Hydrothermal experiments using carbonaceous chondrites: Implications for availability of bioessential elements in Enceladus' ocean

*Shuya Tan[1], Yasuhito Sekine[1], Kento Furuya[2], Takazo Shibuya[3]

1. Earth-Life Science Institute, Tokyo Institute of Technology, 2. Tokyo Institute of Technology, 3. Japan Agency for Marine-Earth Science and Technology

The ocean of Enceladus contains high abundances of gaseous species, such as CO_2, H_2, NH_3, and CH_4 (e.g., Waite et al., 2009). Hydrothermal environments would exist on the seafloor (e.g., Sekine et al., 2015). Based on this environment, the presence of methanogenic life is suggested (Waite et al., 2017). Possible methanogenic life within Enceladus could require specific bioessential elements as same as terrestrial methanogen requires for enzyme activations (e.g., Ni, Zn, P, and Mo). However, the availability of these elements in the ocean of Enceladus has not been investigated.

Here, we perform hydrothermal experiments using carbonaceous chondrites to simulate hydrothermal environments within Enceladus. We analyzed concentrations of dissolved species during hydrothermal reactions at 150 or 250 °C and 30 MPa between rocks and solutions. We performed microscopic analyses of rock samples before and after experiments. Our results show that concentrations of P and Mo are high at ~10^{-2}–10^{-1} mmol/L, and those of Ni and Zn are fluctuated in ~10^{-4}–10^{-3} mmol/L. Fe concentrations are low at ~10^{-3} mmol/L. Although Ca-phosphates are found in rock samples before and after experiments, measured concentrations of P are 3–4 orders of magnitude higher than those based on thermodynamic equilibrium calculations for dissolutions of Ca-phosphate. This implies that P concentrations would be controlled by dissolutions of amorphous phases in matrix and/or organic phosphor, rather than Ca-phosphate. Our results also show that Mo, Ni, and Zn are found in Fe-sulfides in rock samples before and after experiments. Dissolutions of Fe-sulfides might control the concentrations of these elements. In addition, Fe-phyllosilicates (e.g., serpentine and saponite) are found in rock samples after experiments. This suggests that Fe concentrations would be suppressed due to equilibria between solutions and such secondary Fe-minerals.

Our results suggest that dissolved P concentrations in Enceladus' hydrothermal fluids are higher than those in terrestrial seawater. Concentrations of Ni, Zn, and Mo would be also greater than the lower limits for activities of terrestrial methanogen; whereas, concentrations of Fe are comparable to the lower limits for their activities (e.g., Schonheit, 1979). We suggest that activities of possible methanogenic life on Enceladus might be limited by the availability of Fe, rather than other bioessential elements.

Keywords: Bioessential elements, Enceladus, Hydrothermal environments

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