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Reassessing evidence of life in 3,700-million-year-old rocks of Greenland

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Four distinct phases occur in the mapped areas:

1. Fe-Ti-Cr-K rich phase, probable mica, that displays high X-ray fluorescence counts for the trace elements Ba, Co, Ni, Zn and Ga. This phase is prevalent in Map #1, and an example of it can also be seen in the upper-right corner of Map #2.

2. Cr-K rich phase, probable mica, that is Ti- and Fe-poor, and displays high X-ray fluorescence counts for the trace elements Ba, V, and Ga. This phase is more prevalent in Map #2 but is also visible in Map #1 as a bright linear feature in the lower right corner.

3. Fe-Mn-Ca rich phase, probable carbonate, which incorporates some of the detected trace elements, especially 2+ cations such as Co, Ni, and Zn, but at concentrations that yield significantly lower X-ray intensity than is displayed by phases 1 and 2, described above.

4. Probable quartz, represented by dark blue areas of lowest X-ray intensity on Maps #1 and #2. XRF analysis conditions were optimized for the detection of high-Z trace elements to interrogate the distribution of important transition metals, minor elements, and trace elements. Under these conditions, we were not able to detect elements with Z < 16. However, corroborating evidence from element maps collected using the PIXL breadboard instrument at JPL (Fig. 1, Main Text) indicate that these large swaths of low fluorescence intensity represent SiO_2 in quartz, a phase that is not an important trace element carrier – as evident in the synchrotron XRF maps.

It is clear from inspection of Extended Data Figure 6 that trace elements are most strongly associated with micaceous phases in the mapped areas, not carbonate. It is also clear that mineralogy and elemental chemistry varies in the mapped areas on a scale that cannot be recognized in visual images of rock textures. In a single ~mm scale dark band in the rock (Map #1, Extended Data Figure 6), four distinct minerals can be recognized, with grains ranging in size from a few microns to ~100 microns. The same is true within the core of the stromatolitelike feature (Map #2, Extended Data Figure 6). Accordingly, the 20 x 800 □m laser ablation ICP mass spectroscopy (LA-ICP-MS) scans collected by Nutman et al.1, oriented orthogonally to the primary horizontal fabric of the rock (see their Extended Data Figure 4c), could not have unambiguously recognized mineral-trace element associations. Scans of this size would have averaged over at least 4 distinct chemical/mineralogical species, each with its own set of trace element distributions and concentrations. This is especially so in the many cases where Nutman et al.1 combined LA-ICP-MS scans over vertical dimensions > 800 microns in an effort to isolate the chemical composition of visually distinct layers in the rock (see their scan numbers A1 and A7-A11 in their Extended Data Figure 4c)

Supplementary Table 1.

STRELLEY POOL FORMATION (SPF) KEY EVIDENCE PRESENTED IN SUPPORT OF BIOGENIC INTEPRETATION OF STROMATOLITES		
Observation	Implication/importance	Measurement basis **(scale of observation)**
Paleoenvironmental setting: isolated marine transgressive peritidal carbonate platform deposit composed of laminated carbonate + chert with abundant sedimentary structures and textures.	Unequivocally sedimentary origin of host rocks. Typical microbial reef setting. Environment that has nurtured benthic life forms throughout Earth's history,	Field observations centered on correlated stratigraphic sections. REE+Y of petrographically constrained, dolomite and chert. Abundant cross-cutting and stratigraphic relationship constraints, with unique indicators such as paleo-wave-cut platform and sea cliff, evaporite facies, subaerial exposure indicators. **Sub-millimetre - kilometre scale**
Structures show sedimentary onlap at margins, including onlapping storm-wave-generated breccia composed of platey intraclasts of the laminated carbonate-chert	Proves that the structures are synsedimentary - they stood high on the seafloor	Field and hand sample observations of sedimentary structures. **Centimeter – metre scale**
Presence of 7 different conical and domical stromatolite morphologies, each with distinct attributes, and none resembling known abiogenic structures.	Greatly reduces the likelihood that the stromatolite-like morphology can be attributed to a feasible – but highly unlikely—set of purely physical/chemical processes, because it would had to have happened 7 times.	Field and hand sample observations. All morphologies verified in 3D in outcrop with bedding plane and cross-section exposures, all photographed and published. **Centimeter – metre scale**
Presence of primary, microbially-influenced sedimentary textures. Irregular, fenestral textured laminae with cavity-lining cements on domical stromatolites. Also present on intraclast breccias	Microbial mats influenced deposition of laminae. Cements prove presence of early voids (microbial mat gas bubbles). Preservation of these early textural features implies that the dolomite is not a late stage replacement phase	Hand sample and thin section petrography. Micro-XRF element mapping. **Millimetre-centimetre scale**
Organic deposits in unique geometry - stromatolite laminae that extend to steep margins of domical stromatolites, and do not thicken into depositional lows. Organic laminae are present on contemporaneous	Remnants of stromatolite-forming microbial mats: intraclasts prove that the organics are syngenetic. Laminar geometry proves the organics are not transported detritus from an abiotic source	Hand sample observations **Millimetre-centimetre scale.** Raman spectroscopic mapping on polished slab. **Centimetre scale**

platey intraclasts.	(meteoritic or hydrothermal)	
Conical morphology of stromatolites: Isopachous laminae with unchanging cone dimensions through hundreds of layers of vertical growth	The inheritance of the cone dimensions through successive layers indicates vertical growth – inconsistent with isopachous accretion of mineral crusts.	Field and hand sample observations. All morphologies verified in 3D. **Centimetre – metre scale**
Contrasting sedimentary fabrics on/off large conical stromatolites: Very sharp, pronounced lateral transition at margins of conical stromatolites	Internal laminae have a different character to external laminae, indicating localized sedimentary processes.	Hand sample and thin setion observations **Millimetre-centimetre scale**
Vertical growth of pseudocolumnar conical stromatolites on slopes	Indicates phototrophism.	Field outcrop observations **Centimetre – metre scale**
Absence in deeper water	Indicates phototrophism.	Field outcrop observations. **Centimetre– kilometre scale**