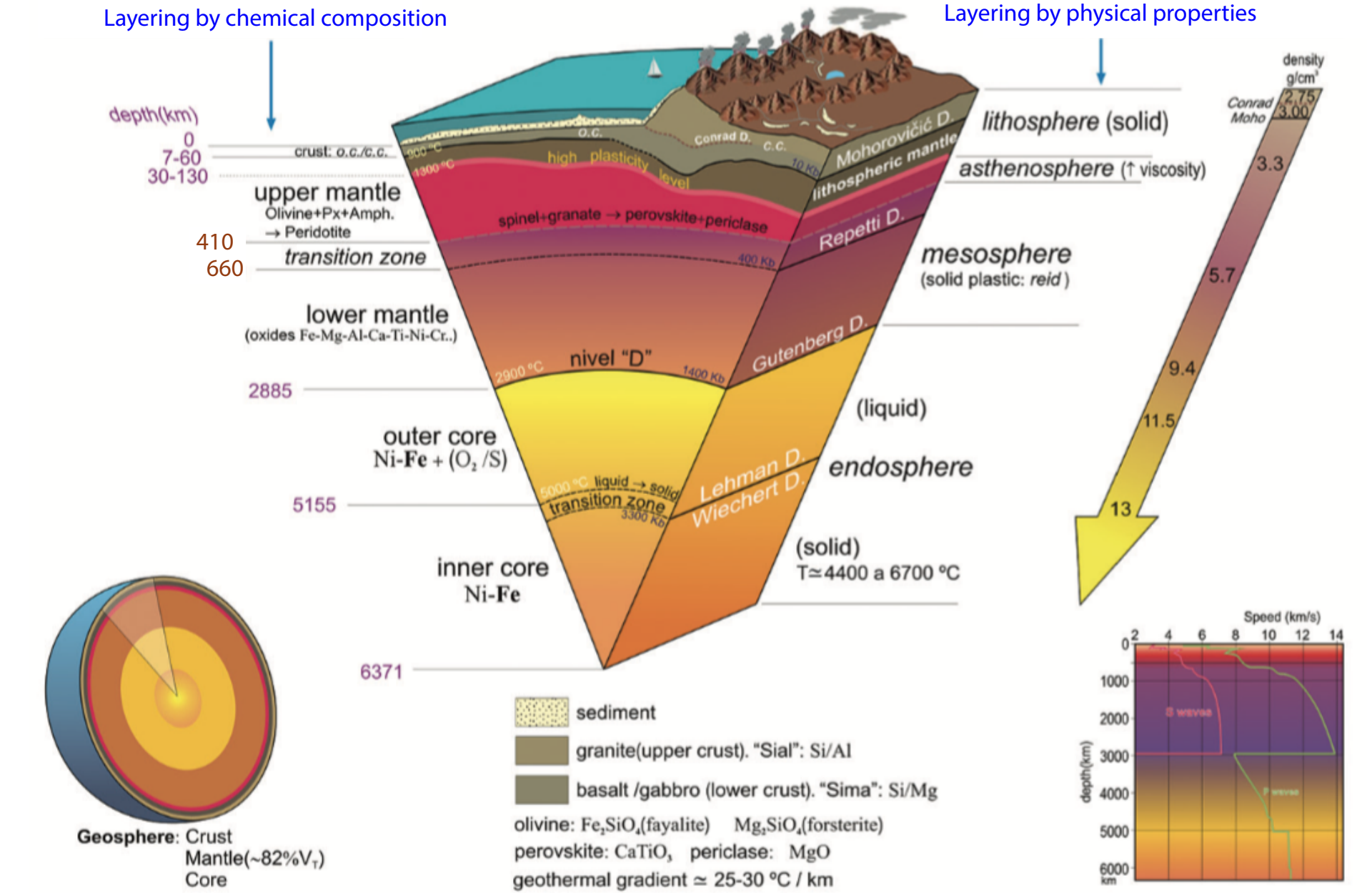
FUNDAMENTALS OF EARTH SCIENCES (ESO 213A)

DIBAKAR GHOSAL
DEPARTMENT OF EARTH SCIENCES

Topic: Plate tectonics

Previous Class: Earth's Internal Structure

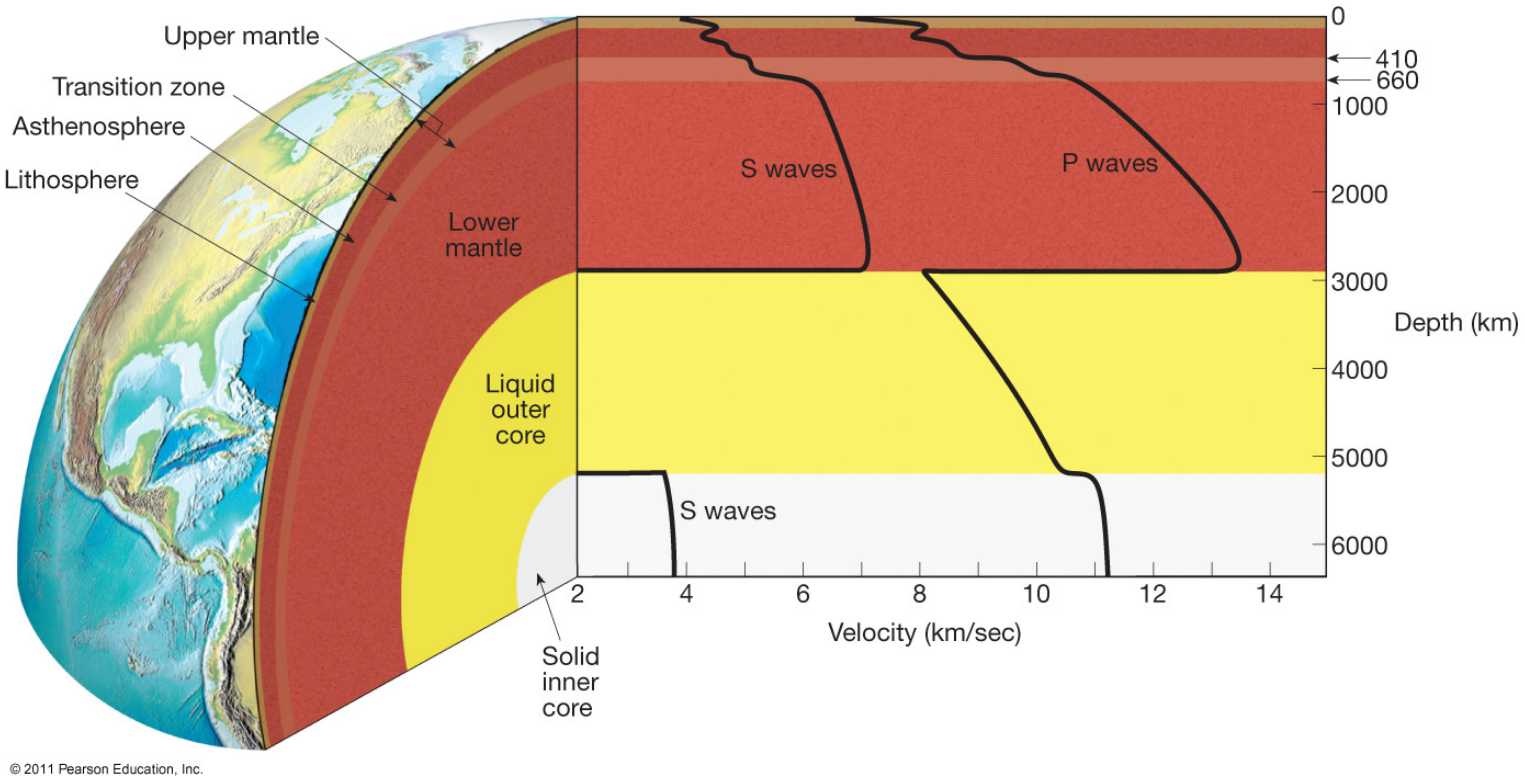
Last Class: Review

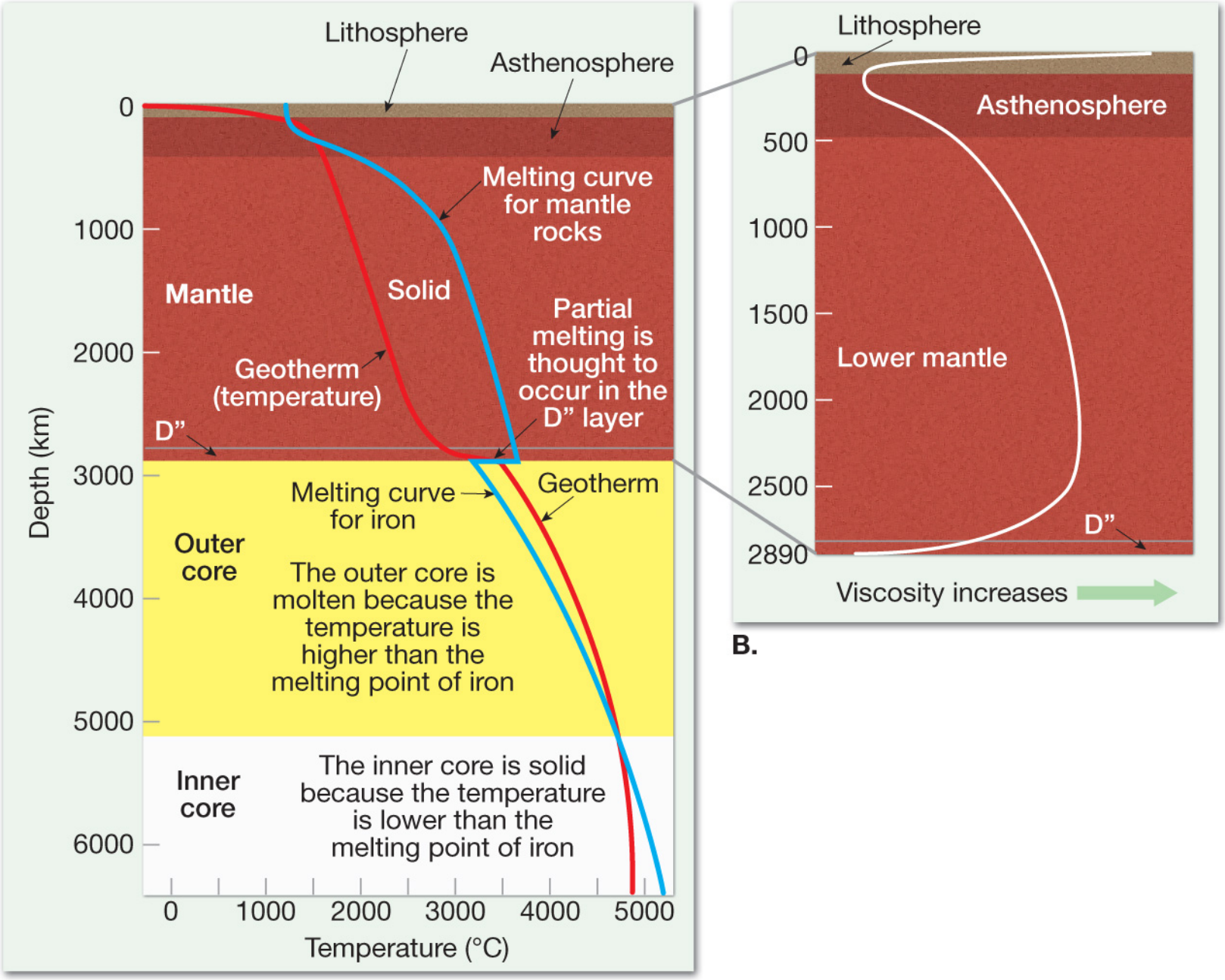


modified after Gervilla et al., 2019

Seismic Waves and Earth's Structure

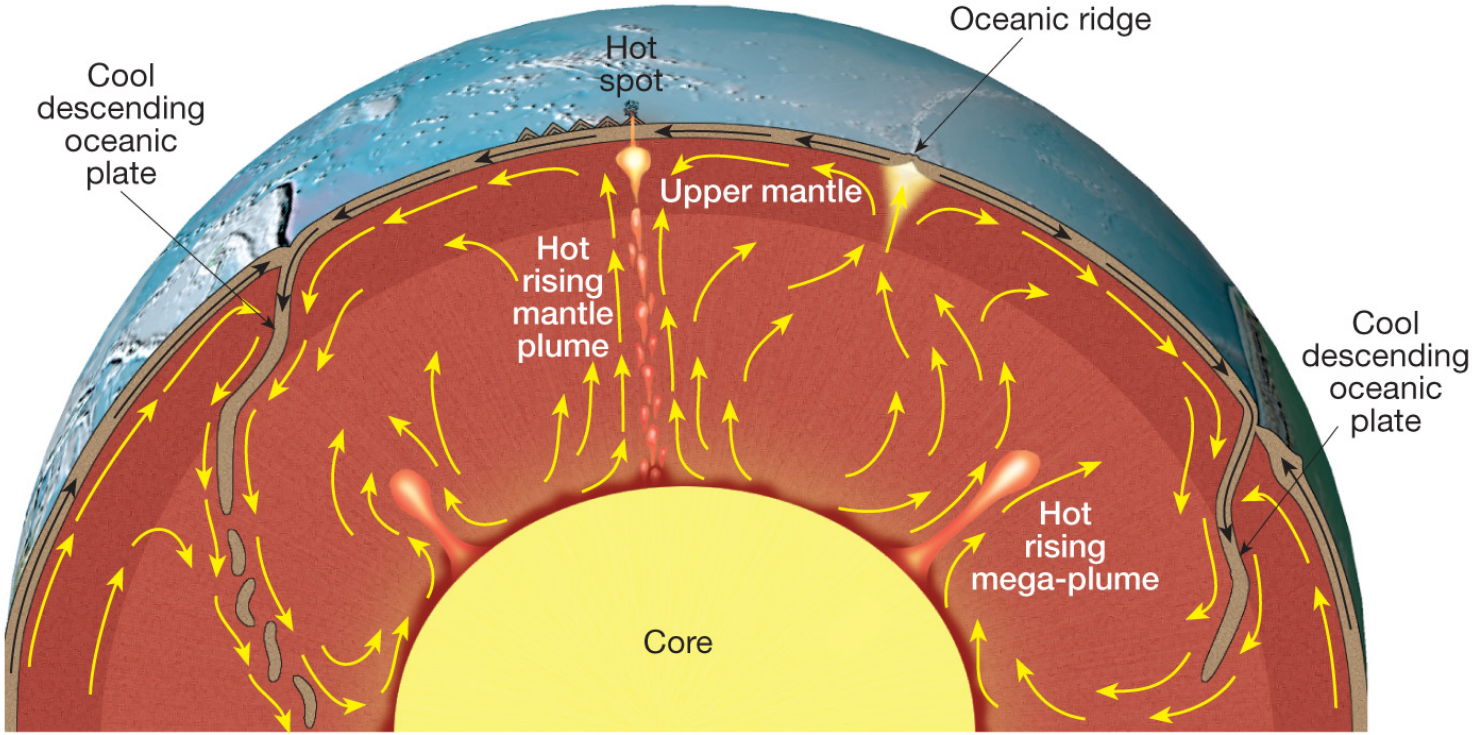
- Abrupt changes in seismic-wave velocities that occur at particular depths helped seismologists conclude that Earth must be composed of distinct shells.



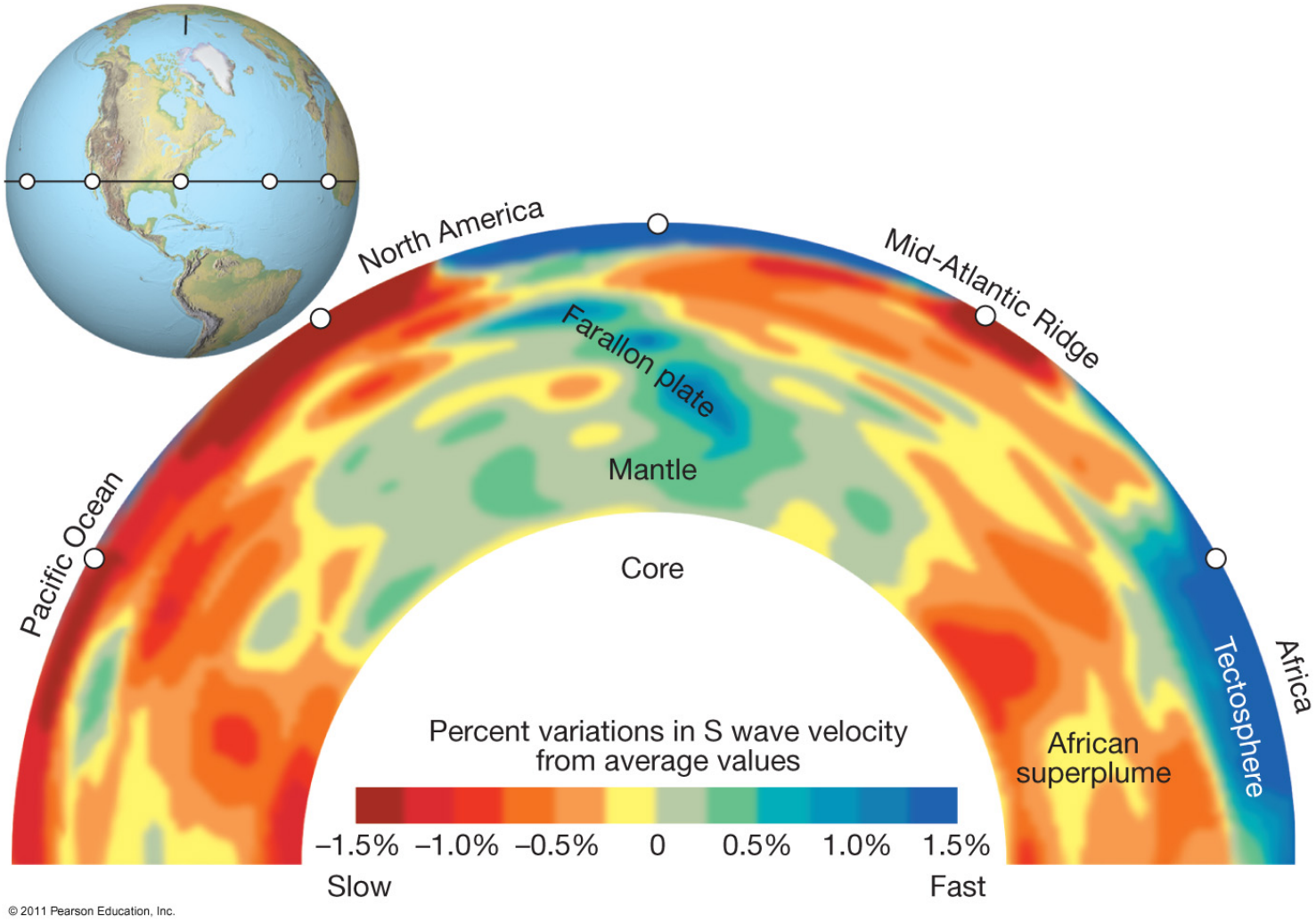


Earth's Internal Heat Engine

- Mantle convection
  - Important process in Earth's interior
  - Provides the force that propels the rigid lithospheric plates across the globe.



Seismic Tomographic Slice Through the Earth



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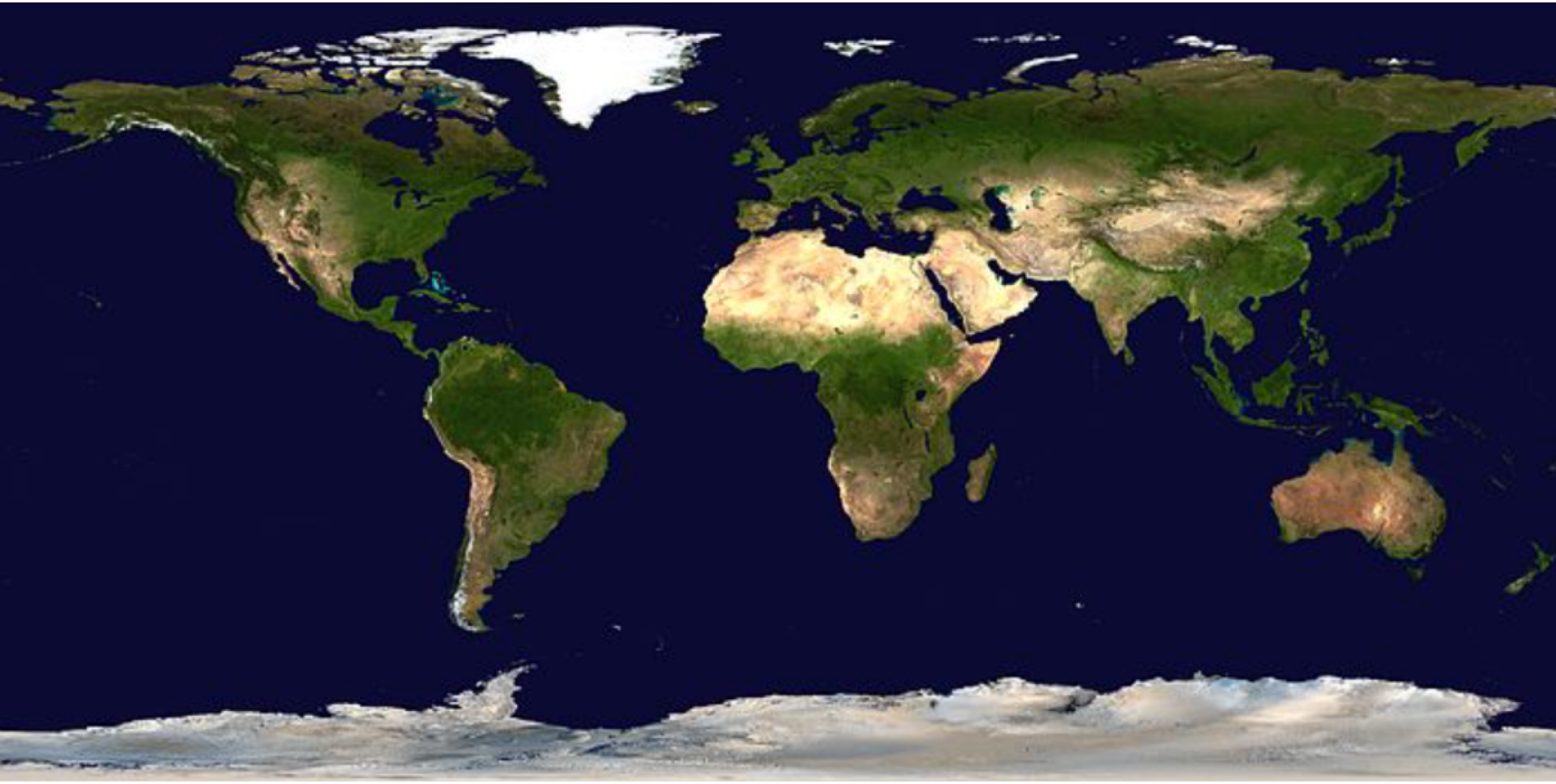
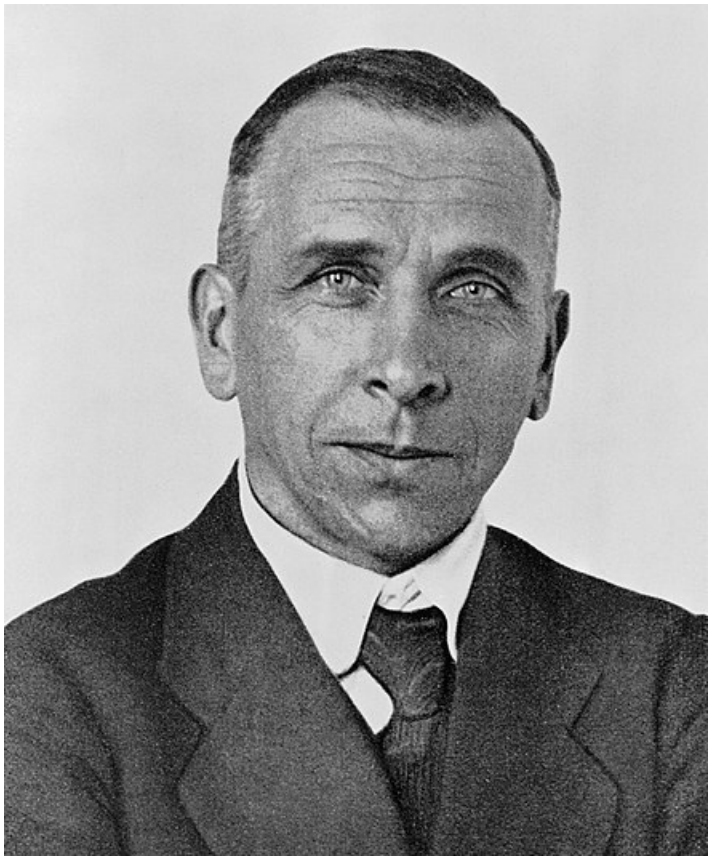
Present day Earth Surface



Continental Drift: An Idea Before Its Time

- **Continental drift hypothesis**
  - **Continents "drifted" to present positions**
- **Evidence used in support of continental drift hypothesis:**
  - **Fit of the continents**
  - **Fossil evidence**
  - **Rock type and structural similarities**
  - **Paleoclimatic evidence**

Alfred Wegner



originator of continental drift hypothesis in 1912

Matching Mountain Ranges Fit of the continents

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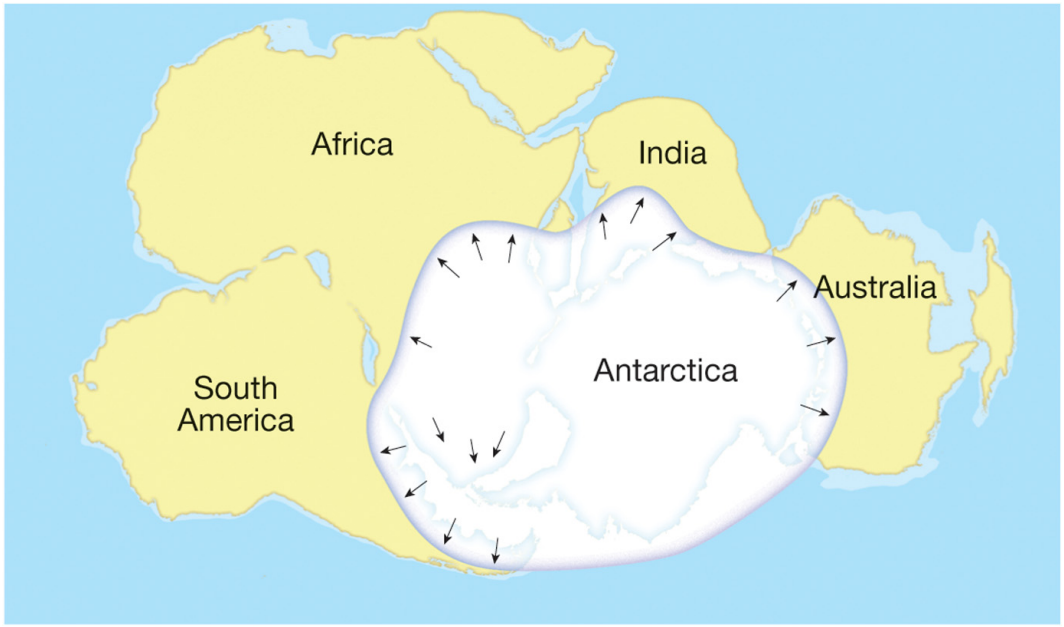
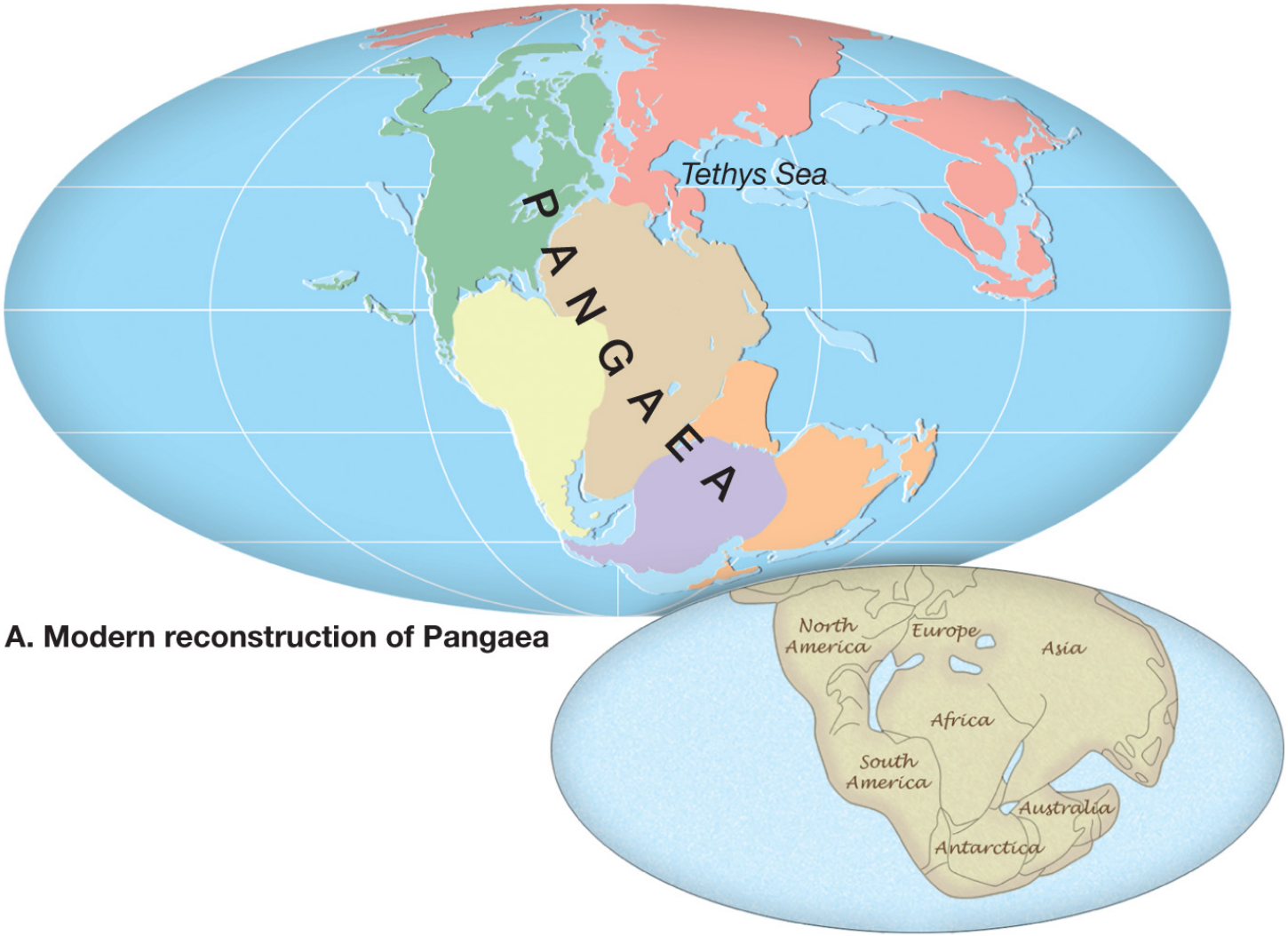
B.



C.

Pangaea Approximately 200 Million Years Ago



A. Modern reconstruction of Pangaea

B. Wegener's Pangaea

The Great Debate

- **Objections to the continental drift hypothesis:**
  - **Lack of a mechanism for moving continents**
  - **Wegener incorrectly suggested that continents broke through the ocean crust.**
  - **Strong opposition to the hypothesis from all areas of the scientific community**

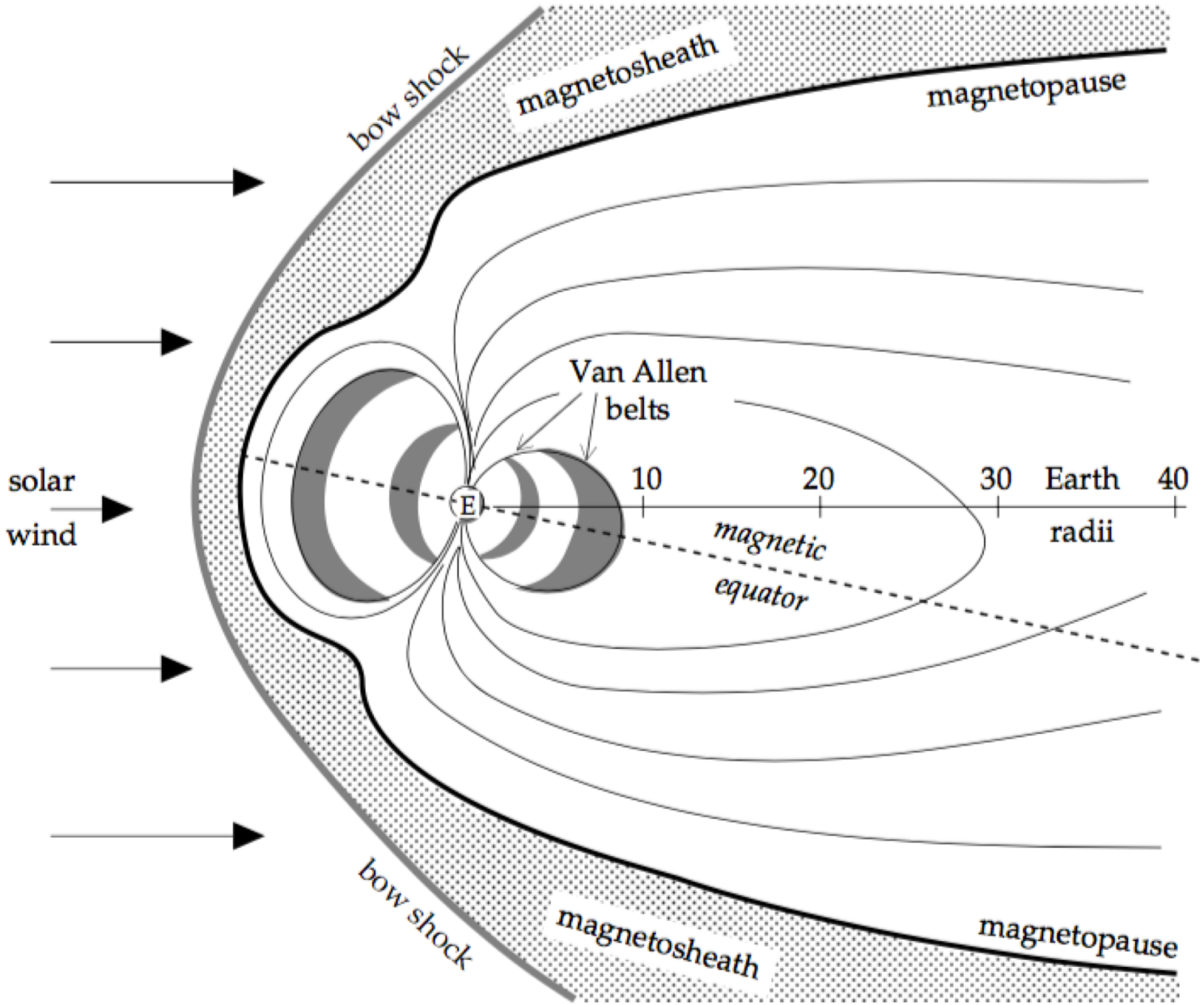
The Great Debate

- **Continental drift and the scientific method**
  - **Wegener's hypothesis was correct in principle, but contained incorrect details.**
  - **A few scientists considered Wegener's ideas plausible and continued the search.**

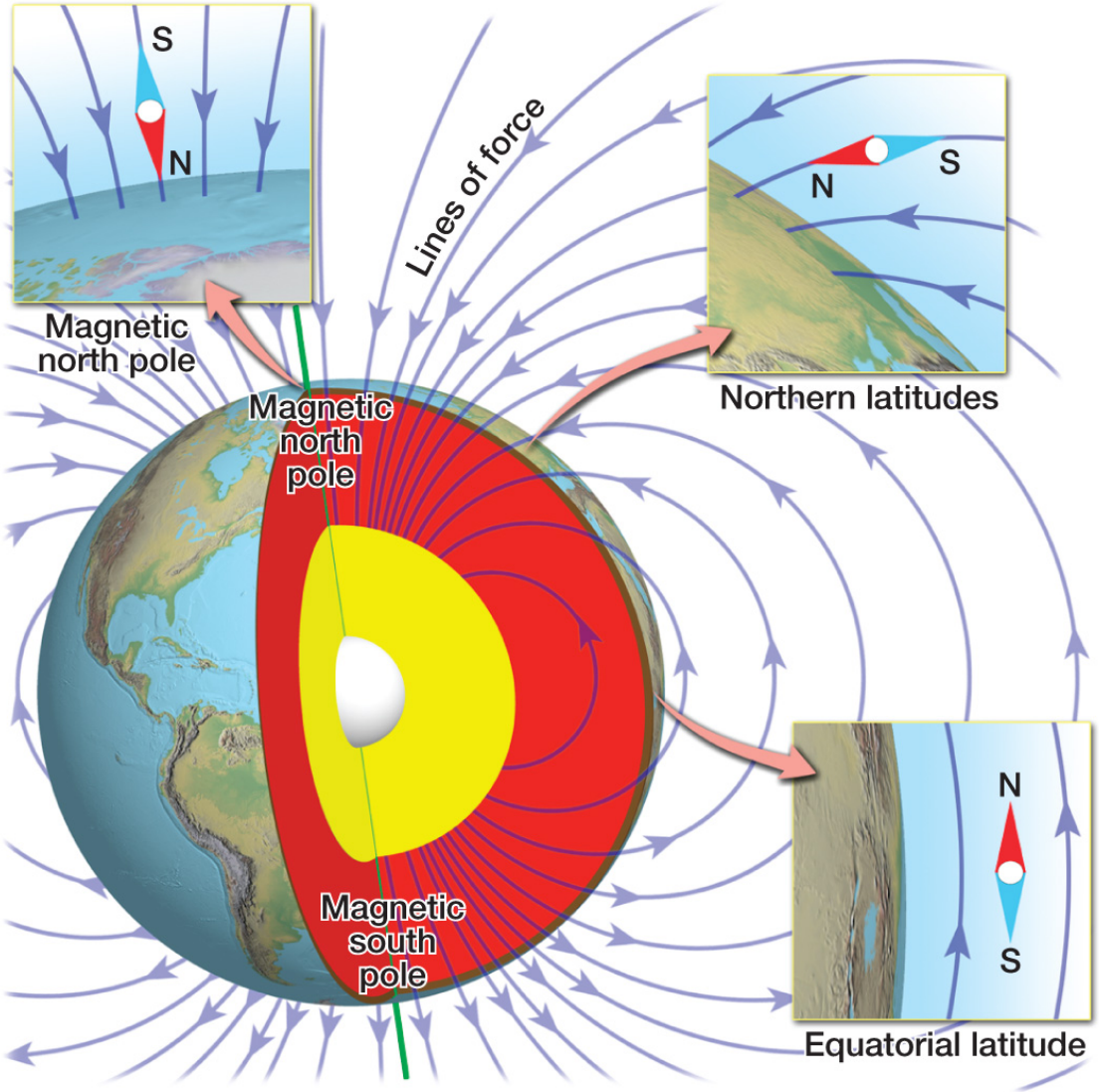
Continental Drift and Paleomagnetism

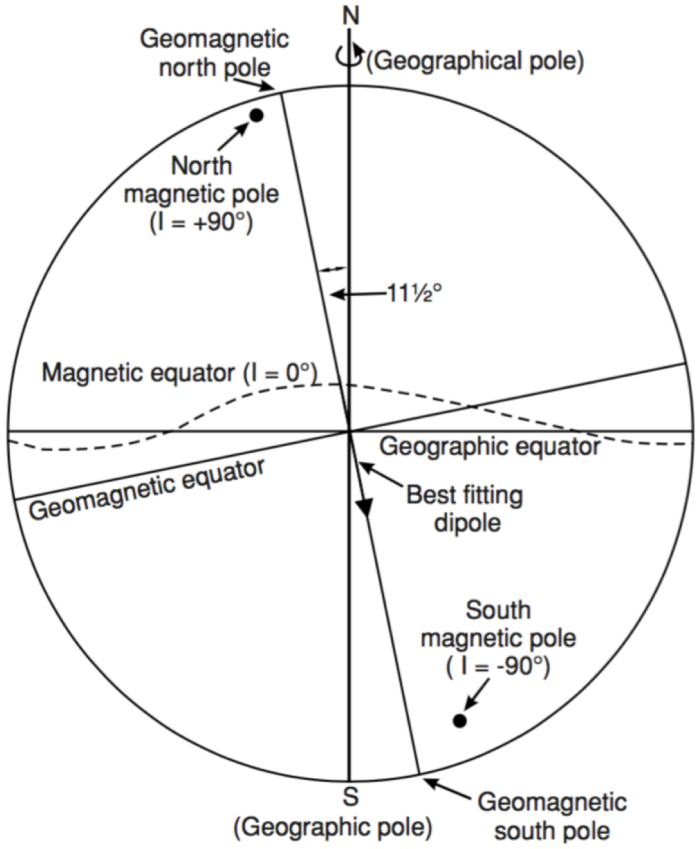
- **A renewed interest in continental drift initially came from rock magnetism.**
- **Magnetized minerals in rocks:**
  - **Show the direction to Earth's magnetic poles**
  - **Provide a means of determining their latitude of origin**

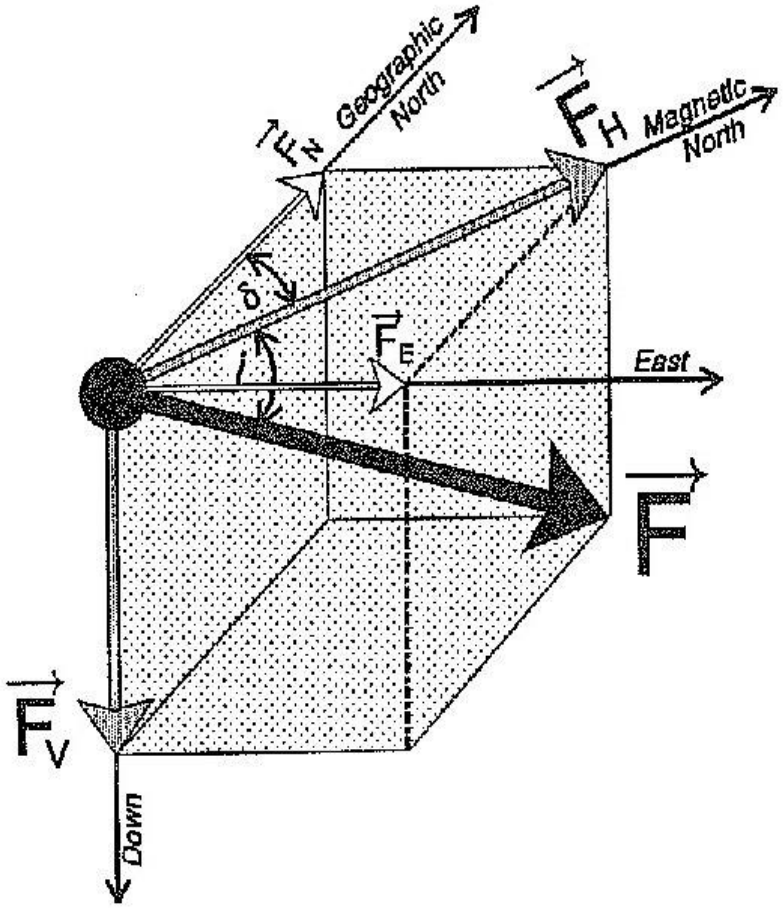
Earth's Magnetic Field

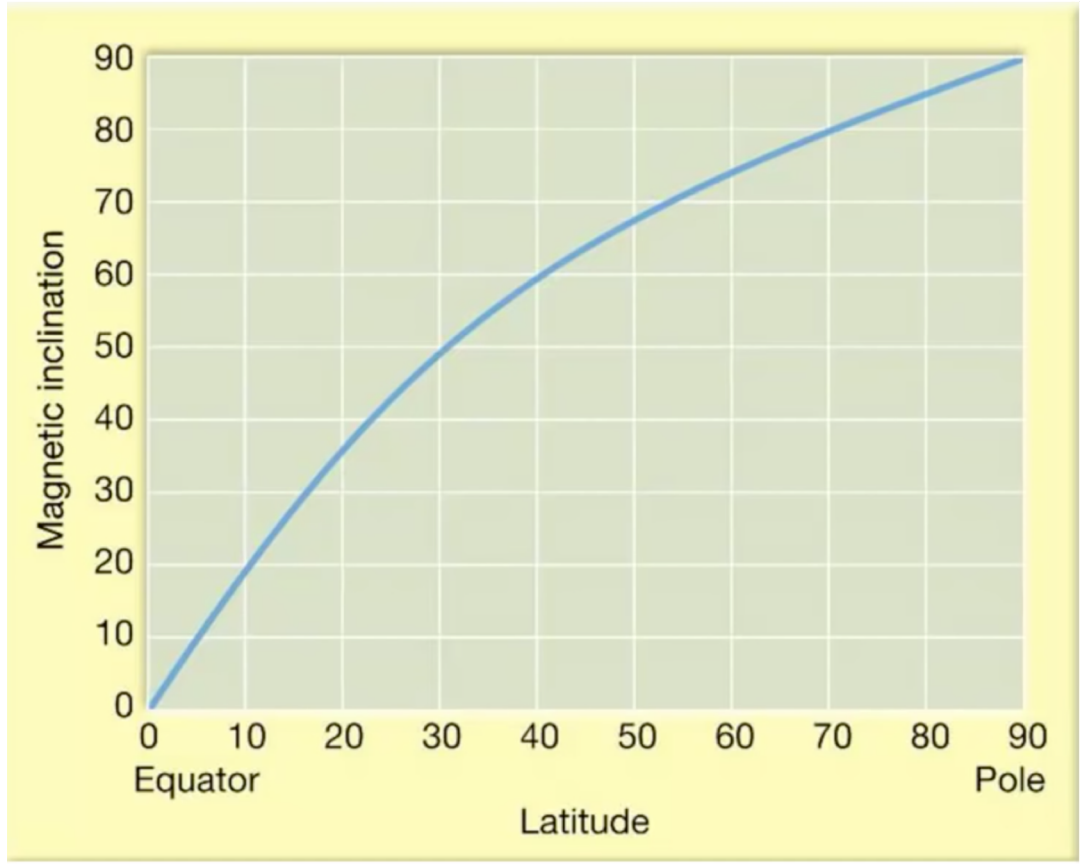


Earth's Magnetic Field









declination : angle of horizontal field with true north

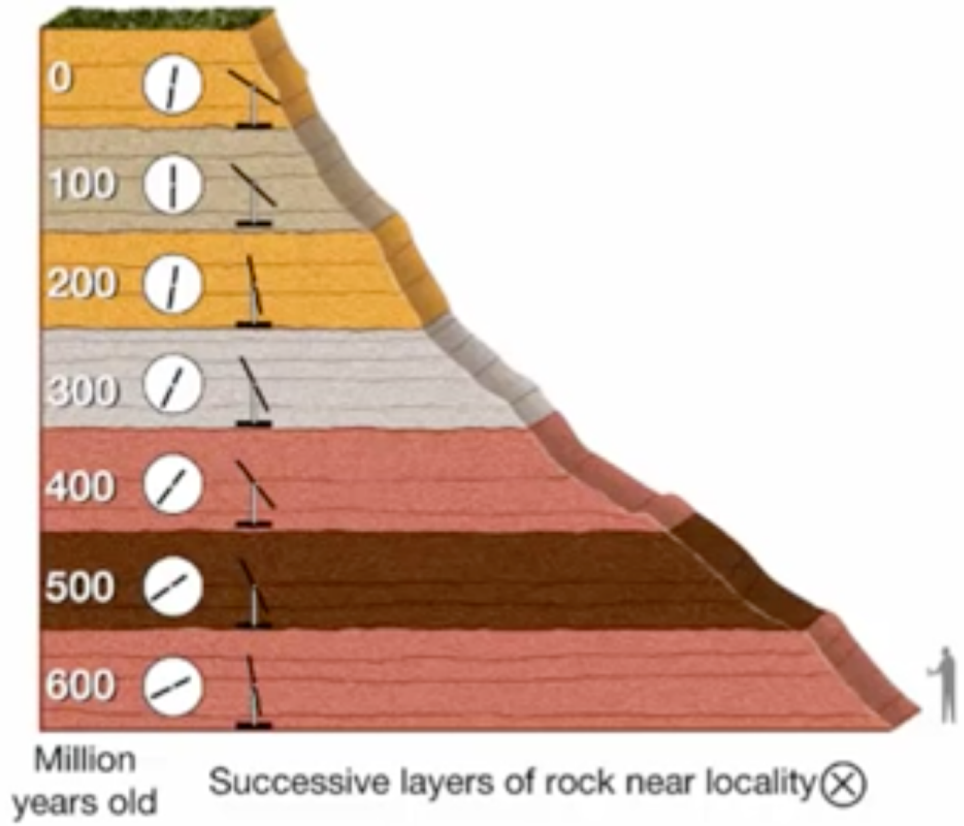
inclination : angle of total magnetic field with horizontal

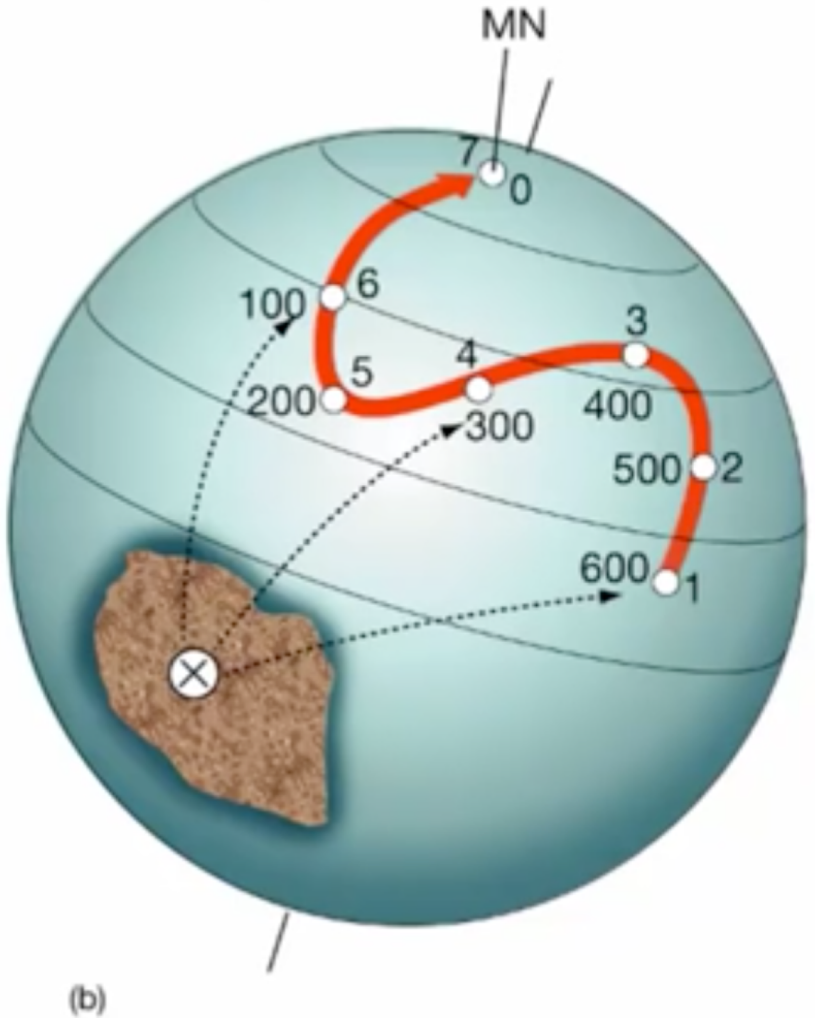
Magnetized minerals in rocks:

Show the direction to Earth's magnetic poles

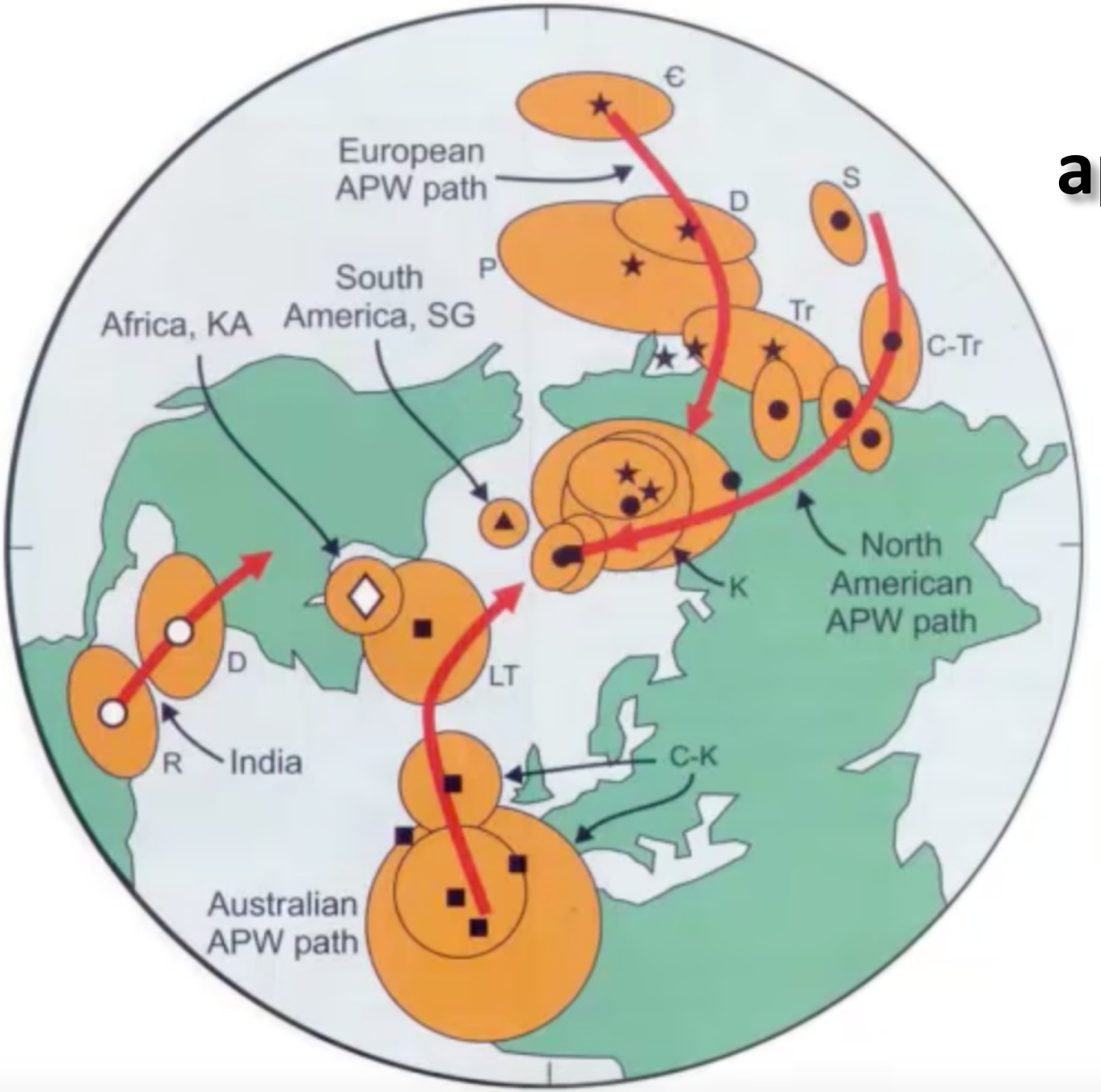
Provide a means of determining their latitude of origin

Apparent Polar wandering path

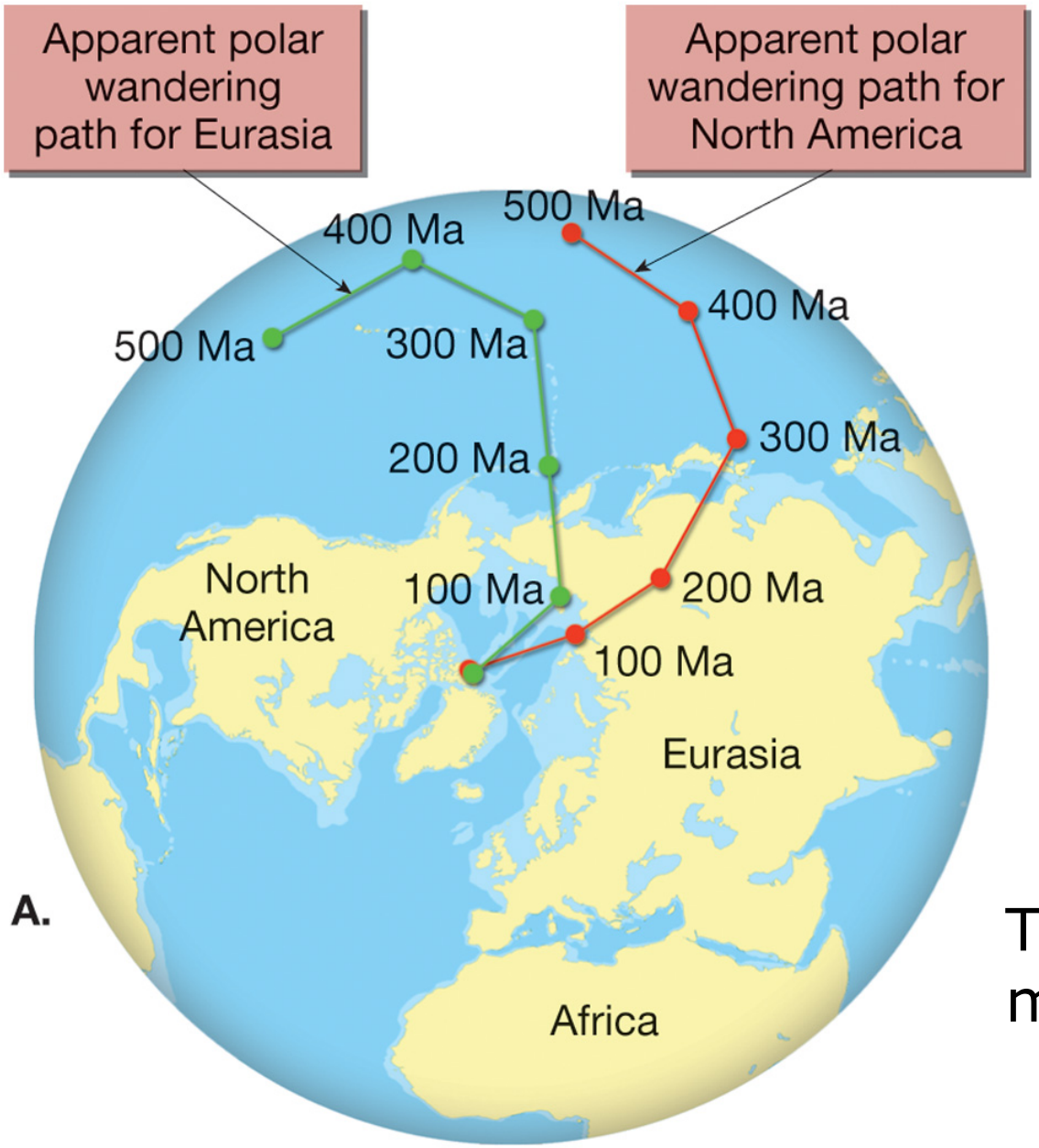




Why apparent?



Polar Wandering Paths for Eurasia and North America



There can't be so many poles !

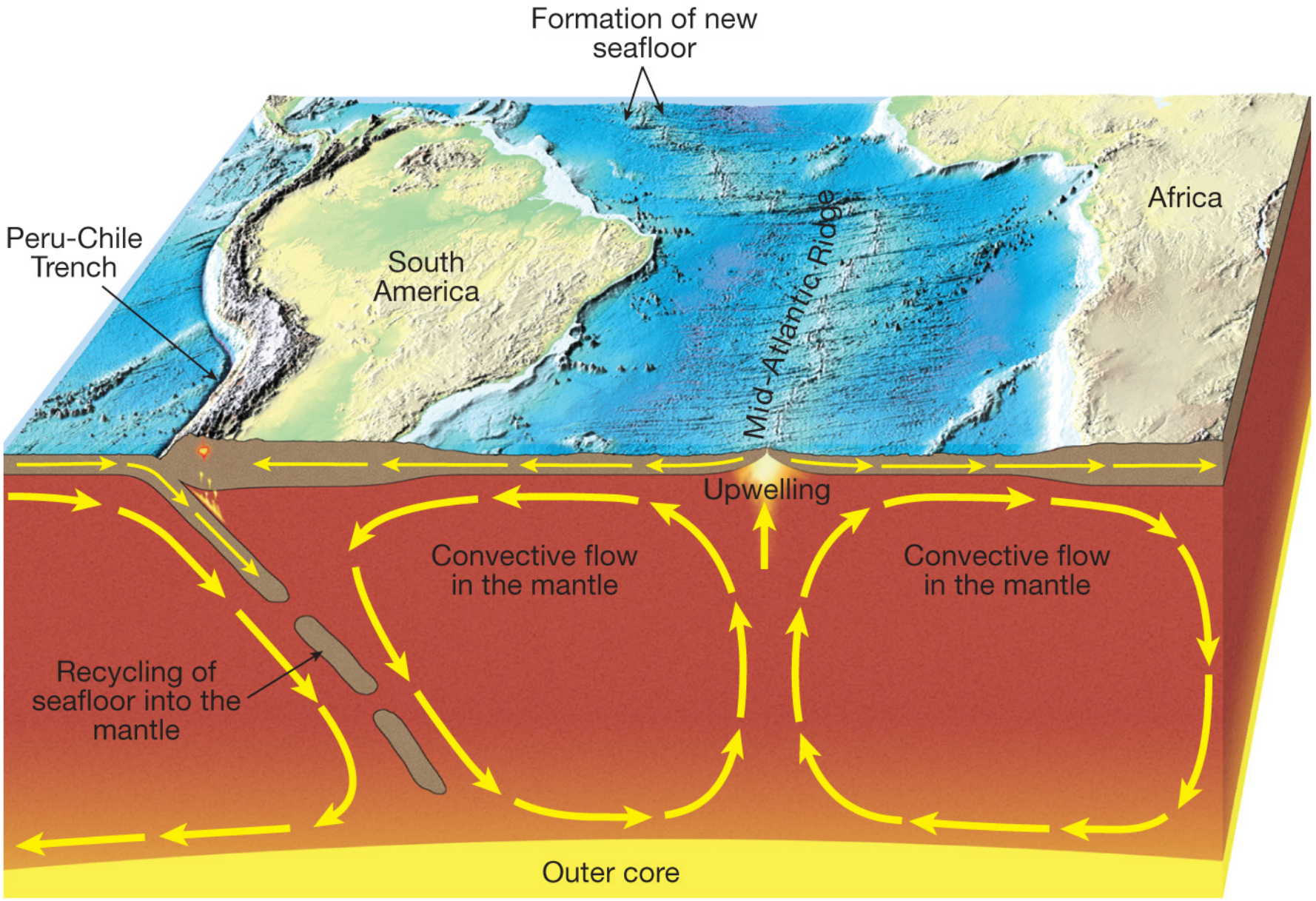
Continental Drift and Paleomagnetism

- **Polar wandering**
  - **The apparent movement of the magnetic poles indicates that the continents have moved.**
  - **It also indicates Europe was much closer to the equator when coal-producing swamps existed.**

A Scientific Revolution Begins

- **During the 1950s and 1960s, technological strides permitted extensive mapping of the ocean floor.**
- **The seafloor spreading hypothesis was proposed by Harry Hess in the early 1960s.**
- **Harry Hammond Hess** was an American geologist and a United States Navy officer in World War II who is considered one of the "founding fathers" of the unifying theory of plate tectonics. He is best known for his theories on sea floor spreading, suggesting that the convection of the Earth's mantle was the driving force behind this process.

Harry Hammond Hess



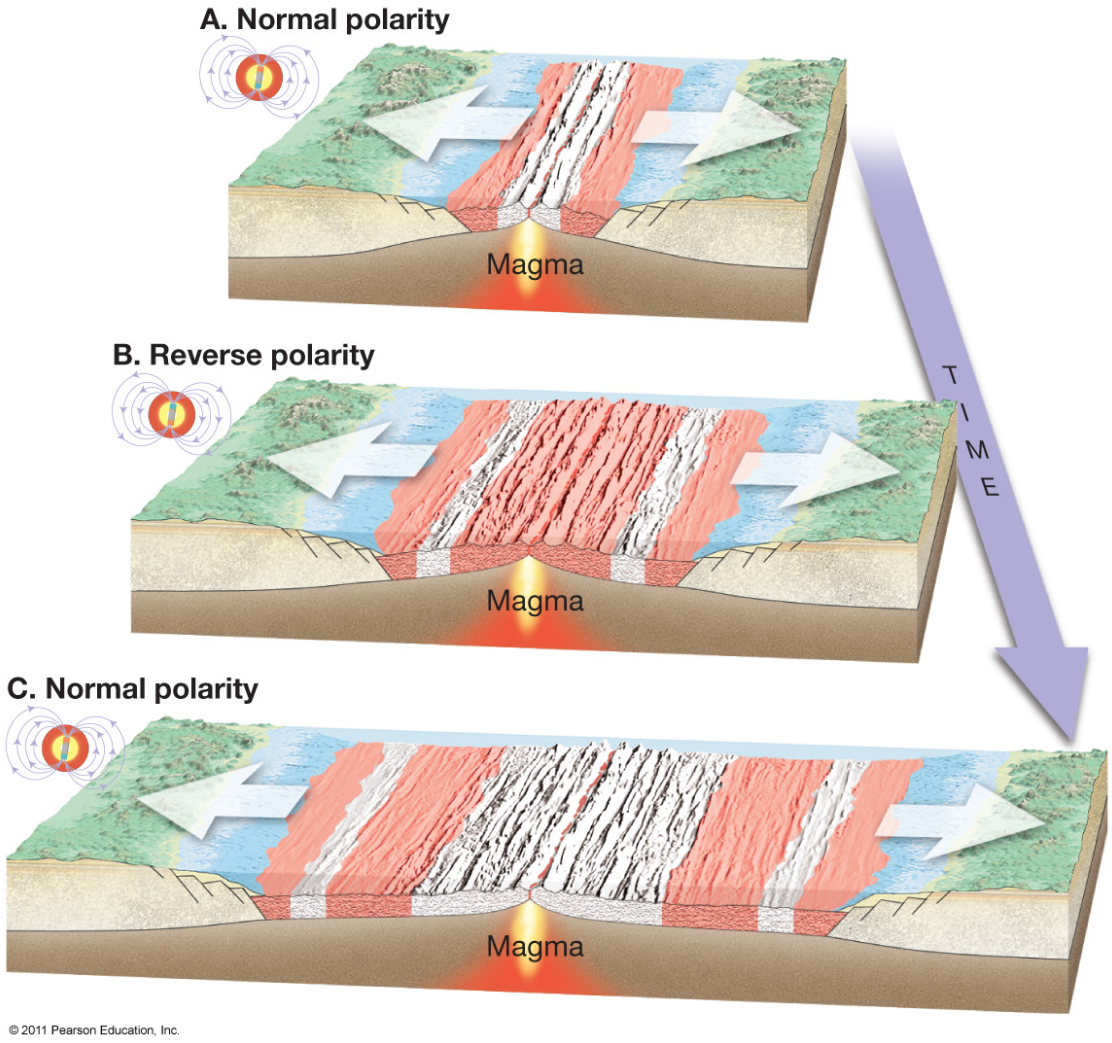
A Scientific Revolution Begins

- **Geomagnetic reversals**
  - **Earth's magnetic field periodically reverses polarity—the north pole becomes the south pole, and vice versa.**
  - **Dates when the polarity of Earth's magnetism changed were determined from lava flows.**

A Scientific Revolution Begins

- **Geomagnetic reversals**
  - **Geomagnetic reversals are recorded in the oceanic crust.**
  - **In 1963, Vine and Matthews tied the discovery of magnetic stripes in the oceanic crust near ridges to Hess's concept of seafloor spreading.**

Paleomagnetic Reversals Recorded in Oceanic Crust



A Scientific Revolution Begins

- **Geomagnetic reversal**
  - **Paleomagnetism was the most convincing evidence set forth to support the concepts of continental drift and seafloor spreading.**

Plate Tectonics: The New Paradigm

- **Earth's major plates**
  - **Associated with Earth's strong, rigid outer layer:**
    - **Known as the lithosphere**
    - **Consists of uppermost mantle and overlying crust**
    - **Overlies a weaker region in the mantle called the asthenosphere**

Plate Tectonics: The New Paradigm

- **Earth's major plates**
  - **Seven major lithospheric plates**
  - **Plates are in motion and are continually changing in shape and size.**
  - **The largest plate is the Pacific plate.**
  - **Several plates include an entire continent plus a large area of seafloor.**

Earth's Tectonic Plates

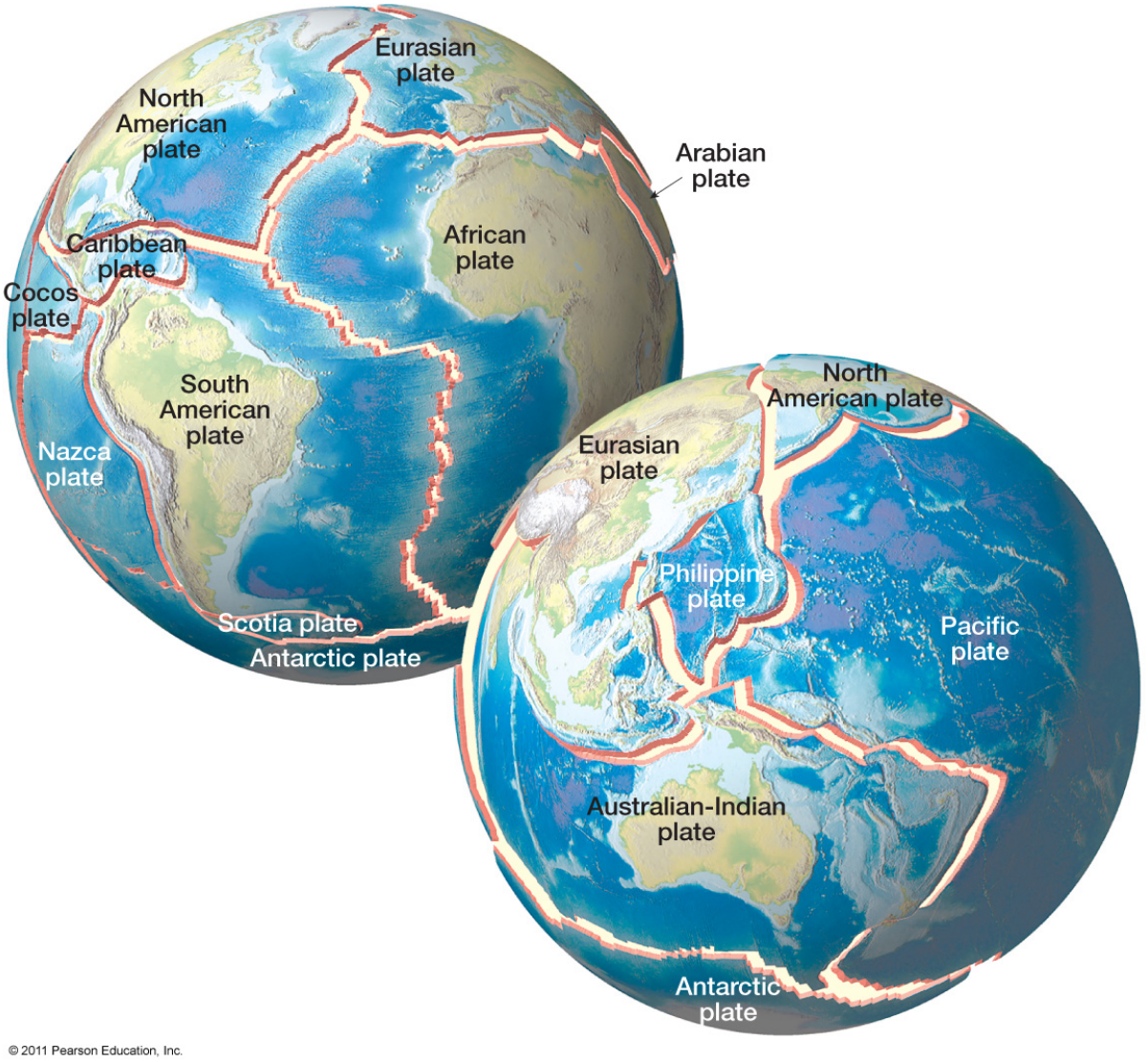


Plate Tectonics: The New Paradigm

- **Earth's major plates**
  - **Plates move relative to each other at a very slow but continuous rate.**
    - **About 5 centimeters (2 inches) per year**
    - **Cooler, denser slabs of oceanic lithosphere descend into the mantle.**

Plate Tectonics: The New Paradigm

- **Plate boundaries**
  - **Interactions among individual plates occur along their boundaries.**
  - **Types of plate boundaries:**
    - **Divergent plate boundaries (constructive margins)**
    - **Convergent plate boundaries (destructive margins)**
    - **Transform fault boundaries (conservative margins)**

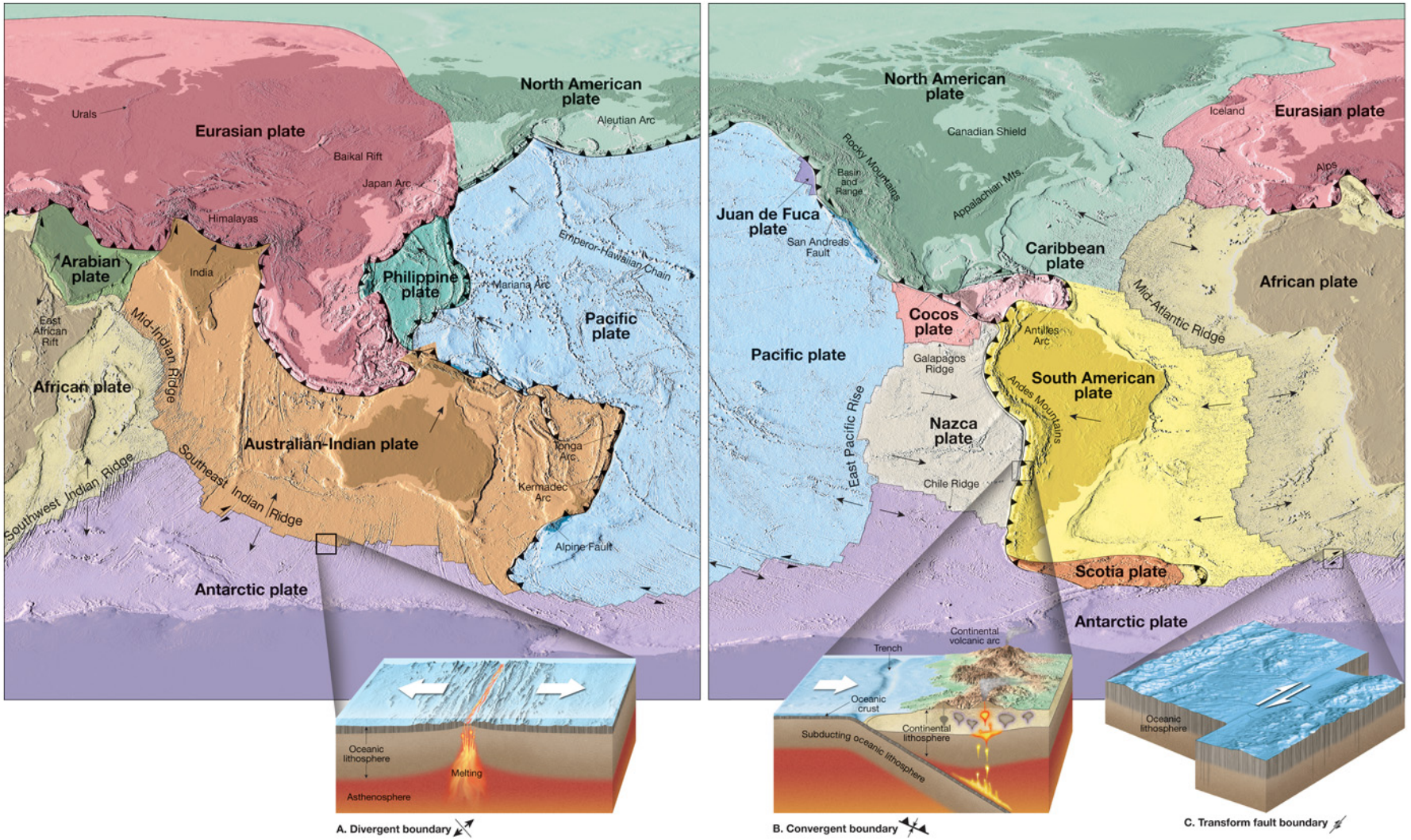


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Plate Tectonics: The New Paradigm

- **Plate boundaries**
  - **Each plate is bounded by a combination of the three types of boundaries.**
  - **New plate boundaries can be created in response to changing forces.**

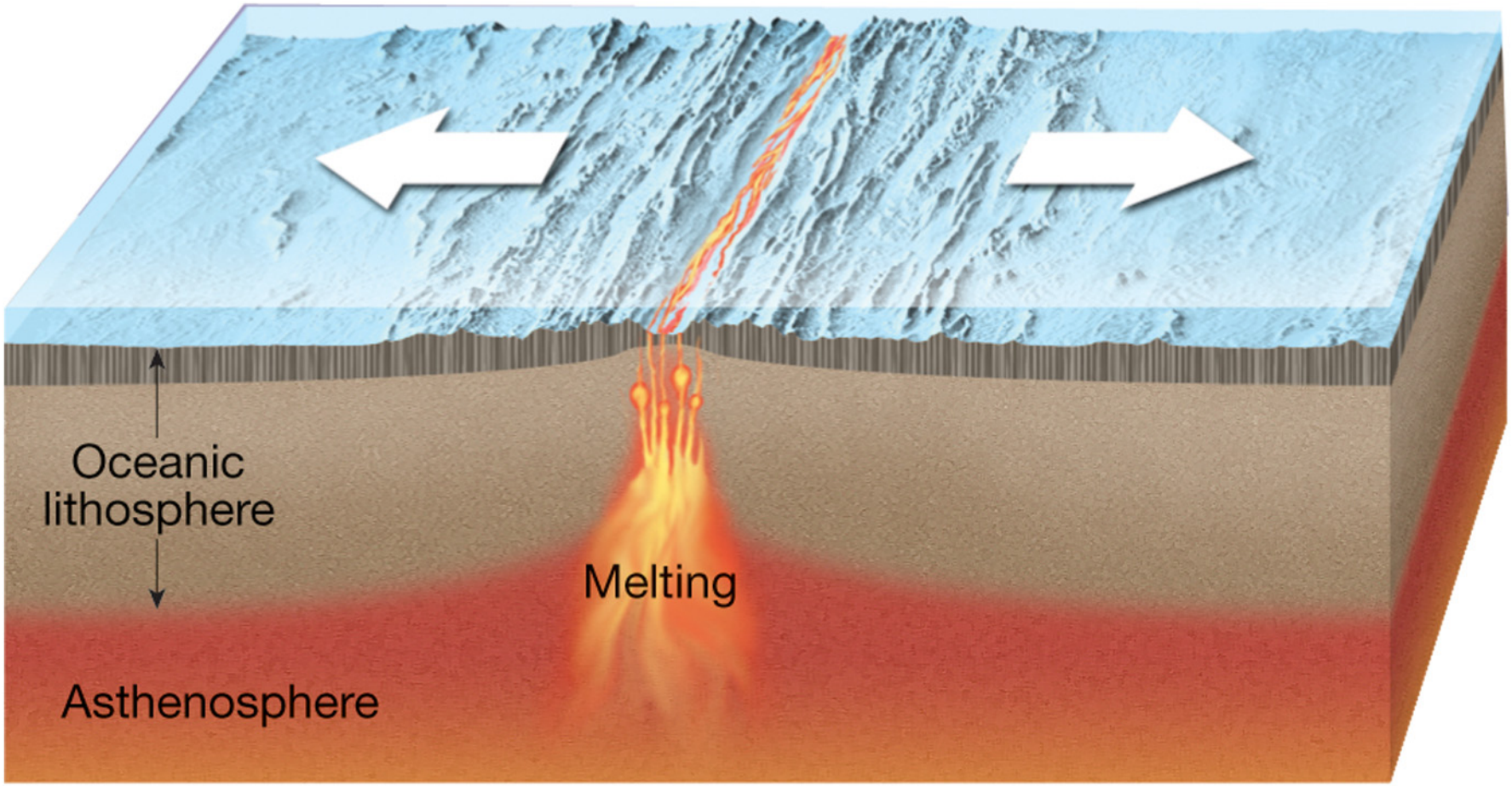
Divergent Plate Boundaries

- **Most are located along the crests of oceanic ridges.**
- **Oceanic ridges and seafloor spreading**
  - **Along well-developed divergent plate boundaries, the seafloor is elevated, forming oceanic ridges.**

Divergent Plate Boundaries

- **Oceanic ridges and seafloor spreading**
  - **Seafloor spreading occurs along the oceanic ridge system.**
- **Spreading rates and ridge topography**
  - **Ridge systems exhibit topographic differences.**
  - **Differences are controlled by spreading rates.**

Divergent Plate Boundary



A. Divergent boundary

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Divergent Plate Boundaries

- **Continental rifting**
  - **Splits landmasses into two or more smaller segments along a continental rift**
  - **Examples include:**
    - **East African Rift Valleys**
    - **Rhine Valley in Northern Europe**
  - **Produced by extensional forces**