NASA Early Career Collaboration Award Report

A Novel Role for Iron Redox Cycling in the Lithification of Microbial Mats and Biogenicity Within the Rock Record

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Research Overview

Stromatolites constitute the most abundant record of life during the first 7/8^{ths} of Earth's history and provide geobiological insights throughout geological time such as evolutionary changes in preserved microbial life and environmental changes such as salinity; however, questions remain regarding their formation. By better understanding the processes that influence stromatolite formation and lithification, we may better understand the geomicrobiology of ancient environments providing useful insight into geochemical and evolutionary conditions throughout Earth's history that may be extrapolated to other worlds. For this work, I proposed to identify mechanisms of biomat community lithification and determine the biotic and geochemical processes necessary for stromatolite formation. I used a combination of field and laboratory work to determine how coupled photosynthesis and iron cycling metabolisms contribute to lithification and the formation of a persistent biomarker. The overarching goal of my research project is to advance understanding of microbially induced lithification in an actively growing modern analogue stromatolite that may reveal novel information regarding life on early Earth and extraterrestrial biosignatures.

Receiving the NASA Early Career Collaboration Award allowed me to tackle this research project by supporting a field campaign to collect samples and to visit and collaborate with Dr. Frank Corsetti at the University of Southern California. In January 2022, I visited Dr. Corsetti in Los Angeles to learn the intricacies of petrographic analysis, microX-ray fluorescence spectrometry, and dispersive Ramon microscopy. The goal of this work was to provide a direct link between spatially collected molecular and geochemical data to elemental and mineralogical data from stromatolites. In addition to my collaboration at USC, I was able to perform a winter field campaign in Yellowstone National Park to perform field-based experiments and collect samples for molecular biology, geochemistry, and geological interrogation. Field sampling provided pivotal information regarding real-time lamination formation, the environmental and biological factors influencing lamination rate, and resolved the seasonal effects on lamination formation. The results from studying the modern stromatolite analogues in Yellowstone National Park may be employed to provide relevant information regarding ancient structures, their distribution, formation, and the environmental conditions during formation.

Collaboration at USC

While working with Dr. Corsetti I was trained how to effectively use a Zeiss Petrographic Axioskop Microscope to construction high resolution photomosaics. The mosaics allow for the detailed inspection of thin sections to determine the two-dimensional orientation and spatial distribution of microbial cells in the biomats that have been lithified. Additionally, while in LA, I worked with Dr. Aaron Celestian, the curator of mineral sciences at the Natural History Museum of Los Angeles. Dr. Celestin taught me the intricacies of two analysis techniques: microX-ray fluorescence spectrometry and dispersive Ramon microscopy. The microXRF analyzer (Horiba XGT-7200) was used for single point, multipoint, and hyperspectral elemental mapping with a specific emphasis on iron, silicon, calcium, and magnesium geospatially. This instrument provided 50 µm spatial resolution resulting in high quality elemental maps and was nondestructive. A Horiba ExploRa+ dispersive Raman microscope was used in conjunction with the same thin sections to measure mineralogical content within the stromatolite sections resulting in the construction of geospatial mineralogical maps with approximately 2 µm resolution. During my collaborations, I learned the entire imaging pipeline; from sample collection and preparation to processing and analysis of results. The resultant analysis provides a direct link between spatially collected molecular and geochemical data to elemental and mineralogical data. In the near future we will begin drafting the results from this work for a publication.

Figure 1. NECCA recipient Kalen Rasmussen at the Natural History Museum of Los Angeles with the microX-Ray fluorescence spectrometer used for a large portion of the analyses conducted during his time in LA.

Yellowstone Field Work

Previous research on the Yellowstone National Park stromatolites indicated that the stromatolites lithify at a faster rate in the winter months. Thus, it was paramount to sample once in the summer and once in the winter. Detailed sampling at the two seasonal growth extremes provides pivotal information regarding lamination formation, the environmental and biological factors influencing lithification, and resolve the seasonal effects on stromatolite formation. The NASA Early Career Collaboration Award supported a winter field campaign to help complete the breadth of samples for this project. In February of 2022, the winter field work was conducted. As part of the field work, hot spring water samples were collected for geochemical analysis and biomass from actively growing and lithifying stromatolites was sampled and preserved for molecular biology analysis. Braving -26°F ambient air temperatures and wind chills of approximately -60°F, we successfully conducted an *in situ* incubation experiment to assess the changes in geochemistry and biological activity under light and dark conditions. Lastly, a cross section of a stromatolite was collected and preserved for thin section analysis to determine the microbial structure of the stromatolites and geological characteristics. These samples will be processed and analyzed and become a pivotal component in a publication.

Figure 2. NECCA Award recipient Kalen Rasmussen bundled up in many layers at the West entrance to Yellowstone National Park at the end of the successful winter field work.

Acknowledgements

Receiving a NASA Early Career Collaboration Award has opened the doors for invaluable opportunities, research, and collaboration that would not have been possible without the awards support. I am incredibly grateful for the amazing learning and scientific experiences provided to me by the NASA Astrobiology Program as part of this award. A huge thank you to Dr. Melissa Kirven-Brooks at the NASA Astrobiology Institute for working with me throughout the award process, her help and guidance has been invaluable. Lastly, I would like to thank Annie Carlson at the Yellowstone Center for Resources for working with us to obtain our Winter 2022 research permit for Yellowstone National Park. All samples were collected under Permit #YELL-05664.