IDENTIFYING SOLAR WIND AND OTHER VOLATILES IN SPACE-WEATHERED SAMPLES FROM ASTEROID BENNU. M. S. Thompson[1], L. P. Keller[2], K. Thomas-Keprta[3], L. Le[4], Z. Rahman[4], L. B. Seifert[2], 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]Department of Earth, Atmospheric and Planetary Sciences, Purdue University, West Lafayette, IN (mthompson@purdue.edu), [2]ARES, NASA JSC, Houston, TX, [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: On September 24, 2023, NASA's Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) mission returned >70 g of material from asteroid Bennu to Earth [1]. The Sample Return Capsule was opened at NASA Johnson Space Center (JSC), and a spillover sample was collected from the avionics deck to perform quick-look (QL) analyses [2]. In addition to providing a reconnaissance investigation of its mineralogy, the sample was also examined for evidence of surface exposure on asteroid Bennu by identifying signatures of space weathering.

Space weathering changes the morphology, microstructure, and chemistry of regolith on the surfaces of airless bodies. Driven by micrometeoroid bombardment and solar wind irradiation, our understanding of how space weathering modifies particles on the surfaces of carbonaceous asteroids is still developing. To bolster the interpretation of remote sensing data and to further address driving Hypothesis 10, we must investigate the nanoscale structural and chemical changes in returned samples from Bennu to understand how space weathering affects carbonaceous surface materials. Here we explore evidence for solar wind irradiation in QL samples from asteroid Bennu.

Samples and Methods: Intermediate (100 to 500 µm) particles from sample OREX-501017-0 were transferred to C-tape on a scanning electron microscopy (SEM) mount for examination in the JEOL 7900F SEM at JSC [3]. Melt splashes attributed to micrometeoroid bombardment were identified on the surface of one of the particles (Fig. 1a) [4]. As this particle was likely exposed on the surface of Bennu, it was also targeted for analysis to identify evidence of solar wind irradiation. Electron transparent thin sections from both melt splashes [4] and a region between these features were prepared via focused ion beam (FIB) milling using the FEI Quanta 3D FIB at JSC (Fig. 1a). The FIB section extracted from the surface between the melt splashes (OREX-501017-102) was analyzed using the JEOL 2500SE scanning and transmission electron microscope (STEM) at JSC equipped with a thin window silicon drift detector (SDD) for energy-dispersive X-ray spectroscopy (EDS) analyses. We will also analyze the sample using the aberration-corrected, monochromated Thermo Themis STEM at Purdue University, equipped with a Super-X EDS system and a Gatan Quantum 965 electron energy-loss spectrometer (EELS).

Results and Discussion: Sample OREX-501017-102 is predominantly composed of phyllosilicates, which have a fluffy, porous, and uncompacted texture throughout most of the section (Fig. 1b). There are also abundant Fe-Ni-sulfides, magnetite, and carbonates dispersed throughout the FIB section. At the surface, there is a layer of material that is less porous than the bulk phyllosilicates and predominantly amorphous (Fig. 1c). This layer ranges in thickness from 50-150 nm and, in some regions, there appears to be an accumulation of defects, possible precursors to vesicles. The texture and thickness of this layer is reminiscent of low-fluence experiments simulating H^+ and He^+ irradiation of carbonaceous chondrites [5], and smooth layers in Ryugu samples attributed to solar wind irradiation [6]. In addition, there are nanophase (<5 nm) Fe-sulfide particles distributed throughout the compacted surface layer (Fig. 1d) which may be indigenous to the sample, or a result of space weathering via solar wind.

Quantitative chemical maps reveal a chemically distinct rim at the surface of the compacted layer. There is a 10 nm-thick layer enriched in Mg and Al at the outermost surface, which also exhibits Si depletion (Fig. 2). This rim is underlain by lenses of Si enrichment that are depleted in Mg. This nanoscale chemical heterogeneity is a known effect of solar wind irradiation and may be driven by radiation-enhanced diffusion (RED) or segregation (RIS), recoil implantation, or sputtering [5,6].

Conclusions and Future Work: The effects of solar wind space weathering have been identified in samples from Bennu. We will continue to characterize these samples and intend to measure solar wind (H, He) and other volatile species (OH) using STEM EELS.

Acknowledgments: Supported by NASA under Contract NNM10AA11C issued through the New Frontiers Program.

References: [1] Lauretta D. S. et al. (2023) AGU. [2] Zega T. et al. (2024) this vol. [3] Thomas-Keprta K. et al. (2024) this vol. [4] Keller L. P. et al. (2024) this vol. [5] Laczniak D. L. et al. (2023) *Icarus 410,* 115883. [6] Noguchi T. et al. (2023) *Nat. Astron. 7*, 170.

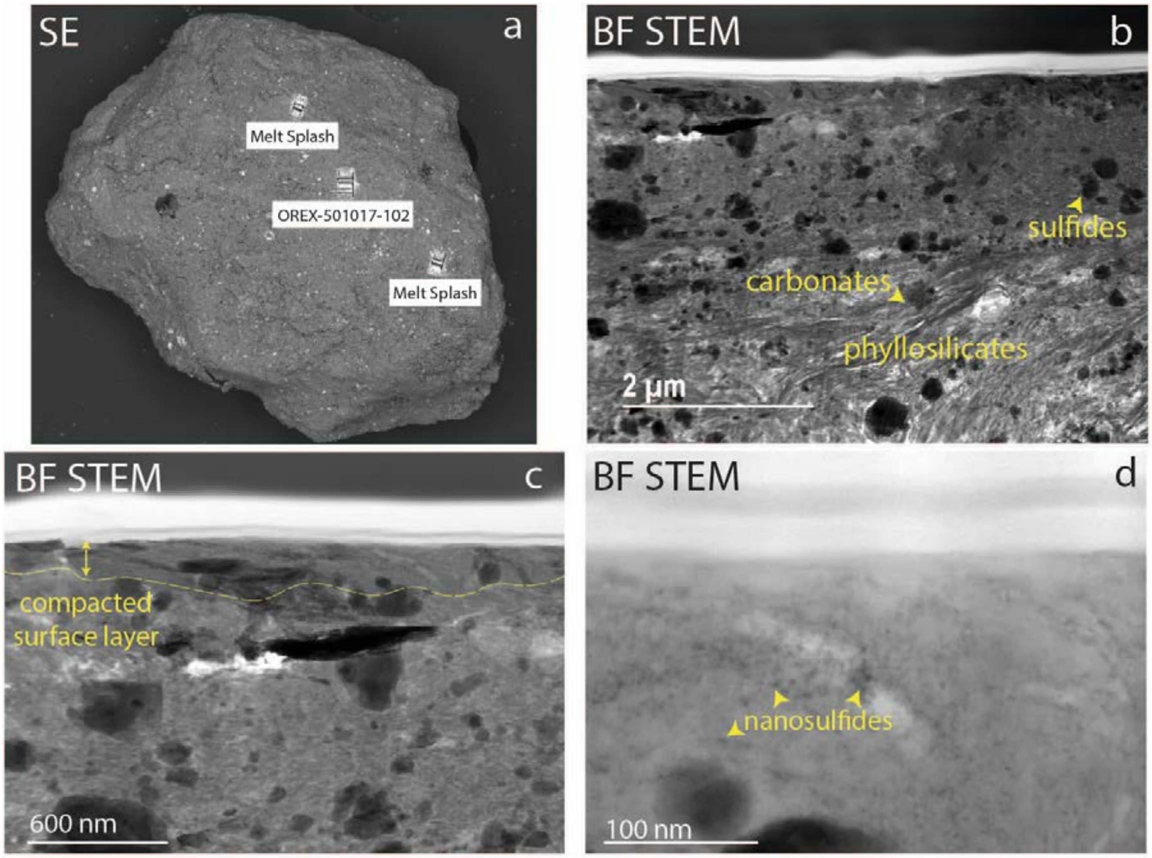

Figure 1: a) SE image showing location of FIB sections extracted from space exposed surface on particle, b) BF STEM image showing mineralogy and texture of the FIB section, c) BF STEM image showing the compacted surface layer attributed to solar wind irradiation, and d) BF STEM image showing nanosulfide inclusions in the surface layer.

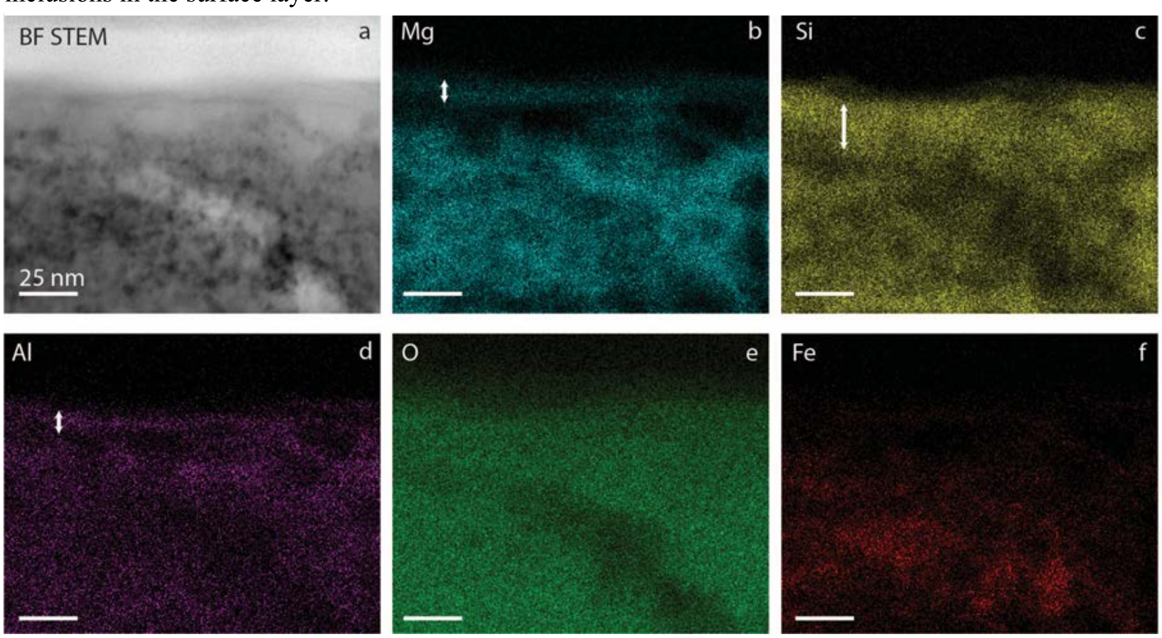

Figure 2: EDS data for solar wind irradiated surface of the sample showing a) BF STEM, b) Mg, c) Si, d) Al, e) O, and f) Fe. White arrows indicate zones of enrichment or depletion.