Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.11202

Earliest fossil record of cyanobacterial microbialites >120 Myr before the Great Oxygenation Event

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The Great Oxygenation Event (GOE) was an unprecedented geobiological revolution in deep time (~2.4–2.3 Ga) and the driver of subsequent geosphere–biosphere interactions. Its timing is widely believed to reflect the rise to dominance of oxygenic photosynthesisers, primarily cyanobacteria, in shallow-water ecosystems. Our understanding of the GOE is complicated by poor preservation of the ancient geological record and an absence of biomarkers diagnostic of the rise of oxygenic photosynthesis; furthermore, the earliest unambiguous cyanobacterial cellular fossils are only 2 Gyr old.

Here, we present high-resolution, organic–inorganic geochemistry evidencing a cyanobacteria-dominated microbialite assemblage >120 million years before the main GOE in the 2.52 Ga Gamohaan Formation, South Africa. These microbialites formed under a micro-oxic manganese-bearing marine water column, were mineralised extremely rapidly during growth, and have not undergone substantial post-depositional alteration. They comprise organic materials with an aliphatic fraction dominated by long, unbranched fatty acid-like membrane lipid residues, consistent with bacterial origins, carbon isotope fractionations diagnostic of oxygenic photosynthesis using Form I Rubisco, and nitrogen isotope fractionations denoting aerobic nitrification–denitrification. EPR and Raman geothermometry using the organic fraction of these microbialites clearly establish the syngeneity of the mat laminations with the host rock. The Gamohaan microbialites thus present the oldest fossil evidence for cyanobacteria, considered the architects of Palaeoproterozoic atmospheric oxygenation. At 2.52 Ga, this postdates the estimated evolution of oxygenic photosynthesis by ~400 Myr and precedes global atmospheric oxygenation by at least 120 Myr.

Finally, using correlated SEM-EDX, Raman and FTIR mapping, we demonstrate the specific co-occurrence of ferroan dolomite with microbial mat laminations, indicating that dolomite nucleated syndepositionally within microbial ecosystems, providing the oldest evidence for microbial dolomite formation, and showing that microbes have played a role in forming this enigmatic phase since at least the terminal Archaean.