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Considering biogenic indicators in proposed ca. 3.7 Ga stromatolites from the Isua Supracrustal Belt (West Greenland) within a multi-scale, multiple working hypotheses framework. Are these structures the oldest morphological evidence of life?

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The biogenicity of proposed stromatolite structures from Eoarchean (ca. 3.71 Ga) rocks of the Isua Supracrustal Belt (ISB) in Greenland is under debate for good reasons [1, 2]. These structures are found within a suite of multiply deformed greenschist- to amphibolite-facies metamorphic rocks. Our combined km- to micron-scale methodology represents a robust argument against biogenicity and a model for multiscale analysis of complex samples where biogenetic criteria need to be applied within a regional context and as part of a multiple working hypotheses framework. To assess their premise as primary sedimentary features – as opposed to products of strain localization in layered, variably ductile rocks – we report field mapping at the appropriate scale and resolution. Our new map guided our micro- and macro-structural investigations and comprehensive geochemical sampling. We report detailed field characterization and structural analysis to show that the structures are linear inverted ridges aligned with azimuths of local and regional fold axes and are parallel to linear structures; they are not deformed conical stromatolites. Combined major element (e.g., Ca, Mg, Si) scanning µXRF maps, and electron backscatter diffraction (EBSD) patterns collected on surfaces cut perpendicular and parallel to the ridges attest to the lack of any residual sedimentary laminae (e.g., compositional layering) within these structures' cores or deformation to support a stretched cone model. Comparing these structures to agreed upon biogenic stromatolites provides a proof-of-concept that µXRF scans can identify stromatolite laminations (Fig 1). Internal layering previously inferred for these features instead arises from variable weathering of outcrop surfaces that otherwise conceals granoblastic quartz ± dolomite cored boudins between semi-continuous layers in calc-silicate schist. Therefore, these features are not of sedimentary origin. Collectively, our results show that the Isua structures are the expected result of a tectonic fabric that preserves no fine-scale primary sedimentary structures and were probably never stromatolites.

[1] Nutman, Bennett, Friend, Van Kranendonk & Chivas (2016) Nature 537, 535-538.

[2] Zawaski, Kelly, Orlandini, Mojzsis, Nichols & Allwood (2020) Earth and Planetary Science Letters v. 545.

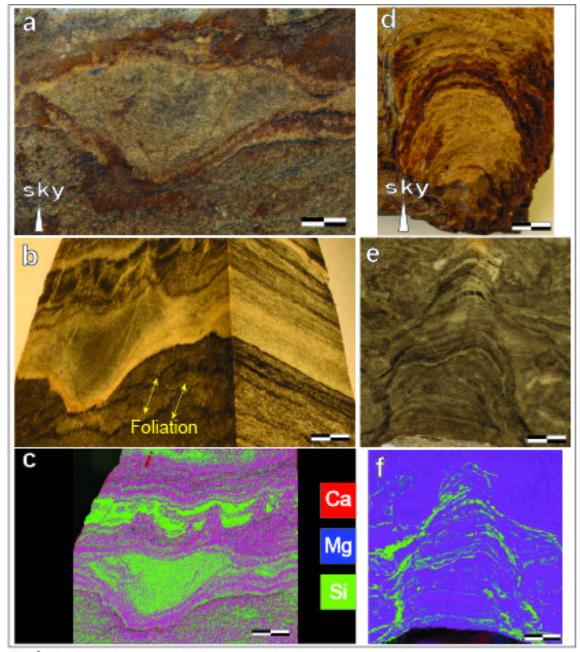

Fig. 1. Hand sample images of ISB structures (a–c), with corresponding element map collected by µXRF compared to a stromatolite from the Wooly Dolomite (d–f). Scale bar is 1 cm for all images. Images are oriented as the rocks appear in outcrop. (a) Photograph of the weathered surface. (b) The cut surfaces of the sample. The quartz-rich core appears gray-blue and the carbonate-rich outer zones appear white. Layering is penetrated by a diagnal foliation that cuts the rock (yellow arrows). (c) Element map of sample collected by µXRF. Purple-pink colors in (c) represent presence of both Ca and Mg, in the absence of abundant Si. Wooly Dolomite. (d) Photograph of stromatolite from weathered surface, 5 cm from stromatolite in e. (e) Photograph of a cut surface on the same hand sample. (f) Element map collected by µXRF. Element combinations are interpreted to represent similar mineral associations as the ISB sample.