

Origin of the Earth

1. EARTH STRUCTURE

- interior, lithosphere, atmosphere, hydrosphere, biosphere
- Earth Internal Structure (radius = 6370 km, avg. density $\sim 5.5 \text{ g/cm}^3$); whole Earth is mostly Fe, O, Si, Mg with smaller amounts of Ni, S, Ca, Al.

Crust- 2 types: oceanic ($\sim 7 \text{ km}$; density $\sim 2.9 \text{ g/cm}^3$); Al- silicates (Ca-Fe-Mg);
continental ($\sim 40 \text{ km}$; density $\sim 2.8 \text{ g/cm}^3$); Al- silicates (Ca-Na-K).

Mantle- (down to 2900 km; density $\sim 4.5 \text{ g/cm}^3$); Fe-Mg silicates

Core- (2900 to 6370 km; density $\sim 10.7 \text{ g/cm}^3$); Fe-Ni-S metal alloy
outer core (2900-5000 km); liquid; generates magnetic field.
inner core (5000-6380 km); solid.

- Atmosphere: 20 km thick, composed of 78% N_2 , 21% O_2 , 1% Ar, 0.03% CO_2 , water vapor and other trace gases. Density decreases with altitude.
- Hydrosphere: oceans, glacial ice, rivers, lakes, contains essentially all of the liquid H_2O ; 97% is contained in oceans;

2. ORIGIN OF THE EARTH & SOLAR SYSTEM

- Bing-Bang Theory: Universe originated 10 to 15 Ga billion years ago from 'cosmic explosion'.
- Earth and our solar system are $\sim 4.56 \pm 0.05 \text{ b.y.}$ old (from radiometric dating of meteorites).
- Nebular Hypothesis: 1755 Immanuel Kant; Solar system originated as a rotating cloud of gas (H, He) and dust particles (chemically similar to whole Earth; meteorites).

- Gravity pulls material toward the center to form proto-Sun and solar nebula is flattened into a disk. Gravitational collapse causes proto-Sun to become dense and hot, nuclear fusion begins (H to He).
- Gas and dust particles surround the proto-Sun, forming solar nebula. Hotter and denser towards the center. Began to cool and condense into liquid and solid phases. Colliding matter began to accrete into planetesimals.
- Planetesimals grow into moon-sized bodies. In final stages, the largest bodies 'swept up' the remaining mass in 'giant impact' events to produce the 9 planets.

- The Solar System (average radius ~ 5.9 billion km; 9 planets + asteroid belt)

- Inner planets (terrestrial, "Earthlike") - small, rocky; volatiles were not retained in quantity because of hot conditions near the center of the solar nebula.

- Outer planets (gaseous) - large, with rocky cores and thick mantles of volatiles that were blown out from the interior of the solar nebula. These bodies were large enough so that their gravity could retain the volatiles (H₂, He, CH₄, NH₃).

- Earth's Early History

- **Initial Heating and Melting** - 1) collision of planetesimals; 2) gravitational collapse; 3) radioactive decay. Also giant impact of Mars-sized body is thought to have formed the Moon and caused 30-65% of Earth to melt ('magma ocean'). Heavy Bombardment period.
- **Differentiation** - (~4.4 to 4.2 b.y.) Heavy elements (Fe, Ni) sank to form core, lighter elements (O, Si, Mg, Al) floated toward surface, forms mantle/'crust'. Degassing of interior (by volcanism; N, O, C, H locked in minerals) and comets produced early atmosphere and hydrosphere. Early atmosphere was much different, more CO₂, CH₄, and not much O₂. Only after photosynthetic algae (~3.5 b.y.) evolved did the O₂ build up.
- **Continents** - (~4.0 b.y.) repeated cycles of melting and processing by early hydrosphere and atmosphere. Light elements (O, Si, Al, Na, K) remained at the surface to produce continental crust.

Plate Tectonics

1. PLATE TECTONIC THEORY (developed in late 1960's)

- Powerful, unifying theory that can account for most geologic processes.
- Earth is made of several large plates that slowly move. Interactions at plate boundaries are what cause EQ's and volcanoes.
- Driving force is internal heat that causes convection in the mantle that "drags" the plates around on the Earth's surface.
- Came about as a consequence of a large body of evidence in support of continental drift and sea-floor spreading.
- **PLATES** = lithosphere = crust + rigid uppermost mantle
avg. ~50-60 km thick beneath oceanic plates (max 100 km); avg. ~100 km thick beneath continents (max ~250-300 km). **asthenosphere** = partially molten upper mantle beneath lithosphere. Plates "ride" on this. (0 to ~250 km thick)

2. PLATE BOUNDARIES (3 basic types)

A. Divergent Boundaries

- occur primarily where plates are spreading apart and new oceanic lithosphere is created (Mid-Atlantic Ridge).
- also can occur under continents (East Africa) and produce rift valleys.
- **small to moderate-sized, shallow EQ's; passive volcanic eruptions.**

B. Convergent Boundaries

- sites at which plate are converging and where oceanic lithosphere is destroyed at **subduction zones**.

- **large, damaging shallow to deep EQ's. Dangerous, explosive volcanism**
- **3 Basic Types**
 1. Oceanic-Oceanic (Caribbean Islands, Aleutians)
produces deep oceanic trench, volcanic island arc.
 2. Oceanic-Continental (Andes Mtns of S. America)
produces deep trench, volcanic arc, and mountain building along the margin of the continent.
 3. Continental-Continental (Himalayan Mtns of Asia)
large, damaging shallow EQ's. No volcanism

C. Transform Boundaries

- plates are sliding laterally past each other. (San Andreas Fault).
- **large, damaging shallow EQ's. No volcanism**