Introduction to Earth Sciences
ESO 213A

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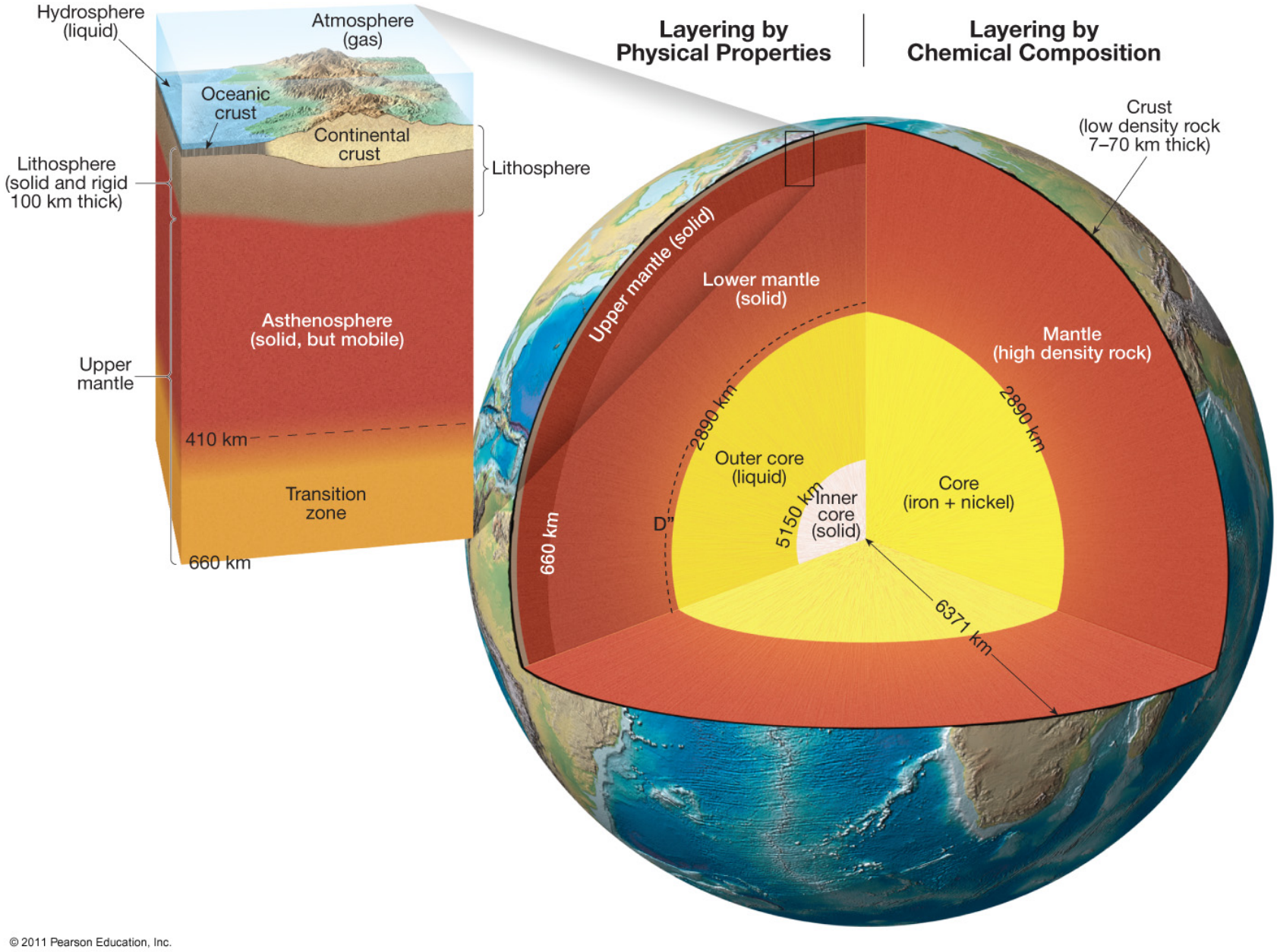
Department of Earth Sciences

Plate tectonics

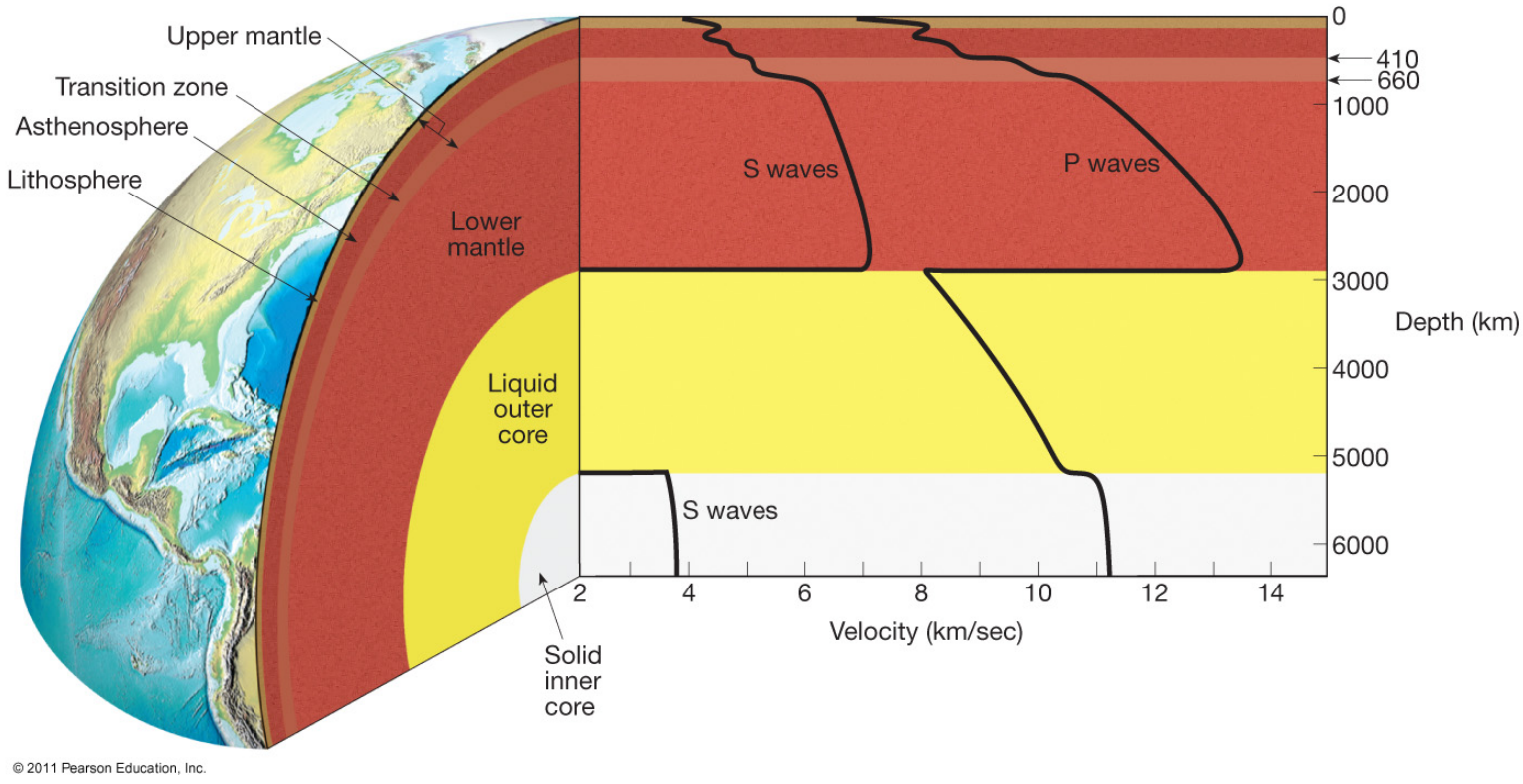
Previous Class: Earth's Internal Structure

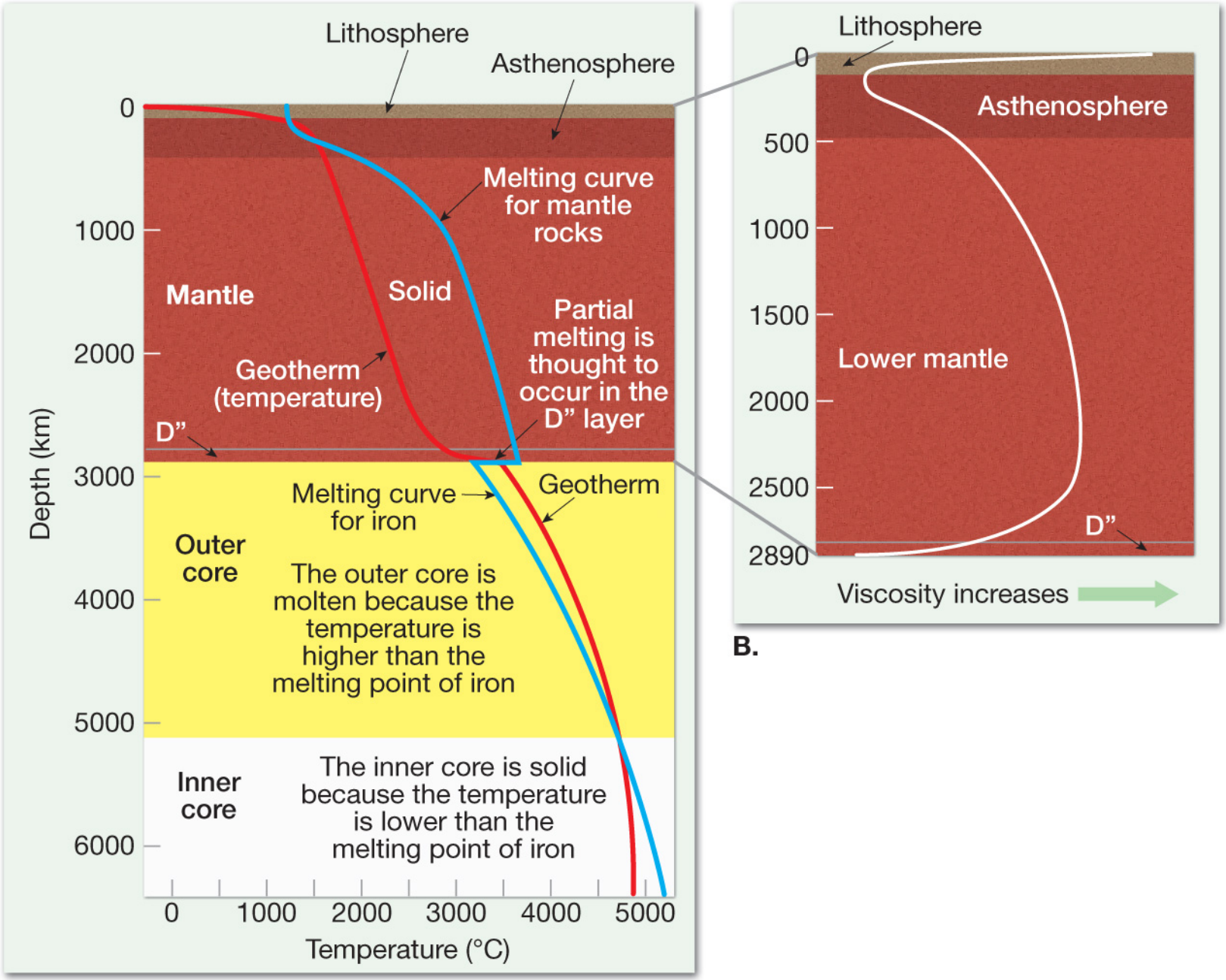
Last Class: Review



Seismic Waves and Earth's Structure

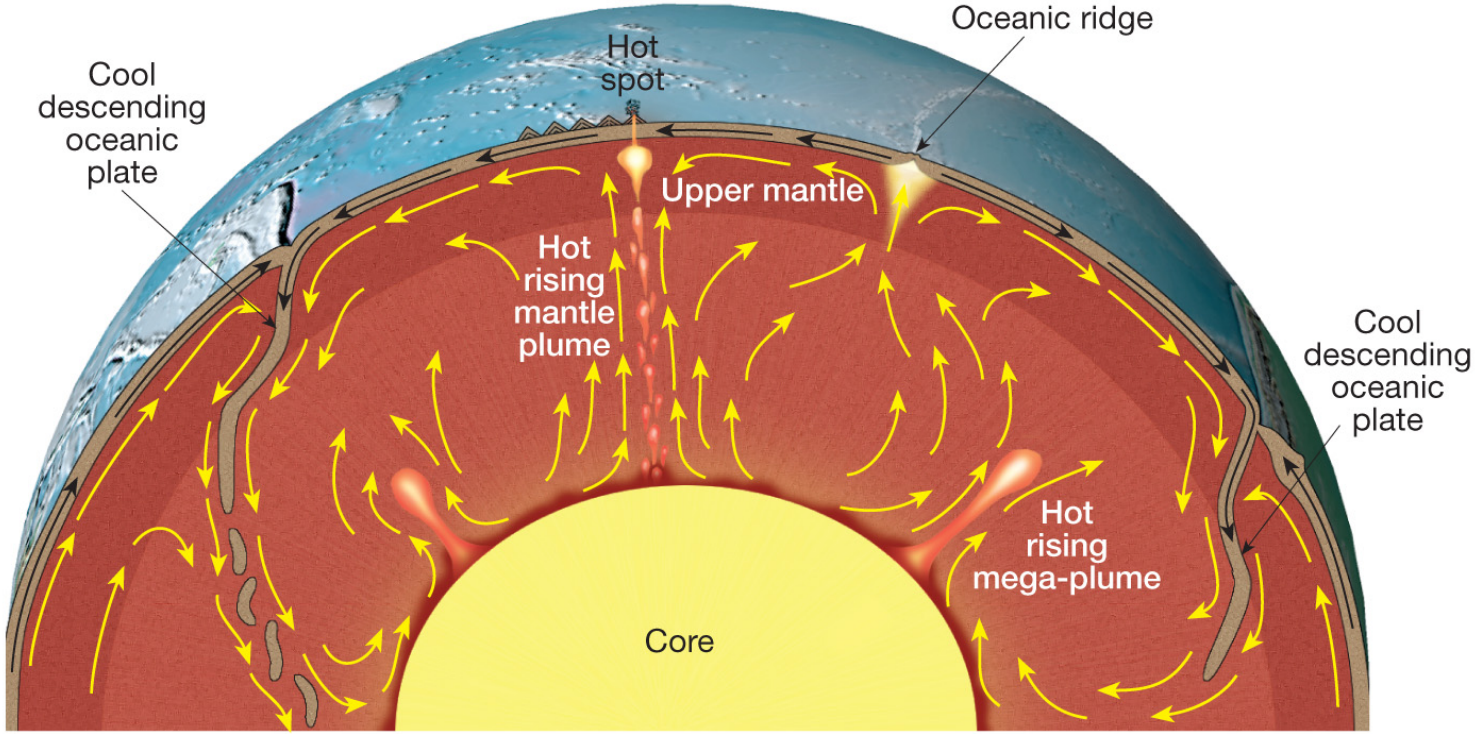
- **Abrupt changes in seismic-wave velocities that occur at particular depths helped seismologists conclude that Earth must be composed of distinct shells.**



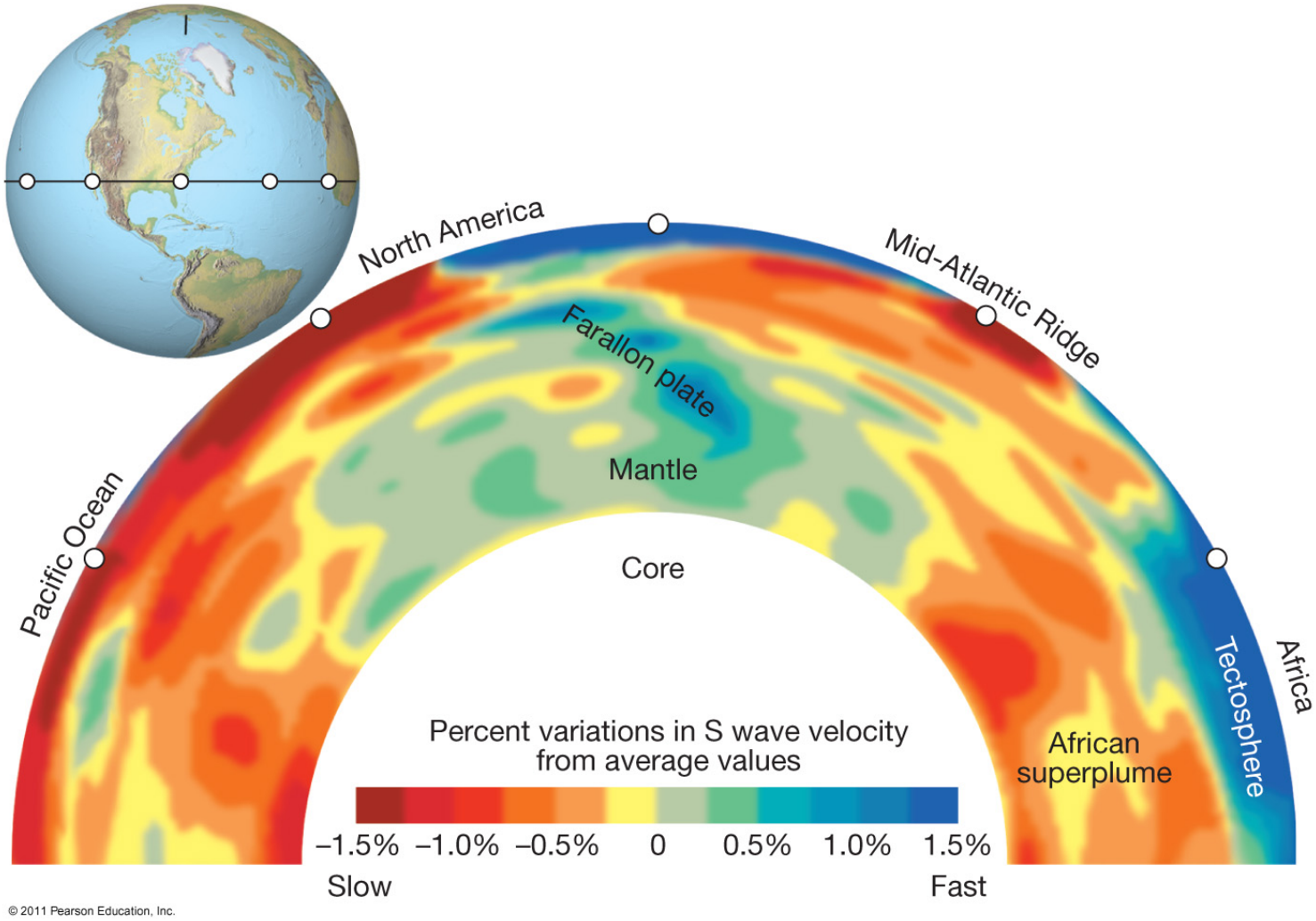


Earth's Internal Heat Engine

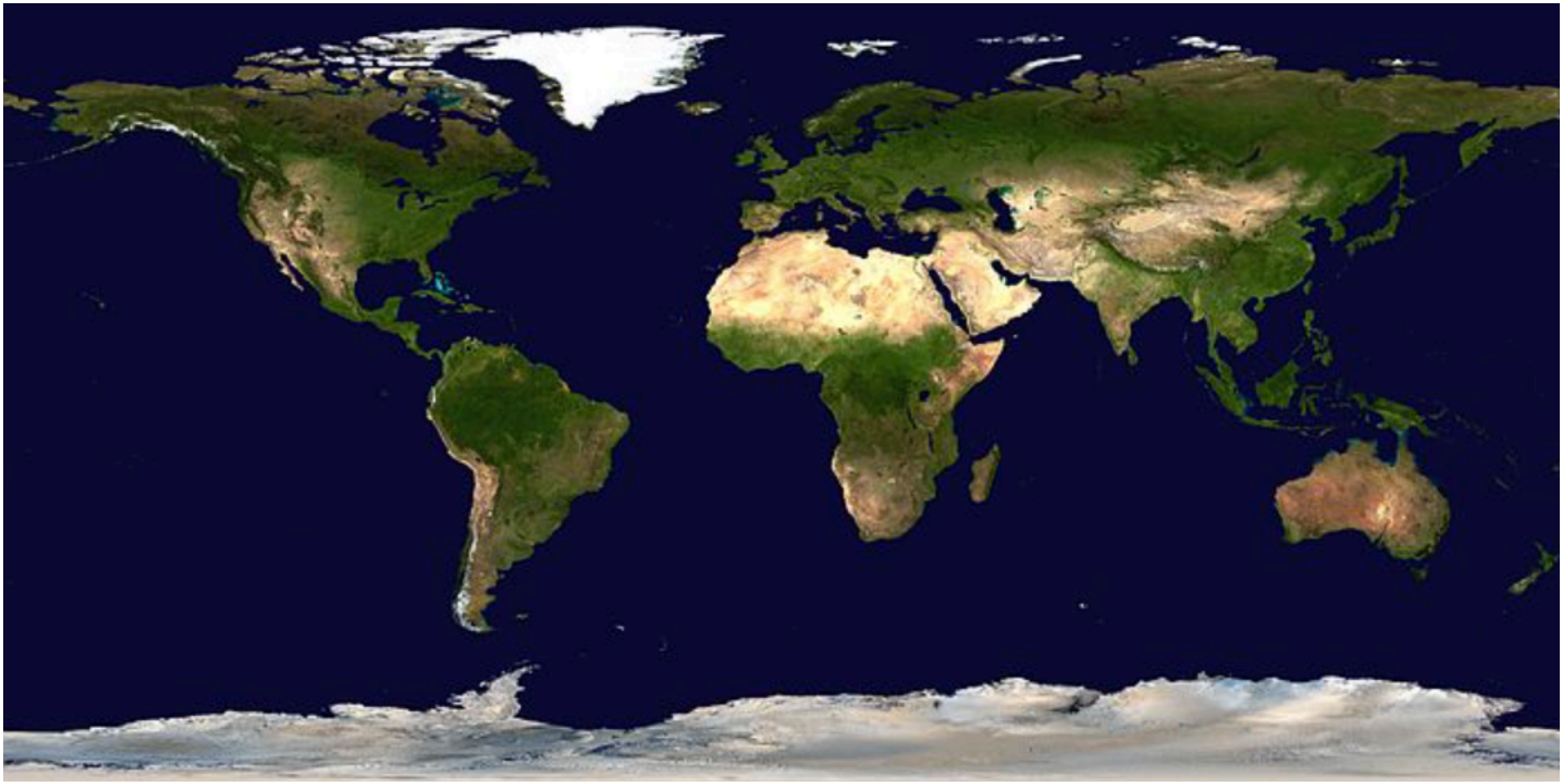
- **Mantle convection**
  - **Important process in Earth's interior**
  - **Provides the force that propels the rigid lithospheric plates across the globe.**



Seismic Tomographic Slice Through the Earth



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**

Matching Mountain Ranges Fit of the continents

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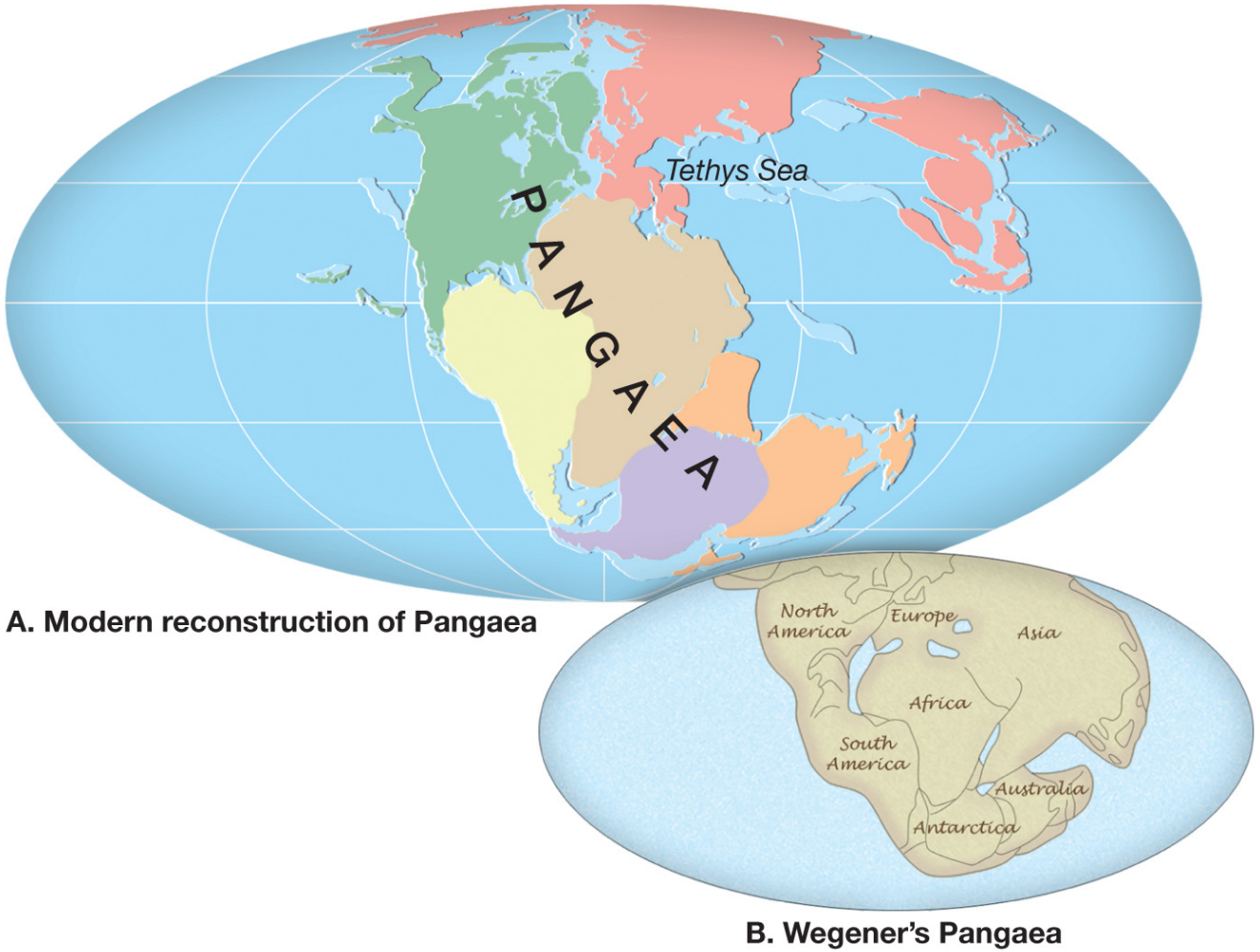
B.

C.

Pangaea Approximately 200 Million Years Ago



A. Modern reconstruction of Pangaea

B. Wegener's Pangaea

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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**

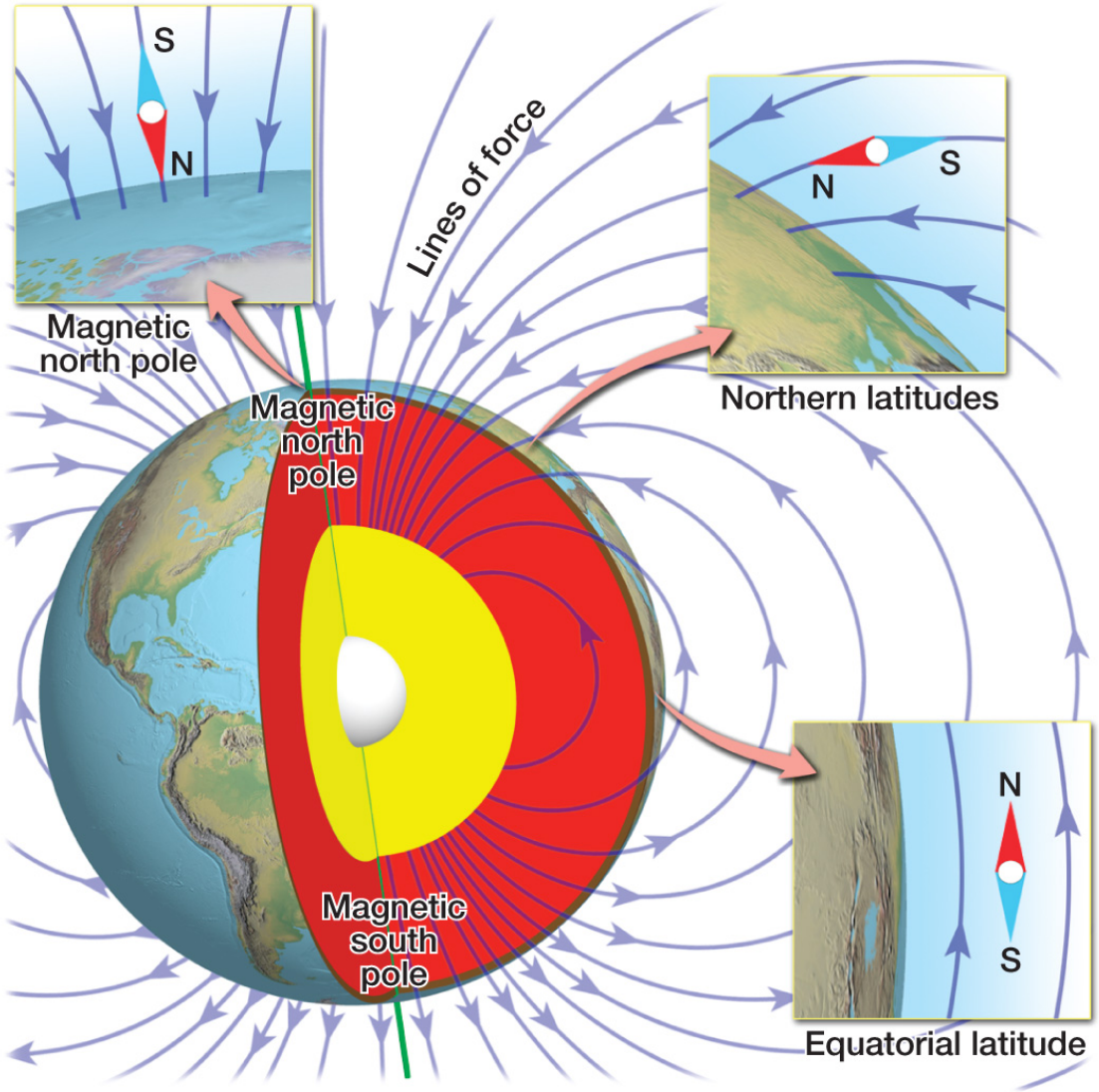
The Great Debate

- **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



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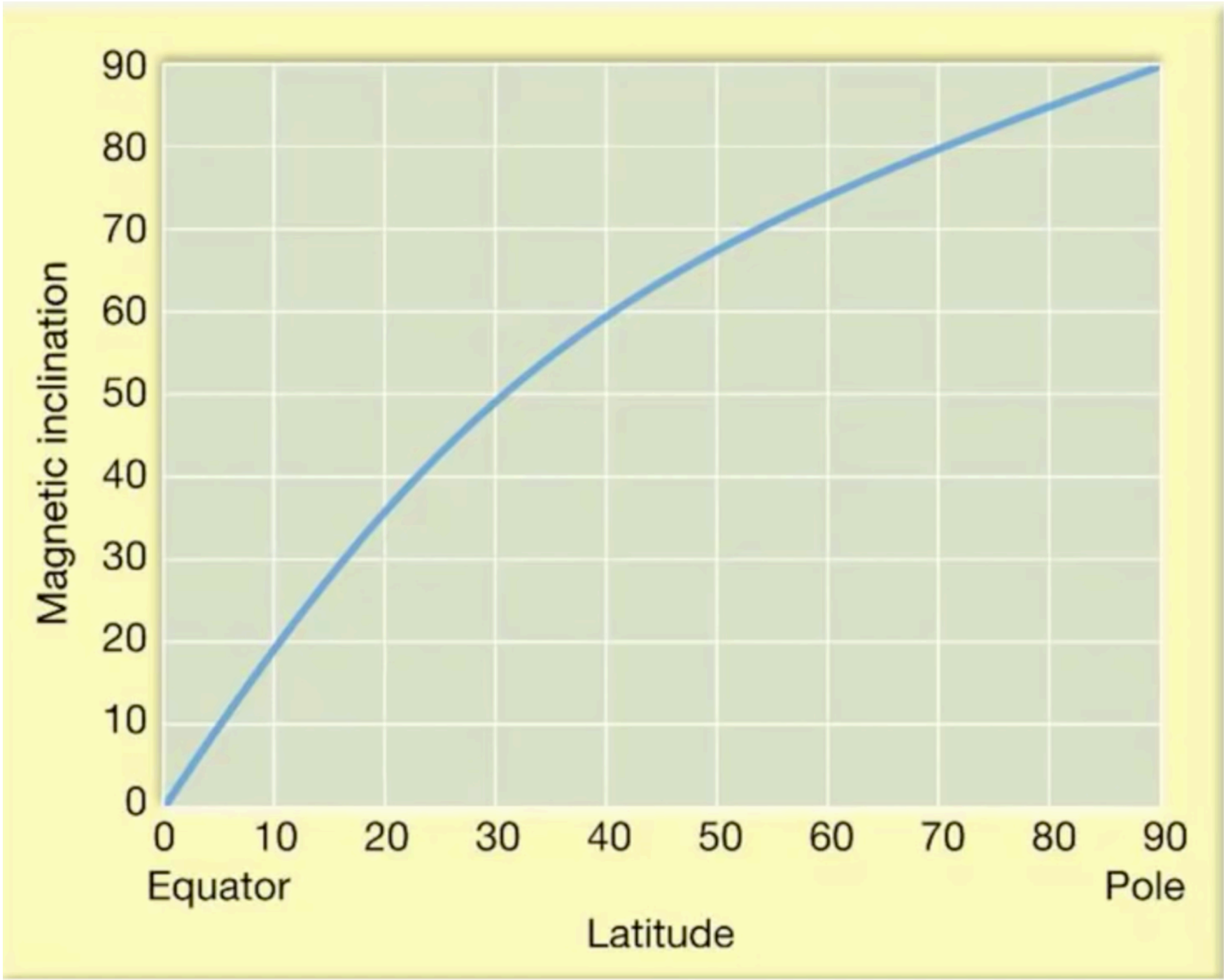
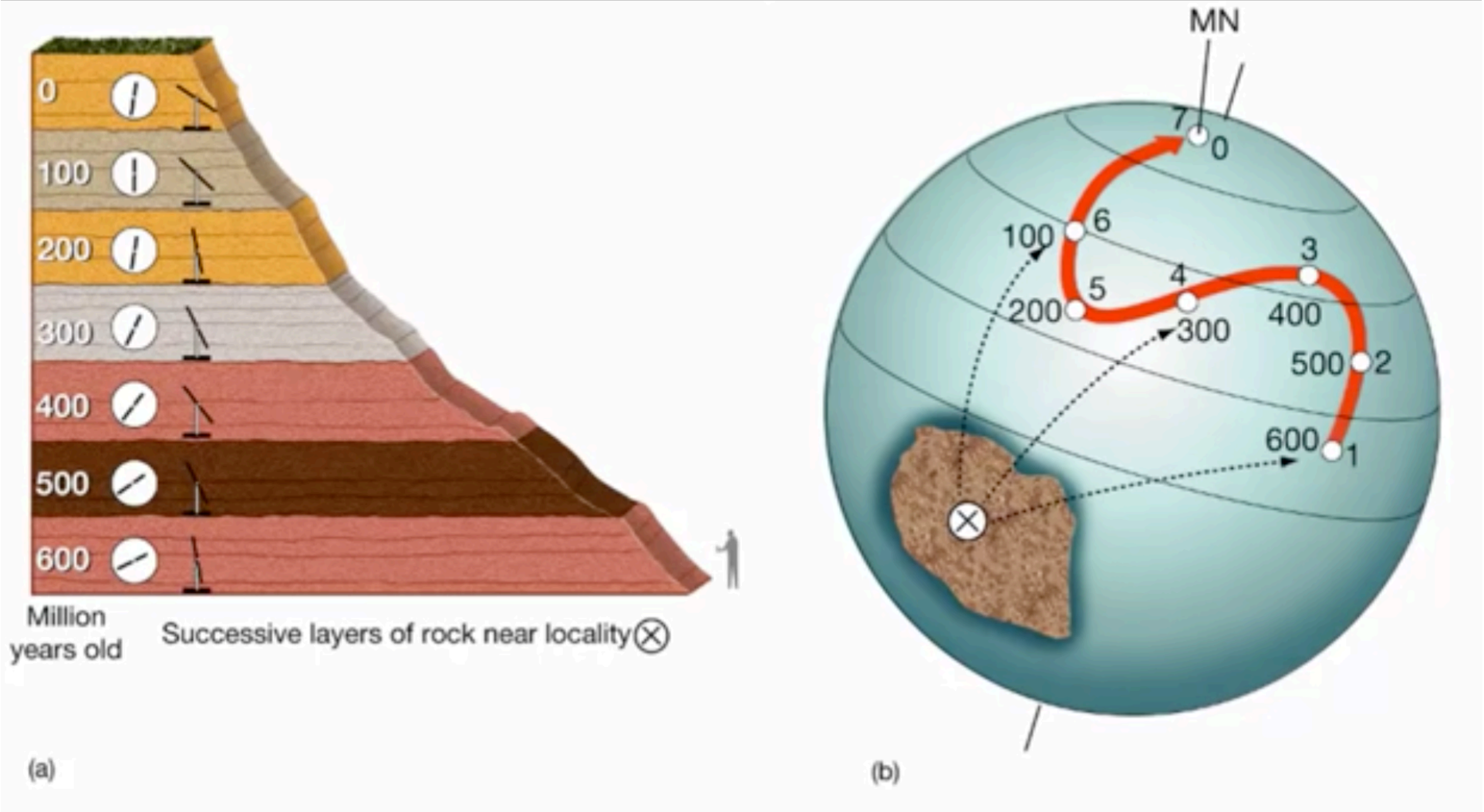
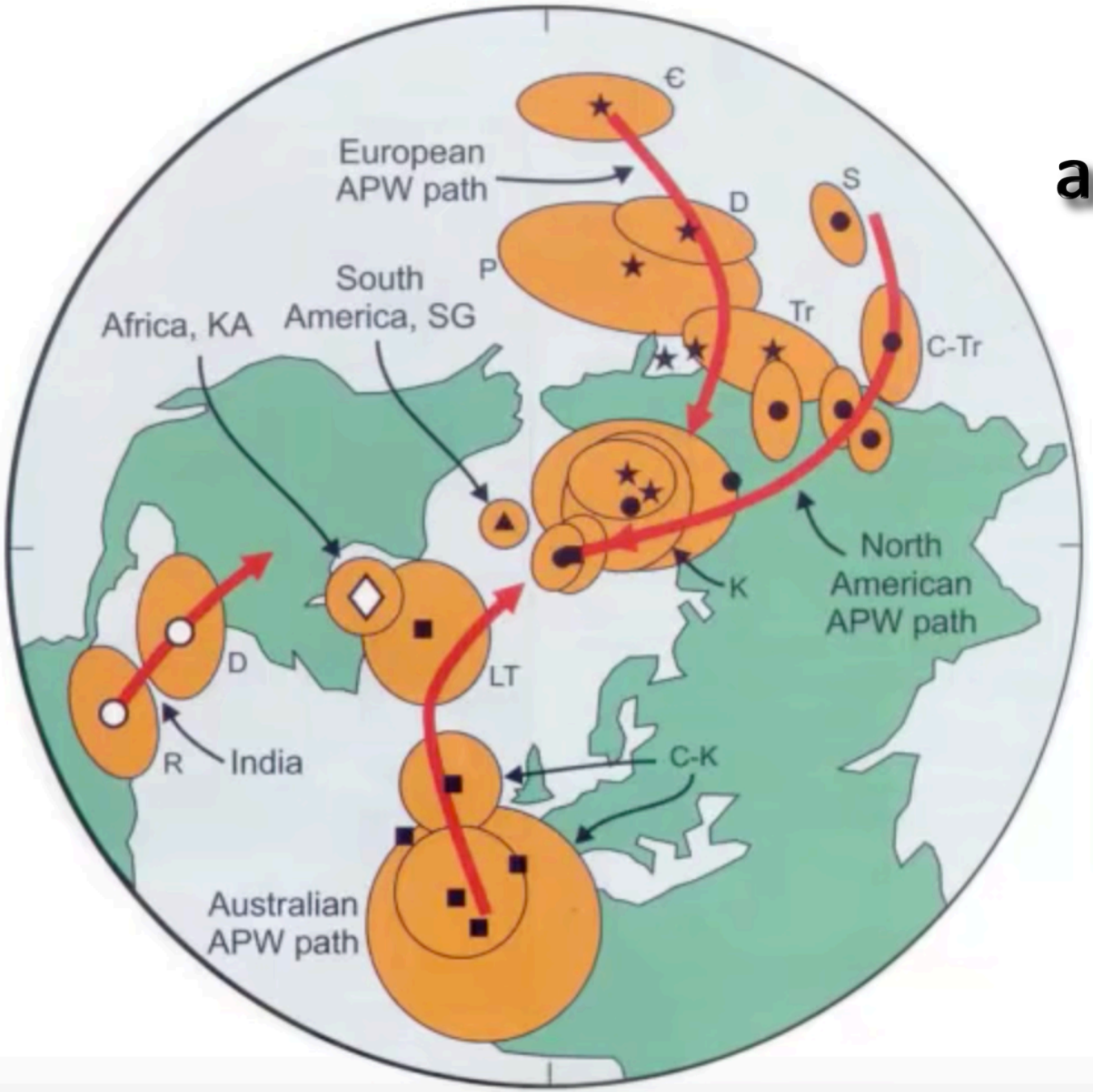

Magnetic inclination
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
Equator
Pole
Latitude

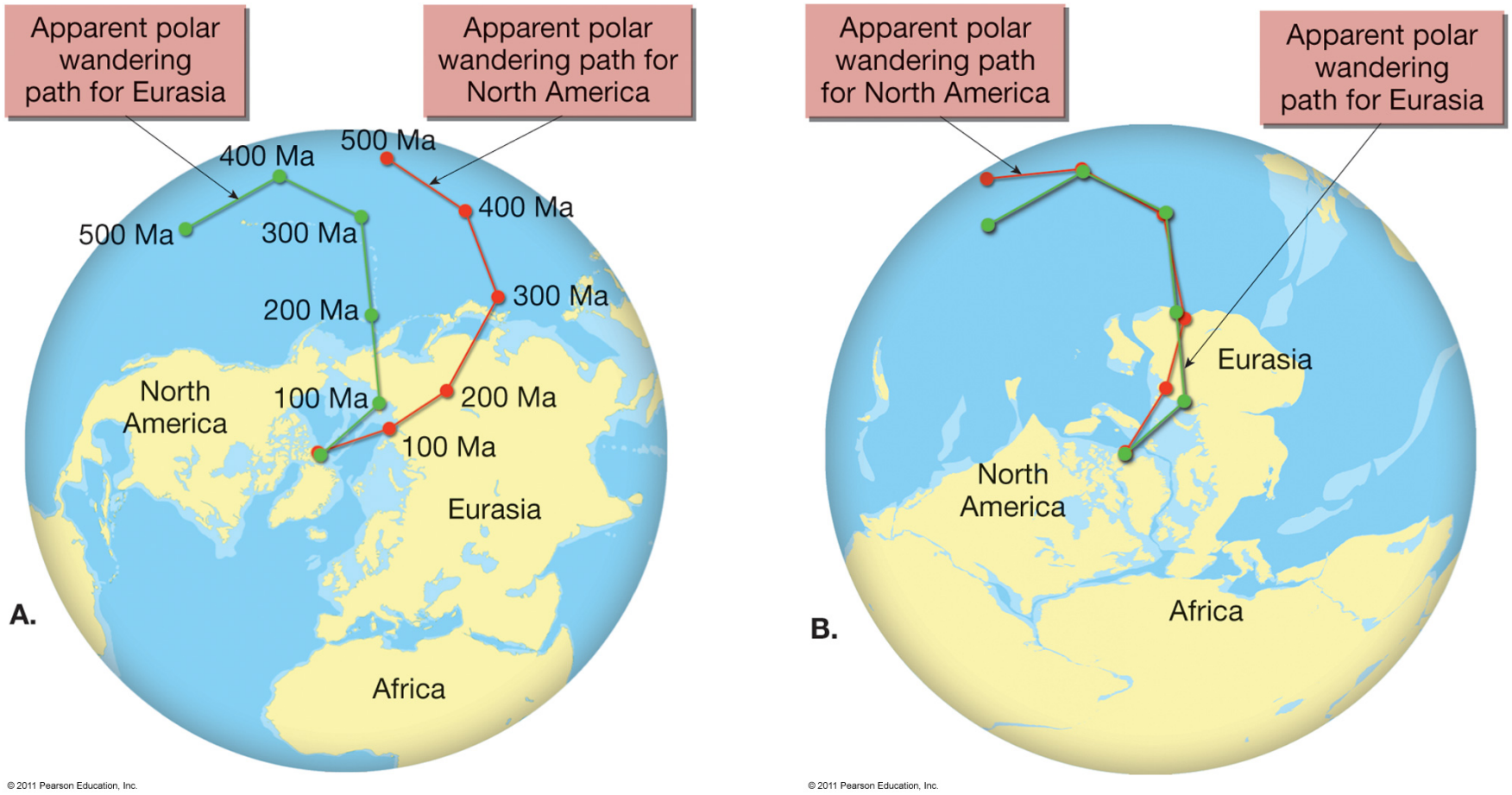
Apparent Polar wandering path



Why apparent?



Polar Wandering Paths for Eurasia and North America

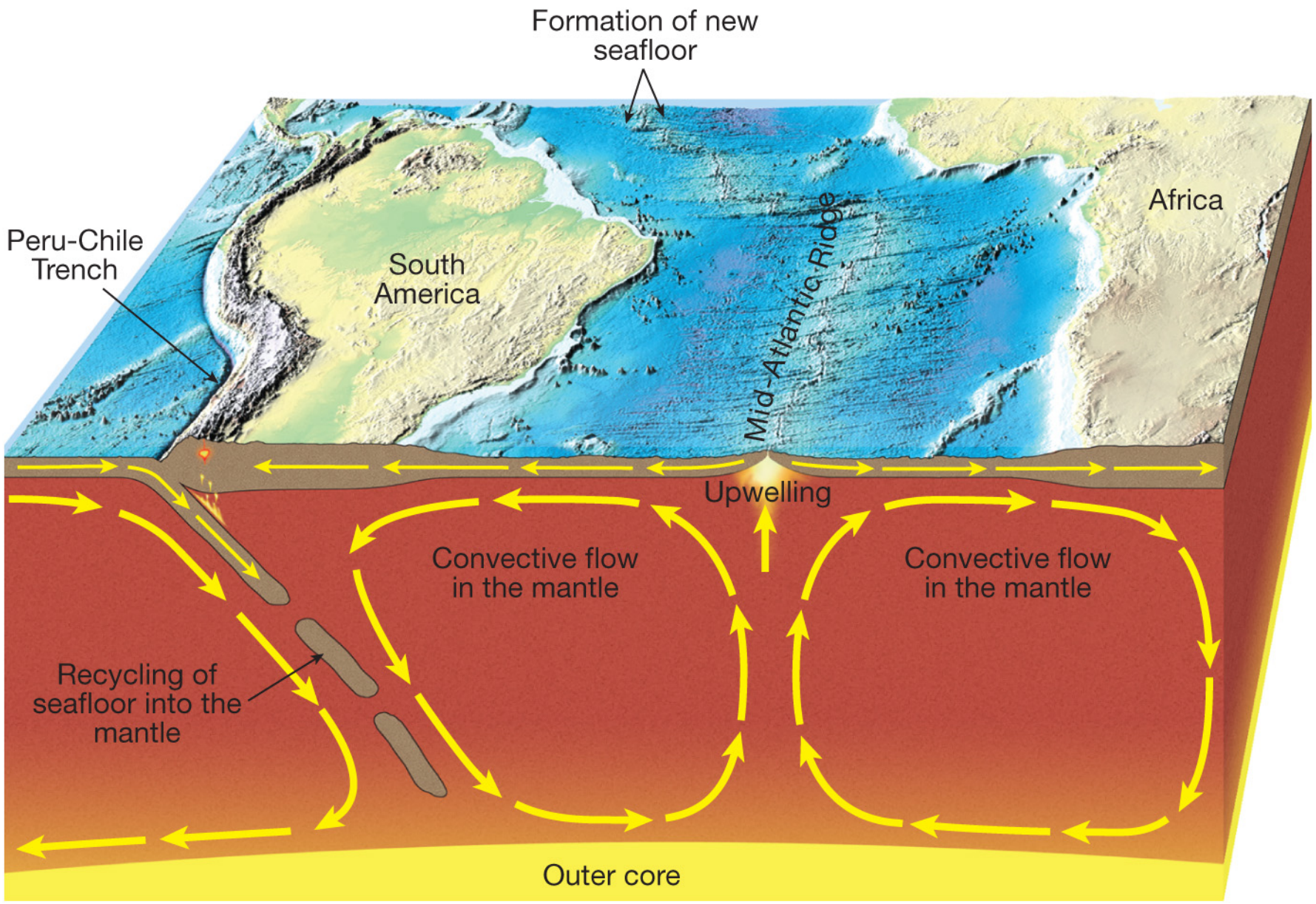


Continental Drift and Paleomagnetism

- **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.



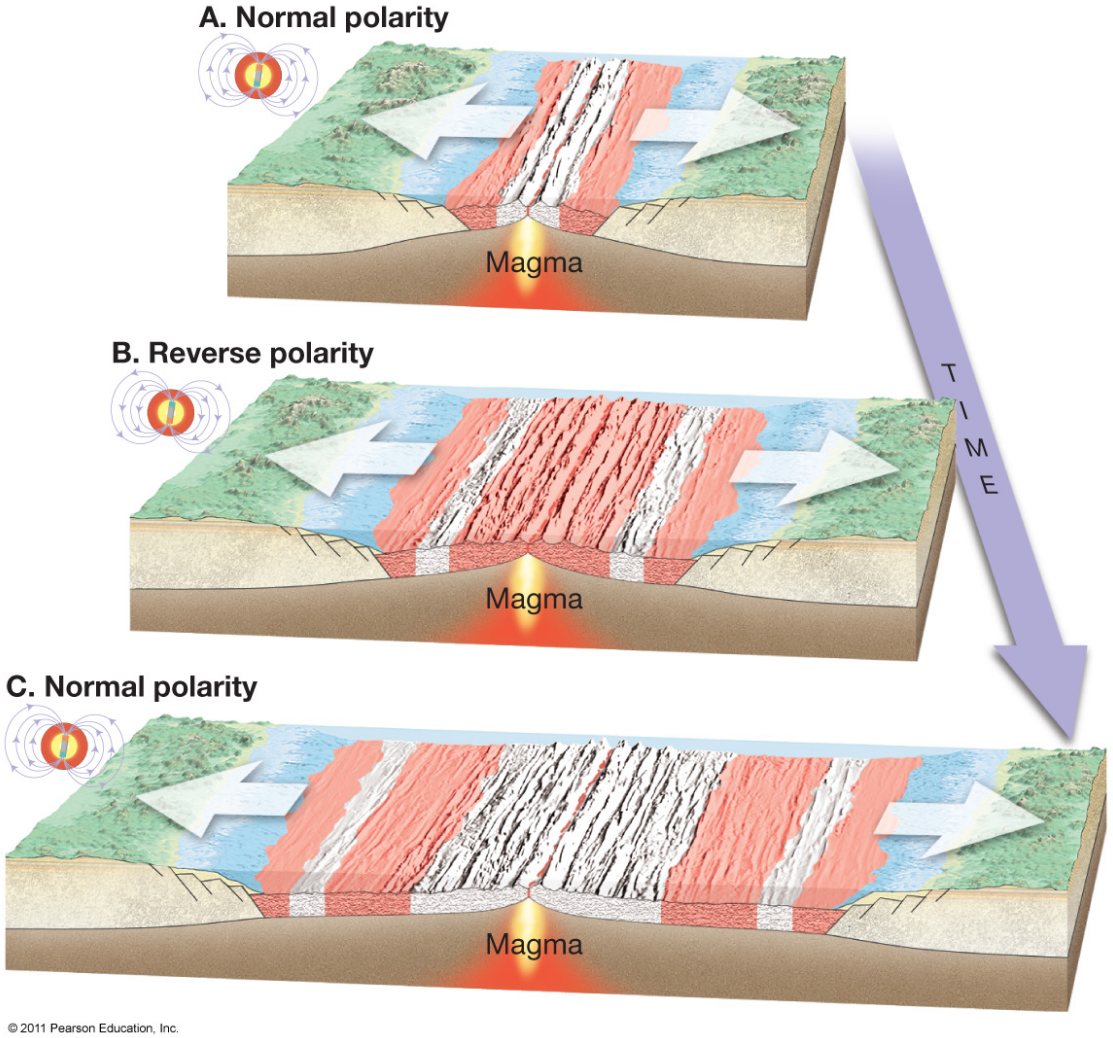
A Scientific Revolution Begins

- 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

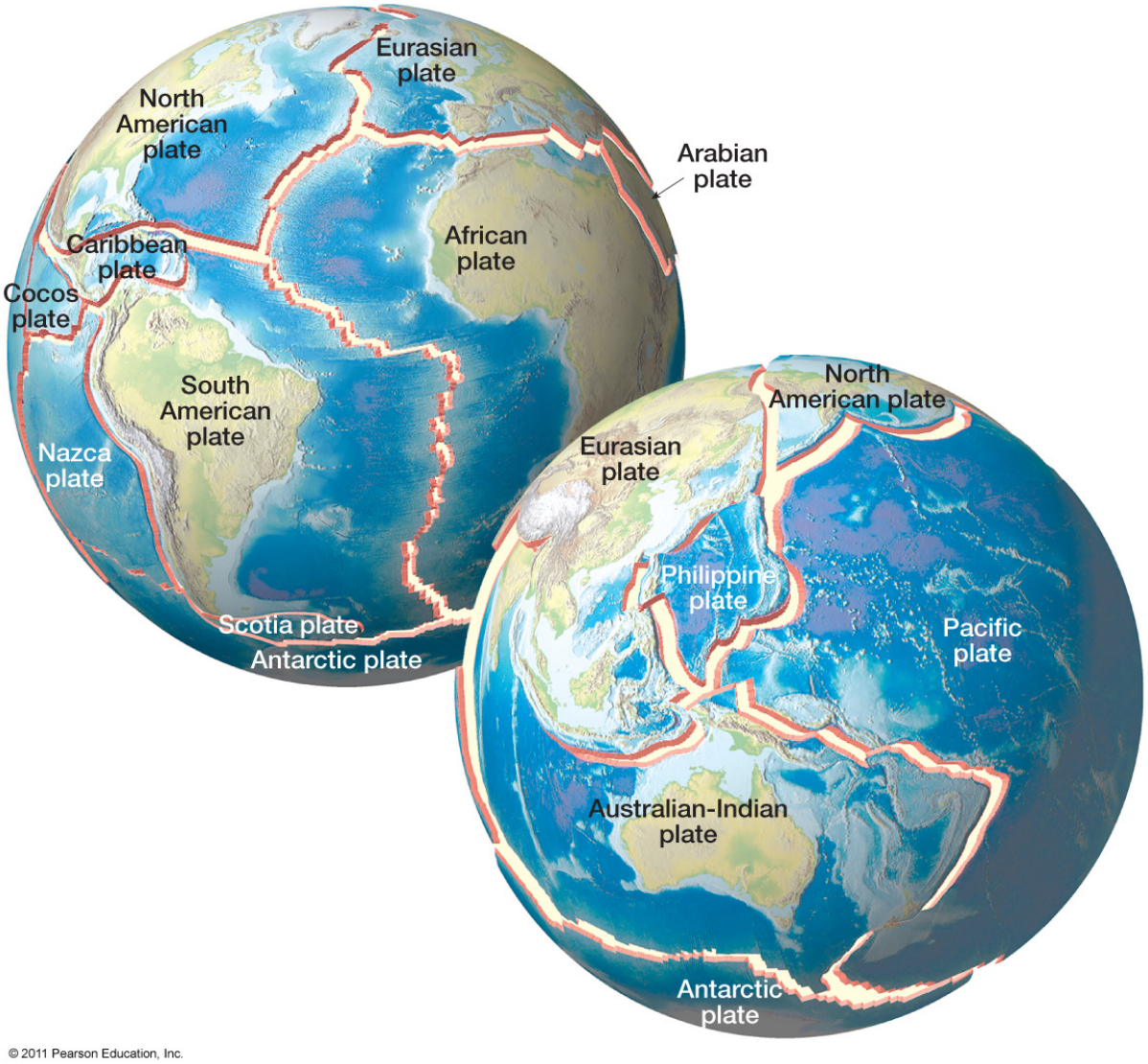


Plate Tectonics: The New Paradigm

- **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)**

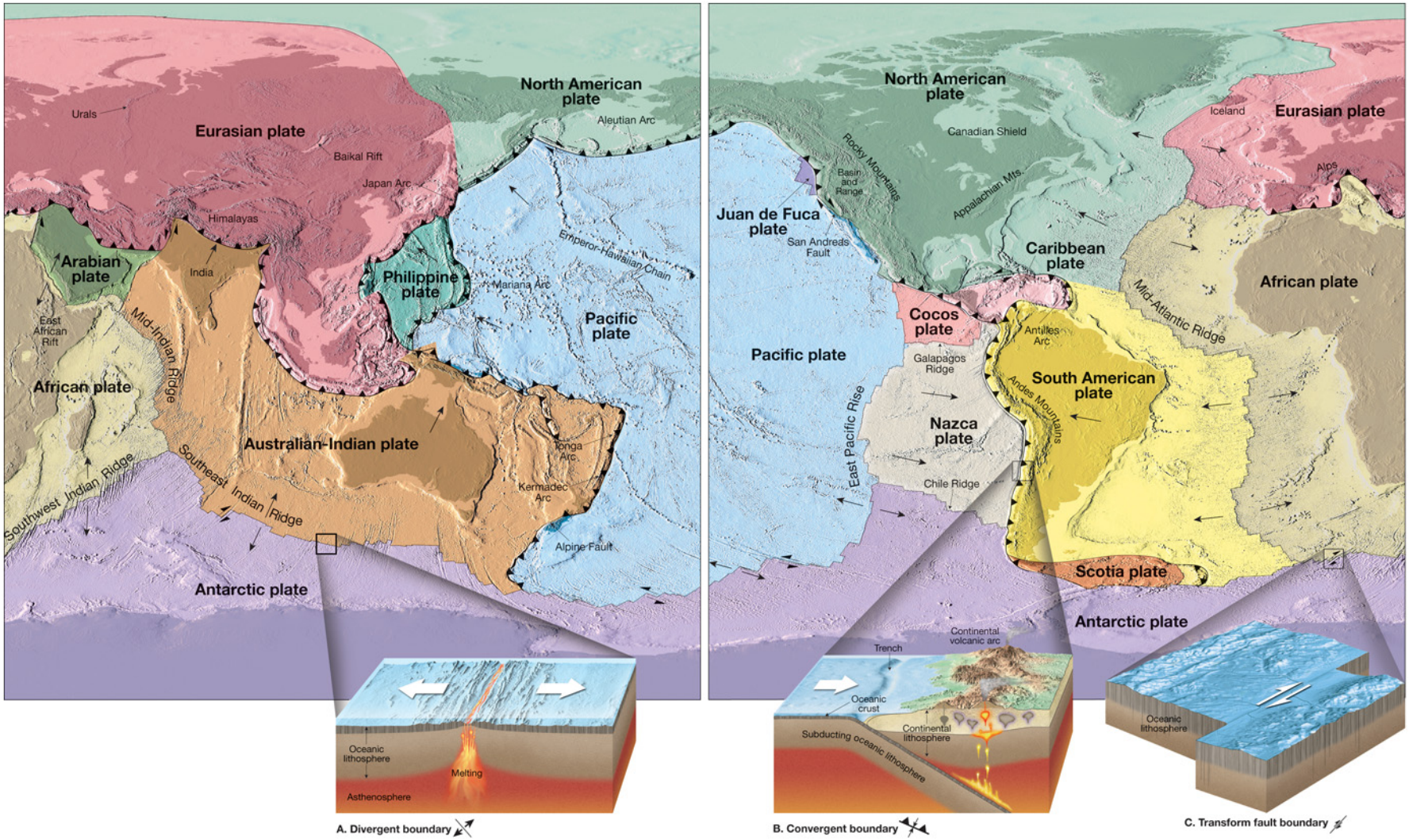


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Plate Tectonics: The New Paradigm

- **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.**

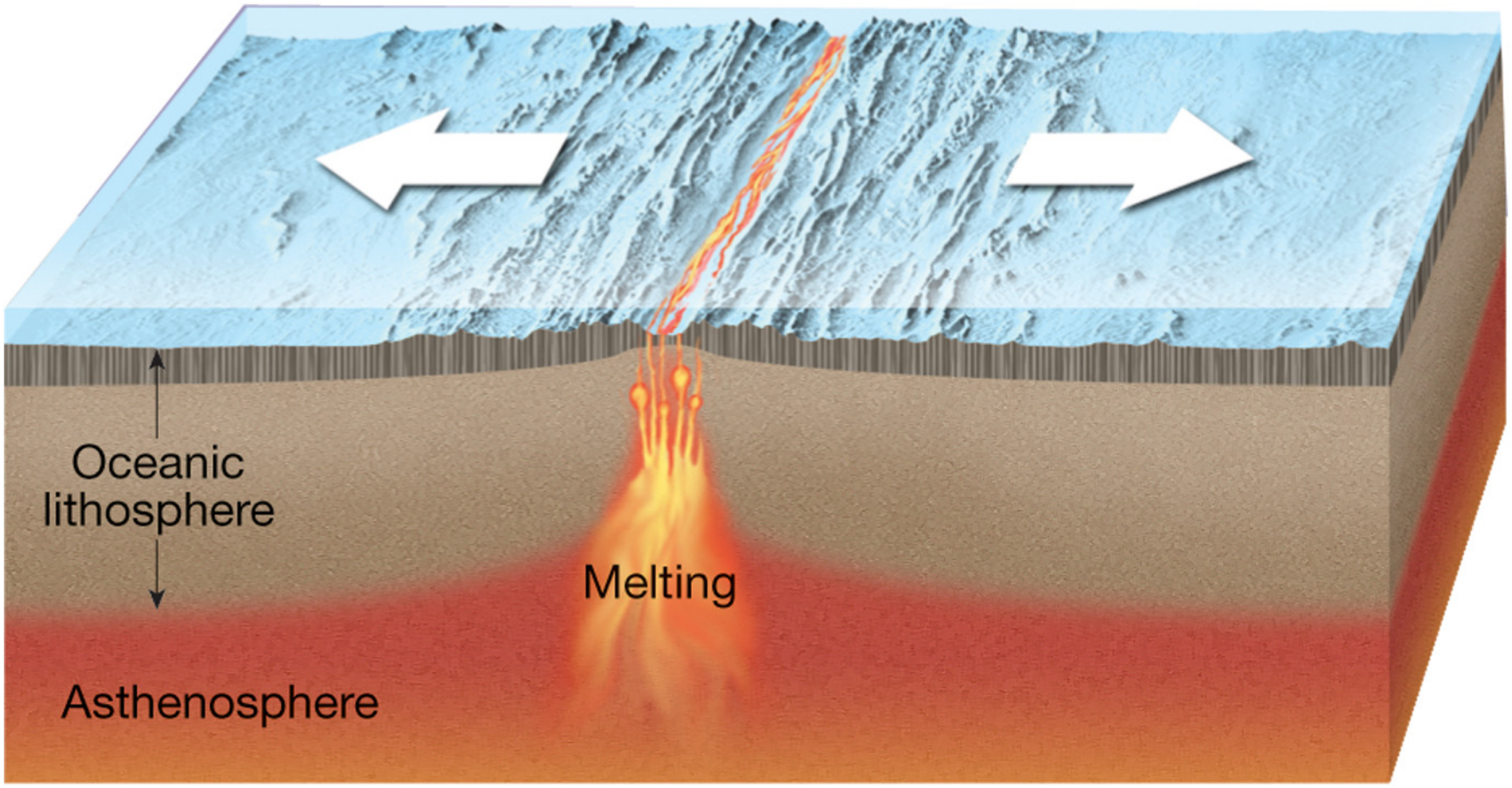
Divergent Plate Boundaries

- **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.**

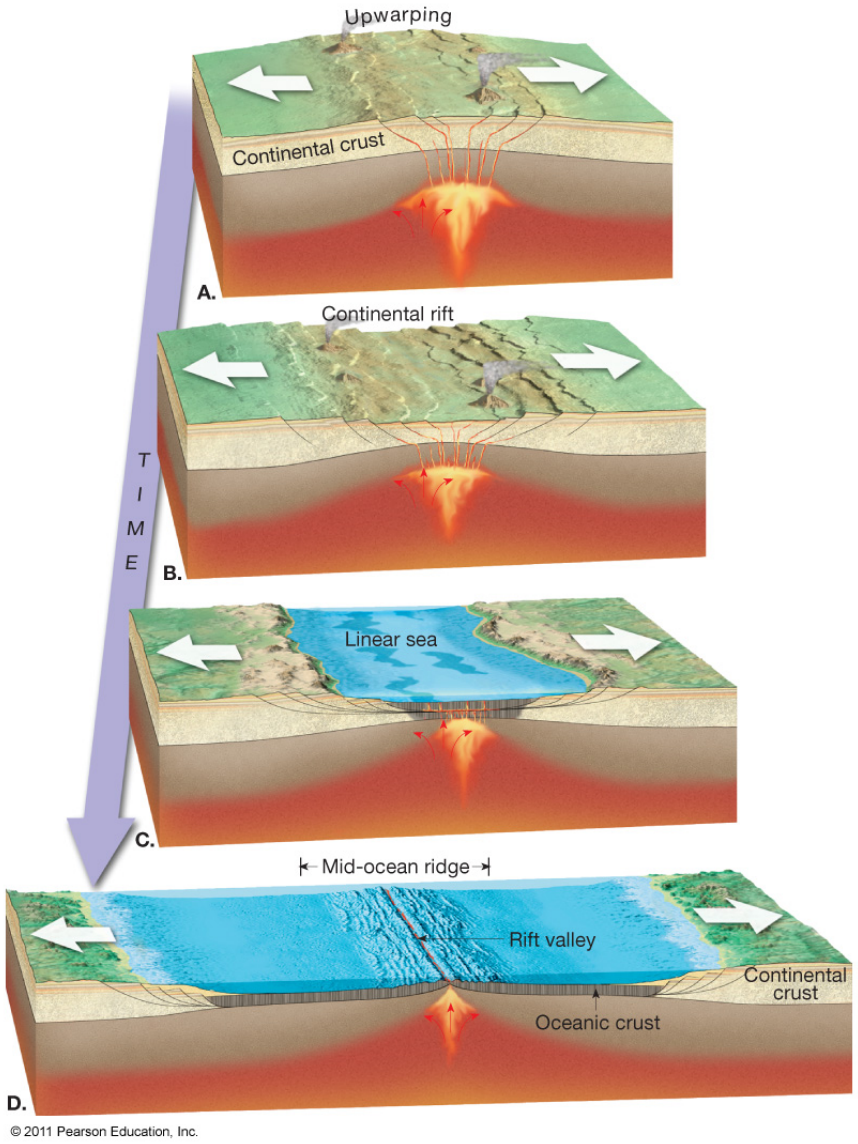
Divergent Plate Boundary



A. Divergent boundary

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**



Convergent Plate Boundaries

- **Older portions of oceanic plates are returned to the mantle at these destructive plate margins.**
  - **Surface expression of the descending plate is an ocean trench.**
  - **Also called subduction zones**
  - **Average angle of subduction = 45 degrees.**

Convergent Plate Boundaries

- **Types of convergent boundaries:**
  - **Oceanic–continental convergence**
    - **The denser oceanic slab sinks into the asthenosphere.**
    - **Along the descending plate, partial melting of mantle rock generates magma.**
    - **The resulting volcanic mountain chain is called a continental volcanic arc. (The Andes and the Cascades are examples.)**