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Exploring relationships between major element cations and organic preservation in silica

KELSEY R MOORE[1], DAVID FLANNERY[2], MICHAEL L TUITE[1], JESSE D TARNAS[1], TANJA BOSAK[3] AND KENNETH H. WILLIFORD[1]

[1]JPL/Caltech
[2]Queensland University of Technology
[3]MIT

Presenting Author: kelsey.r.moore@jpl.nasa.gov

Ancient biosignatures are key to understanding the emergence and evolution of life in its planetary context. Microbes thrived on Earth from at least the early Archean to the present, and similar organisms may have emerged on a warmer, wetter Mars in the past, as well. However, fossil evidence of ancient microbes is often difficult to identify and interpret. Early diagenetic chert preserves numerous examples of microbial biosignatures from the Proterozoic and Archean eons. Despite their presence in the rock record, though, the mechanism behind this biosignature preservation and the biological and abiotic factors that contributed to the precipitation of chert are not well understood. Here, we address these uncertainties through fossilization experiments and analyses of Proterozoic biosignatures and the minerals that preserved them.

Fossilization experiments reveal that exopolymeric substances (EPS) produced by some cyanobacteria can promote the precipitation of amorphous silica by using magnesium as a cation bridge. Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) maps of biosignatures in Proterozoic chert reveal that the organic matter is commonly associated with magnesium-, calcium-, and aluminum- rich phases. In contrast, chert that does not contain organic matter lacks these cation associations. These combined results suggest that interactions among organic matter and major element cations in seawater may have promoted the preservation of organic matter by chert in marine environments during the Proterozoic.

Our findings provide a window into interactions between microbes and their environments on the early Earth and the microbial contribution to geochemical cycles and chert formation. By analyzing these biosignatures and constraining the processes that led to their formation on Earth, we may be better equipped to identify and interpret potential biosignatures in Jezero crater, the landing site of the Mars2020 rover. Based on our results, we suggest that hydrated silica containing calcium, magnesium, and aluminum may be good targets for the Mars 2020 Perseverance rover as potential biosignature-hosting lithologies. If such biosignatures exist, these results will also help us to interpret how organisms may have interacted with the martian environment in the past.