Earth History & Geobiology

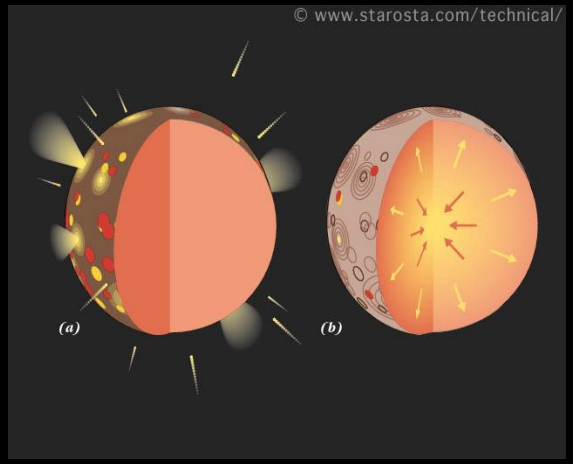
Chronology of the early Earth

4567 Ma: Formation of Solar system (Pb-Pb)	0
4530±10: Core segregation (Hf-W-U-Pb)	30-50
4480±20: Moon forming event (Rb-Sr)	70-110
4450±50: Accretion of Earth nearly complete	120±50
<4450±50: formation of the Atmosphere (I-Xe)	>120±50
4420±80: Formation of the oldest Crust (Sm-Nd)	140±80
4417 Ma: oldest minerals on Moon (Zircon)	150
4404 Ma: oldest minerals on Earth (Zircons from Aus)	163
4000 Ma: oldest preserved continental crust	570

Why does the Earth have so much water ?

Photograph courtesy of NASA. Image in the public domain.

Hydrogen loss



- accretion of the early earth due to impact of numerous planetesimals
- Thereby native iron was added to the >1000 ^{o}C hot surface.
- On the surface iron reacts with H_2O: $Fe^0 + H_2O = FeO + H_2$

- Even today on Earth (final size) H and He can escape,
- Only the two lightest elements can reach the escape velocity
- of ~ 40,300 km/h (11 km/s)
- The early earth had no magnetic field so solar wind reached
- earth surface enhancing the loss of the atmosphere

gas	mass
H_2	2
He	4
CH_4	16
CO_2	44
N_2	28
O_2	32
Ar	40

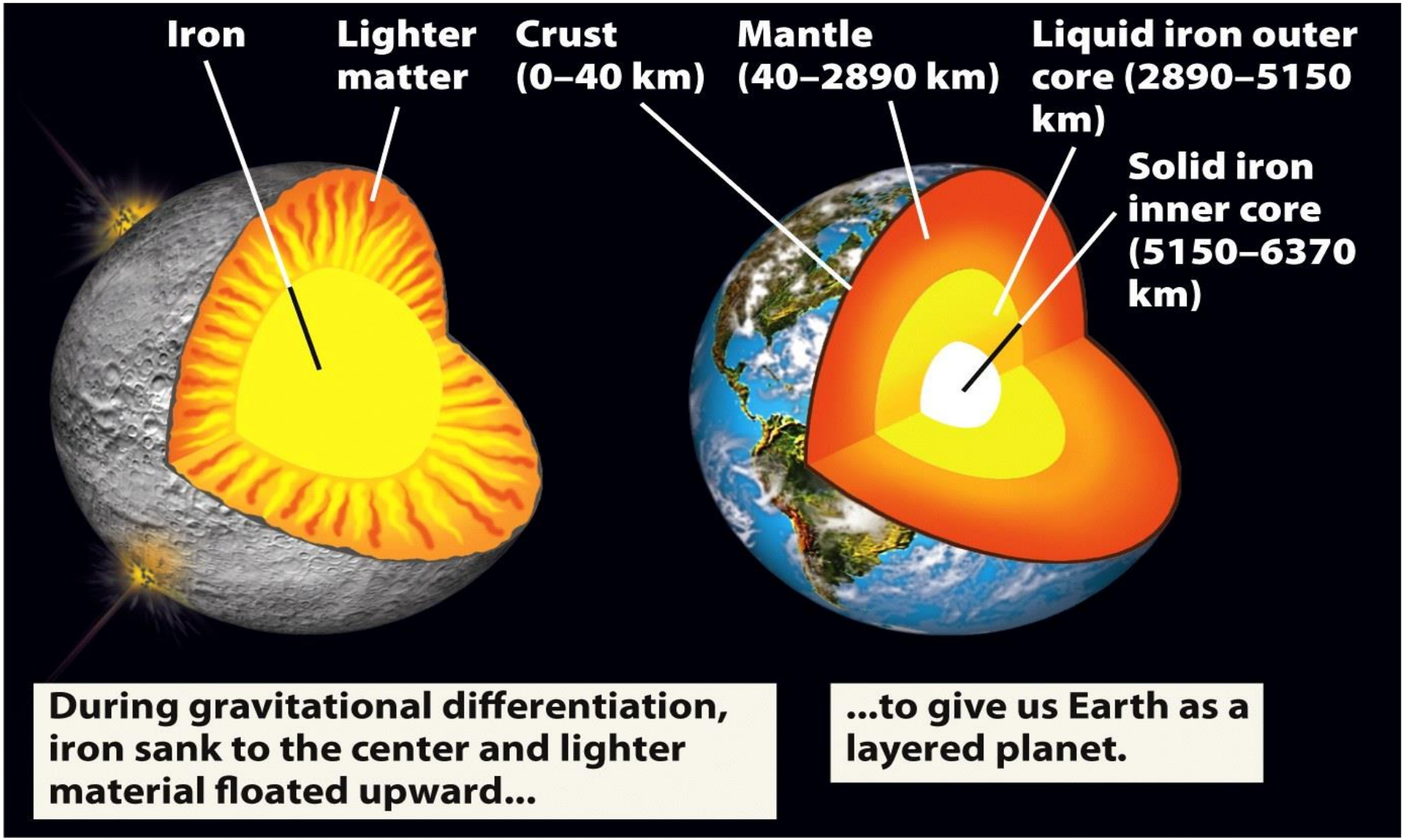
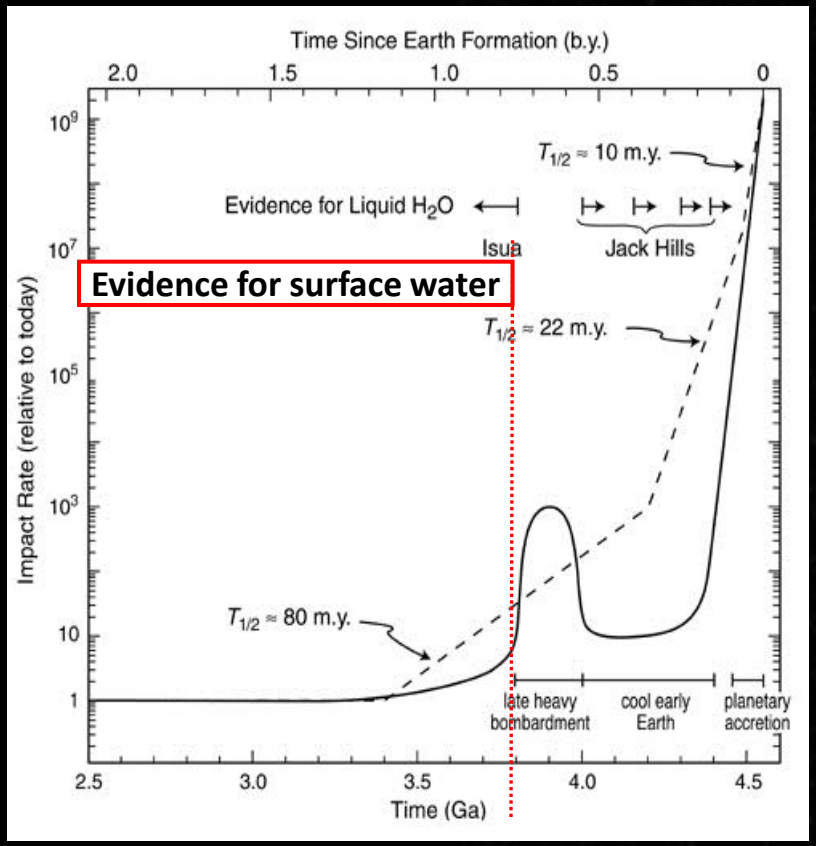


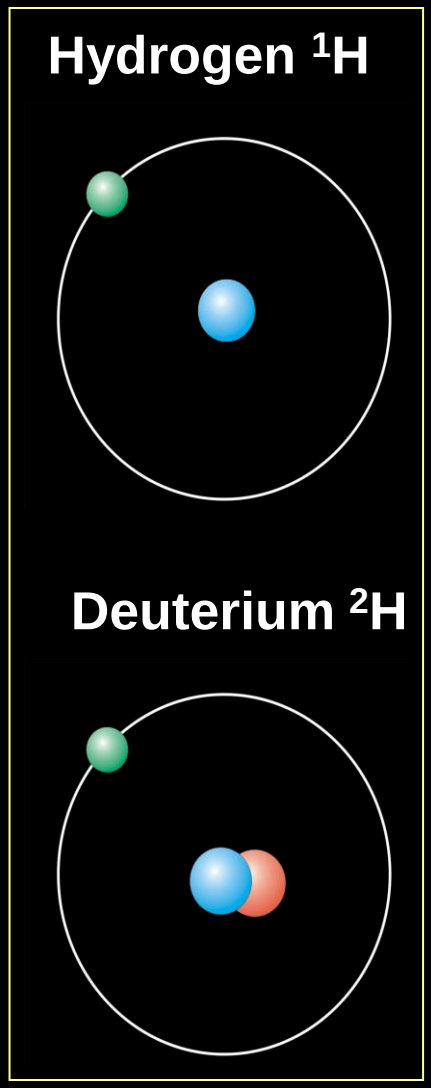
Figure 9.5
***Understanding Earth*, Sixth Edition**

Why does the Earth have so much water ?

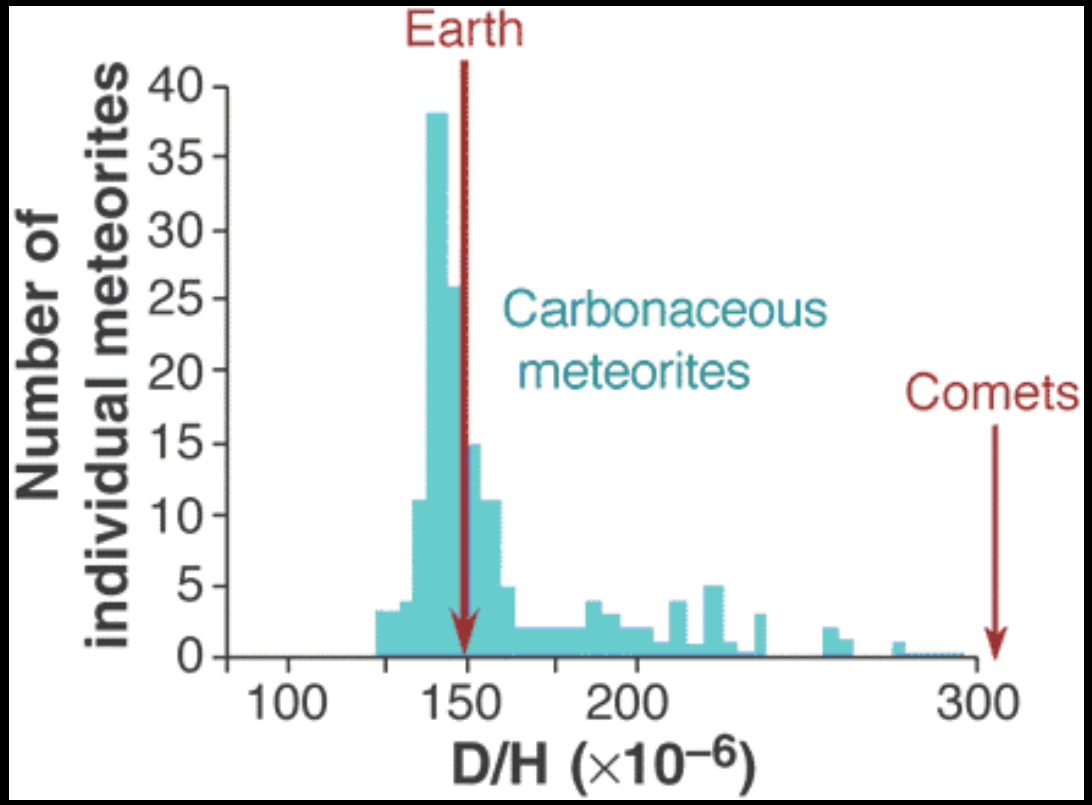


Photograph courtesy of NASA. Image in the public domain.

Likely added by a later event…



Likely most of the volatiles elements originate from meteorites



The D/H of comets is distinctive different from Earth

Comets are “dirty snowballs”, composed of dust and ice

Photograph courtesy of NASA. Image in the public domain.

Halley’s Comet

Artist's recreation of late heavy bombardment event removed due to copyright restrictions.

We think the water was added by the late heavy bombardment event.

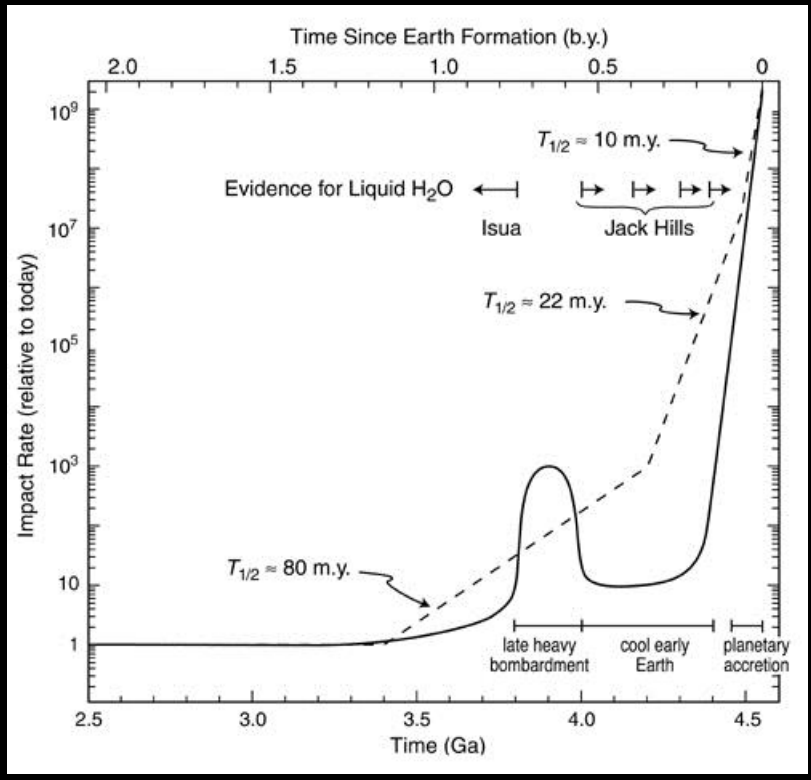
Impact rate on the Earth

Earth is to small during the main accretion event to retain hydrogen
H_2O react with Fe to FeO and H_2
→ depletion of H, noble gases etc.

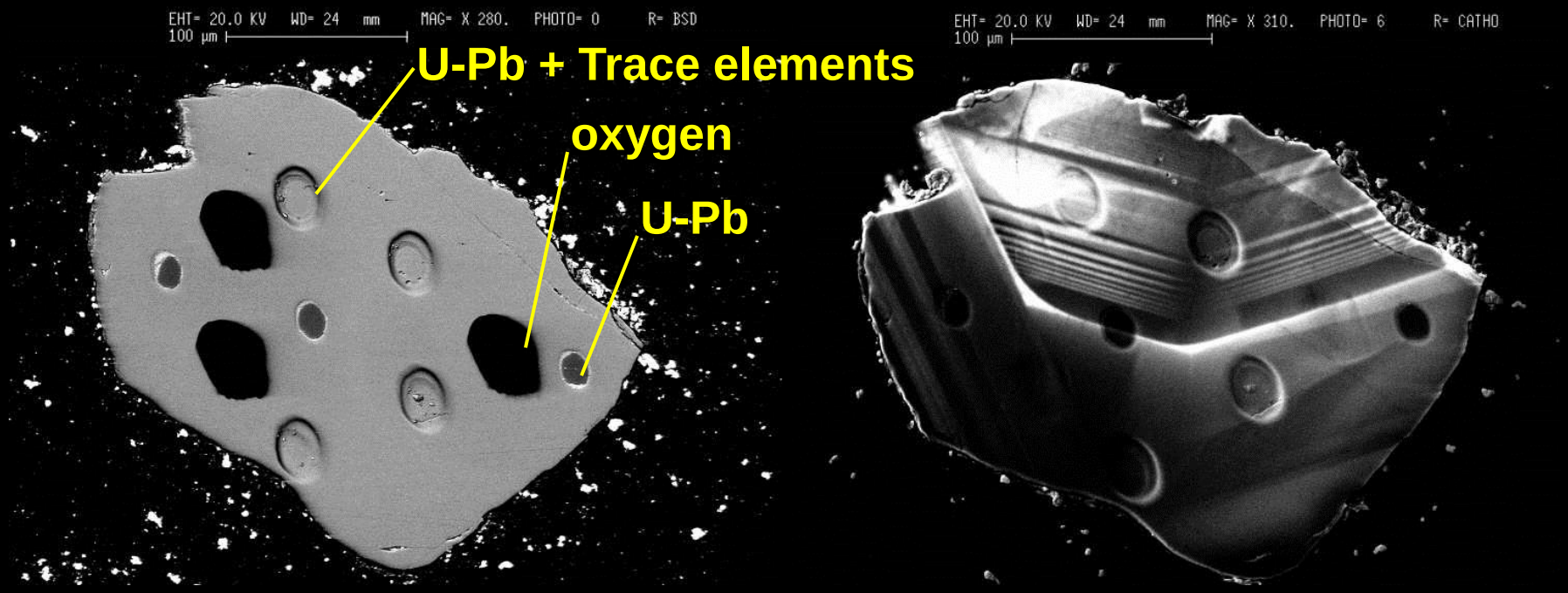
Giant impact add additionally energy –
Volatile elements get "lost in space"

Later addition of volatiles by a "late heavy bombardment"
Evidence for it are observed on the moon
(ages spectra of impact melts), indirect evidences on Earth.

"late heavy bombardment" might not happen
in all planetary systems

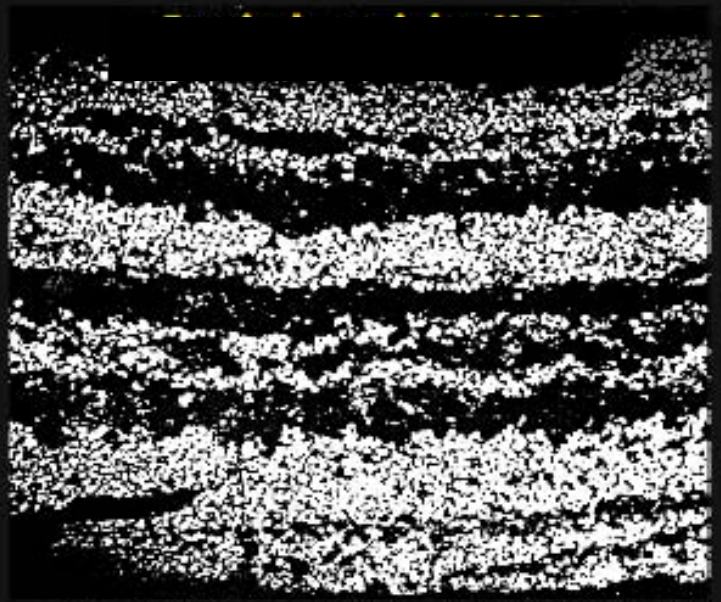


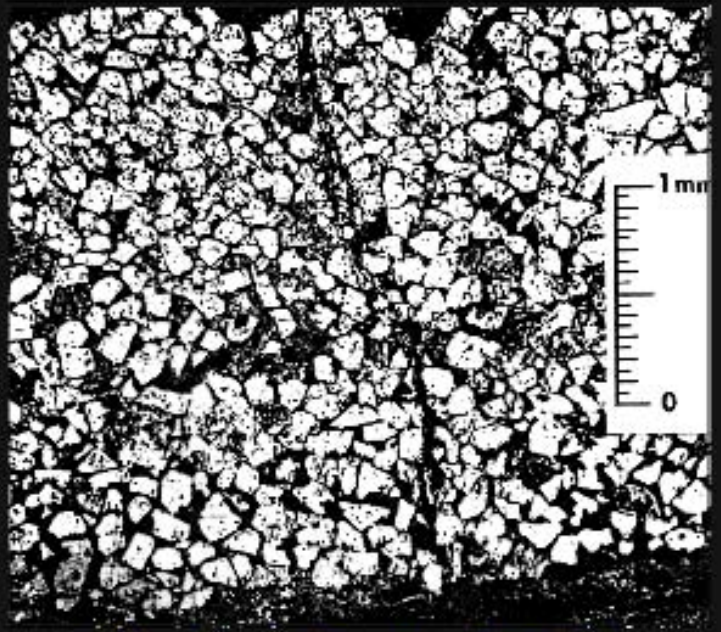
Analyses of oxygen isotopes in Zircons possible indicate presence of water at > 4 Ga



We formed a early earth but what were the condition on It?

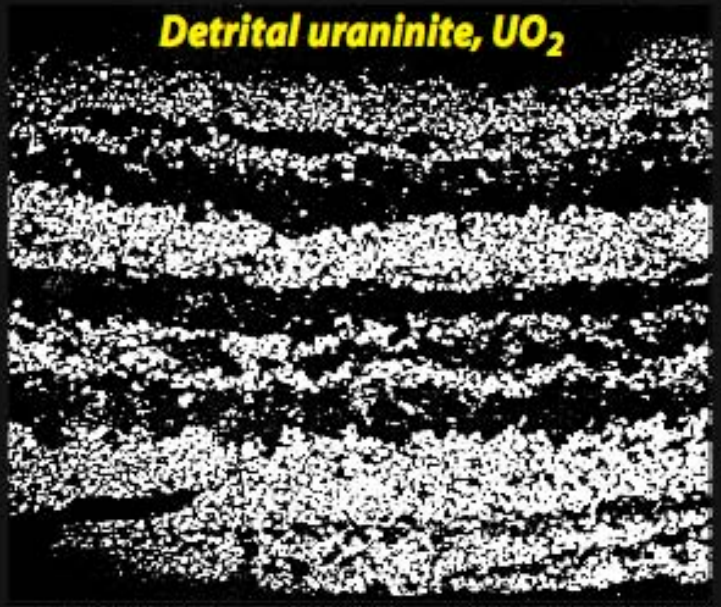
Courtesy of Brian Smallwood. Used with permission.

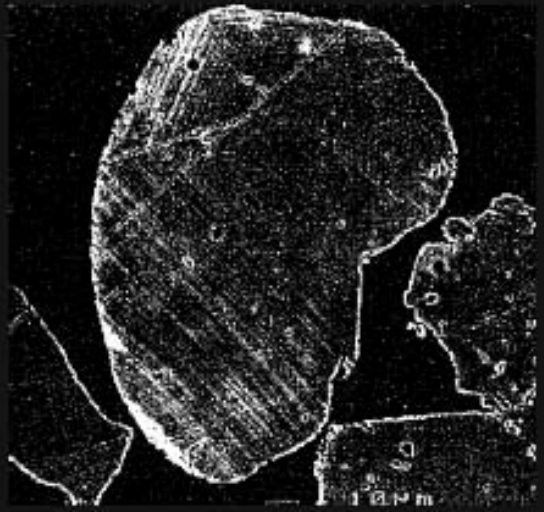




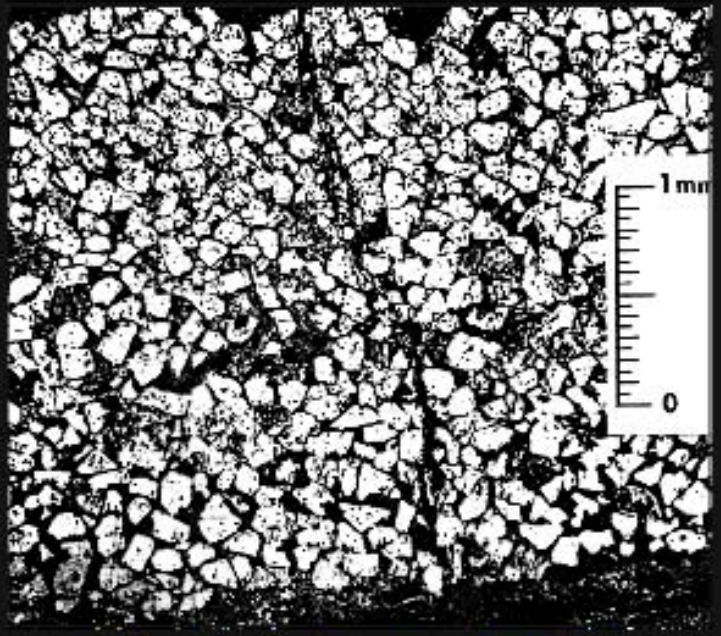
Huronian, Canada ~2.45 Ga

Detrital siderite, $FeCO_3$





Detrital pyrite, FeS_2
Pilbara, Australia ~3.25 Ga



Huronian, Canada ~2.45 Ga

Detrital siderite, $FeCO_3$
Pilbara, Australia ~2.75 Ga

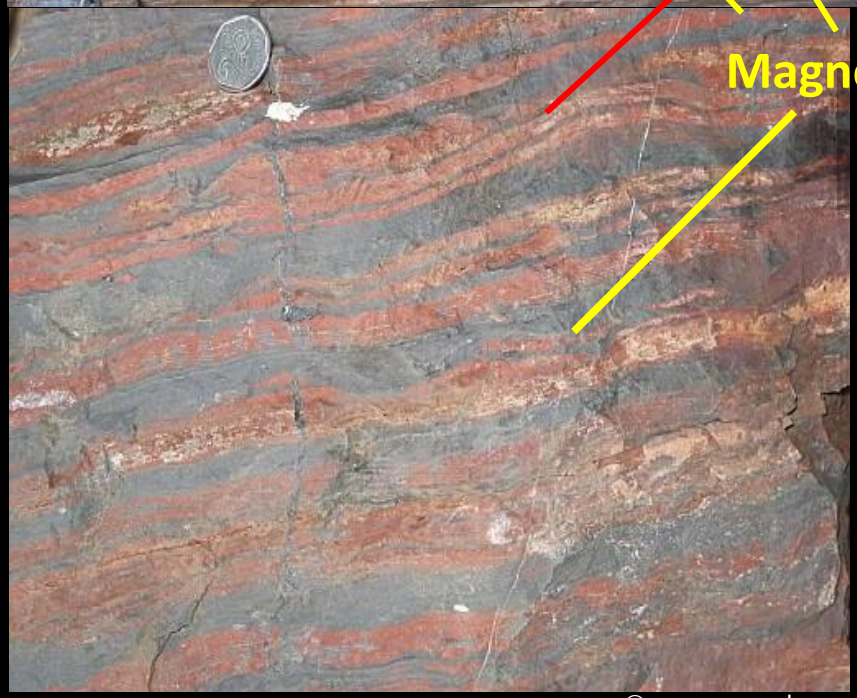
Detrital minerals that are unstable in the presence of "free" oxygen.

FeS_2

UO_2

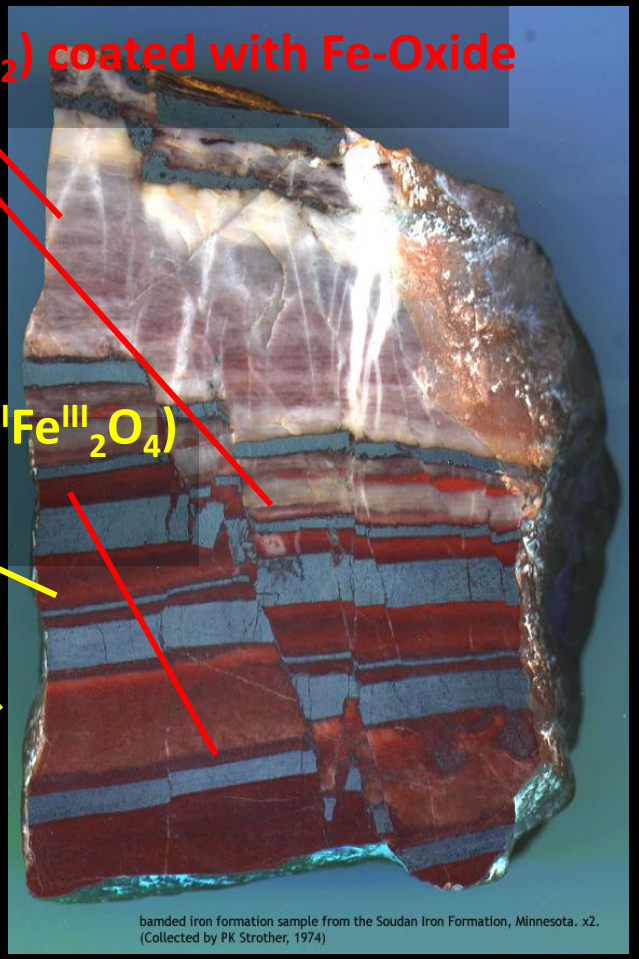
$FeCO_3$

BIF: Banded Iron Formations

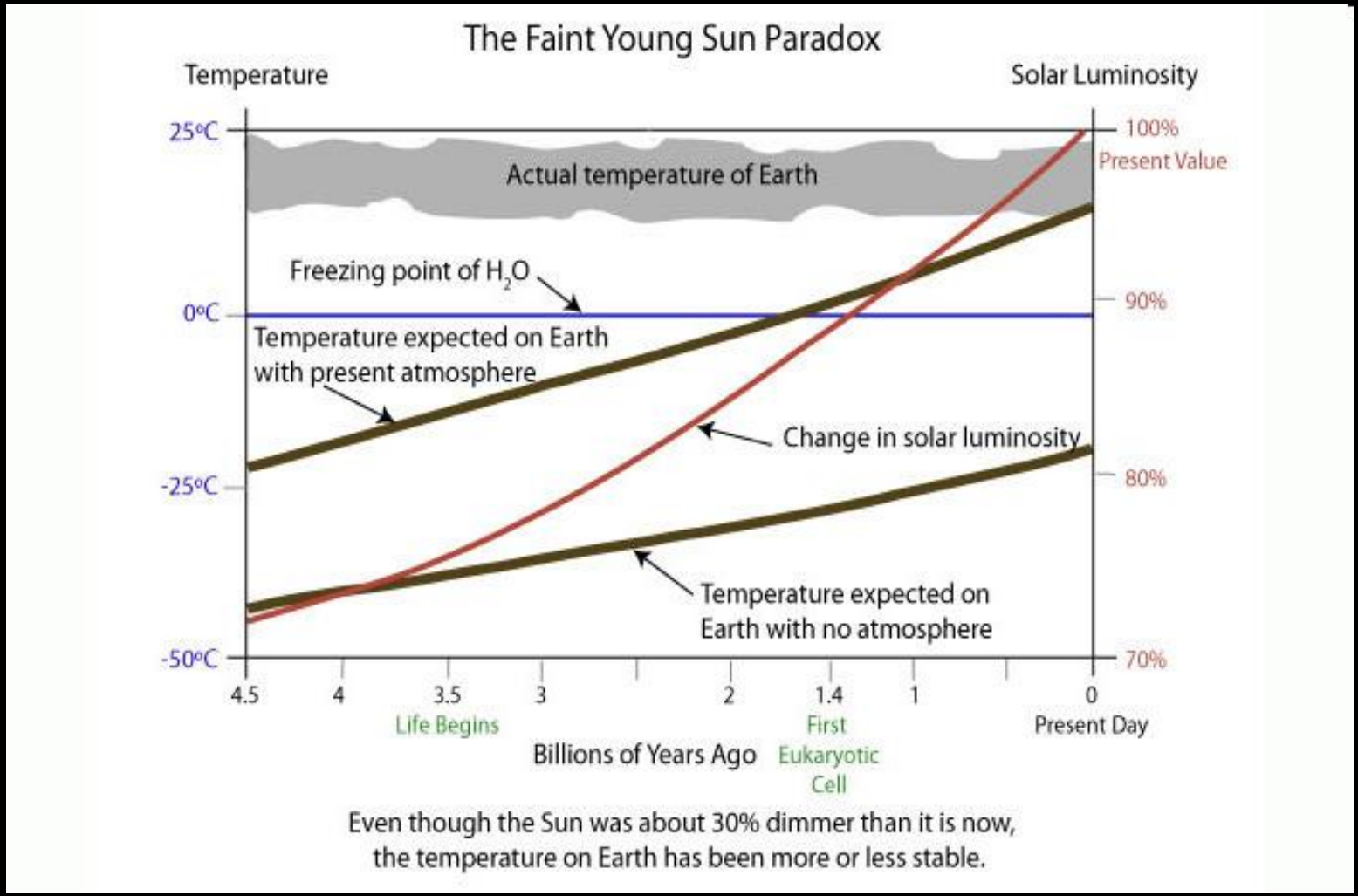


Chert (=SiO_2) coated with Fe-Oxide

Magnetite-layers($Fe^{II}Fe^{III}_2O_4$)



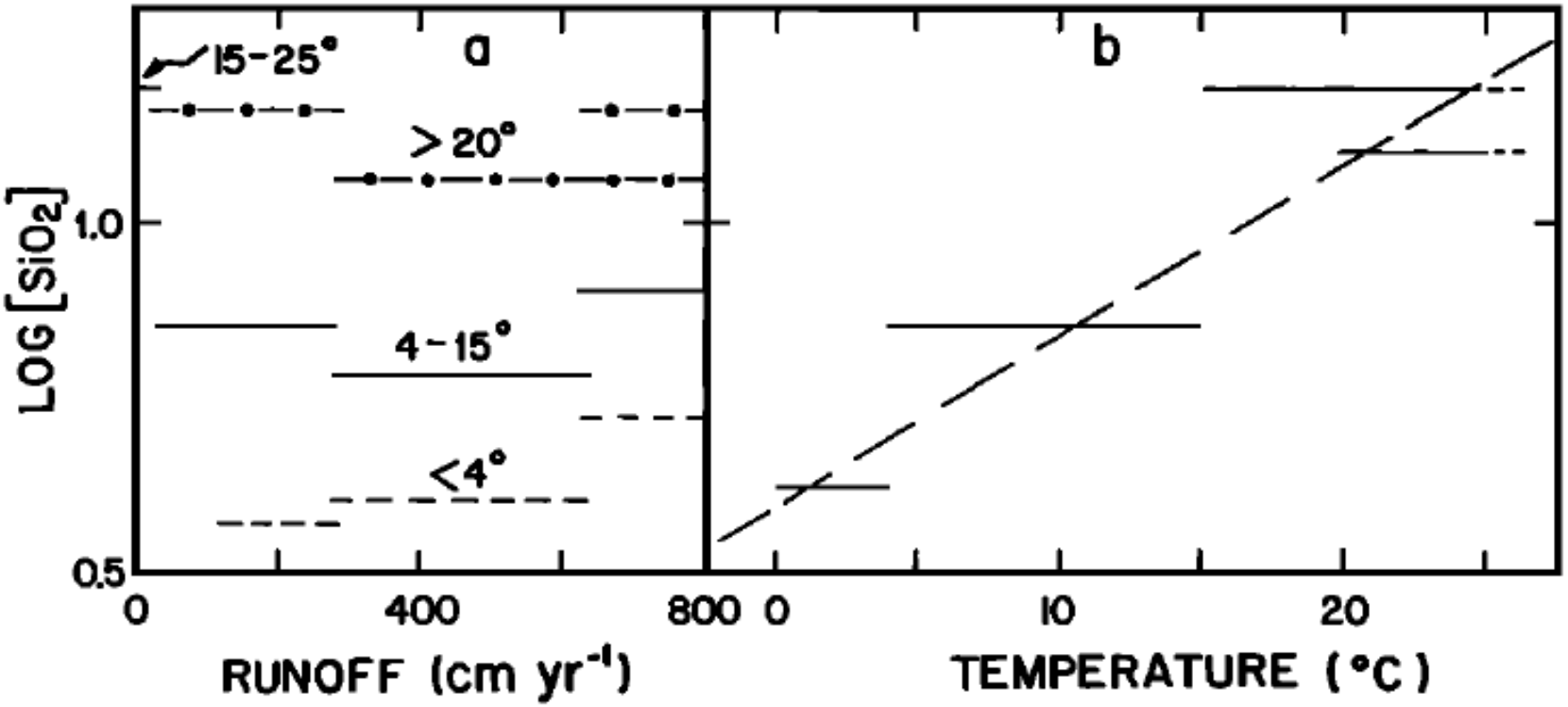
Presence of free water is puzzling given the low luminosity of the young sun



Even though the Sun was about 30% dimmer than it is now, the temperature on Earth has been more or less stable.

Modern oxic soil profile, southeastern Brazil

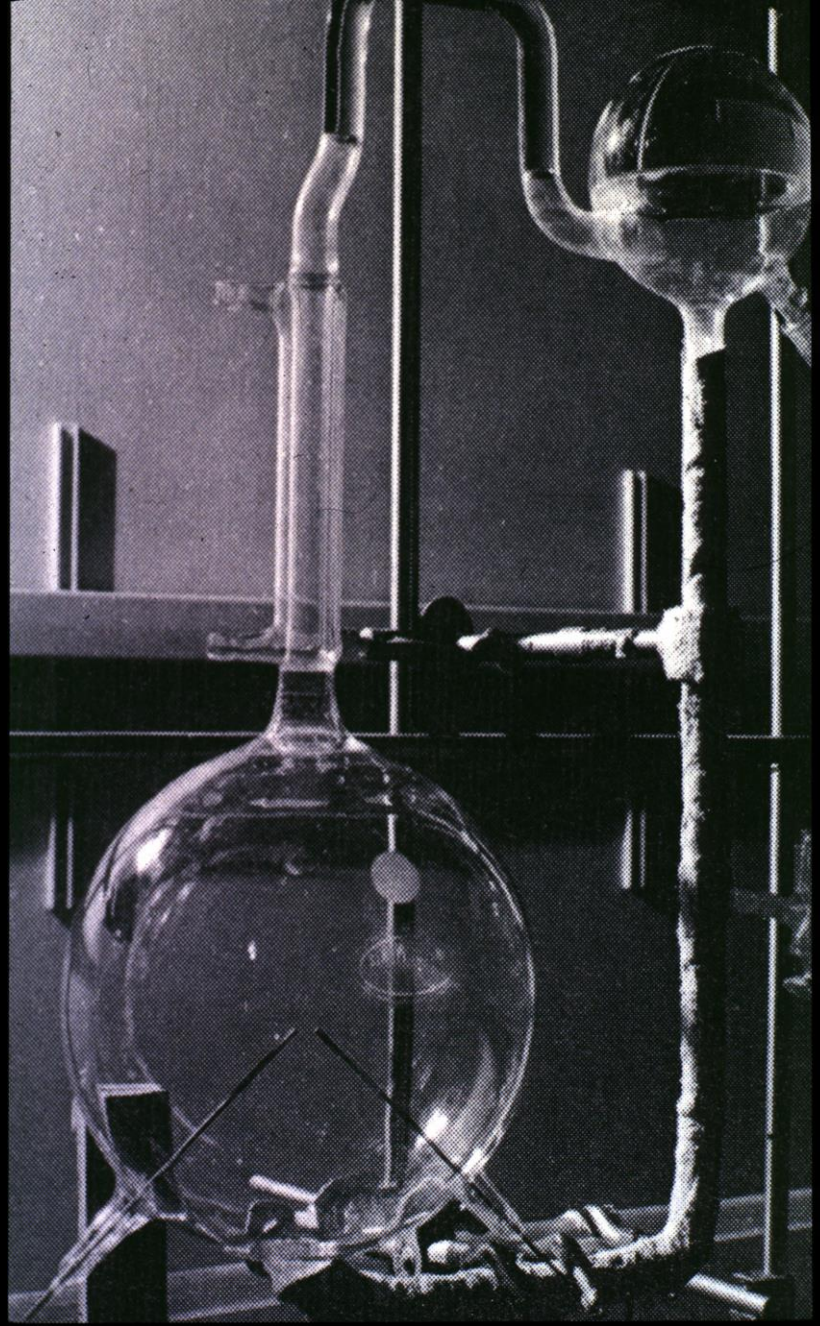
Feedback between silicate weathering and CO_2 sequestering.



Timeline of earth history removed due to copyright restrictions.

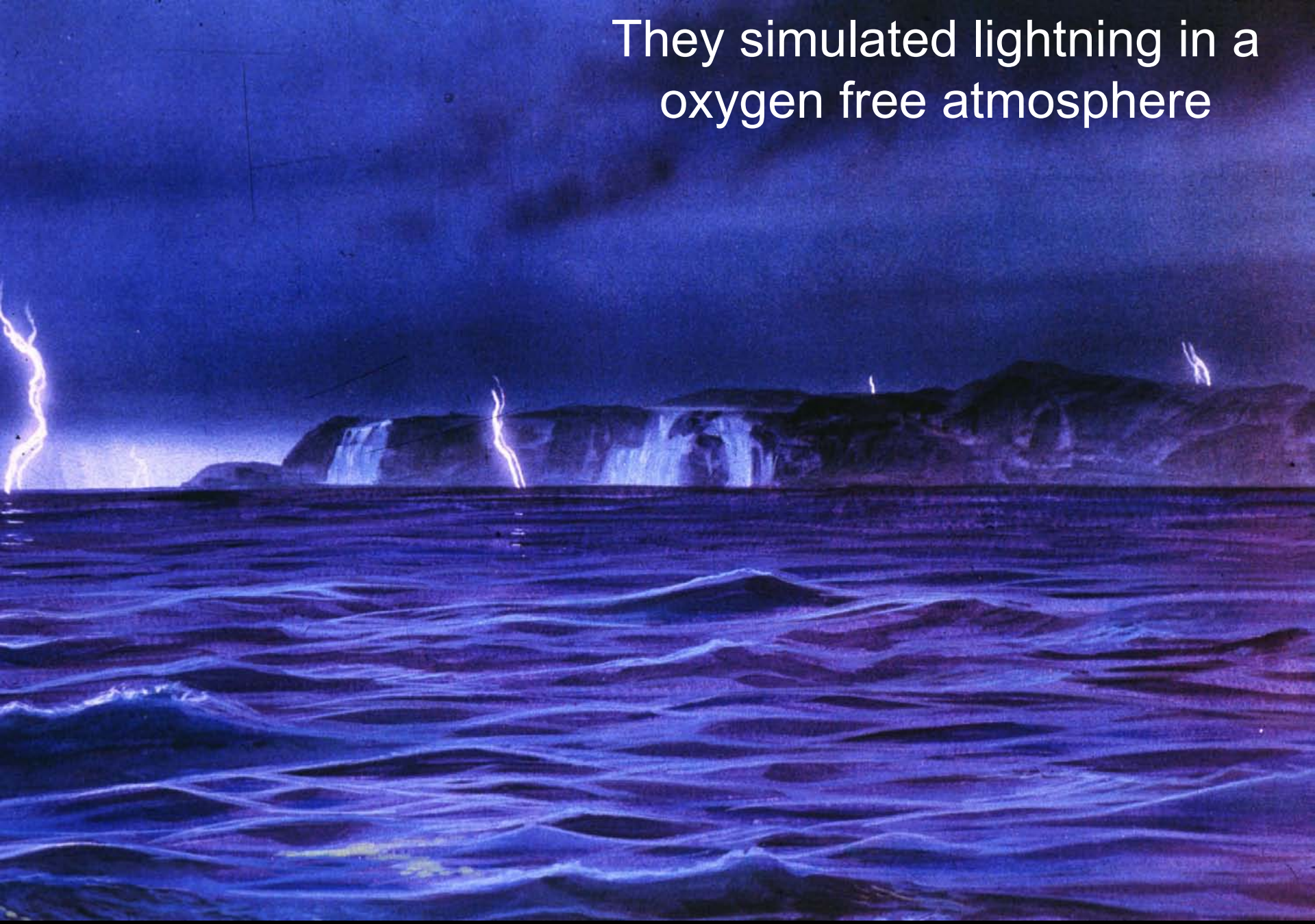
Courtesy of NASA. Image in the public domain.

Some people, like Fred Hoyle, proposed that life came from another planets with the help of meteorites..

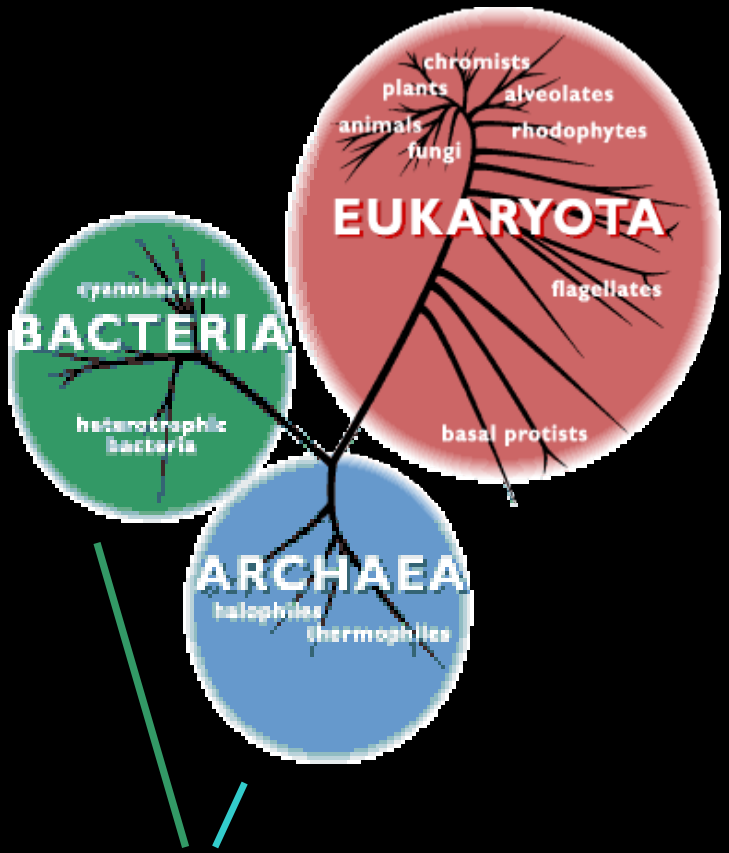


Stanley Miller and Harold Urey showed, that aminoacids can easily be produced on earth surface

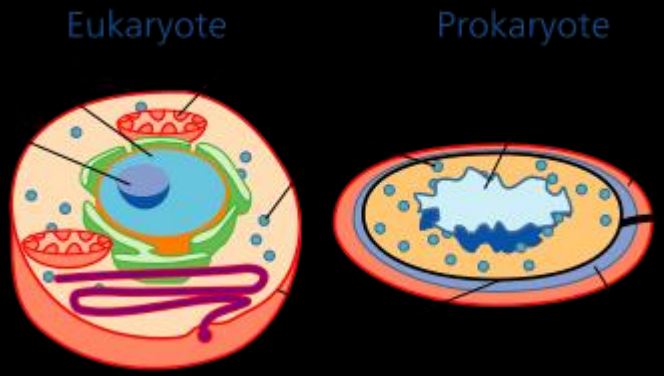
They simulated lightning in a oxygen free atmosphere



Alternatively life might have originated at the bottom of the ocean (distinct advances: strong geochemical gradients, protected from UV, Heat, reducing conditions, not too much convection)



Eukaryote: Cellular life forms with nucleus



Courtesy of National Center for Biotechnology Information. Image in the public domain.

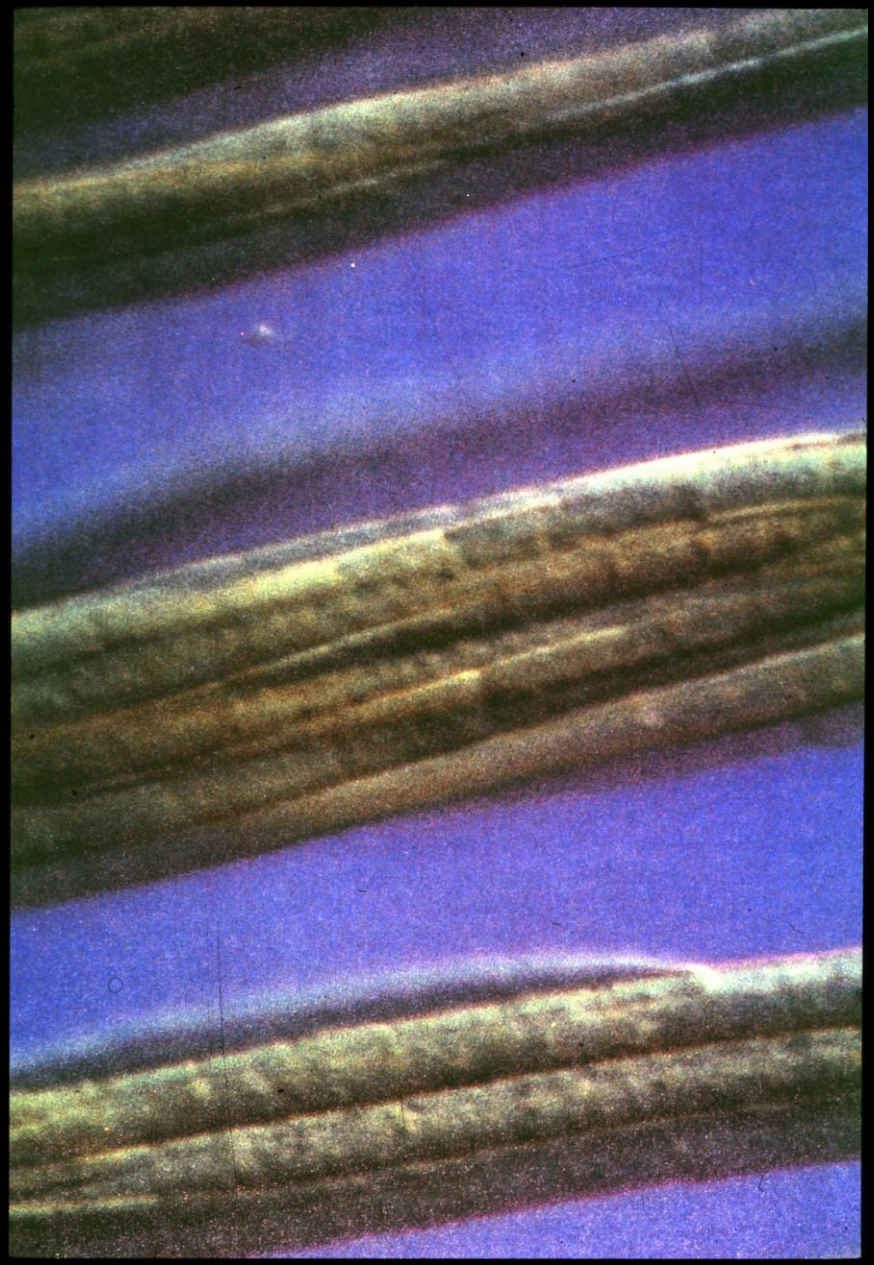
Prokaryote:

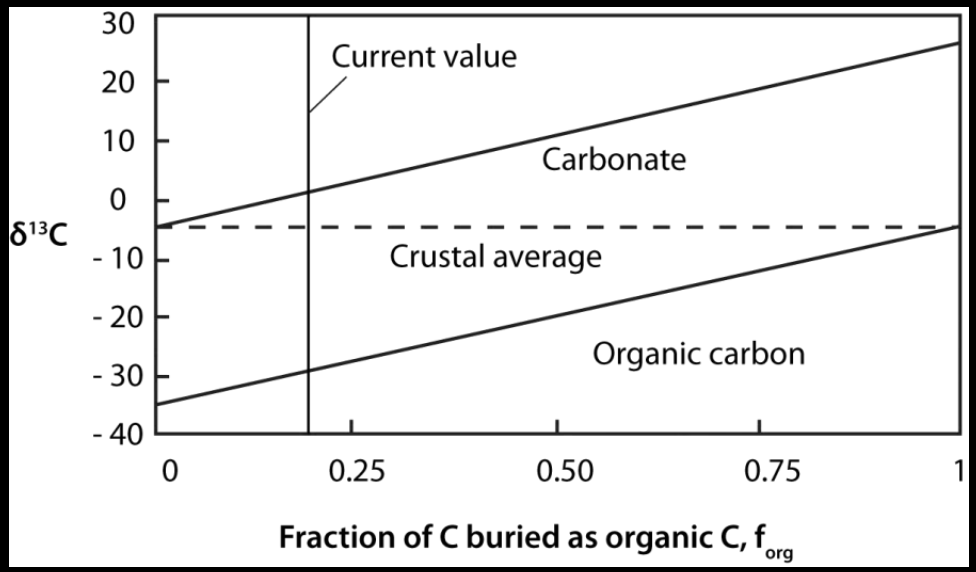
Cellular life forms without nucleus

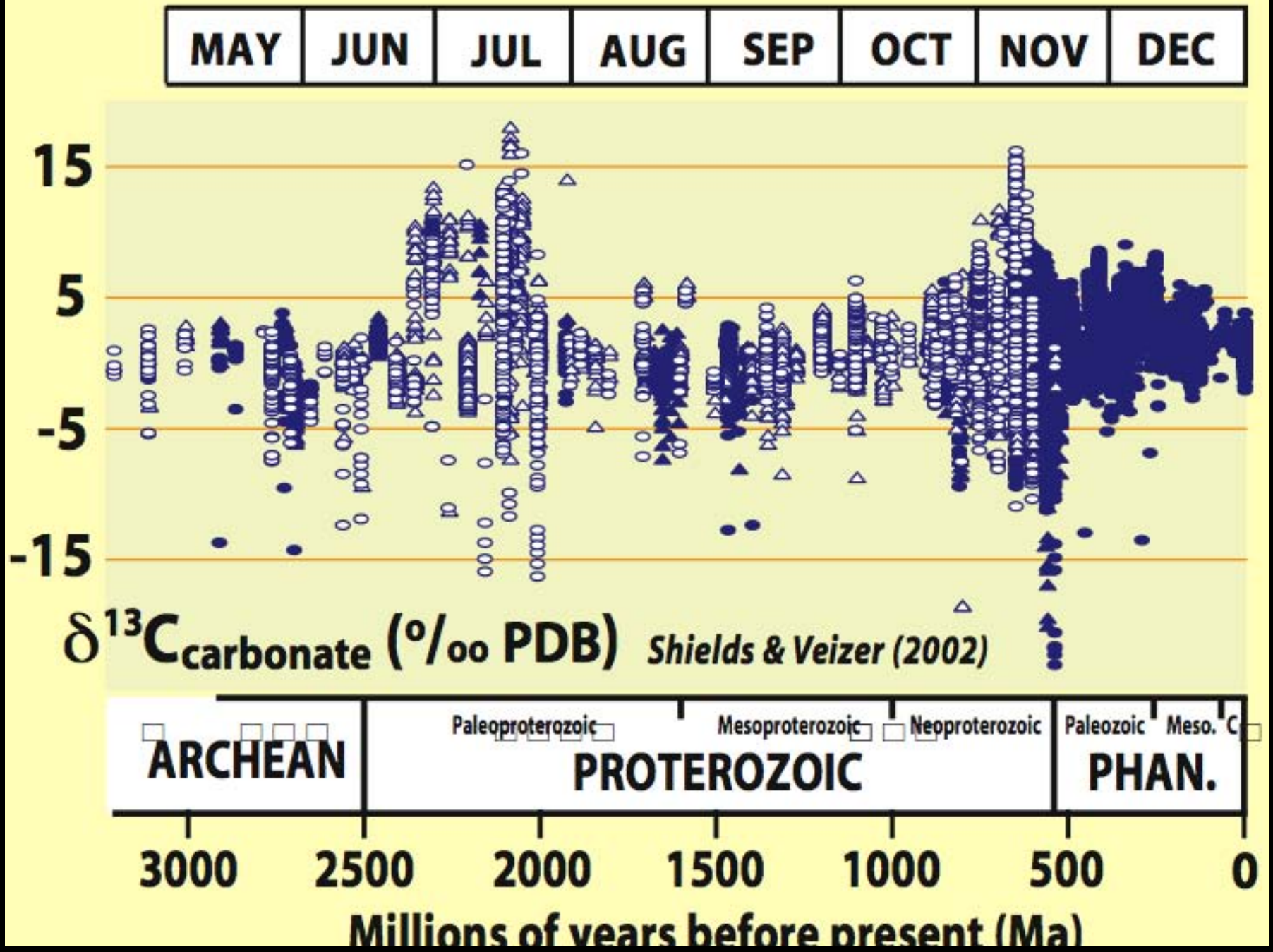
Extremophiles:

T > 100 °C, pH down to 1, P bis 1000 bar

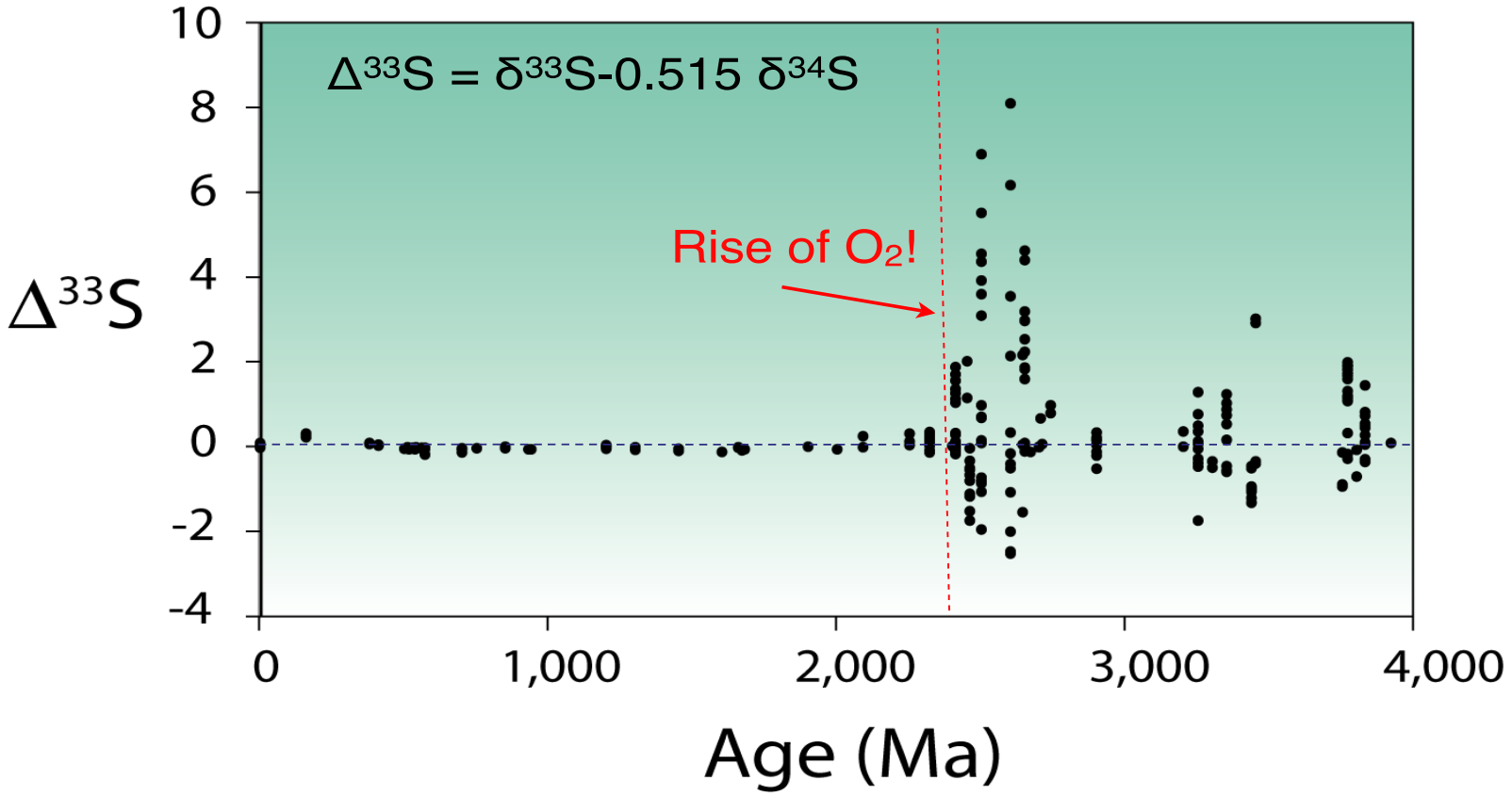
Isotopic fingerprint of life





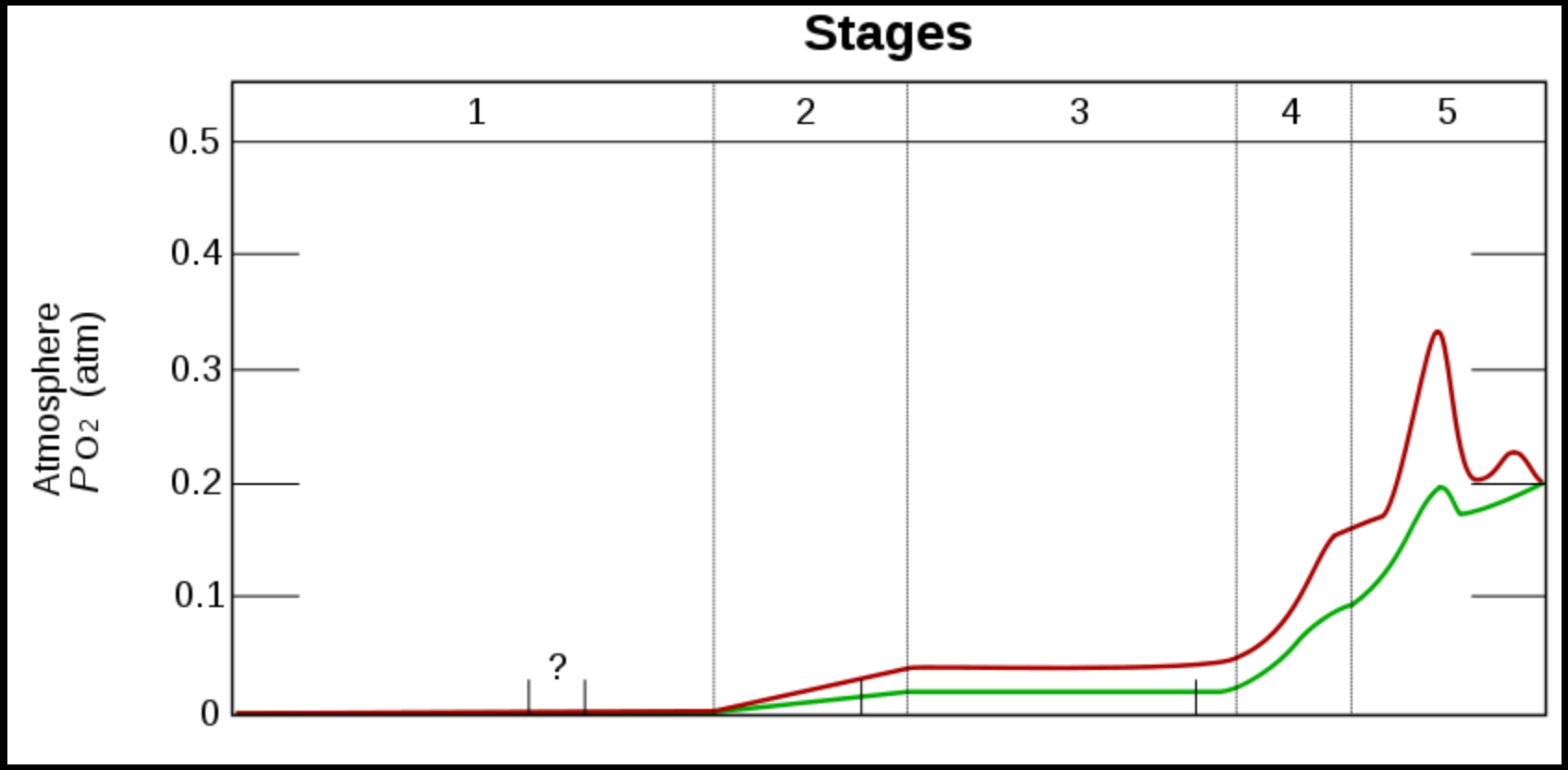


Archean S-33 anomaly and atmospheric O_2



Data source: Farquhar, Ono, Johnston etc.

Rise of oxygen how does it work?

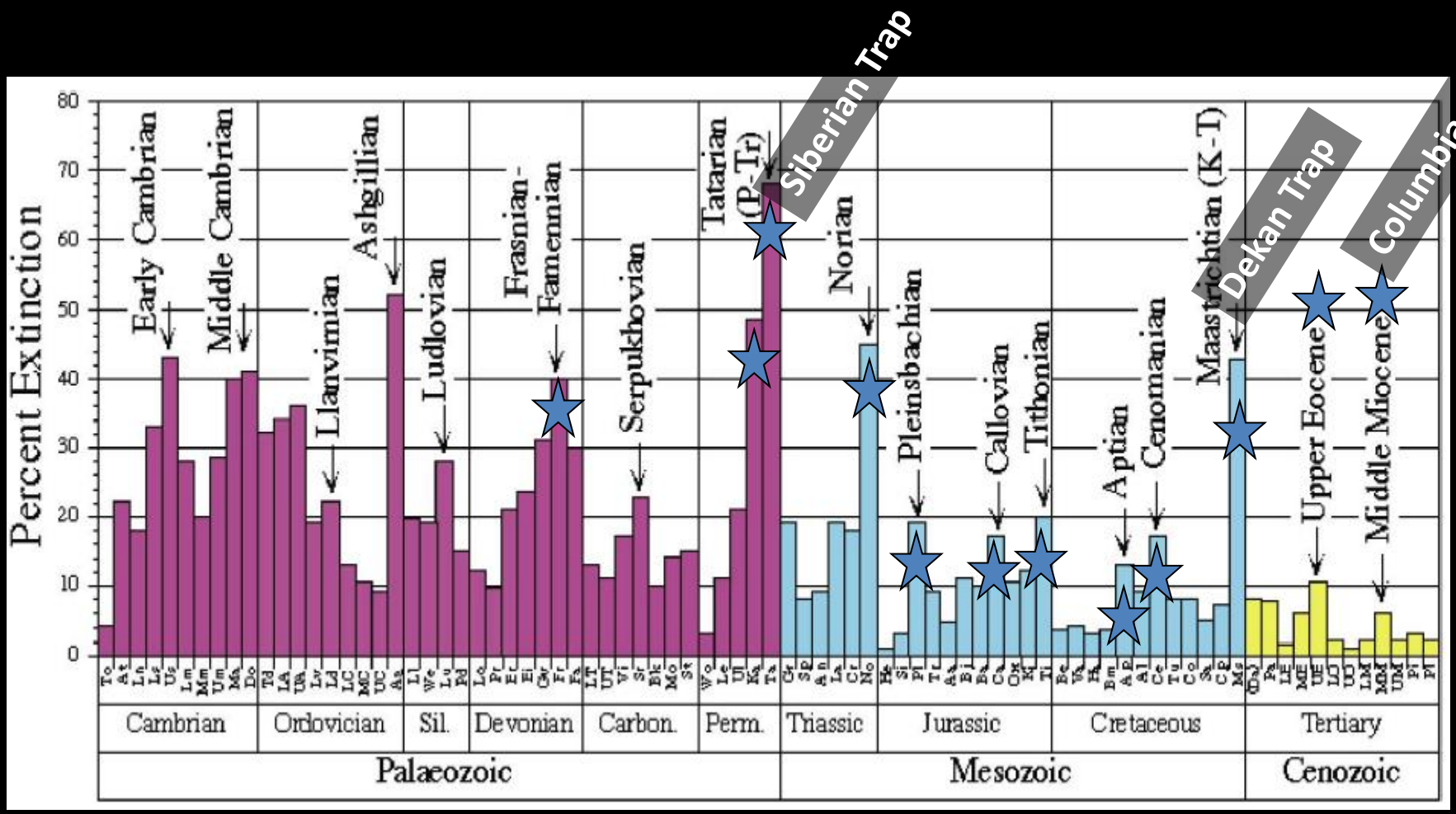


Evolution of Life on Earth

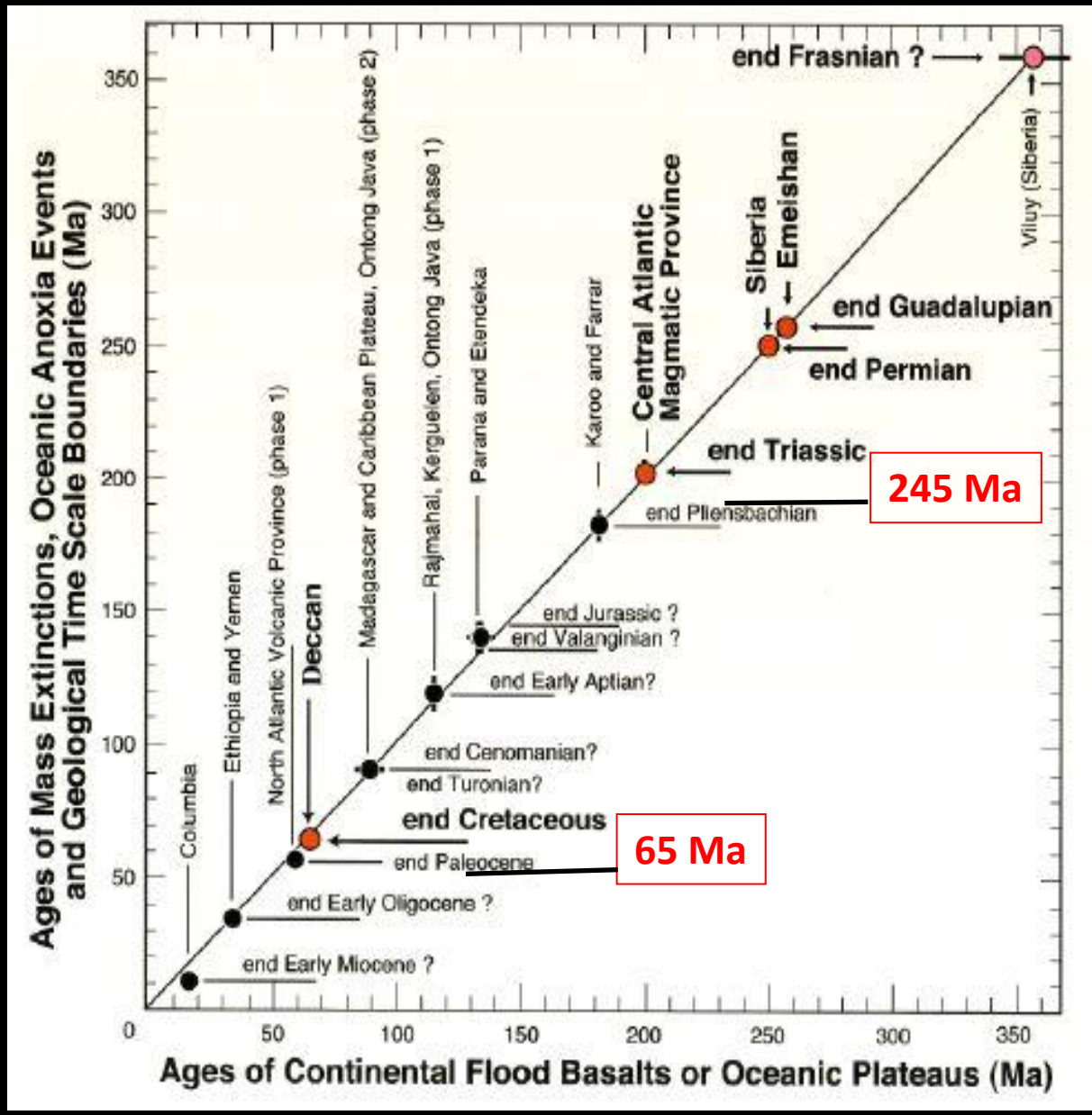
Ga		
4.5	Hadean	Evidence for the earliest evolution of the Earth are largely missing
4.0		Oldest rocks
3.5	Archean	Possible earliest life forms (Discussed)
3.0		Prokaryote
2.5		Rise of Oxygen
2.0	Proterocoic	Proven existents of Prokaryote and Eukaryote
1.5		Proven existents of Prokaryote and Eukaryote
1.0		Proven existents of Prokaryote and Eukaryote
0.5	Phanerocoic	Complex life forms: Cambrian explosion
Heute		Humans

Mass extinction

The mass extinctions of the last 350 Ma correlate (?) with flood basalts



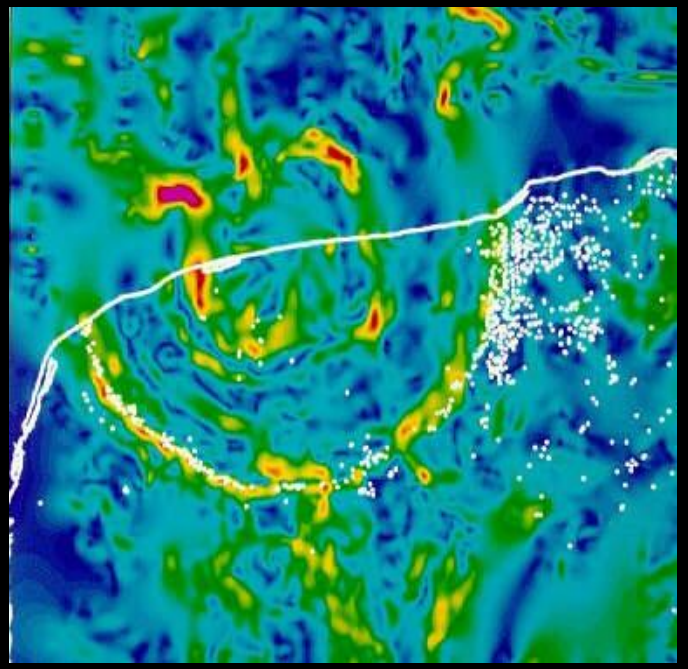
(nearly) perfect
Correlation between major
flood basalts and mass extinction



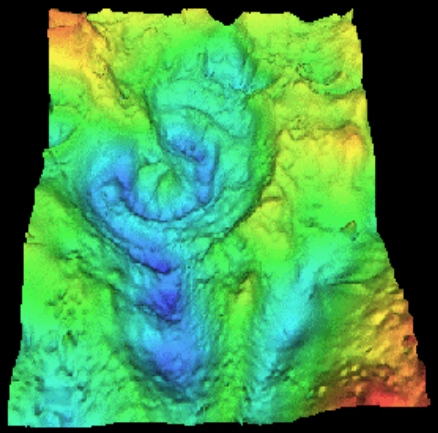
Meteorite impact at the (K-T) ?

Yes – but maybe slightly before mass Extinction (ca. 0.2-0.4 Ma),
So only one factor.

Courtesy of NASA. Illustration in the public domain.

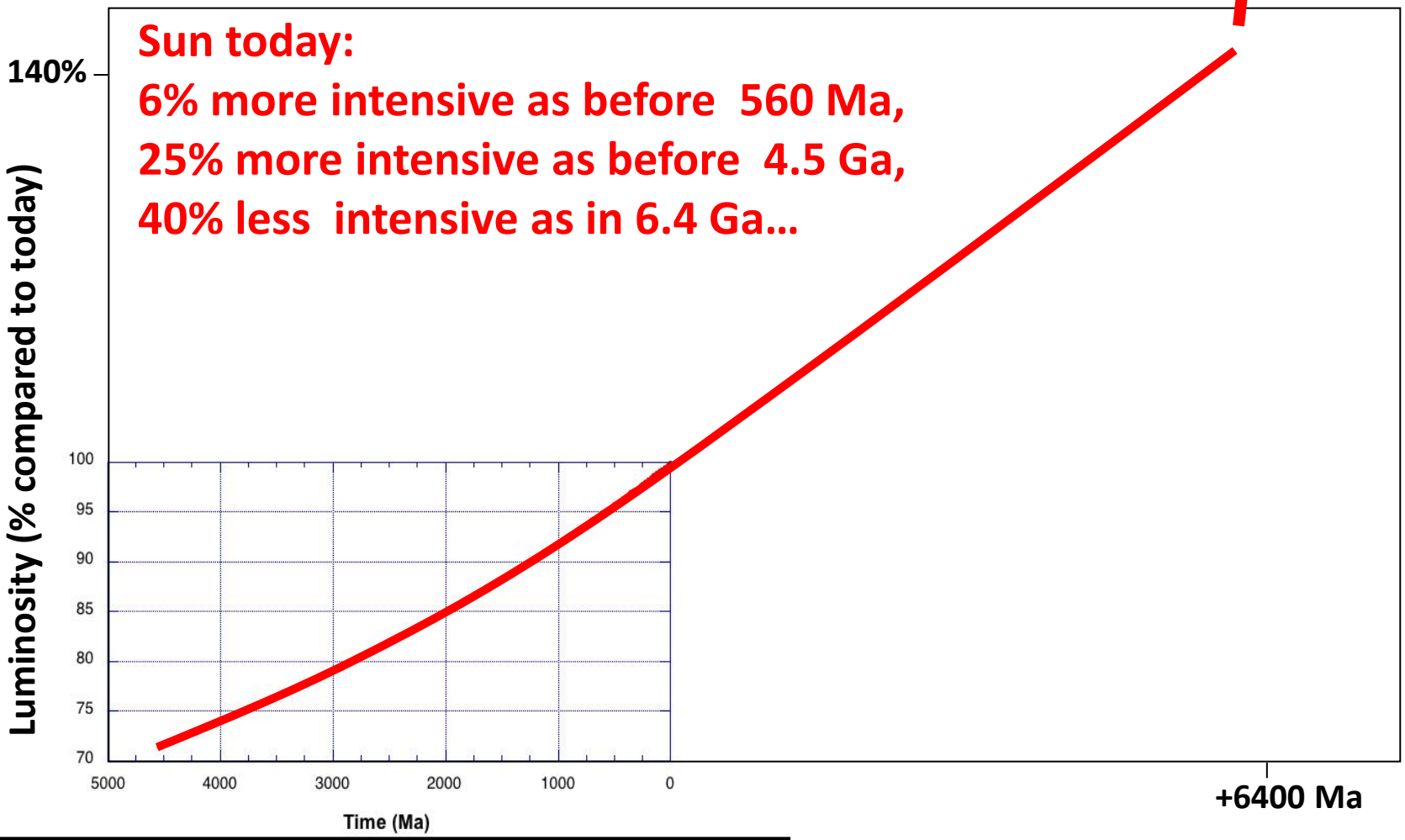


density-anomalies



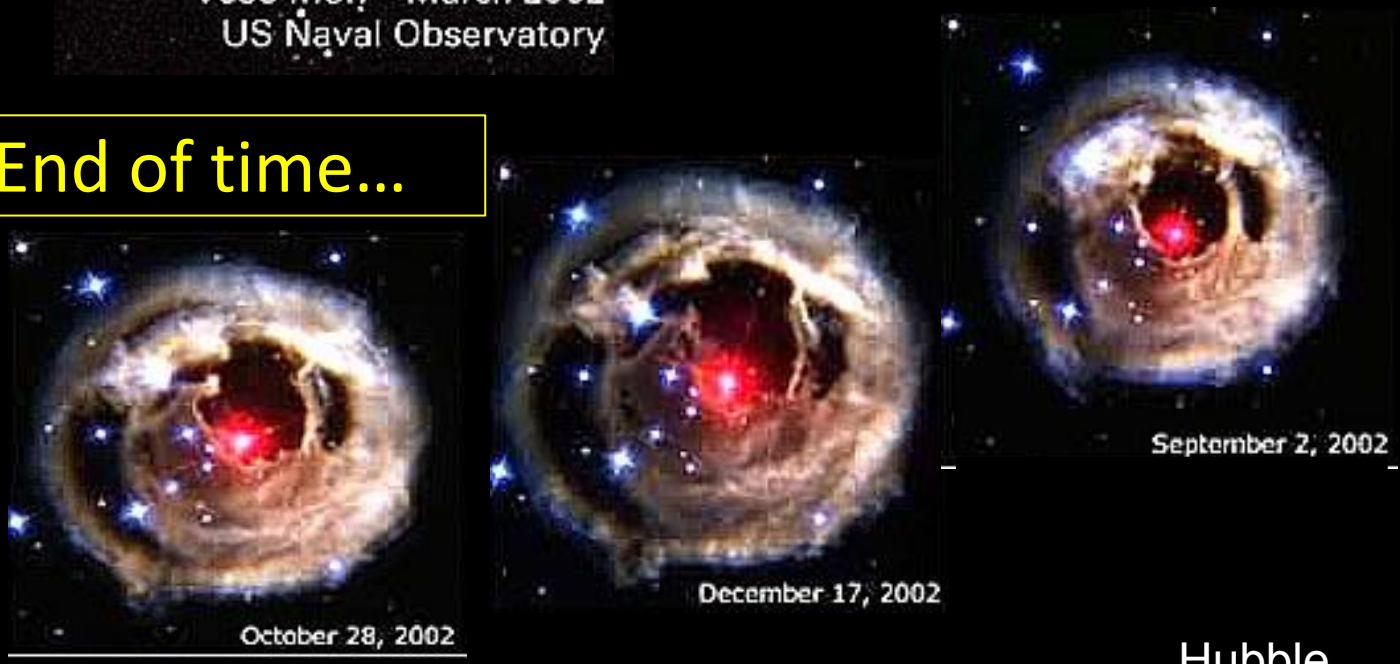
Bathymetric-Model

Outlook: What will happen to the earth in the next few Ga?



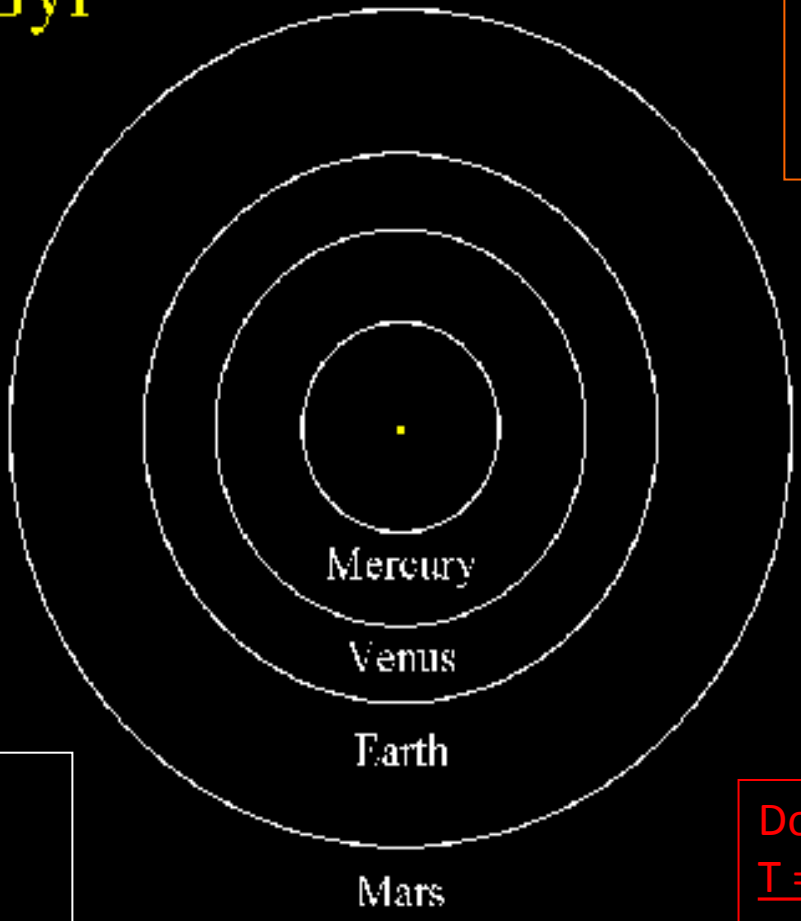
In 6 Ga sun might become a red giant

The End of time…



Hubble

The View From Above Today
T=4.55Gyr



in 1 Ga: +10%

T = 5.6 Ga

$R = 1.0\ R_{Sun}$

$L = 1.1\ L_{Sun}$

→ its gone get pretty warm…

Early Earth

T = 0.1 Ga

$R = 0.9\ R_{sun}$

$L = 0.7\ L_{sun}$

Double the age: + 40%

T = 9.0 Ga

$R = 1.1\ R_{sun}$

$L = 1.4\ L_{sun}$

Now its hot…

12.001 Introduction to Geology

Fall 2013