Geophysical Research Abstracts
Vol. 13, EGU2011-5144, 2011
EGU General Assembly 2011

Origin of methane in the Okinawa Trough hydrothermal fields: Implication for long transport of biogenic methane at subsurface geofluid system.

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Methane concentration higher than 1 mmol/kg is typical feature of hydrothermal fluids venting at sediment-associated hydrothermal systems including the Okinawa Trough hydrothermal fields. As one of the most fundamental questions to the sediment-associated hydrothermal fluids, it has been discussed how and where the high concentrations of methane is generated and supplied into the hydrothermal fluids. Given that little magma-derived methane is estimated by theoretical and observation studies for the sediment-free hydrothermal systems, the notably high methane concentration at sediment-associated hydrothermal systems is directly linked with the existing thick terrigenous sediments. Organics-rich terrigenous sediments promote the widespread occurrence of functionally active microbial communities and the microbiological impacts on the hydrothermal fluid, while thermal degradation of sedimentary organic matter is also possible. Diving observations into deep-sea hydrothermal vents have revealed the compositional and isotopic variation of hydrothermal fluid methane (13C/12C, C1/C2+, H2/CH4, etc.) among the sediment-associated hydrothermal fields. Because each Okinawa Trough hydrothermal field has similar geological and petrologic background, the variation of fluid geochemistry suggests that the generation and incorporation of methane in the hydrothermal fluids should be different among the hydrothermal fields even within the Okinawa Trough.

A model that describes qualitative relationship between geochemical origin of methane in venting hydrothermal fluid and geographical distribution of hydrothermal fluid circulation is proposed in this presentation. Microbial methanogenesis functions in cooler region because of biological survivability, while thermal methanogenesis is more likely at hotter region in terms of reaction kinetics. Recent biological/biogeochemical studies revealed significant microbial methanogenesis even at $\sim$100oC, while thermal methanogenesis is negligible at around the temperature. Given typical thermal gradient of 0.05 oC/m for crust and sediment thickness of at most 2000 m at around the known marginal hydrothermal sites including the Okinawa Trough, almost all the seafloor sediment environment is estimated below 100oC. This estimated temperature of sediment environment suggests dominance of biogenic methane, rather than thermogenic methane, in almost sediment-covered subseafloor environment. In contrast, thermal fluid-sediment reaction including thermal methanogenesis should be activated at around hydrothermal vents due to high temperature (>300oC) based on hydrothermalism. Therefore, there is a simple mode that smaller(larger) fluid circulation cell corresponds to higher thermogenic(biogenic) methane contribution in hydrothermal fluid. Dominance of biogenic methane in the Iheya North hydrothermal fluid at the Okinawa Trough implies spatially widespread fluid circulation cell and potential long transport of biogenic methane with subsurface fluid flow (Kawagucci et al., 2011, Geochemical Journal). The model describing subsurface long transport of biogenic methane may be also applicable to non-hydrothermal geofluid systems, such as mud-volcano, cold seep, and marginal methane hydrate.