Investigating the Origin of Dark Material on Vesta: Locations and Geological Context

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Introduction: Deposits of dark material appear on Vesta's surface as lower-albedo features in the visible wavelength framing camera (FC) images returned by the Dawn spacecraft [1,2]. Dark materials (DM) were found in the first images obtained during the mission's rotational characterization (RC) phase at distances of 5200 km (resolution 490 m/px). DM are often associated with impact craters as outcrops in walls and mass wasting deposits as well as ejecta. According to its geomorphological context DM deposits can be divided into 3 major classes [3]: (1) material in impact craters exposed on the wall and/or floor; (2) DM associated with crater ejecta patches or continuous ejecta blankets (such as small dark halo craters), often associated with hill flanks or impacts on topographic highs; and (3) clusters of dark spots and linear dark features. DM appears to have been exposed by impact excavation from within the regolith, and its distribution is heterogeneous across Vesta's surface [3].

DM in impact craters occurs at different levels in crater walls and is subject to mass movement (Figs. 1and 2).

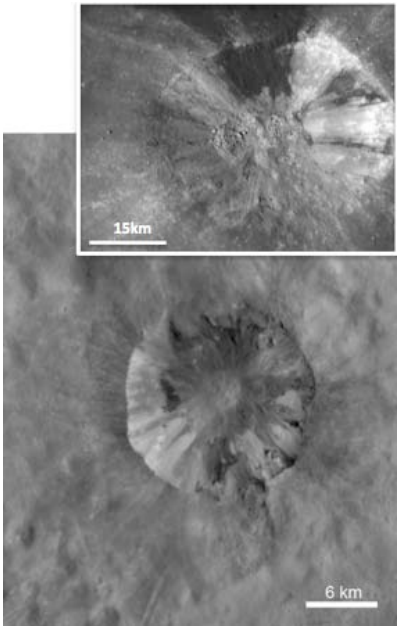

Fig 1: DM emanating from the crater rim either close to the crest or from alcoves ('outcrops') in the crater wall and slumping downslope in fans sometimes reaching the crater floor (Dawn FC 70m/pix). DM correlated with impacts can also be observed on the Moon (inset upper right crater Daguerre; LROC, NAC, NASA/GSFC/Arizona State University).

The source of DM in crater walls is unclear [see also 4, 5, 6] but might be due to fallback ejecta or indicate remnants of strata of DM (Fig. 2) that have been penetrated by the impact. Fans slumping down crater walls and DM on crater floors are the result of gravity-driven mass wasting triggered by steep slopes and impact seismicity.

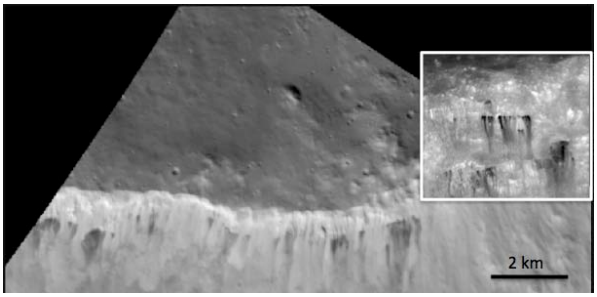

Fig 2: DM exposed below a sharp crater rim (Dawn FC, 20m/pix). The topographic position of all DM sources at the same level suggests the presence of a layer. DM is overlain by talus of bright material that originate from alcoves in the rim crest above the DM. The exposure of DM in crater walls on Vesta resembles that of DM emanating from the wall of the lunar crater Diophantus (inset upper right LROC, NAC, 0.5m/pix, NASA/GSFC/Arizona State University).

DM in impact ejecta indicates that this material is part of the excavation process.

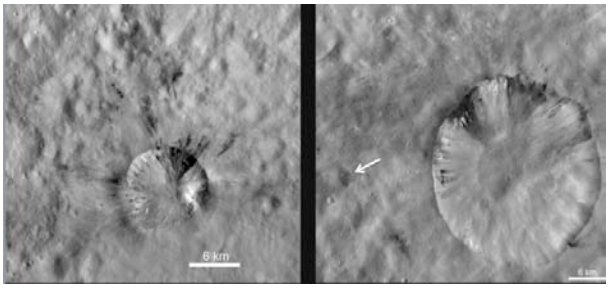

Fig. 3: DM intermixed in the ejecta (left) with subsequent impacts (arrow) excavating DM from beneath or occurs as isolated patches in the ejecta (Dawn FC 70m/pix).

Dark patches within crater ejecta (Fig. 3) might be due to local concentration of the DM either due to density and/or particle size differences in the ejecta plume, or due to the accumulation of ejecta behind obstacles (e.g., large boulders); this would suggest that the DM has been excavated late in the cratering process. DM in the ejecta blanket also may explain the dark regions emanating directly from the crater rim as an accumulation of ejected DM close to the rim that falls

back into the crater by mass wasting. Some small craters (Fig. 4) expose continuous DM ejecta similar to lunar dark-halo craters, indicating that the impact excavated DM (Fig. 3). In the vicinity of dark hills and faint dark rays (Fig. 4) may occur in association with small craters. This could indicate excavation of DM that might be part the hills. Positive relief edifices containing DMs (Fig. 4) were initially considered as potential volcanoes, but in higher-resolution images these appear more likely to be impact-sculpted hills, with DMs associated with dark or dark-rayed impact craters, suggesting either an exogenic origin for the DM, or excavation and exposure of sub-surface dikes by impact erosion.

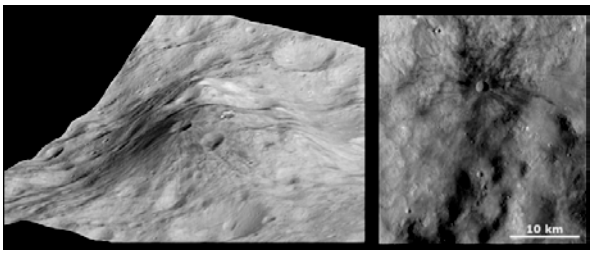

Fig. 4: Dark rayed ejecta associated with hills and hummocky terrain, (Dawn FC 70m/pix)

Clusters of dark spots and linear dark features are exposed as field of dark features (Fig. 3) inside and outside of craters or are arranged in a linear orientation as outcrops along scarps (Fig. 5) or dark streaks crossing different topographies (Fig. 6).

Distribution: The DM is distributed unevenly across Vesta's surface. Clustering occurs for all types of dark material exposure, and some craters expose or are associated with dark material in contrast to others in the immediate vicinity. This indicates local concentrations in the subsurface, rather than widespread distribution [3, 8].

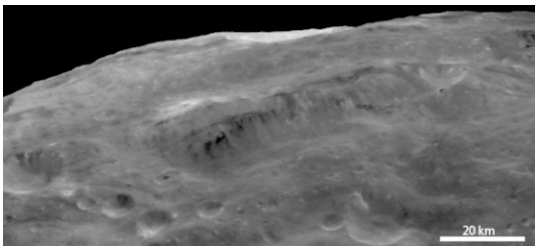

Fig. 5: Dark 'outcrops' in a slope (Dawn FC 260m/pix)

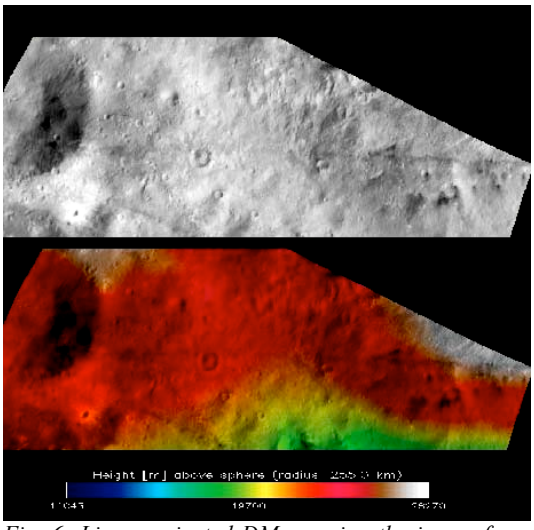

Fig. 6: Linear oriented DM crossing the image from left to right strongly exposed on topographic heights and outcropping in a crater (left) and in the scarp (left). (Dawn FC 70m/pix)

References: [1] Russell, C.T. and Raymond C.A., 2011, Space Sci. Rev., 163, 3-23, DOI 10.1007/s11214-011-9836-2, [2] Sierks, H. et al., 2011, Space Sci. Rev., 163, 263-327, DOI 10.1007/s11214-011-9745-4 [3] Jaumann et al., 2011, AGU #U21-B02; [4] V. Reddy et al., 2012, LPSC 43; [5] E. Palomba et al., 2012, LPSC 43; [6] H. McSween et al., 2012, LPSC 43 [7] T. McCord et al., 2012 LPSC 43; [8] R.A. Yingst et al., 2012 LPSC 43.

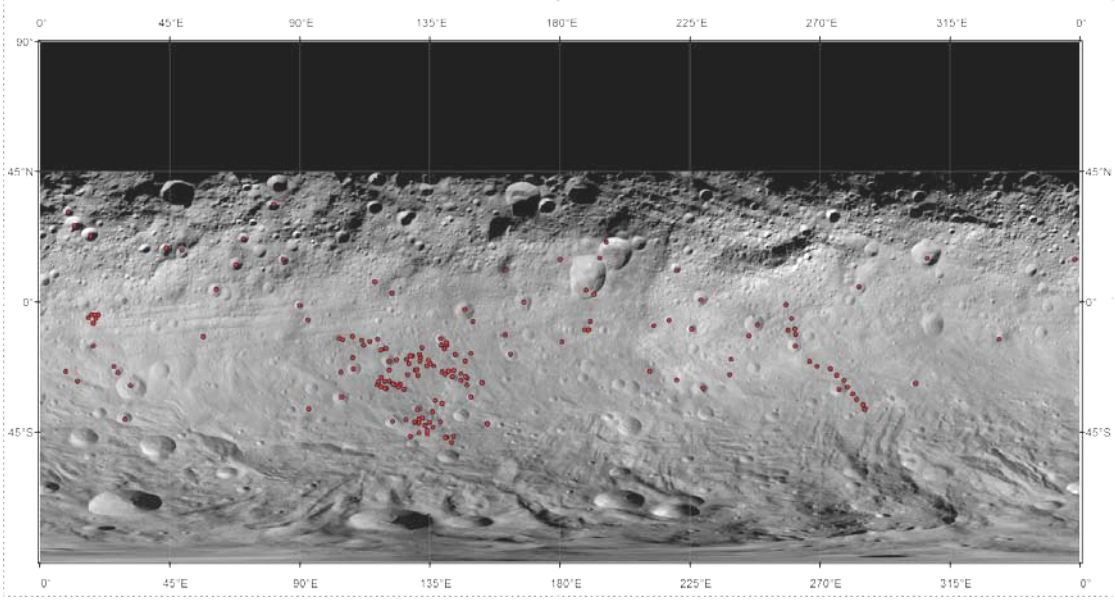

Fig. 7: Distribution of DM on Vesta (red dots indicate concentration of DM)