Vestoids, Vesta, and HEDs: What explains their color differences? B. J. Buratti[1], P. A. Dalba[2], and Michael D. Hicks[1] [1]Jet Propulsion Laboratory California Inst. of Technology (4800 Oak Grove Dr., Pasadena, CA 91109; bonnie.buratti@jpl.nasa.gov)

Introduction: One of the most common classes of terrestrial meteorites, the Howardite-Eucrite-Diogenite (HED) assemblage, presents a similar - although diverse mineralogy - to that of Vesta (as inferred from reflection spectra), and it is believed to originate on the asteroid [1]. The link between the HED meteorites and Vesta are provided by the V-type, or vestoid, class of asteroids that appear to be dynamically related to Vesta [2] and that present similar reflection spectra [1,3,4]. Although this picture presents a fairly consistent story – for example, the spectral properties of vestoids as a group are not consistent with any Main Belt asteroid other than Vesta, many details remain to be worked out and several inconsistencies need to be resolved. It has been known for years that the vestoids and HEDs present generally stronger band strengths and redder visible spectral slopes than Vesta [5,6]. The *Dawn* mission also showed the seeming absence or minor role of lunar-type space weathering on Vesta [7] and possibly vestoids. Possible reasons for the differences among Vesta, vestoids, and the HEDs include different compositions, phase reddening, different particle sizes, or space weathering.

Observations: Three types of observations were used in this analysis: ground-based data which includes high resolution spectra of Near Earth vestoids (the reservoir of the HED meteorites) and archived observations [3], spectra from the RELAB archive of HED spectra at Brown University [8], and observations from the *Dawn* Framing Camera (FC) [9].

Results: Both the ground-based and *Dawn* observations had phase reddening parameters applied [9,10] such that they were at the same effective geometry as the RELAB measurements (see Figure 1). Since these corrections are slight and do not significantly bring into alignment the three data sets, phase reddening cannot explain the differences among the three data sets.

For S-type asteroids and the lunar surface, the effects of space weathering tend to redden the spectrum in the visible and mute the absorption bands (11). For Vesta, no such situation exists; in fact, higher albedo regions tend to be redder. Based on *Dawn* results, another mechanism of space weathering is caused by micron-sized opaque particles reducing the spectral contrast and generally darkening the surface [7]. In the lower impact velocity regime of Vesta, brecciation is more important than impact volatization: this form of space weathering is essentially mechanical rather than chemical ("space weathering" may even be a misnomer). In this scenario, the HEDs are in the correct place in Figure 1 for a "fresher", less weathered surface. The redder color of the vestoids is also explained by space weathering: their surfaces are "fresher" than that of Vesta.

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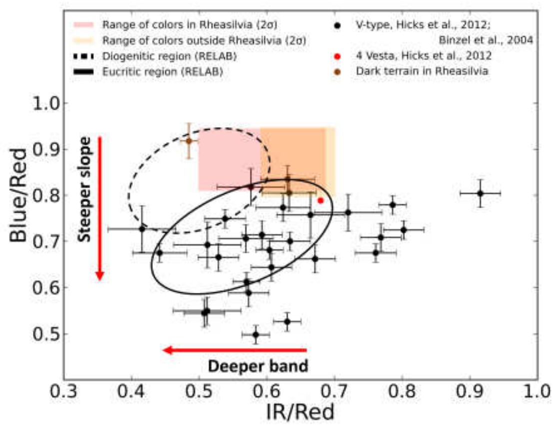

Figure 1. A color-color plot showing the visible slopes (y-axis) and the band depth (x-axis) of vestoids (black dots), Vesta off the Rheasilvia Basin (pastel orange), and on the Rheasilvia Basin (pink). These measurements are from published data from the *Dawn* Framing Camera (FC) [9]. The dotted oval is the position of the diogenite meteorites from the RELAB archive, and the solid oval represents the eucrite samples. (The howardite class of meteorites dwells intermediate between the diogenites and eucrite endmembers.) For comparison, other stony asteroids are shown, illustrating that only the vestoids are near the spectral properties of Vesta. The "dark terrain" on Rheasilvia is the material with the smallest visible slope and deepest pyroxene band: it is represented primarily by the ejecta material surrounding the Oppia crater. It is outside of the 2σ range of the basin's colors. Corrections for phase reddening have been made.

A related alteration mechanism is the addition of spectrally neutral, low-albedo hydrated carbonaceous material to Vesta's surface. [12, 13, 14]. This material should be less prevalent on vestoids, as they possess smaller gravitational wells and thus cannot attract and retain as much exogenous infall. Because the material is spectrally neutral, the vestoids would be redder than Vesta.

Another important factor for explaining the spectral differences may be the particle size of grains in the regolith of Vesta. Pieters et al. [15] showed that the spectrum of Vesta between 0.3 and 2.6 μm fits a typical howardite meteorite if the particle sizes are less than 25 μm. The band depth in both diogenites and eucrites (especially) is less for samples composed of smaller particles; for the eucrites, the band depth is about 20% less for the fine particles [9]. This is about the size of the discrepancy between the meteorites and the FC data for Vesta in Figure 1. Other lines of evidence point to the existence of small particles on the surface of Vesta. The V-type asteroids are very rough at RADAR wavelengths [16]), but at visible wavelengths Vesta appears to be smoother than the typical asteroid [17]. This condition is explained by the infilling of facets and asperities on the surface by fine particles, similar to the "ponding" seen on Itakawa and Eros, but on a smaller scale. With the larger gravity field of Vesta, small particles would be more likely to be retained than on the smaller vestoids. The high albedo of Vesta [18] also suggests an abundance of fine particles.

Conclusions: The two major factors that explain the discrepancies in optical properties between Vesta, the HEDs, and the vestoids are differing particle sizes and the addition of low-albedo spectrally neutral carbon-rich material to Vesta. With its stronger gravity well, Vesta retains small particles that result from collisional processes: these particles render the surface brighter and bluer. Compounding the effect is the additional of spectrally neutral carbonaceous material. The effects of phase reddening are only slight.

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