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Seeing through the pyroxene: distribution of olivine-bearing material on Vesta using VIR/Dawn data

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1. Introduction

The pyroxenes-dominated surface of Vesta has been observed at high spatial resolution in the range 0.3-5.0 µm by the VIR imaging-spectrometer onboard the Dawn spacecraft [1]. These observations allow detailed compositional analysis and can thus provide insights into Vesta volcanic and magmatic processes. Before the arrival of the Dawn spacecraft, the spectral signature of olivine has been expected on the deepest regions of Vesta, which would correspond to exposures of the mantle [2]. Although VIR has revealed the ubiquitous presence of various pyroxenes on Vesta, the search for olivine was first and surprisingly unsuccessful [1, 2]. The apparent lack of olivine would be consistent with a thick crust formed by magmatic instrusions [3]. Further and very recent spectral analyses have nevertheless shown the possible olivine-rich material on one location, which does not however represent clear mantle exposures [4]. To better understand the possible olivine-rich material, we investigate the presence of olivine-bearing material at global scale, by developing a set of specific spectral parameters to isolate and map the signature of the olivine mineral in the VIR data.

2. Method

Any possible spectral signature of olivine on Vesta shall be subdued because of the strong pyroxene absorption bands that dominate each Vesta spectrum [4]. 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 as the basis of the olivine spectral criterion. Such approach was already and successfully used on Mars with other datasets [6, 7, 8]. The value of the criterion (hereafter "FoP") depends on grain size and iron content of olivine, but also on other factors as discussed in Section 3.

The FoP criterion is tested with VIR Survey and High Altitude Mapping Orbit (HAMO-1,-2) data that have spatial resolution of ~700m/px and ~170m/px respectively. VIR radiance spectra are converted to Lommel-Seeliger reflectance spectra as in [9]. A filtering process was applied to the dataset to remove observations, for which the geometries created numerous shadows and/or spectral artifacts. In this way, a filter parameter based on the presence of an artifact located at 1.5 µm was designed.

3. Calibration of olivine parameter

The spectral criterion needs to be quantitatively calibrated with respect to the Vesta surface. This calibration is performed by analyzing numerous data cubes of various illuminations, flux levels and locations, including the ones that exhibit a clear olivine signature [4].

A compositional bias, which mimics the spectral change due to olivine in the 1.0µm/1.6µm, results from the presence of dark material (i.e. impact melt/carbonaceous chondrite) [e.g., 10, Figure 1]. By comparing an olivine rich area with a dark material area, we found that the lowering of the 1 µm band is more affected by dark material than by the presence of olivine. Using dark material regions as a reference, we found that if a band depth at 0.94 µm is <0.45, then dark material is possibly present, precluding the search of olivine signature. A second compositional bias is due to high-Ca pyroxenes that exhibit a pronounced band at 1.2 µm due to iron in the crystallographic M1 site [11, Figure 1]. Most of the pyroxenes have a pronounced band depth at 2 µm. An olivine spectrum, instead, lacks absorption bands at 2 µm. The olivine and high-Ca pyroxenes can thus be distinguished on the basis of the band depth at 2 µm. Visual inspection of VIR data was carried out to find a high-Ca pyroxene rich-region on which the criteria was calibrated. If a band depth at 2.1 µm is >0.2, then high-Ca pyroxene is possibly present and olivine is probably absent. A third compositional bias is represented by Fe-bearing glass of medium albedo [12]. Such material presents a broad band after 1 µm, similar in shape to the bands due to olivine. A diagnostic parameter for its identification is a low 0.45 µm/0.75 µm ratio (i.e., reddening) [12]. However, it has not yet been detected on Vesta and therefore the quantitative calibration of the ratio cannot be performed. Further analyses are needed to better constrain the quantitative effects of Fe-bearing glass.

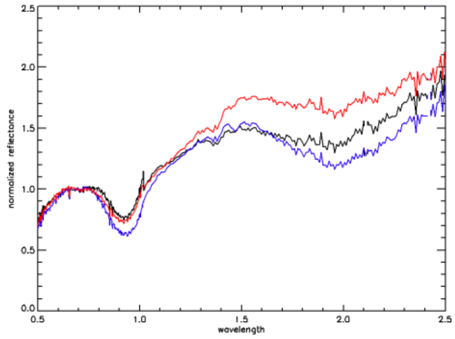

Figure 1: Typical VIR spectra scaled to 0.55 µm. Black curve: dark material. Blue curve high-Ca pyroxene-bearing material. Red: olivine-bearing material.

4. Olivine mapping

We applied the set of spectral criteria on the HAMO-1,-2 VIR dataset. We found that any value with FoP>1.07 for pixels where no compositional bias is present indicates the presence of olivine. In such regions (broadly 70% of the observed surface), we found olivine only within a limited 30°x30° area around the previously identified olivine-rich locations (i.e., northern hemisphere). Within this area, the strongest olivine signature corresponds to the bright walls of 5 craters of diameter ranging between 12 and 50 km. Outside this area, one additional occurrence was discovered (Figure 2).

Where the set of criteria indicates the presence of high-Ca pyroxenes or dark material, we estimate that the Fo parameter detect olivine only above 1.11. In some other regions, it is still unclear whether the values above 1.07 indicate olivine or are affected by compositional biases. For these regions (occurring near the equator), the possible olivine occurrences are broad areas, without a concentration of high values (as in the northern hemisphere). Thus, at this stage of the investigations, we consider them as ambiguous and further analyses (quantitative modeling and testing on HED spectra [13]) shall be necessary to clearly identify these ambiguous terrains.

Our results show that olivine-bearing terrains are mainly concentrated to one region in the northern hemisphere of Vesta. The formation of these deposits will be discussed.

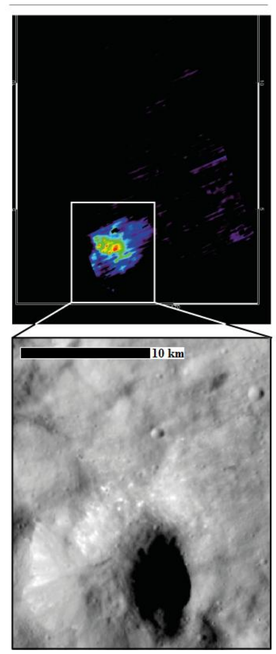

Figure 2: (top) FoP parameter map and close-up (bottom) on olivine-bearing material at 2°N 41°E. Olivine signature corresponds to small and bright-halo craters, indicating fresh exposures.

Acknowledgments

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