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Role of minerals for coexistence of aerobic and anaerobic microorganisms in microbial mat in the Naruko hot spring area.

Shintaro Miyaki[1], Takeshi Kakegawa[2], Hiromoto Nakazawa[3]

[1] Tohoku Univ, [2] IMPE., Tohoku Univ., [3] Div. Earth Sci., Tohoku Univ.

Biological and geological phenomena caused by the action of chemolithoautotrophs may include the information for the activities of early life and origin of life. However, geological studies to chemolithoautotrophs are poor. Therefore in the present study, a microbial mat composed by chemoautotrophic sulfur-oxidizing bacteria (sulfur turf) is examined geochemically and mineralogically.

The microbial mat was collected from the Naruko hot spring area. The studied microbial mat is dominantly composed of sulfur-oxidizing bacteria (SOB; Mori et al., 2001). The Naruko microbial mat is made of aggregation of fibrous materials. Diameter of each fiber is several mm, and length is about several cm. Various observations (optical microscope, TEM, and SEM) are made on this Naruko microbial mat. In addition, elemental analysis (XGT and EDS), and stable isotope analysis of sulfur are performed. The followings are new findings.

(1) Degrees of crystallization are different in surface and inside of the fibrous structure in the Naruko microbial mat. On the surface, amorphous compounds including sulfur, silicon, carbon, and alumino are mainly predominant. On the other hand, several minerals (native sulfur, iron sulfide, trydimite, quartz and so on) are identified inside of the mat. (2) Degrees of crystallization of silica minerals are various. Especially, crystalline form of silica is dominant on the surface of cell wall of SOB. Amorphous silica are abundant in the surface of the mat and often surround the SOB. (3) Distribution of iron sulfide is limited only inside of the microbial mat and rounded shape of crystals (framboid-like) are recognized. (4) The sulfur isotope compositions of iron sulfide and native sulfur are 4.2 to 5.4 per mil and 7.3 to 10.2 per mil, respectively. And the sulfur isotope compositions of dissolved hydrogen sulfide and sulfate in hot spring water are 0 to 3 per mil and 8.6 to 14.0 per mil, respectively. These dissolved S-species has different isotope compositions to these in microbial mat.

The thin layers of microbial mat surface seem to be the intensive growth front. Active biological hydrogen sulfide oxidation is probably occurring on the surface of the mat, accompanied by accumulation of inorganic elements in this layer. (5) Crystallization degrees of silica change gradually from amorphous silica to crystal forms such as quartz and trydimite. These transitions seem to be corresponded to growth of microbial mat. (6) Morphological features and sulfur isotope compositions of sulfide suggest microbial origin of iron sulfides.

Sulfate-reducing bacteria (SRB) and SOB, in general, exist in different redox conditions. Notable feature of the Naruko microbial mat is that SOB and SRB are coexisting in the same mat and each produces diagnostic minerals. It is interpreted that amorphous silica or silica gel may form the redox barrier and these silica are considered to play a role to allow both microorganisms coexist in the same microbial mat.

In conclusion, different microorganisms progressively form new minerals by accumulating many inorganic elements. With the help from minerals or their precursors, microorganisms make suitable environments absolutely by themselves in complexed microbial community. It is expected minerals might have a important role for coexistence and coevolution of aerobic and anaerobic microorganisms in the primitive Earth.