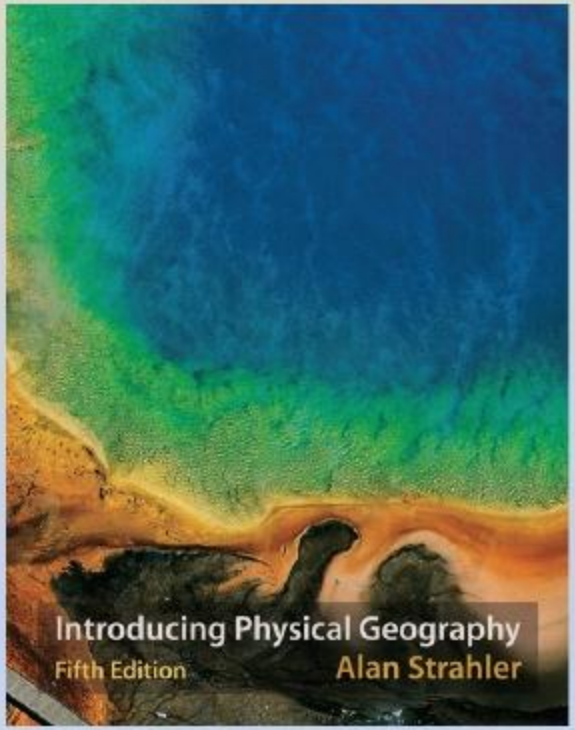

Introducing Physical Geography

Alan Strahler

Chapter 11
Earth Materials and Plate Tectonics

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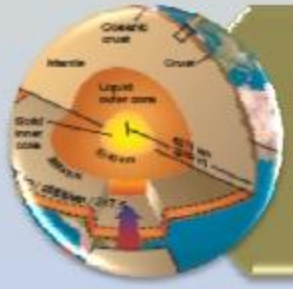
Earth Materials and Plate Tectonics

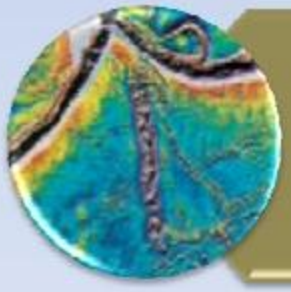
Chapter 11

Chapter Outline



1. Minerals and Rocks of the Earth's Crust

2. Major Relief Features of the Earth's Surface



3. Plate Tectonics

Click Section to go to Main content

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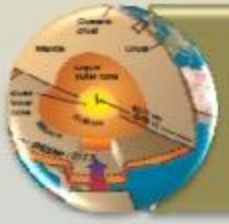

1. Minerals and Rocks of the Earth's Crust

- THE EARTH'S INTERIOR
- MINERALS AND ROCKS
- IGNEOUS ROCKS
- SEDIMENTS AND SEDIMENTARY ROCKS
- METAMORPHIC ROCKS
- THE CYCLE OF ROCK CHANGE
- THE GEOLOGIC TIME SCALE

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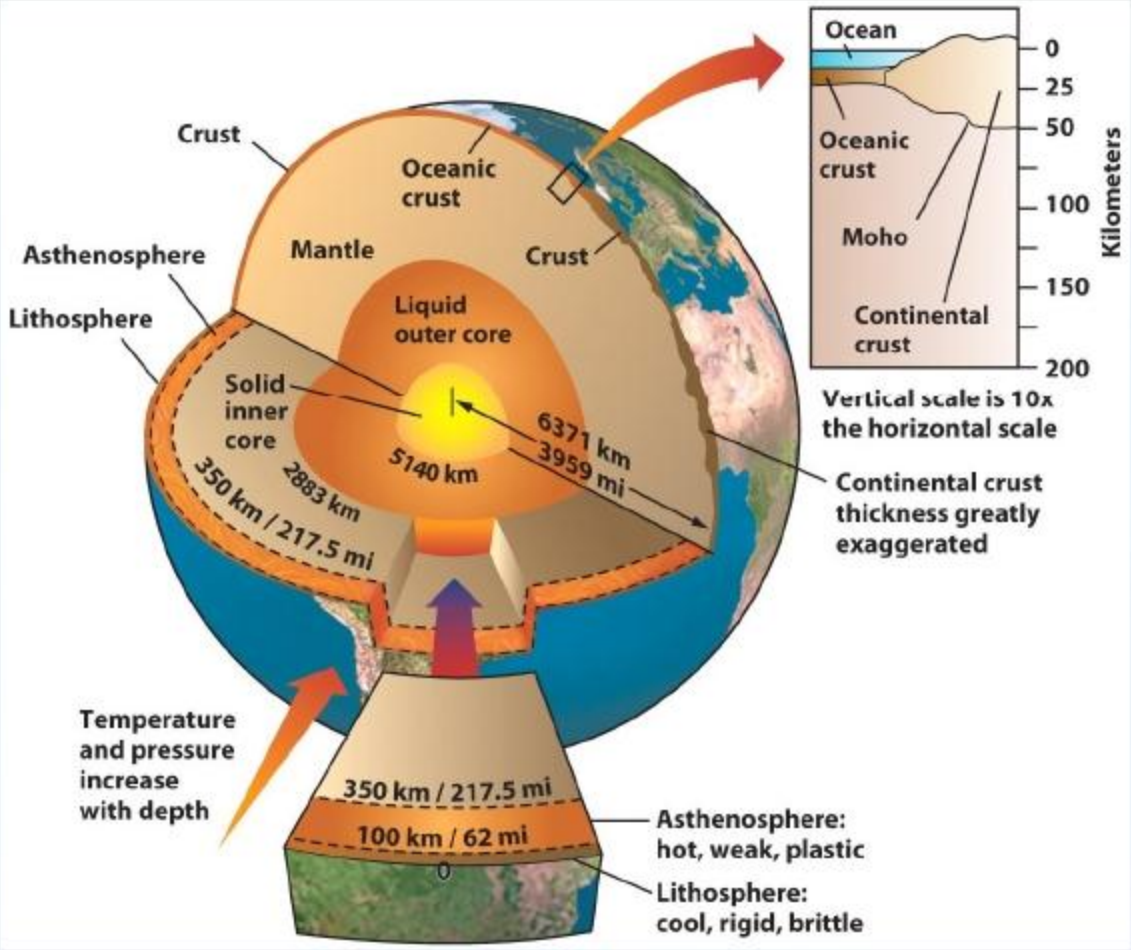
THE EARTH'S INTERIOR

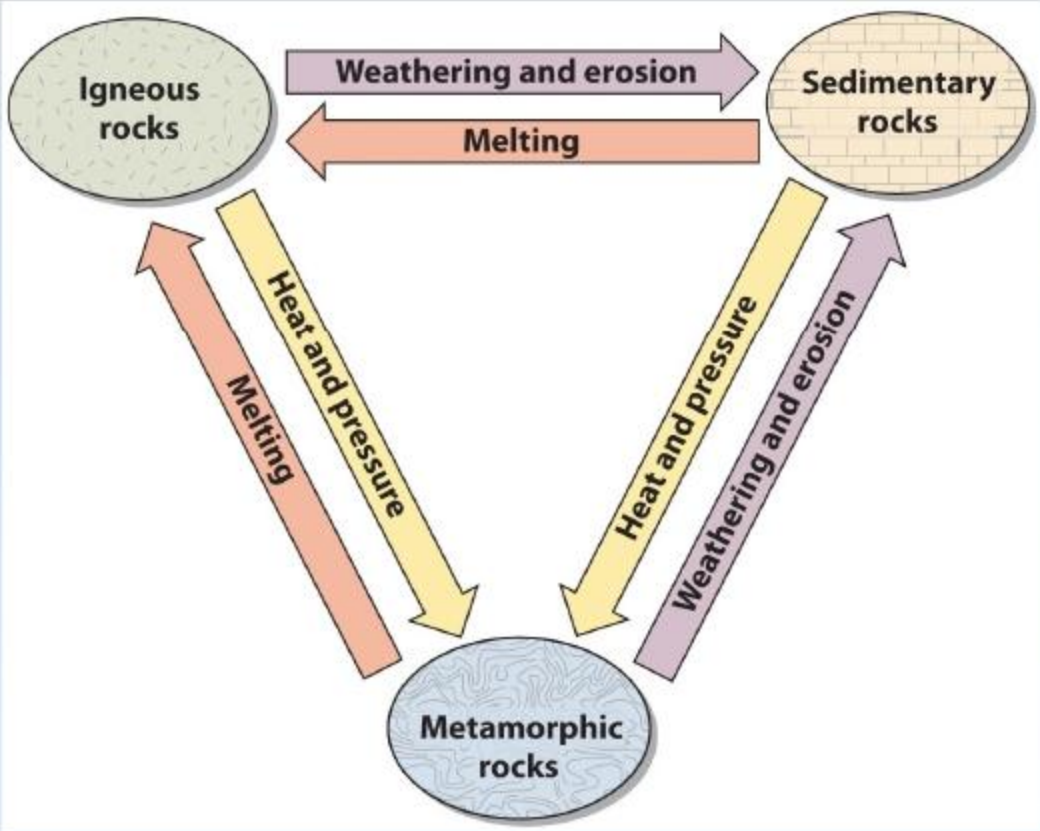


Earth's interior:

- Crust
- Mantle
- Liquid outer core
- Solid inner core

Continental crust has both felsic and mafic rock zones, while oceanic crust has only mafic.

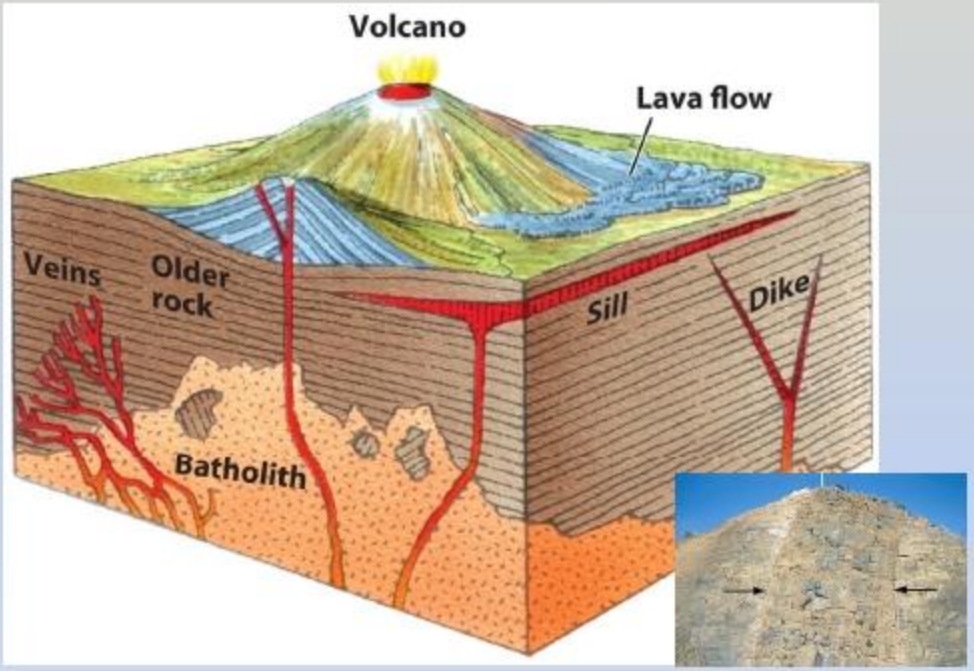
MINERALS AND ROCKS



Three classes of rock are transformed into one another by **weathering** and **erosion**, **melting**, and exposure to **heat** and **pressure**

IGNEOUS ROCKS

Extrusive igneous rocks cool rapidly on the land surface or ocean bottom and show microscopic crystals.



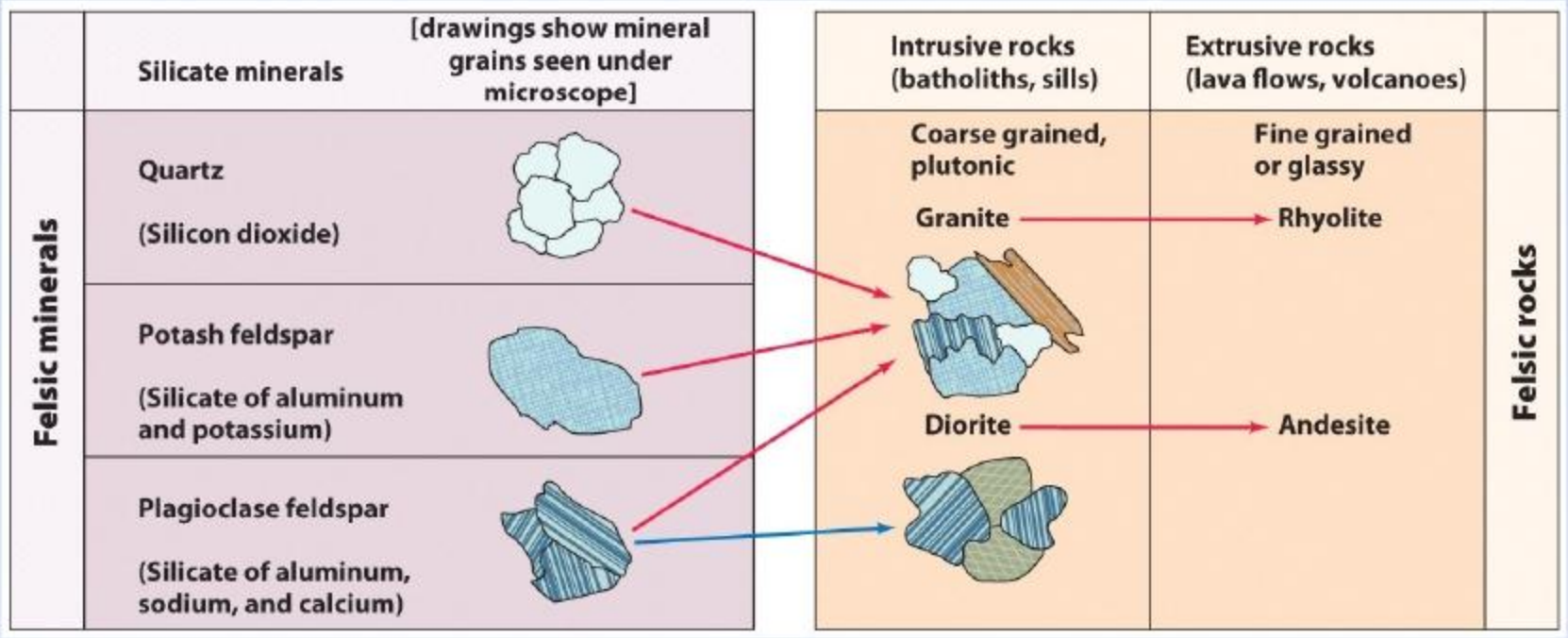
Intrusive igneous rocks cool slowly below the Earth's surface and develop visible mineral crystals.

IGNEOUS ROCKS - Felsic

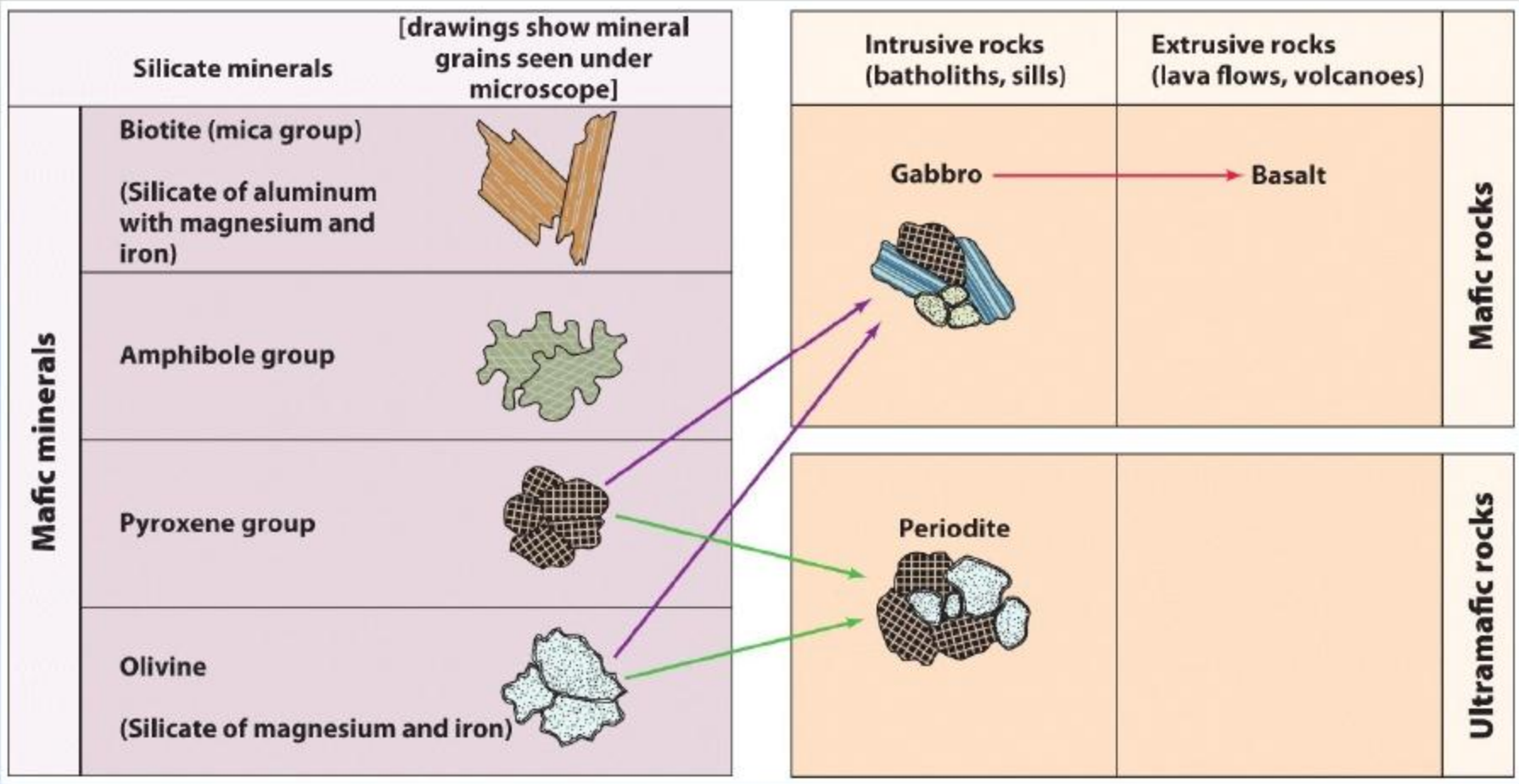
Igneous rocks form when molten rock cools, forming silicate mineral crystals.

Felsic minerals are light colored and less dense.

Mafic minerals are dark colored and more dense.



IGNEOUS ROCKS - Mafic



SEDIMENTS AND SEDIMENTARY ROCKS

Sedimentary rocks - composed of sediment

- **Clastic** (rock and/ or mineral fragments)
- **Chemically precipitated** (formed by chemical precipitation from sea water or salty inland lakes)
- **Organic** (formed from organic materials, coal, peat)

Sedimentary rocks - layers, or *strata,* of mineral particles found in other rocks that have been weathered and from newly formed organic matter. Most inorganic minerals in sedimentary rocks are from igneous rocks.

SEDIMENTS AND SEDIMENTARY ROCKS

- **Clastic** sedimentary rocks are formed when sediments are compressed and cemented. *Sandstone & shale* are examples.
- **Chemical** precipitation forms *limestone* in a marine environment.
- **Organic** or hydrocarbons include *coal, petroleum, natural gas, and peat*.

METAMORPHIC ROCKS

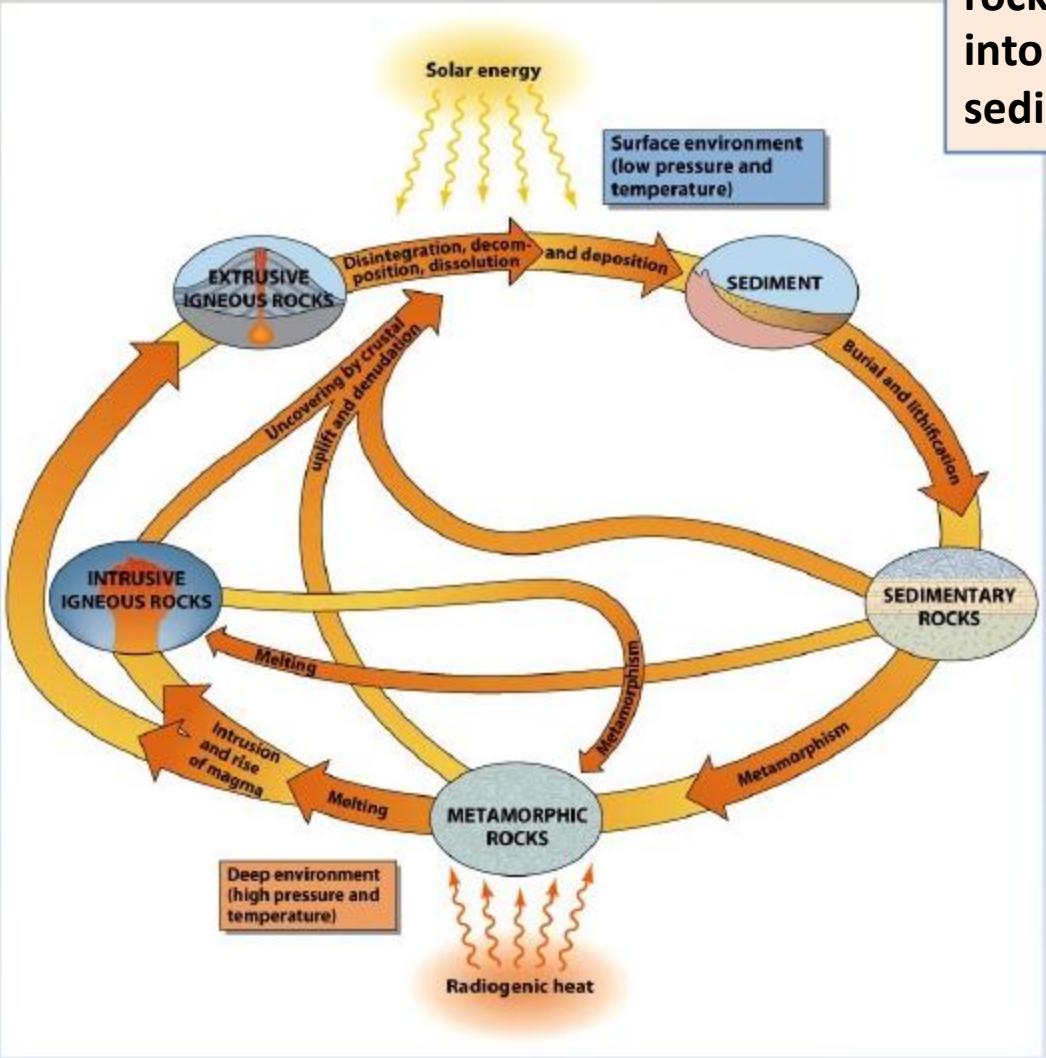
Metamorphic rocks - formed from preexisting rocks by intense **heat** and **pressure**, which alter rock structure and chemical composition.

- Shale is transformed to slate or schist
- Sandstone to quartzite
- Limestone to marble

Rock Type	*Description*
Slate	Shale exposed to heat and pressure that splits into hard flat plates
Schist	Shale exposed to intense heat and pressure that shows evidence of shearing
Quartzite	Sandstone that is "welded" by a silica cement into a very hard rock of solid quartz
Marble	Limestone exposed to heat and pressure, resulting in larger, more uniform crystals
Gneiss	Rock resulting from the exposure of elastic sedimentary or intrusive igneous rocks to heat and pressure

THE CYCLE OF ROCK CHANGE

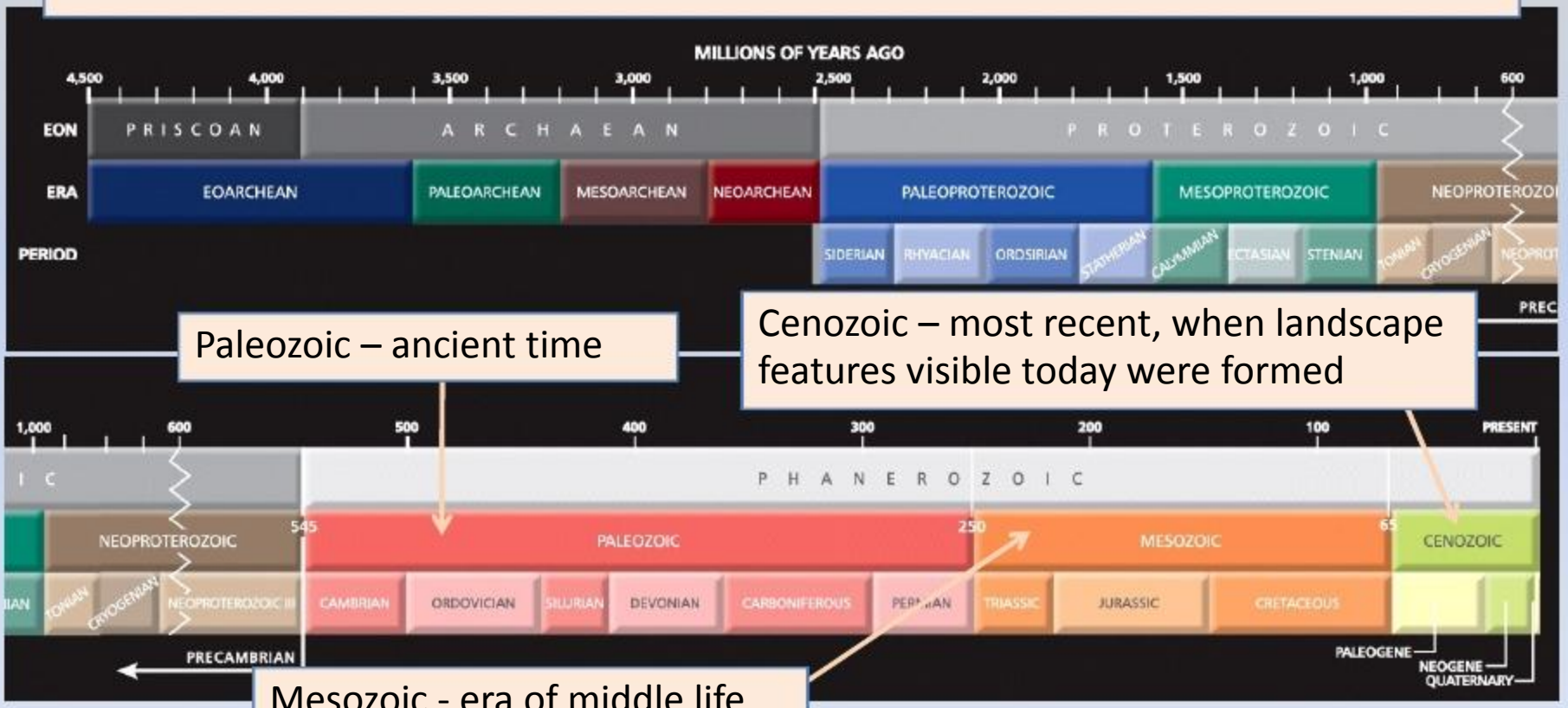
At surface rocks weather into sediment.



In the deep environment, heat and pressure transform sediment into rock that is eventually exposed at the surface.

THE GEOLOGIC TIME SCALE

4.5 billion years since the Earth formed divided into **eons, eras, and periods.**



Paleozoic – ancient time

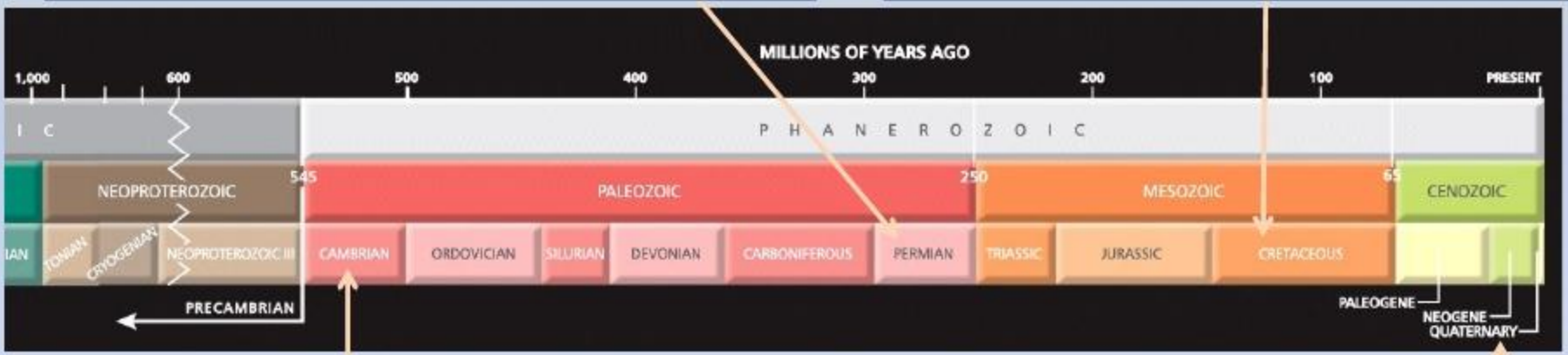
Cenozoic – most recent, when landscape features visible today were formed

Mesozoic - era of middle life dominated by the dinosaurs.

THE GEOLOGIC TIME SCALE

Permian - Primitive reptiles, ancestors of mammals dominated. End of the Permian period, a devastating extinction wiped out more than 90 percent of hard-shelled marine life and left Europe a desert for millions of years.

Cretaceous - Dinosaurs ruled for more than 150 million years. Birds evolved from small predatory dinosaurs, abundant flowering plants. Smaller animals hid in the aftermath of a meteorite impact and emerged.

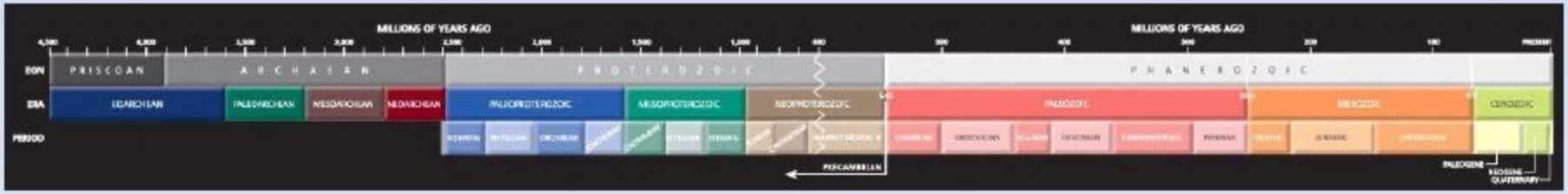


Cambrian – Multicelled animals developed hard shells (evidenced in fossils). Body plans for modern animals evolved, including the multiple arms of sea stars, legs of insects and spiders, and backbones of vertebrates. Creatures lived in warm shallow seas.

Quaternary – Mammals ruled. Mammoths and mastodons were Ice Age giants that survived until 10,000 years ago, dying out when the ice retreated and human populations spread.

THE GEOLOGIC TIME SCALE

- If Geological Time (4,500 million years) were 1 day (24 hours)
  - Precambrian ends at 21:10 (9:10 pm)
  - Human genus emerges at 11:59 pm, and 30 seconds
  - Entire Human Civilization (5,000 years) represented by the **last half second** of the day



2. Major Relief Features of the Earth's Surface

- THE LITHOSPHERE AND ASTHENOSPHERE
- RELIEF FEATURES OF THE CONTINENTS
- RELIEF FEATURES OF THE OCEAN BASINS

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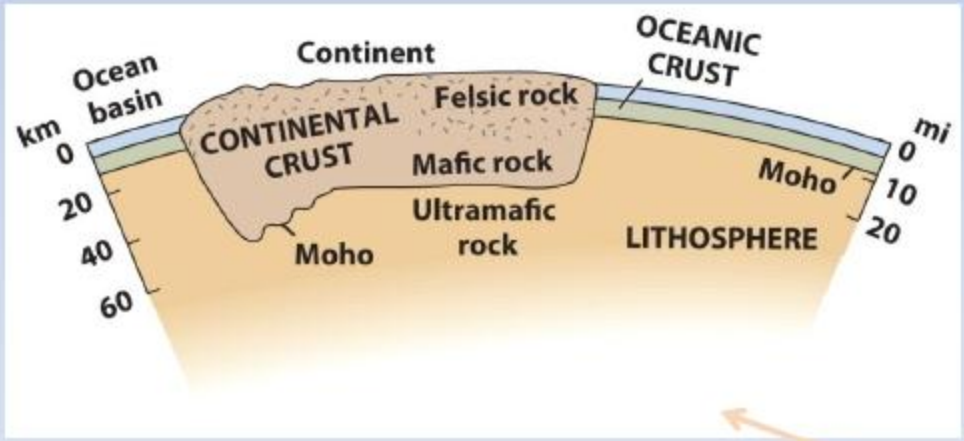
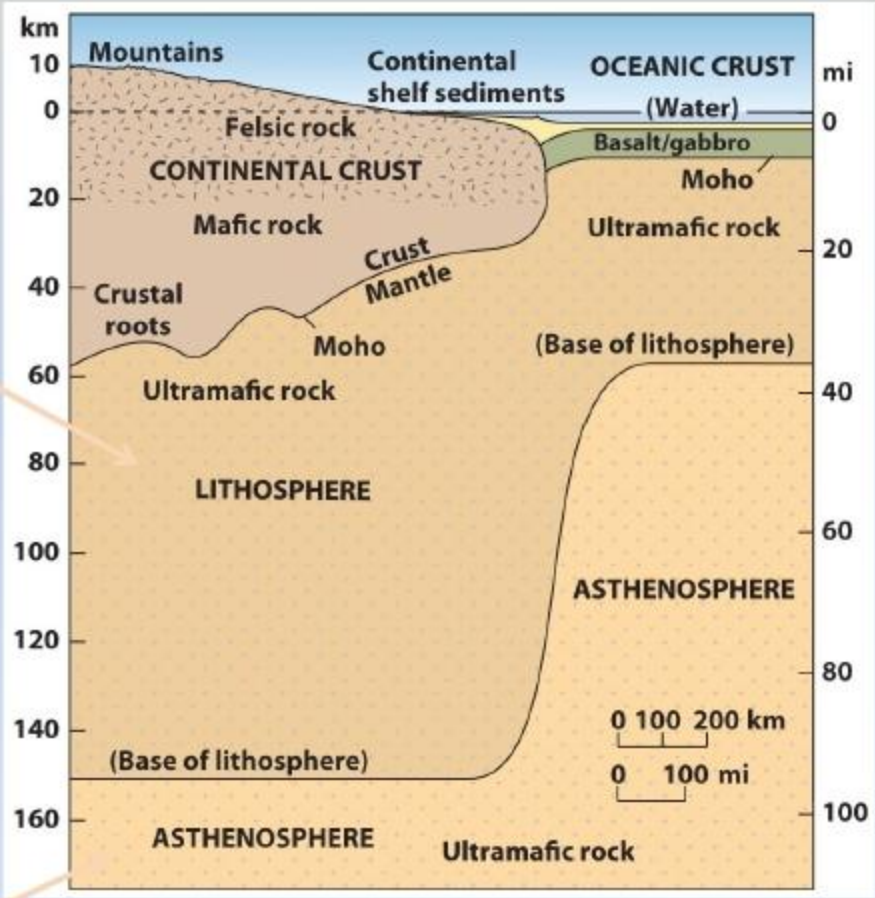
THE LITHOSPHERE AND ASTHENOSPHERE

Lithosphere - solid, brittle outermost layer of the Earth, includes the crust and the cooler, brittle upper part of the mantle.





Asthenosphere is plastic.

2. Major Relief Features of the Earth's Surface

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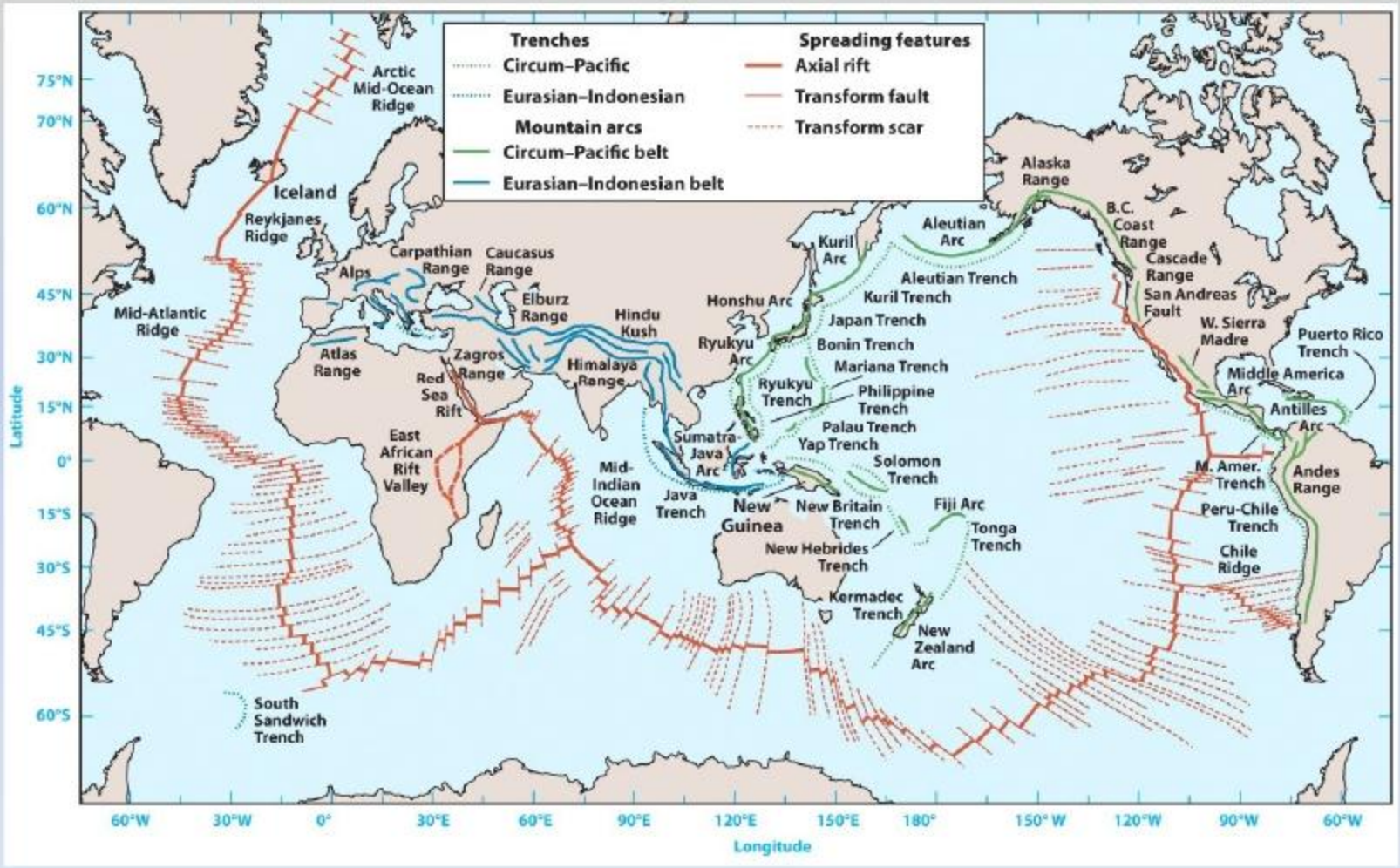
RELIEF FEATURES OF THE CONTINENTS



2. Major Relief Features of the Earth's Surface

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RELIEF FEATURES OF THE CONTINENTS

Continental relief features:
Active - mountain-making belts
Inactive - regions of old, stable rock.

Active Belts:
Volcanism - massive accumulations of volcanic rock formed by extrusion of magma
Tectonic activity —the breaking and bending of the Earth's crust under internal Earth forces. This tectonic activity usually occurs when great lithospheric plates come together

RELIEF FEATURES OF THE CONTINENTS

Continental relief features:
Active - mountain-making belts
Inactive - regions of old, stable rock.

Inactive Belts:
Stable rocks include **continental shields** & **ancient mountain roots.**
Continental shields - low-lying areas of old igneous and metamorphic rock.

RELIEF FEATURES OF THE CONTINENTS

Shields are areas of ancient rocks that have been eroded to levels of low relief. Continental glaciers stripped the Canadian shield of its sediments during the Ice Age, leaving a landscape of low hills, rock outcrops, and many lakes.

RELIEF FEATURES OF THE OCEAN BASINS

Oceans - 71 percent of the Earth's surface. Much of the oceanic crust is less than 60 million years old, (continental crust - Proterozoic age)

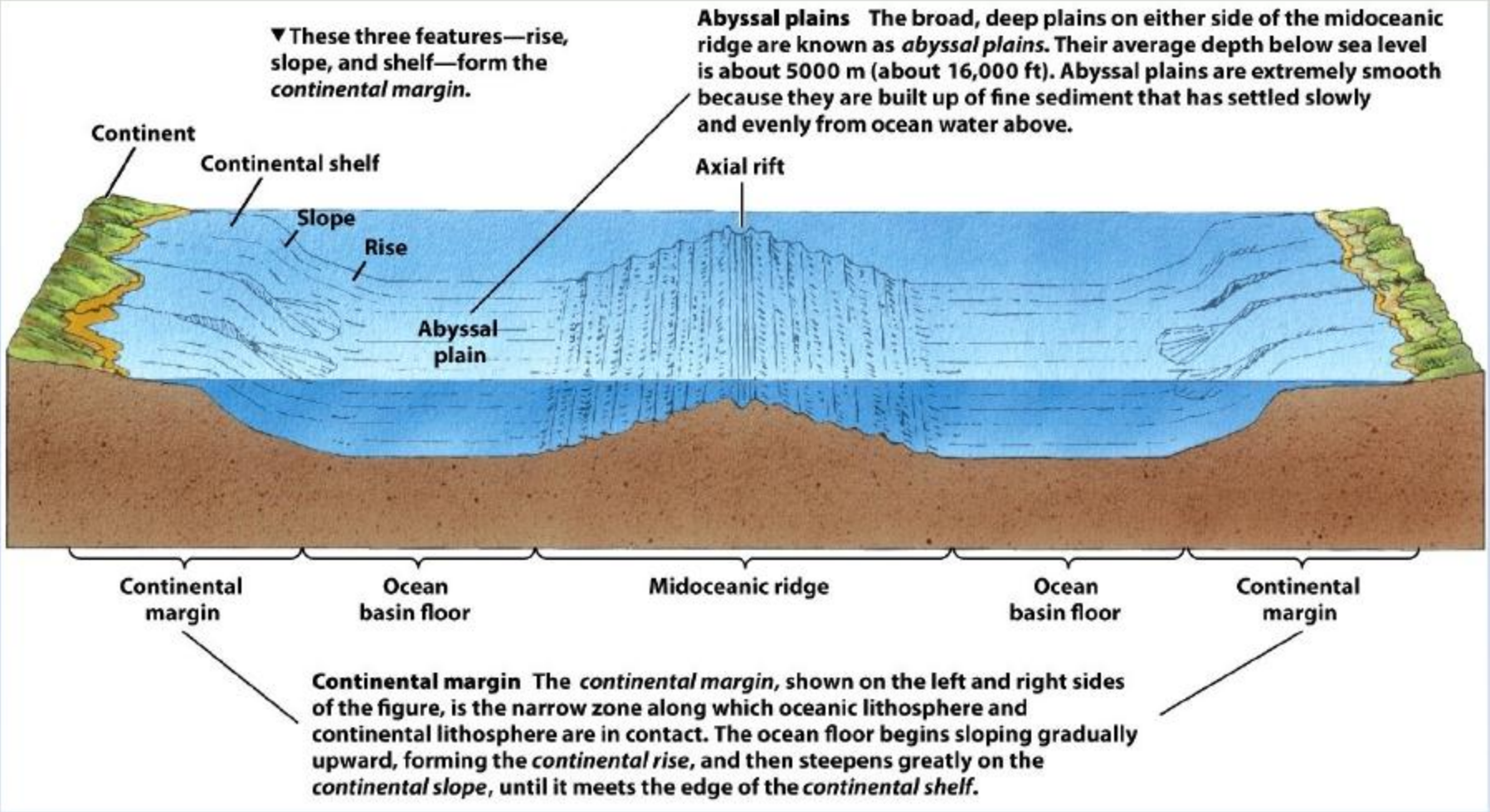
Passive continental margins accumulate thick deposits of continental sediments.

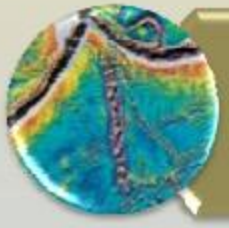
Active continental margins have oceanic trenches where oceanic crust is sliding beneath continental crust.

Ocean basins -

- midoceanic ridge
- central axial rift where crust is being pulled apart

RELIEF FEATURES OF THE OCEAN BASINS





3. Plate Tectonics

- PLATES AND BOUNDARIES
- THE GLOBAL SYSTEM OF LITHOSPHERIC PLATES
- CONTINENTAL RUPTURE AND NEW OCEAN BASINS
- ISLAND ARCS AND COLLISION OF OCEANIC LITHOSPHERE
- ARC--CONTINENT COLLISION

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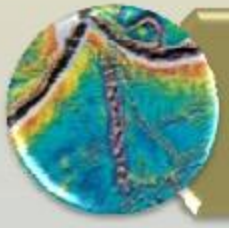

3. Plate Tectonics continued

- CONTINENT-CONTINENT COLLISION
- THE WILSON CYCLE AND SUPERCONTINENTS
- THE POWER SOURCE FOR PLATE MOVEMENTS
- CONTINENTS OF THE PAST

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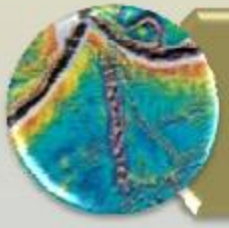

3. Plate Tectonics

Tectonic processes - extension and compression.

Extension

- Fracturing and faulting of the crust.
- Occurs when oceanic plates are pulled apart or when a continental plate breaks up into fragments.
- As the crust thins, it is fractured and pushed upward, producing block mountains.

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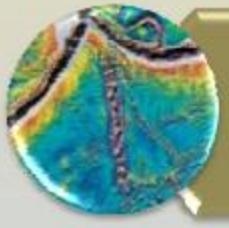

3. Plate Tectonics

Tectonic processes - extension and compression**.**

Compression "squeezing together" or "crushing"

- At converging plate boundaries.
- Results in alpine mountain chain consisting of intensely deformed strata of marine origin.
- Strata tightly compressed into wave-like *folds.*
- Faulted slices of rock move over the underlying rock on fault surfaces (overthrust faults).

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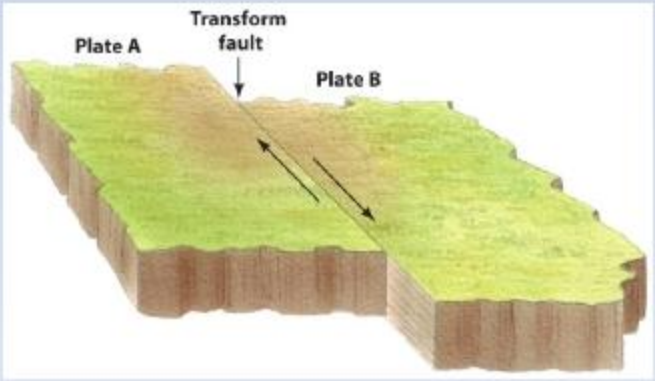
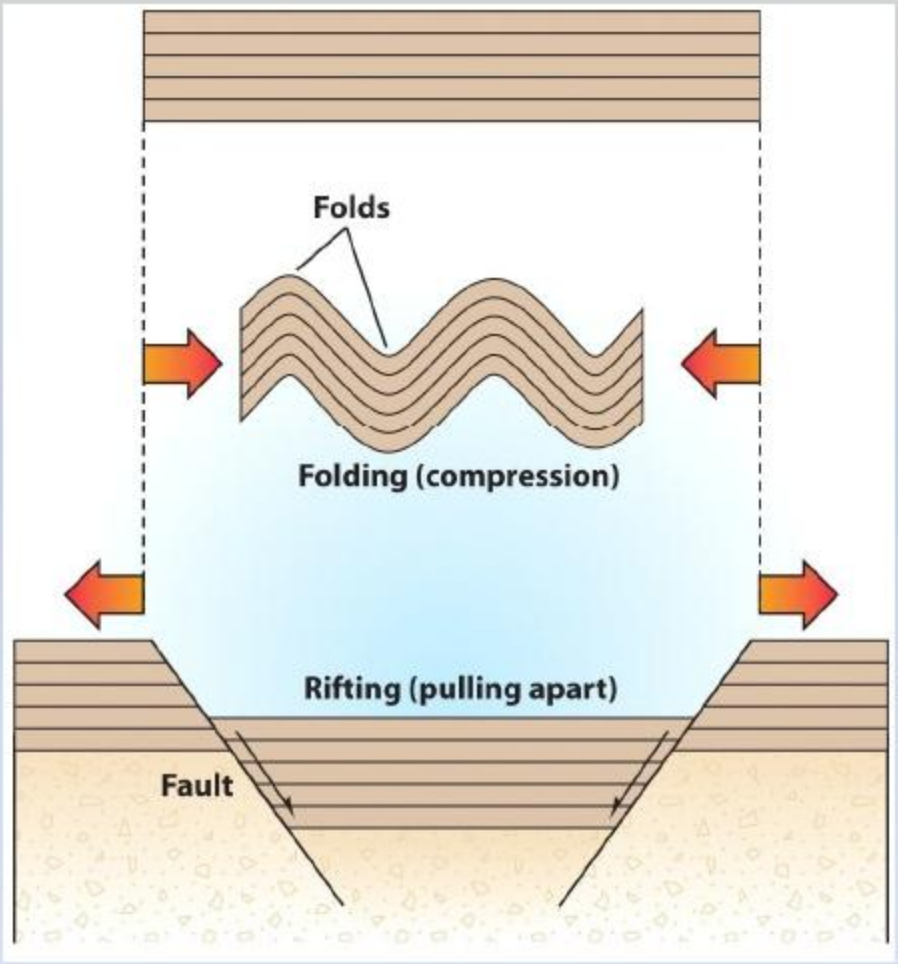
PLATES AND BOUNDARIES

Spreading boundary - crust is being pulled apart.

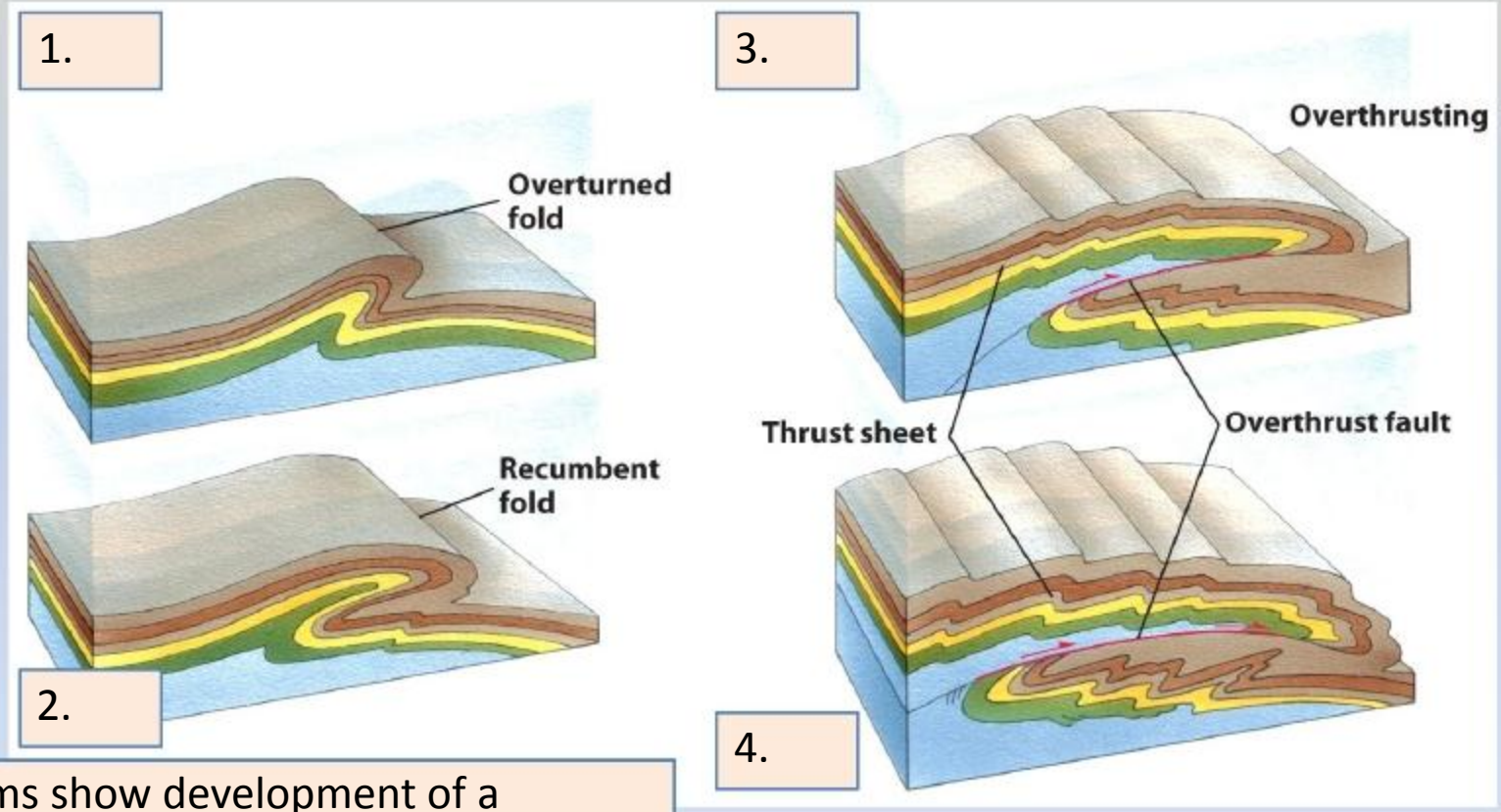
Converging boundary - one plate is subducted beneath another.

Transform boundary -two plates glide adjacent to each other.



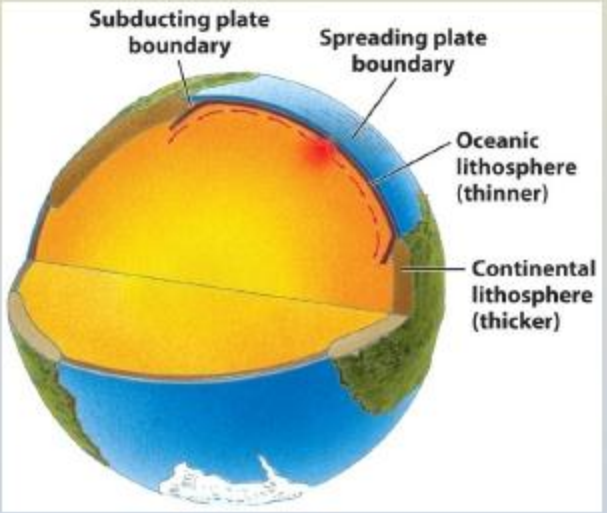


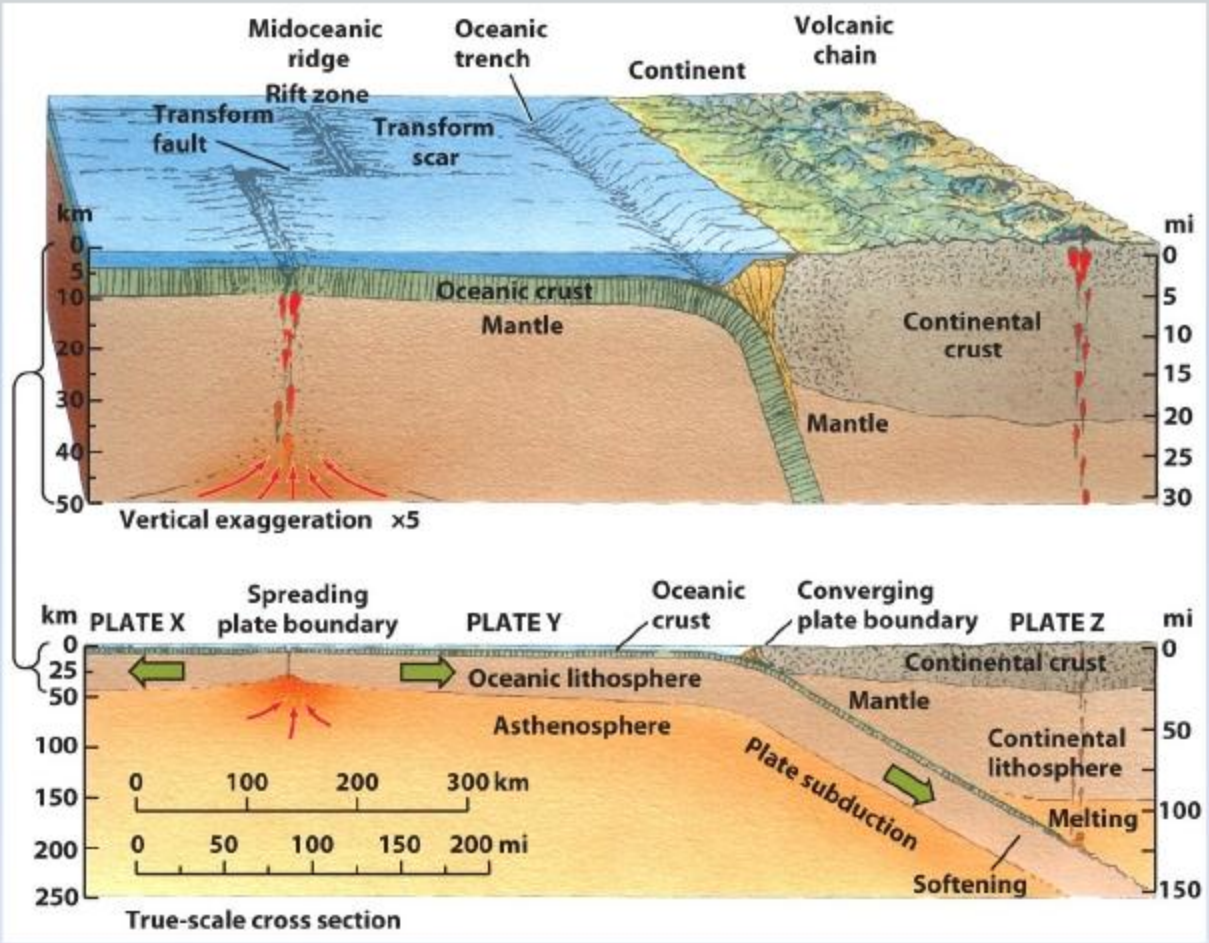
PLATES AND BOUNDARIES



Diagrams show development of a recumbent fold, broken by a low-angle overthrust fault to produce a thrust sheet, or nappe, in alpine structure.

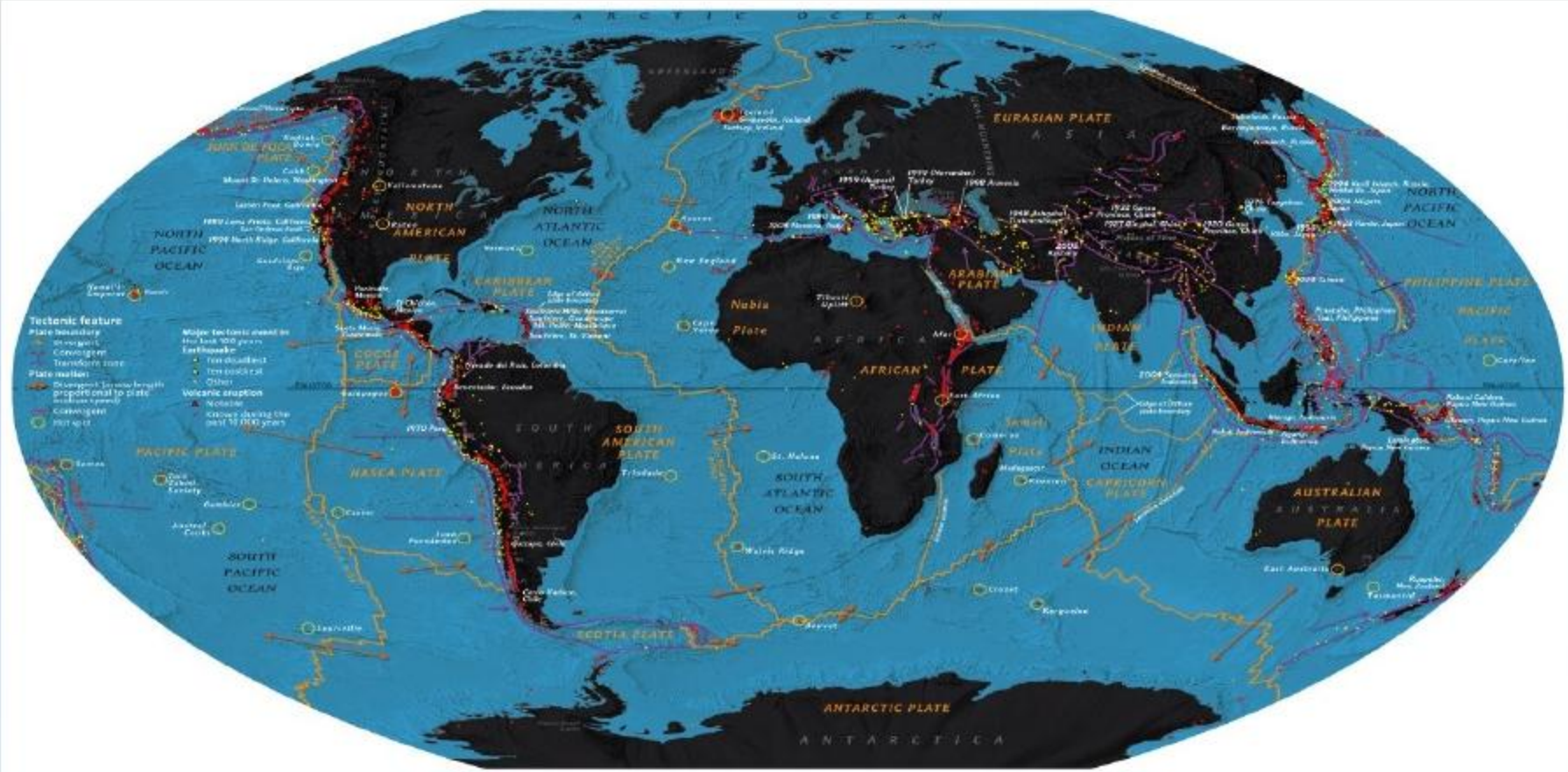
PLATES AND BOUNDARIES



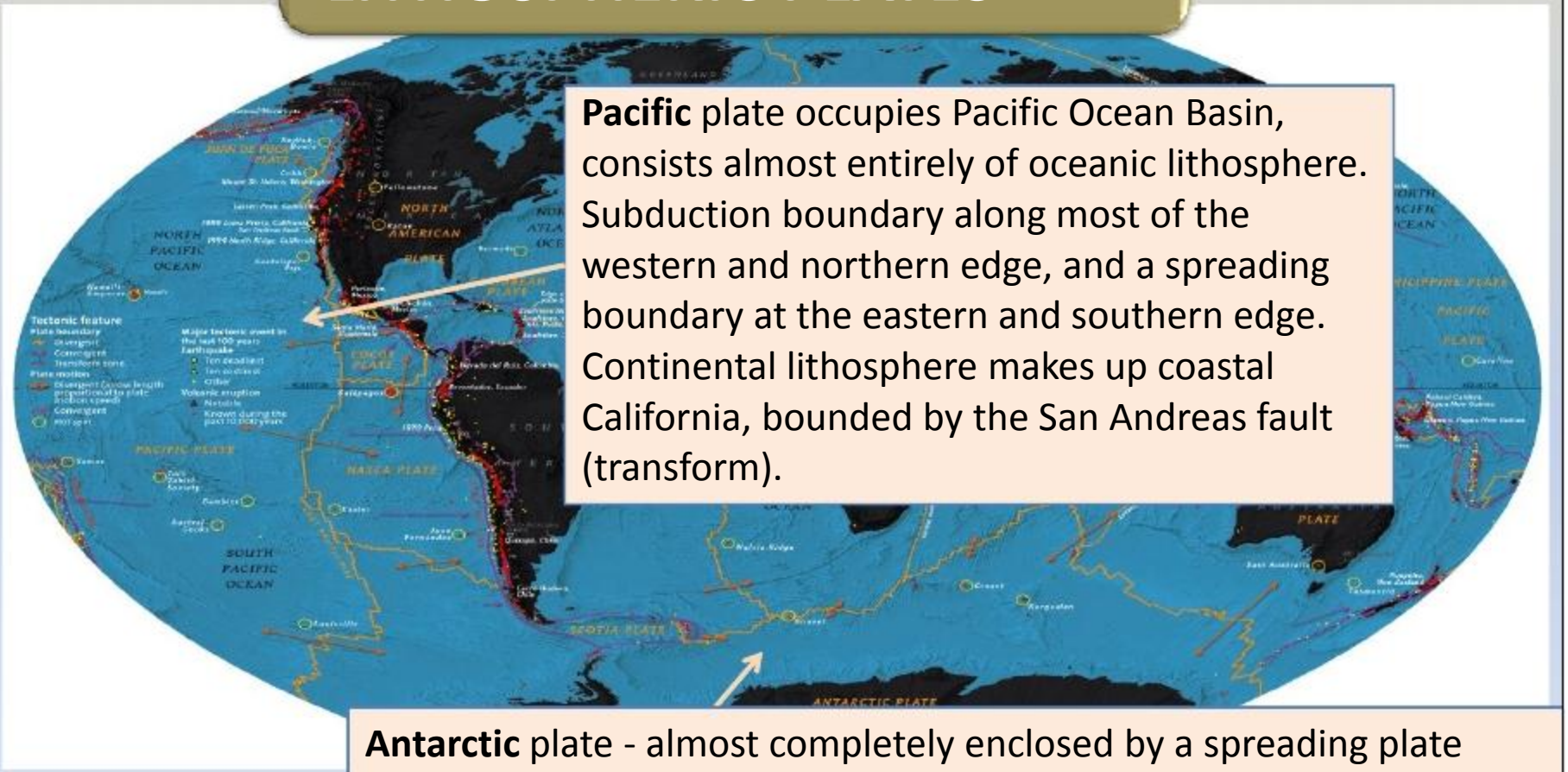


Oceanic plate moving to the right, away from a **spreading** boundary at an axial rift at the left. **Converging** boundary, the plate is subducting under a continental plate.

THE GLOBAL SYSTEM OF LITHOSPHERIC PLATES



THE GLOBAL SYSTEM OF LITHOSPHERIC PLATES



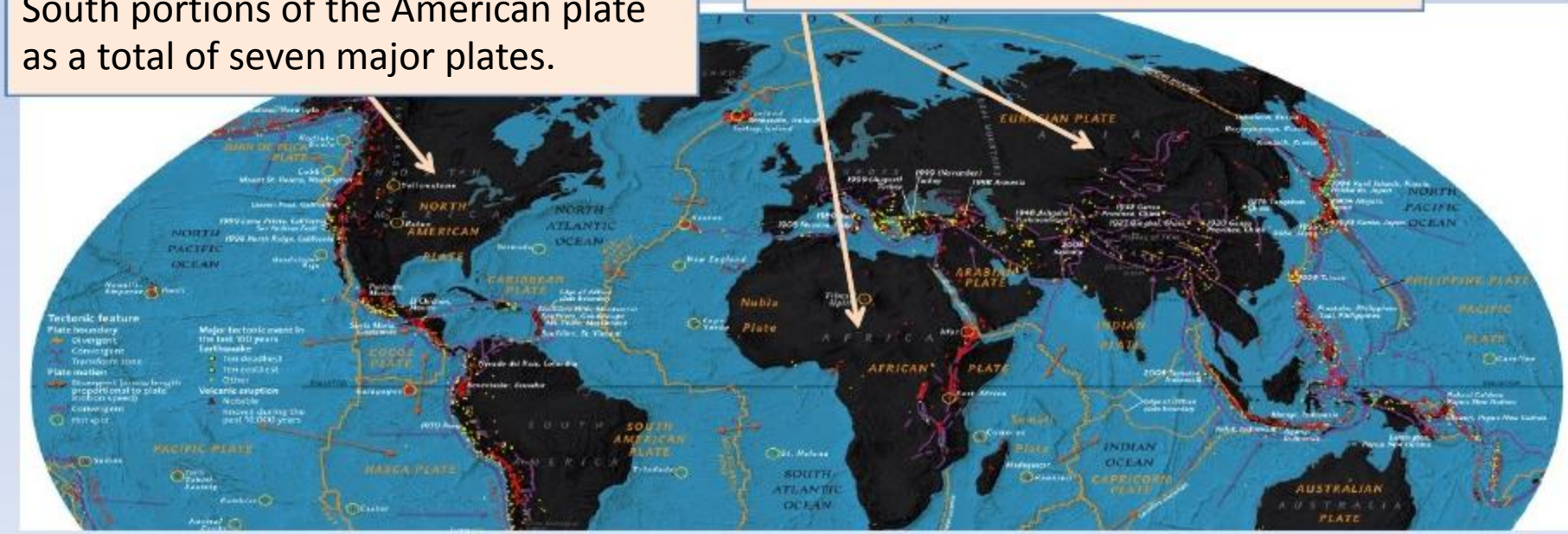
Pacific plate occupies Pacific Ocean Basin, consists almost entirely of oceanic lithosphere. Subduction boundary along most of the western and northern edge, and a spreading boundary at the eastern and southern edge. Continental lithosphere makes up coastal California, bounded by the San Andreas fault (transform).

Antarctic plate - almost completely enclosed by a spreading plate boundary, other plates are moving away from the pole. The continent of Antarctica forms a central core of continental lithosphere completely surrounded by oceanic lithosphere.

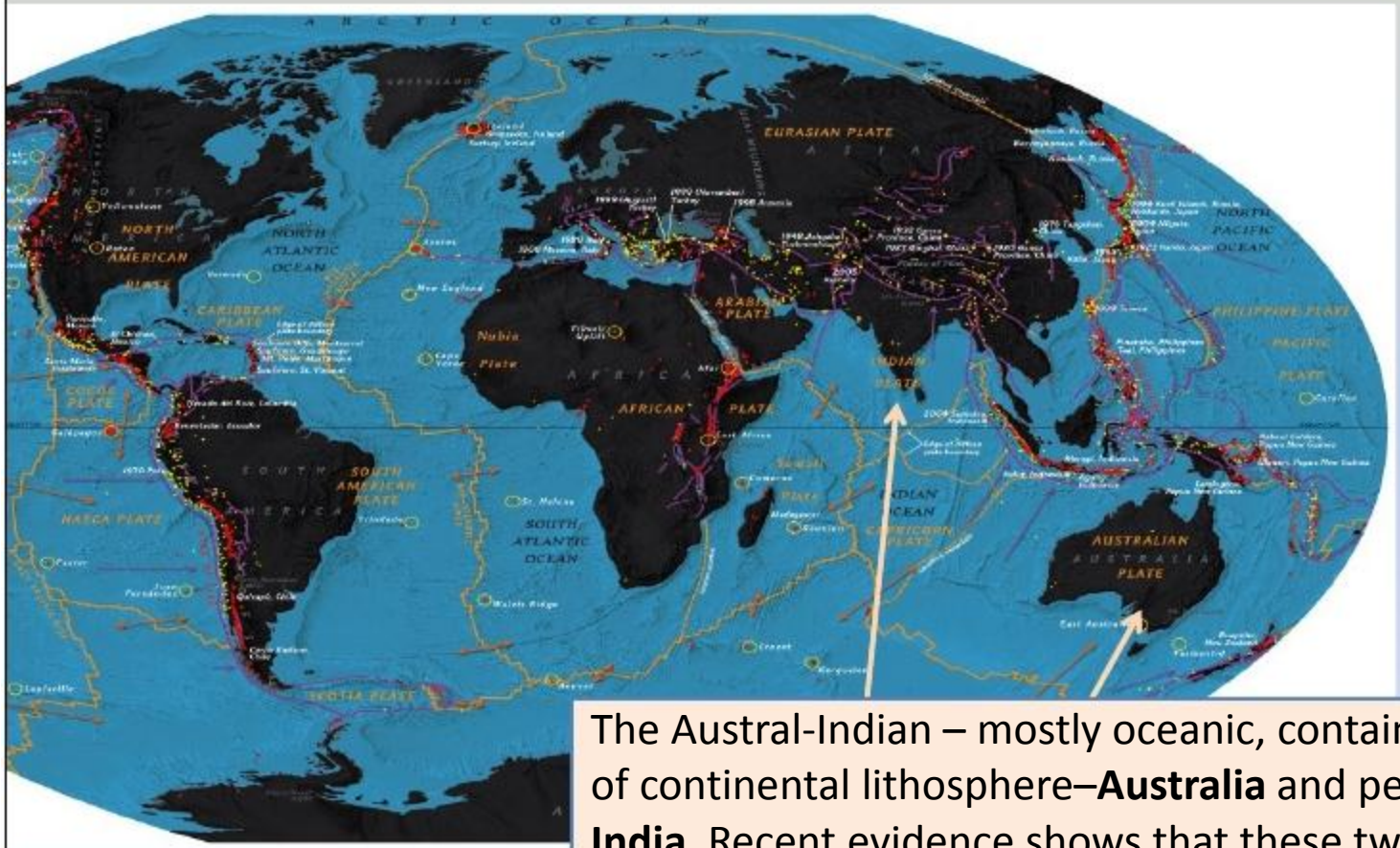
THE GLOBAL SYSTEM OF LITHOSPHERIC PLATES

American plate most of the continental lithosphere of North and South America. Western edge is a subduction boundary. Eastern edge is a spreading boundary. Some scientists regard the North and South portions of the American plate as a total of seven major plates.

Eurasian plate - mostly continental, fringed on the west and north by a belt of oceanic lithosphere. **African** plate (Nubia plate) has central core of continental lithosphere nearly surrounded by oceanic lithosphere.



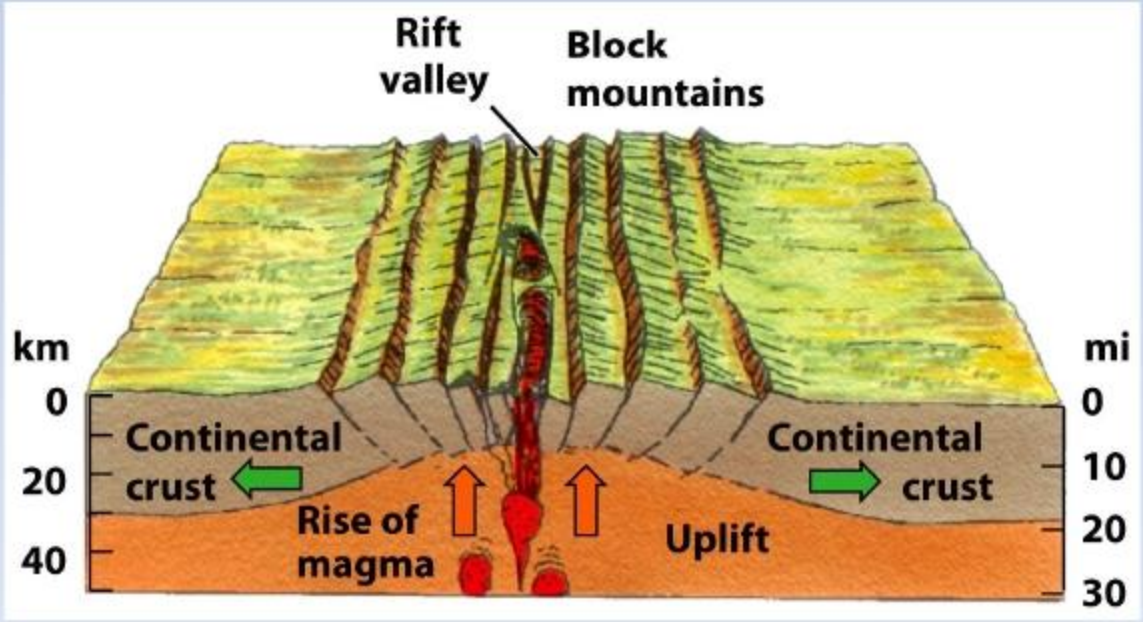
THE GLOBAL SYSTEM OF LITHOSPHERIC PLATES



The Austral-Indian – mostly oceanic, contains two cores of continental lithosphere–**Australia** and peninsular **India**. Recent evidence shows that these two continental masses are moving independently and may actually be considered to be parts of separate plates.

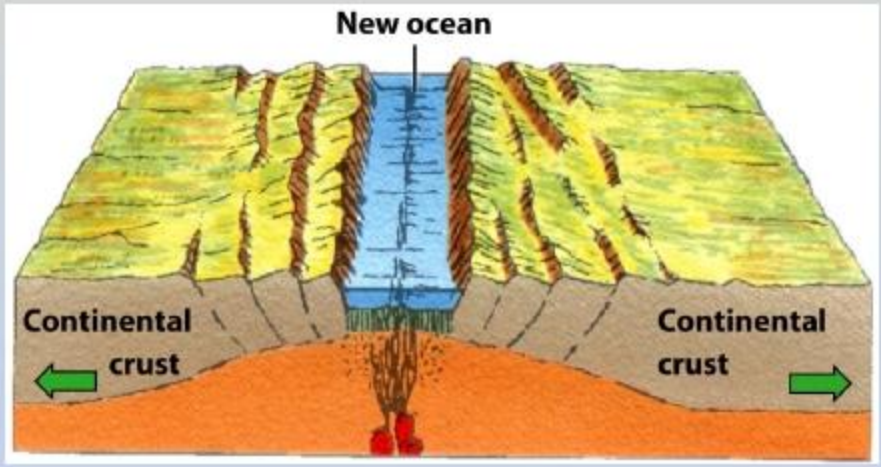
CONTINENTAL RUPTURE AND NEW OCEAN BASINS

Continental rupture begins with the formation of a **rift valley and tilted block mountains.** Ocean soon invades the rift. As the continental crust **recedes, oceanic crust fills the gap.**

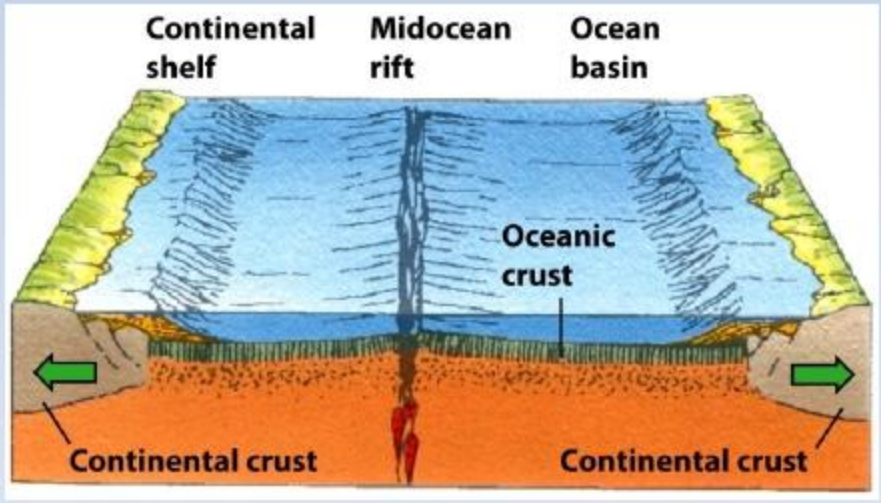


Crust is uplifted and stretched apart, causing it to break into blocks that become tilted on faults. Eventually long narrow *rift valley* appears. Magma rises up from the mantle to fill the widening crack at the center.

CONTINENTAL RUPTURE AND NEW OCEAN BASINS

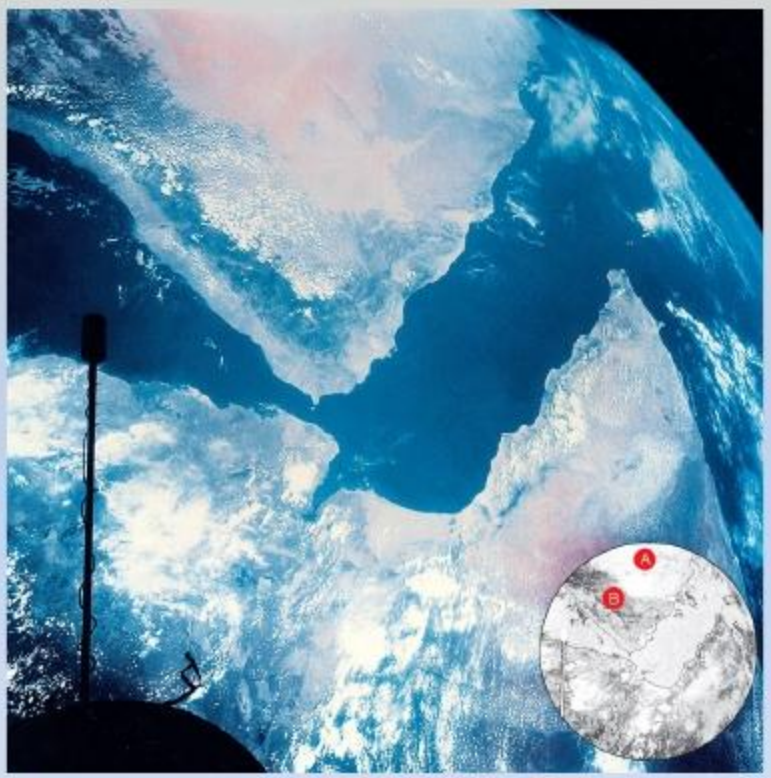


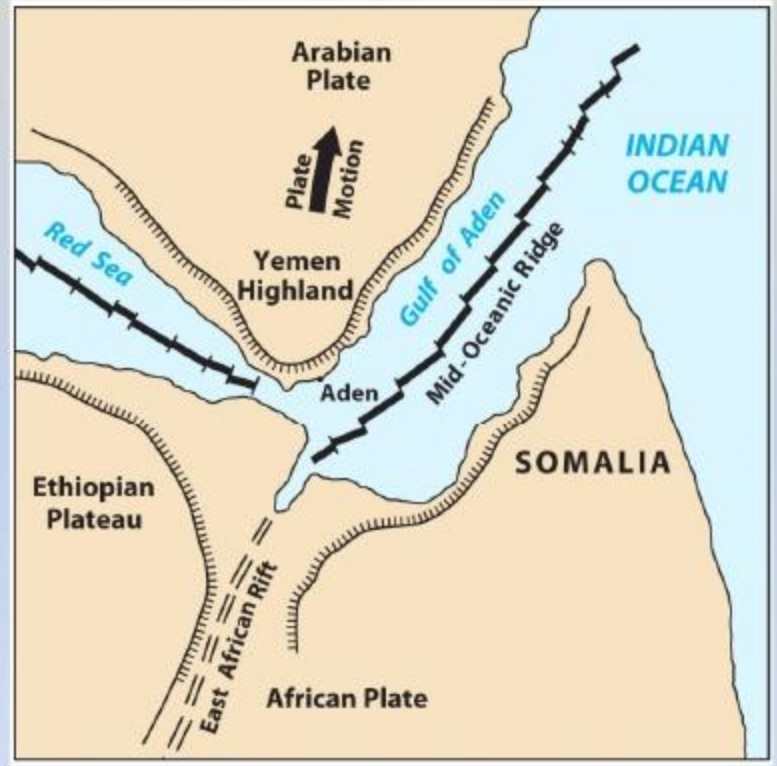
Magma solidifies to form *new crust* in the rift valley floor. Crustal blocks on either side slip down along a succession of steep faults, creating mountains. A narrow ocean is formed , floored by new oceanic crust.



Ocean basin continues to widen until a large ocean forms and continents are widely separated. Ocean basin widens, while the passive continental margins subside and receive sediments from the continents.

CONTINENTAL RUPTURE AND NEW OCEAN BASINS



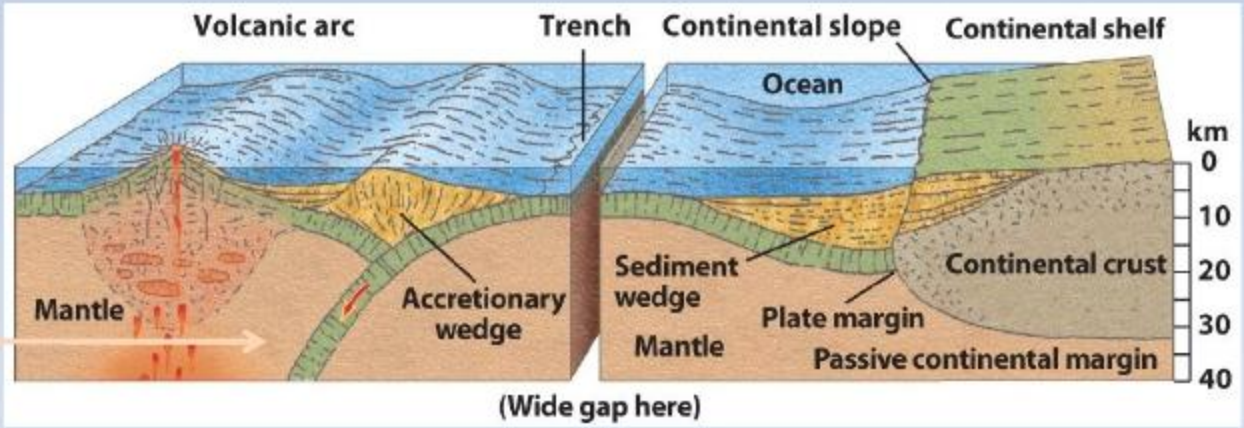


The Red Sea is an example of rupture in progress. This picture shows the southern end of the Red Sea and the southern tip of the Arabian Peninsula.

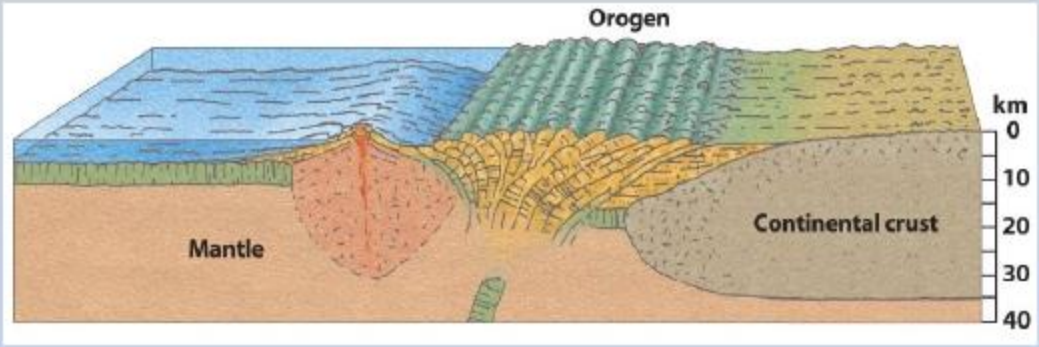
ISLAND ARCS AND COLLISION OF OCEANIC LITHOSPHERE

At a subduction boundary where plates of oceanic lithosphere collide, subducted seafloor sediment melts, rises, and forms a **volcanic island arc.**

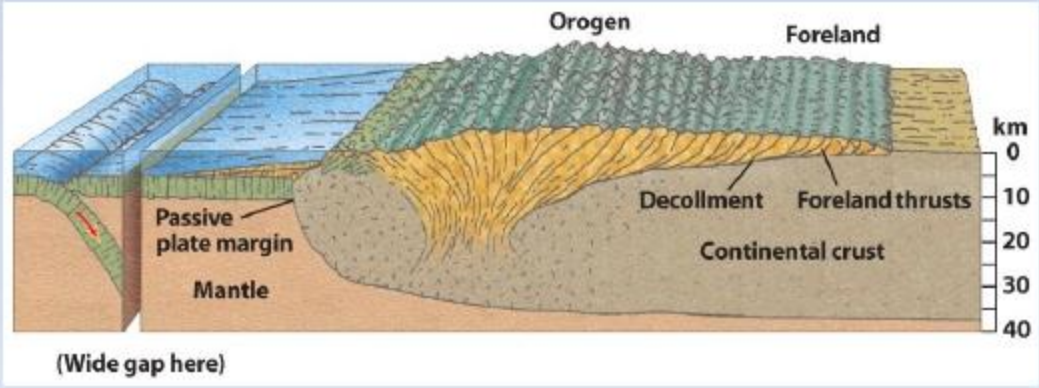
As an ocean basin closes, oceanic lithosphere is subducted below oceanic lithosphere. Sea-floor sediment piles up in an accretionary wedge. Subducted sediment melts and rises, forming the island arc.



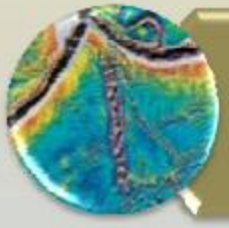
ARC--CONTINENT COLLISION



Large orogen (mountain range) is formed, with ancient volcanoes on one side, metamorphic rocks in the middle, and foreland thrusts and folds on the other. New fracture forms in oceanic lithosphere, and the orogen remains at the edge of a new passive plate margin.



ARC--CONTINENT COLLISION
Island arc collides with the passive continental margin. Sediments of the continental shelf and continental slope are compressed, forming folds and thrust sheets.



3. Plate Tectonics continued

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- THE POWER SOURCE FOR PLATE MOVEMENTS
- CONTINENTS OF THE PAST

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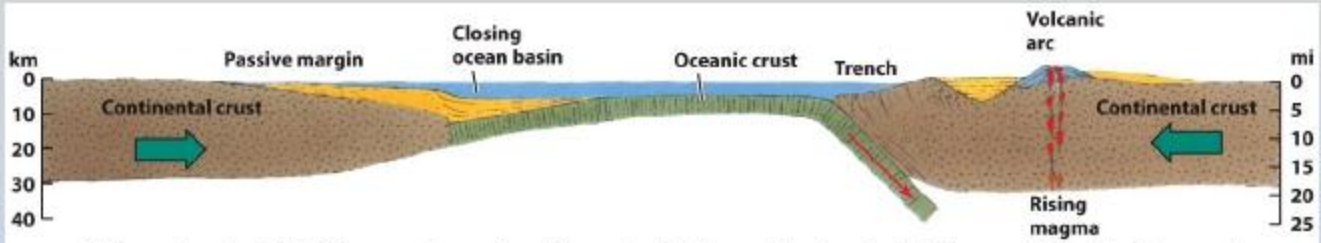
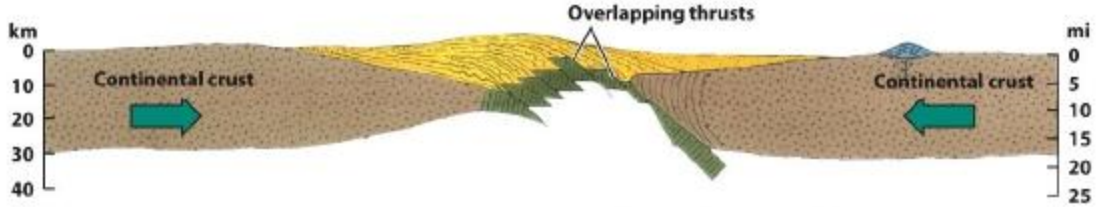
CONTINENT-CONTINENT COLLISION

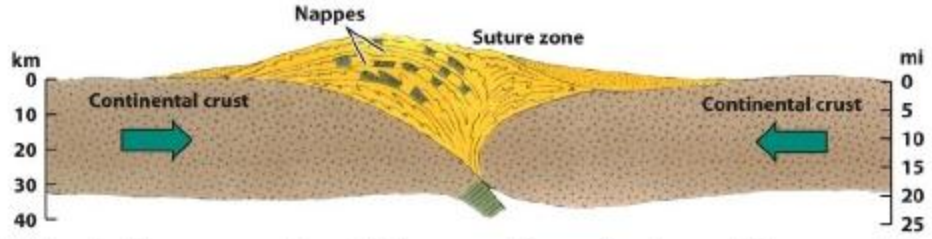
Orogeny - collision of 2 continental lithospheric plates **Continental rocks are crumpled and overthrust.**



▲ The continent on the left has a passive continental margin, while the continent on the right has an active subduction margin.



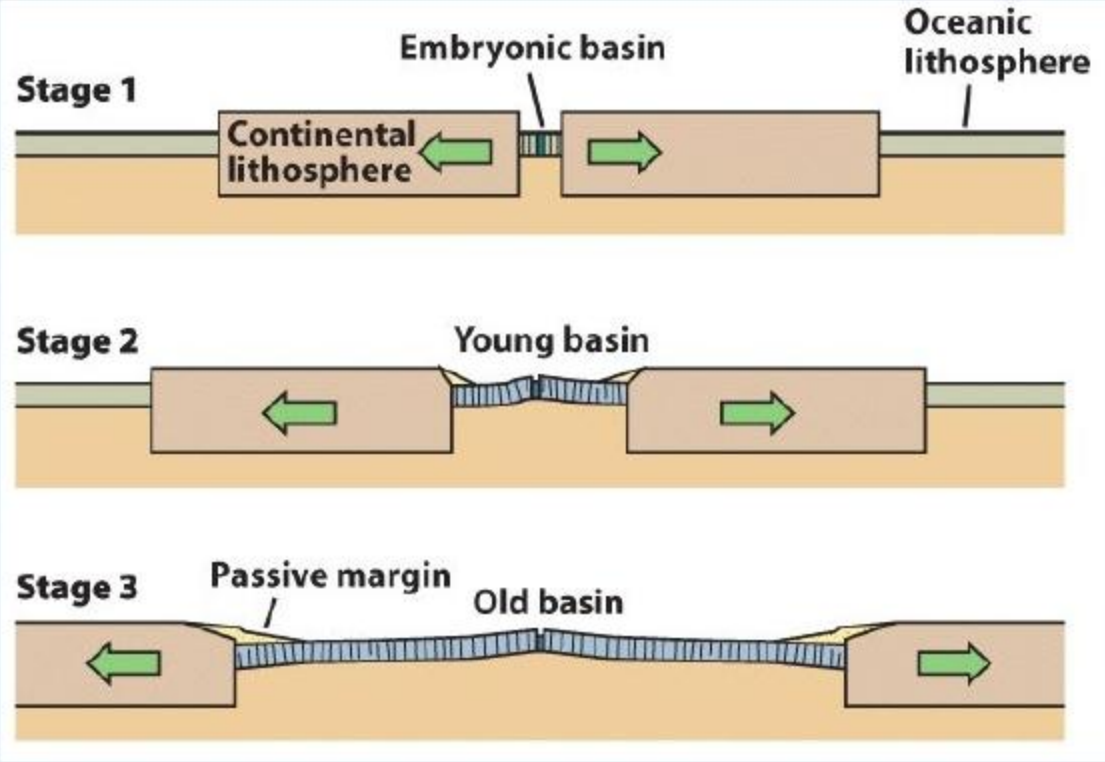
▲ As the continents move closer, the ocean between the converging continents is eliminated. The oceanic crust is telescoped, creating a succession of overlapping thrust faults, which ride up, one over the other.



▲ As the slices become more and more tightly squeezed, they are forced upward. The upper part of each thrust sheet turns horizontal, forming a nappe, which then glides forward under gravity. A mass of metamorphic rock forms between the joined continental plates, welding them together. This new rock mass is the continental suture.

THE WILSON CYCLE AND SUPERCONTINENTS

Ocean basins open and close in the **Wilson cycle,** which describes how continents are split and reunited.

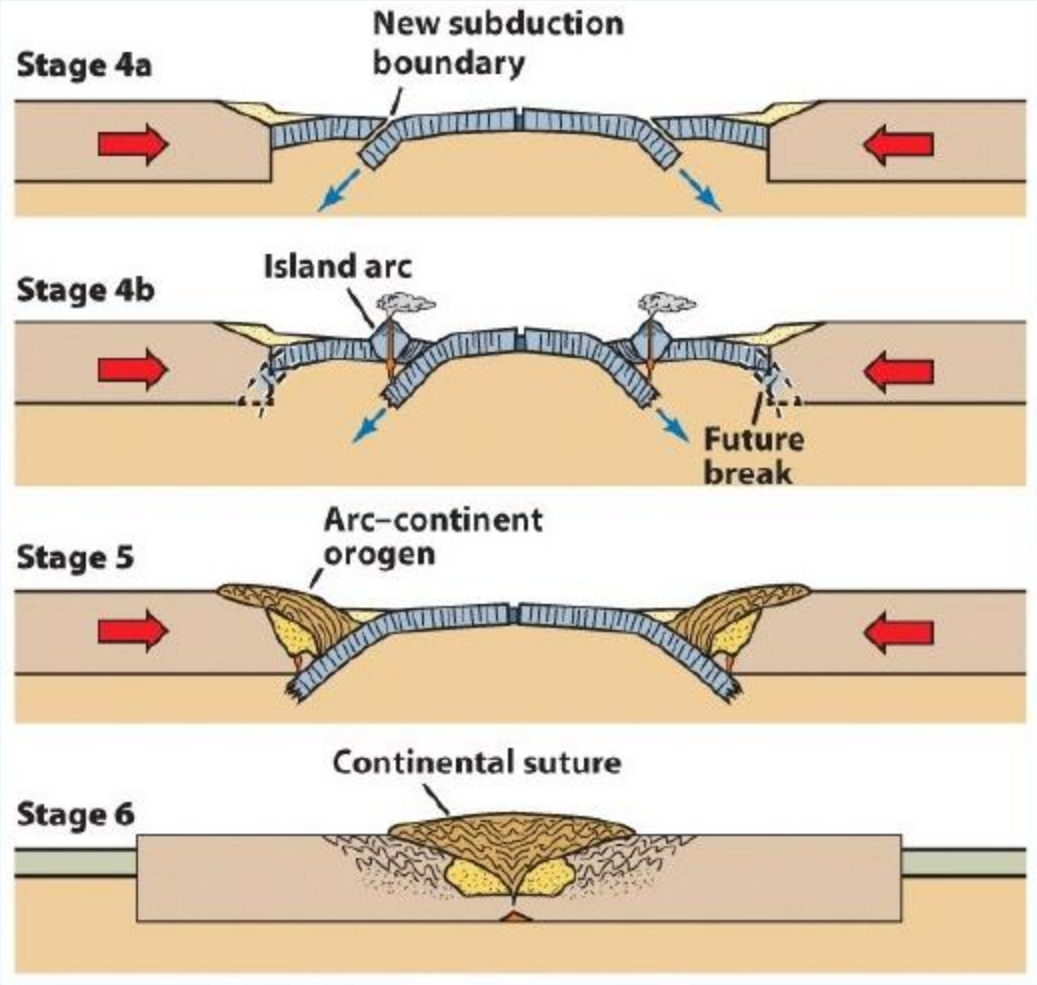


Stage 1 - Embryonic ocean basin. (The Red Sea separating the Arabian Peninsula from Africa)

Stage 2 - Young ocean basin. (The Labrador Basin, a branch of the North Atlantic lying between Labrador and Greenland)

Stage 3 - Old ocean basin. (Includes all of the vast expanse of the North and South Atlantic oceans and the Antarctic Ocean.)

THE WILSON CYCLE AND SUPERCONTINENTS



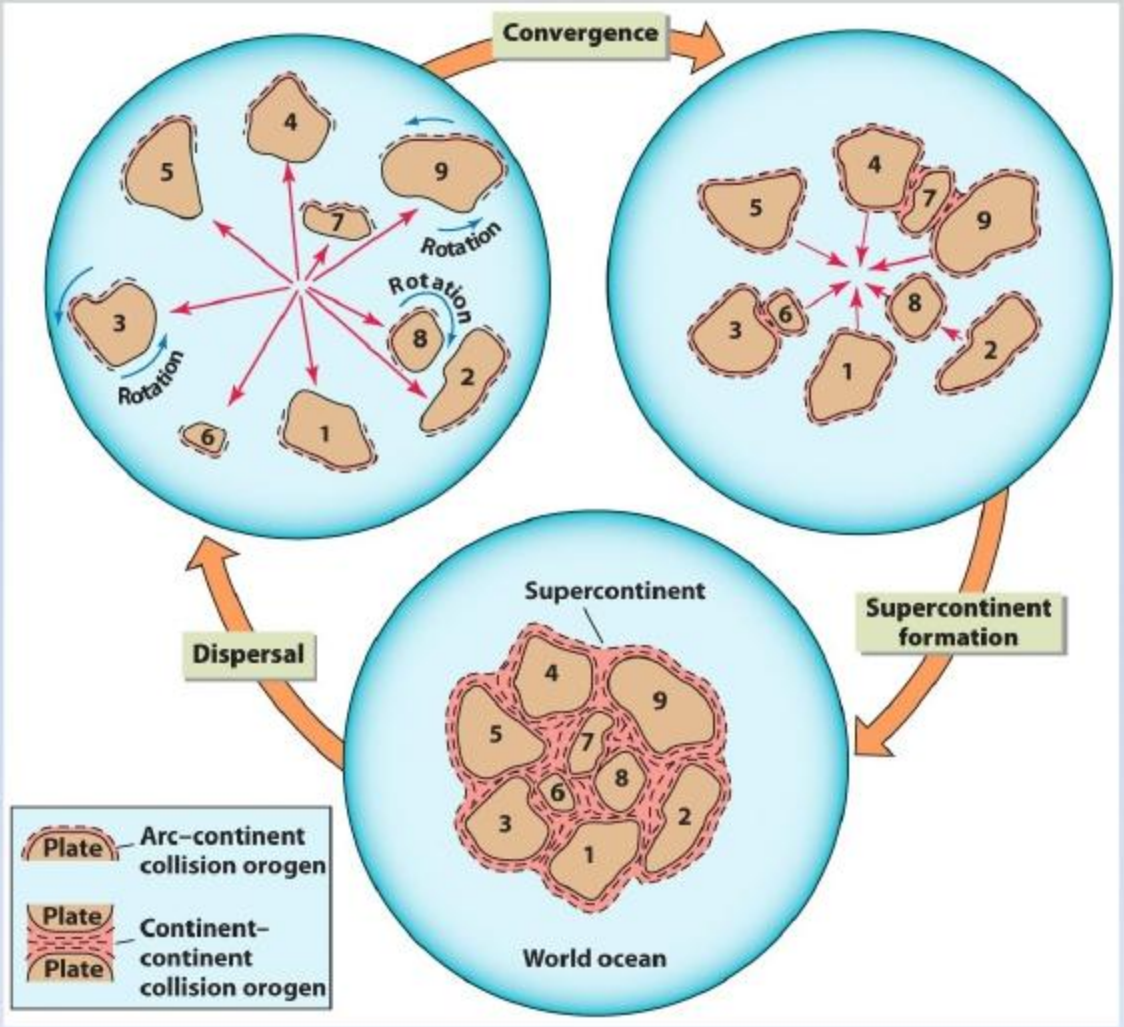
Stage 4a - Ocean basin begins to close as continental plates collide. New subduction boundaries form.

Stage 4b - Island arcs have risen and grown into great volcanic island chains. (Pacific plate, with the Aleutian arc)

Stage 5 - Closing continues. Formation of new subduction margins **close to the** continents is followed by arc-continent collisions. (Japanese Islands)

Stage 6 - Ocean basin closes with a collision orogen, forming a continental suture. (Himalayan orogen)

THE WILSON CYCLE AND SUPERCONTINENTS



Earth's history includes supercontinent cycles in which the continents unite in a single land mass and then break apart.

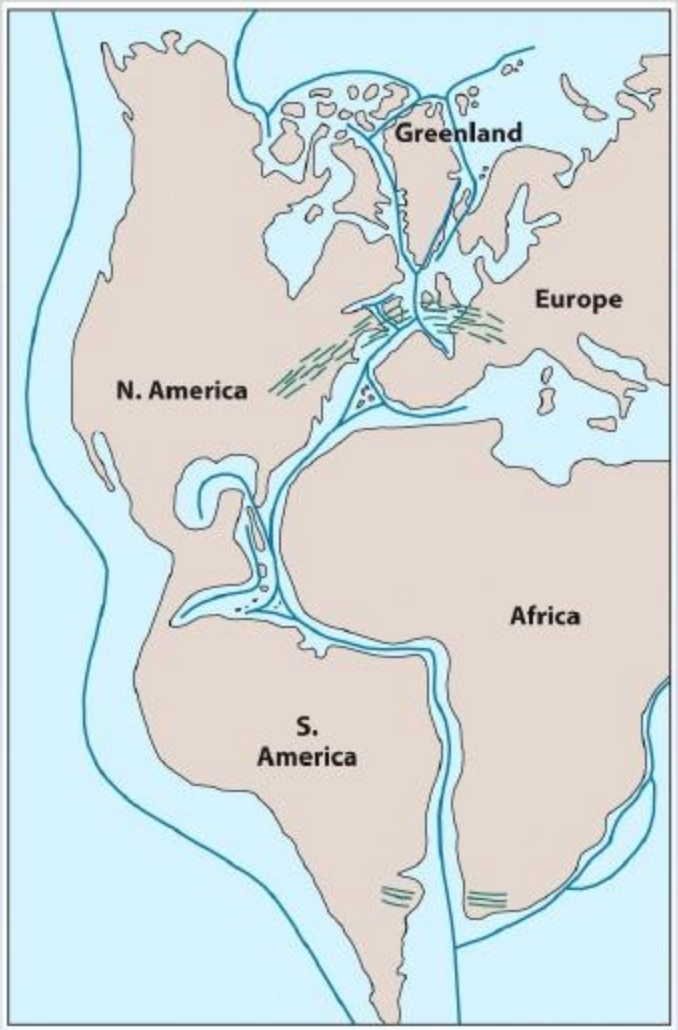
Pangaea is the most recent supercontinent.

THE POWER SOURCE FOR PLATE MOVEMENTS

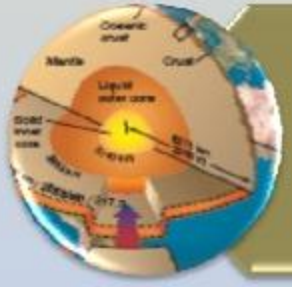
Power to move lithospheric plates - heat released by radioactivity.

- Elements have *unstable isotopes* that spontaneously emit energy or matter through *radioactive decay.*
- The energy is absorbed by the surrounding matter - ***radiogenic heat.***
- Earth's radiogenic heat is released in the rock beneath the continents.
- One theory is that plate motions are produced by *convection currents in hot mantle rock.*

CONTINENTS OF THE PAST

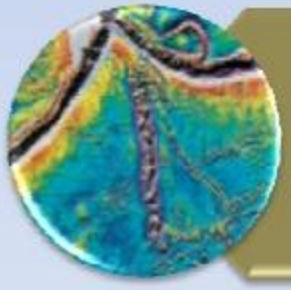


Chapter Review



1. Minerals and Rocks of the Earth's Crust

2. Major Relief Features of the Earth's Surface



3. Plate Tectonics

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