PRF# 57417-DNI2

Project Title: The role of sulfate reduction in microbial carbonate formation across a restricted lagoonal carbonate facies: A modern analog investigation

PI: Jessica Conroy

Research Goals

This project aims to identify microbial drivers of carbonate precipitation using molecular DNA techniques, biomarkers, petrographic, and geochemical methods. The geographical locus for this research question are the brackish to hypersaline microbial mats and carbonate lake sediments of Kiritimati, Republic of Kiribati (2°N, 157°W). This research is useful in the context of petroleum research given the importance of 'microbialite' carbonate reservoirs in recent oil discoveries, but the limited understanding of how these reservoirs formed.

Research Activities

In this first year I leveraged previous samples and preliminary data to assess the relationship between carbonate mineralogy, water chemistry, and bacterial and archaeal communities across a suite of brackish to hypersaline, carbonate precipitating lakes on Kiritimati

We have also assessed the age (via radiocarbon measurements), mineralogy, carbonate morphology, microbial communities, and stable isotopes of carbonate and organic matter in a 2000 year-long core from 'Lake 1,' a hypersaline lake on Kiritimati.

Main findings

- distinct communities of bacteria and archaea vary with carbonate and evaporite mineralogy across brackish to hypersaline lakes (Schmitt et al, in review)
- The existence of 1-2mm diameter aragonite spherules and spherule aggregrates in the Lake 1 core (Figure 1).
- The $\delta^{13}C$ value of the spherules correlates with bulk organic matter $\delta^{15}N$ and the $\delta^{18}O$ of the spherules correlates with bulk organic $\delta^{13}C$ (Figure 2), suggesting specific biotic controls on the formation of this carbonate morphology.
- A buried mat does not have the same microbial community structure as a modern mat in the same lake.
- Overall there is a strong relationship between microbial communities, carbonate spherules, carbonate $\delta^{18}O$, and organic matter $\delta^{15}N$ values, suggesting N-cycle influences on carbonate precipitation should be further investigated.

Future work

In the next year, we will conduct a metagenomic analysis of the Lake 1 sedimentary DNA.
We will also explore extracting DNA from super-cleaned spherules in order to investigate what microbes drive the precipitation of this distinct carbonate morphology.
Our planned field expedition to Kiritimati will occur in January 2019, when we will collect both additional cores and surface samples from a suite of lakes for paired biomarker-microbial DNA analysis as well as additional geochemical, petrographic, and mineralogic analysis. Key in the next year is coupling the DNA and biomarker results with additional geochemical measurements.

Education/Training

I successfully recruited PhD student Mingfei Chen to work on this funded project, beginning in August, 2017. Mingfei was a top candidate to our graduate program and his tuition and stipend have been funded under this grant. He has quickly learned a suite of new molecular and geochemical techniques, and has gained expertise in geobiology and geochemistry through his training at UIUC and as a selected participant at the International Geobiology Course. He will present his results at the Fall 2018 AGU meeting.

Changes in research trajectory

A key lesson learned in this first year is that a singular focus on sulfate reduction as a driving factor of carbonate precipitation is too limiting (also mentioned in the reviewer excerpts). Second, the methodological techniques in this field are changing so quickly that the 16S amplicon sequencing proposed is being supplanted with metagenomic analyses. Hence, we are broadening our investigation of microbial controls on carbonate precipitation with more encompassing metagenomic analysis, which will not only provide insight into what microbes are present in the sediments, but also what metabolic functions are represented and may be driving carbonate precipitation. This will enable us to better answer our proposed research questions.

Publication

Schmitt, S., Conroy, J.L. (corresponding author), Flynn, T.M., Sanford, R. Higley, M.C., and Fouke, B.W. Salinity, microbe, and carbonate mineral relationships in brackish to hypersaline lake sediments: a case study from the tropical Pacific coral atoll of Kiritimati. *The Depositional Record*, in review

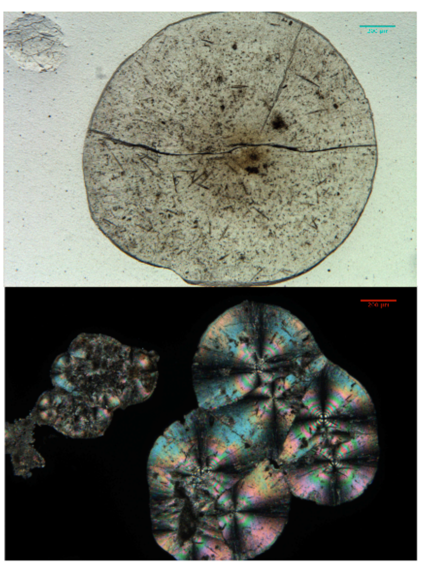

Figure 1: Light microscopy and polarized microscopy images of a representative carbonate spherule and spherules aggregates.

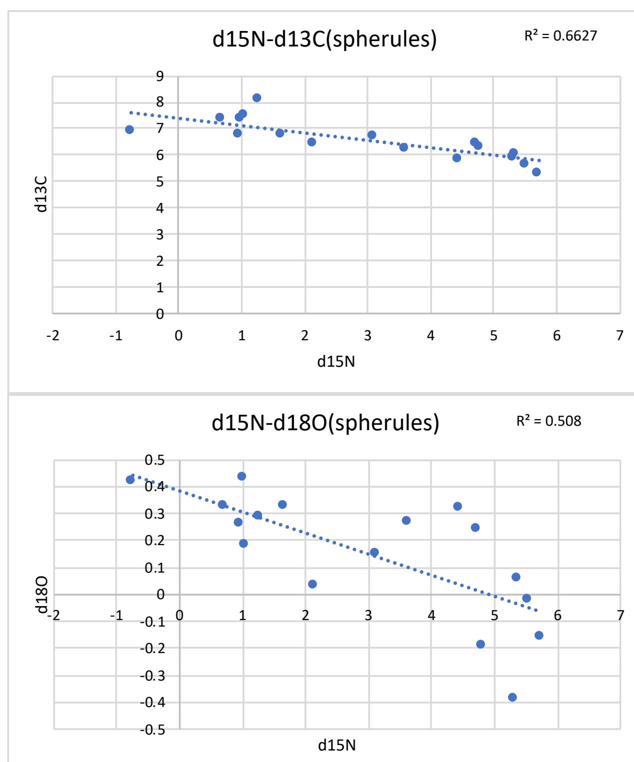

Figure 2: Top: scatterplot of bulk organic $\delta^{15}N$ (‰ AIR) and spherule $\delta^{13}C$ (‰ VPDB), Bottom: scatterplot of bulk organic $\delta^{15}N$ (‰ AIR) and spherule $\delta^{18}O$ (‰ VPDB).