

Origin, evolution, ecology and traces of anaerobic life

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Fossilised remnants of the Archaean microbial biosphere imply that it was dominantly anaerobic; however, the metabolic landscapes of the earliest biomes remain poorly constrained. Fossilised traces of photosynthetic and chemosynthetic life have been identified dating to at least 3.4 Ga in both the Barberton greenstone belt of South Africa [1,2] and the East Pilbara of Western Australia [3,4], however potential earlier traces have also been identified in pervasively metamorphosed sequences in Canada and Greenland [5].

In this presentation, I will discuss the evidence and controversies surrounding a range of putative and probable traces of life of anaerobic life, highlighting how advanced, non-traditional and emerging technologies are being harnessed to elucidate the presence and preservation of anaerobic biomes. Chemometric methods provide a means of distinguishing diversity and disparity within and between organic biogeochemical signatures of life, and may provide sufficiently large datasets to apply unsupervised and supervised machine learning approaches [6]. Coupled organic–inorganic geochemical analyses of microbial biofabrics and microstratigraphies can allow the reconstruction of co-evolving life and environments within exceptionally preserved fossiliferous horizons, even after moderate metamorphism, and are the benchmark for any comprehensive description of a microbial biome [2,7]. Micro–nanoanalytical spatially constrained and *in situ* analyses can identify the metabolic affinity of individual microfossils and microbial mats and present promising avenues for re-assessment of controversial fossils described prior to the development of nanogeoscience approaches [8–9]. Finally, in the absence of obvious cellular preservation, bio-induced metrics, such as trace element concentrations and associations, have the potential to shed light on elemental budgets, changing bio-affinities over geological timescales, and complex metabolic elemental dependencies archived within the rock record, particularly in the case of chemosynthetic biomes, which typically have subtle fossil records [10].

Emerging technologies, correlated datasets and data treatments, and the coupling of high-resolution and high-sensitivity geochemical approaches can shed new light on ancient fossils. I will conclude this talk by discussing future research directions by which we might better understand Earth's early anaerobic biosphere, such as constraining the origins of anaerobic metabolisms from the rock record, their interplay with aerobic metabolisms in the Mid–Late Archaean, and potential modern analogues for early ecosystems.

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