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Lessons Learned from Modern Marine Stromatolites, Bahamas

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Stromatolites on the margins of Exuma Sound, Bahamas are the only known examples of modern stromatolites forming in open marine conditions similar to those that may have existed on Precambrian platforms. Interdisciplinary studies of Exuma stromatolites by investigators in the Research Initiative on Bahamian Stromatolites (RIBS project) over the past 1.5 decades have investigated distribution, growth history, accretion, microstructure, microbial populations and processes forming these stromatolites (e.g. Reid et al 1995; Macintyre et al. 1996; Visscher et al. 1998; Reid et al. 2000, Andres et al. 2009, Baumgartner et al. 2009; Foster et al. 2009; Bowlin et al. 2011; see www.stromatolites.info for complete list of papers). Results provide insight into long standing questions and controversies regarding stromatolites through time, including origin of lamination, Phanerozoic decline, and textural evolution.

Distribution

Living stromatolites, generally unknown in open marine conditions, are 'uncommonly common' in the Exuma Cays (Reid et al. 1995) (Figure 1). Typically associated with migrating oolitic sands, Exuma stromatolites are located in tidal channels, shallow embayments, fringing reefs, and open ocean.

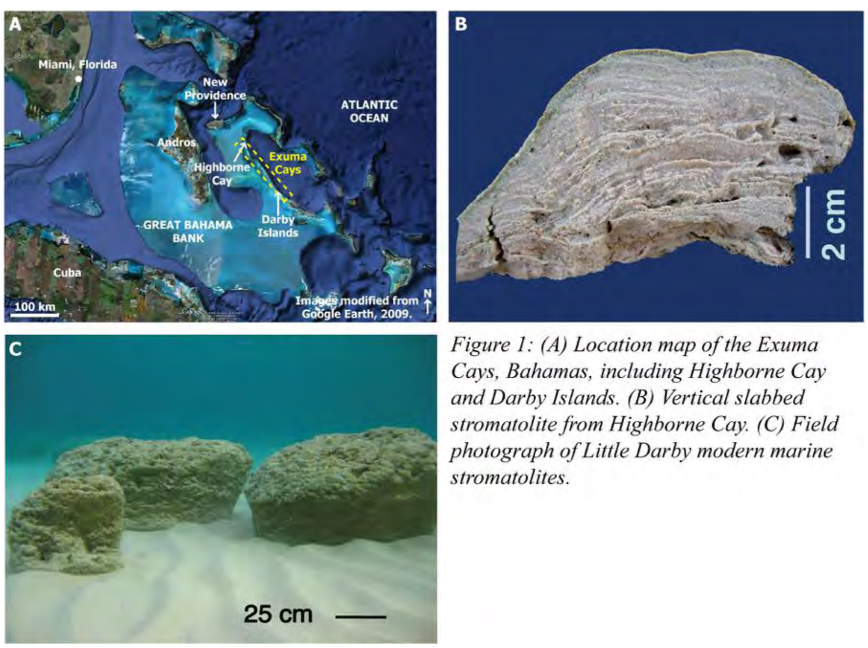

Figure 1: (A) Location map of the Exuma Cays, Bahamas, including Highborne Cay and Darby Islands. (B) Vertical slabbed stromatolite from Highborne Cay. (C) Field photograph of Little Darby modern marine stromatolites.

Lamination

Exuma stromatolites are formed by lithifying microbial mats that form 'living crusts' on the stromatolite surface (Reid et al. 2000). The mats consist of distinctly layered microbial populations, with each layer representing a community that was, at one time, at the stromatolite surface. Three 'mat types' are recognized, each characterized by a distinct community and associated with the accretion of a distinct type of mineral deposit (Figure 2). Cycling of surface communities create laminae with distinct microstructures. Subsurface laminae represent a chronology of former surface mats (Figure 3).

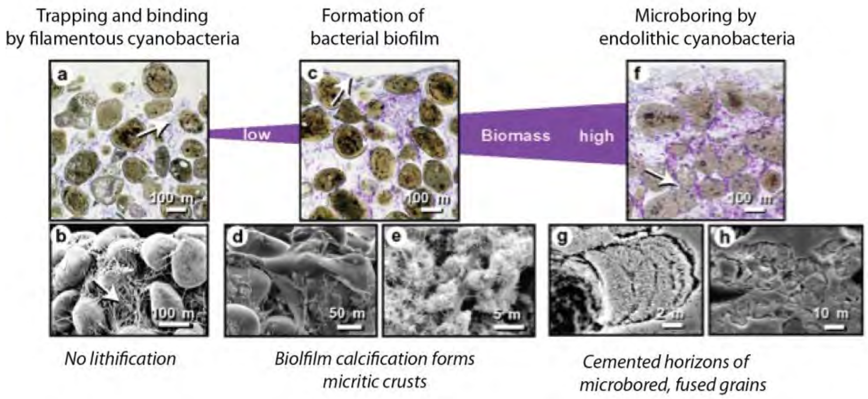

Figure 2: Surface mats on Exuma stromatolites form three distinct microstructures: a,b, Type 1 mats; filamentous cyanobacteria (arrows) bind carbonate sand grains; stalked and tube diatoms can also contribute to grain trapping and binding. c,d,e, Type 2 mats; a continuous sheet of amorphous exopolymer with abundant heterotrophic bacteria drapes the surface (a, arrow; d); aragonite needles precipitate within this film (e). f,g,h, Type 3 mats; a surface biofilm overlies filamentous cyanobacteria and endolith infested grains, which appear gray and are fused (arrow, f). Precipitation in boreholes that cross between grains leads to welding (h). (a,c,f) Petrograhic thin sections, plane polarized light. (b,d,e,g,h) Scanning electron microscope images). Modified from Reid et al. 2003.

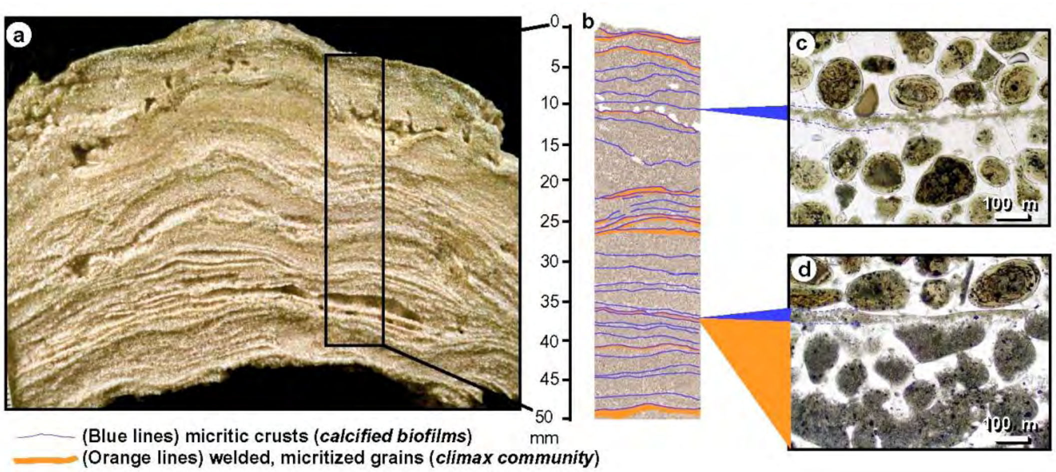

Figure 3: Subsurface distribution of lithified layers in Highborne Cay stromatolites. a, Water-washed vertical section showing lithified laminae, which stand out in relief at 1-2 mm intervals. b, Low magnification thin-section photomicrograph of boxed area in (a) showing the distribution of lithified layers. c, Micritic crust, equivalent to the blue lines in (b). d, Layer of microbored, fused grains, equivalent to the orange lines in (b), underlying a micritic crust. From Reid et al. 2003.

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Environmental Controls on Microbial Community Cycling

An intensive two-year program monitoring microbial mats on the surfaces of modern marine stromatolites at Highborne Cay, Bahamas, documented the effects of environmental factors on community composition and cycling. An integrated model of observed mat transitions (Figure 4) suggests that community cycling and resulting lamination results from both predictable seasonal environmental variation and stochastic events. Results from the long-term monitoring program are an important step in understanding morphogenesis of modern marine stromatolites, with implications for interpreting patterns of stromatolite lamination in the geologic record.

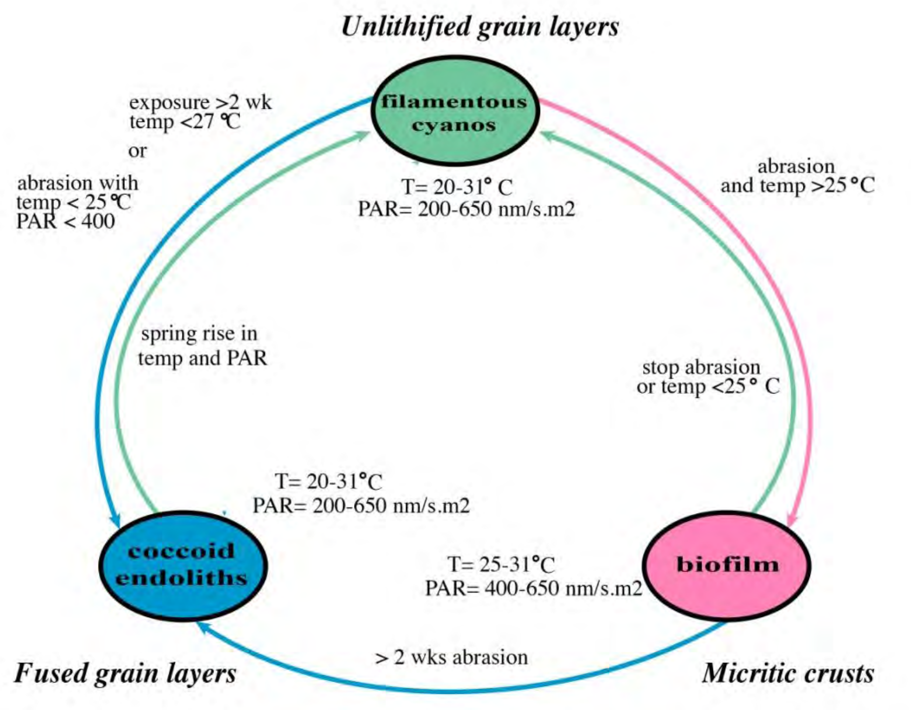

Figure 4: Summary of observed transitions between mat types on the surfaces of modern marine stromatolites and environmental factors responsible for these transitions. Cyanos = filamentous cyanobacteria, mainly Schizothrix; biofilm:mainly heterotropic bacteria; coccoid endoliths, mainly Solentia cyanobacteria; PAR= photosynthetically active radiation; wk: week; T= temperature. Modified from Bowlin et al 2011.

Lessons Learned

Process-oriented studies of modern marine stromatolites in the Exuma Cays provide insight into questions and controversies regarding stromatolites through time. What is the origin of stromatolite lamination? What was the cause of stromatolite decline in late Precambrian? Are modern marine stromatolites useful analogs for ancient stromatolites? Some key findings are as follows:

- Lamination in Exuma stromatolites results from a cycling of microbial surface communities in response to a variety of environmental factors. Microstructures are signatures of microbial processes and record fluctuating environmental conditions. Community cycling in response to environmental conditions may be important in forming laminae in ancient stromatolties.

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- Macroalgae disrupt the continuity of smooth microbial mats on the stromatolite surface and inhibit lamination formation. Eukaryotic competition is at least as important as non-competitive grazing and burrowing by invertebrates (e.g. Garrett 1970) in stromatolite decline.

- Trapping and binding is important in the accretion of modern marine stromatolites, but syndepositional lithification involving microbial precipitation is critical for the build-up of these structures. Filamentous cyanobacteria are the primary microbes responsible for trapping and binding; addition of diatoms to the cyanobacterial community increase accretion rates by an order of magnitude, but diatoms are not essential for formation of coarse-grained stromatolites. Community evolution to include eukaryotes does *not* explain changes in stromatolite texture through time (e.g. Awramik and Riding, 1988).

- Modern marine stromatolites are valuable models for understanding processes of stromatolite formation.

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