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The latest on hydrothermal activity on Enceladus from Cassini and Laboratory work

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1. Introduction

Various observations from the Cassini spacecraft [1,2,3], suggest the existence of subsurface water beneath the south polar region of Saturn's geologically active icy moon Enceladus. They provide information on the composition and physical conditions of water reservoirs occurring at shallow depth from which the plumes emerge [1,2,4], and about the dimensions of the south polar ocean beneath the ice crust at a depth of about 50km [3]. However, constraints on the physical and chemical conditions at the interface of the rocky core and the deep ocean are sparse. We report in situ measurements of tiny grains, so called stream particles, by Cassini's Cosmic Dust Analyser (CDA) in the Saturnian system.

CDA data shows that these nano-particles are composed of silica that were initially embedded in larger µm-sized icy grains emitted from Enceladus subsurface waters and released by sputter erosion in Saturn's E ring. Comprehensive long-term laboratory experiments and model calculations were carried out to investigate the reaction conditions at the bottom of Enceladus' ocean.

2. Results

We found that the formation of these nano-phase silica grains requires on-going hot hydrothermal rock-water interactions at Enceladus ocean floor [5]. Measurements and experiments both point at dissolved silica concentrations at the ocean floor in the order of at least 3 mMol. The formation process is already well known from hydrothermal sites and experiments on Earth [6,7,8,9] and could be reproduced by our experiments for Enceladus conditions. Colloidal nano-silica forms upon supersaturation during cooling of the hydrothermal liquid, and travels upwards towards the near surface waters fueling the plume where the temperatures are close to 0°C. Formation and stability of a nano-colloidal silica phase requires alkaline pH (8.5 – 10.5) and only tolerates a mild salinity, not higher than a few per cent. To sustain the formation of silica nanoparticles, the composition of Enceladus' core needs to be similar to that of carbonaceous chondrites. The high-temperature reactions need to persist in order to sustain the formation of nano-silica particles, which otherwise would readily dissolve in the ocean.

Two principle scenarios are investigated: 1) A chemically closed system where hydrothermal fluid and the Enceladus ocean quickly equilibrate and the oceanic composition is dominated by water–rock reactions. 2) A chemically open system where hydrothermal fluids are in disequilibrium with the surrounding ocean as it is the case on alkaline hydrothermal fields on Earth's ocean. pH values of hydrothermal fluids in a chemically closed system increase upon cooling. To form nano-silica this would require reaction temperatures > 150°C at a rock/water interface on Enceladus' ocean floor or inside a porous core. In the case the hydrothermal sites are chemically open to the icy crust through effective volatile exchanges, pH values of fluids and ocean are not determined simply by a change in dissolved species upon cooling. In this case the pH at the hydrothermal sites might be even higher than in the surrounding cool ocean and temperatures as low as 50°C are sufficient to allow nano-silica formation. Accordingly, the formation of silica nanoparticles is most likely sustained by geologically recent or ongoing hydrothermal activity.

3. Summary and Conclusions

Our results indicate hydrothermal reactions associated with a global-scale geoactivity that transports hydrothermal products from the core-mantle boundary up to the plume. Such high temperatures imply either that Enceladus formed shortly after the formation of the solar system or that the current activity was triggered by a recent heating event. In the case of a chemically closed system (scenario 1) hydrogen production would proceed efficiently, which could provide habitable environments for chemoautotrophic life. In the case of a chemically open system (scenario 2) steep gradients, not only in temperature but also in pH and composition of dissolved species, would allow similar conditions as on alkaline hydrothermal sites on Earth (E.g., 'Lost City'). These sites do not only sustain life independent from the sun but are also considered to be good candidates where life first emerged on Earth [10].

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