Reconstruction of a ~3.5 Ga ecosystem in the sea-floor hydrothermal system

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The hydrothermal system is one of the candidates for the birthplace of life and is also a candidate for site of the first metabolic evolution. In order to understand the role of hydrothermal systems for the origin of life and/or subsequent early evolution, it is necessary to investigate the ancient hydrothermal systems preserved in Archean geological record. The North Pole area, Pilbara craton, Western Australia is one of the best study field of the Early Archean seafloor hydrothermal system. Recent finding of 13C-depleted kerogens in ~3.5 Ga synsedimentary hydrothermal veins in this area (Ueno et al., 2004, GCA 68, 573-589) suggests that both seafloor and sub-seafloor hydrothermal system were inhabited by primitive organisms at that time. We have tried to reconstruct the hydrothermal ecosystem through the study of C, S isotope geochemistry. At first, the organic carbon in the seafloor sediment systematically show 13C-enriched isotopic composition relative to those in sub-seafloor veinlets (-38 ~ -34 permil). The kerogen in the sub-seafloor is probably derived from anaerobic chemoautotrophs (for example methanogens or acetogens), because the mineral assemblage of the veinlets suggests oxygen- and sulfate-poor reducing condition. In contrast with the sub-seafloor veinlets, seafloor sediments, which composed of Fe-oxide-bearing chert and barite, have more oxidizing mineral assemblages. The13C-enrichment of kerogens in them could be explained by metabolic difference of the primary producers and/or post-depositional isotopic effects under relatively oxidizing condition. On the other hand, sulfur isotopic compositions of barite and sulfide show mass independent signature (non-zero D33S value). The bedded barite always have negative D33S, suggesting seawater sulfate had negative anomaly. The sulfide minerals (mainly pyrite) show both positive and negative D33S values, though negative anomalies are observed only in the seafloor sediment or shallowest sub-seafloor veinlet. This suggests that some pyrite would have been produced by sulfate reduction, though the sulfate reducers would have be in active only at the shallower part of the hydrothermal system. Therefore, these C and S isotopic distributions are correlated with the vertical redox gradient of the system, and could be reflected by spatial distribution of the metabolically different organisms (i.e., anaerobic chemoautotrophs in deep sub-seafloor and sulfate reducers in seafloor surface).