Microbial community development in deep-sea hydrothermal vents in the Earth, and the Enceladus

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Over the past 35 years, researchers have explored seafloor deep-sea hydrothermal vent environments around the globe and studied a number of microbial ecosystems. Bioinformatics and interdisciplinary geochemistry-microbiology approaches have provided new ideas on the diversity and community composition of microbial life living in deep-sea vents. In particular, recent investigations have revealed that the community structure and productivity of chemolithotrophic microbial communities in the deep-sea hydrothermal environments are controlled primarily by variations in the geochemical composition of hydrothermal fluids (Takai and Nakamura, 2010; 2011). This was originally predicted by a thermodynamic calculation of energy yield potential of various chemolithotrophic metabolisms in a simulated hydrothermal mixing zone (McCollom and Shock, 1997). The prediction has been finally justified by the relatively quantitative geomicrobiological characterizations in various deep-sea hydrothermal vent environments all over the world (Takai and Nakamura, 2010; 2011).

Thus, there should be a possible principle that the thermodynamic estimation of chemolithotrophic energy yield potentials could predict the realistic chemolithotrophic living community in any of the deep-sea hydrothermal vent environments in this planet.

In 2005, a spacecraft Cassini discovered a water vapour jet plume from the sole pole area of the Saturnian moon Enceladus. (Hansen et al., 2008; Waite et al., 2009). The chemical composition analyses of Cassini's mass spectrometer strongly suggested that the Enceladus could host certain extent of extraterrestrial ocean beneath the surface ice sheet and possible ocean-rock hydrothermal systems. In addition, a recent research has suggests that there is silica nanoparticles in Saturn's E-ring derived from the Enceladus plume. An experimental study simulating the reaction between chondritic material and alkaline seawater reveals that the formation of silica nanoparticles requires hydrothermal reaction at high temperatures. Based on these findings, we attempt to build a model of possible hydrothermal fluid/rock reactions and bioavailable energy composition in the mixing zones between the hydrothermal fluid and the seawater in the Enceladus subsurface ocean. The results indicate that the pH of fluid should be highly alkaline and H_2 concentration in the fluid is elevated up to several tens mM through the water/rock reaction. The physical and chemical condition of the extraterrestrial ocean environments points that the abundant bioavailable energy is obtained maximally from redox reactions based on CO_2 and H_2 but not from with other electron accepters such as sulfate and nitrate. Our model strongly suggests that the abundant living ecosystem sustained by hydrogenotrophic methanogensis and acetogenesis using planetary inorganic energy sources should be present in the Enceladus hydrothermal vent systems and the ocean.

References

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