Molly PATTERSON
Lewis and Clark Fund for Exploration and Field Research in Astrobiology

Project Report

Thrombolite Fabric Development in Hardwater, Marine, and Hypersaline Environments

Thrombolites are non-laminated, clotted microbialites that can form by the lithification of microbial communities through the trapping and binding of sediments and mineral precipitation. This precipitation is highly controlled by both extrinsic (environmental) and intrinsic (microbial) factors. These factors combined dictate the carbonate saturation index and ultimately the precipitation of carbonate minerals within the thrombolites. Thrombolitic structures appear in the rock record ca. 1.9 Gya and currently are found around the world in various climates and conditions including the Bahamas, northern New York, and Western Australia.

In this study I used geochemical and physical data to characterize extant thrombolite-forming environments, analyzed thrombolitic structure, and studied the processes of microbe-mineral interactions that lead to the formation of a microbialite. In this report I focus on the results of my research accomplished under this grant. However, it should be noted that ion chromatography work, alkalinity, and other physicochemical measurements were also completed under this grant.

Although for this project we initially hoped to compare three extant thrombolite-forming communities, financial and time constraints did not allow for us to travel to Lake Clifton, Australia. We were, however, able to make essential trips to Green Lake, NY in December 2014 and Highborne Cay, Bahamas in February 2015.

Prior to this work we had made five trips to Green Lake (43.0519, -75.9646) during October 2012, May 2013, September 2013, November 2013, and May 2014. Green Lake is unique in that it experiences seasonal variation in water depth, temperature, and alkalinity. The water in Green Lake is enriched with respect to calcium and sulfate compared to other lacustrine environments, and as a result, has saturation indices that favor carbonate precipitation throughout the year. This precipitation plays a role in microbialite formation (Figure 1).

From the spring (after ice melt) through the fall, thrombolite samples from Green Lake show the development of a microbial mat at the surface of a clotted, lithified, carbonate structure. This resulting microbial mat is often < 2 cm thick and is composed of vertically-oriented filamentous cyanobacteria and trapped and bound carbonate sediment (Thompson et al., 1990; Myshrall, 2012). Our research found that the thickness of the mat varies seasonally with the thinnest mat present following the spring ice melt, continuing to grow throughout the summer, and resulting in a thicker mat existing in the fall.

During the winter, ice covers the surface of the microbialite platform at Green Lake, killing, or slowing the growth of the microbes. Throughout this time, an unknown reworking of the surface mat occurs. On our trip to Green Lake in December 2014, we hoped to observe the state of the microbial mat under ice cover. However, an absence of ice allowed us to observe through thin section and scanning electron microscopy a very dense microbial community with a micritic crust at the surface (Fig. 2).

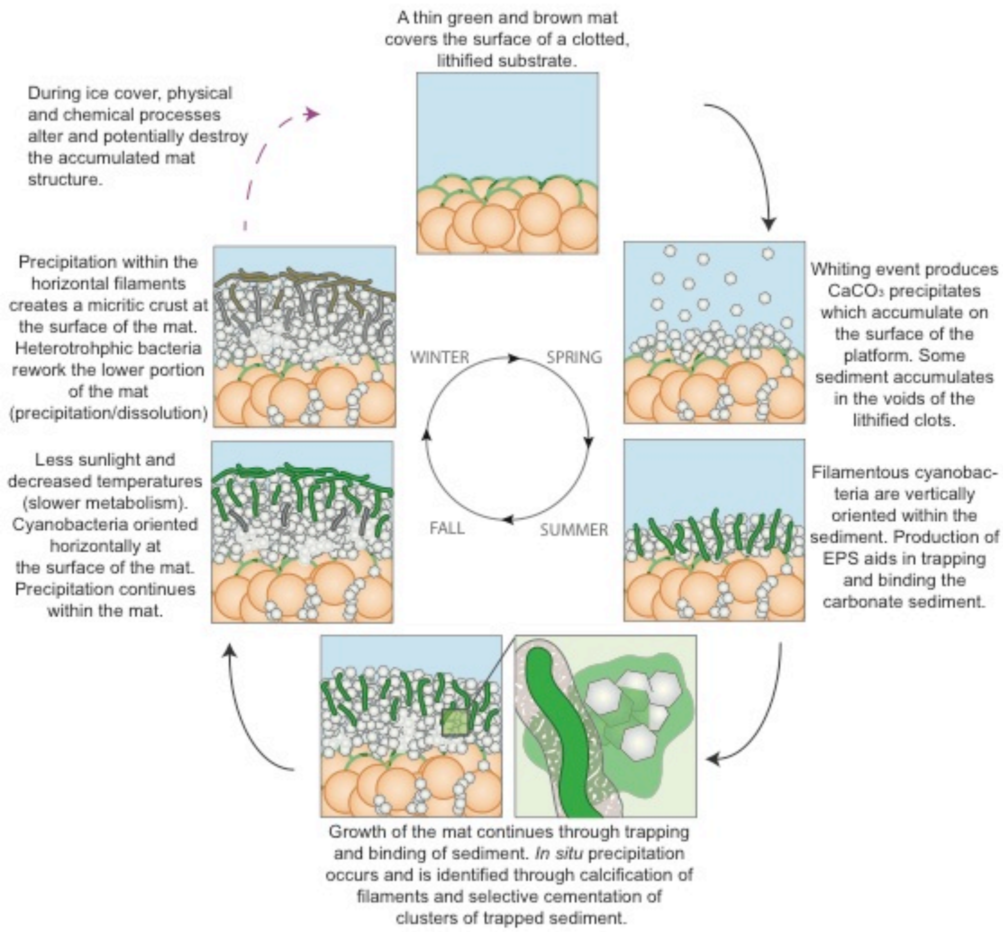

Figure 1. An ecological model of thrombolite formation in Green Lake. During the spring, whiting events provide to help (along with precipitation) build the mat throughout the growing season (spring to fall). Changes in temperature and light supply impact the lithification potential in the mat, influencing the preservation of the fabric.

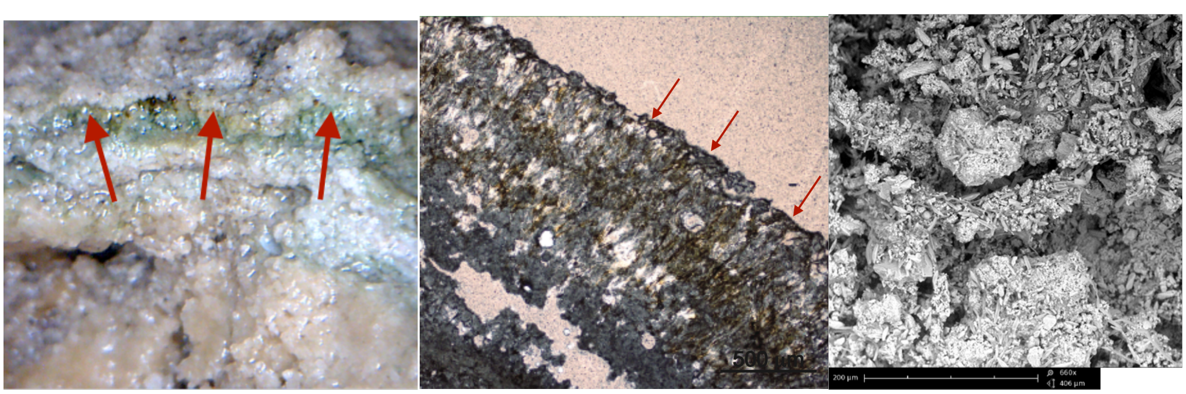

Figure 2. Hand sample, thin section, and scanning electron microscope images showing the formation of a micrite crust at the surface of the microbial mat at Green Lake prior to ice cover.

Our trip to Highborne Cay (24.720, -76.818) allowed us to observe any “seasonal” differences between February 2015 and our previous trips in October 2013 and November 2012. Our prior trips were made following the end of hurricane season in the Bahamas, when we would expect an increase in microbialite platform burial, exhumation, alteration, and potential destruction. This trip allowed us to observe a period of low sediment supply, meaning a period of precipitation, cementation, and preservation of the microbialite structure, which was observed through microscopic analysis.

The thrombolites in Highborne Cay, Bahamas are found in an intertidal environment that has the potential for ooid sand burial during storm events and is also influenced by exposure during daily tidal cycles. Although physicochemical data does not vary seasonally at this location like it does in Green Lake, the variation in sediment burial and exposure during tidal and storm periods play an important role in the formation and preservation of the microbial mat (Figure 3).

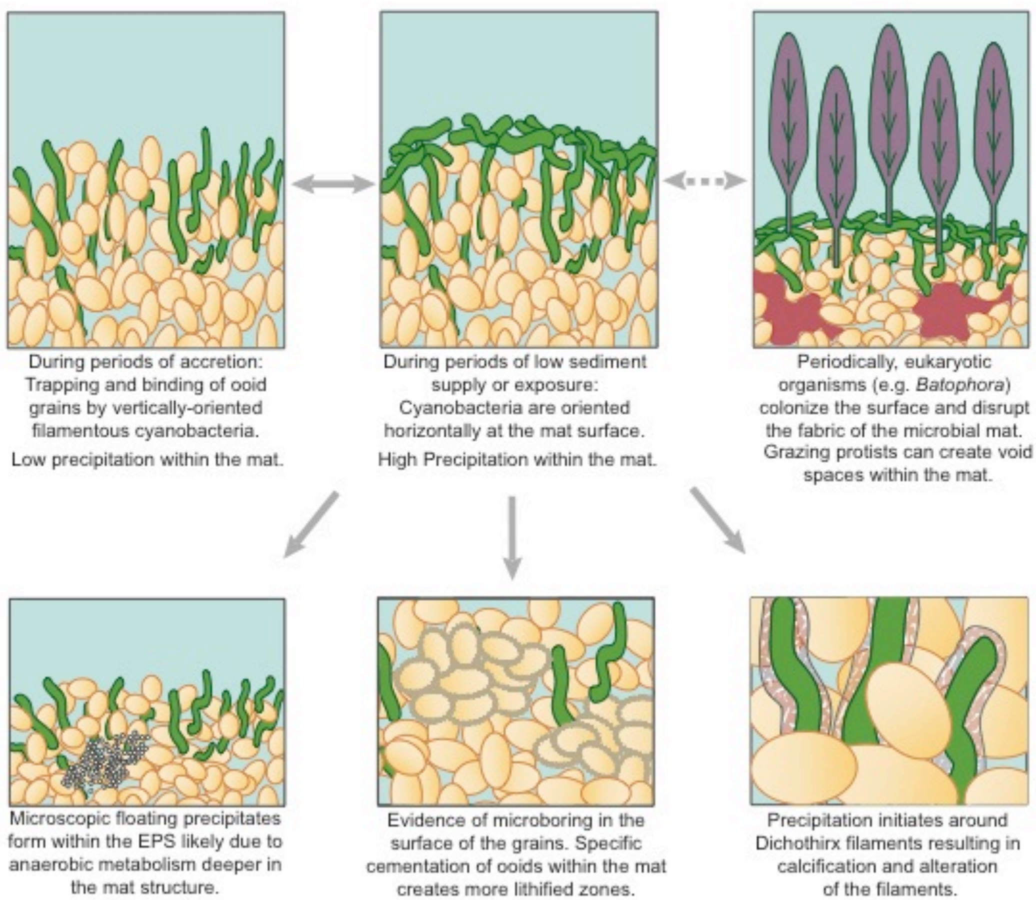

Figure 3. An ecological model of thrombolite formation in Highborne Cay. Changes in sediment supply impact mat accretion, degree of mineral precipitation and location of that precipitation, as well as eukaryotic colonization. Changes in sediment supply and exposure can impact the lithification potential in the mat, ultimately influencing the creation and preservation of the thrombolitic fabric.

The research completed under the Lewis and Clark Fund for Exploration and Field Research in Astrobiology was integral to the continuation of my research. Through to travel to these locations we were able to confront unanswered questions regarding seasonal (chemical and physical) impacts on microbial mat growth. By following up our observations in the field with chemical (ion chromatography, alkalinity) and microscopic (thin section, scanning electron microscopy) analyses, we are able to further understand how thrombolites are forming in different environments around the world.