H_2-rich hydrothermal environment in the Enceladus' subsurface ocean

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Saturn's icy moon Enceladus has a global ocean beneath the icy crust and is presently discharging water-vapor plume from its south pole. The discovery of silica nanoparticles derived from the plume strongly suggested the presence of ongoing seafloor hydrothermal activities hosted by chondritic rocky core (Hsu et al., 2015; Sekine et al., 2015). Furthermore, the Cassini spacecraft detected molecular hydrogen (H_2) from the plume, which pointed to the energetic habitability of H_2-utilizing living forms sustained by the hydrothermal serpentinization of the rocky core (Waite et al., 2017). In this work, we conducted a hydrothermal experiment using synthetic metal-free chondrite and alkaline fluids at 200 ˚C, 200 bars to assess (1) whether the serpentinization of rocky core has the potential to satisfy the observed hydrogen flux from the subsurface ocean to the space and (2) the habitability of H_2-utilizing living forms based on the H_2 concentration of potential hydrothermal fluid generated in the seafloor hydrothermal systems.

The results show that the H_2 concentration in the fluid increased up to 14.6 mmol/kg 5,760 hours after the beginning of the experiment, which indicates that water-chondrite reactions likely generate H_2-rich hydrothermal fluid. 3D tidal heating simulations indicates that more than 10 GW of heat can be generated by tidal friction and that water transport in the tidally heated permeable core can also generate hotspots (1–5 GW) at the seafloor in the south pole region (Choblet et al., 2017). If it is assumed that the heat flux of hotspots is totally carried by 200-degree C hydrothermal venting, the H_2 flux at the south pole seafloor is estimated to be 5.2×10^8–2.6×10^9 mol/year, corresponding to 10–260 % of the H_2 flux (1–5×10^9 mol/year) observed by Cassini spacecraft. Therefore, the observed H_2 flux can be partially or completely explained by hydrothermal activities near the south pole hotspots. Of course, if lower-temperature but global hydrothermal activities are present, the seafloor water-chondrite reactions would sufficiently account for the observed H_2 flux.

The high H_2 concentration of fluid in the experiment corresponds to those of peridotite-hosted seafloor hydrothermal systems on Earth. Considering that hydrogenotrophic methanogens certainly exist in most of the terrestrial peridotite-hosted hydrothermal systems, the results suggest that the hydrothermal systems on Enceladus are capable of sustaining hydrogenotrophic methanogenesis if temperature of venting hydrothermal fluids is close to 200 degrees C. Further water-chondrite experiments at temperatures lower than 200 degrees C would provide more constraints on the temperature of hydrothermal systems and the habitability of H_2-utilizing living forms within Enceladus.