Comparison of organo-mineral biosignatures in dolomitic stromatolites from the Palaeoproterozoic Nastapoka Group and the Eorchean Isua Supracrustal Belt

Looking for signs of early life preserved in Archean rocks

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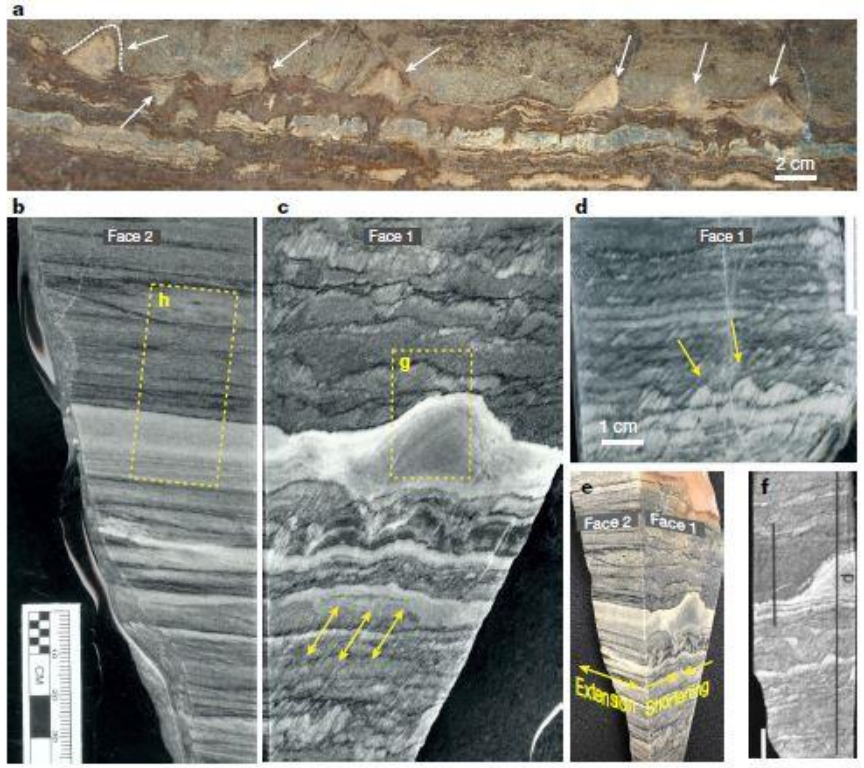
Motivation of the proposed research

- The Archean is the earliest geological age for which we have a widespread rock record so finding *bona fide* biosignatures in such rocks could:

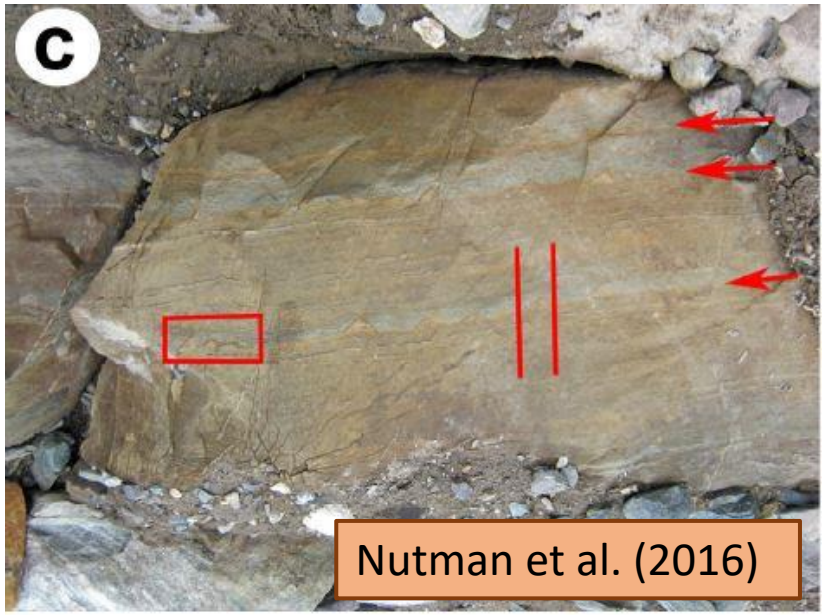
  - push back the earliest records of known life on Earth
  - identify the environmental contexts early life thrived
  - how organisms obtained nutrients and energy from this environment
  - identify extra-terrestrial environments/ rocks to look for extant or past life

The scientific problem



Allwood et al. (2018)

- Allwood et al. (2018) found a lack of internal lamination, and no unique chemical compositions that can point to a microbial influence on the sedimentary environment of deposition.
- They propose a non-biological origin—the structures being products of structural deformation and carbonate alteration of layered rocks.



Nutman et al. (2016)

- Nutman et al. (2016) studied the **morphologies** (geometries of domes & peaks), laminations, and the **trace element chemistries** of the Isua stromatolitic structures and proposed a biogenic origin

Previously proposed biosignatures

"A biosignature is an object, substance, and/or pattern whose origin specifically requires a biological agent.

The usefulness of a biosignature is determined, not only by the probability of life creating it, but also by the improbability of non- biological processes producing it.

Categories of biosignatures can include:

- ***cellular and extracellular morphologies***
- ***biogenic fabrics in rocks***
- ***bioorganic molecular structures (graphitic carbon)***
- ***chirality***
- ***biogenic minerals***
- ***biogenic stable isotope patterns in minerals and organic compounds***
- ***atmospheric gases & remotely detectable features on planetary surfaces (photosynthetic pigments, etc.)"***

- **To address this scientific problem, we try to look for *bona fide* biosignatures in these rocks**

Des Marais et al. (2003)

Can we find signs of early life preserved in Archean rocks?

- Are there biosignatures preserved through the metamorphic recrystallisation in the Isua stromatolitic dolomite?

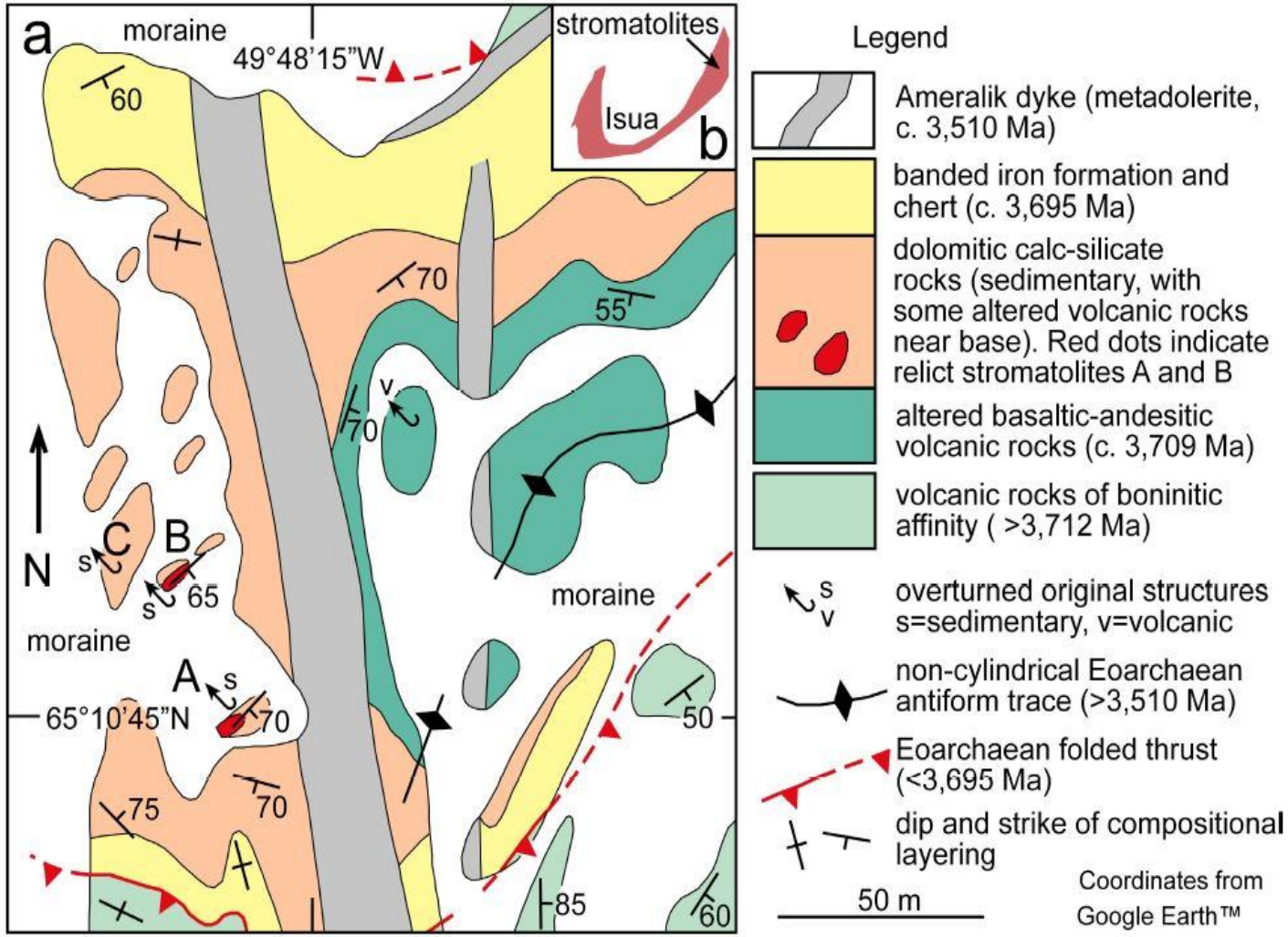
- Can we detect carbonaceous material in the form of graphite occurring in the stromatolite sample?
- Is the graphitic carbon **indigenous** to the host Archean rocks and **syngenetic** with the rock's formation
- Does graphite occur in mineral associations that are known in younger rocks (where biogenicity is well established) to be linked to biological activity

- The rocks of the Isua supracrustal belt have been recrystallised to amphibolite facies
- Graphitic carbon in highly metamorphosed rocks could have been formed through decarbonation reactions of ferrous carbonate minerals
- Finding graphite is the first step in assessing the biogenicity of the Isua stromatolite structures
- We need to ascertain whether the graphite is likely metamorphosed biomass

- Does the graphite posses $\delta^{13}C$ isotopic values as well as structural heterogeneities which could indicate biological origin

Stromatolites of the Isua Supracrustal Belt

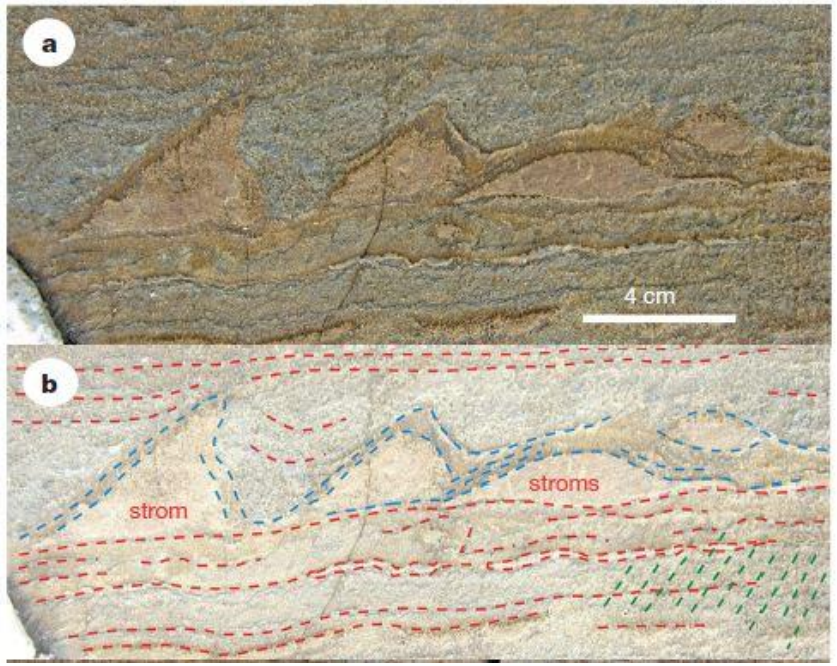
- The (interpreted) stromatolites are 3.7 Ga structures within outcropping dolomitic rocks
- These are found in the context of the metasedimentary rocks of the Isua Supracrustal belt SW Greenland
- The discovery locality is situated in the hinge of an anticline that's cored by andesitic metavolcanic rocks
- Here, pillowed metavolcanic rocks occur locally & are overlain by bedded dolomite rich metasedimentary rocks that are in turn overlain by interlayered quartzites and metamorphosed BIFs
- The 30 by 70 meter low strain lacuna of the discovery locality preserves the dolomitic composition of the rock as well as the fine-scale primary structures of the rock



Nutman et al. (2016)

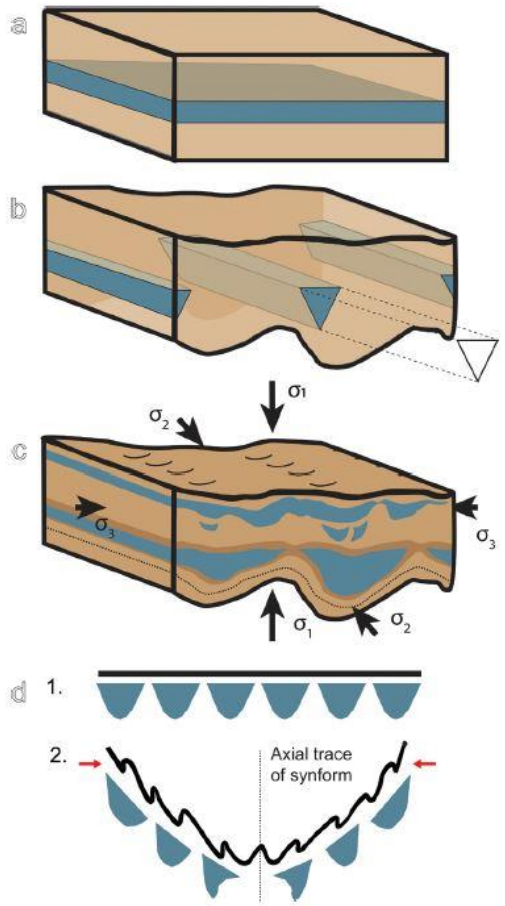
Field observations

- At two outcrops- Site **A** and **B**- there are several beds with 1–4 cm high, coniform and domical stromatolites interbedded with sedimentary rocks
- The outcrop only preserves these structures in cross section
- Some of the coniform structures are asymmetrical (similar to asymmetry in better preserved stromatolites from the 3,400 Ga Strelley Pool Formation and 2,030 Ga Wooly Dolomite)
- Amphibolite facies metamorphism recrystallized some of the stromatolites to 100–200 μm aggregates of dolomite & quartz
- But the outer margins of stromatolites from site A show internal lamination along the crests
- At an outcrop scale, horizontal sedimentary beds onlap the sides of the stromatolites— a characteristic feature of stromatolites.



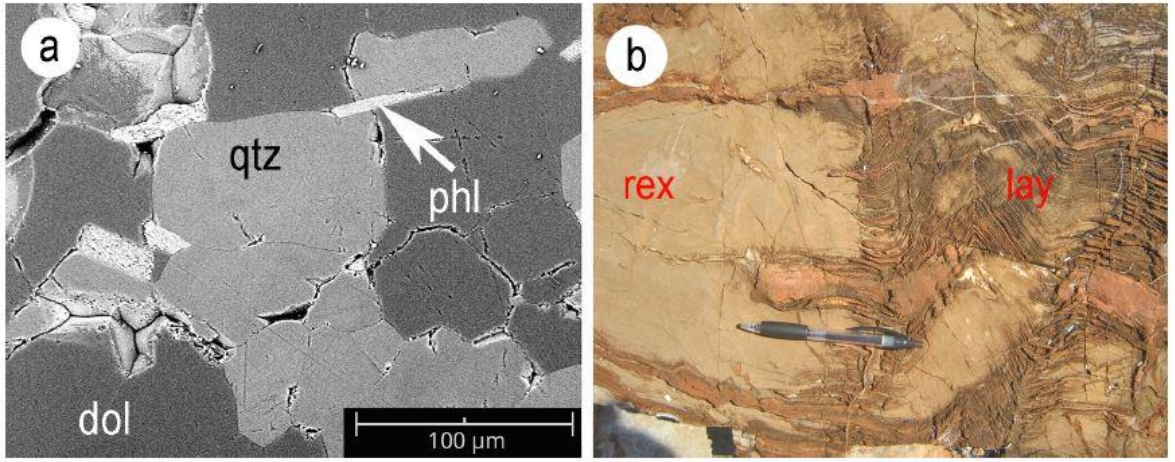
Nutman et al. (2016)

Controversies



Zawaski et al. (2020)

- Zawaski et al. (2020) argue that the original Isua rocks were overturned and that the dolomitic structures are boudins- structural deformation features in rocks
- These were studied with Electron backscatter diffraction and no true layering was found



Nutman et al. (2019)

- Nutman et al. (2019) re-examined the Isua rocks and using Scanning Electron Microscopy
- The mineralogy of the stromatolitic structures represents *synsedimentary* materials and not deformational features
- Fine scale layering may have been destroyed by metamorphic recrystallisation but dolomite grain textures are similar to other stromatolites

The MSc project

- Analyse and compare the 3.7 Ga stromatolite sample from Isua (South-West Greenland) with the younger, 2.25 Ga stromatolite sample from the Nastapoka Group (Québec, Canada)

- Signs of life in Paleoproterozoic rocks are well established

- Identifying potential biosignatures in the Eoarchean Isua stromatolite sample that are analytically similar to those of the Paleoproterozoic Nastapoka Group stromatolite will aid interpretations of biogenicity

Analytical Techniques

- Correlated microscopy techniques to be used:
  - Optical (transmitted light) microscopy
  - Micro-Raman spectroscopy
  - Scattered Electron Microscopy (SEM)

- If organic matter is detected:
  - Mass spectrometry

Some References

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Thank you

- Questions?