Indian Institute of Technology, Kanpur

Department of Earth Sciences

ES0213A: Fundamentals of Earth Sciences

Lecture 10. Concept of Plate Tectonics - III

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IITK Experimental Rock Deformation Laboratory

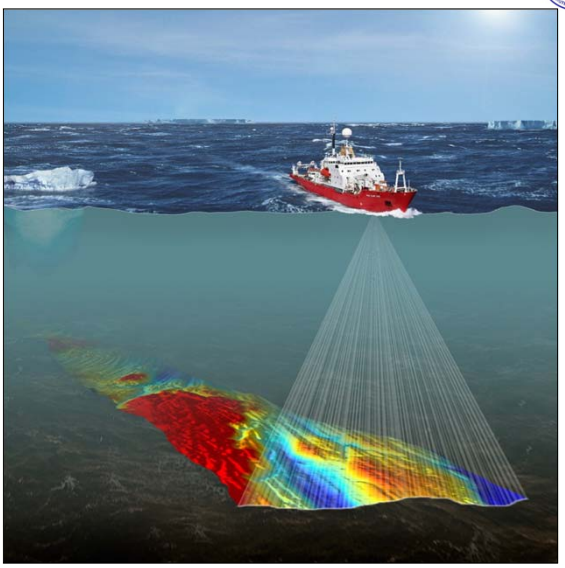
Aims of this lecture

- Sea-Floor Spreading
- Scientific evidences of Plate Tectonics
- Plate and Plate Boundaries

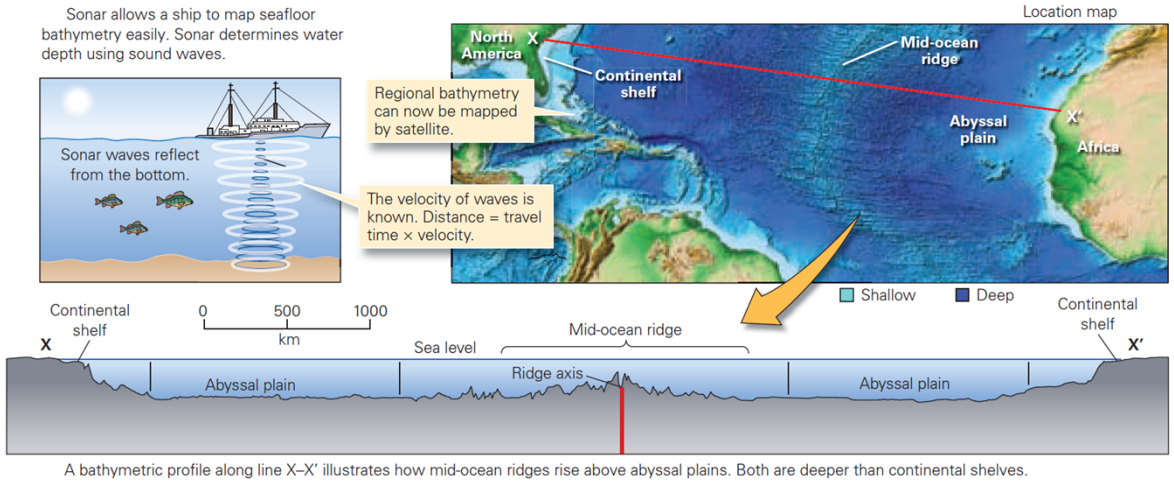
Reference: Chapter 3 & 4, Marshak's Book

Role of World War – II [1939-1945]

- Before the WW2, people had no idea about the floor of the oceans (topography, composition)
- Point measurements (dropping heavy objects with a long-long cable) was common. 360 such measurements in 5 years (1872-76) by HMS Challenger.
- Submarines were heavily introduced during the WW2. Navies required detailed information about bathymetry for smooth fleet of the submarines. The invention of ***sonar*** (echo sounding) permitted such information to be gathered quickly. ALSO OPENED A NEW WINDOW FOR GEOLOGISTS.



See the Sea-floor Bathymetry



A bathymetric profile along line X–X′ illustrates how mid-ocean ridges rise above abyssal plains. Both are deeper than continental shelves.

Observations from Sea-floor Bathymetry

- Oceanic crust is quite different from continental crust, it is not flat but extremely rough.
- The sediment thickness: Thicker near the coastal region; thinner at the middle. The age of the base of the thickest sediments is very young (150-200 My or less).
- The sea-floor includes **Abyssal Plains**, broad flat regions (4 to 5 km depth), and **Mid-Ocean Ridges (MOR)**, elongate, hot, symmetrical submarine mountain ranges whose peaks, with a depression, lie about 2 to 2.5 km below sea level. The tip of the mid-ocean ridges are ridge-axes. [Features of Atlantic]
- Along the perimeter of the Pacific Ocean, and at several other localities, the ocean floor depths are greater than 5 km; these are elongate troughs (**Trenches**). All the trenches border **Volcanic Arcs**, curving chains of active volcanoes. Numerous volcanic islands poke up from the ocean floor, and not always along volcanic island arcs (**Seamounts**).
- The mid-ocean ridges are sliced and shifted laterally by number of vertical fractures (**Fracture Zones**)
- Most of the earthquakes and volcanisms happen along the Mid-Oceanic Ridges, Fracture Zones and Trenches

Let's look at some of these features in Google Earth !!

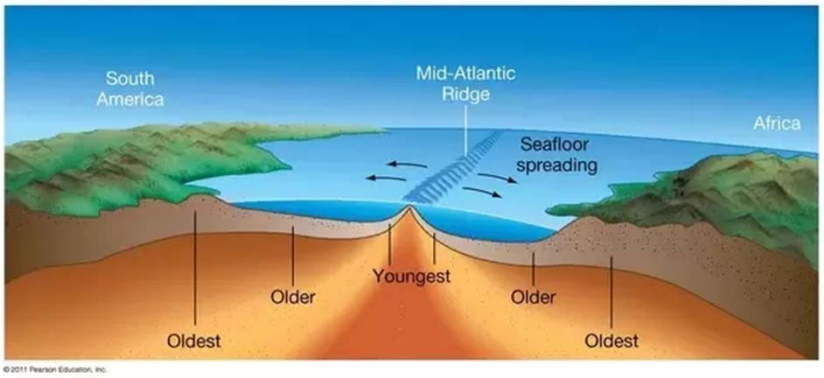
Sea-floor Spreading and Harry Hess

- The age of the base of the thickest sediments is very young (150-200 My or less) → **Ocean Floor must be younger than continents.**
- The sediment thickness is thicker near the coastal region; thinner at the middle → **the MOR are younger than the deeper parts of the ocean floor.**

New Oceanic Crust must be forming at the MORs and the oceans could be wider with time. BUT HOW??

- Earthquakes and volcanisms happen along the Mid-Oceanic Ridges, Fracture Zones → **Sea-floor breaking and addition of new materials.**
- High heat flow along the MORs → **molten rock rising up beneath ridges and that the seafloor crust was stretching**
- **In 1960, Hess** proposed that this material from the mantle rose beneath mid-ocean ridges; that at the ridge axis melt derived from the mantle solidified to form oceanic crust; and that, once formed, the new crust cracked, split apart, and moved away from the ridge – **SEA-FLOOR SPREADING** (*R. Dietz)*

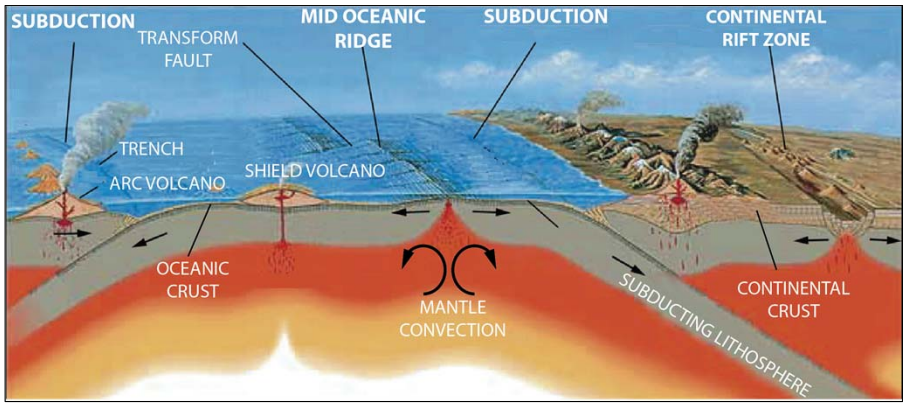
Sea-floor Spreading



PROBLEM CONTINUES: if new ocean floor formed, old ocean floor must be consumed or destroyed somewhere, or the Earth's circumference would have to increase, but earth's diameter is more or less constant with time.

Sea-floor Subduction

Earthquakes also occur along the Trenches → **the places where the seafloor sank back into the mantle and that the earthquakes occurring at trenches were evidence of this movement.. The SUBDUCTION ZONES.**



Hypothesis:

Rising magma erupts at the MOR.

New oceanic crust moves away from the MOR; sediments deposit.

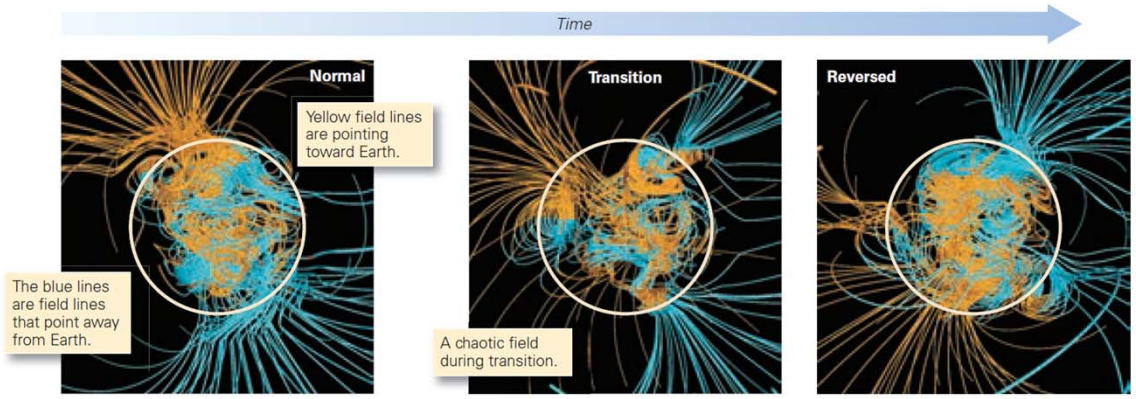
Sea-floors are driven back in to the mantle at trenches through subduction.

The continental drift and seafloor spreading were convincing including the mechanisms, but it must be tested.

Evidence of Sea-floor Spreading

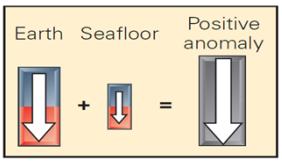
Marine Magnetic Anomalies and Magnetic Pole Reversals

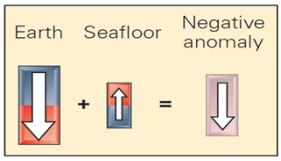
If the new oceanic crusts are being formed continuously at the MOR, the magnetic minerals of the oceanic crust should record and store the magnetic histories of the Earth !

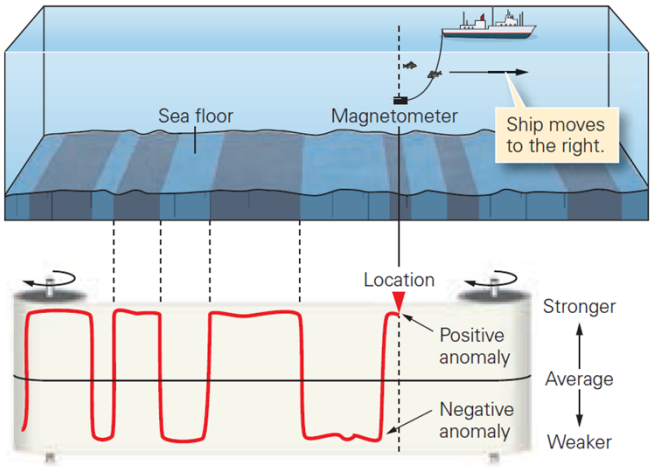


Evidence of Sea-floor Spreading

Marine Magnetic Anomalies and Magnetic Pole Reversals

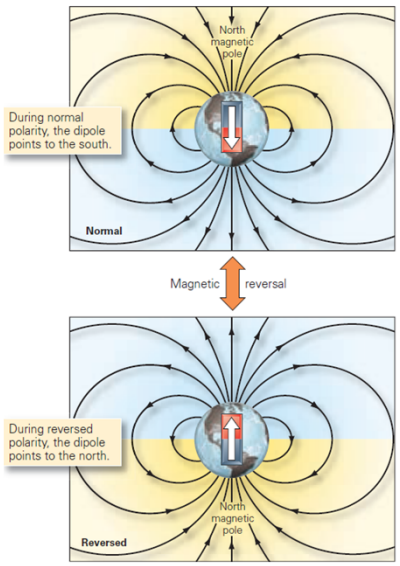


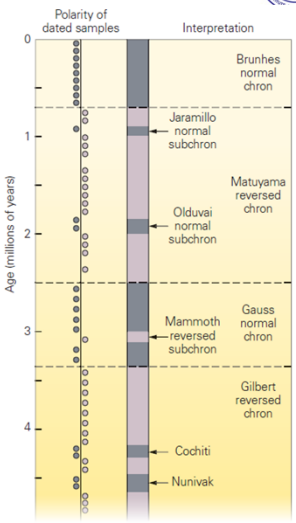




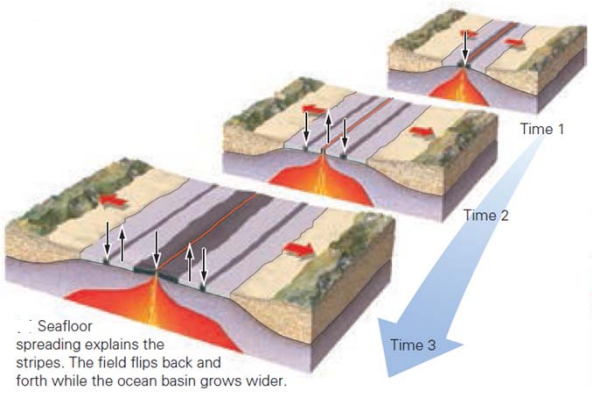
Evidence of Sea-floor Spreading

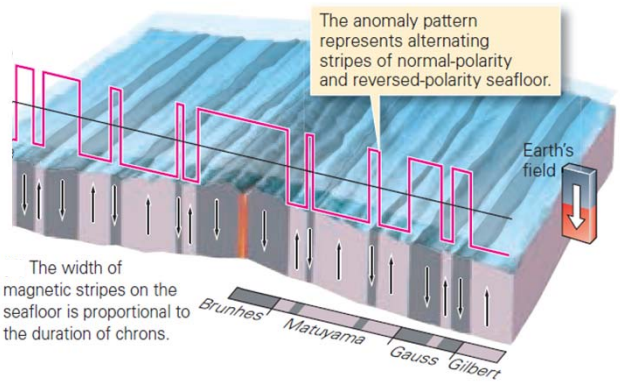
- Reversals do not occur periodically, the time intervals between reversals (**polarity chrons)**, are different.
- The last change from reverse to normal happened about 700,000 years ago and we are living in a normal polarity chron… the time that *Homo erectus*, who first learned to control fire.
- The youngest four polarity chrons (Brunhes, Matuyama, Gauss, and Gilbert) are named after scientists who made important contributions to the study of rock magnetism.



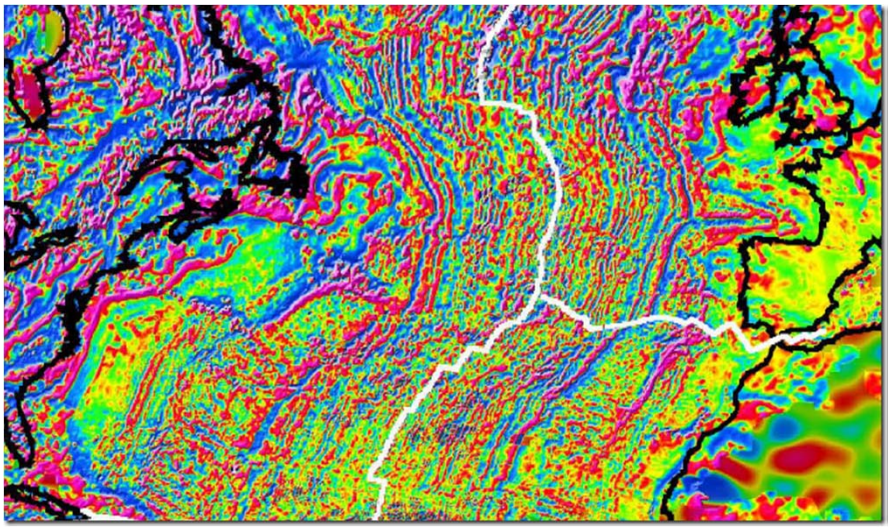


Evidence of Sea-floor Spreading





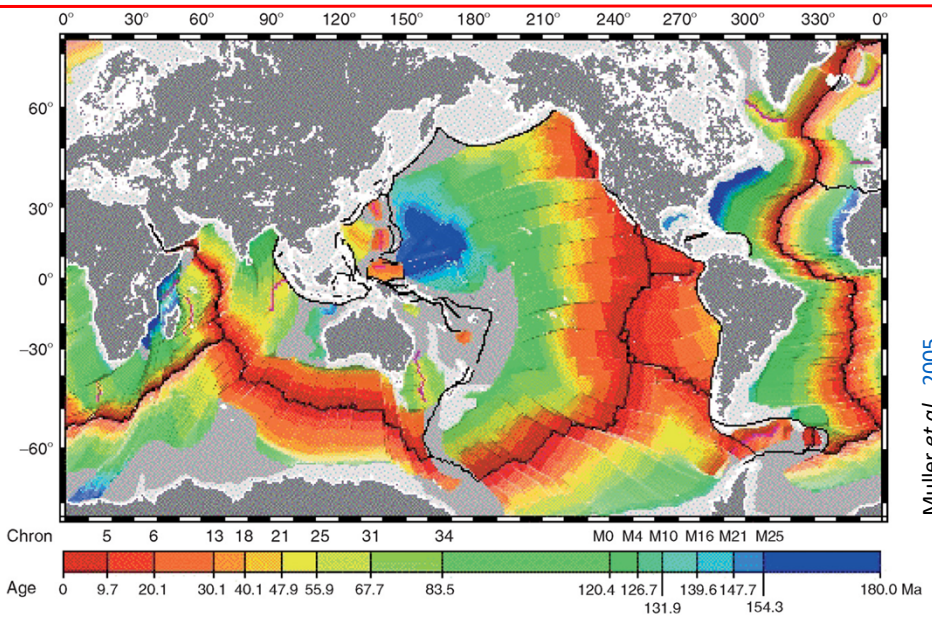
Evidence of Sea-floor Spreading



Magnetic Anomaly Map of Atlantic (Korhonen, et al., 2007,)

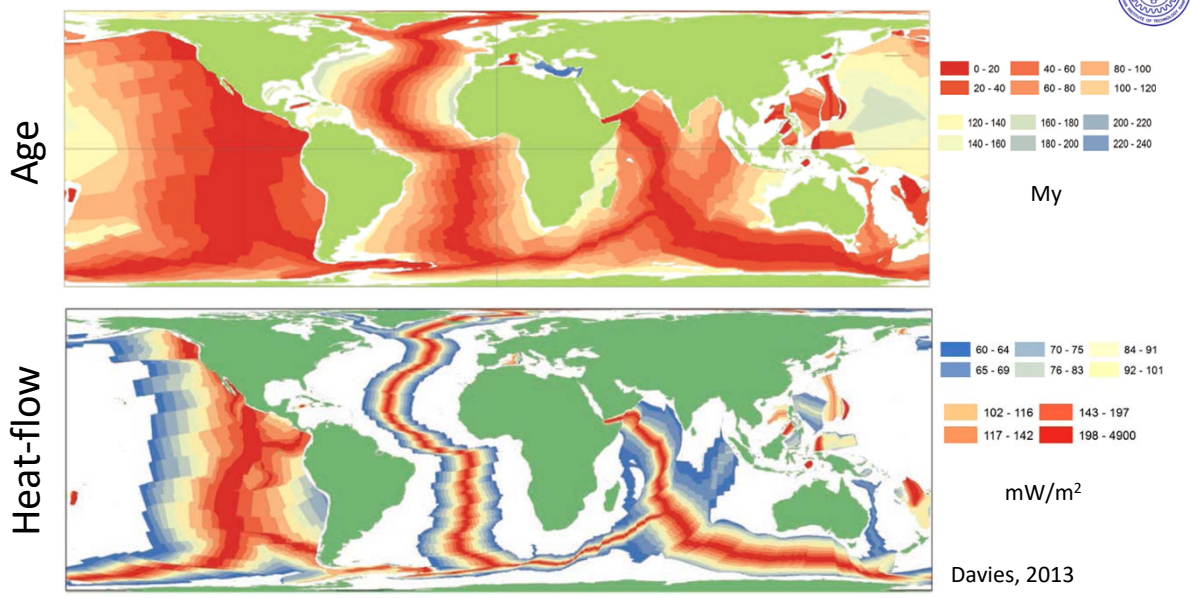
Evidence of Sea-floor Spreading

Age of the Sea-Floors



Muller *et al.*, 2005

Evidence of Sea-floor Spreading



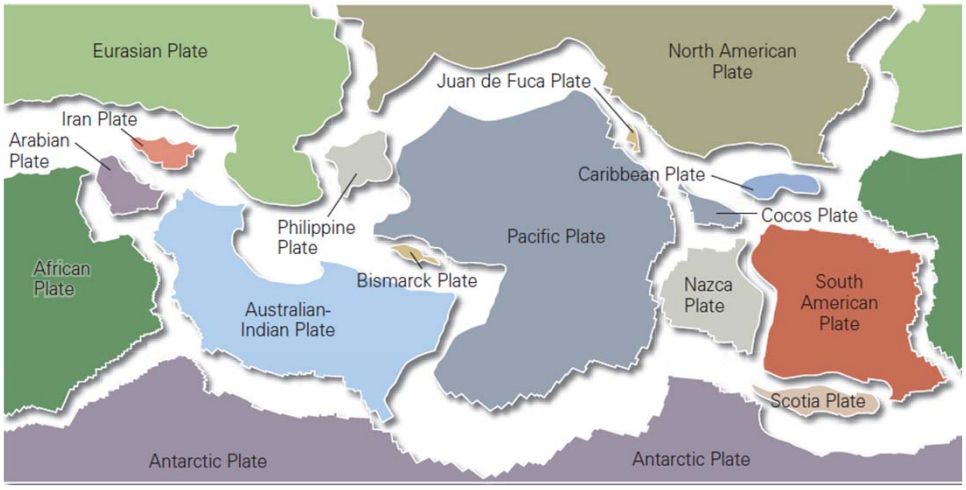
What is Plate Tectonics?

- The **lithosphere**, which consists of the crust plus the uppermost part of the upper mantle, behaves as a relatively hard layer, meaning that when a force pushes or pulls on it flow but rather bends or breaks.
- The **lithosphere** is discontinuous and broken in to pieces… which are known as **PLATES**
- The contact of the plates are knows as **PLATE BOUNDARIES.**
- The PLATES move relative to each other along the **PLATE BOUNDARIES.**

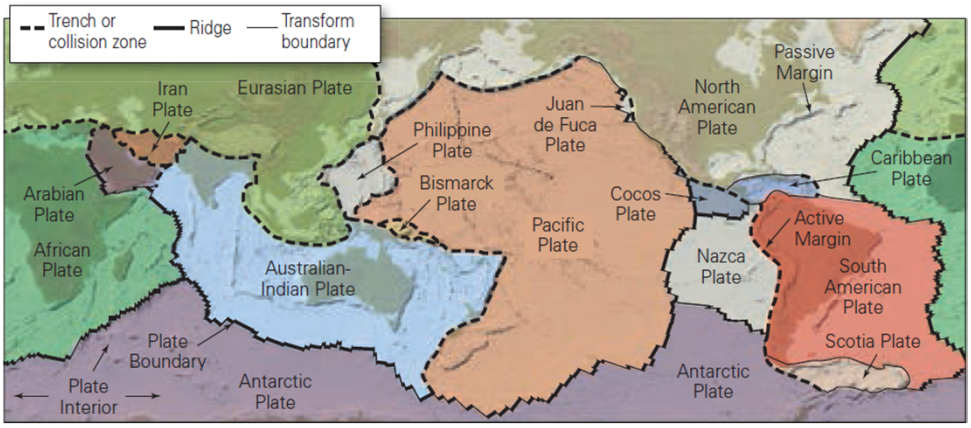
The entire process is known as PLATE TECTONICS

Why do the plates move? The quick answer is: due to MANTLE CONVECTION. We shall learn more later on this.

Major Plates of the Earth



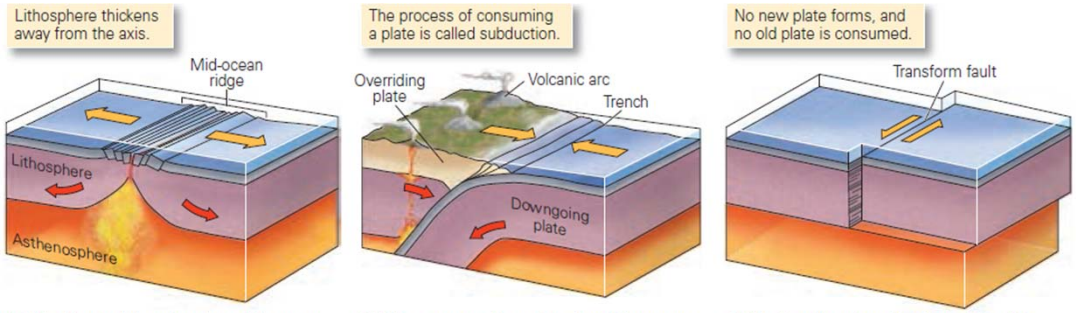
Major Plates of the Earth



Some consist entirely of oceanic lithosphere, whereas others consist of both continental and oceanic lithosphere.

Plate Boundaries

- **Divergent Plate Boundary**
- **Convergent Plate Boundaries**
- **Transform/Sliding Plate Boundaries**



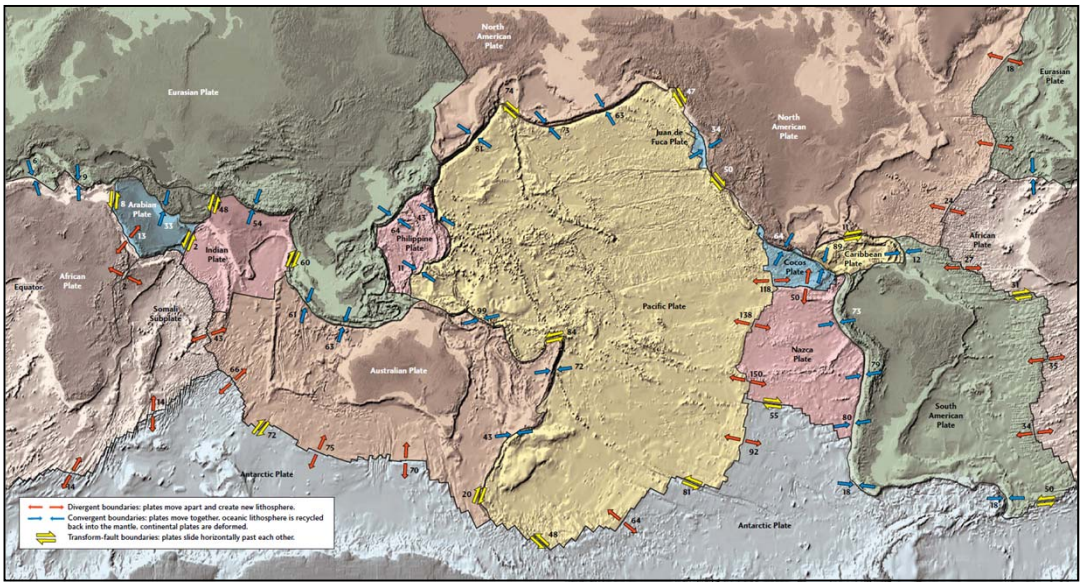
(a) At a divergent boundary, two plates move away from the axis of a mid-ocean ridge. New oceanic lithosphere forms.

(b) At a convergent boundary, two plates move toward each other; the downgoing plate sinks beneath the overriding plate.

(c) At a transform boundary, two plates slide past each other on a vertical fault surface.

Areas of modern & challenging research

Global Plate Boundaries and Plate Velocities



Alfred Wegener Song !!

https://www.youtube.com/watch?v=T1-cES1Ekto

Next Lecture

Minerals and Rocks