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Composition of Vesta's Regolith and the HED Connection

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Abstract

Mapping of the composition of Vesta's regolith by the NASA Dawn mission strengthens the connection between Vesta and Howardite, Eucrite, and Diogenite (HED) meteorites. The geologic context for HED rock types on Vesta's variegated surface provides constraints on thermal evolution and impact history. On Vesta, compositions outside the HED clan, such as mesosiderites, are rare or absent. Evidence for exogenic materials delivered by impacts provides a connection to howardites, which are thought to be representative of Vesta's ancient regolith. Elemental and mineralogical measurements by Dawn are combined with meteorite studies to provide a better understanding of the geochemical processes that shaped Vesta.

1. Introduction

The HED meteorites are thought to have originated from Vesta. This connection is supported by the close match between the reflectance spectra of these achondritic meteorites and that of Vesta [1], along with a plausible mechanism for delivery of bits of Vesta to Earth (via the 3:1 resonance) [2], and many other lines of evidence [3]. The meteorites tell a tale of a planetary embryo that accreted from volatile-poor material and underwent igneous differentiation to form a basaltic crust, ultramafic mantle, and metallic core. Vesta has somehow survived massive impacts, remaining largely intact to the present day. Giant basins in the southern hemisphere provide a window into Vesta's interior, exposing the lower crust and upper mantle. These are represented in the HED collection by the diogenites and cumulate eucrites. Portions of Vesta's ancient, basaltic crust can be found at equatorial latitudes in association with Vesta's "dark" hemisphere. Dark, hydrogen-rich material, with an albedo lower than basalts, may have been delivered to Vesta's surface by carbonaceous chondrite (CC) impactors [4-7]. This interpretation is supported by the presence of CC clasts in howardites, thought to be lithified samples of Vesta's regolith. While Dawn has not changed the widely-held view of Vesta as the HED parent body, the mission does bring the context of these meteorites clearly into focus. Here, we describe how compositional measurements by Dawn have improved our understanding of Vesta.

2. Observations

Compositional measurements were made by the three payload instruments on Dawn. These include a visible to near-infrared (VIR) mapping spectrometer [8] and redundant framing cameras (FC) with color filters [9]. Reflectance data acquired with nearly global coverage provided high spatial resolution measurements (~decameters/pixel), of spectral parameters useful for petrologic classification of igneous materials as well as OH/H_2O absorption features at ~3 μm [8][9]. A gamma ray and neutron detector (GRaND) provided measurements of the elemental composition of Vesta's entire surface with a broad spatial resolution (~300 km), sufficient to sample the interior of large impact basins and other regional features. GRaND is sensitive to the abundance of H as well as major rock-forming elements (e.g. Fe, Si, and Mg) [4] [Yamashita et al., *MAPS*, in review]. Measurements of neutron absorption, average atomic mass, and high energy gamma rays provide additional constraints on bulk regolith elemental composition [*MAPS* articles in review by Prettyman et al., Lawrence et al., and Peplowski et al.]. When combined, the mineralogical and elemental measurements by Dawn enable a substantial petrologic characterization of Vesta's surface.

3. Results

Global mapping by GRaND, VIR, and FC reveal similar, compositional patterns. The Rheasilvia basin is mapped by VIR and FC as diogenitic (Fig. 1). Similarly, GRaND elemental maps show that the basin composition is consistent with orthopyroxenitic (opx.) diogenite (Fig. 1). An olivine signature on the scale sampled by Dawn's instruments has not been detected within Rheasilvia basin. This observation may be diagnostic of differentiation processes that led to a compositionally-stratified mantle, with opx.-diogenite representing the upper mantle [10]. A prominent, diogenitic "ejecta-lobe" extending northward from Rheasilvia in the eastern hemisphere is present in both GRaND and reflectance maps (Fig. 1), perhaps indicative of an oblique impact. Finally, both data sets reveal relatively high concentrations of eucritic material near the equator in association with H-bearing, low albedo materials [3-9][11]. These regions are thought to contain remnants of Vesta's ancient basaltic crust.

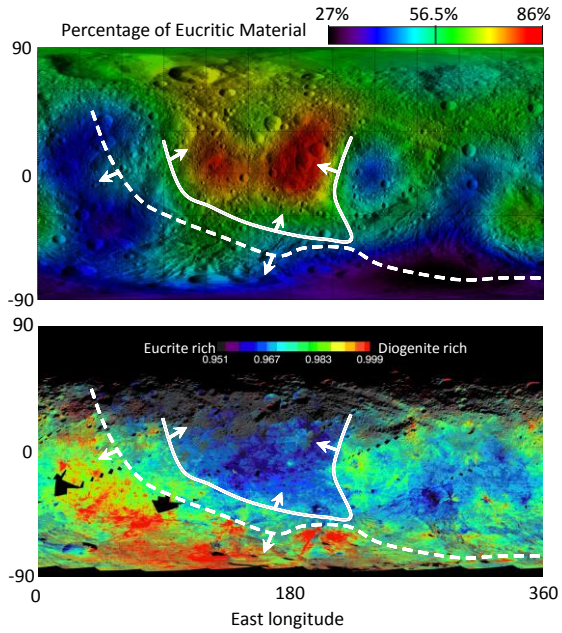

Figure 1: Map of the percentage of eucritic material in the vestan regolith determined by GRaND (top) is compared to Eucrite-Diogenite indices derived from FC data [9] (bottom). A common diogenite-rich region is identified by the dashed line. An eucrite-rich region is indicated by the solid line.

4. Synthesis

The aforementioned qualitative comparisons of elemental and mineral data sets have provided useful information on the context of HED compositions on Vesta's present-day surface. Work is underway to combine and further inter-compare these measurements for quantitative petrology. For example, it may be possible to combine the abundance of ferrosilite and wollastonite derived from reflectance data [11] with total Fe and other elemental parameters measured by GRaND to constrain the non-pyroxene (plagioclase) content of Vesta's regolith. Preliminary results of various integrative analyses, guided by meteorite studies, will be presented.

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