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Role(s) of oxygenic photosynthesis in Precambrian stromatolite formation

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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 key process in stromatolite formation is mineral precipitation by microbial metabolisms for producing and consolidating the deposits, while particle trapping/binding and crystal nucleation by microorganisms play rather passive roles. Among the metabolisms, oxygenic photosynthesis, which appeared in Archean, is expected to be one of most important metabolism for stromatolite formation throughout the Earth history, because it can induce $CaCO_3$ precipitation and occur in a wide range of shallow marine environments where light and dissolved inorganic carbon (DIC) are available. However, the researches based on modern open marine stromatolite suggested that carbonate mineral precipitated by photosynthesis is dissolved by aerobic respiration, and results in little or no net precipitation (Reid et al. 2000, Nature 406, 989-992). In addition, the researches based on numerical simulations suggested that the influence of photosynthesis on carbonate mineral precipitation is negligible in high DIC condition such as Precambrian ocean (Arp et al. 2001, Science 292, 1701-1704; Aloisi 2008, GCA 72, 6037-6060). Nevertheless, these suggestions based on indirect observations, which are still need to be confirmed by direct measurement.

The present study measured chemical profiles of pH, O_2, CO_2, Ca^{2+} and $CO_3{}^{2-}$ at the stromatolite surface using microelectrodes, in order to evaluate the actual influences photosynthesis on stromatolite formation. The measurements conducted in natural water condition revealed that photosynthesis significantly induced $CaCO_3$ precipitation, while the influence of respiration on carbonate chemistry was negligible and no detectable dissolution was observed. The measurements conducted in various DIC condition revealed that photosynthesis significantly induced precipitation even in high DIC condition (up to 300 mM), indicating that tiny influence of photosynthesis on carbonate chemistry is sufficient for inducing precipitation if ambient saturation is high enough.

Therefore, it is considered that oxygenic photosynthesis played important role(s) in stromatolite formation even in Precambrian ocean.

Keywords: stromatolite, photosynthesis, cyanobacteria, microelectrode