NATURE OF DARK MATERIAL UNITS ON VESTA: IMPLICATIONS FOR REGOLITH FORMATION AND CARBONACEOUS MATERIAL DELIVERY

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Introduction: Recent studies of the dark material (DM) and bright material (BM) units revealed that the Vesta surface have undergone intense fracturing, production and comminution of regolith [1,2,3]. Geomorphological analysis of DM units and their spatial distribution suggest that patches of dark materials are buried at various depth in the subsurface (down to ~2 km). DM is excavated and brought to the surface by impacts [1]. The results is an uneven distribution of DM on Vesta that is covered by a fine regolith composed of a mixture of dark and bright, fresher materials. By using Framing Camera images and VIR hyperspectral data two different catalogues of Dark material units were built [1,2]. Even if the two instruments have different spatial resolution and their spectral regimes are only partially overlapped, the two catalogues show large consistency, and both show larger concentration of DM units around the Veneneia impact basin.

Nature of DM units: More than 100 DM units are listed in the VIR catalogue [1]. Their spectra are dominated by the two large absorption band at 1 and 2 μm, typical of the pyroxenes, with variable band depths (BD) and reflectance, similar to the average Vestan surface. The inferred composition of the different dark deposits is very homogenous among them, i.e. a mixture of eucritic and darkening agents in various proportions.

The majority of DM units show a weak, but well identified, 2.8 μm band due to OH, that indicates the hydrated carbonaceous chondrite material as the most probable darkening agent, as suggest by earlier studies, too [4,5,6]. These studies claim that the DM originated in a low-velocity (<2 km/s) carbonaceous body impact during the formation of the 400 km diameter Veneneia basin ([4] delivery).

Hoewever, few DM (<10%) do not show a detectable OH absorption feature. This could imply the presence of a dehydrated CC or a material of different origin (e.g. impact melts, or metal rich materials). It will be important to assess what kind of darkening agent is present here and if it is different from the CC.

Regolith grain size and CC abundance: Typically for pyroxene rich material, reflectance is inversely related to grain size and directly to band depths [7]. For Vesta we observe a similar behavior at least for the band depths, being the grain size an unknown parameter.

The reflectance vs BDII scatterplot allow to disentangle the combined effect of these two parameters since it is very sensitive both to the grain size and to the abundance of a darkening agent. In Fig.1 we show how the bright and dark materials behave in this scatterplot. These behaviors have been compared with those of mixtures of eucritic material and carbonaceous chondrite contaminant (with different CC amount), together with those of three eucrites at different grain size. Two arrows indicate the CC amount increasing and the smaller size direction. The different grain sizes/darkening agent abundance in the considered dataset allows us to build boundaries for these two parameters that we use to evaluate grain size and CC abundance on Vesta.

With only very few exceptions, the Vestan dark and bright materials lies between the 0-25 and 25-45 micron size boundaries. Therefore on Vesta, the regolith grain size seems to be nearly homogeneous, suggesting that the difference between the dark and bright stands in the abundance of the dark contaminant, only.

If the considered mixture is representative of HED+CC mixtures, nearly all the DMs on Vesta would be located within the boundaries of 10-30 vol% of CC. This global result does not exclude that on a local scale, single units may show larger abundance of carbonaceous material. However, it is important to remark that at spatial resolution of the data among all the DM units we were not able to find a single unit composed of a pure carbonaceous chondrite. Extrapolating this result to the bright units, it seems that many of them are still contaminated by smaller amounts (<10 %) of carbonaceous chondrite material and that it is very difficult to find bright materials completely uncontaminated.

Implications for regolith formation and carbonaceous chondrite delivery: The apparent size homogeneity observed on the surface of Vesta indicates that the regolith is well mixed horizontally and vertically, at least in the first hundreds of meters beneath the surface. Moreover, the fact that thick patches of DM are found at depth, suggest that their fine grain size is not the result of subsequent evolution (e.g. collisional erosion), but rather it is the original accreted size. If true, this result argues against the scenario of large blocks of spall material from impacts with carbonaceous asteroids at the origin of the DM units, and supports the idea that DM was accreted in the form of dust [8]. The burial further constrains the accretion to be older than Rheasilvia basins (the last major event that may have generated a thick layer of regolith) but not necessarily older that Veneneia basin. A model of regolith redistribution due to the major observed craters [9] is needed in order to see if this scenario is consistent with the spatial distribution of the DM units.

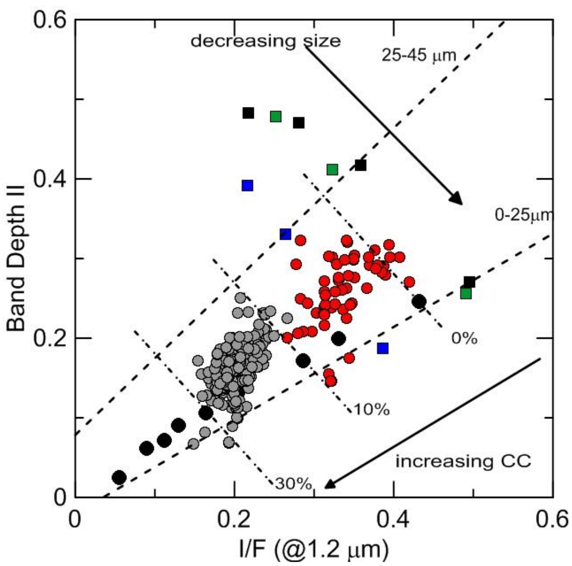

Fig.1 The black circles represent the mixture of a eucritic material (Millbillillie) and the Murchison meteorite at increasing abundance of the carbonaceous chondrite contaminant and with grain size (0-25 μm) [7]. The three eucrites are Juvinas (black square), Y-74450 (blue square), ALH78132 (green square) in the grain sizes interval (0-25, 25-45, 45-75μm). The BM cluster (red circles) is located in the eucrite region and is placed together with the DM cluster (grey circles). The dashed lines are the 0-25 and the 25-45 μm boundaries. The dash-dotted lines are the 0%, the 10% and the 30% boundaries.

References:

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