Geophysical Research Abstracts, Vol. 7, 01630, 2005
SRef-ID: 1607-7962/gra/EGU05-A-01630

Lithifying microbial mats in Lagoa Vermelha, Brazil: A model system for Precambrian carbonate formation?

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Fossilized microbial mats are one of the first signs of early life on Earth and are widely found in sedimentary rocks beginning in the Neo-Archean, but are quite rare today. Modern analogue structures are still found, mainly in marine or hypersaline environments, such as in the Exuma Cays, Bahamas or Lagoa Vermelha, Brazil, respectively. A common feature of the ancient and rarely some of the modern microbial mats is the precipitation of carbonate minerals, which can be the result of photosynthesis or anaerobic respiration processes. As it is impossible to ascertain the original Precambrian microbial population, which was probably more primitive than today, we have focused our microbial mat studies on bacteria with phylogenetically old biochemical pathways.

Lagoa Vermelha, a moderate hypersaline coastal lagoon located 100 km east of Rio de Janeiro, Brazil, offers the ideal conditions to study lithification processes in microbial mats. Calcified, sometimes dolomitic, microbial mats grow on the sediment surface. The factors controlling carbonate precipitation in Lagoa Vermelha are the water chemistry and the special hydrology, combined with a high primary production by cyanobacteria, a high rate of anaerobic respiration and the absence of higher organisms. Here, we present a study of the physico-chemical parameters, microbial processes and bio-minerals associated with these microbial mats. This approach also provides information on the boundary conditions promoting dolomite formation.

Several discrete lithified calcium carbonate layers occur in the uppermost mat. The first lithified layer forms in a 2-mm-thick biofilm, which contains the cyanobacteria Microcoleus, Spirulina and Gloeocapsa. A second micrite deposit is observed at 4-5 mm depth, with an underlying layer comprising phototrophic purple bacterium Thiocystis. Carbon isotope values of the carbonate layers indicate a contribution of organic derived carbon associated with microbial processes, such as sulfate reduction. We propose that the sulfate reduction probably induces formation of carbonates, whereas the anaerobic sulfide oxidation may play an indirect role in dolomite stabilization by dissolving calcium carbonate and preservation of dolomite by the daily pH changes. Understanding this unique and highly dynamic model ecosystem, which controls microbial carbonate, including dolomite, precipitation can provide important insights about ancient biomineralization processes, especially during the Precambrian.