SPECTRAL REFLECTANCE PROPERTIES OF HED METEORITES AS A FUNCTION OF GRAIN SIZE AND PRESENCE OF CM2 MATERIAL. E. A. Cloutis[1], V. Reddy[2,3], L. Le Corre[3], L. Pompilio[4], P. Mann[1], A. Nathues[3], and H. Hiesinger[5]. [1]Dept. of Geography, University of Winnipeg, 515 Portage Ave., Winnipeg, MB, Canada R3B 2E9, e.cloutis@uwinnipeg.ca, paul.mann347@gmail.com, [2]Dept. Of Space Studies, Box 9008, University of North Dakota, Grand Forks, ND, USA 58202, reddy@mps.mpg.de, [3]Max-Planck-Institute for Solar System Research, Katlenburg-Lindau, Germany, lecorre@mps.mpg.de, nathues@mps.mpg.de, [4]D'Annunzio University, via Dei Vestini, 30-I 66013, Chieti, Italy, pompilio@irsps.unich.it, [5]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany, hiesinger@uni-muenster.de.

Introduction: The DAWN spacecraft, in orbit around 4 Vesta, is providing our first detailed look at a largely intact differentiated asteroid, which is the likely source of most of the howardite-eucrite-diogenite (HED) meteorites [e.g., 1]. Framing Camera (FC) images show diverse terrain types, including dark spots (Fig. 1). At least two explanations exist for dark spots: (1) increasing HED grain size, or (2) the presence of dark, possibly exogenous material.

The presence of dark exogenous material on Vesta is supported by the fact that some HEDs contain clasts of carbonaceous chondrites (CCs), most similar to CM2-type CCs [e.g., 2-9]. To address whether increasing grain size and/or the presence of CM2 material can account for low-albedo regions, we measured reflectance spectra of different grain sizes of the Millbillillie eucrite, the PRA 04401 CM2-bearing howardite [7-9], and <45 μm-size intimate mixtures of Millbillillie eucrite + the Murchison CM2 chondrite.

Experimental Procedure: Reflectance spectra (0.35-2.5 μm; i=30°, e=0°) were measured at the University of Winnipeg HOSERLab. Spectra were measured relative to Spectralon®, using an in-house 100 W quartz-tungsten-halogen light source for illumination; 200 spectra were averaged to increase SNR.

Results: Reflectance spectra of the Millbillillie and PRA 04401 grain size fractions are shown in Fig. 2 and 3, respectively. The Millbillillie + Murchison CM2 <45 μm intimate mixture spectra are shown in Fig. 4.

Millbillillie grain size spectra. The Millbillillie eucrite spectra (Fig. 2) demonstrate that overall reflectance decreases with increasing grain size, as expected. The 90-250 and 250-500 μm spectra are nearly identical, and the two pyroxene bands are still apparent.

PRA 04401 grain size spectra. The PRA 04401 show broadly similar behavior. The CM2 content of this meteorite, estimated from the visible extent of CM2 xenoliths is ~40 vol.%. The two pyroxene bands are apparent in all the spectra, but are weaker than those of Millbillillie. With increasing grain size, overall reflectance decreases and the spectra become more blue-sloped. The 90-250 μm spectrum is slightly brighter than the 45-90 μm spectrum. The reason for this is unknown but likely is attributable to a lower abundance of CM2 in the largest size fraction.

Discussion: The intimate mixture spectra demonstrate that reflectance decreases quite dramatically, even with small amounts of CM2 material: visible region reflectance decreases to half its starting value with <20 wt.% CM2. Similarly, eucrite band depths are reduced to approximately half their starting value with 20-30 wt.% CM2 material. However, even 60 wt.% intimately mixed CM2 (the highest CM2 abundance that was examined) does not lead to the appearance of the weak CM2 absorption bands near 0.7 and 1.17 μm (attributable to Fe-bearing phyllosilicates) [10]. For areal mixtures, >90% CM2 is required for the CM2 bands to appear. Also of note is the fact that PRA 04401 is less red-sloped than the intimate mixtures. This is likely because Murchison and the CM2 material in PRA 04401 have different spectral slopes [10].

For the intimate mixture spectra, band I minima show a gradual decrease in wavelength position with increasing CM2 content; however, continuum removal results in a band center that varies by <2 nm from the pure eucrite value. The shift in band I minimum is due to the overall red slope of the Murchison spectrum; it may be possible to use shifts in band minima to recognize the presence of red-sloped CM2 materials. Band II shows a greater shift in minimum position with increasing CM2 content, likely due to its being shallower and broader than band I. Band area ratios (BARs) are not significantly affected by the presence of CM2 material. BAR varies by <10% for the intimate mixtures.

With increasing eucrite grain size, band depths suggest that the two pyroxene absorption bands become saturated at different grain sizes: ~67 μm (i.e., 45-90 μm) for band I and 148 μm (i.e., 90-250 μm) for band II. Increasing grain size affects band minima (shift to shorter wavelength), while band area ratio is only significantly affected for the 60 wt% CM2 mixture (increasing from the pure eucrite value by ~15%).

Increasing CM2 abundance and grain size both lead to reductions in overall reflectance, however many other spectral parameters are largely unaffected by either of these two processes: band centers and BARs are largely unchanged. The most significant spectral differences between increasing CM2 abundance and grain size are in terms of band depths, widths, and overall slopes. Band depths (starting from <45 μm size eucrite) increase for both band I and II with increasing grain size, and may decrease slightly when the bands become saturated. Using FC band passes, the 0.713/0.917 µm ratio increases with increasing grain size and decreases with increasing CM2 abundance. Band widths increase with increasing grain size, and decrease with increasing CM2 abundance.

Implications for Vesta: The DAWN FC and VIR should both be capable of discriminating the cause of albedo variations (CM2 material versus grain size variations), as these two mechanisms lead to different trajectories for pyroxene band depths. Ongoing research is examining other spectrum-altering properties, such as pyroxene composition, plagioclase abundance, and phase angle variations. It appears that visible region albedo of ~10% can only be achieved by CM2-bearing HEDs with >30 wt.% CM2; HEDs with grain sizes up to 375 µm always have albedos of >25% (we are also currently examining HED slab spectra).

References: [1] Gaffey M.J. (1997) *Icarus, 127,* 130-157. [2] Buchanan P.C. et al. (1997) *Meteoritics, 25,* 659-682. [3] Zolensky M.E. et al. (1996) *Meteorit. Planet. Sci., 31,* 518-537. [4] Buchanan P.C. and Mittlefehldt D.W. (2003) *Antarct. Meteorite Res., 16,* 128-151. [5] Gounelle M. et al. (2003) *Geochim. Cosmochim. Acta, 67,* 507-527. [6] Lorenz K.A. et al. (2007) *Petrology, 15,* 109-125. [7] McCoy T.J. and Reynolds V. (2007) *Antarct. Meteorite Newsl., 30.* [8] Herrin J.S. et al. (2010) *Meteorit. Planet. Sci., 45,* abstract #5438. [9] Herrin J.S. et al. (2011) *LPSC XLII,* Abstract #2806. [10] Cloutis E.A. et al. (2011) *Icarus, 216,* 309-346.

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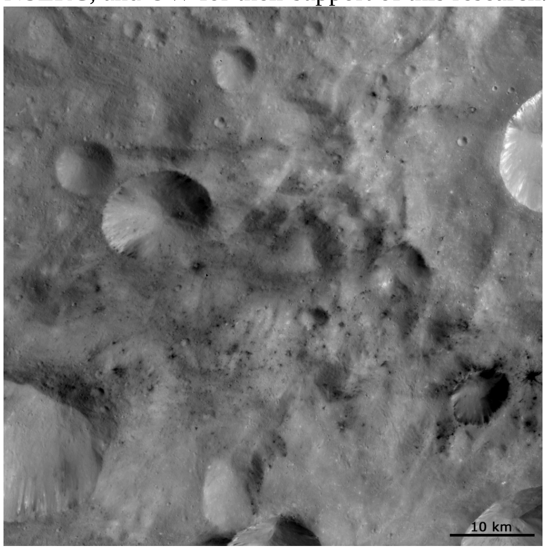

Fig. 1. DAWN FC image of Vesta showing darker areas (http://dawn.jpl.nasa.gov/multimedia/imageoftheday/image.asp?date=20111118).

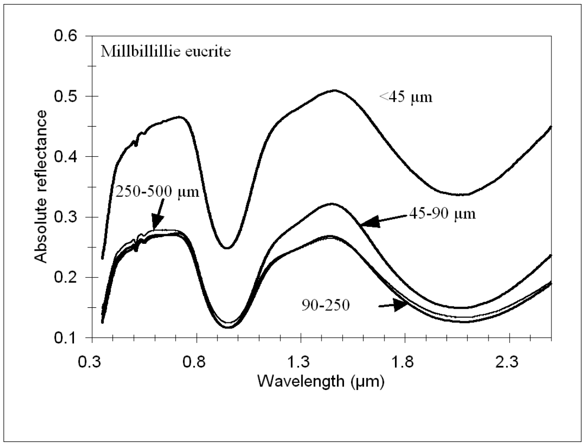

Fig. 2. Reflectance spectra of different size fractions of the Millbillillie eucrite.

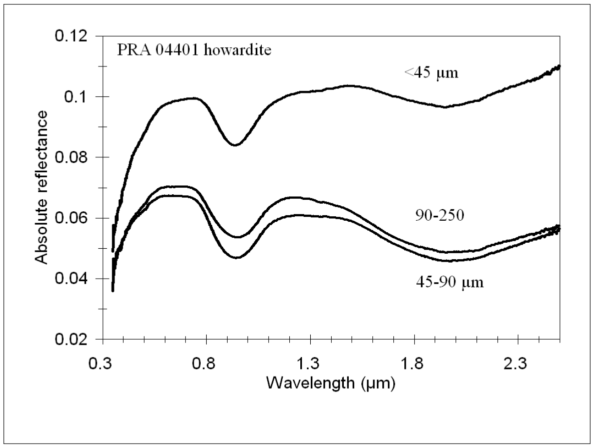

Fig. 3. Reflectance spectra of different size fractions of the PRA 04401 CM2-bearing howardite.

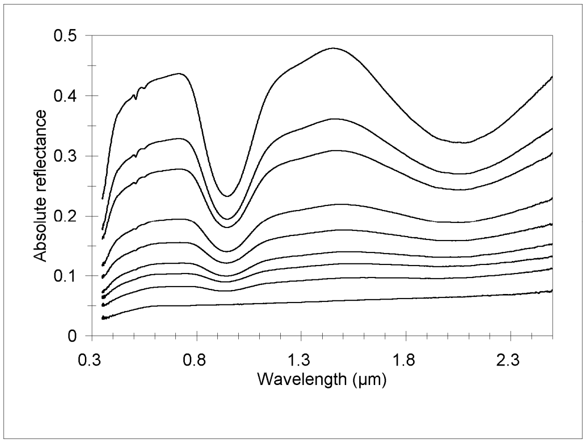

Fig. 4. Reflectance spectra of <45 µm size intimate mixtures of the Millbillillie eucrite + the Murchison CM2 chondrite. % Murchison from top to bottom: 0, 5, 10, 20, 30, 40, 50, 60, 100.