

Biosphere / lithosphere interface: microbially-mediated CaCO₃ precipitation in hypersaline and freshwater environments

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Microbial mats very efficiently cycle elements, such as C, O, N, S and H, which makes them key players of redox processes at the biosphere-lithosphere interface. They are characterized by high metabolic activities and high turnover rates (production and consumption) of biomass, which mainly consists of cell material and of extra cellular organic matter (EOM). The EOM forms a matrix, embedding the microbial cells and fulfilling various functions within the microbial mat, including: mat attachment to surfaces; creation of micro-domains within the mat; physical stabilization under hydrodynamic stress and the protection of the cells in multiple other stress conditions. EOM mainly consists of polysaccharides, amino acids, and a variety of chemical functional groups (e.g., -COOH, -SH -OH). These groups strongly bind cations such as Ca²⁺ and Mg²⁺ and thus exert a strong control on carbonate mineral formation within the microbial mat. A feedback mechanism between community metabolisms, their products, and the surrounding physicochemical microenvironment thus influences the degree of carbonate saturation favoring either carbonate precipitation or dissolution.

We investigated the driving forces and mechanisms of microbialite formation in the Sarine River, FR, Switzerland, the hypersaline lake, Big Pond, Bahamas and in laboratory experiments. The two fundamentally different natural systems allowed us to compare the geochemical conditions and microbial metabolisms, necessary for carbonate formation in microbial mats. Although carbonates are oversaturated in both environments, precipitation does not occur on physicochemical substrates (i.e. outside the microbial mats). In the Sarine a high crystal nucleation threshold exceeds the carbonate saturation, despite the high carbonate alkalinity in the water column. Cyanobacterial photosynthesis strongly locally enhances the carbonate alkalinity, whereas the EOM attract and immobilize calcium, which increases the saturation state and finally leads to carbonate precipitation within the EOM (in this case the cyanobacterial sheath) as nucleation template. In Big Pond, the presence of calcium chelating anions (i.e. sulfate) and EOM, as well as the presence of magnesium, lowers the calcium activity in the water column and mat, and thus inhibits carbonate precipitation. Coupled with other heterotrophic metabolisms, sulfate reduction uses the EOM as carbon source, degrading it. The resulting EOM consumption creates alkalinity, releases calcium and consumes sulfate in mat-micro domains, which leads to the formation of carbonate layers at the top of the microbial mat.