Archean mid-ocean ridge hydrothermal system in the North Pole Dome (3.5 Ga), Pilbara Craton, Western Australia

Kouki Kitajima[1]; Soichi Omori[2]; Shigenori Maruyama[3]

[1] Earth and Planetary Sci., Tokyo Tech.; [2] Res. Centr. Evolving Earth and Planets, Tokyo Tech.; [3] Earth and Planetary Sci., Tokyo Institute of Technology

The purpose of this study is quantitative reconstructions of a habitat for the Earth's early life. We discuss the Archean oceanic chemistry by observations of extensive hydrothermal-carbonation in the Archean oceanic crust and by chemical analyses of fluid inclusions.

Geology: North Pole Dome is an Archean accretionary complex which is composed of at least 5 chert-greenstone units bounded by layer-parallel thrusts. Seafloor hydrothermal system of the Early Archean was identified in the MORB-type greenstones in the North Pole area, and the microfossil-bearing cherts are involved with the greenstones.

Hydrothermal alteration: Greenstones in the lowermost unit are divided into three zones (Zone A, B and C) by secondary mineral assemblages. Zone A greenstones contain carbonate-bearing mineral assemblages instead of Ca-Al silicates. Zone B is defined by the occurrence of actinolite and lacks carbonates. Zone C is the highest metamorphic grade in this area, characterized by the occurrence of hornblende together with Ca-plagioclase. The metamorphic grade increases toward the stratigraphically lower level and three mineral zones (Zone A, B and C). Ca-Al silicates in Zone A were replaced by carbonates due to reaction with high-XCO2 hydrothermal fluid. Mode of carbonates is up to 90%, and the mean value is about 30% in upper 1000 m (Zone A) from ancient seafloor, and mode of carbonates in lower part, deeper than1000 m, is almost 0%. Similar extensive carbonation in the oceanic crust was reported from Cleaverville area in Pilbara Craton at 3.2 Ga (Shibuya et al., 2005). The carbonates in the oceanic crust transfers their CO2 to drugged hanging-wall peridotite in the subduction zone, and the CO2 should be carried into the deep mantle (Omori et al, 2003). Consequently, it is estimated that 1E20-3E20 kg of CO2 was subtracted from the ocean into the mantle during 3.5 to 3.2 Ga in the MOR-carbonation-subduction system. This amount corresponds to 5.6-17% of the CO2 amount in the Archean atmosphere estimated by Kasting (1987).

Fluid inclusions: Homogenization temperature (Th) of fluid inclusions in the deepest sample has a sharp peak at 150 degrees Celsius, but Th of other shallower samples show relatively broad peaks. These fluid inclusions indicate occurrence of phase separation between the deepest sample and other shallower samples: this depth is about 1000 m from the ancient seafloor. The phase separation temperature was estimated to be 150 degrees Celsius by Th of pre-phase separation sample. Phase relation of H2O-CO2 system suggests that CO2 mole fraction of hydrothermal fluid which has been subjected to phase separation at 150 degrees Celsius and larger than 260 bar estimated from secondary mineral assemblages is restricted to 0.027-0.044. This XCO2 values are about 5-9 times higher than the value of present-day vent fluids collected near mid-ocean ridges. This high-XCO2 hydrothermal fluid is consistent with carbonate-bearing (Ca-Al silicate absent) secondary mineral assemblages in upper greenstones. The REE contents of fluid inclusions were analyzed by ICP-MS using crush and reaching method. Chondrite-normalized REE patterns of all samples show nearly flat patterns (La/Yb = 1.22-5.89) except one sample (La/Yb = 12.74), and they all have a positive Eu anomaly. The positive Eu anomaly in the North Pole fluid inclusions suggests that the Archean hydrothermal fluids circulating in the upper oceanic crust at the mid-ocean ridge was a relatively reductive fluid similar to that in present-day mid-ocean ridge hydrothermal fluids.