

# Origins of the Solar System, Earth, Oceans and Atmosphere



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## Precambrian Time Scale

Precambrian Eon (4567 years to present)	Chthonic Era (4567 years to 3800)	<ul style="list-style-type: none"> <li>Archaean (3.8 Ga to 4.5 Ga)</li> <li>Proterozoic (2.5 Ga to 541 Ma)</li> <li>Phanerozoic (541 Ma to present)</li> </ul>
	Archaean Era (4.5 Ga to 3.8 Ga)	<ul style="list-style-type: none"> <li>Archaean (3.8 Ga to 4.5 Ga)</li> <li>Proterozoic (2.5 Ga to 541 Ma)</li> <li>Phanerozoic (541 Ma to present)</li> </ul>
	Proterozoic Era (2.5 Ga to 541 Ma)	<ul style="list-style-type: none"> <li>Archaean (3.8 Ga to 4.5 Ga)</li> <li>Proterozoic (2.5 Ga to 541 Ma)</li> <li>Phanerozoic (541 Ma to present)</li> </ul>
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- ◆ Universe is between 13 and 14 Ga old, with estimates between 10 and 20 GA
- ◆ Solar System is about 4.6 Ga old
- ◆ Earth is about 4.6 Ga old
- ◆ Oldest terrestrial rocks are about 4.3 Ga old
- ◆ Precambrian represents about 88% of earth's history

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## Origin of the Solar System



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Any theory for the origin of the solar system, must explain the main observable features of the solar system:

- ☆ All planets revolve around Sun counterclockwise
- ☆ All planets except Venus rotate on axis counterclockwise
- ☆ All planets orbits lie in plane of ecliptic
- ☆ Axes of planets except Uranus perpendicular to ecliptic
- ☆ Compositional variation (Inner planets - Terrestrial; Outer planets - Gaseous)

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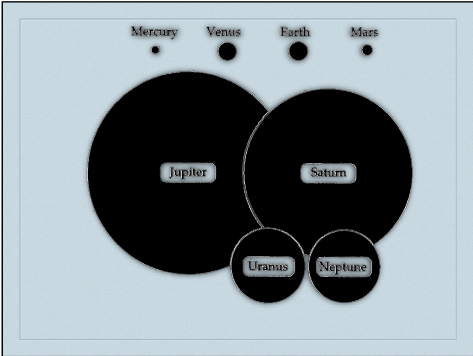
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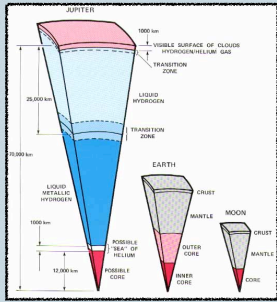
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Gas Giant Interior



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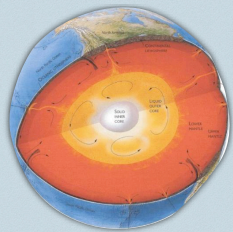
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The Earth's Interior



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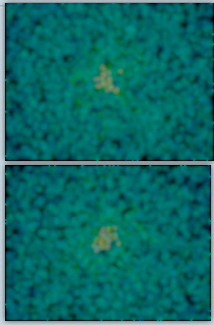
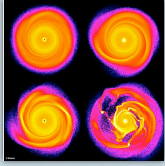
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Collapsing  
Nebula



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Origin of the Planets



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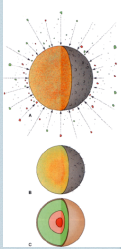
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- ★ Start with a cool and solidified Earth of uniform composition
- ★ Compression & short-lived radioactive isotopes heat interior
- ★ Heavy metals (Fe/Ni) melt and sink to the core
- ★ Light elements (Ca/Na/K) and silicates float to form mantle and crust
- ★ Problem: Unlikely that enough heat could be generated to remelt the Earth

Cold Protoplanet



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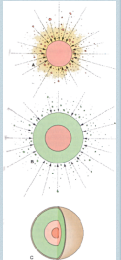
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Hot Protoplanet

- ★ Core/mantle/crust condensed in sequence
- ★ Ni/Fe condense at higher T than silicates to form the core
- ★ Ca/Na/K, silicates condense at slightly lower T to form mantle and crust



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# Meteorites

- ✧ Meteorites are material left over from the creation of the solar system and have ages of 4.4 to 4.6 Ga.
- ✧ For the first 700 Ma the earth was probably subjected to major meteorite bombardment as the solar system was cleared of remaining pieces of solid material not already assimilated into planets or moons.
- ✧ Evidence for this:
  - ✧ Lunar maria are huge basalt flows representing impact scars of huge meteorites
  - ✧ Rest of moon scarred by smaller meteorites
  - ✧ Dates of rocks associated with large lunar craters are 4.0 to 4.6 Ga.
- ✧ Why no evidence on earth?

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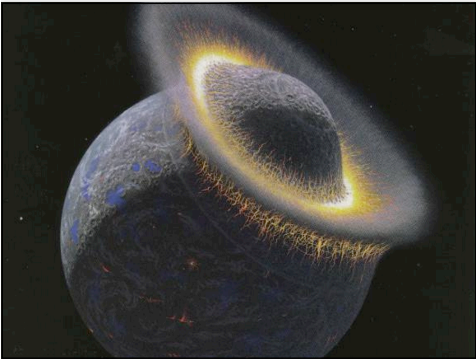
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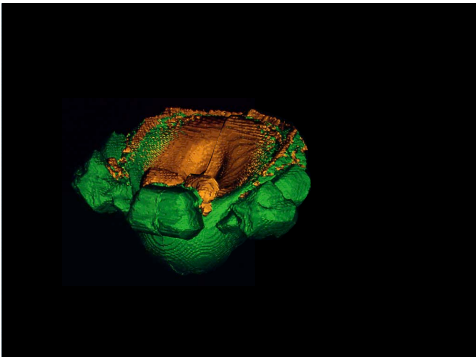
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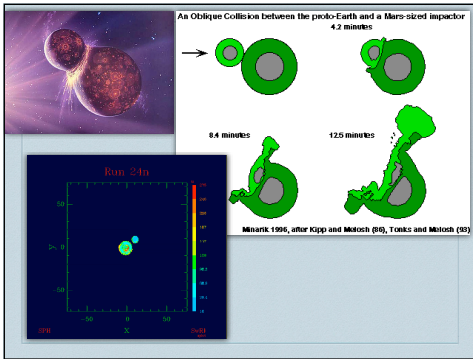
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### Earth's Early Crust

	Oceanic Crust	Continental Crust
First appearance	About 4.5 ga	About 4.0 ga
Where formed	Ocean ridges	Subduction zones
Composition	Komatiite-basalt	Tonalite-granodiorite
Lateral extent	Widespread	Local
How generated	Partial melting of ultramafic rocks in upper mantle.	Partial melting of wet mafic rocks in descending slabs.

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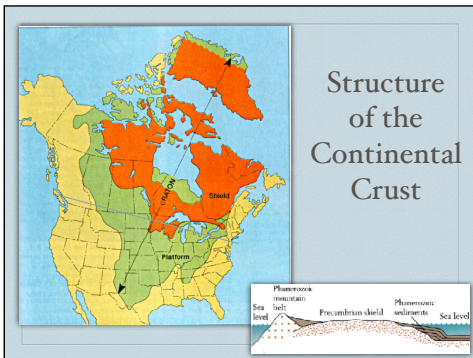
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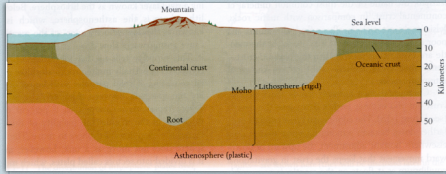
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# Craton Anatomy



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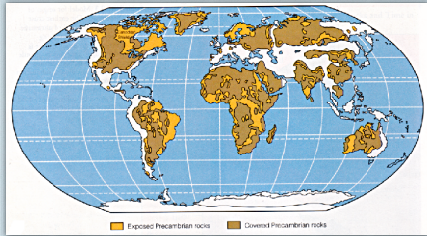
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The Age Structure of the North American Craton

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## Origin of the Atmosphere

### ★ Archean

- ★ Incredible outpouring of igneous rocks. Hundreds of thousands of cubic miles of granitic and basaltic rocks.
- ★ Early on sedimentary rocks are rare, but when they first start to appear they are "dirty", i.e. no multicycle sedimentary rocks.
- ★ Early in Archean there are no evaporites such as halite, gypsum or anhydrite.
- ★ Pyrite (FeS) and Uranite (US) are present in shallow water as detrital grains, so they were forming at the surface.
- ★ Starting about 3.5 Ga we see the first carbonate rocks, the *stromatolites*. These are formed during the growth of blue-green algae (*cyanobacteria*). These are photosynthetic, so it is the first evidence of release of O<sub>2</sub>.

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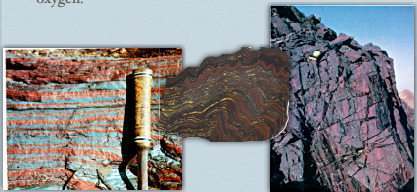
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### ★ Archean

- ★ Starting about 3.1 Ga we see the first Banded Iron Formations (BIFs). BIFs are cherts that contain alternating bands of oxidized iron (FeO) and bands that contain unoxidized iron (Fe<sup>+</sup>) and minerals that cannot form in the presence of free oxygen.



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### ★ Proterozoic (2.5 Ga to 5.4 Ma)

- ★ 2.5 Ga - First evidence of glaciation
- ★ 2.7 Ga - First evidence of eukaryotes (biomarkers in ancient oil)
- ★ 2.7 - 2.4 Ga - Great increase in stromatolite diversity and abundance. Indicates a much greater influx of oxygen into ocean water.
- ★ 2.4 - 2.3 Ga - Last surface pyrite and urinate crystals. Also time of last abundant BIFs.
- ★ 2.1 Ga - First eukaryotic body fossils - *Grypania*
- ★ 2.0 Ga - First terrestrial red beds. These are fluvial and lacustrine shales in which abundant iron appears in the oxidized form. These indicate the first 'abundant' atmospheric oxygen and may be 1% to 3% of PAL.



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☆ **Proterozoic** (2.5 ga to 5.4 ma)

- ☆ 1.9 Ga - First widespread, large-scale carbonate deposits and first abundant clean quartz sandstones.
- ☆ 1.6 Ga - First abundant terrestrial red beds.
- ☆ 1.6 Ga - End of the BIFs.
- ☆ 1.4 Ga - Sedimentary sulfates (such as gypsum) begin to appear in the record.
- ☆ 0.6 - 0.5 Ga - Stromatolites sharply decline in abundance.

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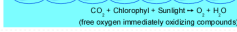
**Origin of the Atmosphere**

Phase 1 - 4.6 to 4.0 GA  $H_2, He, CH_4, NH_3, H_2O, CO_2$

Phase 2 - 4.0 to 2.5 GA  $CO_2, N_2, H_2O$

**Photochemical dissociation**

UV rays +  $H_2O + NH_3 + CH_4 \rightarrow N_2 + CO_2 + O + H_2$  (which bleeds off into space)



Phase 3 - 2.5 GA to Today  $CO_2, O_2, N_2, H_2O$

**Photosynthesis**  $CO_2 + \text{Chlorophyl} + \text{Sunlight} \rightarrow O_2$

**Respiration**  $O_2 + \text{Animal} \rightarrow CO_2$

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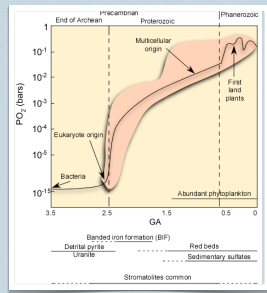
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