GEOLOGIC MAPPING METHODS FOR SMALL, ROCKY BODIES: THE VESTA EXAMPLE.

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Introduction: Defining criteria for mapping the boundaries of material units on airless, rocky bodies has its own particular challenges. Where the primary geologic process for the bulk of a small body's history is impact cratering, the traditional mapping approach of using morphology as the primary criterion of unit definition can be problematic, because the differences in morphological characteristics among the various cratered surfaces can be subtle to absent. Additionally, surface morphology is muted by the regolith's physical and mechanical properties.

We are constructing a global geologic map of Vesta at 1:300,000-scale using the Dawn Framing Camera (FC) images as a basemap, while DTM-derived slope and contour maps yield the shape of the surface. Our map also incorporates color (visible wavelength) and spectroscopic data; previous maps were not able to fully utilize these data as they were not yet calibrated [1-3]. As we map, we evaluate how much weight each dataset should be given in defining criteria for unit boundaries, and what the consequences of those choices are. Using Vesta as a test case, our ultimate goal is to explore best practices for geologic mapping with multiple, disparate datasets, under the challenges presented by an airless, rocky body.

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 that Vesta has 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], 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, 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 relatioships). Color data from the FC (and VIR) were 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 this method did not provide us with sufficient ability to assess and interpret the spectroscopic and color data on its own merits. As a result, the color and morphologic data were not being incorporated synergistically into interpretations.

Recently we have begun a different approach, one that has been used to map the lunar Aristarchus plateau region [15]. Initially used to test how the availability (or lack thereof) of various types of datasets affects mapping results, this method requires creating a GIS map based on each available dataset in isolation, then comparing the resulting maps to assess what information is unique to each dataset, and of that, what best summarizes the geologic history of the region.

Progress: The initial mapping linework (**Figure 1**), shows a variety of structures, geocontacts, and crater locations. Important potential units outlined by this linework include heavily cratered, presumably ancient terrain, and hummocky and curvilinear trough terrain associated with the Rheasilvia impact structure. Heavily-cratered surfaces contain a range of crater morphologies. A large percentage of the heavily cratered terrain is intersected by ridges and troughs with two distinct orientations (near the equator and to the north); further mapping and data analysis will determine whether this dissected terrain should be mapped as a standalone unit or not.

Preliminary lessons learned: Isolating mapping results as a first step in creating a geologic map has revealed some key points. Firstly, and not surprisingly, we have seen that boundaries defined by compositional data (e.g., color, VIR) overlap clear morphological boundaries. 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 how a regolith is classified if only compositional data is used. This should not necessarily be seen as "contamination" however; compositional boundaries may still indicate genetically distinct material.

Secondly, we have confirmed that compositional data provides unique insight into pre-impact stratigraphy. On an airless body, the ejecta of an impact event can persist relatively unchanged, potentially over geologic timescales. 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).

There are a number of colors in the FC visible wavelength data (e.g., light teal ejecta, darker mantling, orange surface material) that may indicate unique subsurface lithologies important to reconstructing the body's geologic history. It is currently unclear, however, how the compositional map based on these "colors" should be used in a consistent manner to define or refine unit boundaries on a map that utilizes all datasets. Craters deep enough to excavate through the overlying regolith to the layer in question are distributed in more or less random locations, rather than in locations where they would reveal the extent of a subsurface layer; in other words they occur without respect to our convenience in interpreting vertical layering. This issue will be a key one to address as we continue our work.

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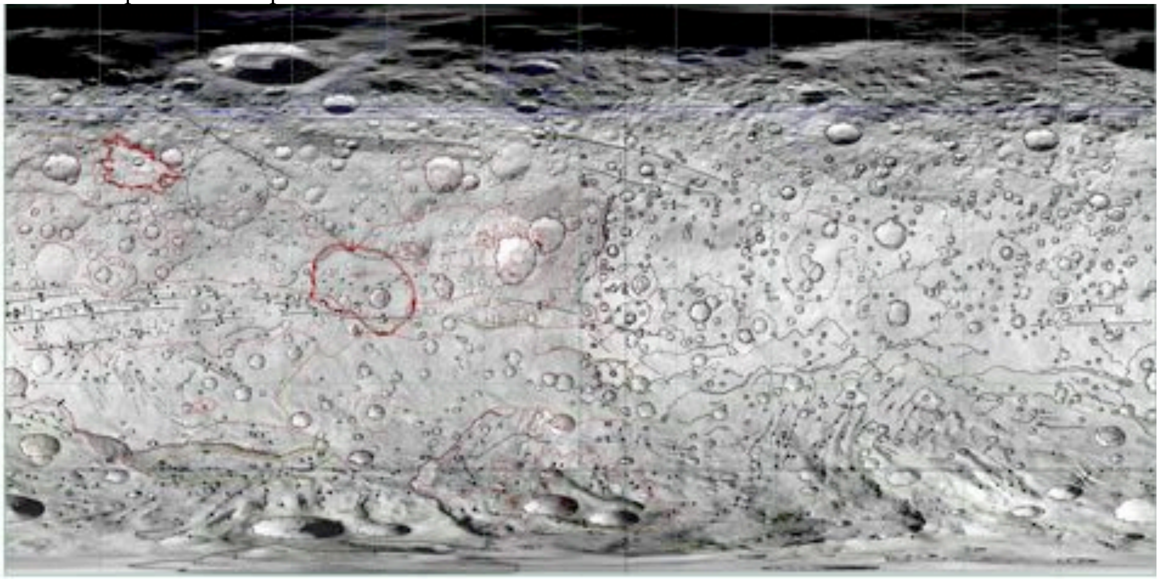

Figure 1. Preliminary linework for global map of Vesta.