

アルカリ熱水系と海洋リン酸塩濃度: 生命出現場として熱水環境の再検討 Alkaline hydrothermal system: High phosphate-bearing hydrothermal fluid and seawater in the early earth

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The earth is the unique planet which large population of organisms inhabits. There are some requirements for the emergence of the life. The most important, and popular requirement is presence of liquid water on the earth, so-called a habitable planet. But, enrichment in bioessential elements is also important because they are demanded for the metabolic activity. In addition, it is required that the elements are continuously supplied to biosphere through the elemental cycle. Especially, phosphate is one of the most important nutrients because the DNA and RNA contain large amounts of phosphorus contents. Recently, terrestrial, anoxic geothermal fields are proposed as a candidate for a geologic place of the first organism because the hydrothermal fluids contain much phosphate and possibly potassium (Mulkiidjanian et al., 2012, PNAS). On the other hand, it is often pointed out that low phosphate contents in ocean floor hydrothermal fluid, even compared with modern phosphate-poor seawater, is unfavorable to emergence of life. Kakegawa et al. (2002) proposed that the input flux of phosphorous in pre-biotic oceans was probably dominated by submarine hydrothermal activities associated with carbonated oceanic crusts. Recently, Shibuya et al. (2010) proposed alkaline hydrothermal systems were common even in the basaltic ocean floor in the early earth because higher CO₂ content of seawater or hydrothermal fluid promoted formation of carbonates but inhibited mafic minerals such as chlorite and amphibolite. In addition, the thermodynamic calculations of phase equilibria also predict a generation of SiO₂-rich, Fe-poor hydrothermal fluids in the Archean subseafloor hydrothermal system. This work presents comparison of major element compositions between non-altered and altered Archean basalts in an accretionary complex, Pilbara Craton, and proposes that high CO₂ content of seawater yielded hydrothermal fluid with high phosphate contents and possibly high potassium contents in the early earth.

We compared among major element compositions of modern altered and non-altered MORB (Alt & Honnorez, 1984, CMP), and Archean altered and non-altered MORB each other (Nakamura & Kato, 2004, GCA). Present-day hydrothermal alteration increased phosphorus contents relative to titanium contents in the altered basalts so that altered MORBs commonly contain over four times higher phosphorus contents than the fresh equivalents. On the other hand, the Archean altered basalts contain relatively lower phosphorus contents than the fresh equivalents. The different behavior of phosphate during the hydrothermal alteration of basalts suggests higher phosphate contents in the Archean hydrothermal fluids. Generally speaking, precipitation of carbonate and phosphate minerals is mutually exclusive. Increase in pH enhances precipitation of carbonate minerals so that it promotes dissolution of phosphate as well as silica. The dissolution of phosphate leads to higher phosphate-bearing hydrothermal fluid as well as higher SiO₂-bearing hydrothermal fluid due to the dissolution of silica. The Archean altered basalts contain high potassium contents compared with the non-altered equivalents but the enrichment factor of potassium contents between the altered and non-altered basalt is lower than that of the modern equivalent, suggesting the Archean hydrothermal fluid contained higher potassium content than the modern equivalents. Alternatively, the altered MORB due to silicification or hydrothermal alteration under the high CO₂ condition exclusively contained more K₂O than Na₂O contents, suggesting that hydrothermal fluid from the altered MORB contains extremely high K₂O contents and K₂O/Na₂O ratios in the early earth than the modern equivalents. The possibility that the Archean hydrothermal fluid contained more phosphate and potassium favors a model that hydrothermal system was a cradle of life in the early earth.