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Enceladus' Geochemistry: When? Where?

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We consider further the suggestion by Matson et al. (2007) that the molecular nitrogen, methane, acetylene and small organic molecules observed in Enceladus' South pole geyser by the Cassini mission (Waite et al. 2006; Hansen et al. 2006) result from high-temperature hydrothermal conditions. Temperatures between 575 K and 850 K are required for ammonia to decompose into molecular nitrogen. For temperatures lower 850 K, catalysts are necessary. The formation of methane from CO or CO_2 takes place between 350 and 610 K (Fiebig 2004). Acetylene can be formed by cracking longer chain hydrocarbons. All these reactions can occur at relatively low temperatures in the presence of the appropriate catalysts.

Thermal evolution models can be used to constrain the periods when temperatures were sufficient to enable these reactions. Models of Enceladus (Castillo et al. 2007) including live ^{26}Al and ^{60}Fe are the only models proposed so far in which (a) differentiation completed and, (b) temperatures inside the core can reach the hydrated silicate melting point, between 900 and 1100

K. During the first My after accretion complete melting of the ice is achieved. During that period, hydrothermal alteration of the silicate phase results in the production of a core made of hydrated silicate and the release of salts in the liquid phase (Kargel 1991). Different scenarios for the above reactions include: (1) interaction between the liquid layer and the core after differentiation took place; (2) and reaction in the water trapped within the hydrated silicate phase. In the first case the entire liquid volume circulates more or less deeply inside the core. The maximum temperature that the core reaches is a function of the liquid penetration depth. Throughout the entire core the temperatures can be suitable for most of the above reactions to take place. Ammonia decomposition and the Fischer-Tropsch reactions can take place at superficial depths,

as observed in terrestrial hydrothermal vents (Giggenbach 1980; Yoshida 1984). In the second case the hydrated silicate phase traps about 15%wt. of the water. NH_3, CO, or CO_2 and other reactants are trapped in confined spaces. Thus the reactions take place within the hydrated silicate phase. The products can be released later when the temperature reaches the silicate melting point.

In both cases, clays and Cr, Ni, and Fe are natural catalysts available to facilitate the reactions (as is observed in terrestrial hydrothermal systems). Conditions are suitable for storing all of the products as clathrate hydrates in liquid water except for CO_2 (as suggested by Prieto- Ballesteros et al. 2005; see also Kieffer et al. 2006). It is thought that Enceladus does not shelter a global ocean, but only liquid pockets, one of them being located under the South pole (Nimmo and Pappalardo 2006).

References

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