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Global Variations in Regolith Depth on Asteroid Vesta

B. W. Denevi (1), E. I. Coman (1), U. Carsenty (2), D. T. Blewett (1), D. W. Mittlefehldt (3), D. L. Buczkowski (1), J.-P. Combe (4), M. T. Capria (5), M. C. De Sanctis (5), R. Jaumann (2), J-Y. Li (6), S. Marchi (7), A. Nathues (8), N. E. Petro (9), C. M. Pieters (10), P. Schenk (11), N. Schmedemann (12), S. Schröder (8), J. M. Sunshine (6), M. Toplis (13), D. A. Williams (14), C. A. Raymond (15), and C. T. Russell (16).

(1) Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA, (2) DLR, Institute of Planetary Research, Berlin, Germany, (3) NASA Johnson Space Center, Houston, TX, USA, (4) Bear Fight Institute, Winthrop, WA, USA, (5) INAF, Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy, (6) University of Maryland, College Park, MD, USA, (7) NASA Lunar Science Institute, Boulder, CO, USA, (8) Max Planck Institute for Solar System Research, Katlenburg-Lindau, Germany, (9) NASA Goddard Space Flight Center, Greenbelt, MD, USA, (10) Brown University, Providence, RI, USA, (11) Lunar and Planetary Institute, Houston, TX, USA, (12) Freie Universität, Berlin, Germany, (13) Institut de Recherche en Astrophysique et Planétologie, Université de Toulouse, France, (14) Arizona State University, Tempe, AZ, USA, (15) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, (16) University of California, Los Angeles, CA, USA. Corresponding author's email address: Brett.Denevi@jhuapl.edu.

1. Introduction

Regolith, the fragmental debris layer formed from impact events of all sizes, covers the surface of all asteroids imaged by spacecraft. Here we use Framing Camera (FC) clear filter images [1] acquired by the Dawn spacecraft [2] from its low-altitude mapping orbit (LAMO) of 210 km (pixel scales of ~20 m) to characterize regolith depth and variability in depth. These results will help to evaluate how the surface of this differentiated asteroid has evolved over time, and provide contextual information for understanding the origin and degree of mixing of the surficial materials for which compositions are estimated [3–5] and the causes of the relative spectral immaturity of the surface [6].

2. Distribution of blocky craters

A standard technique for estimating regolith depth, developed for the Moon [7], is to identify the presence (or lack) of blocks in crater ejecta. This method assumes that craters without blocky ejecta formed solely within the unconsolidated regolith, and when blocks are present, they were excavated from the more competent substrate beneath the regolith. We use the Small Body Mapping Tool [8] to project FC images onto a shape model and to map the diameters and distributions of all block-rich craters. We found 156 blocky craters in total, ranging in diameter from 680 m to 75 km. We focus on the distribution of blocky craters <10 km in diameter, which give information of the upper ~1 km of the regolith (crater excavation depth is conservatively 10% of transient diameter [9]). We find an asymmetric distribution of such craters. The largest concentration is within and just to the north of the Rheasilvia basin, between longitudes ~260° and 360° E (Fig. 1). The abundance of block-rich craters <10 km in this region suggests that the regolith is <1 km deep in many places, and has a regionally thinner regolith depth than average Vesta. This is consistent with results from crater size-frequency distributions near Lepida crater (307°E, 16°N) predicting regolith depths of ~0.8 km [10]. A large equatorial region from ~95° to 260° E contains very few blocky craters both <10 km and larger (Fig. 1). This area also largely corresponds to a broad region of low albedo [3,4]. The regolith is likely substantially deeper here, with depths >1 km.

3. Observations of Crater Walls

Many FC images reveal a spur-and-gully type erosional pattern within crater walls (Fig. 2). This morphology is consistent with mass wasting of materials downslope, and indicates material resistant to erosion near to the surface. We have also mapped the sizes and distributions of craters with this erosional pattern (we identify 118 such craters). Just under 70% of these craters also have block-rich ejecta, and we see regional correlations between the two datasets. For example, the large region with a dearth of blocky craters (Fig. 1) also lacks the gully-type erosional patterns, while they are found throughout the Rheasilvia basin. This association is consistent with exposure of competent material within these craters; whether whether this indicates bedrock (likely heavily fractured) or consolidated breccias and large blocks from within the megaregolith is unclear. We are currently mapping the depths of layering within crater walls on the shape model to examine their depths of origin and implications for regolith depth.

3. Conclusions

Based on our preliminary work, large, contiguous areas on Vesta have regolith depths greater than 1 km. Regolith is thinner within a portion of the Rheasilvia

basin, though image resolution precludes an interpretation of minimum regolith depth in this region. Future work comparing our results with modeled depths of ejecta from the Rheasilvia basin [11], thermal properties of the surface [12], laboratory studies of howardites [13], and the mixing of compositional units [3–5] will help elucidate the depth, origin, and evolution of Vesta's regolith.

References

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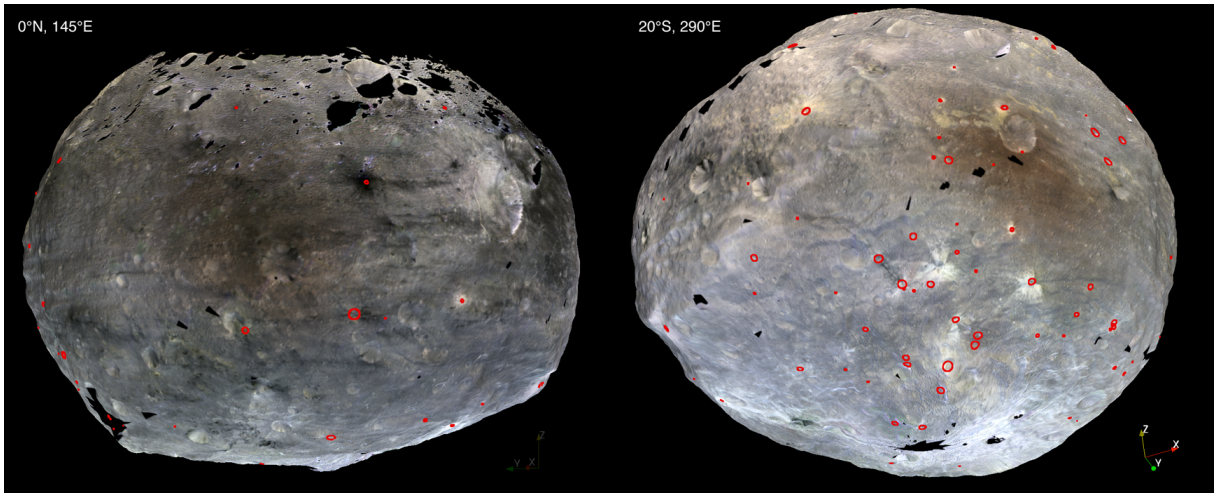

Fig. 1. Examples of regional variations in the distribution of blocky craters <10 km in diameter, which sample the upper 1 km of the surface. Left: A region of low albedo (both images are stretched the same) with a paucity of craters that have excavated boulders. Right: A portion of the Rheasilvia basin with a higher abundance of block-rich craters, consistent with a region of thinner regolith. 749, 555, and 438 nm filters shown in red, green, and blue. Latitudes and longitudes are given for the center of each projection.

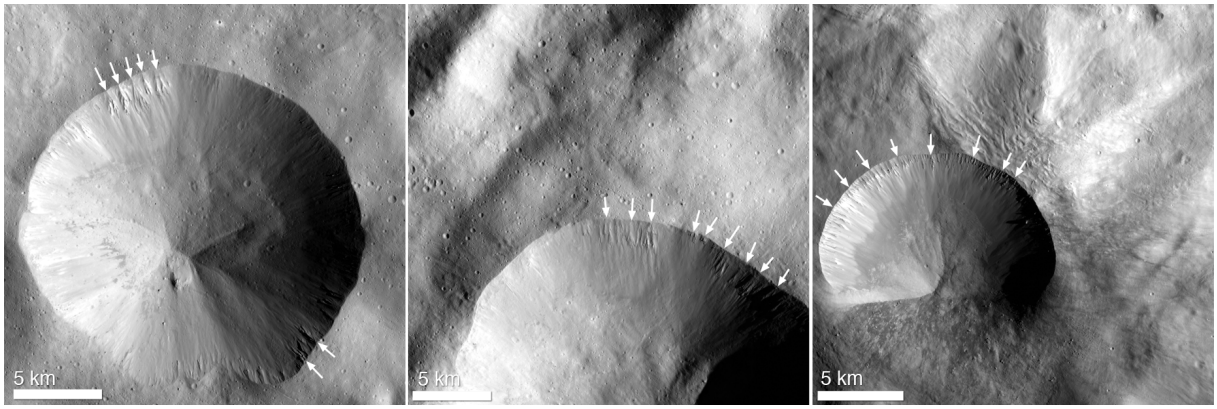

Fig. 2. Examples of erosional patterns consistent with exposure of more competent material (e.g. from within the megaregolith or possible bedrock) within crater walls.