Lecture 11:
The History of the Earth

Astronomy 141
Winter 2012

This lecture reviews the geological history of the Earth.

Reconstruction of this history from geologic strata, rock analysis, and radiometric analysis.

Four major eons of Earth's history: Hadean, Archaean, Proterozoic, and Phanerozoic.

The Phanerozoic is the current eon when complex life arose in the past 600Myr.

The Hadean Earth was the early eon when the oceans and atmosphere arose.

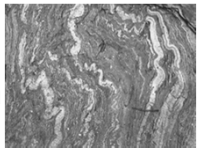
Very early life may have arisen but been wiped out by massive impacts.

The three main types of rock are classified by how they were formed…

Sedimentary rocks are made of sand and silt compressed in ocean and lake beds.

Igneous rocks are cooled molten rocks

Metamorphic rocks are transformed by high pressure and high heat.



The *Rock Cycle* describes how the three types of rocks can be transformed into each other.

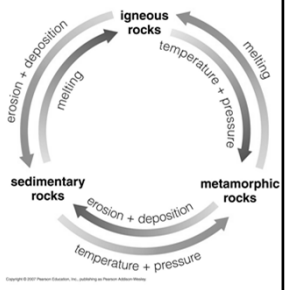
The Rock Cycle is driven by weathering and plate tectonics

Erosion & Deposition

Subduction

Volcanism

Upthrust (continent collisions)



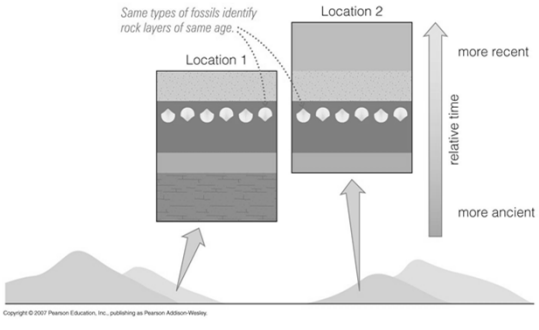
Sedimentary rocks are deposited into layers or *strata* that are ordered in time.

Youngest on the top.

Oldest on the bottom

Compare mineral and fossil content to compare the ages of sedimentary strata in different locations.

Stratigraphy is the practice of dating rock strata from different locations relative to one another.



Detailed analysis of rocks let you reconstruct the histories of the rocks

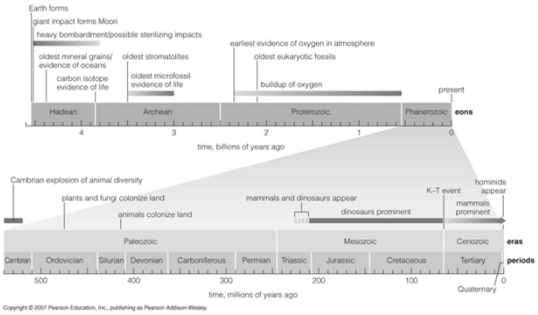
Mineralogy tells you what minerals are present, giving you the pressures and temperatures they formed under.

Chemistry tells you the elemental composition, especially useful if unusual amounts of rare elements are present.

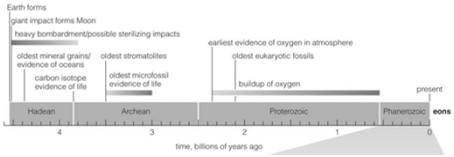
Isotopic Analysis tells you the mix of isotopes present (e.g., ^{14}C vs. ^{13}C or ^{16}O vs. ^{18}O) in the air and water when the rock formed.

Radioactive isotopes can be used for radiometric dating.

The Geological Time Scale is our reconstruction of the Earth's history from stratigraphy.



The four Eons are the main divisions of geological time.



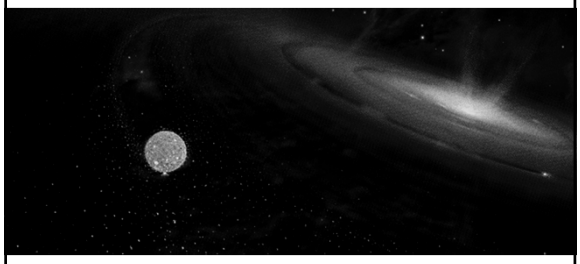
Hadean: 3.8 – 4.5 Gyr ago – traces in the oldest rocks

Archaean: 2.5 – 3.8 Gyr ago – stromatolites & fossil bacteria

Proterozoic: 540 Myr – 2.5 Gyr ago – oxygen and first multi-cellular life

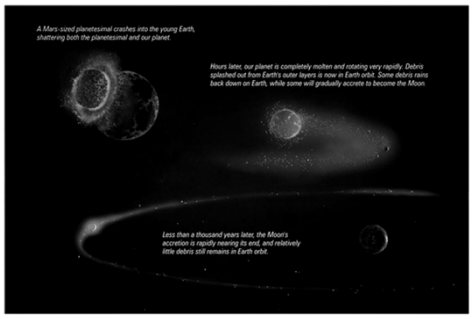
Phanerozoic: <540 Myr ago – first animal life to the present

The Earth formed from accretion of rocky material from the disk of gas and dust that formed the Sun.



The proto-Earth was entirely molten and began to differentiate about 10 Myr after it began forming.

The Moon was formed out of a giant impact with the early Earth ~50 Myr after formation.



The Hadean Eon was the earliest phase of the Earth's history.

The giant impact that formed the Moon would have stripped off any atmosphere on the Earth.

Airless

Dry surface

But, gases were trapped under pressure in the deep interior.

Volcanic outgassing released the trapped gasses, building the primordial atmosphere.

Water Vapor (H_2O)

Carbon Dioxide (CO_2)

Hydrogen Sulfide (H_2S)

Small amounts of N_2, CO, SO_2, and CH_4

The water vapor condensed and rained out, leaving CO_2 behind.

The oceans probably formed from both volcanic outgassing and comet and asteroid impacts.

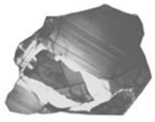
Volcanoes emit copious H_2O,

But not enough to form the oceans by themselves.

Asteroids & comets are rich in water and other ices.

Carbon-rich chondrites have D/H ratios like ocean water.

4.4 Gyr old zircons have Oxygen isotope ratios that imply the existence of abundant liquid water.

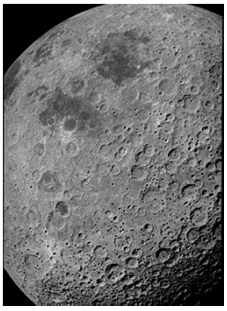


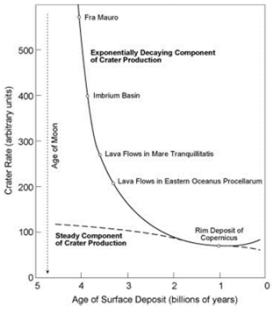
Oceans formed very early in the Earth's history.

Left behind an early CO_2-rich atmosphere.

Conditions may have been favorable for life as early as 100 Myr after the Earth cooled.

The cratering history and ages of Moon rocks record an 800 Myr long epoch of heavy bombardment.



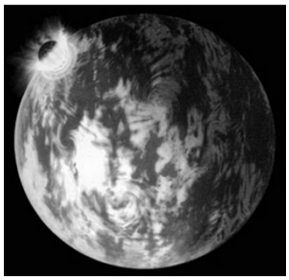


Impacts from 300-500km diameter asteroids would have sterilized the early Earth.

Impact energy would vaporize the oceans and melt much of the crust.

"*Steam atmospheres and magma seas.*"

Any early life would have been wiped out.



Last such sterilizing impacts happened 4.3 – 3.8 Gyr ago.

The end of heavy bombardment ~3.8 Gyr ago marks the end of the Hadean Eon.

Earth began to settle down to conditions conducive to life, but still no Oxygen in the atmosphere.

The first microfossils appear within a few 100 Myr of the end of the Hadean.

There have been oceans on the Earth continuously from ~3.8 Gyr ago to the present.