MECHANISMS FOR ENRICHMENT OF ORGANICS IN THE ENCELADUS PLUME. M. L. Cable[1], F. Postberg[2], S. Q. Lang[3], L. Aluwihare[4], J. Huber[5], B. Clark[6], L. J. Spilker[1] and J. I. Lunine[7], [1]NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA (Morgan.L.Cable@jpl.nasa.gov), [2]University of Heidelberg, Germany, [3]University of South Carolina, Columbia, SC, [4]University of California, San Diego, CA, [5]Marine Biological Laboratory, Woods Hole, MA, [6]Space Sciences Institute, Boulder, CO, [7]Cornell University, Ithaca, NY.

Introduction: Enceladus is the sixth largest moon of Saturn. Like several moons in the outer solar system, it maintains a global liquid water ocean underneath an icy crust [1]. Unlike any of the others, though, this ocean is accessible without the need to dig or drill. In 2005, Cassini discovered a plume emanating from over one hundred jets in the south polar terrain of Enceladus [2]. In situ measurements by the Ion and Neutral Mass Spectrometer (INMS) and the Cosmic Dust Analyzer (CDA) confirmed that the plume is sourced from the subsurface ocean [3,4]. Detection of organic molecules in the plume [5], along with strong evidence of hydrothermal activity [6,7], make Enceladus arguably one of the prime targets to search for life.

The CDA team recently reported the discovery of highly complex organic material in approximately 3% of the ice grains of the Enceladus plume [8]. This organic material is comprised of aliphatic and aromatic species with molecular masses exceeding 200 u. Importantly, the organic fraction of these grains is on the percent level. What processes might lead to organic enrichment in these plume particles, or in the ocean itself? We suggest here several mechanisms that might explain the presence of high molecular weight organics at high concentrations in the Enceladus plume.

Sea spray aerosols: Ice clouds generated by sea spray aerosols (also called atmospheric marine aerosol) in the polar regions of the Earth generate ice particles enriched in organic material. Wind stress leads to the bursting of air bubbles at the sea-surface microlayer, which is a layer of organic material floating on the ocean surface [9]. Sub-micron sea spray aerosol generated in this process is enriched in organic material, with enrichment factors varying from 10-1000.

On Enceladus, the insoluble, high molecular weight organic material could be present in a similar boundary layer at the water-ice interface. Bubbles bursting from this boundary layer could generate aerosols in the plume that would be enriched in organic material, as described by Postberg et al. [9].

Anoxic conditions: Evidence suggests that organic matter is degraded much more slowly in the absence of molecular oxygen. In homogeneous sediment deposits in the northeast Atlantic Ocean, which had a clear 'oxidation front', samples in the oxygen-poor layer had significantly more organic material. The introduction of oxygen about 10 kyr ago destroyed about 80% of the organics in that layer, which had survived for about 140 kyr prior to that exposure [10].

On Enceladus, the high pH of the ocean and lack of sulfate-bearing clusters in the plume both indicate the absence of strong oxidants such as O_2 in the ocean [11]. Any enrichment of organics in the ocean due to anoxic conditions would be reflected in ice grains in the plume.

Nutrient accumulation: Smaller bodies of water on Earth, where the area-to-volume ratio is more favorable for nutrient accumulation, often become biologically saturated. High levels of organic stasis may be achieved by any anabolic metabolism as long as the rate of production outweights the rates of destruction/degradation and dilution. Submarine hydrothermal vents such as Lost City boast high biological loads, even though their soluble products are rapidly dispersed by dilution and thermally-driven currents [12]. In laboratory liquid culture experiments, high concentrations of metabolic products are also achieved in the equilibrium following the point at which a culture reaches the stationary phase.

The ocean of Enceladus is smaller in volume than those of other ocean worlds such as Europa. Given the presence of hydrothermal energy and organic molecules, nutrient accumulation could reach saturation and also lead to enrichment of organics in the plume.

Conclusions: The unusual enrichment of high molecular weight organics in the Enceladus plume may be due to one or several mechanisms. A future mission to this tantalizing moon may reveal the answer.

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