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Preservation of biogenic calcium carbonate precipitates in hypersaline microbial mats (Eleuthera, Bahamas)

C. Glunk (1), C. Dupraz (1), O. Braissant (2), A. Wieland (3), E. P. Verrecchia (1), and P. T. Visscher (2)

(1) Institut de Géologie et d'Hydrogéologie, Université de Neuchâtel, Emile-Argand 11, CH 2009 Neuchâtel, (2) Center for Integrative Geoscience, University of Connecticut, 354 Mansfield Road, U-2045 Storrs CT-06269 USA, (3) Institute of Biogeochemistry and Marine Chemistry, University of Hamburg, Bundesstrasse 55, 20146 Hamburg, Germany

Fossilized evidence of biologically induced calcium carbonate precipitation is rare and often controversial. Modern calcium carbonate ($CaCO_3$)-producing microbial ecosystems are valuable models for interpretation of the past. One such ecosystem is Big Pond, a hypersaline lake on the Bahamian island Eleuthera, which harbours a microbial mat containing large amounts of $CaCO_3$. The $CaCO_3$ minerals are preserved in about 20 well-defined microbial mat layers overlying a mineral base.

Single layer investigations, using X-ray diffraction (XRD), thin sections, $\delta^{13}C$, $\delta^{18}O$ isotopic analysis and electron microscopy (SEM equipped with a cryo transfer unit) reveal diverse mineralogy, ranging from aragonite and calcite to a Mg-calcite solid solution, and even Ca-dolomite. This mineralogy is coupled to five different macro- and micromorphologies of the carbonate crystals. Additionally, we investigated the respective organic strata found in between the mineral layer, which consisted mainly of EPS (exopolymeric substances). Geochemical depth profiles were measured using O_2, pH, Ca^{2+} and S^{2-} microelectrodes. Mineralogical and microbiological investigations were complemented by physical and chemical measurements of the environment.

Our data suggest several processes of mineral formation, varying with seasonal climate changes, coupled to which the microbial community and its activity changes. While in evaporitic systems carbonate precipitation can be reduced to evaporation/dilution events and to sediment input by storms, hypersaline Big Pond represents a more complex, biologically induced precipitation scenario. Big Pond is high

in CO_3^{2-} and Ca^{2+} and Mg^{2+}, physicochemical precipitation could occur. However, our data show that EPS are inhibiting carbonate precipitation by chelating cations like Ca^{2+} and Mg^{2+}. Degradation of EPS by e.g. heterotrophic bacteria (e.g., sulfate reducers), ends this inhibition resulting in subsequent calcification of the EPS matrix. These data, as well as abiotic mineralization experiments, suggest a strong control of EPS functional groups (e.g., -COOH, - SH -OH, -NH_2) on mineralogy and morphology of carbonate minerals. The EPS composition provides a specific snapshot of extrinsic factors as well as of production and consumption of this exopolymeric matrix by the microbial community. Consequently, mineralogy and morphology of the carbonate biominerals specifically reflect certain environmental and biological conditions.