Origin of Life on Earth: The Physical Conditions

Geology 230, Fossils and Evolution
Origin of Earth’s Matter

• The earth is made of recycled elements formed in stars that existed prior to our Sun.

• Supernova explosions produced nebular dust clouds of various elements.

• Our solar system formed from a nebular dust cloud.
The Crab Nebula, remnant of a supernova explosion in 1054 AD
Formation of Earth

• Our planet formed along with all the other planets when our solar system formed 4.6 BY ago.
• The planets formed by planetary accretion.
• Gravity slowly brought solids and gases together.
The proto-sun and rings of matter that formed the planets.
Formation of Earth

- All the planets had rocky cores and gaseous outer layers, just like modern Jupiter or Saturn.
- Earth was 1200 times more massive.
- Ignition of the sun stripped the inner planets of their gaseous outer layers.
Formation of Earth

- The early earth formed from meteorites, asteroids, and planetesimals. It was cold and lumpy.
- It heated up and completely melted.
The earth formed by planetesimal accretion and meteorite impact
The Early Molten Earth

Heat sources:

1. Gravitational compaction
2. Impact energy converted to heat
3. Heat from radioactive decay
Heat generated by impact and radioactive decay began to melt the early earth.
Eventually the earth became completely molten and separated into layers by density.
A view of earth from the moon about 4.5 BY ago.
The Early Molten Earth

Earth became layered according to density.

Core, 14% of volume; iron
Mantle, 84% of volume; iron-rich silicate materials
Crust, 2% of volume; silicate rocks
Crust (0–40 km)
Mantle (40–2890 km)
Liquid iron outer core (2890–5150 km)
Solid iron inner core (5150–6370 km)
Origin of Oceans and Atmosphere

• Formed by degassing of the mantle.

• Modern oceanic volcanic gases:
  
  $\text{H}_2\text{O}$, 79%, as steam
  $\text{CO}_2$, 12%
  $\text{SO}_2$, 7% (combines with water to form sulfuric acid)
  $\text{N}_2$, 1%
  $\text{Cl}$, <1%
Water from Rocks?

- Meteorites are 0.5% water.
- An equivalent amount of water in the mantle would fill the ocean basins 20 times!
- Volcanoes today release enough water to have filled the ocean basins 100 times during earth history!
Solid crust and liquid water, 4.4 BY ago?
The First Atmosphere

- Order of abundance after water vapor, H₂O:
  - Carbon dioxide, CO₂
  - Sulfuric acid, H₂SO₄
  - Ammonia, NH₃
  - Methane, CH₄
The First Atmosphere

- Poisonous to modern life.
- No free oxygen.
- Contained the basic elements of life: carbon, oxygen, nitrogen, sulfur, and hydrogen.
The Modern Atmosphere

- 78% nitrogen
- 21% oxygen
- 1% argon
- 0.03% carbon dioxide
- What happened to all the CO$_2$?

Photosynthesis
The Modern Atmosphere

• Created by biological processes. The only planet with free oxygen.

• Photosynthetic bacteria used water and carbon dioxide to make sugar and the by-product oxygen.

\[ 6\text{H}_2\text{O} + 6\text{CO}_2 \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 (\text{sugar}) + 6\text{O}_2 \]