Plate Tectonics

Shape of the Earth

Elliptical shape:

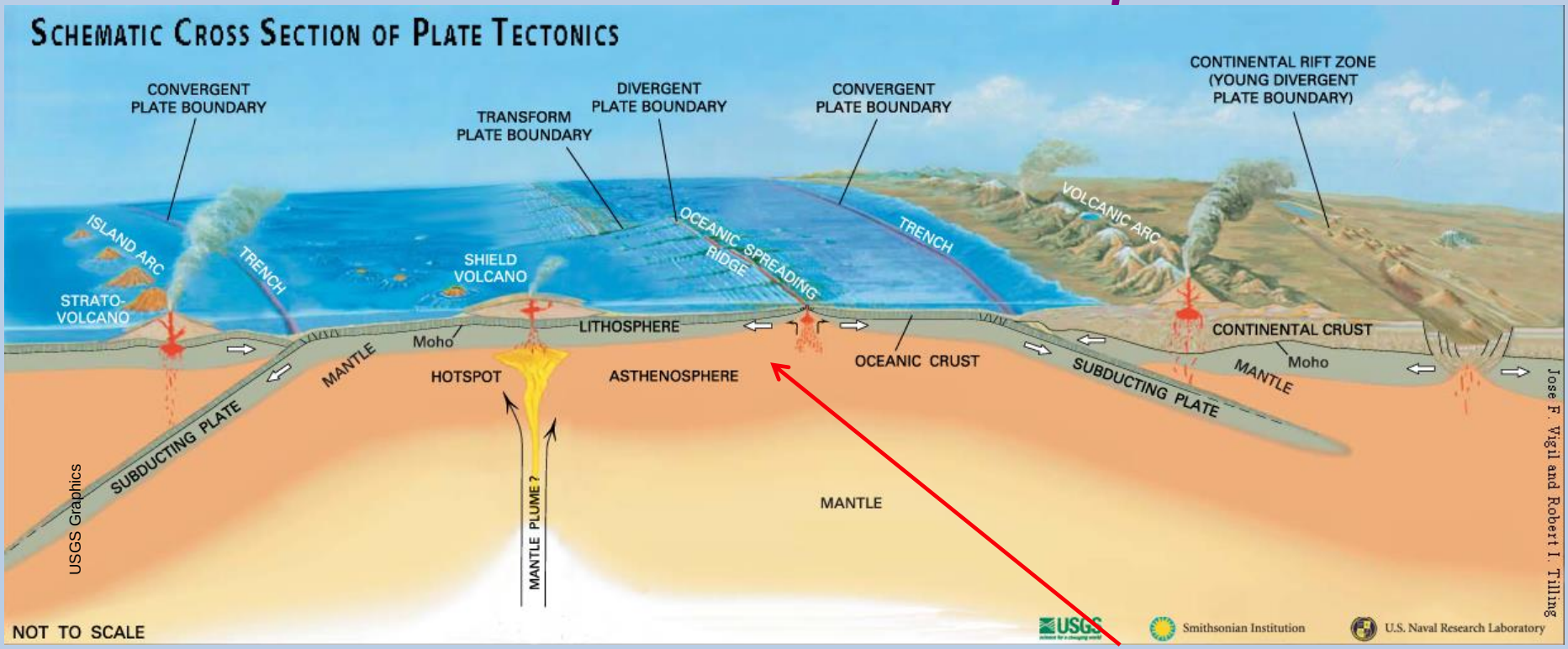
Diameter of the earth in the pole = 12640 km

Diameter of the earth in the equator = 12683 km

Rotational velocity of the earth around them self in the equator = 1659 km/h

Rotational velocity of the earth around the sun = 106560 km/h

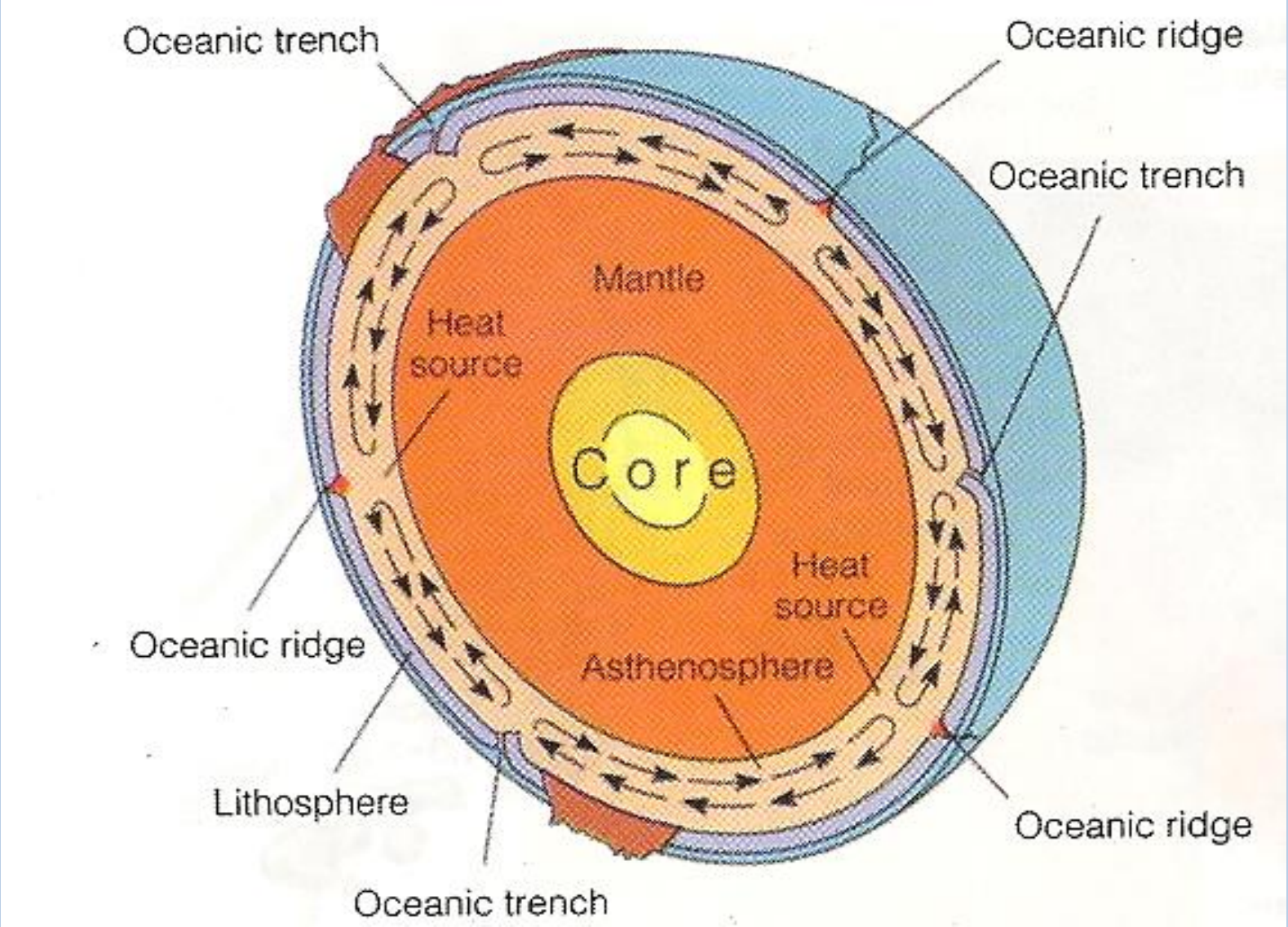
What is the *asthenosphere*?



Asthenosphere:

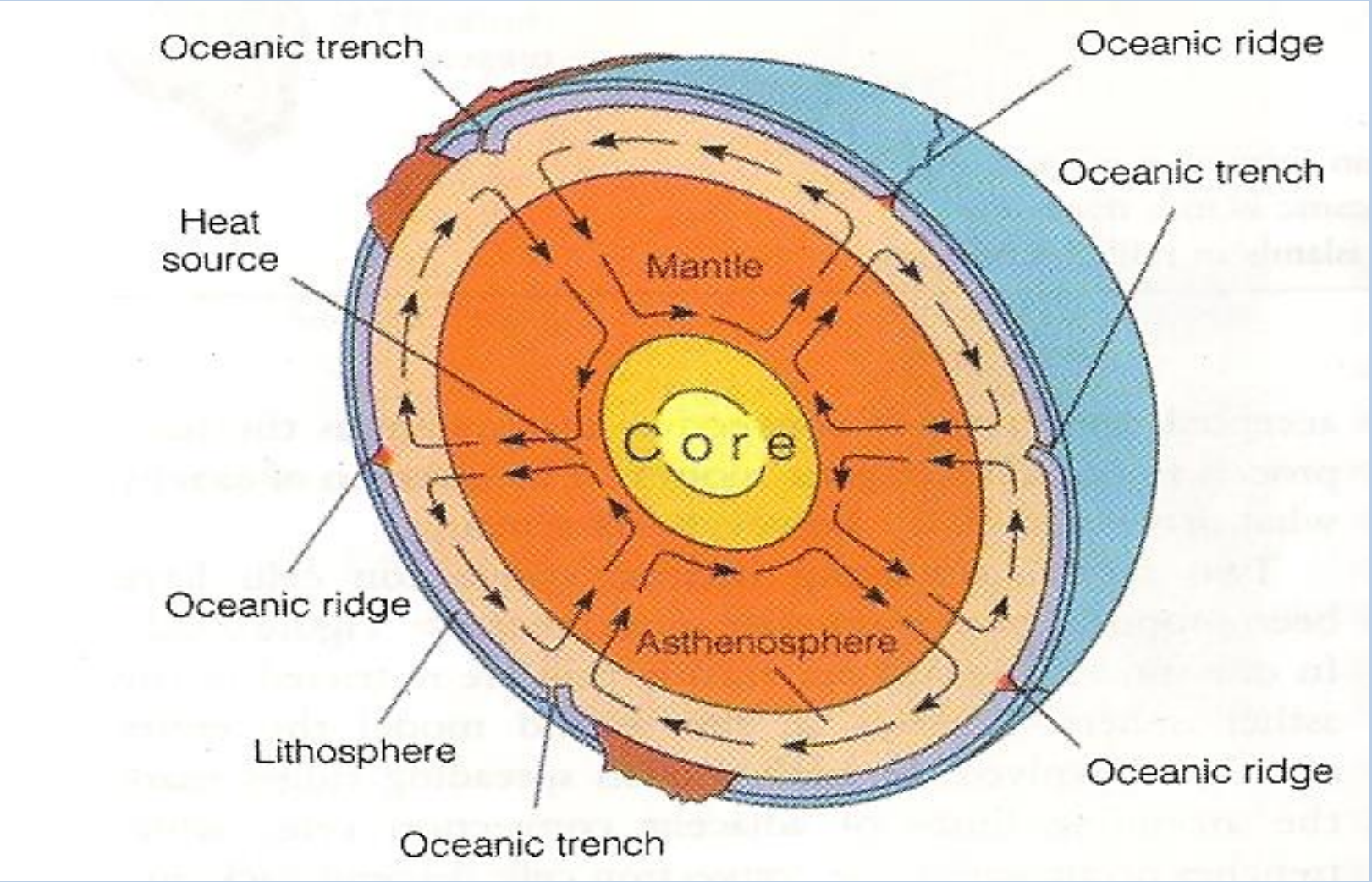
- Is the hotter upper mantle below the lithospheric plate;
- Can flow like silly putty; and
- Is a viscoelastic solid, <u>NOT</u> liquid!!

Thermal convection model 1



Thermal convection cells are restricted to the asthenosphere.

Thermal convection model 2



Thermal convection cells involve the entire mantle.

Continental drift: An idea before its time

Alfred Wegener
First proposed his continental drift hypothesis in 1915 before the theory of Plate Tectonics

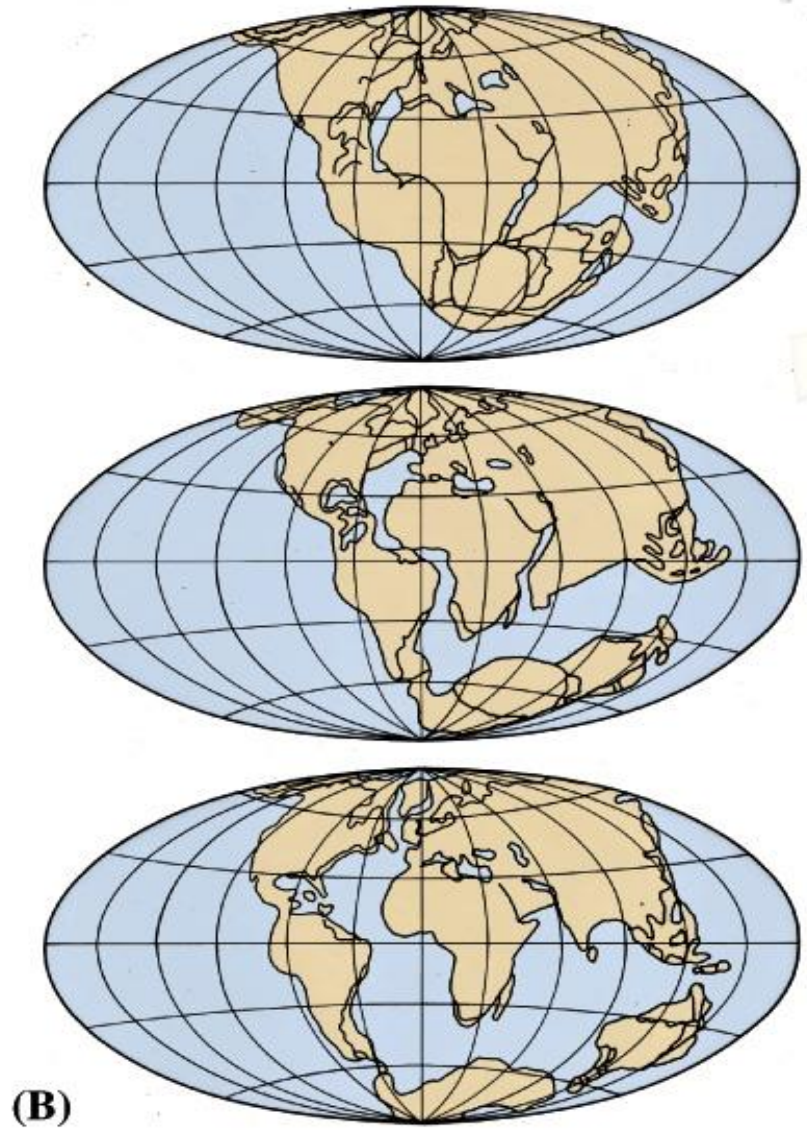
Continental drift hypothesis

- **Supercontinent called Pangaea began breaking apart about 200 million years ago**
- **Continents "drifted" to present positions**

Continental drift: An idea before its time

Evidence used in support of continental drift hypothesis

1. Fit of the continents.
2. Fossil evidence
3. Rock type and structural similarities
4. Paleoclimatic evidence



Continental drift maps by Wegner (1915)

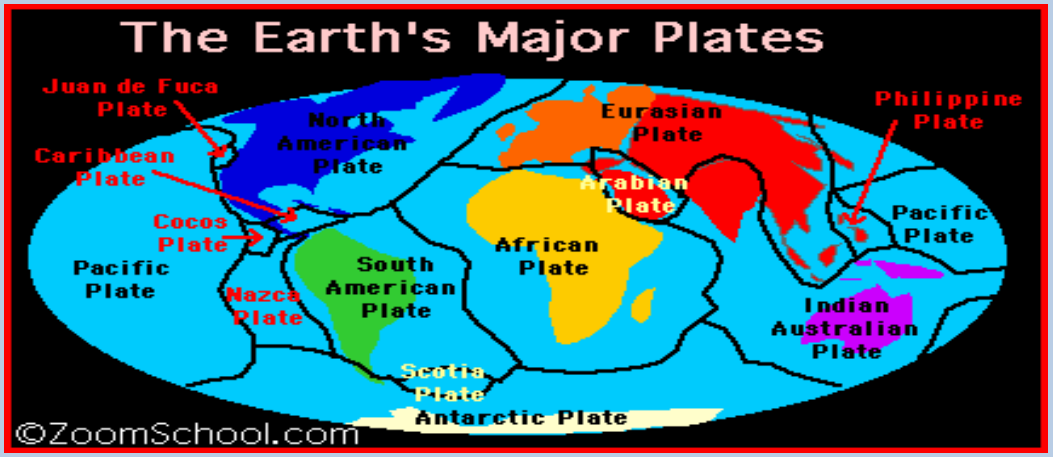
A scientific revolution begins

- During the 1950s and 1960s technological strides permitted extensive mapping of the ocean floor
- Seafloor spreading hypothesis was proposed by Harry Hess in the early 1960s
  - Oceanic crust created and spread apart at shallow mid-oceanic ridges
  - Oceanic crust destroyed at deep trenches

Plate Tectonic Theory

About forty years ago, scientists exploring the seafloor found that it is full of tall mountains and deep trenches, a single seafloor mountain chain circles Earth and contains some of Earth's tallest mountains.

Along this mountain chain is a deep crack in the top layers of earth. Here the seafloor is pulling apart and the two parts are moving in opposite directions, carrying along the continents and oceans that rest on top of them. These pieces of Earth's top layer are called *tectonic plates*. They are moving very slowly, but constantly. (Most plates are moving about as fast as your fingernails are growing -- not very fast!) Currently Earth's surface layers are divided into nine very large plates and several smaller ones.



What drives plate motions

- **I: Gravitational forces driving plate motion**
  - **Slab-pull combined with plate sliding**
  - **Ridge-push combined with plate sliding**
- **II: Mantle convection directly driving plates**
  - **Two layer convection separated at a 660 kilometer discontinuity**
  - **Whole-mantle convection**
  - **Deep-layer model with mantle convection separated from a deep layer near the core-mantle boundary**

Plate tectonics: The new paradigm

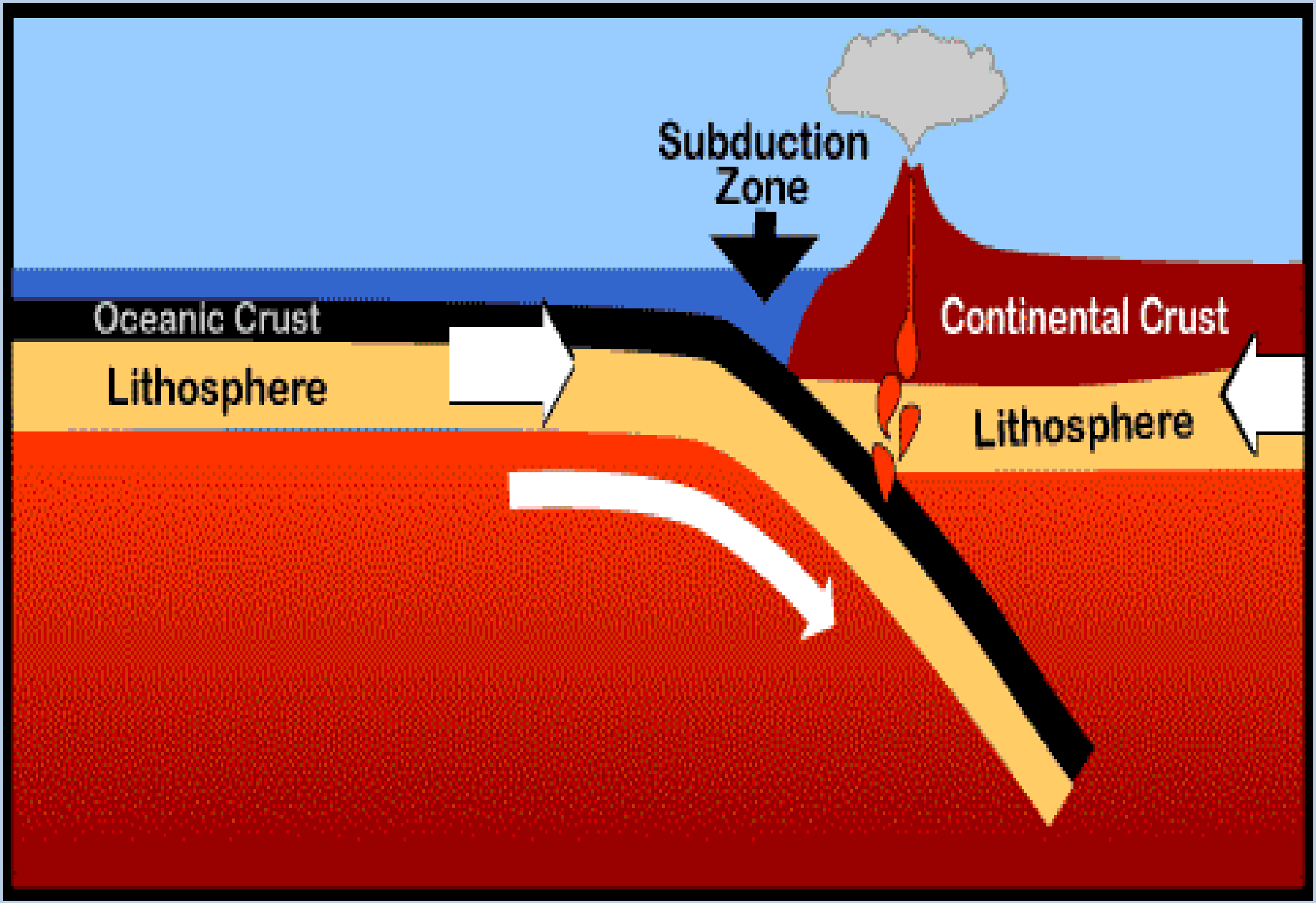
- **Earth's major tectonic plates**
  - **Earth is divided into seven to sixteen major lithospheric plates and several other minor plates that are relatively rigid.**
  - **Plates are composed of the oceanic and/or continental crust and the uppermost mantle.**
  - **Several plates include an entire continent plus a large area of seafloor.**

Plate tectonics: The new paradigm

- **Earth's major tectonic plates cont.**
  - **Plates are in constant slow motion with respect to one another and are continually changing in shape and size.**
  - **Earthquakes, deformation and volcanic eruptions occur where these plates meet.**
  - **The interior of plates generally have fewer earthquakes, less deformation and less volcanic activity compared to the margins.**

What drives plate motions

- **Many, but not all researchers agree that convective flow in the mantle is the basic driving force of plate tectonics**
  - **Theory I: Causing elevation and density differences due to temperature variations, creating gravitational forces**
  - **Theory II: Causing frictional drag on the plates above the convecting mantle**


Subduction Zone
Oceanic Crust
Lithosphere
Continental Crust
Lithosphere

- These areas are likely to have a rift valley, earthquake, and volcanic action.

For example: Here, the San Andreas Fault lies on the boundary between two tectonic plates, the north American Plate and the Pacific Plate. The two plates are sliding past each other at a rate of 5 to 6 centimeters each year. This fault frequently plagues California wit hearthquakes.

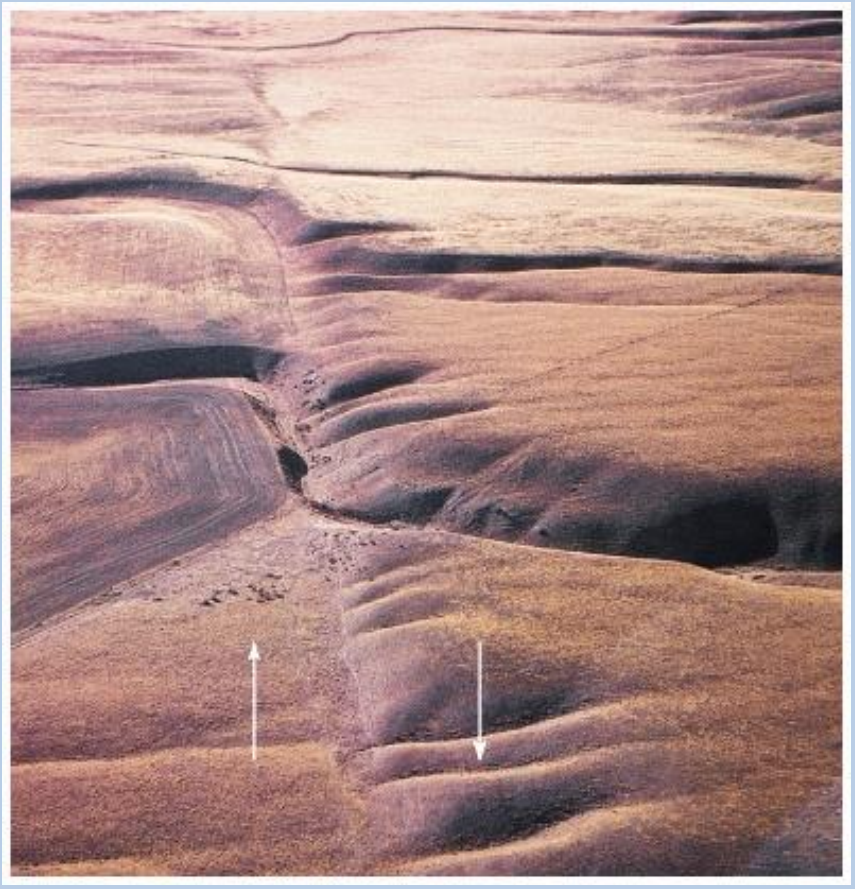
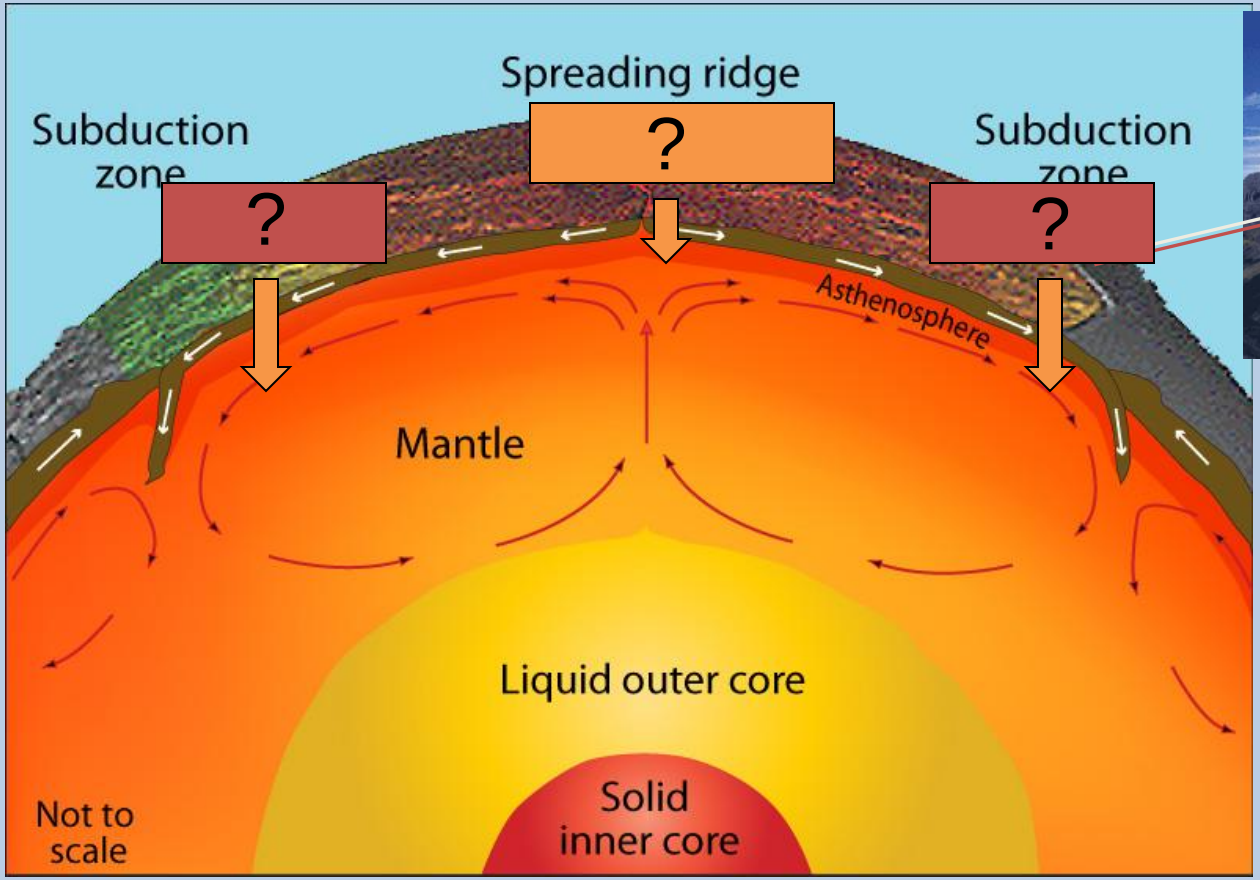
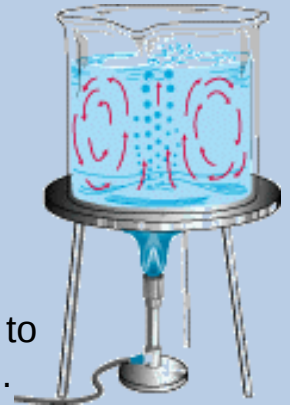


Plate tectonics

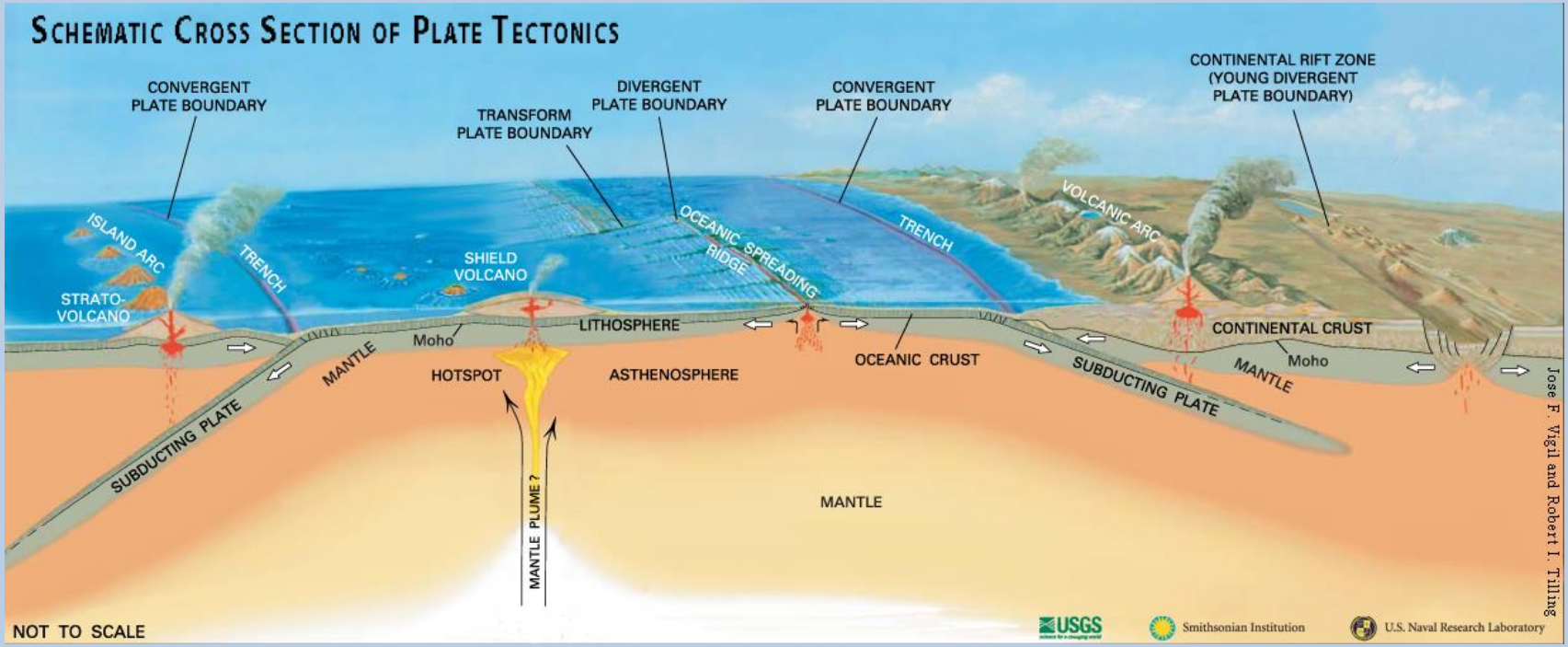
Plates are driven by cooling of Earth (convection)
Gravity provides additional force to move plates.





Convection is like a boiling pot. Heated soup rises to the surface, spreads and begins to cool, and then sinks back to the bottom of the pot where it is reheated and rises again.

What are the tectonic plates?

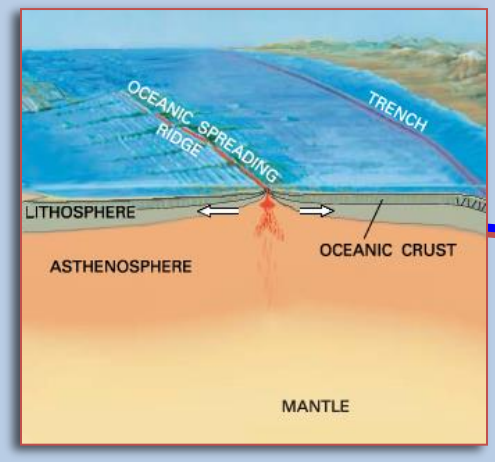


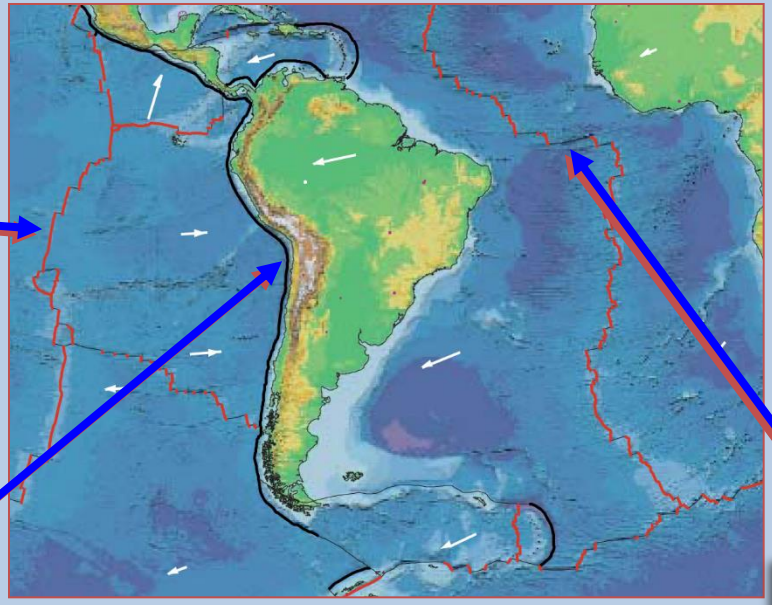
AKA: Lithospheric plate

- The ~100-km-thick surface of the Earth;
- Contains crust and part of the upper mantle;
- It is rigid and brittle;
- Fractures to produce earthquakes.

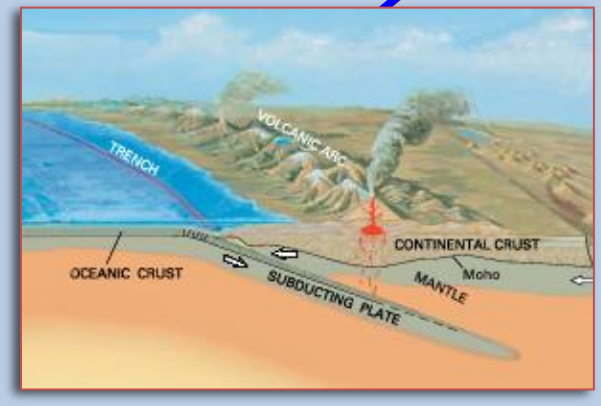
Three Basic Types of Plate Boundaries

Divergent

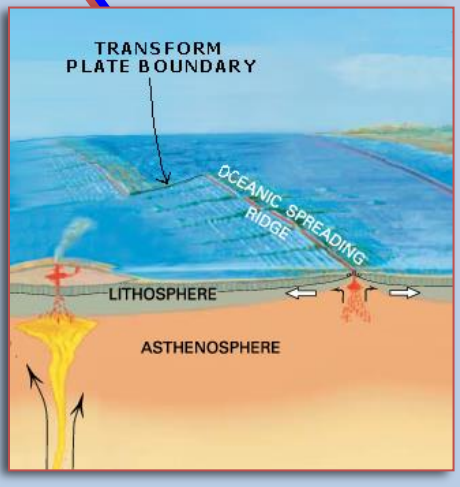




Convergent



Transform

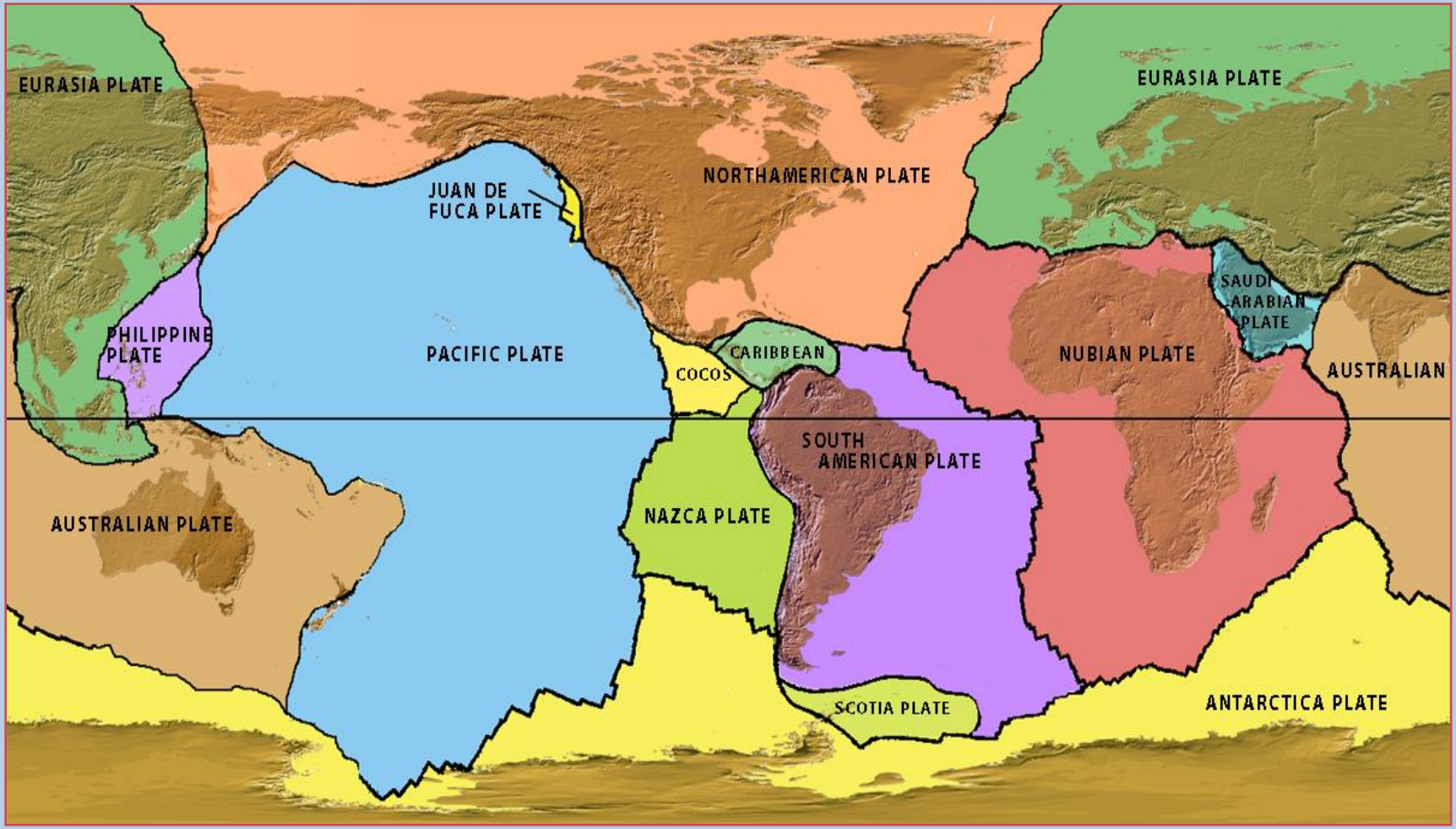


USGS Graphics

Tectonic Plates

There are a dozen large lithospheric plates (smaller plates not shown). Some plates have continents; some don't. All are in motion.

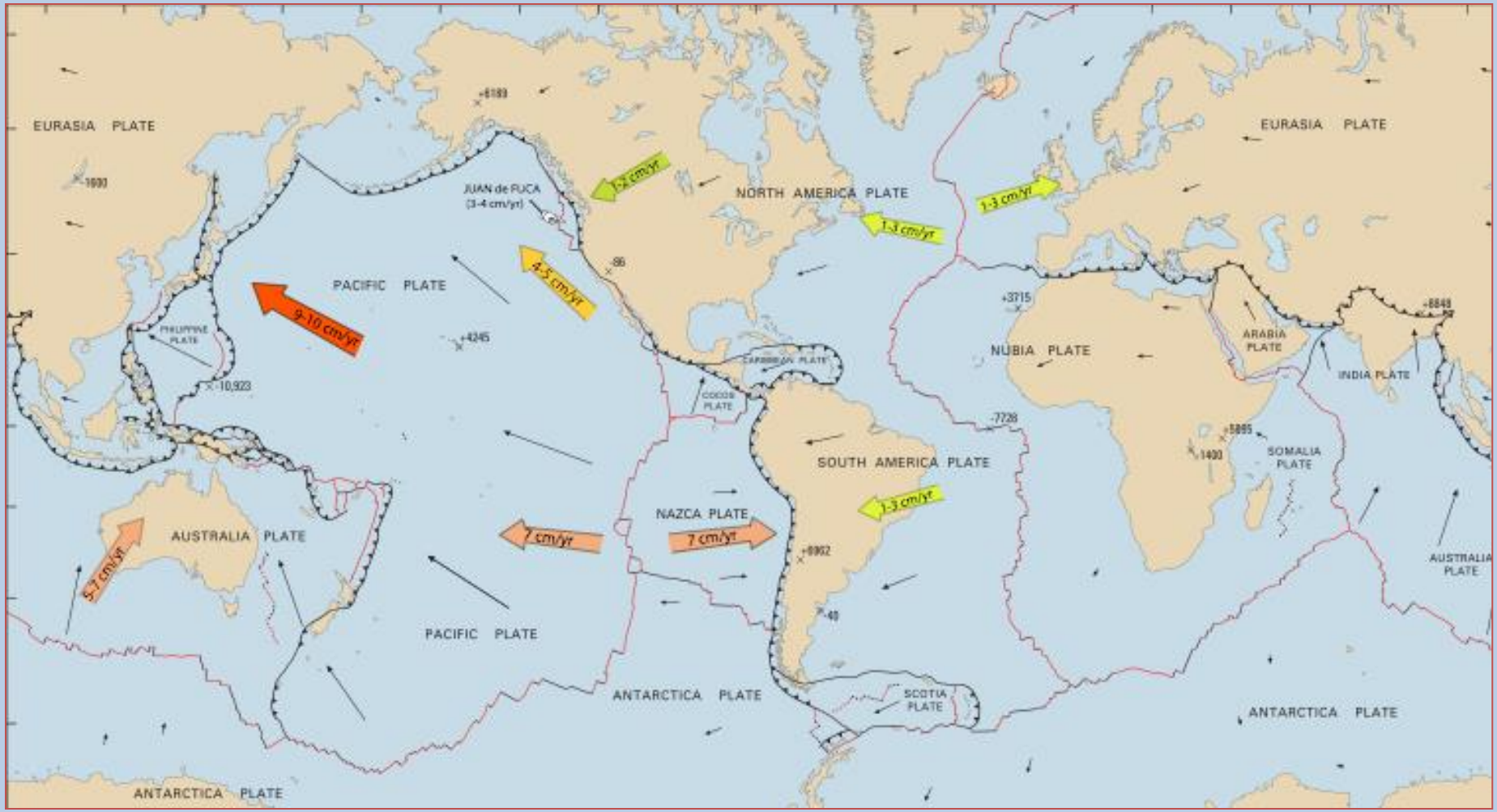
Question: What evidence is there for these plate boundaries?

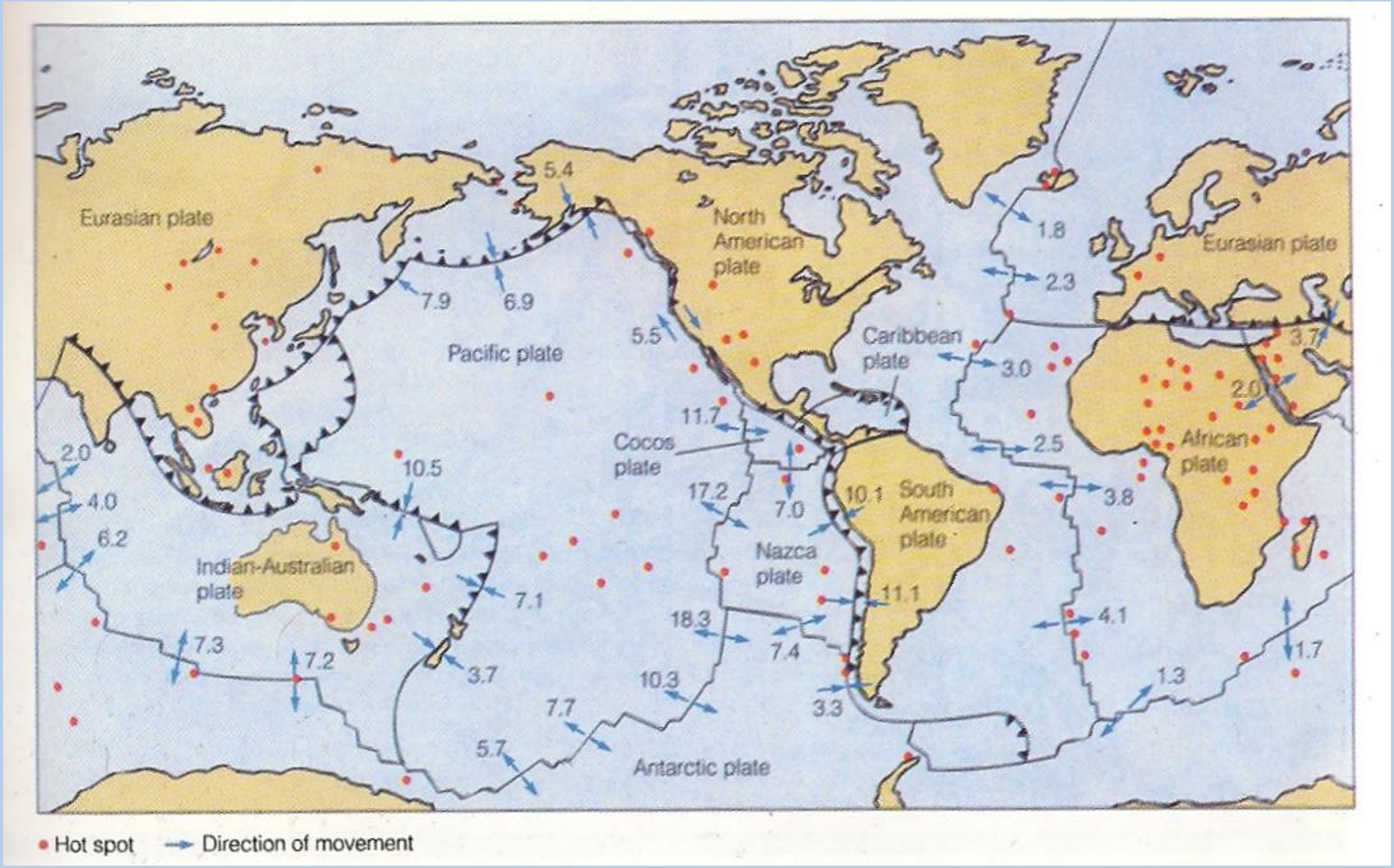


Tectonic Plates

How fast are the plates moving?

Plates move 1-10 centimeters per year (≈ rate of fingernail growth).





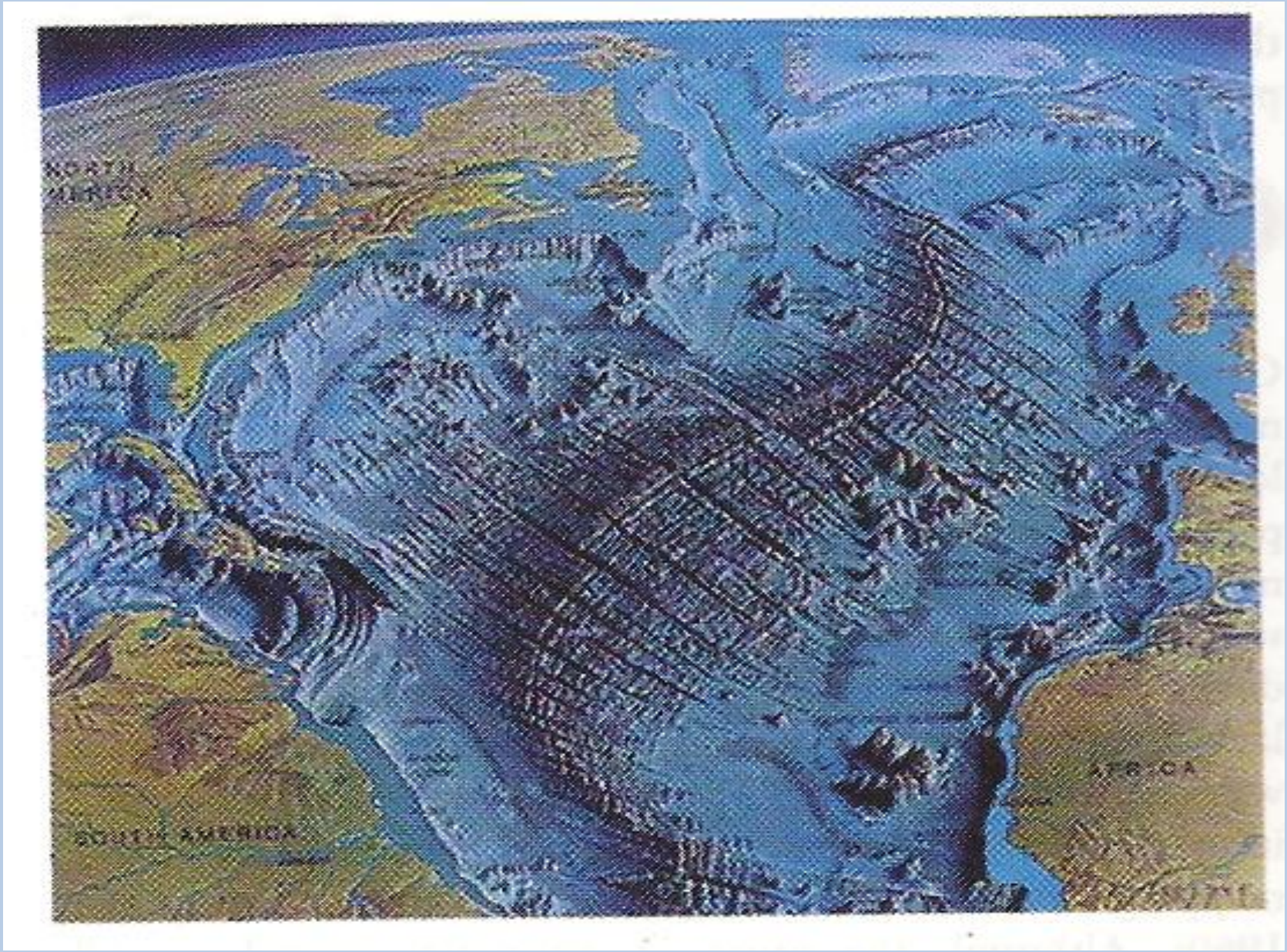
A map of the world showing the plates, their boundaries, relative motion and rates of movement in centimeters per year, and hot spots.

Plate tectonics: The new paradigm

- **Plate boundaries**
  - **Interactions between individual plates occur along their boundaries**
- **Types of plate boundaries**
  - **Divergent plate boundaries (constructive margins formed by extension)**
  - **Convergent plate boundaries (destructive margins formed by compression)**
  - **Transform fault boundaries (conservative margins formed by side-to-side shear)**

Divergent plate boundaries

- Most are located along the crests of oceanic ridges
- Oceanic ridges and seafloor spreading
  - The seafloor is elevated along well-developed divergent plate boundaries, forming oceanic ridges
- Geologic features include
  - crustal and lithospheric thinning
  - rift zones formed by extensional faulting
  - volcanic activity
  - shallow earthquakes



Mid-oceanic ridge of Atlantic ocean

Divergent plate boundaries

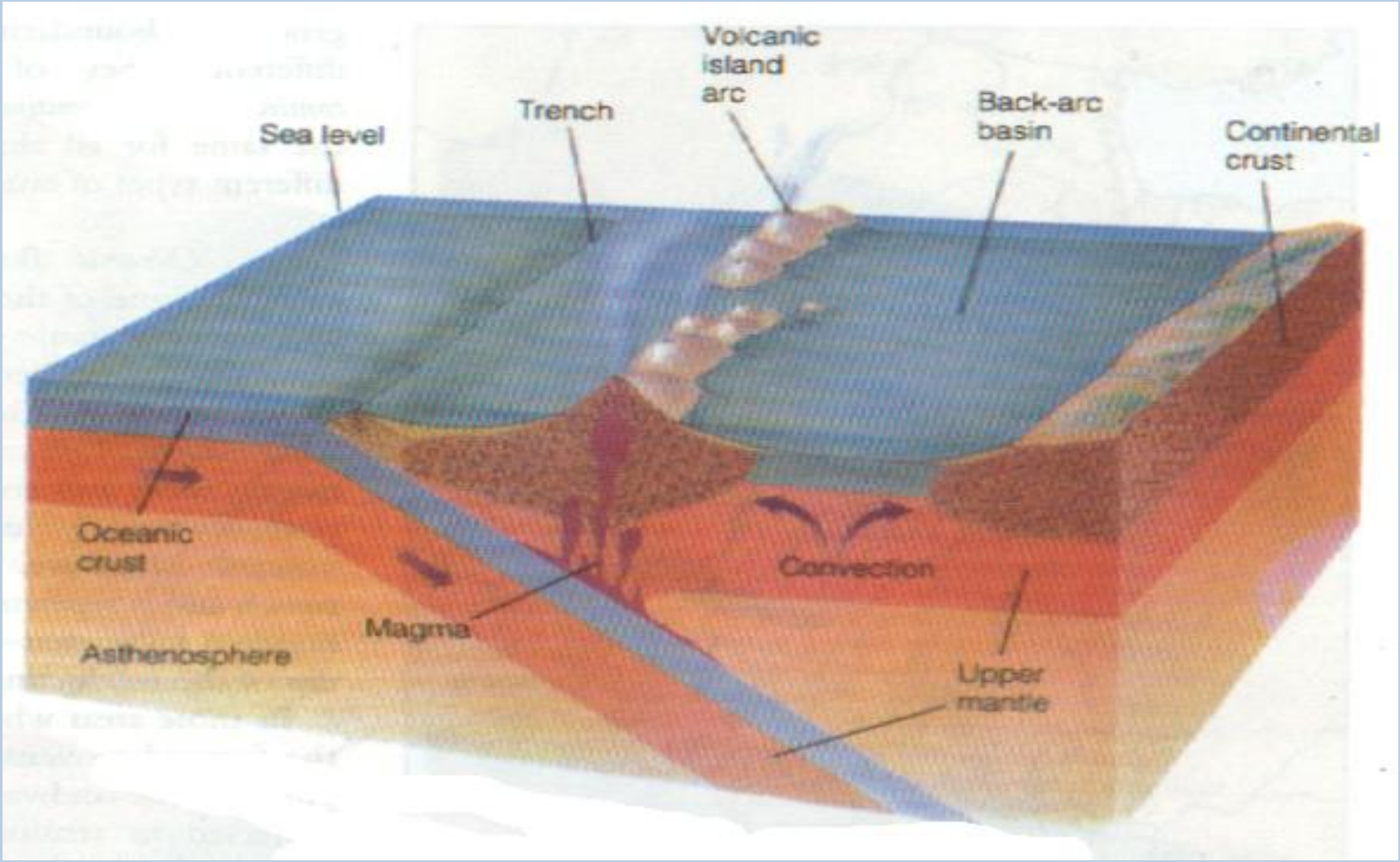
- **Continental rifting**
  - **Splits landmasses into two or more smaller segments along a continental rift**
  - **Examples include the East African rift valleys and the Rhine Valley in northern Europe**
  - **Produced by extensional forces acting on lithospheric plates**

Convergent plate boundaries

- **Older portions of oceanic plates are returned to the mantle or subducted in these destructive plate margins**
  - **Surface expression of the descending plate is an ocean trench**
  - **Oceanic plate moves downward along subduction zones**
  - **Geologic features include**
    - **volcanic arcs**
    - **shallow-deep earthquakes**
    - **mountain belts**

Convergent plate boundaries

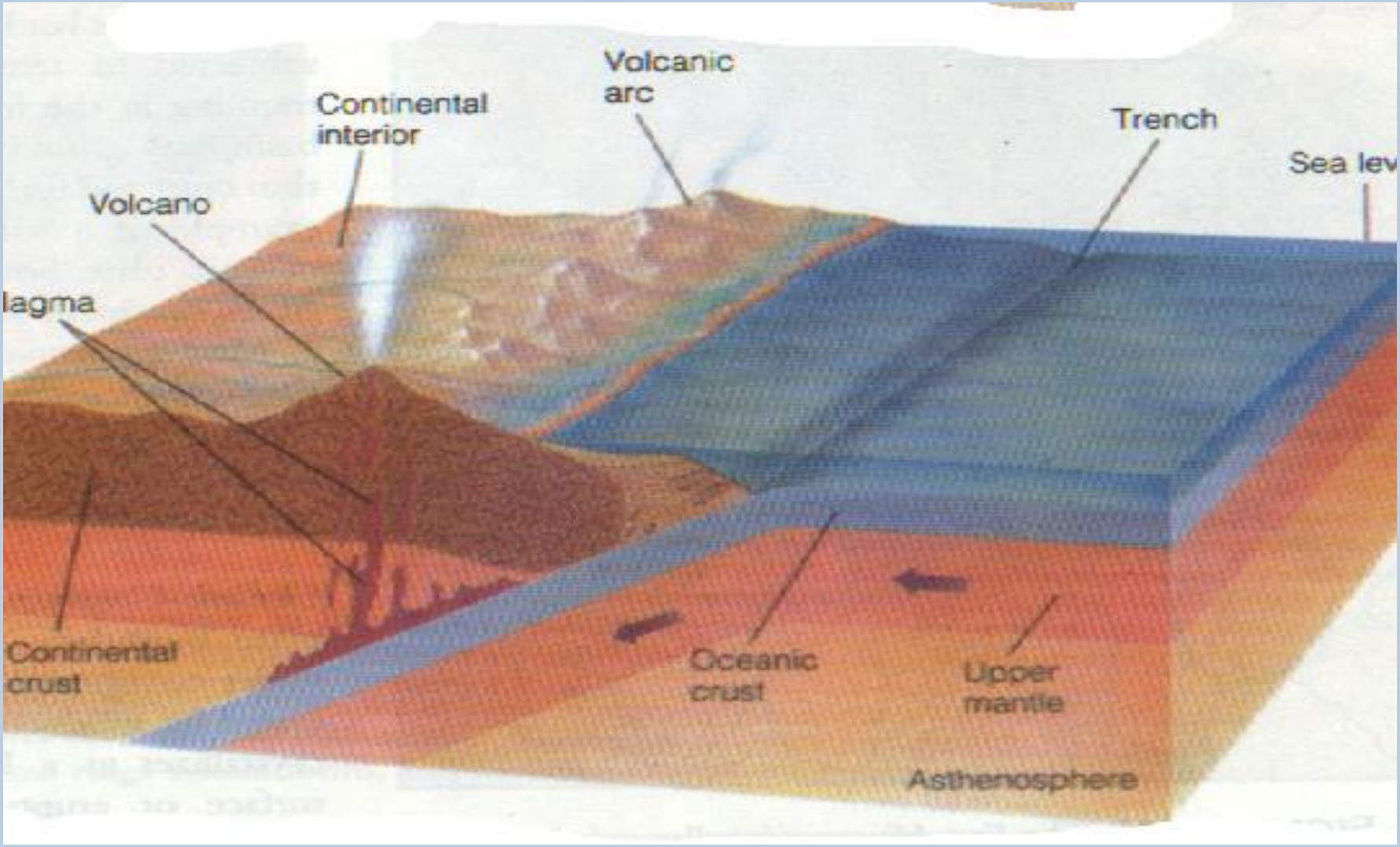
- **Types of convergent boundaries**
  - **Oceanic-oceanic convergence**
    - **When two oceanic slabs converge, one descends beneath the other**
    - **Often forms volcanoes on the ocean floor**
    - **If the volcanoes emerge as islands, a volcanic island arc is formed (Japan, Aleutian islands, Tonga islands)**



Oceanic – Oceanic plate boundary. An oceanic trench forms where one oceanic plate is subducted beneath another. On the nonsubducted oceanic plate, a volcanic island arc forms from the rising magma generated from the subducting plate.

Convergent plate boundaries

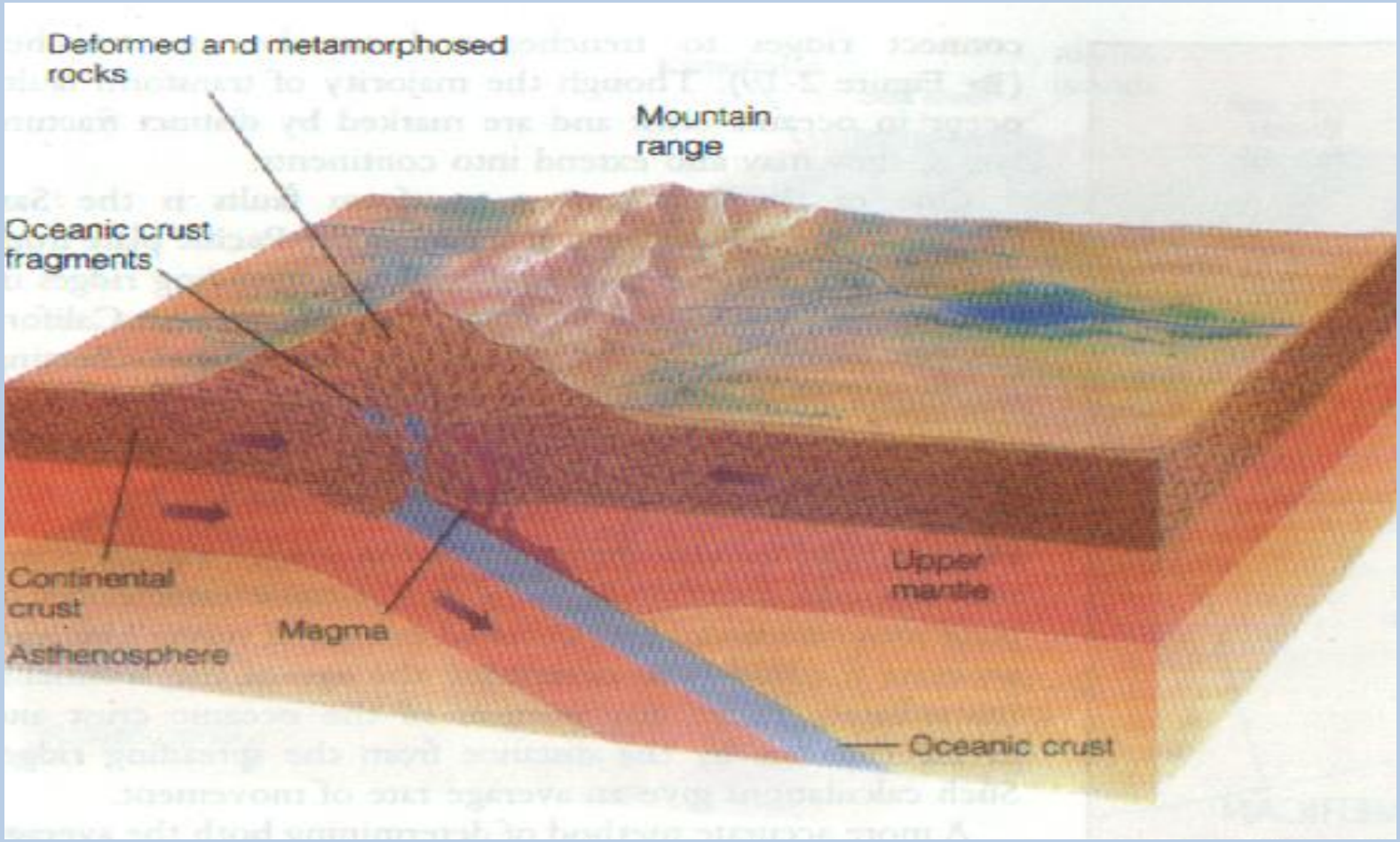
- **Types of convergent boundaries**
  - **Oceanic-continental convergence**
    - **Denser oceanic slab sinks into the asthenosphere**
    - **Along the descending plate partial melting of mantle rock generates magma**
    - **Resulting volcanic mountain chain is called a continental volcanic arc (Andes and Cascades)**



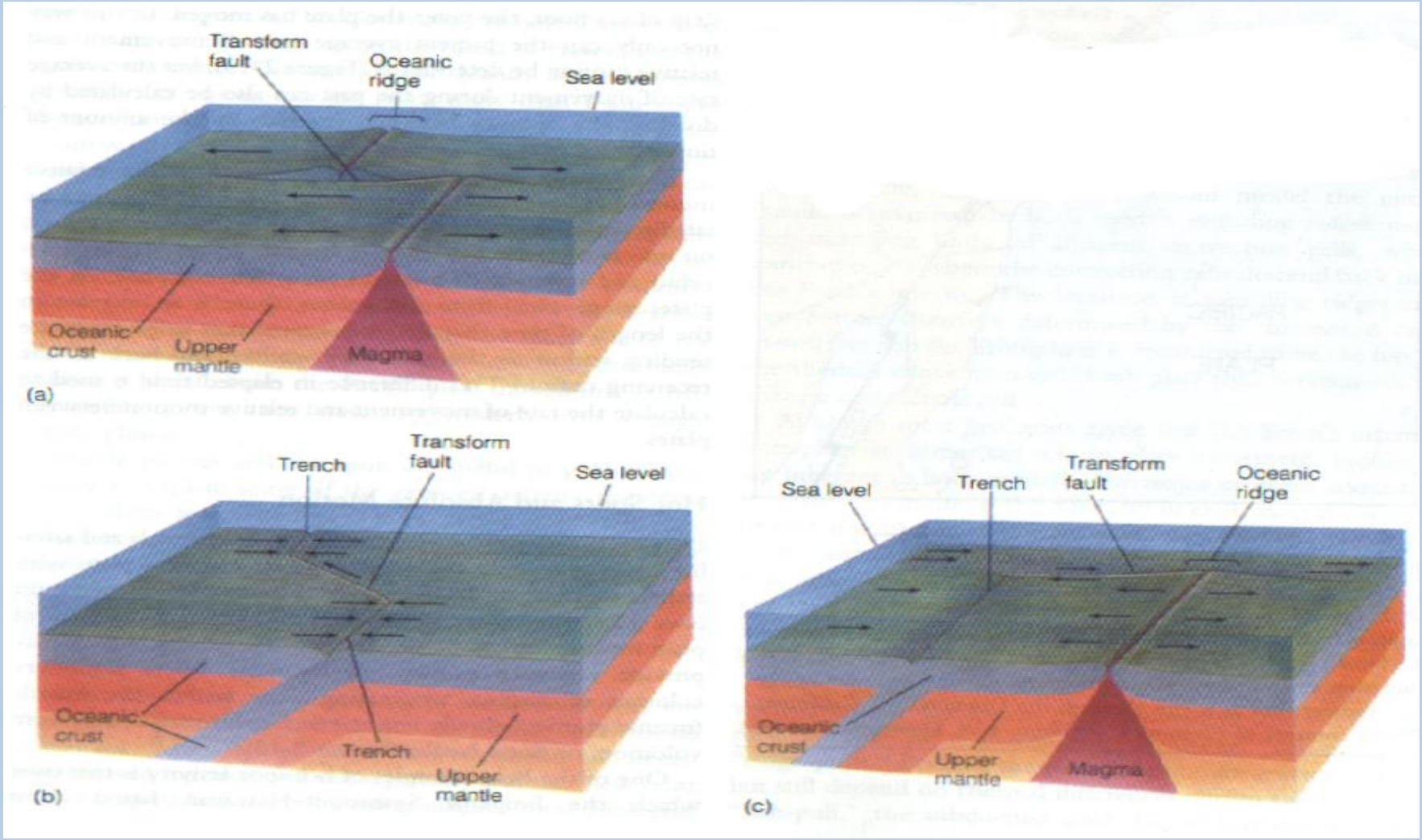
Oceanic – continental plate boundary. When an oceanic plate is subducted beneath a continental plate, a volcanic mountain range is formed on the continental plate as a result of rising magma.

Convergent plate boundaries

- **Types of convergent boundaries**
  - **Continental-continental convergence**
    - **Continued subduction can bring two continents together**
    - **Less dense, buoyant continental lithosphere does not subduct**
    - **Resulting collision between two continental blocks produces mountains (Himalayas, Alps, Appalachians)**



Continental – continental plate boundary. When two continental plates converge, neither is subducted because of their great thickness and low and equal densities. As the two plates collide, a mountain range is formed in the interior of a new and large continent.



Horizontal movement between plates occurs along a transform fault. (a) The majority of transform faults connect two oceanic segments. Note that relative motion between the plates only occurs between the two ridges.(b) A transform fault connecting two trenches. (c) A transform fault connecting a ridge and a trench.

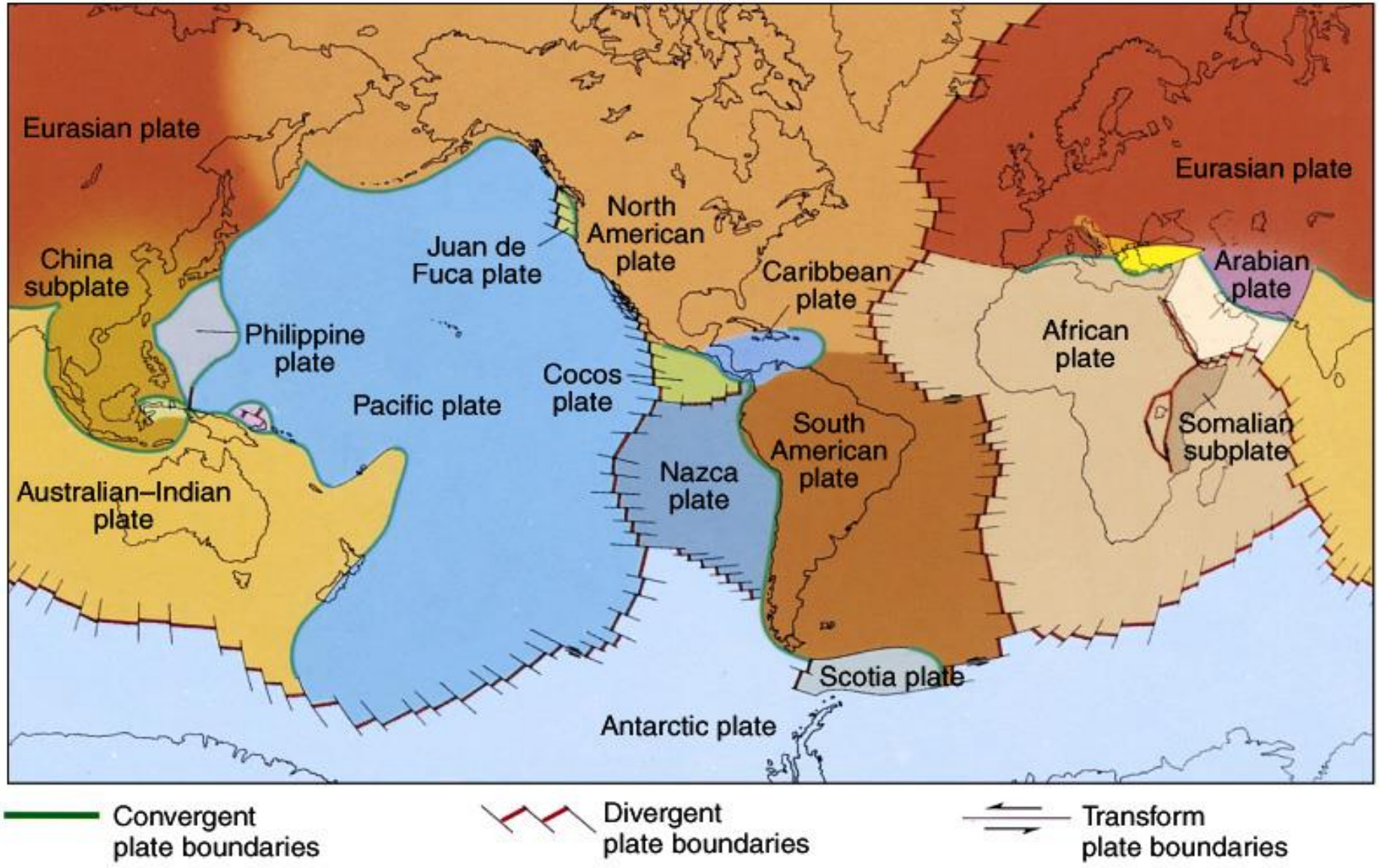
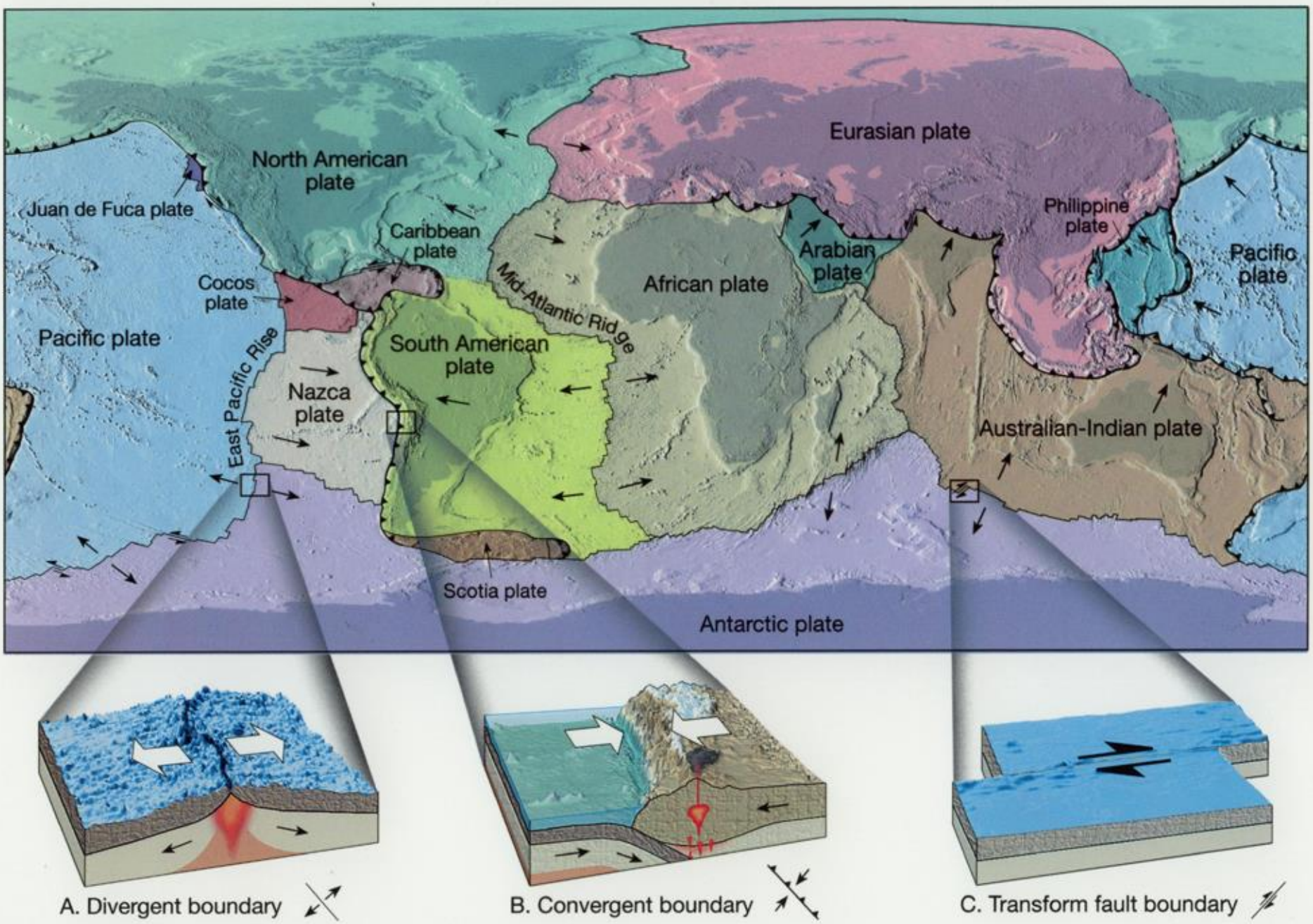
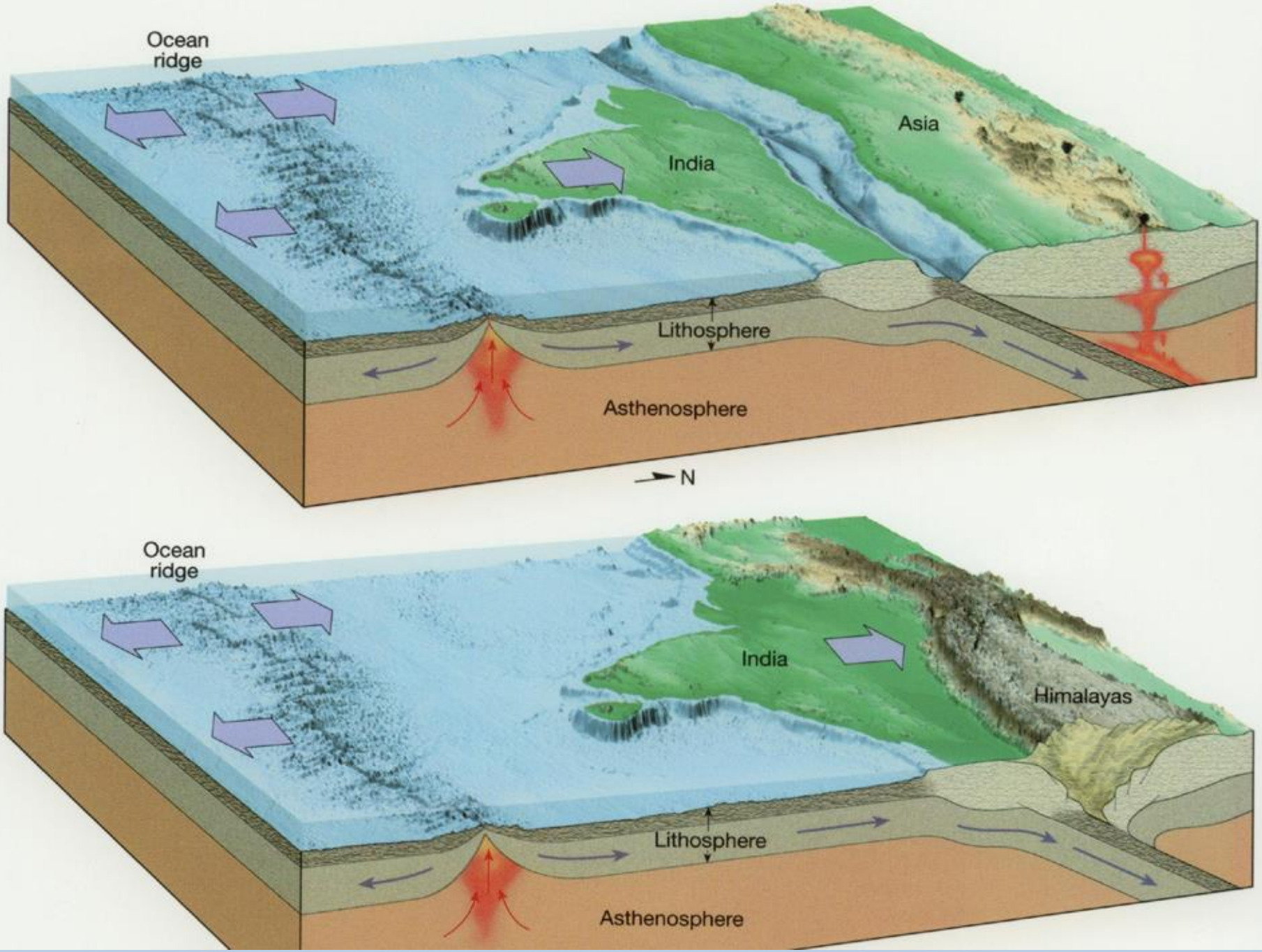

Eurasian plate
China subplate
Philippine plate
Pacific plate
Australian–Indian plate
Juan de Fuca plate
North American plate
Cocos plate
Nazca plate
Caribbean plate
South American plate
Scotia plate
Antarctic plate
Eurasian plate
Arabian plate
African plate
Somalian subplate
Convergent plate boundaries
Divergent plate boundaries
Transform plate boundaries

Table 2–1 • CHARACTERISTICS AND EXAMPLES OF PLATE BOUNDARIES

TYPE OF BOUNDARY	TYPES OF PLATES INVOLVED	TOPOGRAPHY	GEOLOGIC EVENTS	MODERN EXAMPLES
Divergent	Ocean-ocean	Mid-oceanic ridge	Sea-floor spreading, shallow earthquakes, rising magma, volcanoes	Mid-Atlantic ridge
	Continent-continent	Rift valley	Continents torn apart, earthquakes, rising magma, volcanoes	East African rift
Convergent	Ocean-ocean	Island arcs and ocean trenches	Subduction, deep earthquakes, rising magma, volcanoes, deformation of rocks	Western Aleutians
	Ocean-continent	Mountains and ocean trenches	Subduction, deep earthquakes, rising magma, volcanoes, deformation of rocks	Andes
	Continent-continent	Mountains	Deep earthquakes, deformation of rocks	Himalayas
Transform	Ocean-ocean	Major offset of mid-oceanic ridge axis	Earthquakes	Offset of East Pacific rise in South Pacific
	Continent-continent	Small deformed mountain ranges, deformations along fault	Earthquakes, deformation of rocks	San Andreas fault

Mosaic of Rigid Plates




Ocean ridge
India
Asia
Lithosphere
Asthenosphere
N
Ocean ridge
India
Himalayas
Lithosphere
Asthenosphere