Constraining preservation, chemistry and metabolisms during climate extremes at the dawn of complex life

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Project Objective:

Our investigation of fossil assemblages and of the products of modern fossilization experiments provide insight into the processes that preserve organic matter, mineral-organic and microbe-mineral interactions, and the fossilization potential of microbial systems on Earth during intervals of extreme climatic perturbations. This work provides a framework for targeted search and interpretations of biosignatures in clay- or silica-rich environments on Mars.

FY18/19 Results:

The results of this work provide important insights into preservation of organic matter today and in the past. The chemical maps obtained using the nanoSIMS show the spatial distribution of mineral and organic components of fossilized microbial mats and eukaryotes. Isotopic analyses of Cryogenian fossils demonstrated that the nanoSIMS does not have the precision and accuracy necessary to analyze microfossil samples with relatively small organic domains embedded in clay minerals due to surface irregularity, low carbon counts, and potential clay matrix effects. These results are important, as they inform how future work on similar fossils and preservation modes should be carried out. Additionally, chemical maps produced through this work are informative because they demonstrate: 1) the presence of organic matter preserved in both clay rich eukaryotic microfossils and microbial lamination preserved in carbonate rocks, and 2) the association between organic matter and aluminosilicate clays in microfossils and in microbial lamination. These results point to a potentially important role of aluminosilicate clays in the preservation of organic matter in carbonate depositing environments.

In addition to the analysis of Cryogenian microfossils and microbial lamination, our results from fossilization experiments reveal potential biochemical-mineral interactions that inform our understanding of fossilization processes. Results showed an association between sulfur and silica in fossilized mats and revealed that microbial mats containing less sulfur do not become silicified to the same extent as those that do. This points to a role of sulfur in preservation of organic matter and cells by silica, and provides insight into ancient fossil assemblages and the specific

Significance of Results:

The results of this project inform future work on both Earth and Mars regarding the location and analysis of biosignatures. The close association between aluminosilicate clays or silica and organic matter demonstrated by chemical maps of both fossils and modern organisms indicates that these minerals are likely to preserve biosignatures in ancient rock formations. Additionally, the mode of preservation of ancient and modern organisms provides insight into the ecological interactions and chemical conditions necessary for fossilization. This in turn informs how we interpret ancient biosignatures and what they can tell us about ancient ecology, biochemistry and environments. These results are therefore informative in creating a foundation and framework as we target and interpret biosgnatures from early Earth and from Mars.

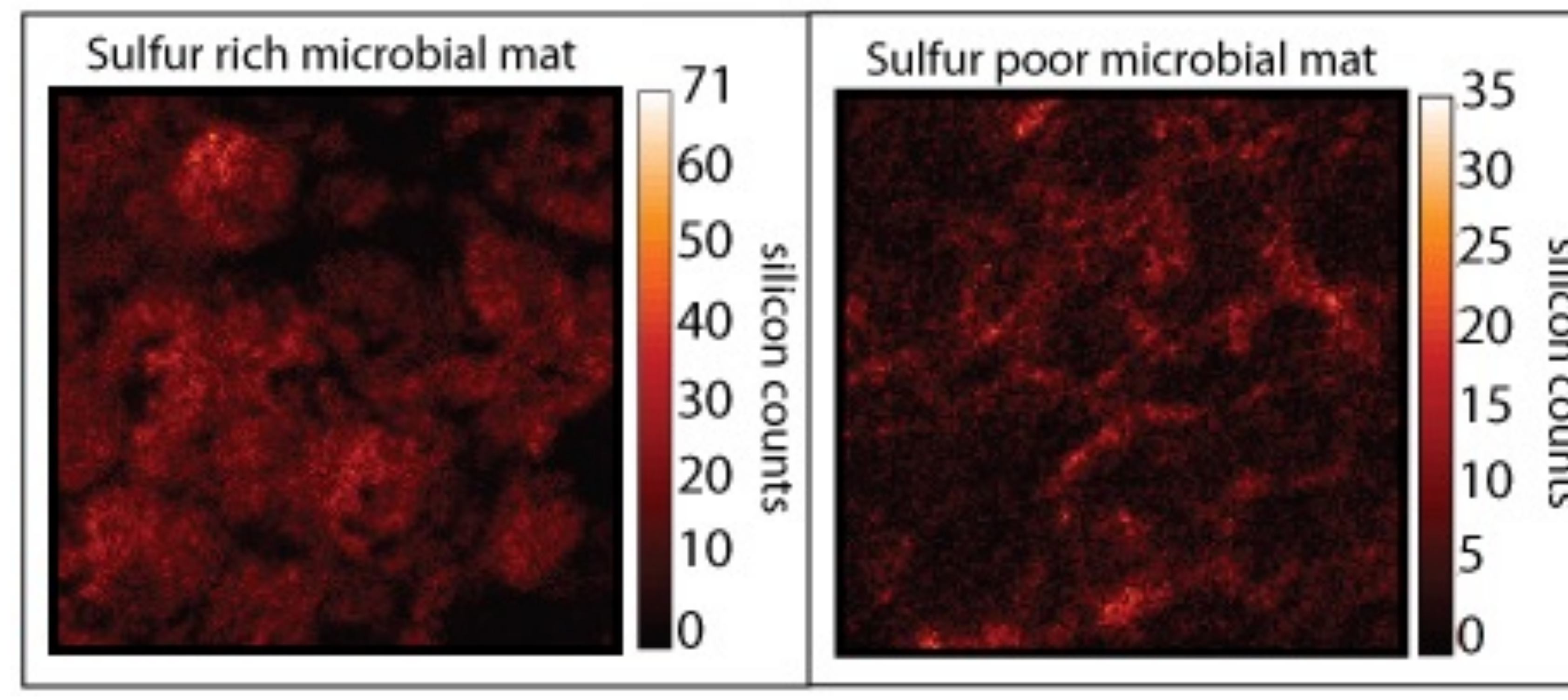

Figure 1:
NanoSIMS maps showing silicon distribution in microbial mats silicified through taphonomy experiments. Maps show that sulfur rich mats accumulate more silica than sulfur poor mats.

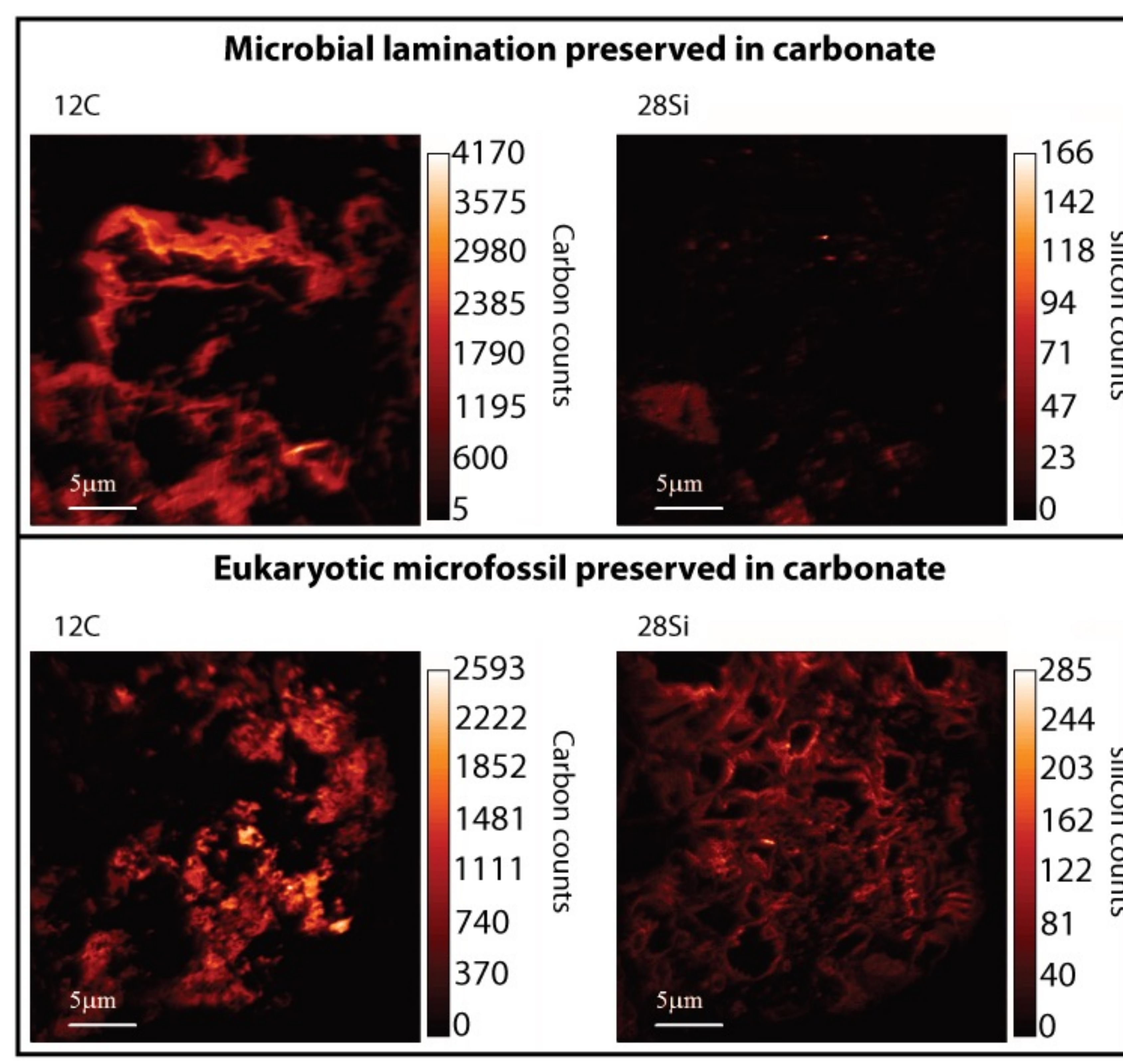

Figure 1:
NanoSIMS maps showing organic carbon distribution in clay rich microbial lamination (top) and in aluminosilicate-walled eukaryotic microfossils (bottom) preserved in cap carbonate.

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