Abiogenic formation of short-chain organic compounds within a serpentinite mud volcano over the Marianna Trench (IODP Exp. 366)

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The only known active sepentinite-hosting mud volcanoes, located in the Marianna forearc subduction zone, were drilled during IODP Expedition 366. Recovered samples from Asùt Tesoru seamount provide new insights on the generation of organic matter from fluid-rock interactions in deep oceanic environments, through Fischer-Tropsch-Type (FTT) reactions. The reduction of water by ferrous iron produces hyperalkaline pore fluids (pH 12.5) rich in H_2 (up to 2 mM), prone to react with accompanying DIC (up to 4.5 mM). High amounts of sulfide/oxide minerals observed within the mud may have catalyzed the reaction. This situation is ideal to produce carbon species like volatile fatty acids (VFAs), short-chain alcohols, and light hydrocarbons.

We acquired the full set of stable carbon isotope information of those compounds. VFAs are mostly composed of formate and acetate (up to 100 and 40 µM), associated with methanol (up to 30 µM). These short-chain components have extreme carbon isotope compositions, with heavy $\delta^{13}C$ values of up to +4.8‰ for formate, -8.0‰ for acetate and +2.3‰ for methanol, strongly suggesting an abiogenic origin and formation during CO_2 reduction with H_2. The gas phase of the serpentine mud is composed of a mix of H_2 and CH_4 (up to 95%). Associated molecular composition monitored via C1/C2+ ratios barely varies down to 100 mbsf, implying low or even absent microbial activity. Corresponding $\delta^{13}C$ values of methane as positive as -16 ‰ are in good agreement with reported abiogenic values. In addition, measured ^3He concentration and extrapolated $^3He/CO_2$ ratios suggest a primarily mantle-derived inorganic carbon source. The fractionation between the δD values of CH_4, H_2 and H_2O was also measured, and can be used to discuss potential temperature formation conditions at isotopic equilibrium.

Our dataset thus points to the abiogenic formation of low molecular weight organic compounds in the Marianna's mud volcanoes. Furthermore, it brings new constraints on the reaction pathways leading to the formation of precursor molecules essential to life in serpentinizing environments.