THE GEOLOGY OF BENNU'S BIGGEST BOULDERS. Erica R. Jawin[1], Kevin J. Walsh[2], Olivier S. Barnouin[3], Tim J. McCoy[1], Ron-L. Ballouz[4], Jamie L. Molaro[5], Marco Delbo[6], Maurizio Pajola[7], Dante S. Lauretta[4], Michael C. Nolan[4], Keara N. Burke[4], Carina A. Bennett[4], Dani N. DellaGiustina[4], Harold C. Connolly, Jr.[8], Michael G. Daly[9], and the OSIRIS-REx Team. [1]Smithsonian National Museum of Natural History, Washington, DC, USA (jawine@si.edu), [2]Southwest Research Institute, Boulder, CO, USA, [3]Applied Physics Laboratory, Laurel, MD, USA, [4]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA, [5]Planetary Science Institute, [6]UNS-CNRS-Obs. de la Côte d'Azur, Laboratoire Lagrange, Nice, France, [7]INAF-Astronomical Observatory of Padova, Italy, [8]Dept. of Geology, Rowan University, Glassboro, NJ, USA, Centre for Research in Earth and Space Science, York University, Toronto, Canada,.

Introduction: The asteroid (101995) Bennu is a B-type near-Earth asteroid and the target of the OSIRIS-REx sample return mission [1]. Preliminary analyses of Bennu suggest it is a rubble pile asteroid with a diverse geologic history including large impact craters, linear features, and boulders [2] (**Figure 1A**).

Measured boulder diameters on the surface of Bennu include objects up to ~90 m diameter [3, 4]. This abstract assesses the geologic characteristics of the largest boulders on Bennu (>30 m diameter) including their distribution, morphology, and geologic context, focusing on the largest two boulders. Analyses of these large boulders allow us to (1) probe the origin and evolution of large boulders on Bennu, (2) determine how surface transport of fine-grained materials has affected (and been affected by) large boulders, and (3) make inferences about the interior structure of Bennu.

Data: The analyses were performed using PolyCam images as well as topography data derived from stereophotoclinometry (SPC) [5] within the Small Body Mapping Tool [6]. Panchromatic PolyCam data was acquired at a scale of ~33 cm/pixel during the approach phase. Resolution will increase dramatically during the Detailed Survey phase of the OSIRIS-REx mission (~5 cm/pix) [7].

Observations: There are nine boulders >30 m on the surface of Bennu that are visible with current images [3, 4]. All the boulders are located in the mid-latitudes (20-60°), and all except one are in the southern hemisphere.

Boulder 1, the first boulder identified. The first boulder to be identified on Bennu from Earth-based data [9] is also visible in the PolyCam images (we refer to it as Boulder 1, **Figure 1A**). Located at 128° E, 44° S, Boulder 1 is notable based on its large diameter, ~50 m [3, 4], and because it protrudes off the surface of Bennu by ~30 m with a visible overhanging portion. The surface texture of this boulder appears fine-grained with no visible particles or clasts, although at least two distinct surface textures are present, including a smooth and a hummocky section (solid arrows, **Figure 1B**). A large fracture is also evident (dashed arrow, **Figure 1B**).

The northern portion of Boulder 1 appears to have an irregular texture and is adjacent to a deposit of fine-grained material at the base of the rock. The fine-grained material may have formed due to erosion via exfoliation of the rock surface [9].

Boulder 2, the largest potential boulder. The largest potential boulder on the surface of Bennu is partly buried (and may in fact be an outcrop of a larger structural unit; in this abstract we assume it is a boulder and refer to it as Boulder 2, **Figure 1C**). The exposed portion of Boulder 2 has an observed diameter of ~90 m [4]. It is distinct from Boulder 1 in its reflectance, surface texture, and aspect ratio: Boulder 2 has a mean geometric albedo of 0.034±0.02, while Boulder 1 is closer to the average surface of Bennu (~0.042) [10-12]. In addition to its low albedo, Boulder 2 appears flatter, more hummocky, and less angular than Boulder 1. Boulder 2 also contains several fractures oriented approximately N-S that appear smaller than the large fracture in Boulder 1, more similar to other fractured boulders observed elsewhere on Bennu [9, 13].

Boulder 2 protrudes off the surface of Bennu ~10-20 m. However, its relief is less pronounced than that of Boulder 1 because the southern portion of the boulder appears to be buried. The northern face of Boulder 2, however, remains at least partly exposed (**Figure 1C**).

The northern hemisphere boulder. Only one boulder >30 m diameter has been identified on Bennu in the northern hemisphere. This boulder is highly fractured and extends off the surface. It may also be partly buried, similar to Boulder 2, although the northern hemisphere boulder does not have the same vertical relief off the surface of Bennu as Boulder 1 or Boulder 2.

Interpretations: *Origin of large boulders.* There is diversity in the geology of the largest boulders on Bennu: Boulders 1 and 2, the two largest boulders presently visible on the surface, do not appear to be of the same lithology based on variations in albedo, surface texture, and fracture characteristics. Both boulders may be too large to have been excavated by impacts on Bennu [14], suggesting that the formation of these boulders predated the formation of Bennu from the fragmentation of its parent body. In addition, the large fracture in Boulder 1 has no evidence of associated mass wasting, suggesting it may have formed before reaching its current location on the surface of Bennu. If the formation of this large fracture pre-dated the formation of

Bennu, it may represent layering within the original rock on the parent body or evidence of strain on the body before fragmentation.

The diversity in Boulders 1 and 2 suggests the Bennu progenitor may have been a compositionally diverse body with distinct lithologies which mixed after fragmentation and formation of Bennu. Conversely, the boulder diversity could indicate a distinction between remnants of the Bennu parent body and the impactor.

Mass movement and boulders. Boulders 1 and 2 both lie on the surface; however, a portion of Boulder 2 may have been buried extensively via the movement of smaller rocks northward. Boulder 2 may have protruded off the surface as much as Boulder 1 in the past; if so, ~10-20 m of material may have accumulated on the southern flanks of Boulder 2. The lack of burial of the northern face of Boulder 2 suggests that material did not flow southward in this region, which agrees with slope maps of Bennu [15]. In addition, the presence of Boulder 2 may have blocked sediment flow, therefore causing a buildup of material on its southern flank.

Conversely, the entirety of Boulder 2 may have been buried, and the northern face has become exhumed, leaving the southern portion buried. Similarly, Boulder 1 may have been buried in the past, similar to Boulder 2, and it may have become exhumed through the winnowing of fines away from its edges. In this case, surface deflation of several meters may have occurred to exhume the ~30-m-tall boulder.

Interior structure. If these large boulders originated at the surface of Bennu and Boulder 2 has been buried by several tens of meters of material, this may suggest that objects travel randomly across the surface and interior of rubble pile asteroids, with no grain size dependence with depth, especially on small rubble piles where the ratio between boulder size and the size of the asteroid is large. The addition of higher-resolution images, topography, and spectra in the coming months will provide abundant information about these large boulders and will aid in the interpretation of their origin and evolution on the surface of Bennu.

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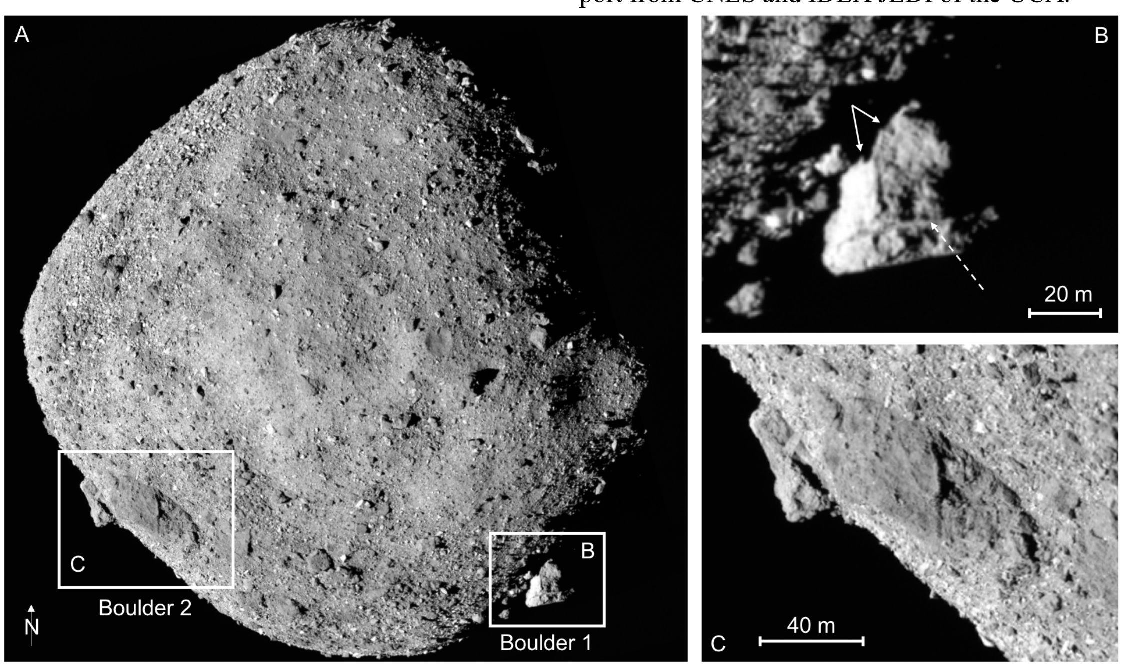

Figure 1. (**A**) Bennu mosaic of PolyCam images from December 2, 2018. (**B**) Boulder 1. Solid arrows indicate textural differences (smooth and hummocky), dashed arrow indicates linear through-going fracture. (**C**) Boulder 2. The visible face (NE-facing) of the boulder is exposed, while the far side (SW-facing) is buried.