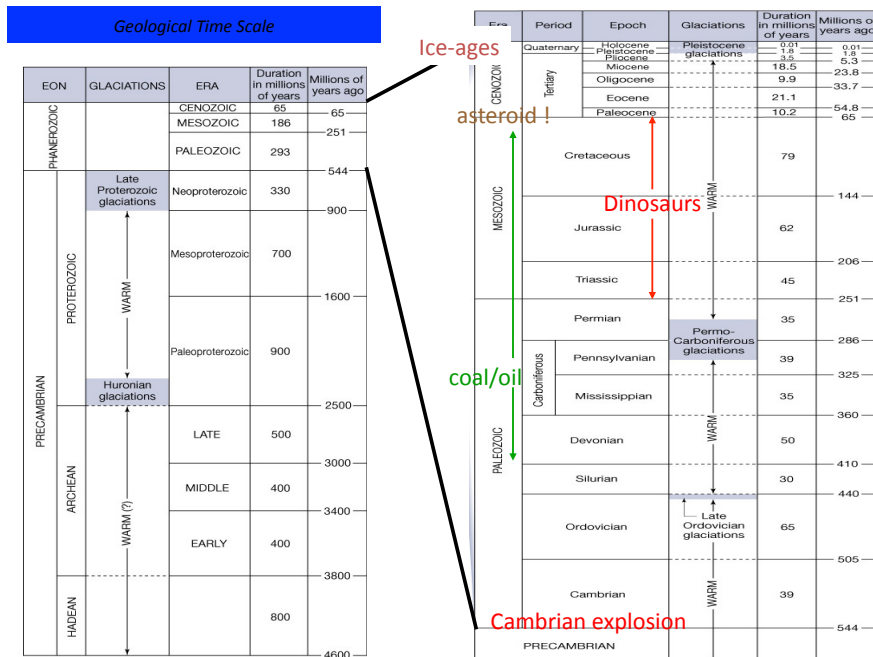
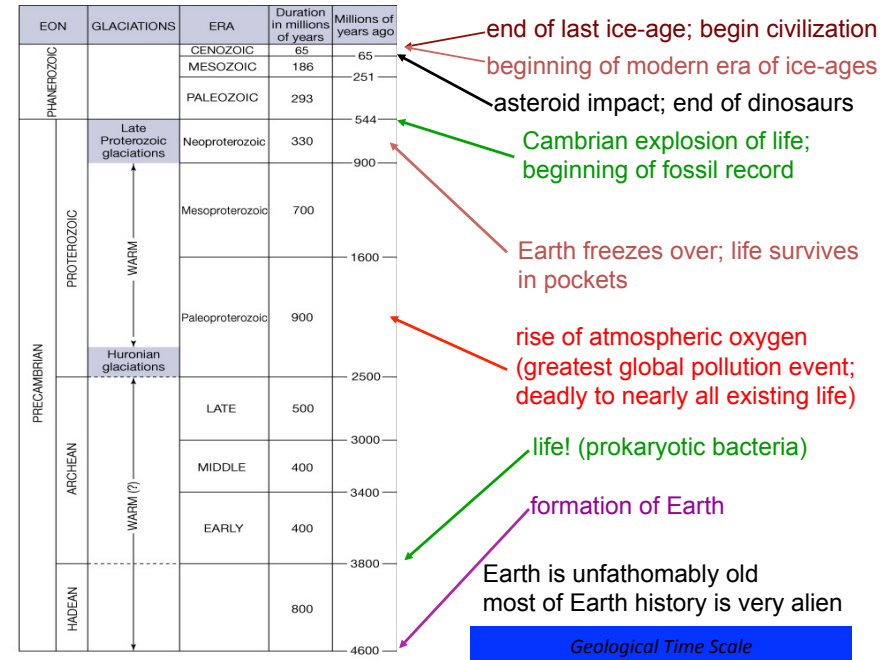
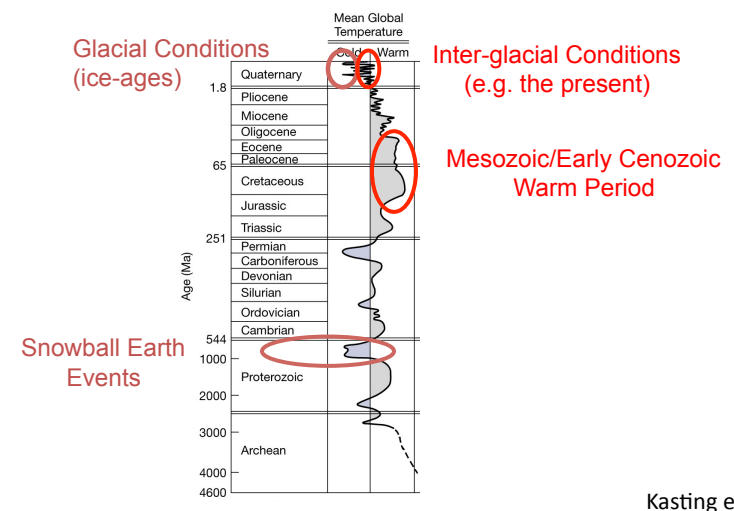


Evolution of the Earth's Atmosphere



Descent into the Ice-Ages



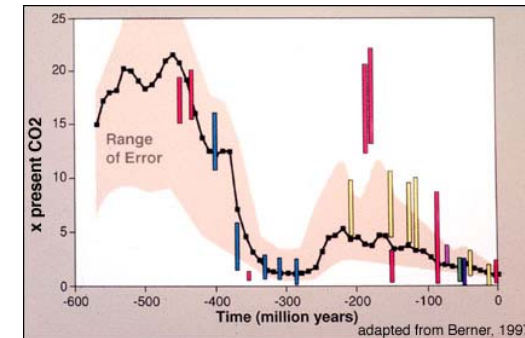
Stromatolites



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 CO_2 from the atmosphere by rock erosion (C goes into ocean/sediments)
 - Input of CO_2 from volcanoes
 - The former depends on climate (thus on CO_2); the latter depends on outgassing rate (plate tectonics)



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	0.037 375* 392
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.

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Note: All of the *trace* gases are greenhouse gases!

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

Grand 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