Essentials of Geology, 11e

Plate Tectonics: A Scientific Revolution Unfolds, Chapter 15

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Continental Drift

- **Alfred Wegener**
  - First proposed hypothesis, 1915
  - Published *The Origin of Continents and Oceans*
- **Continental drift hypothesis**
  - Supercontinent called Pangaea began breaking apart about 200 million years ago
  - Continents "drifted" to present positions
  - Continents "broke" through the ocean crust

Pangaea Approximately 200 Million Years Ago

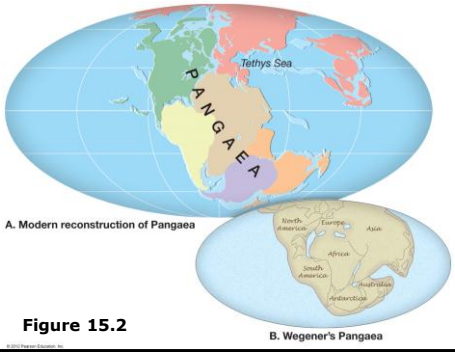


Figure 15.2

Continental Drift

- **Wegener's continental drift hypothesis**
  - *4 points of evidence* used by Wegener
    - Fit of South America and Africa
    - Fossils match across the seas
    - Rock types and structures match
    - Ancient climates
  - Main objection to Wegener's proposal was its inability to provide a mechanism

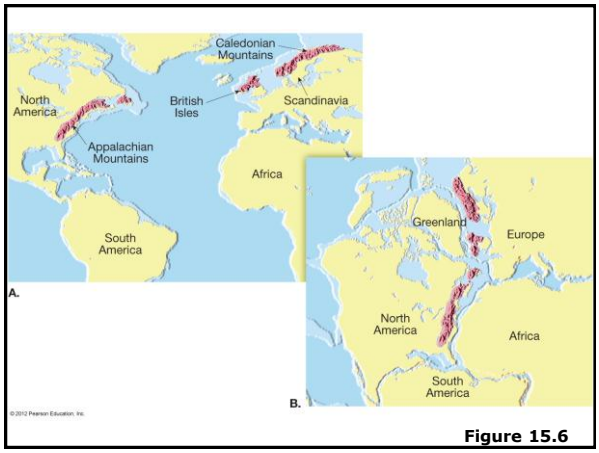


Figure 15.6

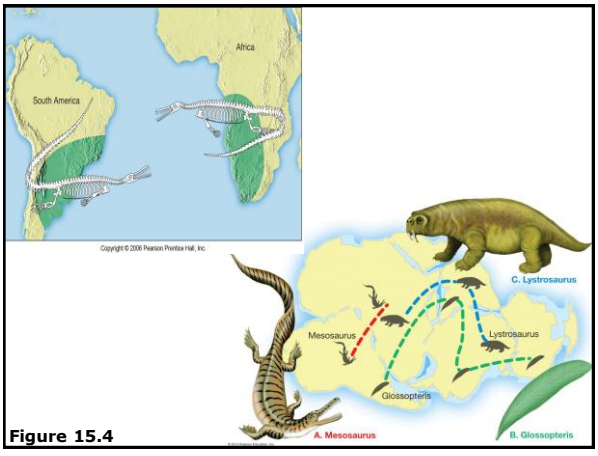


Figure 15.4

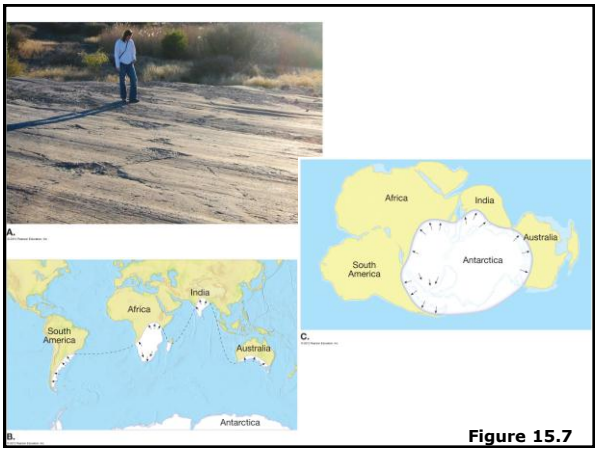


Figure 15.7

Plate Tectonics: the New Paradigm

- ❖'Plate Tectonics,' term is more encompassing than continental drift
- ❖Associated with Earth's rigid outer shell-
  - Called the lithosphere
  - Consists of several plates
    - Plates are moving slowly
    - Largest plate is the Pacific plate

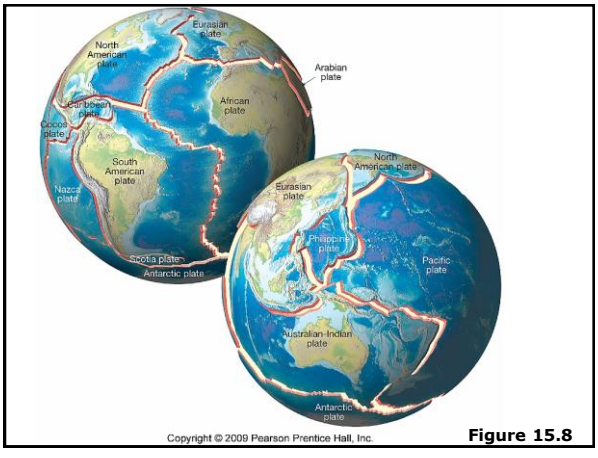


Figure 15.8

Plate Tectonics: the New Paradigm

- ❖Also associated with Earth's Asthenosphere-
  - Exists beneath the lithosphere
  - Hotter and weaker than lithosphere
  - Allows for motion of lithosphere
- ❖Plate boundaries
  - All major interactions among plates occur along their boundaries

Plate Tectonics: the New Paradigm

Types of plate boundaries:

- Divergent plate boundaries (constructive margins, ex. Mid-Atlantic Ridge)
  - Two plates move apart
  - Mantle material upwells to create new seafloor
  - *Ocean ridges* and seafloor spreading
    - Oceanic ridges occur on well-developed boundaries
    - Along ridges, seafloor spreading creates new seafloor
  - *Continental rifts* form at spreading centers within a continent

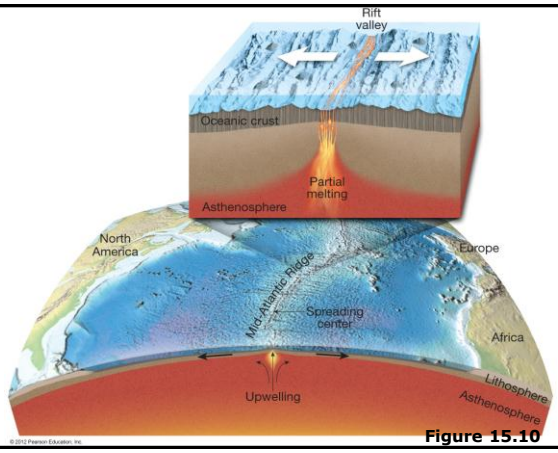


Figure 15.10

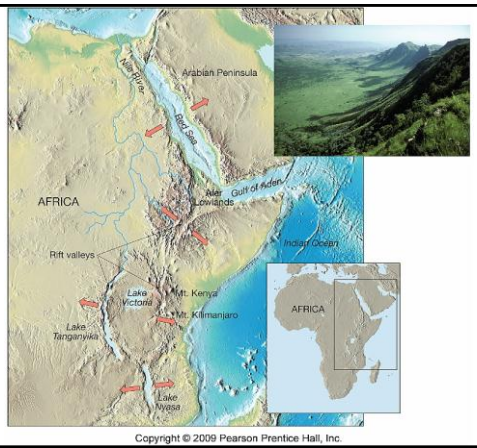


Plate Tectonics: the New Paradigm

Types of plate boundaries:

- **Convergent plate boundaries (destructive margins, Cascade Continental Volcanic Arc in western N.A.)**
  - **Plates collide, an ocean trench forms and lithosphere is subducted into the mantle**
  - **Three sub-types:**
    - **O-C**
    - **O-O**
    - **C-C**

Plate Tectonics: the New Paradigm

Types of plate boundaries:

- **Convergent plate boundaries**
- ***Oceanic-continental* convergence-**
  - **Denser oceanic slab sinks into the asthenosphere**
  - **Pockets of magma develop and rise**
  - **Continental volcanic arcs form**
  - **Examples include the Andes, Cascades, and the Sierra Nevadan system**

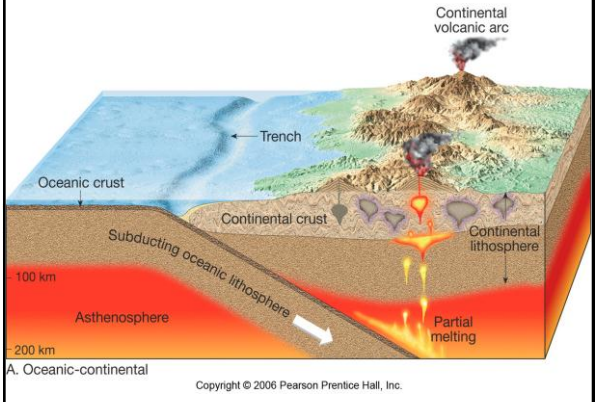


Figure 15.12

Plate Tectonics: the New Paradigm

Types of plate boundaries:

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

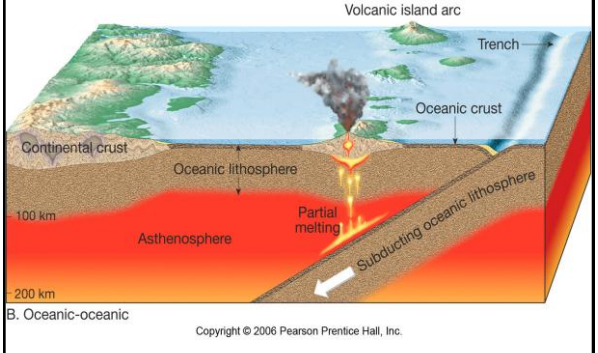


Figure 15.14 B

Plate Tectonics: the New Paradigm

Types of plate boundaries:

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

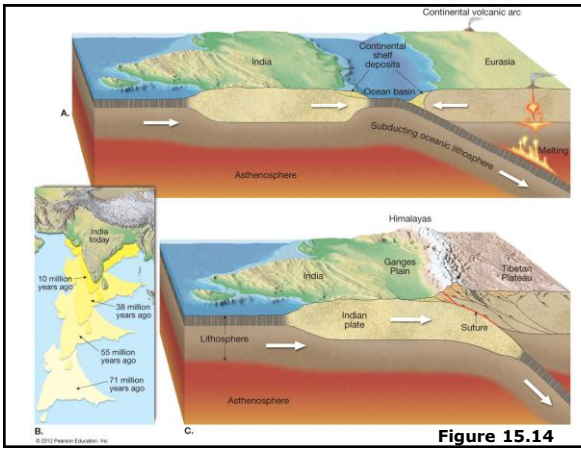


Figure 15.14

Plate Tectonics: the New Paradigm

Types of plate boundaries:

- **Transform plate boundaries (conservative margins, ex. San Andreas Fault)**
  - **Separate plates slide 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**

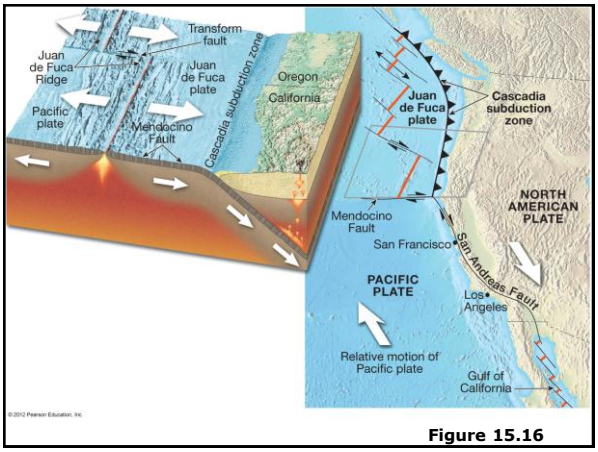


Figure 15.16

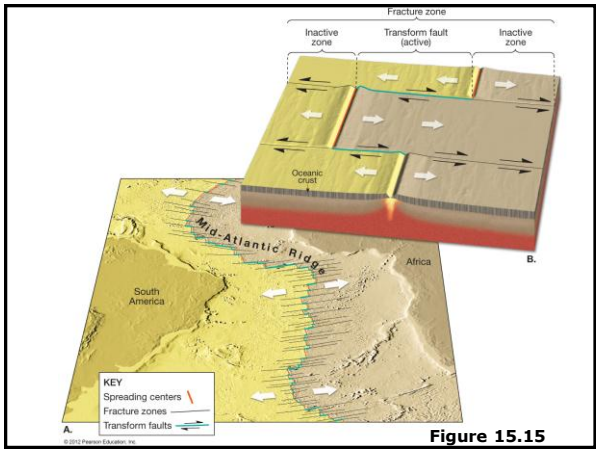


Figure 15.15

Testing the Plate Tectonics Model

❖**Evidence from ocean drilling**

- **Some of the most convincing evidence confirming seafloor spreading has come from drilling directly into ocean-floor sediment**
  - **Earthquake patterns in subsurface**
  - **Age of deepest sediments and fossils**
  - **Thickness of ocean-floor sediments verifies seafloor spreading**

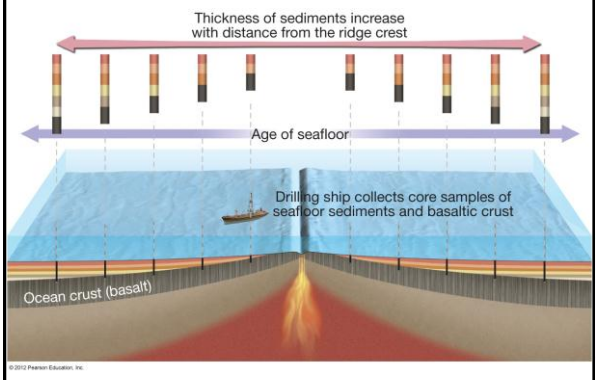


Figure 15.18

Testing the Plate Tectonics Model

- **Hot spots and mantle plumes**
  - Caused by rising plumes of mantle material
  - Volcanoes can form over them (Hawaiian Island chain)
  - Mantle plumes
    - Long-lived structures
    - Some originate at great depth, perhaps at the mantle-core boundary

The Hawaiian Islands

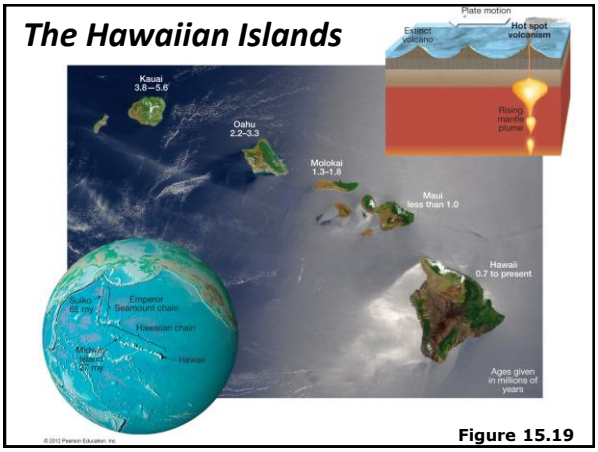


Figure 15.19

Testing the Plate Tectonics Model

- **Evidence for the plate tectonics model**
  - Paleomagnetism
    - Probably the most persuasive evidence
    - Ancient magnetism preserved in rocks
    - Paleomagnetic records show
      - Polar wandering (evidence that continents moved)
      - Earth's magnetic field reversals
        - » Recorded in rocks as they form at oceanic ridges

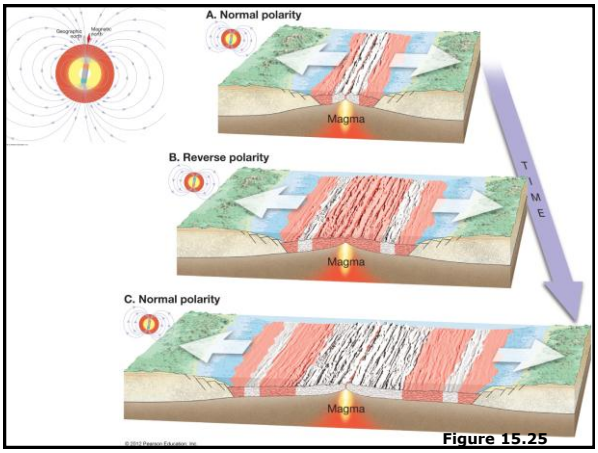


Figure 15.25

Measuring Plate Motion

- **Measuring plate motion**
  - By using hot spot "tracks" like those of the Hawaiian Island - Emperor Seamount chain
  - Using space-age technology to directly measure the relative motion of plates
    - Very Long Baseline Interferometry (VLBI)
    - Global Positioning System (GPS)

Directions and Rates of Plate Motions

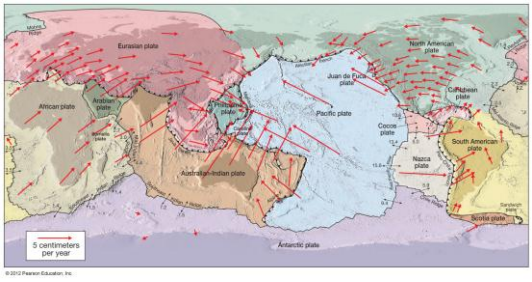


Figure 15.27

What Drives Plate Motion?

- ❖Driving mechanism of plate tectonics
  - No one model explains all facets of plate tectonics
  - Earth's heat is the driving force
  - Several models have been proposed
    - Slab-pull and slab-push model
      - – Descending oceanic crust pulls the plate
      - – Elevated ridge system pushes the plate

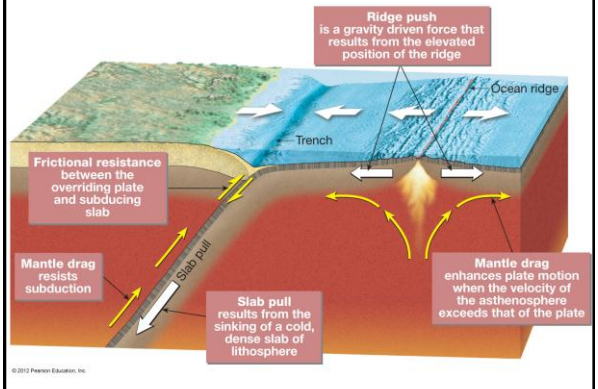
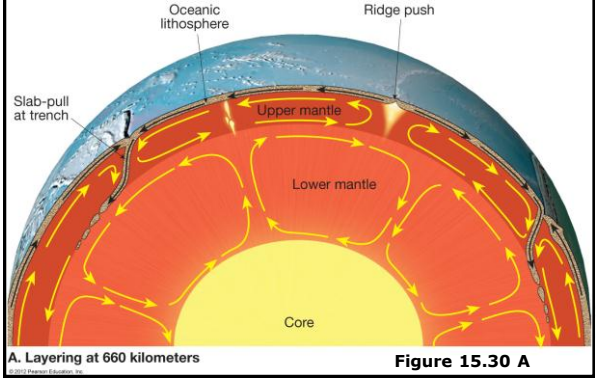


Figure 15.26

What Drives Plate Motion?

- ❖Several models have been proposed
  - Plate-mantle convection
    - Mantle plumes extend from mantle-core boundary and cause convection within the mantle
    - 3 Models:
      - – Layering at 660 kilometers
      - – Whole-mantle convection
      - – Deep-layer model

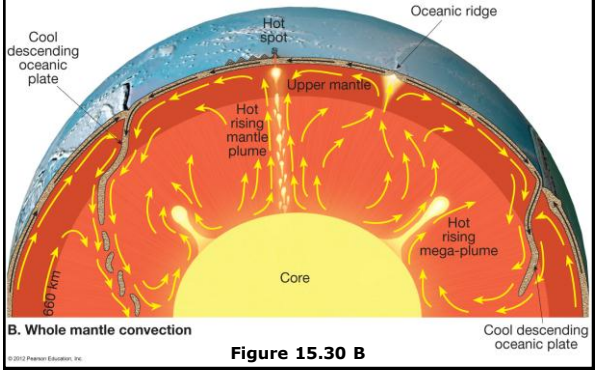
Layering at 660 Kilometers



A. Layering at 660 kilometers

Figure 15.30 A

Whole-Mantle Convection

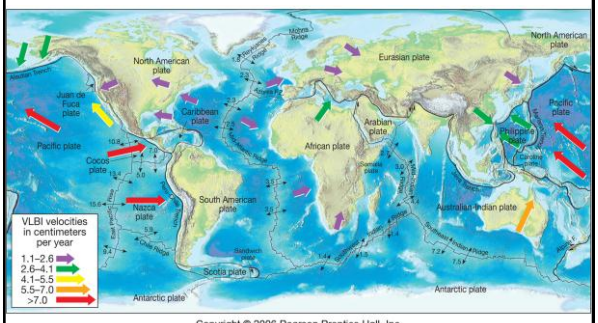


B. Whole mantle convection

Figure 15.30 B

Plate Tectonics into the Future

- **Present-day motions have been extrapolated into the future some 50 million years**
  - **Areas west of the San Andreas Fault slide northward past the North American plate**
  - **Africa collides with Eurasia, closing the Mediterranean and initiating mountain building**
  - **Australia and new Guinea are on a collision course with Asia**



50 million years from now…

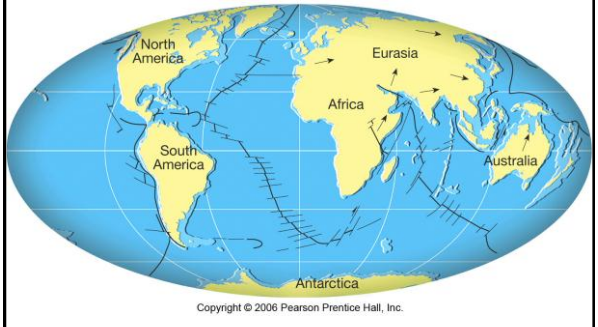


Figure 15.31

250 million years from now…

Figure 15.32