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The appearance and size-frequency distribution of candidate impact craters on (101955) Bennu

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Abstract

We present new observations of Bennu's candidate crater population, derived from images and lidar data acquired during the spring and summer of 2019. In addition to an updated size-frequency distribution, these data demonstrate a spectrum of crater morphologies, which are correlated with size and location on the asteroid. We provide preliminary analysis to explain the appearance of the candidate craters, with implications for Bennu's physical properties and age.

1. Introduction

The OSIRIS-REx spacecraft approached asteroid (101955) Bennu in the late summer and fall of 2018, and began official proximity operations in December 2018 [1]. In March of 2019, the spacecraft collected a series of observations with its sophisticated suite of remote sensing instruments, including images taken by the OCAMS visible imagers [2] that achieve pixel scales as fine as 2 cm/pix, and lidar scans by the OLA laser altimeter [3] that provide direct topographic measurements of the surface.

These increasing-fidelity data sets provide a rigorous means to investigate the distribution of surface features on Bennu, as well as their relationship to one another and to the overall asteroid shape. Bennu's candidate impact craters have several compelling characteristics that constrain Bennu's surface age [4], as well as its surface and sub-surface properties.

2. Observations

To date, observations of craters include:

(i) The candidate craters are distributed across the surface, though with an apparent concentration of more distinct craters along the equator or at low latitudes. Because the equator is a region of near equipotential, compared with the mid-latitudes, this may indicate that classical crater features are better preserved in regions (such as the equator) with lower average slope and geopotential. The spatial distribution of undegraded craters may be an important signature of regolith mobility on Bennu and a measure of the conditions that lead to mobility.

(ii) Some candidate craters are expressed in elevation (which is related to gravity and rotation) and geometric 3D space (i.e., depressions in the asteroid shape), whereas others are expressed only in 3D space. One candidate crater is expressed only as an annular ring of boulders. This diversity, and characteristics such as depth-to-diameter ratios [5], are crucial to understanding the formation and evolution of craters in the rubble-pile structure of Bennu, as well as Bennu's structure in terms of porosity and impact strength.

(iii) The candidate crater population may reach saturation at the largest diameters [6], indicating that the global shape of Bennu is old [1,4,6], and may date to Bennu's accretion as a rubble pile.

(iv) Extrapolation of the large crater population to smaller diameters predicts many more craters than seen at small sizes, i.e. small craters are underabundant. This could be due to erosional effects [e.g. 7], formation effects [8], or both.

(v) There is a fascinating transition in crater morphology at approximately 20 m diameter. The floors of craters greater than 20 m diameter have similar, or even enhanced, boulder abundance relative to the surrounding terrain. In contrast, the floor of craters less than 20 m diameter are generally rock-free and appear to have a greater abundance of finer-grained material (Figure 1). The correlation between the dominance of finer particles and smaller crater sizes suggests that there is a near-subsurface layer, perhaps up to a few meters deep, of finer-grained material. Because finer-grained material is more easily lost to space, or recirculated into the subsurface, these regions could be younger than other parts of the surface.

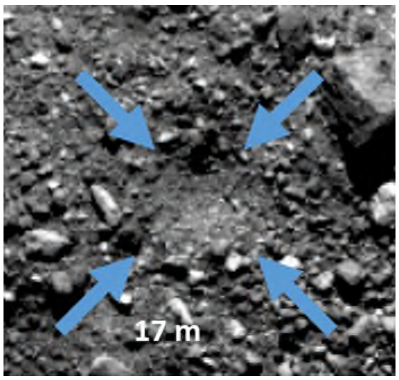

Figure 1. A 17-m-diameter crater illustrating the contrast between the smooth interior of the crater, and the rougher surface outside the crater.

(vi) The latest, high-resolution images provide evidence of a population of craters that may be generated by the low-speed re-impact of rocks. Like other small craters, these features express a smoother (finer-grained) interior. In addition, they have a neighboring rock, of comparable size to the crater itself, that may be the object that formed the crater (Figure 2). Further work will quantify differences between these craters and other small craters to determine whether, in fact, slow-speed impact of boulders are the formation mechanism.

3. Summary

Collectively, these observations suggest complex interplays among the crater formation process and Bennu's rubble-pile structure [9], the evolution of material on the surface, and the re-accumulation of slow-speed ejecta from a primary impact or other ejection mechanism.

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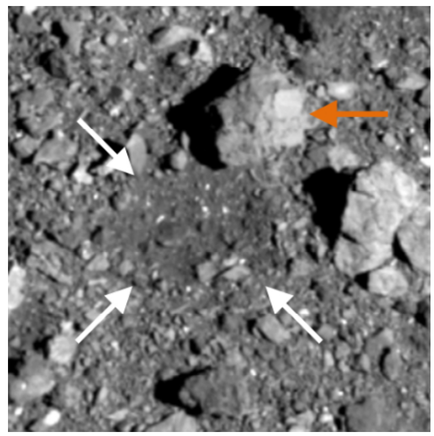

Figure 2. An example of a shallow, crater-like circular feature (white arrows) next to a boulder (orange arrow). The boulder is about 5 m across.

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