Plate Tectonics

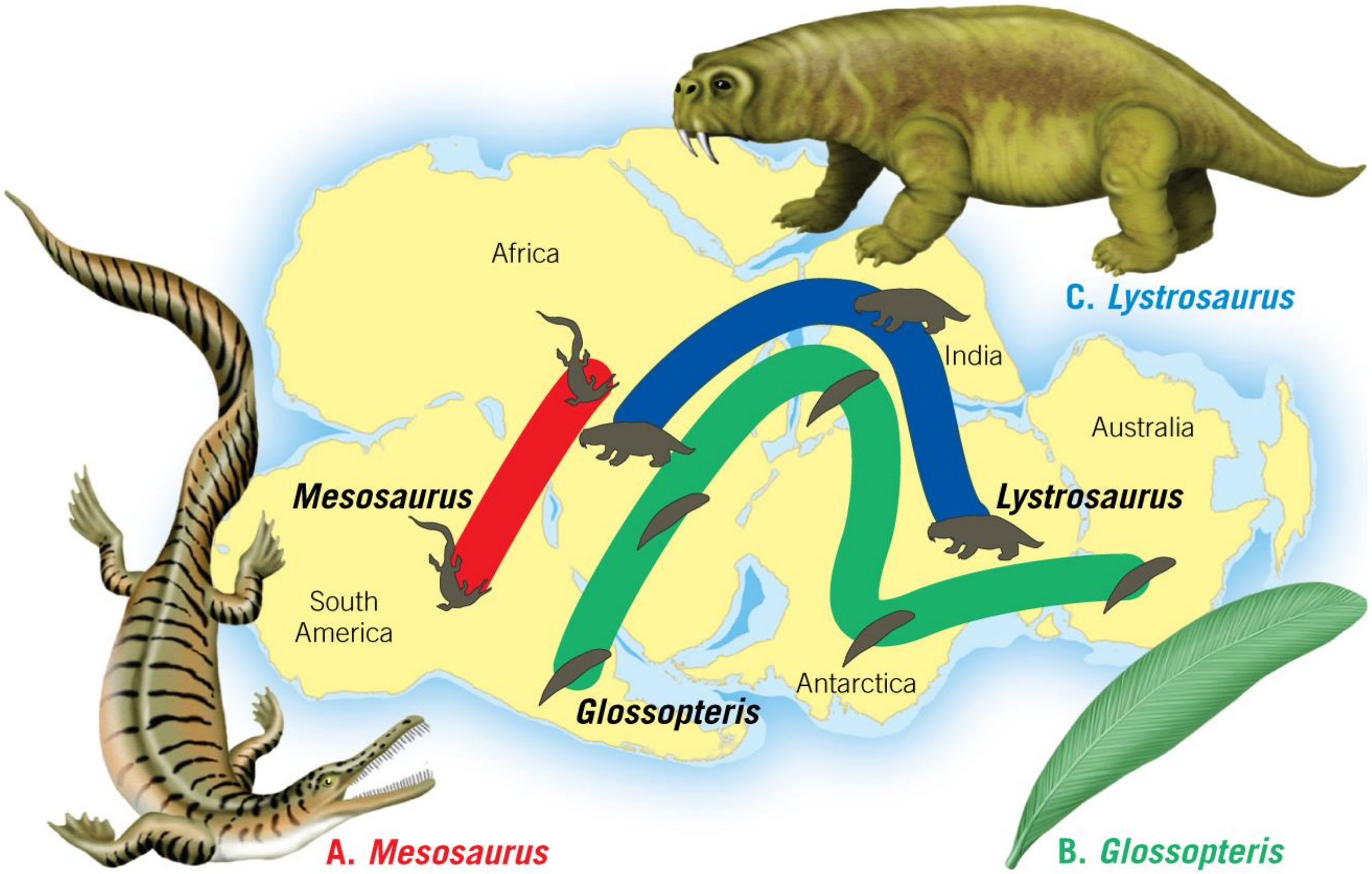
THE UNIFYING THEORY OF GEOLOGY

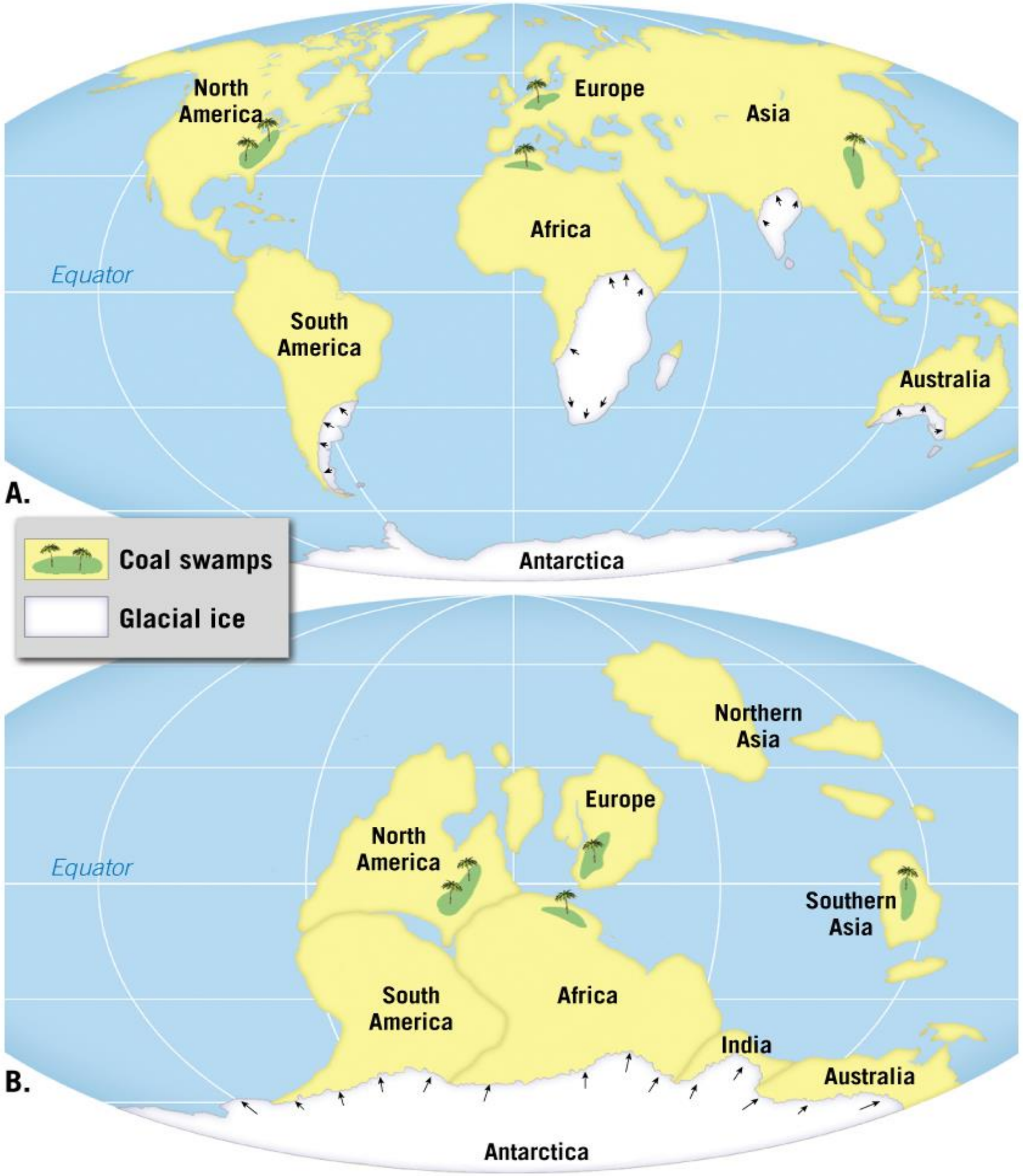
Modern reconstruction of Pangaea

Wegener's Pangaea, redrawn from his book published in 1915.

Wegener’s Continental Drift

- Wegener's continental drift hypothesis
  - Evidence used by Wegener
    - Fit of South America and Africa
    - Fossils match across the seas
    - Rock types and structures match
    - Ancient climates


Africa
C. Lystrosaurus
India
Australia
Mesosaurus
Lystrosaurus
South America
Antarctica
Glossopteris
A. Mesosaurus
B. Glossopteris


North America
Europe
Asia
Africa
Equator
South America
Australia
A.
Antarctica
Coal swamps
Glacial ice
Northern Asia
Europe
North America
Equator
Southern Asia
South America
Africa
India
Australia
B.
Antarctica

Why Was Wegener's Theory Rejected

He published his theory in 1915 in a book called "The Origin of Continents and Oceans".

He was recognized as a climatologist not a geologist.

Many geologists believed that the Earth was contracting. They believed that land bridges that once existed had sunk into the ocean.

He could not provide a mechanism for the movement, and he was incorrect in thinking the continents plowed through the oceanic crust (like a ship through ice).

He died at the age of 50 in 1930 so he never lived to see his theory morph into the modern theory of plate tectonics.

Wegener's theory of continental drift was largely dismissed because __________.

a) He could not explain the age of the ocean floor
b) He could not explain the location of mountain ranges
c) He could not explain how the continents moved
d) He could not explain volcanic activity
e) He could not provide fossil evidence

Wegener's theory of continental drift was largely dismissed because ________.

c) He could not explain how the continents moved

One of the main objections to Wegener's hypothesis was that he could not identify a credible mechanism for continental drift.

The jigsaw-like fit of __________ provided evidence for continental drift.

a) Asia and North America
b) North America and South America
c) South America and Africa
d) Europe and South America
e) Australia and North America

The jigsaw-like fit of __________ provided evidence for continental drift.

c) South America and Africa

The best of South America and Africa occurs along the continental slope.

The range of the fossil remains of *Mesosaurus* helped to support the idea of continental drift because:

a) The fossils were found worldwide which indicated they roamed Pangaea freely.

b) The fossils were only found in South America.

c) The fossils are still being discovered today off the coast of North America in deep marine sediments.

d) The fossils are found only on landmasses that are now widely separated, and it is unlikely that that the living organism could have crossed the barrier of a broad ocean.

e) The fossils provided numerical dates to correlate rocks across the present day ocean basins.

The range of the fossil remains of *Mesosaurus* helped to support the idea of continental drift because:

d) The fossils are found only on landmasses that are now widely separated, and it is unlikely that that the living organism could have crossed the barrier of a broad ocean.

New Evidence

Other evidence supported a new idea

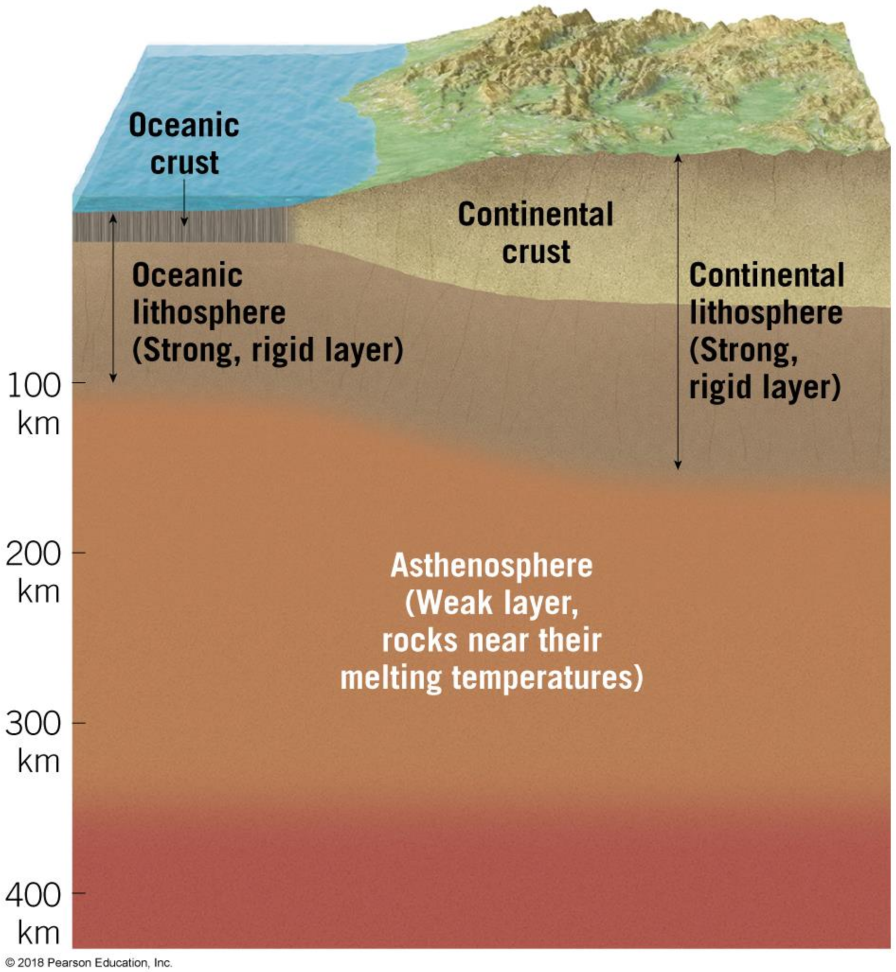
- Seafloor mapping showed a global oceanic ridge system winding through the major oceans
- Earthquakes were occurring at great depths beneath deep-ocean trenches
- Youngest seafloor discovered was 180 million years old
- Sediment accumulations in ocean basins were thin

Plate Tectonics

Theory of Plate Tectonics

- Rigid lithosphere overlies weak asthenosphere
  - Lithosphere: the strong layer formed from the crust and uppermost mantle
    - Varies in thickness and density
    - Continental is thicker and less dense
    - Rigid and therefore breaks
  - Asthenosphere: hotter, weaker region in the mantle
    - Solid, but near melting temperature
    - “Flows” beneath the lithosphere

The Rigid Lithosphere Overlies the Weak Asthenosphere



Pearson

The asthenosphere is part of __________.

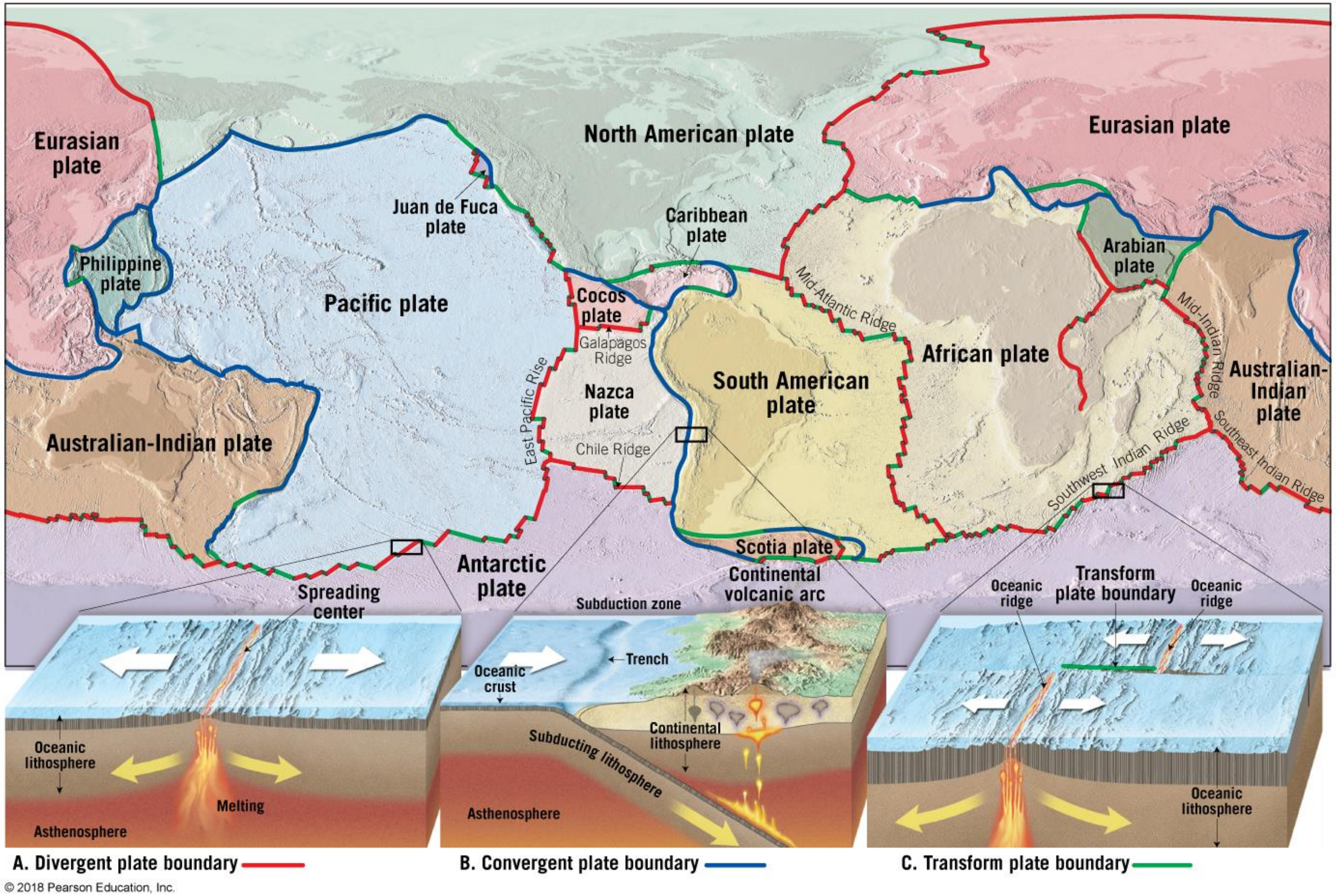
a) the continental crust
b) the mantle
c) the inner core
d) the outer core
e) The asthenosphere isn’t part of any of these layers.

The asthenosphere is part of __________.

b) the mantle

The asthenosphere is a hotter, weaker region in the mantle that lies beneath the lithosphere.

Figure 4.10
Earth’s Major Lithospheric Plates



Pearson

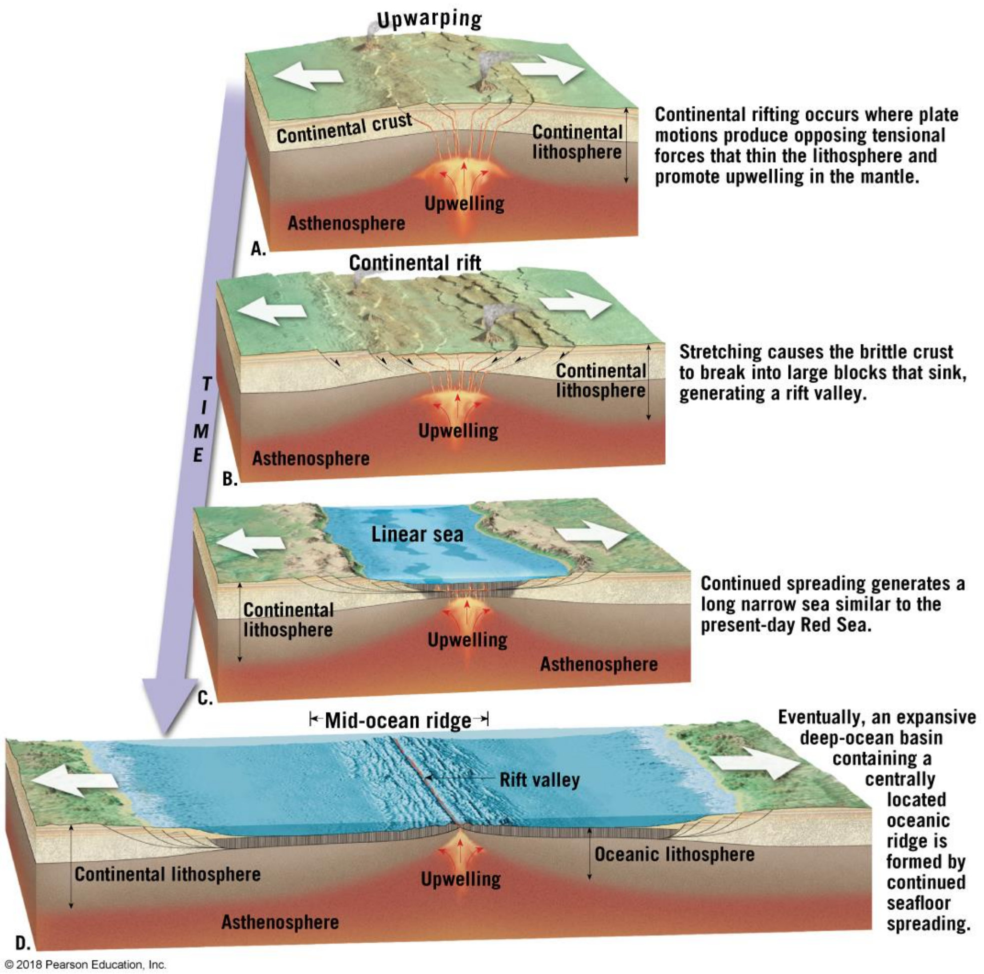
Plate Movement

- Lithospheric plates are in constant motion and major interactions occur at their boundaries
  - Divergent plate boundaries
    - Plates move apart from each other, making oceanic crust
  - Convergent plate boundaries:
    - Plates move toward each other, making mountains or volcanoes
  - Transform plate boundaries
    - Plates grind past each other without making or destroying crust

Divergent Plate Boundaries and Seafloor Spreading

- Two plates move apart
- Mantle material upwells to create new seafloor
- Ocean ridges and seafloor spreading
  - Oceanic ridges develop along well-developed boundaries
  - Along ridges, seafloor spreading creates new seafloor
- Continental rifts form at spreading centers within a continent

Continental Rifting: Formation of New Ocean Basins

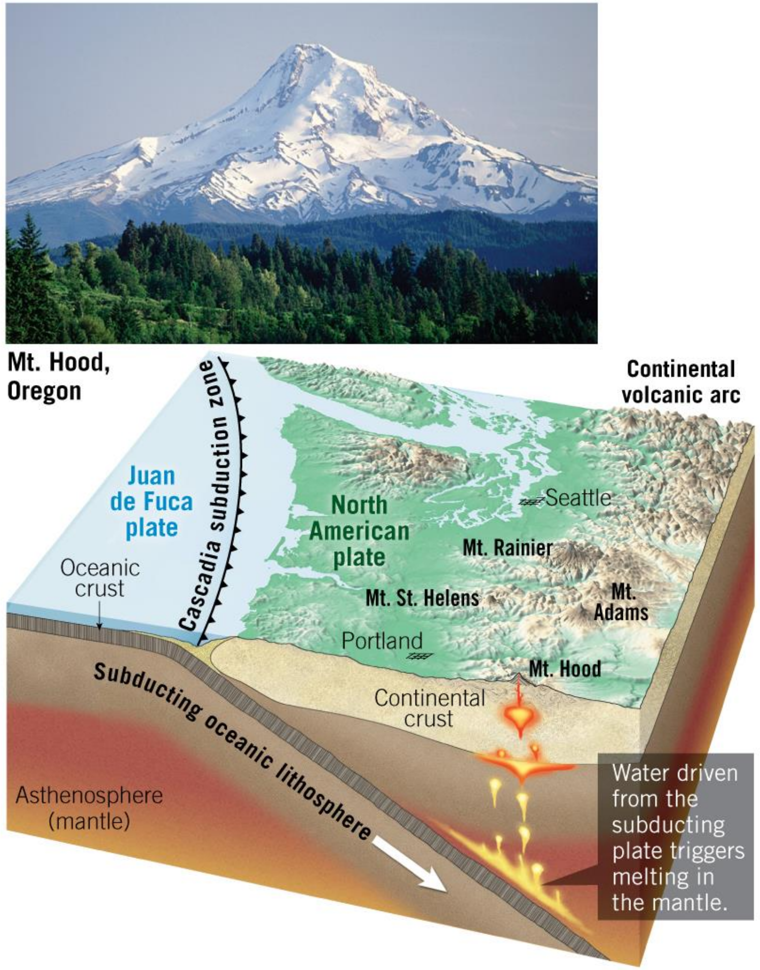


4.5 Convergent Plate Boundaries and Subduction

Compare and contrast the three types of convergent plate boundaries and name a location where each type can be found.

- Convergent plate boundaries (destructive margins)
  - Plates collide, an ocean trench forms and lithosphere is subducted into the mantle
  - Oceanic–continental convergence
    - Denser oceanic slab sinks into the asthenosphere
    - Pockets of magma develop and rise
    - Continental volcanic arc forms
    - Examples: Andes, Cascades, and the Sierra-Nevadan system

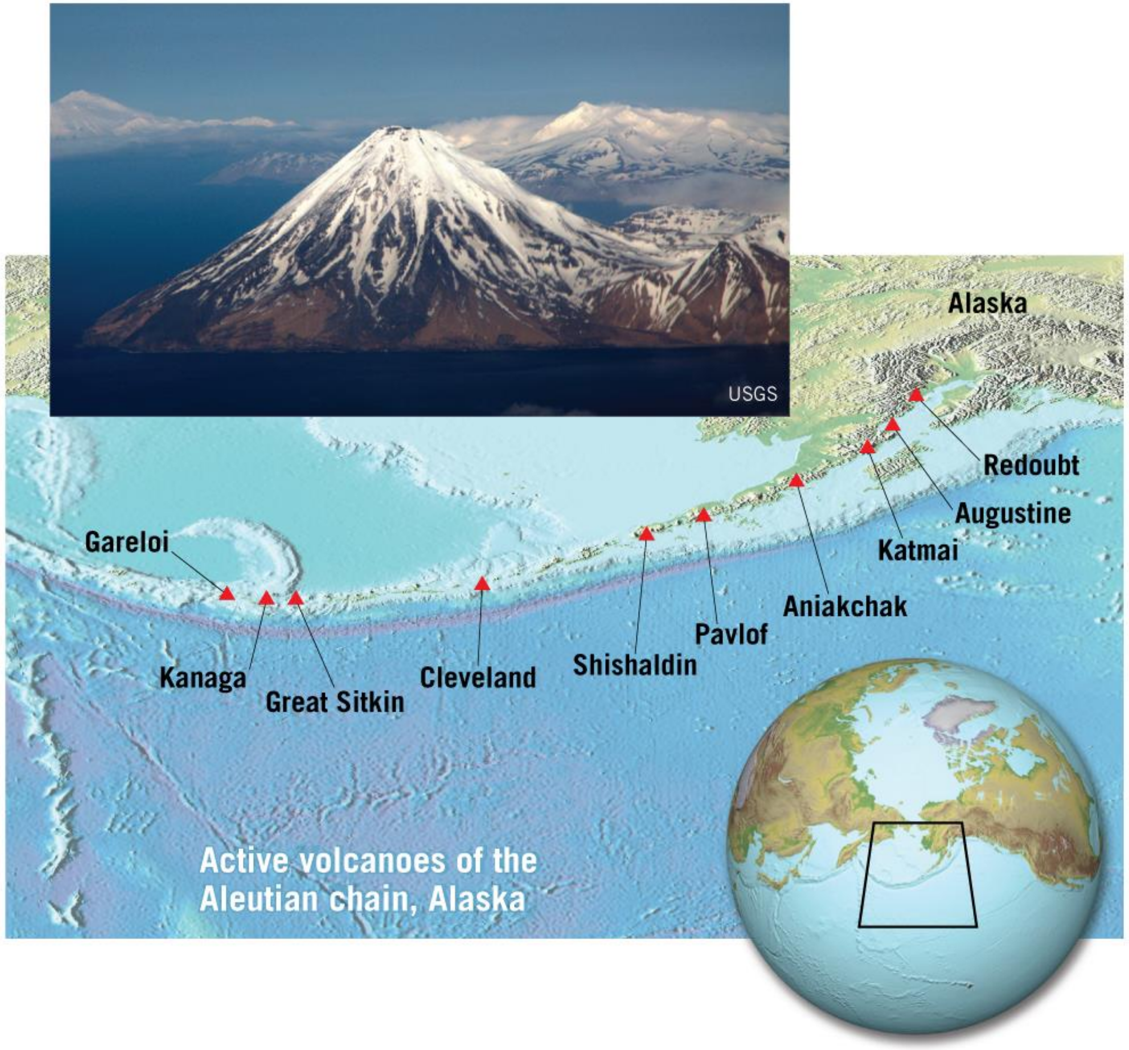
Example of Oceanic–Continental Convergent Plate Boundary



Convergent Plate Boundaries and Subduction

- Convergent plate boundaries (destructive margins)
  - Oceanic–oceanic convergence
    - Two oceanic slabs converge and one descends beneath the other
    - Often forms volcanoes on the ocean floor
    - Volcanic island arc forms as volcanoes emerge from the sea
    - Examples include the Aleutian, Mariana, and Tonga islands

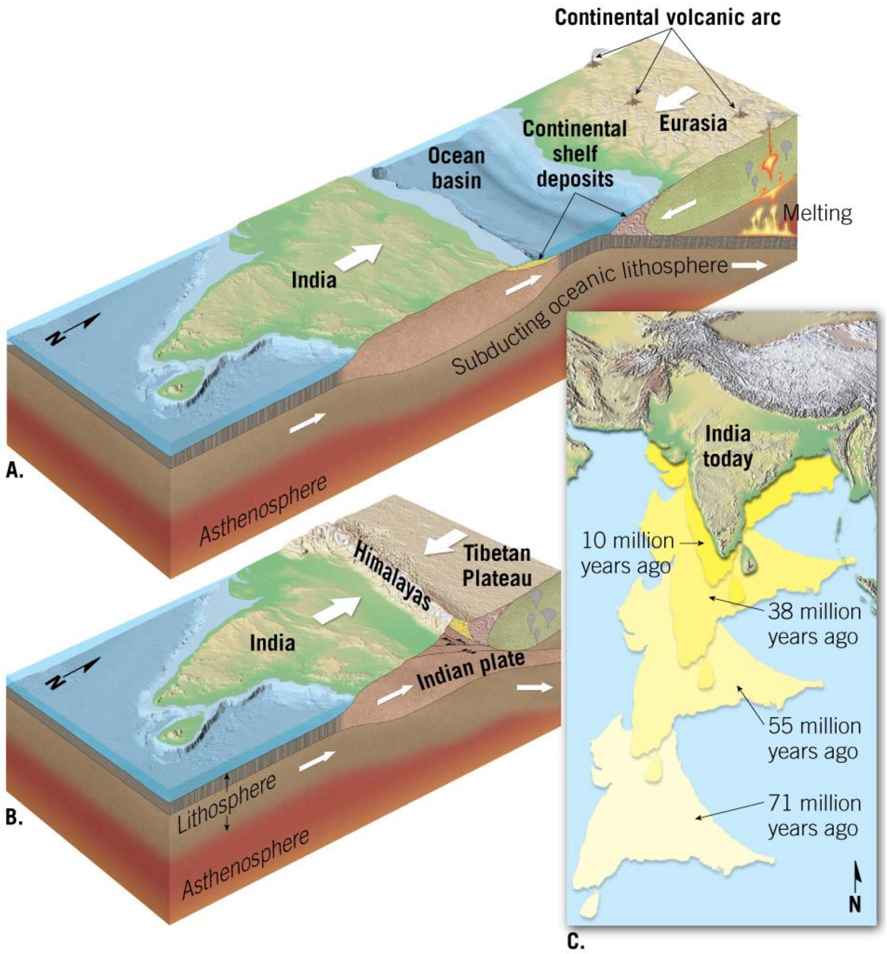
Volcanoes in the Aleutian Chain



Convergent Plate Boundaries and Subduction

- Convergent plate boundaries (destructive margins)
  - Continental–continental convergence
    - When subducting plates contain continental material, two continents collide
    - Can produce new mountain ranges such as the Himalayas

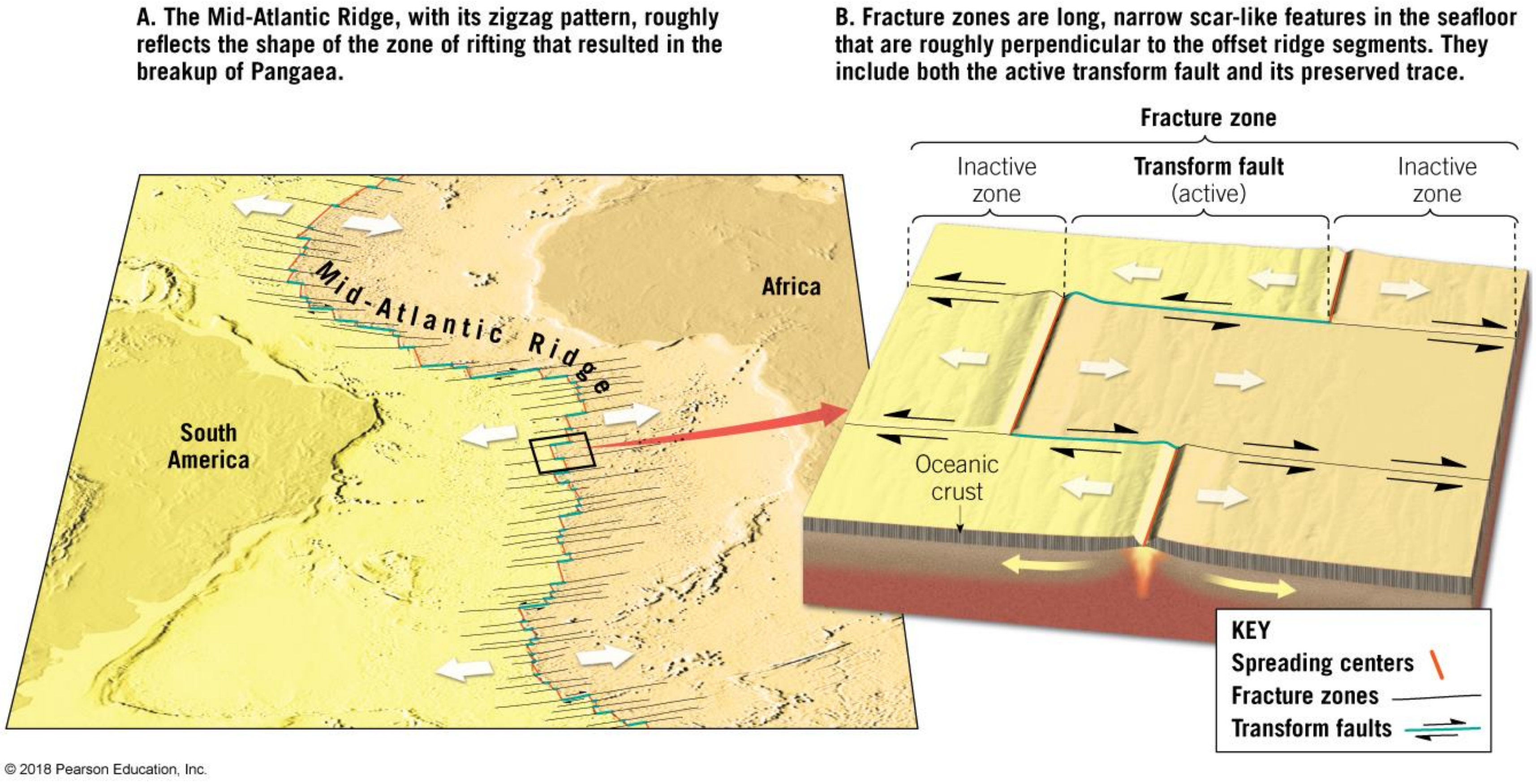
The Collision of India and Eurasia Formed the Himalayas



Transform Plate Boundaries

- Plates grind past one another
  - No new crust is created or destroyed
- Transform faults
  - Most join two segments of a mid-ocean ridge
  - Aid the movement of oceanic crustal material

Transform Plate Boundaries



__________ occur(s) where plates move apart.

a) Convergent boundaries
b) Transform boundaries
c) Divergent boundaries
d) Continental collisions
e) The destruction of seafloor

Pearson

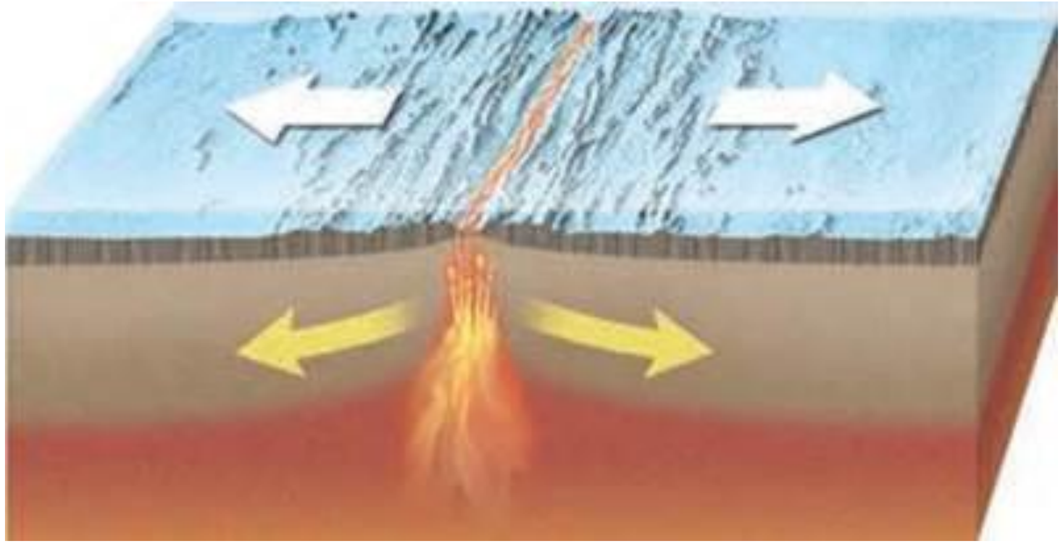
__________ occur(s) where plates move apart.

c) Divergent boundaries

Divergent boundaries occur where plates are moving apart from one another.

The figure below shows a ________ plate boundary.

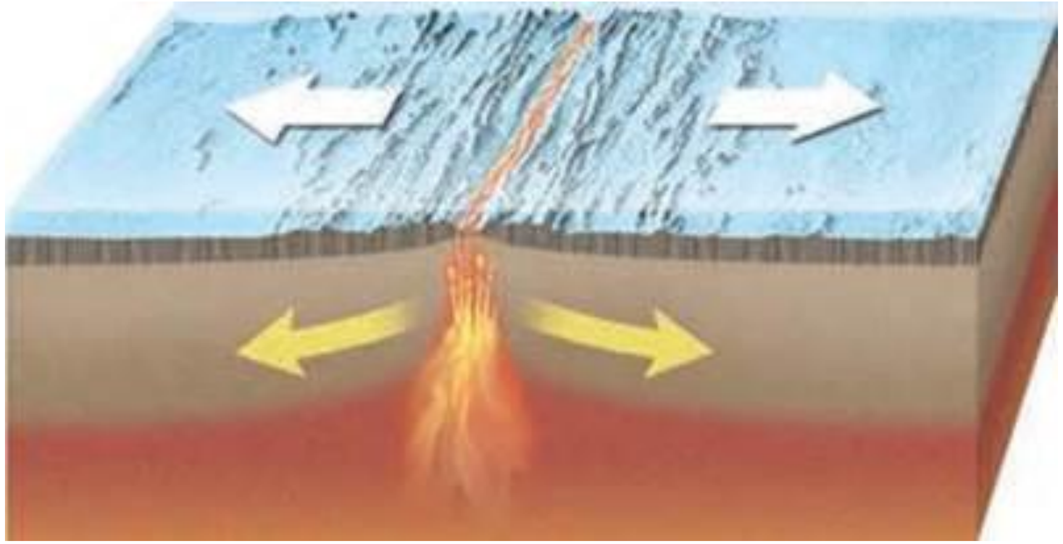
a) convergent
b) divergent
c) transform
d) hot Spot
e) collisional



The figure below shows a _______ plate boundary.

b) divergent

At divergent boundaries, two adjacent plates move away from each other.



Oceanic ridges occur above __________.

a) divergent boundaries
b) convergent boundaries
c) subduction zones
d) transform fault boundaries
e) deep ocean trenches

Oceanic ridges occur above ________.

a) divergent boundaries

Oceanic ridges form at nearly all divergent boundaries.

Deep-ocean trenches are found above __________.

a) divergent boundaries
b) subduction zones
c) hot spots
d) sea-floor spreading zones
e) rift valleys

Deep-ocean trenches are found above __________.

b) subduction zones

Deep-ocean trenches are long, linear depressions located along subduction zones.

Island arcs form at __________ boundaries.

a) oceanic-continental
b) continental-continental
c) oceanic-oceanic
d) divergent
e) transform

Island arcs form at __________ boundaries.

c) oceanic-oceanic

Oceanic-oceanic convergence results in a chain of volcanic islands known as an island arc.

A transform plate boundary is characterized by ________________.

a) a deep, vertical fault along which two plates slide past one another in opposite directions

b) stratovolcanoes on the edge of a plate and shield volcanoes on the adjacent plate

c) two converging oceanic plates meeting head-on and piling up into a mid-ocean ridge

d) a divergent boundary where the continental plate changes to an oceanic plate

e) a deep oceanic trench, where one plate plunges beneath another

A transform plate boundary is characterized by _______________.

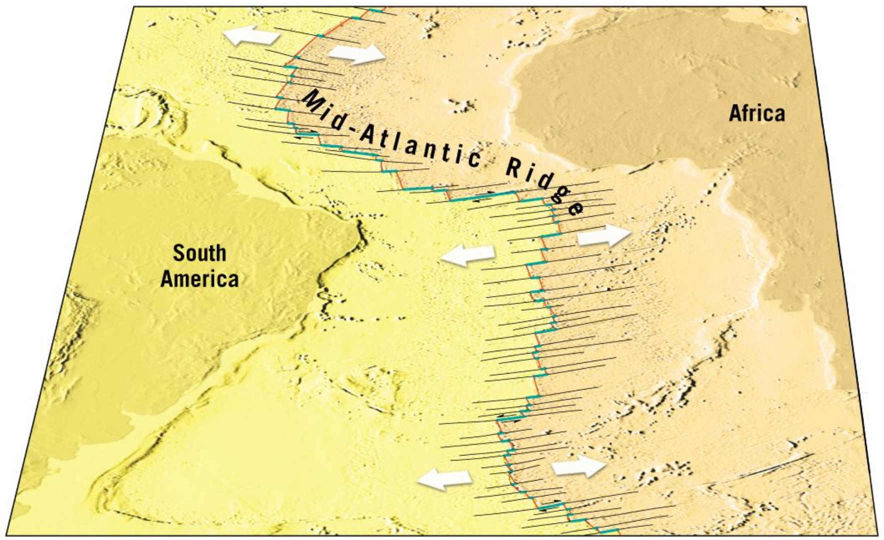
a) a deep, vertical fault along which two plates slide past one another in opposite directions

At a transform boundary, plates slide horizontally past one another without the production or destruction of lithosphere.

Which types of plate boundary is indicated by the green lines.

a) divergent boundary
b) convergent boundary
c) transform boundary
d) subduction zone
e) spreading center

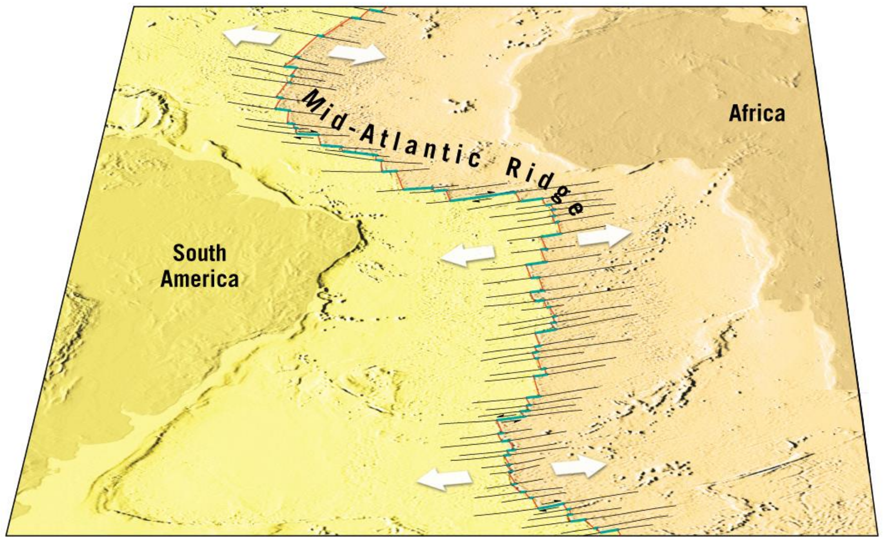
A. The Mid-Atlantic Ridge, with its zigzag pattern, roughly reflects the shape of the zone of rifting that resulted in the breakup of Pangaea.



Which types of plate boundary is indicated by the green lines.

c) transform boundary

A. The Mid-Atlantic Ridge, with its zigzag pattern, roughly reflects the shape of the zone of rifting that resulted in the breakup of Pangaea.

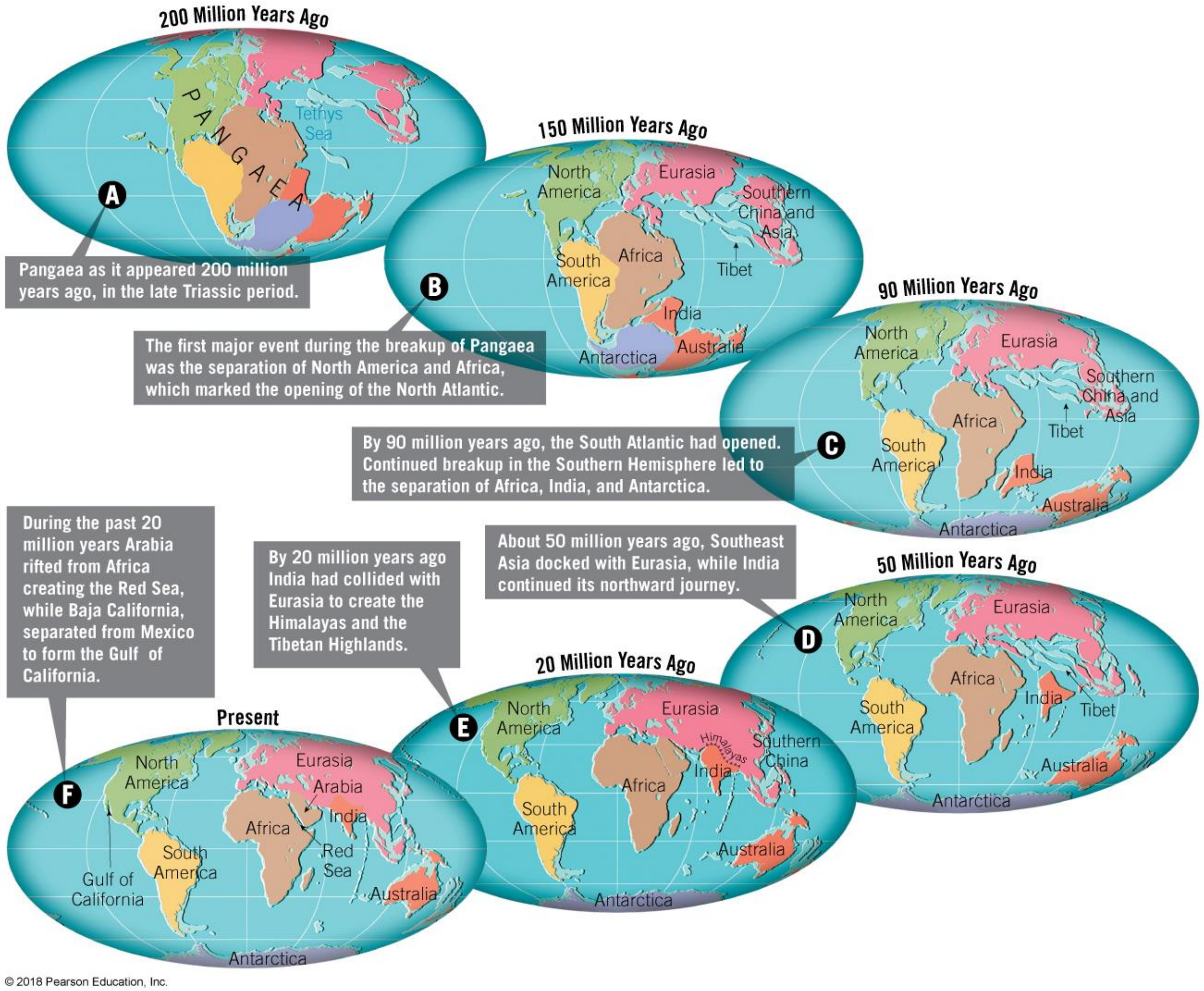


The green lines represent transform boundaries, where two plates are grinding past each other.

How Do Plates and Plate Boundaries Change?

- Plates and boundaries migrate and are created and destroyed
- Breakup of Pangaea
  - Formed a new ocean basin—the Atlantic
  - Did not occur all at one time
- Will continue to move over time

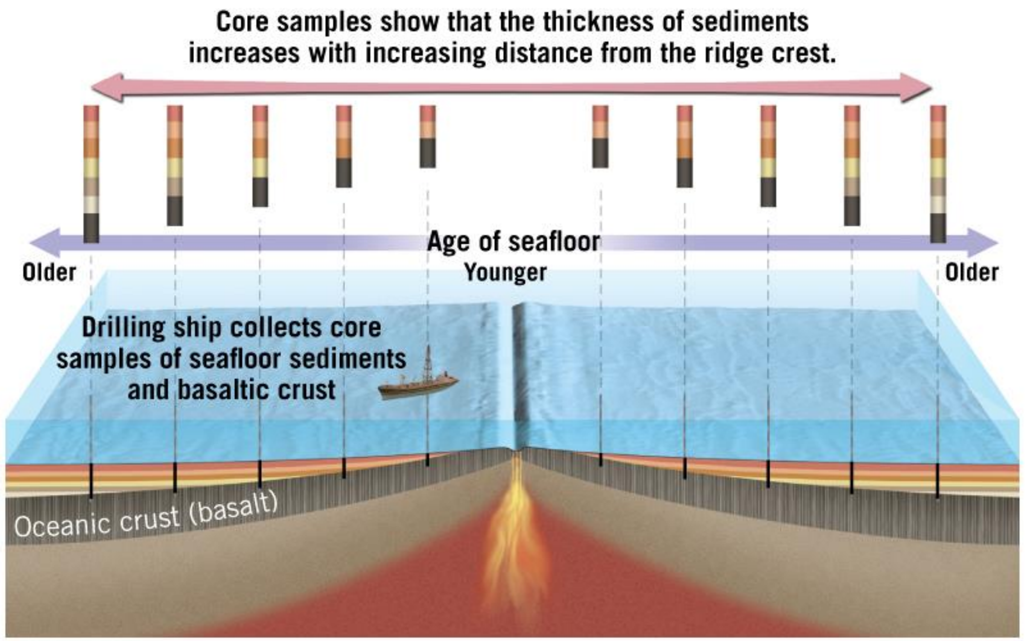
The Breakup of Pangaea



Testing the Plate Tectonics Model

- Evidence: Ocean drilling
  - Some of the most convincing evidence confirming seafloor spreading has come from drilling directly into ocean-floor sediment
    - Age of deepest sediments
    - Thickness of ocean-floor sediments verifies seafloor spreading

Deep-Sea Drilling



A.

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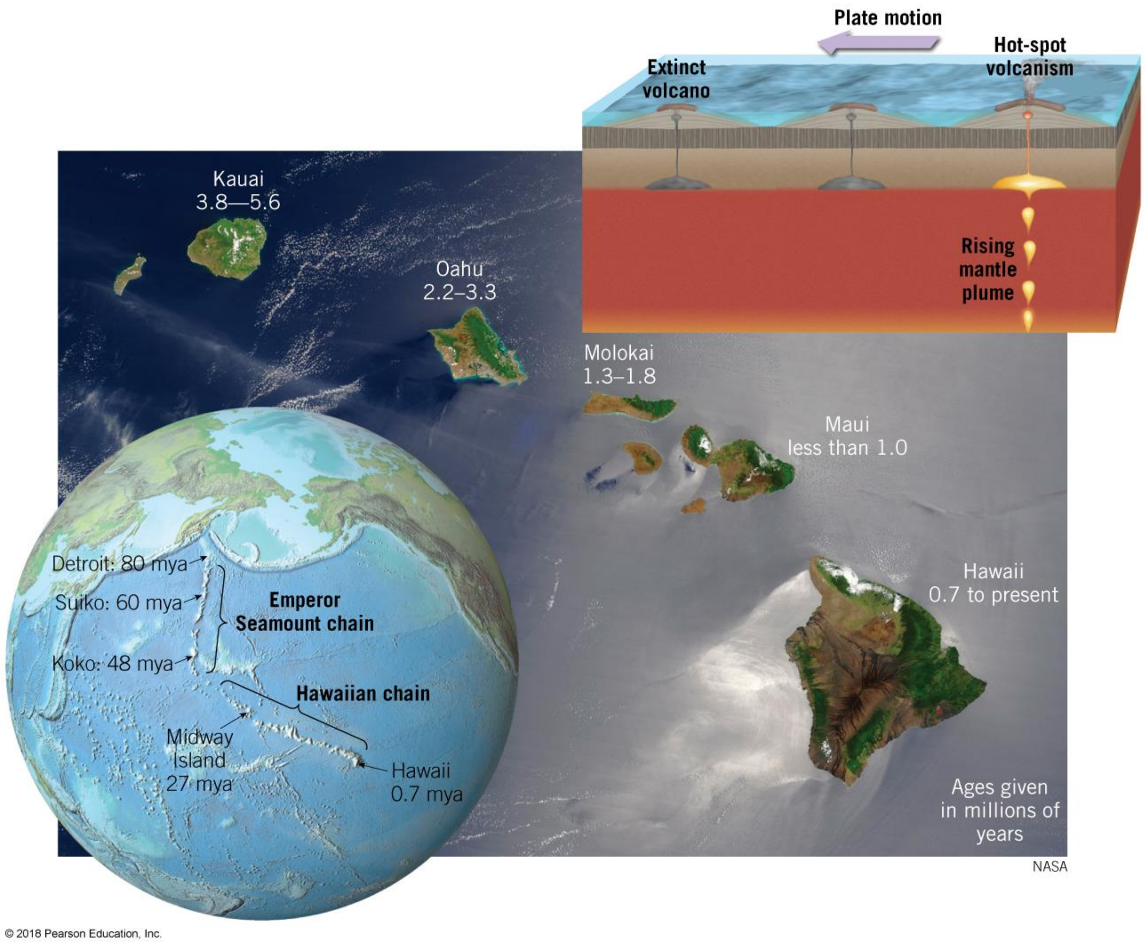
B.

Testing the Plate Tectonics Model

- Evidence: Mantle plumes and hot spots
  - Caused by rising plumes of mantle material
  - Volcanoes can form over them (Hawaiian Island chain)
  - Form a hot-spot track

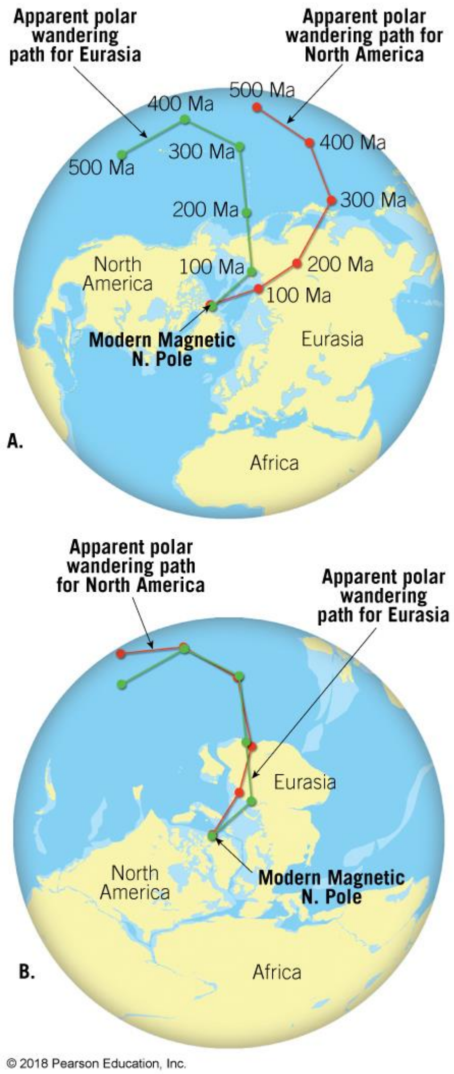
Hot-Spot Volcanism
Formation of the Hawaiian Chain



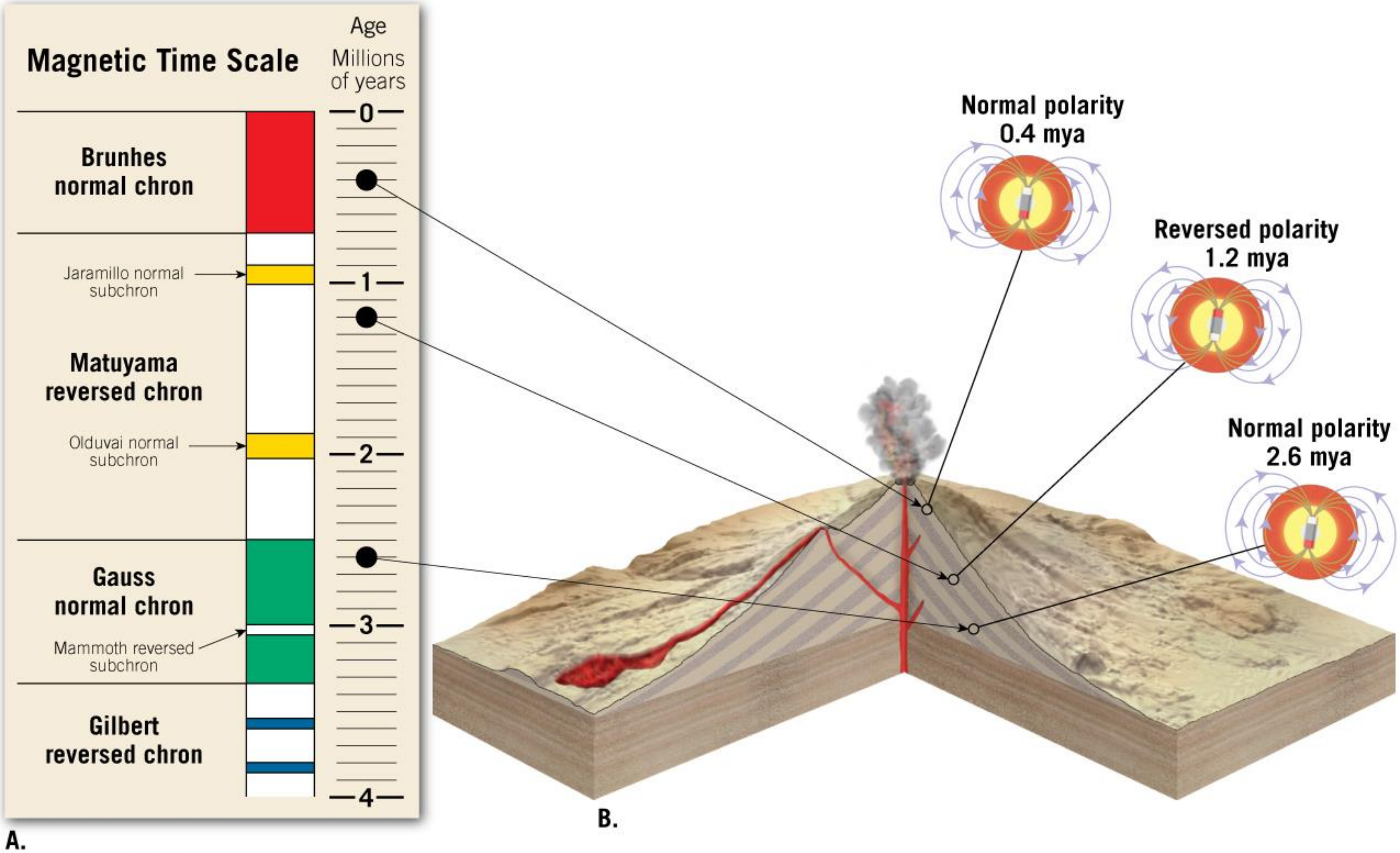
Testing the Plate Tectonics Model

- Evidence: Paleomagnetism
  - Probably the most persuasive evidence
  - Ancient magnetism preserved in rocks
  - Paleomagnetic records
    - Polar wandering
      - Shows conflicting evidence in rocks of the same age
    - Earth’s magnetic field reversals
      - Recorded in rocks as they form at oceanic ridges

Figure 4.28
Apparent Polar-Wandering Path



SmartFigure 4.29
Time Scale of Magnetic Reversals



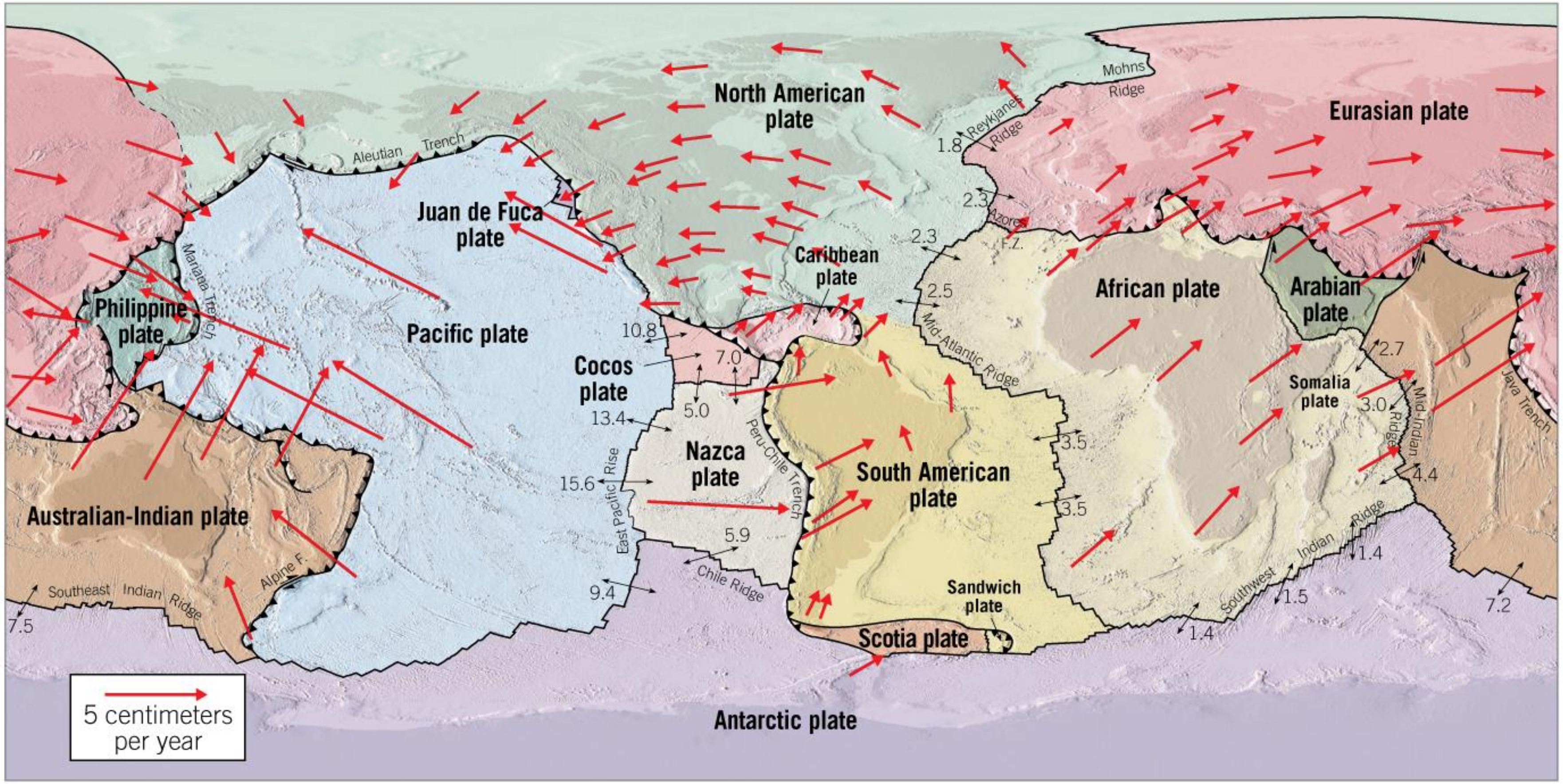
4.9 How Is Plate Motion Measured?

Describe two methods researchers use to measure relative plate motion.

- Ocean-drilling ships
  - Age dates of seafloor
  - Paleomagnetism
  - Examination of long fracture zones
- Using space-age technology to directly measure the relative motion of plates
  - Very Long Baseline Interferometry (VLBI)
  - Global Positioning System (GPS)

Figure 4.33
Rates of Plate Motion

Directions and rates of plate motions measured in centimeters per year



Pearson

What Drives Plate Motions?

- No one model explains all facets of plate tectonics
- Earth's heat is the key driving force, called convection

Figure 4.34 Convection in a Cooking Pot

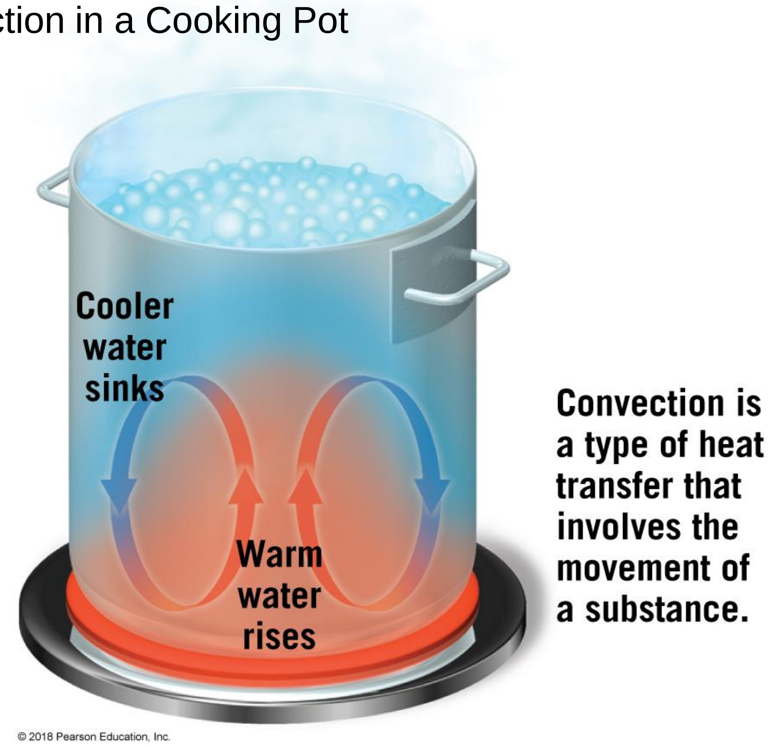
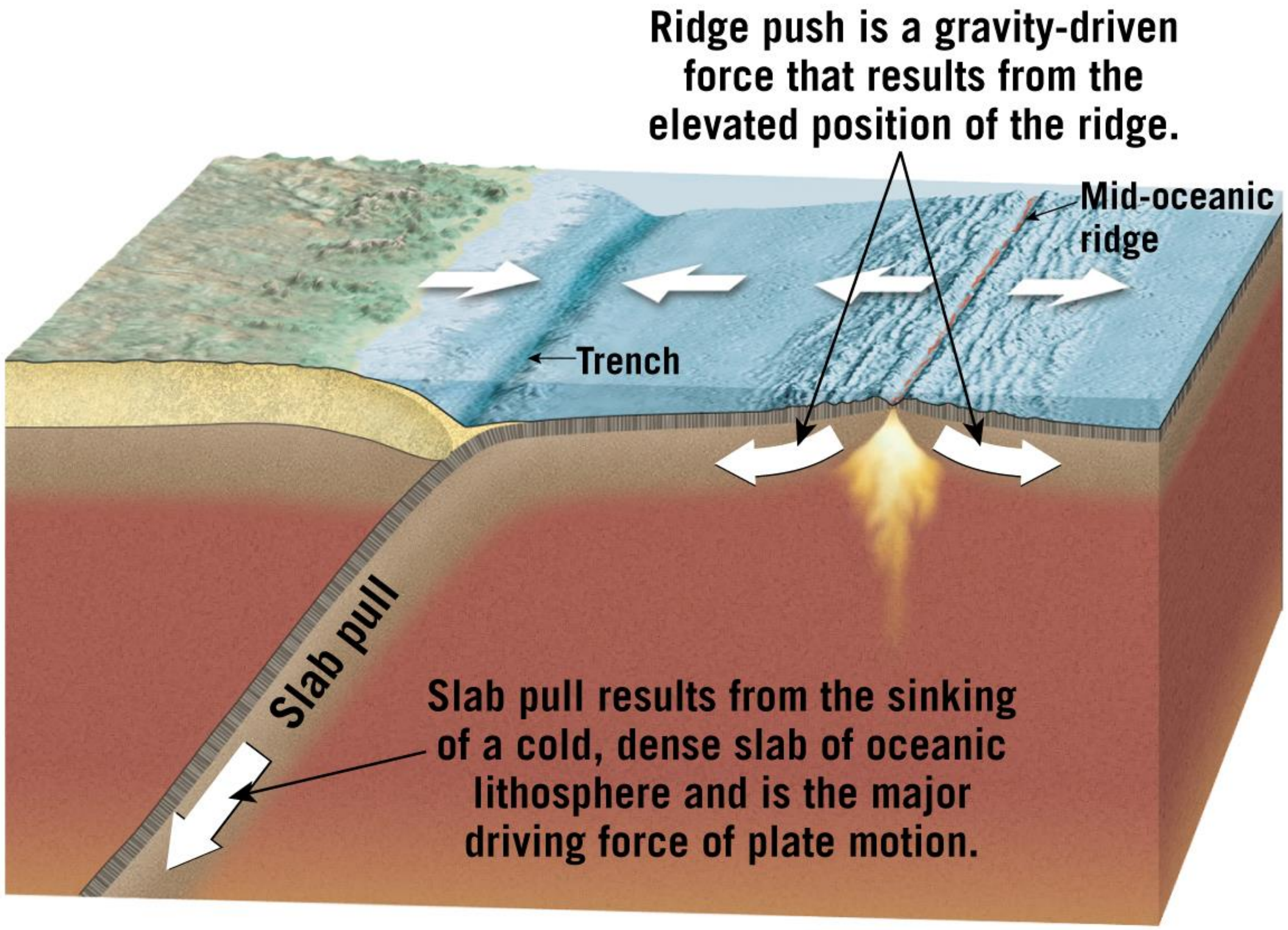


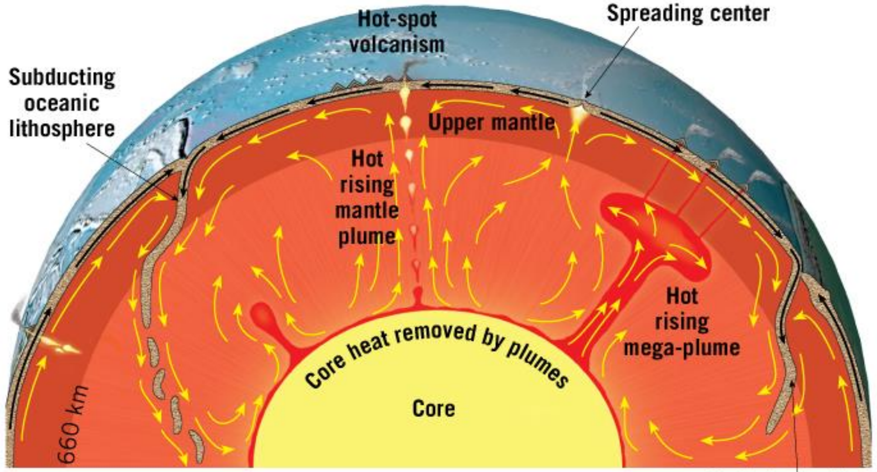
Figure 4.35
Forces That Act on Lithospheric Plates



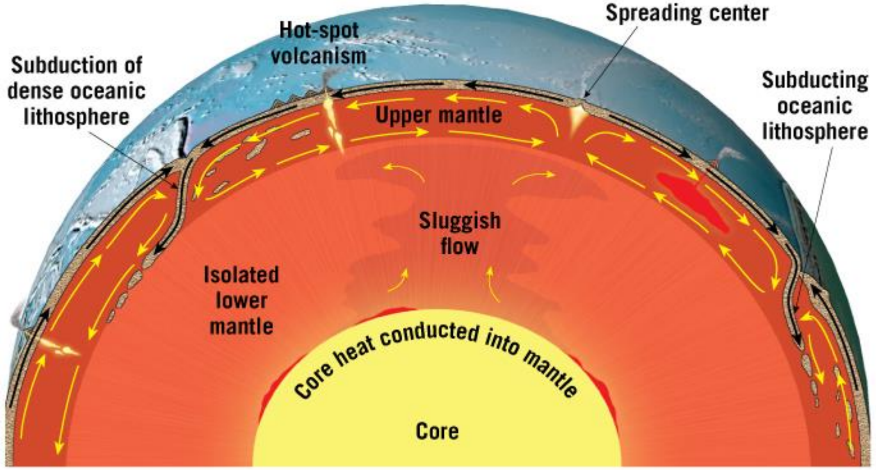
Models of Plate–Mantle Convection

- Several models have been proposed
  - Whole-Mantle Convection Model
    - Descending oceanic crust descends to great depth
    - Buoyant plumes transfer heat to the surface from the core-mantle boundary
  - Layer Cake Model
    - Mantle is divided at depth and there are two zones of convection
    - The upper convection cell is the only one that reaches the surface

Models of Mantle Convection



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.

Today, _________ is in about the same geographic position as it was about 90 million years ago.

a) India
b) South America
c) Australia
d) Antarctica
e) none of the above

Today, ________ is in about the same geographic position as it was about 90 million years ago.

d) Antarctica

Antarctica is in roughly the same geographic position it occupied about 90 million years ago.

Plate tectonic evidence indicates that which of the following is likely to occur in the future?

a) The Baja Peninsula will move southward and collide with South America.

b) Africa will collide with Australia.

c) The Atlantic Ocean will continue to widen.

d) The Atlantic Ocean will eventually close.

e) A new ocean basin will form in central South America.

Plate tectonic evidence indicates that which of the following is likely to occur in the future?

d) The Atlantic Ocean will eventually close.

Well into the future, continued subduction of the Atlantic Ocean floor will result in the closing of the Atlantic basin.

The temperature below which magnetic material can retain a permanent magnetization is called the ___________.

a) Darcy temperature
b) Vine temperature
c) Bullard point
d) Curie point
e) Absolute temperature

The temperature below which magnetic material can retain a permanent magnetization is called the __________.

d) Curie point

The Curie point is about 585°C.

The Hawaiian Islands formed above a __________.

a) divergent zone
b) subduction zone
c) hot spot
d) sea-floor spreading zone
e) rift valley

The Hawaiian Islands formed above a __________.

c) hot spot

The Hawaiian Islands provide evidence of plate tectonics because they have formed over a stationary hot spot while the plate they are on has moved over it.

Examine the map of magnetic stripes below. What can you conclude about the central red zone?

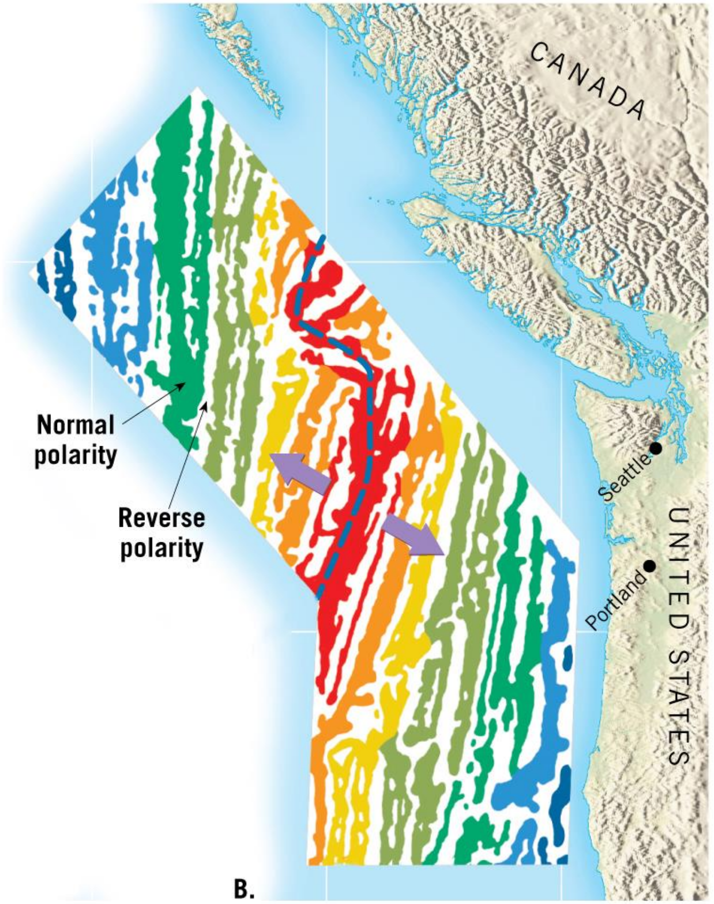
a) It represents the oldest rocks.

b) It represents the youngest rocks.

c) It is a spreading center.

d) It is a spreading center, and the oldest rocks on this map.

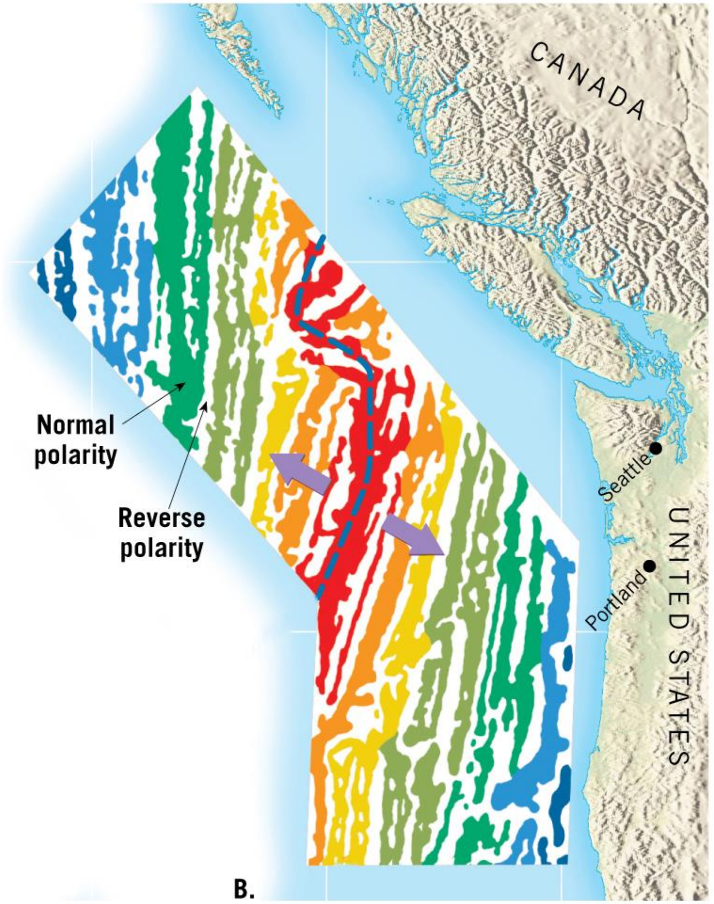
e) It is a spreading center, and the youngest rocks on this map.



Examine the map of magnetic stripes below. What can you conclude about the central red zone?

e) It is a spreading center, and the youngest rocks on this map.

The red zone is a spreading center along the Juan de Fuca Ridge, and therefore contains the youngest rocks on this map.



Which one of the following is used by researchers to measure relative plate motion?

a) mapping the age of the ocean floor
b) mapping the temperature of the ocean floor
c) the location of hot spots
d) mapping of the composition of the ocean floor
e) None of these provide evidence for measuring plate motion.

Which one of the following is used by researchers to measure relative plate motion?

a) mapping the age of the ocean floor

The ocean floor is youngest near mid-ocean ridges, and gets older further away.

The map below shows the age of ocean floor with red being the youngest and blue and purple the oldest. Based on this map, which area must have the fastest spreading rate?

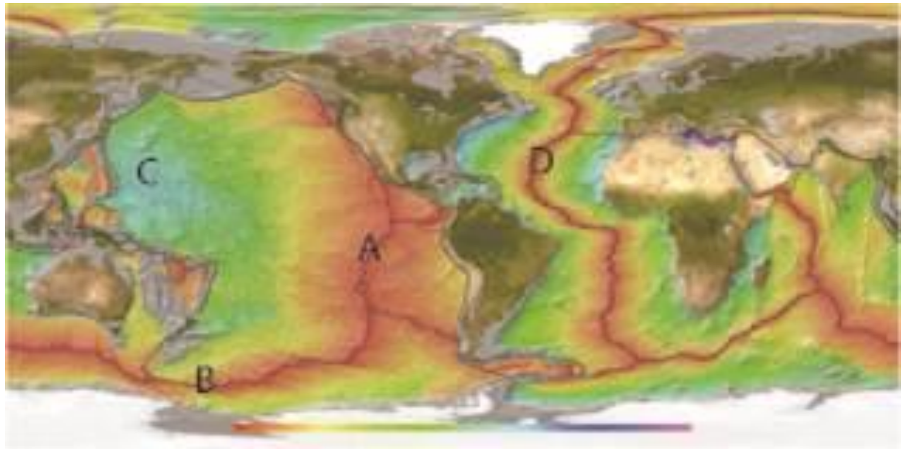
a) A

b) B

c) C

d) D

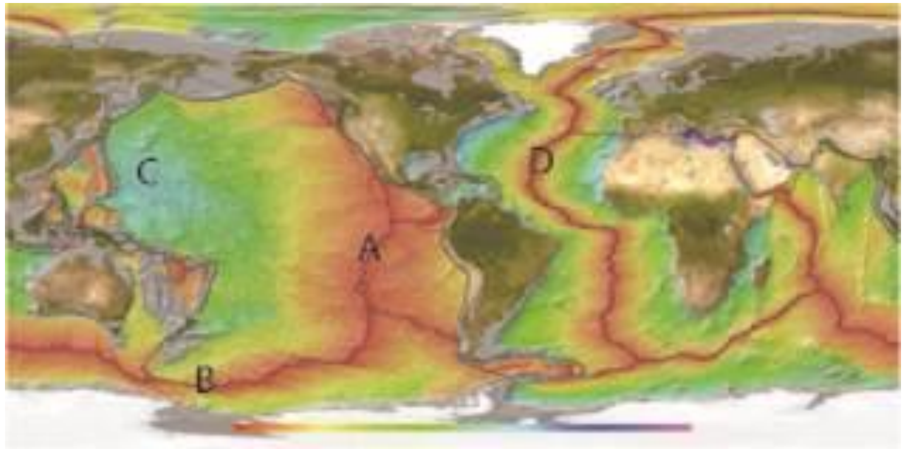
e) It is impossible to determine.



The map below shows the age of ocean floor with red being the youngest and blue and purple the oldest. Based on this map, which area must have the fastest spreading rate?

a) A

A has the fastest spreading rate because it has the widest section of young ocean floor, so more material has formed there than in any of the other labeled areas.



Which of the following energy sources is thought to drive the lateral motions of Earth's lithospheric plates?

a) gravitational attractive forces of the Sun and Moon
b) electrical and magnetic fields localized in the inner core
c) swirling movements of the molten iron particles in the outer core
d) the hydrologic cycle
e) none of the above

Which of the following energy sources is thought to drive the lateral motions of Earth's lithospheric plates?

e) none of the above

Some type of convection appears to drive the motion of plates.