Decoding the Archean fossil record: clues from experimental fossilization and natural sample characterization

J. ALLEON[1*], N. FERRALIS[2], K. H. WILLIFORD[3], D. T. FLANNERY[3], J. A. SCHUESSLER[4], Y. ZHANG[2], AND R. E. SUMMONS[1]

[1]EAPS, MIT, Cambridge MA USA ([*]alleon@mit.edu)
[2]DMSE, MIT, Cambridge MA USA
[3]JPL, Caltech, Pasadena CA USA
[4]GFZ, Potsdam, Germany

Identifying organic biosignatures in the oldest geological record is challenging, mainly because (1) abiotic processes can generate organic microstructures having morphological and isotopic characteristics similar to biotic ones and (2) organic precursors are degraded during burial [1, 2]. Recent experimental studies [3, 4] and characterization of Precambrian organic microfossils [5] have nonetheless demonstrated that the molecular degradation of fossilized microorganisms can be significantly limited during burial, depending on the associated mineralogy (e.g., silica protects, in contrast to carbonates). As the molecular composition of originally distinct organic precursors may not evolve the same way under similar burial conditions [6], distinguishing biotic from abiotic organics appears thus possible.

Here, using advanced spectrometry and spectroscopy techniques, we constrain the depositional environment and burial history of organo-mineral associations preserved in a chert (i.e. silica-rich rock) from the 3.47 Ga Mount Ada Basalt Formation (Pilbara, Australia), to eventually assess the possible origin of organic matter. Trace element and Si isotopic compositions of quartz indicate its precipitation in a marine seafloor environment influenced by hydrothermal fluids. Highly reducing conditions favorable for the abiotic synthesis of organic molecules may have existed in the hydrothermal system, as evidenced by the presence of Fe-Cr-Ni alloys. The molecular characteristics of the investigated organic material clearly differ from those of microfossils in cherts having experienced similar peak temperature conditions, possibly indicating a distinct origin. The poorly constrained synthesis and fate of abiotic hydrocarbons in such hydrothermal systems, however, make it very difficult to draw definitive conclusions.

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