CH 3 – Plate Tectonics

Marine Science

Chapter Highlights: 1) understanding the principal features of the Earth 2) grasp the principal features of the plate tectonic theory 3) understand how the evolution of the Earth has affected ocean basins, seawater, and atmosphere.

Origin of Earth:

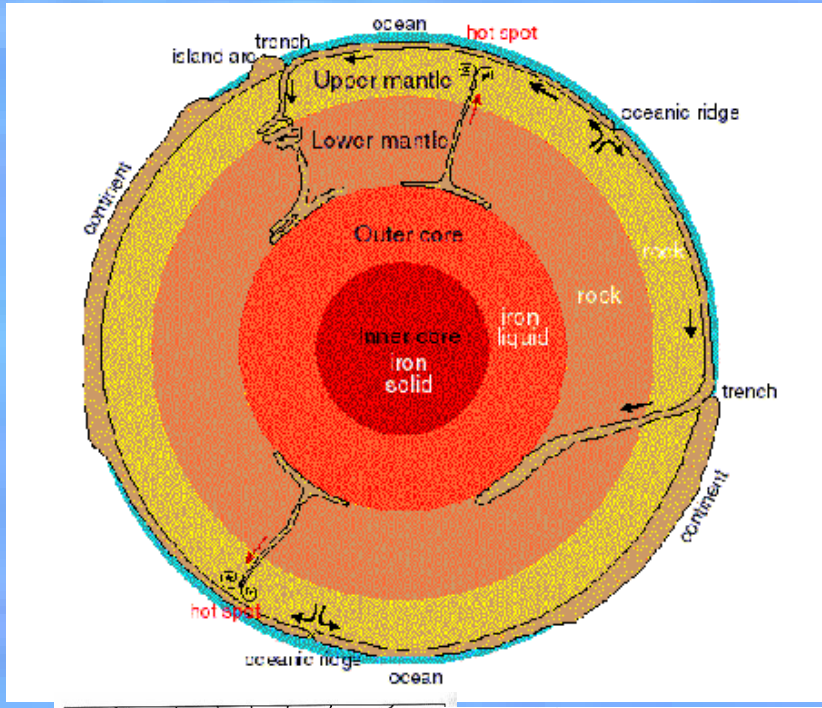
- Earth formed 4.6 billion years ago from a nebula and accretion of matter to form the rocky inner planets and the gaseous outer planets and Sun. While each planet has a different history, each was subjected to comet & asteroid impacts and rates of cooling which affect their appearance today.

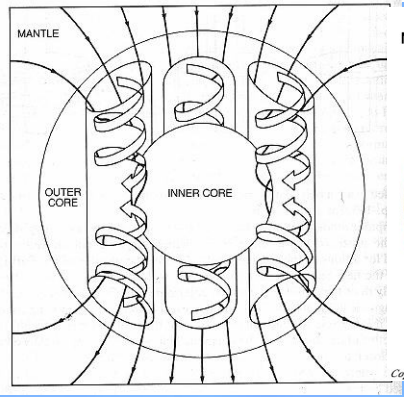
Volcanic Outgassing

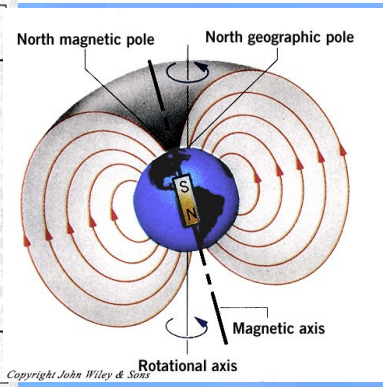
- Volcanic outgassing is the key reason for our atmosphere and oceans as much gasses and water are released during eruption. The planet's size helped retain the gases.

Earth Structure:

- Earth's layers…the center is a dense core of iron & nickel with a solid inner core and a liquid outer core. Movement in the outer core create the magnetic field. Next is the mantle which is mostly solid, but the upper part (asthenosphere) is molten and flows slowly. Lithosphere is the rigid outer layer floating on the asthenosphere the top part of which is called the crust.

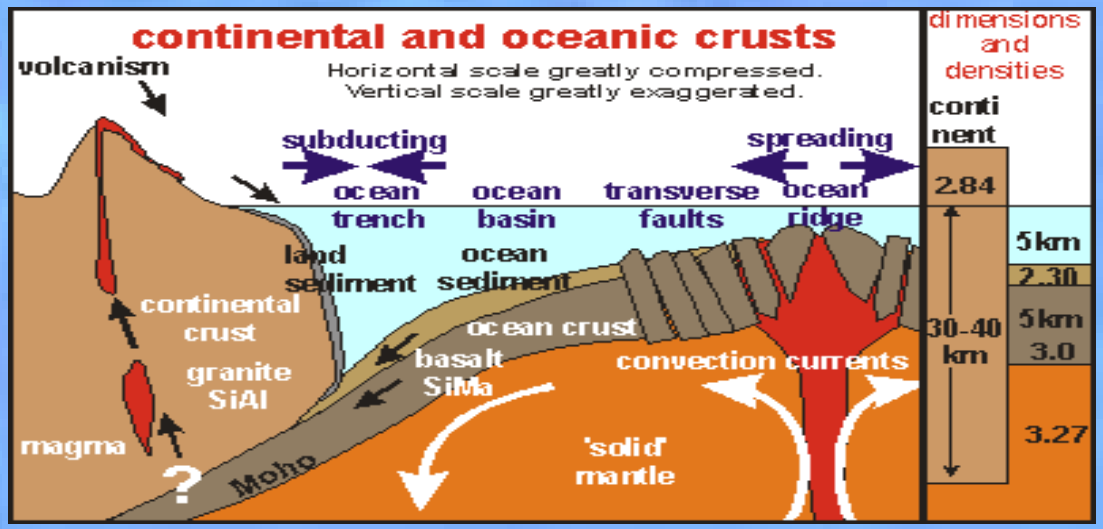






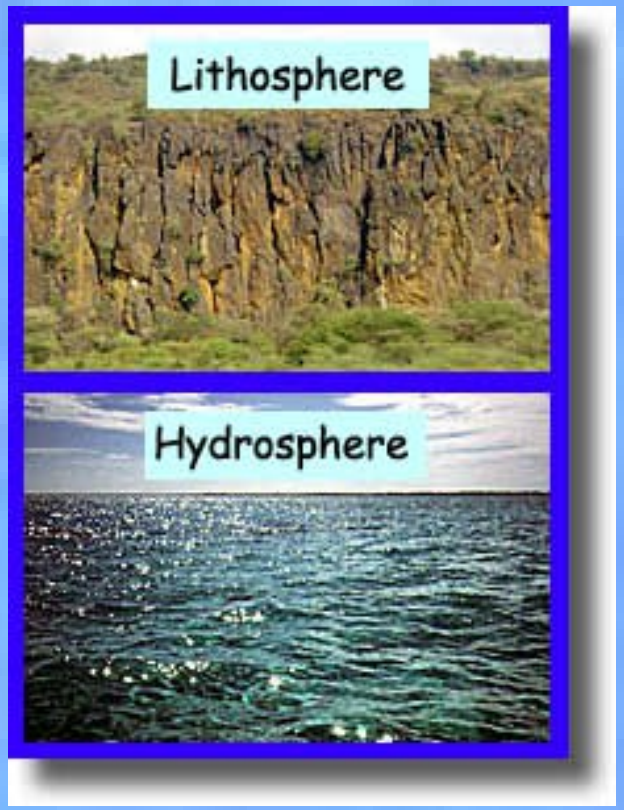
There are 2 types of crust… oceanic and continental.

- Oceanic crust is 5-7 km thick and composed of basaltic rock made of iron and magnesium. Continental crust is 30-40 km thick and composed of aluminum and silicas.



Hydrosphere vs Lithosphere

- The hydrosphere refers to free water not locked in rocks and minerals. 98% of it is the oceans while 2% is glaciers and only a fraction is the atmosphere (with other gases like nitrogen, oxygen, and carbon dioxide).



Isostasy:

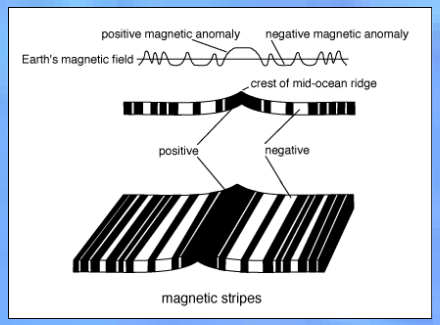
- Lithospheric plates float in the asthenosphere in a balance called isostasy. This accounts for two levels of the earth's crust.
- Visualize blocks of wood floating in water…thicker ones float higher, and extend down further while skinnier ones float lower and don't extend down as far below…this is isostasy.
- As a continent loses mass (ice melts etc…) it floats higher…as it adds mass (volcanic activity) it floats lower but is balanced by the addition of mass.

Figure 9.3
This drawing illustrates how wooden blocks of different thicknesses float in water. In a similar manner, thick sections of crustal material float higher than thinner crustal slabs.

Plate Tectonic Theory – History of an Idea (box 3-1)

- Controversial, this idea took decades to gain wide support. Alfred Wegener (1880-1930) a German meteorologist and balloonist first devised the continental drift theory and Pangaea based on continental margins, fossils, mountain ranges, etc.
- Harry Hess (1906-1969) used echosoundings & volcanic activity at the mid-ocean ridges to predict that the sea floor moved and was destroyed at trenches…called his idea “geo-poetry” and the American geophysicist R. Dietz renamed it “sea-floor spreading.”

Plate Tectonics Continued…



- F. Vine & D. Matthews of Cambridge put together the magnetic banding found in sea floor rocks and showed paleomagnetic reversals in Earth's magnetic field and the pattern enabling them to date the age of the sea floor.
- Edward Bullard redid Wegener's map idea in 1965 using the 100 & 1000 meter contour lines and showed that the continents did fit together. Other drillings showed the ages of rocks older farther away from the ridge.

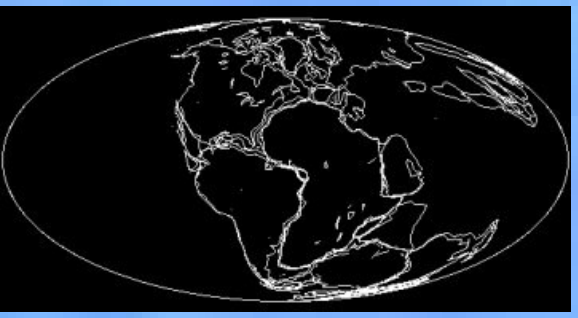
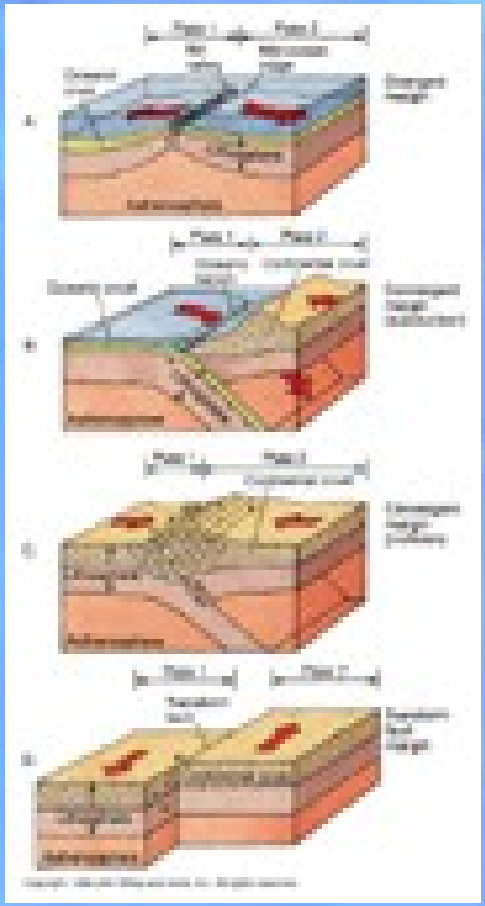


Plate Tectonics:



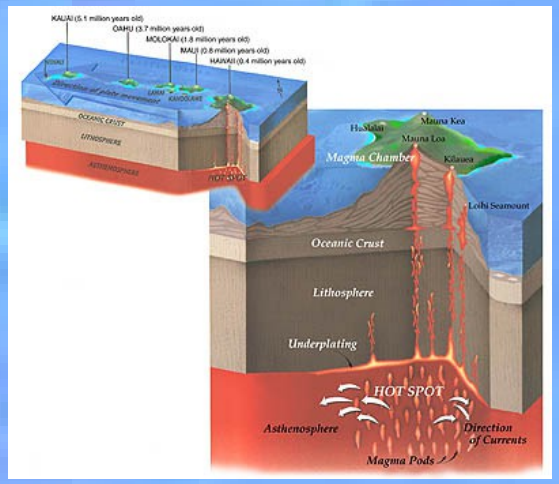
- Plates move.
- Boundary types: Mid-ocean ridges have plates moving away from each other (divergent). Trenches have plates coming together (convergent). Transform faults have plates slide past each other (transform).

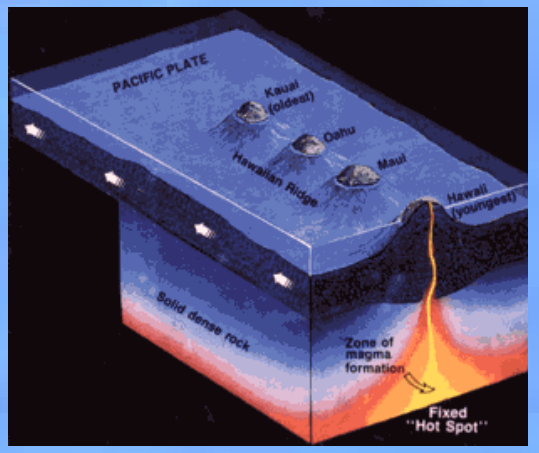
Earth's shape doesn't really change

- Lithosphere is destroyed at the same rate as it forms (~20 cubic km per year) and is destroyed at subduction zones. The process is a "gravity driven conveyor belt" with the oldest ocean crust sinking as it goes and the newer ocean crust at the highest elevations.
- Because Earth is a sphere, the rate of crust formation depends on geographic location… crust near equator forms more, crust near poles not as much.

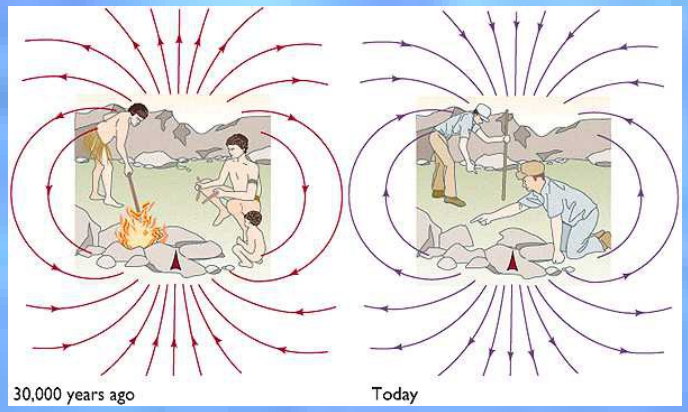
Hot Spots:

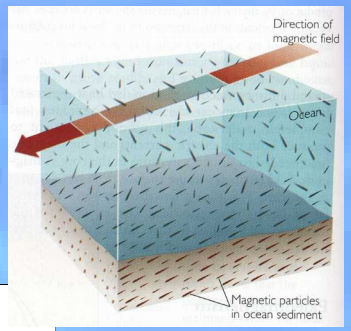
- Stationary plumes of hot magma rise up through the mantle and cause hot spots… centers of prolonged volcanic activity. Iceland, Hawaii…may form islands and the lithospheric plate moves over the hot spot. Islands off the hot spot are eventually eroded away.

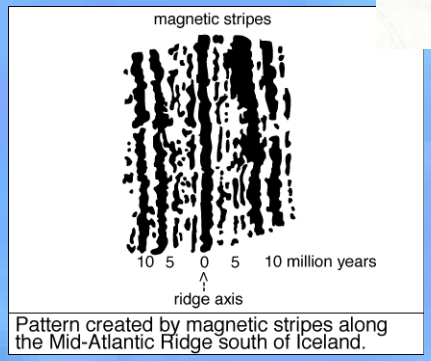




Magnetic Anomalies:





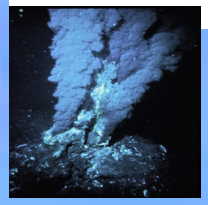


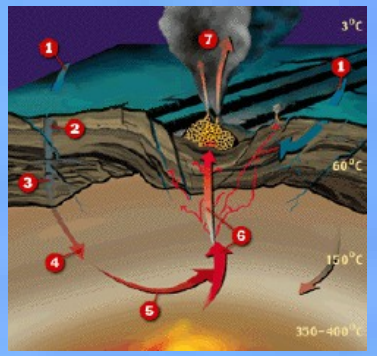
Pattern created by magnetic stripes along the Mid-Atlantic Ridge south of Iceland.

- Magnetic studies showed how sea floor crust was created. Rocks record the direction of Earth's magnetic field and the field reverses every hundred thousand years or so. (no one knows why yet)
- Sensitive magnetometers map the variations & rocks also provide physical evidence…the banding shows differing rates of magma extrusion and help show why older rocks are farthest from the ocean ridge.

Hydrothermal Circulation:

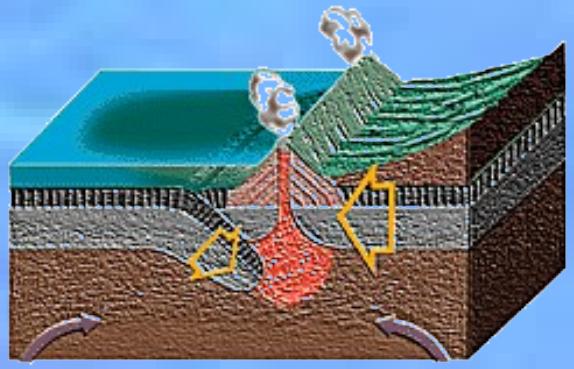
- Much heat from newly formed crust is removed by the water of the oceans flowing in and out of the fissures. The ocean's waters circulate every 5-10 million years.
- 3 types of vents are identified: black smokers discharge waters 300-400˚C like a fire hose. Chemical reactions cause them to look black and they build up a tube like chimney from which they continue to vent the super hot water. White smokers are cooler versions (25-250˚C). Fissure flows are the coolest type (5-25˚C) yet all 3 types support life.

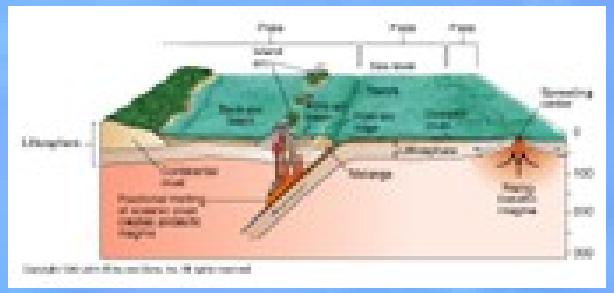




Active Margins:

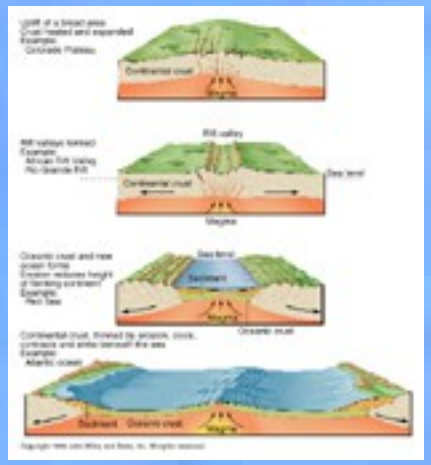
- Convergent plate boundaries are really active. Also called Pacific type margins. Deep earthquakes occur here (100-700 km below the surface) as subduction occurs… so does magma rising up and creating new land.
- Ocean ocean collisions form island arc volcanoes, ocean continent collisions form volcanic mountains, and continent continent collisions form mountains.
- Copper, lead, zinc, & silver may be found as a result of continent continent collisions.

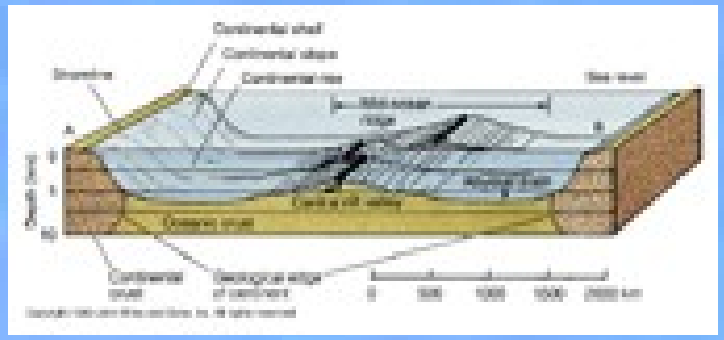




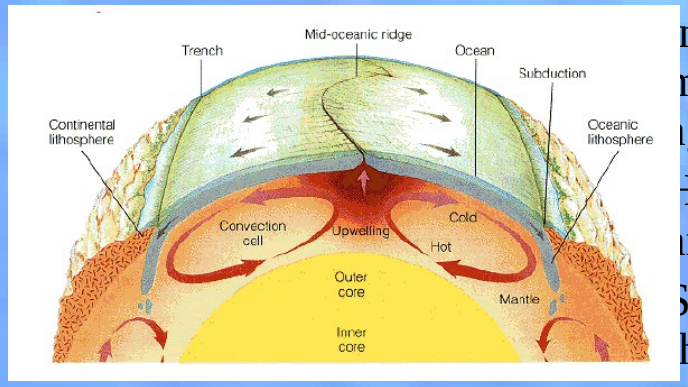
Passive Margins:

- Also called Atlantic Type Margins, have no mountain building. Instead, plates separate. Oil & gas accumulations are important resources found as a result of these.





Mantle Convection:



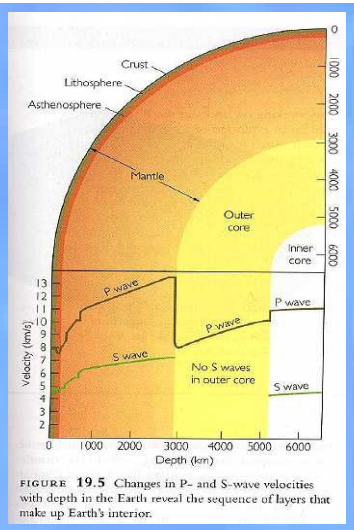
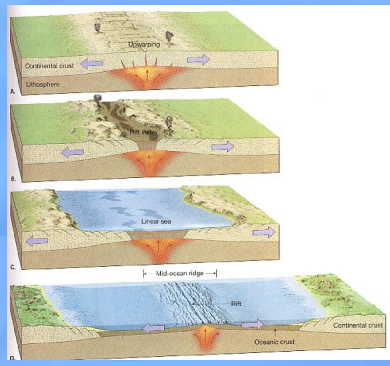


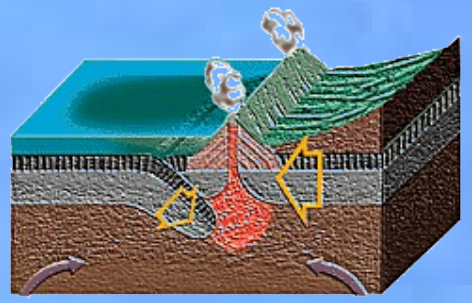
FIGURE 19.5 Changes in P- and S-wave velocities with depth in the Earth reveal the sequence of layers that make up Earth's interior.

- Movements of plates are caused by mantle convection deep in the interior. Convection driven by heat from the core-mantle boundary rising to the surface, cooling, and sinking again. The plates ride along top.
- Hot spots originate at hot areas at the core-mantle boundary and therefore do not move.
- Seismic tomography uses seismic waves from earthquakes that pass through Earth and are detected and show where cooling and hot rock are also showing the subduction/reheating process.

Formation and Destruction of Ocean Basins:



- As a continent is over a hot area, the rock may heat and expand and eventually form a rift valley. This leads to an ocean basin and the rift area may become a mid ocean ridge.
- As oceanic crust ages, it cools and becomes denser, and sinks into the underlying mantle creating a subduction zone.



Present Spreading Cycle:

- Began 225 million years ago with the breakup of Pangaea (ocean was called Panthalassia). 180 million years ago Pangaea was spilt into Laurasia & Gondwanaland. As the Atlantic mid ocean ridge was formed, the ocean basins grew and the continents also moved apart.

History of the Pacific:

– The Pacific is the oldest ocean deriving from Panthalassia. It is now surrounded with subduction zones and is smaller. Emperor Seamounts and Hawaii help record plate motion.

History of the Atlantic:

- Atlantic expands East West due to the Mid-Atlantic Ridge…thick salt and sediment deposits at the edges from early basin formation have somewhat been buried. As it spread, arctic waters rushed in and filled the basin. Now subduction is beginning at the oldest parts near Antarctica & the West Indies, indicating that the Atlantic will someday get smaller.

History of the Indian:

- The Indian is the youngest ocean. It began with the breakup of Gondwanaland 125 million years ago when Africa, Antarctica, India & Australia separated. It has 4 major ridges with 2 still active.