MULTI-COMPONENT CLASSIFICATION OF BENNU'S BOULDERS: RESULTS FROM TOPOGRAPHIC VARIABILITY AND OLA REFLECTANCE. Francis Rossmann[1], M. Al Asad[1], C. L. Johnson[1,2], M. G. Daly[3], J. Seabrook[3], G. A. Neumann[4], E. R. Jawin[5], L. C. Philpott[1], H. C. M. Susorney[1], O. S. Barnouin[6], D. N. DellaGuistina[7], K. J. Walsh[8], B. Rizk[7], and D. S. Lauretta[7]. [1]Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, Canada, [2]Planetary Science Institute, Tucson, AZ, USA, [3]York University, Toronto, Ontario, Canada, [4]NASA GSFC, Greenbelt, MD, USA, [5]Natural History Museum, Smithsonian Institute, Washington, D.C., USA, [6]JHUAPL, Johns Hopkins Rd, Laurel, MD, [7]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ [8]Southwest Research Institute, Boulder, CO, USA.

Introduction: Images of the surface of asteroid (101955) Bennu suggest that surface boulders are heterogeneous in terms of their exposure age and/or their chemical composition [1,2]. Here, we investigate whether these differences can be quantified using properties derived from the OSIRIS-REx Laser Altimeter (OLA) [3] aboard NASA's OSIRIS-REx spacecraft. Jawin et al. [4] have used high-resolution images of Bennu's surface from the OSIRIS-REx Camera Suite (OCAMS) [2] to classify rocks and boulders into morphologically distinct groups based on visual image analysis. Different lithologies on the asteroid's surface are expected to weather and fracture differently in response to erosive processes (e.g. thermal forcing and micrometeorite bombardment) based on their physical and chemical compositions and their exposure age, resulting in potentially quantifiable differences in their surface morphologies. We quantify this using a metric that represents topographic variability [see Method section]. Furthermore, different physical (roughness) or chemical (composition) properties of these boulders are expected to produce differences in reflectance at 1064 nm, which are observable in OLA return intensity, as is seen in the map produced by [5]. We investigate five large boulders on the asteroid's surface using OLA-derived topographic variability and reflectance. Boulders in this study are among the largest on Bennu's surface; have broad, well-sampled surface areas; and, on the basis of surface properties in imagery, have been classified in [4]. We use unofficial, mission-colloquial boulder names throughout this abstract.

Data: Two of the examined boulders—which we colloquially call Roc (~150 m across) and Huginn (~75 m across)—are dark-toned, appear to have a hummocky texture and are classified as Type A by Jawin et al. [4]. Both Roc and Huginn are nearly completely buried and outcrop near the equator. The three remaining boulders, colloquially referred to as Benben (~85 m), Archaeopteryx (~55 m), and Gamayun (~25 m), appear to be relatively lighter-toned, smoother than the Roc and Huginn. These three units are also generally brighter and more angular than the aforementioned type, consistent with a Type B classification in [4]. OLA point clouds from the Orbital B phase [6,7] were self-registered [8] so that each point cloud has consistent position in the Bennu body-fixed reference frame. The point clouds were then combined for the regions surrounding five boulders/outcrops. OLA coverage for each region has a density of approximately 500 points per meter squared and spot size of approximately 6-7 cm.

Method: Point clouds for each of the five boulders and their surrounding regions are binned in latitude and longitude by approximately 0.5, 1 and 2 meters in linear dimension. This results in approximately 125, 500, and 2000 points per cell, respectively. For each cell, we remove the regional trend from the radial position by fitting and subtracting the best-fit plane from the subset of points contained in the cell. The standard deviation of the detrended points in each bin represents the local variability in geometric height at the length scale of each bin. We also take the mean value of the OLA reflectance in each cell. The topographic variability in each cell is dominated by the resolvable variations at scale lengths less than the bin size, and not by differences among the overlapping OLA scans which account for up to 2.5 cm in error [7]. Finally, we apply a polygonal mask to separate the properties of each boulder from the surrounding region. Here, we summarize the topographic variability results.

Results and Discussion: Figure 1 shows maps of topographic variability for the so-called Roc, Benben, Huginn, Archaeopteryx, and Gamayun boulders at a length scale of 0.5 meters. Boulder edges are identified by high variability, similar to the results seen in global surface roughness maps [9]. Both Roc and Huginn are partially buried, outcropping boulders and their edges are poorly resolved. At the 0.5 and 1 meter length scales, the hummocky boulders show a lower mean variability than the more competent, angular, smooth units, but exhibit spatial variations across the boulder, once sharp edges are removed (not shown in Figure 1). Archaeopteryx and Gamayun show a more spatially uniform variability across the boulders with few high relief edges. Benben shows a similar texture along smooth planes, interjected by angular step-like features which are resolved as areas of high standard deviation.

Figure 2 shows histograms of topographic variability over the 0.5 meter length scale for each of the five boulders, with relative probability in the vertical axis. At the 0.5 meter length scale, the distributions for Type A boulders, Roc and Huginn, are similar and show a lower mode than the other three boulders. Gamayun and Archaeopteryx show a similar distribution shape, while the distribution for Benben exhibits a relatively longer right tail and lower mode. At the 1 meter length scale, the distributions for Benben, Archaeopteryx and Gamayun appear have similar modes, with Roc and Huginn having lower modal values. For both the 0.5 and 1 meter length scale, the mode of each distribution appears to group roughly with boulder class [3]. At the 2 meter scale, there is no discernible relationship between boulder morphologies and probability density estimates of topographic variability. We interpret this behavior as consistent with Type 2 boulders being more competent and able to maintain sharp edges and topographies of differing length scales. This could be a result of metamorphism, dehydration history, or thermal history in the parent body. Therefore, examination of the results from different instruments is required to determine the cause or causes.

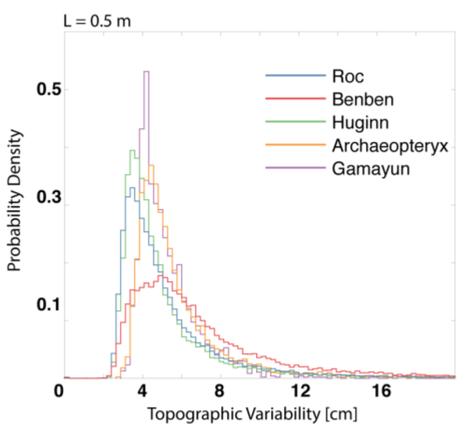

Figure 2:Histograms of topographic variability within the polygonal boundary of each boulder, at the 0.5 meter length scale. The histogram is normalized by the total number of bins covering the boulder, so that the vertical axis is probability density.

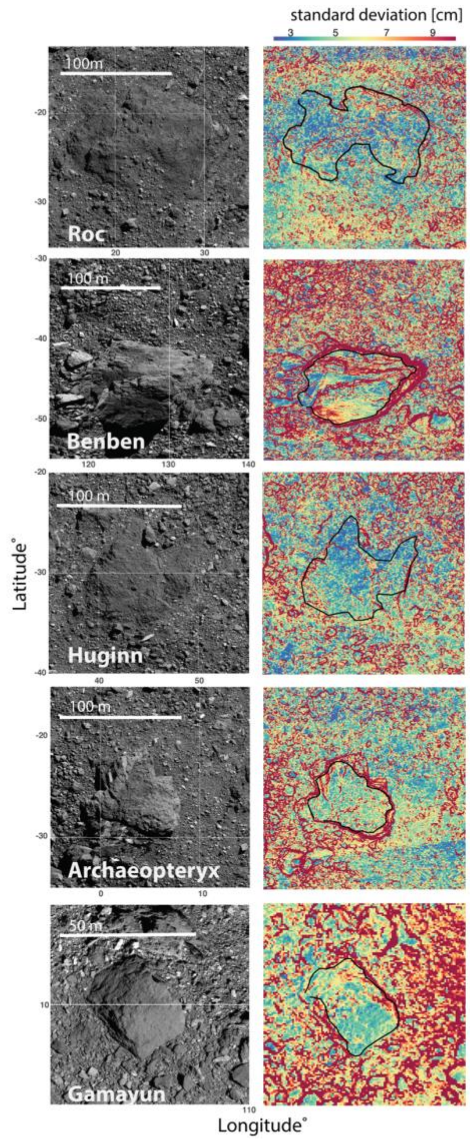

Figure 1: Boulders are arranged per row, where the left column shows OCAMS imagery of the region taken from the mosaic produced from Detailed Survey phase (Flybys 3, 4, 5, and 6). Morphological differences among boulders are observed, with Roc and Huginn showing a dark, clastic, hummocky texture, and Benben, Archaeopteryx, and Gamayun showing a lighter and a more angular texture [3]. The right column show maps of topographic variability for each region at the 0.5 meter length scale.

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