

Evaluating biosignatures in planetary analogue systems

Frank A Corsetti

University of Southern California



Searching for signs of life in rocks on Earth in case that is useful for searching for life elsewhere

Frank A Corsetti

University of Southern California



Biosignatures

- **Biosignature: a sign of life**
 - broadly defined
 - living or fossil
- **Fossil: record of ancient life**
 - preserved in rocks
 - specific kind of biosignature

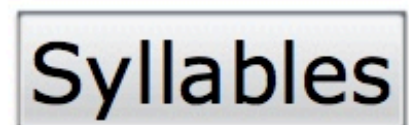




fossil

[**f**os-uh l]

 Spell

 Syllables



CITE

A→あ



[Examples](#)

[Word Origin](#)

[See more synonyms on Thesaurus.com](#)

noun

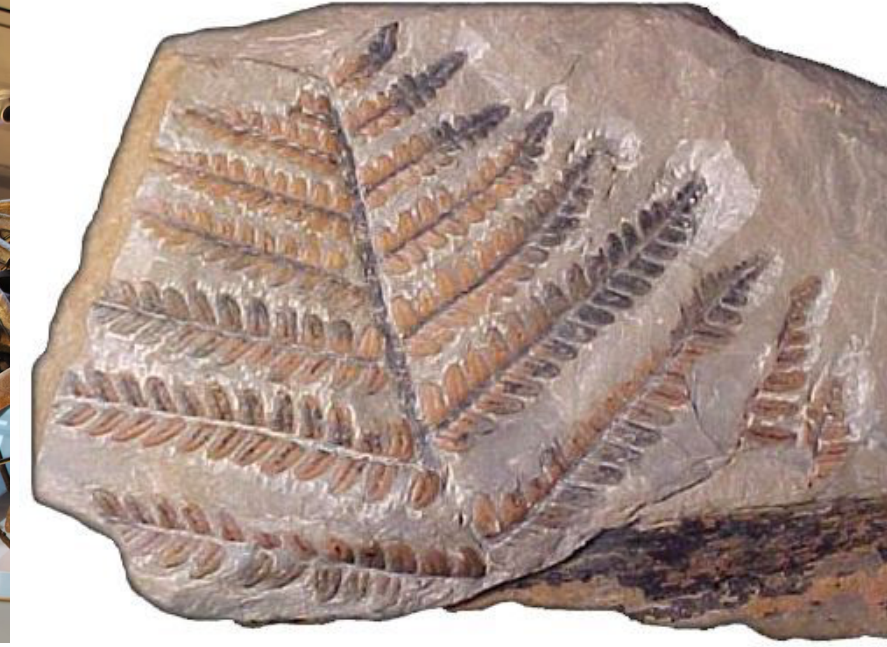
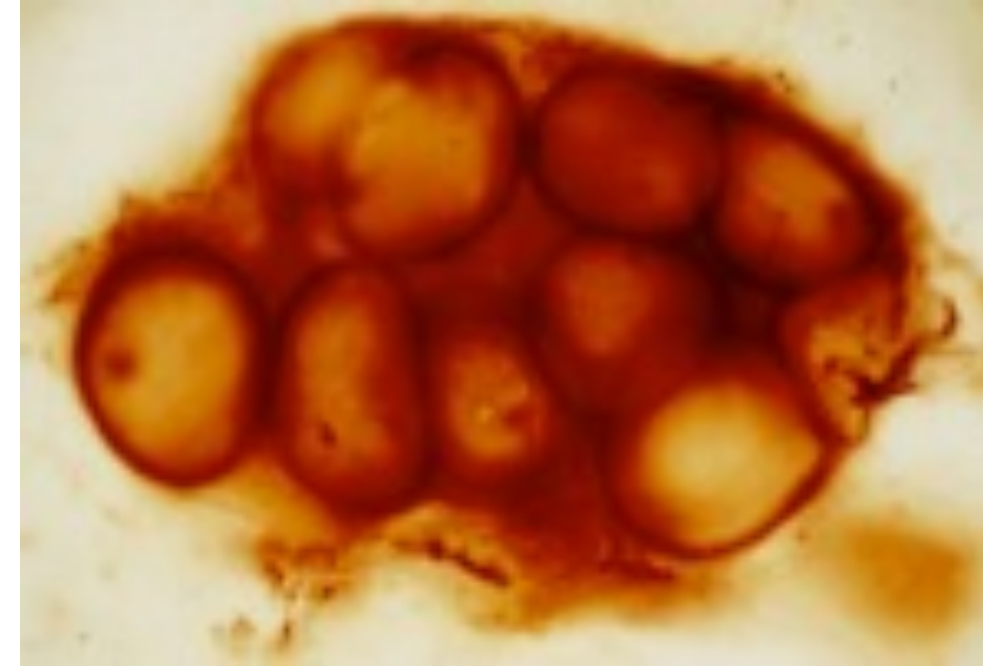
1. any remains, impression, or trace of a living thing of a former geologic age, as a skeleton, footprint, etc.
2. a markedly outdated or old-fashioned person or thing.

Fossil: Evidence of Past Life



Kinds of Fossils

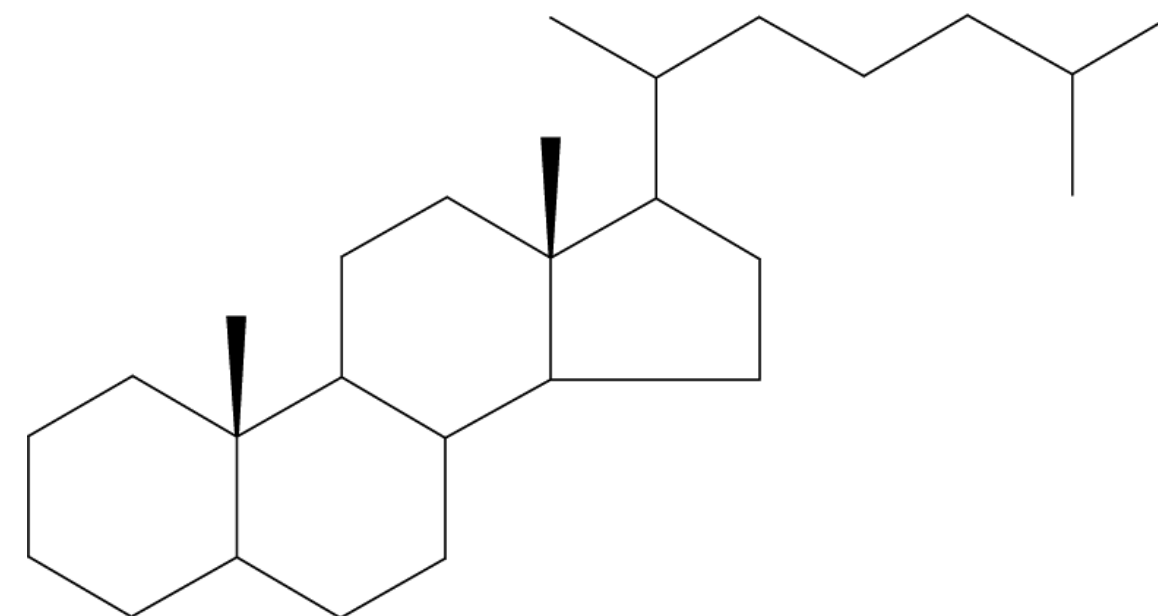
- Body Fossils



- Trace Fossils



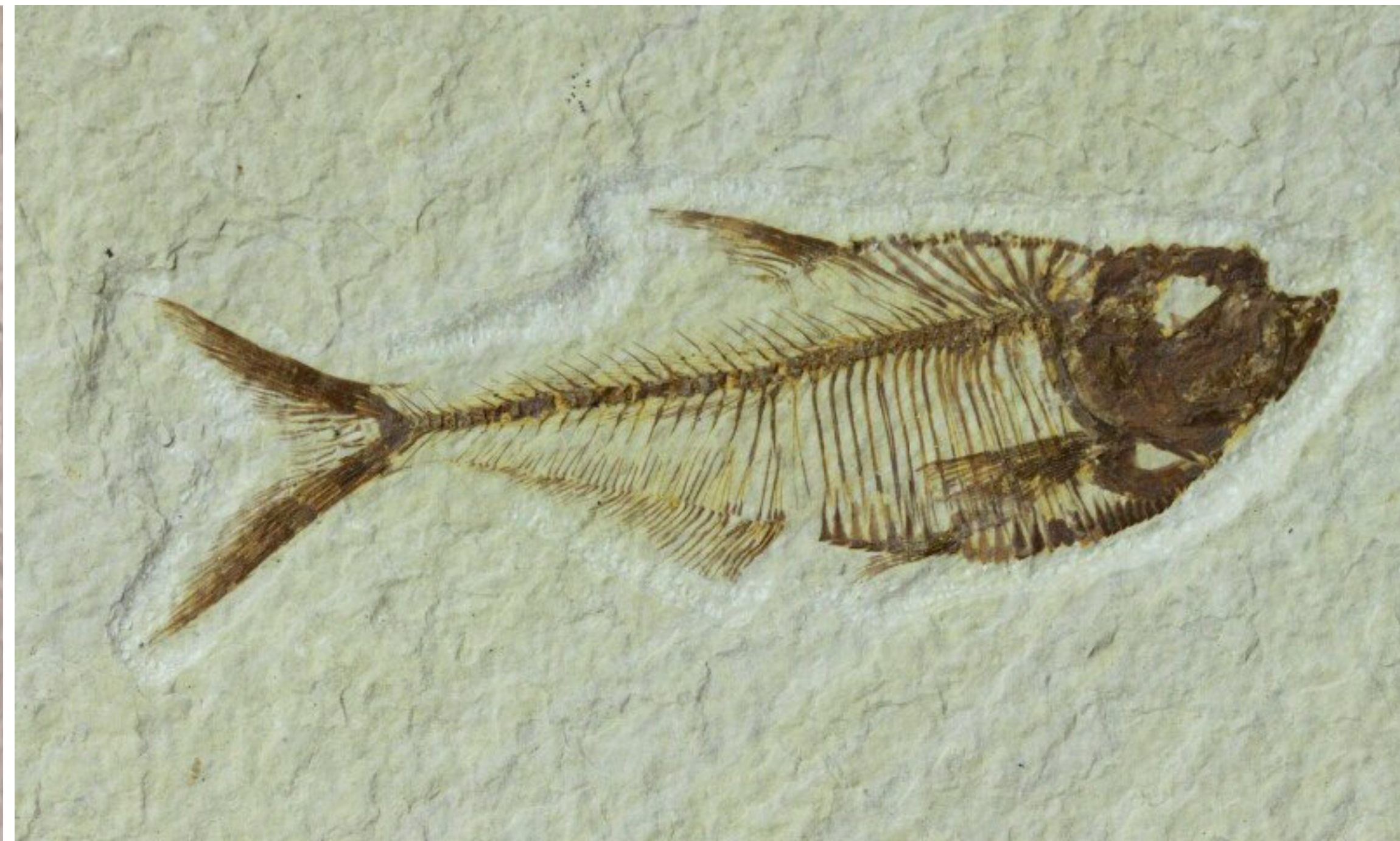
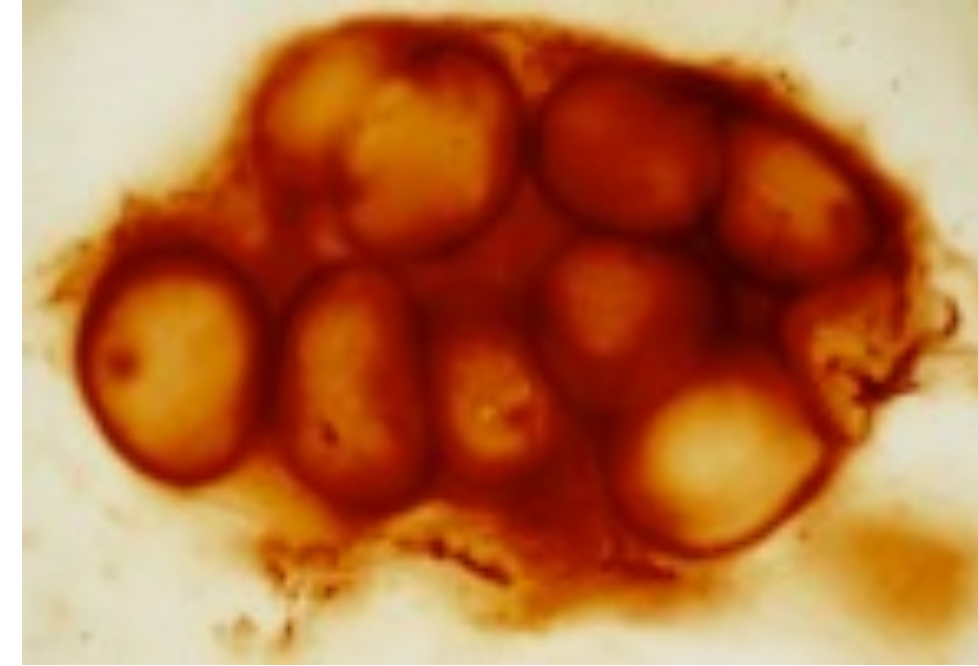
- Chemical Fossils



Morphologic
Biosignatures

Body Fossils

- The physical remains of an organism
 - Shells
 - Bones
 - Petrified wood, compressed plants
 - Etc.



Body Fossils

- The physical remains of an organism (its body)
- Informs about the functional morphology of the past organism
 - e.g., what could it do when it was alive?



Trace Fossils

- Evidence of activity of the past organism
 - footprints
 - worm trails
 - borings
 - coprolites
 - etc.



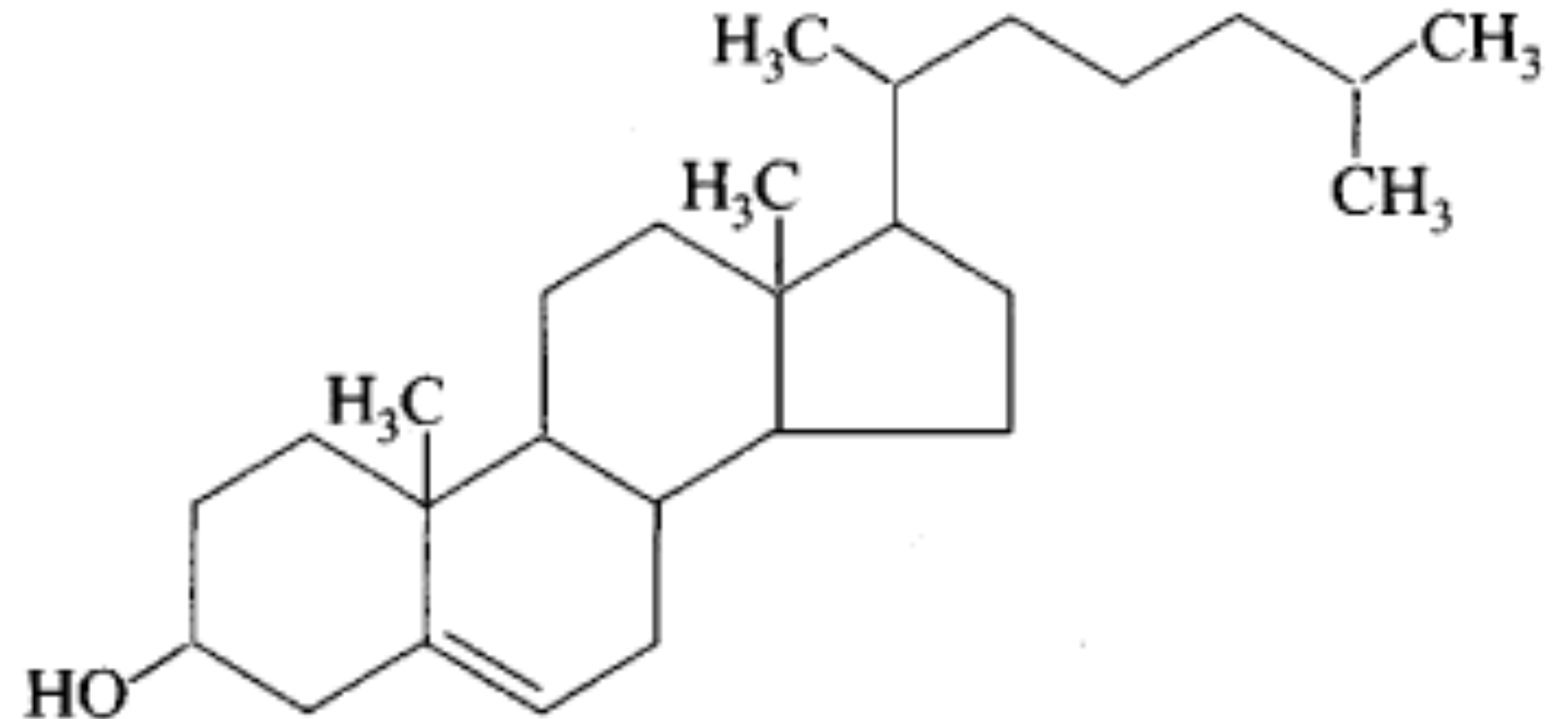
Trace Fossils

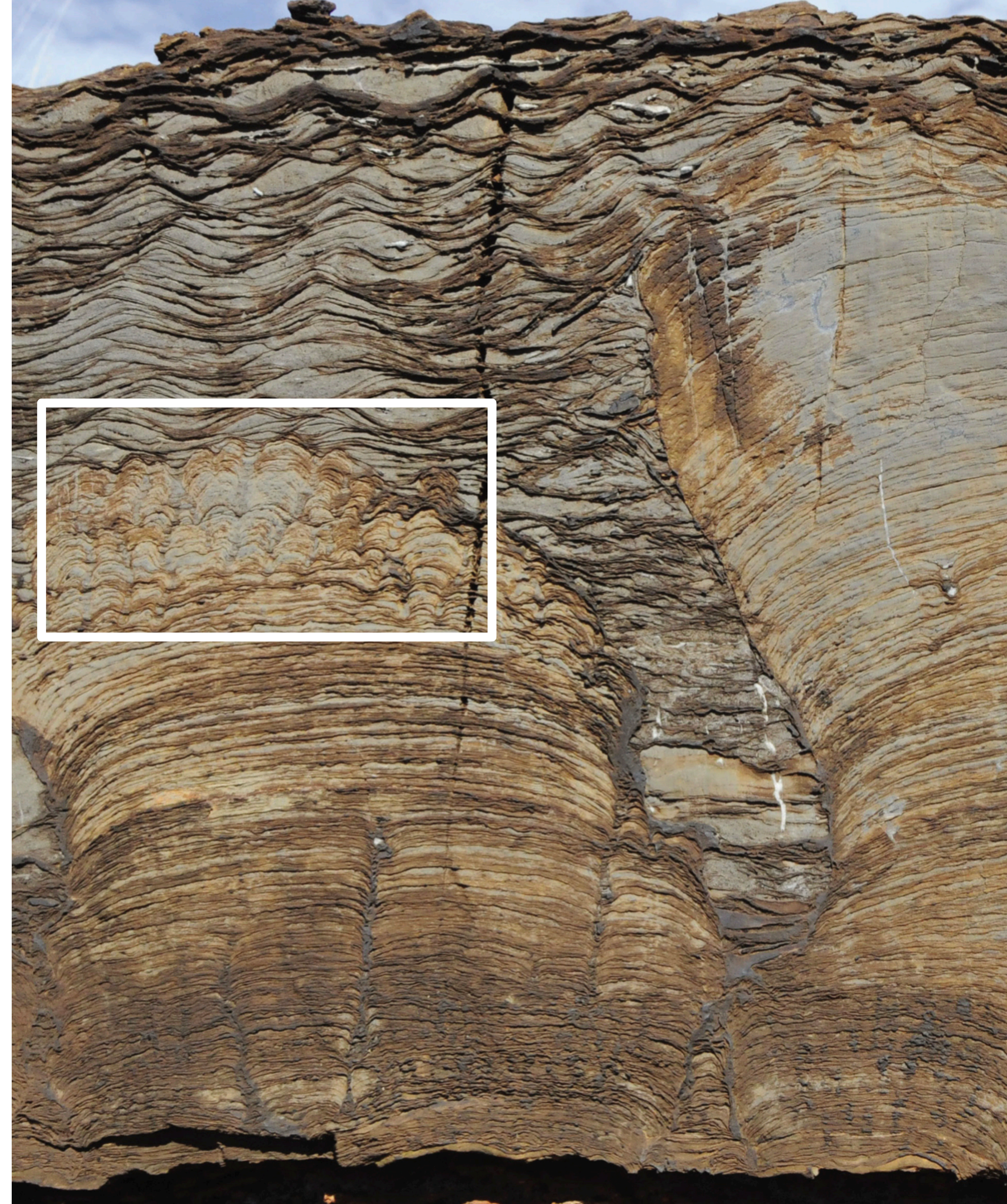
- Evidence of activity of the past organism
- Informs about what the organism did, how it interacted with the environment.



Chemical Fossils

- Chemical evidence of past life preserved in the rocks
 - e.g., isotopic signatures
 - organic molecules attributed to life
- Informs the metabolism and the presence of certain clades

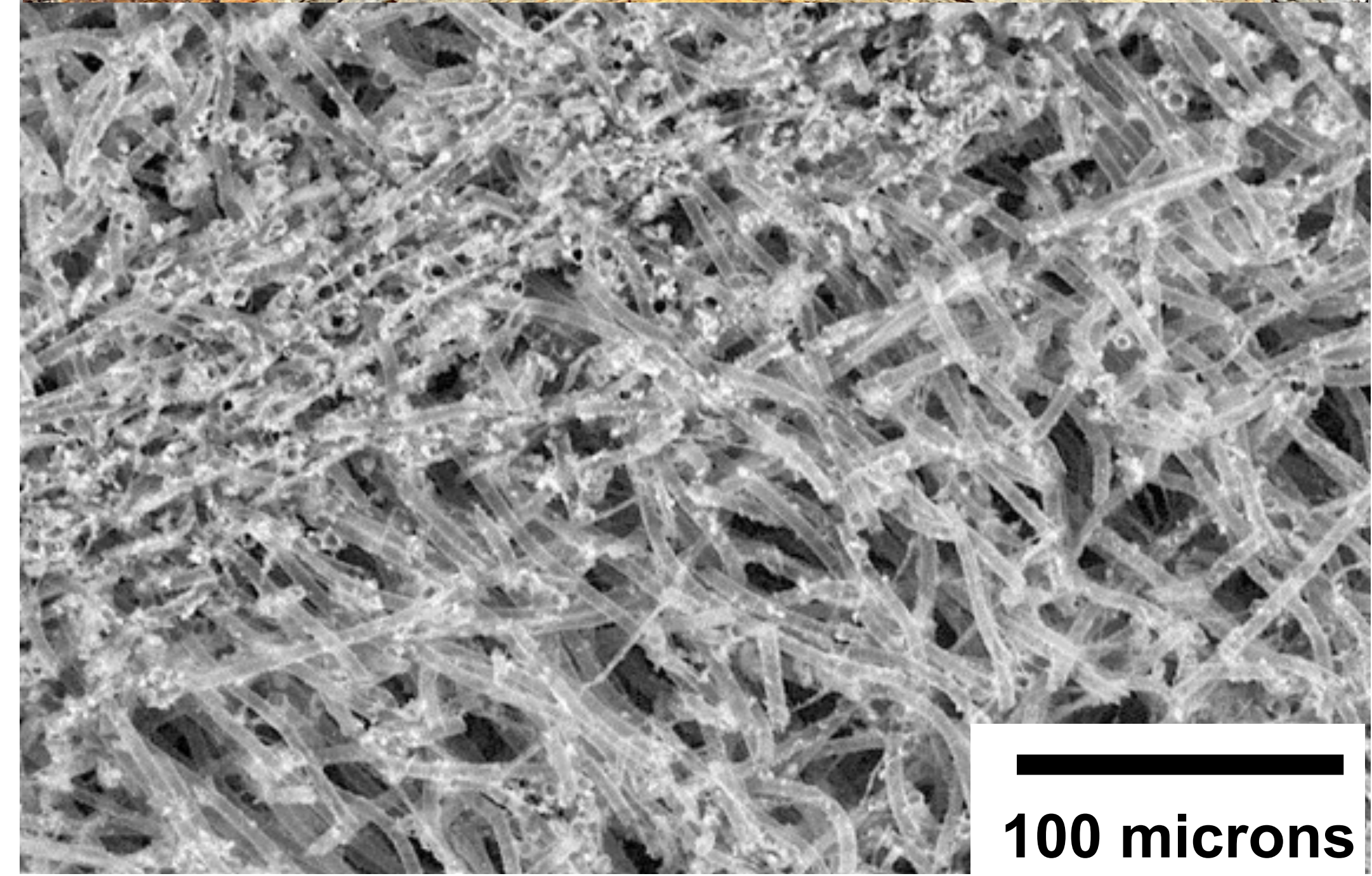




Stromatolite

Textbook Definition

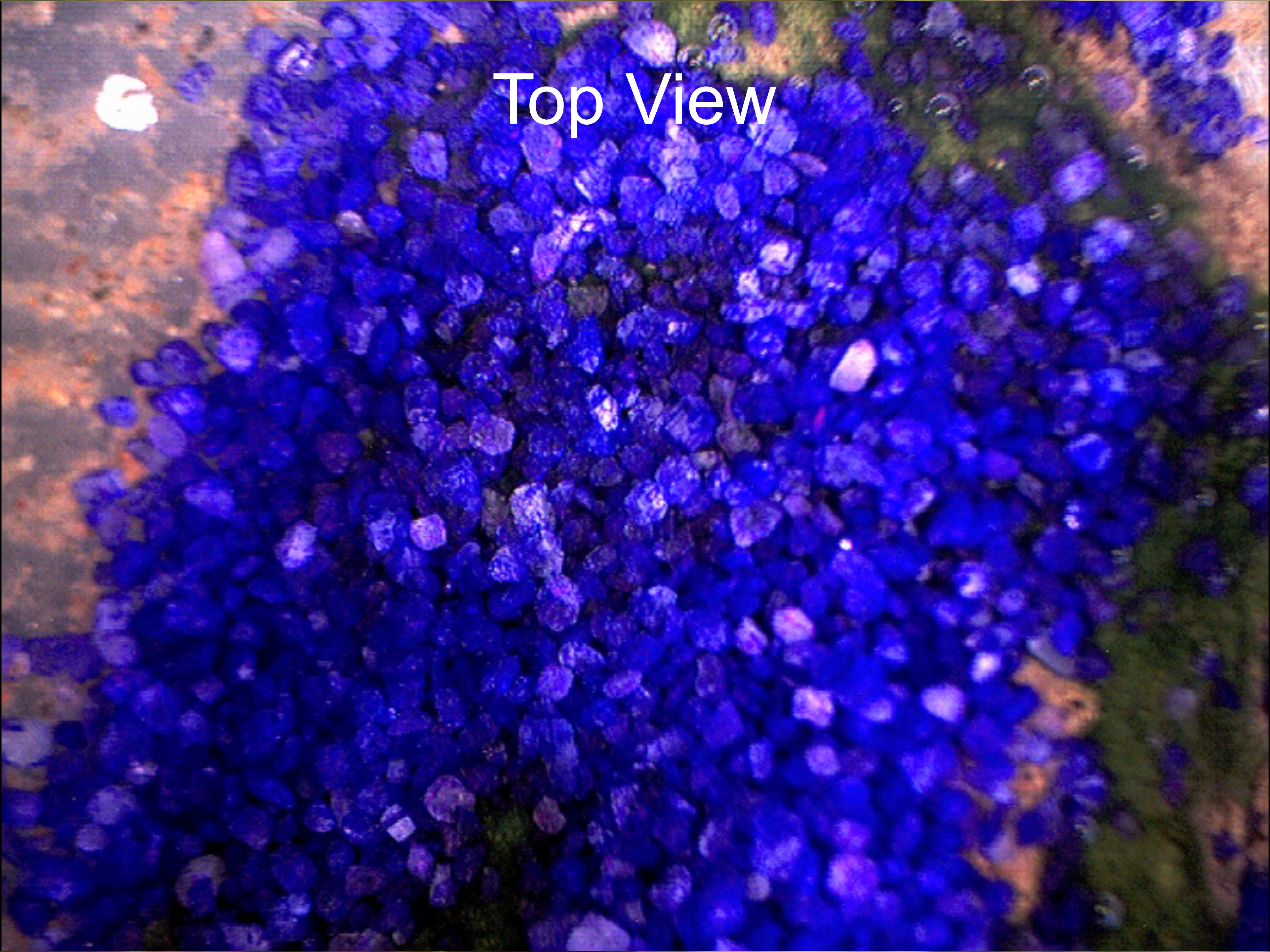
- laminated
- organo-sedimentary structure
- built by microbes

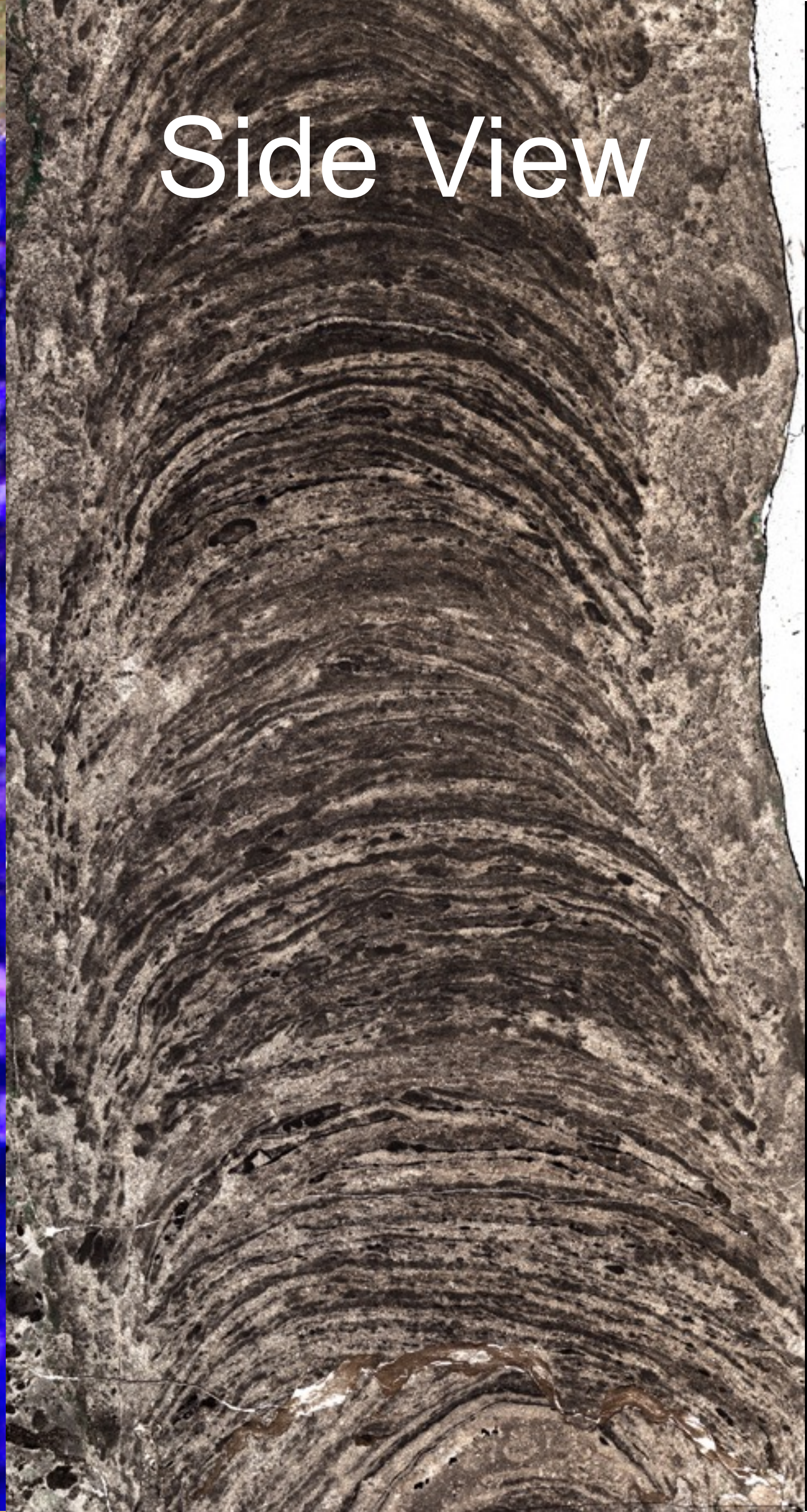
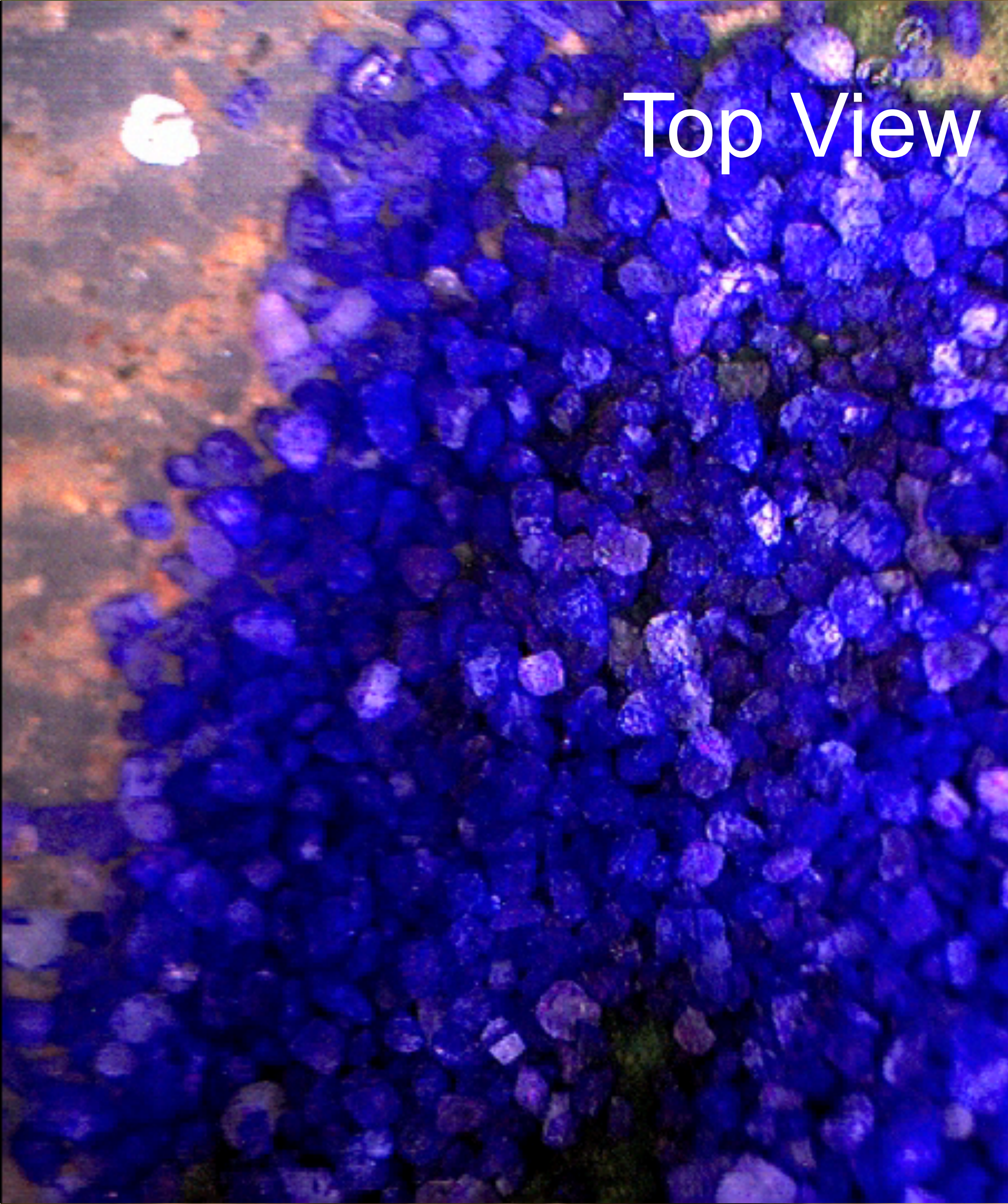


microbial mat
("pond scum")

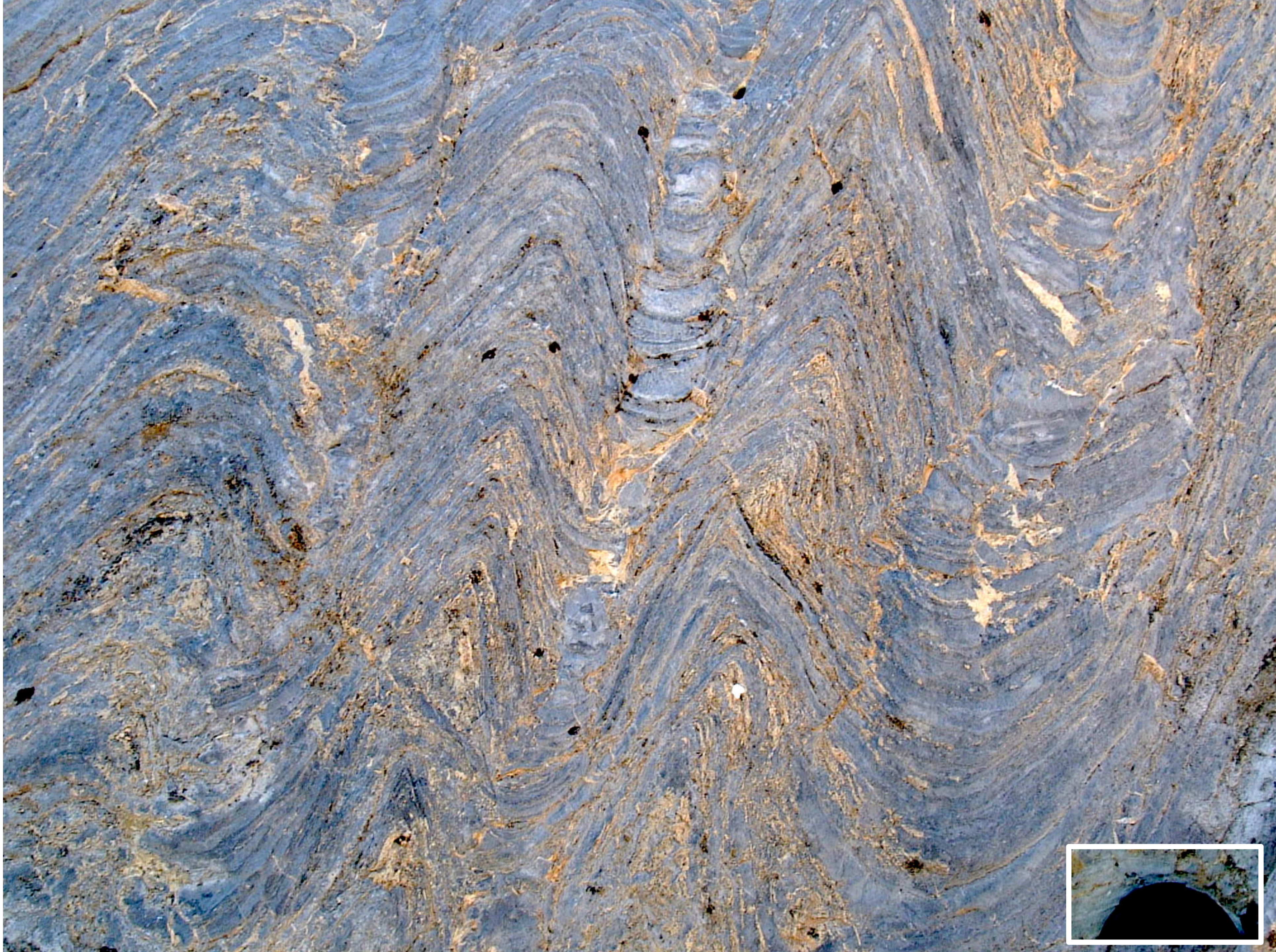


Top View

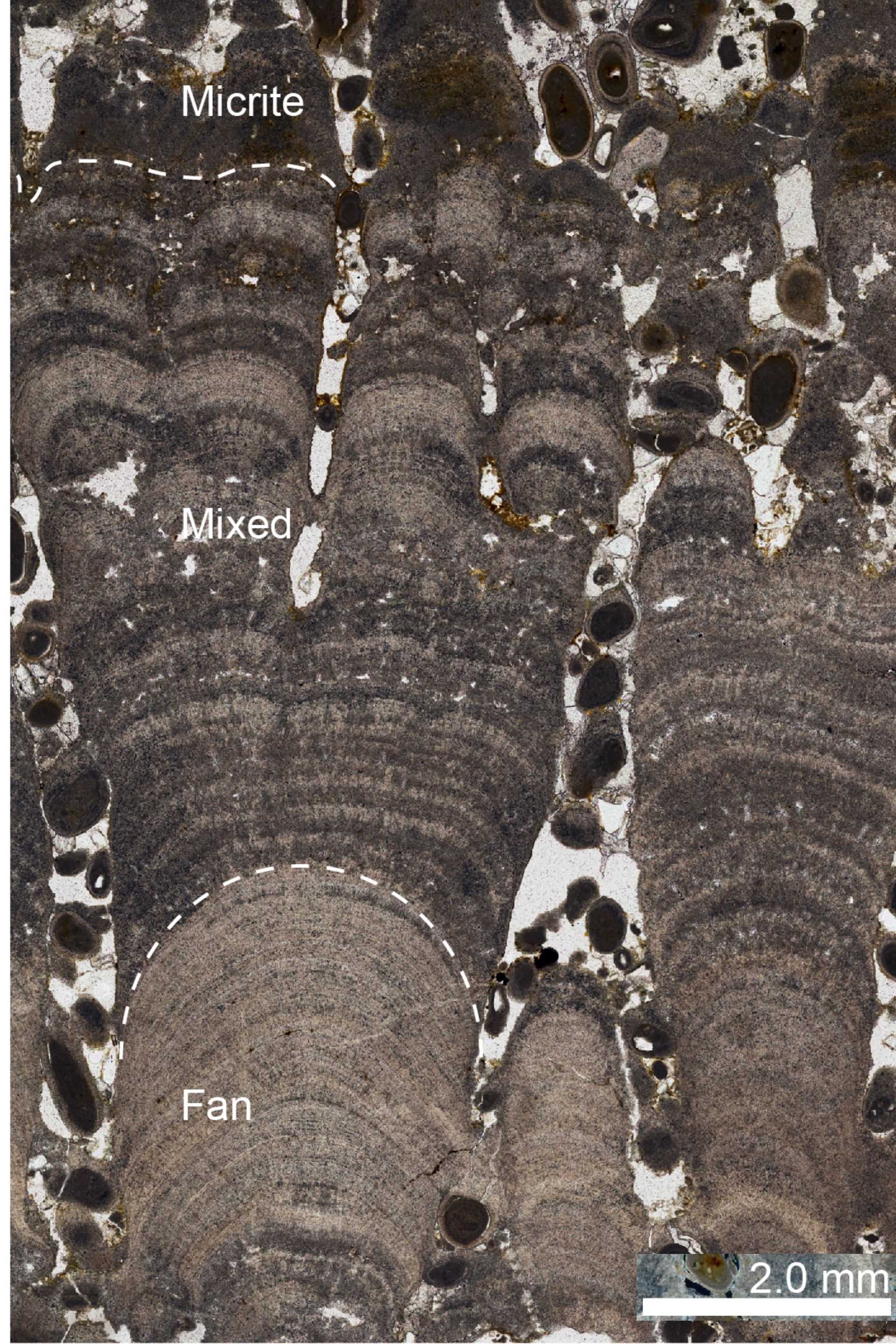












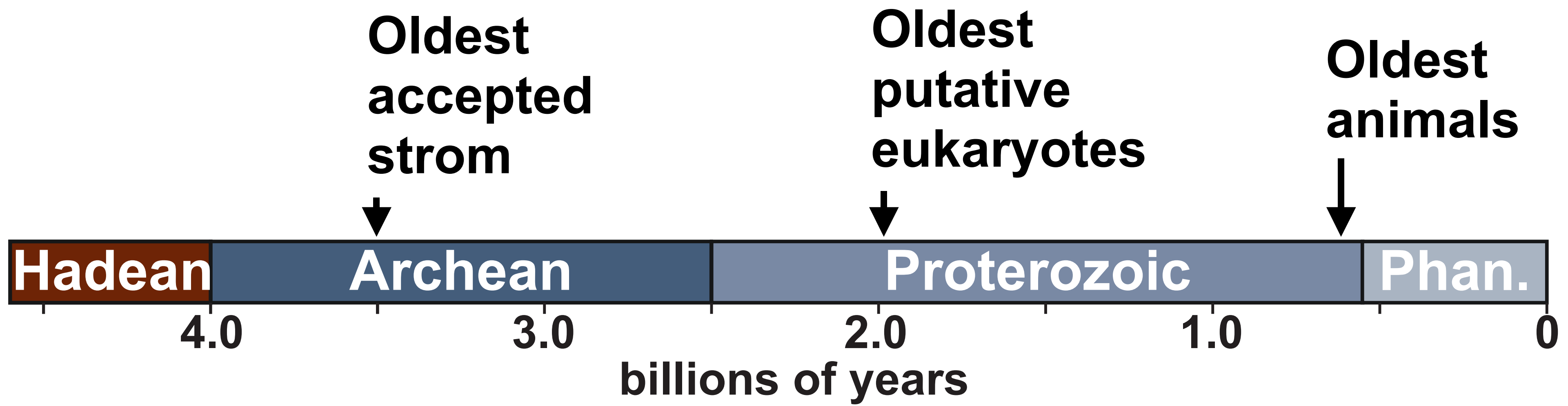
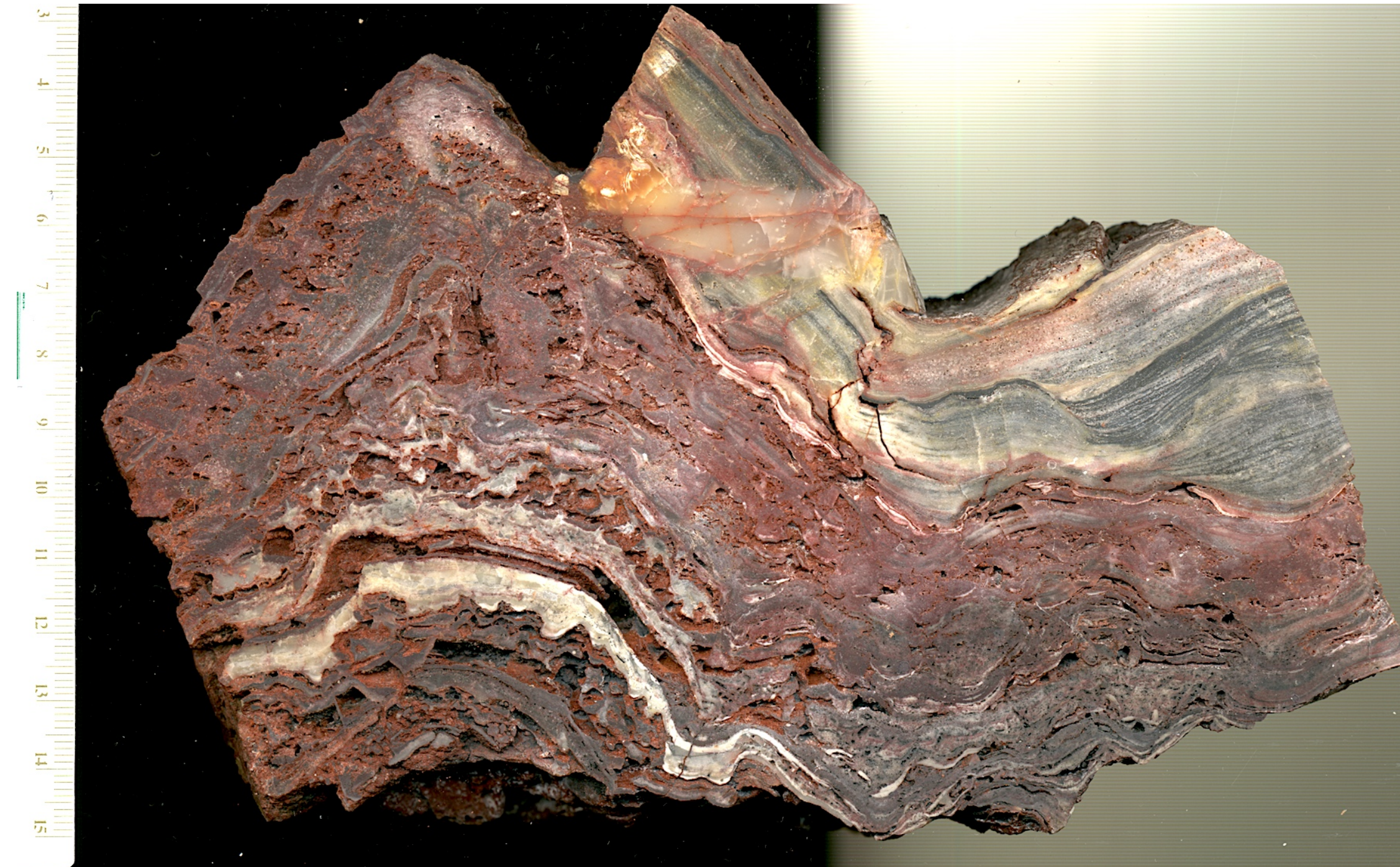




courtesy of L. Kah



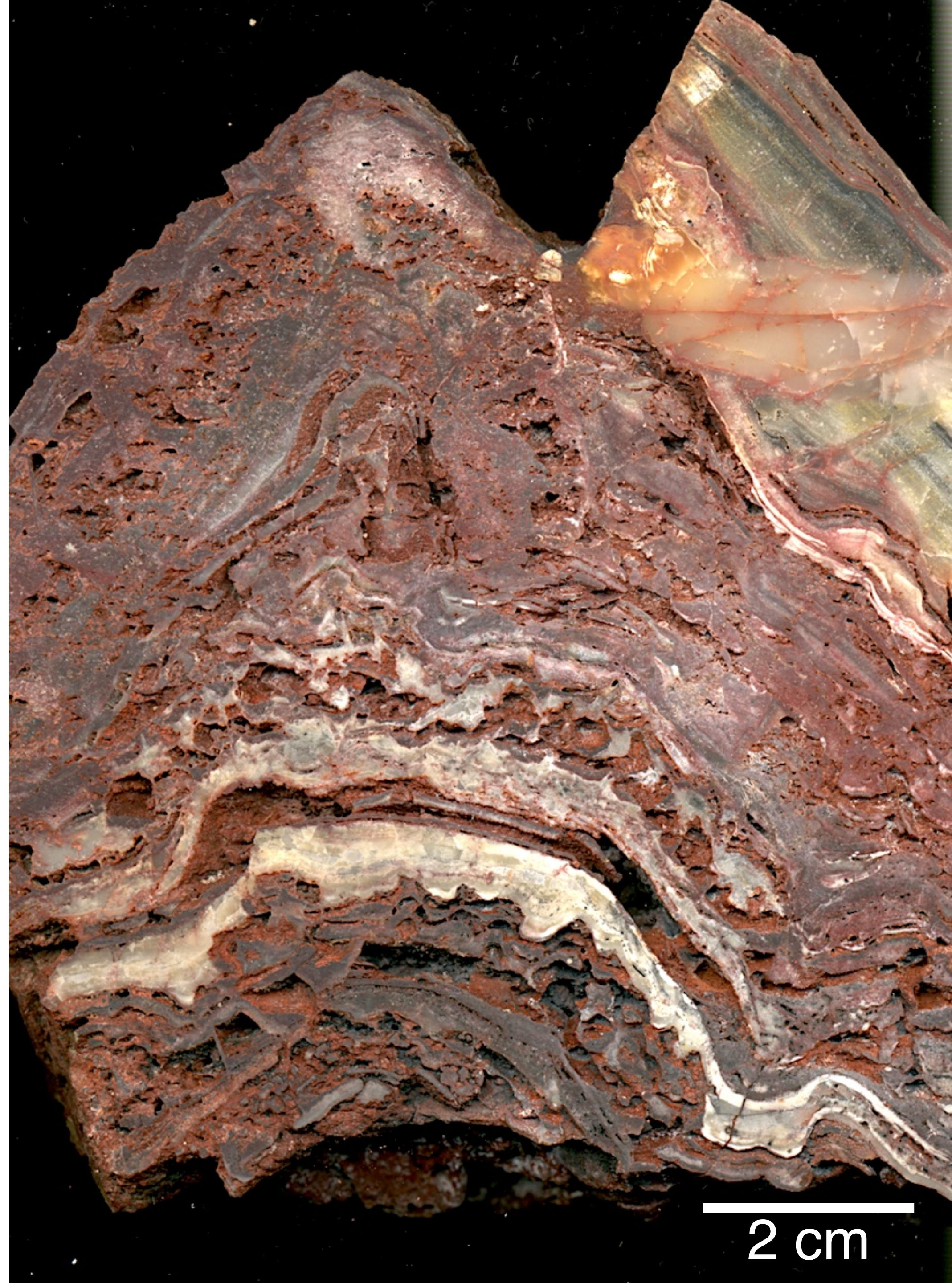
Ancient Life: Greatest Hits



Stromatolite Significance

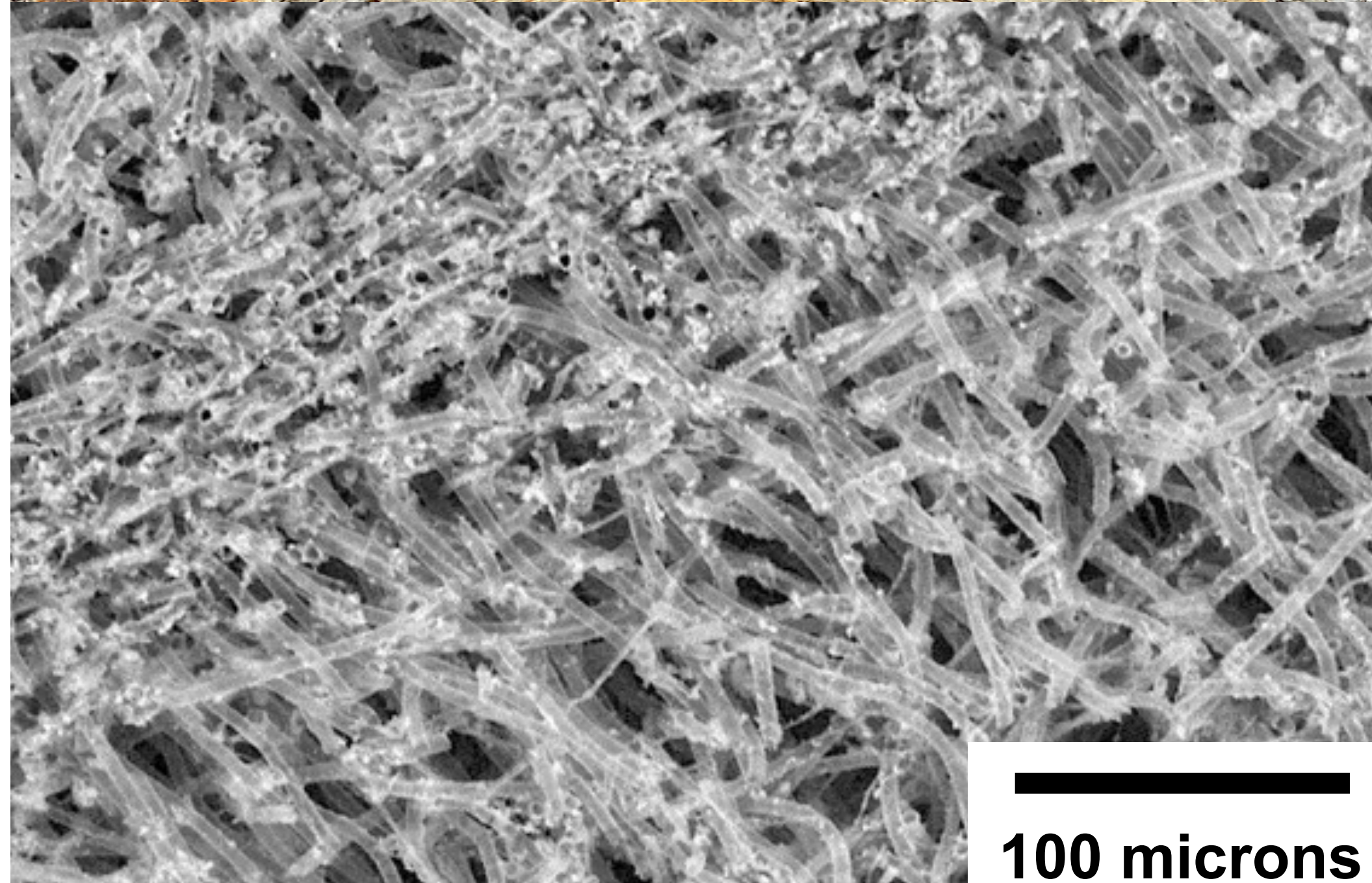
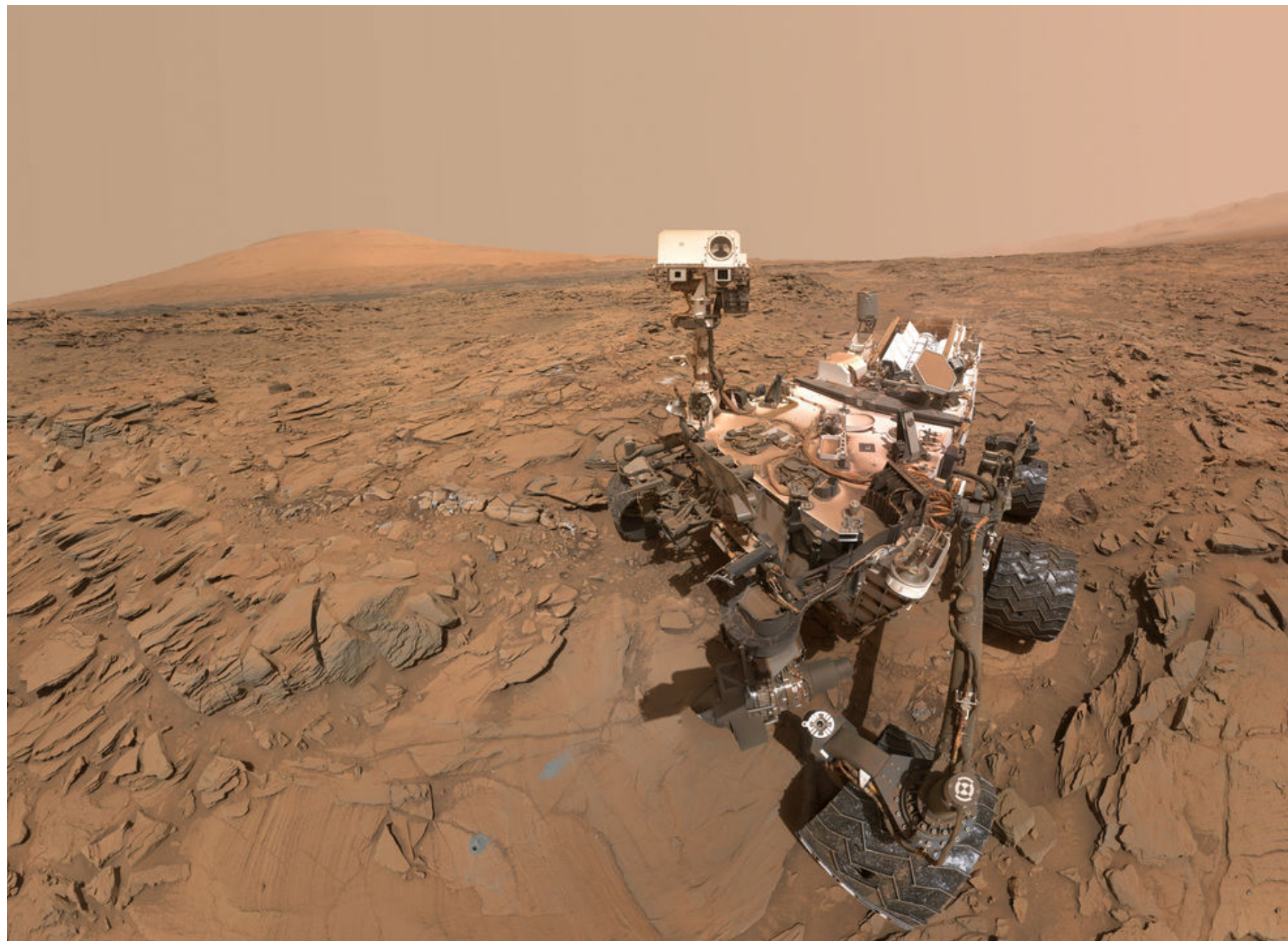
- Oldest fossils in the world

Warrawoona Fm
Western Australia
3.5 Ga



Stromatolite Significance

- Macroscopic from
Microscopic



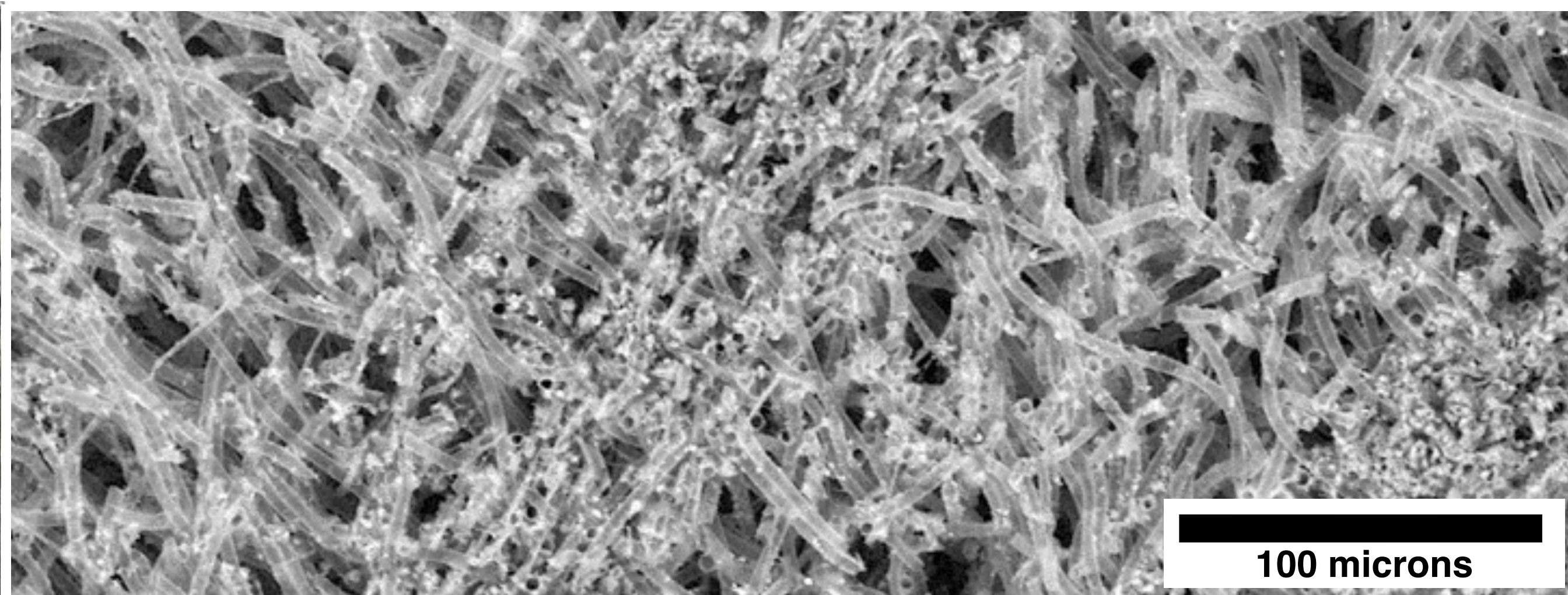
2008 Joint Meeting of The Geological Society of America, Soil Science Society of America, American Society of Agronomy, Crop Science Society of America, Gulf Coast Association of Geological Societies with the Gulf Coast Section of SEPM

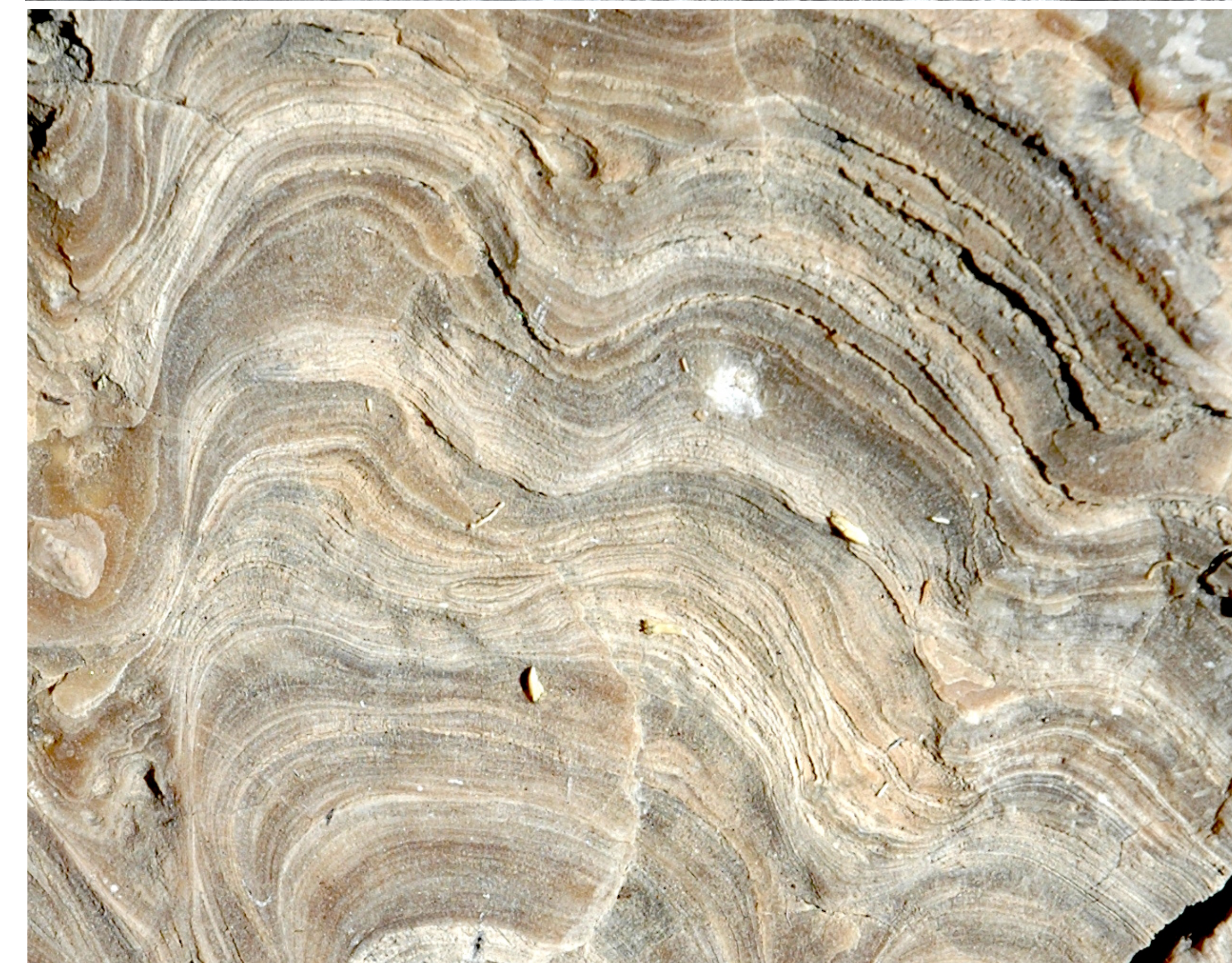
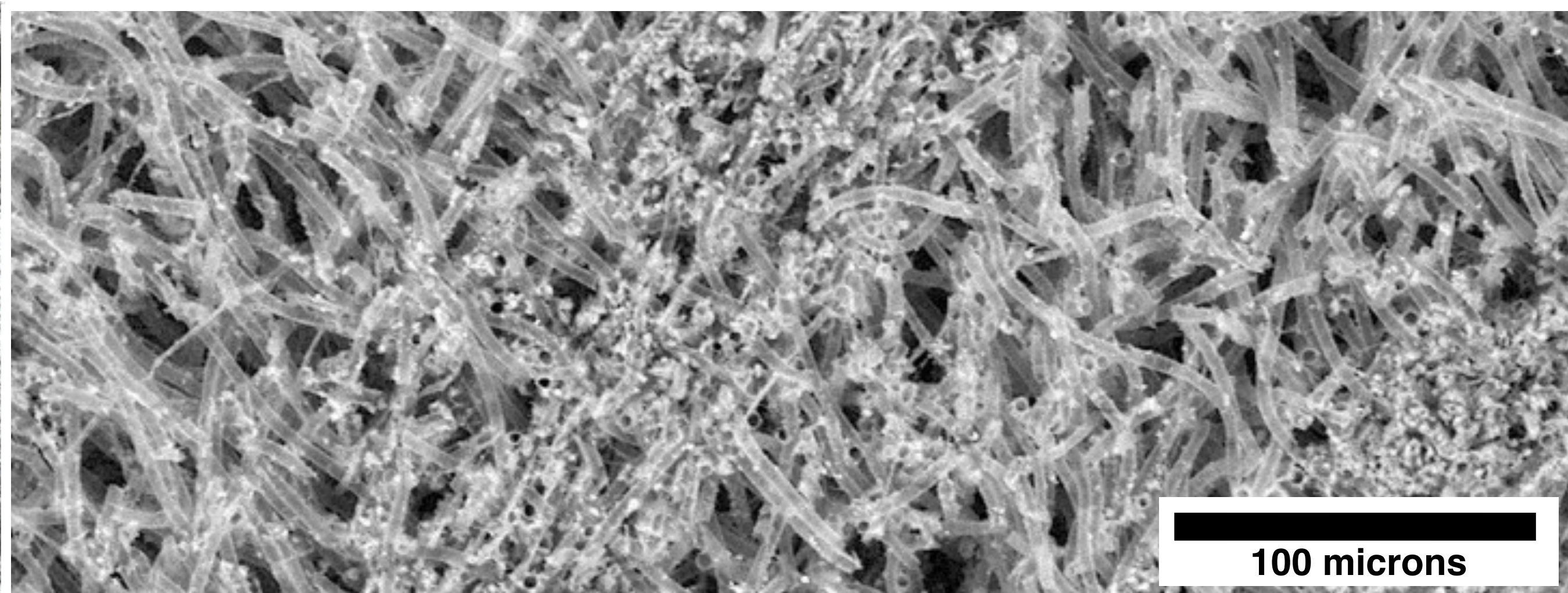
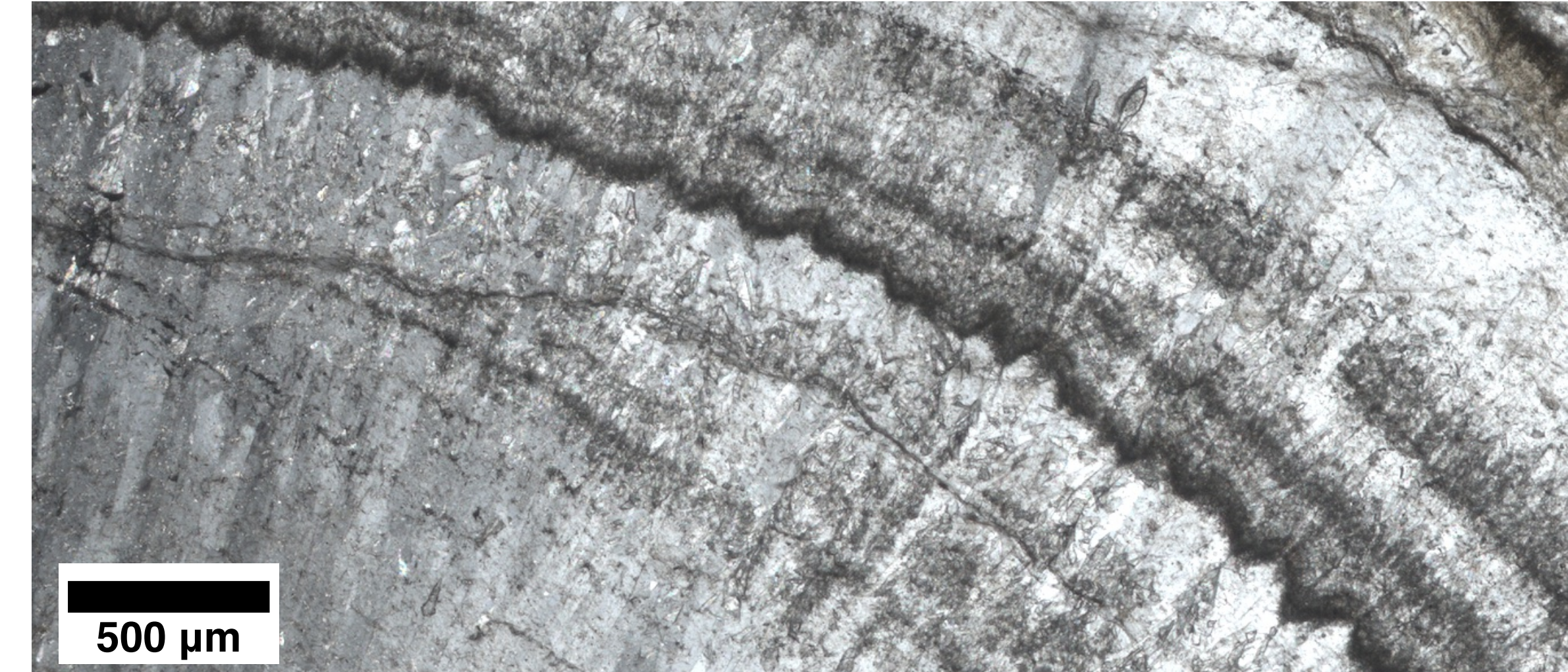
Paper No. 15

Presentation Time: 5:15 PM

A Tale of Two Stromatolites

CORSETTI, Frank A.¹, BERELSON, William M.¹ and SPEAR, John R.², (1)Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089, (2)Division of Environmental Science and Engineering, Colorado School of Mines, Golden, CO 80401-1887, fcorsett@usc.edu







Conclusion, 2008

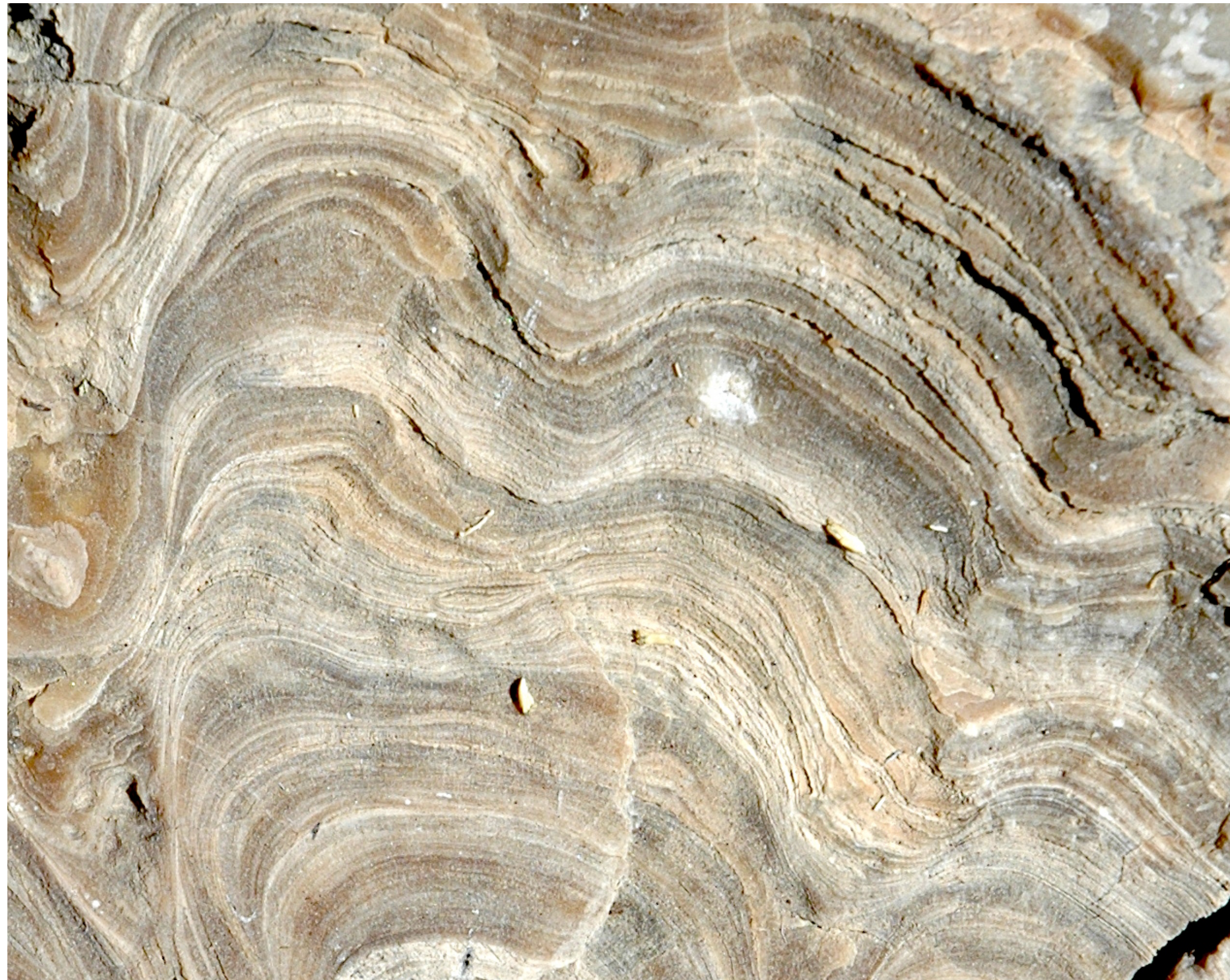
Stromatolites are not always evidence for life

“cautionary tale”

Abiogenic



Biogenic



Hallmarks of Life



1. Grains trapped beyond angle of slide

• Frantz et al. 2015

2. Magnetic susceptibility patterns

• Petryshyn et al. 2016

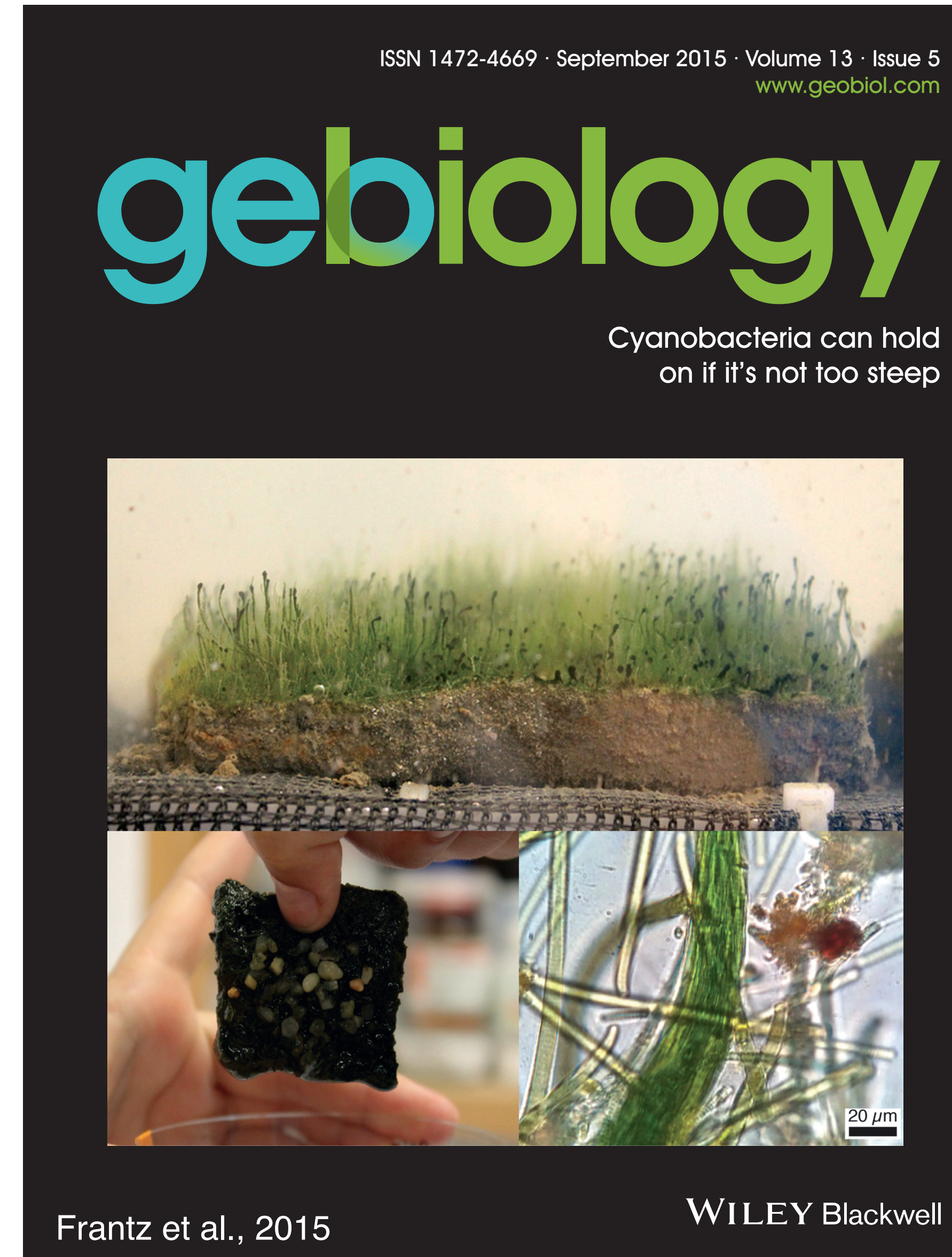
3. Bubbles!

• Ibarra et al. 2016, Wilmeth et al., 2015, 2019



1. Grains trapped beyond angle of slide as a biosignature

- What can cyanobacteria trap and bind?
- Utility as a biosignature



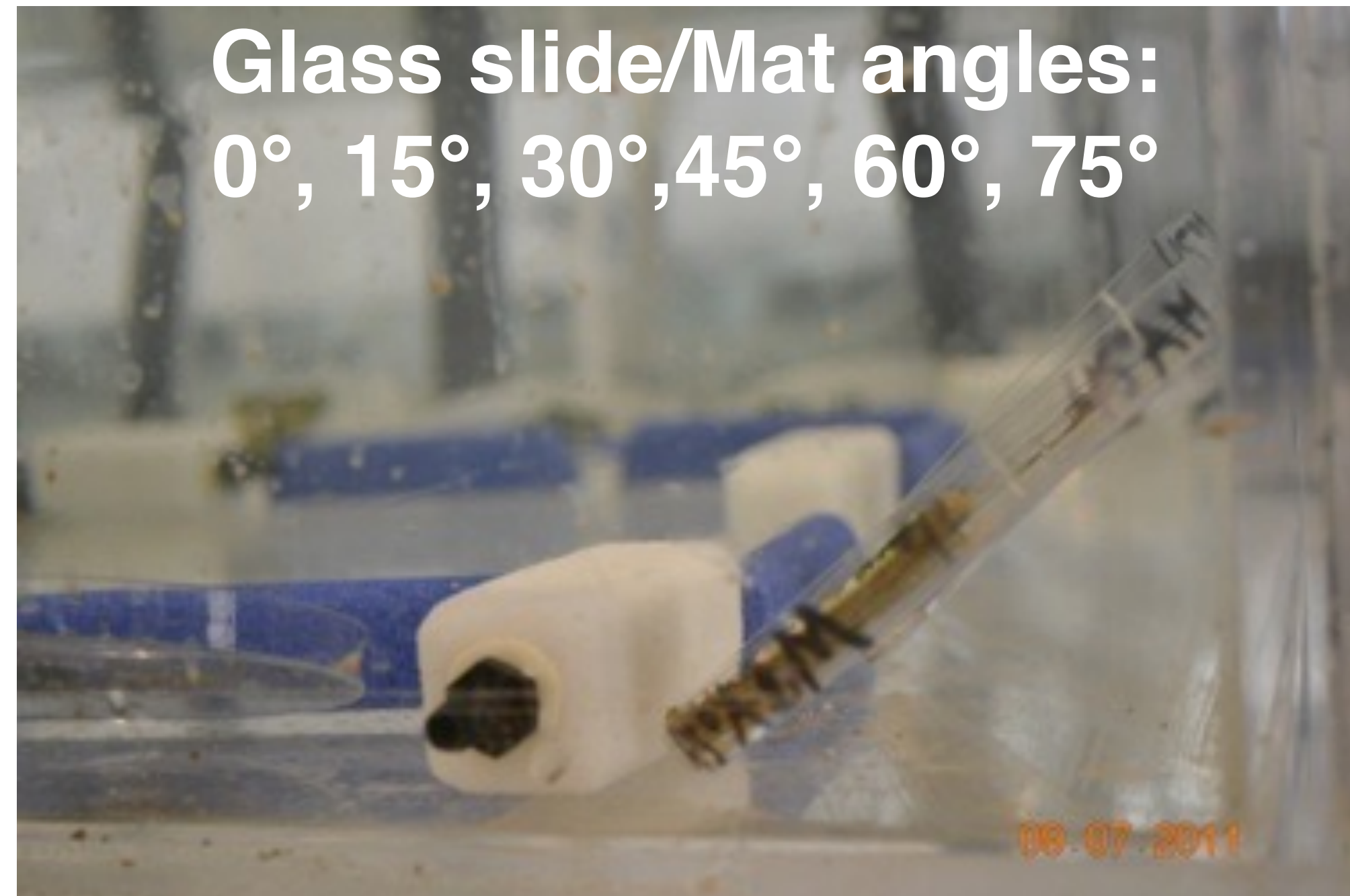
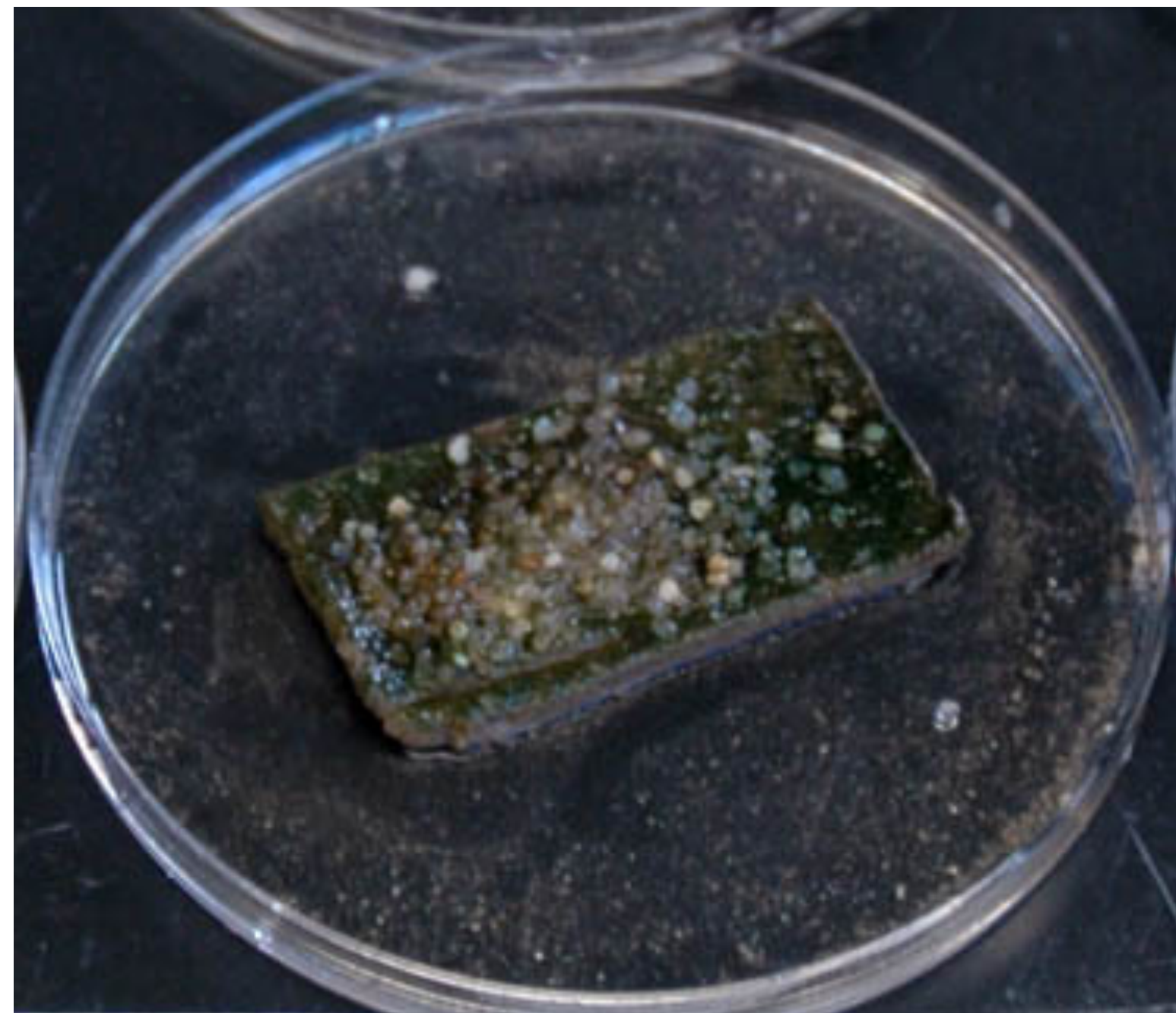
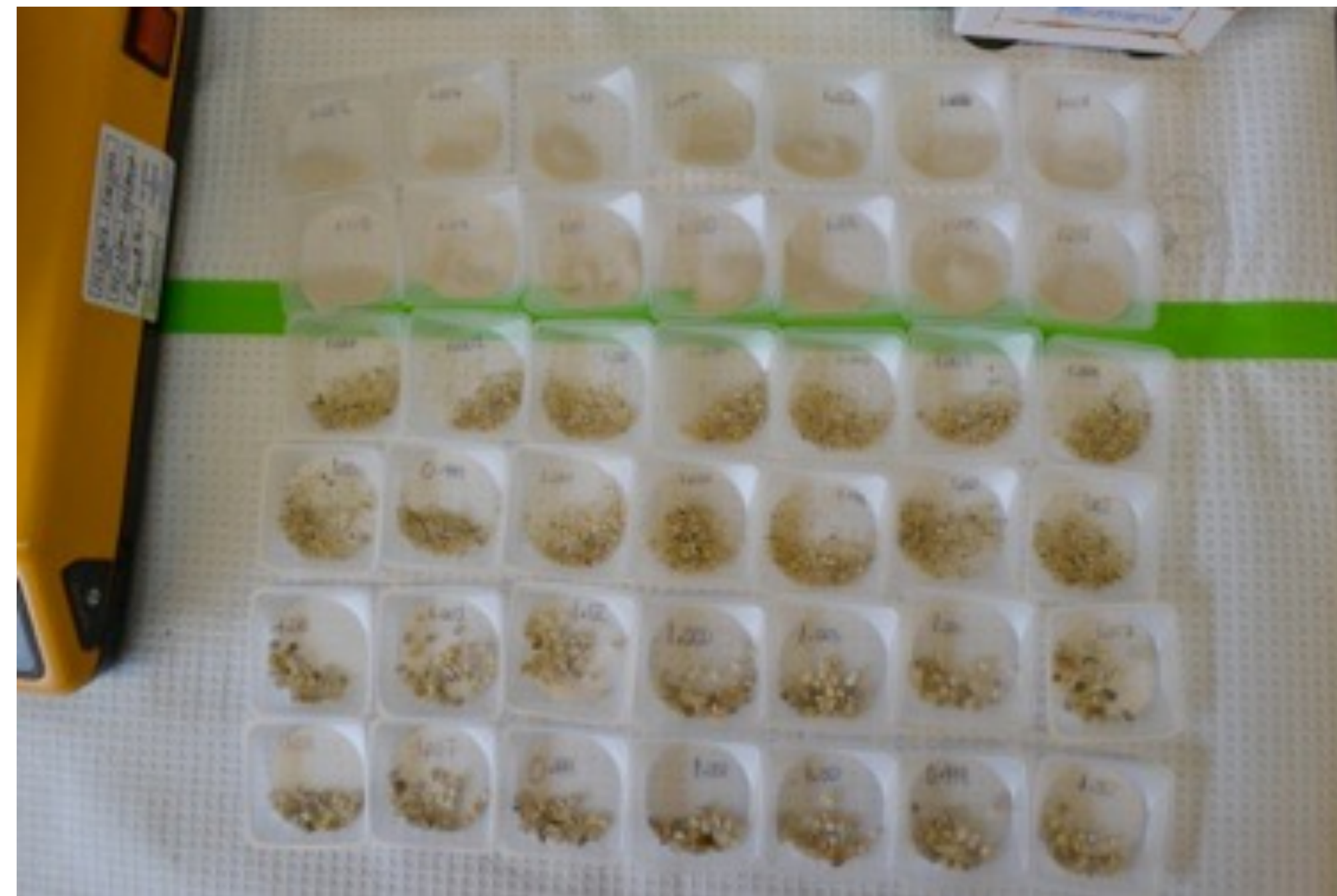


Grain size

Fine: 0.125-0.250 mm

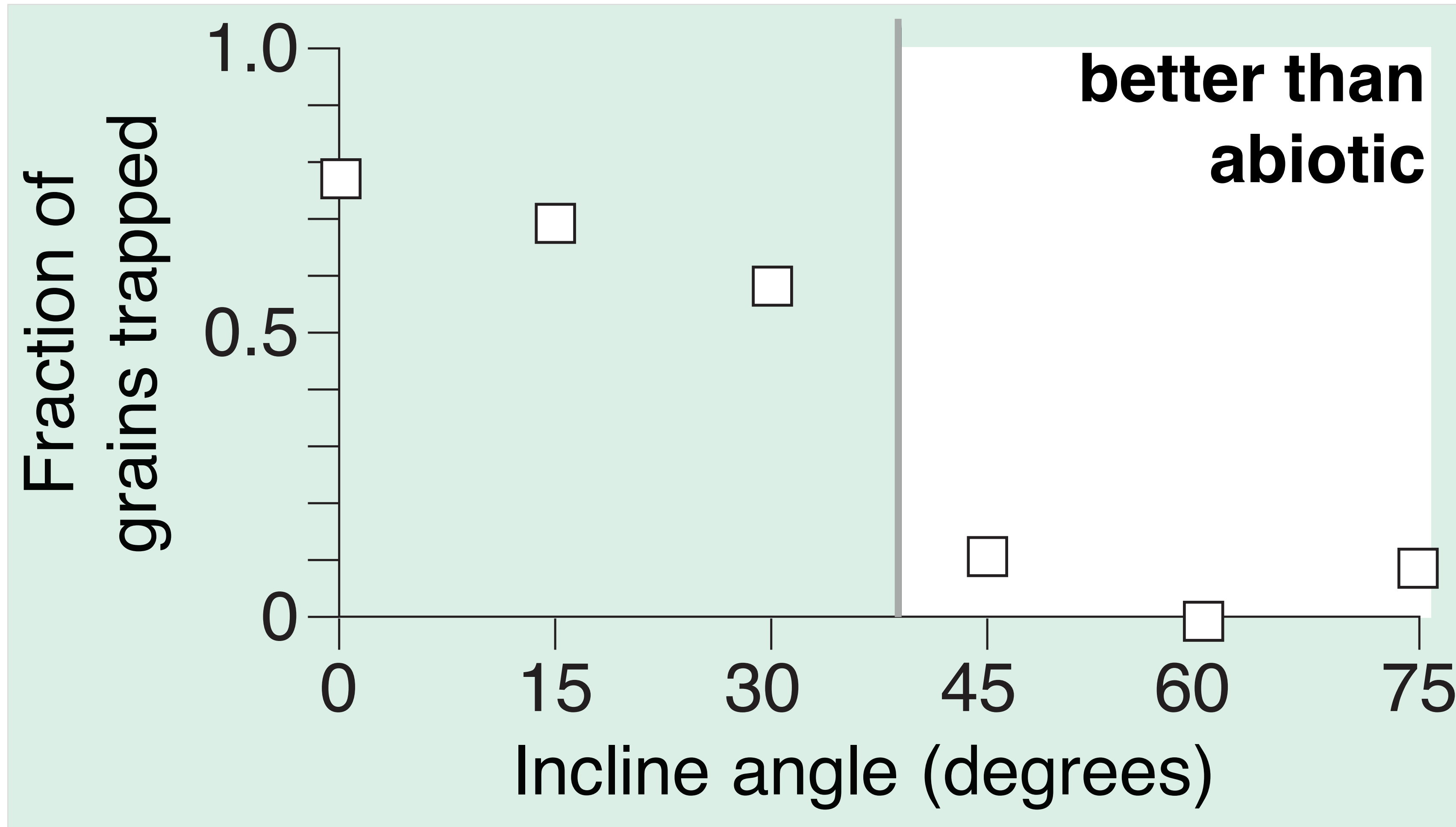
Medium: 0.50-1.0 mm

Coarse: 1.0-2.0 mm

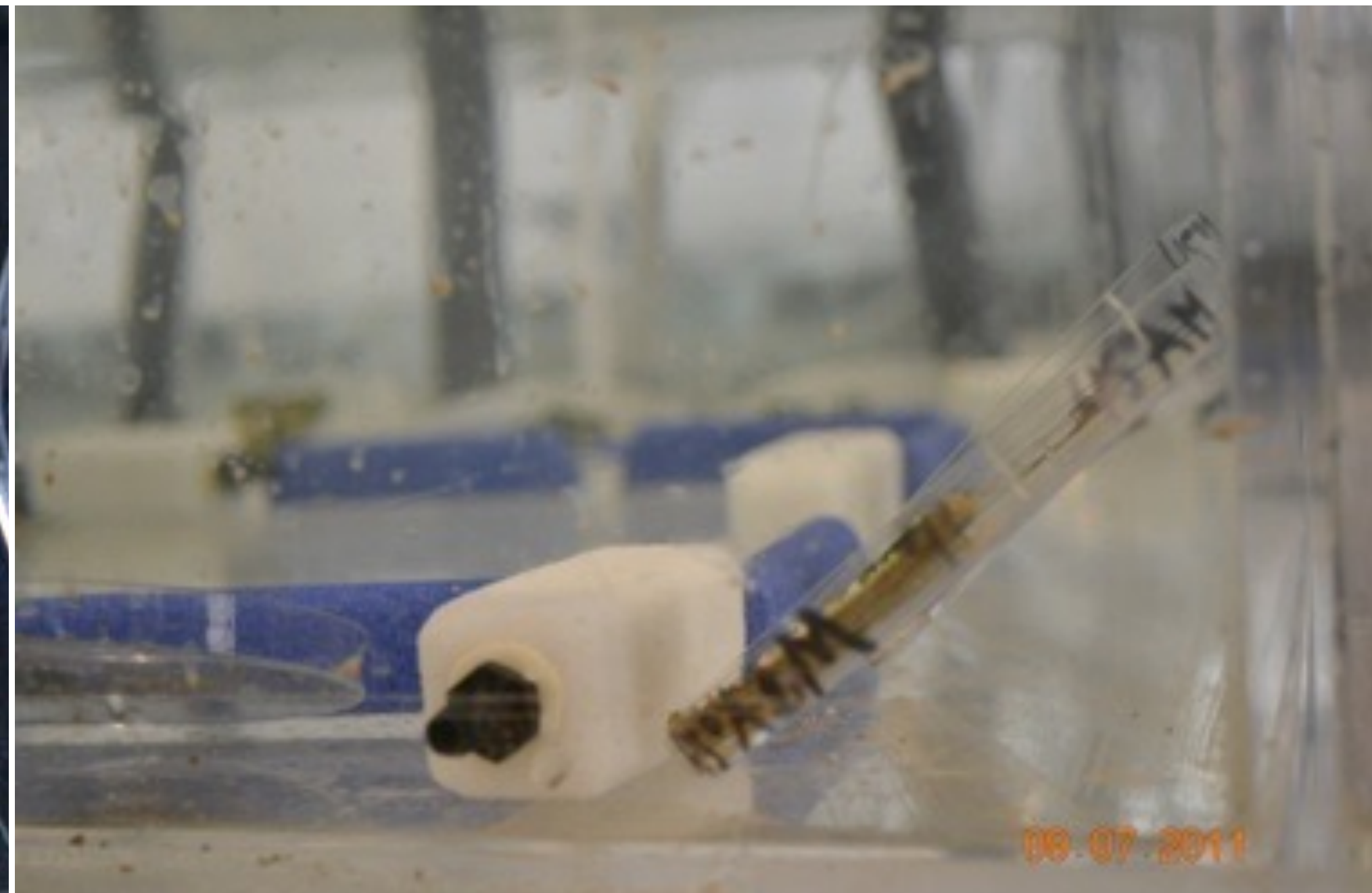
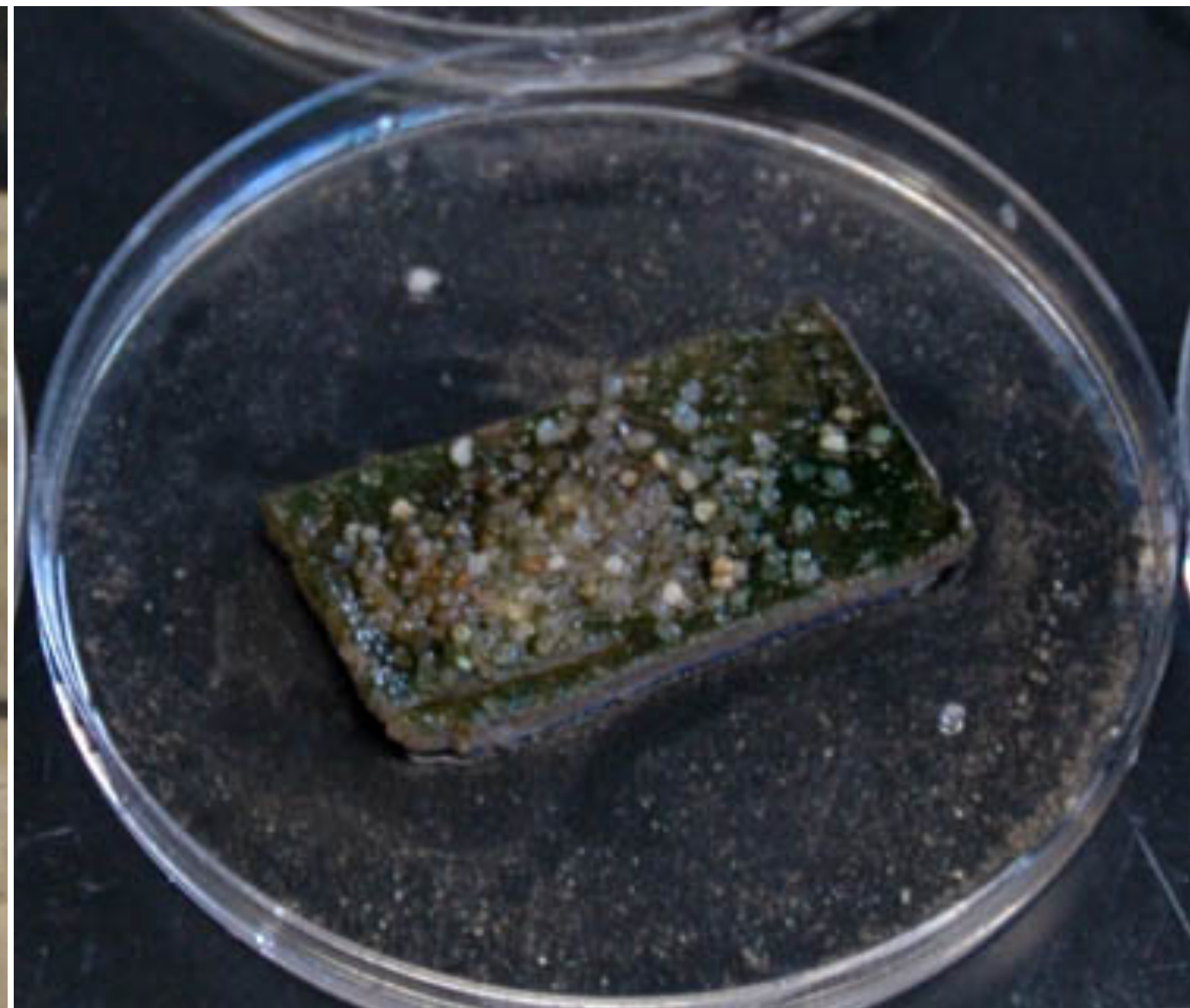
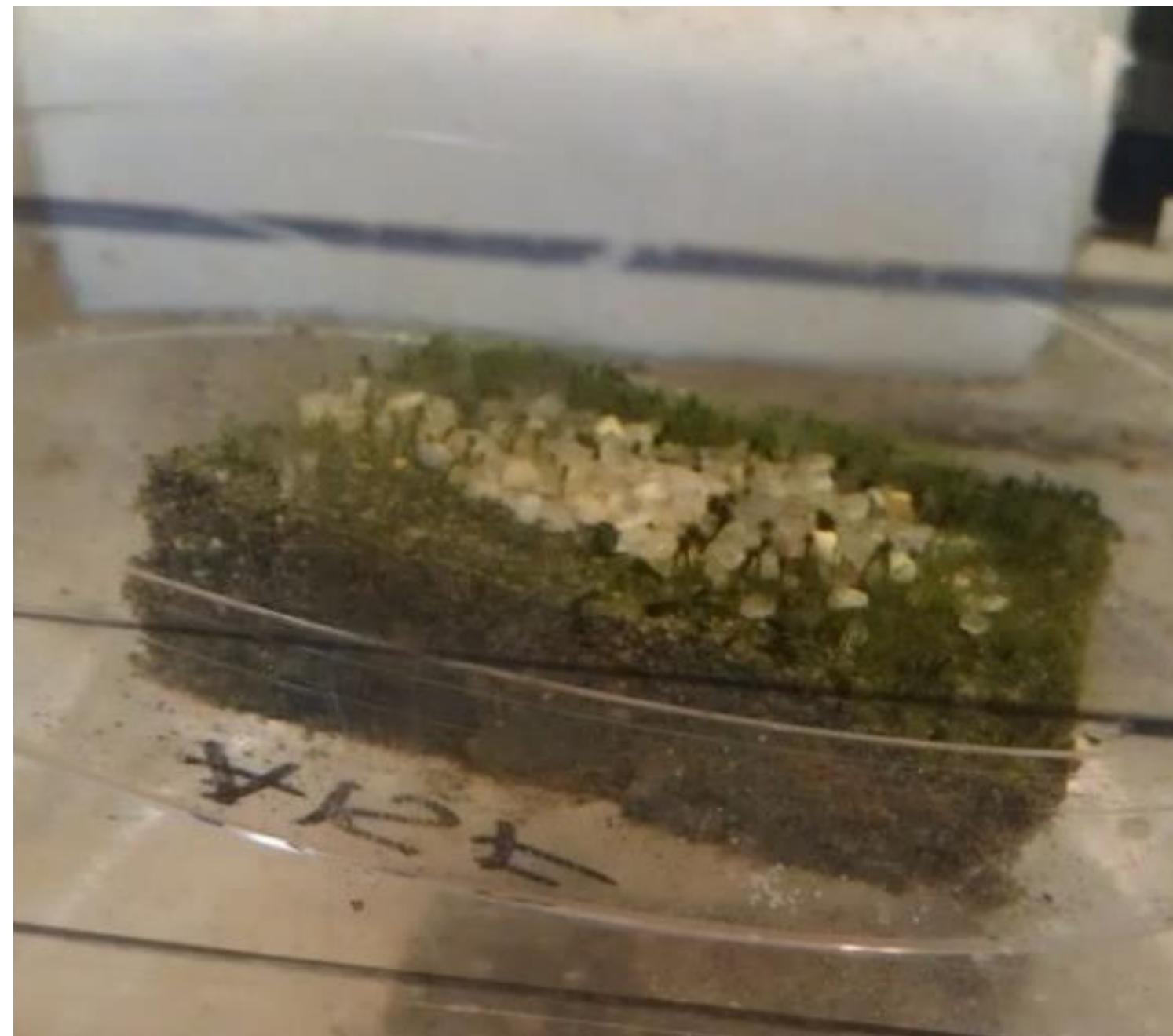
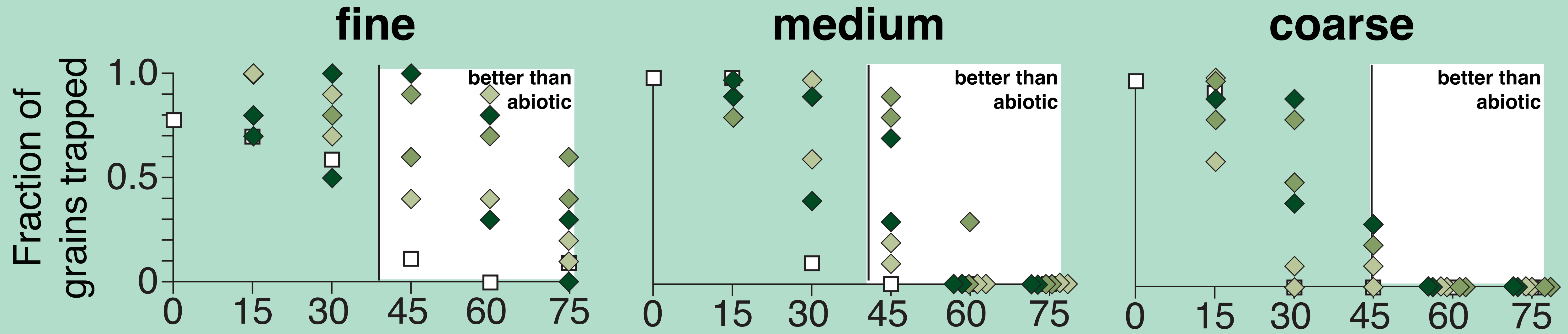


Glass Slide

fine grain

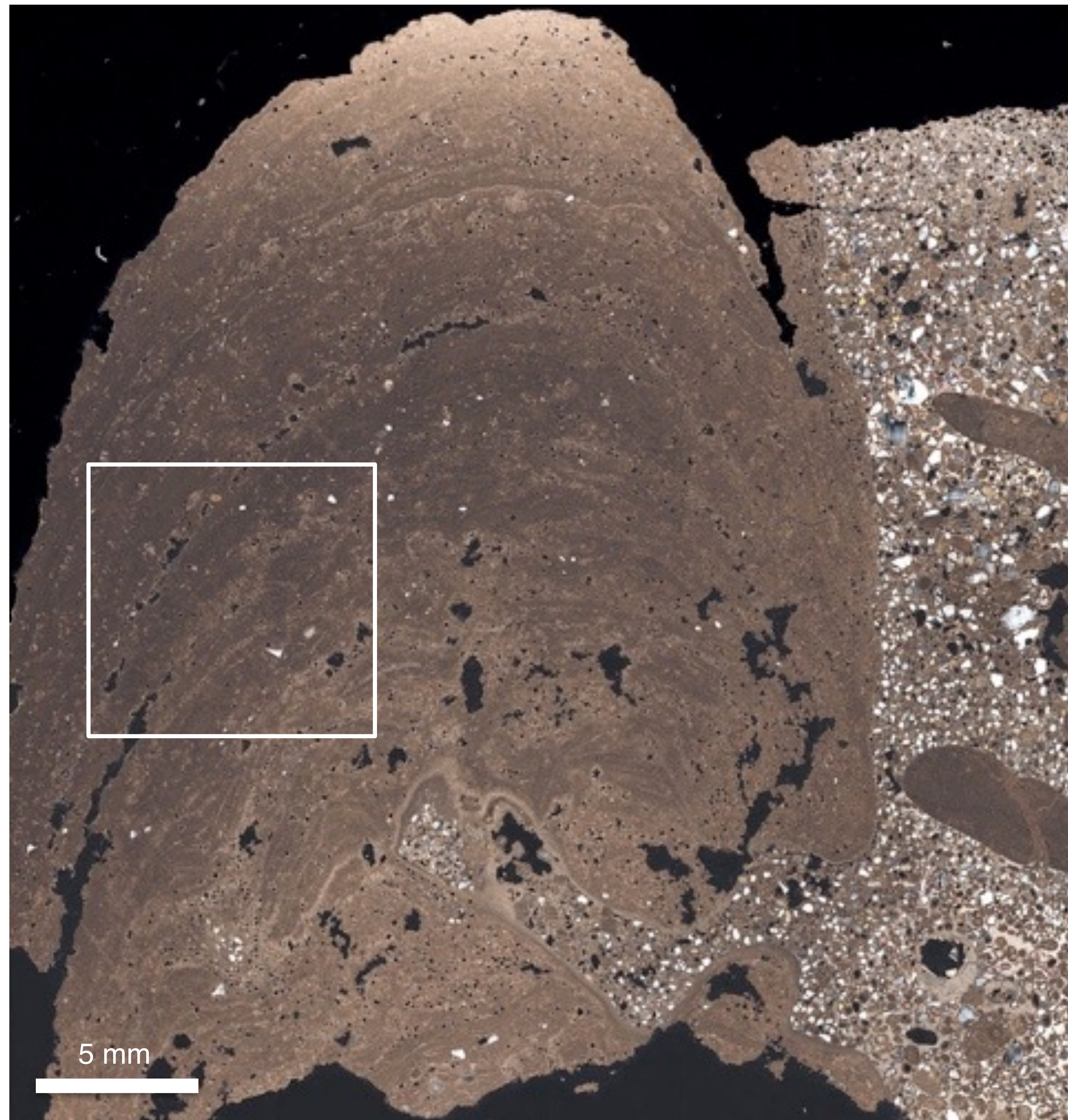
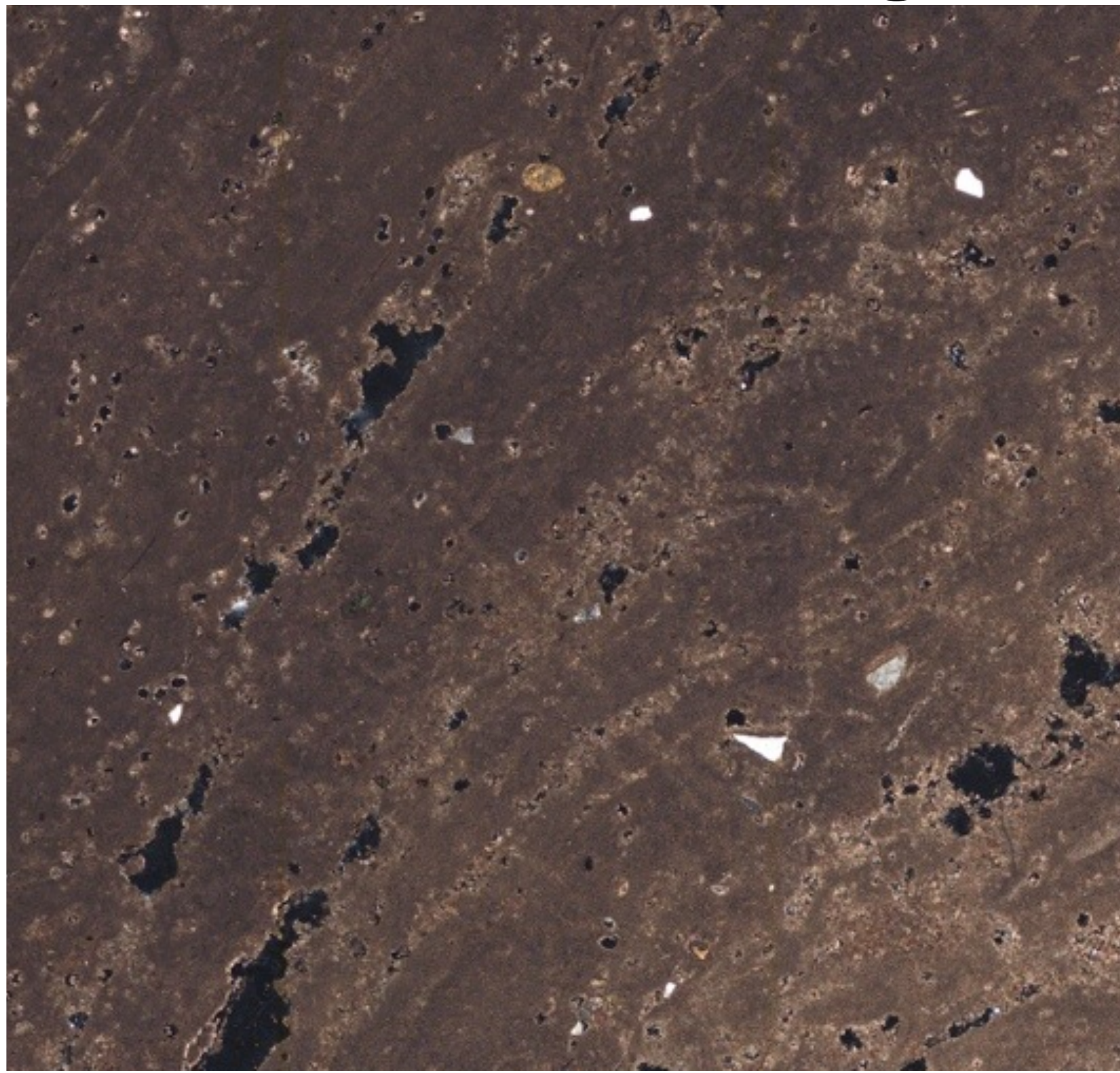


Cyanobacterial Mat trapping



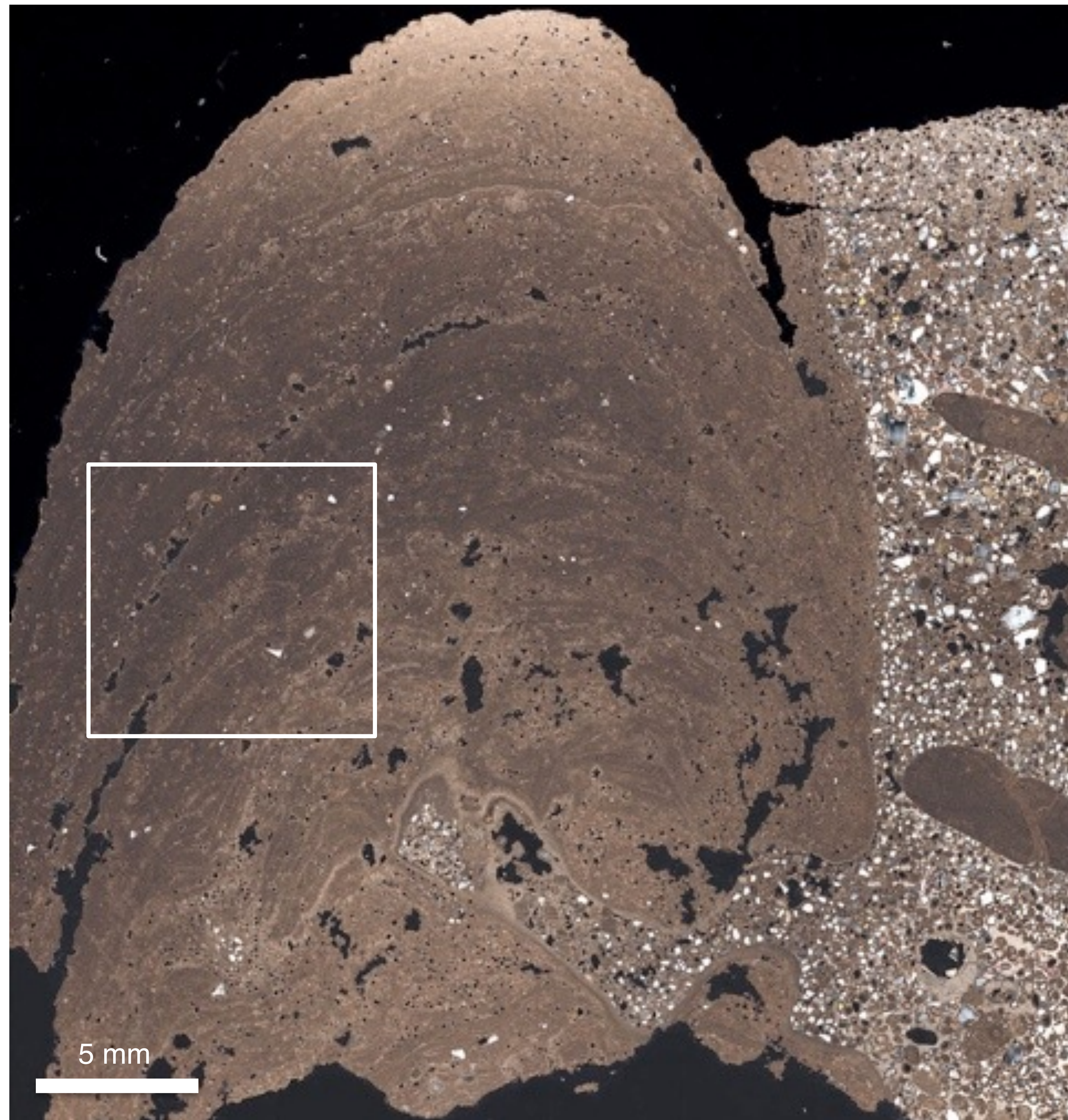
Implications for Biogenicity

- prominent grains trapped beyond the angle of slide constitute a biosignature



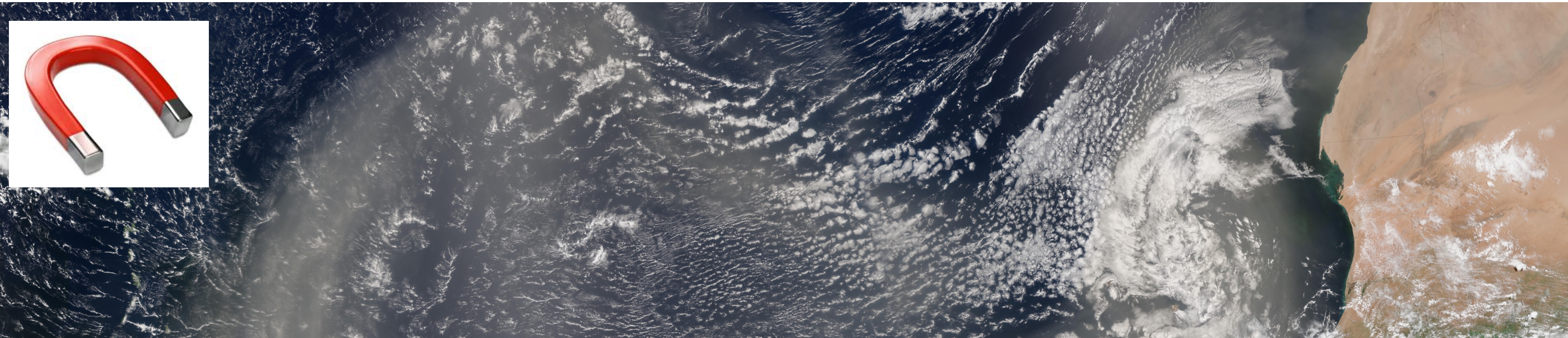
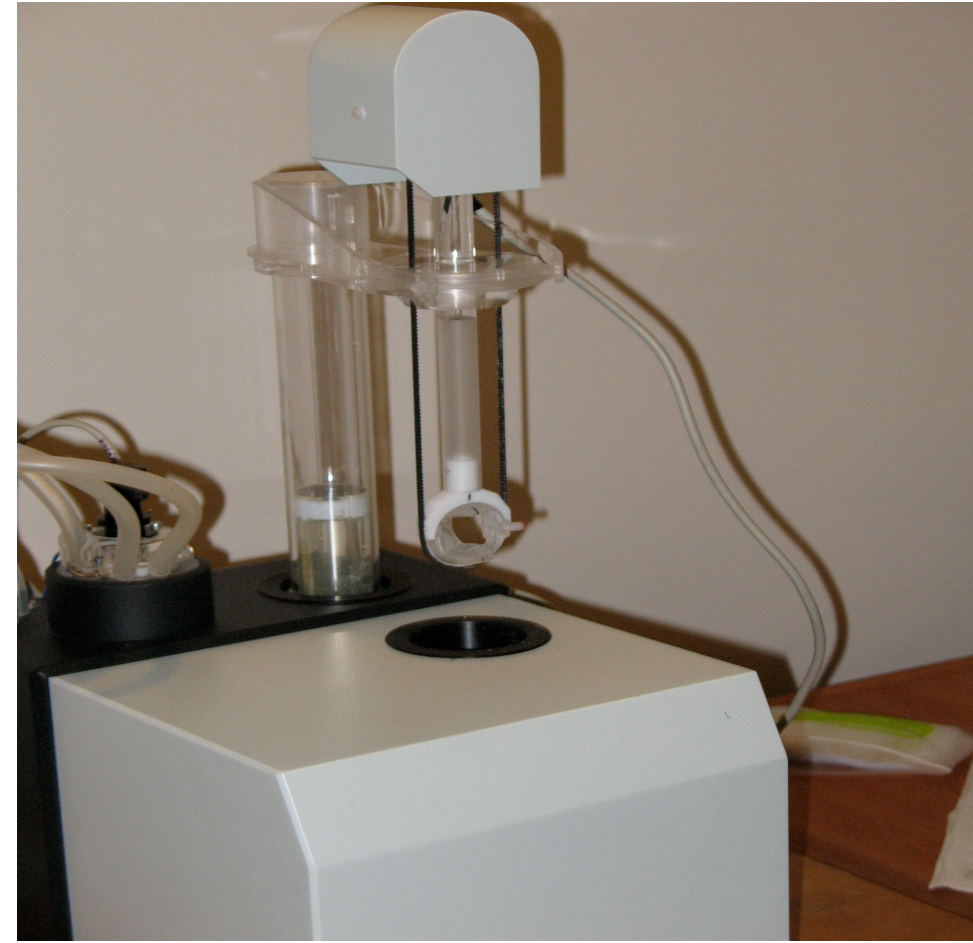
Implications for Biogenicity

- prominent grains trapped beyond the angle of slide constitute a biosignature
- But many ancient stromatolites are micritic/
lack coarser grains

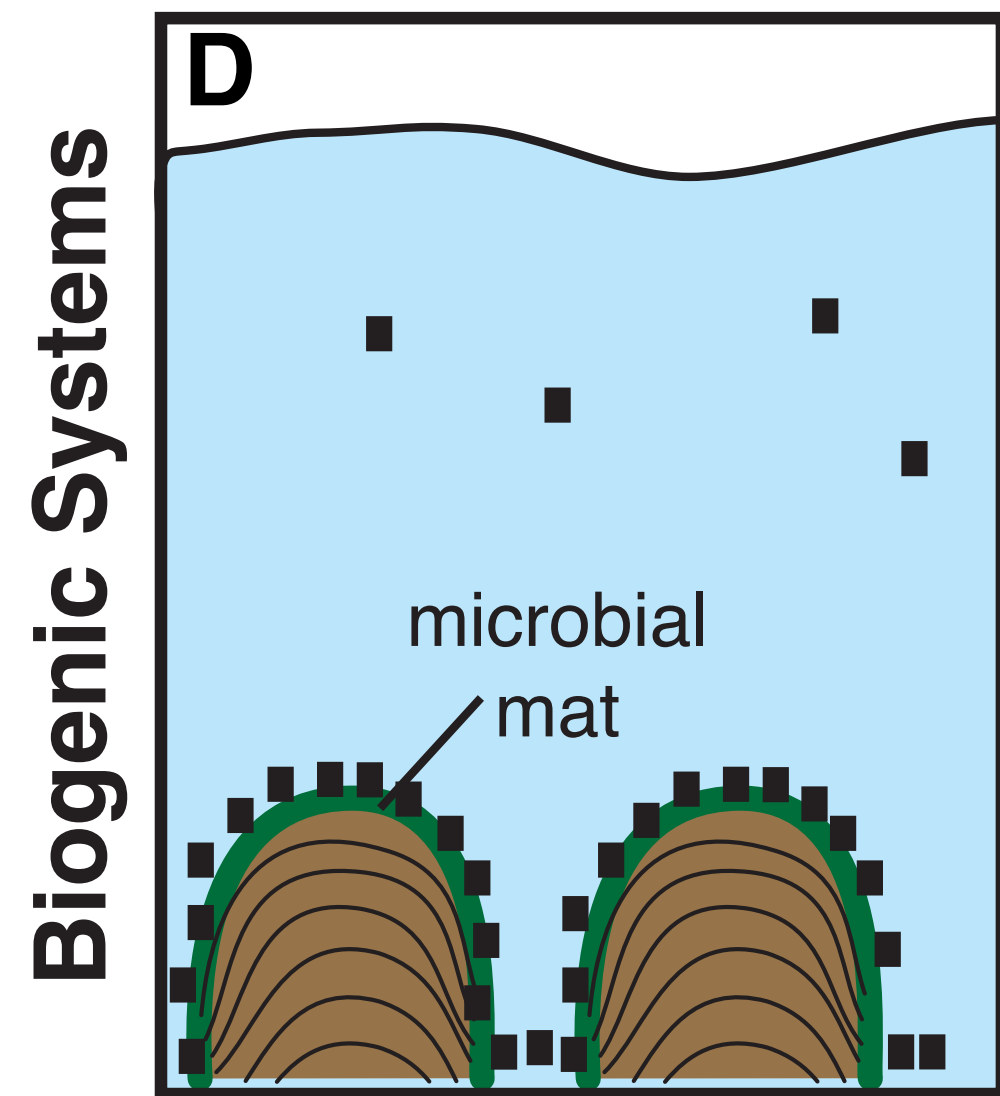
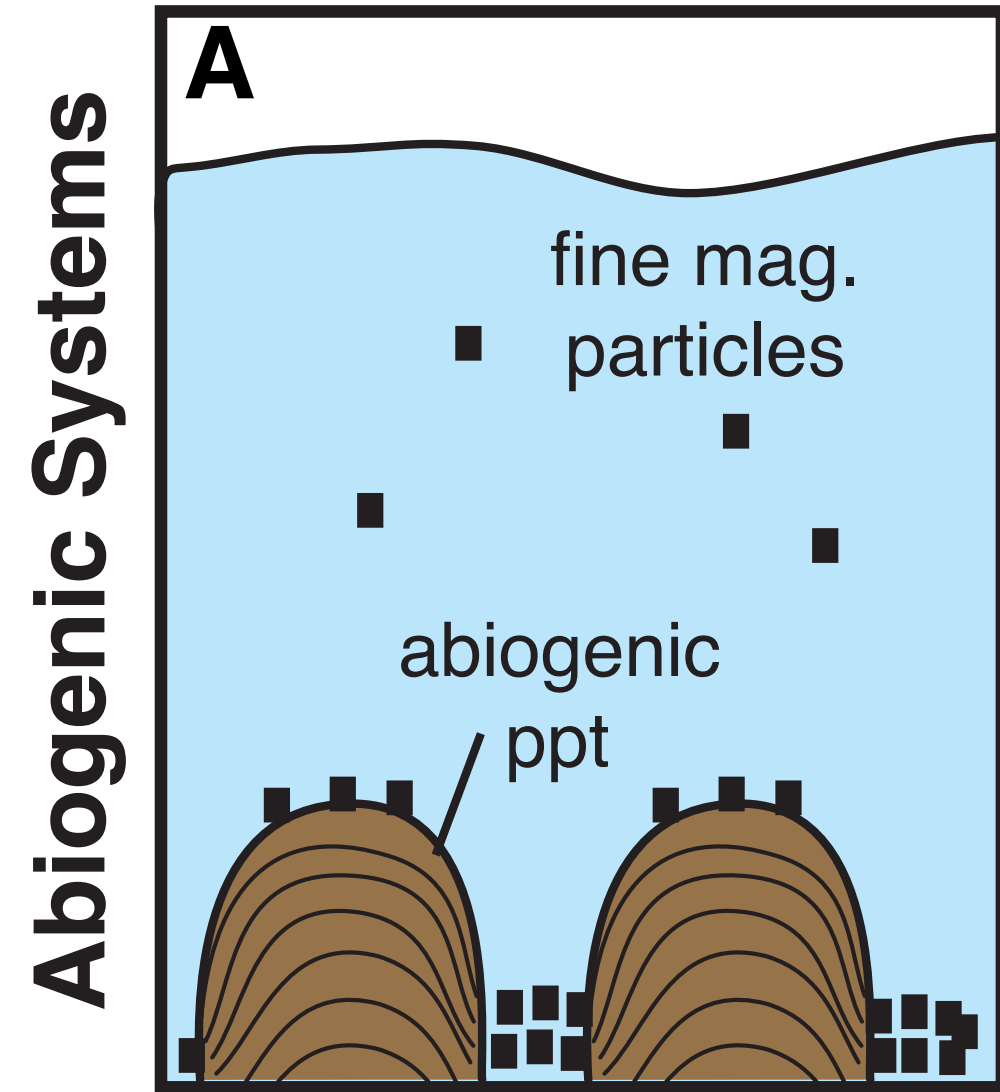


2. Magnetic Susceptibility as a Biosignature

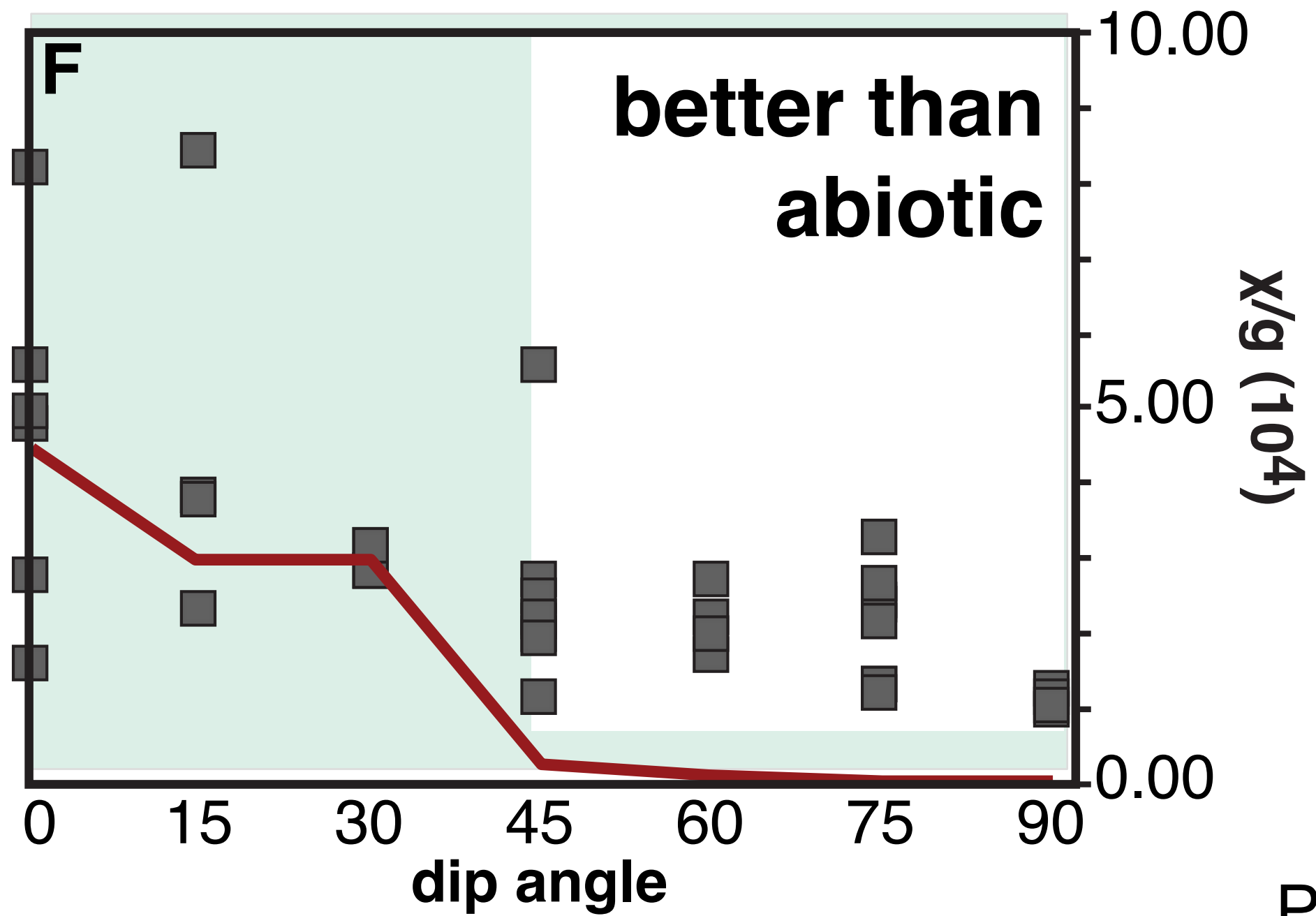
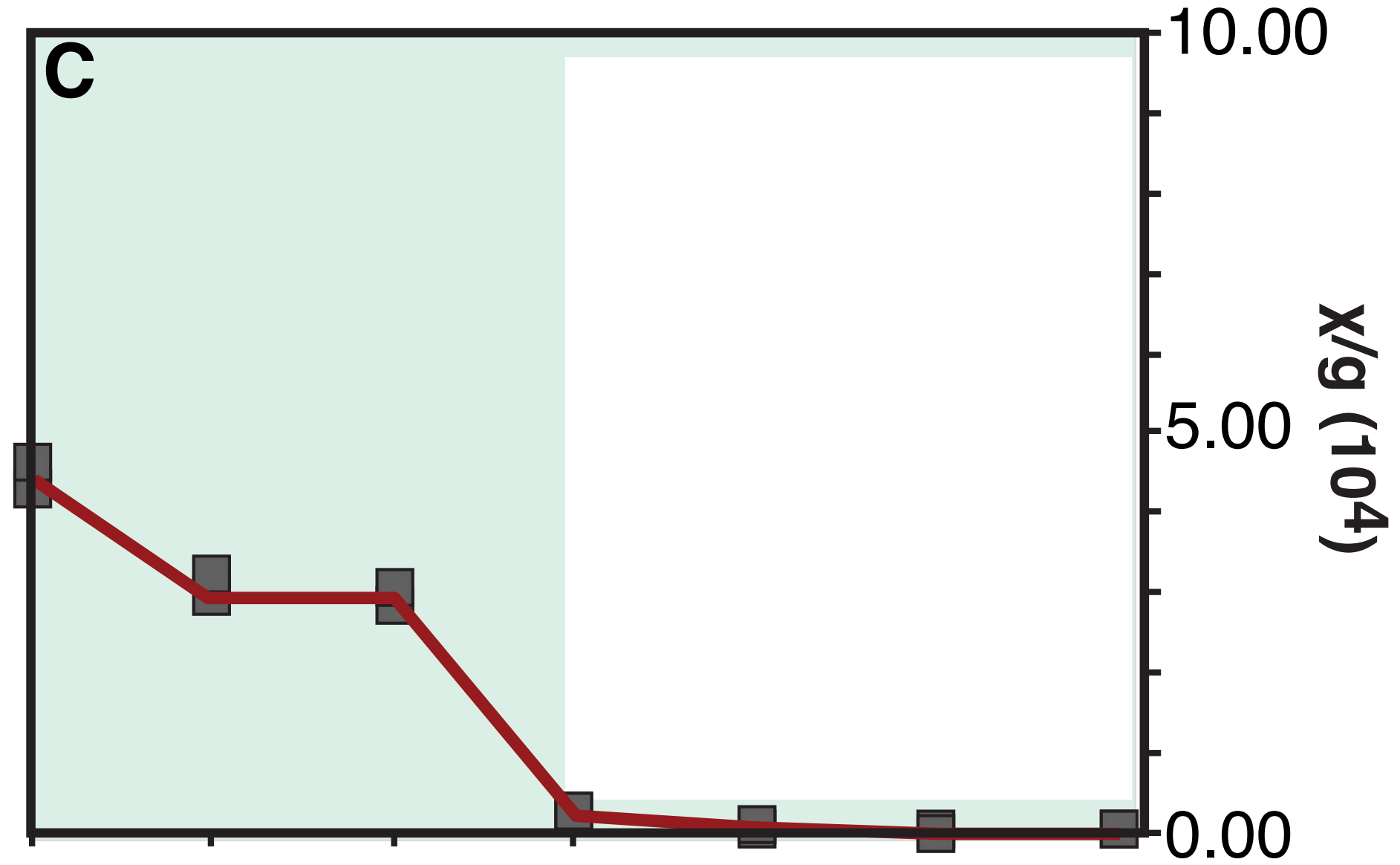
- Most terrestrial environs have a magnetic fraction that has the potential to be trapped
- Very small amounts of magnetic material can be measured
 - Magnetic susceptibility...same theory, different method.



Hypothesis (schematic)

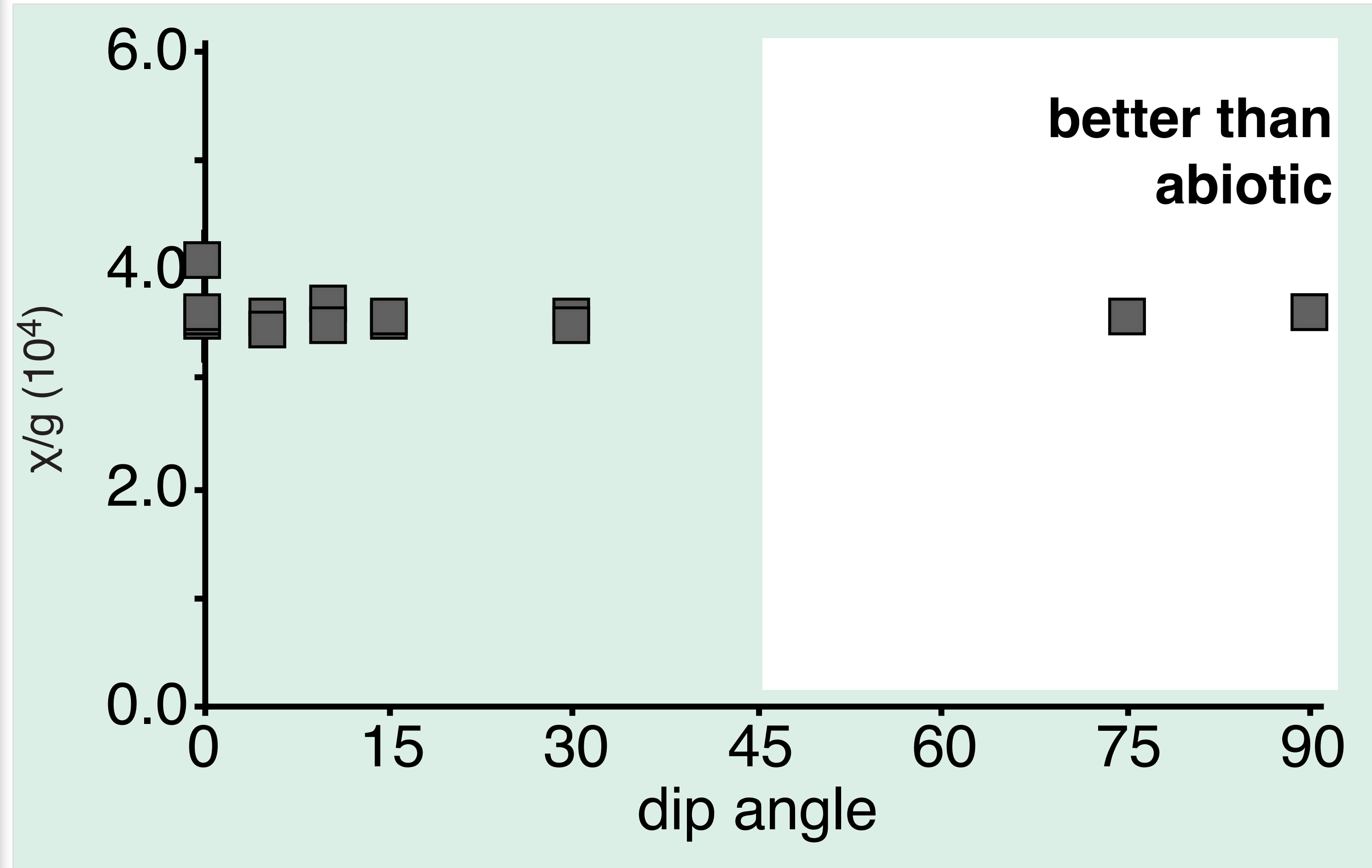


Experimental Data

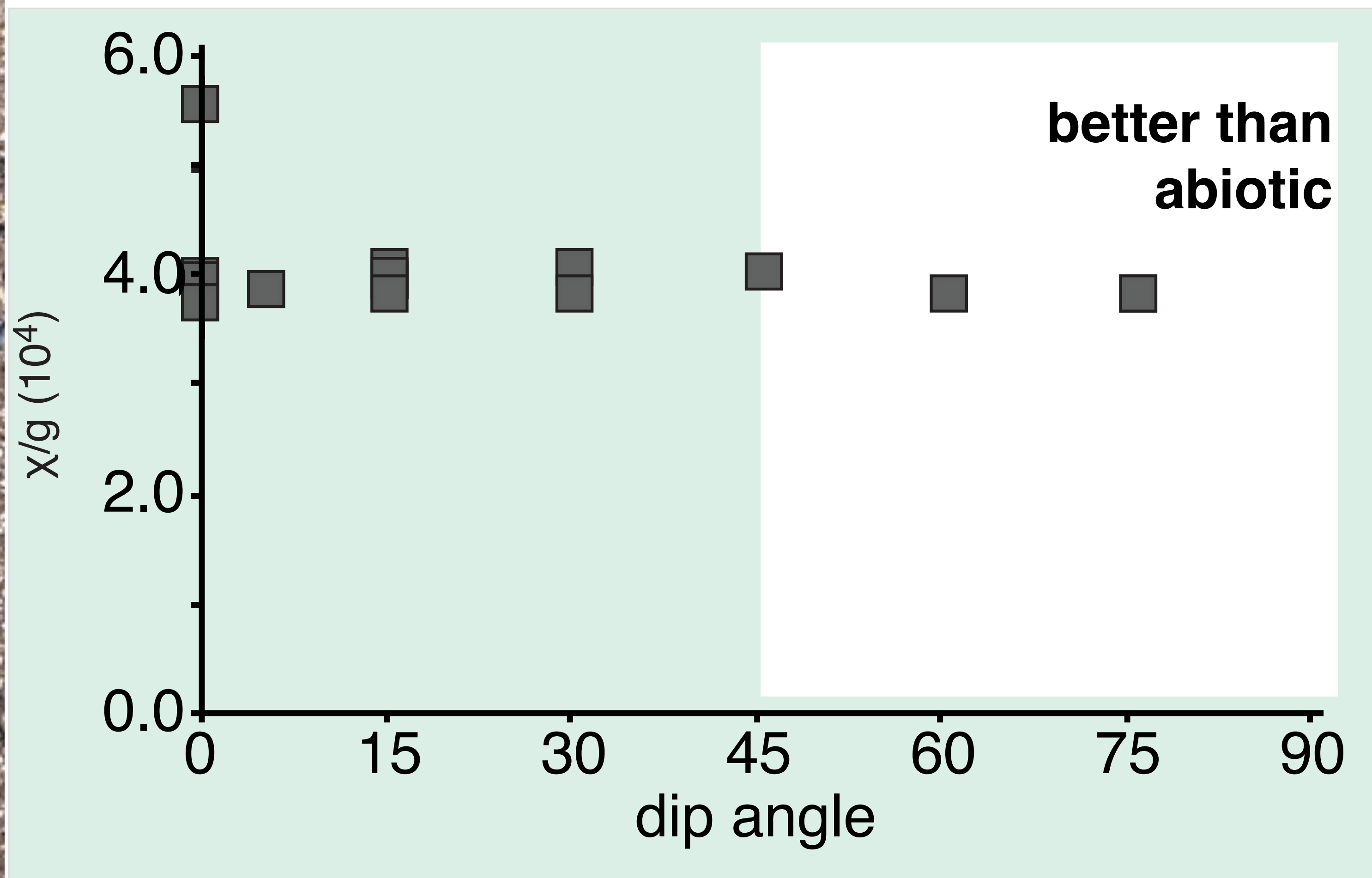
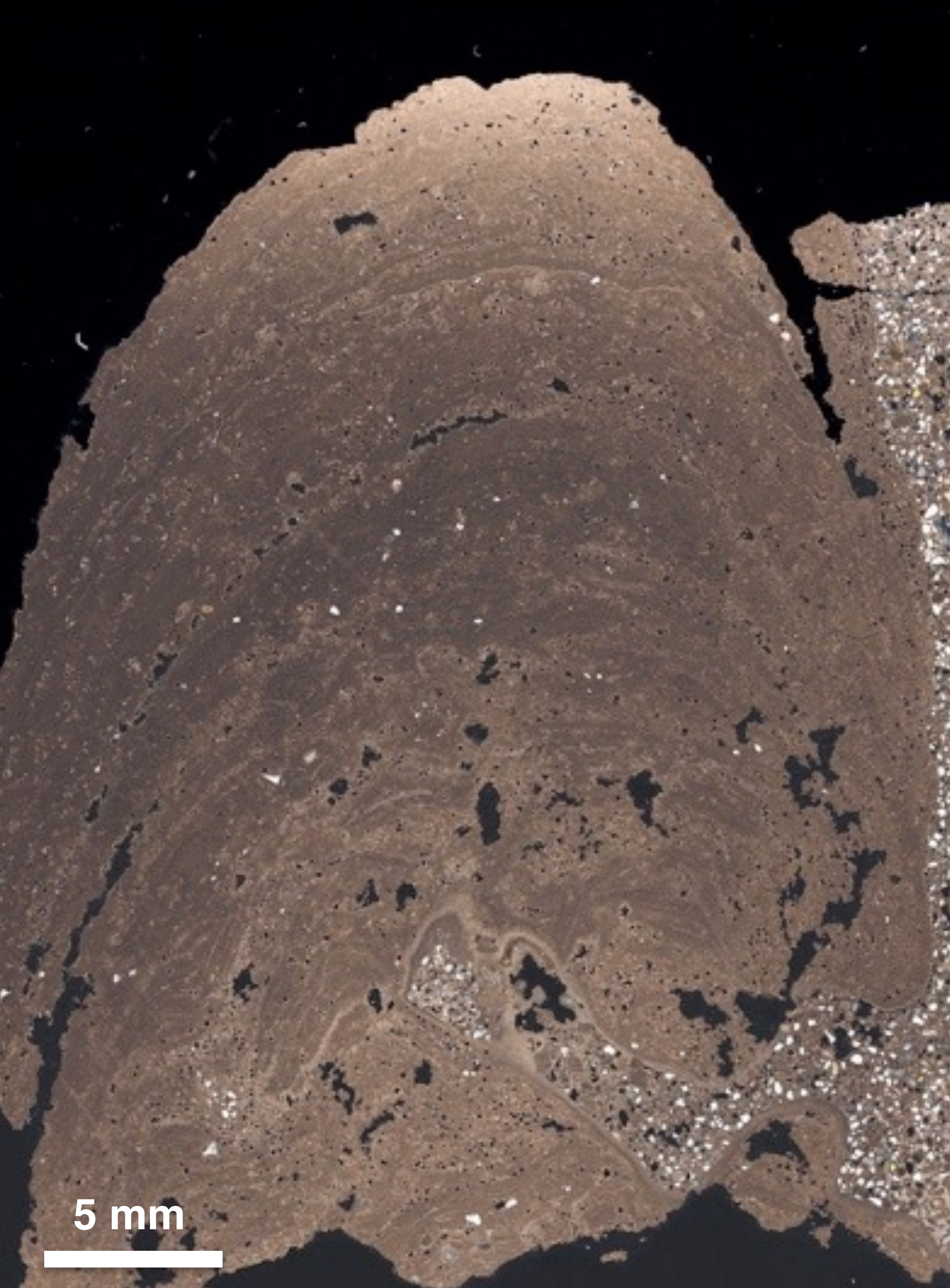


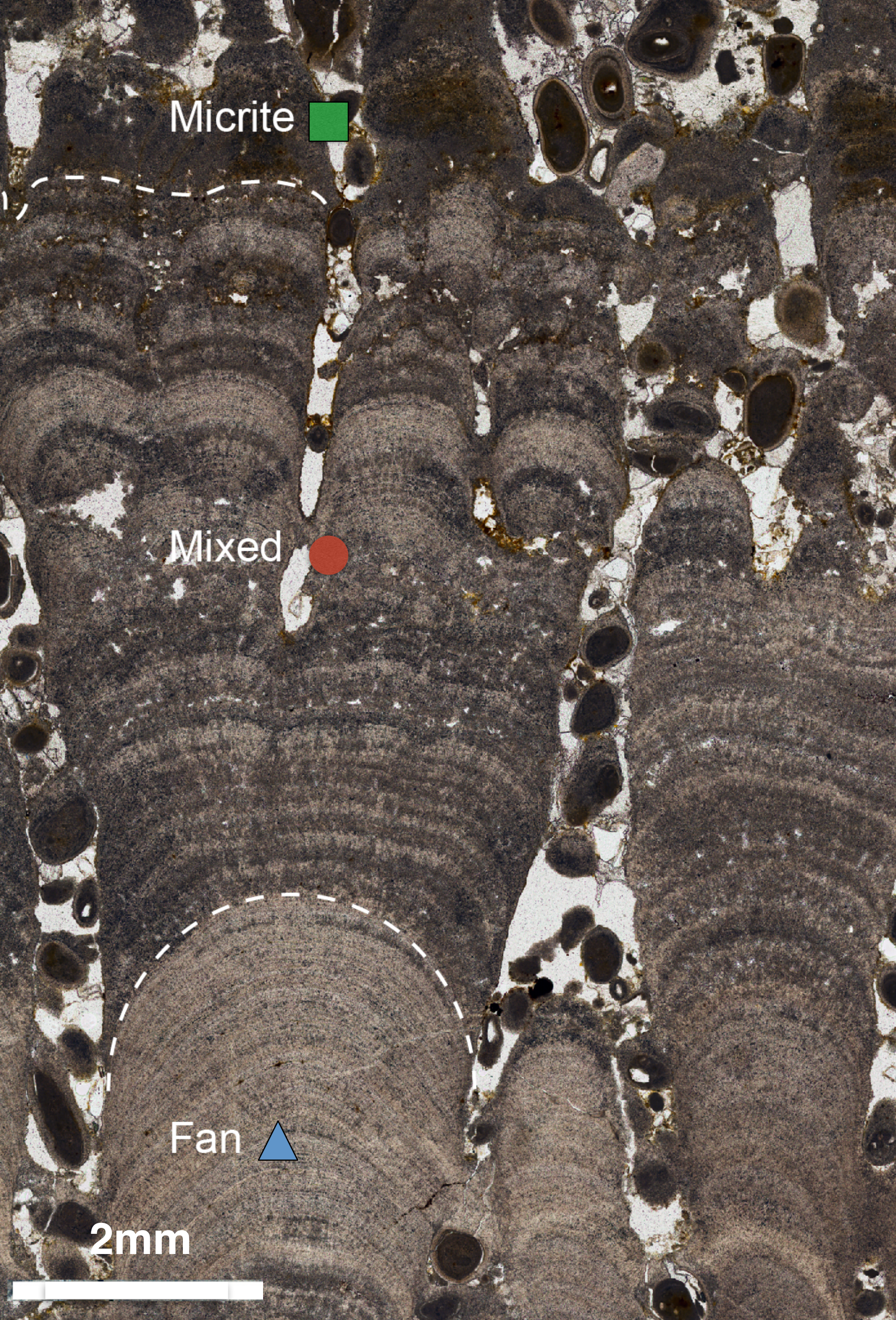


Yellowstone Stromatolite Biotic (watched it grow)

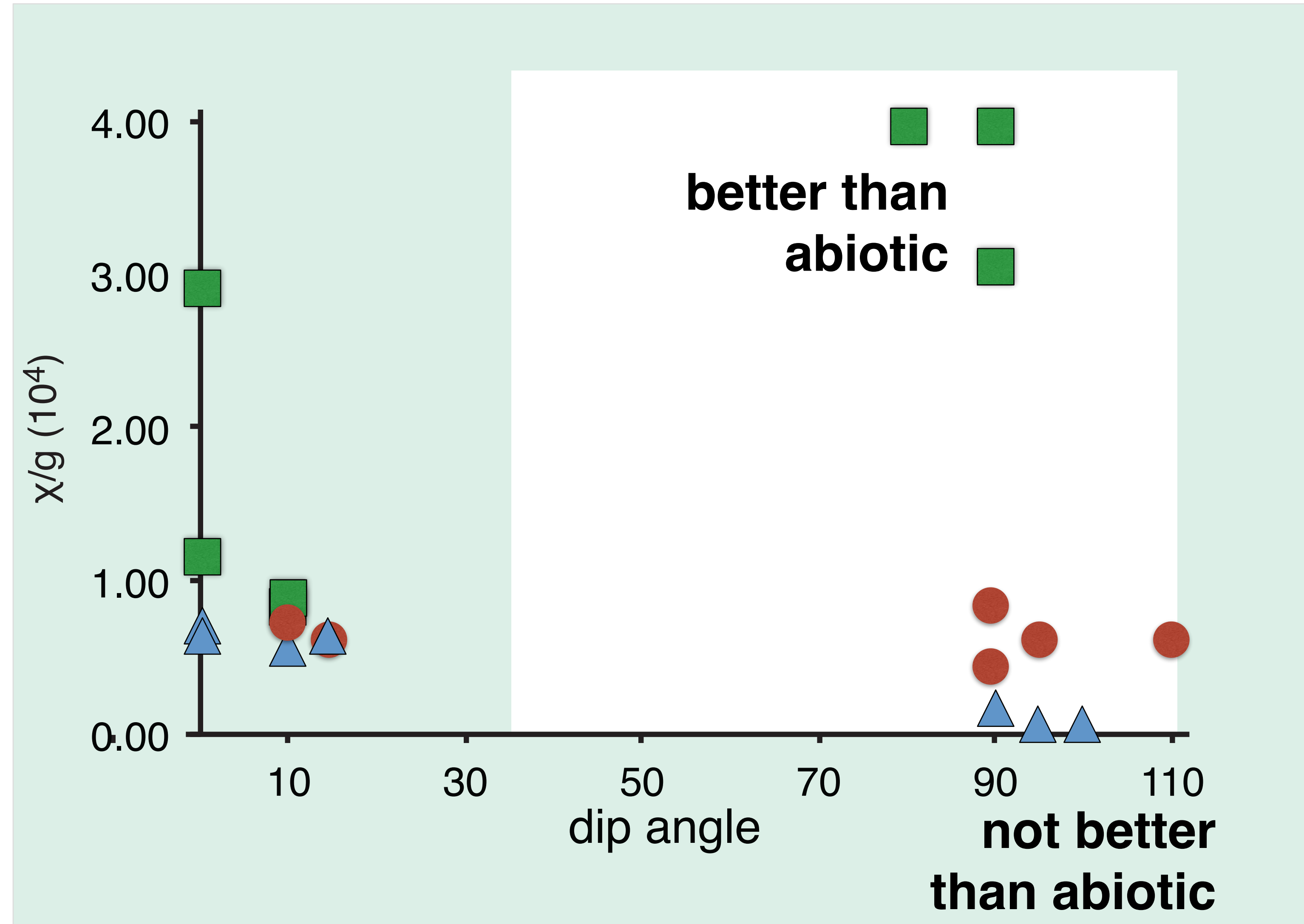


Green River Stromatolite Suspected Biotic (grains trapped at high angles)



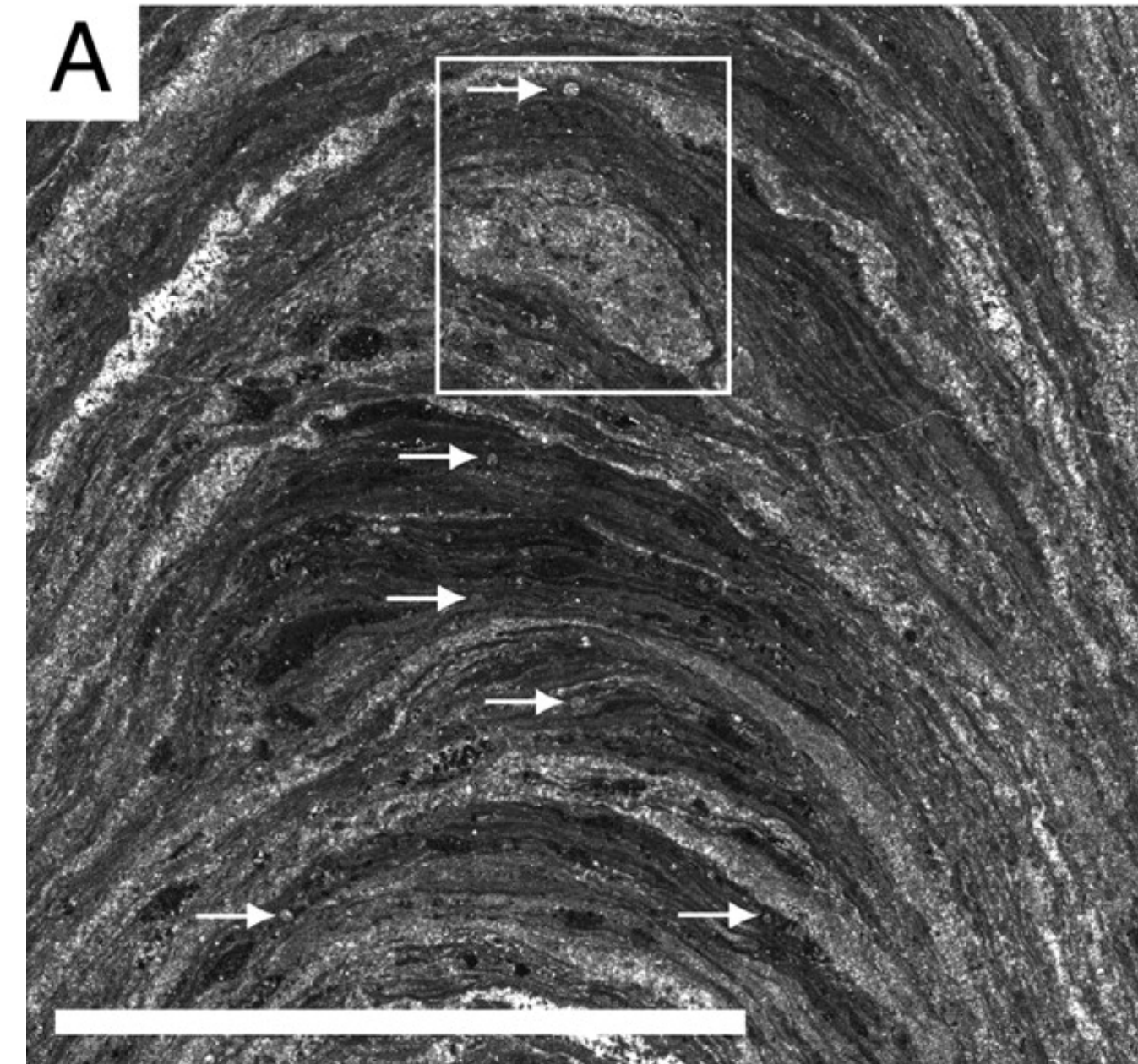
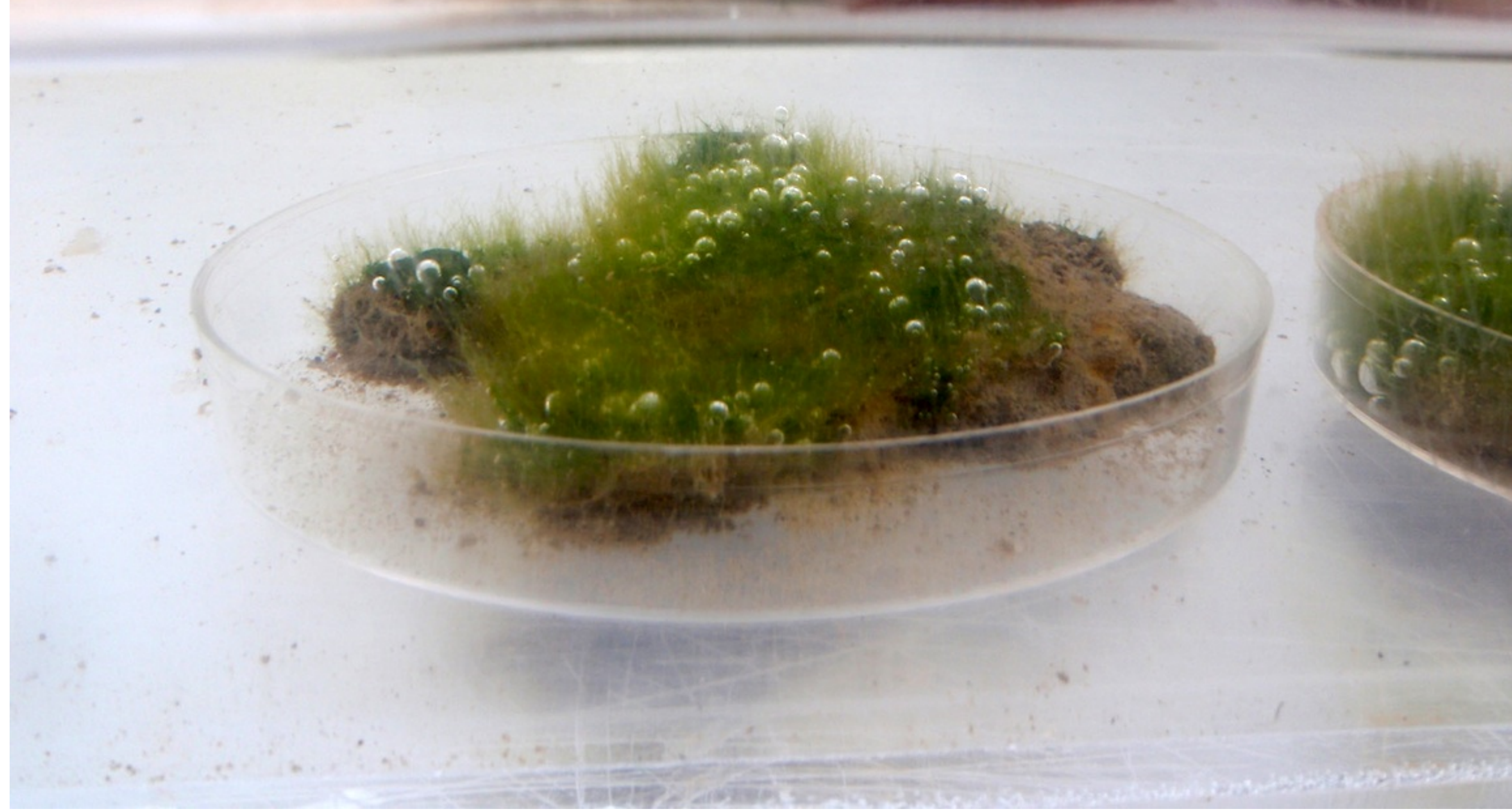


Green River Stromatolite Unknown (mixed fans and micrite)



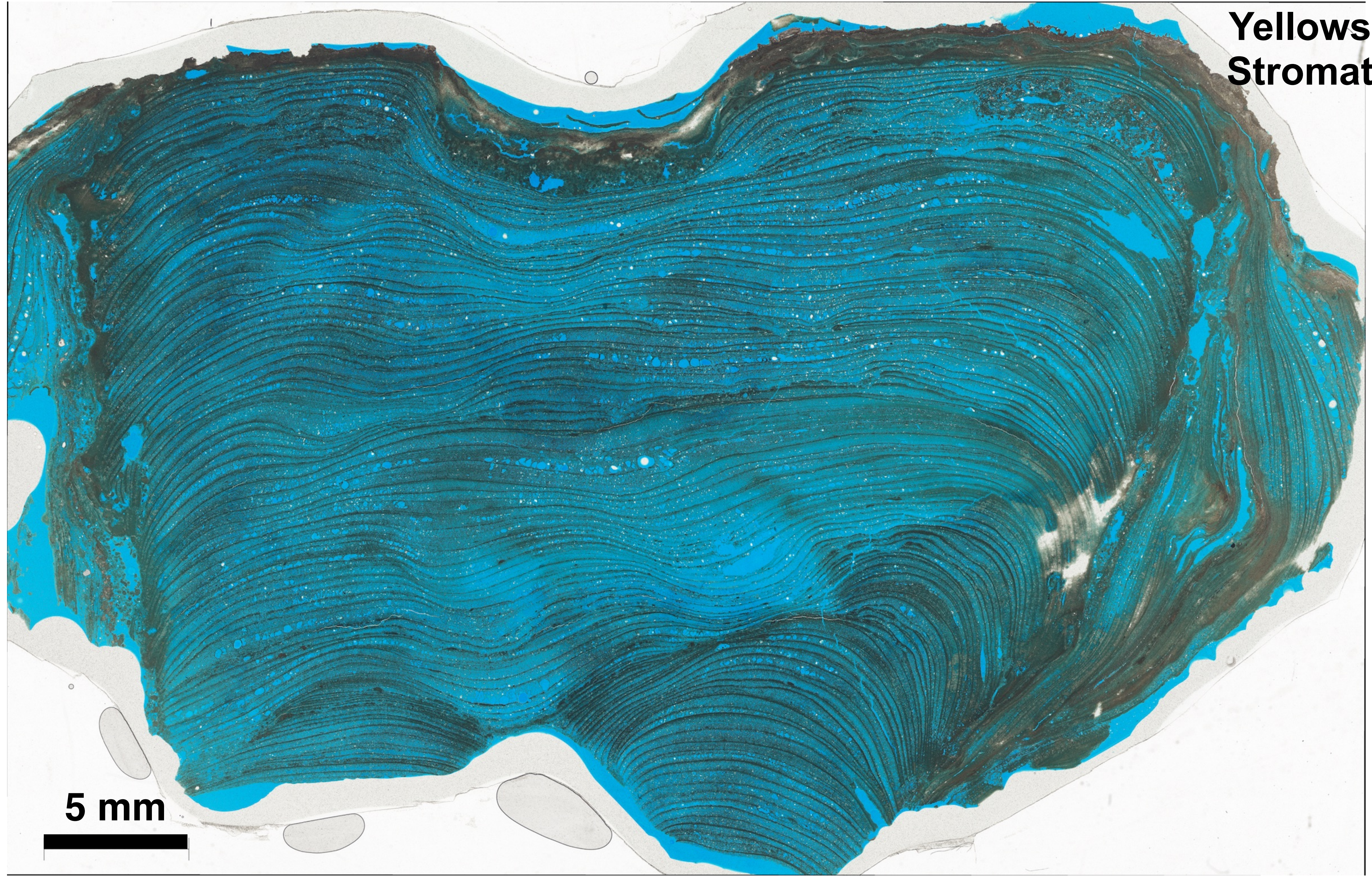
3. Bubbles as biosignatures!

- Mats can be gassy
 - Can we exploit gassy mats?

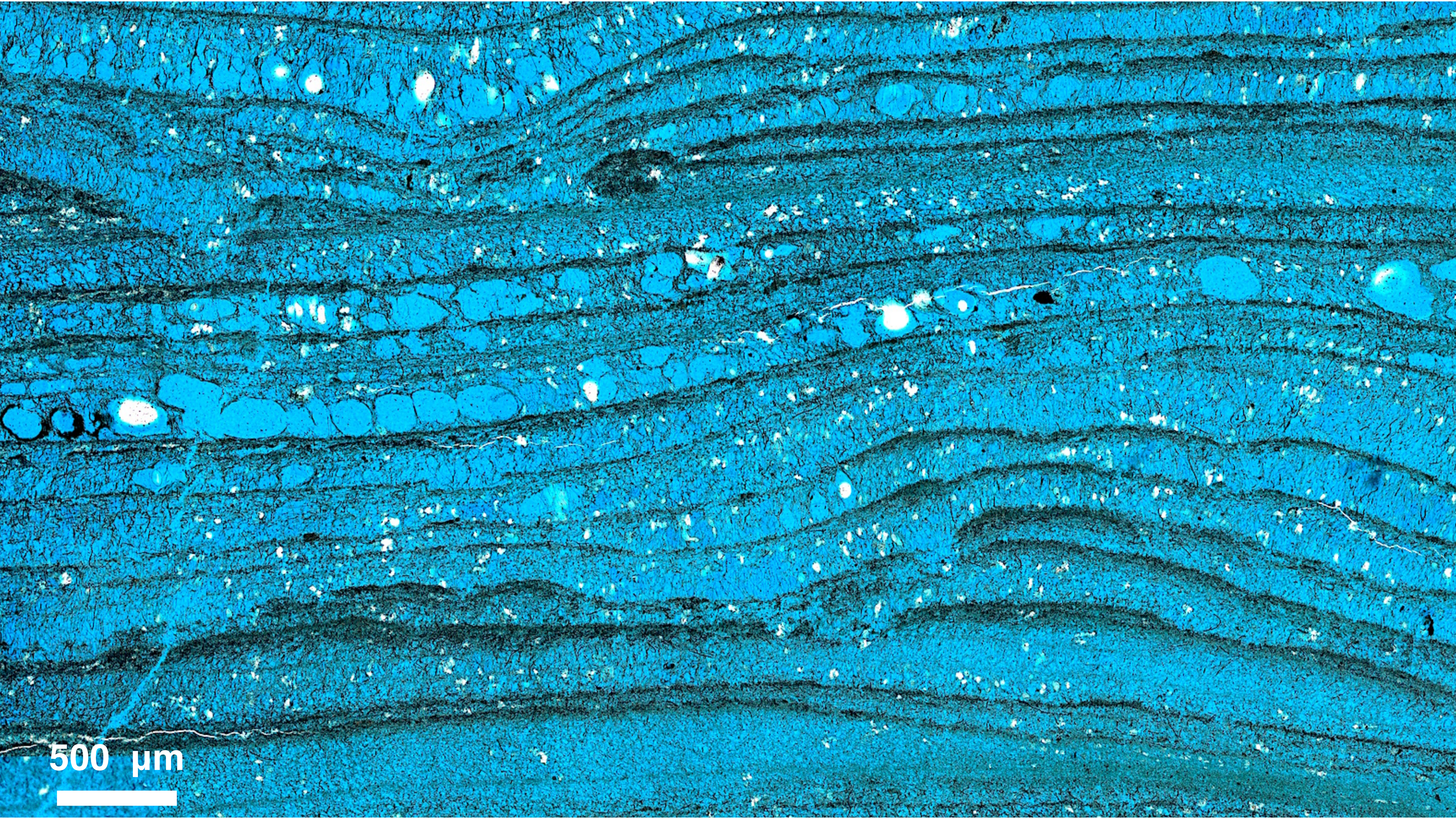


Bosak et al., 2009

Yellowstone Stromatolite

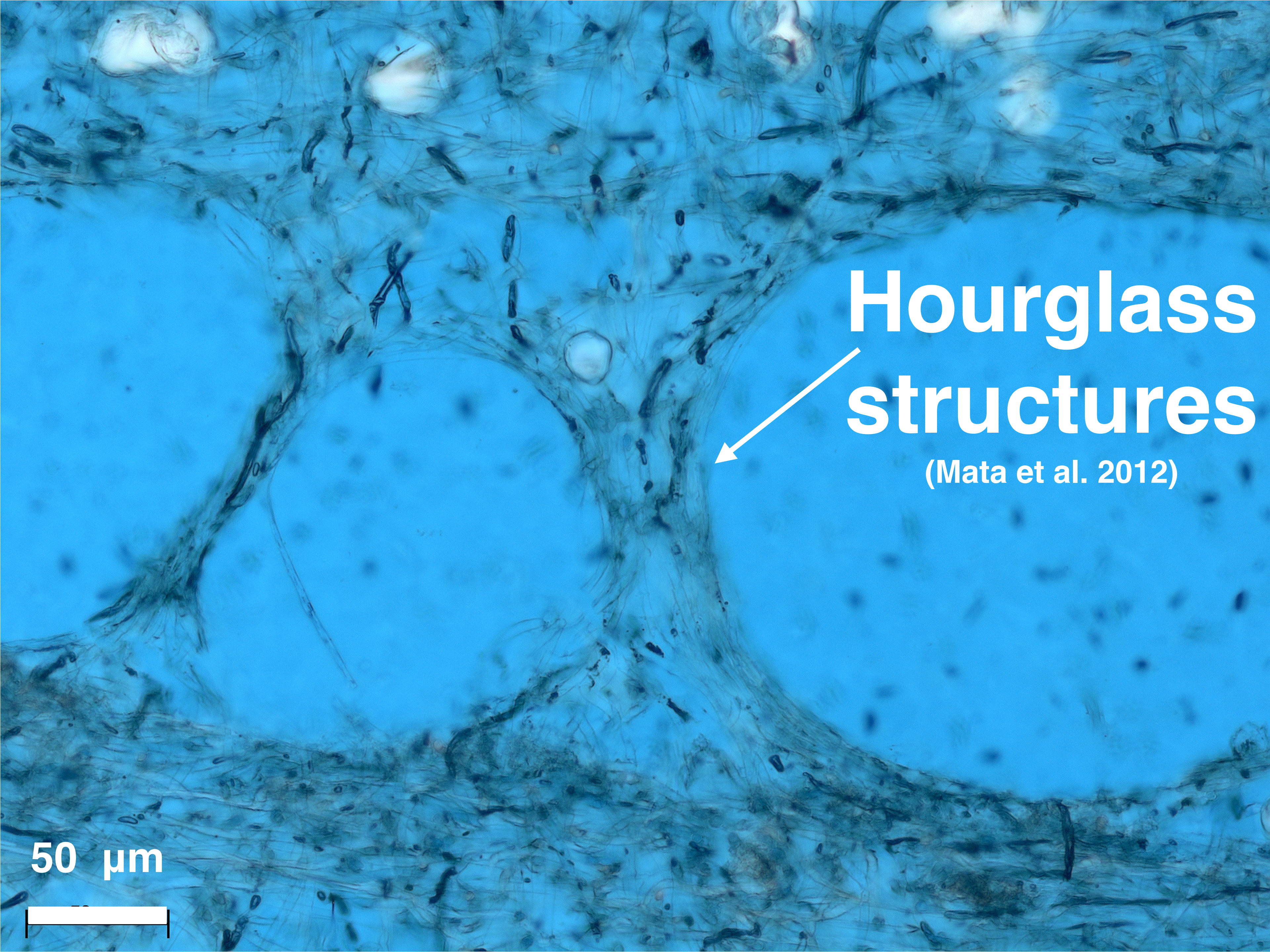


5 mm



500 μm

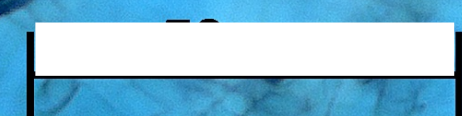


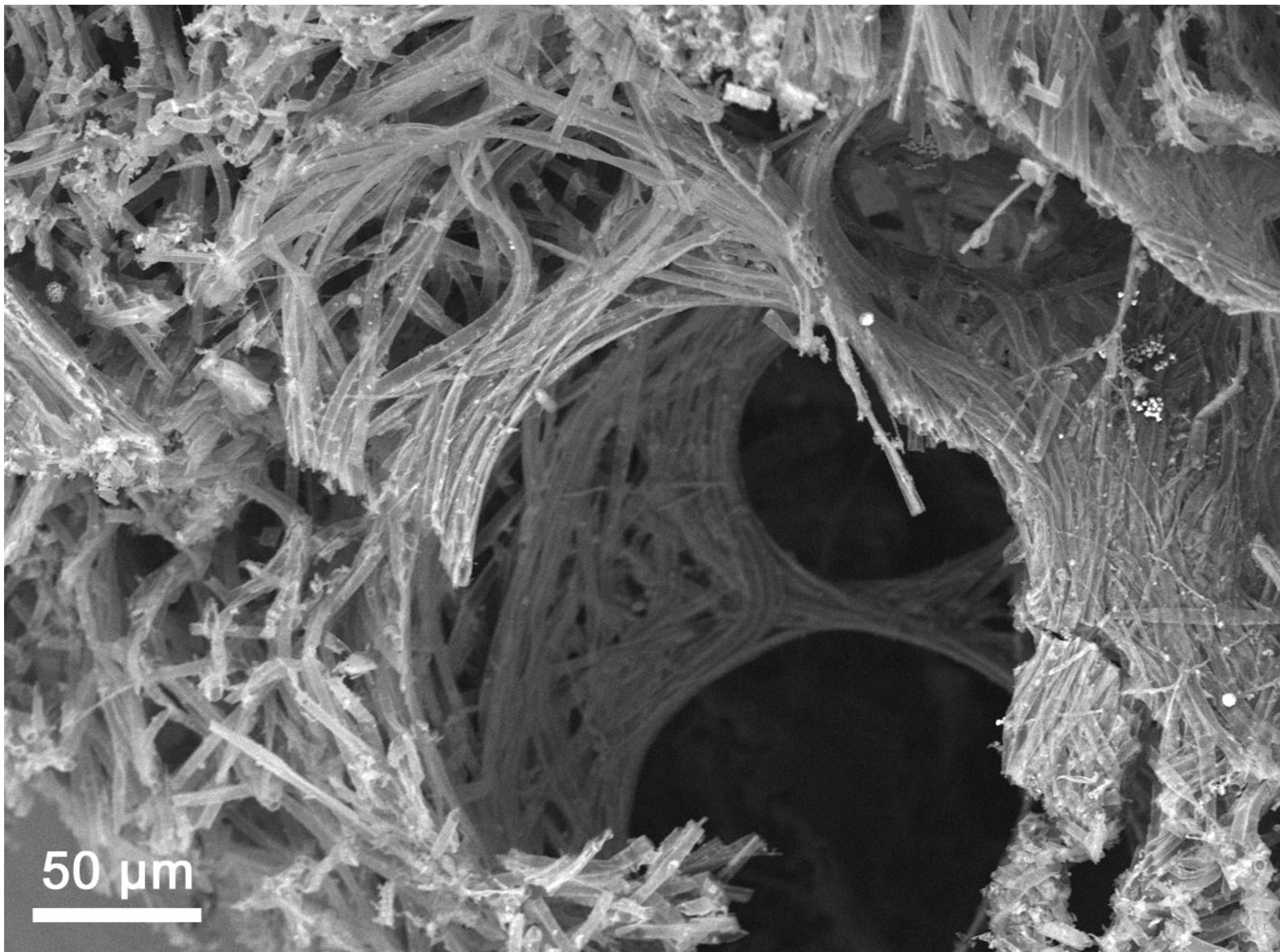


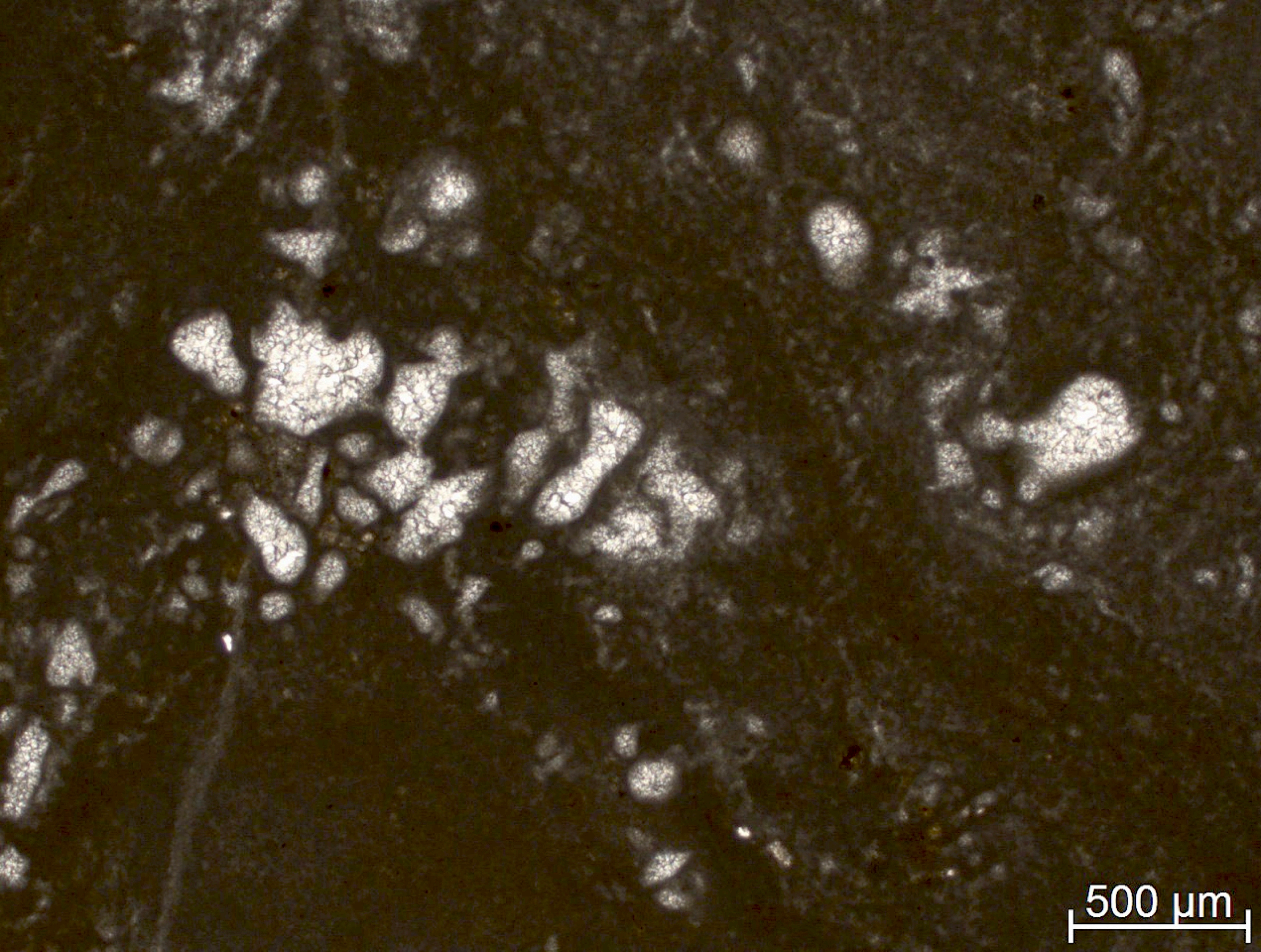
Hourglass structures

(Mata et al. 2012)

50 μm





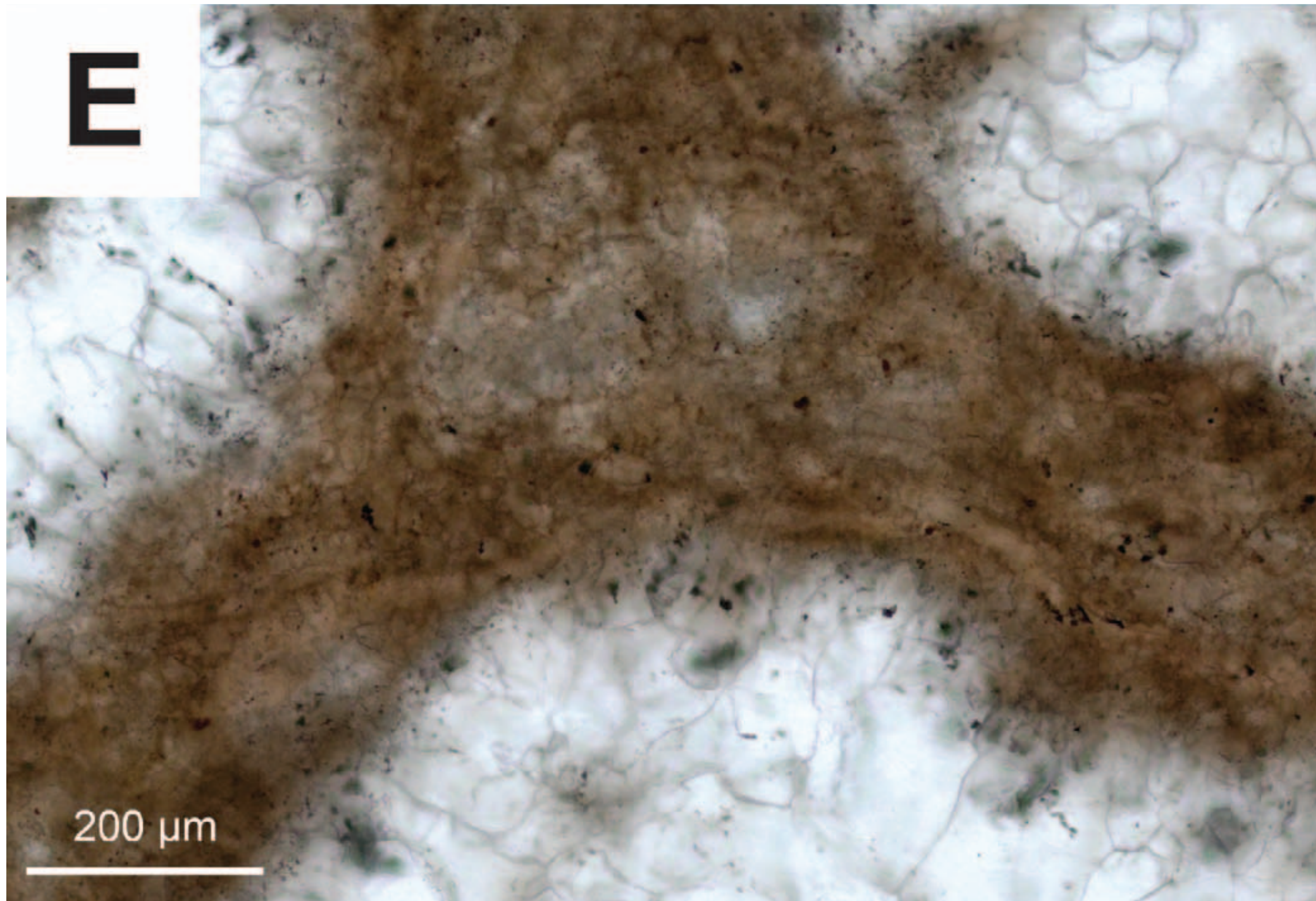
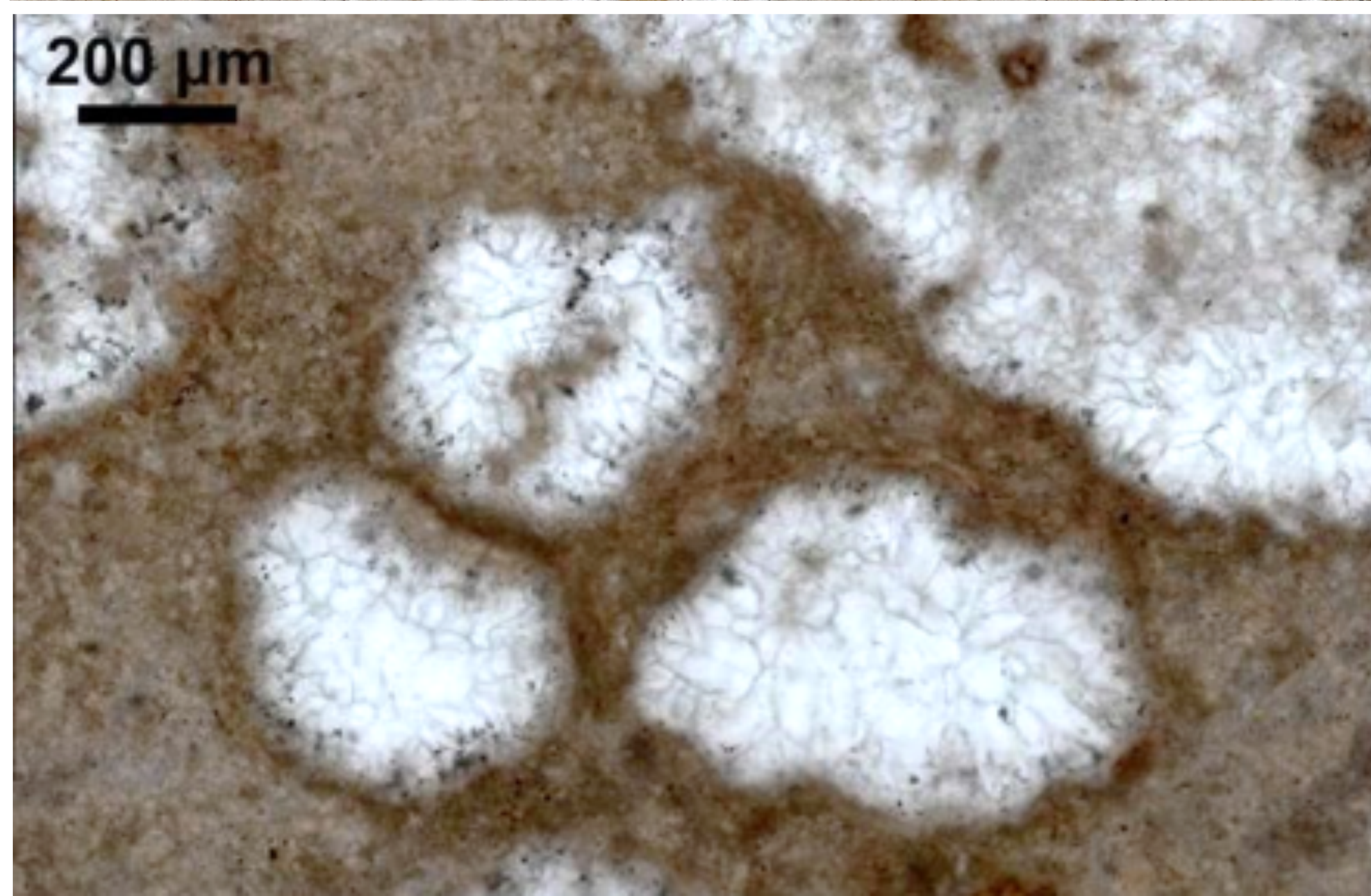
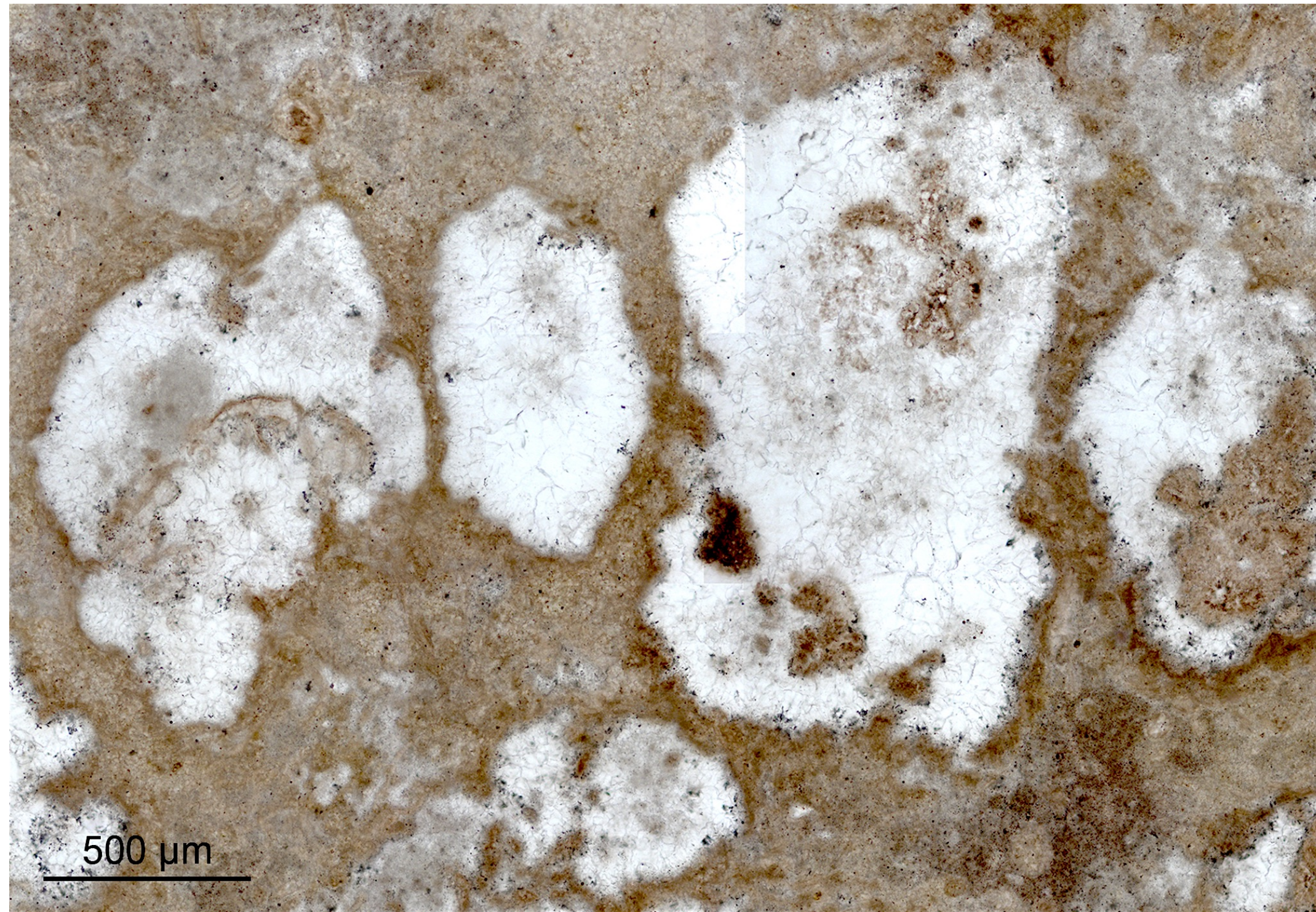


Triassic Cotham
Marble

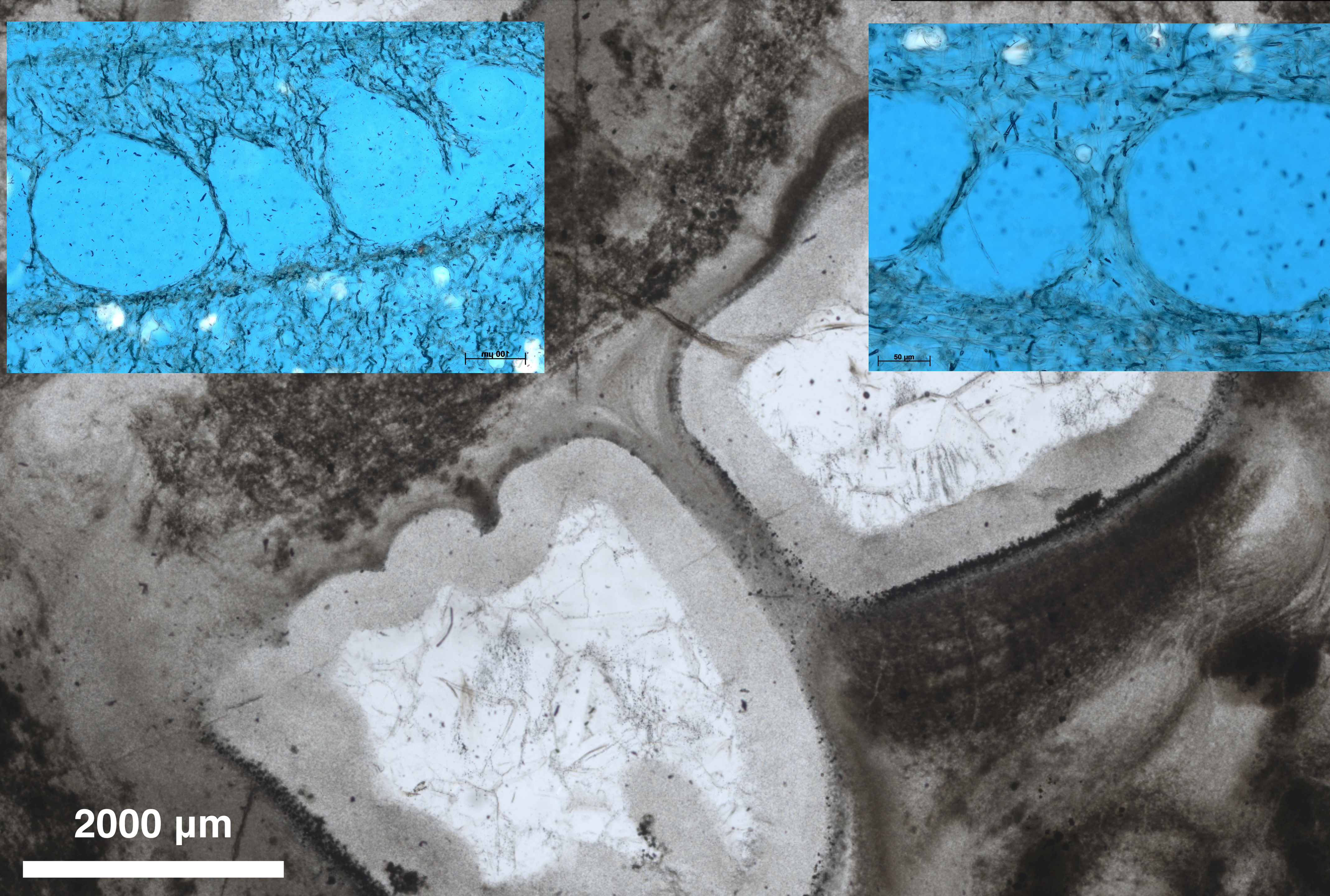
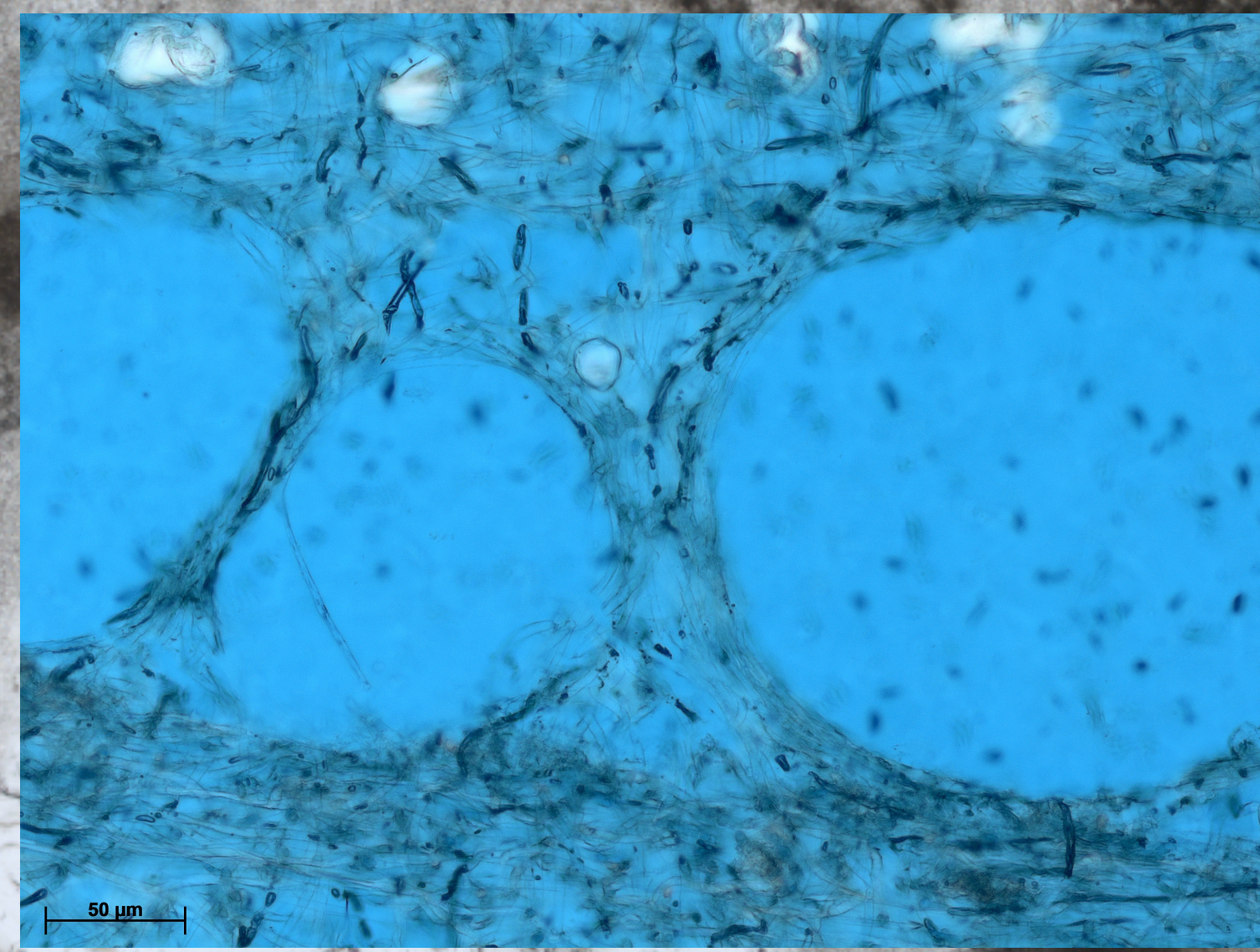
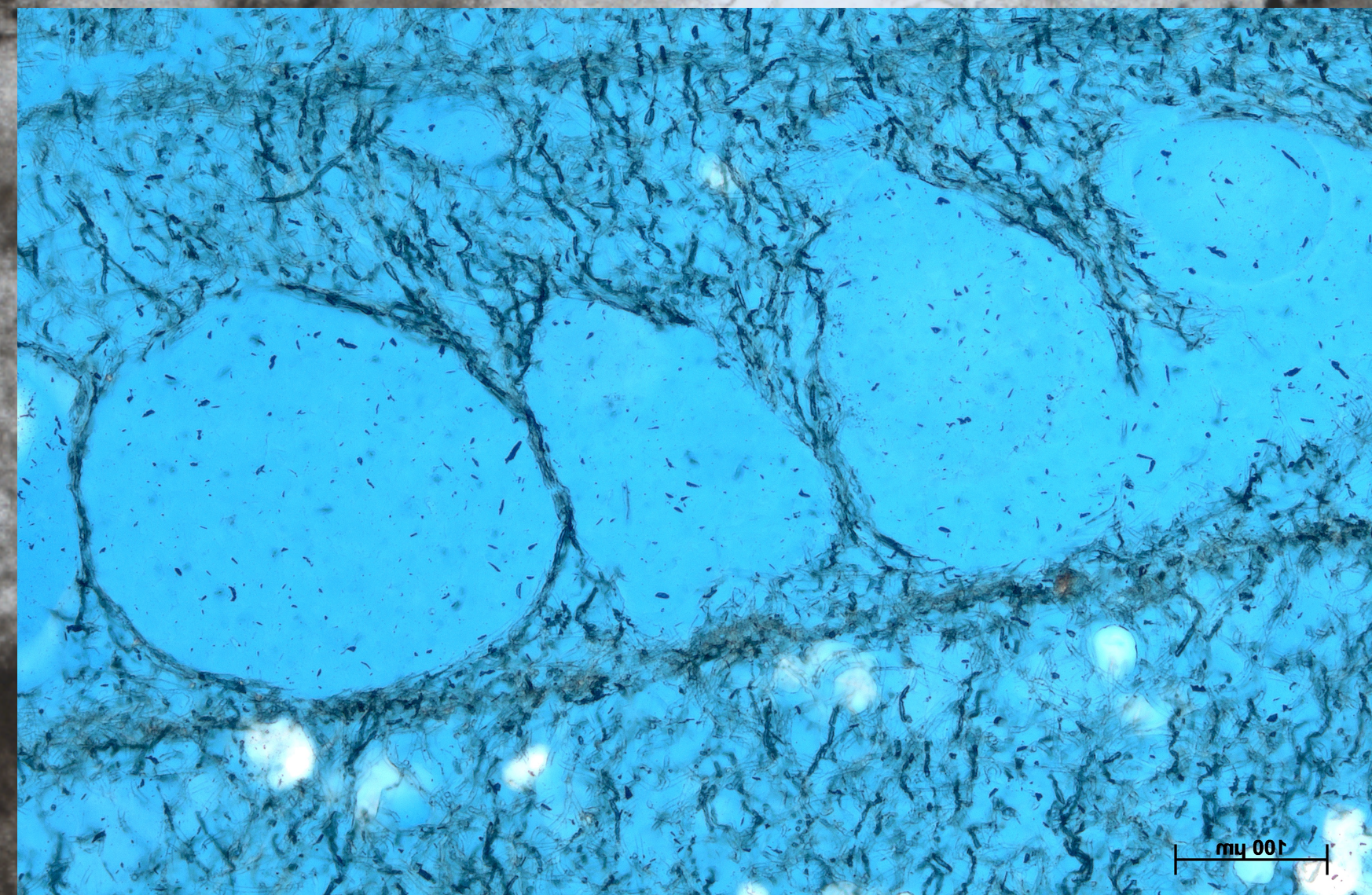
Lilstock
Formation

500 μm

Cambrian Oncoid



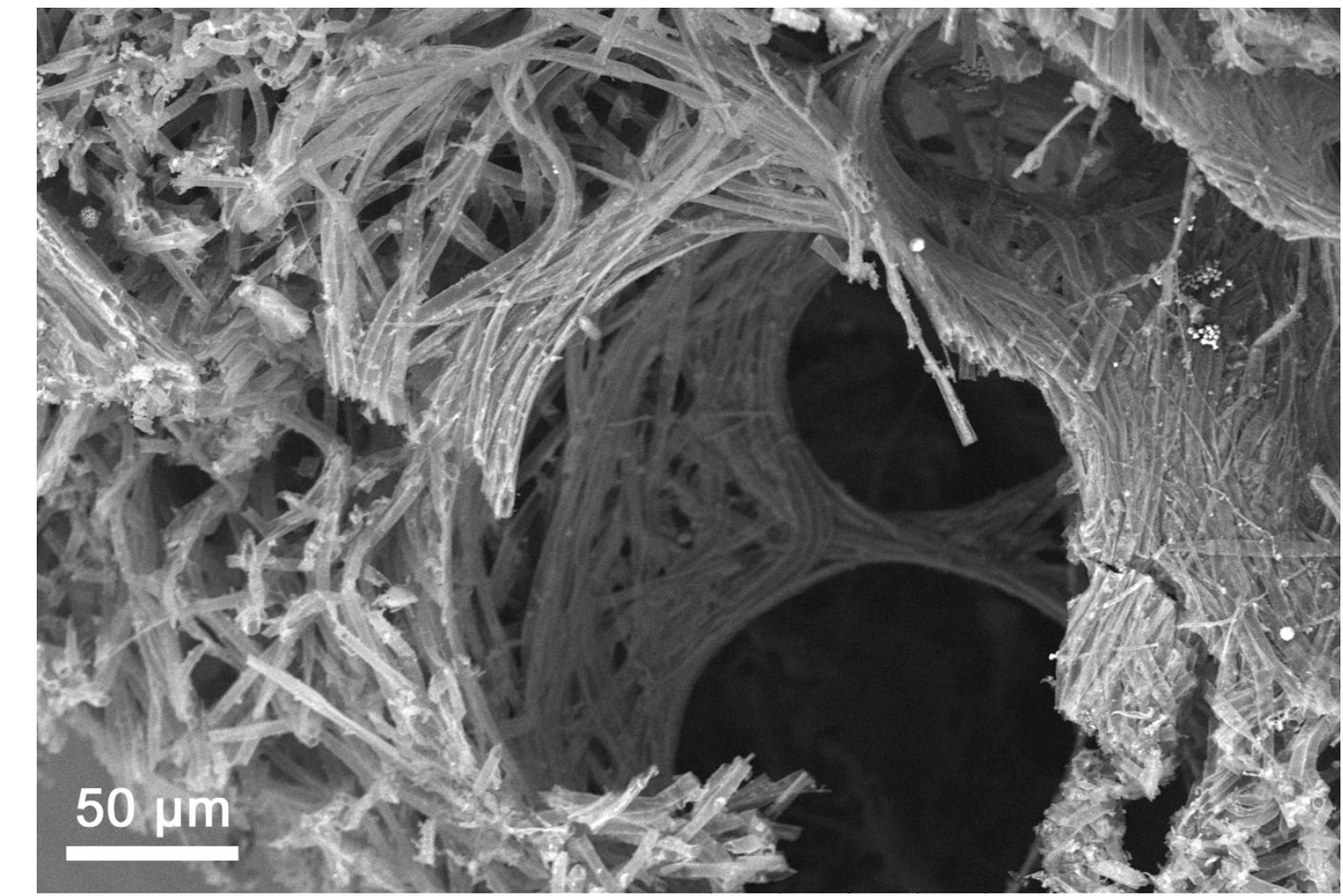
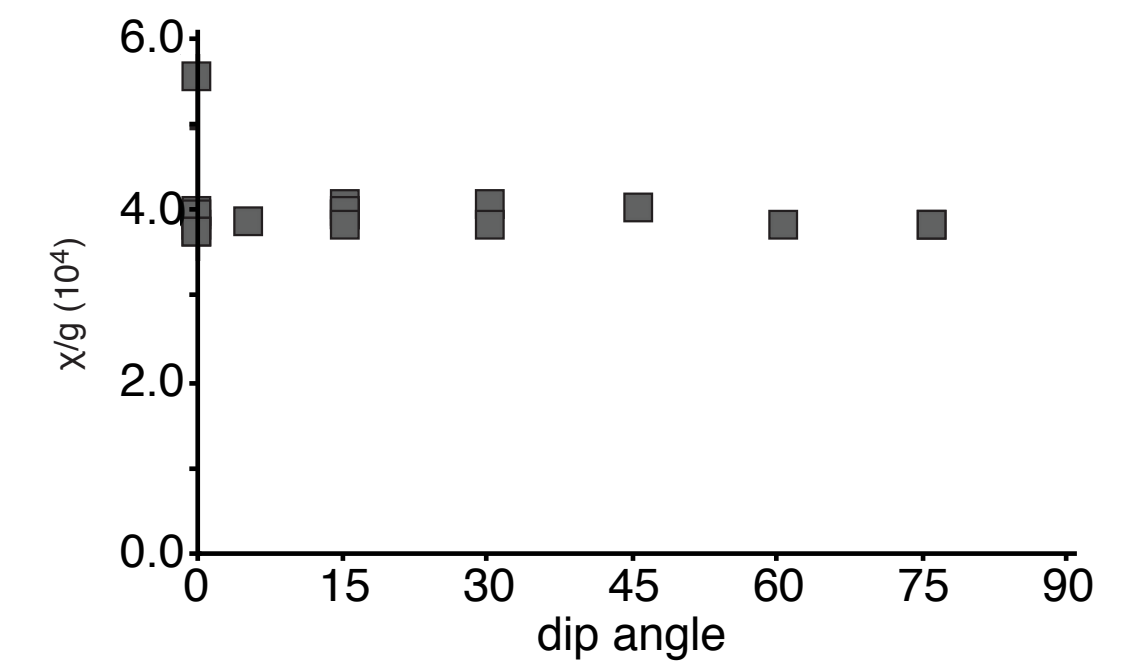
Archean Stromatolite



2000 μm

Hallmarks of Biogenicity summary

1. Grains beyond the angle of slide
2. Magnetic susceptibility patterns
3. Bubbles! (Hourglass structures)
4. Others



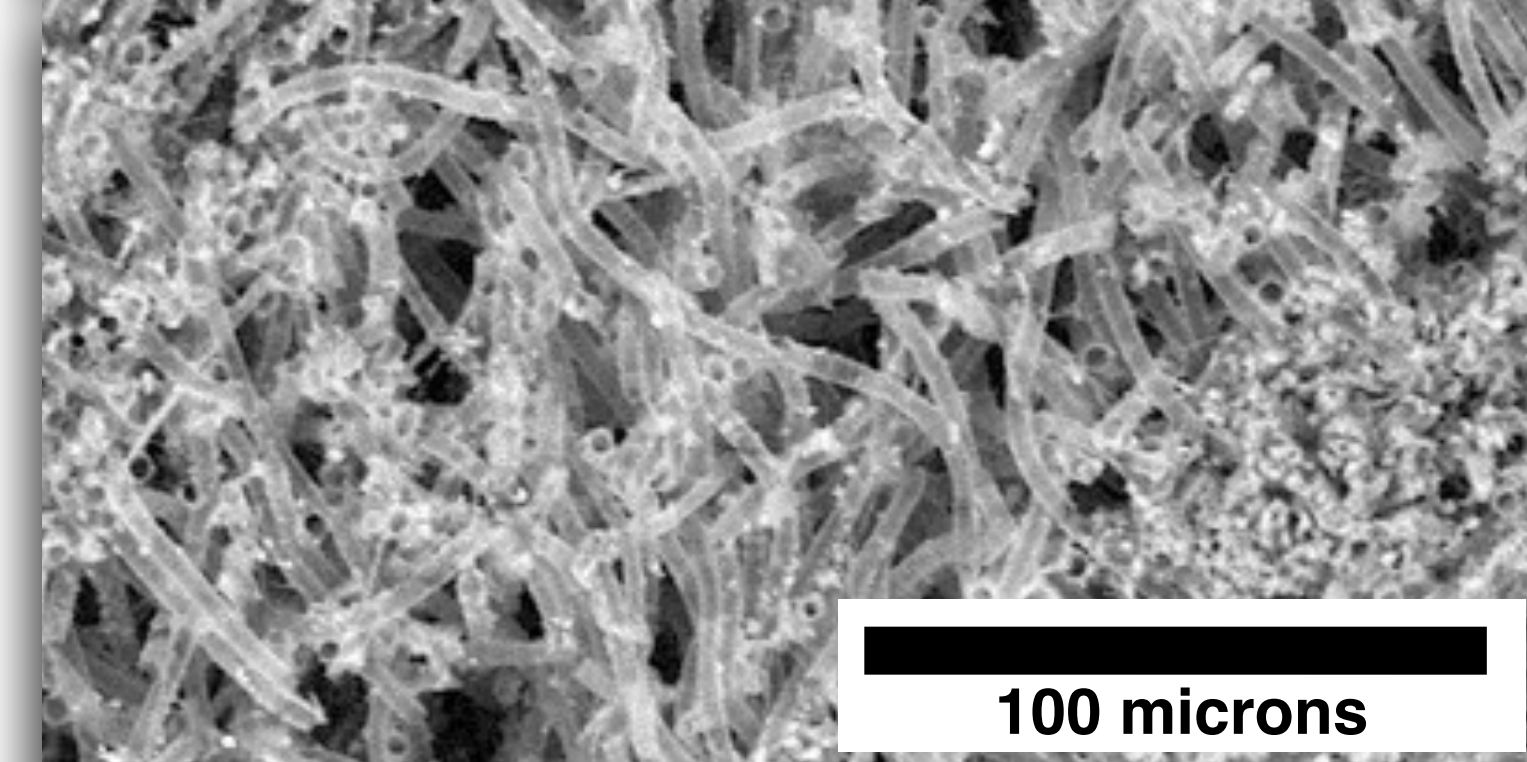
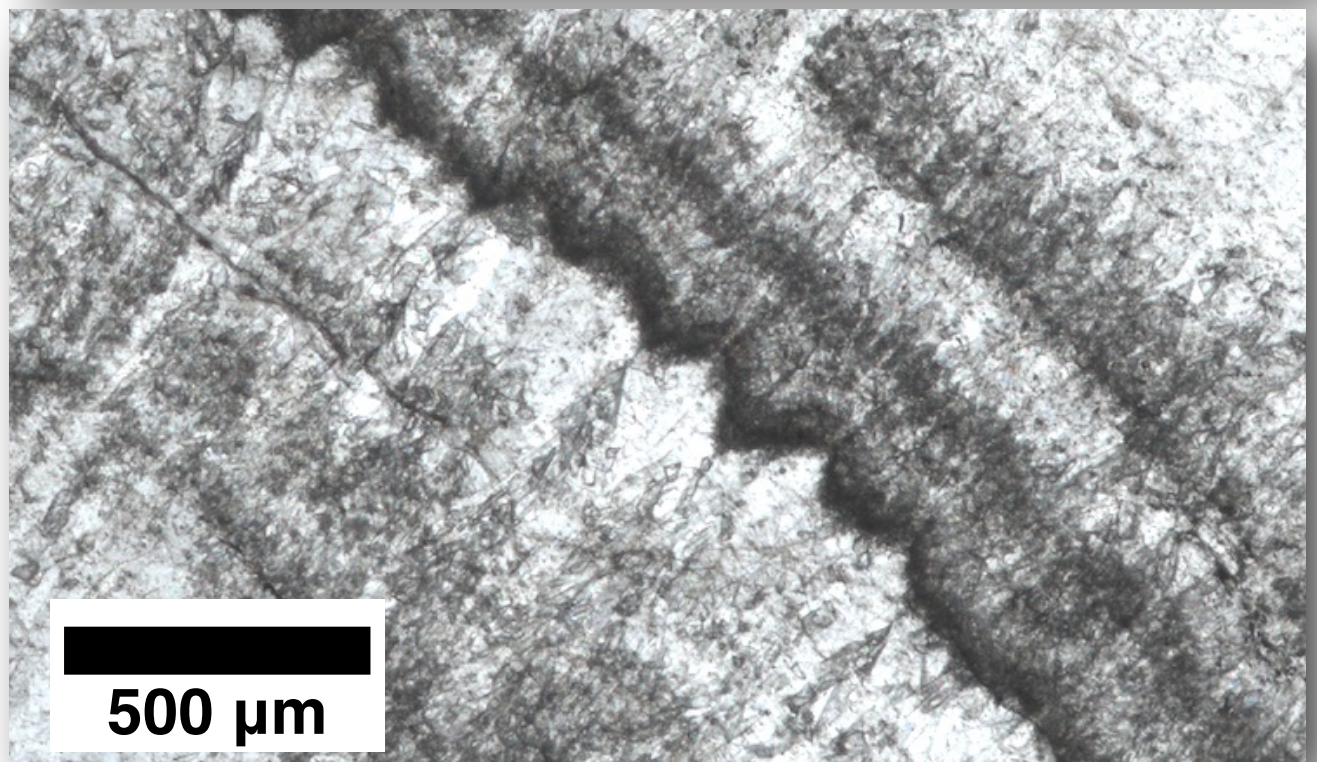
Conclusions 2023

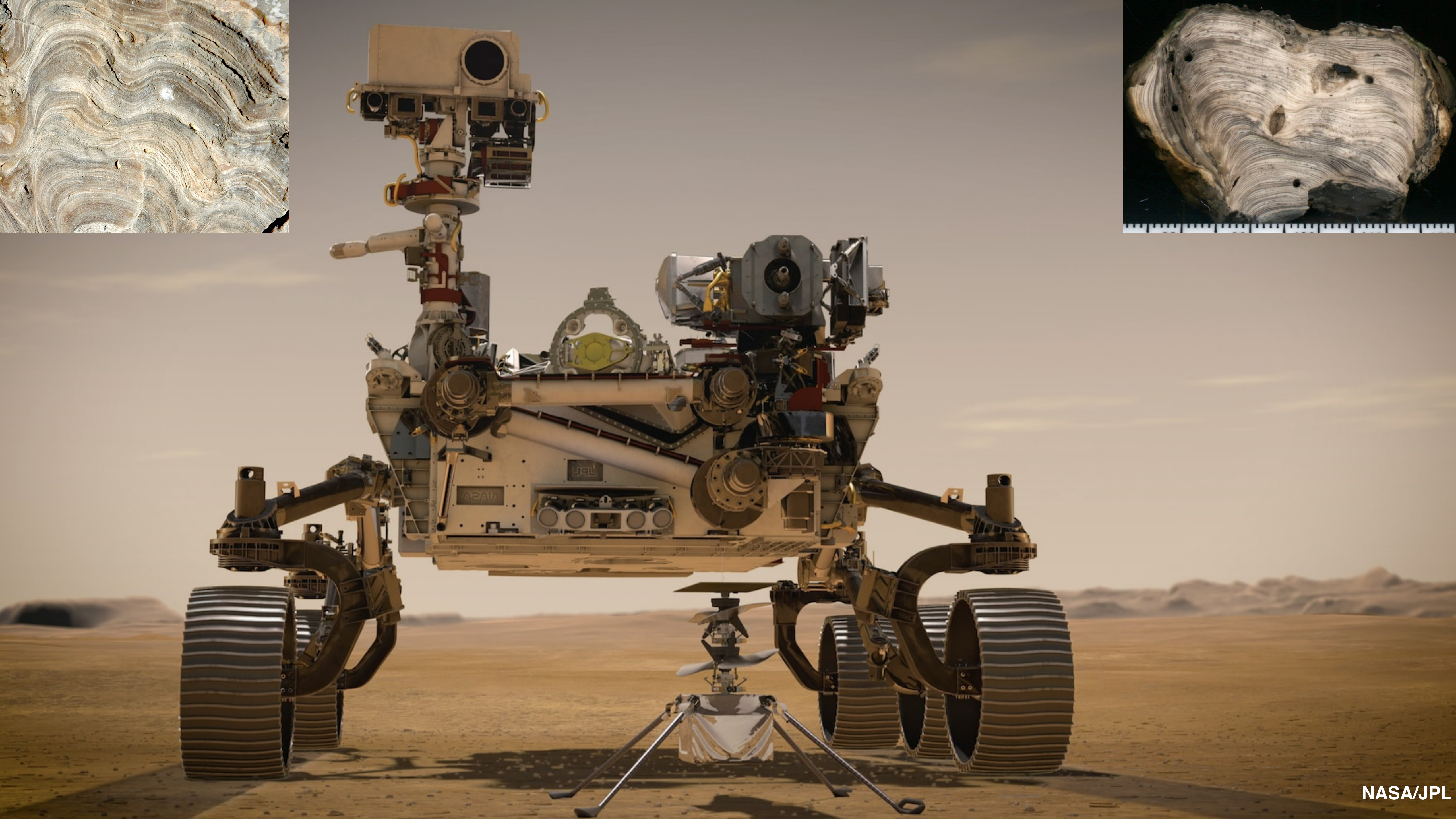
Stromatolites are not always evidence for life

“still a cautionary tale”

Abiogenic

Biogenic





Additional complications: Diagenesis

Modern



Ancient



Additional complications: Diagenesis

Modern
mesostructure,
microstructure,
DNA, RNA, pH,
salinity, nutrients,
isotopes, and
everything else



mesostructure,
microstructure,
maybe some
geochem?



Ancient
mesostructure



formed in the
absence of life

Abiotic



formed by organisms
(on purpose)

Biotic



A b i o t i c

not
significantly
influenced
by organisms

A b i o g e n i c

significantly
influenced by
organisms

B i o t i c

B i o g e n i c

A b i o t i c

B i o t i c

The
Grey
Area

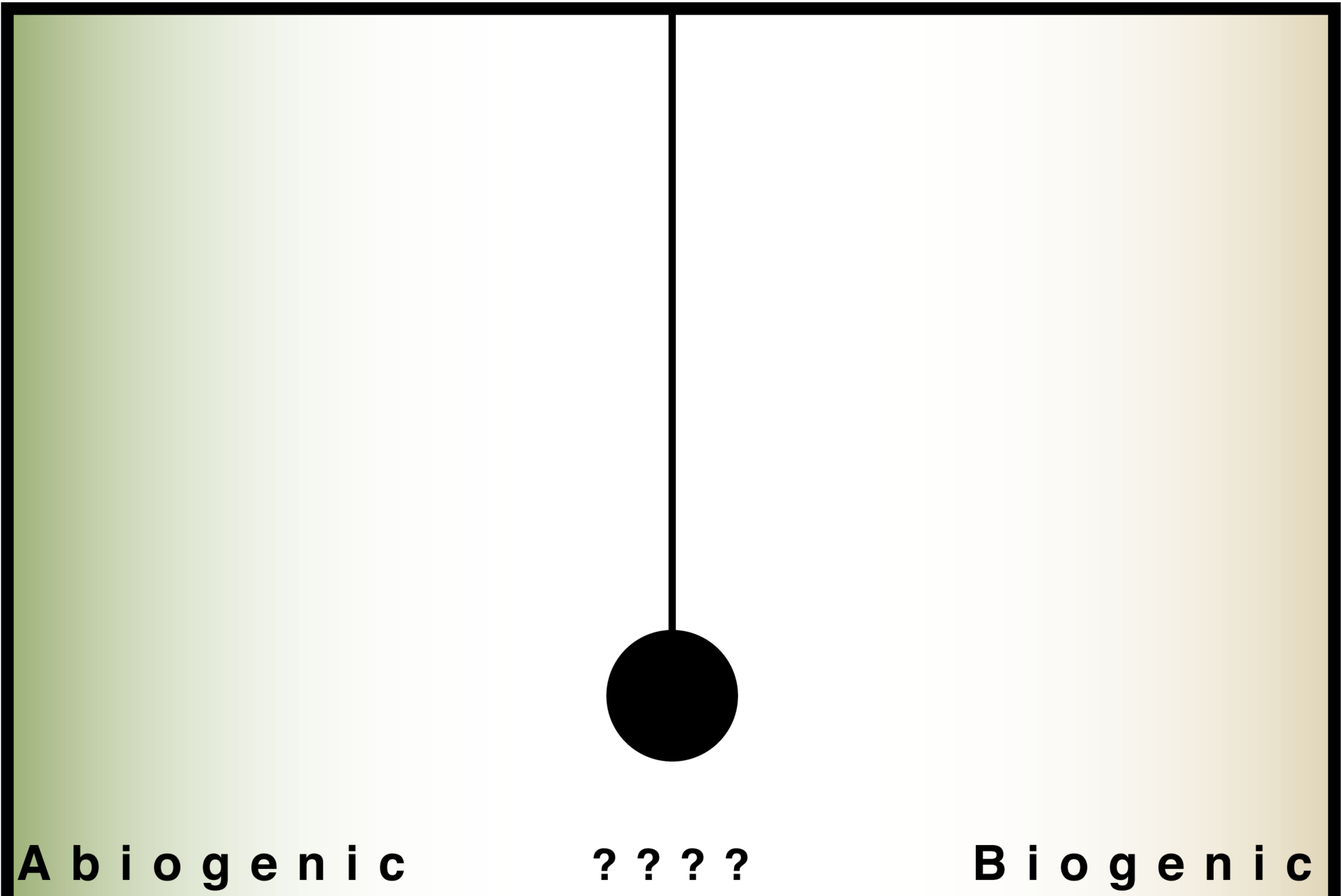
A b i o g e n i c

? ? ? ?

B i o g e n i c

A b i o t i c

B i o t i c



A b i o g e n i c

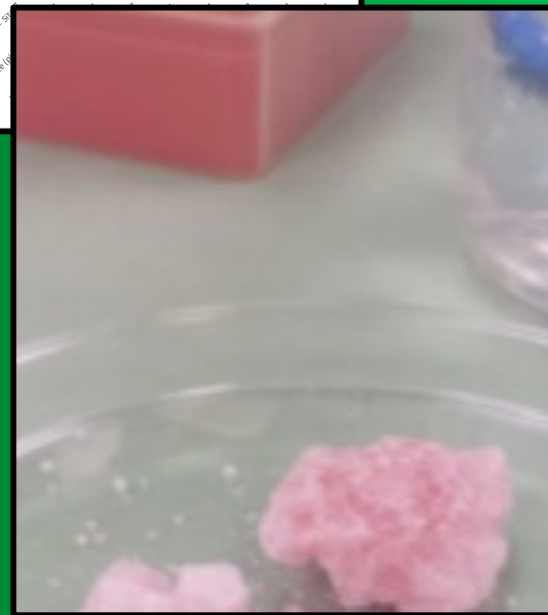
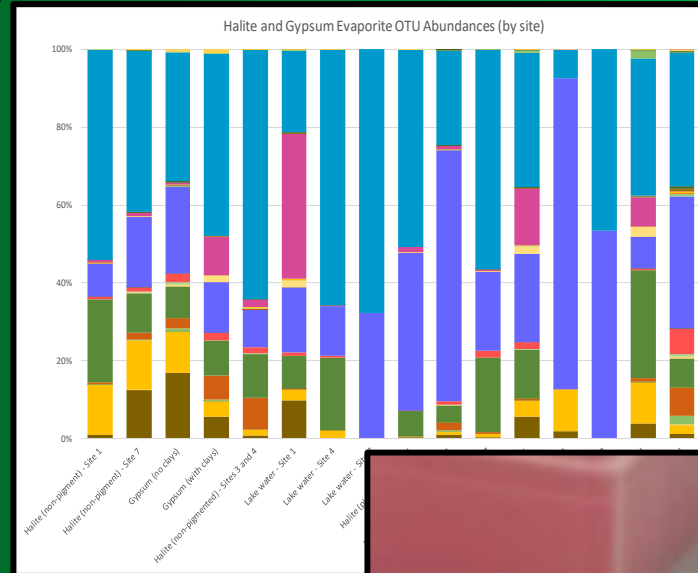
?? ??

B i o g e n i c

Biology or biological processes
(as we know it)

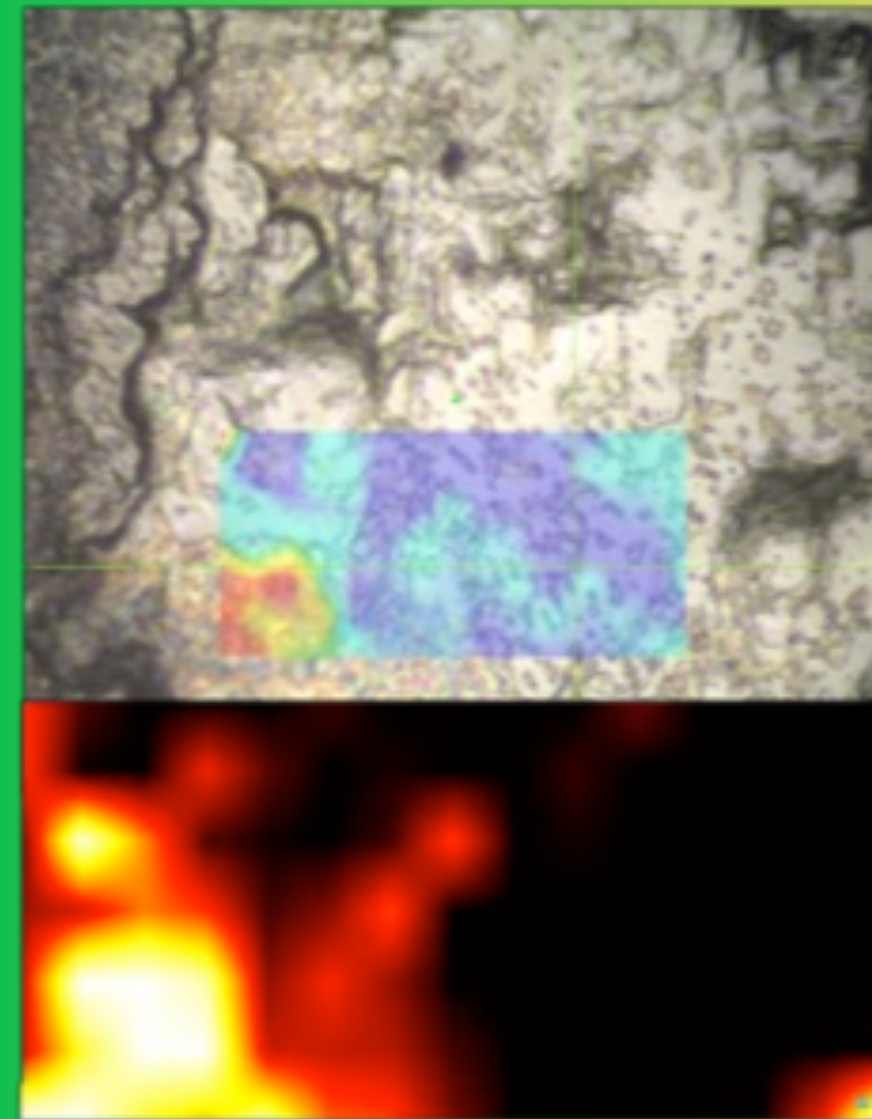
Not from life
(as we know it)

Biotic



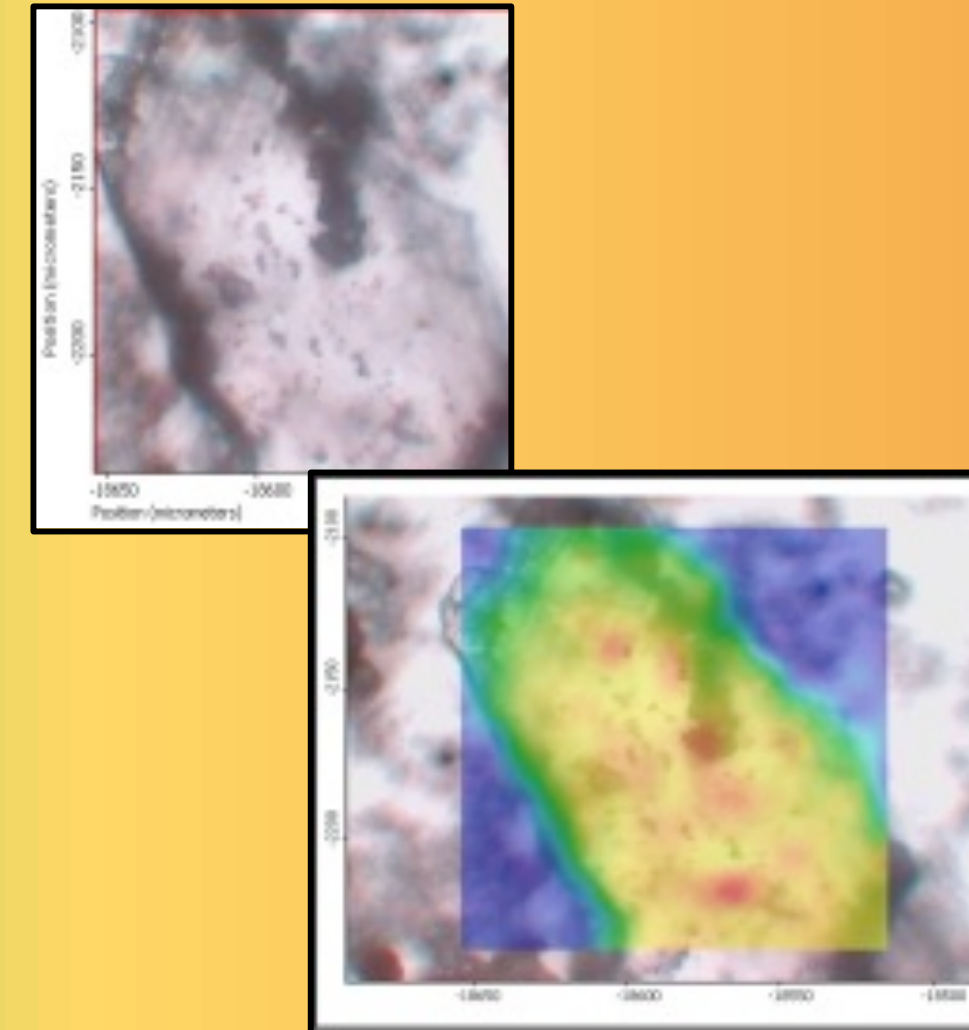
- DNA and measured preserved OTUs
- Carotenoid pigments from biological processes

Biogenic



- Gradients in elemental observed chemistry used for nutrient cycling in fluid inclusions

Abiogenic



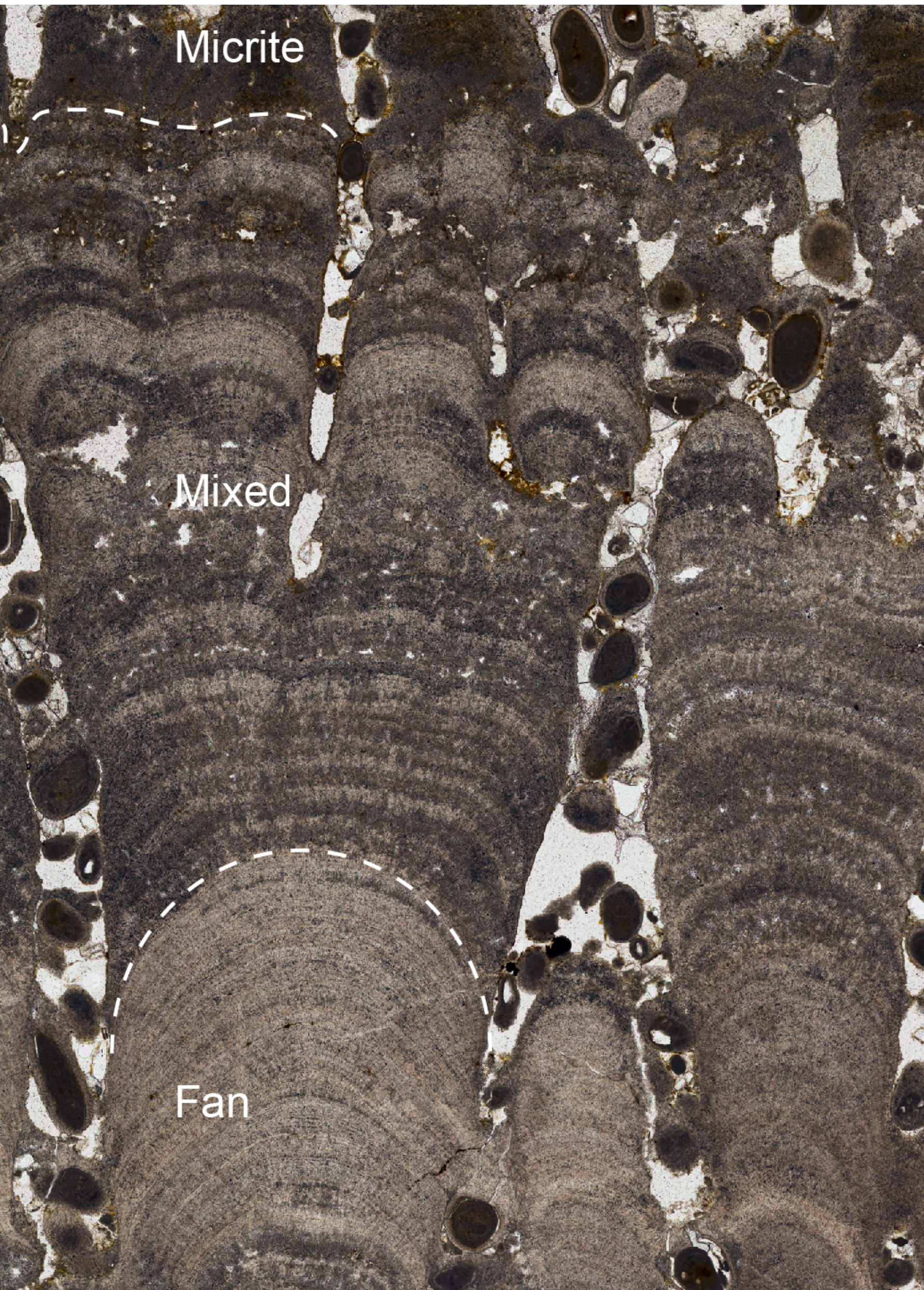
- Elemental chemistry present in fluid inclusions
- Entombed fluids that are from the original evaporite precipitation

Abiotic

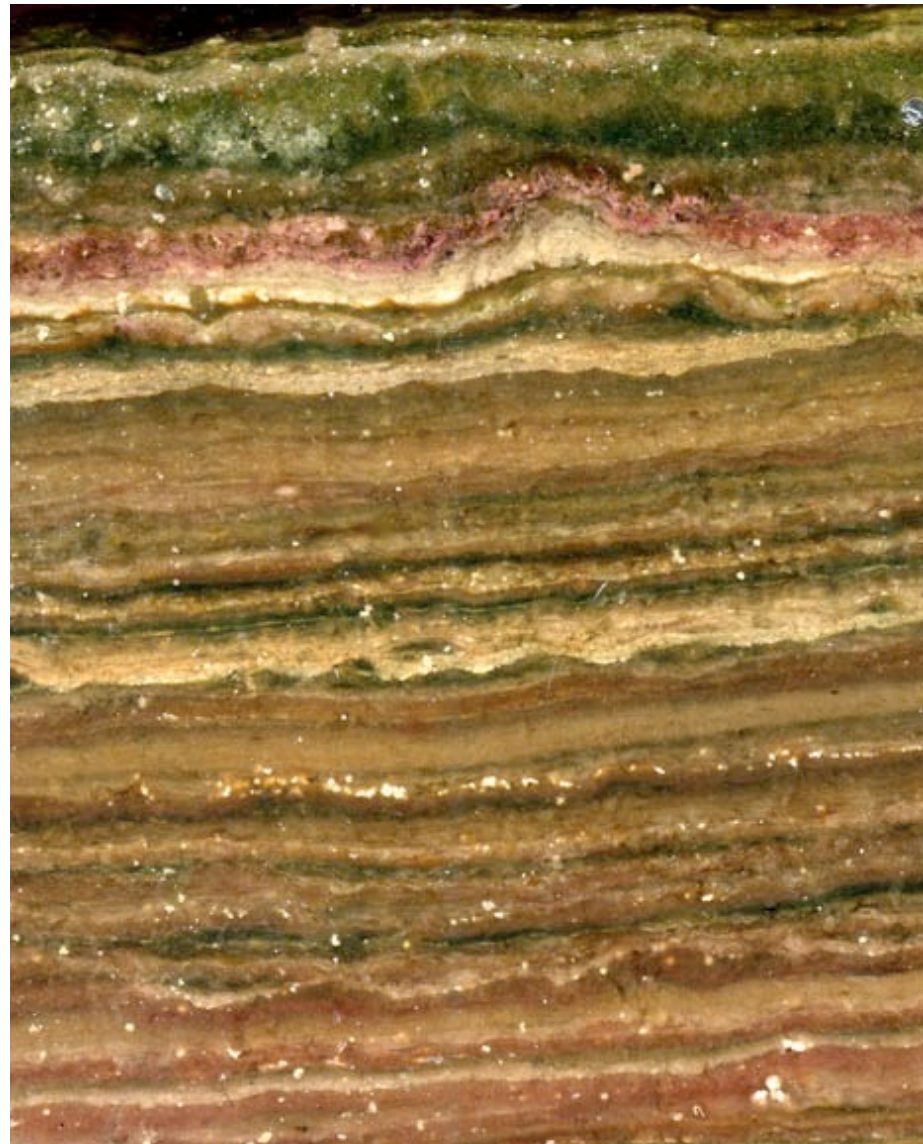


- The evaporite mineralogy and fluid inclusions, if present
- Trace minerals within

Thanks!



Modern



← see through the lens of diagenesis

→ use the modern to inform the ancient

Ancient



Daily Mail .com

Home | U.K. News | Sports | U.S. Showbiz | Australia | Femail | Health | Science | Money | Vid

Latest Headlines | Royal Family | News | World News | Arts | Headlines | Most read | Wires | Games

Get it out, snappy! Liz the pregnant crocodile undergoes urgent operation to remove Coca-Cola can from her stomach

- Took 8 hours and several operations to remove can from the 9ft reptile

