ASTR/GEOL-2040: Search for life in the Universe: Lecture 15

- Geological record
- Fossil record
- Early oceans & life

Axel Brandenburg
(Office hours: Mondays 2:30 – 3:30 in X590 and Wednesdays 11-12 in D230)

Reading the geological record

- Written history 5.4 kyr (3400 BC)
- Geological record 4 Gyr

Perspective

- Football stadium 50 m ←→ 5 Gyr
- This room 5 m ←→ 500 Myr
- 0.5 m ←→ 50 Myr
- 5 cm ←→ 5 Myr
- 5 mm ←→ 500,000 yr
- But written record only 5000 yr.

If 5 Gyr = 50 m, then what is 5000 yr?

Factor (m)	Multiple	Value	Item
10^{-6}	1 micrometre (μm) (also called one micron)	1–4 μm	Typical length of a bacterium.[18]
		4 μm	Typical diameter of spider silk.[19]
		7 μm	Typical size of a red blood cell.[20]
10^{-5}	10 μm	10 μm	Typical size of a fog, mist or cloud water droplet.
		10 μm	Width of transistors in the Intel 4004, the world's first commercial microprocessor.
		12 μm	Width of acrylic fiber.
		17-181 μm	Width range of human hair. [21]
10^{-4}	100 μm	340 μm	Size of a single pixel on a 17-inch monitor with a resolution of 1024×768.
		560 μm	Thickness of the central area of a human cornea.[22]
		750 μm	Maximum diameter of *Thiomargarita namibiensis*, the largest bacterium ever discovered (as of 2010).
		1.5 mm	Length of an average flea.[23]

A.

B.

C.

D.

E.

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6 orders of magnitude, so 5 kyr ←→ 50 μm

Rock types

- Igneous
  - From molten rock → cools, solidifies
- metamorphic
  - Not from molten, but altered (chem & struct) by pressure & temperature
- sedimentary
  - Compression of sediments

Igneous rocks

granite

gabbro

basalt

Felsic

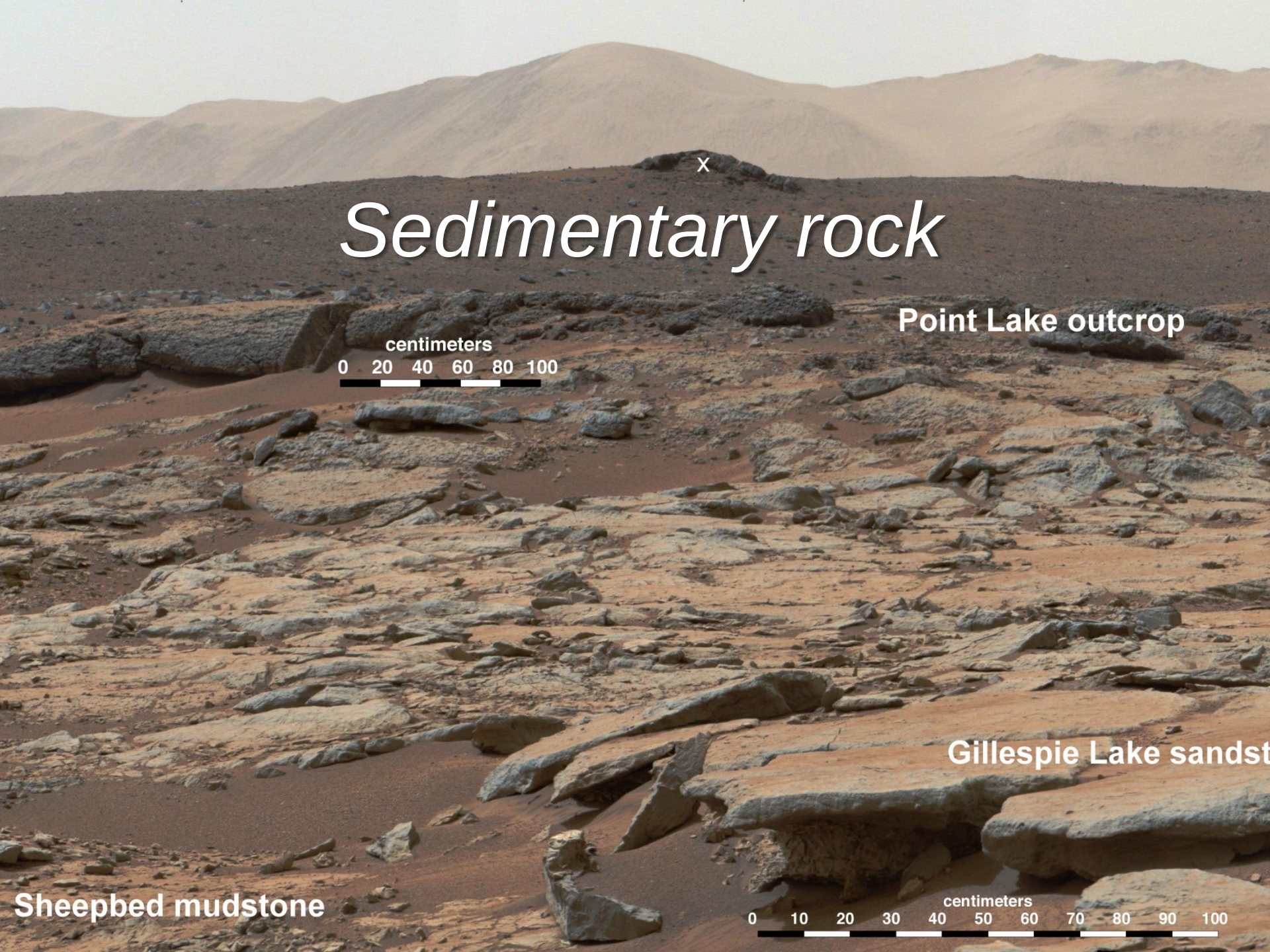
> 63% SiO_2

~2.7 g/cm^3

Mafic

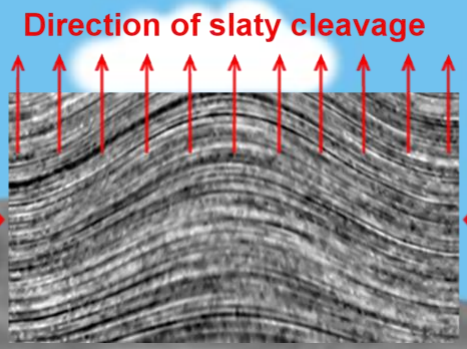
< 52% SiO_2

~3.0 g/cm^3


Sedimentary rock
Point Lake outcrop
centimeters
0 20 40 60 80 100
Gillespie Lake sandst
Sheepbed mudstone
centimeters
0 10 20 30 40 50 60 70 80 90 100

More sedimentary rocks

Here: limestone $CaCO_3$



Metamorphic rocks

Increasing conta
metamorphism

Magma
(forming of igneous rock)

The Giant Impact Theory

The Moon forming event ~4.5 Ga

Billions and billions of years ago...

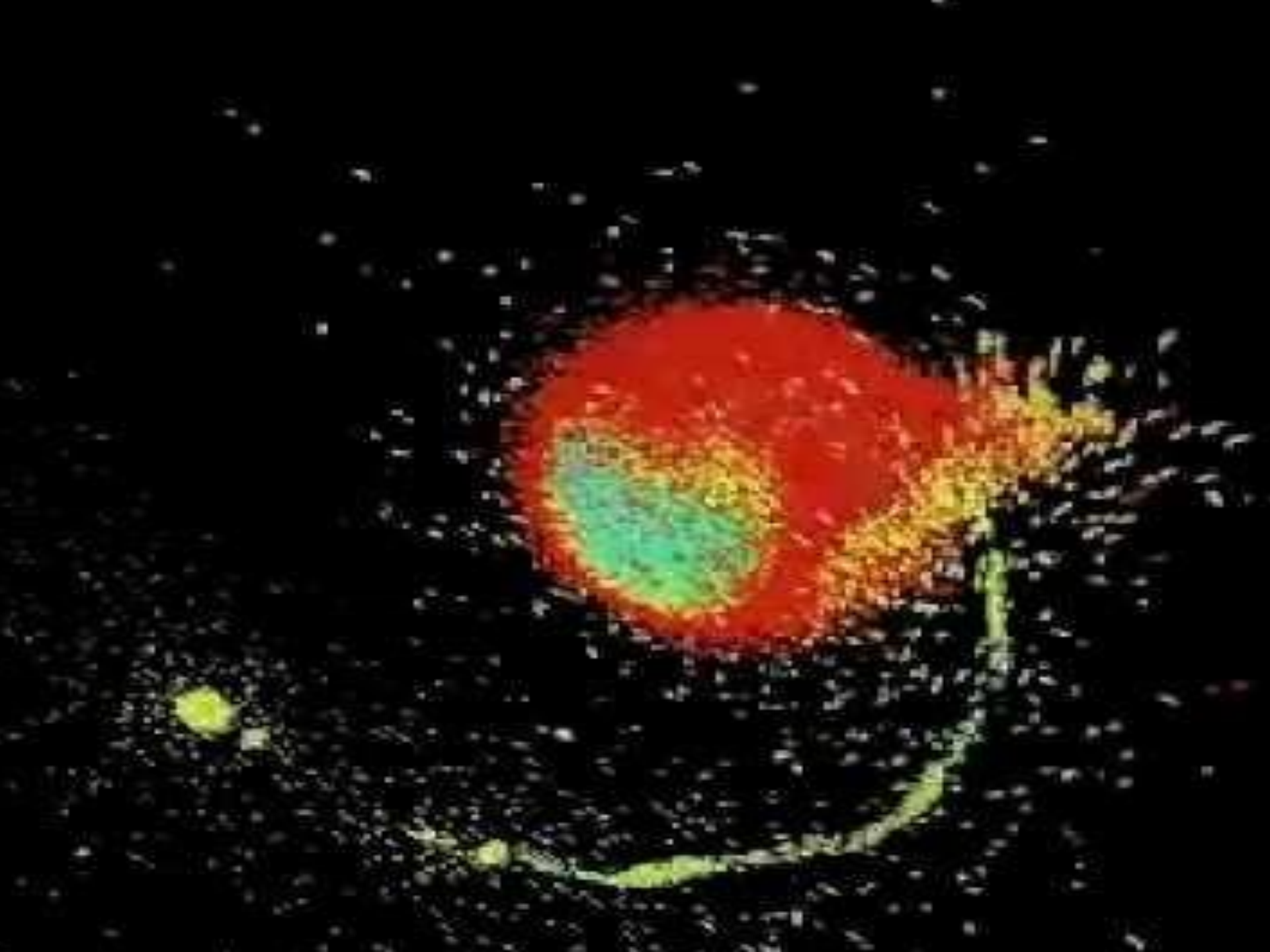
Numerous Mars-sized objects orbiting the Sun.

Occasional impacts with protoplanets are believed to have produced some interesting results:

- Mercury's large iron core
- Venus' awkward rotation
- Earth's moon

The set-up

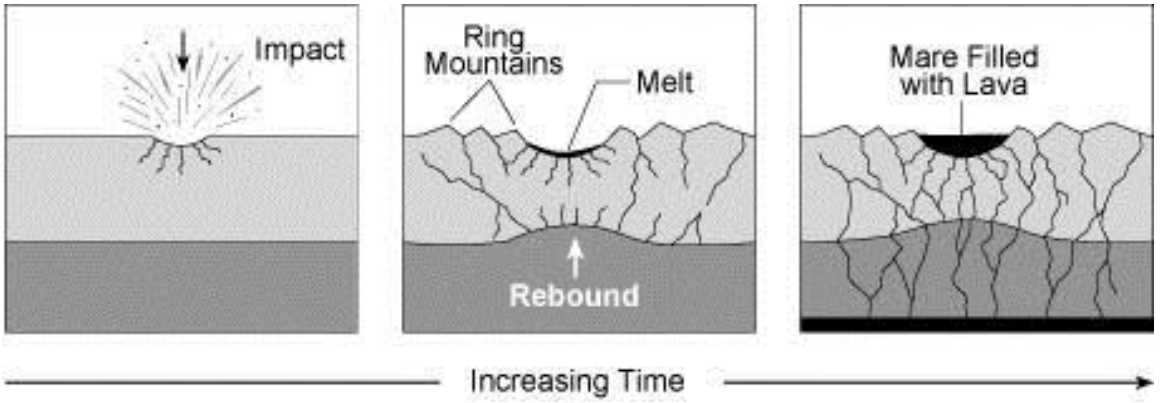
- Proto-Earth is orbiting the young Sun at approximately its current distance.
- A Mars-sized planetoid, often termed Theia, strikes proto-Earth at a glancing blow.
- Both bodies are liquified:
  - Most of Theia's rocky mantle and a bit of its iron core are ejected into orbit.
  - The remaining material accretes back onto Earth.
  - Roughly one year later, the Moon has mostly accreted from the material in orbit around the Earth.



Now we play the waiting game...

- After formation, the Moon stays in Earth's orbit.
- The Moon experienced the full force of the Late Heavy Bombardment (LHB), responsible for the formation of the lunar maria.
- Lunar volcanism completely ceased as late as 1 Gyr ago.
- The Moon's surface has been, and continues to be, a target for asteroids and meteors crossing its path since its formation.


Near Side
Far Side


Impact
Ring Mountains
Melt
Rebound
Mare Filled with Lava
Increasing Time

Another Movie!
Life of the Moon - *NASA GSFC*

What type of rock on the Moon?

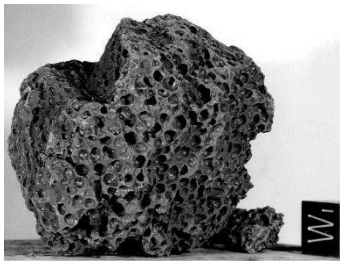
A. Granite

B. Basalt

C. Marble

D. Sandstone

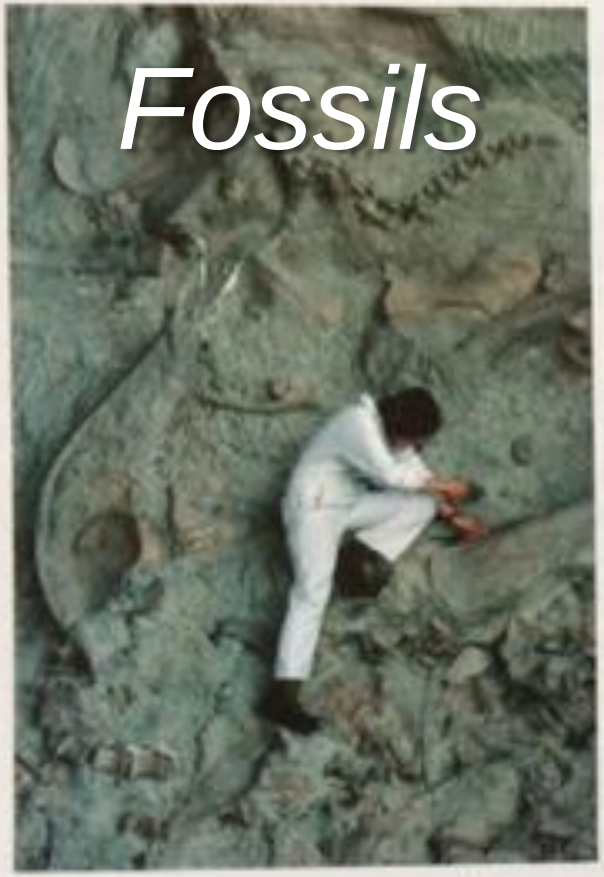
E. Limestone



Comparison with fossils

- Fossils from mineral-rich portions
- Or filled w/ mineral-rich water
- Minerals cast shape

Fossils



a Dinosaur bones preserved in sandstone in Dinosaur National Monument, which straddles Utah and Colorado.

b A more than 200-million-year-old petrified (stone) tree in Arizona's Petrified Forest National Park.

c These 200-million-year-old impressions are casts of snail-size, extinct organisms (called ammonites) made when minerals filled the empty space left after the organisms decayed.

d An insect preserved in hardened tree resin (often called *amber*), 45 million years old.

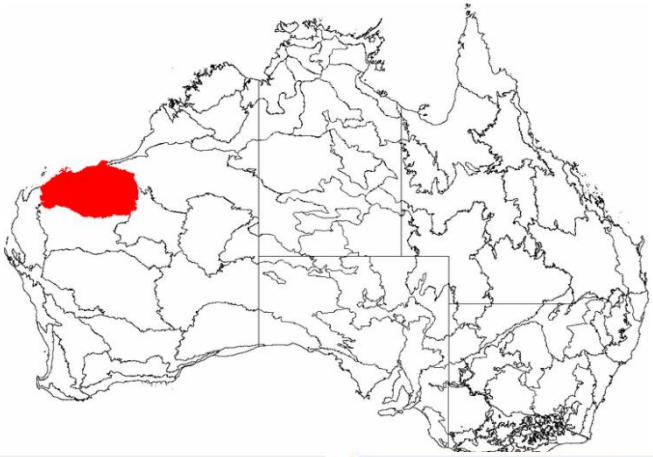
e These tusks belong to a whole 23,000-year-old mammoth discovered in Siberian ice in 1999.

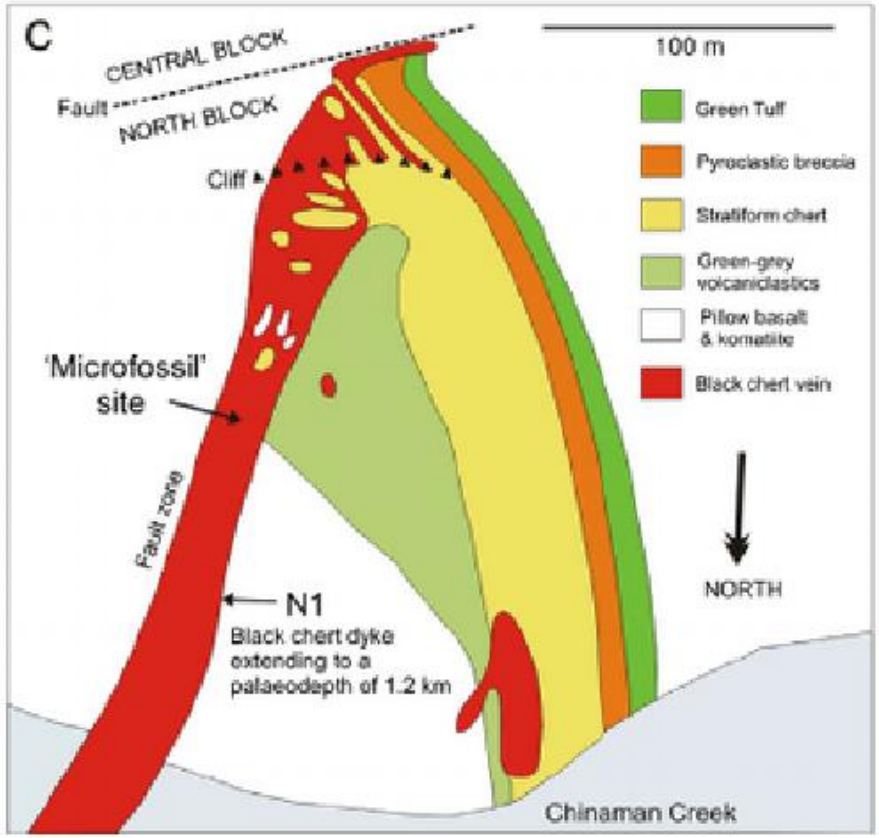
f This man is looking at a 150-million-year-old dinosaur track in Colorado.

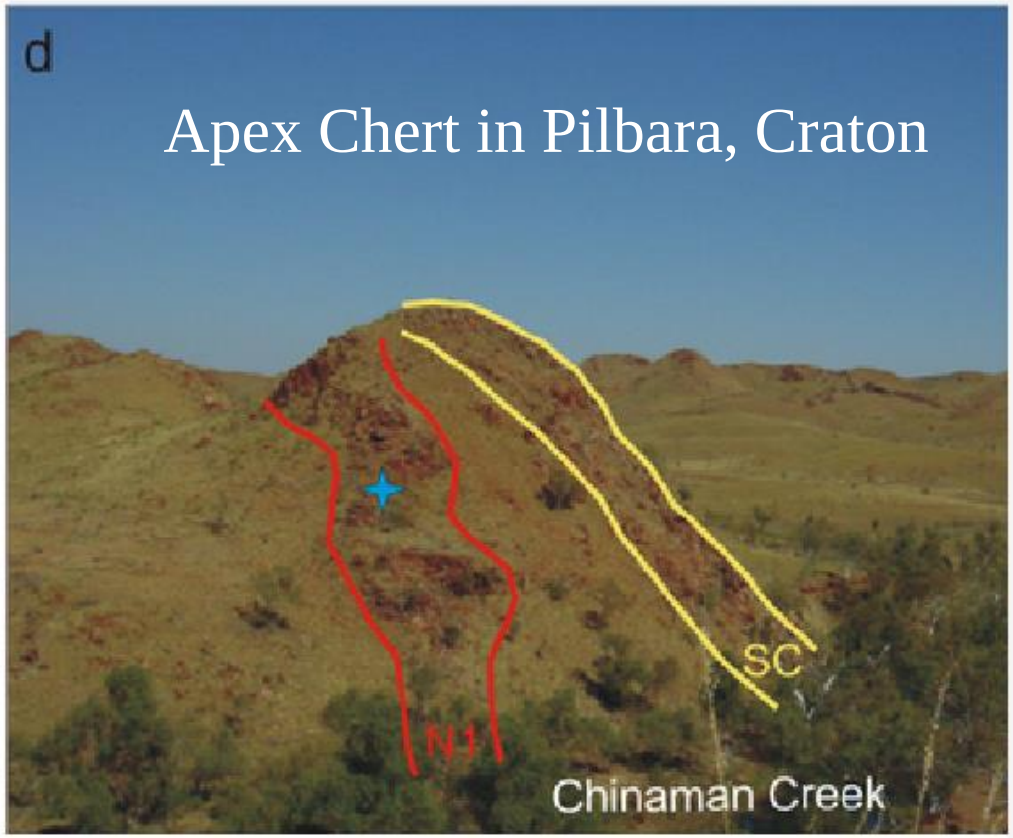
Cherts

- Microcrystalline sedimentary rock
- Silica-rich
- Resist metamorphism
- Example next: Apex Chert

Fossil evidence for life







RESEARCH ARTICLE

Microfossils of the Early Archean Apex Chert: New Evidence of the Antiquity of Life

J. William Schopf

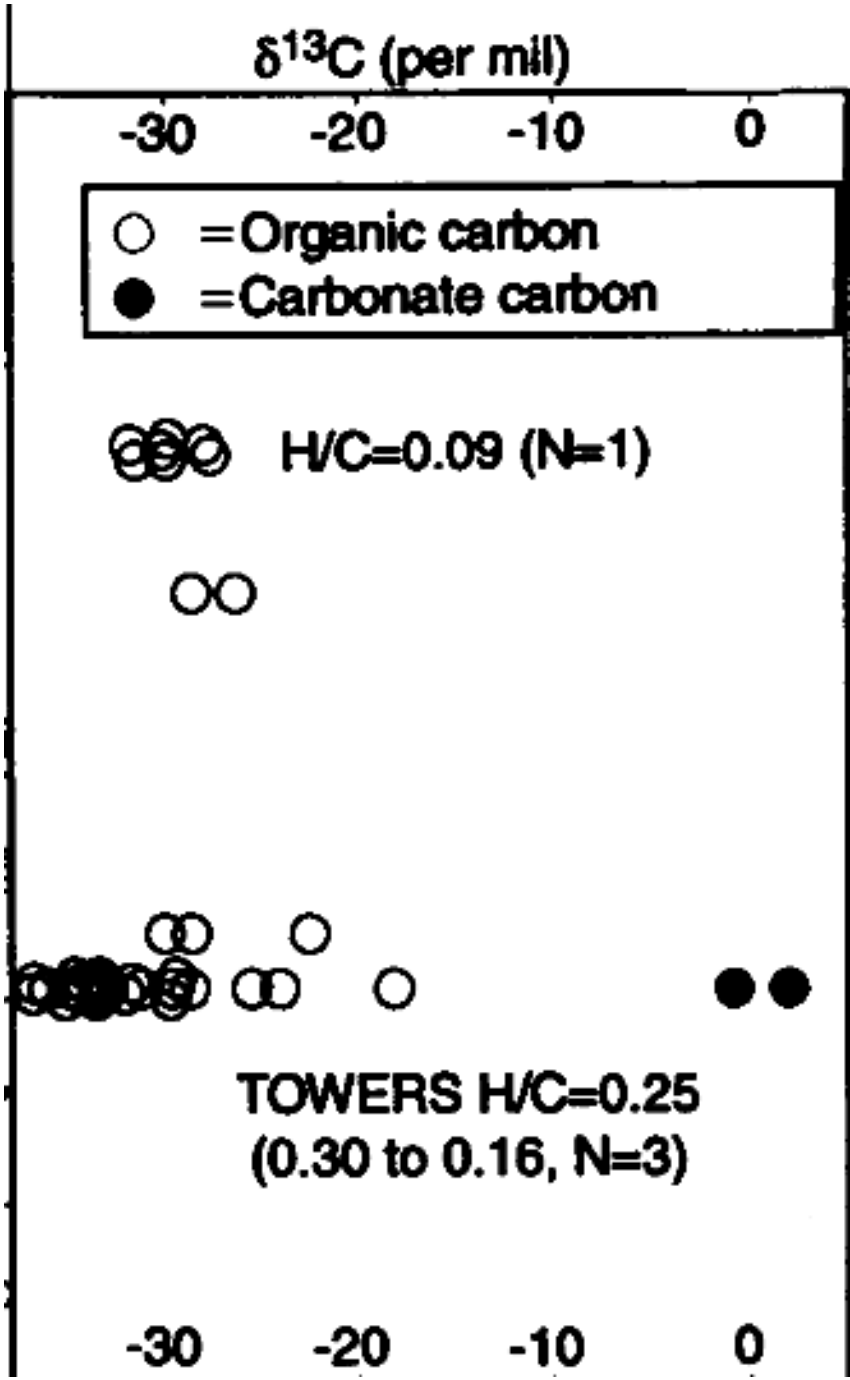
Eleven taxa (including eight heretofore undescribed species) of cellularly preserved filamentous microbes, among the oldest fossils known, have been discovered in a bedded chert unit of the Early Archean Apex Basalt of northwestern Western Australia. This prokaryotic assemblage establishes that trichomic cyanobacterium-like microorganisms were extant and morphologically diverse at least as early as ~3465 million years ago and suggests that oxygen-producing photoautotrophy may have already evolved by this early stage in biotic history.

Nature 260, 640 (1993)

0
mm
0.25
D
F
I
J
K
E
G
L
M
N
H
O
10
µm
0
10µm

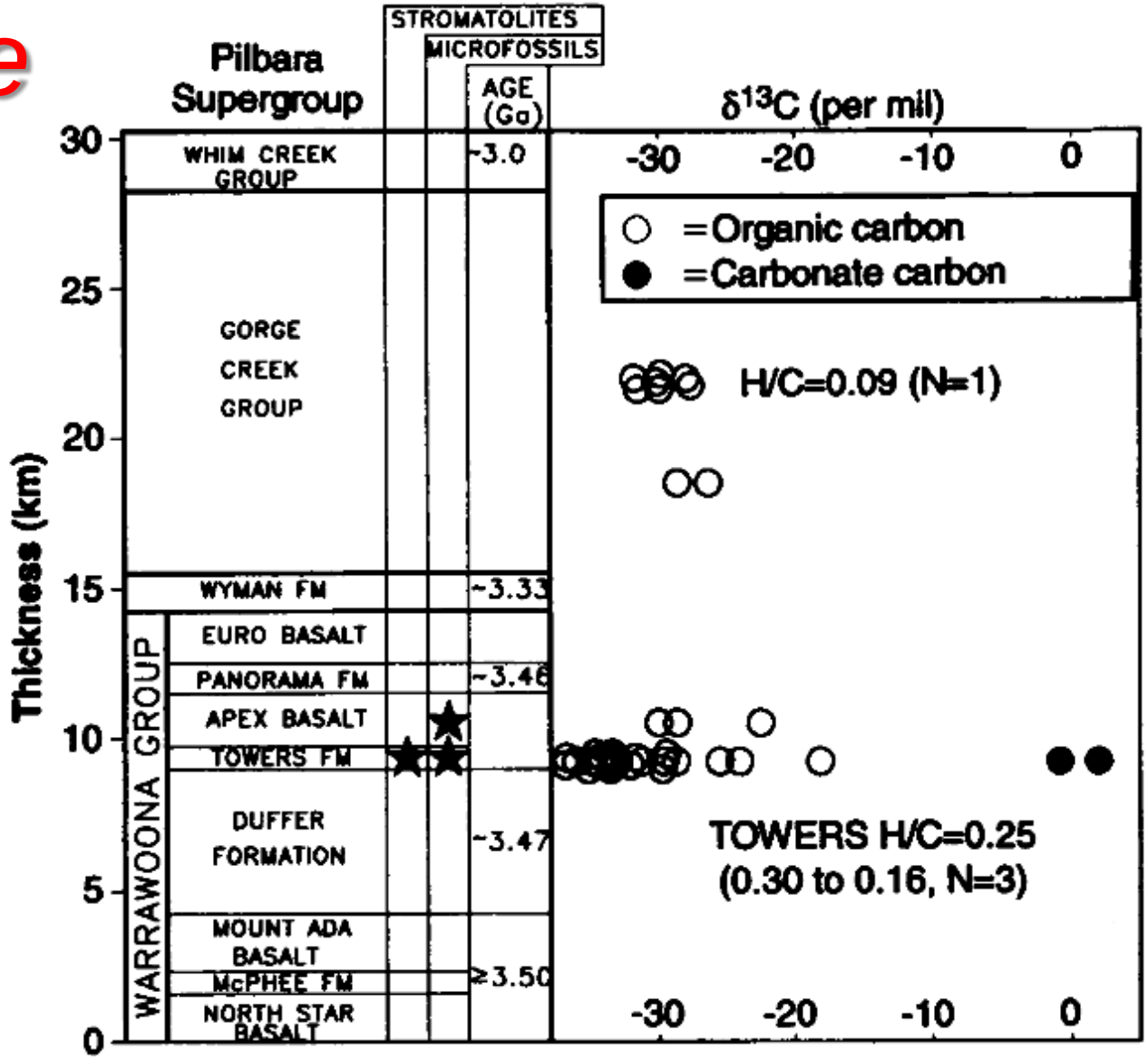
Isotope fingerprints on fossils

- Carbonate carbon
- Always ~0
- Organic carbon
- -20 … -30 per mil



Look at age

- No trend with age



Next time

- Hydrothermal vents
- Cambrian explosion of life
  - RGS box 2.6, plate 2.19
  - Longstaff 223 – 233

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