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Distribution of olivine rich materials on Vesta: application of spectral indices to the VIR-Dawn data

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Abstract

We apply spectral indices that are well suited to identify the presence of olivine-rich materials in Dawn/VIR hyperspectral data. These indices (created for Martian studies) were deeply studied to be applied to Vesta materials. If used in combination among them, olivine detection can be more robust. Here we display the global distribution maps of the different indices, showing that potential olivine-rich sites are indeed present on Vesta.

1. Introduction

The occurrence of olivine on Vesta is supported by petrogenetic models involving chondritic precursors (e.g. [1]), by the presence of olivine-rich members in the Howardite-Eucrite-Diogenite (HED) [2,3,4].
The Dawn mission has been in orbit around Vesta for approximately one year. During this period, the Visual and InfraRed spectrometer (VIR) [5] obtained high quality spectra in the range (0.2-5) μm with spatial resolution spanning from 1.3 km (Approach phase) to 0.18-0.07 km (Low Altitude Mapping Orbit). So far no clear spectroscopic evidence for extensive olivine deposits has been found at Vesta. Only recently, by using high resolution High Altitude Mapping Orbit-2 data, possible detections have been reported [6]. We investigate here the possibility to detect olivine-rich regions on the vestan surface by applying specific spectral indices to VIR hyperspectral data.

2. Spectral indexes

In our analysis we use spectral indices sensitive to the olivine presence that have been created to analyse Martian materials, i.e. Forsterite Index [7], OLVIndex [8], and HCP Index [9]. In addition to these, we included the Band Area Ratio (BAR) [10].
These indices have been tested on laboratory olivine-pyroxene mixtures and on HED [11]. It has been found that all of them behave in a linear fashion with the olivine content (inverse proportionality for BAR and HCP Index, direct proportionality for Forsterite Index and OLVIndex). But they are affected also by other variables. For example, presence of high Calcium pyroxenes in a mixture tends to increase both the Forsterite Index and the OLVIndex, and hence can lead to a false detection of olivine. This occurs also for lower grain-sized mixtures, since at decreasing grain size again both the Forsterite Index and the OLVIndex increase, whereas BAR decreases. In addition, presence of metal tends to underestimate the olivine amount, even if this circumstance is not expected on Vesta.
Furthermore, a well-combined use of the different spectral indices is needed in order to avoid false positives. For example, an olivine deposit cannot be discerned by a high Calcium pyroxene-rich deposit by probing it with the Forsterite Index and the OLVIndex, only. Contrarily, the two kinds of deposits will show a very different HCP index value.

3. Vesta indices maps

Spectral indices have been calculated on the whole VIR dataset (including Approach, Survey, High Altitude and Low Altitude Mapping Orbit) a total of about 13 millions of spectra. However, we noted a not negligible influence of the observation geometry on the indices retrieval. Therefore we selected only observation with incidence angle <70° and with phase angle <65°. A mosaic of images covering nearly almost the whole surface of Vesta has been obtained for each spectral index (Fig. 1).

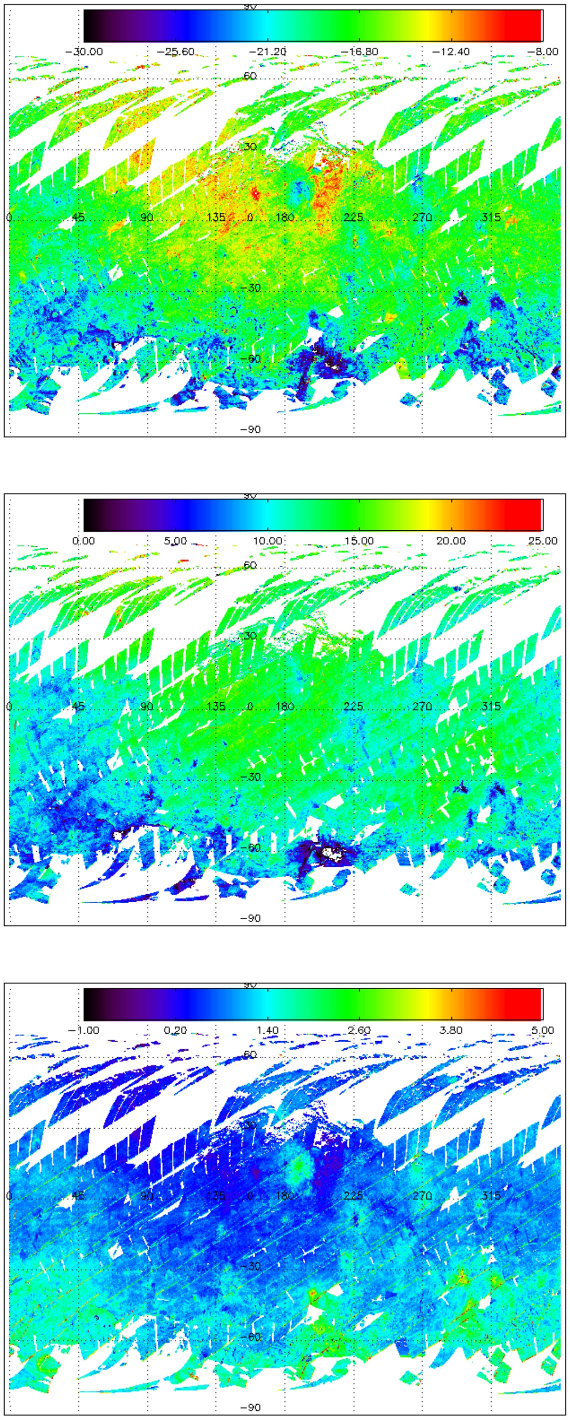

Fig.1. OLVIndex (up), Forsterite Index (center) and HCP Index (down) plotted on the Vesta cylindrical map. Indices values in the colorbars are multiplied by 100. White areas refer to too low indices, extreme illumination conditions or missing values.

By comparison of Vestan spectra with laboratory mixture spectra, we can fix the following thresholds for the olivine detection: -0.15/-0.10 for the OLVIndex, 0.15/0.20 for the Forsterite Index, <0.01 for the HCP Index. These thresholds can vary, since they are also affected by presence of other components (such as dark material) or grain size.

Two broad regions having these requirements emerge from the three maps: the largest is centred equatorially at 180° and the second one is located at latitudes 0°,-30° and longitudes 250°,360°. These are two regions proved to be eucritic [12], and hence the positive olivine indices could be justified by a combined effect of smaller grain size and small amount of olivine.

Other smaller features are present. Two very intense spots located in the northern hemisphere are clear in the Forsterite Index map. Conversely, the OlvIndex is more intense in one individual spot located in the southern hemisphere and in several small spots are located eastward of the Calpurnia crater. Interestingly, the HCP parameter map shows an opposite trend with respect to the previous two, indicating that where the OlvIndex and Forsterite Index are more intense, high Calcium pyroxenes are essentially absent at the explored spatial scale.

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