MAPPING VESTA USING A HYBRID METHOD FOR INCORPORATING SPECTROSCOPIC AND MORPHOLOGIC DATA.
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Introduction: Defining criteria for mapping material units on airless, rocky bodies is challenging. Where the primary geologic process for the bulk of a small body's history is impact cratering, traditional mapping approaches can be problematic, because differences in morphological characteristics among the various cratered surfaces can be subtle to absent, and surface morphology is muted by the regolith's physical and mechanical properties. In constructing a global geologic map of Vesta at 1:300,000-scale using the Dawn Framing Camera (FC), DTM-derived slope and contour, and color (visible wavelength) and spectroscopic data [1-3], we have utilized a hybrid method of mapping, in which morphologic and color-based maps are produced independently, and then the unique aspects of each are combined into a single map product.

Background: Vesta is an ellipsoidal asteroid of approximately 286 km long axis [4]. Earth-based and Hubble Space Telescope data suggested it had sustained large impacts, including one that produced an enormous crater at the south pole. Measured and inferred mineralogy results indicated that Vesta has an old, differentiated surface, with spectrally-distinct regions that can be geochemically tied to the HED meteorites [5-7]. Dawn data confirmed a heavily-cratered surface, with large craters evident in numerous locations. The two largest impact structures resolved are the degraded Veneneia crater (~395 km diameter), and the younger, larger Rheasilvia crater (505 km diameter), both located near near the south pole. Vesta's surface is also characterized by a system of deep troughs and ridges.

Data: The Dawn Framing Camera (FC) Low-Altitude Mapping Orbit (LAMO) images constitute the basemap. The Digital Terrain Model (DTM), derived from High-Altitude Mapping Orbit (HAMO) FC stereo data of 93 m/pxl horizontal resolution [8,9], provides topography, while DTM-derived slope and contour maps yield the shape of the surface and assist in evaluating the extent of geologic materials and features. Color data provided by the FC (e.g., **Figure 1**), and high-resolution, calibrated spectroscopic data by the VIR and Gamma Ray-Neutron Detector Spectrometer (GRaND), allow compositional and elemental information about Vesta's surface materials to be evaluated. VIR provides spectral data in the visible and near infrared wavelengths. GRaND yields abundances for rock-forming elements (O, Si, Fe, Ti, Mg, Al and Ca), radioactive elements (K, U and Th), trace elements (Gd and Sm), and H, C and N (major constituents of ices).

Mapping Procedure: Our initial approach was to follow the methods developed and described by [10-13]. Units were initially defined and characterized based on morphology, surface textures, and albedo, as well as traditional methods of relative age dating (e.g., crater size-frequency distribution, superposition relationships). Color data from the FC (and VIR) were initially examined as an overlay on the first draft of units, to refine unit boundaries where the morphologic characteristics provided more than one possible interpretation, or the interpretation of the unit type was ambiguous. Where unit boundaries were obscured by subsequent geologic activity (through emplacement of impact ejecta, or through vertical or lateral mixing of the surface regolith), ejecta from craters that post-date the activity were used as a proxy for the unmodified composition of the unit (e.g., lunar dark halo craters [14]). However, we found that unique information provided by color data (stratigrapic information in particular) was being lost in the mapping process and as a result, not being incorporated synergistically into interpretations.

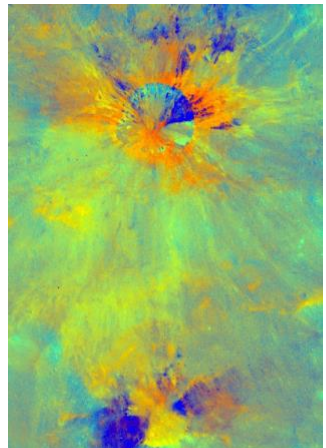
Figure 1. Craters Rubria (top) and Occia (bottom), in FC color data.

To counter this problem, we are using a hybrid method based on that of [14], that requires creating two maps: one based on morphology/topography, and another based primarily on color/spectral data (**Figure 2**). The unique results of each will then be combined, with the ultimate objective being to integrate color data into meaningful map units, presented in a new visual scheme that documents stratigraphic information that is subtle or absent in morphologic data.

Progress and lessons learned: We have completed the morophologic and color-based maps and are currently assessing ways in which to retain the unique information in both maps to create a data-rich hybrid map. In doing this, we note the following:

(1) Boundaries defined by compositional data tend to be gradational rather than discrete. While this is also true for some geomorphologic boundaries, it is the rule rather than the exception when using color. Spectroscopy in the shorter wavelengths (UV-VIS-near IR) can only sample the upper few µm of the surface, and it takes very little unique material to affect the signal of a regolith in particular. Thus, in the absence of other information it is not always clear how or whether that color data correlate with a surficial unit. However, on an airless body, the ejecta of an impact event can persist relatively unchanged, potentially over geologic timescales. Color should thus not necessarily be seen as "contamination"; compositional boundaries may still indicate genetically distinct material, such as is often the case with crater ejecta.

(2) We have confirmed that compositional data provide unique insight into pre-impact stratigraphy. For example, color differences in ejecta in **Figure 1** indicate both subsurface coherent layers (as can be seen as teal and blue layers in vertical cross-section along the rim of Rubria crater) and ejecta mechanics (as can be noted in the asymmetric deposition of orange- and deep blue-colored ejecta in both craters). Thus, even the upper microns of the surface can contain records of the vertical composition of the rock body. On the Moon, in particular, this fact has been used to identify mare material that has been obscured by regolith maturation [14]. On Vesta, certain spectral features can be interpreted to indicate composition at depth (eucrite/diogenite differences being most pronounced).

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References: [1] Yingst, R.A., et al. (2012) LPSC, abs. 1359. [2] Williams, D.A., et al. (2014), Icarus, 244, 1-12. [3] Yingst, R.A., et al. (2014) Planet. Space Sci., http://dx.doi.org/10.1016/j. pss.2013.12.014i. [4] Russell, C.T. et al. (2012) Science, 684–686, http://dx.doi.org/10.1126/ science.1219122. [5] Binzel, R.P. et al. (1997) Icarus, 128, 95-103. [6] Gaffey, M.J. (1997) Icarus, 127, 130-157. [7] Li, L. et al. (2010) Icarus, 208, 238-251. [8] Jaumann, R., et al. (2012) Science, 336, 687-690. [9] Preusker, F. et al. (2012) LPSC, abs. 2012. [10] Shoemaker, E.M. and Hackman, R.J. (1962) The Moon, Kopal, Z., Mikhailov, Z.K. (Eds.), Internat. Astronomical Union Symposium 14, Academic Press, London, UK, pp. 289–300. [11] Wilhelms, D.E. (1990) Planetary Mapping, Greeley, R. and Batson, R.M. (Eds.), Cambridge Univ. Press, pp. 208–260. [12] Tanaka, K.L. et al. (2010) The Planetary Geologic Mapping Handbook, USGS Open File Report, 21 pp. [13] Greeley, R. and Batson, R.M. (1990) Planetary Mapping, Cambridge Univ. Press, p. 296. [14] Lough, T.A. and T.K.P. Gregg (2010), LPSC, abs. 2370.

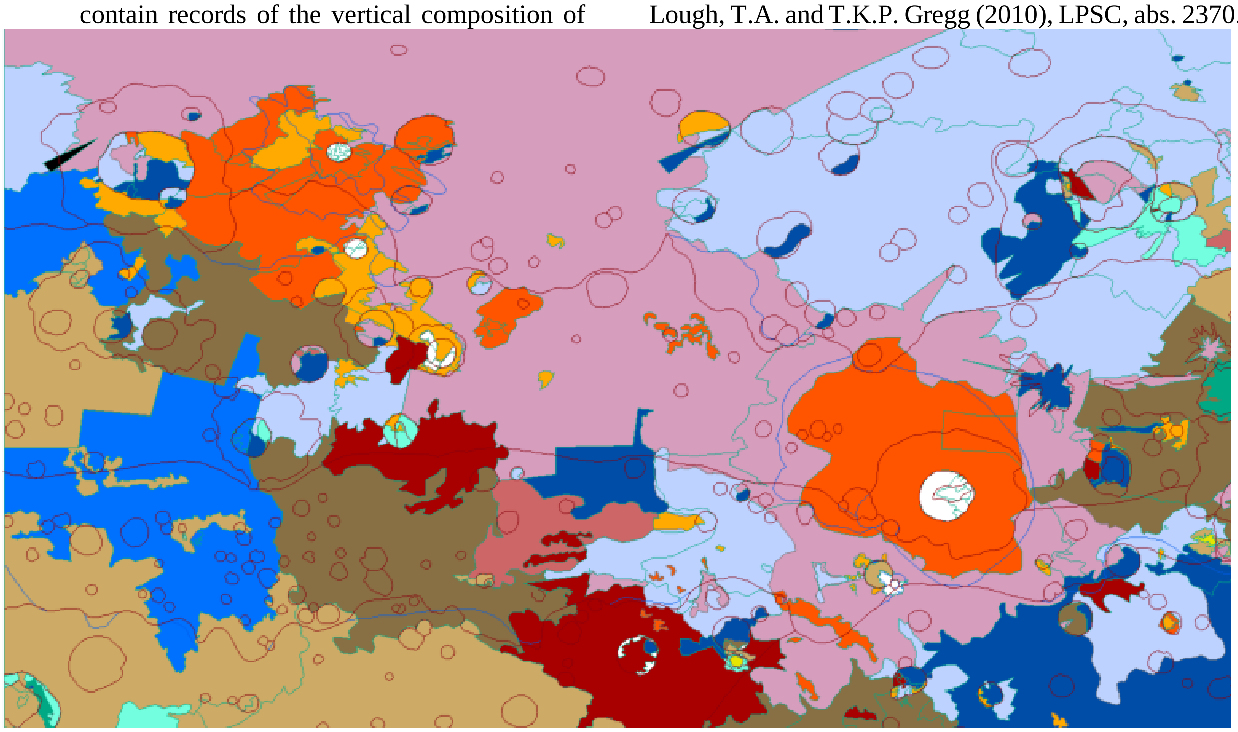

Figure 2. Vesta map of color units overlaid with morphologic unit boundaries (maroon and green lines). Note that color units sometimes, but not always, coincide with morphologic units.