Apparently Layered Boulders with Multiple Textures on Bennu's Surface

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The OSIRIS-REx mission is exploring asteroid (101955) Bennu, carbonaceous near-Earth asteroid whose surface is covered with boulders of various sizes larger than 50 m [1]. Bennu is a top-shaped, rubble-pile asteroid with diameter of about 500 m [2]. Because of its small size, the collisional lifetime of Bennu is much shorter than the age of the solar system [3]. It is probably a fragment of a larger "parent-body" asteroid with diameter of approximately 100 km [4]. The OSIRIS-REx Camera Suite (OCAMS) [5] provided high-resolution images (<2 cm/pix) of the surface of Bennu. Some boulders appear to have layering in multiple, distinct units demarcated by different textures [6]. The layer-like texture might have formed by parent-body processing [1, 7]. In this work, layered boulders on the asteroid surface were identified and categorized by texture and average normal albedo. We offer two hypotheses about how the apparent layering could have originated in the parent body.

We used OSIRIS-REx Laser Altimeter (OLA) altimetry data and PolyCam images with a scale of ~1.5 cm/pix in the Small Body Mapping Tool (SBMT) [8]. The images typically had phase angles between 30 and 50°, and our search was up to 80° north or south latitudes. The total search explored ~80% of the entire surface of the asteroid under similar illumination and pixel scale.

Identifying layered boulders with multiple textures: SBMT [8] was used to examine the surface by projecting images onto a shape model. Fourteen boulders were identified as apparently layered boulders with multiple textures. We selected three large boulders (Figure 1) that show clear variations in texture for detailed photogeological analysis.

Categorizing the textures: Textural differences can be caused by variation in composition and the size of the constituent particles. Both these aspects can result in variation of the normal albedo. A global normal albedo map was utilized with SAOImageDS9 [9] to calculate the average albedo of each texture in the three analyzed boulders. In SAOImageDS9, a region was selected for each texture, and the average within the region was calculated. To obtain normal albedo values with higher precision, local shape models were created for some boulders with OLA data, and boulder images were registered onto a corresponding shape model using USGS' s Integrated Software for Imagers and Spectrometers 3 (ISIS3, [10]). Albedo ranges are (from darkest to brightest): bin 1, 3.0 to 3.4%; bin 2, 3.5 to 3%; bin 3, 4.0 to 4.2%; bin 4, 4.3 to 4.5%; and bin 5, 6.0 to 6.5%.

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Hypotheses of the formation of layered boulders with multiple textures: This work is designed to test two hypotheses of multi-texture layered boulder formation. One is brecciation in the parent body. Boulders could be fractured by thermal fatigue [6], impact, or internal pressure, and fragments with various textures could be melded together by melting or internal pressure. Second, Bland and Travis [11] modeled mud convection in a 100-km asteroid parent body and showed that particle size sorting could occur. Catastrophic disruption of a parent body with a size-sorted interior could produce some rock fragments that include a boundary between two textures.

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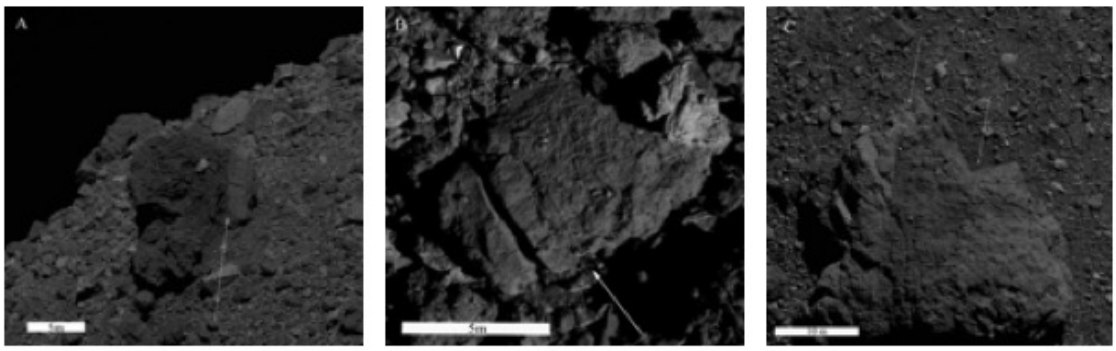

Figures. PolyCam images of multi-textured boulders which are selected for detailed photogeological analysis. They are all large (>10 m) and clearly show boundaries between different textures. (A) An image of a boulder (93° E, 5° N) acquired on April 5, 2019 at a scale of 3.8 – 4 cm/pix. It has both a dark and rugged texture and brighter and smoother texture. The arrow indicates a linear boundary which divides the two textures. (B) An image of a boulder (25.4° N, 190° E) acquired on March 29, 2019 at a scale of 4.8 cm/pix. It also has both a dark and rough texture and a brighter and smoother texture, divided by a linear boundary indicated by the arrow. (C) An image of a boulder (25° S, 3° E) acquired on March 21, 2019 at a scale of 4.7 cm/pix. This boulder contains three textures with two boundaries, which are indicated by the arrows. The texture on the right is the brightest, the one in the middle is the darkest, and the one on the left has medium brightness.

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