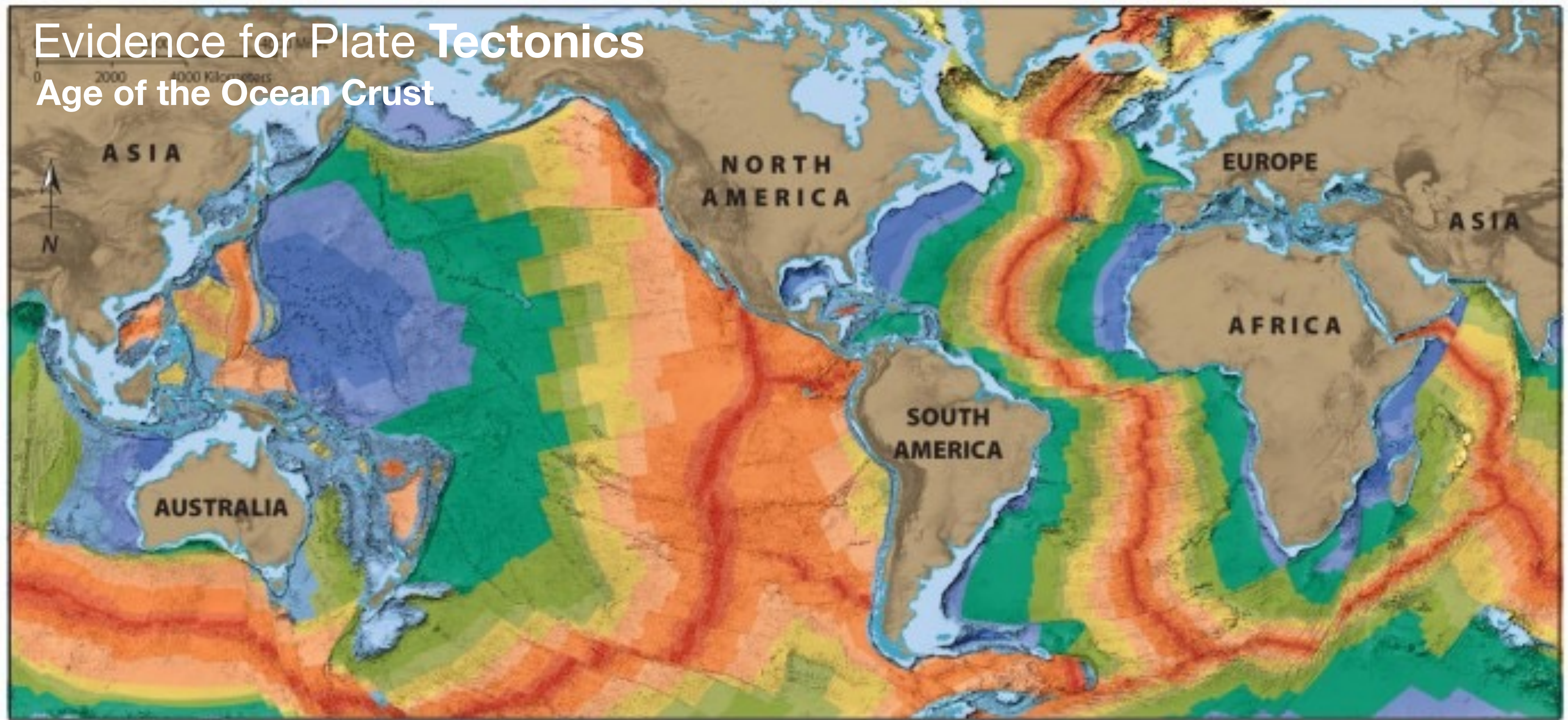
Paleomagnetism

When new basaltic rocks form at mid-ocean ridges, they magnetize according to Earth's existing magnetic field. Hence, oceanic crust provides a permanent record of each reversal of our planet's magnetic field over the past 200 million years.



Evidence for Plate Tectonics

Age of the Ocean Crust



Age of Ocean Floor



Up Next

- Plate boundaries - most geologically important actions take place at plate boundaries.
- Rocks and the rock cycle.
- Formation of the oceans.