**A GLOBAL COLOR MAP OF ASTEROID BENNU.** D. N. DellaGiustina[1], D. R. Golish[1], K. N. Burke[1], E. B. Bierhaus[2], L. Le Corre[3], C. A. Bennett[1], K. Becker[1], P. H. Smith[1], B. Rizk[1], C. Y. Drouet d'Aubigny[1], H. Campins[4], H. H. Kaplan[5], A. A. Simon[6], V. E. Hamilton[5], K. J. Walsh[5], R.-L. Ballouz[1], E. R. Jawin[7], J. L. Molaro[3], M. Delbo[8], J. L. Rizos[9], E. Tatsumi[9], M. Popescu[9], M. A. Barruci[10], J.D.P. Deshapriya[10], M. Al Asad[11], B. E. Clark[12], H. C. Connolly Jr., and D. S. Lauretta[1]. [1]Lunar and Planetary Laboratory, University of Arizona, USA,[2]Lockheed Martin Space, USA, [3]Planetary Science Institute, USA, [4]University of Central Florida, USA, [5]Southwest Research Institute, USA,[6]Goddard Spaceflight Center, USA, [7]Smithsonian Institution National Museum of Natural History, USA, [8]UCA-CNRS-Observatoire de la Côte d'Azur, France, [9] Instituto de Astrofísica de Canarias, Spain, [10]LESIA, Observatoire de Paris, France, [12]Ithaca College, USA, [11]University of British Columbia, Canada, [14]Rowan University, USA (danidg@lpl.arizona.edu)

**Introduction:** The surface of Bennu displays significant albedo and color diversity [1][2]. In mosaics created from the OSIRIS-REx Camera Suite (OCAMS) [3] MapCam images, boulders are the dominant source of spectro-photometric heterogeneity on the asteroid, but craters also show subtle color trends. Relationships between surface morphology, texture, albedo, and color can provide insight into the composition, structure, and evolution of Bennu's surface materials. Reflectance (I/F) values of individual boulders range from 3.4% to >20%. Although Bennu's average terrain is blue-sloped, slopes from the near UV to the near IR vary from negative (blue) to positive (red) at spatial scales <2 m.

**Color and Albedo Trends:** Studies of Bennu's surface from PolyCam images taken during the Preliminary Survey phase indicated that bright (>6.5% normal reflectance) boulders are well sorted and primarily exist at smaller sizes (<8 m), whereas dark-to-average (3.4 to 5.5% normal reflectance) boulders are poorly sorted [2]. Notably, Bennu's 30 largest boulders (>20 m) all have low to average reflectance [2]. MapCam color images from the Detailed Survey phase confirm these findings, and also reveal relationships between color and albedo among Bennu's boulder population.

Global trends and examination of individual areas show that red units on the asteroid are often darker, whereas smaller, brighter boulders tend to be bluer (Fig. 1). Although albedo and color variation are commonly found between discrete boulders, differences are also observed along the face of individual large boulders (Fig 2). Studying the spectrophotometric changes within a single geologic feature can untangle the relationship between color, albedo, morphology, and exposure age. Certain boulders contain rough, hummocky surface textures and tend to be darker and redder, while smoother boulders tend to be brighter (>30%) and bluer (Fig. 2a). However, in some cases color changes do not correspond to any resolvable textural changes across the boulder surface.

The very brightest areas (>15% reflectance) appear as small boulders (<5 m) primarily in Bennu's southern hemisphere. These have a distinct w/x band ratio indicative of an absorption beyond 847 nm, which is consistent with the presence of mafic minerals, such as pyroxene or olivine. The substantial albedo and colour deviation of this population of boulders, as well as their rarity, suggests a separate provenance from rest of Bennu's regolith. Kaplan et al. [4] has shown that these boulders bear pyroxene and have a compositional affinity with the HED meteorites.

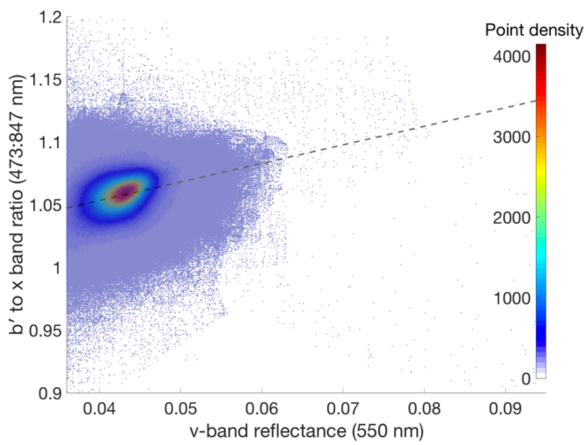


**Figure 1.** The b'/x band ratio (473:847 nm) versus normal reflectance at 550 nm across Bennu. In general, higher albedo areas correlate with bluer materials, as indicated by the best-fit dashed line, but other populations of material are also evident.

We have uncovered preliminary trends among morphology, color, and albedo for the global crater population. Smooth areas of unresolvable fine material (including small candidate craters) are generally lower albedo and redder than Bennu's average terrain. The observed reddening may be linked to space weathering or can result from particle size effects; decreasing grain size tends to redden and brighten laboratory spectra of CM chondrites (and silicates in general) [5]. The latter brightening effect is difficult to reconcile with the presence of darker, finer material, unless that material is compositionally distinct or contains opaques [5].

**Interpretation:** Bennu's population of large boulders (>20 m) could not have originated from impacts on Bennu itself [2]. Instead, crater scaling laws suggest that these blocks are fragments from the catastrophic disruption of Bennu's parent body and the subsequent rubblepile reaccumulation. Therefore, large boulders represent the oldest intact material on the surface of Bennu. As noted earlier, the largest boulders also maintain low-to-average mean reflectance. Though some boulders <20 m may have been inherited by the catastrophic disruption of Bennu's parent body, it is likely that many were formed on Bennu's own surface through impacts and thermal fatigue [6]. Boulder breakdown represents an irreversible process in the absence of lithification, so while the relationship between boulder size and age on Bennu is not yet well constrained, we hypothesize that younger boulders are likely smaller, though the corollary is not necessarily true.

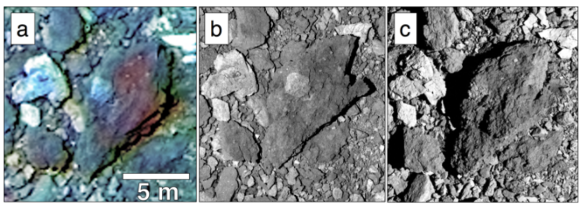


**Figure 2.** [a] Color and albedo variation across a single boulder (–5°, 250°). MapCam x/b' and b'/v band ratio mosaic (25 cm/pix). Here, negative-sloped areas appear blue and positive-sloped areas appear red. [b] A higher-resolution PolyCam image of this boulder acquired at a similar phase angle as panel a (7 cm/pix). [c] The same boulder acquired by PolyCam at a 40° phase angle at the opposite side of the subsolar point (5.5 cm/pix). Differences in texture and relief on the bright area of this boulder are more visible at these illumination conditions.

Examining the color and albedo across an individual boulder face can further inform this relationship. Some recessed areas on the face of individual boulders have an appearance suggestive of recent exfoliation or fragmentation in high-resolution PolyCam images (Fig. 2b-c); these areas also correspond to albedo and color differences in MapCam data (Fig. 2a). Specifically, surfaces that appear recently exposed are both bluer and brighter than their surroundings on individual larger boulders. If we extend this result to the wider population of boulders on Bennu, we can predict that the smaller, brighter, and commonly bluer boulders are likely younger than the average terrain. Brighter boulders follow a power-law size-frequency distribution that is different from the global distribution and appear to be a statistically distinct population of boulders developed by a separate formation mechanism [2].

Accordingly, we also hypothesize that younger boulder surfaces will be bluer and brighter, and that the population of young boulders on Bennu's surface has fragmented in situ from the population of boulders inherited from Bennu's parent body. These small bright boulders are typically morphologically distinct from the dark hummocky-texture boulders, which could also suggest a distinct composition or formation rather than an age relationship.

If low reflectance (<3.5%) boulders are compositionally distinct and more friable than their brighter counterparts, they may be more susceptible to breakdown, and dust on Bennu may contain a higher proportion of fine material from dark red constituents. Dust cover or microscopic roughness could explain why visible reddening does not always correspond to resolvable textural changes across individual boulders. The presence of fine particles may also account for the dark red material found in smooth areas associated with candidate craters. Otherwise the finding that craters are redder than Bennu's global average spectrum potentially links reddening to freshness, which is a different trend than what is observed for boulder surfaces. This may indicate that multiple space weathering trends are at work on Bennu.

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