



Lecture 19 - The First Living Things on Earth

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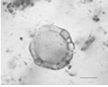


Astronomy 141 – Autumn 2012


This lecture is about searches in the geological record for traces of the first living things on Earth.



Fossil Stromatolites, remnants of layered mats of cyanobacteria, are among the oldest fossils.

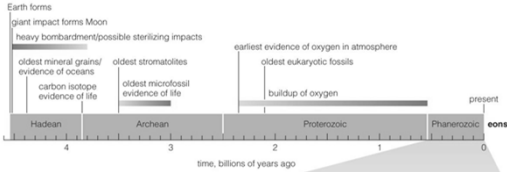


Microfossils are preserved in some rocks that are the oldest known prokaryotes.



Carbon isotope ratios due to biological metabolism could signal earlier life that did not leave fossil remnants.

The oldest living things on Earth arose sometime during the Archaean Eon.



The diagram is a horizontal timeline from 4.5 billion years ago to the present. Key events are marked with vertical lines: Earth forms (4.5 Gyr), giant impact forms Moon (4.5 Gyr), heavy bombardment/possible sterilizing impacts (4.5-3.8 Gyr), oldest mineral grains/evidence of oceans (4.4 Gyr), carbon isotope evidence of life (3.8 Gyr), oldest stromatolites (3.8 Gyr), oldest microfossil evidence of life (3.5 Gyr), earliest evidence of oxygen in atmosphere (2.4 Gyr), oldest eukaryotic fossils (1.8 Gyr), and buildup of oxygen (1.8 Gyr). The timeline is divided into eons: Hadean (4.5-2.5 Gyr), Archaean (2.5-2.4 Gyr), Proterozoic (2.4-0.5 Gyr), and Phanerozoic (0.5 Gyr to present).

Hadean: 3.8 – 4.5 Gyr ago – traces in the oldest rocks
Formation of the Earth, oceans, and first atmosphere punctuated by sterilizing asteroid bombardments

Archaean: 2.5 – 3.8 Gyr ago – starts at end of heavy bombardment

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But, because Earth is geologically active, most of the oldest rocks have been destroyed.

Most of the Earth's crust is less than 100Myr old

Most surface rocks have been melted & solidified many times.

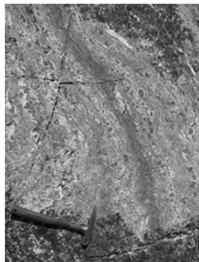
The World's Oldest Rocks:

Jack Hills of Australia (4.4 Gyr Zircons)

Acasta Gniess in Canada (4.03 Gyr)

Isua Greenstone Belt in Greenland (3.8Gyr)

Finding the oldest fossil remnants of early life is extremely challenging.



4.28 Gyr rock in Canada

Stromatolites are layered rocks formed in shallow water from sediments trapped by microbe mats.



Shark Bay, W. Australia

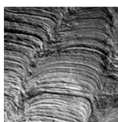
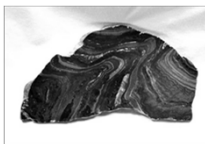
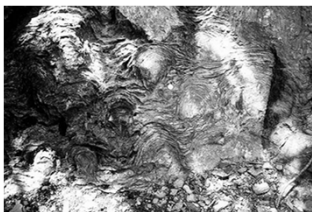
Colonies of cyanobacteria found in shallow marine lagoons and hypersaline lakes.

Lake Thetis, W. Australia

Sediments get trapped by mucous-like secretions from the microbes.



Fossil stromatolites were very abundant about 2.8 Gyr ago during the Archaean Eon.



Late Archaean (2.8 Gyr old) stromatolites from Michigan. These are confirmed to be of microbiological origin.

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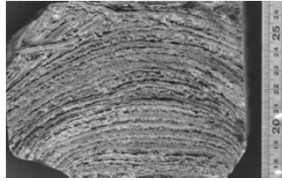
Stromatolites are found back to the Early Archaean, up to 3.5 Gyr old.

Older stromatolites are subjected to geological processing.

Heat & pressure destroys the microbes and their organic compounds.

Only carbon and the layered shape remain.

Recent analysis of 3.5 Gyr old Stromatolites from western Australia has shown they are microbiological in origin.



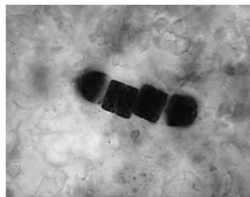
Strelley Pool Stromatolite, W. Australia (Abigail Allwood, Caltech)

Microfossils are the preserved remains of individual cells.

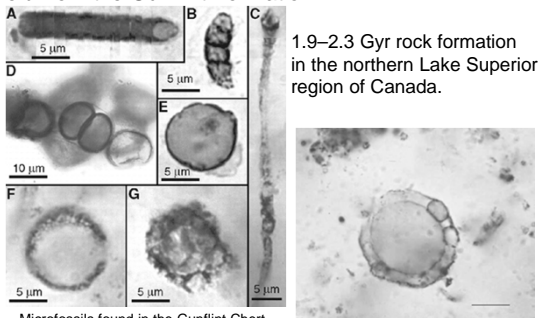
Very challenging to find:
oldest rocks are rare
heat/pressure destroy fossils

A few manage to survive.

Seen the outlines of the cellular structures, and detect complex organic compounds.

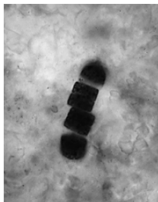


The best examples of microfossils are about 2 Gyr old from the Gunflint Formation.

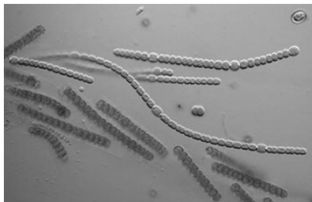


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Some microfossils resemble modern-day bacteria and archaea in shape.



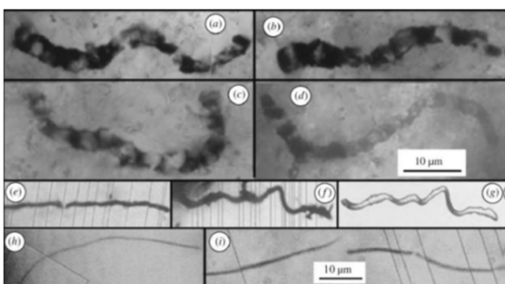
Microfossil
(Bitter Springs Chert)



Modern cyanobacteria

Interpretation of the oldest candidate microfossils is contentious – hard to establish proof of biological origin.

Microfossil candidates from the Apex Chert in Western Australia are claimed to be ~3.5 Gyr old.



Apex Chert & Dresser Formation, Western Australia
(Schopf 2006)

Isotopic analysis of Carbon is another way to find traces of biological metabolism.

Carbon has 2 stable isotopes: ^{12}C and ^{13}C

Cosmic isotope ratio is $^{13}\text{C} / ^{12}\text{C} = 1 / 90$.

Cell metabolism can take up ^{12}C more readily than ^{13}C , leaving more ^{13}C behind in the environment.

Carbon left behind by biological organisms is “depleted” in ^{13}C relative to ^{12}C .

But, there are also abiotic ways to alter the $^{13}\text{C}/^{12}\text{C}$ ratio.

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Oldest claim of biogenic ^{13}C depletion is for 3.85Gyr old sediments in Greenland.

Oldest known sediments on Earth on Akilia Island in western Greenland.

Dates from Late Hadean (from zircons found in the igneous rocks).

Result is still very controversial.



Akilia Island Banded Iron formation.

Were *Extremophiles* the first forms of life on Earth?

The earliest life was probably like prokaryotes today.

Prokaryotes tend to be more heat tolerant.

Deep hydrothermal vents are isolated from the harsh surface of the young Earth, and rich in inorganics.

Did chemosynthesis come before photosynthesis?



Life may have arisen and colonized the Earth within a few 100Myr of the end of heavy bombardment.

Don't know what the first organisms were.

Don't know if photo- or chemosynthesis came first.

Many lines of evidence show that life arose fairly quickly after conditions on Earth stabilized.