SPACE WEATHERING IN OSIRIS-REx SAMPLES FROM BENNU: IMPACT MELT DEPOSITS. L. P. Keller[1], M. S. Thompson[2], K. Thomas-Keprta[3], L. Le[4], Z. Rahman[4], L. B. Seifert[1], P. Haenecour[5], A. J. King[6], T. J. McCoy[7], T. J. Zega[5], H. C. Connolly Jr.[5,8,9], and D. S. Lauretta[5], [1]ARES, NASA JSC, Houston, TX, [2]Department of Earth, Atmospheric and Planetary Sciences, Purdue University, West Lafayette, IN, [3]Barrios Technology/Jacobs, NASA JSC, Houston, TX, [4]Jacobs, NASA JSC, Houston, TX, [5]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, [6]Natural History Museum, London, UK, [7]Smithsonian Institution, Washington, D.C., [8]Department of Geology, Rowan University, Glassboro, NJ, [9]Department of Earth and Planetary Science, American Museum of Natural History, New York, NY.

Introduction: Early analyses of regolith samples from asteroid Bennu delivered by the OSIRIS-REx spacecraft showed a mineralogy dominated by hydrated silicates, sulfides, magnetite, phosphates, and abundant organic matter, in addition to other minor/trace phases [1, 2]. A major objective of the sample analysis campaign is to understand the nature and extent of space weathering processes recorded by returned samples from Bennu. Here we report our preliminary transmission electron microscope (TEM) observations of impact melt deposits on surfaces of Bennu sample particles.

Samples and Methods: A scanning electron microscopy (SEM) search revealed areas of vesicular impact melt on the surface of particle OREX-501017-0, and a larger area of impact melt on OREX-803080-0 (Fig. 1). We prepared an electron transparent cross section through each of the melt deposits on OREX-501017-0 by focused ion beam (FIB) milling. The first FIB section is OREX-501017-100 and the second is OREX-501017-101. The FIB sections were extracted using the FEI Quanta3D FIB at JSC and were analyzed using the JEOL 2500SE scanning and transmission electron microscope (STEM) equipped with a JEOL 60 mm^2 thin window silicon drift detector for energy-dispersive X-ray (EDX) analyses.

Results and Discussion: The first melt deposit is a vesiculated smooth deposit that extends across the surface for ~8 µm (Fig. 2). The melt is an amorphous silicate with inclusions of Fe-metal/FeNi sulfides. The sulfide inclusions in the melt are widely dispersed, circular in cross section, and are typically ~ 10-50 nm in size. Some of the circular inclusions are eutectic melts with Fe metal cores surrounded by FeS rims. The larger sulfide inclusions within the silicate glass are flattened parallel to the particle surface. Large (~500 nm) vesicles occur at the base of the melt deposit. In addition, there is a thin layer of small ~50 nm vesicles at the interface between the melt and the substrate particle. We hypothesize that the large vesicles were made by water evolved from underlying phyllosilicates, whereas the layer of smaller vesicles may be related to evolved solar wind gases [3]. On the right edge of the melt, the FeNi sulfide and Fe metal have crystallized into the melt. X-ray mapping shows that the melt is homogeneous but that it contains more Fe and is Ca-rich compared to the substrate material. However, the bulk chemical composition of the melt deposit is within error of solar (CI) for major elements except S which is depleted by ~50%.

The second melt deposit contains two different textures and compositions (Fig. 3). The left portion of the melt is a crystalline mixture of FeNi sulfide and Fe metal, while the right portion is a silicate melt with Fe-sulfide and Fe metal inclusions and large vesicles. The uppermost (~10 nm) surface of the Fe/FeNiS deposit is S-depleted and enriched in N (Fig. 4), likely in the form of Fe-nitride (cubic Fe_4N roaldite). A similar Fe-nitride layer was observed on a Ryugu magnetite grain [4]. The nitride layer likely formed via reaction of the Fe metal surface with indigenous NH_3 detected by [5]. Solar wind damage is recorded in the region of the particle between the two melt deposits [3]. The inclusions in the silicate deposit show two sizes and there is a 200 nm wide band of nanophase inclusions near the upper surface of the silicate melt. The bulk chemical composition of the combined Fe/FeS-rich and silicate rich melts is also within error of solar (CI) for major elements, except S, which is depleted by ~50%.

Both bulk melt deposit compositions are ~solar but are more Ca and Fe-rich than the underlying material, suggesting that the source impact(s) for these melts homogenized a large volume of material. The impact(s) incorporated more Ca- and Fe-bearing materials, such as carbonates and magnetite/Fe sulfides, than are present in the underlying substrates.

Conclusions: The melt deposits formed by an impact large enough to produce an ~solar composition melt. The presence of nanophase inclusions of Fe metal and FeNi sulfides are known to contribute to modified optical properties of carbonaceous chondrite samples in terms of spectral slope, darkening, and attenuated absorption features [6].

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References: [1] Zega T. *et al*. (2024) this vol. [2] Thomas-Keprta K. *et al*. (2024) this vol. [3] Thompson M. S. et al. (2024) this vol. [4] Matsumoto T. (2023) *Nat. Astron.* doi.org/10.1038/s41550-023-02137-z. [5] Clemett S. J. (2024) this vol. [6] Thompson M. S. et al. (2020) *Icarus* 346, doi: 10.1016/j.icarus.2020.113775.

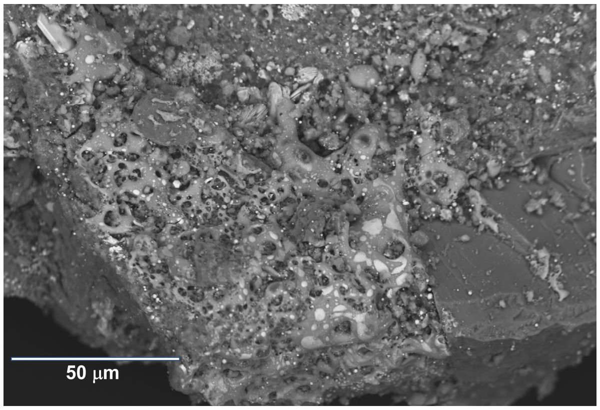

Figure 1. SEM image of a large area of melt deposited on the surface of OREX-803080-0.

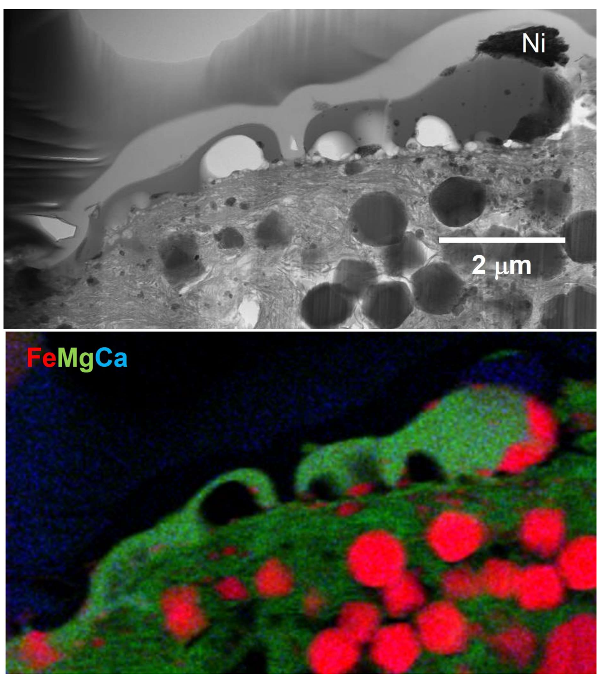

Figure 2. A brightfield STEM image from melt deposit in OREX-501017-100 (top) and a RGB (FeMgCa) composite (bottom). The pure Ni metal grain on top of the deposit (“Ni”) is a likely contaminant.

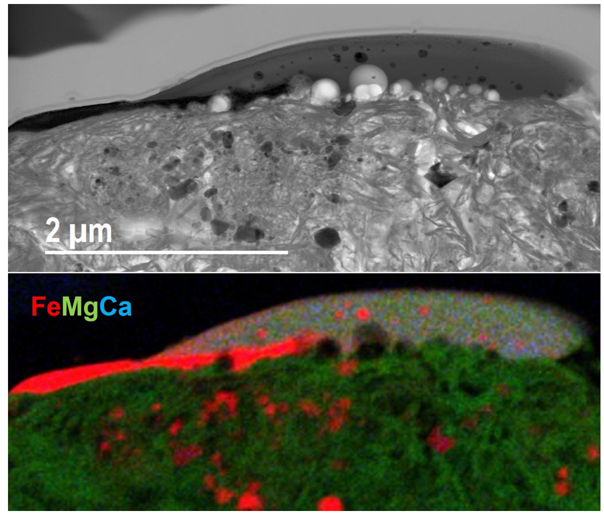

Figure 3. A brightfield STEM image from a melt deposit in OREX-501017-101 (top) and a RGB (FeMgCa) composite (bottom). The silicate melt partly overlies the Fe/FeS deposit.

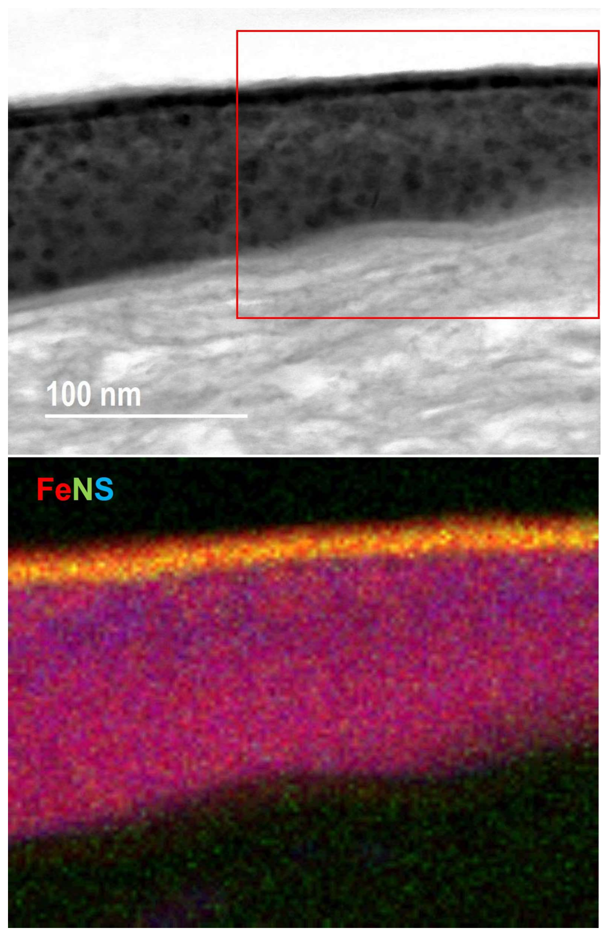

Figure 4. Brightfield STEM image of the Fe/FeS melt in OREX-501017-101 (top). The area in the red box was mapped and the RGB (FeNS) composite (bottom) shows the thin Fe-nitride layer.