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Bacterial symbiosis forming lamination of iron-rich deposits in hot spring

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Laminated iron deposits called BIFs are the most characteristic sediment records during Archean-Paleoproterozoic. They generally exhibit laminations consisting of Fe-rich layers and cherty layers and that were categorized in terms of the band thickness; such as, macrobands (m-order), mesobands (cm-order), and microbands (mm to sub-mm order; Trendall and Blockley, 1970). Processes and timing of these lamination types may provide information for ancient marine environment, but have been poorly understood. A traditional formation model emphasized reaction between Fe(II) form hydrothermal vents and oxygen generated by cyanobacteria (Cloud, 1973), but it cannot explain the presence of BIFs before the evolution of cyanobacteria. Thus two additional models have been proposed. One considers anoxygenic photosynthesis of purple and green bacteria, which couple Fe(II) oxidation to the reduction of CO2 (Ehrenreich and Widdel, 1994). The other is based on chemolithoautotrophic iron-oxidizing (Konhauser et al., 2002). These models could explain the deposition in deepsea settings and before the evolution of cyanobacteria, but involve difficulty to form the lamination.

BIF-like laminated textures can be observed in modern hot spring environments. We investigate forming processes of the lamination using sedimentological and microbiological techniques and consider the origin of lamination textures.

The study subject is a laminated iron-rich deposit at Okuoku-hachikurou Hotspring in Akita Prefecture. Water of intermediate temperature comes out and precipitates an iron-rich deposit around the vent. It appears mm-order lamination composed of red-color layers and white-color layers. Result of XRD shows that it mostly consists of amorphous ferrihydrite and aragonite. Microscopic observation recognized bands about 100-tens micron thick occurring in red-colored layer, which consist of fine ferrihydrite particles. The space between bands is filled with aragonite. On the other hand, white layer is mainly consists of columnar aragonite crystals and contains spherical aggregates of radially expanding crystals (diameter of 100-500 micron). Moreover, ferrihydrite particles and filament textures of 10-30 micron wide were confirmed in white layers.

The specimens treated with acetic and citric acids were observed by SEM. The ferrihydrite occur aggregates of spherical particles (diameter of about 5 micron) that are associated with meshwork like bacterial sheath. Theses textures and occurrences indicate that precipitation of the ferrihydrite is induced by bacterial metabolisms.

Results of phylotype analysis show that the extracted sequences are close to cyanobacteria reported hot spring environment and anoxygenic phototrophs belonging to alpha-proteobacteria. In addition, another detected phylotype was nearly identical to iron oxidizing bacteria discovered from iron-rich deposits of Shionoha hot spring in Nara Prefecture. The textures of iron-rich deposit in Shionoha hot spring are very similar to those of the study material (Takashima and Kano, 2008). However, the former lacks photosynthetic bacteria that were identified in this study. The presence of phototroph may indicate the possibility that iron precipitation is influenced by the daily cycle of sun light. A likely symbiotic relationship is oxygen transfer from cyanobacteria to iron oxidizing bacteria that certainly require some oxygen. This relationship suggest the daily cycle of the lamination in iron-rich deposits, which could be potentially adapted to BIFs, especially microbands.