Essentials of Oceanography

Eleventh Edition

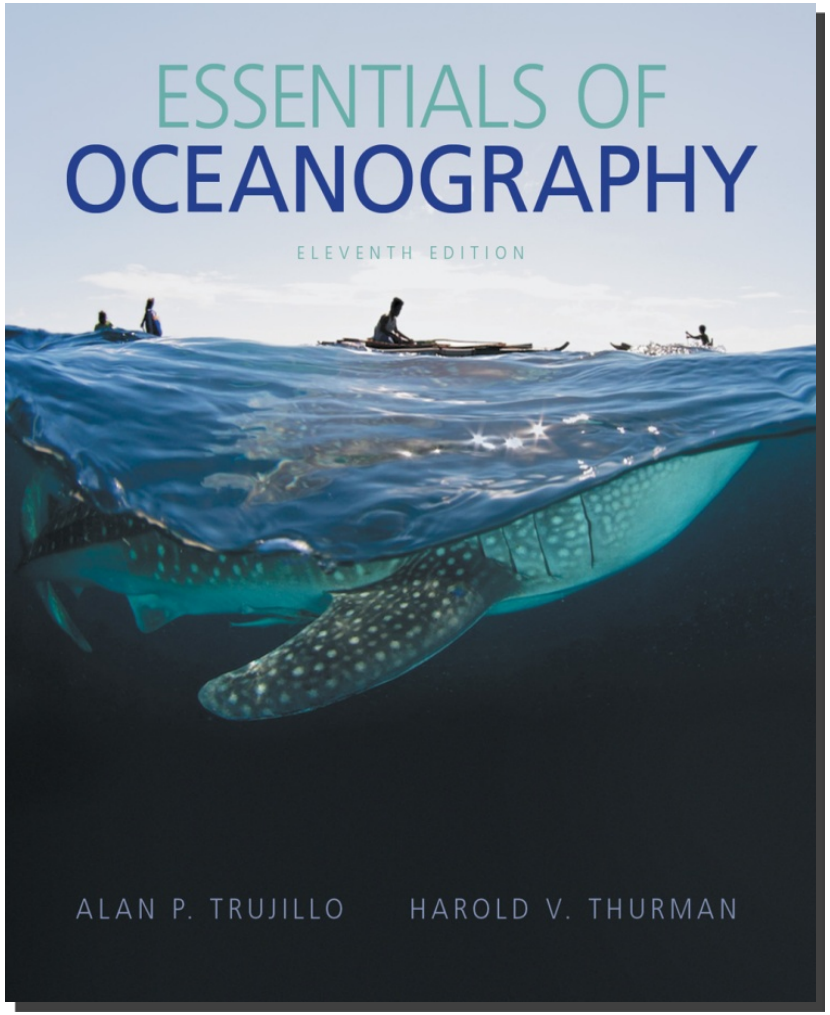

Plate Tectonics and the Ocean Floor

Alan P. Trujillo
Harold V. Thurman

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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.

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Plate Tectonics

- Alfred Wegener first proposed in 1912
- Called it “Continental Drift”

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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

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Evidence for Continental Drift

- Puzzle-like fit corroborated in 1960s
- Sir Edward Bullard used computer models to fit continents.

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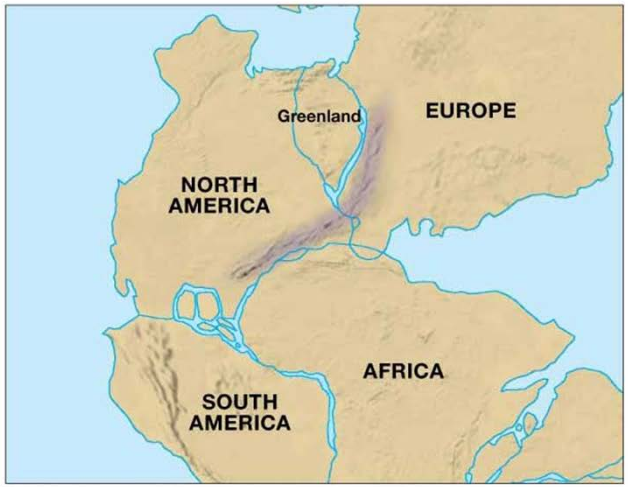
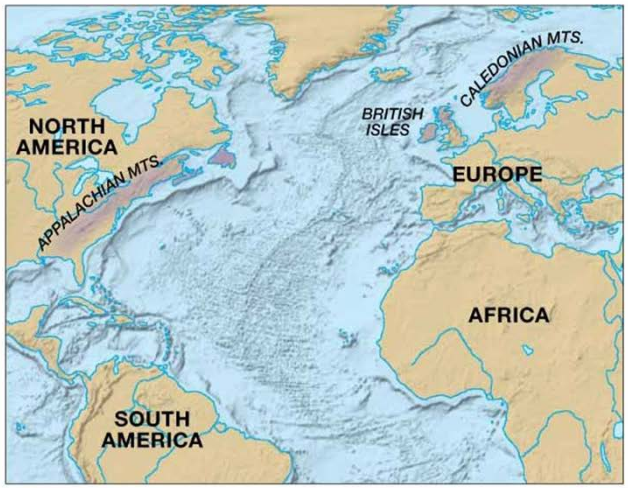
Evidence for Continental Drift

- Matching sequences of rocks and mountain chains
- Similar rock types, ages, and structures on different continents





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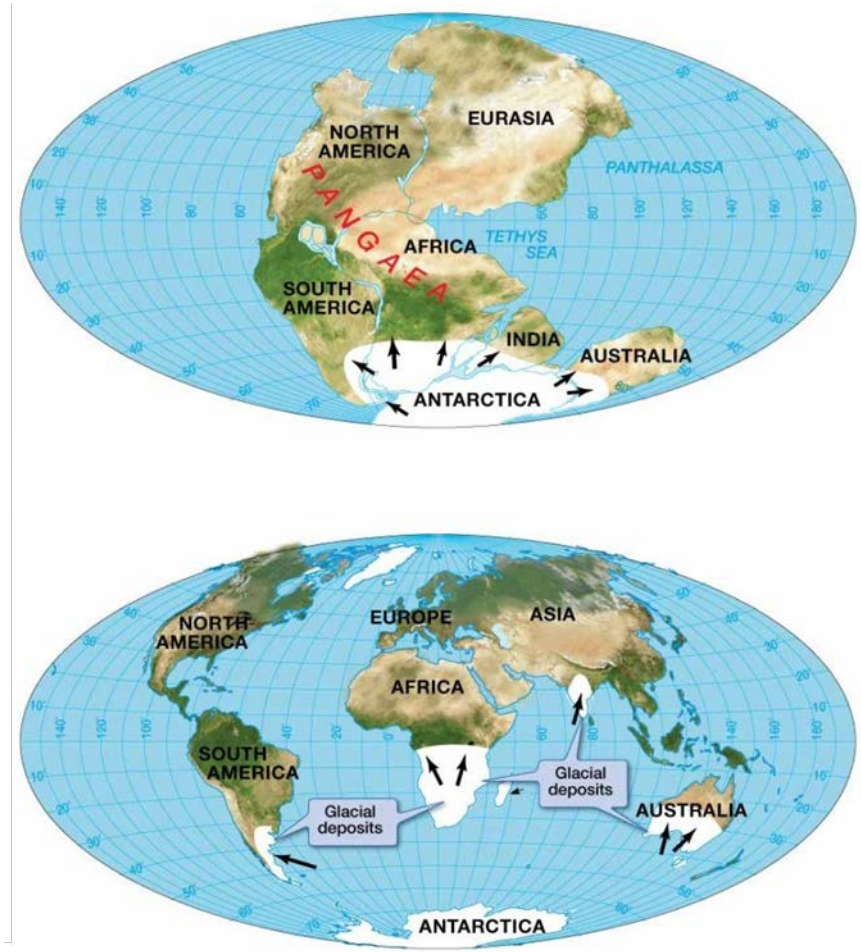
Evidence for Continental Drift

- 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.



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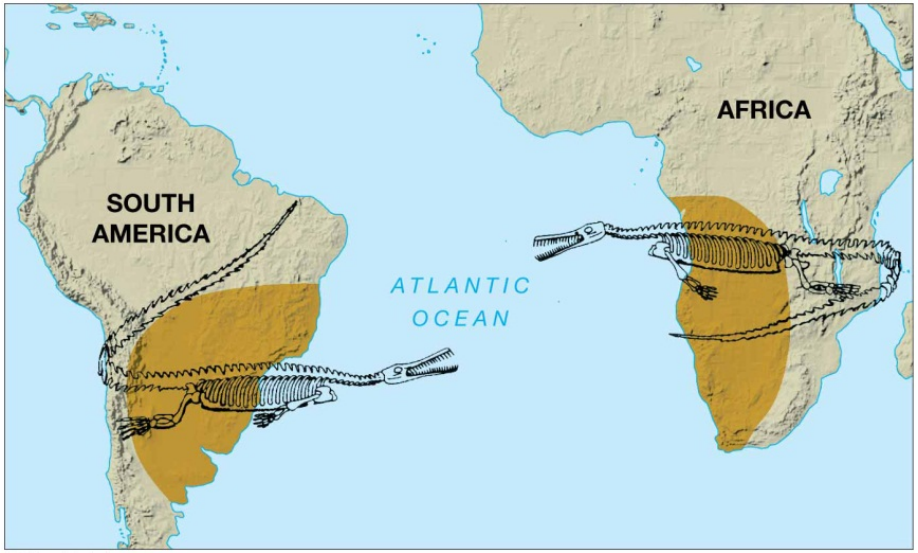
Evidence for Continental Drift

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



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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

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Evidence for Plate Tectonics

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

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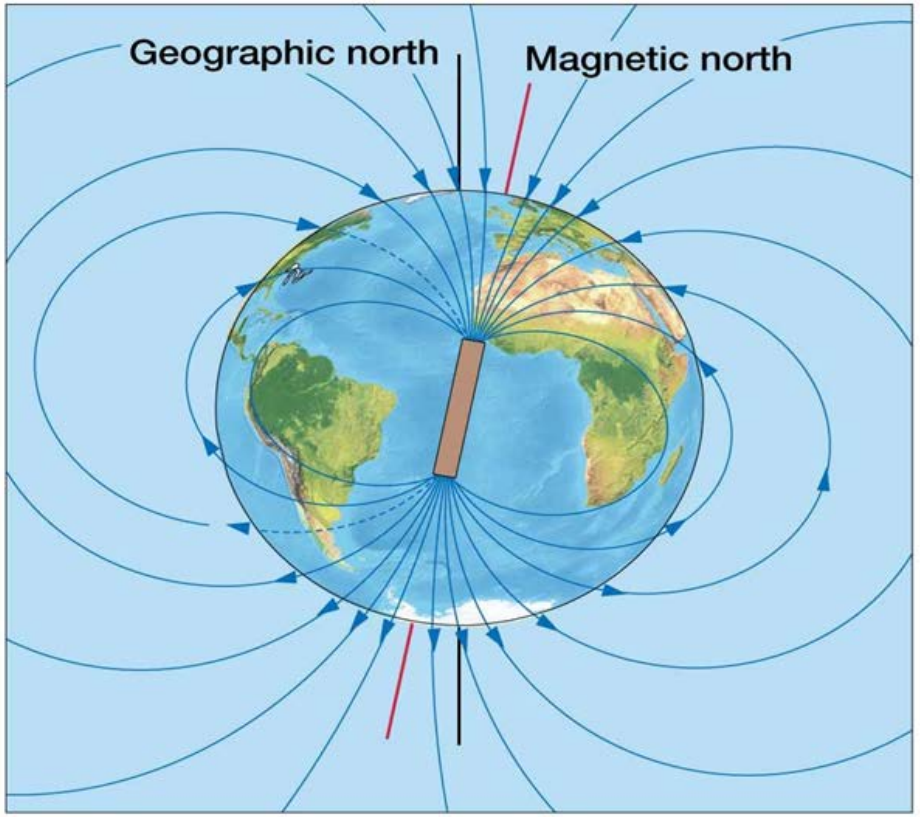
Evidence for Plate Tectonics

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



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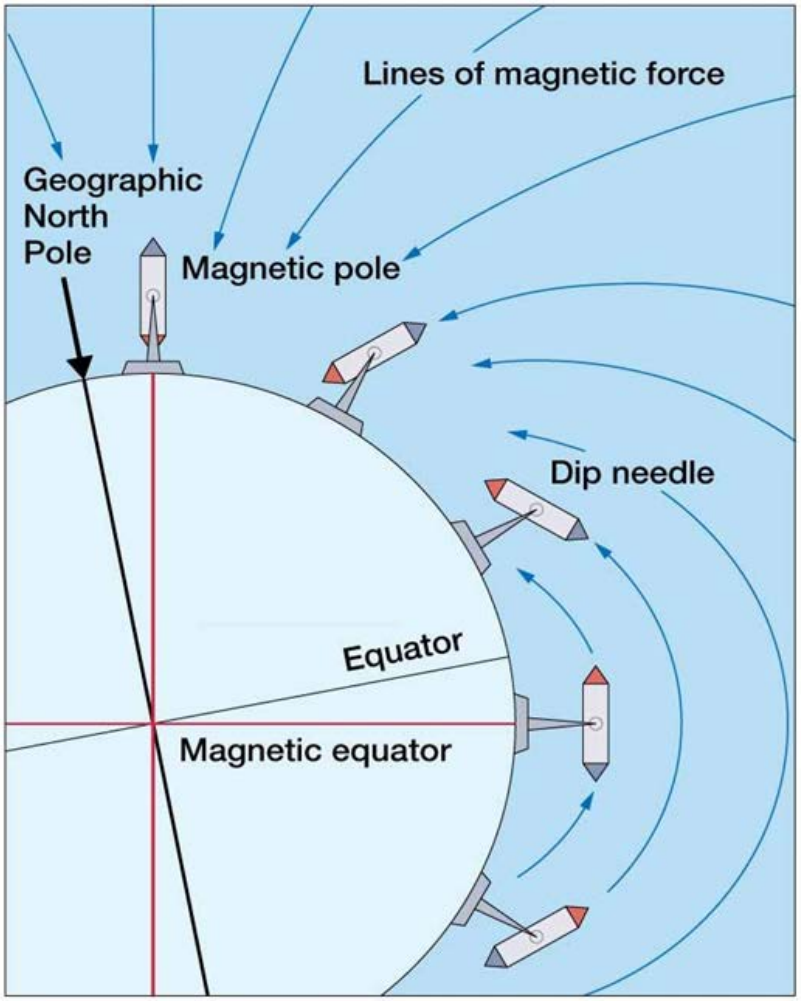
Evidence for Plate Tectonics

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



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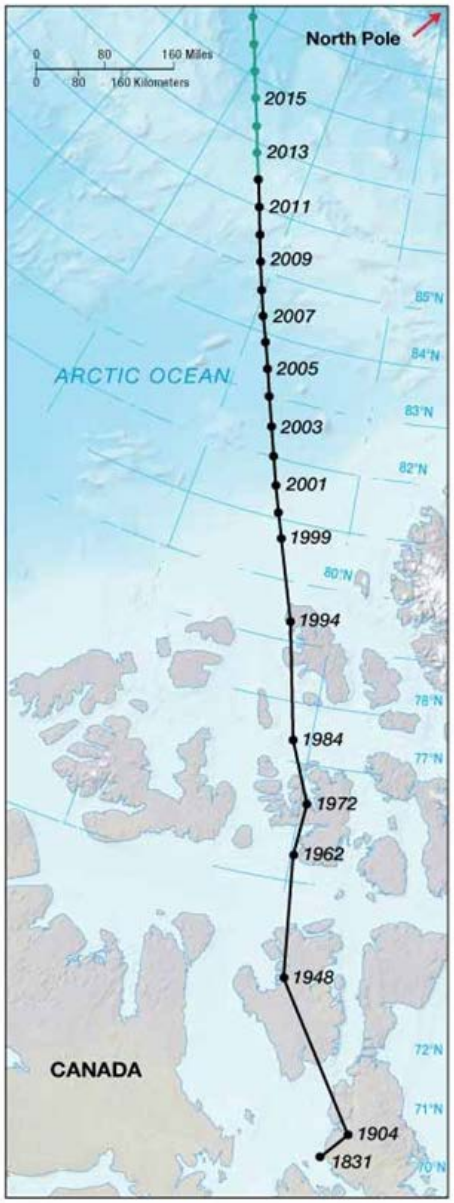
Earth's Magnetic Pole



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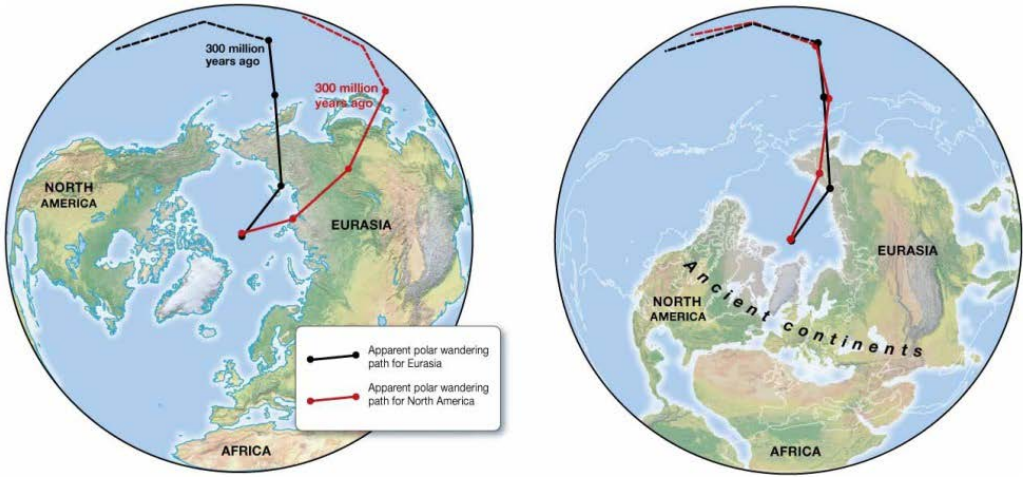
Evidence for Plate Tectonics

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



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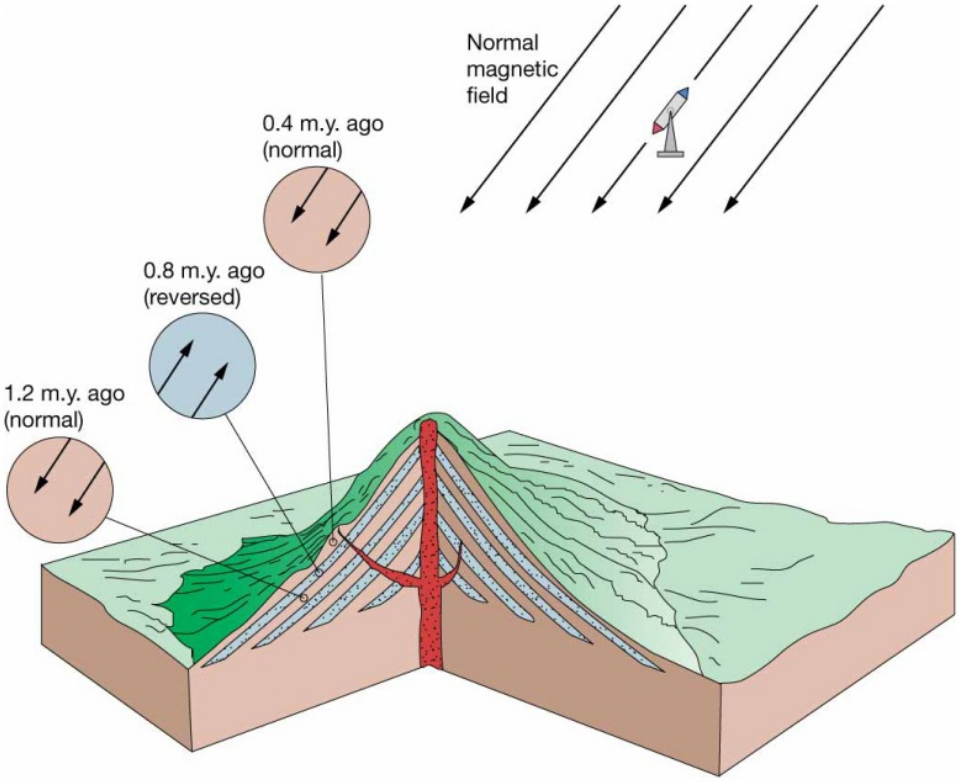
Magnetic Polarity Reversals

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



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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

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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

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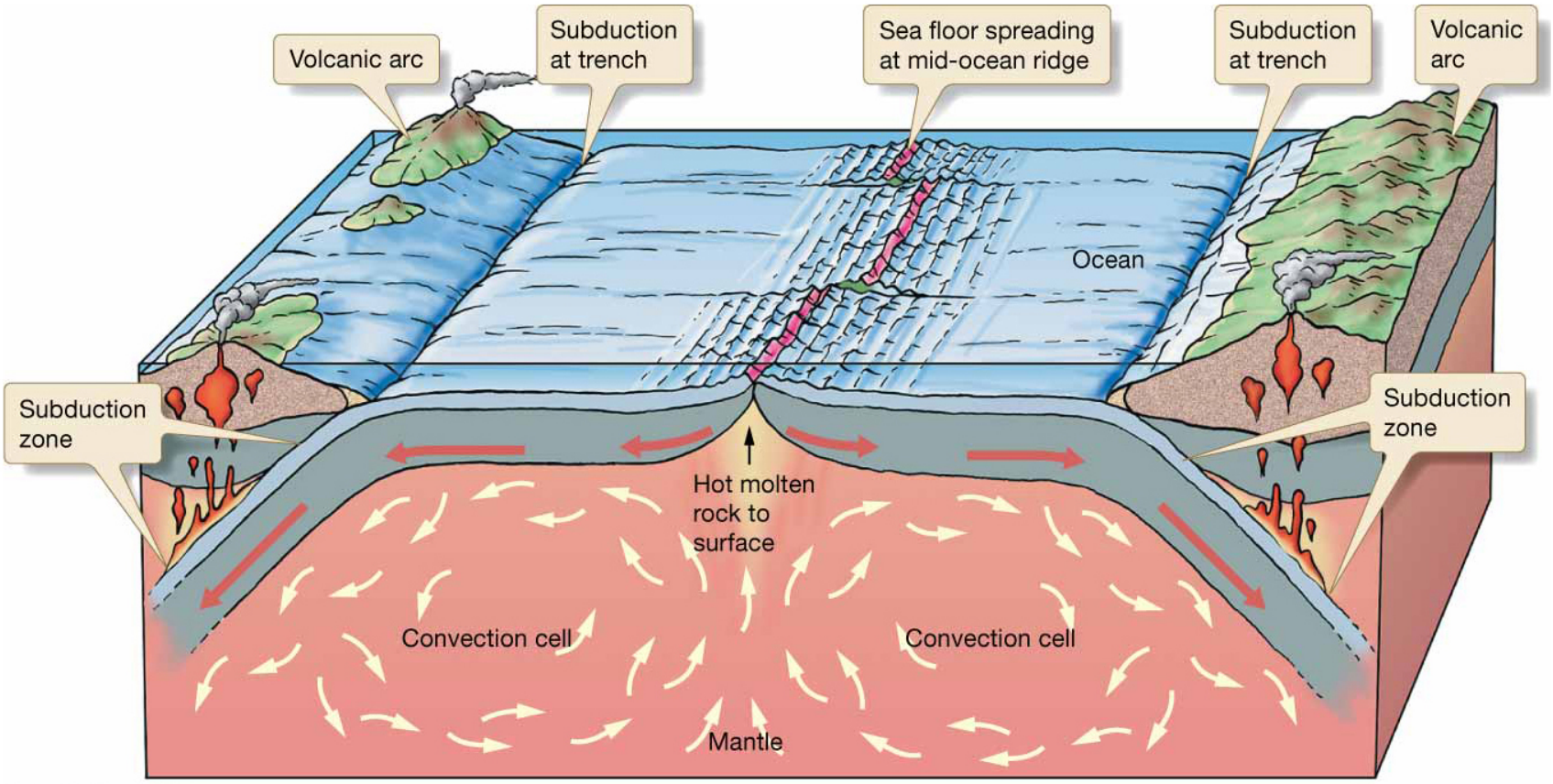
Plate Tectonic Processes



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Sea Floor Spreading

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

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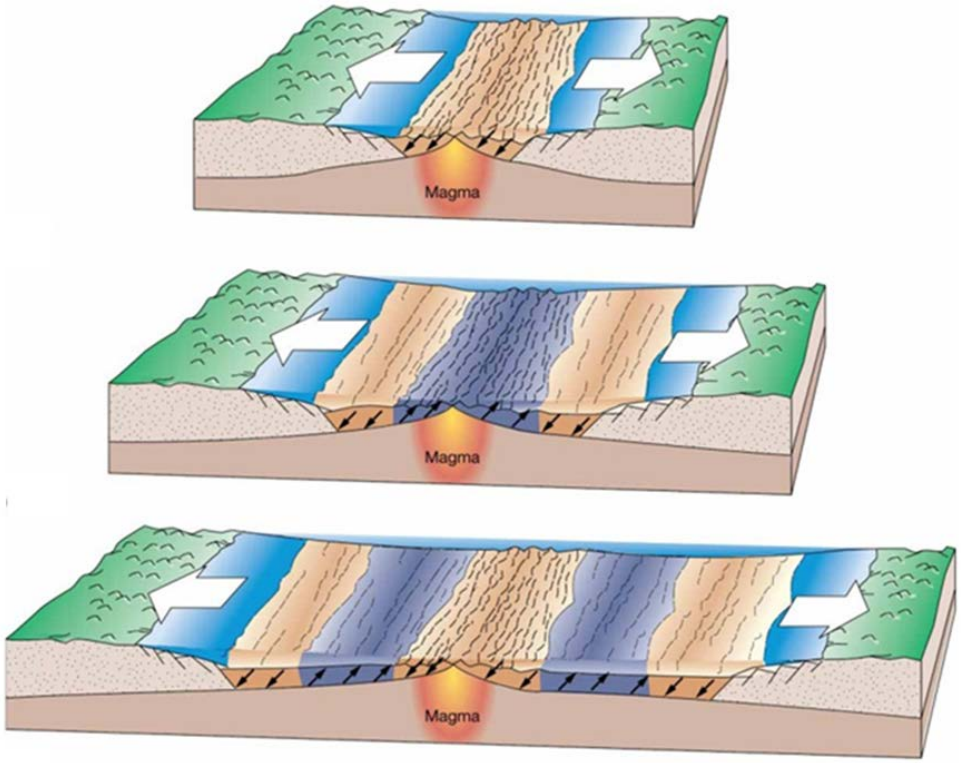
Sea Floor Spreading Evidence

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



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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

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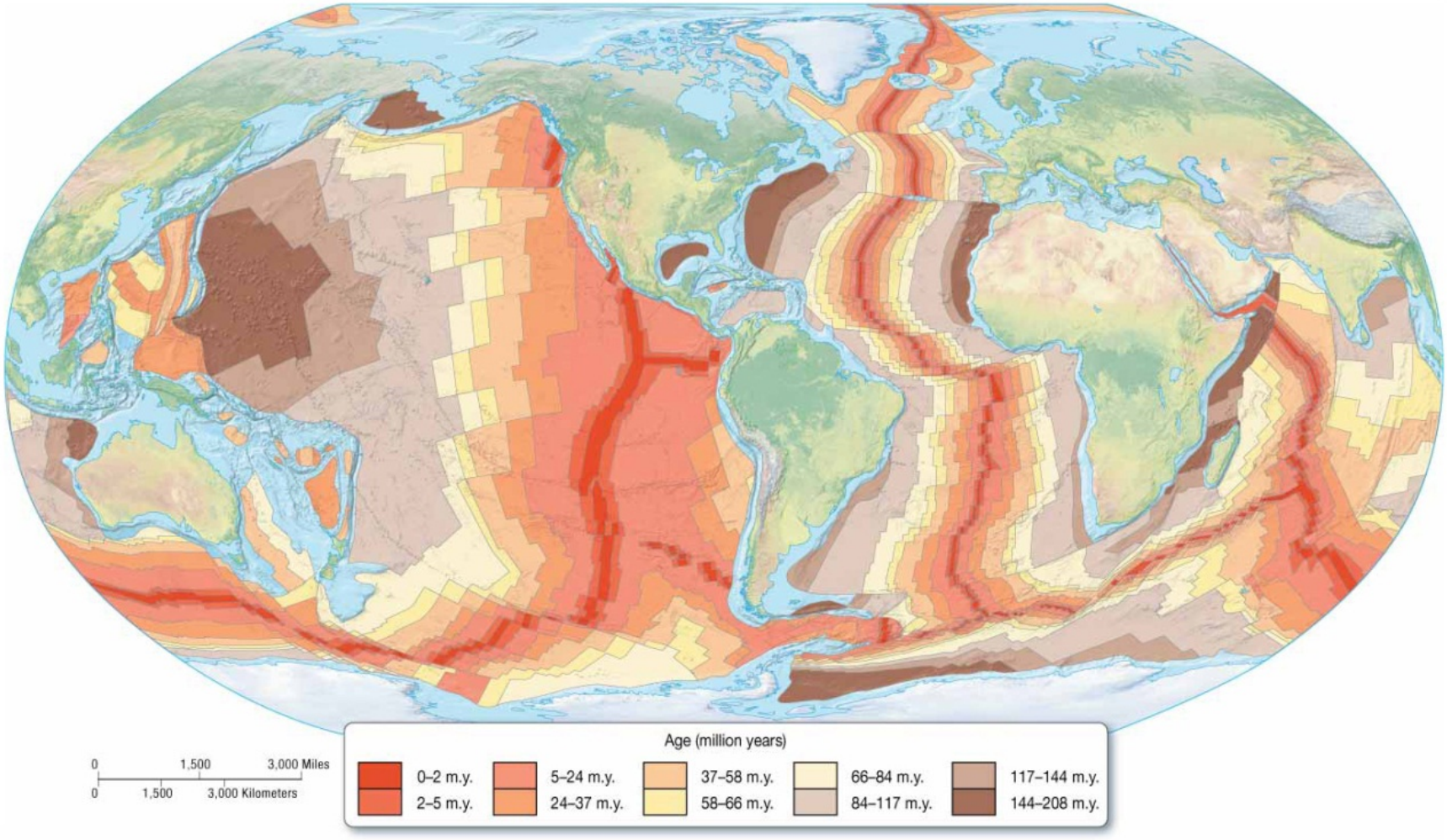
Age of Ocean Floor



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Heat Flow

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

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Earthquakes as Evidence

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

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Global Plate Boundaries

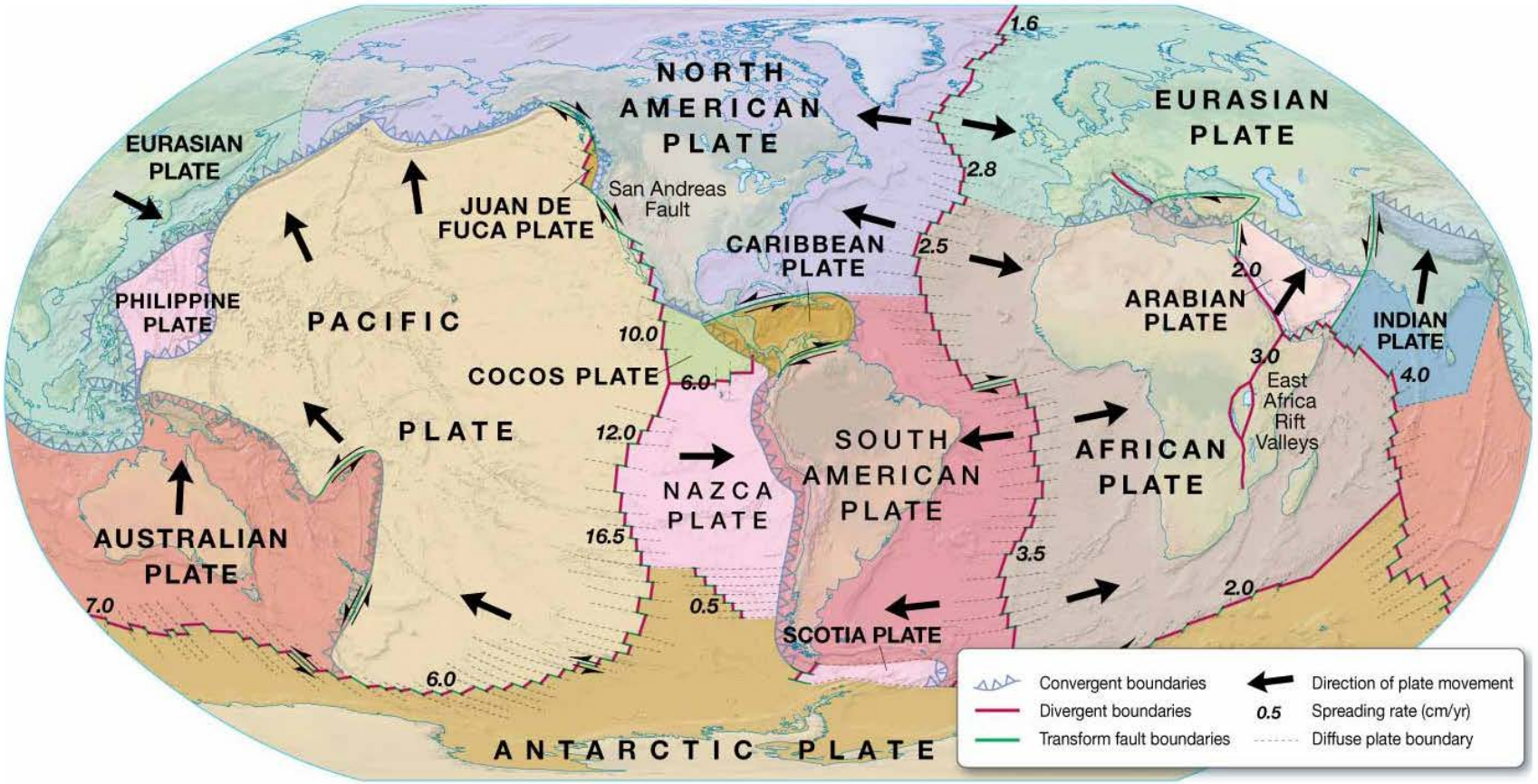

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Plate Tectonics Theory

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

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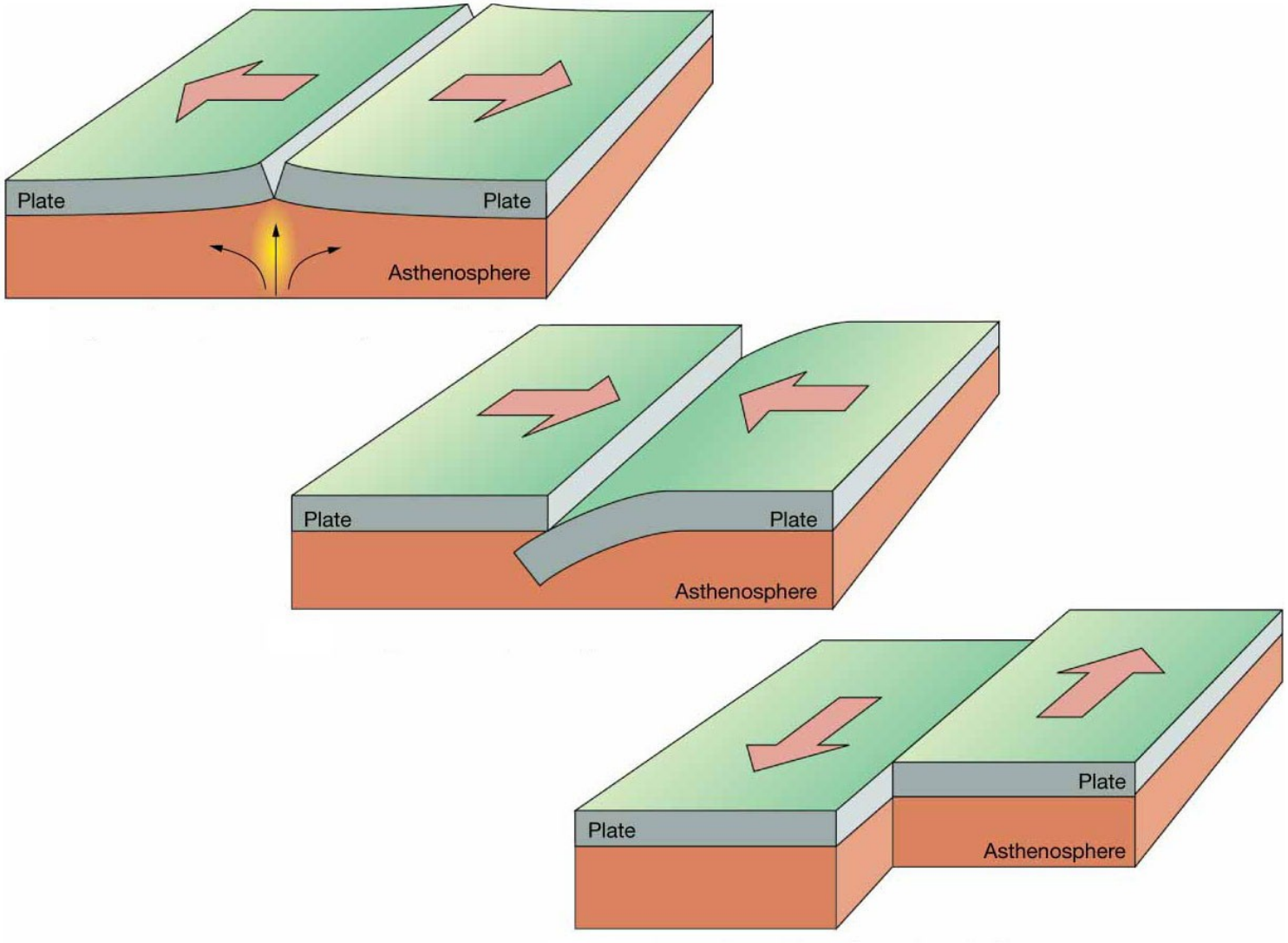
Types of Plate Boundaries



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Examples of Plate Boundaries

TABLE 2.1 CHARACTERISTICS, TECTONIC PROCESSES, FEATURES, AND 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 Valleys, 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, Eltanin Fault (between mid-ocean ridges)
		Continental	N/A	Transform Faulting	Fault	San Andreas Fault, Alpine Fault (New Zealand)

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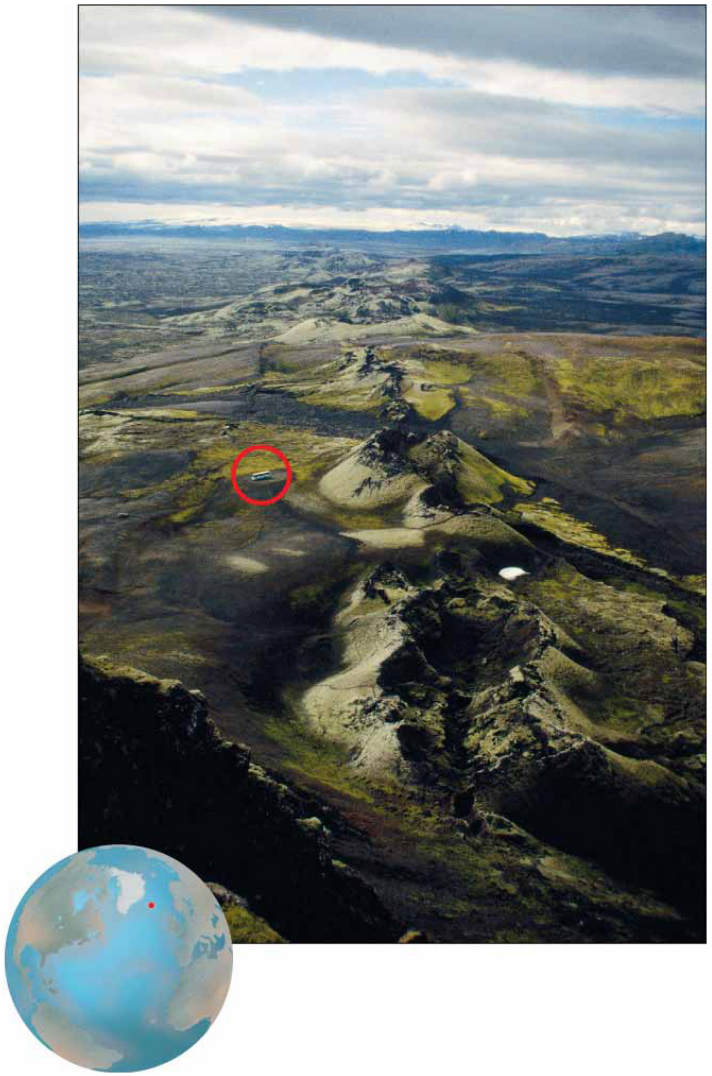
Divergent Boundary Features

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



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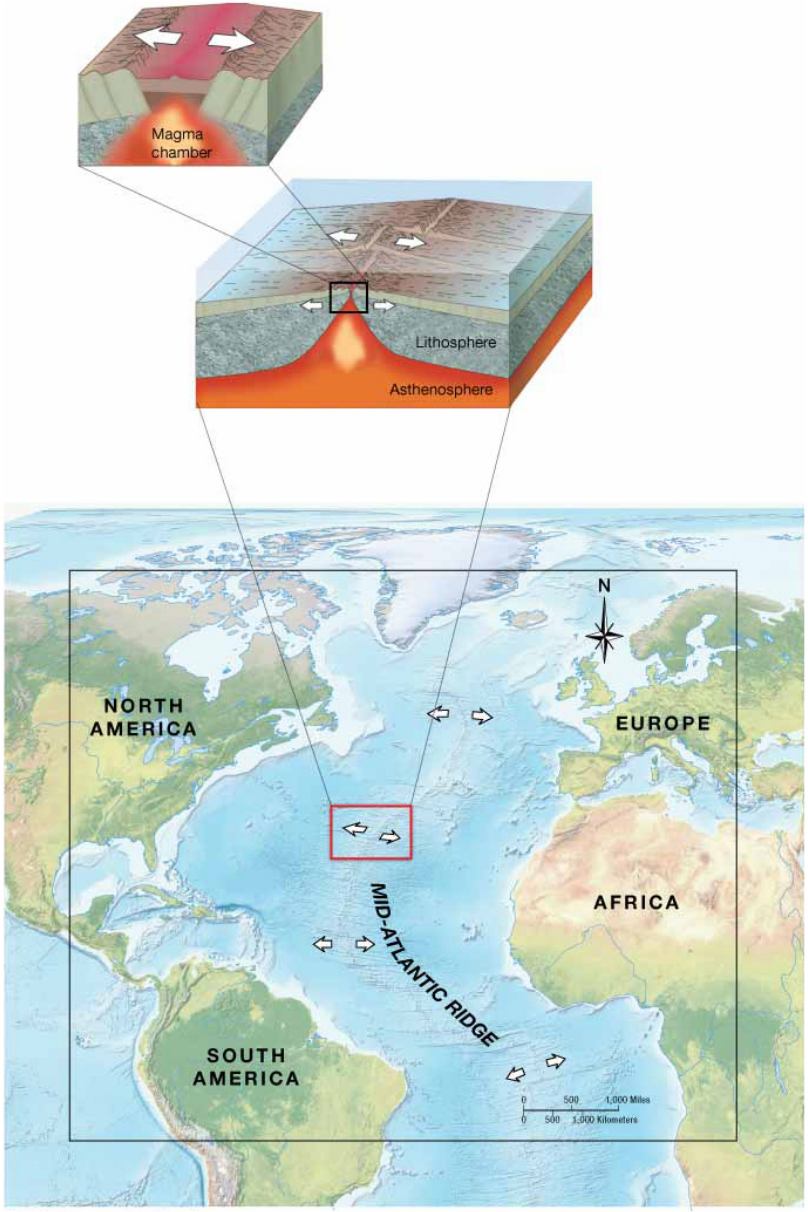
Divergent Plate Boundary



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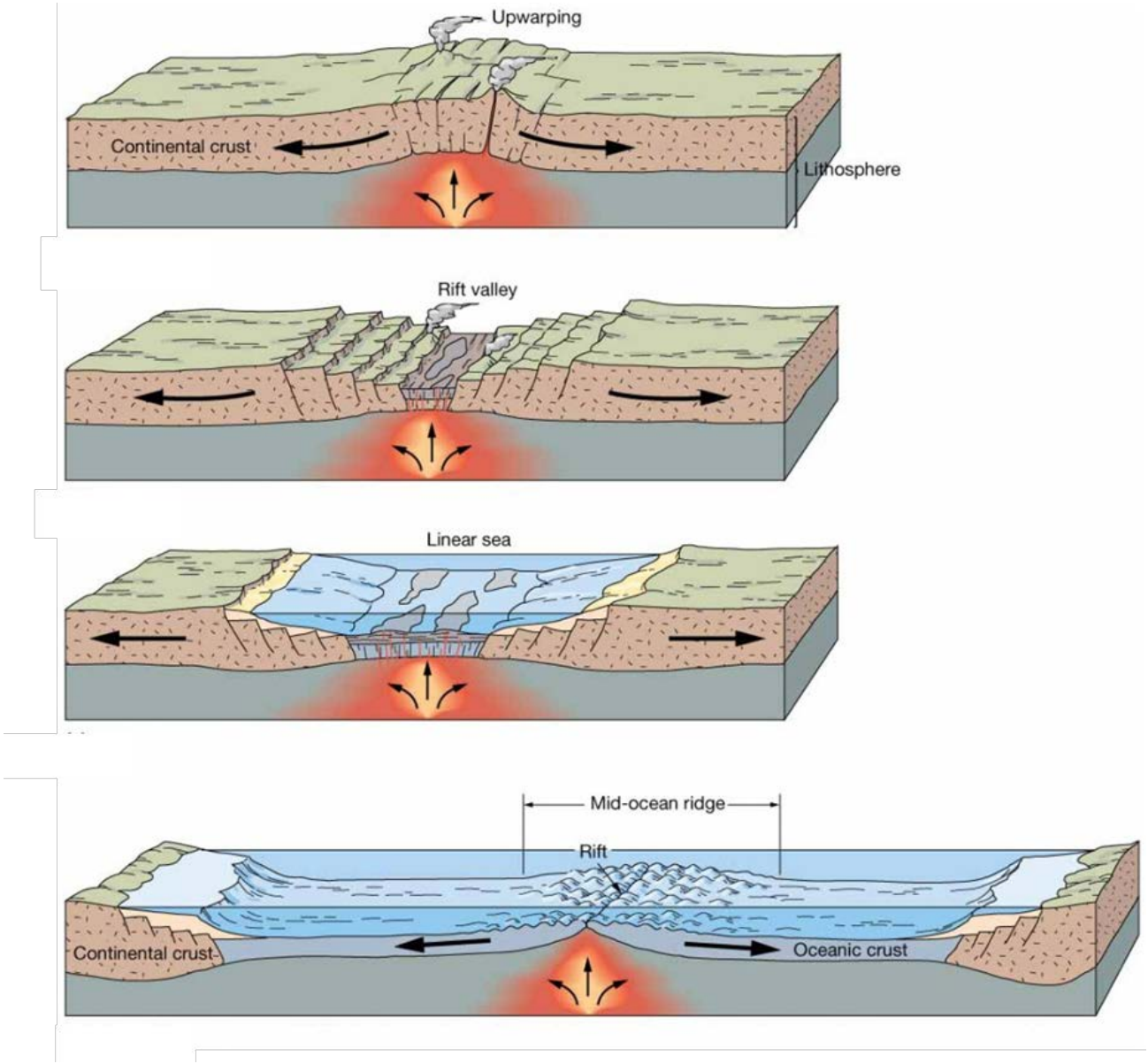
Generation of a Divergent Boundary



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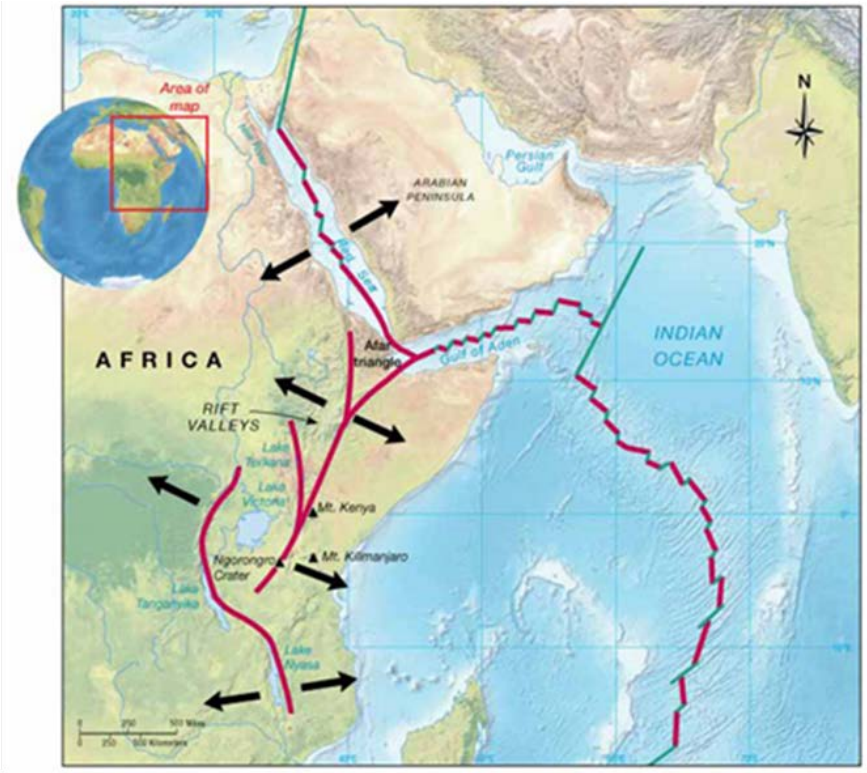
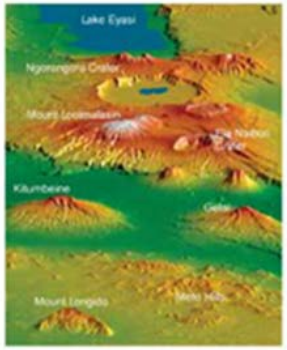
Formation of a Rift Valley





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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

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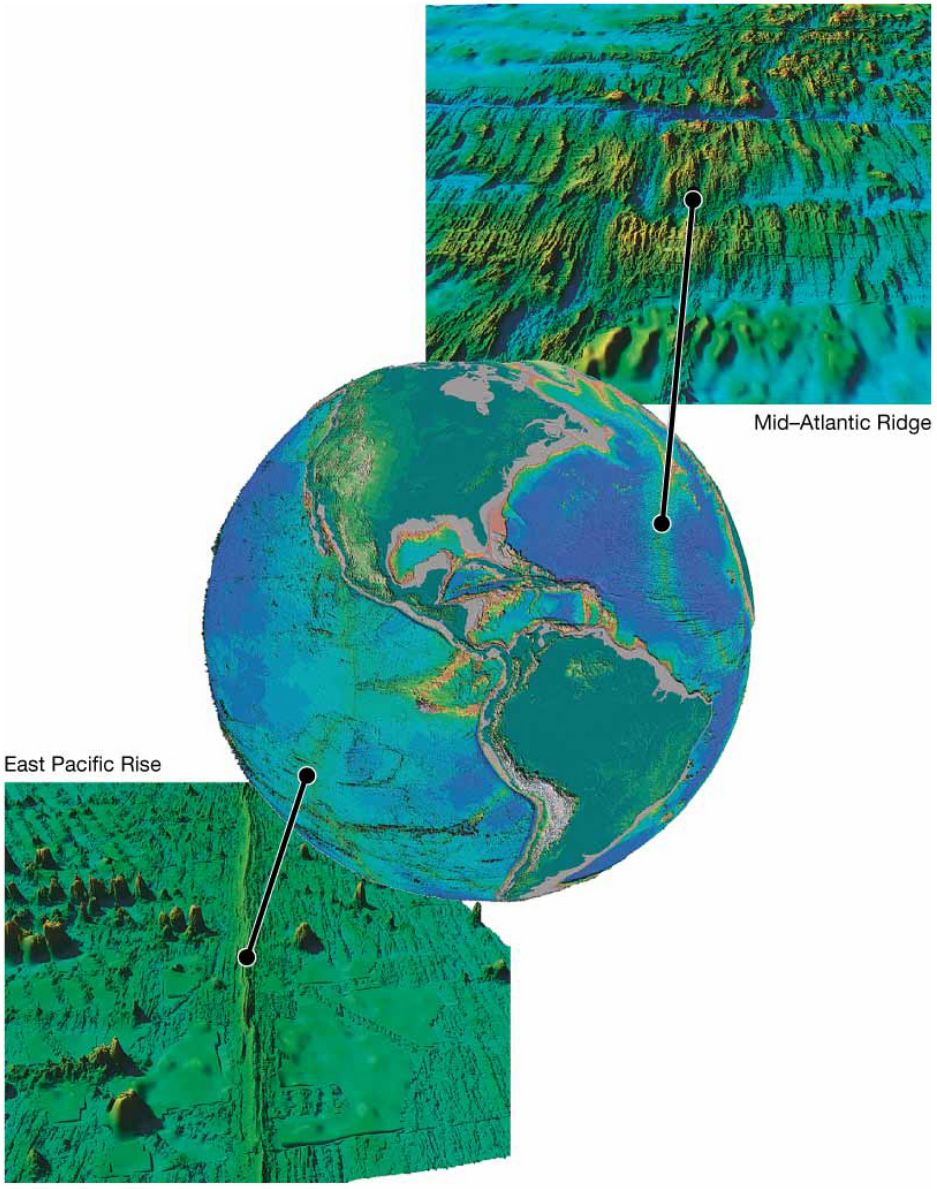
Types of Spreading Centers



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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

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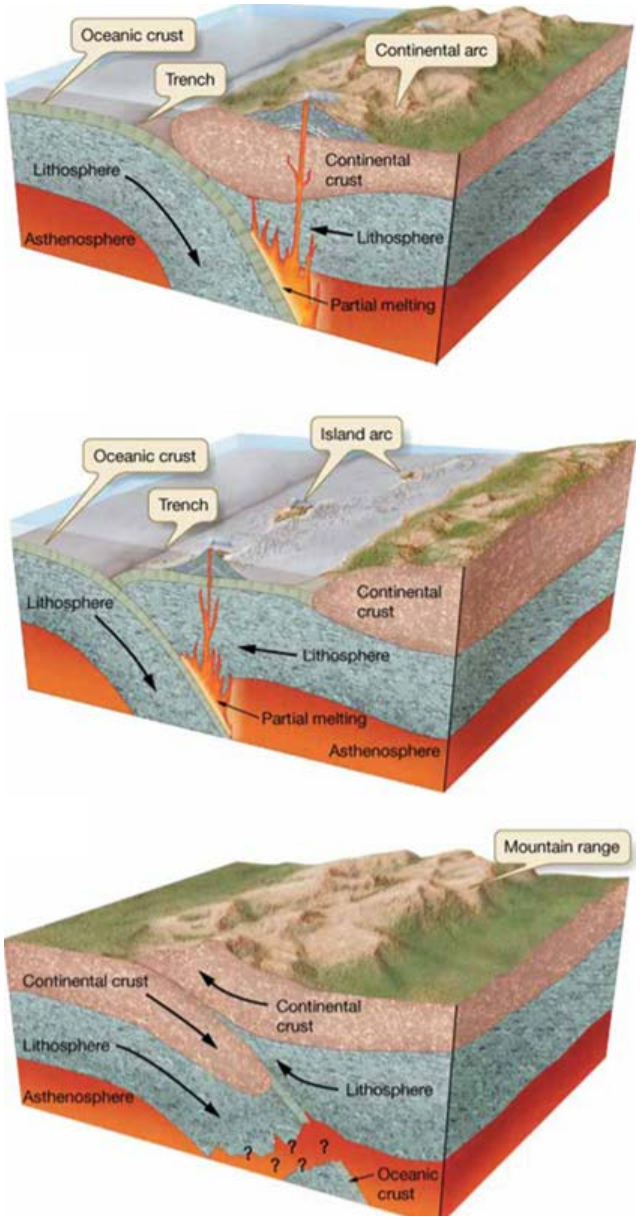
Three Types of Convergent Boundaries



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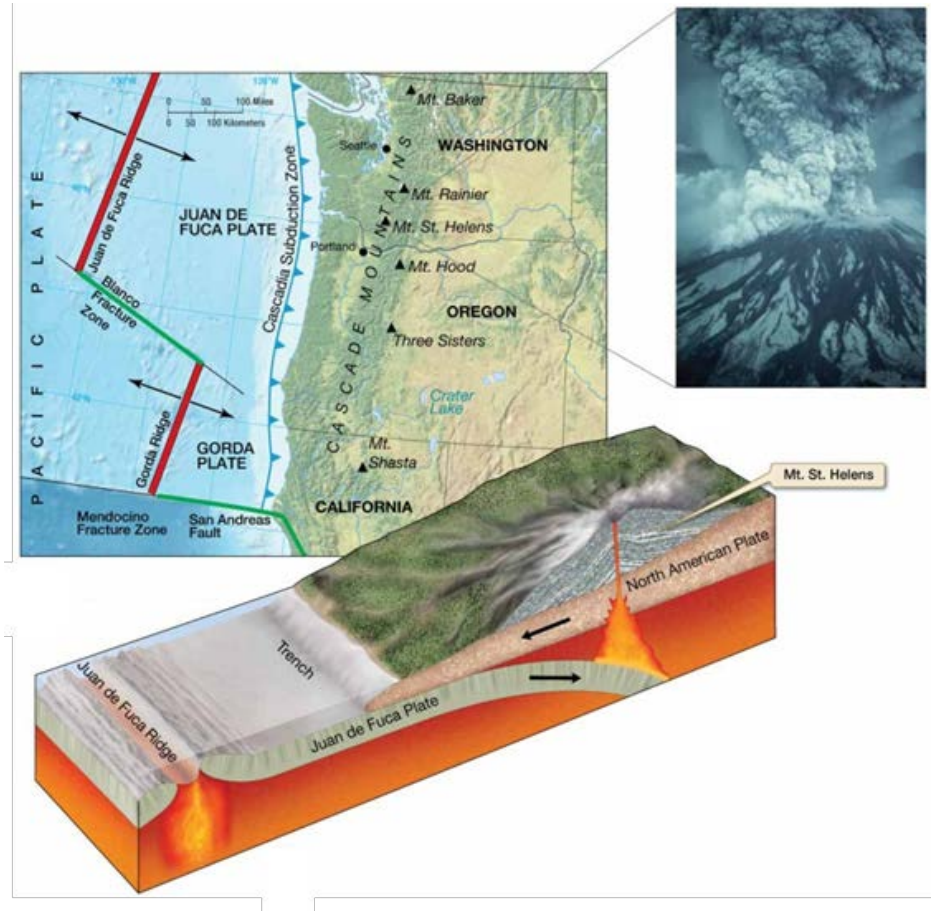
Types of Convergent Boundaries

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



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Types of Convergent Boundaries

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

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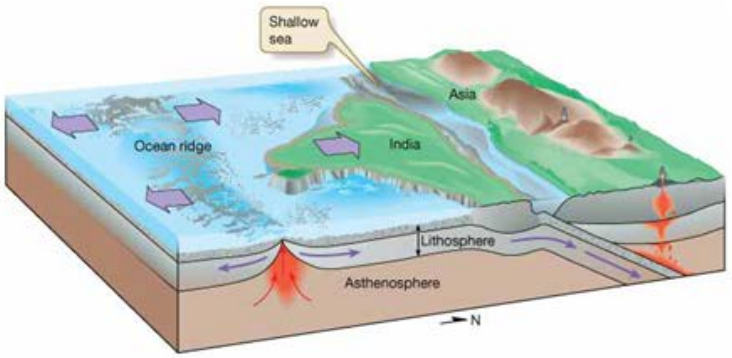
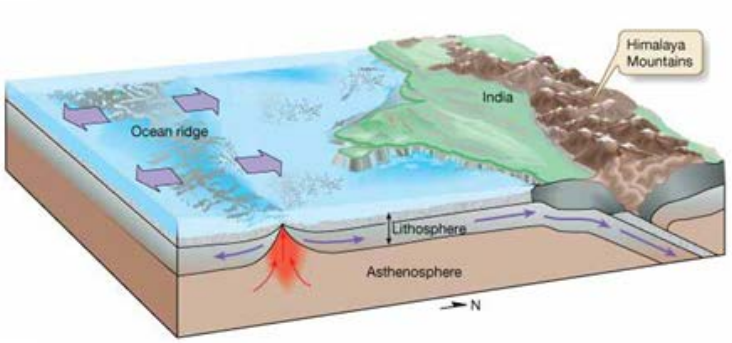
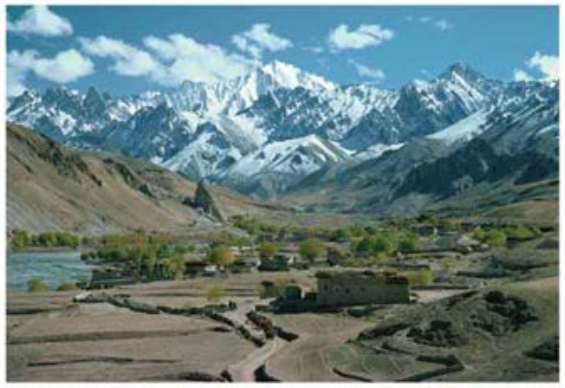
Types of Convergent Boundaries

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







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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

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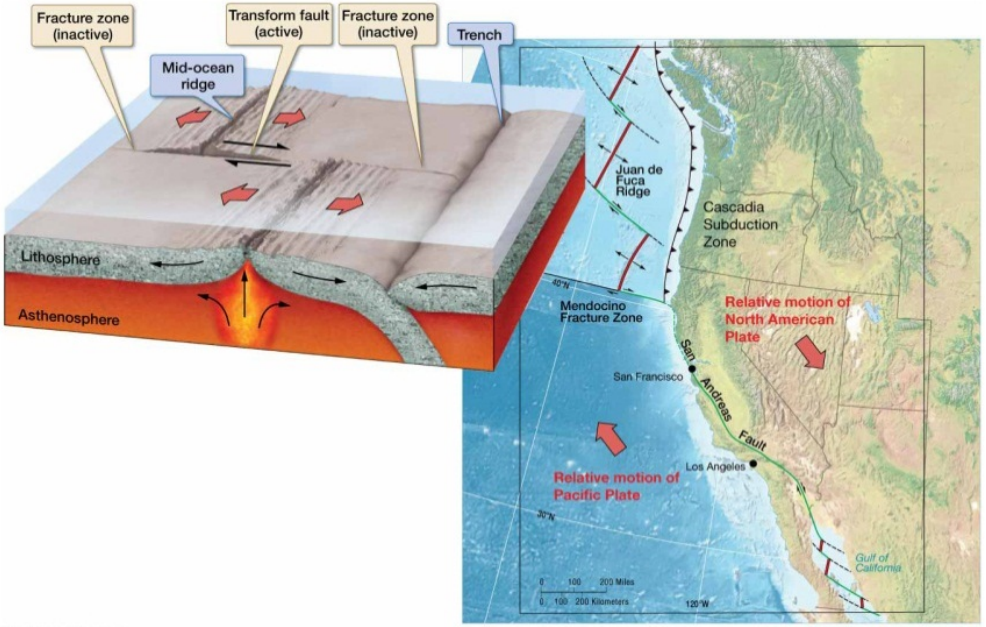
Transform Boundary Features

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



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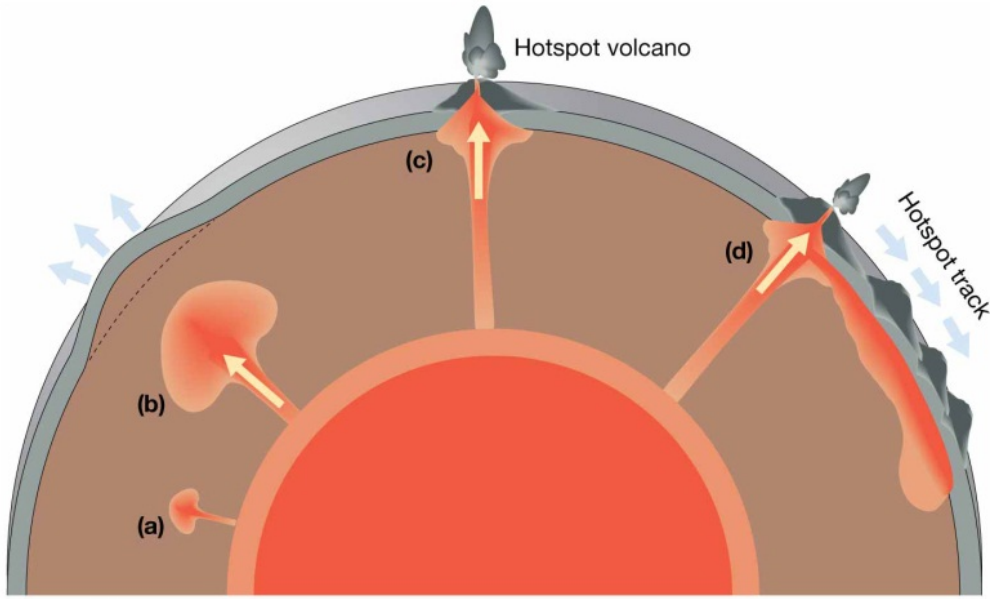
Applications of Plate Tectonics

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



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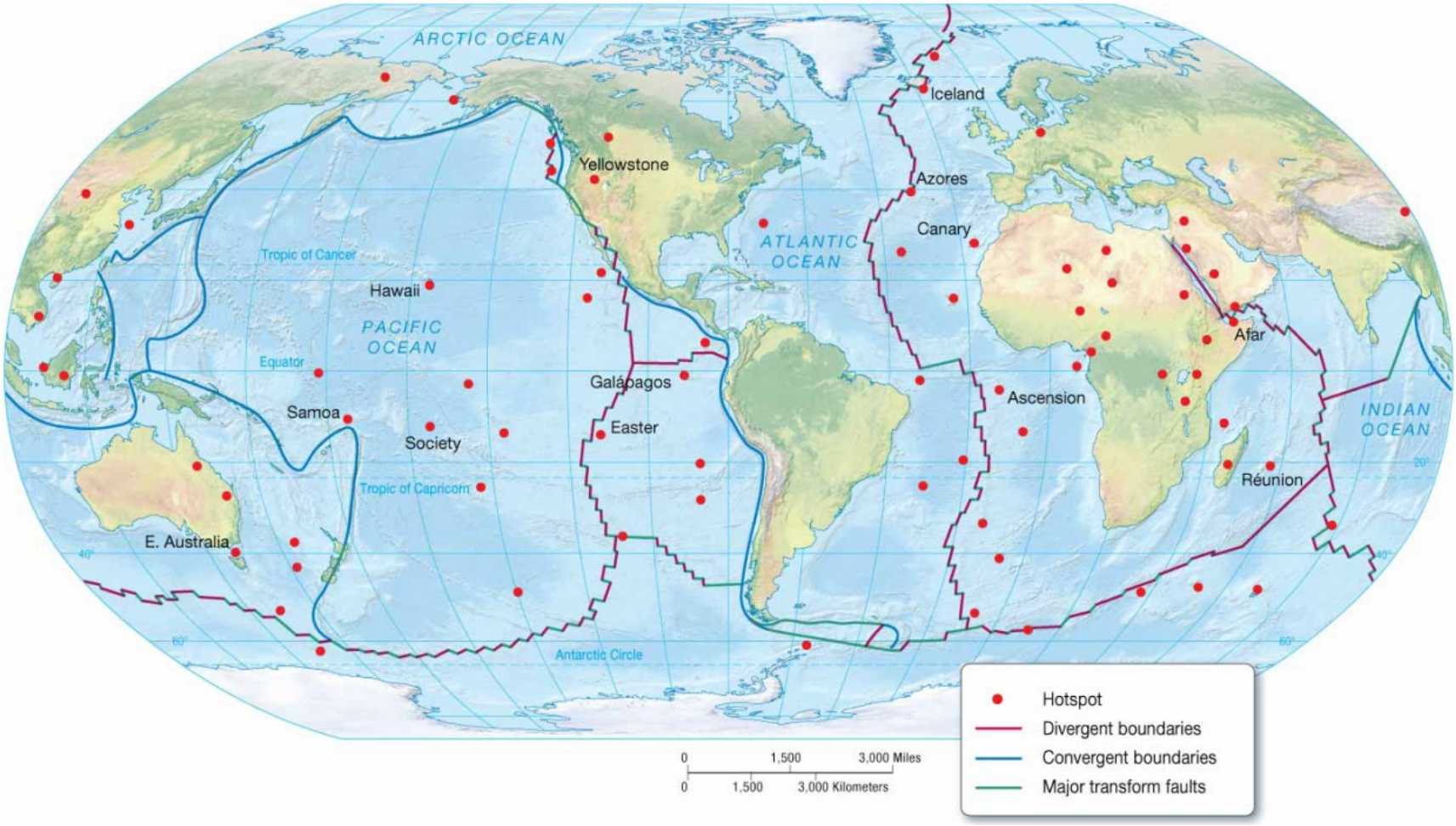
Global Hotspot Locations



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Hawaiian Island – Emperor Seamount Nematath

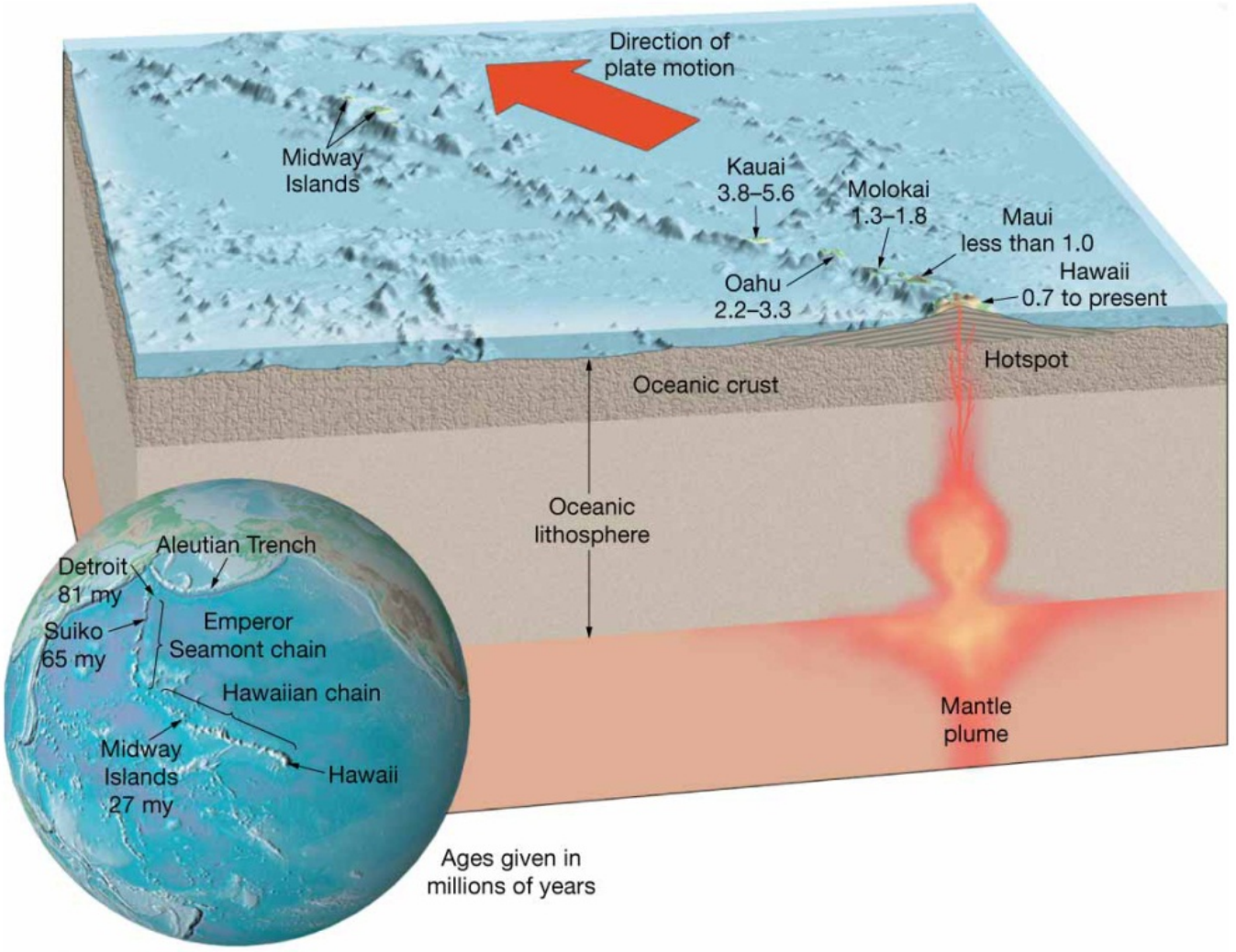

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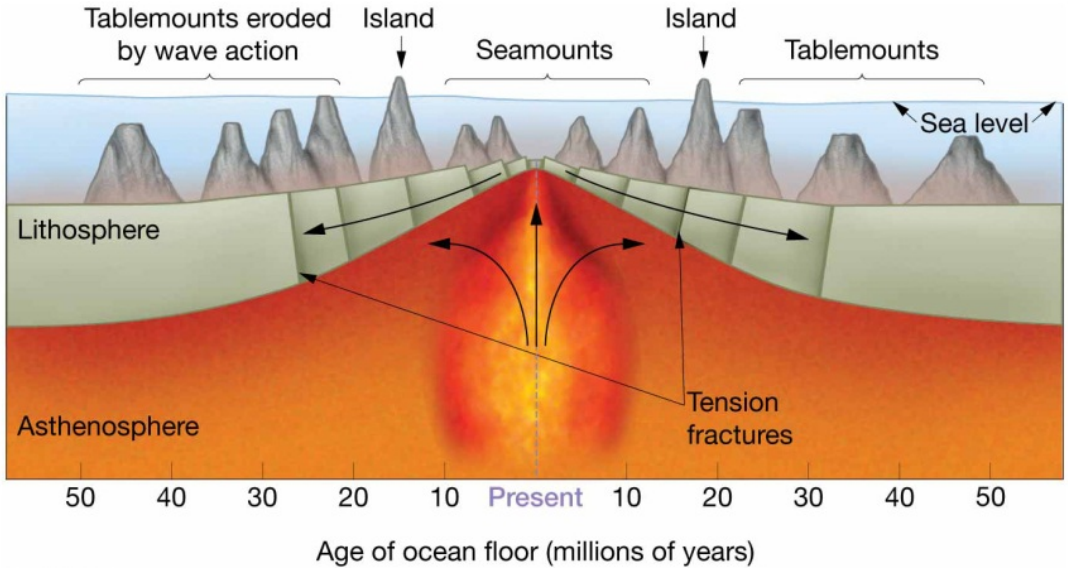
Plate Tectonics and Intraplate Features

- Seamounts
  - Rounded tops
- Tablemounts or guyots
  - Flattened tops
- Subsidence of flanks of mid-ocean ridge
- Wave erosion may flatten seamount.



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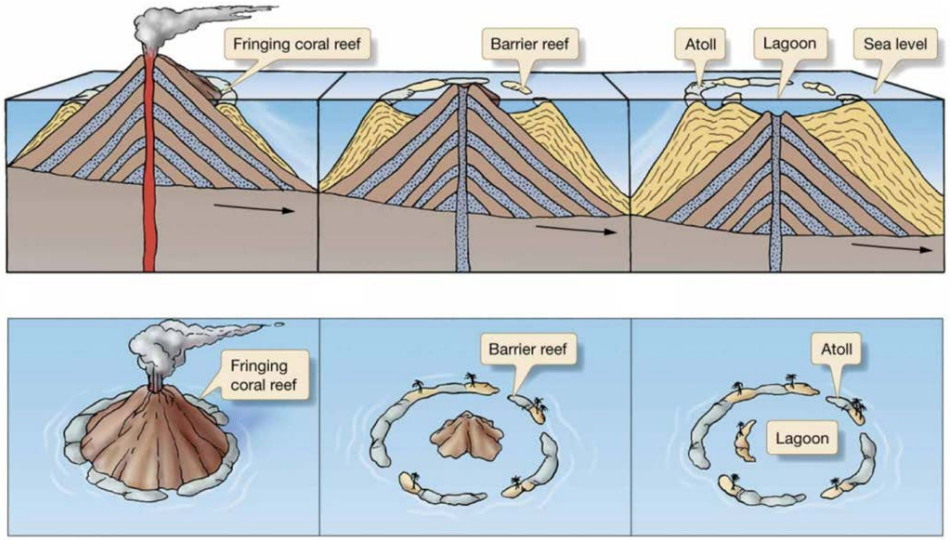
Coral Reef Development

- Fringing reefs – develop along margin of landmass
- Barrier reefs – separated from landmass by lagoon
- Atolls – reefs continue to grow after volcanoes are submerged



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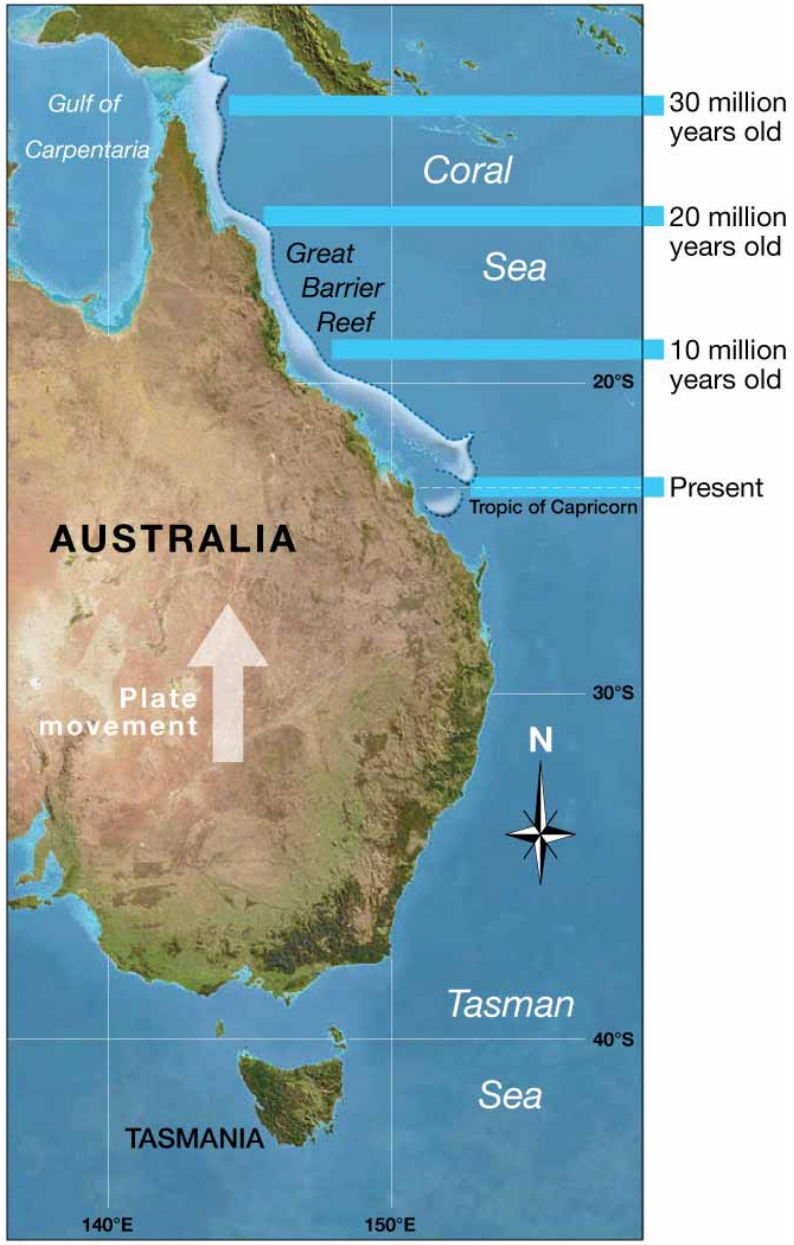
Great Barrier Reef Records Plate Movement



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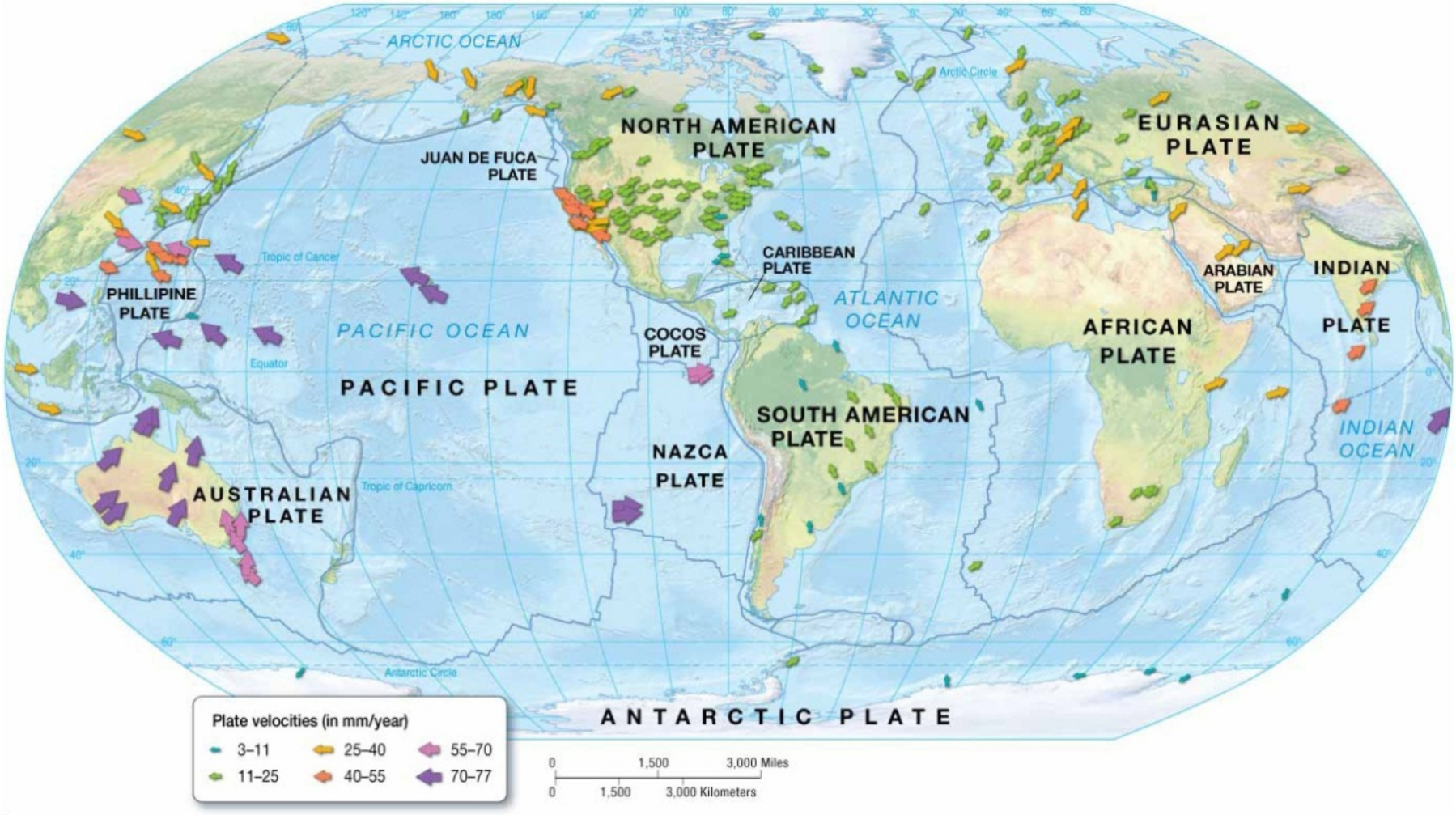
Detecting Plate Motion with Satellites



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Paleogeography

- Paleogeography – study of ancient continents
- Continental accretion
  - Continental material added to edges of continents through plate motion
- Pangaea – 540 million to 300 million years ago

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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

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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

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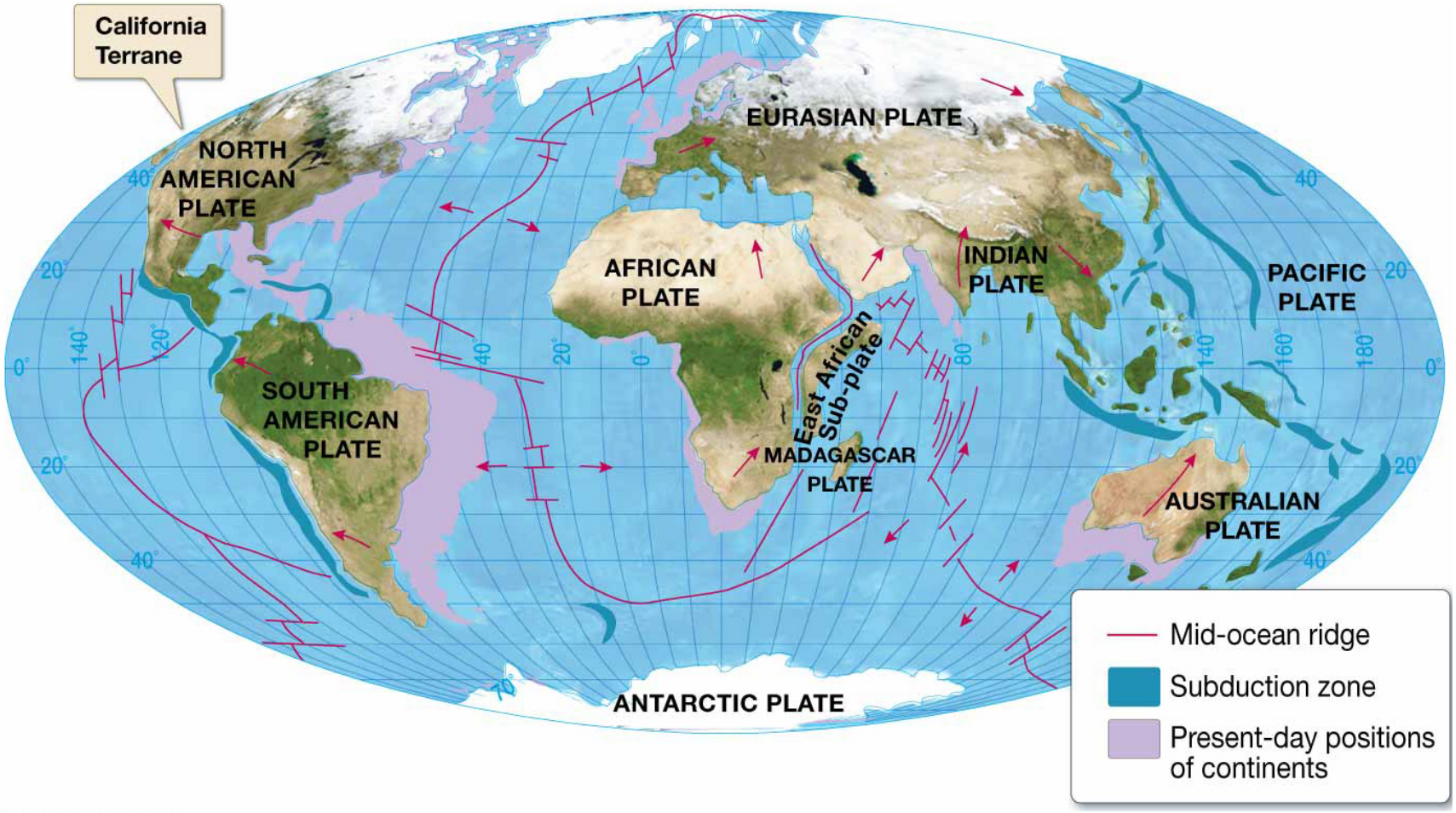
World Map 50 million Years in Future



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Wilson Cycle

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

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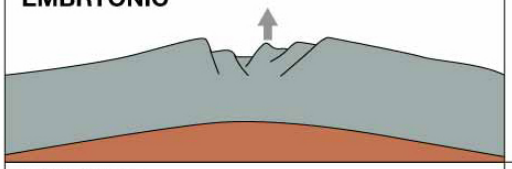
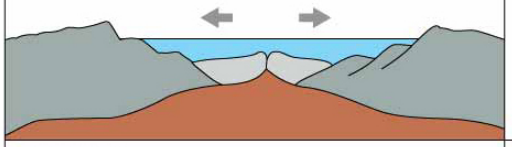
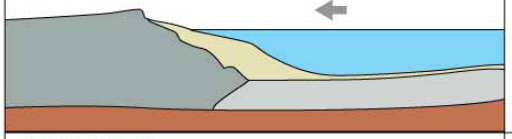
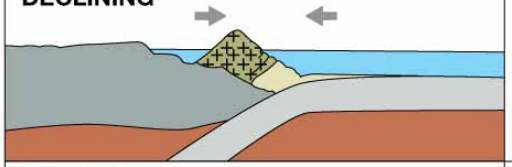
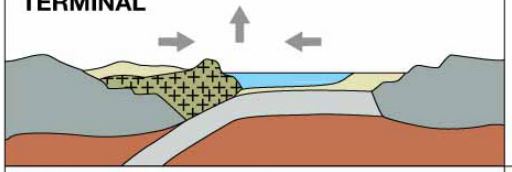
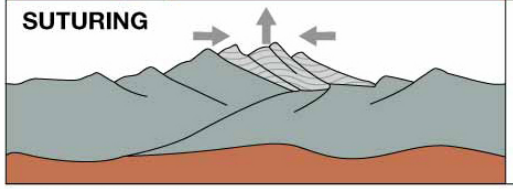
Wilson Cycle

Stage, showing cross-sectional view	Motion	Physiography	Example
EMBRYONIC 	Uplift	Complex system of linear rift valleys on continent	East Africa rift valleys
JUVENILE 	Divergence (spreading)	Narrow seas with matching coasts	Red Sea
MATURE 	Divergence (spreading)	Ocean basin with continental margins	Atlantic and Arctic Oceans
DECLINING 	Convergence (subduction)	Island arcs and trenches around basin edge	Pacific Ocean
TERMINAL 	Convergence (collision) and uplift	Narrow, irregular seas with young mountains	Mediterranean Sea
SUTURING 	Convergence and uplift	Young to mature mountain belts	Himalaya Mountains

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End of CHAPTER 2
Plate Tectonics and the Ocean Floor

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