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Introduction: The near-Earth Asteroid (101955) Bennu is currently being visited and surveyed by NASA's OSIRIS-Rex sample return mission. Building a global geologic map of its surface is a primary mission objective, as it helps to guide the sample-site selection process and provides important context to aid in analysis of the returned sample. It is also a valuable opportunity to help understand the history of this rubble pile asteroid, which will provide valuable insight into the evolution of the Solar System.

The global survey of the asteroid will be done with a powerful arsenal of imagers and spectrometers [1]. The analysis presented here relies heavily on global imaging done during the Approach and Preliminary Survey phases of the mission where imaging resolutions approached 30cm/pixel. We also combined this analysis with the shape and mass measurements, providing a more comprehensive story of Bennu.

Shape: Bennu has a "top" shape (i.e., a spheroidal shape with an equatorial bulge), as measured previously by radar ranging and delay-doppler observations [2] and confirmed with the first resolved imaging from OSIRIS-REx [3,4]. This shape is quite common, especially among rapidly rotating near-Earth asteroids, and particularly those with known orbiting satellites [5]. The near-Earth asteroid Ryugu also displays a similar top-shape as observed by the Hayabusa2 sample return space mission [6].

The origin of this shape is not yet understood, but hypotheses include surface failure and flow [7,8,9,10], internal failure and uplift [11], in-falling of satellites and pieces of satellites [12], and as part of the asteroid's formation via reaccumulation from a larger asteroid's ejecta fragments [13]. Searching for geologic expression of these various processes is an important aspect of these investigations.

Craters: Large candidate craters are found superposed on the equatorial regions of Bennu [14], suggesting that the formation of this ridge by re-shaping or other processes pre-date the craters (see Figure 1). The largest craters exceed 100 meters in diameter. Crater scaling laws (often used for larger and more coherent bodies) [15] combined with crater production functions derived for asteroids in the Main Asteroid Belt [16] suggests a surface age of 150 – 750 Ma.

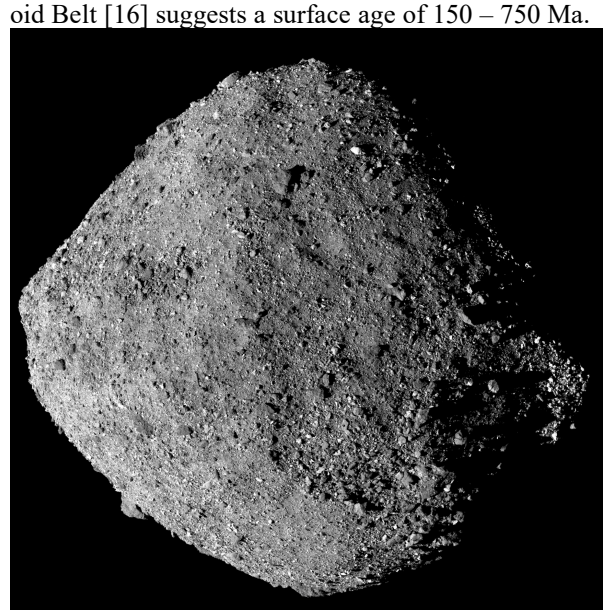

Figure 1: A mosaic of images of Bennu taken by the PolyCam instrument on OSIRIS-REx on December 2, 2018. Note the large crater candidate on the right side of the image just south of the equator.

Linear Features: The northern hemisphere of Bennu has a series of topographic highs running longitudinally from near the north pole down towards the equator, but not crossing the equator [17]. There are regions of high boulder abundance between these topographic highs, and large craters that are quite apparent

between ridges. These large-scale features are found primarily in the northern hemisphere (see Figure 2).

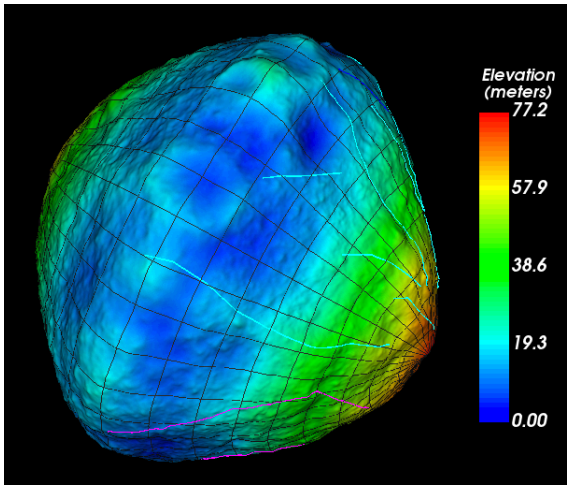

Figure 2: The geopotential altitude (meters) of the northern hemisphere of the shape of Bennu. The magenta lines outline a series of topographic highs that are candidate linear features.

Boulders: The boulder population on Bennu is diverse [18]. The notable observations include: (1) boulders approaching 50 m in length in the southern hemisphere that appear to be quite elevated above the surface [19,20]. (2) Boulders with a wide range of geometric albedos [4]. (3) Numerous boulders with through-going and spiderweb-like fracture patterns [21,22]. (4) Boulders with polymict or brecciated appearance on meter lengthscales [23]. (5) Piles of boulders that appear to possibly be disaggregated polymict or brecciated boulders. (6) Several regions of Bennu, typically topographic lows, that are nearly completely covered with meter and larger sized boulders.

Regolith: Current viewing geometry and range does not permit observations that can directly resolve centimeter-size particles. Inferences about the regolith from the current data rely on either the quantified lack of resolvable boulders, or dynamic aspects of the surface—finding evidence of mass movement on higher dynamical sloped regions [18].

Notably, some of the smaller crater candidates, with diameters around or below 20m, show a significant lack of boulders relative to their surroundings. This trait alone makes them good candidates for locations of smaller grains.

A region of Bennu stretching from the equator to -40° latitude and spanning nearly 30° of longitude is vastly more abundant in boulders than its surrounding region, and is also located in a topographic low. On the steeper slopes in this region, boulders show signs of runup of smaller material on their uphill sides, and piling of unresolvable material behind the larger boulders.

Conclusions: Bennu's shape and surface appear to be old with numerous large craters on its equatorial ridge. On shorter lengthscales there appear to be erasure and erosive processes moving material and removing geomorphologic signatures of smaller craters. The boulder population is diverse in morphology and shows a heterogenous distribution, pointing to a variety of interesting surface processes to create, move, and degrade them.

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