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New olivine deposits detected on the surface of Vesta

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Abstract

To detect new olivine deposits on Vesta, we applied two new methodologies to the hyperspectral data taken by the VIR spectrometer onboard the Dawn mission. We confirmed the olivine occurrence in the Arruntia and Bellicia regions and we were able to find six other regions which could host olivine. All but one are located in the northern part of the asteroid and this means that the old petrogenetic models should be reshaped to explain the observed olivine distribution.

1. Introduction

The recent discovery of olivines on Vesta by the VIR imaging spectrometer onboard the Dawn space mission changed dramatically the vision about the Vestan petrogenetic models [1]. Before that, olivines were expected to be present in the Vesta depths: in the mantle of a vertically layered body as invoked by the magma ocean models [2], or at the base (or within) the mantle-crust boundary as claimed by fractionation models [3]. Olivines were detected by VIR-Dawn in two wide areas near the Arruntia and Bellicia regions, located in the northern hemisphere, far from where the Rheasilvia and the more ancient Veneneia huge basins should have excavated the crust down to reach the mantle [4]. In this work we present new detections of olivine rich areas on Vesta that were retrieved by applying two alternative and new methods on the hyperspectral data obtained by the VIR instrument.

2. Spectral indices

In our analysis we use spectral indices sensitive to the olivine presence that have been created to analyse Martian materials, i.e. a Forsterite Index [5] (FOR-x), a Fayalite Index [5] (FAY-x), a generic Olivine Index [6] (OLV-x). In addition to these, we included the Band Area Ratio (BAR) [7].

These indices have been tested on laboratory olivine-pyroxene mixtures and on many HED IR spectra [7]. It has been found that all of them behave in a linear fashion with the olivine content (inverse proportionality for BAR, direct proportionality for FOR-x, FAY-x and OLV-x). However, their values are affected also by other variables. For example, presence of high calcium pyroxenes in a mixture tends to increase both the FOR-x and the OLV-x, and hence can lead to a false detection of olivine.
For this reason we also considered to investigate the behaviour of the HCP index (HCP-x) [8], in order to discern olivines from HCPs.
Effects of albedo: The Vesta surface exhibit a large variation in albedo with many dark and bright material units [7,8], therefore the influence of albedo on the spectral indices should be assessed in detail. Among all of the indices, the BAR and FOR-x only are nearly insensible to albedo, whereas the others show a monotonic trend.
Influence of grain size: The general trend is a larger variation of all the indices for grain size smaller than 100 μm, and a weak variation above this value.
FOR-x is the only index which seems to be only weakly affected by grain size, since in all the analysed samples, variations with grain size are between 2-6%.

3. Methods and olivine detection

Spectral indices have been calculated on the whole VIR dataset (including Approach, Survey, High Altitude and Low Altitude Mapping Orbit) [9], including about 20 million 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.
We selected the BAR and the FOR-x as the best parameters that can be used on Vesta and applied two independent methods to detect olivine on the VIR

hyperspectral cubes: a cross-correlation and an anti-correlation analysis.

Cross correlation analysis. The thresholds which would indicate the olivine occurrence have been defined by considering HED and olivine-LCP-HCP mixture spectra in the FOR-x vs BAR scatterplot.

The FOR-x (BAR) threshold is the value above (under) which no HED would be found but only mixtures containing even a low olivine amount.

According to these criteria, we consider that olivine on Vesta occur when BAR is lower than 1 and FOR-x is larger than 1.1, simultaneously.

Anti-correlation analysis. To test the validity of the anti-correlation analysis as a suitable method to detect olivine, we selected a 1°x1° area in the Arruntia (i.e. between 41°N and 42°N latitudes and 70°E and 71°E longitudes) and in the Bellicia regions (i.e. between 39°N and 40°N latitudes and 52°E and 53°E longitudes), where the olivine presence has been already detected [1] and confirmed by our cross-correlation analysis. The pixels that fall in the selected areas (even if taken in different observations) are then plotted in the FOR-X vs BAR plane and the Pearson coefficient is calculated. For both the areas a strong anti-correlation is evident for BAR values smaller than 1, with Pearson coefficient values of -0.79 for Bellicia and -0.73 for Arruntia.

We decided to apply this alternative method to all the Vesta surface. Firstly, we re-gridded the Vesta data surface in a 1°x1° pixels. The linear behavior observed in Arruntia and Bellicia is very clear for BAR values smaller than 1 only. Areas with a Pearson coefficient >-0.5, i.e. showing a weak anti-correlation as well as areas with less than 5 pixels were considered not reliable and were discarded.

4. Conclusions

In agreement with the recent discovery, Arruntia and Bellicia resulted as the most olivine rich areas, i.e. where the parameter values are more intense for both the applied methodologies. In addition to these two locations, we detected 6 other new regions, all but one located in the Vesta north hemisphere (Figure 1). This result confirms again that the old petrogenetic models cannot be straightforwardly applied to Vesta and should be reshaped in the view of these new detections. An alternative and very recent option can be represented by the model described in [10], in which surface "eruption" of material from the mantle, including olivine can reach the surface of Vesta.

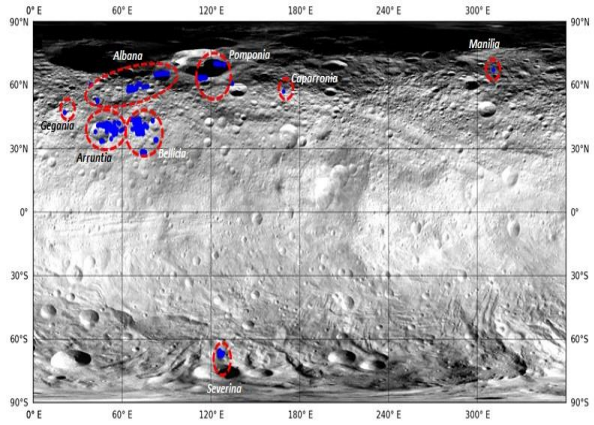

Figure 1: Olivine deposits detected by cross-correlation and anti-correlation analysis

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