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Biogenic stromatolites as lacustrine oxygen oases ~2.7 Ga: synthesizing textural and geochemical data

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The evolution of oxygenic photosynthesis fundamentally altered the global environment, but the history of oxygen production prior to the Great Oxidation Event (GOE) ~2.4 billion years ago (Ga) remains unclear. Increasing evidence suggests that non-marine microbial mats served as localized “oxygen oases” for hundreds of millions of years before the GOE. Such microbial communities are preserved in Archean lacustrine stromatolites, including samples with exquisitely preserved biosignatures such as bubble fenestrae recording microbial gas production. While stromatolites in Archean lakes form excellent opportunities to test oxygen oasis hypotheses, evidence specifically linking textural biosignatures with geochemical proxies for oxygenic photosynthesis remains relatively limited.

Here, we report fabric-specific patterns of positive and negative Ce anomalies in lacustrine stromatolites from the 2.74 Ga Ventersdorp Supergroup, indicating dynamic redox conditions within ancient microbial communities driven by oxygenic photosynthesis. Ventersdorp stromatolites include fenestral textures produced by microbial gas bubbles entrained within mats, and finely laminated textures formed by progressive mat growth. Oxides surrounding former bubbles exhibit positive Ce anomalies, while oxides in stromatolite laminae typically contain strong negative Ce anomalies. Petrographic analyses and rare earth element signatures support a primary origin for Ce anomalies in stromatolite oxides. The spatial patterns of Ce anomalies in Ventersdorp stromatolites are most parsimoniously explained by localized Ce oxidation and scavenging around oxygen bubbles produced by photosynthesis in microbial mats. Our new data from Ventersdorp stromatolites supports the presence of oxygenic photosynthesis ~300 million years before the GOE and adds to the growing evidence for early oxygen oases in Archean non-marine deposits. Furthermore, the combined biosignatures and redox analyses in this study can be applied in other ancient stromatolites to directly analyze the evolution of various metabolisms in ancient microbial communities.