Fundamentals of Physical Geography 2e

Earth Materials and Plate Tectonics

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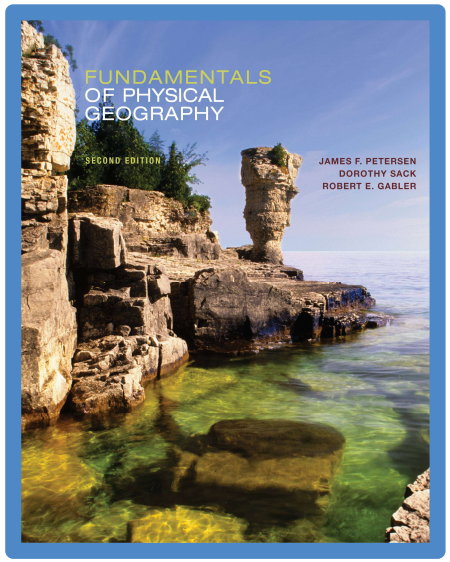


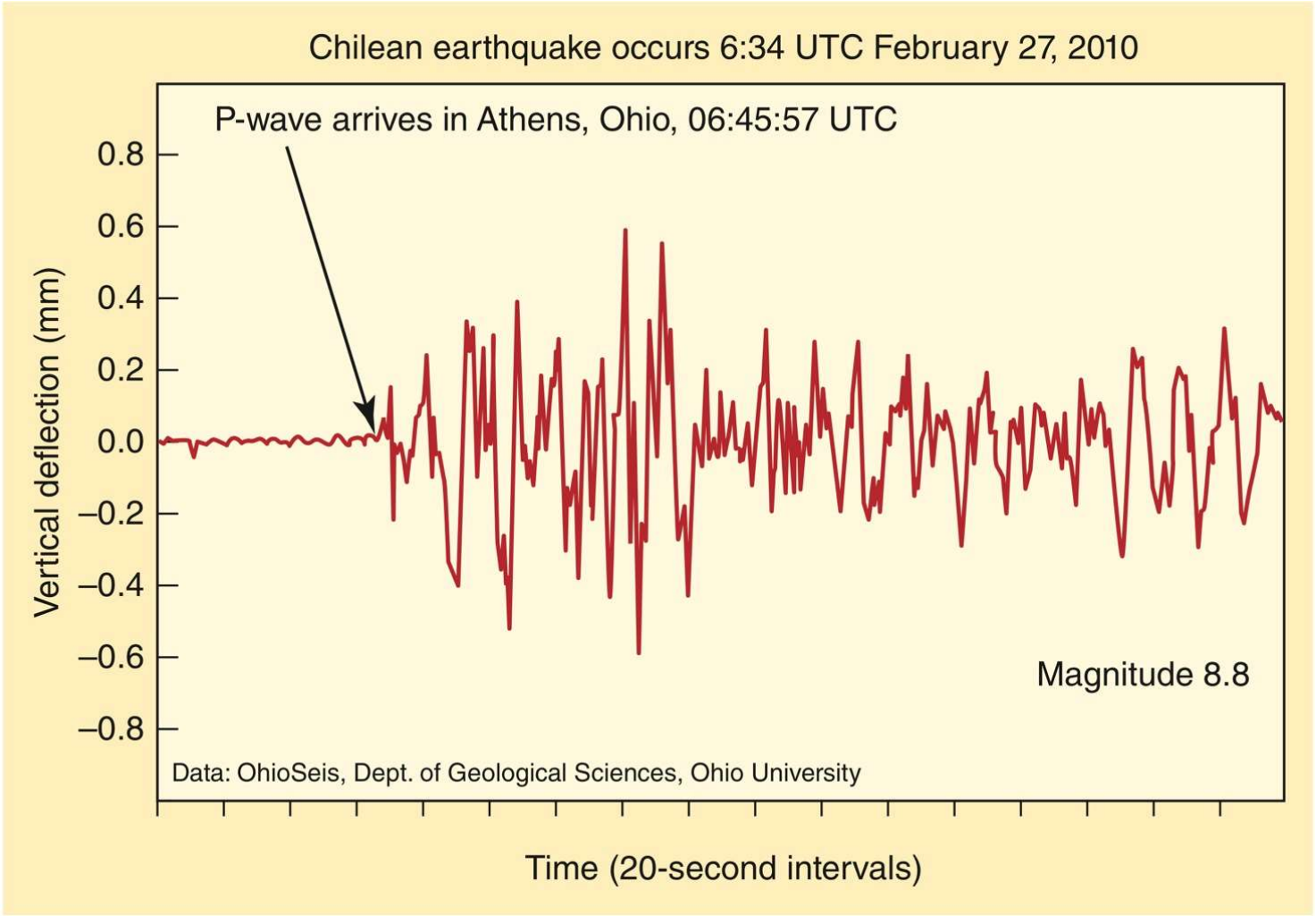
- Peterson
  - Sack
    - Gabler

Earth's Planetary Structure

- Gravity holds all matter within Earth's system
  - Materials with greatest density
    - Greatest gravitational force
  - Density continuum
    - Earth's center (densest) to the outer edge of the atmosphere (least dense)
- Earth's radius: 6,400 km (4,000 mi)
  - Very small portion examined directly
    - Mining and drilling

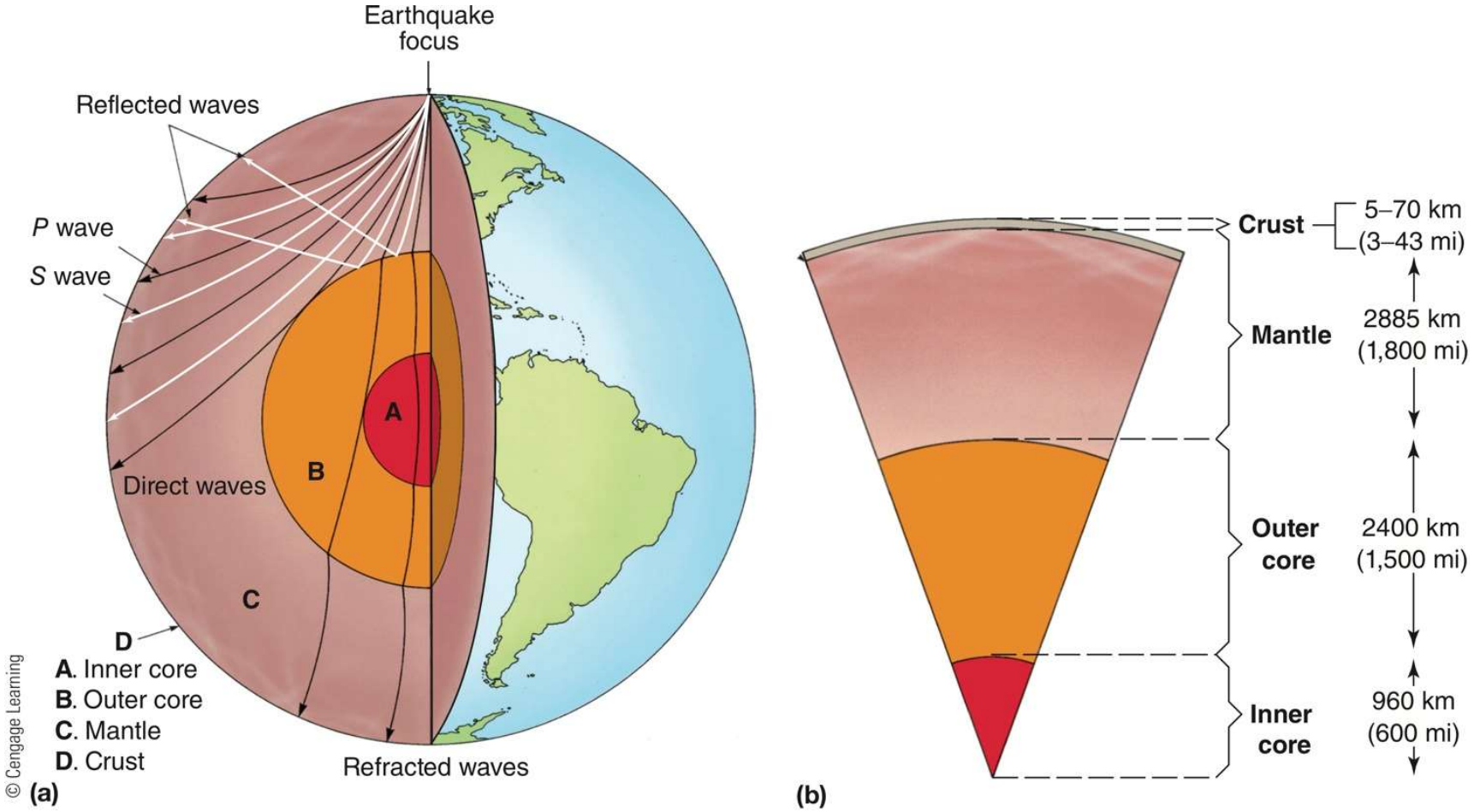
Earth's Planetary Structure (cont'd.)

- Indirect means of studying
  - Remote sensing
  - Seismic waves of earthquakes
  - Data collected over decades
    - Analyzed to develop a general model
- Principal zones
  - Core
  - Mantle
  - Crust



D. Sack

At what average speed did the seismic waves travel through Earth to Athens from Chile?



Which of Earth's internal zones is the largest?

Earth's Planetary Structure (cont'd.)

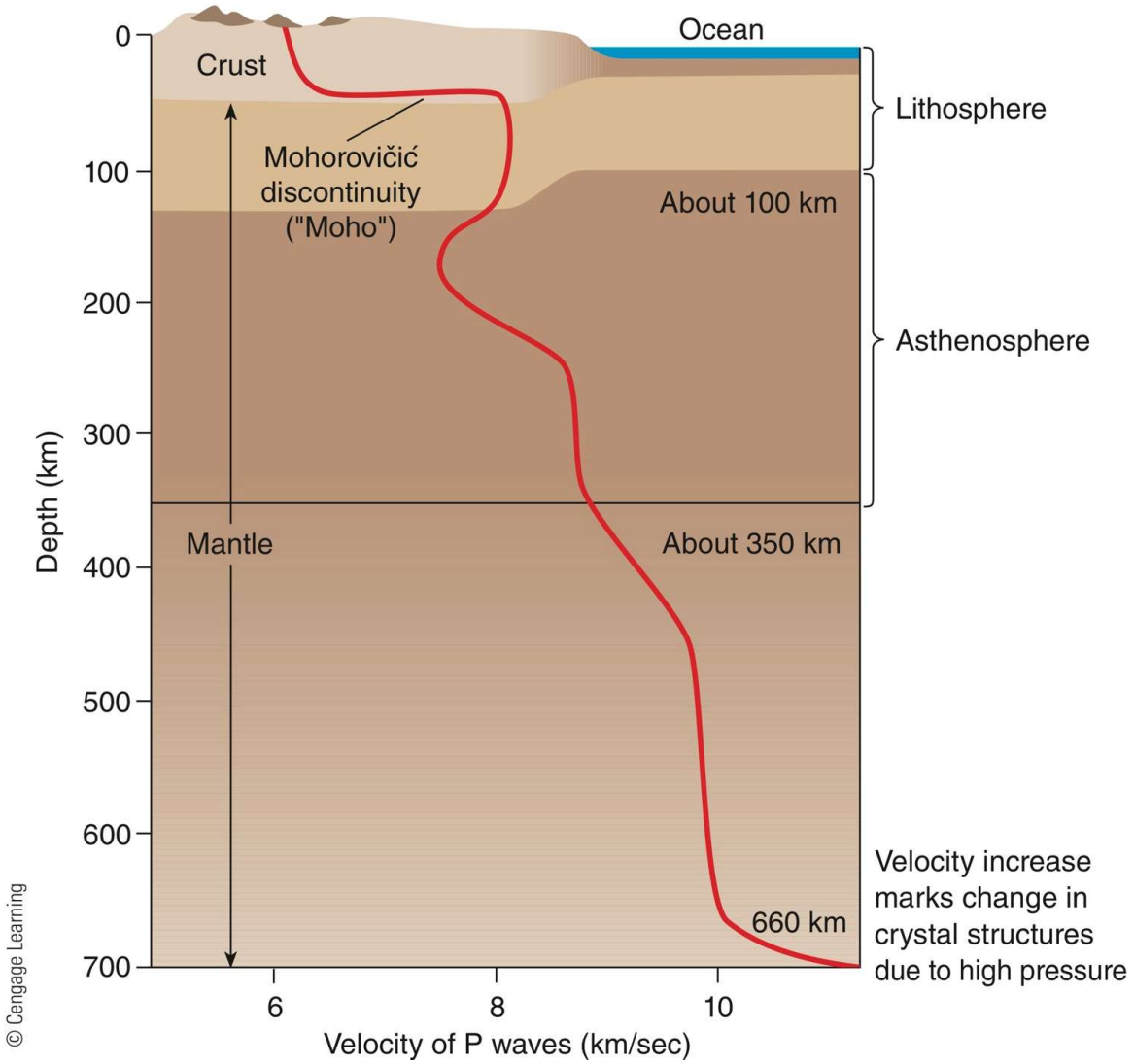
- Core: innermost section
  - One third of Earth's mass
  - Radius: 3,360 km (2,100 mi)
  - Under extreme pressure
  - Composition: iron and nickel
  - Sections
    - Inner core: solid; very high density (13 g/cm^3)
    - Outer core: molten rock matter; high density (10 g/cm^3)

Earth's Planetary Structure (cont'd.)

- Core
  - Temperatures
    - Top of outer core: 4,800°C (8,600°F)
    - Center of earth: 6,900°C (12,400°F)
  - Why is the inner core solid if the cooler outer core is molten?
- Mantle
  - Thickness: 2,885 km (1,800 mi)
  - Two thirds of Earth's mass

Earth's Planetary Structure (cont'd.)

- Mantle
  - Largest interior zone
  - Composition: solid rock material
    - Silicate, iron, and magnesium
  - Less dense than core
  - Mohorovičić discontinuity: Moho
    - Interface between the mantle and crust
    - Significant change of density



Where is the most abrupt change in material density in the upper 700 kilometers of the solid Earth?

Earth's Planetary Structure (cont'd.)

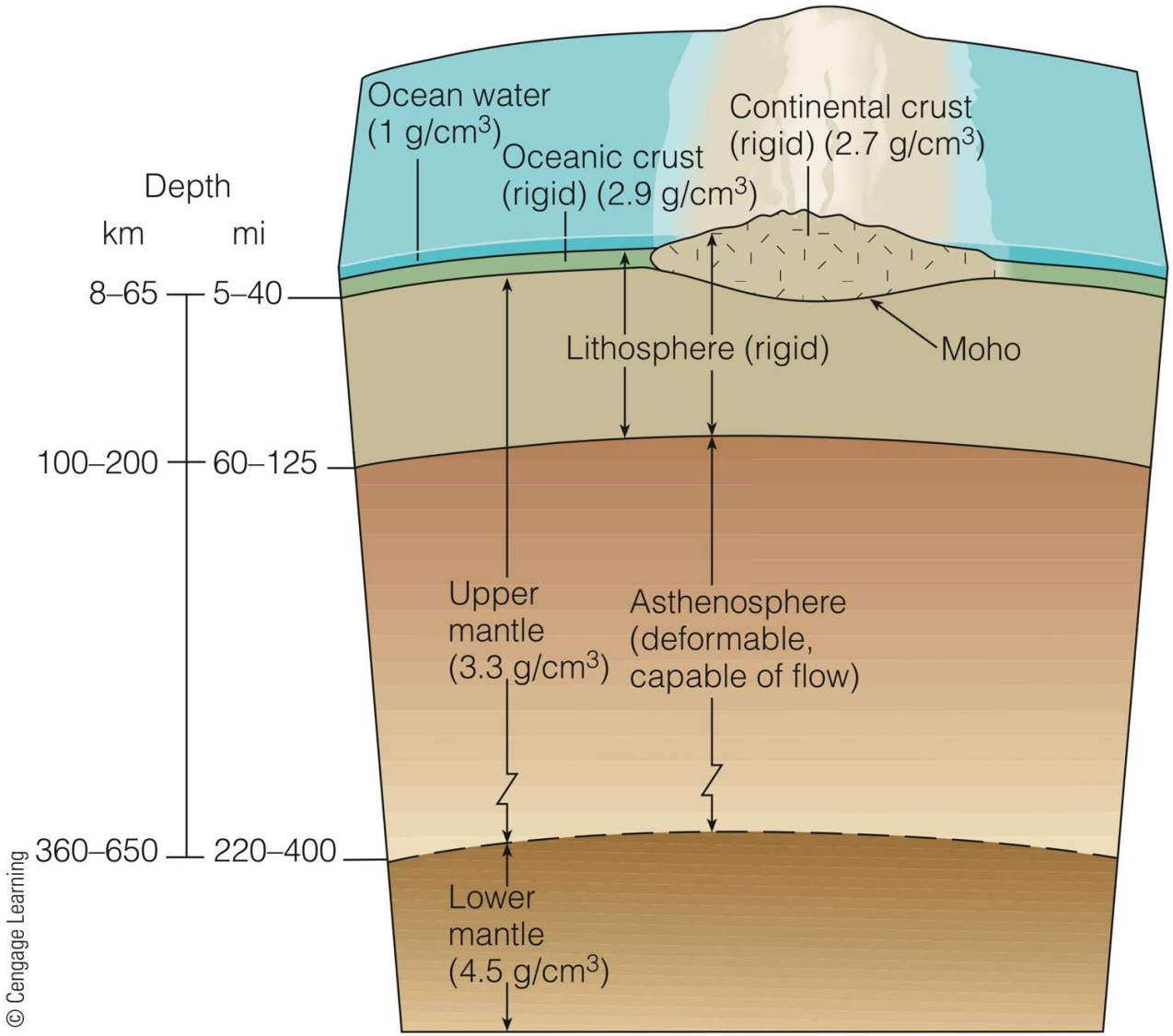
- Crust
  - Solid exterior
  - One percent of Earth's mass
  - Ocean floor and continents
  - Density: significantly less than core and mantle
  - Types
    - Oceanic crust
    - Continental crust

Earth's Planetary Structure (cont'd.)

- Oceanic crust
  - Basalt
    - Most common on Earth
- Continental crust
  - Much thicker than oceanic crust
  - Less dense than oceanic crust
  - Granitic composition

Earth's Planetary Structure (cont'd.)

- Lithosphere
  - Uppermost mantle and overlying crust
  - Elastic solids: rigid and brittle
    - Little deformation under applied stress until threshold limit reached ► fractures
- Asthenosphere
  - Thick layer of the upper mantle
  - Plastic solid
    - Deforms and flows under stress



Which is denser, oceanic crust or continental crust?

Earth's Planetary Structure (cont'd.)

- Asthenosphere
  - Movement
    - Provides energy for tectonic forces
    - Produced by thermal convection currents below

Minerals

- Building blocks of rocks
- Inorganic; crystalline substance
  - Distinct chemical formula
- Most common mineral groups
  - Silicates: 92% of Earth's crust
  - Oxides
  - Carbonates
- Hardness and resistance
  - Depends on chemical bonds

Table 10.1
Most Common Elements in Earth's Crust

Element	Percentage of Earth's Crust by Weight
Oxygen (O)	46.60
Silicon (Si)	27.72
Aluminum (Al)	8.13
Iron (Fe)	5.00
Calcium (Ca)	3.63
Sodium (Na)	2.83
Potassium (K)	2.70
Magnesium (Mg)	2.09
Total	98.70

Source: J. Green, "Geotechnical Table of the Elements for 1953," *Bulletin of the Geological Society of America 64* (1953).

Rocks

- Consolidated aggregate
  - One or more minerals
- Properties (Appendix E)
  - Composite of the mineral constituents
- Fundamental building materials of the lithosphere

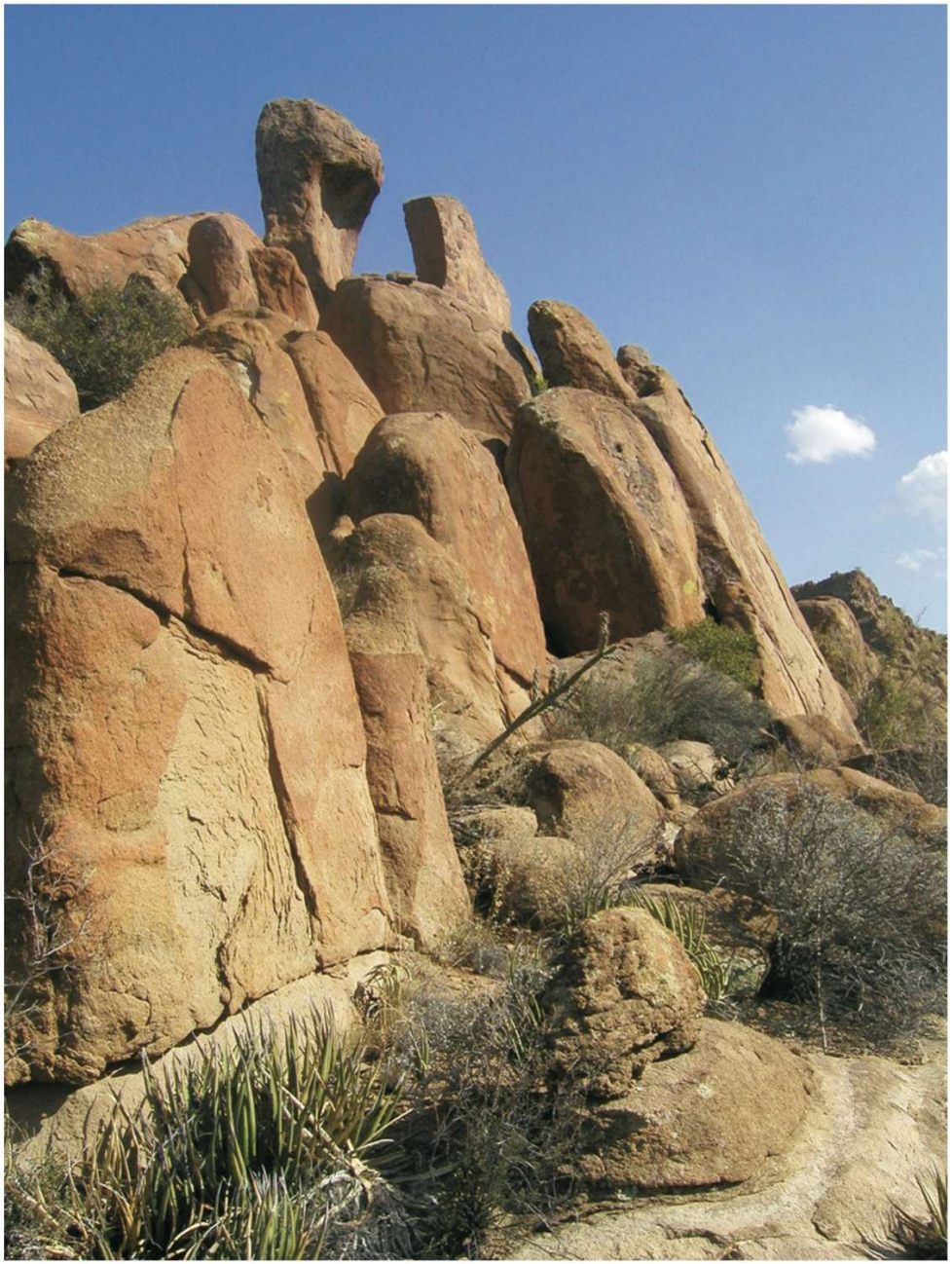
J. Petersen

How many different mineral types visually dominate this sample of granite?

Rocks (cont'd.)

- Bedrock
  - Consolidated rock
  - Not weathered
- Regolith
- Outcrop
- Rock types
  - Igneous rocks
  - Sedimentary
  - Metamorphic

What physical characteristics of this rock outcrop have caused it to protrude above the general land surface?



J. Petersen

Rocks (cont'd.)

- Igneous rocks
  - Solidified molten rock material
  - Magma: below surface
  - Lava: at surface
  - Categories
    - Extrusive
    - Intrusive

USDI/US Geological Survey

What features besides the red color indicate the part of the flow that was added most recently?

Rocks (cont'd.)

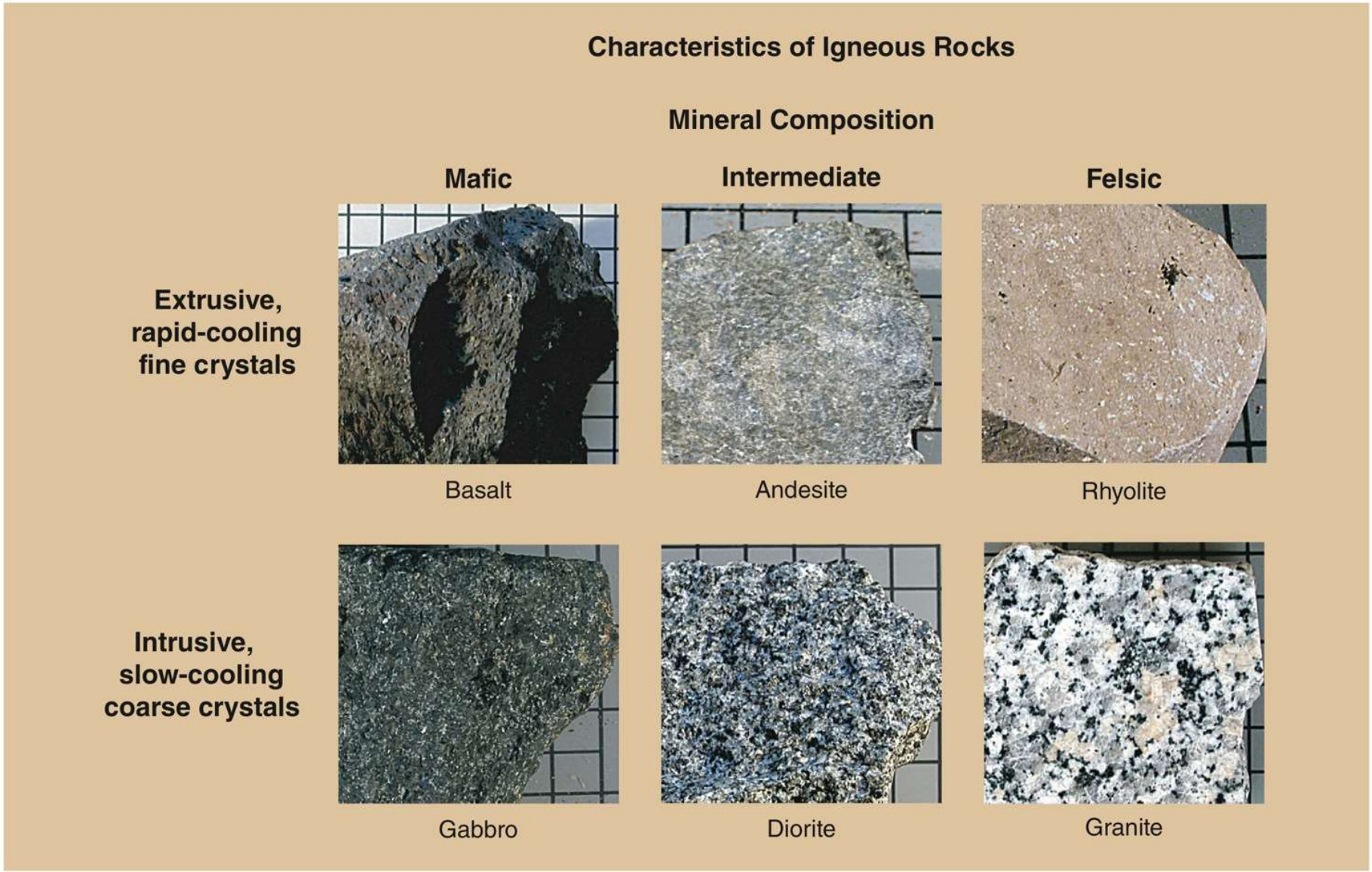
- Extrusive igneous rock: volcanic rock
  - Solidifies at Earth's surface
  - Pyroclastics: fragments
- Intrusive igneous rock: plutonic rock
  - Magma solidifies (freezes) beneath Earth's surface

J. Good, National Park Service

J. Good, National Park Service

Rocks (cont'd.)

- Igneous rocks
  - Classification
    - Based on mineral composition and texture
  - Chemical composition
    - Felsic: light-colored, lower density minerals
    - Mafic: rich in heavy minerals
    - Intermediate composition: diorite and andesite
  - Joints
    - What causes cracks to form in igneous rocks?



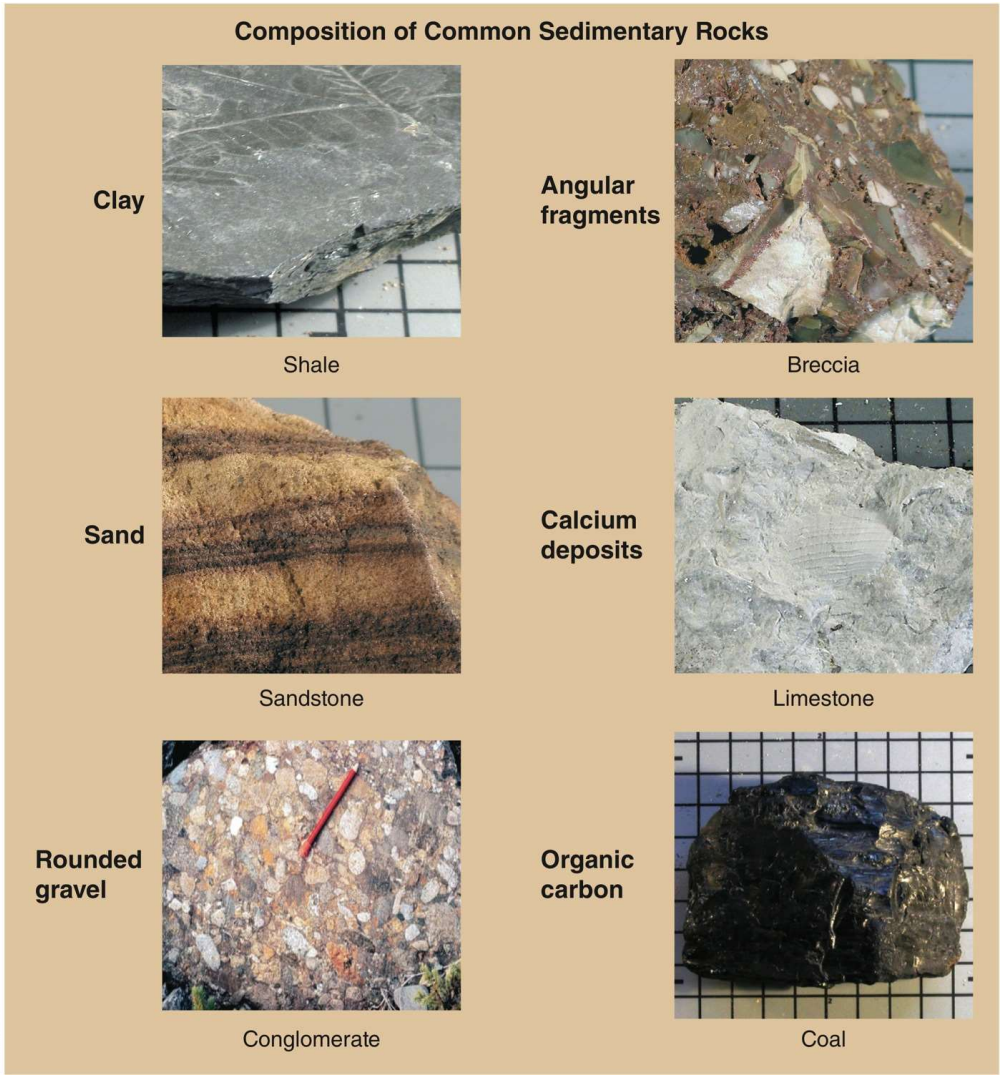
How does basalt differ from granite?

Rocks (cont'd.)

- Sedimentary rocks
  - Accumulated sediment
    - Lithified: solidified by compaction and cementation
  - Three major categories
    - Clastic
    - Organic
    - Chemical

Rocks (cont'd.)

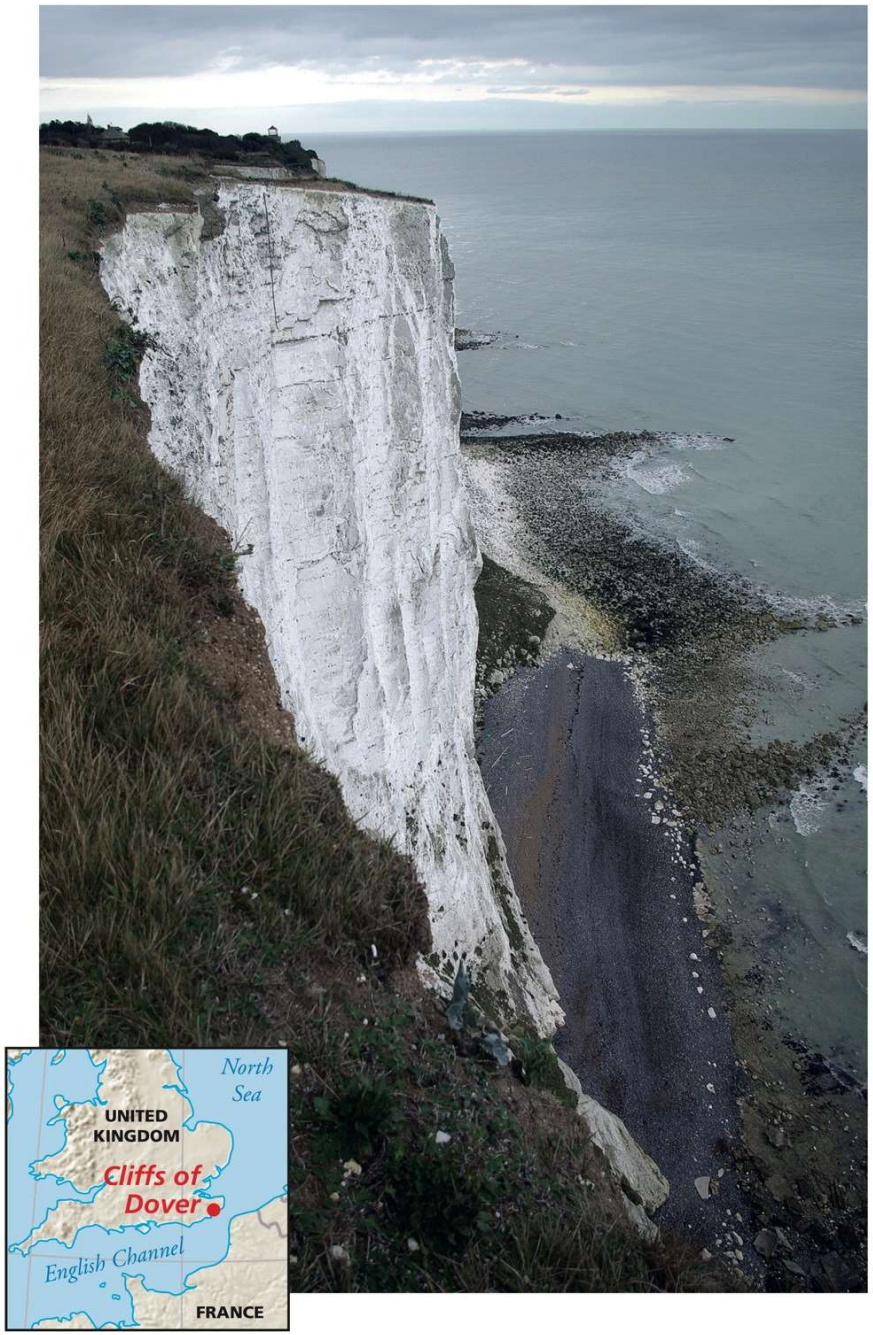
- Clastic sedimentary rocks
  - Composed of clasts
    - Fragments of previous rocks; may also include shells and bones
  - Conglomerate, sandstone, siltstone, and shale
- Sedimentary rocks: described by origin
  - Marine or terrestrial



Why are there different sizes and shapes of clastic sediments?

Rocks (cont'd.)

- Organic sedimentary rocks
  - Remains of organisms, both plants and animals
  - Coal: decayed vegetation
  - Limestone: remains of shellfish, corals, and plankton


North Sea
UNITED KINGDOM
Cliffs of Dover
English Channel
FRANCE

Rocks (cont'd.)

- Chemical precipitate sedimentary rocks
  - Dissolved minerals in oceans or lakes
    - Reach saturation → precipitate → lithified
  - Dolomite
  - What are examples of chemical sedimentary deposits that are useful to humans?
  - Stratification: distinct layers (strata)
    - Bedding plane
    - Unconformity
    - Cross bedding

G. Nadon, Ohio University

What are some characteristics that differ among the various strata seen in this photograph?

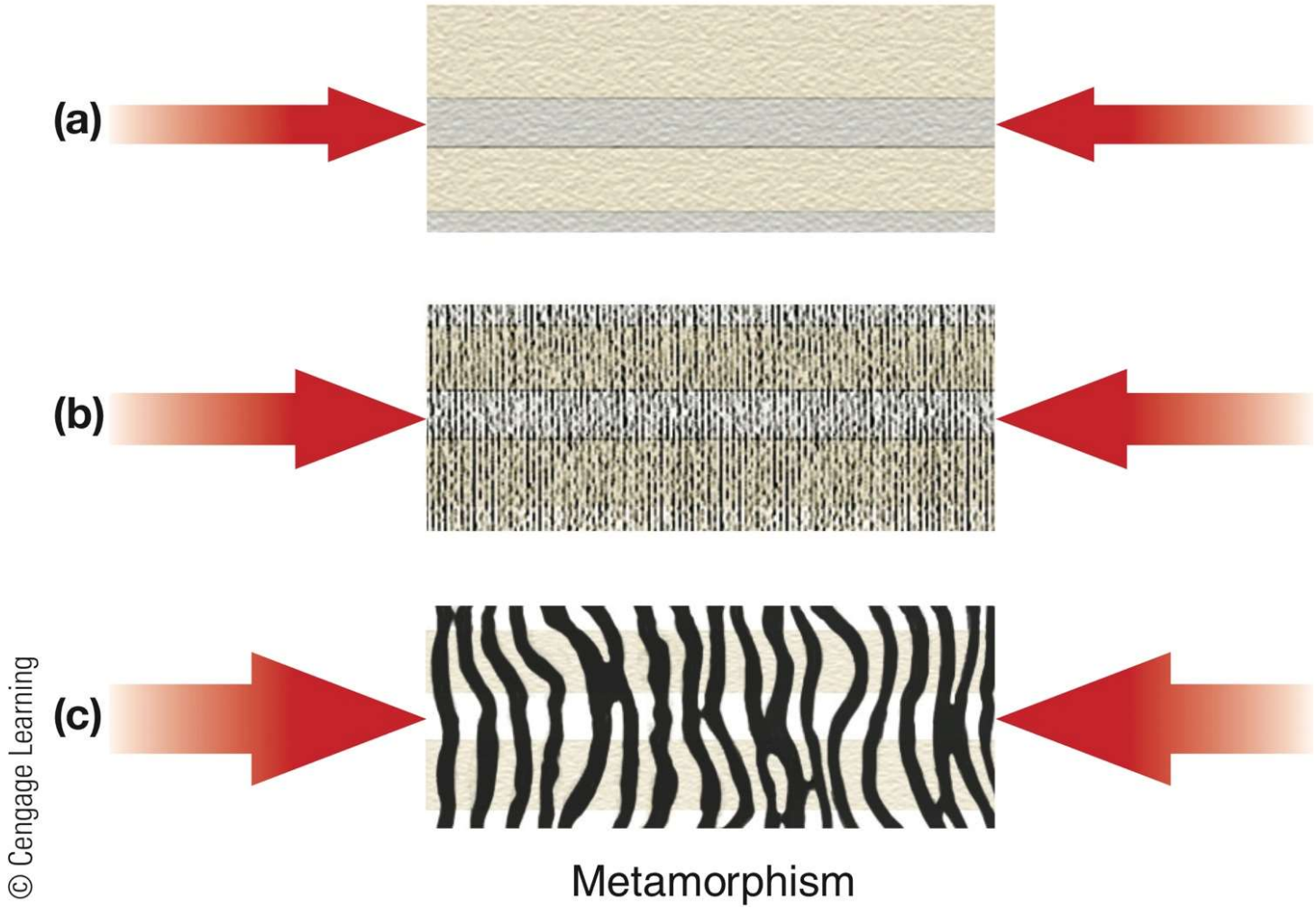

OREGON
IDAHO
NEVADA
UTAH
Valley of Fire
ARIZONA
CALIFORNIA
Pacific Ocean
120°
MEXICO

D. Sack

D. Sack

Rocks (cont'd.)

- Metamorphic rocks
  - Existing rock changed to a new rock type
    - Extensive heat and pressure
    - Harder and more compact; reoriented crystalline structure; more resistant to weathering
  - Two main categories
    - Foliated: presence of parallel flat surfaces or wavy bands
    - Nonfoliated: absence of foliation



How does foliation differ from bedding planes?

Rocks (cont'd.)

- Metamorphic rocks
  - Where does metamorphism most commonly occur?
  - Slate, schist, gneiss, marble, and quartzite

Foliated Metamorphic Rocks

Foliation/Crystal Texture

Fine

Slate

Medium

Schist

Coarse

Gneiss

J. Petersen

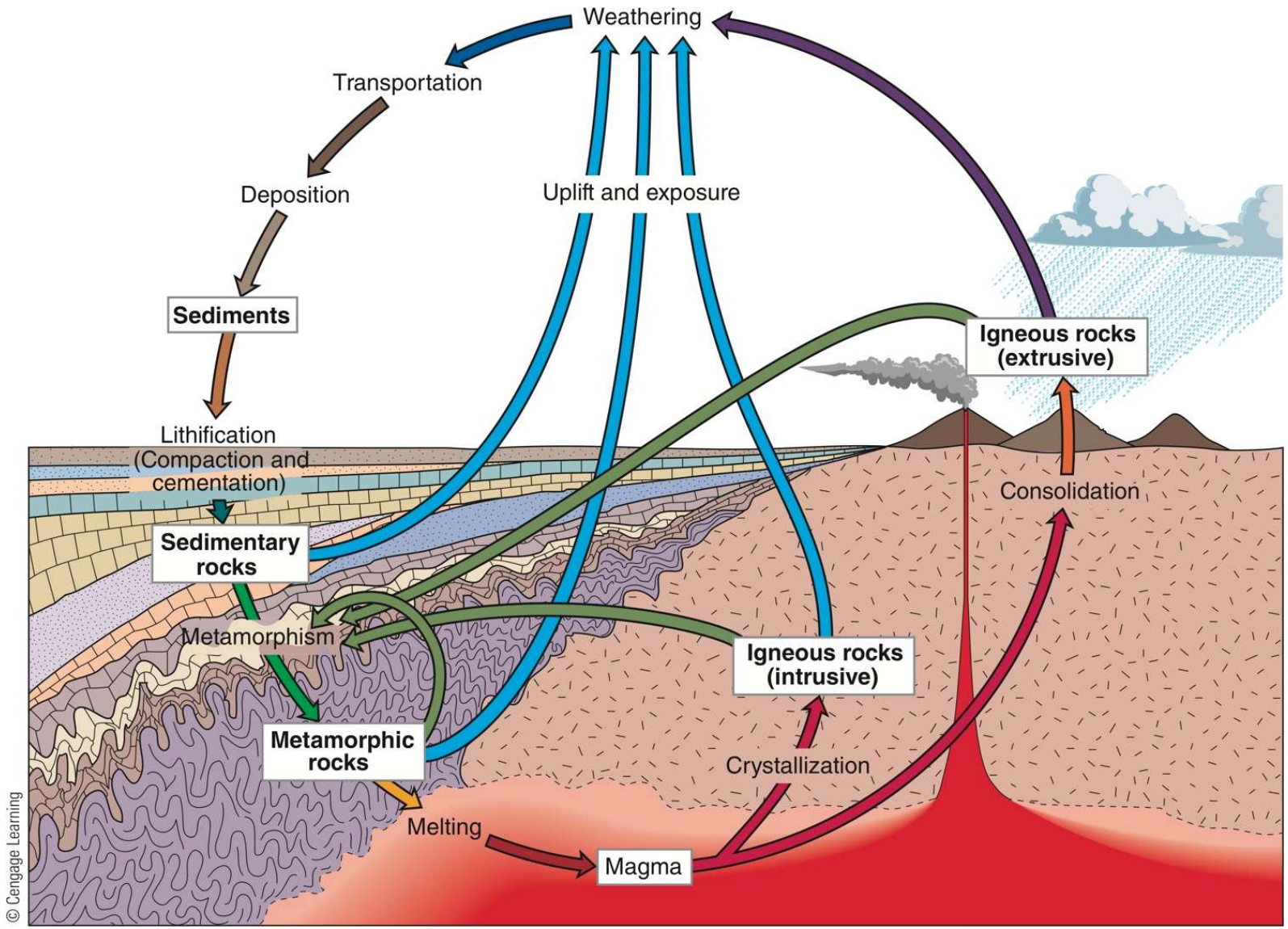
Nonfoliated Metamorphic Rocks

Original Rock Type	Metamorphic Rock
Limestone	 Marble
Sandstone	 Quartzite

J. Petersen

Rocks (cont'd.)

- The rock cycle
  - Conceptual model
    - Processes that generate, alter, transport, and deposit mineral materials to produce different kinds of rocks
  - Encompasses all the possible pathways
    - Recycling of rock matter over time



Can a metamorphic rock be metamorphosed?

Plate Tectonics

- Wegener's theory of continental drift
  - Single supercontinent: Pangaea
    - Divided into Gondwana and Laurasia
    - Subdivided into present continents and drifted to current positions
  - What could explain the source of energy needed to break apart and move the landmasses?

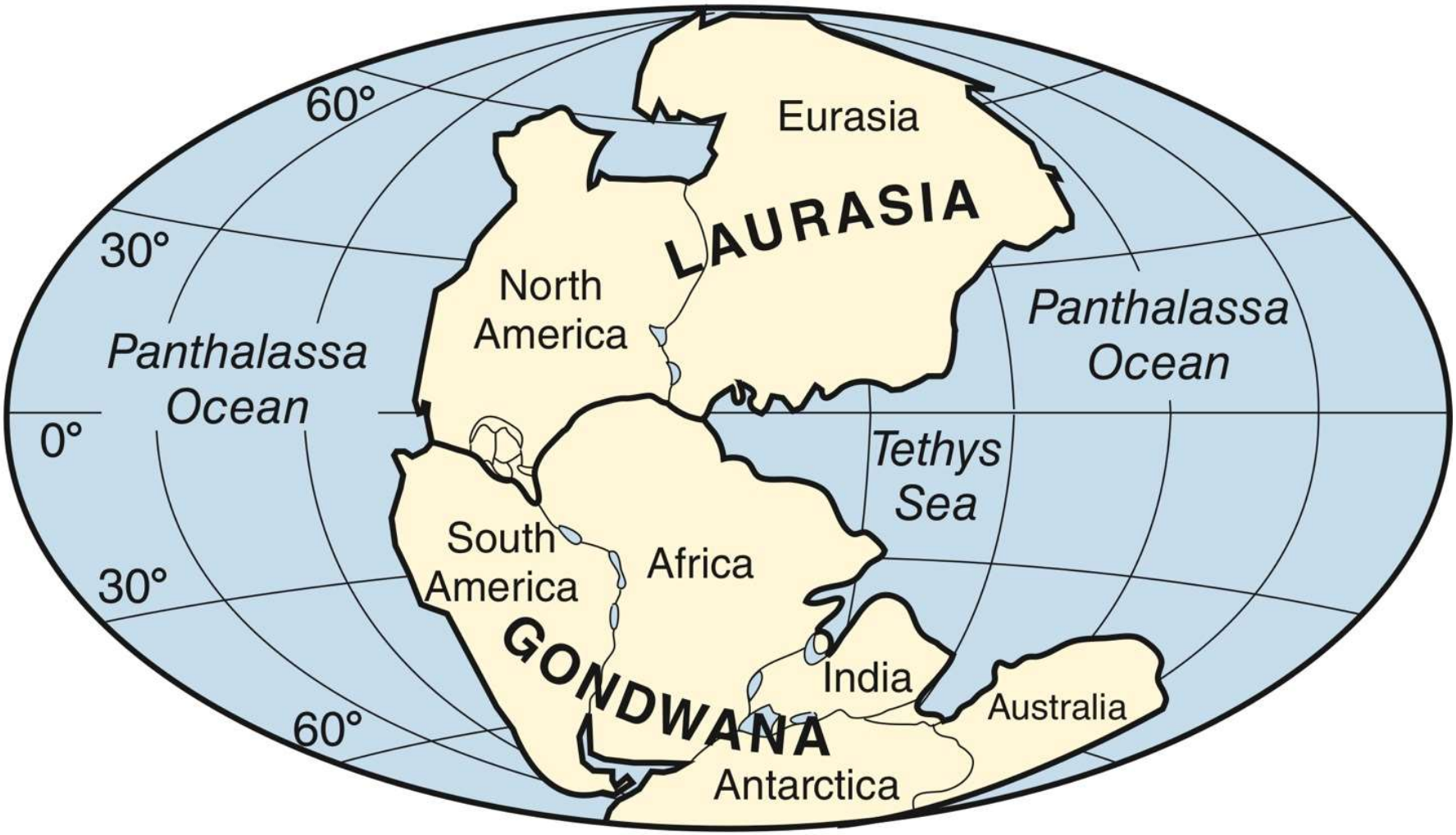
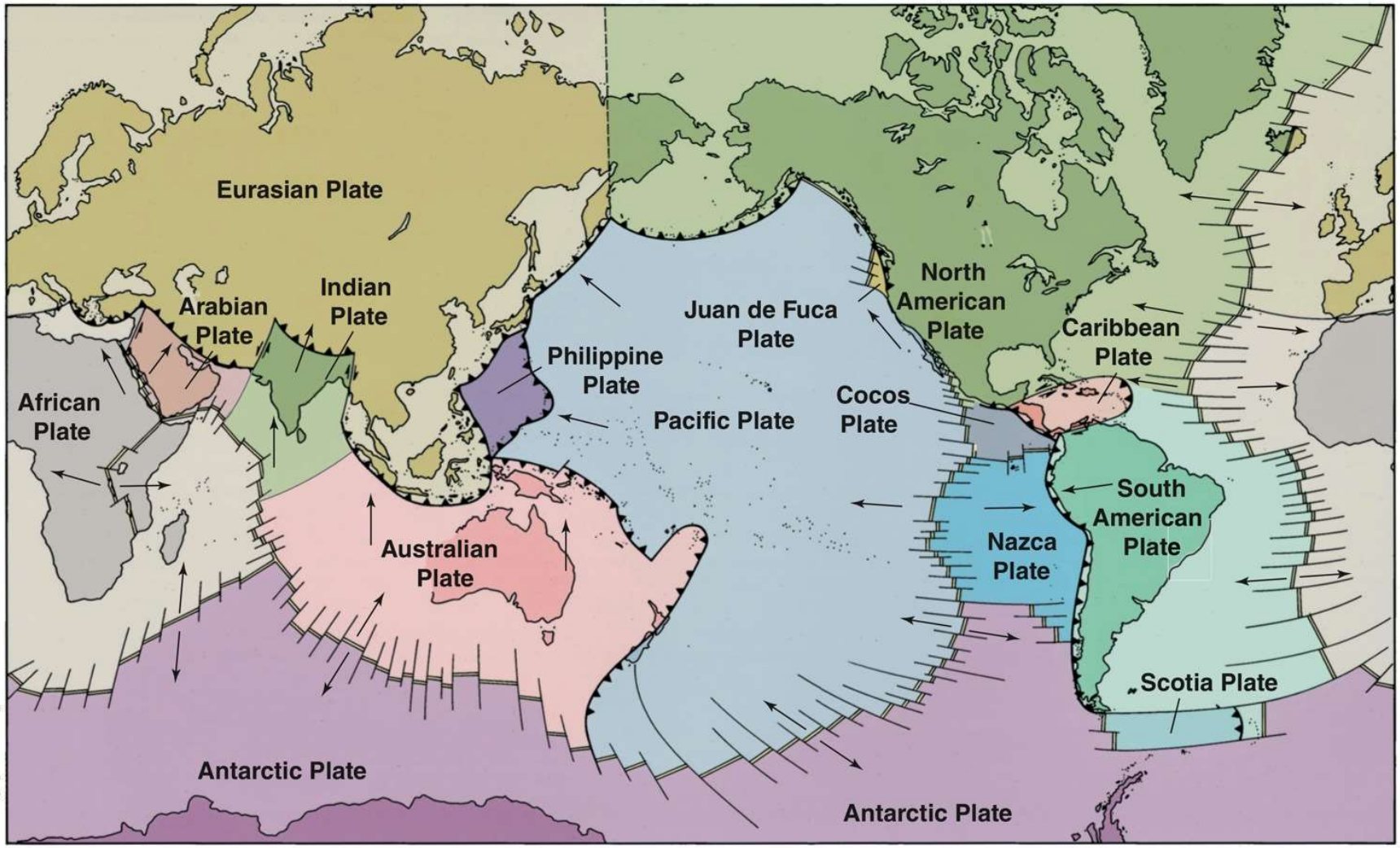


Plate Tectonics (cont'd.)

- Modern plate tectonics theory
  - Explains the movement of the lithosphere
  - Lithospheric plates
    - Move as distinct and discrete units: diverge, converge, or move laterally



Does every lithospheric plate include a continent?

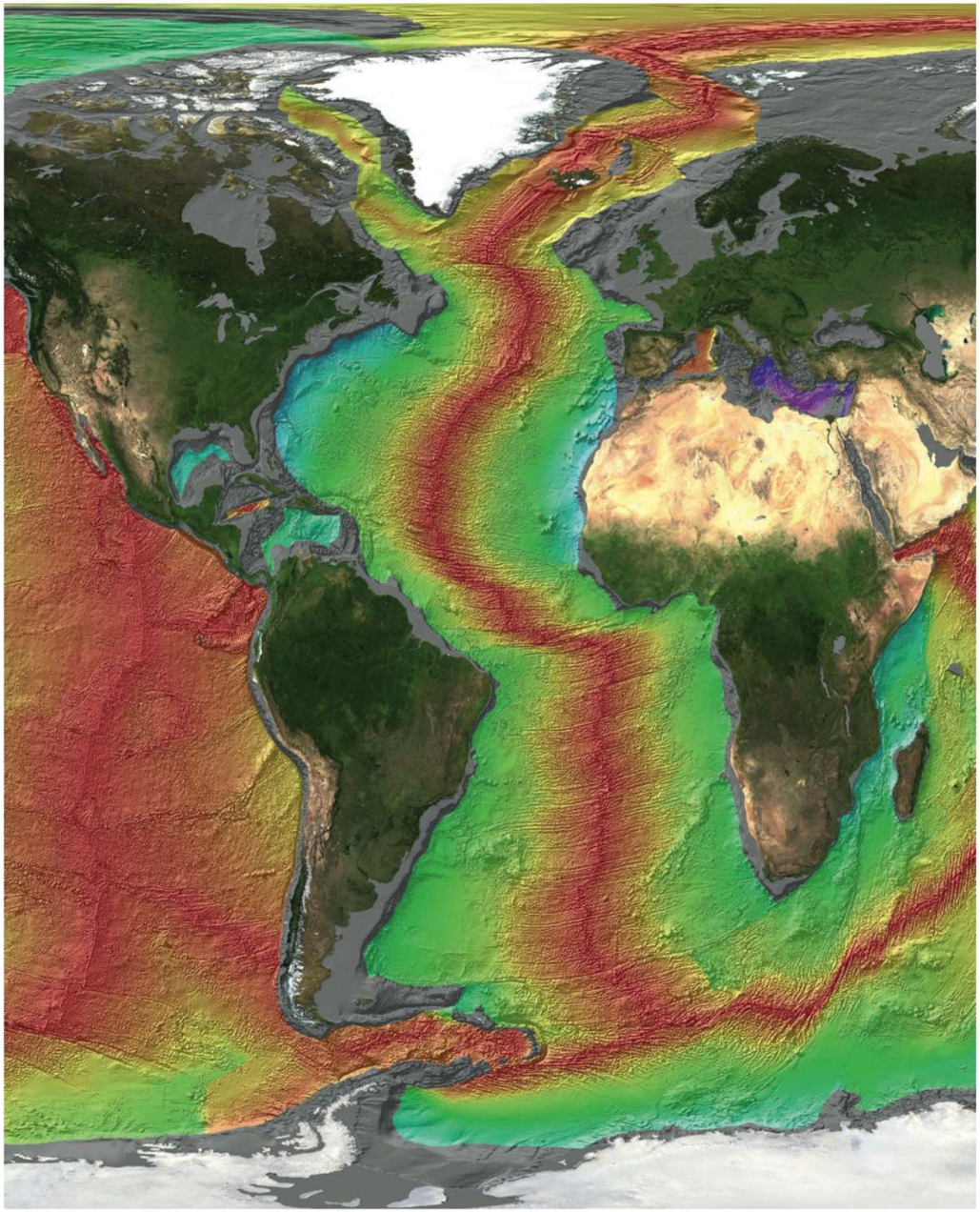
Plate Tectonics (cont'd.)

- Evidence to support plate tectonics: study and mapping of ocean floor
  - Midoceanic ridges: submarine mountain chains
    - Similar to continental coastlines
  - Rocks on opposite sides of midoceanic ridges
    - Matching patterns of magnetic properties
  - Ages of rocks
    - Continental: some 3.6 billion years old
    - Ocean floor: less than 250 million years

Plate Tectonics (cont'd.)

- Evidence to support plate tectonics: study and mapping of ocean floor
  - Locations of oldest and youngest ocean rocks
    - Oldest: trenches in deepest waters or close to continents
    - Progressively younger approaching midoceanic ridges
  - Temperatures of ocean floor rocks
    - Hottest near the midoceanic ridges

What is the relative age of oceanic crust along the East Coast of the United States?



Elliot Lim, CIRES & NOAA/NDGC

Plate Tectonics (cont'd.)

- Seafloor spreading
  - New oceanic crust forms along the midoceanic ridges
    - Moves slowly in opposite directions away from the axis of each ridge
  - Subduction
    - Earth material moves down to the subsurface
  - How is the historical record of Earth's magnetic field (including polarity reversals) preserved in the seafloor?

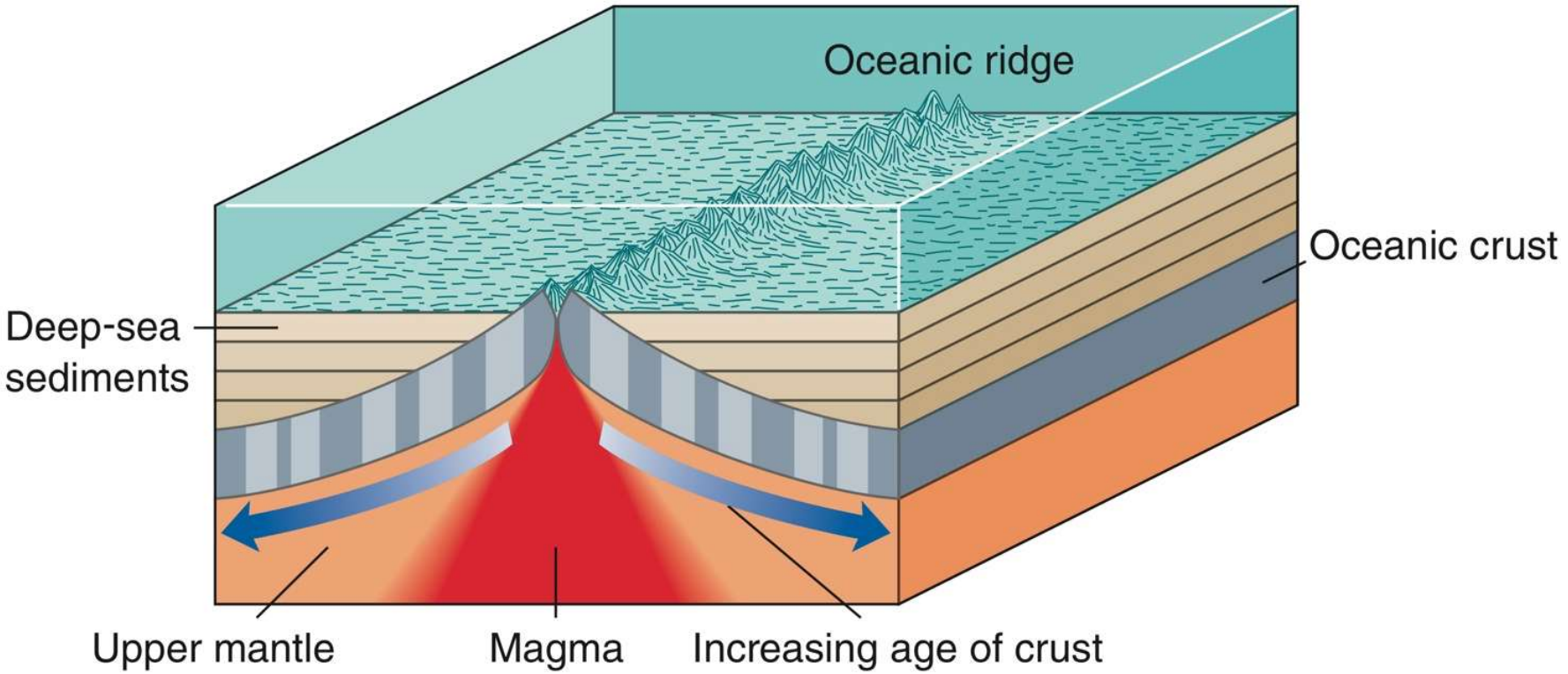


Plate Tectonics (cont'd.)

- Convection in the mantle
  - Explanation for plate movement
  - Rigid lithospheric plates separate along midoceanic ridges
    - Average rate: 2–5 cm (1–2 in) per year

Why is plate tectonics a better name than continental drift for the lateral movement of Earth's solid outer shell?

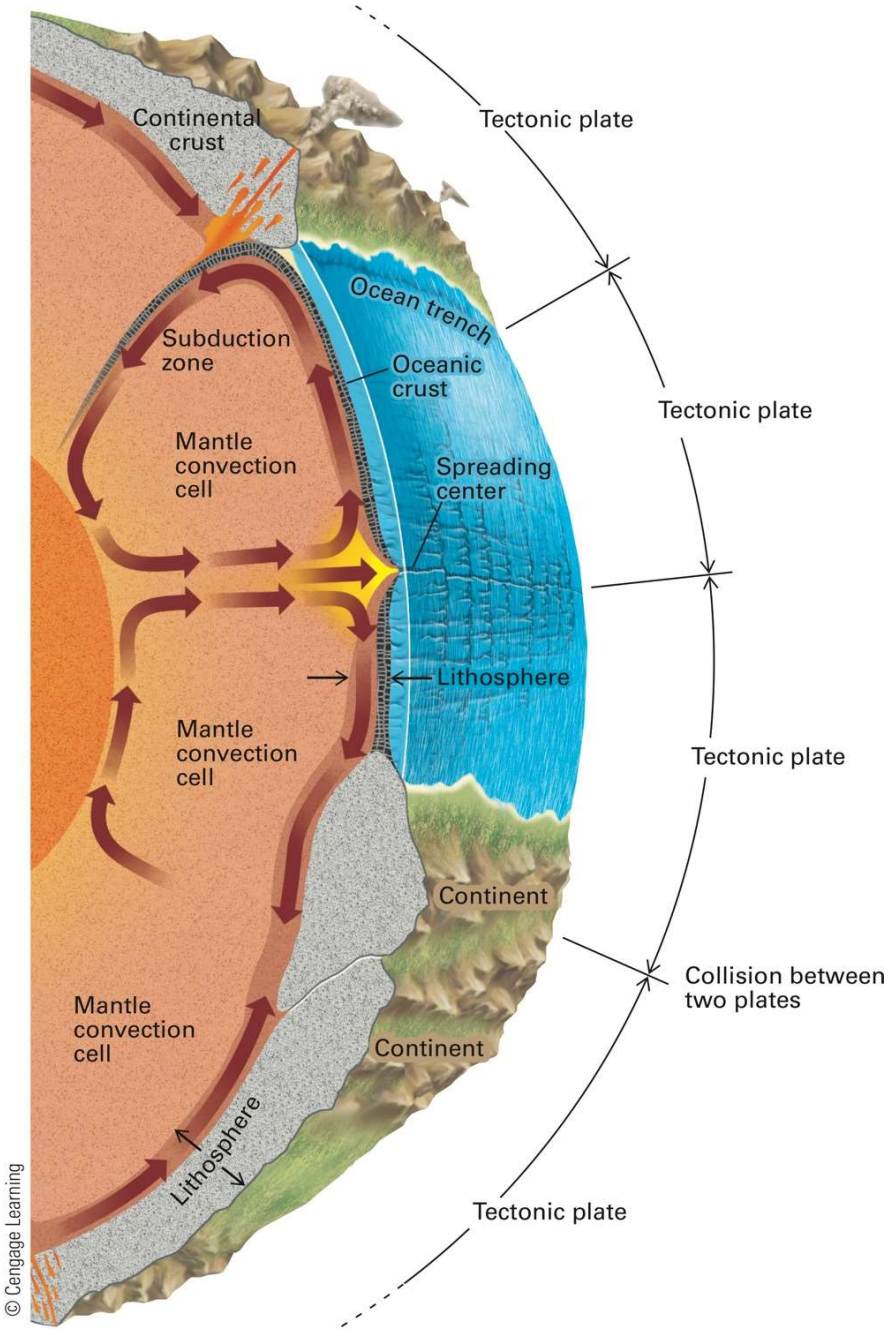


Plate Tectonics (cont'd.)

- Plate tectonics theory enables us to:
  - Understand planet's ancient history
  - Recognize modern global distributions and spatial relationships among
    - Earthquakes, volcanic activity, zones of crustal movement, and major landform features

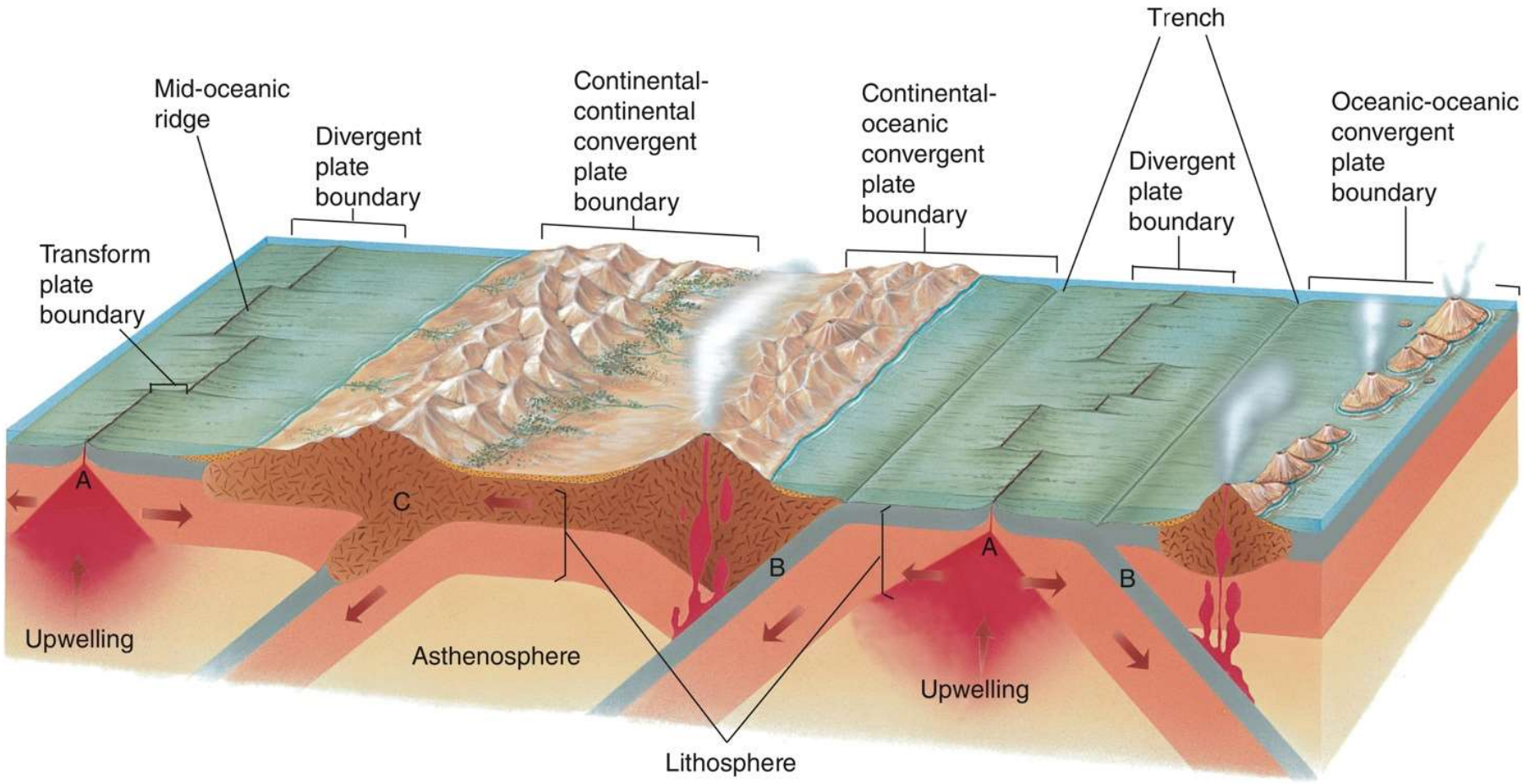
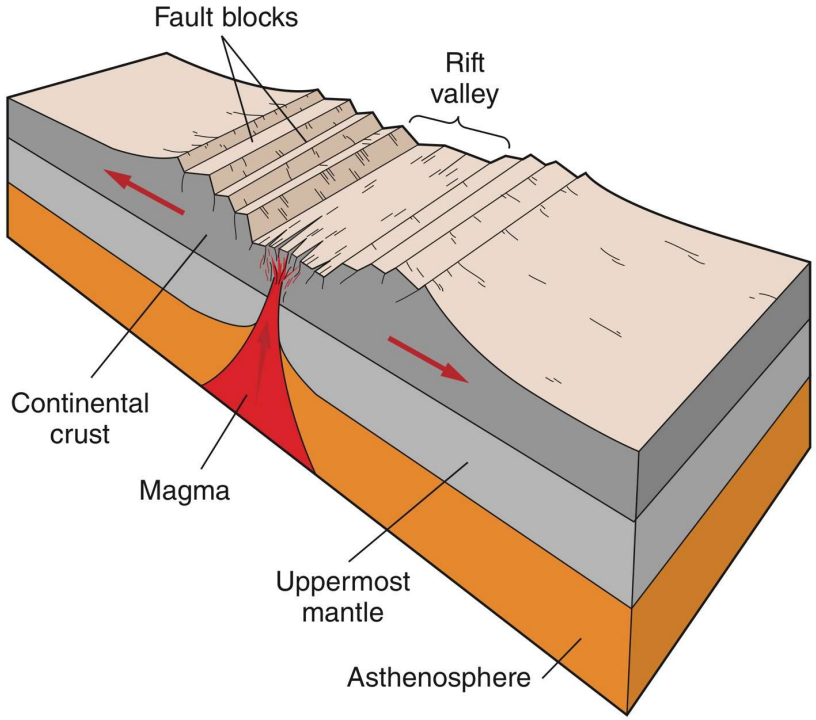


Plate Tectonics (cont'd.)

- Tectonic plate divergence (pulling apart)
  - Crust thins and weakens
  - Weak earthquakes
  - Creates new ocean floor
  - Constructive plate margins
  - Mid-Atlantic Ridge: refer to Figure 10.27
  - Rift valley system of East Africa



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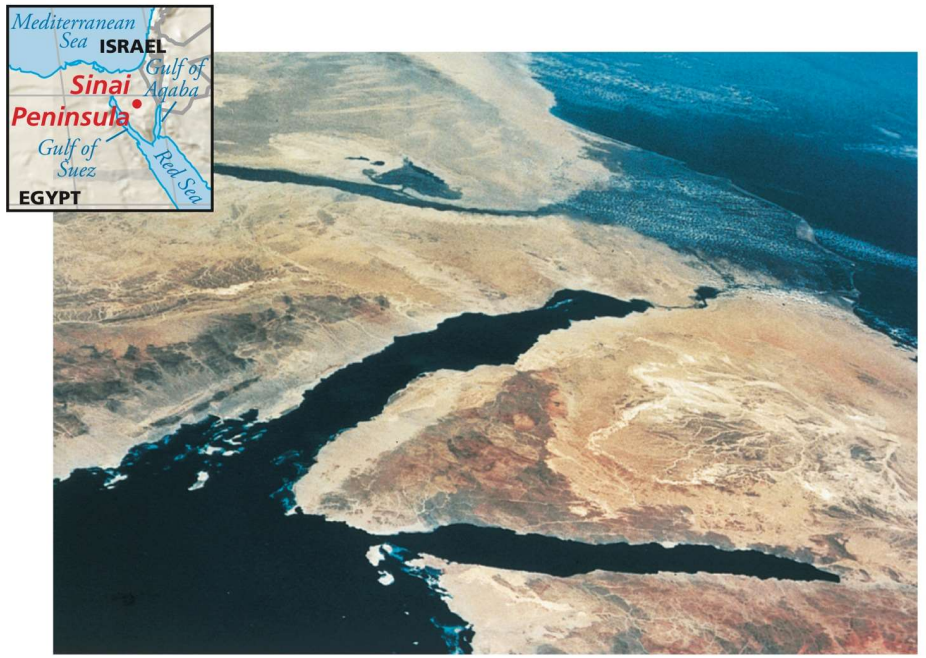


(b)

Plate Tectonics (cont'd.)

- Tectonic plate convergence (collision)
  - Trenches, volcanic activity, and mountain ranges
  - One or more oceanic crust plates results in subduction
    - Peru-Chile trench, Japanese trench, South America's Pacific coast, etc.
    - Volcanoes: island arcs on the overriding plate, e.g., Aleutians
    - What determines which plate subducts beneath the other plate?

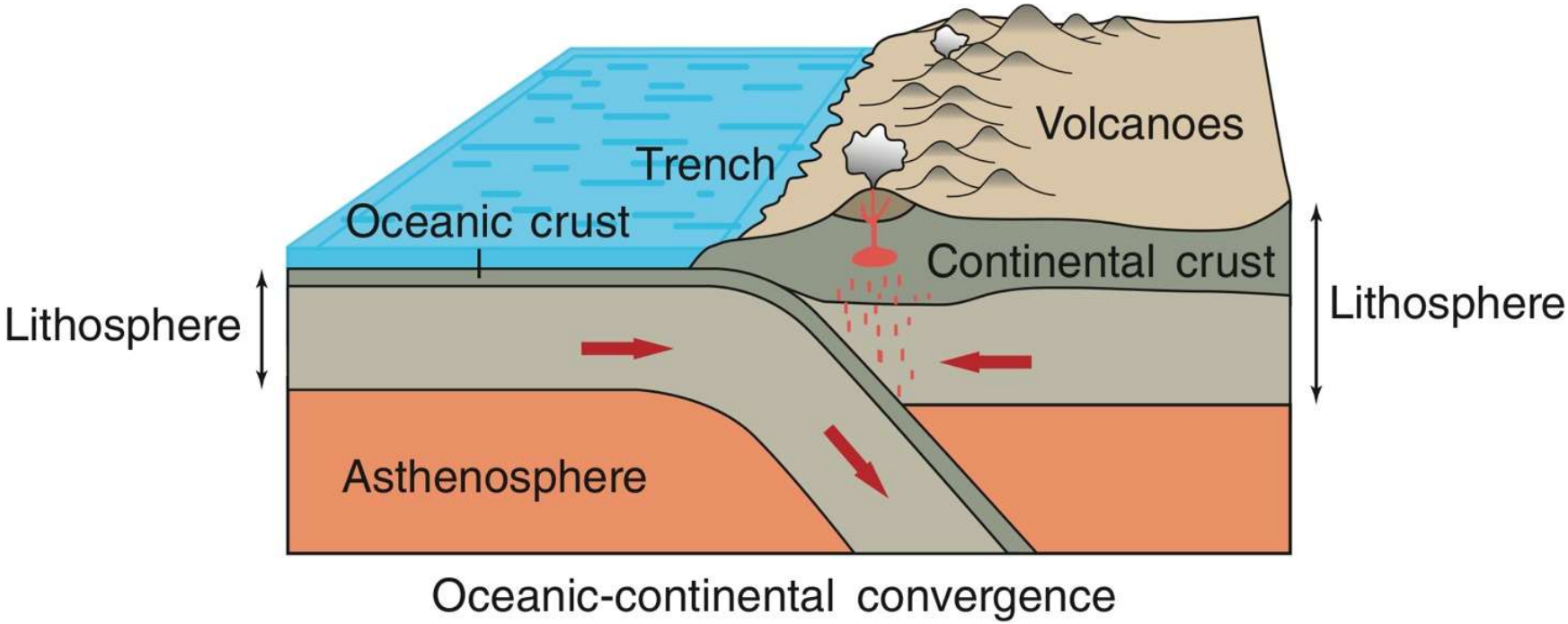
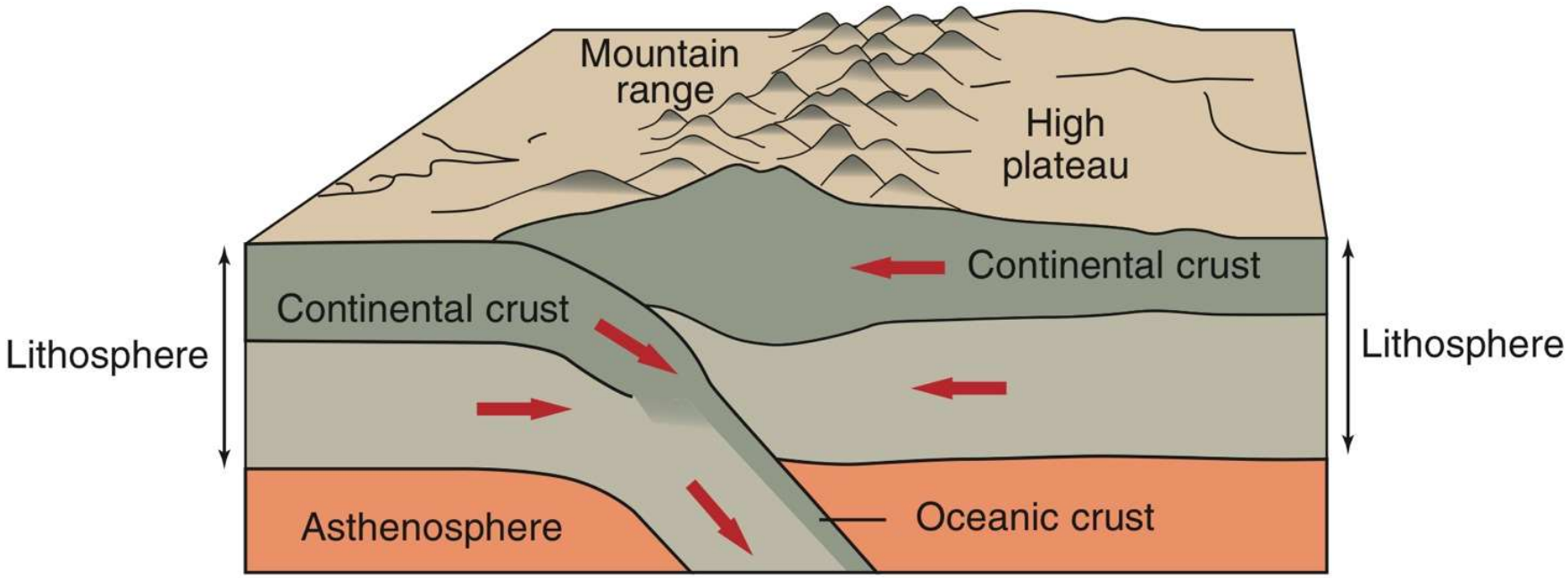


Plate Tectonics (cont'd.)

- Tectonic plate convergence
  - Continental collision
    - Two continental crusts
    - Continental suturing: closes an ocean basin; two landmasses fused
    - Mountain ranges: Himalayas, Tibetan Plateau, Alps, etc.



Continental-continental convergence

Plate Tectonics (cont'd.)

- Transform movement
  - Lateral sliding
  - Example: San Andreas Fault zone in California
  - Transform faults (fracture zones) occur on ocean floors
  - What causes transform faults?

What boundary type is found north of San Francisco, and what types of surface features indicate this change?

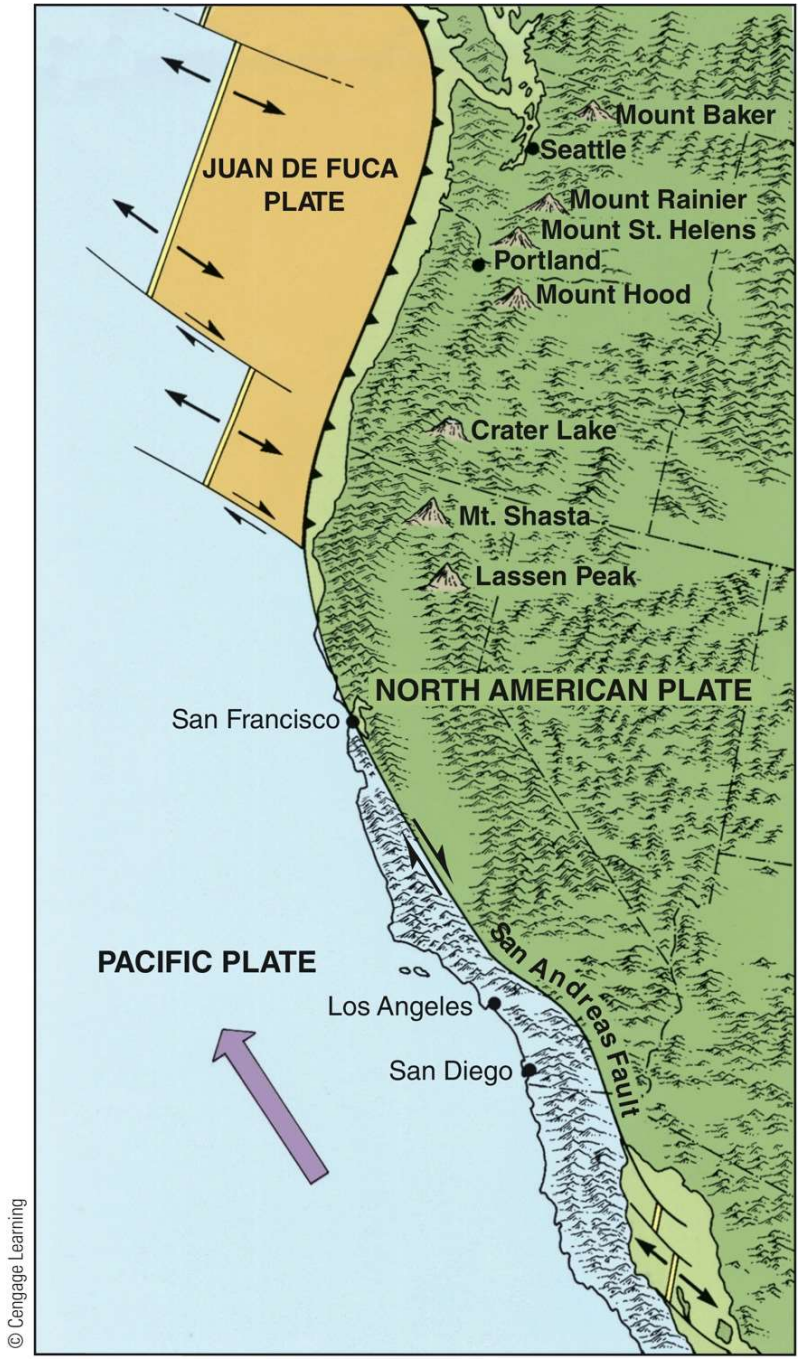
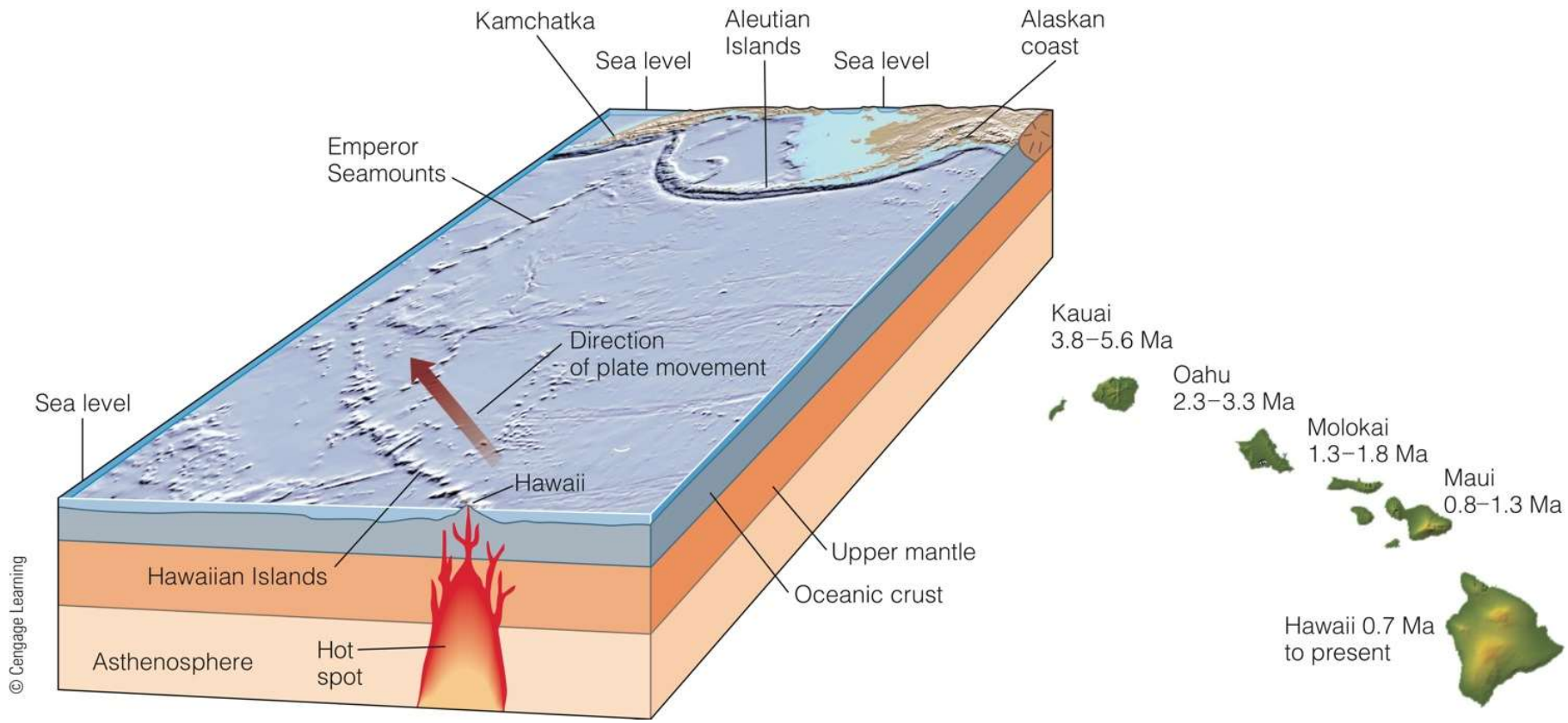


Plate Tectonics (cont'd.)

- Paleomagnetism: evidence of earth's ancient geography
  - Study of magnetic fields in mineral crystals within rocks of varying ages
  - Characteristics recorded in basaltic rocks
    - Polarity
    - Declination
    - Inclination

Plate Tectonics (cont'd.)

- Hot spots in the mantle
  - Nearly stationary molten masses in the mantle
  - Melting of upper mantle and oceanic crust
    - Basaltic lava pours onto the seafloor ► builds a volcanic island
  - Hawaiian Islands



Approximately how long did it take the Pacific plate to move Oahu to its present position?

Plate Tectonics (cont'd.)

- Growth of continents
  - Continental shields
    - Ancient crystalline rock
    - Canadian shield (Figure 10.33)
    - Younger sedimentary rocks at the peripheries
  - Accretion: collision
    - Microplate terranes

Geologic Time and Paleogeography

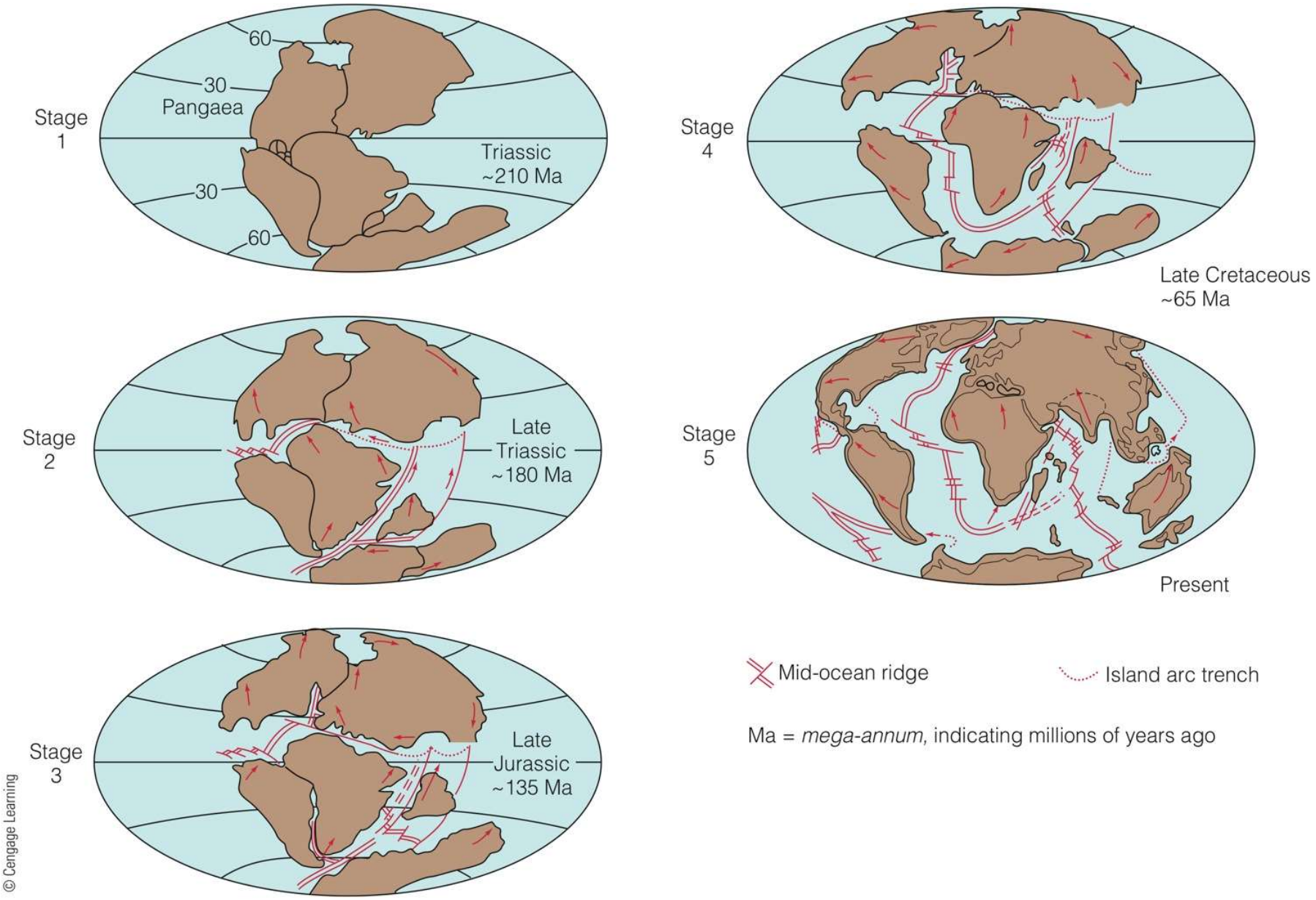
- Paleogeography
  - Study of past geographic environments
  - Goal: reconstruct the past environment of a geographic region
    - Based on geologic and climatic evidence
  - What are the benefits of these studies?

Geologic Time and Paleogeography

- Paleogeography
  - Geological timescale of Earth history (Figure 10.34)
    - Eras: (e.g., Mesozoic Era)
    - Periods (e.g., Cretaceous Period)
    - Epochs (e.g., Pleistocene Epoch)
  - Each era, period, and epoch
    - Unique paleogeography: distribution of land and sea, climate regions, plants, and animal life

Geologic Time and Paleogeography

- Paleogeography
  - Maps depicting Earth in early geologic times
    - Simplified models of the regions and times they represent
  - Applying the theory of plate tectonics
    - Provides better understanding of Earth's geological past and it's present
    - Facilitates better forecasts of Earth's future



Fundamentals of Physical Geography 2e

Earth Materials and Plate Tectonics

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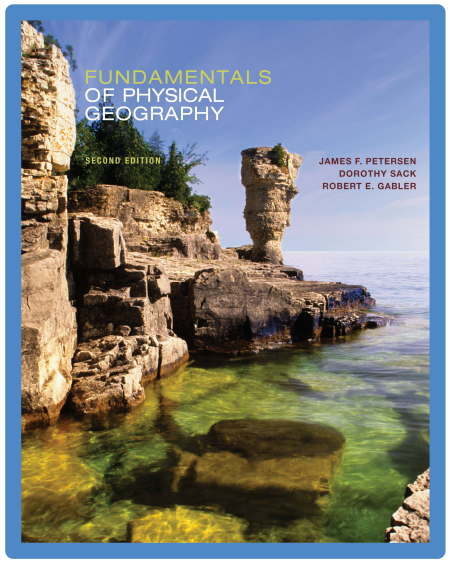

- Peterson
  - Sack
    - Gabler