MORPHOLOGICAL COMPARISON BETWEEN RETURNED SAMPLE PARTICLES AND BOULDERS OF ASTEROID BENNU. K. Ishimaru, D. S. Lauretta, H. C. Connolly Jr., A. J. Ryan, R.-L. Boylouz, R. J. Macke, C. D. Schultz, J. Aebersold, and E. H. Blumenfeld; Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA. (kana@arizona.edu) 2Department of Geology, Rowan University, Glassboro, NJ, USA. 3Department of Earth and Planetary Science, American Museum of Natural History, New York, NY, USA. 4Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA. 5Vatican Observatory, V-00120 Vatican City-State, 6Department of Earth, Environmental & Planetary Sciences, Brown University, Providence, RI, USA. 7LZ Technology-JETS contract, NASA JSC, Houston, TX, USA.

Introduction: NASA’s OSIRIS-REx mission returned rock samples from asteroid Bennu on September 24, 2023 [1]. The samples appear to consist of multiple lithologies on the basis of morphology and brightness, as predicted by the remote sensing studies.

Remote sensing of Bennu’s surface revealed that most boulders larger than 5 m can be categorized into two populations—dark boulders and comparably bright boulders—based on their reflectance, morphology, and thermal properties [2,3,4]. Dark boulders have normal reflectance ranging from 3.4 % to 4.9 %, with the mode at 4.5 % [2] (Types A and B in [4]). Their surfaces are rough, especially Type A, where a hummocky texture often results from embedded clasts. Bright boulders have normal reflectance ranging from 4.9 % to 7.4 %, with the mode at 5.5 % [2] (Types C and D in [4]). They are smoother and angular, particularly Type C. Bright boulders are estimated to have higher thermal inertia than the dark boulders, which corresponds to lower porosity and higher tensile strength.

In this work, we test the hypothesis that the dark and bright boulder populations identified by remote sensing are represented in the sample [5] by describing the morphology of particles in the returned sample and comparing them to those of surface boulders. Similar fracturing patterns are seen in the returned sample and surface boulders. Therefore, fractures will be analyzed to investigate whether their pattern varies with lithologies.

Data and Methods: Approximately 70 g of the returned sample was placed in four trays and imaged by Advanced Imaging and Visualization of Astromaterials (AIVA) camera system at NASA’s Johnson Space Center in October 2023 (image resolution ~1.6 µm/pix). Selected AIVA images were used to morphologically characterize the returned sample. Selected images of the boulders used for visual comparison in this work were obtained by the OCAMS PolyCam imager from March 2019 to May 2020 (Detailed Survey and Reconnaissance mission phases) [6], and their pixel scale is 2 mm/pix – 6 cm/pix.

For fracture analysis, we plan to use data from X-ray computed tomography and structured light scanning to map the fractures on the exterior and interior of the particles as well as to measure their angles and length. Fractures in boulders will be analyzed with the PolyCam images and shape models obtained by the OSIRIS-REx Laser Altimeter.

Results and Discussion: The returned samples have a size range from fine particles to pebbles up to 35.3 mm in the longest dimension. They overall appear very dark, which was expected from Bennu’s low global reflectance of 4.4 ± 0.2 % [7]. They show variation in angularity, surface roughness, and abundance and colors of inclusions. Therefore, we preliminarily classified the particles into three candidate lithologies. We focused on particles larger than about 5 mm (127 particles) because they exhibit the surface texture more clearly.

Angular candidate lithology: These stones are very dark and characterized by their angular to subangular shape and smooth surfaces. Some of them have a shiny, oily luster on some faces.

Hummocky candidate lithology: These stones are also very dark and have rough—hummocky, cauliflower-like, and knobby—surfaces. Their angularity is subangular to subrounded. Some include visible clasts.

Mottled candidate lithology: These stones are brighter in visible light than those described above and have distinct colors: white, bluish gray, and brown. Their angularity ranges from rounded to subangular.

Although reflectance data of each stone are not yet available, there are some visible characteristics that returned sample particles and boulders share (also discussed in [8]). Particles of the angular candidate lithology have angular shapes and smooth surfaces in common with brighter Bennu boulders (especially Type C; note that “brighter” Bennu boulders are still very dark, with normal reflectance of 4.9 % to 7.4 %). Meanwhile, the hummocky candidate lithology could be related to dark Bennu boulders (particularly Type A) because of their rough and hummocky surfaces. Bright materials in the mottled candidate lithology could be linked to high-reflectance materials observed in some boulders [9]. In addition, some millimeter- to centimeter-sized particles exhibit fracturing patterns similar to those of meter-sized boulders on the asteroid surface. This fractal behavior will be investigated as described in the Data and Methods section. Investigating how the returned samples are related to boulders based on morphology adds more geologic context to the samples and other sample analysis work.
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