

Chapter Overview

- Much evidence supports plate tectonics theory.
- The plate tectonics model describes features and processes on Earth.
- Plate tectonic science has applications to Earth Science studies.
- Configuration of land and oceans has changed in the past and will continue to change into the future.

© 2014 Pearson Education, Inc.

Plate Tectonics

- **Alfred Wegener** first proposed in 1912
- Called it "**Continental Drift**"



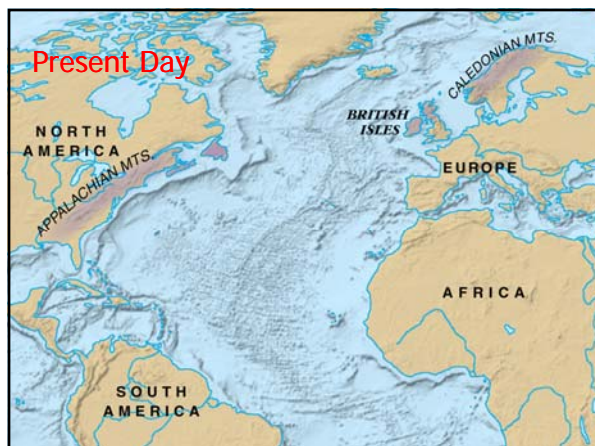
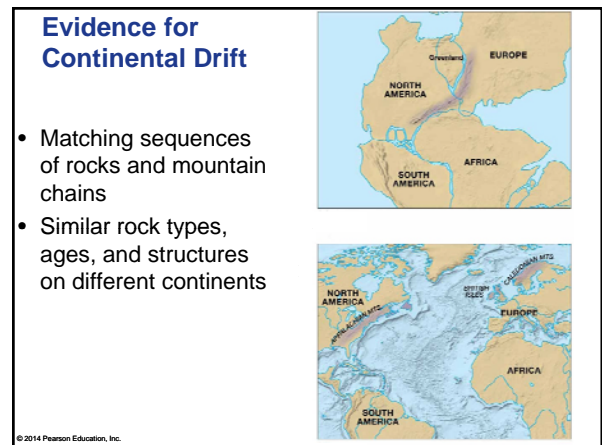
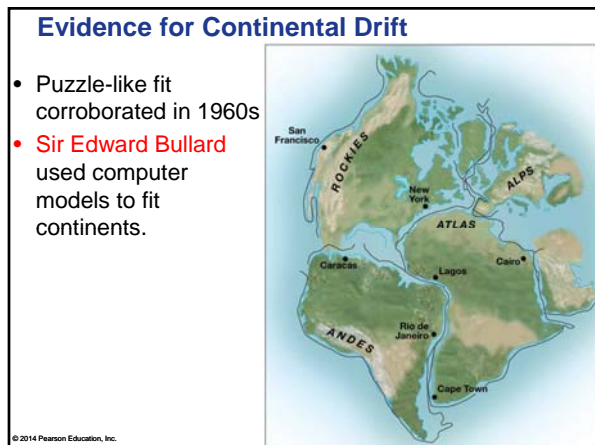
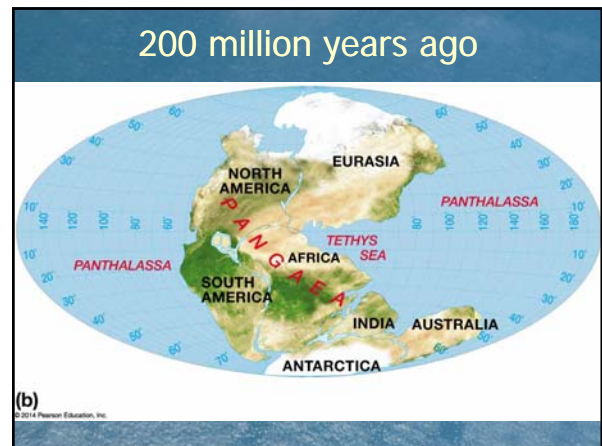
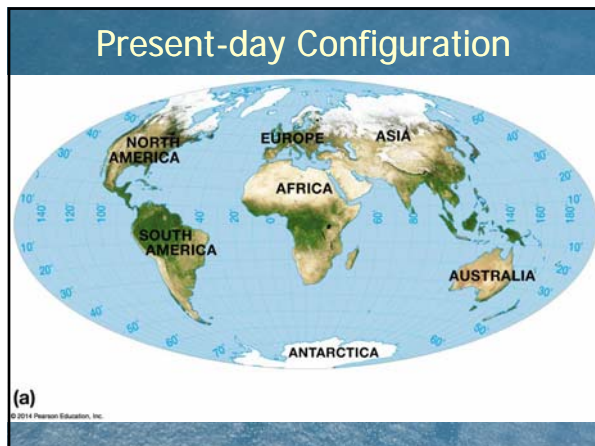
© 2014 Pearson Education, Inc.

Evidence for Continental Drift

- Wegener proposed **Pangaea** – one large continent existed 200 million years ago
- **Panthalassa** – one large ocean
 - Included the **Tethys Sea**
- Noted puzzle-like fit of modern continents

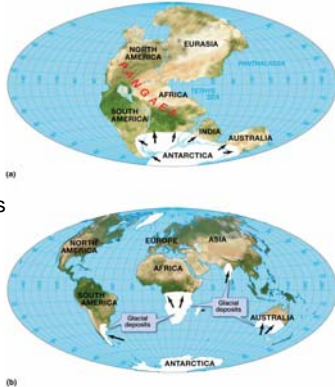


© 2014 Pearson Education, Inc.



Evidence for Continental Drift

- Glacial ages and other climate evidence
- Evidence of glaciation in now tropical regions
- Direction of glacial flow and rock scouring
- Plant and animal fossils indicate different climate than today.



© 2014 Pearson Education, Inc.

(b)

Evidence for Continental Drift

- Distribution of organisms
 - Same fossils found on continents that today are widely separated
 - Modern organisms with similar ancestries



© 2014 Pearson Ed

Objections to Early Continental Drift Model

- 1915 – Wegener published *The Origins of Continents and Oceans*
 - Suggested continents plow through ocean basins
- Met with hostile criticism and open ridicule
- Tidal gravitational attractions too small to move continents
- Proposed mechanism defies laws of physics

© 2014 Pearson Education, Inc.

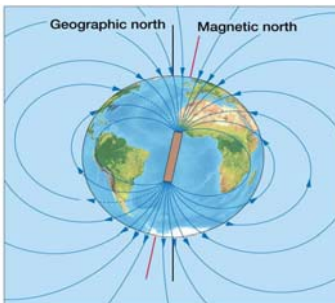
Evidence for Plate Tectonics

- New evidence from World War II
 - Sea floor studies with sonar
 - New technology enabled study of Earth's magnetic field

© 2014 Pearson Education, Inc.

Evidence for Plate Tectonics

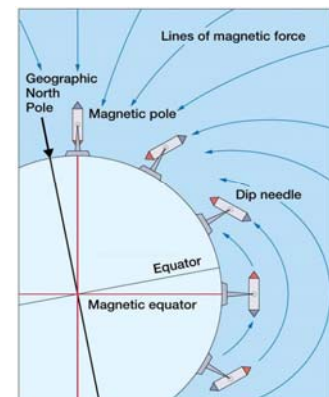
- Earth's magnetic field and paleomagnetism
- Earth has magnetic polarity
- North and South polarities
- Magnetic polarity recorded in igneous rocks
 - Magnetite in basalt



© 2014 Pearson Education, Inc.

Evidence for Plate Tectonics

- Paleomagnetism – study of Earth's ancient magnetic field
 - Interprets where rocks first formed
 - Magnetic dip



© 2014 Pearson Education, Inc.

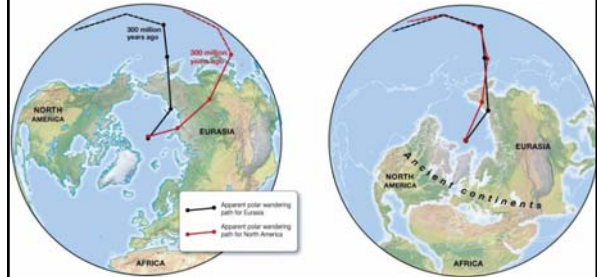
Earth's Magnetic North Pole



© 2014 Pearson Education, Inc.

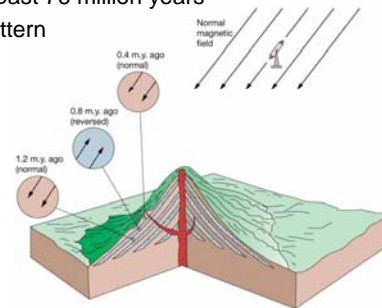
Evidence for Plate Tectonics

- Apparent **polar wandering**
- Location of North Pole changed over time
- Magnetic dip data



Magnetic Polarity Reversals

- Earth's magnetic polarity reverses periodically
- Recorded in ancient igneous rocks
- 176 reversals in past 76 million years
- Unpredictable pattern



© 2014 Pearson Education, Inc.

Paleomagnetism and the Ocean Floor

- 1955 – deep water rock mapping
- **Magnetic anomalies** – regular pattern of north-south magnetism “stripes”
- Stripes were symmetrical about long underwater mountain range

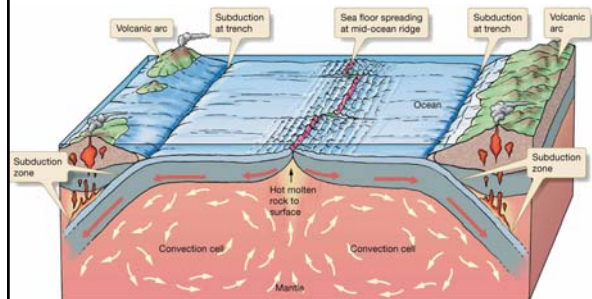
© 2014 Pearson Education, Inc.

Sea Floor Spreading

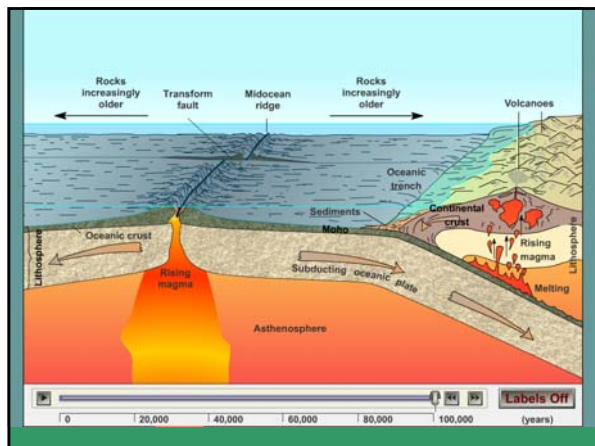
- **Harry Hess**
 - World War II submarine captain and geologist
- Depth recordings show sea floor features
- *History of Ocean Basins*
 - Seafloor spreading
 - Mantle convection cells as driving mechanism

© 2014 Pearson Education, Inc.

Plate Tectonic Processes



© 2014 Pearson Education, Inc.



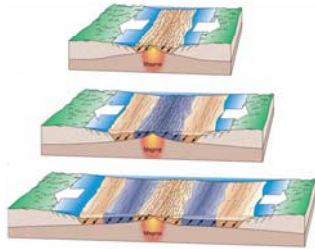
Sea Floor Spreading

- **Mid-ocean ridge** – spreading center
- **Subduction zones** – oceanic trench site of crust destruction
- Subduction can generate **deep ocean trenches**.

© 2014 Pearson Education, Inc.

Sea Floor Spreading Evidence

- **Frederick Vine** and **Drummond Matthews** (1963)
- Analysis of igneous rock stripes around mid-ocean ridge
- Sea floor stripes record Earth's magnetic polarity



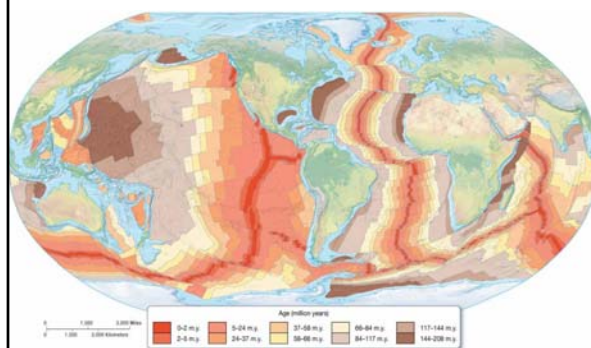
© 2014 Pearson Education, Inc.

Age of Ocean Floor

- Late 1960s deep-sea drilling
- Radiometric dating of ocean rocks
- Symmetric pattern of age distribution about mid-ocean ridges
- Oldest ocean floor only 180 million years old

© 2014 Pearson Education, Inc.

Age of Ocean Floor



© 2014 Pearson Education, Inc.



Heat Flow

- **Heat flow** – heat from Earth's interior released to surface
- Very high at mid-ocean ridges
- Low at subduction zones

© 2014 Pearson Education, Inc.

Earthquakes as Evidence

- Most large earthquakes occur at subduction zones.
- Earthquake activity mirrors tectonic plate boundaries.



Global Plate Boundaries

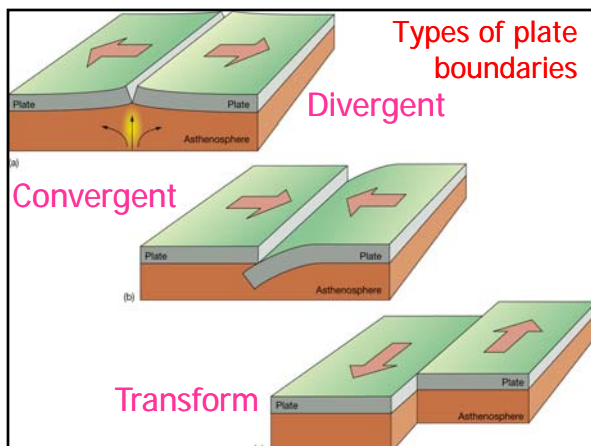


© 2014 Pearson Education, Inc.

Plate Tectonics Theory

- **Lithosphere** – tectonic plates that float on ductile **asthenosphere**
- Large-scale geologic features occur at plate boundaries.
- Two major tectonic forces
 - Slab pull
 - Slab suction

© 2014 Pearson Education, Inc.

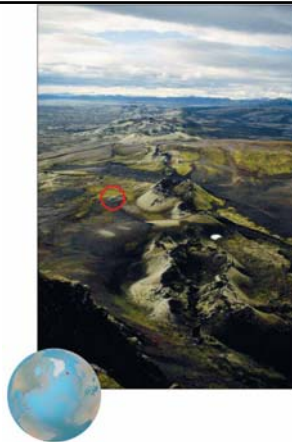


Examples of Plate Boundaries

Plate boundary	Plate movement	Crust types	Sea floor created or destroyed?	Tectonic process	Sea floor feature(s)	Geographic examples
Divergent plate boundaries	Apart ← →	Oceanic-oceanic	New sea floor is created	Sea floor spreading	Mid-ocean ridge; volcanoes; young lava flows	Mid-Atlantic Ridge, East Pacific Rise
		Continental-continental	As a continent splits apart, new sea floor is created	Continental rifting	Rift valley; volcanoes; young lava flows	East Africa Rift Valley, Red Sea, Gulf of California
Convergent plate boundaries	Together → ←	Oceanic-continental	Old sea floor is destroyed	Subduction	Trench; volcanic arc on land	Peru-Chile Trench, Andes Mountains
		Oceanic-oceanic	Old sea floor is destroyed	Subduction	Trench; volcanic arc as islands	Mariana Trench, Aleutian Islands
		Continental-continental	N/A	Collision	Tall mountains	Himalaya Mountains, Alps
Transform plate boundaries	Past each other → ←	Oceanic	N/A	Transform faulting	Fault	Mendocino Fault, Etnan Fault (between mid-ocean ridges)
		Continental	N/A	Transform faulting	Fault	San Andreas Fault, Alpine Fault (New Zealand)

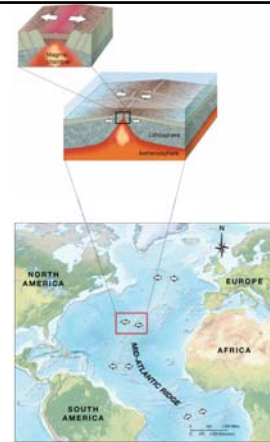
Divergent Boundary Features

- Plates move apart
- Mid-ocean ridge
 - Rift valley
- New ocean floor created
- Shallow focus earthquakes
 - Intensity measured with seismic moment magnitude

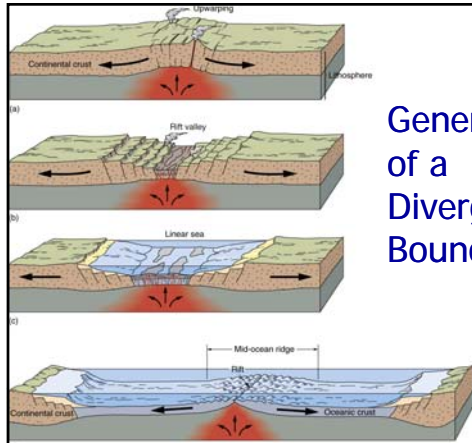


© 2014 Pearson Education, Inc.

Divergent Plate Boundary

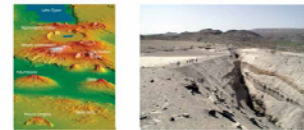


© 2014 Pearson Education, Inc.



Generation of a Divergent Boundary

Formation of a Rift Valley



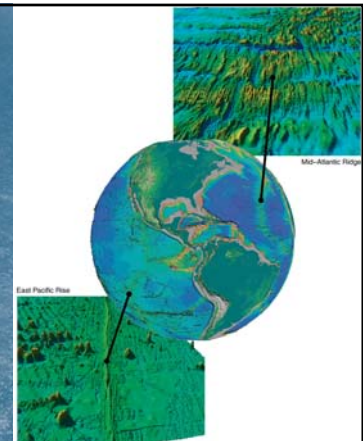
© 2014 Pearson Education, Inc.

Types of Spreading Centers

- **Oceanic rise**
 - Fast-spreading
 - Gentle slopes
 - East Pacific
- **Oceanic ridge**
 - Slow-spreading
 - Steep slopes
 - Mid-Atlantic
- **Ultra-slow**
 - Deep rift valley
 - Widely scattered volcanoes
 - Arctic and southwest India

© 2014 Pearson Education, Inc.

Fast vs. Slow:

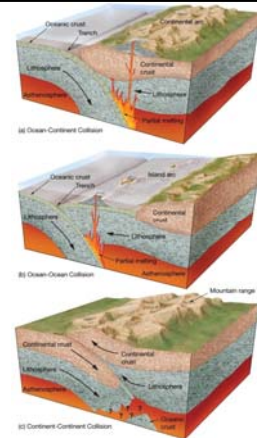


Convergent Boundary Features

- Plates move toward each other
- Oceanic crust destroyed
 - Ocean trench
 - Volcanic arc
- Deep focus earthquakes
 - Great forces involved
 - Mineral structure changes associated

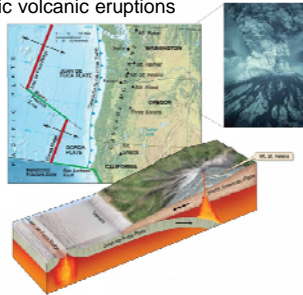
© 2014 Pearson Education, Inc.

Three types of convergent plate boundaries:



Types of Convergent Boundaries

- Oceanic-Continental Convergence**
 - Ocean plate is subducted
 - Continental arcs generated
 - Explosive andesitic volcanic eruptions



© 2014 Pearson Education, Inc.

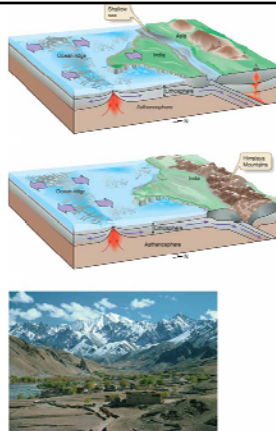
Types of Convergent Boundaries

- Oceanic-Oceanic Convergence**
 - Denser plate is subducted
 - Deep trenches generated
 - Volcanic island arcs generated

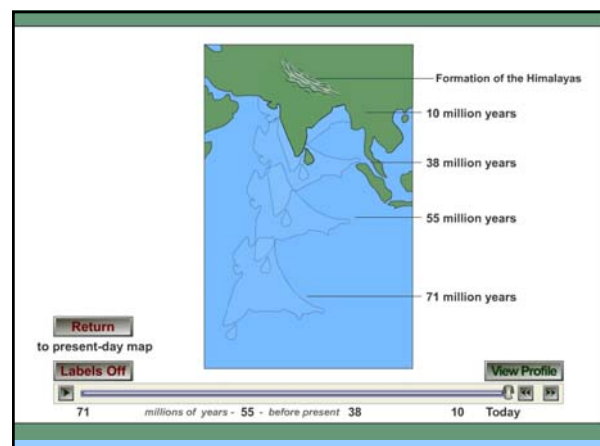
© 2014 Pearson Education, Inc.

Types of Convergent Boundaries

- Continental-Continental Convergence**
 - No subduction
 - Tall mountains uplifted
- Himalayas from India-Asia collision



© 2014 Pearson Education, Inc.



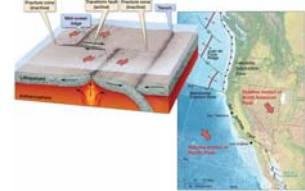
Transform Boundary Features

- Offsets oriented perpendicular to mid-ocean ridge
 - Segments of plates slide past each other
- Offsets permit mid-ocean ridge to move apart at different rates
- Shallow but strong earthquakes

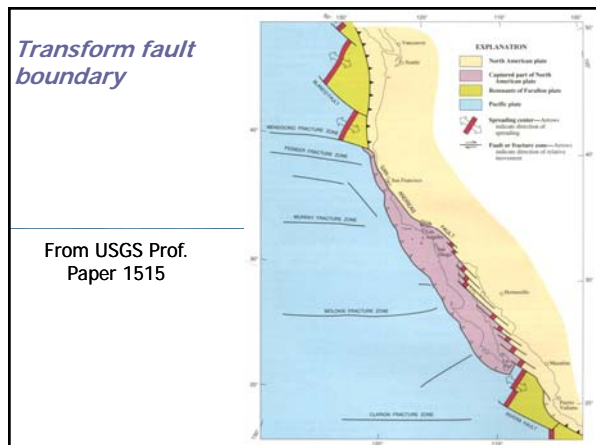
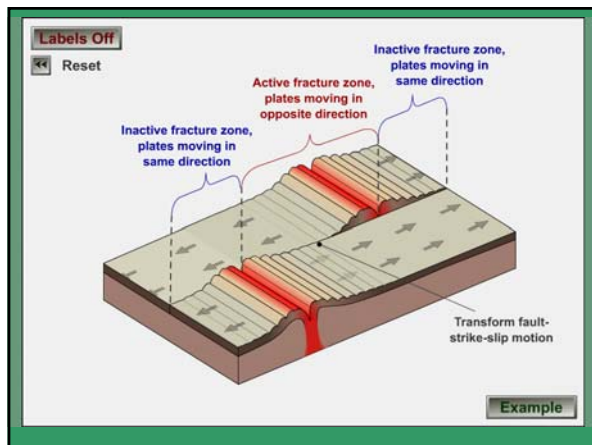
© 2014 Pearson Education, Inc.

Transform Boundary Features

- **Oceanic Transform Fault** – ocean floor only
- **Continental Transform Fault** – cuts across continent
 - San Andreas Fault
- Transform faults occur between mid-ocean ridge segments.

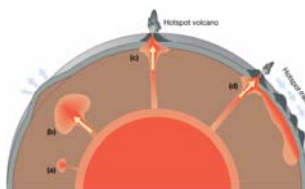


© 2014 Pearson Education, Inc.



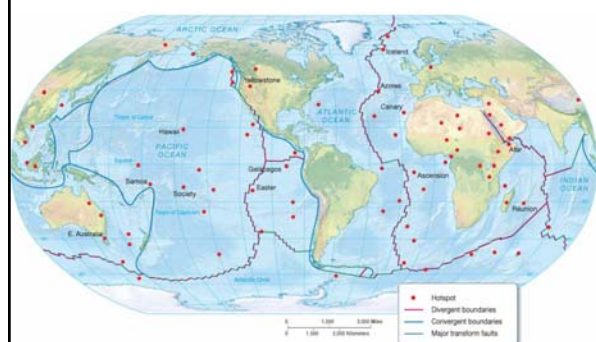
Applications of Plate Tectonics

- **Mantle Plumes and Hotspots**
 - Intraplate features
 - Volcanic islands within a plate
 - Island chains
- Record ancient plate motions
 - **Nematath** – hotspot track

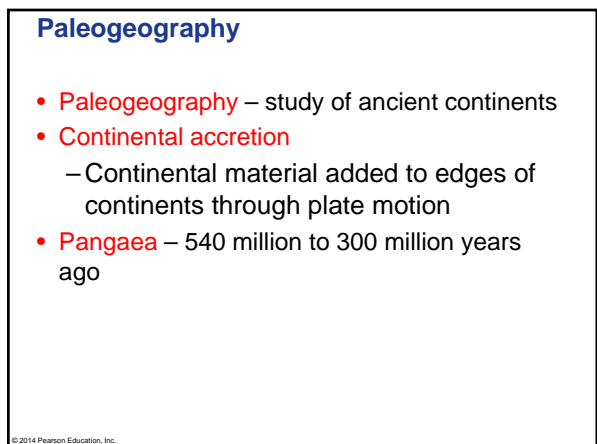
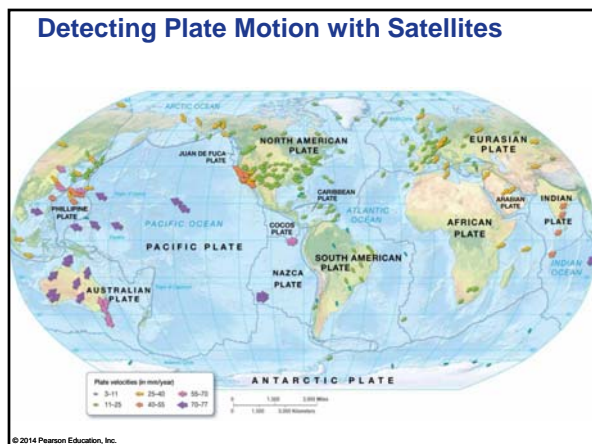
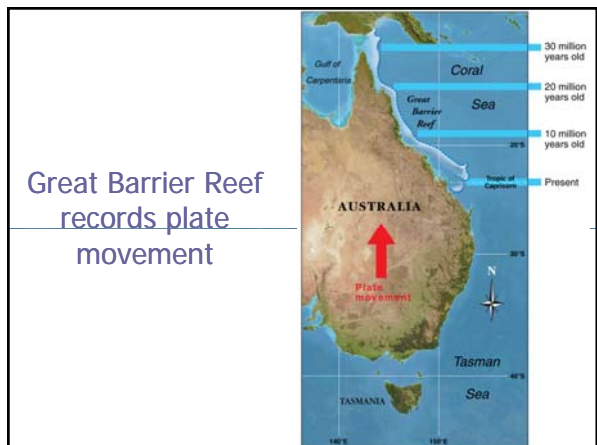
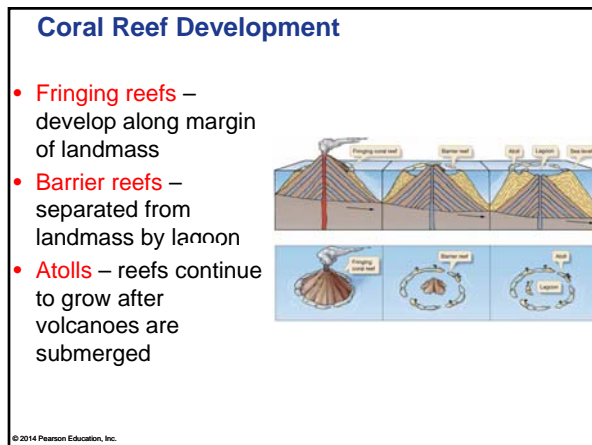
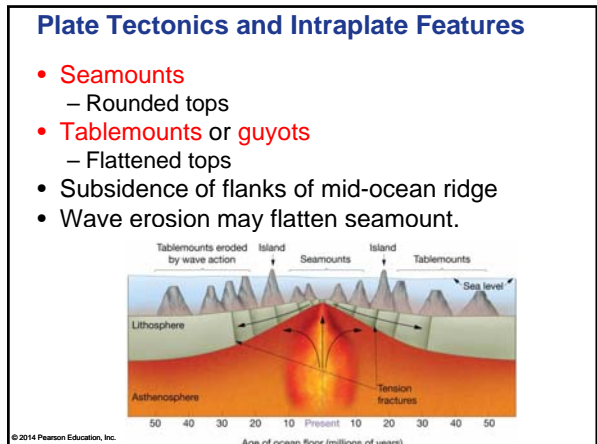
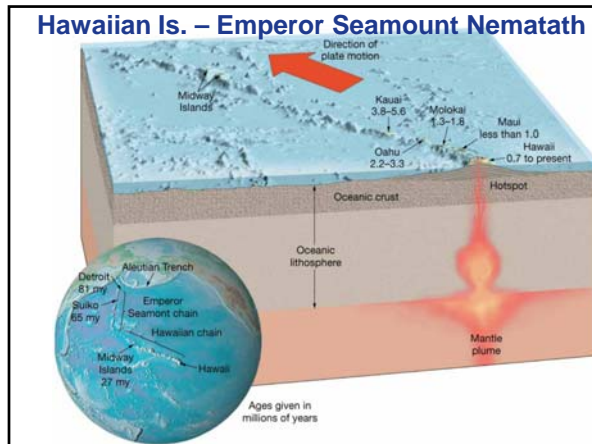


© 2014 Pearson Education, Inc.

Global Hotspot Locations



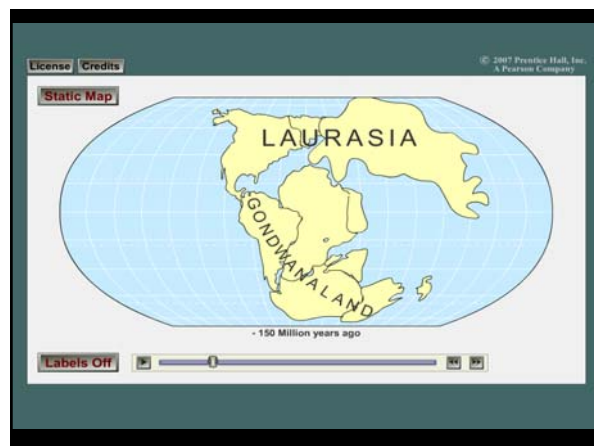
© 2014 Pearson Education, Inc.



Breakup of Pangaea

- 180 million years ago – Pangaea separated
 - N. and S. America rifted from Europe and Africa
 - Atlantic Ocean forms
- 120 million years ago – S. America and Africa clearly separated
- 45 million years ago – India starts Asia collision
 - Australia moving north from Antarctica

© 2014 Pearson Education, Inc.

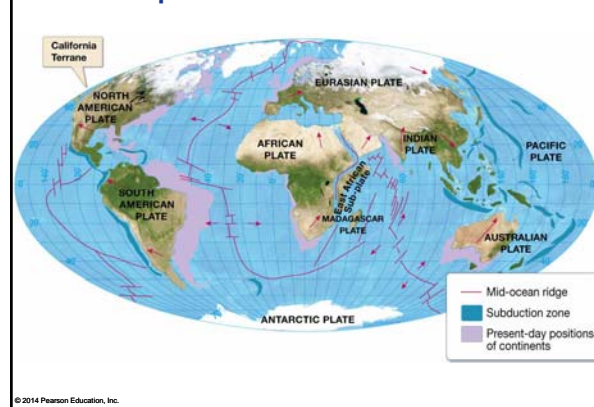


Future Predictions

- Assume same direction and rate of plate motions as now
 - Atlantic will enlarge, Pacific will shrink
 - New sea from East Africa rift valleys
 - Further Himalaya uplift
 - Separation of North and South America
 - Part of California in Alaska

© 2014 Pearson Education, Inc.

World Map 50 million Years in Future

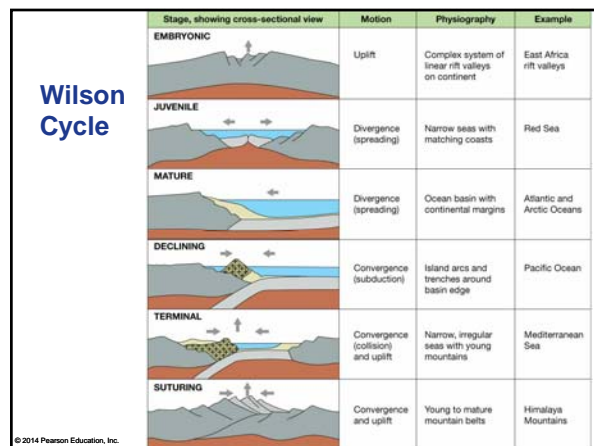


© 2014 Pearson Education, Inc.

Wilson Cycle

- **John Tuzo Wilson**
- Plate tectonics model shows life cycle of ocean basins
 - Formation
 - Growth
 - Destruction

© 2014 Pearson Education, Inc.



© 2014 Pearson Education, Inc.

End of Chapter 2 -
Plate Tectonics and the Ocean Floor

