OVERVIEW OF THE SEARCH FOR SPACE WEATHERING SIGNALS ON BENNU: ONE ROCK TYPE, OR TWO? B.E. Clark[1], S.M. Ferrone[1], H.H. Kaplan[2], X.-D. Zou[3], D. Trang[4], D.N. DellaGiustina[5], L. LeCorre[3], D.R. Golish[5], J.-Y. Li[3], R.-L. Ballouz[5], C.W. Hergenrother[5], B. Rizk[5], K.N. Burke[5], C.A. Bennett[5], L. Keller[6], E.S. Howell[5], C. Lantz[7], M. A. Barucci[7], S. Fornasier[7], M. Thompson[8], P. Michel[9], J. Molaro[3], E.R. Jawin[10], M. Delbo[11], A. Simon[12], D. Reuter[12], M. Pajola[11], and D.S. Lauretta[5]. [1]Ithaca College Dept. of Phys. and Astro., Ithaca, NY, USA, (bclark@ithaca.edu), [2]Southwest Research Institute, Boulder, CO, [3]Planetary Science Institute, Tucson, AZ, [4]Hawai‘i Institute of Geophysics and Planetology, University of Hawai‘i, HI, [5]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, [6]ARES, NASA Johnson Space Center, TX, [6]CNRS Université Paris Sud, France, [7]LESIA, Paris Observatory, France, [8]Purdue University, IN, [9]Côte d’Azur Observatory, France, [10]Smithsonian Institution, Washington, DC, [11]INAF, Observatory of Padova, Italy, [12]NASA Goddard Space Flight Center, Greenbelt, MD.

Introduction: We report on progress in the search for signs of space weathering on Bennu. We provide an overview of the space weathering evidence to date, and summarize relevant findings from several ongoing parallel studies of surface processes and surface properties. We examine trends from these studies in the context of space weathering, and what is known about near-Earth asteroid surface maturation [1,2].

Because Bennu is covered with blocks, boulders, and rocks of various sizes, our search for space weathering signals has inevitably led to a study of the properties of Bennu’s rocks. *Our research question is – do Bennu’s bright and dark rock populations form a maturity continuum due to space weathering, or alternatively, do the bright and dark rocks provide compelling evidence for two distinct rock populations on Bennu?* In particular, we present our best estimate of the sub-field-of-view OVIRS (OSIRIS-REx Visible and Infrared Spectrometer) spectral properties of the largest bright boulders and compare them with the darker materials on Bennu’s surface to see if the observed spectral and albedo differences are consistent with space weathering effects, or not.

Space Weathering: We know that space weathering processes occur on asteroid surfaces and change the optical properties of a thin top layer over time [1, 2 and references therein]. Most airless bodies we’ve examined thus far have shown space weathering effects, so it is not likely that Bennu has escaped them. With some success, surface alteration processes have been simulated in the laboratory [3,4]. On many Solar System bodies, space weathering tends to darken and redden exposed material over time [1,2]. However on carbonaceous bodies rich in hydrated minerals, space weathering effects are more complicated [3,4]. In particular, the experiments reported by Thompson et al. [3] suggest that the high volatile and water content of carbonaceous materials produce vesiculated textures, both in the matrix of the substrate, and in the re-condensed phases.

Rocks on Bennu: Imaging data suggest that higher albedo rocks show relatively fresh surfaces as compared with the darker mottled background rocks on Bennu [5,6]. If these rocks are related on a maturity continuum, it is reasonable to suppose that the older rocks on Bennu are those with darker and more weathered appearances due to exposure to space environment surface alteration processes over time. It would then follow that the brighter, more angular rocks on Bennu are closer to fresh unweathered material. For example, we suggest that the large darker boulder in **Figure 1** is an example of the highly space-weathered end-product boulder type on Bennu, and its perched guest (smaller brighter rock) is an example of a recently exposed fresh surface.

Figure 1: A 17m boulder on Bennu at approximately lon. 100E, lat. +20 shows an example of a smaller bright rock on top of a dark boulder [18].

Size-Frequency Distribution: DellaGiustina & Emery [5] showed that the rocks on Bennu can be divided into two populations with separate power-law size-frequency distributions: The higher-albedo boulders on Bennu (those with radiance factor (I/F, RADF) at normal geometry greater than 6.8%), show a cumulative size-frequency distribution (CSFD) slope of –4.4 ± 0.07, with a longest dimension of about 11 meters. The remaining boulders on Bennu show a CSFD of –2.5 ± 0.2 with a longest dimension of about 60 meters. These data suggest that their formation scenarios differ [5,6,7,8]. Perhaps we're seeing a bimodal distribution of the rocks on Bennu, one that argues for two distinct rock types that may have come from two distinct precursor asteroids, or two distinct regions from one precursor asteroid.

However, the large boulders on Bennu seem to show a continuum in brightness from a low of 3% to highs of ~12-15%. A bi-modal distribution is not observed for these large boulders [5,9]. This suggests that many of the rocks on Bennu (bright and dark) could have the same original composition, but exhibit different amounts of total optical alteration due to space weathering [9,10].

Other Surface Processes: Thermal and mechanical weathering (cracking and disaggregation of rocks) are apparently active processes at Bennu's surface [11,12], and these processes may serve to expose fresh unweathered material over time. This could explain why the brighter rocks found on Bennu tend to be smaller on average than darker rocks that occur with the same frequency [5].

There are several competing mechanisms for resurfacing processes on small bodies: a) impacts and crater erasure by subsequent seismic shaking [7]; b) mass movement created by rotational acceleration (and subsequent geoid) due to YORP [8], c) micrometeorite impacts, d) thermally induced surface degradation [13], d) solar wind ion implantation, and now f) particle ejection and re-impact [14]. All of these processes have the potential to create patterns in spectral/albedo properties on the surface of Bennu, and hence contribute to the story of space weathering on Bennu.

Summary: We will summarize evidence from the following lines of investigation and search for a consensus: does a preponderance of the evidence support one rock type or two rock types on Bennu?

(A) A search for transitional examples: due to active thermal and mechanical rock breakdown [11,12], there should be rocks showing both the advanced space-weathered texture on one side, and a brighter less weathered texture on the other side (i.e. on freshly exposed faces) [15].

(B) A census of the bright rocks [9,18]: Bright rocks should differ from dark rocks in placement, albedo and color patterns that are consistent with a maturity relationship, similar to what we observed at Eros and Itokawa, and/or similar to what we find with carbonaceous chondrites in the laboratory [10].

(C) Any spectral or albedo variations that correlate with active surface processes such as cratering, downslope movement, and/or seismic shaking. [5,16].

(D) An inventory of the compositionally distinct lithologies on Bennu [17]. If there are two distinct compositions among the rocks that correlate with morphological or textural properties, this would be good evidence for a two-rock-component model for Bennu.

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