TOPIC 4.1
PLATE TECTONICS

Enduring Understanding: Earth's systems interact, resulting in a state of balance over time.

Learning Objective: Describe the geological changes and events that occur at convergent, divergent and transform plate boundaries

Related Readings: pg. 33 – 43, "Environment: The Science Behind the Stories" 4th edition, By: Withgott, Jay and Laposota, Matthew

Geology: The Physical Basis for Environmental Science

- **Geology is the study of Earth's physical features, processes, and history**
  - A human lifetime is just the blink of an eye in geologic time
- **Through plate movements and the resulting forces along plate boundaries, earth's landforms are created**
  - Builds mountain ranges, shapes ocean basins and continents, creates islands, and gives rise to earthquakes and volcanoes.
- **The topography created by tectonic processes in turn shapes climate**
  - Alters patterns of rainfall, wind, ocean currents, heating and cooling
  - Changes in climate affect rates of weathering and erosion
- **Changes in climate, rocks, soils, and landforms affect the ability of organisms to inhabit different regions of the earth**
  - Thus plate tectonics has influenced the distribution of Earth's biome and the evolution of life itself.
- **Provide raw materials for industry such as iron, copper, and steel**
- **Provide energy from fossil fuels and geothermal sources**

Geological Time Scale

ERA	PERIOD	EPOCH / AGE	Million Years Ago	EVENTS
CENOZOIC *Age of Mammals* 65.5 mya – present day	*Quaternary*	*Holocene*	*Today* – *0.01*	Ice Age ends Humans are dominant
		Pleistocene	*0.01* – *1.6*	Earliest Humans appear Ice Age begins
	Tertiary	*Pliocene*	*1.6* – *5.3*	Hominids (human ancestors) appear
		Miocene	*5.3* – *23.7*	Grass becomes widespread
		Oligocene	*23.7* – *36.6*	Mammals are dominant
		Eocene	*36.6* – *57.8*	Eocene – Oligocene extinction event
		Paleocene	*57.8* – *65.5*	First large mammals appear
MESOZOIC *Age of Reptiles* 245 mya – 65.5 mya	*Cretaceous*	*Extinction of Dinosaurs*	*65.5* – *144*	K-T extinction event Earth looks closer to present-day Flowering plants appear
	Jurassic		*144* – *208*	First Birds appear Pangaea splits into Laurasia, Gondwanna Dinosaurs are dominant
	Triassic	*First Dinosaurs*	*208* – *245*	Pangaea cracks First mammals appear Reptiles are dominant
PALEOZOIC 570 mya – 245 mya	*Permian*	*Age of Amphibians*	*245* – *286*	Permian – Triassic extinction event Pangaea forms
	Carboniferous		*286* – *360*	First reptiles appear First large cartilaginous fishes appear
	Devonian	*Age of Fishes*	*360* – *408*	Late Devonian extinction event First land animals appear First amphibians appear
	Silurian		*408* – *438*	First land plants appear First jawed fishes appear First insects appear
	Ordovician	*Age of Invertebrates*	*438* – *505*	Ordovician – Silurian extinction event First vertebrates appear
	Cambrian		*505* – *570*	End Botomian extinction event First fungi appear Trilobites are dominant
PRECAMBRIAN 4600 mya – 570 mya	*Proterozoic Eon*		*570* – *2500*	First soft-bodied animals appear First multicellular life appear
	Achean Eon		*2500* – *3800*	Photosynthesizing cyanobacteria appear First unicellular life appear
	Hadean Eon	*Priscoan Period*	*3800* – *4600*	Atmosphere and oceans form Oldest rocks form as Earth cools
Formation of Earth				

Earth consists of layers

- **Core**
  - solid iron in the center
  - Molten iron in the outer core
- **Mantle**
  - less dense, elastic rock
  - Includes the ***Asthenosphere***, a layer of very soft or melted rock
  - Energy is harnessed in geothermal systems
- **Crust**
  - the thin, brittle, low-density layer of rock at earth's surface
- **Lithosphere**
  - the uppermost mantle (above the asthenosphere) and the crust
  - Made up of a series of tectonic plates that "float" on the molten asthenosphere

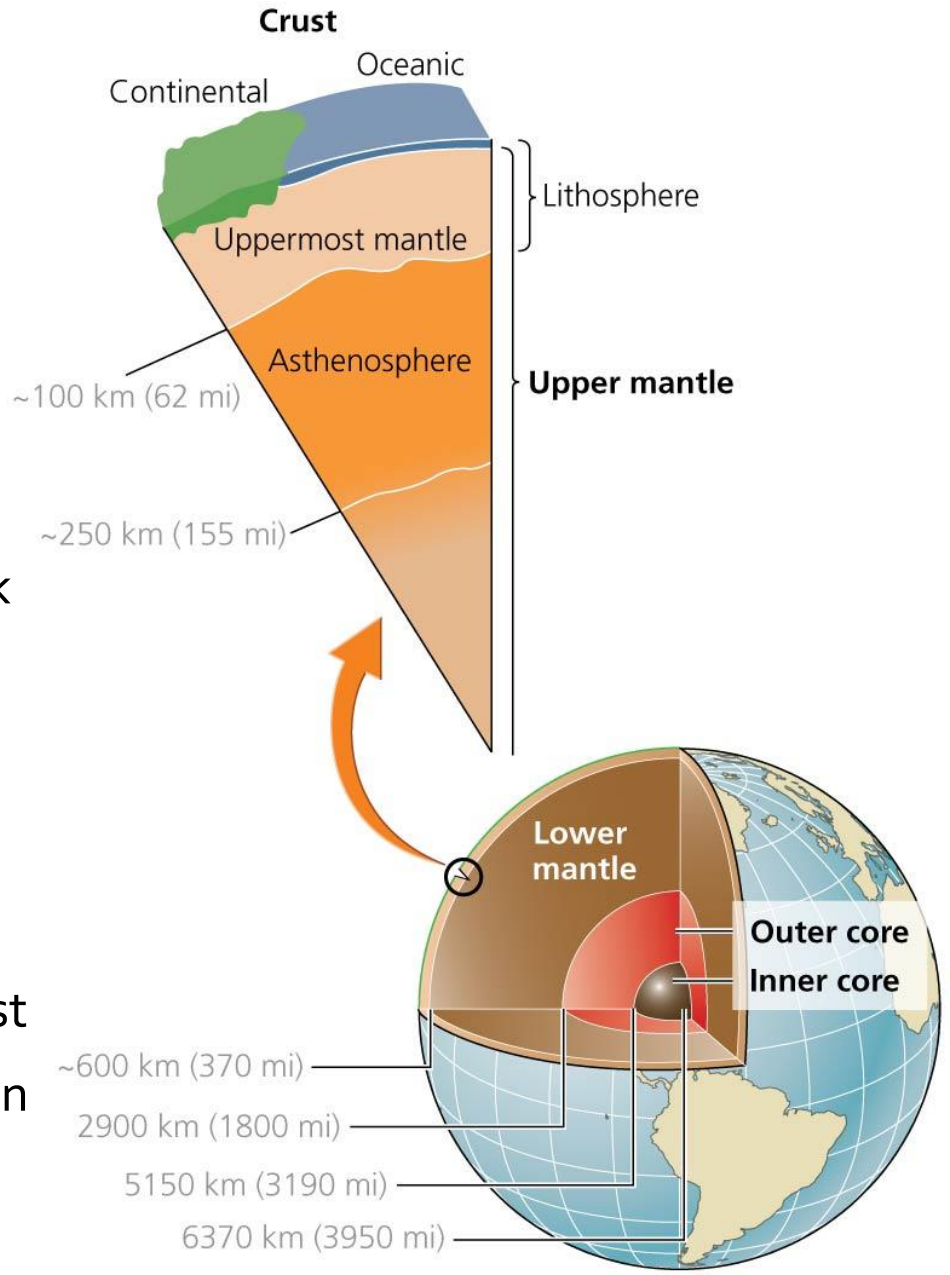


Plate tectonics shapes Earth's geography

- **Earths surface consists of about 15 major *tectonic plates.***
  - Plates are pieces of the lithosphere (crust and uppermost mantle) that fit together like puzzle pieces
  - Lithospheric plates ride on the molten rock of the asthenosphere.
    - Their movement results from convection currents created by the heat generated by the core.
- ***Plate tectonics* is the movement of lithospheric plates.**
  - Continents have combined, separated, and recombined over millions of years
  - All landmasses were joined into a supercontinent called *Pangaea* from 335 million years ago until about 200 million years ago..


PERMIAN
225 million years ago

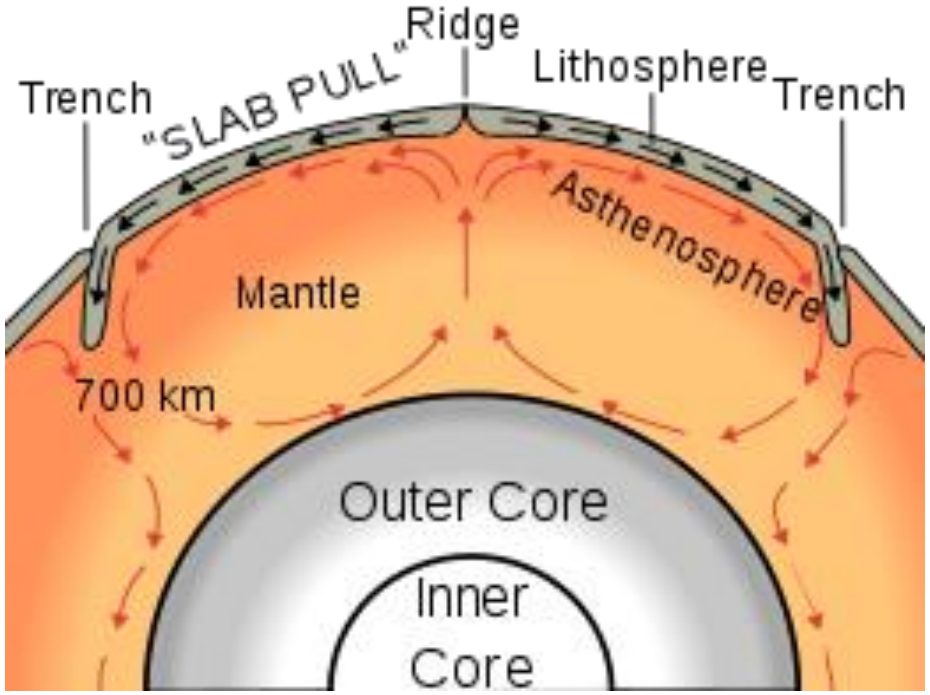
TRIASSIC
200 million years ago


PRESENT DAY

Plate tectonics shapes Earth's geography

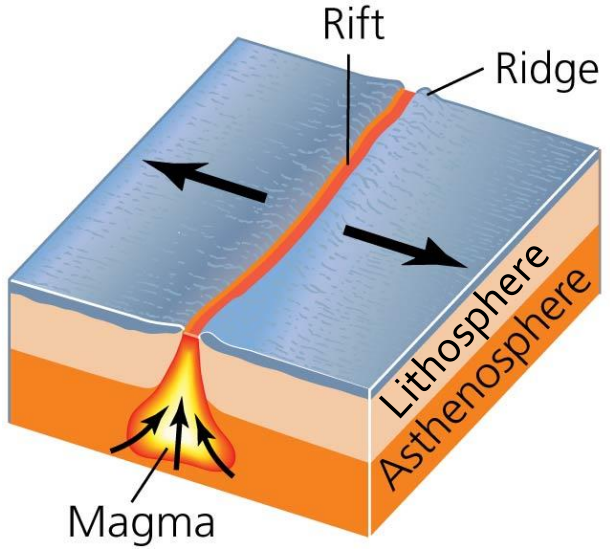
- **Heat from Earth's inner layers drives convection currents**
  - *Radiogenic Heat:* The radioactive decay of isotopes in Earths core releases energy that continues to warm earth
  - *Primordial Heat*: The earth today continues to cool and release energy from its core as a result of the forces that created it.
- **Heat from the core rises to the surface, passing through the mantle, and dissipates at earths surface**
  - Creates *convection currents* within the mantle

- **The tectonic plates of earths lithosphere ride on these currents**
  - Plates move at a rate of about 2-15cm / year (1-6 inches)
  - Interactions between plates explain many geologic phenomena

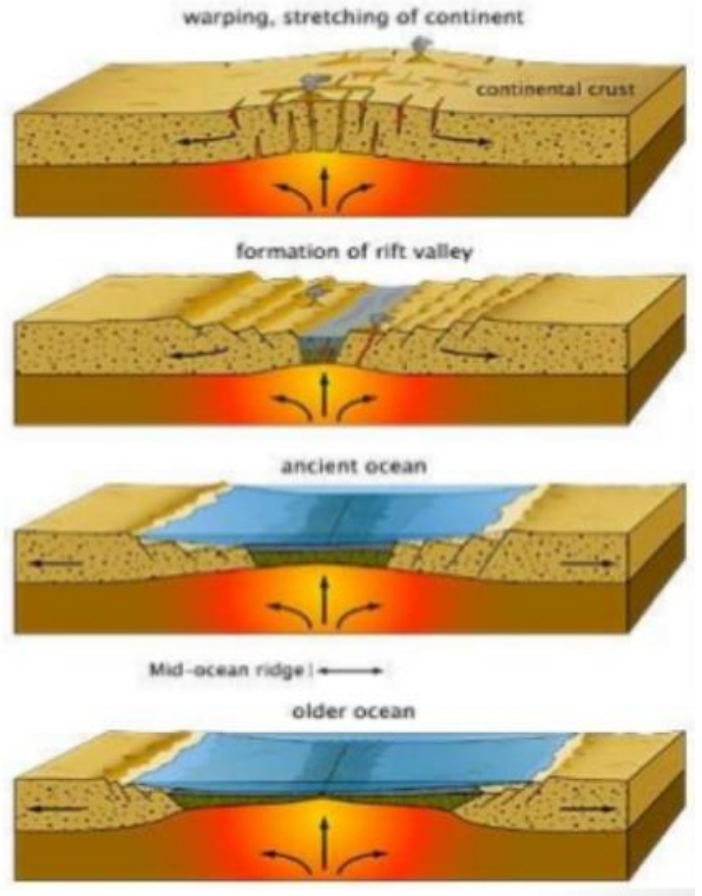


There are three types of plate boundaries

- **Divergent plate boundaries**
  - As hot magma rises, it stretches out the lithosphere, and fractures (rifts) the surface, forming a ***rift valley***.
  - Magma seeps through the rift as the plates on either side ***diverge*** (move apart) from one another.
  - As magma cools, it hardens into basaltic rock, forming ***mid-ocean ridges.***
    - This represents the formation of new crust.
    - Often results in small volcanoes, earthquakes and hydrothermal vents at divergent boundaries
  - Example: ***Mid-Atlantic ridge, Thingvellir, Iceland***



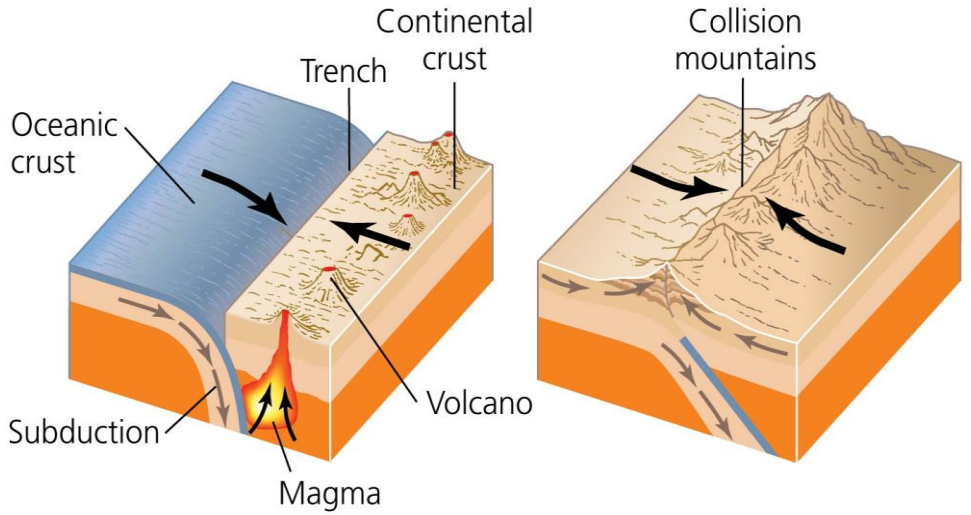
(a) Divergent plate boundary



There are three types of plate boundaries

- ***Convergent plate boundaries***
  - As newly formed lithosphere cools, it becomes more dense, eventually diving down into the asthenosphere as a less dense plate rides over it's top resulting in *subduction*.
- **Continental Plate Collisions**
  - The colliding edges of continental plates collide, buckle, and form mountains
  - Built the Himalaya Mountains

- ***Subduction* is the process in which the oceanic plate slides beneath continental crust**
  - Forms ocean trenches where oceanic plate and continental plate meet.
  - Generates immense heat and pressure, melting the subducted plate, forming ***Magma***, which is pressurized and may erupt through the surface of the overriding continental plate.
  - Example: Cascade Volcanoes, Aleutian Islands, Japan, Indonesia (***Ring of Fire***)



(c) Convergent plate boundary

Seafloor Spreading Model

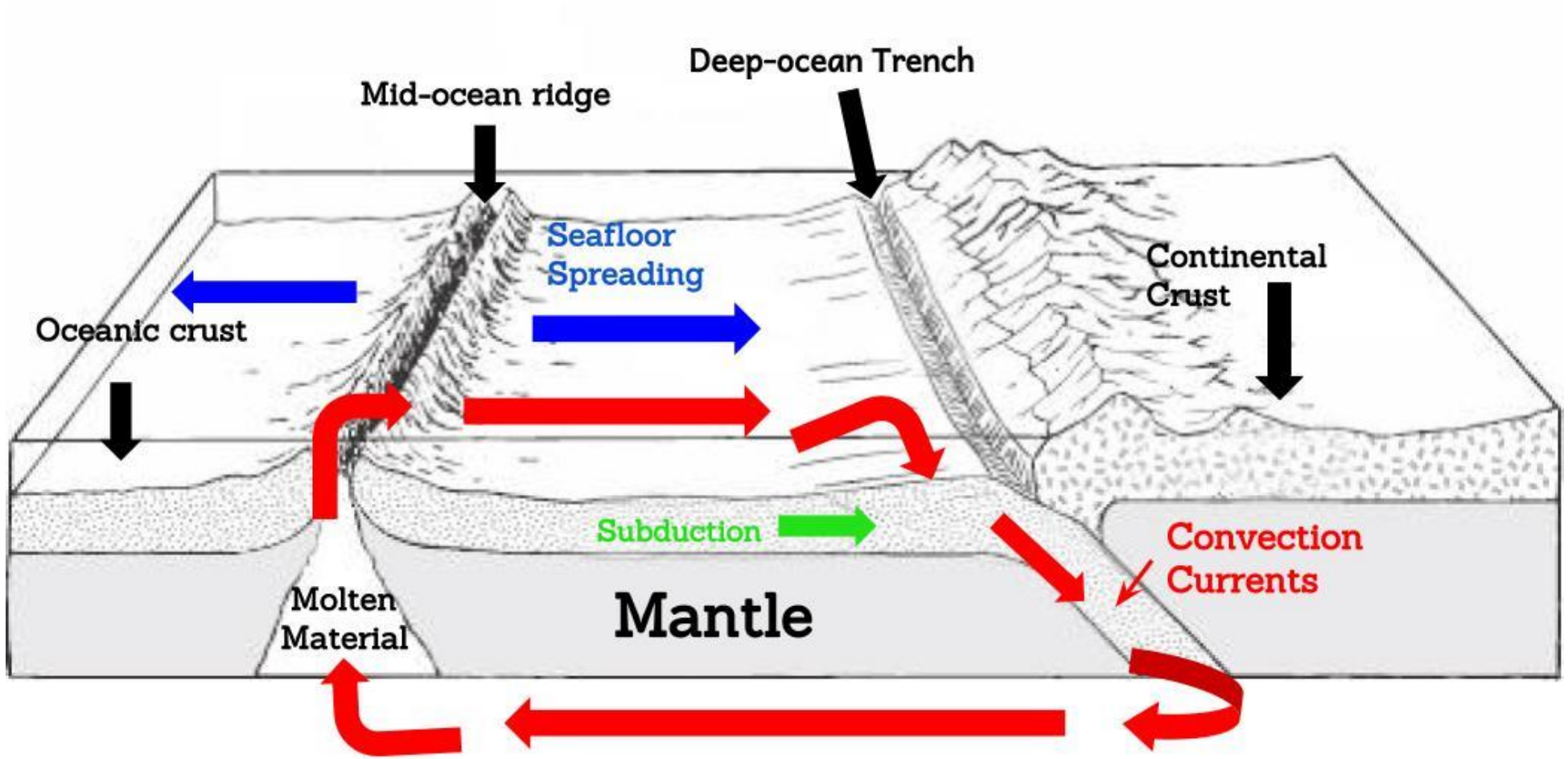
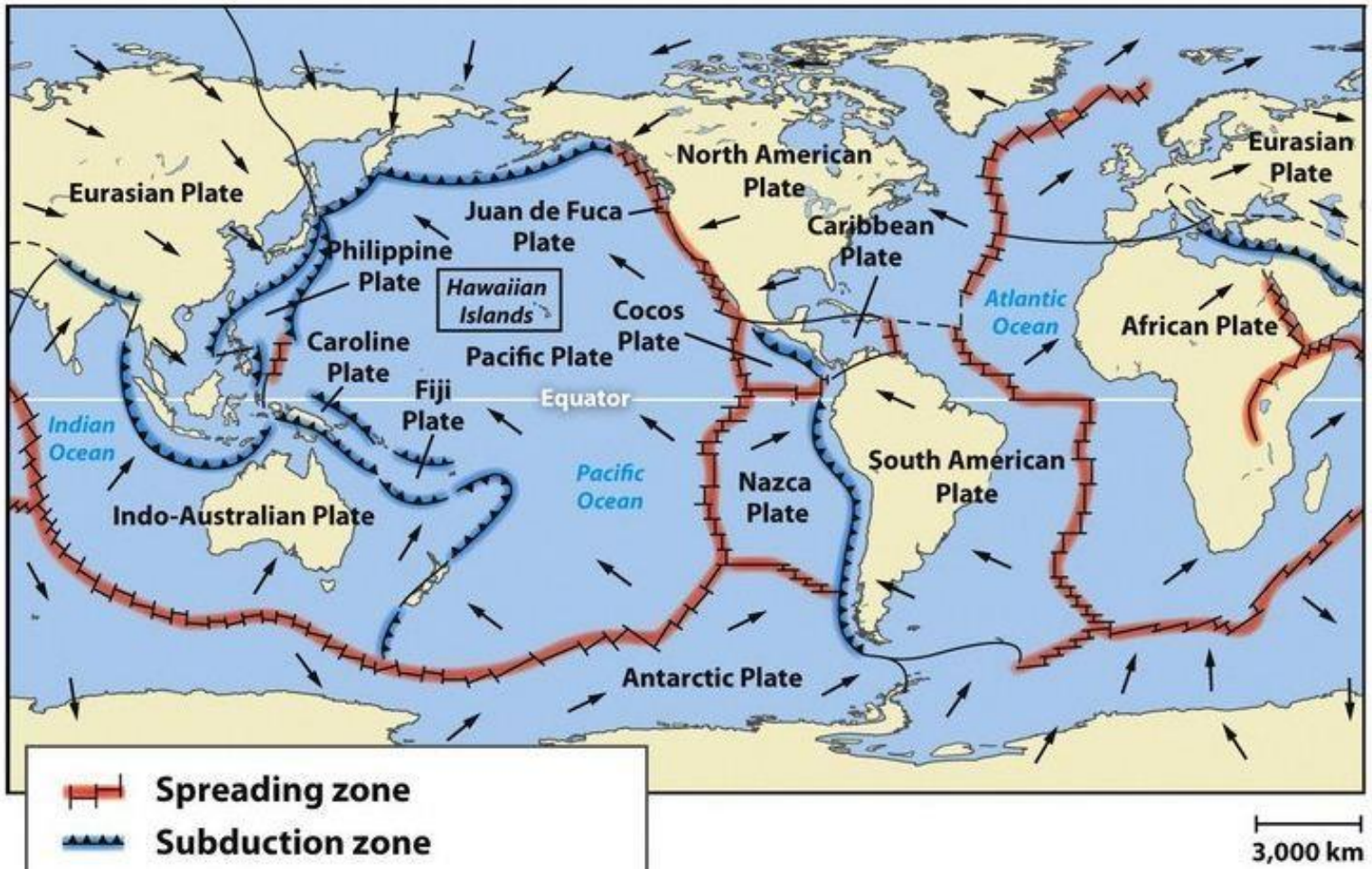
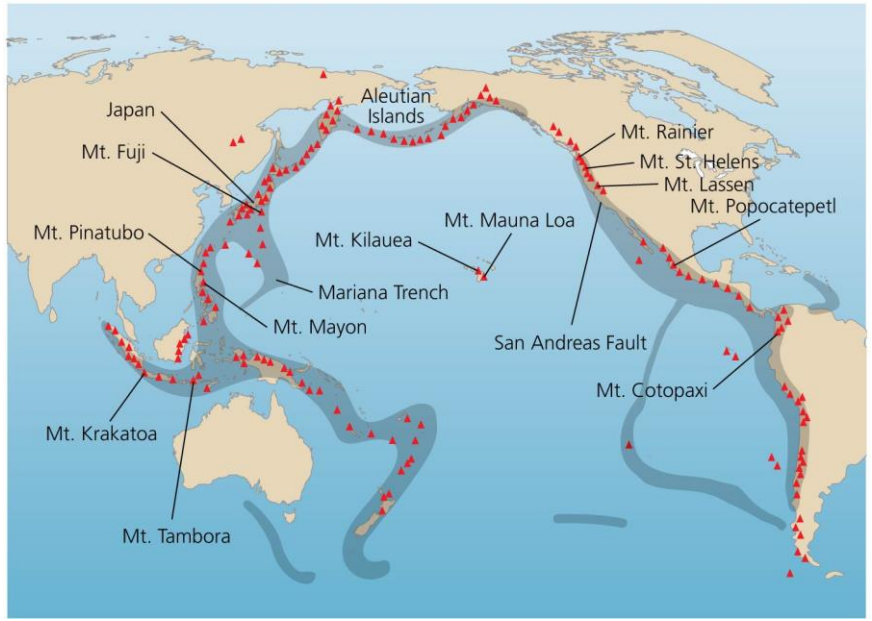


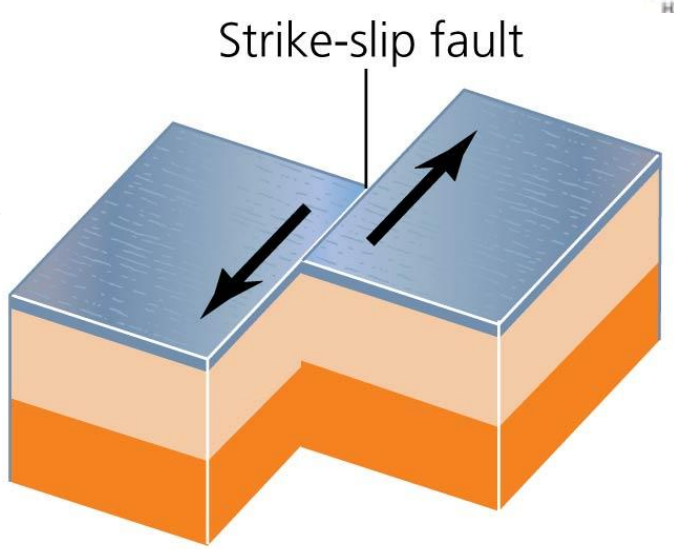
Plate Motion and the "Ring of Fire"



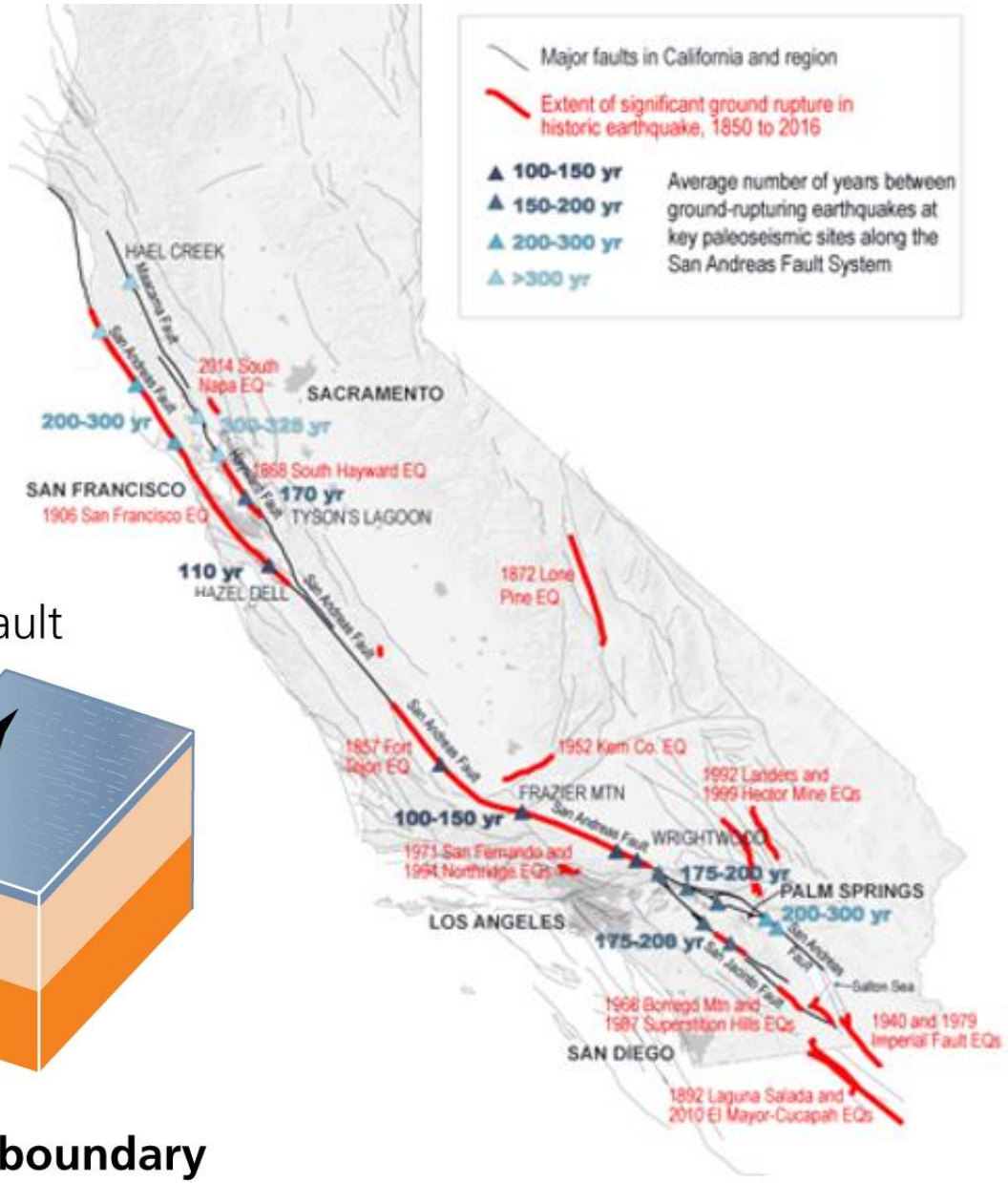


There are three types of plate boundaries

- **Transform plate boundaries**
  - Two adjacent plates, slipping and grinding past one another.
  - Friction spawns earthquakes along strike-slip faults at transform plate boundaries
    - Plates spend most of their time bound up causing pressure to build.
    - Earthquakes are the release of built up pressure and allow plates to mov pat one another before binding again.
  - Example: ***San Andreas Fault***

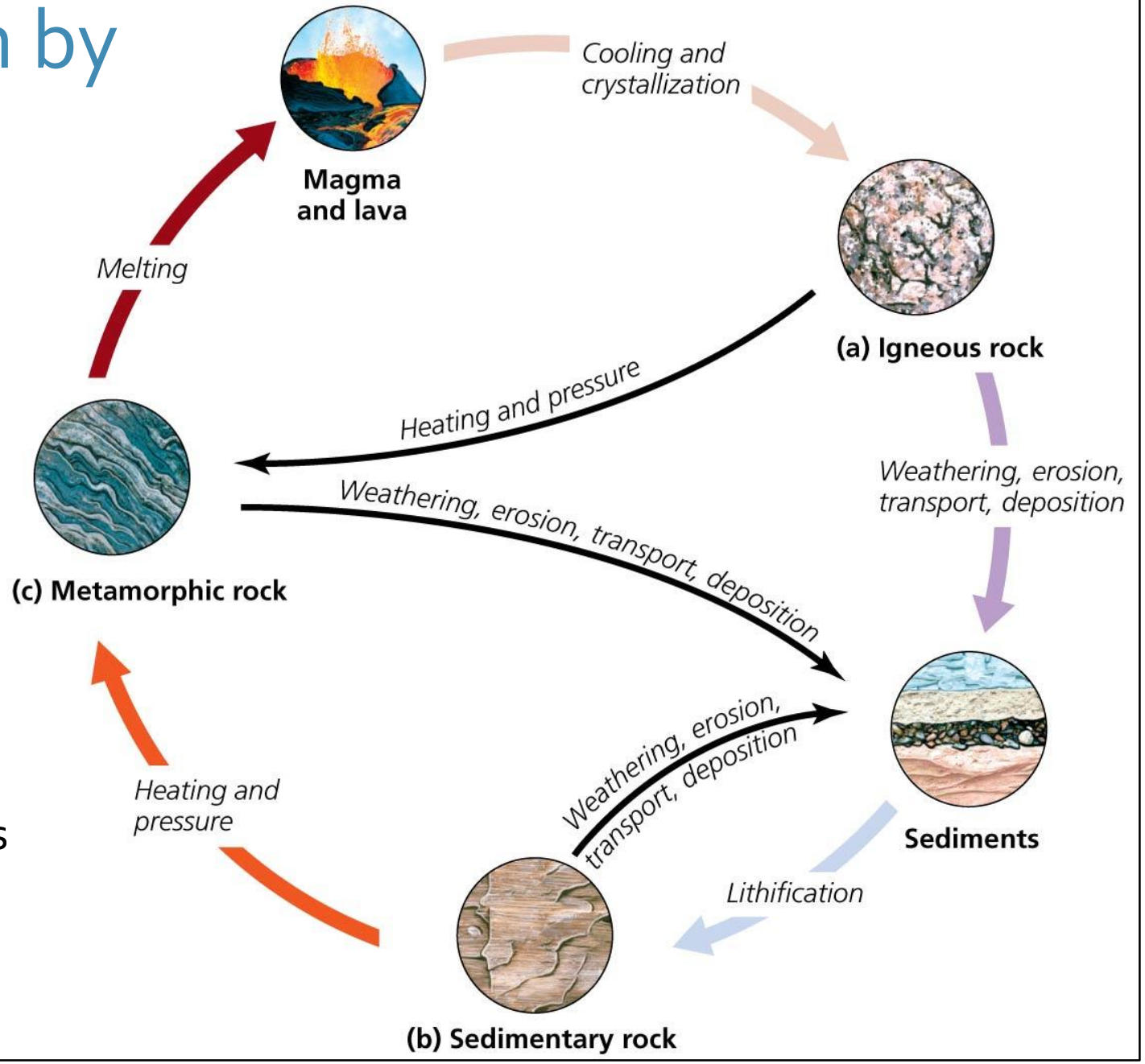


(b) Transform plate boundary



The rock cycle is driven by tectonic forces

- ***Rocks*** **are any solid aggregation of minerals**
  - Rocks help determine soil characteristics, which influences the region's plants community
  - ***Minerals*** are any element or inorganic compound with a crystal structure, specific chemical composition, and distinct physical properties
- **The Rock Cycle involves the heating, melting, cooling, breaking, and reassembling of rocks and minerals**
  - Understanding the rock cycle helps us appreciate the formation and conservation of soils, minerals deposits, fossil fuels, and other natural resources



Igneous rock

- **Magma** is molten, liquid rock below the surface of the earth
- **Lava** is magma released from the lithosphere
- **Igneous rock** forms when magma cools
  - ***Intrusive*** igneous rock = magma that cools slowly and evenly below Earth's surface (e.g., granite)
  - ***Extrusive*** igneous rock = magma ejected from a volcano (e.g., basalt) that cools rapidly

Sedimentary rock

- ***Sediments*** = rock particles created by erosion of rocks.
- ***Sedimentary rock*** is formed by ***lithification***
  - sediments are *compacted* or *cemented* (dissolved minerals crystallize and bind together)
  - Sandstone, limestone, shale

Metamorphic rock

- ***Metamorphic rock*** is formed when great pressure and some heat on a rock changes its form
  - Partial melting and great pressure reshapes crystals, changing rock's appearance and physical properties
  - Marble = metamorphosed limestone
  - Slate = metamorphosed shale

(a) Intrusive igneous rock: Granite at Yosemite National Park

(b) Extrusive igneous rock: Basalt in the Canary Islands

(c) Sedimentary rock: Sandstone in Arizona

(d) Metamorphic rock: Gneiss in Utah