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論 文 要約

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Microbial sulfate reduction is important for Earth's sulfur cycling. Owing to high concentration of dissolved sulfate in modern ocean (28 mM), microbial sulfate reduction is one of the most dominant microbial metabolisms in marine sediment. Recent studies of ocean floor drillings have demonstrated that microbial sulfate reduction takes place not only within sediments, but also within oceanic crusts. However, the activity of microbial sulfate reduction in modern and past crustal environment was poorly understood. Particularly, seafloor hydrothermal systems may possibly host active microbial communities sustained by hydrothermal/seawater circulation. Therefore, in this thesis, modern and past activities of microbial sulfate reduction within the crustal environment and their influence on global sulfur cycling are evaluated using stable sulfur isotopes.

In chapter 1, recent development of quadruple sulfur isotopes is reviewed. In addition to the conventional technique using $^{34}S/^{32}S$ ratio, ^{33}S and ^{36}S signature can be used for monitoring microbial sulfate reduction.

In chapter 2, activity of microbial sulfate reduction below seafloor within Iheya North Knoll hydrothermal field in the Okinawa Trough is evaluated using the quadruple sulfur isotope technique. Pore water sulfate and sulfide minerals in sediment were sampled in Integrated Ocean Drilling Program Expedition 331. The result of the isotope analysis indicates that sub-seafloor microbial sulfate reduction potentially contribute approximately 20% of the total sulfide mineral formation below sub-seafloor. The microbial activity was probably promoted by significant input of seawater sulfate into sub-seafloor through the vigorous hydrothermal circulation in the Iheya North field.

In chapter 3, the same isotopic technique is applied to hyper alkaline environment of the South Chamorro serpentinite seamount in Mariana forearc. The activity of sulfate reducers in the highly alkaline subseafloor environment is yet to be justified, though abundant hydrogen input via abiotic serpentinization process may facilitate the microbial activity. Quadruple sulfur isotopes of sulfide minerals in core sample, dissolved sulfate in squeezed pore water, and dissolved sulfate and hydrogen sulfide in bore-hole fluid were analyzed to evaluate the microbial activity. The results indicate that microbial sulfate reduction takes place even in the hyper alkaline environment ($pH > 12$). Furthermore, a part of the dissolved sulfate within the seamount exhibits mass independent fractionation of sulfur isotopes, suggesting the deep sulfate may be derived from Archean crusts potentially present in the modern mantle.

In chapter 4, microbial sulfate reduction Archean ocean crust is studied by analysing 3.5

Ga Dresser Formation, Western Australia. The large sulfur isotope fractionation up to 25‰ is observed for sulfide minerals in komatiitic basalts, suggesting the activity of microbial sulfate reduction below Archean seafloor. The model results further suggested that the substrate sulfate derived not only from Archean seawater but also from volcanic or hydrothermal source via sulfur disproportionation reaction.

In chapter 5, the quadruple sulfur isotope technique is newly applied to Phanerozoic and Archean granitoids. In contrast to sedimentary rocks, the older granitoids may be useful to trace the older activity of microbial sulfate reduction potentially date back to 4.0 Ga. The analysis of sulfide minerals within Phanerozoic granitoids confirmed the previous hypothesis that a part of the sulfur in the granites derived from seawater sulfate that was reduced into sulfide by microbial activity and was transferred into granitoid magma through subduction of oceanic plate. This result indicates that sulfide minerals within Archean granitoids is also useful to trace microbial sulfate reduction in Archean ocean. The analyses of sulfide in Archean granitoids from Acasta Gneiss Complex in Northwest Canada, Mount Edgar Granitoids Complex in Western Australia and Darwar gnanitoids in South India strongly suggest that part of the granitoid sulfur was derived from Archean seawater, which had negative $\Delta^{33}S$ value. Furthermore, the distinctive $\Delta^{36}S/\Delta^{33}S$ trend observed in several granitoids including 4.0 Ga samples suggests that microbial sulfate reduction should be involved in the conversion processes from the seawater sulfate to the granitoid sulfide. The results provide the oldest evidence of microbial sulfate reduction, likely operating in a global scale since 4.0 Ga.