DARK MATERIAL ON VESTA: SYNTHESIS AND INTERPRETATIONS FROM DAWN OBSERVATIONS. T. B. McCord[1], J.-Ph. Combe[1], R. Jaumann[2], E. Palomba[3], V. Reddy[4], D. T. Blewett[5], H. McSween[6], C. A. Raymond[7], D. Williams[8], and the Dawn Team. [1]Bear Fight Institute, 22 Fiddlers Rd., Winthrop WA 98862 USA, [2]DLR Berlin Germany, [3]INAF-IAPS, Via del Fosso del Cavaliere 100, I-00133 Rome, Italy, [4]Max Planck Inst. Solar System, Lindau Germany, [5]Johns Hopkins University Applied Physics Laboratory, Laurel MD USA, [6]U. of Tenn, Knoxville TN USA, [7]Cal. Inst. Tech Jet Prop. Lab. Pasadena CA USA, [8]ASU, Tempe AZ USA. tmccord@bearfightinstitute.com

Introduction: Unusual deposits of "Dark Material" (DM) on Vesta's surface were recently discovered by the Dawn Mission [1,2]. A focused study of these deposits is underway within the Dawn team and the three preceeding presentations in this session [3,4,5] treat different aspects (geological, morphological and compositional) of the Dawn observations analysis. This report is a synthesis of these findings, presents some further analysis and interprets them in terms of origin(s) and processes.

Background: Analyses of the Dawn Framing Camera (FC) and Visible and IR (VIR) Mapping Spectrometer observations of DM are described in accompanying abstracts [3,4,5]. The DM's most obvious occurances, as illustrated in the FC broadband visible imagery [3], are small, well-defined deposits that are often but not always associated with impact craters, including in ejecta, and outcrops in walls and mass wasting deposits from these. Further, DM is shown to be distributed non-randomly across the Vesta surface, again suggesting association with Vesta's geology [3]. The color images from the Framing (FC) help to map and show the structural and compositional complexity of the small deposits [4], suggesting deposit altering processes. These DM depositions are clearly associated in many cases with the impact process, likely created and/or revealed by it, but the origin of DM is less clear in these images. VIR data show that the reflectance spectrum of DM is similar to, but more muted than the average Vesta spectrum, and reveals no obvious additional spectral features [5]. The pyroxene absorptions near 1 and 2 µm still appear but more weakly. VIR data also help in cataloging examples of DM deposits, especially using thermal emission to separate shadows from DM [5].

A Mixing Process: One apparent conclusion from these [3,4,5] and additional investigation reported here is that the nature of the DM deposits, whatever their source(s), are strongly influenced by impact mixing and gardening. In addition to the, sometimes-spectacular, small, well-defined DM deposits, there are also large regions of low albedo surface material, often with indistinct boundaries, that appear also to include DM. For example, Fig. 1 shows a 1.7-µm I/F map at 1 km/pixel of Vesta. Albedos range from about 0.25 to 0.40, and three different classes of the lower albedo range are mapped. There is a broad concentration of DM centered on approximately 135º E, with albedos as low as some of the smaller DM deposits, some of which also appear in this relatively low spatial resolution map (Fig. 1). These broad dark regions may be older and better mixed (DM into background material) than the smaller deposits, perhaps from a larger or more extensive event. Intermediate scale evidence of mixing also exists [Fig. 2], which shows wispy and mottled dark material deposits.

The VIR spectra of DM, discussed in [5], all may represent intimate and/or macro mixtures of materials. We modeled these spectra in an attempt to determine the basic spectral endmembers of Vesta soil, as measured by VIR, and to isolate the purest DM [Fig. 3]. This analysis indicates that most or all regions on Vesta can be modeled as a linear mixture of just two materials, a bright, pyroxene-rich soil and a darker, reddish material. No other material is needed.

Origin(s) of Dark Material Deposits: The main hypotheses for DM origin identified so far are: 1) low velocity infall from objects containing DM, 2) basalt flows, dikes or sills on/in Vesta that are broken and redistributed by impacts, and 3) impact melt from major cratering events. From the imagery, there is no conclusive evidence of basalt flows, and evidence of basaltic intrusions is equivocal. In addition, it is difficult to understand how a Vesta-like object could retain sufficient heat to create secondary melting and near surface extrusion of lava late enough in Vesta's evolution that the flows or major pieces of them would survive the impact history. On the other hand, there is morphological evidence of impact melt deposits that appear darker on Vesta. This would be expected, given the apparent active impact history of Vesta, which must have included some higher-velocity impacters. Infall origin for some material also seems probable. Surely, dark material from carbonaceous chondrite-rich (CC) objects, especially from the outer parts of the asteroid belt and perhaps from comets must strike Vesta's surface. The small mass of Vesta and its location far away from the Sun are likely to result in a larger percentage of low-velocity impacts than for the inner planets and the Moon, resulting in preservation of major fractions of the impacter material. Further, the spectrum for the DM endmember, derived above, is similar to that for CC material and for organic-rich material in the outer solar system in general. The infall explanation is also supported by certain HED (howardites, eucrite, diogenite) meteorites, thought to come from Vesta, that contain clasts of carbonaceous chondrite material within a matrix of pyroxene-rich basaltic material [e.g., 6,7]. Vesta retaining large quantities of exogenic impacting material, may be yet another way that Vesta is unusual or unique in the solar system, and a very interesting object to study further.

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References: [1] Russell, C.T. et al., 2011, Space Sci. Rev., [2] Sierks, H. et al., 2011, Space Sci. Rev., [3] Jaumann et al. 2012 LPSC 43 this session. [4] Reddy et al., 2012 LPSC 43 this session. [5] Palomba et al., 2012 LPSC 43 this session. [6] McSween et al. 2012 LPSC 43 this session. [7] Reddy et al.2012 LPSC 43 poster.

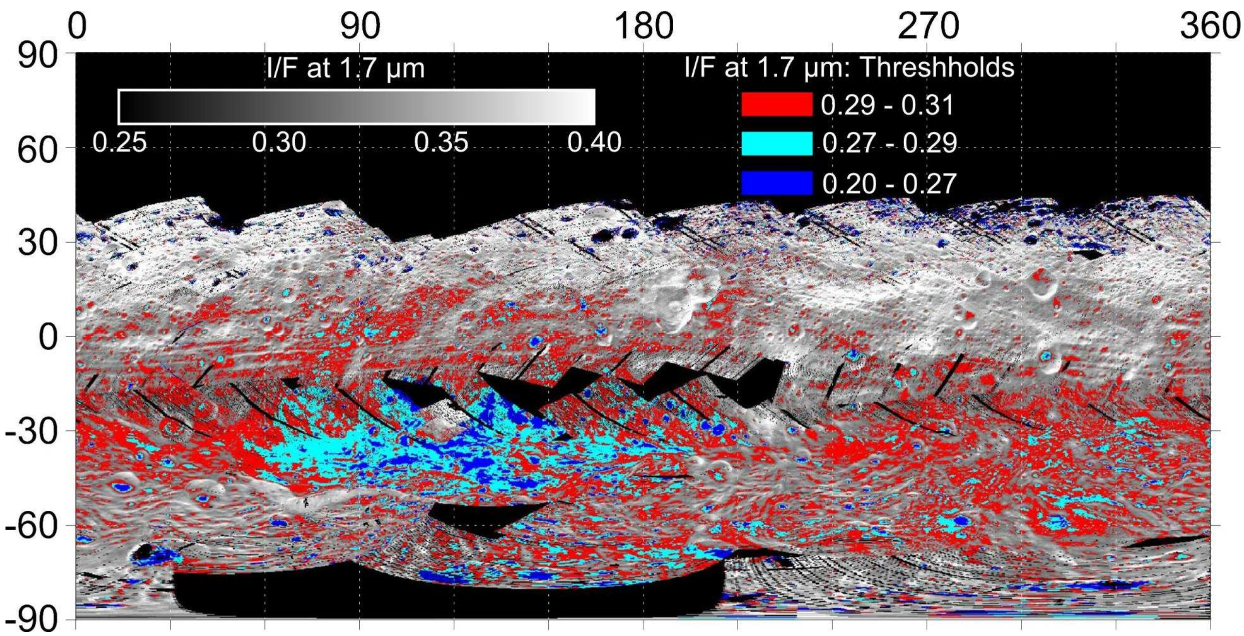

Figure 1. I/F map from Dawn VIR at 1.7 µm showing distribution of lower albedo areas.

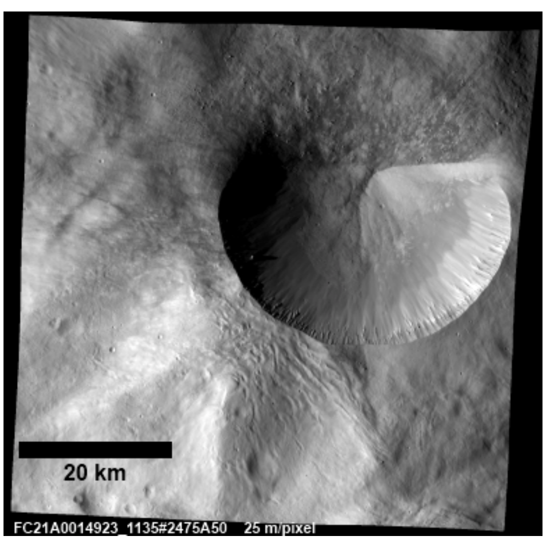

Figure 2. Example of DM filimentary and mottled deposits (top). FC21A0014923_11355163605F1A image center about 57.5 S, 205.3 E, 25 m/pixel.

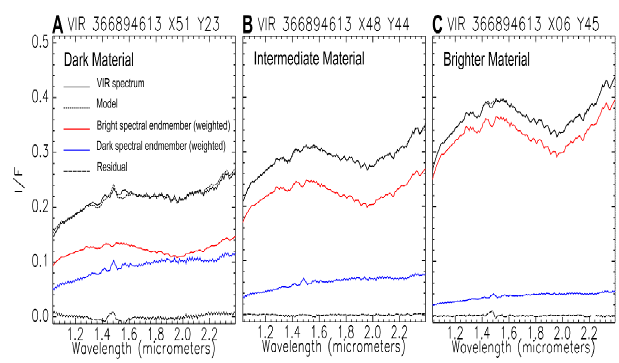

Figure 3. In each panel are shown the same two endmember spectra (called bright and dark), weighted differently, combined linearly (dotted spectra) to sucessfully model spectra (solid black) for three different regions.