

SURVIVAL OF ORGANIC MATERIALS IN ANCIENT CRYOVOLCANICALLY-PRODUCED HALITE CRYSTALS. M. Zolensky¹, M. Fries¹, Q. H.-S. Chan¹, Y. Kebukawa², R. Bodnar³, A. Burton¹, M. Callahan⁴, A. Steele⁵, S. Sandford⁶. ¹ARES, NASA JSC, Houston, TX 77058, USA (michael.e.zolensky @nasa.gov); ²Yokohama National University, Yokohama 240-8501, Japan; ³Virginia Tech, Blacksburg, VA 24061, USA; ⁴NASA GSFC, Greenbelt, MD 20771, USA, ⁵Geophysical Lab., Washington, DC 20015, USA; ⁶NASA ARC, Moffett Field, CA 94035, USA.

Introduction: Spectroscopic evidence supports the presence of Mg-Na-K salts derived from cryovolcanism on the surface of Europa [1]. Halite (NaCl) is effective at very long-term preservation of organic phases and structures [2,3]. Collection of salt crystals from European plumes would provide solid inclusions of organics, potentially also biomaterials, all suitable for analysis.

Two thermally-metamorphosed ordinary chondrite regolith breccias (Monahans 1998 (H5) and Zag (H3-6)) contain fluid and solid inclusion-bearing halite crystals [4-6], dated to ~4.5 billion years [4,5,7,8], and thus the trapped aqueous fluids and solids are at least as old. Heating/freezing studies of the aqueous fluid inclusions in these halites [4] demonstrated that they were trapped near 25°C, and their continued presence in the halite grains requires that their incorporation into the H chondrite asteroid occurred after that body's metamorphism ended, since heating would have desiccated the halite [4]. O and H isotopes of the trapped fluids are consistent with mixing of asteroidal and cometary water [9].

Cryovolcanic Origin of the Halite: We hypothesize that these meteoritic halites derive from ancient cryovolcanism [10] based on the following points. (1) Salts crystals are observed as products of current cryovolcanism on Enceladus [11]. (2) In-situ spacecraft analysis of some of the icy grains associated with the Enceladus salt found minor organic or siliceous components [12,13], including methane, also found in the Monahans halite. (3) Cryovolcanic fluids are observed to be in chemical disequilibrium, reflecting incomplete reactions between interior volatiles and rocky materials [14]. The coexistence of N₂ and HCN in Enceladus' cryovolcanic fluids requires that the plume consists of a mixture of materials whose sources experienced different degrees of aqueous processing, including primordial material trapped in ice that has not been in contact with liquid water. The observed mineral assemblage within the Monahans and Zag halites is also far from equilibrium [15]. Cryovolcanoes on Ceres are a potential source of our halite [16], however the processes that form halite should also be operating within Europa.

Dissolution of Monahans halite grains has revealed a remarkable variety of organics, which dominate the population of solid inclusions. Thermal alteration of this macromolecular carbon (measured by Raman spectroscopy [16,17]) shows remarkable diversity [16]. We have identified highly-condensed aromatics, diamond, carbonates and chloromethane. Light organic compounds

like methane tend to be water soluble and require cold formation temperatures at high hydrogen fugacity – i.e. require water ice. Another indication that these halites have not been heated is that light organics readily volatilize or aromaticize into PAHs. We are currently analyzing the organics by Raman and C-XANES, and measuring the content and exploring the potential chirality of amino acids in the halite.

Implications for Europa Plumes: Organic materials and structures erupted by a Europa cryovolcano should be similarly preserved within halite, and other salts, which will be a convenient form for capture and analysis, since halite will serve to encapsulate and protect the organics from spacecraft contamination. Also, being transparent at many wavelengths halite will permit analysis by spacecraft-mounted spectroscopic techniques. In addition, halite is readily dissolved, permitting further analysis of entrained organics.

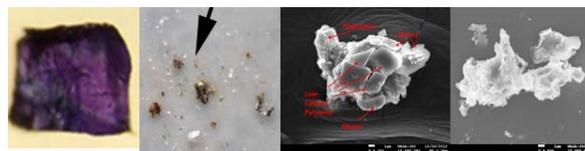


Figure 1. From left to right: Monahans halite measuring 1 mm; Residue from dissolution of this halite crystal, arrow indicates small grain in the next image; IDP-like grain from residue with major inorganic phases indicated, set within an organic matrix; a residue grain consisting entirely of carbonaceous material.

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