ASTR 380

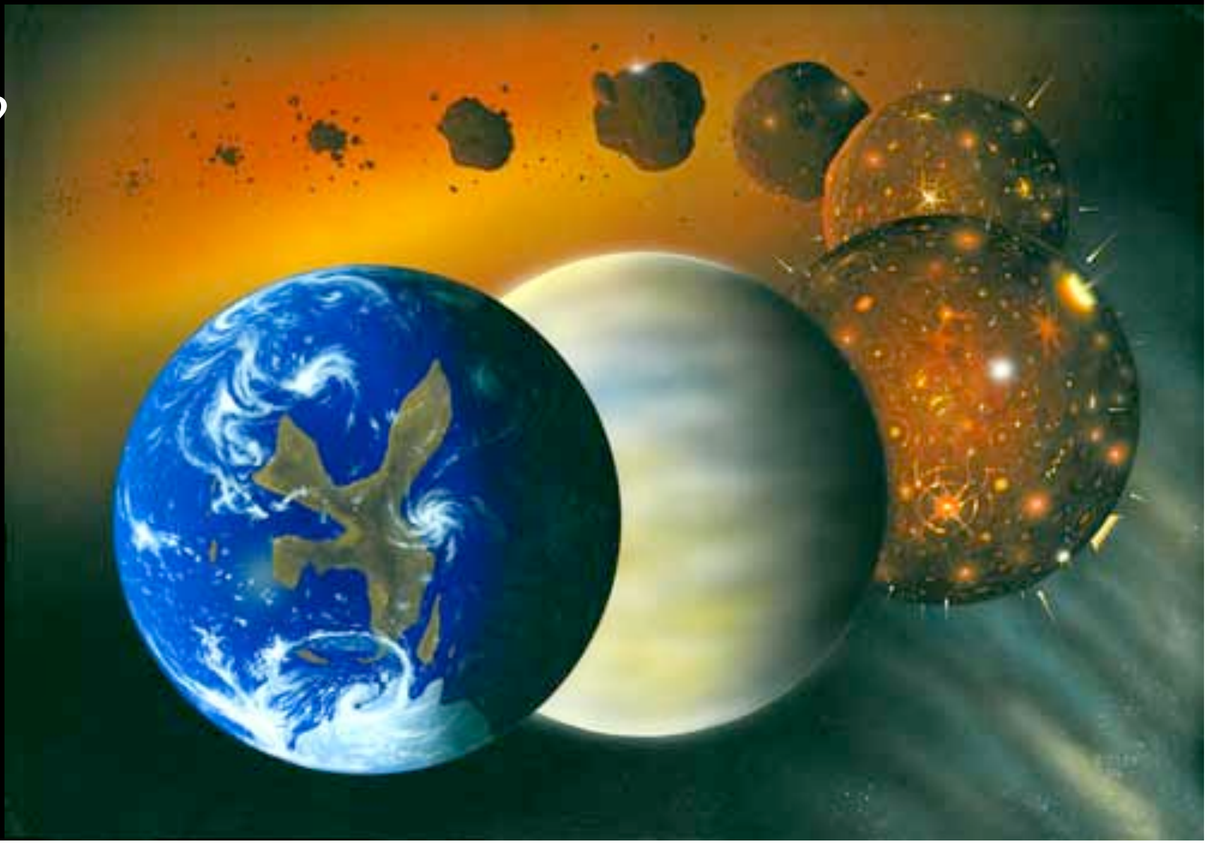
The History of the Earth

The real purpose of Stonehenge

The History of the Earth

Earth's formation and bombardment
Formation of Moon and late heavy bombardment
Continental Motion
The Early Earth's Atmosphere
Life's interaction with the Atmosphere

What is important to life?



Reminder

- First homework due at beginning of class this Thursday
- For essay-type questions, need to type or print out from computer to save grader's eyesight :)

Composition of Terrestrials

- Terrestrial planets: those like Earth
- Earth by mass: 32% iron, 30% oxygen, then silicon, magnesium, ...
- Sun by mass: 74% hydrogen, 24% helium, 2% other
- What could explain differences?

Did heavy elements just sink closer to the Sun?

Did [illegible]y elements ju[illegible]
sink cl[illegible]to the Sun?

No!

Grains and Ices

- Grains can stick together to make big things
- But grains need to be made of either heavy elements (silicon, iron, etc.) or ices
- Close to Sun, only heavies work
  Very little mass in them
  Can only make small planets
- Farther (beyond "frost line"), ices can form
  Incorporates hydrogen; lots of mass
  Later, gravity grabs H, He; big planets!

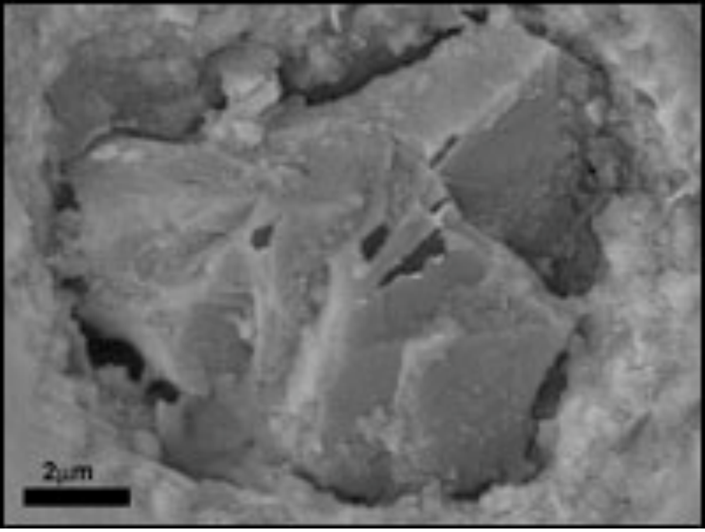
Growth Through Collisions

- Grains come together, get bigger
- Collisions happen; sticking together eventually gets planetesimals
- Now gravitationally attracted, collisions escalate in strength
- Mopping-up process
  A violent early solar system!

Formation and Bombardment

Radioactive dating of meteorites finds that they date back to 4.57 billion years ago, with an uncertainty of 20 million years

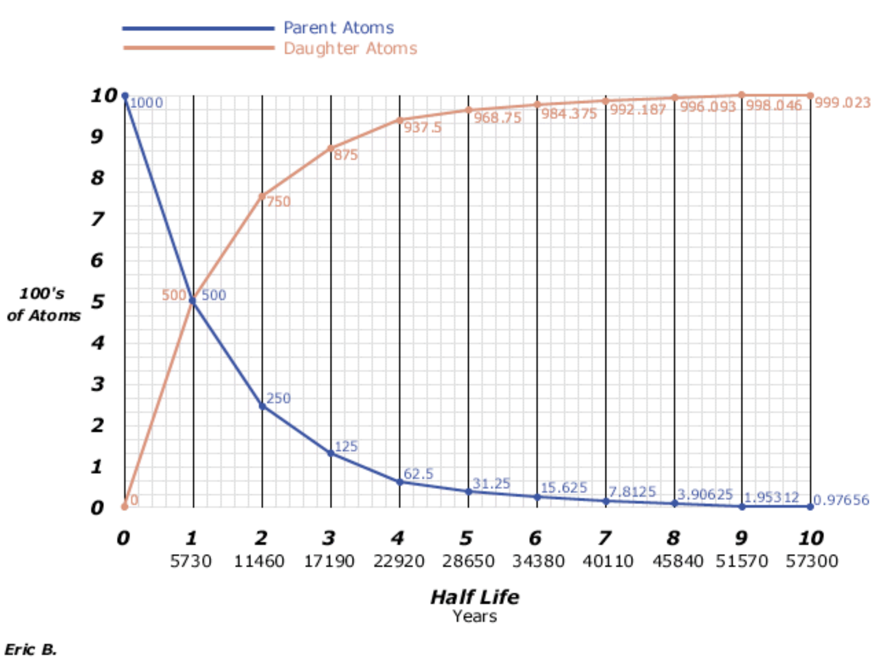
Tiny Mineral grains called Zircons have radioactive ages of 4.4 B yrs
Oldest grains in Earth material

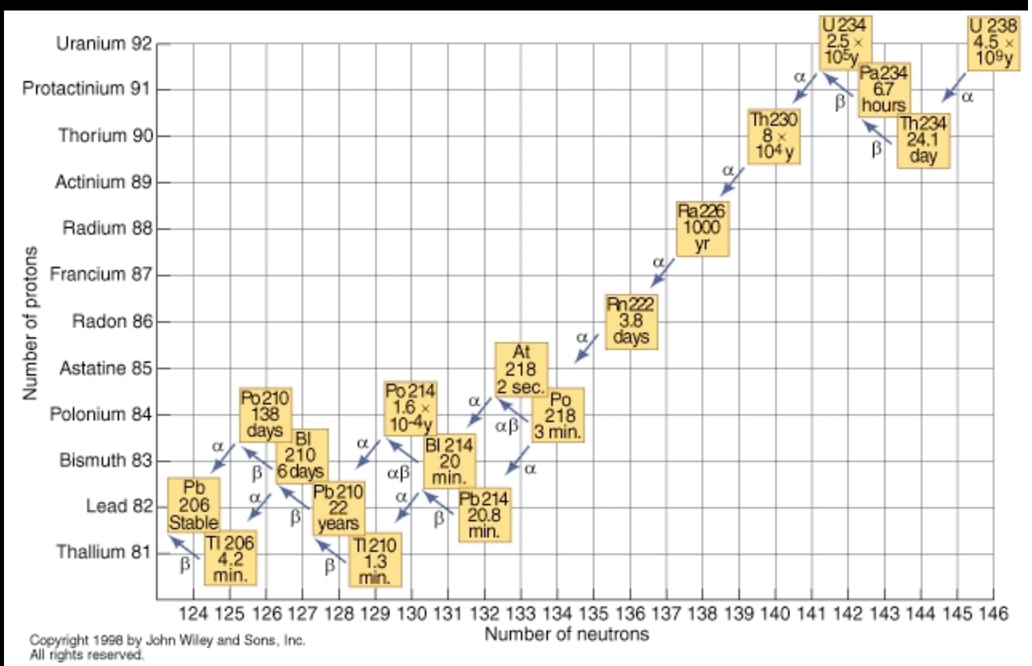


Formation and Bombardment

Radiometric Dating: determine the age of something using the radioactive decay of an element.

Over time, radioactive parent atoms decay into stable daughter atoms and you count the relative numbers of atoms of the two types.





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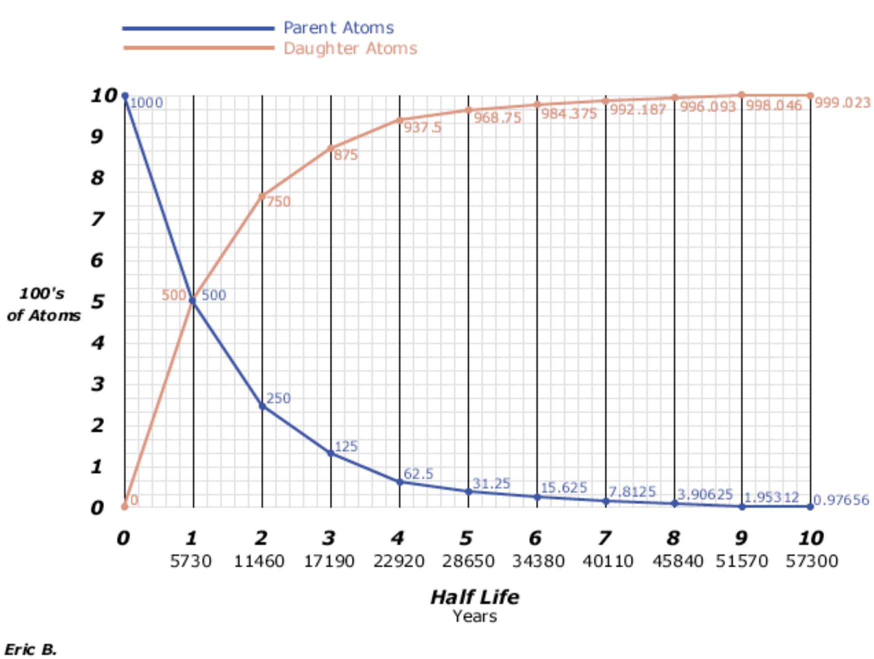

Isotope		Half - life
Carbon	^{14}C	5700 years
Iodine	^{131}I	8 days
Polonium	^{214}Po	$1{,}6\times10^{-4}$ seconds
Radium	^{226}Ra	1620 years
Uranium	^{238}U	$4{,}5\times10^{9}$ years

Formation and Bombardment

The oldest intact rocks date from
about 4.0 B yrs ago, found in the Canadian shield

Implications: Earth formed in less than 170 Million years.
Earth had a stable surface after around 500 Million years.

Formation and Bombardment

The Earth formed through the collection of planetesimals over a period of 50 - 100 Million years.

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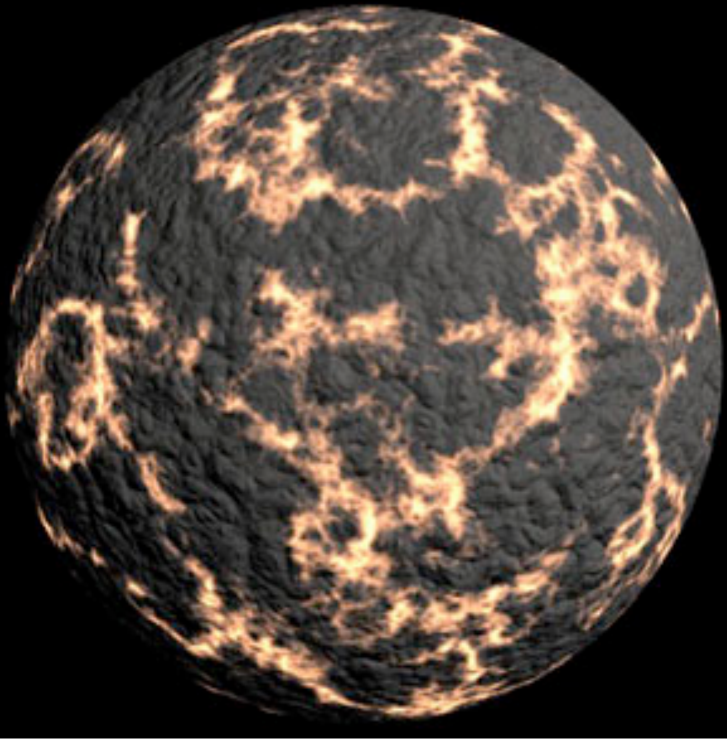

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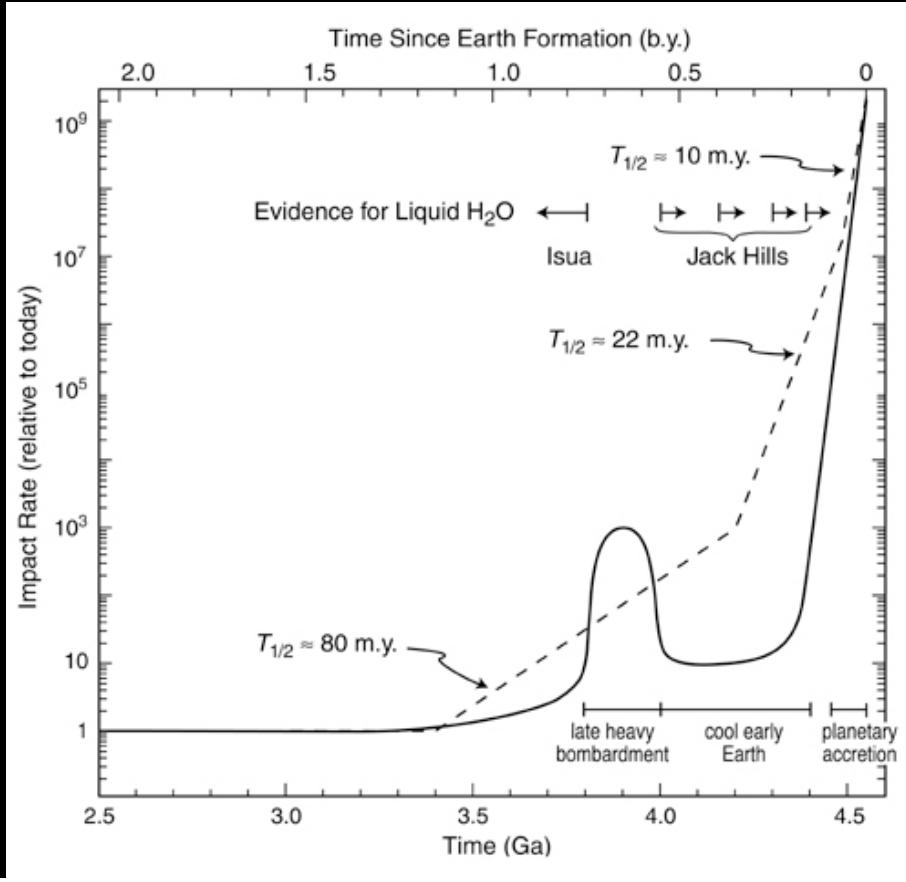

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By the end of this period the Earth was nearly its present mass and the surface was mostly solid.

What about the Moon?

- Our moon is much larger relative to Earth than any other moon to a major planet
- Helps stabilize our rotation axis
  Therefore, seasons not extreme
- How did this happen? Would it be likely to happen elsewhere?

Not Everyone Likes the Moon...

- Alexander Abian, late Iowa State math prof
- Said destroying the moon would give us eternal spring, remove hurricanes!
- Thoughts???

http://wearscience.com/img450/destroy_the_moon.gif

Formation of the Moon and Late Heavy Bombardment

Evidence:

- Moon has less iron than Earth
- Moon’s orbit was much closer to Earth in past
- Moon’s rocks contain little gaseous material

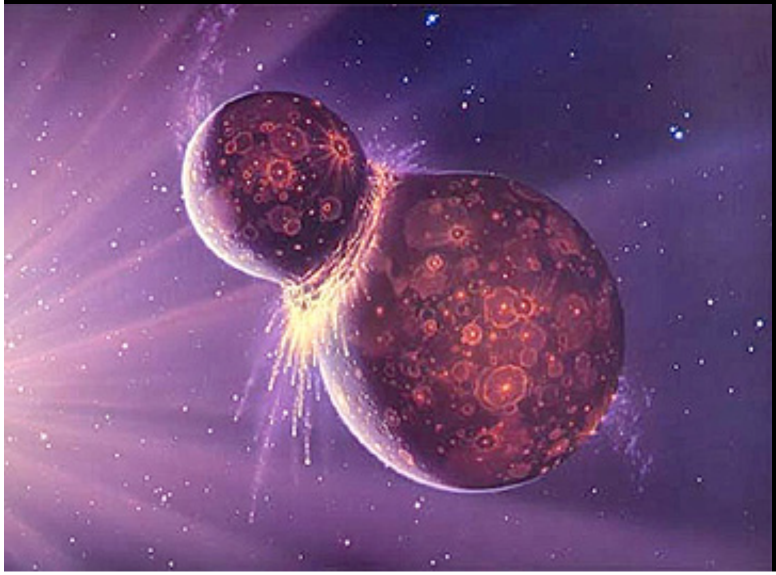
What could have caused this?

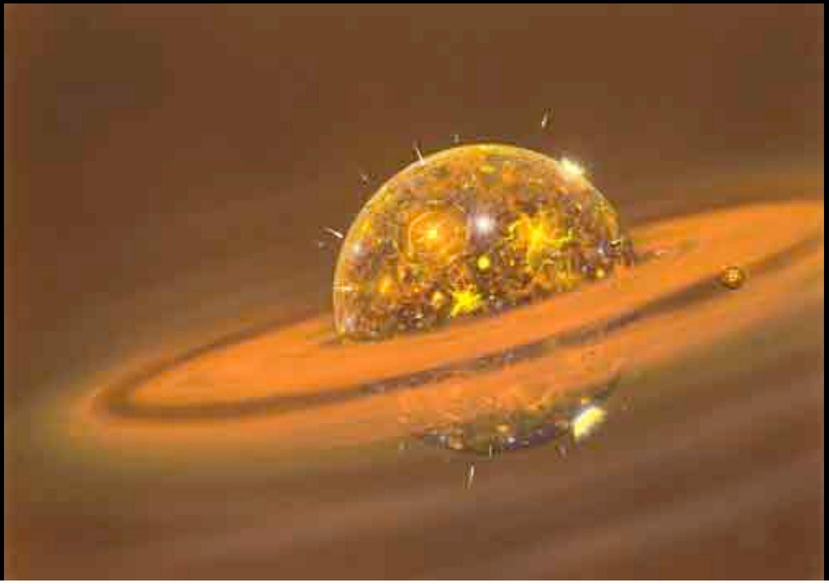
Formation of the Moon and Late Heavy Bombardment

At around 70 Million years, the Moon was created by the impact of a Mars-sized body

It was a glancing impact which threw material into orbit around the Earth.

That material collected together to become the Moon

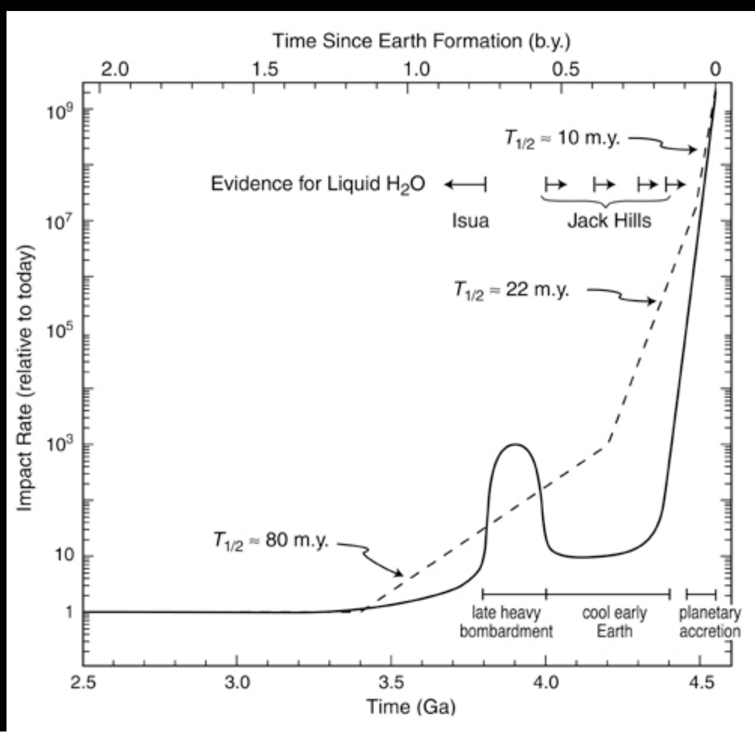




Formation of the Moon and Late Heavy Bombardment

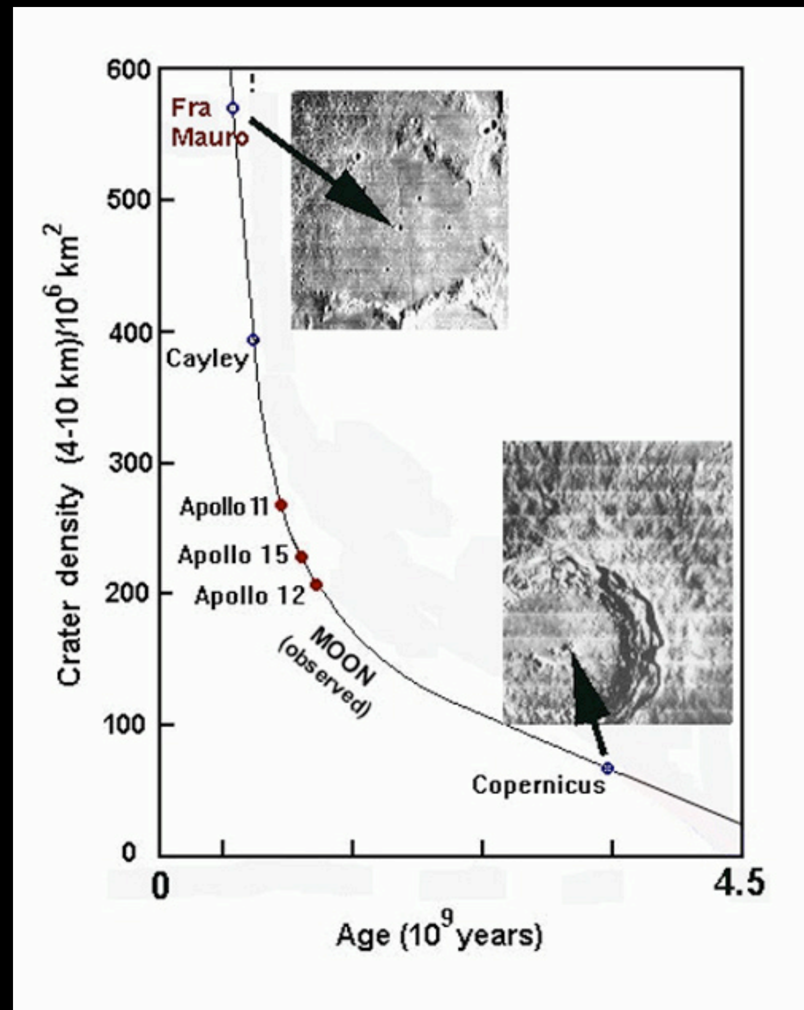
After its formation, the Moon's surface became a record of the continued bombardment of the Earth.

The big Maria on the Moon are evidence of a period of heavy impact activity around 3.9 Billion years ago



Decreasing Rate of Impacts

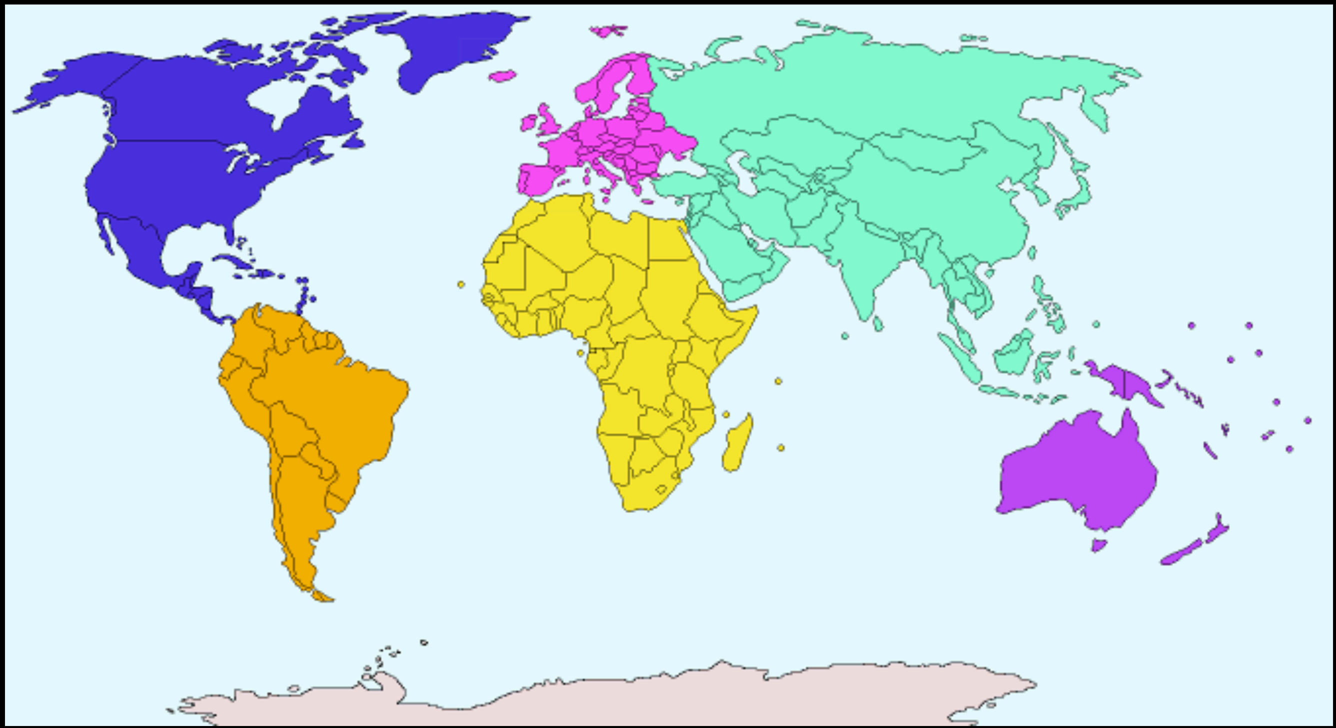
- Rate of impacts has gone down a lot
- Early Earth: no place for life
- Later, although impacts happened, not enough to wipe out all life
- Probably a general feature of planet formation



http://ircamera.as.arizona.edu/NatSci102/images/cramoon1.jpg

The Crust of the Earth

- Continents fit together like jigsaw pieces
- Coincidence, or does it tell us about Earth's crust?



http://www.naturalhistoryonthenet.com/Continents/images/continents.gif

Continental Drift

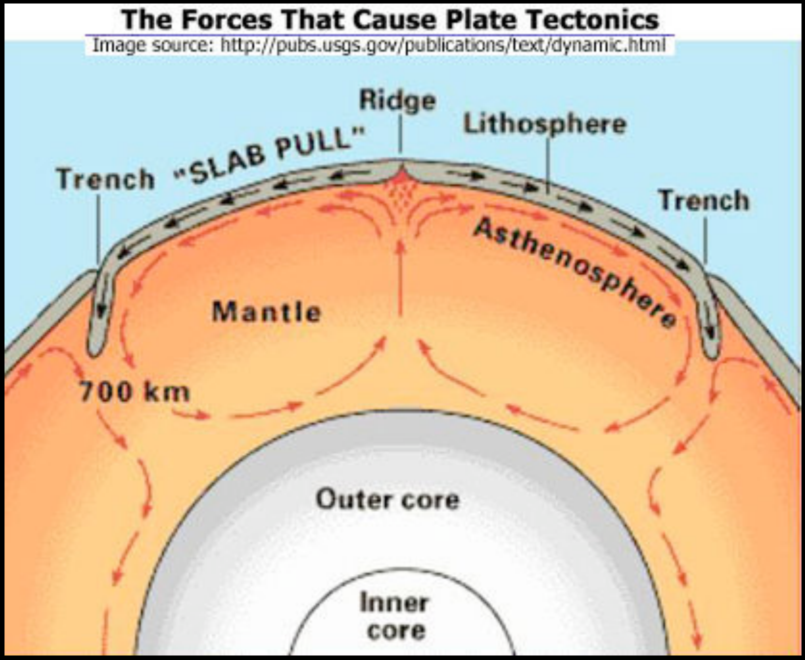
- Meteorologist
- Continental shelves of Africa, South America fit together even better
- Suggested continents drift all over Earth
  No physical mechanism
  How would light granite plow through dense basalt?
- Not believed, but idea kept alive

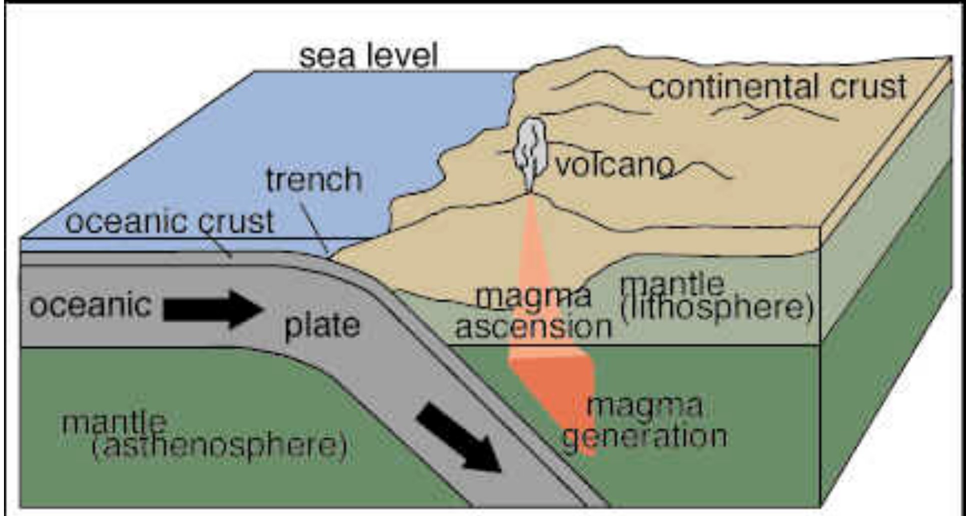
Alfred Wegener

http://upload.wikimedia.org/wikipedia/commons/0/07/Alfred_Wegener.jpg

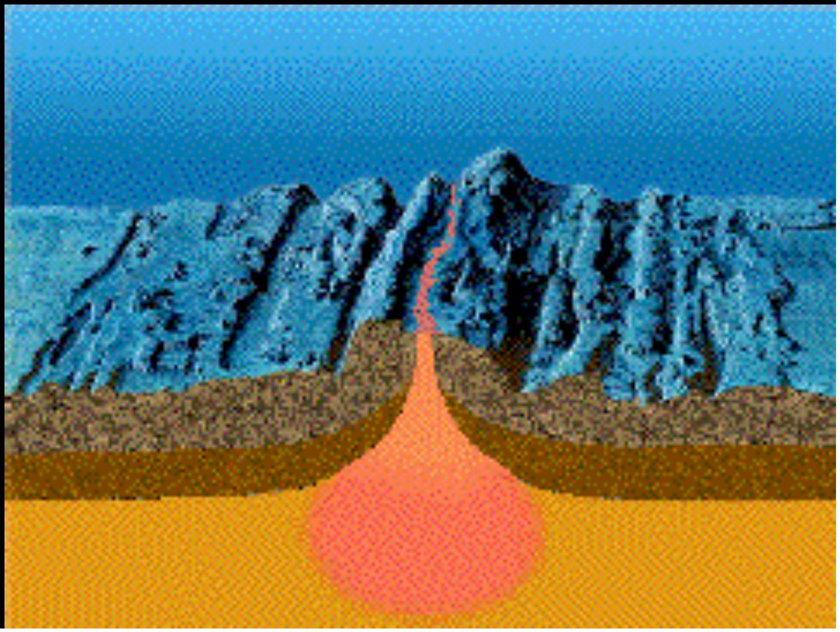
Continental Formation and Motion

The crust of the Earth – the continents sit on a molten interior with strong convection which drives the continents around.

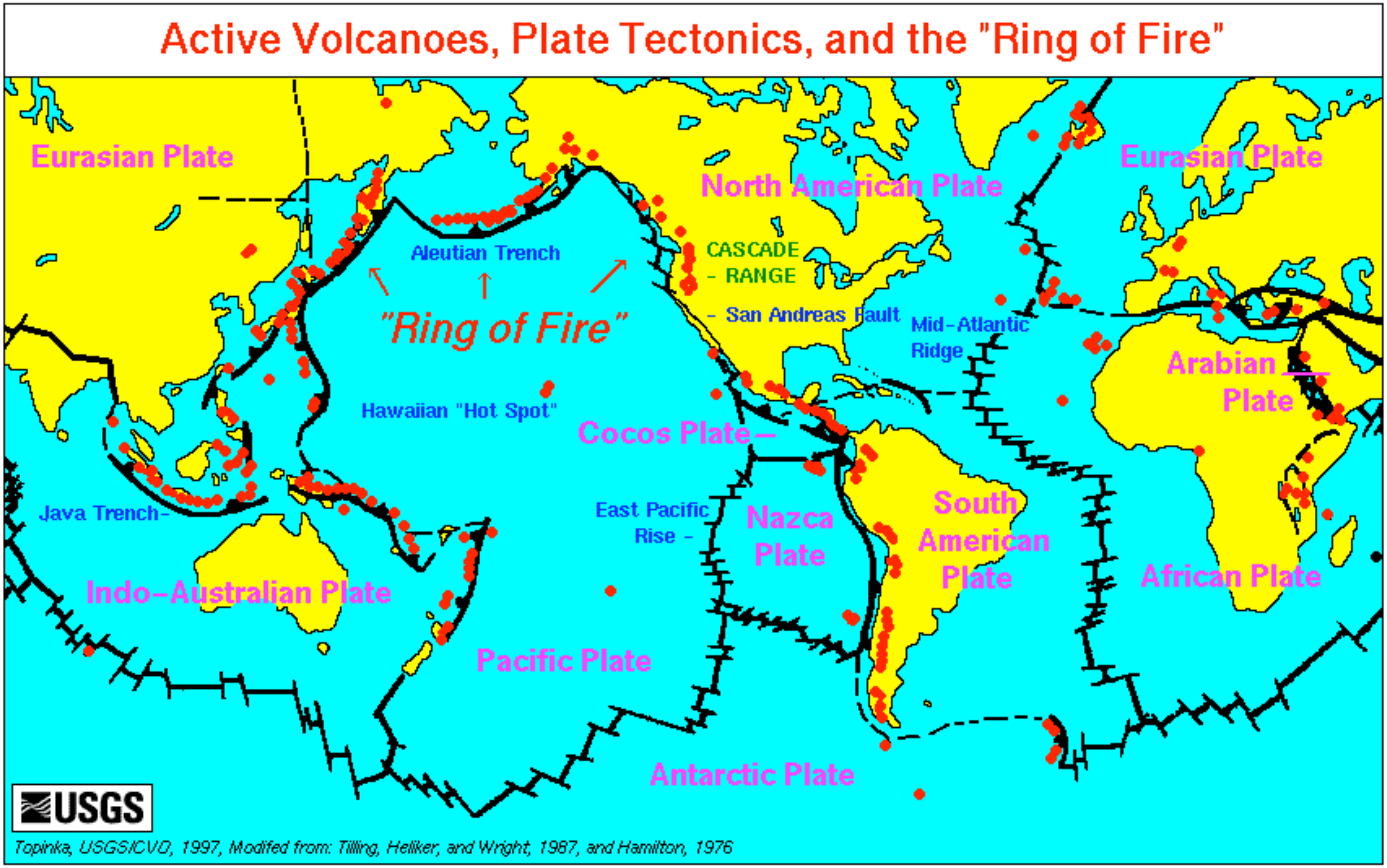




Magma is generated at subduction zones where dense oceanic plates are pushed under lighter continental plates.



Continental Formation and Motion



Continental Formation and Motion

Because of plate tectonics, the continents are reformed on the scale of a few 100 Million years

250 Million years ago, all of the current continents were in one big super continent, Pangaea.

Before that there were many other arrangements of continents.

Plate tectonics drives change. Keeps mixture of land and water covering the Earth.

Effects of Plate Tectonics

- Constantly changing environment may be an important driver for evolution
- Cycling of water may also play an important role

Perspective: Other Terrestrials

- No other terrestrial planet (Mercury, Venus, Mars, even the Moon if you like) has active plate tectonics
- Why not?

Perspective: Other Terrestrials

- No other terrestrial planet (Mercury, Venus, Mars, even the Moon if you like) has active plate tectonics
- Why not?
- Too small! Internal heat cools off too rapidly
- Is tectonics necessary for life?

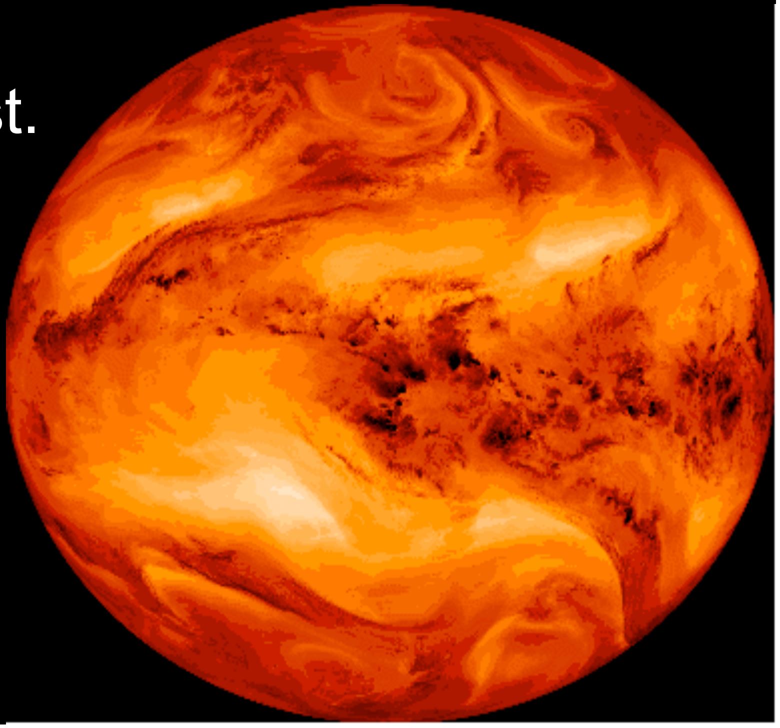
The Early Earth's Atmosphere

The Earth may have started with a Hydrogen atmosphere which it could not hold on to for long.

The lava surface outgassed carbon dioxide, sulfur dioxide, water and ammonia.

During the collision that created the Moon all of this atmosphere was lost.

The lava surface continued outgassing – restoring the atmosphere.

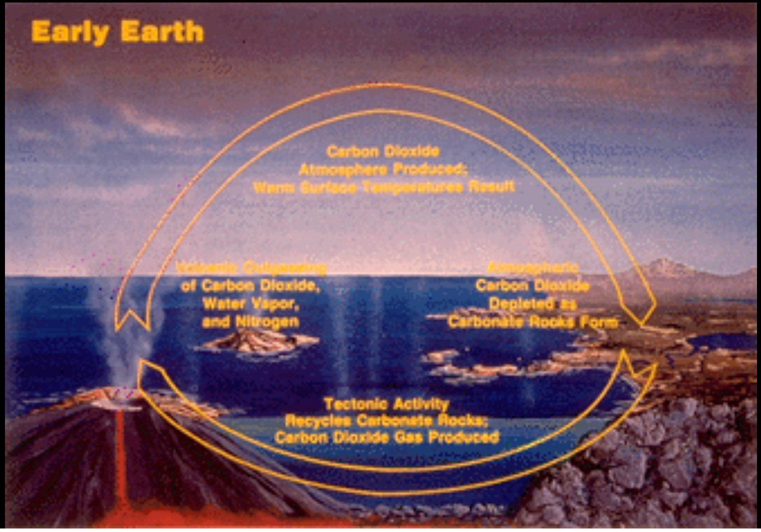


The Early Earth's Atmosphere

When the surface cooled sufficiently, water rained out to form seas, mountains grew.

Rainwater with dissolved CO_2 is a mild acid which erodes rocks

In the oceans, the CO_2 goes into carbonate minerals which form rock such as limestone over time.



The Early Earth's Atmosphere

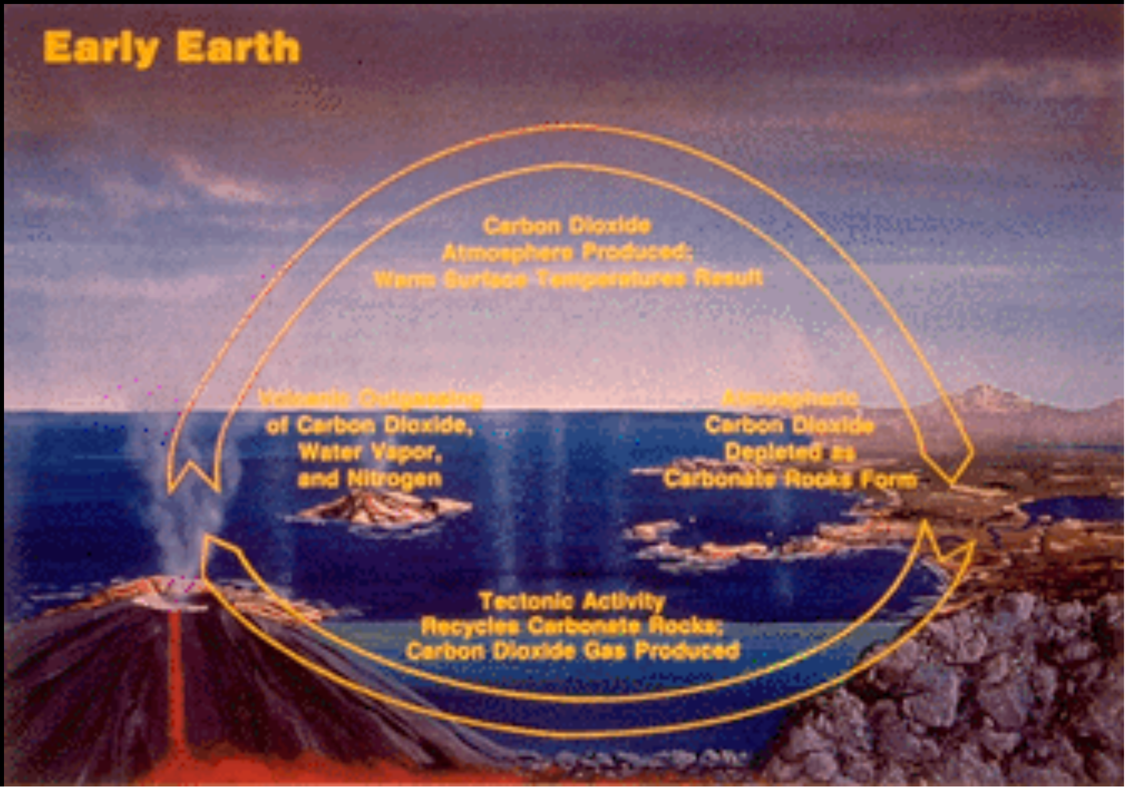
Amount of carbon dioxide tied up in rocks is comparable to the amount of CO_2 in the present Venus atmosphere!

The feedback loop of:

hotter => more water vapor => more rain => more acid rock erosion => more carbonate rock

may have regulated the amount of atmosphere in the early earth.

Until CO_2 was no longer dominant.



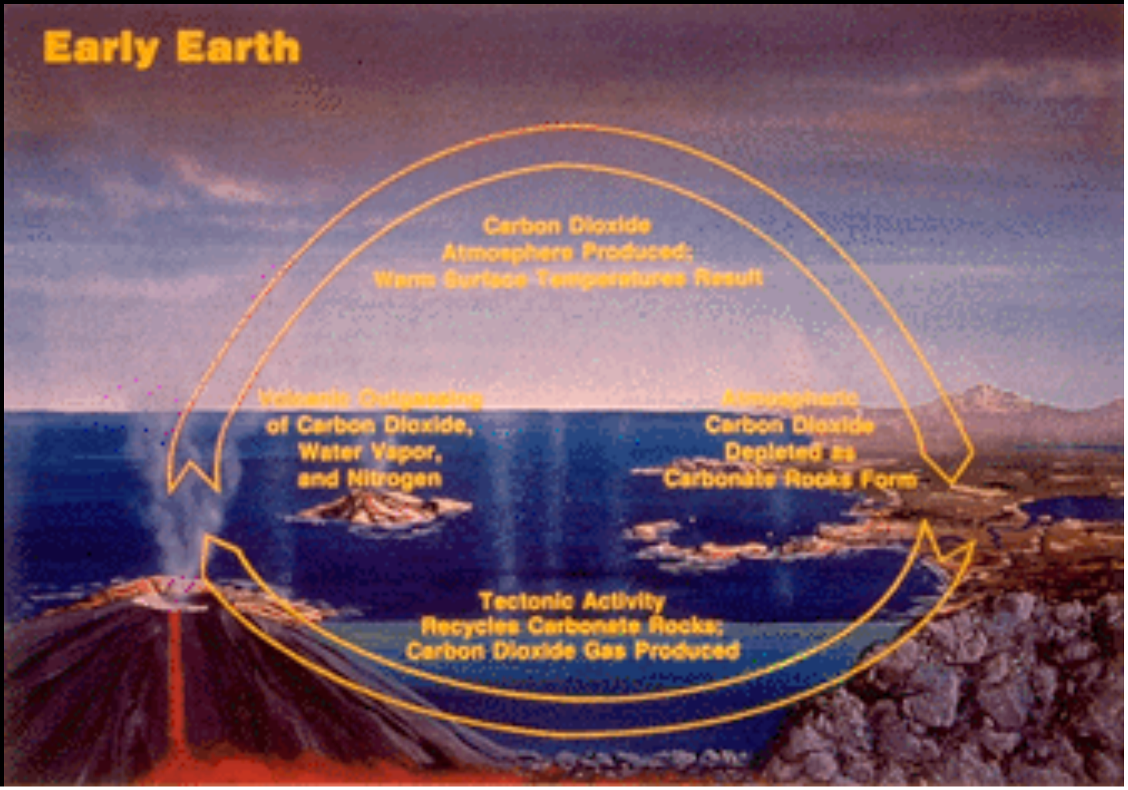
The Early Earth's Atmosphere

When life came along, this cycle was sped up by cells joining in locking up CO_2 into rocks

Then later turning CO_2 into O_2 when photosynthesis came along.

All along volcanoes dumped more CO_2 into the atmosphere.

Life arose in this CO_2 rich atmosphere --- not the present one



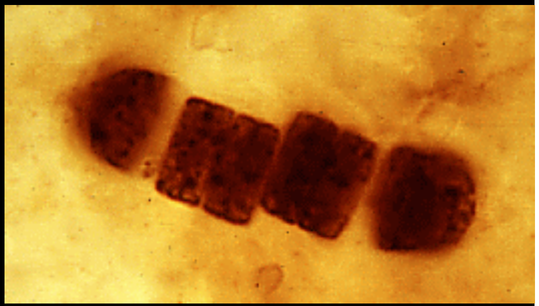
Life's Interaction with the Atmosphere

The Archean, from 3.8 B yrs ago to 2.6 B yrs ago

Bacteria that lived in a world with CO_2, methane, and ammonia atmosphere.

Limited fossil evidence.

Did their part by dying and locking up carbon into sedimentary rocks.



Life's Interaction with the Atmosphere

During the Proterozoic, free O_2 in the atmosphere rose from 1 - 10%. Mostly released by the cyanobacteria – fossils in stromatolites. Stromatolites are rocks made from millions of microscopic layers comprised of the remains of bacteria.

2.5 billion years ago
to 540 million years ago

By the end of this period there were oceans, continents, and surface temperature similar to today.

Specifics of our Solar System

- Low-eccentricity planets; extrasolar systems often have high eccentricities
- Our large moon stabilizes our rotation axis
  Never have super-extreme seasons
- Jupiter: might protect us from asteroids
  Or, might be Mafia protection: without Jupiter, would be planet at asteroid belt!
- Do you think these are critical to life?

Debate: Earth is Just Right

- Position 1: many aspects of Earth and the Solar System are crucial; without them, life would not be possible
- Position 2: not so! Life could originate in much different circumstances

What is important to life?

Energy

Liquid water

Atmosphere

Plate tectonics?

Moon?

What is important to intelligent life?

Photosynthesis?

A mix of land and oceans?

What else?

Summary

- Formation of terrestrials appears to require a reasonable amount of heavy elements
- In early solar system, sweeping up of debris meant a high collision rate
- Our Earth is large enough for plate tectonics