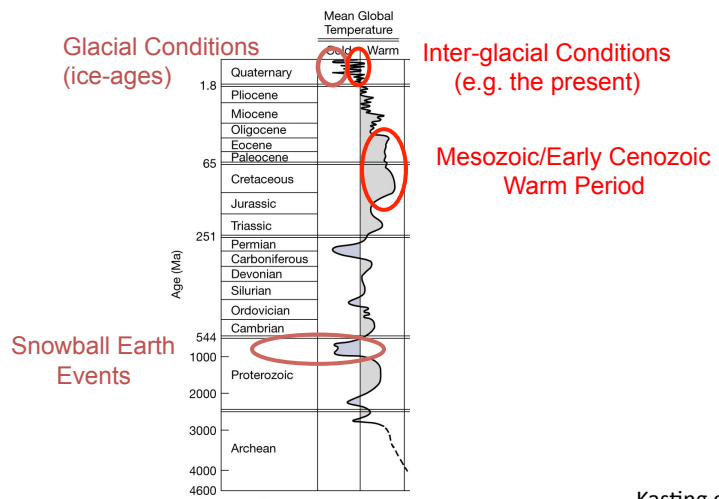
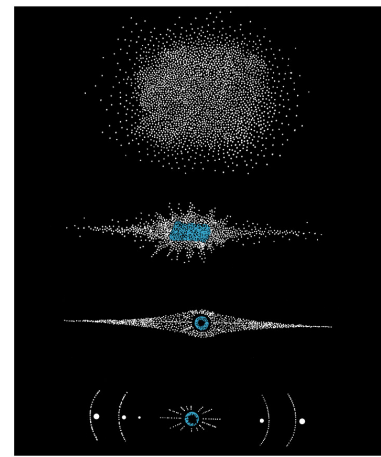


Descent into the Ice-Ages



Kasting et al



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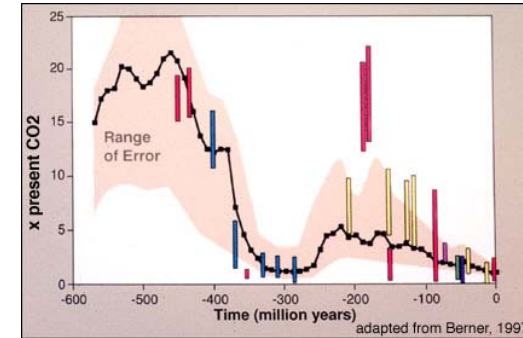
Stromatolites



Similar to those in the fossil record (3.5 Byr BP) that use anoxygenic photosynthesis

Atmospheric Carbon Dioxide

- Nature's *Long-term Carbon Cycle* is a balance between
 - Removal of CO₂ from the atmosphere by rock erosion (C goes into ocean/sediments)
 - Input of CO₂ from volcanoes
 - The former depends on climate (thus on CO₂); the latter depends on outgassing rate (plate tectonics)
 - Time scale of adjustment: millions of years.



Earth's Atmosphere Today

Permanent Gases			Trace Gases			
Gas	Symbol	Percent (by Volume) Dry Air	Gas (and Particles)	Symbol	Percent (by Volume)	Parts per Million (ppm)*
Nitrogen	N ₂	78.08	Water vapor	H ₂ O	0 to 4	
Oxygen	O ₂	20.95	Carbon dioxide	CO ₂	0.037	376* 394
Argon	Ar	0.93	Methane	CH ₄	0.00017	1.7
Neon	Ne	0.0018	Nitrous oxide	N ₂ O	0.00003	0.3
Helium	He	0.0005	Ozone	O ₃	0.000004	0.04†
Hydrogen	H ₂	0.00006	Particles (dust, soot, etc.)		0.000001	0.01–0.15
Xenon	Xe	0.000009	Chlorofluorocarbons (CFCs)		0.00000002	0.0002

*For CO₂, 375 parts per million means that out of every billion air molecules, 375 are CO₂ molecules.
 †Stratospheric values at altitudes between 11 km and 50 km are about 5 to 12 ppm.

Note: All of the trace gases are greenhouse gases!

Also important: aerosols - small particles of material in the atmosphere (dust, soil salts, soot, ...)

How do we explain the different climate of these three terrestrial planets?

Venus (runaway greenhouse) Earth ("just right") Mars (virtually no greenhouse)



Color	Orange	Blue	Red
Dist to Sun	108 x 10 ⁹ km	150 x 10 ⁹ km	228 x 10 ⁹ km
Surf. Temp	460°C	15°C	- 60 °C
Main Gas	CO ₂	N ₂ , O ₂	CO ₂
Surf. Pressure	93 bars	1 bar = 1000mb	0.06 bar