Early Earth History

339 Hadean bombardment
Key Events of Hadean (4.5-3.8 by)

• Earth Accretes (4.55)
• Earth Differentiates
• Moon forms from giant collision (all by about 4.45 by)
• Oceans and early atmosphere (anoxic) form
• ‘Magma ocean’ in mantle and thin skin tectonics
Accretion of Planets

- Earth accretes about 4.55 by ago
Layers in Earth
(from seismic waves, based on density)

- crust (5-60 km thick)
- mantle (2900 km thick)
- core (3500 km radius)
  - outer 2/3 is liquid
  - inner 1/3 is solid

• Earth differentiates within <100 my
Formation of the Moon

Fig. 17-2. Cartoon illustrating formation of the moon

- Moon forms after giant impact (lack of high Fe -> after Earth core has formed)
• Frequent impacts during Hadean
Heat Production in the Earth

Assumes present
Th/U=4, K/U = 10000

• greater heat production than today
• Earth interior much hotter during Hadean -> 'magma ocean' in upper mantle, thin skin tectonics
• Oldest rocks (4.0 by) were initially sediments deposited in an ocean
Conditions on Early Earth

Temperature

• Intense Bombardment by asteroids
• Sun was less luminous than today
• Liquid water present, but temperature not well constrained

Atmosphere

• Contained N2, CO2, CH4 (?)
• Lacked free O2
• No Ozone (O3) layer to screen UV from sun
Key Events of Archean (3.8-2.5 by)

- Life appears (prokaryotes before 3.5 by)
- Eukaryotes probably evolve (biomarkers found at 2.7 by)
- Present style of plate tectonics begins (2-3 by)
- O2 in atmosphere is very low
Possible sequence for origin of life

Hydrothermal systems (source of primordial soup?)
- have persisted through geologic time
- can synthesize amino acids inorganically
- provide source of hydrogen for metabolism
- have thermophiles (archaea that love high temperature)

Scenario
- Molecules needed are synthesized inorganically
- They are assembled into a structure
- Structure figures out how to catalyze reactions and extract energy
- Structure becomes self-replicating (probably RNA world at first)
- Clay minerals may have served as a template

Life appears (>3.5 by ago)
Stromatolite
Warawoon Fm
Western Au 3.5 by
Cyanobacteria (prokaryote) - a living stromatolite
Key Events of Proterozoic (2.5-0.5 by)

• Oxygen rises substantially about 2.2 by ago
• Earth endures a great ice age (about 2.3-2.0 by)
• Metazoans develop (Ediacaran Fauna, multi-cellular, prior to 1.1 by)
• Supercontinent Rodinia forms (Grenville orogeny about 1 by)
• Earth again gripped in great ice age (snowball Earth) with glaciers extending nearly to equator (probably several events 0.8-0.6 by)
• Rodinia breaks up
• Earth emerges from snowball state about 600 my)
Banded iron deposits can only form if O2 is low.
Hammersley, Australia
(2.2 by banded iron)
Banded Iron Deposits through Time

- Atmospheric O₂ rises rapidly about 2 by ago

**Diagram:**
- Y-axis: 10^14 tons banded iron
- X-axis: Time before present (by)
- Bar graph showing the distribution of banded iron deposits over time.
• Redbeds abundant last 2 by
• Eukaryote fossils appear (about 2.2 by)
Earth plunges into a severe ice age

• Glacial deposits called tillites appear 2.3-2.1 by
What regulates atmospheric O2 abundance? (a dynamic system)

Kinetic Balances:

At steady state,

rate of input = rate of loss

so mass in reservoir does not change with time
The O2 Cycle Dynamics

Photosynthesis
CO₂ + H₂O ---> CH₂O (plant matter to bury) + O₂ (to atmosphere)

Respiration
CH₂O (plant matter not buried or weathered from rocks)
  + O₂ (from atmosphere) ---> CO₂ + H₂O

These reactions are nearly in balance.
• Kinetics of production (by organic carbon burial) and removal (by weathering) regulate O2 abundance.

• A change in the efficiency of either would change O2 abundance.
• metazoans evolve (>1.1 by)

Kimberella (Vendian)
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• Supercontinent Rodinia forms about 1.1 by (Grenville orogeny)

• Rodinia breaks up
• Severe ice age (0.8-0.6 by) 
  -> Snowball Earth