THE CRATER MORPHOMETRY OF (101955) BENNU FROM THE OSIRIS-REX MISSION. R. T. Daly¹, E. B. Bierhaus², O. S. Barnouin³, H. C. M. Susorney⁴, C. L. Johnson⁴, C. M. Ernst¹, E. Palmer⁴, B. Gaskell⁴, J. Weirich⁴, M. Daly⁵, K. Walsh⁶, D. S. Lauretta⁷, and the OSIRIS-REx Team. ¹The Johns Hopkins Univ. Applied Physics Laboratory, Laurel, MD, USA (olivier.barnouin@jhuapl.edu); ²Lockheed Martin Space Systems Company, Denver, CO, USA; ³Department of Earth, Ocean and Atmospheric Sciences, Univ. of British Columbia, Vancouver, Canada; ⁴Planetary Science Institute, Tucson, AZ, USA; ⁵The Centre for Research in Earth and Space Science, York Univ., Toronto, Ontario, Canada; ⁶SWRI, Boulder CO; ⁷Lunar Planetary Laboratory, Univ. of Arizona, Tucson, AZ, USA.

Introduction: The Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) spacecraft encountered the asteroid (101955) Bennu in late 2018. Bennu has multiple crater-like features on the surface [1]. In this study, we discuss preliminary measurements of the depth/diameter of impact crater candidates on Bennu. For simplicity, we refer to these candidates as impact craters hereafter.

The morphometry of impact craters on asteroids has primarily focused on the depth, d, and diameter, D, with particular attention on the depth-to-diameter ratio, d/D [2,3]. On both Eros and Itokawa, craters tend to be shallower than on terrestrial planets. On Eros, the 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., 4–6]. For example, the d/D of craters on Eros increases with distance from the large, young Shoemaker crater, a change that has been interpreted as evidence that seismic shaking reduced the depths of craters [7].

Method: We selected a handful of craters identified by [1] for preliminary morphometric analysis (Fig. 1).

![Figure 1](image1.png)

**Figure 1.** Locations of analyzed craters. Craters are labeled with preliminary identifiers based on Bierhaus_crater_list_v3 (e.g., BeV304 is crater #4).

First, we created stereophotoclinoimetry (SPC)–derived regional digital terrain models (DTMs) centered on each crater. For this preliminary study, we used regional DTMs with a 50-cm ground-sample distance that were derived from the 12/17/18 Gaskell shape model. After creating the regional DTMs, we extracted topographic profiles across each crater at eight different azimuths. The rim-to-rim diameter and rim-to-floor depth were determined along each profile. The measurements from 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 used this to define a best-fit plane to the crater rim. The maximum depth in this zone provided a second estimate of crater depth. We computed depth in two ways. The first used the geometric shape of the crater; the second was based on elevation (i.e., heights relative to a geoid). The latter method accounts for the effect of gravity on crater topography.

The irregular shapes and morphologies of impact crater candidates on Bennu pose challenges to morphometric analysis. We omitted profiles that passed through obvious boulders or depressions on the rim (although it is possible that these features were emplaced syn-impact). In addition, several of the craters adjoin mound-like features or occur on slopes (Fig. 2). These factors further complicate depth and diameter measurements. Finally, the craters used in the preliminary study can be quite large relative to the size of Bennu (up to160 m in diameter), which means that the curvature of the body may influence the measurements.

![Figure 2](image2.png)

**Figure 2.** Regional DTM of crater BeV301 (4.1°S 126.2°E) contoured by geometric height. This crater is on a slope. The crater rim is also fairly wide. We assume that the rim is located at the highest point. However, we cannot rule out the possibility that the rim is actually at the inner edge of the thickened region.
We report uncertainties in depth and diameter measurements by taking the standard deviation of the diameters and depths measured from the eight profiles for profile-based measurements or using the standard deviation associated with the plane fit to the crater rim for plane-based measurements. Therefore, the uncertainties reported here reflect the irregular crater morphologies. This natural variation exceeds the errors determined by comparing the shape model to OSIRIS-REx laser altimeter returns (see Barnouin et al., this meeting).

**Results (Figures 3 and 4):** Profile-based and plane-based methods gave comparable results; here we report the values from the profile-based method. Using geometric height to compute crater depth, we found an average $d/D$ of $0.13 \pm 0.03$. Measuring crater depth based on elevation led to larger values: an average $d/D$ of $0.16 \pm 0.03$. The largest crater measured is also the shallowest; $d/D$ typically decreases with increasing crater size.

![Figure 3](image3.png)  
*Figure 3. Topographic profiles across crater BeV309 with respect to geometric height (top) and geopotential elevation (bottom). When viewed in terms of geometric height, this crater is asymmetric with a rough floor. The elevation reveals that this crater is on a slope, which may contribute to the crater’s asymmetry. (The orange profile was omitted due to the boulder on the crater rim.)*

**Discussion:** This preliminary analysis indicates that the $d/D$ of craters on Bennu is more similar to that of craters on Eros than to craters on Itokawa. In addition, the data suggest that craters on Bennu show a range of $d/D$ for a given crater diameter. Recent impact experiments into coarse, rubble-like targets have revealed similar behavior for the coarsest targets [8]. The larger $d/D$ of these few craters relative to Itokawa, for example, may be indicative of differences in target porosity. On Bennu, the combined macroporosity + microporosity could be as much as 70 vol.% (~40–50% macroporosity, plus 10–20% microporosity), and gravity is weak (~10$^{-6}$ g); thus, the impactor will penetrate a target substantially, but the crater might not collapse on itself. The implication would then be that a combination of target strength and porosity would control the cratering process. The morphometry of these craters, therefore, should be well represented by geometric height, not by height defined relative to the local gravitational field.

![Figure 4](image4.png)  
*Figure 4. Diameter vs. depth for the impact craters analyzed in this preliminary study. These data are derived from the topographic profiles. The depths measured with respect to elevation exceed those measured with respect to geometric height. Dashed lines indicate the trends for $d = 0.1D$ and $d = 0.2D$, respectively.*

However, we observe that the depths of profiles for a given crater are often more consistent with each other when based on elevation, especially for the largest crater. This may mean that the minute gravity on Bennu still influences the cratering process in a way that affects crater shape; maybe there is a late-stage, gravitation-dominated collapse process even on this small object.

**Future Work:** The quality of the Bennu shape model will increase as the mission progresses. We will refine our analysis as better models (including those that include laser altimetry data) become available, refine our treatment of large craters where the curvature of the body is significant, and include more impact craters.

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