Stromatolitic Knobs in Storrs Lake, San Salvador, Bahamas: Insights into Organomineralization

Alexandré Fowler* and Christophe Dupraz

Center for Integrative Geosciences,
University of Connecticut, Storrs, CT 06268
christophe.dupraz@uconn.edu

Abstract

Storrs Lake, a hypersaline lake on the east coast of San Salvador Island, Bahamas, contains well-developed microbial mats, some of which have developed calcified structures called microbialites. Many of these microbialites are laminated, and therefore classified as stromatolites. This study focuses on small stromatolitic knobs located in the southern portion of Storrs lake, which are still actively forming, to gain insights into the early stages of stromatolite formation. These knobs appear to be forming as the result of *in situ* micritic precipitation mediated by both photosynthetic and heterotrophic microbial metabolisms. By comparing these small stromatolitic knobs to larger stromatolitic heads in deeper portions of the same lake, as well as other modern closed-system and open-marine stromatolites, a mechanism for organomineralization and laminae formation can begin to be determined. The mechanism for *in situ* precipitation is relatively comparable in each of these systems, though the mechanism of laminae formation varies from microbial to more extrinsic controls. This project can be used to inform future studies of fine-grained stromatolites in the fossil record, providing crucial knowledge about the history of Earth's carbon cycle.

Acknowledgements

- Christophe Dupraz
- Pieter Visscher
- Andrew Bush
- Marie Cantino
- David Griffing
- Lisa Park
- The Gerace Research Center
- Donors of the American Chemical Society Petroleum Research Fund (Grant 635169)

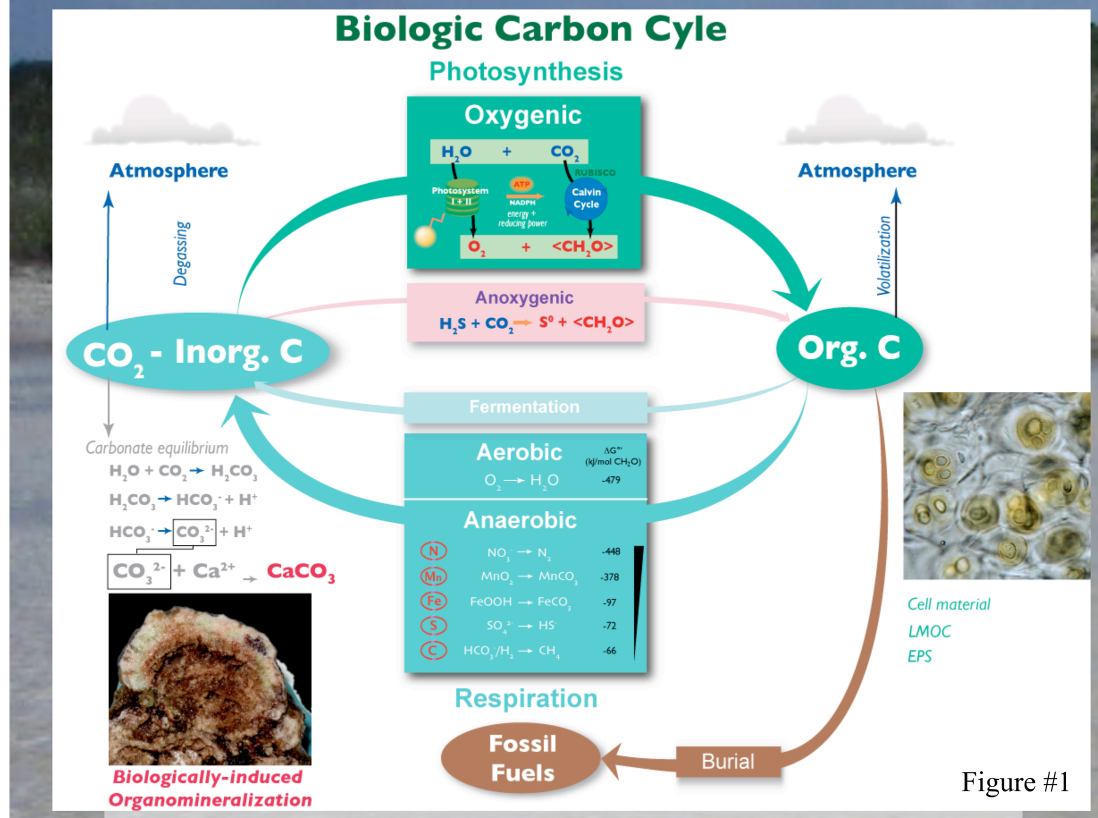
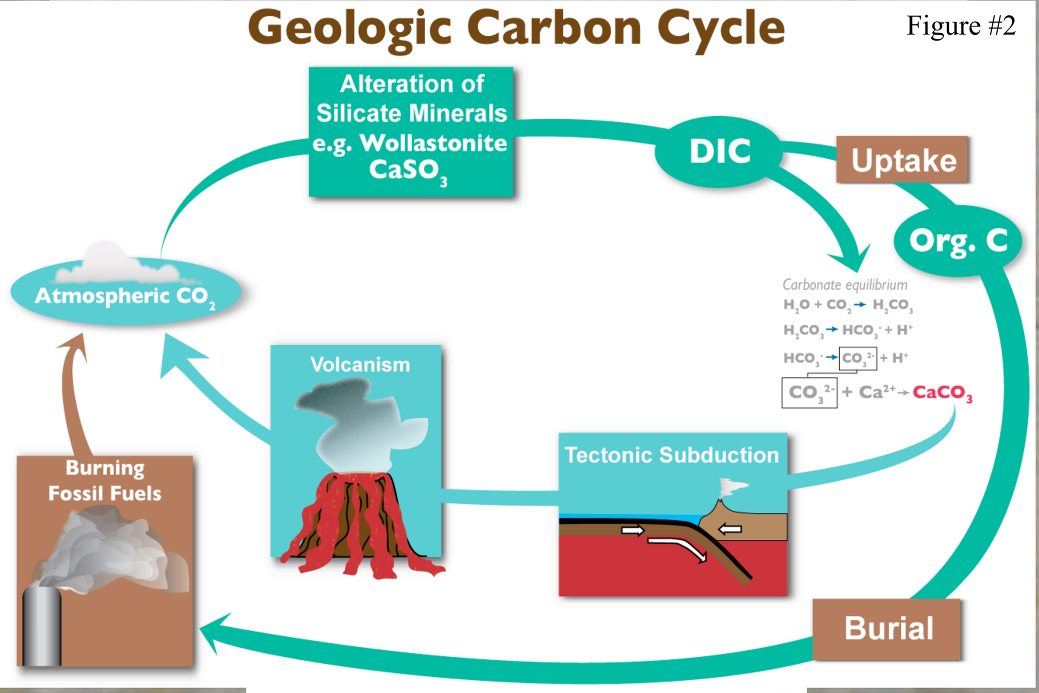


Figure #1: Biologic Carbon Cycle and Figure #2: Geologic Carbon Cycle



$$CaCO_3 + H_2O + CO_2 \longrightarrow 2HCO_3^- + Ca^{2+}$$

Carbonic Acid (H_2CO_3)

Carbonate Buffering Equation (Stumm & Morgan, 1996)

Biomineralization vs. Organomineralization

The role of organisms in driving calcium carbonate precipitation is fundamental to this study. Organisms influence calcium carbonate precipitation via two major mechanisms: biomineralization and organomineralization. Biomineralization is induced calcium carbonate precipitation, where the morphology of the mineral is genetically controlled by organisms such as found in coral or clams. Organomineralization, on the other hand, is not genetically controlled. Organomineralization is calcium carbonate precipitation that is influenced by microbial metabolisms, but the morphology of the mineral is mainly controlled by environmental conditions (Dupraz et al., 2009). One microbial community can produce an infinite number of morphologies depending on the conditions, and the same community can produce different morphologies as conditions change.

Microbialites

When microbial communities drive organomineralization to form calcium carbonate structures, the structure is known as a *microbialite* (Burne & Moore, 1987). A *microbialite*, as defined by Burne & Moore (1987), is an "organosedimentary deposit formed from interaction between benthic microbial communities and detrital or chemical sediments (in calcareous microbialites, processes include trapping and binding, inorganic calcification (tufa), and biologically influenced calcification)."

History & Definition of Fossil & Modern Stromatolites

Stromatolites are thought to be the oldest macroscopic traces of life in the fossil record. Kalkowsky (1908) defined *stromatolith* as "layered stone," created by "simply organized plant-like organisms," today known as microbes. This definition is controversial, because it is difficult to prove the biogenicity of fossil stromatolites, since the microbial fossils are generally not preserved. For this reason, some authors use a purely descriptive definition (Semikhatov et al., 1979). Fossil stromatolites show high morphological variability, but are mostly micritic. Ancient stromatolites dominated early Earth's carbon cycle. Modern stromatolites have a very minor influence on today's global carbon cycle, but can be used as an analog for studying fossil stromatolites. Modern stromatolites are always defined as biogenic, and can be found in locations such as Shark Bay, Australia, Highborne Cay in the Exuma Islands of the Bahamas, and Storrs Lake on San Salvador Island, Bahamas.

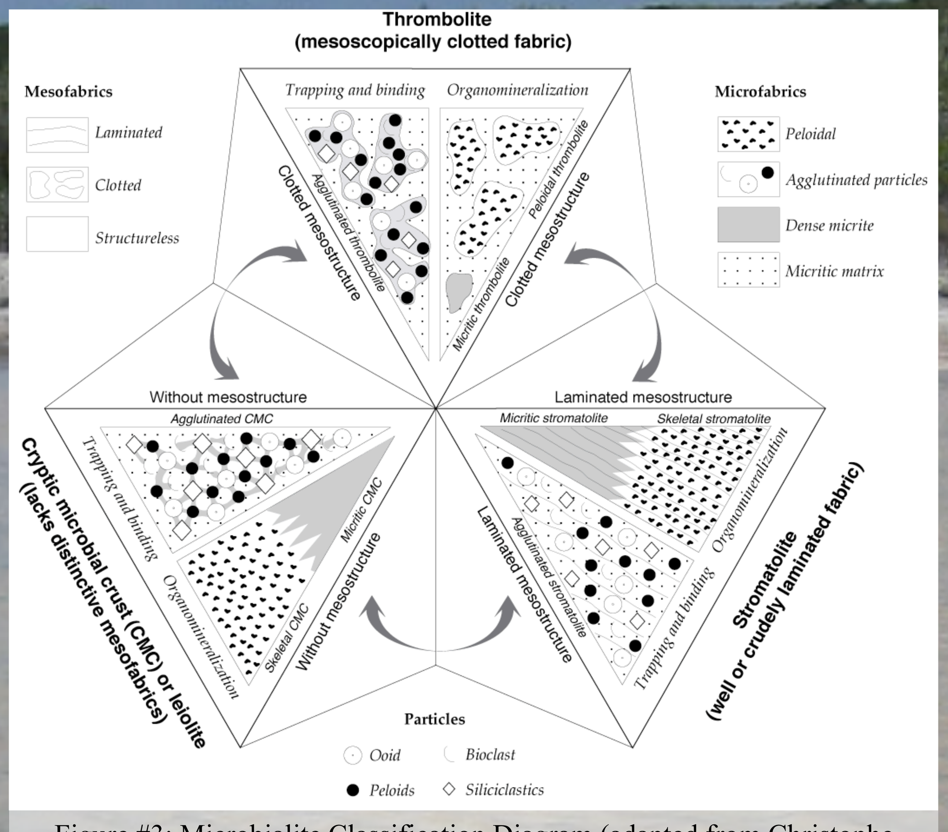


Figure #3: Microbialite Classification Diagram (adapted from Christophe Dupraz, based on Kennard & James, 1986 and own observations)

Highborne Cay

The mechanism for the formation of Highborne Cay stromatolites is relatively well understood. They are the only known truly open marine stromatolites. The high sedimentation rate results in coarse-grained microbialites, created by a combination of trapping and binding of coarse grains, *in situ* precipitation of micrite in biofilm layers, and grains that are degraded and fused together by coccoidal cyanobacteria. (Figure #4)

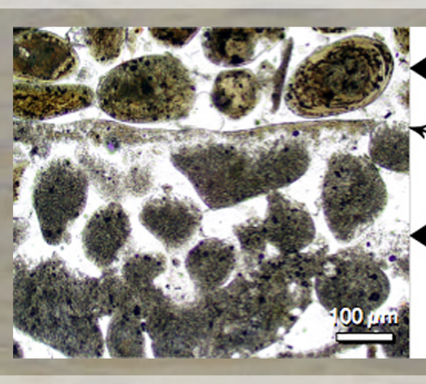


Figure #4: Highborne Cay Stromatolites

Goals of this Study

In order to develop a better understanding of the formation of ancient fossil stromatolites, which are primarily fine-grained and micritic, it makes sense to study modern fine-grained, micritic stromatolites, unlike the coarse-grained stromatolites of Highborne Cay. The first step is to compare recent coarse- and fine-grained stromatolites to determine if similarities in the mechanisms responsible for organomineralization exist between the two types, followed by a determination of what creates the laminated structure characteristic of stromatolites. If similarities do exist, a model for stromatolite formation can then be formulated, and potentially used to test fine-grained fossil stromatolites, despite differences in microbial communities between modern and ancient forms.

Storrs Lake, a hypersaline lake located on San Salvador Island, Bahamas, contains modern, fine-grained stromatolites, first described by Hattin in 1982. Although a significant amount of data has been collected on these stromatolites, particularly in the northern portion of the lake, the mechanisms of calcium carbonate precipitation and laminae formation are not well understood.

In addition to the existence of large, 'sub-fossil' stromatolites, Storrs Lake also contains smaller, younger, fine-grained stromatolitic knobs (Dupraz et al., 2006), which are the main focus of this project. The goals of this study include thoroughly describing the small stromatolitic knobs, determining the mechanisms for organomineralization and laminae formation in these knobs, and comparing Storrs Lake stromatolites with other closed-system and open marine stromatolites in order to create a model of stromatolite formation that may inform future studies of fossil stromatolites.

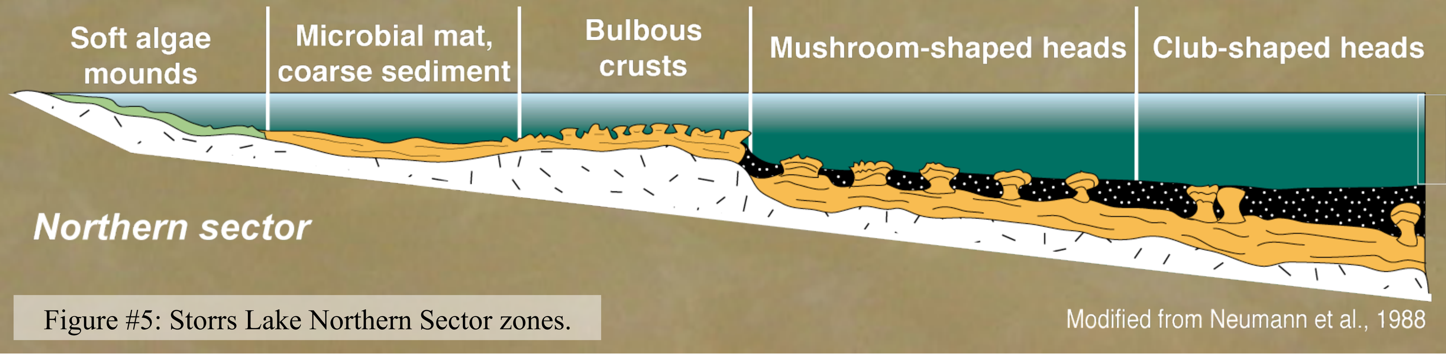


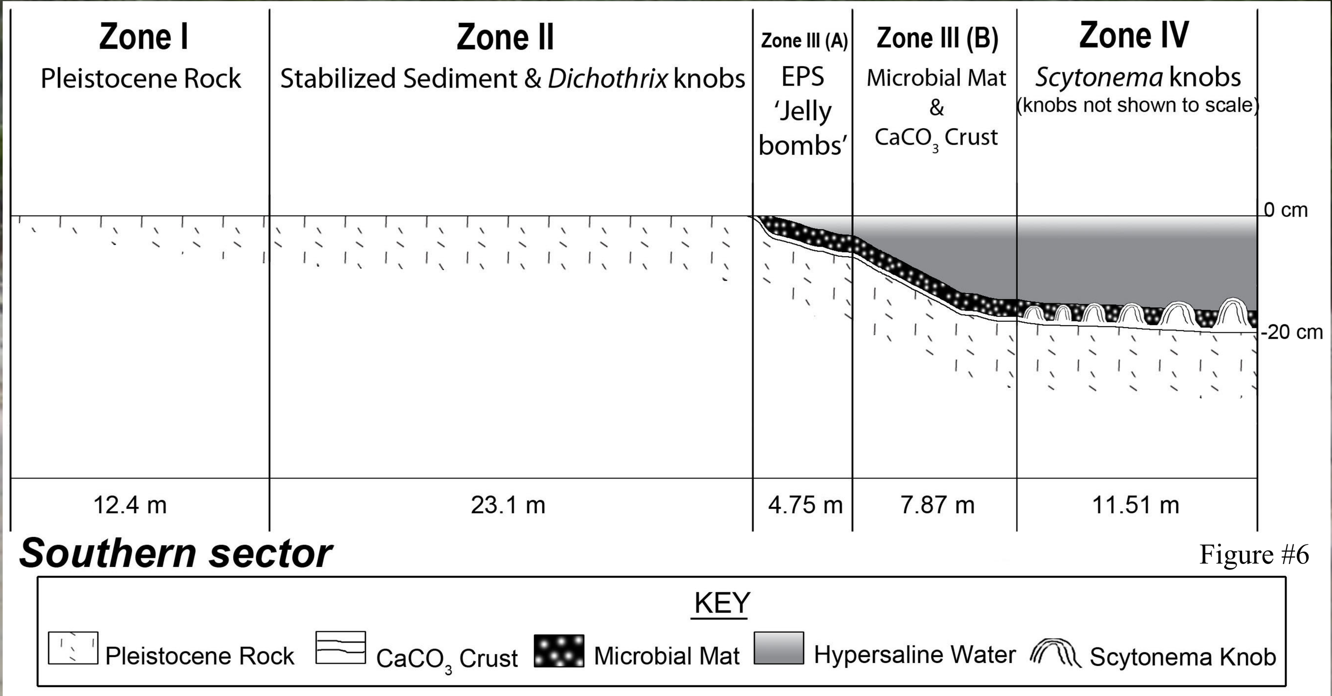
Figure #5: Storrs Lake Northern Sector zones.

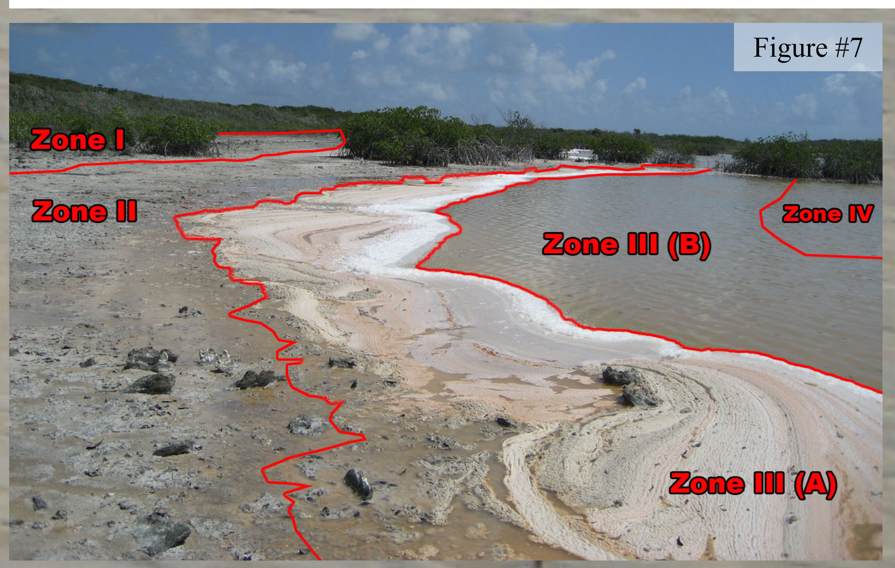
Mapping transects and sampling locations: Storrs Lake Southern Sector, June 2010

Field Observations and Hydrochemistry

June 18-20, 2010:

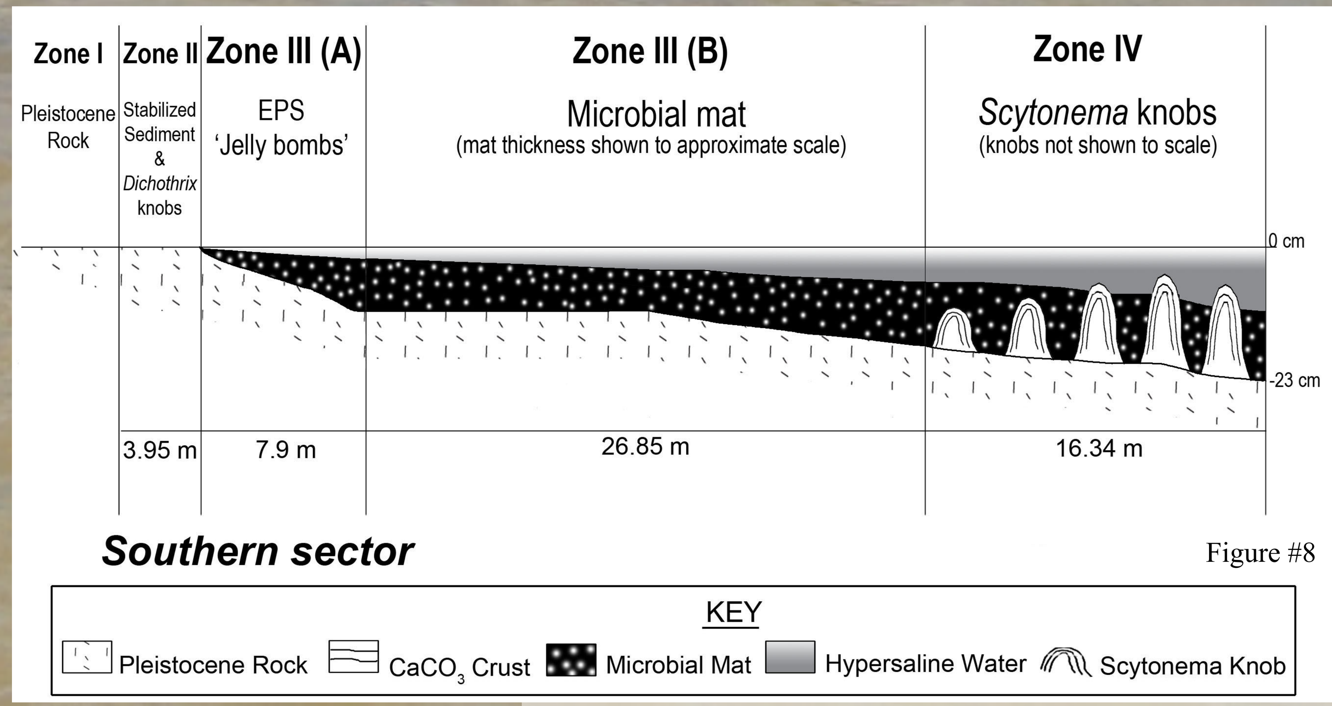
- •Distinct sulfurous smell
- •Water is red-brown and turbid with visibility only 1-2 cm depth
- •Water thick and slimy due to suspended extracellular polymeric substances (EPS)
- •Average water temperature ~40°C (sea water ~28°C)
- •Average salinity ~60 psu (sea water ~35 psu)
- •pH of water samples between ~8.1 to ~8.6 (sea water ~8.3)
- •Alkalinity ~803 mg/L HCO_3^- (sea water ~141 mg/L HCO_3^-)
- •Supersaturated with respect to calcite and aragonite

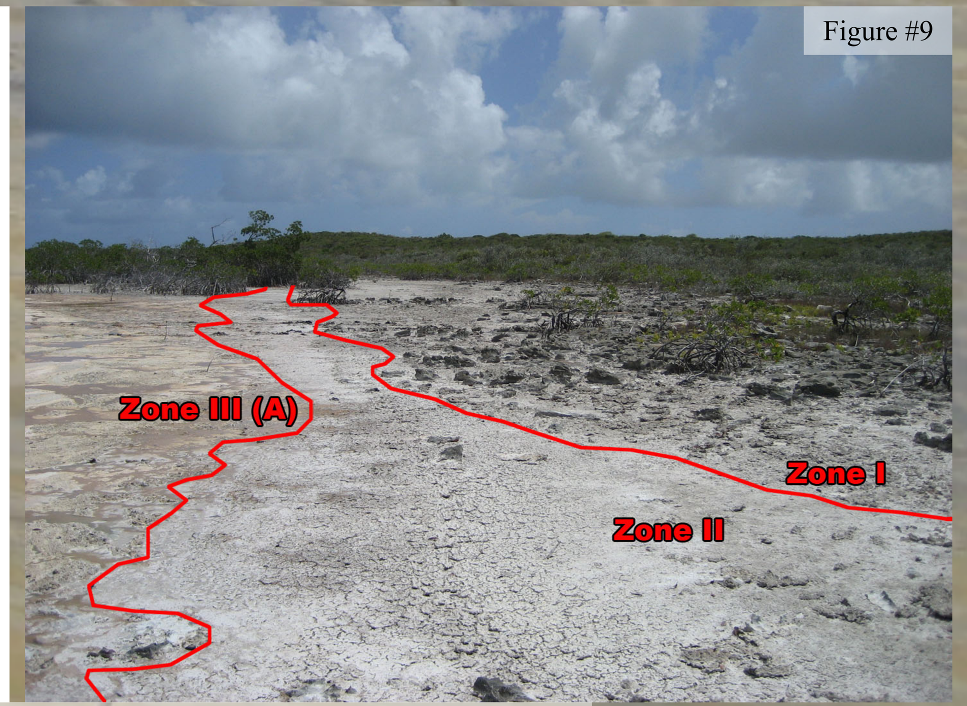




Mapping Transect 1: Storrs Lake Southern Sector: Zones of Microbial and Carbonate Features: Zones Shown to Scale

"Jelly Bomb"





Core Sample: Thick Microbial Mat: Transect 2

Mapping Transect 2: Storrs Lake Southern Sector: Zones of Microbial and Carbonate Features: Zones Shown to Scale

Morphology of Microbialites in Southern Storrs Lake

The morphology of microbialites can be described in detail by their macrostructure, mesostructure, and microstructures (Figure #3). Two main types of microbialites occurred along the two transects in the southern sector of Storrs Lake. These are the small, thrombolitic *Dichothrix* knobs found in the exposed portion along the shoreline of both transect, and the stromatolitic *Scytonema* knobs found fully submerged further lakeward along both transects.

Macrostructure of thrombolitic *Dichothrix* knobs: Transect 1: found on dry sediment

Macrostructure of thrombolitic *Dichothrix* knobs: Transect 2: found on wet sediment

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*Present Address:
320 Burgoyne RD
Saratoga Springs, NY 12866
alexandre.fowler@gmail.com