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Calcite precipitation and stromatolite formation induced by photosynthetic bacteria

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Stromatolite is a microbial sedimentary structure formed by the life-water-mineral interactions, and widely spread especially in Precambrian sedimentary successions. The formation mechanism of fossil stromatolite has been interpreted by basing on the research of recent marine stromatolites that are still seen in some localities (e.g., Shark Bay in western Australia). However, the recent marine stromatolites are composed mainly of agglutinated sand grains, and are different from those of ancient one composed mainly of fine minerals precipitated in situ. Therefore, it is necessary to seek and investigate another modern analog having similar composition to ancient stromatolites in order to reinterpret their formation mechanism. The present study selected freshwater stromatolite composed of fine-grained calcite as a modern analog, and aimed to understand its formation mechanism.
First, modified CARD-FISH (catalyzed reporter deposition fluorescence in situ hybridization) protocol was developed to visualize bacteria in the mineralized stromatolite biofilm. This new technique revealed that the investigated stromatolite was composed of a number of filamentous cyanobacteria as well as non-phototrophic bacteria (Shiraishi et al., 2008). Second, pH, O_2, $Ca^{2+}$and CO_3^{2-} concentrations were measured by microelectrodes at the biofilm vicinity, in order to evaluate the metabolic influence of stromatolite biofilm on calcite precipitation. The results showed that the metabolic activity of microorganisms had significant influence on carbonate equilibrium at the biofilm vicinity (ca. several hundred micrometers from the surface, which is called as diffusive boundary layer), and had different influence between light and dark conditions (Bissett et al., 2008 a,b; Shiraishi et al., 2008b,c). Under the illumination, CO_3^{2-} concentration, and thus saturation state of calcite, near the biofilm surface increased due to CO_2 removal by cyanobacterial photosynthesis, and calcite precipitation occurred that resulted in Ca^{2+} decrease at the biofilm surface. Under the dark condition on the other hand, CO_3^{2-} concentration decreased due to CO_2 release by microbial respiration, which resulted in the decrease of saturation state and the absence of calcite precipitation. These results indicated that the investigated stromatolite biofilm induced calcite precipitation by photosynthesis in the light and inhibited by respiration in the dark, and thus, controlled calcite precipitation. This interpretation was supported by ^{45}Ca tracking experiment that demonstrated the occurrence of radioactive calcium accumulation at the stromatolite surface only under light condition (Bissett et al., 2008a). Microelectrode measurements conducted on the biofilm-free limestone surface with the same water chemistry could not detect spontaneous calcite precipitation, despite of 5- to 10-fold supersaturation for calcite in the surrounding water. This observation indicated that the microbial photosynthesis has significant role for the formation of microbial carbonate deposits such as stromatolites.

References

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