The Earth and the Moon

ASTR 101

11/09/2018

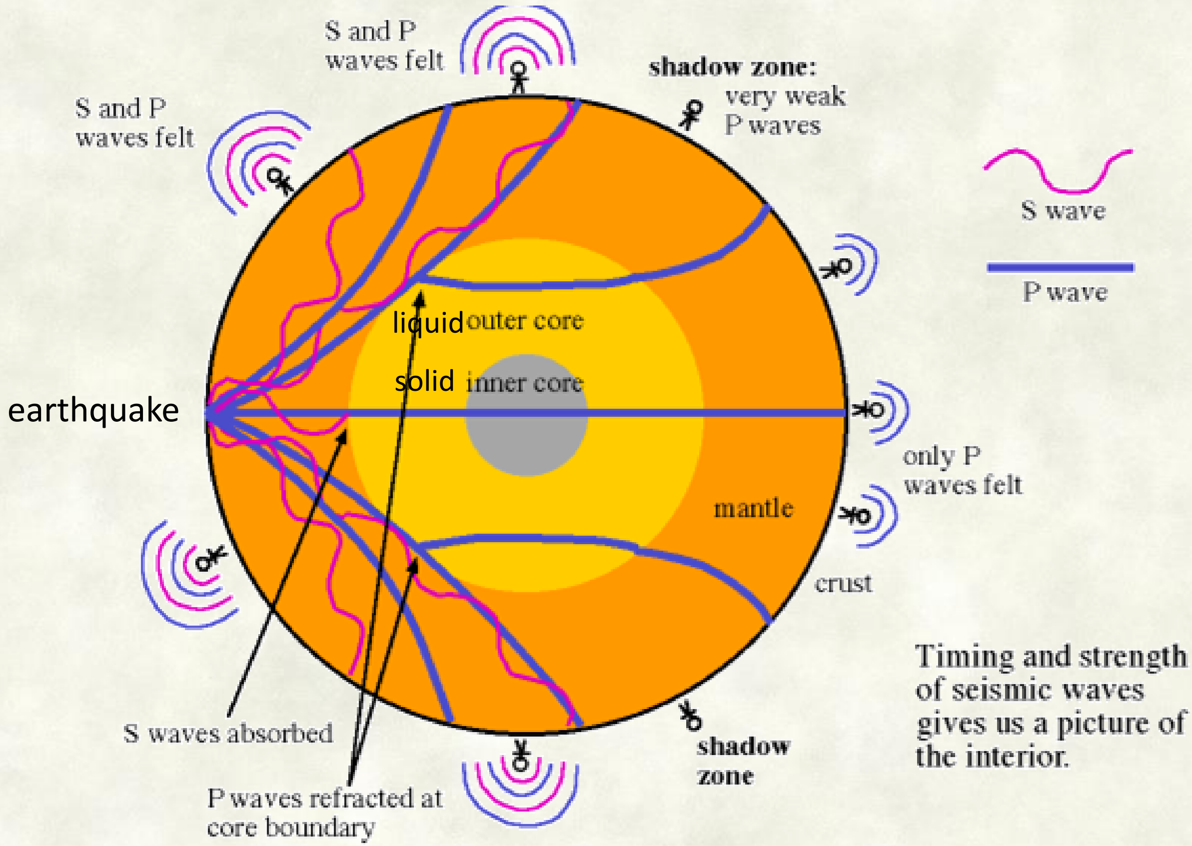
The Planet Earth

- Diameter: 12756
- Mass : $6x10^{24}$
- Density 5515 kg/m3
- Escape velocity 11.2 km/s
- Albedo 0.31
- Average distance from the Sun: $1.496x10^{8}$ km

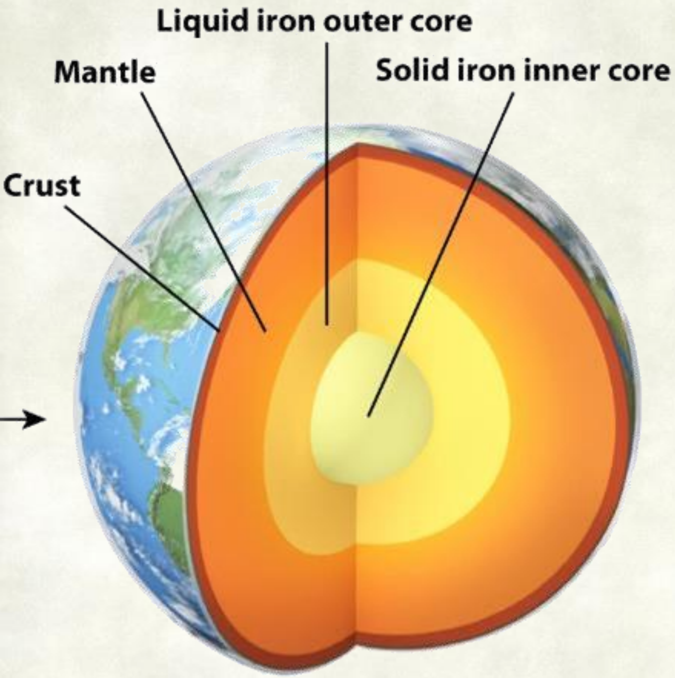
- Atmosphere composition (dry):
  - 78% nitrogen
  - 21% oxygen
  - 0.93% Argon
  - 0.04% Carbon dioxide

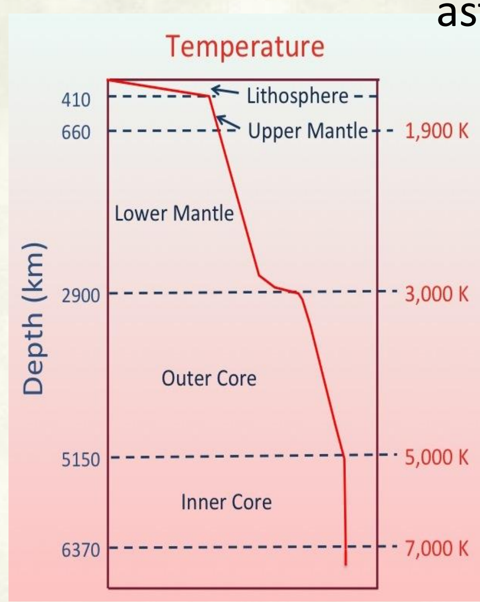
  - Water vapor 0.001% - 5%

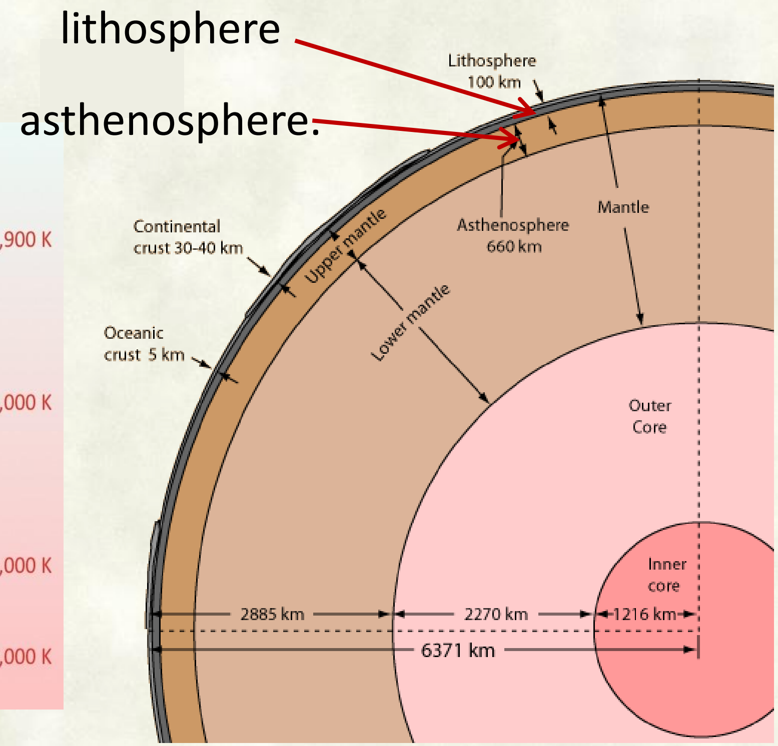
Interior of the Earth



- Most of our knowledge about the interior of the Earth has comes from the study seismic waves
  - Pressure waves generated by natural events like earthquakes, volcanos or artificially by explosions and mechanical devices
  - P-waves: longitudinal waves that can propagate in both solids and liquids.
  - S-waves: transverse waves that can propagate in solids but not in liquids

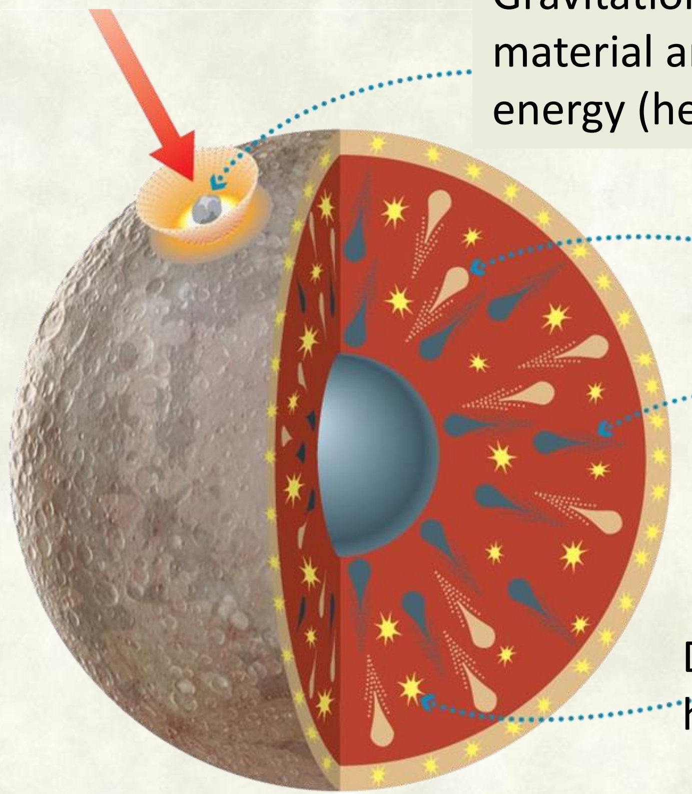






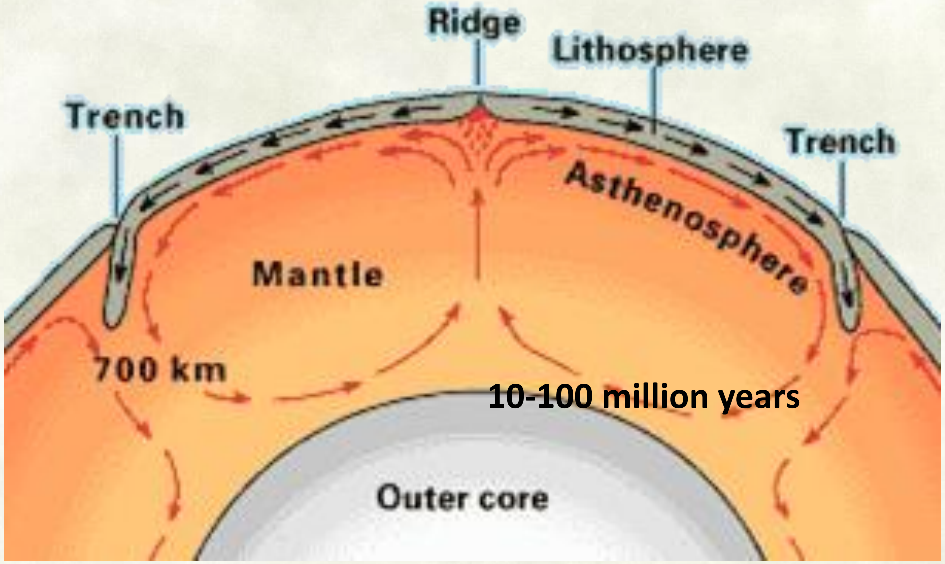
The Earth seems to have:

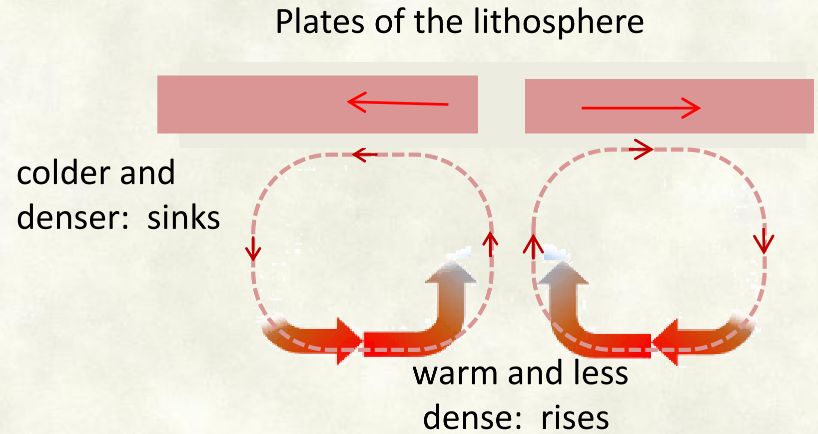
- A Solid inner core surrounded by a liquid outer core, made mostly of iron and nickel. The diameter of the core is estimated to be ~7000 km.
- A Crust, only a few tens of kilometers thick made of rock (granite and basalt)
- The region between the core and the crust is called the mantle, made of silicates .
  - The upper part of the mantle and the crust together are called the **lithosphere.**
  - Sitting just below the lithosphere is a region of plastic consistency called the **asthenosphere.**



- The Earth (or other planets) did not have this interior structure when it was formed.
- Earth was probably molten when formed due to heat from bombardment by space debris and radioactivity.
- Heavier materials sank to the center while lighter materiel rose to upper layers. This process is called differentiation

Plate Tectonics

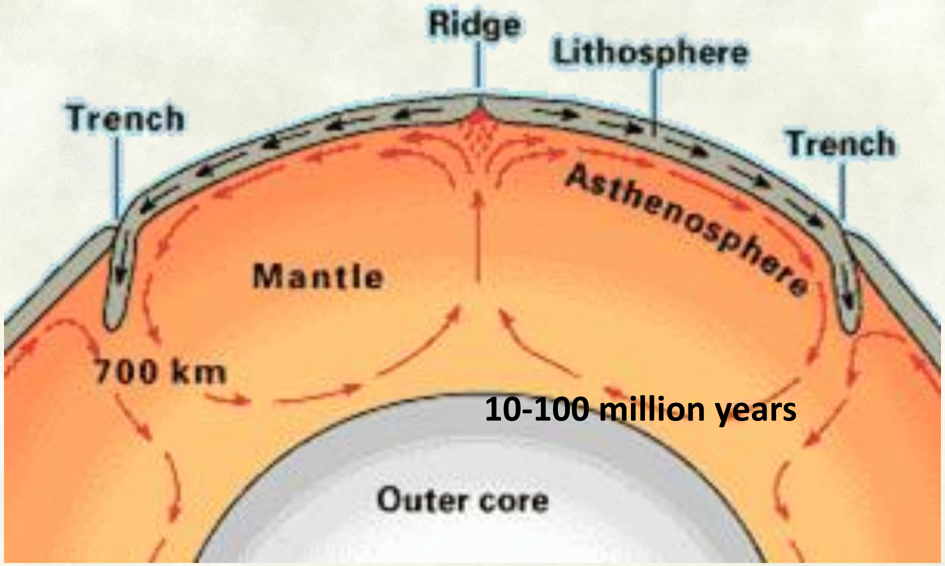


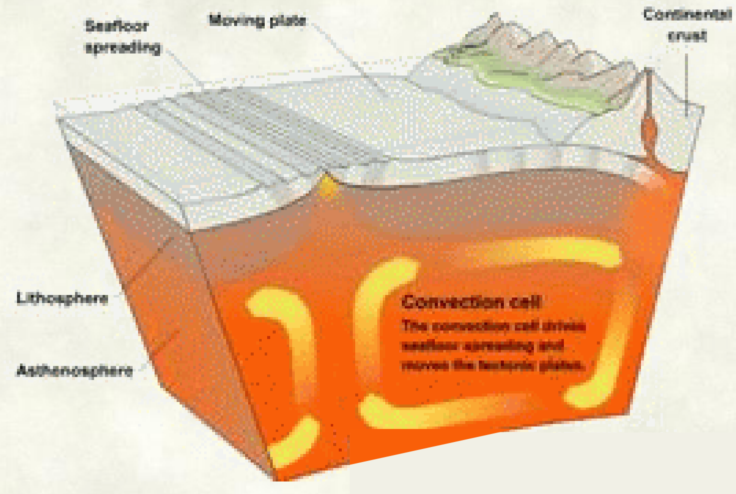


Convective currents in the mental

- The **lithosphere**, typically 50-100 km thick is broken into large plates called tectonic plates. These plates sit on the asthenosphere.
- The asthenosphere is kept plastic (deformable, can flow) largely through heat generated by radioactive decay.
- Very slow convection currents flow in this plastic layer, and these currents provide horizontal forces on plates of the lithosphere, and slowly moving them (like a giant conveyor belt)
- This movement of tectonic plates (few centimeters a year) drifts continents with them and cause other major geological activities like earthquakes and volcanos.

Plate Tectonics





warm and less dense: rises

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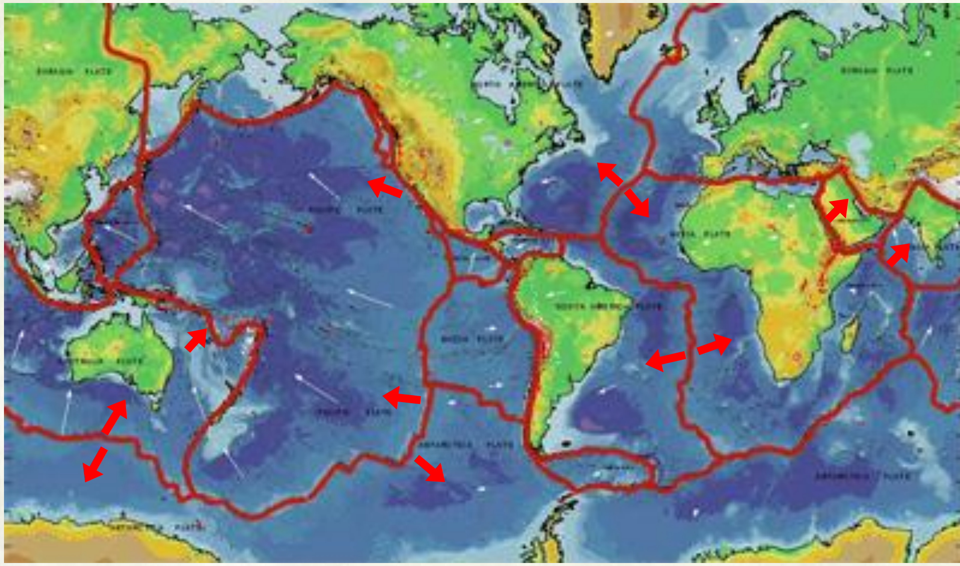
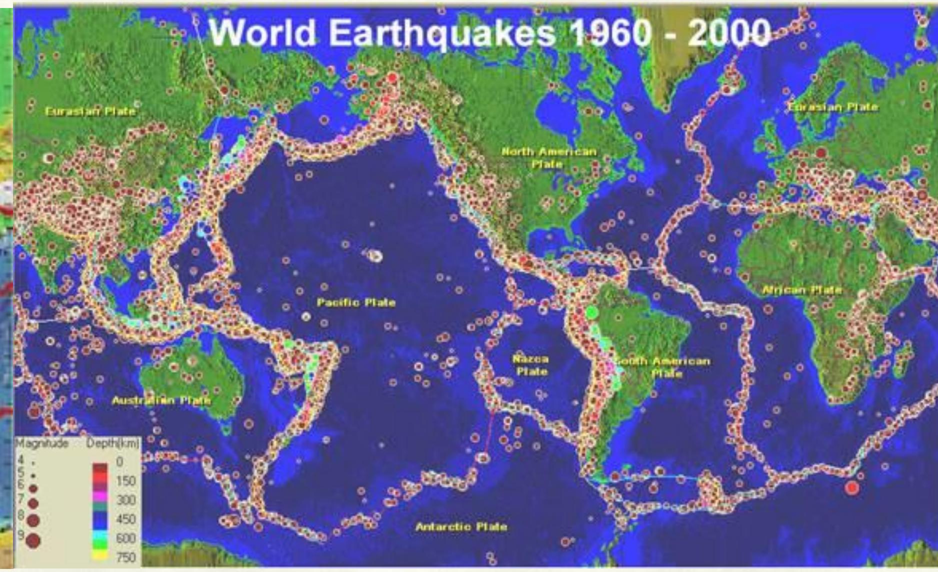
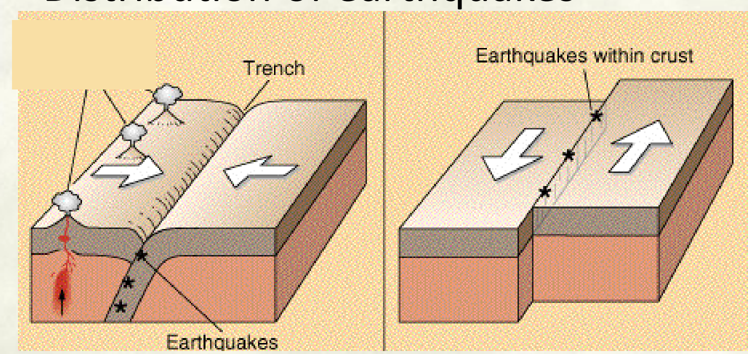


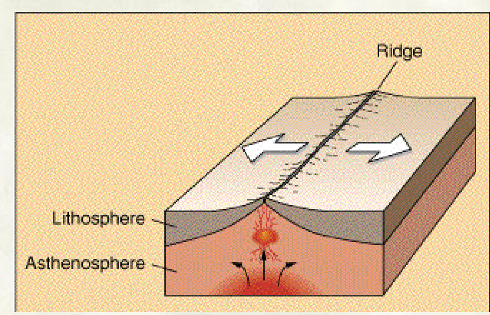
map of the Earth's tectonic plates



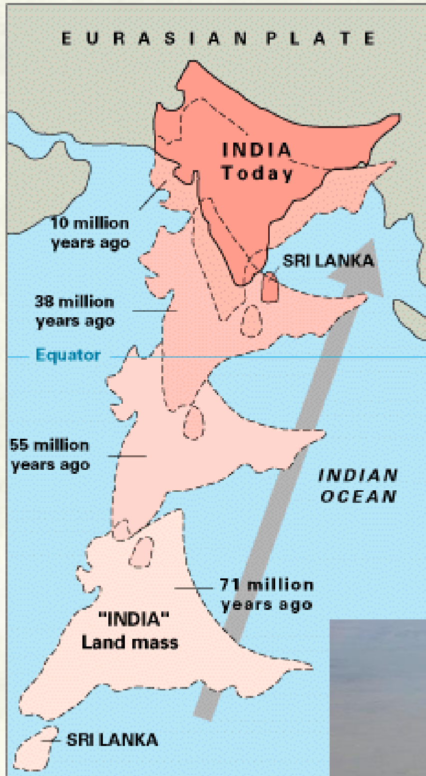
Distribution of earthquakes

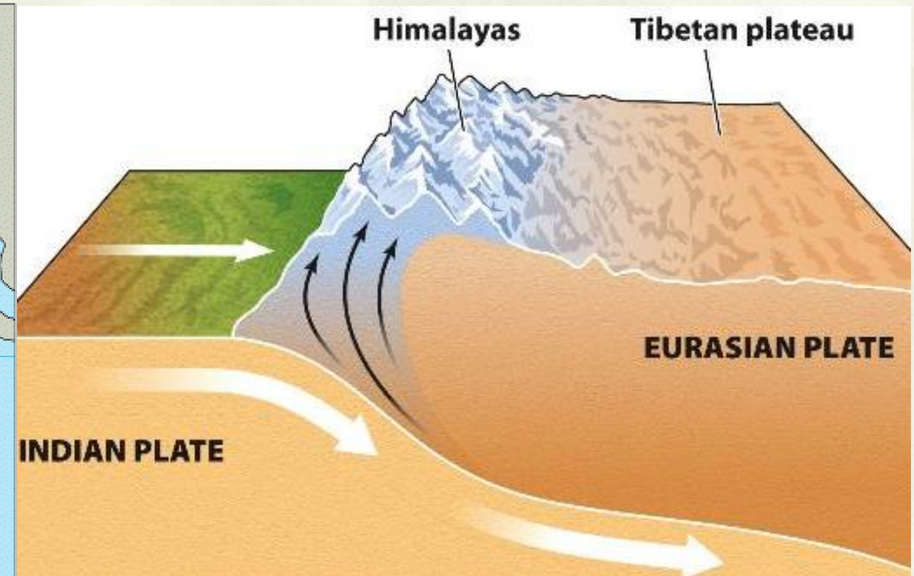


- At tectonic plate boundaries, plates press or grind against each other, rise or subduct and develop different inter-plate stresses.



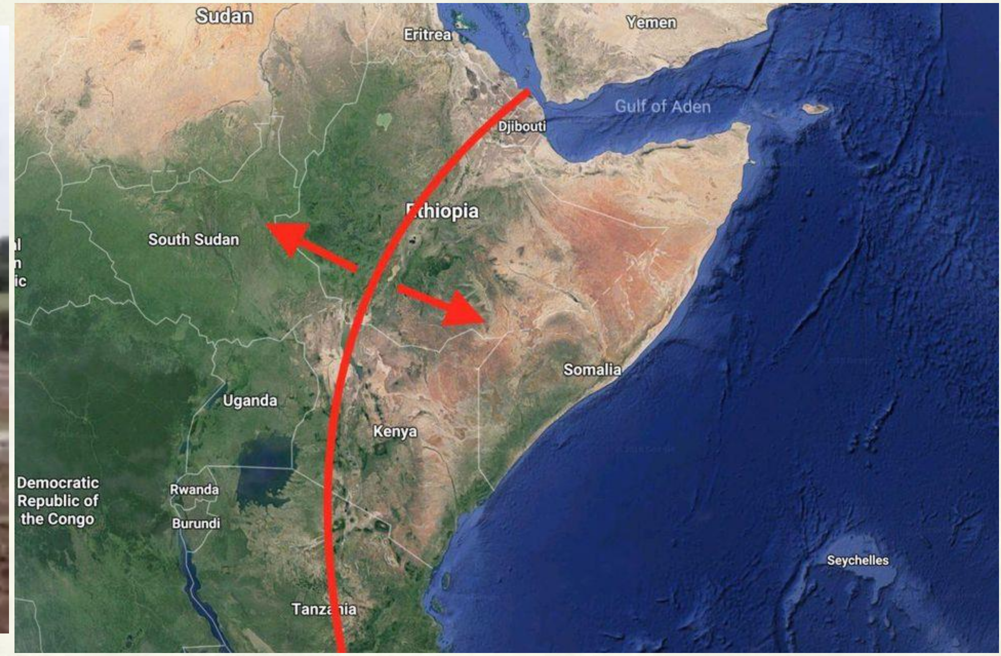
Himalaya is a result of uplifting the Eurasian plate when Indian plate collided and subducted beneath the Eurasian plate, about 50 million years ago





The plates that carry Africa and Arabia are moving apart, leaving a great rift that has been flooded to form the Red Sea.

The San Andreas Fault , where north American plate meets the pacific plate



A large crack suddenly appeared in south-western Kenya few months ago (in March).

The rift is probably a sign of Nubian and Somali plates splitting in two.

A piece of East Africa is expected to break off the main continent in about 30 million years.

Pangea – the Supercontinent

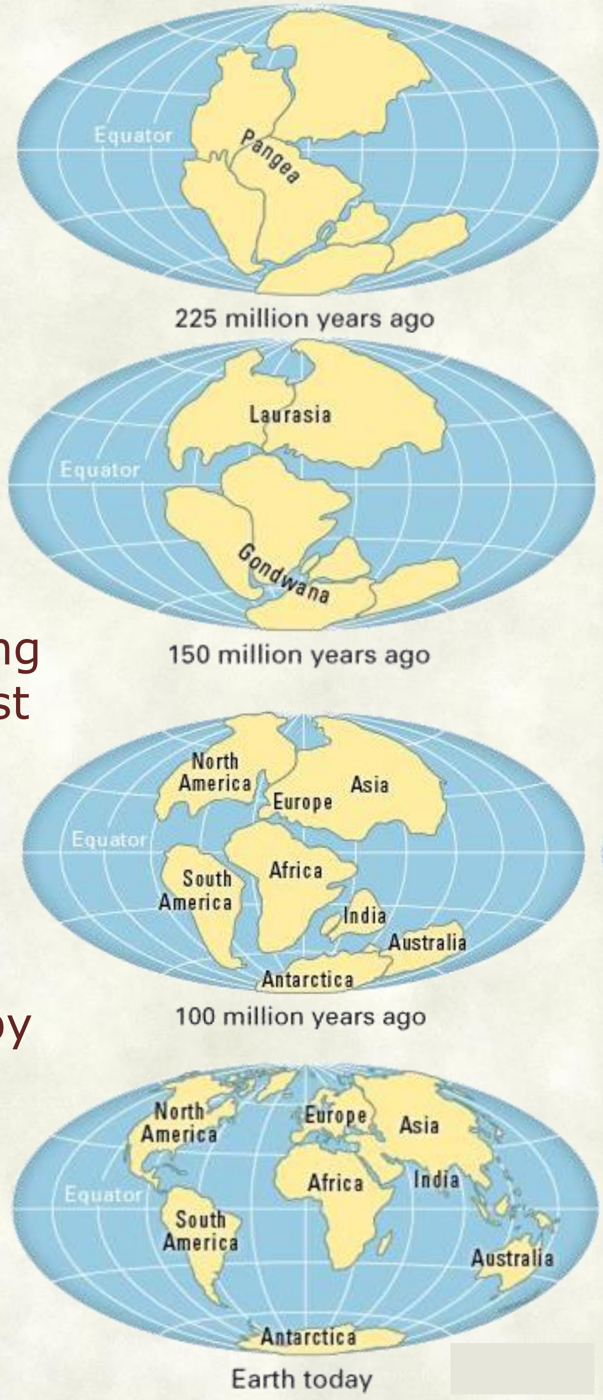
- In early 20th century, Alfred Wegener, a German geologist noticed that large-scale geological features on different continents match.
  - e.g. coasts of western Africa and eastern South America looked like the edges of interlocking pieces.
- Wegener hypothesized that there was a gigantic supercontinent 200 million years ago, which he named Pangaea (All-earth).
  - It broke up and drifted atop a liquid core to leading to oceans, continents, and other land masses exist today.
- Continental drift idea is now replaced by plate tectonic mechanism,
  - otherwise the idea of supercontinent and is breakup 225 million years ago is well supported by geological and fossil evidence.

Read more at the USGS:

http://pubs.usgs.gov/gip/dynamic/historical.html

Watch the NOVA video Making North America

http://www.pbs.org/video/nova-making-north-america-origins/

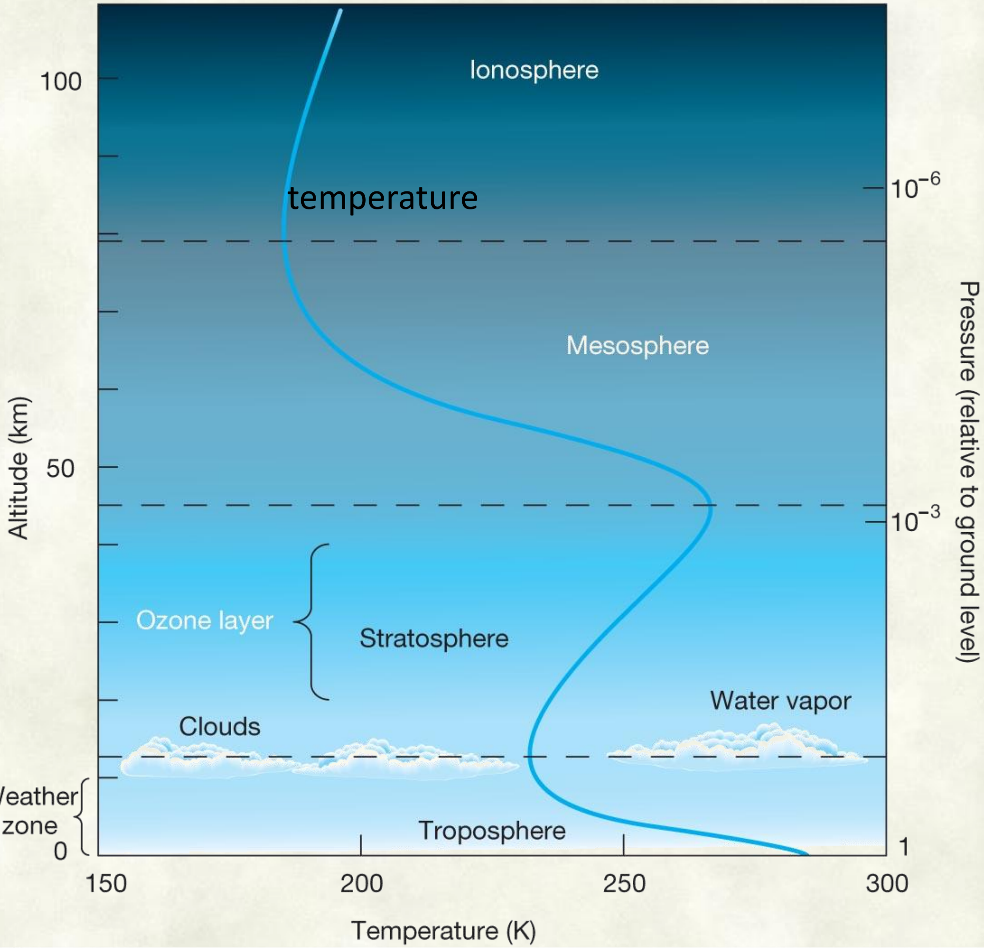


- Fossilized tropical conifer trees at the Petrified Forest National Park (latitude 35^0).
- During the Triassic Period ~200 million years ago it was a tropical river basin at latitude 10^0

Earth's Atmosphere

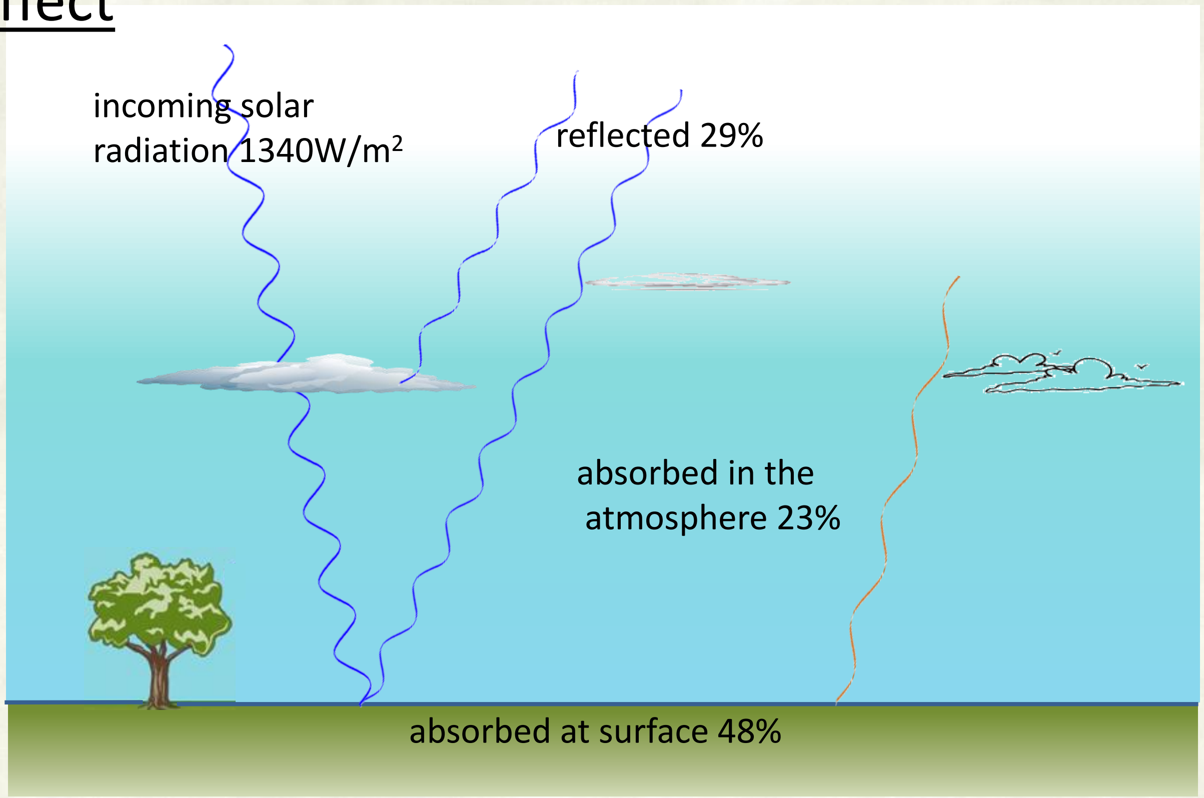
Earth's atmosphere can be divided into several distinct layers:

- **The Troposphere:** where all weather phenomena takes place temperature decreasing with altitude.
- The **Stratosphere** and **Ozone Layer**: where air flow is mostly horizontal, temperature rising with altitude.
- The **Mesosphere** and **Ionosphere**



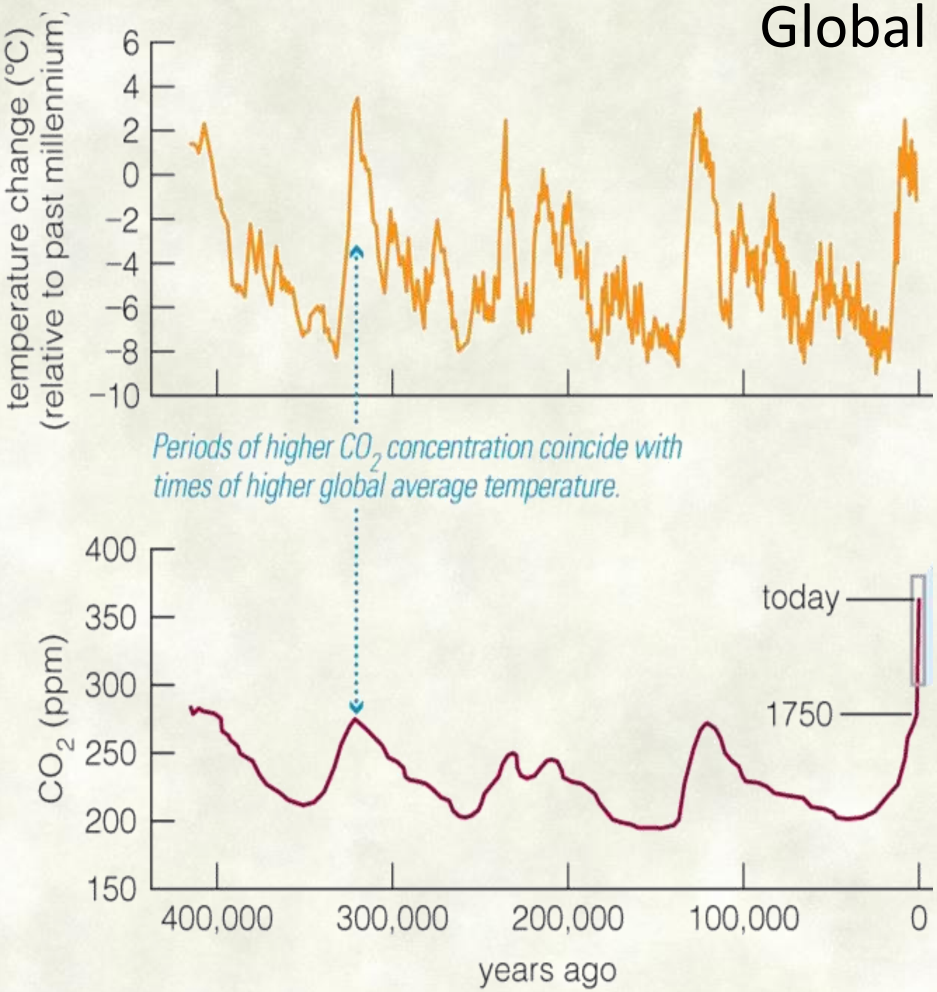
- The original earth atmosphere which contained nebular gases similar to atmosphere of Jovian planets was lost to space at hot early stages of forming the Earth.
- Current atmosphere was formed from compounds outgassed from the crust (volcanos) or have come from the impacts of comets and other planetesimals rich in volatile materials.

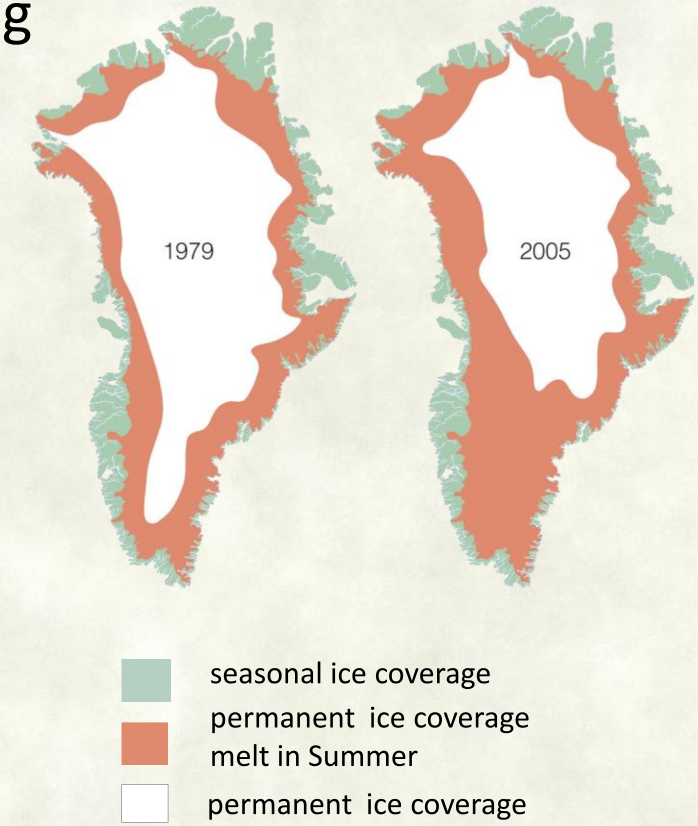
Greenhouse Effect



- About 30% of sunlight is reflected back to the space, rest is absorbed by the Earth's surface, warming it.
- Earth surface re-radiates as infrared thermal radiation (since earth is at a lower temperature ~300K compared to 6000K of Sun)
- But atmosphere is not very transparent to this infrared radiation and absorb some causing further heating
- Greenhouse gases like water, carbon dioxide and methane increases the absorption of infrared radiation which makes the atmosphere warmer, which in turn increase the overall surface temperature leading to an overall temperature rise.

Global Warming

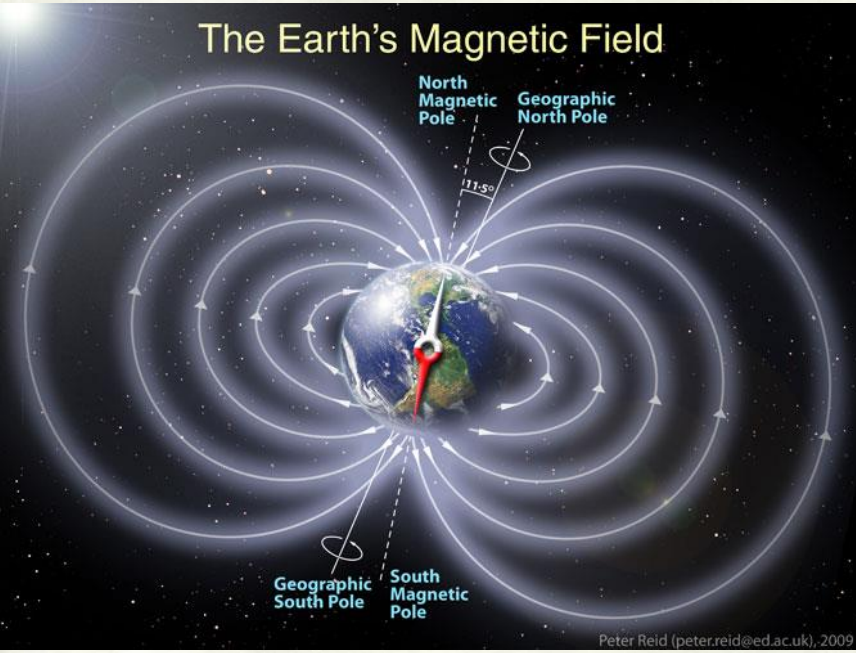


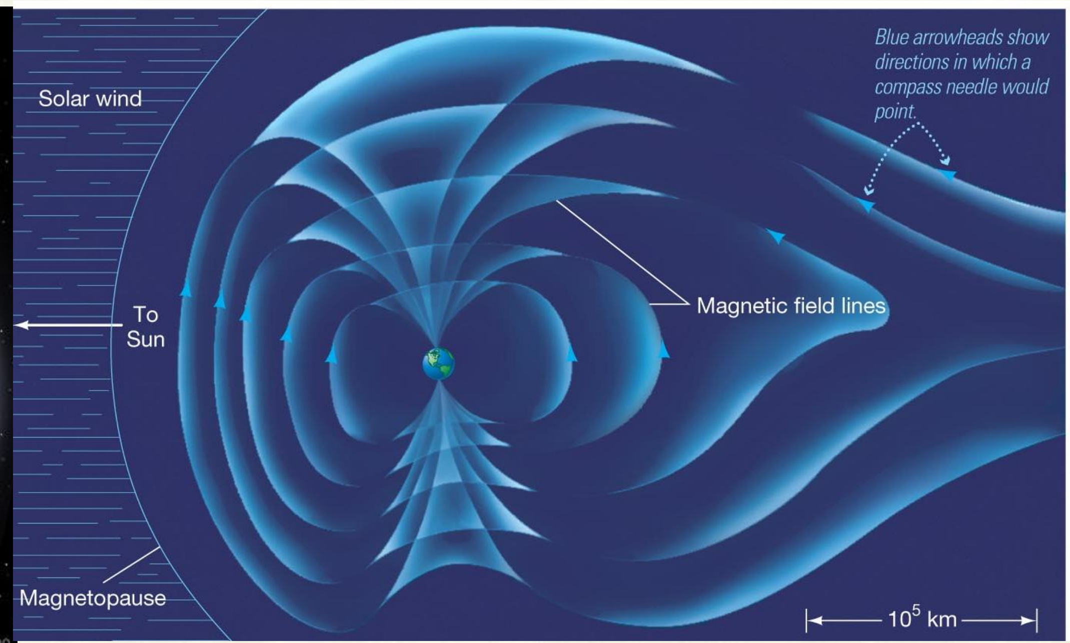


Changes in Antarctic ice sheet

- Current “ideal” conditions are due to Earth’s unique geology and biology, which keeps green house gases (CO_2) and thus temperature at equilibrium. Human activity seems to be causing change faster than the natural CO_2 cycle can correct for it.
- ***Consequences of Global Warming***: many potential problems. Sea level rise (melting Antarctic ice) , climate effects of ocean current change, etc.,
- key is global concerted understanding and action.

Earth's magnetic field and the **magnetosphere**

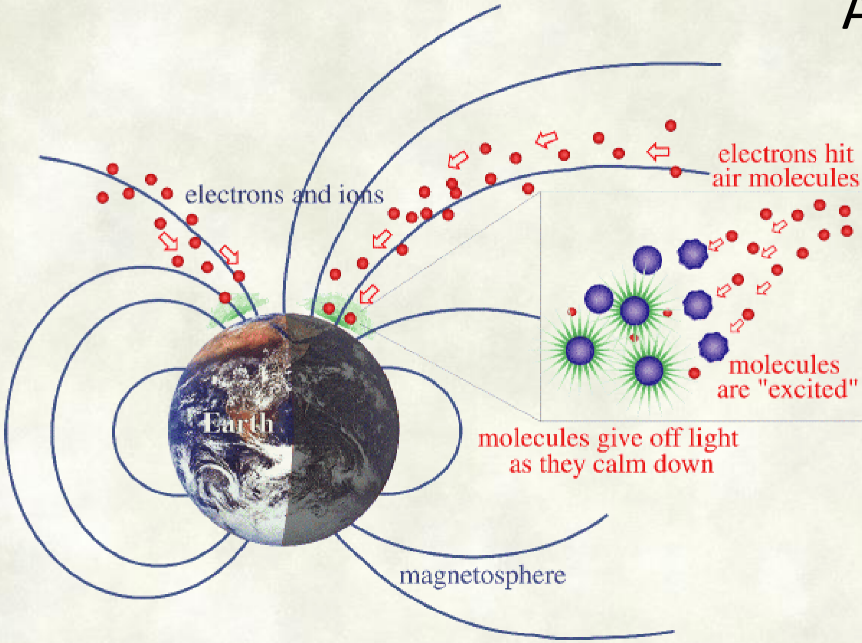




Charged particles in the solar wind get trapped in magnetic field and form radiation bands

- Earth acts like a giant bar magnet, source of the Earth's magnetic field is believed to be the electric currents in of its molten metallic core, created by convection currents.
- Sun emits charged particles, mostly electrons and protons, some of which reach the Earth
- They interact with the Earth's magnetic field to create the magnetosphere .
- These charged particles are trapped in areas called the Van Allen belts, where they spiral (move) along the magnetic field lines.

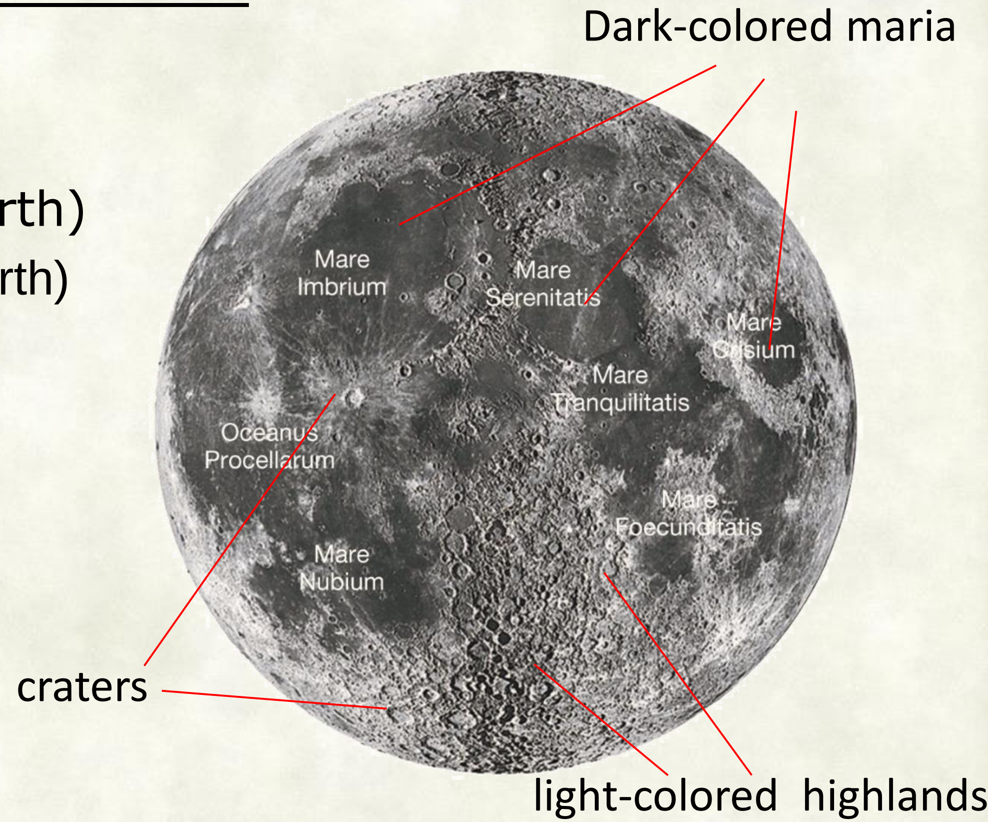
Aurora lights



- Earth's magnetic field shields the earth from solar wind,
  - Thus protecting the earth's atmosphere
  - There are evidence that there was a thick atmosphere (and water) on Mars, very likey that atmosphere was stripped off by solar wind (Mars has no magnetic field)
- On Earth those charged particles are trapped by Earth's magnetic and taken to polar regions along the magnetic field lines, where they interact with atmosphere and produce auroras.
  - The Aurora Borealis (northern lights) or Aurora Australis (southern lights) are caused by charged particles from the Sun exciting oxygen and nitrogen atoms in the atmosphere.

The Moon

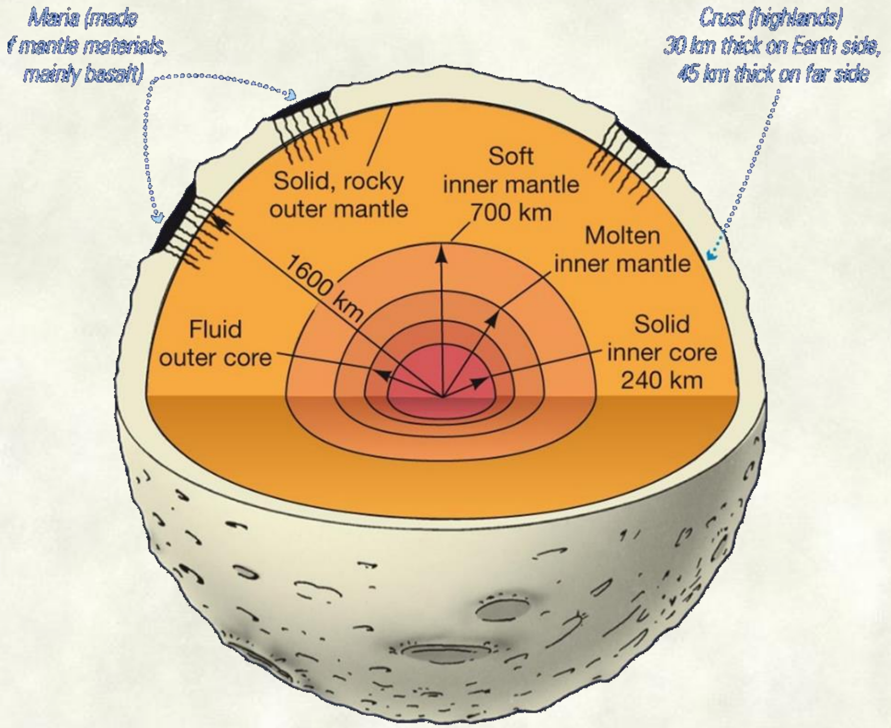
- Diameter: 3474 km (0.27 of Earth)
- Mass: 7.3×10^{22} kg (0.012 of Earth)
- Density: 3300 kg/m^3
- Escape Speed: 2.4 km/s
- Distance to earth: 384399 km



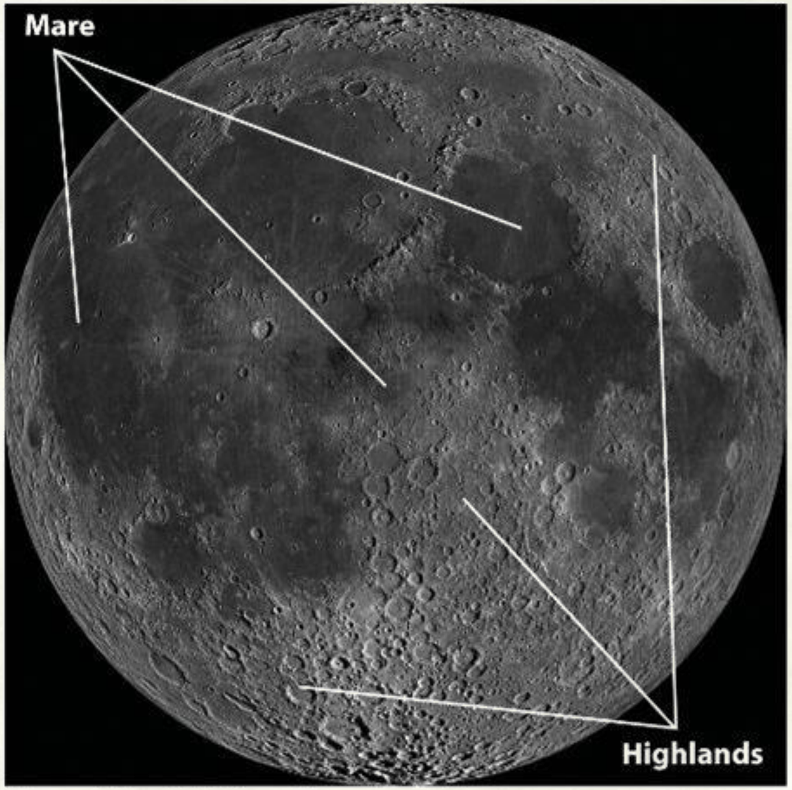
- Moon has large dark flat areas, due to lava flow, called maria (early observers thought they were oceans)

- Moon also has many craters formed by meteorite impacts.
  - Few craters in maria, lava flows (3 billion years ago) had erased craters, there has not been much meteor bombardment since then.
  - Most lunar craters date to at least 3.9 billion years ago; much less bombardment since then

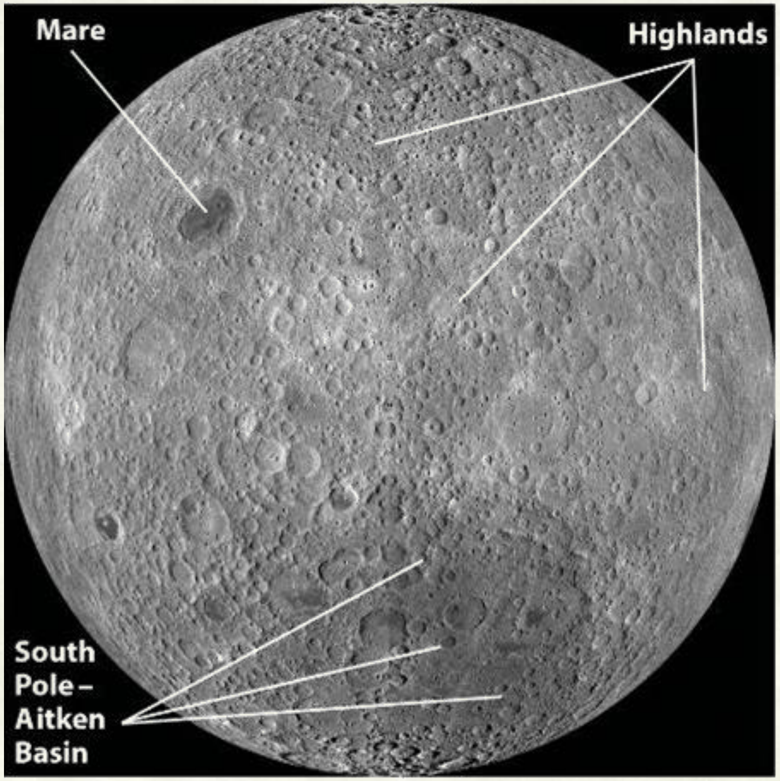
Moon's Interior



- Like Earth, the Moon has a crust, a mantle, and a core, a liquid outer core surrounded by a solid inner core.
- Crust is much thicker than that of earth (smaller size ⇒ faster cooling)
- Moon's density is relatively low, and it has no magnetic field, so cannot have sizable iron/nickel core
- Moon has no atmosphere, its gravity is too weak and temperatures are too high to retain an atmosphere.



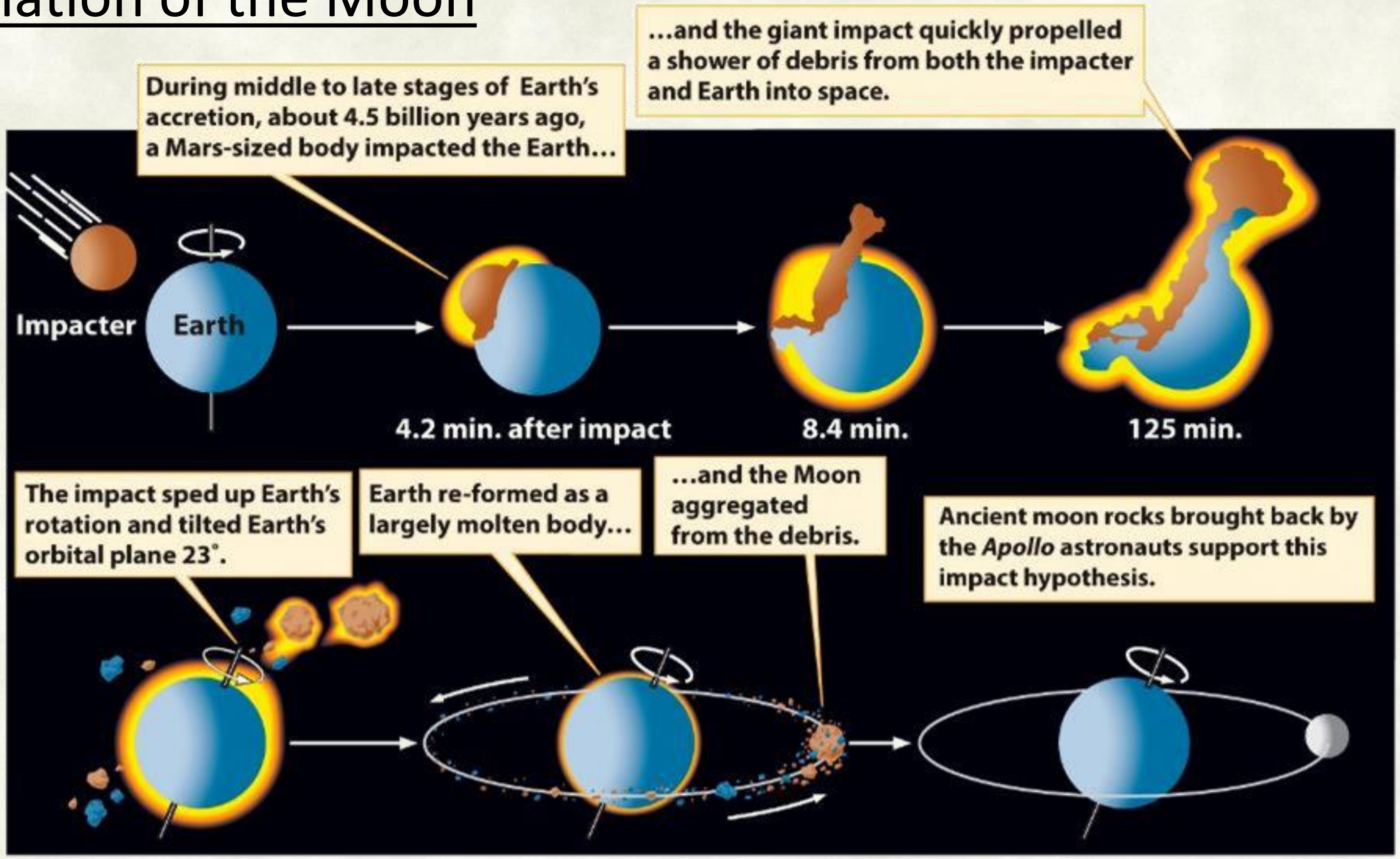
Near side: highlands and maria



Far side: highlands but almost no maria

- The iron-rich darker maria are a younger surface made from ancient lava flows and are 2 to 5 km below the average surface elevation.
- The cratered highlands are an older surface several kilometers above the average elevation.
- We see only one side of the moon, far side of the moon is observed by spacecrafts. Far side have had less volcanic activity, thus no major maria.
  - Near side lunar crust is thinner due to Earth's tidal forces on the Moon, so more volcanic activity in the past.

Formation of the Moon



- The leading moon formation theory is that some 4.5 billion years ago a planetary body (size of Mars) collided with the young Earth.
- That collision ejected a large amount of planetary material into space, which accreted to create our Moon.
- It is widely accepted due to the similarity in composition of the Moon and Earth's crust. Another piece of supportive evidence is the absence of a liquid metallic core

Lunar Exploration

Moon is the only place in the universe people have visited beyond Earth:

- First spacecraft to fly past Moon (Luna 1): January 1959
- First spacecraft to (crash) land on Moon (Luna 2): September 1959
- First pictures of far side of Moon (Luna 3): October 1959
- The United States is (so far) the only country to send people to the Moon:
- First manned mission to Moon (Apollo 11): July 1969
- Last manned mission to Moon (Apollo 17): December 1972

Apollo 15 landing site

Lunar Reconnaissance Orbiter
Launched 2009

Review Questions

- How do we know about the interior composition and structure of the Earth.
- What make the earth interior hot.
- What are the three most abundant gases in the atmosphere (at ground level)?
- What are plate tectonics. What makes plate tectonics to move?
- What are the results of plate tectonics movements.
- What are the evidence that about 200 million years ago there was one giant continent.
- What are greenhouse gases? What is the greenhouse effect?
- Why melting of Antarctic ice more of a problem than melting Arctic ice.
- What are Auroras? Why do they are visible only in polar regions?
- Why is it unlikely that the Moon Earth from at the same time from the Solar nebula?
- How did the moon form according to the most accepted theory?
- Why could have caused the tilt of Earth’s axis?