Terrestrial Planets: The Earth as a Planet

"Earthrise" from Apollo 8, 1968

"Earthset" from Lunar Reconnaissance Orbiter, 2015

In today's class, we want to look at those characteristics of the Earth that are also important in our understanding of the other terrestrial planets. This is know as **Comparative Planetology**.

Stages of Planetary Evolution:

1. Differentiation: Layering by density

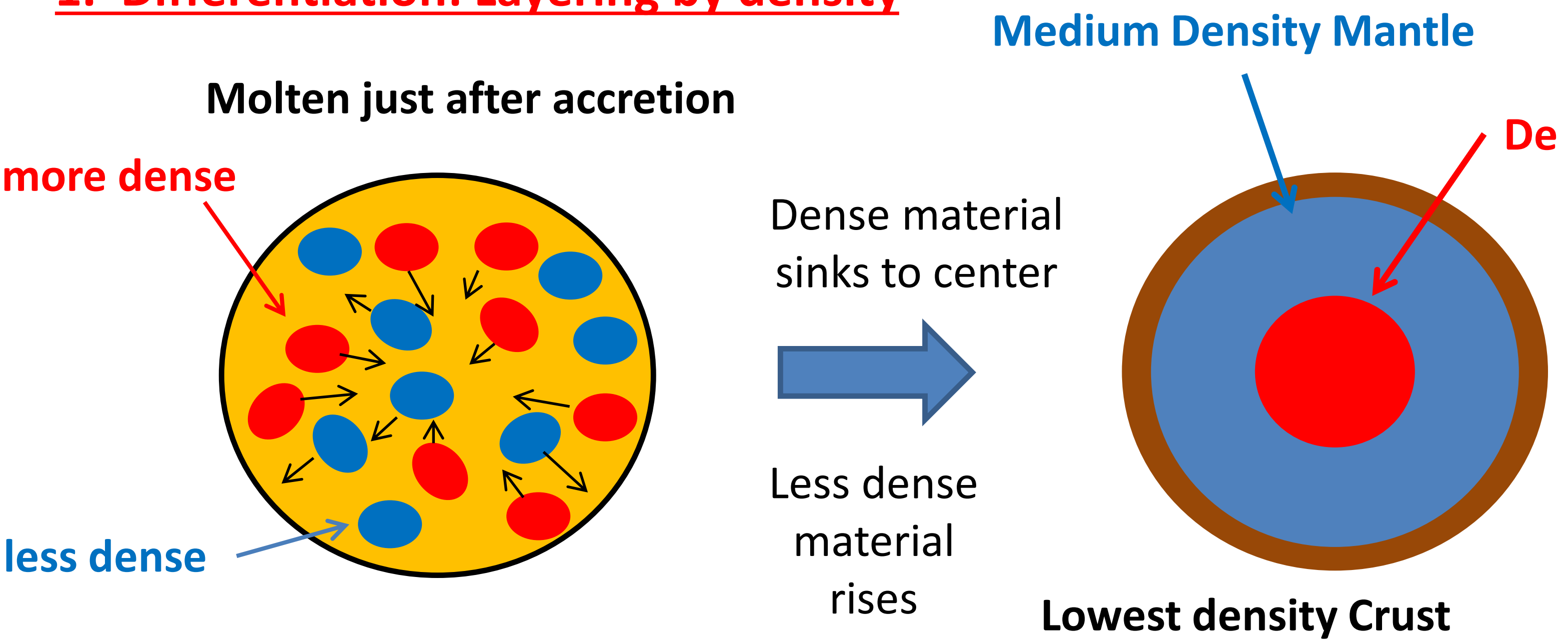
Just after formation in the Solar Nebular, it is likely that the terrestrial planets were completely molten – **why?**

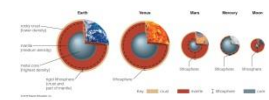
Two Possible Ways:

- During accretion, gravitational potential energy is converted to thermal energy, and/or **(LC)**
- Decay of radioactive material releases energy that is trapped in the interior. *(in fact, this is likely still occurring to some degree)*

Stages of Planetary Evolution

1. Differentiation: Layering by density





2. Cratering

Impacts of both large and small bodies scar the surface. Impacts were common early in the history of the solar system, especially during the Late Heavy Bombardment, but it does continue to the present.

Stages of Planetary Evolution

3. Flooding of Basins

Molten lava from the mantle would fill the larger impact sites creating a large smooth region, e.g. the **Lunar Maria**.

4. Slow Surface Evolution

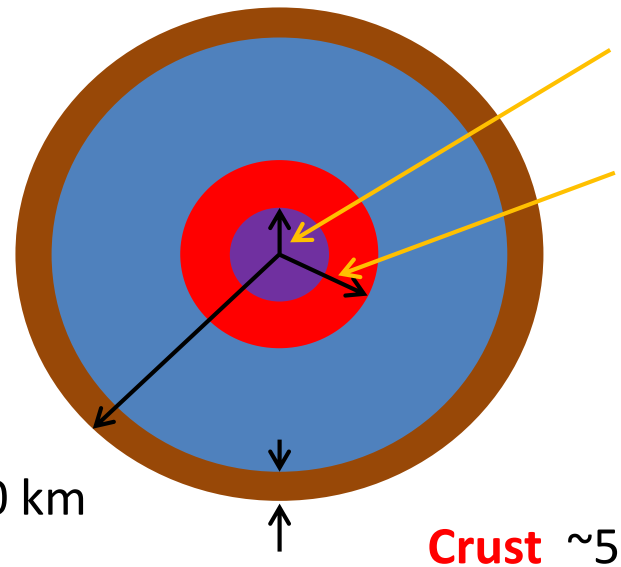
Changes that take place over 100’s of millions of years, e.g. atmospheric erosion, volcanism, and plate tectonics.

Note:

- Depending on a planet’s size, these stages can take different amounts of times, e.g. Saturn is still differentiating.
- Also, if a planet is small and has no atmosphere, it can be frozen in a stage – e.g. the Moon and Mercury are geologically dead and have no atmospheric erosion

Geology of the Earth

Core: solid inner & liquid outer
Dense metal,
Iron & Nickel



~1300 km

~3500 km

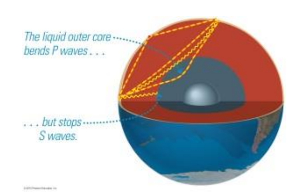
Mantle:
Densest Rock with some metal

6400 km

Crust ~50 km thick
Least dense rock

How do we know this? (LC)

Vibrations from Earthquakes create waves that can be used to probe the interior of the Earth - **Seismology**



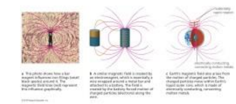
P-Waves are longitudinal compressions that propagate through both solid and liquid.

S-Waves are transverse vibrations that propagate only through solid material.

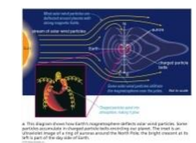
Geology of the Earth

Planetary Magnetic Fields:

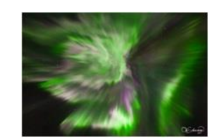
- If a planet has a liquid convecting metallic core and high enough rotation period, electric currents set up in the spinning metal will create a magnetic field.



- The Earth has the strongest magnetic field of the Terrestrial planets. It extends out into space and provides a shield from high energy particles (electrons and protons) emitted by the Sun – The Solar Wind



- During times of intense Solar Wind emission, the solar wind particles can be trapped in the Earth's magnetic field and be channeled to the polar regions where they collide with molecules creating the Aurora.

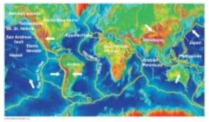


Geology of the Earth

Plate Tectonics:

- In 1912, the German meteorologist/geologist, **Alfred Wegener**, proposed that the continents were not fixed, but were drifting around.

- His idea was based on the similarities of the coastlines of Africa and South America and similarities between plant and animal species, both extinct and living.
- This idea was not taken seriously at all - until the 1960's when the the **Mid-Atlantic Ridge** was discovered to have mantle material rising upward to form new crust and causing the ocean floor to spread.



- The **Theory of Plate Tectonics** today describes the motion of several crustal plates that move in response to convection currents in the mantle. The average drift speed of the plates is a few centimeters/year.
- The **boundaries between the plates** are regions of geological activity like earthquakes, volcanism, mountain building, etc.
- For planetary science, **plate tectonics is a mechanism where the surface of a planet can be completely recycled in in timescales of 100's of millions of years**.

The Atmosphere of the Earth

Present Day Characteristics of the Earth's Atmosphere:

Chemical Composition:

77% Molecular Nitrogen, N_2
21% Molecular Oxygen, O_2
2% other (H_2O vapor, CO_2, etc.)

Average Surface Temperature: 288 K (15^o C)
(we'll talk about the green house effect on Earth later)

Average Surface Pressure: 1 atmosphere

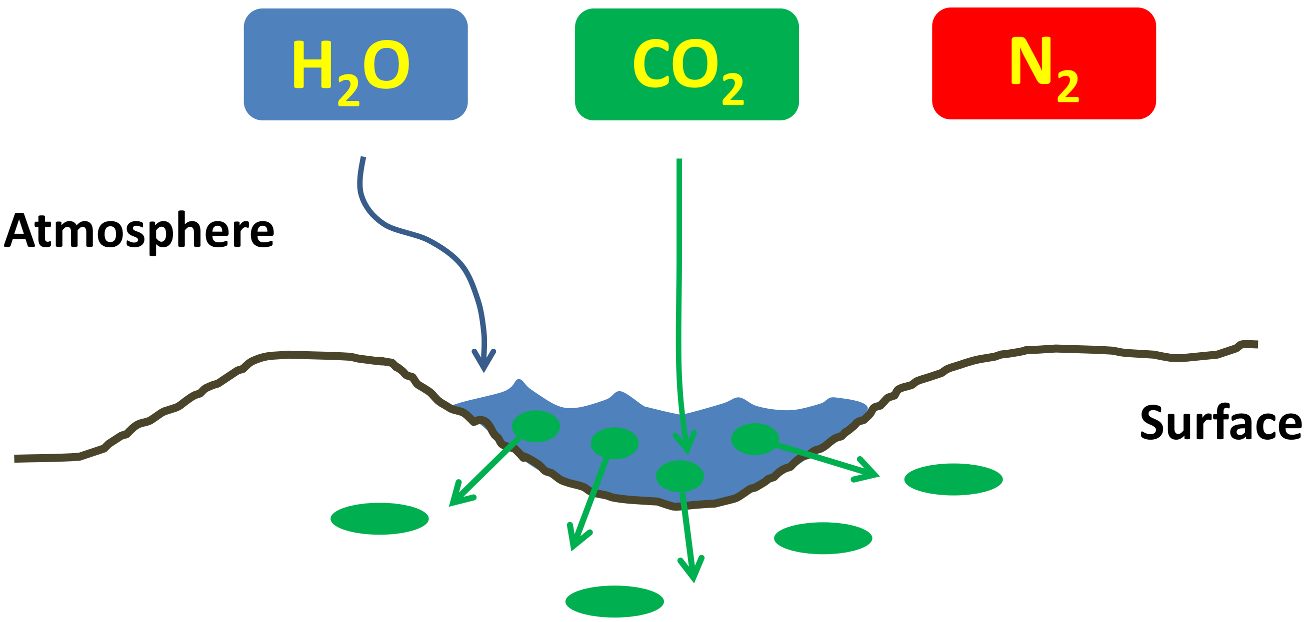
Where did this atmosphere come from?

- Right after formation, the Earth likely had an atmosphere of Hydrogen and Helium, **but what likely happened to this atmosphere? (LC)**
  Ans: it would have quickly escaped to space – see the video from last class.
- A second atmosphere could have formed from outgassing (volcanism) and/or impacts of cometary bodies.
- Either or both of these paths would produce an early atmosphere for the Earth that would be dominated by these gases:

H_2O **CO_2** **N_2**

How did this evolve to the present day atmosphere as the Earth cooled?

The Evolution of the Earth's Atmosphere



1. As the atmosphere cooled, H_2O condensed to liquid – most of the Earth's water is trapped in liquid and ice form.
2. Liquid H_2O dissolves CO_2. The CO_2 then precipitates into the surface forming carbonaceous rocks. Most of Earth's CO_2 is trapped in rocks below the surface.
3. We are left with an atmosphere of N_2, **but where did the free oxygen come from? (LC)**

The O_2 is the product of 2 to 3 billion years of plant photosynthesis. This also provides an ozone (O_3) shield that absorbs solar UV.