EPSC Abstracts
Vol. 13, EPSC-DPS2019-962-1, 2019
EPSC-DPS Joint Meeting 2019
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EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Are the brighter rocks on Bennu products of recent mechanical weathering, and therefore less space-weathered?

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1. Abstract

Our hypothesis is that the higher-albedo rocks on the surface of Bennu are products of thermal/mechanical weathering. If this suggestion is correct, then the higher albedo (~7–15%) of some rocks relative to the average background on Bennu (~4.5%) could be explained by their relatively fresh surfaces. Older rocks on Bennu would then be the darkest rocks—those that have experienced the most space weathering over time due to exposure to the space environment. Thermal/mechanical weathering (cracking of rocks) is a candidate mechanism for the particle ejection events observed to occur with regular frequency from the asteroid surface [1,2].

2. Size-Frequency Distribution

DellaGiustina & Emery [3] showed that the rocks on Bennu can be divided into two populations with separate power-law size-frequency distributions:

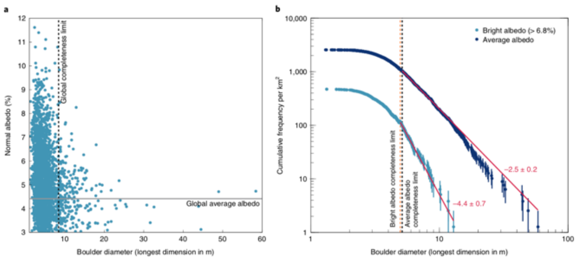

Figure 1: Reproduced from DellaGiustina & Emery [3] this figure shows boulders on Bennu: (a) albedo vs. size and (b) cumulative size distribution for rocks with bright albedo (>6.8%) (light blue), and average albedo (dark blue).

The higher-albedo boulders on Bennu (those with radiance factor (I/F, RADF) at normal geometry greater than 6.8%), show a cumulative size-frequency distribution (CSFD) slope of –4.4 ± 0.07, with a longest dimension of about 11 meters. The remaining boulders on Bennu show a CSFD of –2.5 ± 0.2 with a longest dimension of about 60 meters (see **Figure 1**). These data suggest that their formation scenarios differ [3]. However, the large boulders on Bennu seem to show a continuum in brightness from a low of 3% to highs of ~12-15% (**Figure 1a**). A bi-modal distribution is not observed for these large boulders. This suggests that many of the rocks on Bennu (bright and dark) could have the same original composition, but exhibit different amounts of total optical alteration due to space weathering.

3. Surface Processes

There are several competing mechanisms for resurfacing processes on small bodies: a) impacts and crater erasure by subsequent seismic shaking [4]; b) mass movement created by rotational acceleration (and subsequent geoid) due to YORP [5], c) micrometeorite impacts, d) thermally induced surface degradation [6], d) solar wind ion implantation, and now f) particle ejection and re-impact [1,2]. We are evaluating whether the particle ejection events could contribute to the resurfacing on Bennu.

4. Timescales for Bennu's Orbit

Bottke et al. [7] integrated the equations of motion of a large number of asteroids from their potential source regions in the main belt and observed which of them reached the current orbits of each known NEA. Using this model, we trace the average time that Bennu's orbit had a perihelion < 1 AU, and find it to be 7.9 Myr [7]. It is possible that the particle ejection events on Bennu are driven by a thermal mechanical weathering mechanism that is linked to solar heating [8]. If this is true, then the particle ejection events on Bennu may have acted for about ~8 Myr; the time Bennu's perihelion was < 1 AU.

5. Bright Rocks

We suggest that mechanical weathering may operate preferentially on smaller boulders, and further decrease their size over time. This could explain why the brighter rocks found on Bennu tend to be smaller on average than darker rocks that occur with the same frequency. In **Figure 2** we show an example of a small, bright, smoother rock (towards the upper right) perched on top of a big, darker boulder.

Figure 2: A 17m boulder on Bennu at approximately lon. 100E, lat. +20 shows an example of a smaller bright rock on top of a dark boulder. See Rizk et al. [10].

6. Space Weathering

We know that space weathering processes occur on asteroid surfaces and change the optical properties of a thin top layer over time [11]. With some success, these alteration processes have been simulated in the laboratory [12]. In particular, the experiments reported by Thompson et al. [13] suggest that the high volatile and water content of carbonaceous materials produce vesiculated textures, both in the matrix of the substrate, and in the re-condensed phases. On many Solar System bodies, space weathering tends to darken and redden exposed material over time. We suggest that the large darker boulder in **Figure 2** is an example of the highly space-weathered end-product boulder type on Bennu, and its perched guest (small brighter rock) is an example of a recently exposed fresh surface.

7. Tests of This Hypothesis:

We will report on the following tests of this hypothesis:

1. Search for transitional examples: there should be rocks showing both the advanced space-weathered texture on the outside, and a brighter less weathered texture on freshly exposed faces.
2. Take a complete OVIRS census of the bright rocks: Bright rocks should differ from dark rocks in albedo and color patterns, similar to what we observed at Eros, Itokawa, or Ryugu.
3. Examine the returned samples: Higher-albedo material should have lower cosmic ray exposure ages.
4. Examine particle ejection event sites: There should be more bright rocks at an event site than dark boulders.
5. Measure lightcurves of short-lived orbiting objects: The particles should have a fresh, bright side and a weathered, dark side if they were once part of a pre-existing rock on Bennu.
6. Examine the OSIRIS-REx touch-and-go sampler divot on Bennu: subsurface material should be brighter than surface material.

Acknowledgements

This material is based upon work supported by NASA under Contract NNM10AA11C issued through the New Frontiers Program. M. Delbo acknowledges support from the Centre National d'Études Spatiales, and Academies of Excellence on Complex Systems and Space, Environment, Risk and Resilience of the Initiative d'EXcellence 'Joint, Excellent, and Dynamic Initiative' (IDEX JEDI) of the Université Côte d'Azur.

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