SOME MORE LOCATIONS OF POSSIBLE EXPOSED OLIVINE ON VESTA USING VIR/DAWN DATA.
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Introduction: The large asteroid Vesta underwent global-scale differentiation and intense magmatism. Although impact events on Vesta have oblitered the structure of the original igneous crust [1], the surface mineralogy (pyroxenes, olivine) has likely kept the record of the magmatic processes [2]. In addition to studying the surface mineralogy, a major contribution to the understanding of Vesta magmatism is provided by studies of mafic and ultramafic achondrites (the Howardite, Eucrite, Diogenite (HED) suite), that likely formed on Vesta [3, 4]. The diversity of pyroxene minerals and their spatial distribution across Vesta has been studied with the Dawn mission data and is broadly consistent with a pervasive melting of primordial Vesta, perhaps with the formation of a magma ocean [2]. More regional processes, however, also seem to have played a role during Vesta´s differentiation and crust formation [5,6]. Recently, using the Dawn mapping spectrometer (VIR) [7], olivine mineral was found to be rare and only locally exposed on Vesta´s surface [8]. In order to better understand the processes responsible for the origin and distribution of olivine on Vesta, we performed a detailed mapping of the olivine signature across the entire surface of Vesta. For such purpose, we developed a set of specific spectral parameters and specific thresholds to isolate and map the signature of olivine in the VIR/Dawn data.

Method: *Spectral parameters.* In the near-IR spectral range (0.6-2.5 µm) Vesta´s surface is a multi-component surface dominated by pyroxenes absorption bands. We use the slope increase in the 1.1-1.6 µm range, measured by a parameter defined in [9] (hereafter named FoP), to detect increasing olivine content in pyroxene-dominated mixtures. Because the parameter is also sensitive to dark material, glass, and pyroxenes with Fe^{2+} in the M1 crystallographic site, additional parameters are developed in order to discriminate between olivine and the other 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 BD2.2/BD1.8.

Thresholds on parameters. Two thresholds on the FoP parameter are defined to avoid spectral signatures of dark material and pyroxenes with Fe^{2+} in the M1 site. Their values are not chosen as constant, instead, they vary as a function of the parameter variations within each cube. To avoid effects of dark material, the threshold varies as a function of the BD1 parameter, which decrease with increasing dark material content [10]. To avoid Fe^{2+}/M1 pyroxenes, the threshold varies proportionally to the BD2.2/BD1.8 ratio, which increase with a higher amount of Fe^{2+}/M1 pyroxene [11]. Such parameter trends were verified using the available laboratory data on mineral mixtures. Variations due to grain size and observation geometry effects [12, 13] were constrained. Quantitatively, (1) a FoP moving average is calculated across the BD1 (and the BD2.2/BD1.8 ratio) variation range in each image, and (2) the threshold is defined by adding to the moving average the 3σ (chosen after visual analyses of numerous VIR cubes of various illuminations and locations) of the FoP parameter. Because each cube is treated separately, and the threshold values slightly vary across Vesta´s surface, this method allows detecting olivine enrichment at a local scale.

By comparison with potential glass-rich regions [14], we found that (1) the FoP increase due to potential glass is below the 3σ threshold and (2) the spatial pattern of relatively high FoP values is different from that of previously identified olivine-rich spots. With the current understanding of glass spectral characteristics on Vesta [14] we conclude that glass does not influence olivine detections with the above method.

Results: The analyses of more than 700 cubes (Survey and HAMO-1-2) with global coverage led to the identification of 13 different potential olivine-rich locations on Vesta (Fig. 2). 10 of the sites have been detected in at least two VIR cubes acquired at different times and spatial resolutions, thus excluding instrumental artifacts. 3 of the sites have been previously detected by [8]. Relative to surrounding olivine free/poor spectra, the 10 newly identified sites have the highest 1.1-1.6 µm spectral slope, a weaker band depth at 2 µm, and a high albedo. These key features, in addition to no changes in the band centers, indicate the presence (<~50 vol.%) of olivine (Fig. 1)

At each site, generally 2-5 km wide, the morphology is consistent with fresh, un-gardened, surface exposures. As seen in Figure 2, the global spatial distribution indicates a hemispherical concentration. The northern olivine-rich sites are found on the rims of 100-200 km large basins, possibly representing ejected material from depth to 9-12 km (using [15]), as well as in areas with regionally higher elevations. At the equator, the sites are located within a large-scale trough and ridge system. The southern sites are found at the edge and within the Rheasilvia ejecta, with the southernmost sites having pyroxenes rich in Mg (diogenite-like). This latter geologic context is illustrated in the topographic profile of Figure 2.

Discussion and Conclusion: This study tentatively identified kilometers-sized olivine exposure, with the newly identified locations (olivine content <~50 vol%.) occurring around previously identified sites (>50 vol.% [8]). The hemispherically limited distribution suggests a regional/local formation process. The relatively shallow depths of origin and the geologic context of the olivine-rich spots found in this study are less consistent with a mantle origin. Thus, if an olivine-dominated mantle is present on Vesta, it should be at depth greater than the excavation depth of Rheasilvia (30-45 km [16]). Olivine in association with a diogenite-like pyroxene composition is interpreted as a deep seated magmatic lithology being overturned by the Rheasilvia impact event, as schematically illustrated in Figure 2 cross section (layer 2). Olivine-rich material lacking enrichment in Mg-rich pyroxenes (howardite-like) could have been ejected from shallower depths (Figure 2 layer 1).

Future investigations will need to focus on quantitative analyses of the olivine abundances on the detected sites.

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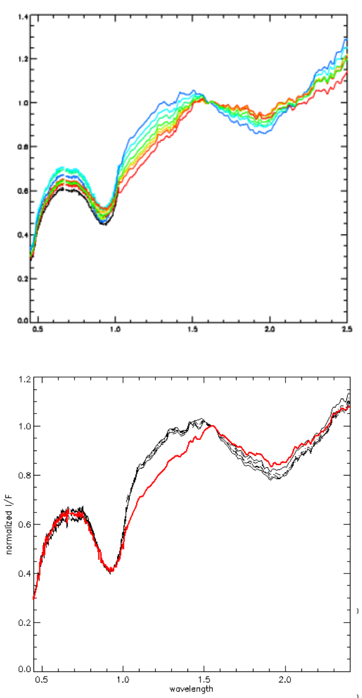

Figure 1. (top) Visible and near-IR spectral variations of an olivine free/poor area an an olivine-rich spot [7], as revealed by VIR/Dawn data. (bottom) VIR spectrum of a newly identified olivine-rich spot (red) compared to surrounding olivine free/poor spectra (black).

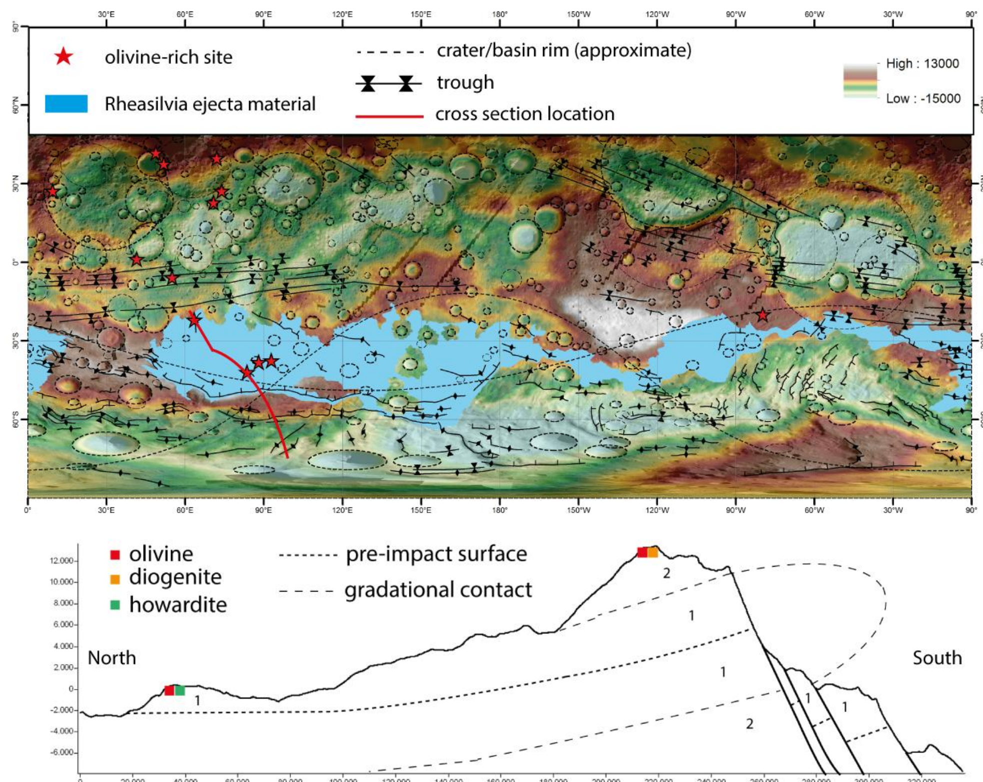

Figure 2. (top) Location of olivine-rich sites on a global topographic map of Vesta, identified in VIR/Dawn data. Rheasilvia ejecta material map from [17]. (bottom) Topographic profile and interpreted structure of the Rheasilvia ejecta and associated olivine-rich site with their pyroxene compositions.