DISTRIBUTION OF THE NEAR-IR SPECTRAL SIGNATURE OF OLIVINE ON VESTA WITH VIR/DAWN DATA: THE ULTRAMAFIC SIDE OF VESTA'S SURFACE.

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Introduction: Pyroxenes are a major component of Vesta's regolith [1]. Their absorption bands dominate the visible to near-IR (0.5-2.5 μm) observations of Vesta [1] performed by Dawn´s Visible to near-IR mapping spectrometer (VIR) [2]. Recently, the absorption band of olivine was identified in the VIR data despite being partly masked by pyroxenes bands [3]. Because the identified olivine occurs in locations that are difficult to reconcile with the current understanding of Vesta's differentiation [3], we expanded our investigation to globally include additional occurrences of olivine-bearing material not identified in the earlier study of [3]. Olivine-bearing materials on Vesta's surface are thought to derive from magmatic rocks [3]. Thus, a comparison is performed throughout this study with diogenite, howardite and eucrite meteorites, possibly representing samples of magmatic lithologies formed on Vesta [4].

Method: *Spectral parameters.* Laboratory measurements of pyroxenes and olivine mixtures have shown that the spectral slope between 1.0 and 1.6 μm increases with increasing olivine content [5]. We use this slope to spectrally identify olivine. Such approach was already and successfully used on Mars with other datasets [6, 7]. On Vesta, the value of the identification criterion (hereafter named FoP) also depends on the amount of high-Fe pyroxenes [8] present in the mixture, and, to a lesser amount, to dark material [9] and potential Fe-bearing glass [10]. Therefore, additional spectral parameters are used in order to discriminate these components: (1) the band depth at 1 μm (BD1), (2) the band depth at 1.8 μm (BD1.8) and (3) at 2.2 μm (BD2.2), (4) the ratio BD1.8/BD2.2. The latter ratio is high for low-Fe pyroxenes ("Diogenite"-like) and low for high-Fe (and low-Ca) pyroxenes ("Eucrite-like", Fe^{2+}/M1 pyroxenes).

Thresholds on parameters. The mentioned mineral components have absorption bands close to 1.2 μm that mimic the olivine absorption band. Thus, thresholds on the FoP parameter need to be defined in order to avoid false identification of olivine. The thresholds will depend on the amount of each of the components. In each VIR observation the amount of high-Fe pyroxene is evaluated using the ratio BD1.8/BD2.2, and the dark material with the BD1 parameter. These thresholds will lead to the identification of enrichment in olivine on a regional scale. Variations on the parameters due to pyroxene grain size and observation geometry effects were constrained using laboratory data [11; 12]. As expected, we found an increase of the FoP parameter in potentially glass-rich regions of [10]. The spatial pattern is, however, different from that of previously identified olivine-rich spots [3] and the FoP increase is considerably smaller, so that possible Fe-bearing glass does not create false identification.

Prior to the application of the above spectral parameters, we have corrected VIR Survey and High Altitude Mapping Orbit (HAMO-1-2,~170 m/px) data for spikes in the spectral dimension and reduced stripes effects in the spatial dimension. A filter process was specifically designed to avoid shadow-related artifacts.

Results: *Global distribution:* We have identified possible olivine-enriched material in 11 new locations with, where available, multiple VIR observations. The spectral signatures of these locations have lower FoP values and deeper band depth at 2 μm relative to the two previsouly identified sites [3], indicating lower olivine contents (<50 vol % [5].) Often the signature is associated with morphologically fresh areas of a few kms in size, such as crater ejecta or brighter slope material (Fig. 2a,c). The global-scale distribution of the 11 newly identified locations reveals a concentration in the eastern hemisphere of Vesta (Fig. 1a). This clustering coincides with the two previously identified sites [3] and with a hemispherical enrichment in low-Fe pyroxene (i.e., similar to the pyroxenes of diogenite and howardites) [13; 14].

Association with the Rheasilvia ejecta: Three newly identified olivine-rich sites are located ~50 km north from the South Pole Rheasilvia basin rim (Fig.1), within its thick ejecta blanket as mapped by [15]. Fig. 2b shows that these olivine detections are in close proximity to high BD1.8/BD2.2 areas. An analysis on the high BD1.8/BD2.2 areas indicates pyroxene band centers at 0.929 μm and 1.919 μm (or shorter). This pyroxene composition corresponds to diogenite-howardite (or diogenite), consistent with previsous work [13]. At these sites, the sequence of VIR spectra (Fig.2d) shows the expected "regolith" pyroxene absorption bands at 1 and 2 μm. The sequence also exemplifies subtle but mineralogically consistent and diagnostic spectral shape variations (see caption Fig.2). Our global survey indicates that this is a unique location on Vesta where VIR spectral data indicate relative enrichment in both olivine and diogenite-like composition within relatively small, 5 km sized areas. It must be emphasized, however, that these enrichements are small, as the spectra still preserve prominent pyroxenes bands at 1 and 2 μm.

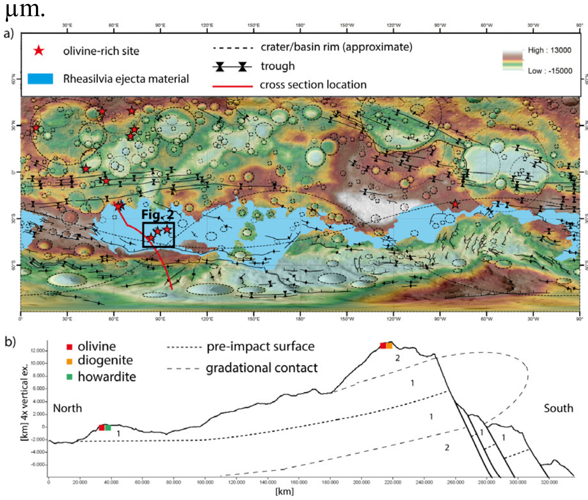

Figure 1. (a) Topographic map of Vesta with detected olivine-enriched sites (red stars) and geologic features. (b) Topographic section from profile (red line) in (a) with a proposed interpretation. The subsurface has been schematically subdivided into two layers. The deeper layer (#2) might host local enrichment in olivine and diogenite-like pyroxene. The shallower (#1) could bear local olivine alone. The Rheasilvia impact would have overturned these two layers.

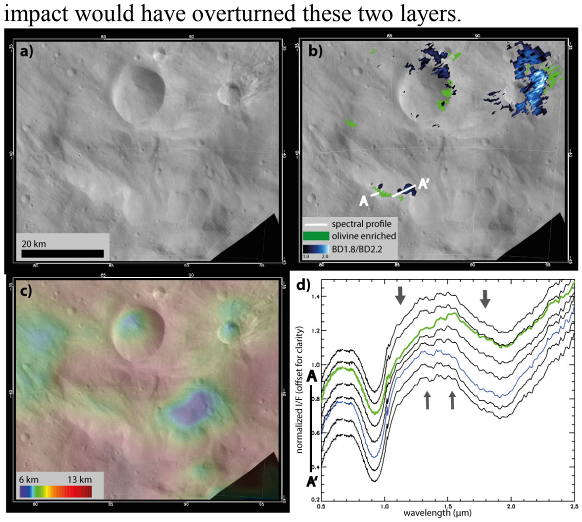

Figure 2. (a) Framing Camera (FC) mosaic of the southernmost olivine-enriched sites. (b) VIR spectral parameters maps superimposed on the FC mosaic. (c) Topography superimposed on the FC mosaic. (d) VIR spectra corrected for spikes and even-odd effects, extracted from the profile shown in (b). Relative enrichment in low-Fe pyroxene (blue spectrum) is identified with a shallow 1.1-1.6 slope, and a deeper band at 2 μm (large arrows). A steeper 1.1-1.6 slope, a band maximum between 1 and 2 μm located at longer wavelengths (small arrows), and a shallower band at 2 μm (yellow spectrum) can be explained by a relative enrichment in olivine. The shallower band at 2 μm and no variations in the band center exclude the alternative possibility of an enrichement in high-Fe pyroxene.

Discussion and Conclusion: This study identified new possible local enrichments in olivine. Although the quantitative amount of olivine was not constrained, in some locations the deep pyroxene bands indicate a relatively small amount of olivine, maybe as low as 10 vol. % [6]. We propose that the hemisperical (equator and northern hemisphere) occurrence of olivine-enriched sites together with a hemispherical diogenite-howardite-like composition of pyroxenes [14] is reminiscent of a distinct compositional terrane. Further studies are needed to discriminate whether this terrane is the result of a compositional province of the crust or affected by material ejected from the Rheasilvia basin. The southernmost olivine-rich sites identified in this study, which are associated with an enrichment in diogenite-like pyroxene, are most probably brecciated material ejected by the Rheasilvia impact. Figure 1b shows a possible interpretation suggesting that the olivine and diogenite-like pyroxenes material were ejected from a depth of 10-25 km. Subsequently, impact gardening resulted in a mixing with other pyroxene-rich ejecta material. The rarity of such co-occurrence, the depth of origin, and the relatively low olivine content (although impact gardening might decrease the olivine abundance) seem to suggest the presence of relatively small ultramafic lithologies within the crust. The observations are more difficult to reconcile with an olivine-dominated mantle origin, as conceived by some studies [e.g., 16]. If an olivine-dominated mantle is indeed present on Vesta, it is restricted to depths greater than the excavation depth of Rheasilvia, estimated at 30-45 km by [17].

References: [1] DeSanctis M.C., et al. (2013) *MPS*, doi;10.1111/maps12138. [2] DeSanctis M.C., et al. (2011) *SSR* doi10.1007/s11214-010-9668-5. [3] Ammannito E., et al. (2013) *Nature*, 122, vol. 504. [4] Mittlefehldt D.W. (2003) *Treat. on Geochem.* vol 1.11. [5] Cloutis E.A., et al. *(1986), Icarus* 91, B11. [6] Poulet F., et al. (2007) *JGR 112* E08S02. [7] Ody A., et al. (2012) *JGR* 118 E004149 [8] Klima R.L., et al. (2011) *MPS 46, 379-395.* [9] McCord T.B., et al. (2012), *Nature,* 83, vol. 491. [10] LeCorre L., et al. (2013) *Icarus 226, 1568-1594.* [11] Cloutis E., et al. (2012) *Icarus 223, 850-877.* [12] Ruesch O., et al. *(2013) 44th LPSC #2236.* [13] Ammannito E., et al. (2013) *MPS* doi :10.1111/maps 12192. [14] Yamashita N., et al. (2013) *MPS* doi :101111/mpas 12139. [15] Yingst A., et al. (2013) *Icaurs* in revision.[16] McSween H., et al. (2013) *JGR* 118 doi:10.1002/jgre.20057. [17] Ivanov and Melosh (2013) *JGR 118, 1545-1557.*