Formation of lithified micritic laminae in modern marine stromatolites (Bahamas): The role of sulfur cycling

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ABSTRACT

Microbial mats on the surfaces of modern, marine stromatolites at Highborne Cay, Bahamas, were investigated to assess the role of microbial processes in stromatolite formation. The Highborne Cay stromatolitic mats contain Schizothrix as the dominant cyanobacterium and show millimeter-scale lamination: Some layers in the mat are soft (unlithified), whereas other layers are crusty (lithified). Lithified layers within the mats correspond to micritic horizons composed of thin (20–50 μm) micritic crusts, which commonly overlie truncated, micritized carbonate sand grains. These features are identical to lithified laminae in the underlying stromatolite; the micritic crusts are similar in thickness to micritic laminae in many ancient stromatolites. Biogeochemical parameters in a representative stromatolitic mat from Highborne Cay were measured to identify the role of bacteria in precipitation and dissolution of CaCO3. Depth distributions of O2, HS−, and pH were determined with microelectrode measurements in the field. Oxygen profiles were used to calculate photosynthesis and aerobic respiration. Sulfate reduction was determined using 35SO42− and sulfoxide oxidation potential was measured in homogenized samples. Our results indicate that cyanobacterial photosynthesis, sulfate reduction, and anaerobic sulfoxide oxidation in stromatolitic mats at Highborne Cay are responsible for CaCO3 precipitation, whereas aerobic respiration and aerobic sulfoxide oxidation cause CaCO3 dissolution. A close coupling of photosynthesis and aerobic respiration in the uppermost few millimeters of the mats results in no, or very little, net lithification. Sulfur cycling, on the other hand, shows a close correlation with the formation of lithified micritic layers. Photosynthesis, combined with sulfate reduction and sulfoxide oxidation results in net lithification. Sulfate reduction rates are high in the uppermost lithified layer and, on a diel basis, consume 33–38% of the CO2 fixed by the cyanobacteria. In addition, this lithified layer contains a significant population of sulfoxide-oxidizing bacteria and shows a high sulfoxide oxidation potential. These findings argue that photosynthesis coupled to sulfate reduction and sulfoxide oxidation is more important than photosynthesis coupled to aerobic respiration in the formation of lithified micritic laminae in Highborne Cay stromatolites.

INTRODUCTION

Stromatolites record the interactions of biological and geological processes throughout the 3.5 billion year history of life on Earth (Awramik 1992). Earth’s oldest macrofossils, stromatolites are not individual organisms, but rather lithified, laminated sedimentary structures produced by the activities of benthic microbial mats. Interpretation of ancient stromatolites, which dominate the fossil record for 85% of Earth’s history, is limited by a lack of understanding of geomicrobiological processes in modern stromatolites. Until recently, modern stromatolites forming in open marine settings, environments in which many ancient stromatolites are thought to have formed, were unknown.

Modern stromatolites forming in open ocean water of normal marine salinity were first discovered in the Schooner Cays, on the east margin of Exuma Sound, Bahamas (Fig. 1), in the early 1980s (Dravis 1983). Since then, they have been found at numerous locations throughout the Exuma Cays, on the west margin of Exuma Sound (Fig. 1; Dill et al. 1986; Reid and Browne 1991; Reid et al. 1995). Typically forming domal buildups ranging in height from several centimeters to over 2 m, these Exuma stromatolites are well-laminated structures composed...