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The Isua (Greenland) relict stromatolites cannot be confidently interpreted as original sedimentary structures

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The biogenicity of proposed stromatolite structures from Eoarchean (ca. 3.71 Ga) rocks of the Isua Supracrustal Belt (ISB) in West Greenland is under debate. Our 2020 publication argues against biogenicity for the proposed stromatolites. The subsequent Comment to our work challenged some of our fundamental arguments for a tectonic origin to the structures. This Comment has been an opportunity for us to elaborate on these structures and further refine and solidify our initial conclusion that they represent the expected outcome of the tectonic deformation displayed in the ISB. This dialogue between groups is essential as the consequence of these structures being biogenic would move the date for complex microbial communities 200 million years closer to Earth's formation, to a time when Earth's surface would have been even less habitable. Here we reexamine our four key observations that support our tectonic origin. First, 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 parallel to linear structures; they were never primary linear, deformation-parallel stromatolites or deformed conical stromatolites. Second, our combined major element (e.g., Ca, Mg, Si) scanning μ XRF maps fail to reveal internal laminations for the cores of these structures, but other authors argue layers are present. In the instance where layers appear to be preserved, we argue that an amorphous core is still present. Also, layering on its own is inconclusive of a biogenic origin as relict internal laminations could be preserved. Third, the gross morphology of these structures being nearly identical in morphology and dimensions to clearly tectonic structures only tens of meters away is a more reliable indicator of a tectonic versus biogenic origin than internal laminations. Lastly, discontinuous field relationships and absence of primary sedimentary structures that could serve as way-up indicators preclude confident assignment of these outcrops as being structurally overturned, as

originally argued. Collectively, our results reinforce 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.