EPSC Abstracts
Vol. 13, EPSC-DPS2019-263-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

The preliminary depths and diameters of impact crater candidates on the asteroid Bennu

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Abstract

Bennu has multiple candidate impact craters (henceforth called impact craters) on its surface [1]. These impact craters inform our understanding of Bennu by constraining the physical properties of the surface, the age of the surface, and the processes that have shaped Bennu into its present state. We use data from OSIRIS-REx to characterize the depths and diameters of impact craters on Bennu.

1. Introduction

The morphometry of impact craters on asteroids has primarily focused on depth, *d*, and diameter, *D*, with particular attention on the depth-to-diameter ratio, *d/D* [2,3]. On Eros, *d/D* is typically ~0.13 [3]. Craters on Itokawa are even shallower, with a d/D of 0.08 ± 0.03 [2]. Simple craters on the terrestrial planets typically have larger *d/D* ratios (e.g., ~0.2 for simple craters on the Moon [4]). The *d/D* can provide clues to crater formation, collapse, target properties, crater scaling, degradation, and resurfacing [e.g., 4–8].

2. Methods

For this study, we used regional DTMs derived from the version 20 Bennu shape model, which was developed using stereophotoclinometry [9]. The pixels in the DTMs have a 44-cm ground-sample distance. In places with sufficient coverage by data from the OSIRIS-REx Laser Altimeter (OLA), the SPC DTMs have RMS height errors of ~45 cm (1 sigma) relative to OLA. Each DTM has many maplets (stereo points) across its surface. After creating the regional DTMs, we extracted topographic profiles at eight different azimuths. The rim-to-rim diameter and rim-to-floor depth were determined along each profile. The eight profiles were averaged to compute the rim-to-rim diameter, rim-to-floor depth, and *d/D* for each crater. In addition, we mapped the circumference of the craters in the DTMs and defined a best-fit plane to the crater rim. The maximum depth in this zone provided a second estimate of crater depth.

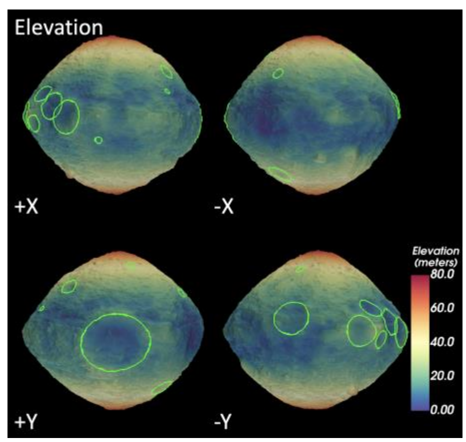

Figure 1: Views along four of the principal axes of the version 20 highest-resolution shape model of Bennu. Facets are colored by elevation. Green ellipses mark the crater candidates used in this study.

The irregular shapes and morphologies of impact crater candidates on Bennu pose challenges. We omitted profiles that passed through obvious boulders or depressions on the rim (although it is possible that these features were emplaced during crater formation). In addition, several of the craters adjoin mound-like features or occur on slopes (Fig. 2). Finally, the biggest craters are large relative to the size of Bennu (up to ~160 m in diameter), and surface curvature may influence the measurements. These factors further complicate depth and diameter measurements.

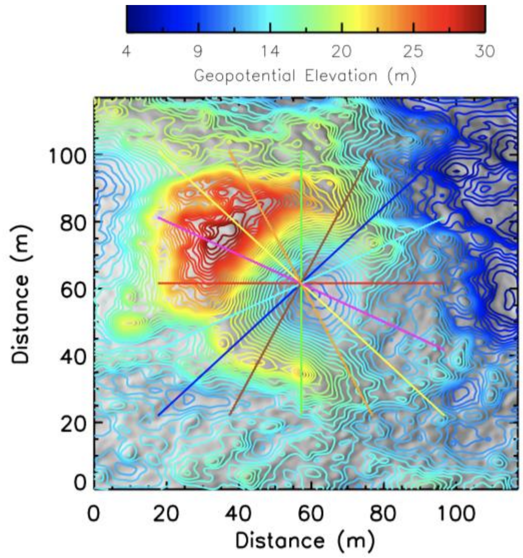

Figure 2. Regional DTM of a crater a 4.1°S 126.2°E contoured by elevation. This crater is on a slope. The crater rim is also fairly wide. We assume that the rim is at the highest point of the thickened annulus.

3. Results

Profile-based and plane-based methods gave similar results. Measuring crater depth based on elevation in the SPC-based DTMs led to a wide range of *d/D* ratios from ~0.6 to 0.25. Craters of similar sizes exhibit a fairly large range in *d/D* (Fig. 3). The largest crater measured is also the shallowest; d/D typically decreases with increasing crater size.

A crater located at 13.6° N, 124.7° E has good coverage with data collected by OLA. OLA data give similar results for the *d/D* of this crater (e.g., 0.13 ± 0.03 from OLA vs. 0.14 ± 0.02 from SPC DTMs). This similarity indicates that the *d/D* ratios measured using the SPC DTMs are accurate.

4. Discussion and Conclusions

Cratering on Bennu occurs in a challenging regime for impact cratering studies: gravity is very weak, target strength is low but poorly known, target porosity is high, and the target is very coarse and boulder-rich [10].

Most craters on Bennu are shallower than those on the terrestrial planets, consistent with results from Itokawa [2] and Eros [3]. The large variation in *d/D* for craters of a similar size is intriguing. It may be a consequence of impacts into coarse-grained targets [11], but other factors may also be at work, including crater degradation, regional variations in target properties, rapid changes in target strength with depth, and/or changes in the spin rate of Bennu through time. The additional data returned by OSIRIS-REx over the next year will provide the information needed to assess how the interplay of impact variables and Bennu's geophysical evolution have led to the cratering record observed today.

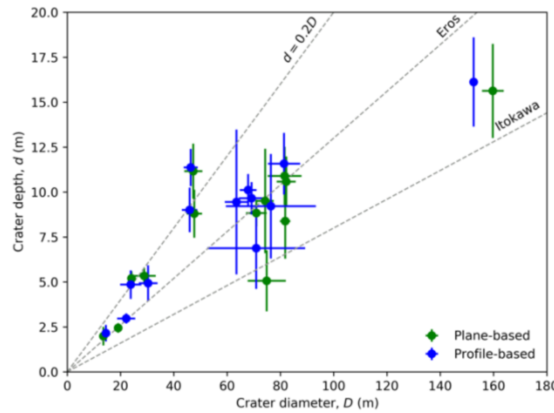

Figure 3. Depths and diameters of high-confidence impact crater candidates on Bennu measured based on the plane method (green) and profile method (blue). Dashed lines show *d/D* trends for other bodies. Uncertainties due to azimuthal variations around the crater (shown as error bars) are caused by the rubble-rich surface of Bennu and dwarf uncertainties in the DTMs themselves.

Acknowledgements

This material is based on work supported by NASA under Contract NNM10AA11C issued through the New Frontiers Program.

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