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Laboratory Experiments on Earth and Detection of Organics by Cassini

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Observations of Enceladus have shown water jets expelling from the surface. These jets originate from a subsurface ocean and formed Saturn's E-ring. Further observations of the plumes have led to the consensus that Enceladus likely holds a porous chondritic mineralogy, hydrothermal environments, and several building blocks necessary for the formation of life (e.g., HCN, NH3, CO2). Numerous research has documented the viability of synthesizing organic material in chondritic hydrothermal systems, which has given credence to life forming on chondritic ocean worlds. On Enceladus, a freezing phase is likely to occur during cycling at an overlying icy shell interface. As demonstrated by Miyakawa et al. (2002), this freezing phase is equally valuable in forming organic material. Aromatic hydrocarbon structures and amines have been investigated within Enceladean ice grains. However, no previous experiment has attempted to explain these organics or how a hydrothermal freeze cycle could affect chemical evolution and variety. Furthermore, previous experiments neglected abundant concentrations of phosphate (1-20 mM) which were recently calculated from geochemical modeling and surveying Type III (salt-rich) ice grains. Our research aims to simulate possible geochemical cycling scenarios within Enceladus and to identify organic compounds and processes that could exist within its ocean by laboratory analog experiments. We also plan to determine the role of phosphate in this organic synthesis.

We subjected mixtures similar in compositions revealed by Cassini to several temperature ranges, pH ranges, and maximum pressures thought to exist within Enceladus within a Au/Ti pressure vessel. During heating, sampling was taken in 24-hour intervals and stored at 4 °C until analysis. Afterwards, samples were frozen in temperatures and time periods ranging from -20 to -40 °C and 2 days to ≥8 weeks respectively. Cycling continued until neglectful sample amounts were left. Analysis was conducted through HPLC, UPLC, H1-NMR, P31-NMR, IC, and LILBID-MS.

Preliminary results showed a temperature-dependent darkening of solution and the formation of a wide array of amino acids (notably serine, histidine, glycine and alanine) and other organic compounds aligning with predicted pathways. HPLC indicated potential Strecker-cyanohydrin synthesis during long-term freeze phases from the formation of glycine and a peak that aligned with Histidine's standard. Phosphate concentration and identity stayed consistent through all reactions. Thus, detection of phosphorus in a from other than orthophosphate or phosphite may be indicative of biological activity. LILBID-MS confirmed the detection of most HPLC amino acids (glycine, alanine, aspartate, and serine); however, some results were heavily impacted by Na+ and K+ concentrations. Additionally, some laboratory LILBID organic peaks aligned cautiously well with Type II (organic rich) spectra peaks from Cassini, yet Cassini's spectra could also be due to fragmentation of benzene or other carbon molecules. In future studies, we plan to incorporate a mineral phase consisting of chondrite relevant material and modify starting reactant concentrations to minimize the effects of positive salt ions on organic detection.

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