SALTY BENNU: HALITE AND SYLVITE IN FINES RETURNED BY OSIRIS-REx. N. E. Timms[1], W. D. A. Rickard[2], J. J. Barnes[3], P. A. Bland[1], D. W. Saxey[1], F. Jourdan[1,2], S. M. Reddy[1], C. Mayers[2], X. Sun[2], T. Ireland[4], A. N. Nguyen[5], P. Haenecour[3], M. S. Thompson[6], L. P. Keller[5], A. J. King[7], H. C. Connolly Jr.[3,8,9], and D. S. Lauretta[3], [1]Space Science and Technology Centre, School of Earth and Planetary Sciences, Curtin University, GPO Box U1987, Perth, WA 6845, Australia, [2]John de Laeter Centre, Curtin University, GPO Box U1987, Perth, WA 6845, Australia, [3]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, USA, [4]School of the Environment, University of Queensland, St Lucia, QLD 4072, Australia, [5]ARES, NASA JSC, Mail Code XI3, Houston, TX 77058, USA, [6]Department of Earth, Atmospheric and Planetary Sciences, Purdue University, West Lafayette, IN 47907-2051, USA, [7]Planetary Materials Group, Department of Earth Sciences, Natural History Museum, London, SW7 5BD, UK, [8]Department of Geology, Rowan University, Glassboro, NJ, USA; [9]Department of Earth and Planetary Science, American Museum of Natural History, New York, NY, USA.

Introduction: Salt phases such as halite (NaCl) and sylvite (KCl) are important hosts of halogens (e.g., Br and I) and volatile alkali metals (i.e., Na, K) and are very rare in extra-terrestrial materials. Halite and sylvite have been discovered in carbonaceous chondrite clasts in ordinary chondrite meteorite falls Zag H3-6 regolith breccia (Zag), Monahans (1998) breccia (Monahans), and Sidi El Habib H5 chondrite, as well as on the surface of particles from asteroid Itokawa [1–5]. Yet, it is uncertain whether the evaporites are indigenous or exogenous to their respective parent bodies, and their origin is debated [6–8]. Analysis of the extinct $^{129}I/^{129}Xe$ decay system and $^{40}Ar/^{39}Ar$ show that halite in Zag may have formed within the first 8 Myr of the solar system [6, 7], possibly from aqueous fluids during local and episodic low-temperature alteration on the parent body [8, 9]. Halite and sylvite in Zag are characterized by light $\delta^{37}Cl$ values of −1.7 ‰ [8]. Halite in Zag could have been transported from the outer solar system, perhaps a P- or D-class asteroid, as indicated by O, H, N, and C isotopes [10]. An alternative is a cometary or interstellar ice origin due to their deuterium-rich and ^{16}O-poor composition [9].

The rarity of salts in extraterrestrial materials makes them highly valuable targets for study and the range of possible origins makes them key to understanding the origin and evolution of halogens on primitive asteroids.

This study reports the presence of halite and sylvite in fine particles recovered from the OSIRIS-REx sample return capsule. Studying these evaporites has potential to test specific OSIRIS-REx mission hypotheses [11], such as whether the initial constituents of Bennu's parent asteroid were materials that were inherited from the protosolar molecular cloud or were formed and altered in the protoplanetary disk (Hypothesis 4.3), or whether heating of Bennu's parent asteroid resulted in hydrothermal alteration in which melted ice reacted with the initial constituents at 25-375˚C (Hypothesis 5.3).

Samples & Methods: Three 20 to 50 μm opaque grey particles (OREX-501070-0) were manually separated from 1 mg of aggregate fines for quick-look (QL) analysis and were mounted on a carbon tab and ion-milled parallel to the substrate using a focused ion beam (FIB) to reveal the particle interiors. A 5 nm evaporative carbon coat was applied before characterization via secondary electron (SE) and backscattered electron (BSE) imaging, electron backscatter diffraction (EBSD) and energy-dispersive spectroscopy (EDS) mapping, and time-of-flight secondary ion mass spectrometry (ToF-SIMS) mapping using facilities at Curtin University, Australia.

Results: A ~30 μm particle contains a central Ca-Mg-Fe-Ti-Al-bearing clinopyroxene. EBSD mapping shows that the pyroxene is a fractured fragment of a larger single crystal and does not preserve any shock deformation features. Surrounding the pyroxene are remnant patches of texturally heterogeneous, dark carbonaceous asteroid matrix material, which incorporate ovoid patches of organic material, 0.1 to 5 μm clasts of plagioclase, Fe-sulfide, halite and sylvite with various degrees of solid solution, and unidentified BSE bright nanophases.

Halite and sylvite occur as 1 to 4 μm angular fragments embedded within the carbonaceous matrix. Low-energy FIB-milling of a 2 × 4 μm surface of a halite-sylvite grain yields good EBSD patterns, indicating that it is highly crystalline, and EBSD mapping shows that the grain preserves ~5º of crystallographic disorientation around one of the <100>.

Discussion: The halite and sylvite are interpreted to be integral components of the Bennu sample assemblage, rather than terrestrial contamination, because they are embedded in the matrix. and represent This is the first discovery of evaporites in Bennu remote sensing or laboratory data. Their presence, depending on their abundance, may explain the higher abundance of halogens and alkalis in Bennu samples relative to CI chondrites [12]. However, the prevalence of halite and sylvite in the OSIRIS-REx samples remains to be seen.

The mixture of angular anhydrous silicates and evaporite mineral fragments within an organic-rich phyllosilicate matrix indicate that they are clasts within a parent breccia, with a provenance comprising both anhydrous and hydrated sources with heterogeneous evaporite compositions. The crystallographic distortion preserved by the analysed halite-sylvite clast is consistent with either accumulation of defects during crystal growth or {110}<110> dislocation slip [13] from impact-related deformation prior to incorporation of the clast into the breccia.

The small sizes of the evaporite grains in this study remains challenging for many in situ quantitative isotopic analytical techniques. Analysis of these grains using atom probe tomography (APT) are planned. The presence of halite and sylvite may shed light on whether the initial constituents of Bennu were inherited from the protosolar molecular cloud or formed and altered in the protoplanetary disk (Hypothesis 4.3), or possibly an indicator of hydrothermal alteration of Bennu's parent body (Hypothesis 5.3).

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