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Olivine on Vesta: clues for the interior

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Abstract

Data from the Dawn VIR (Visible InfraRed mapping Spectrometer) instrument [1,2] have been used to characterize and map the distribution of minerals on Vesta. Howardite, eucrite and diogenite meteorites represent the basaltic crust and possibly ultramafic mantle samples of Vesta, the only surviving large basaltic differentiated rocky protoplanet. Olivine is a major component of the mantles of differentiated bodies, including Vesta. Here we report on the discovery of olivine and its constraints on the Vesta evolution models.

1. Introduction

VIR acquired data during Approach, Survey, High Altitude Mapping (HAMO) and Low Altitude Mapping (LAMO) orbits provided very good coverage of the surface, especially over the equatorial and southern regions. Data acquired during HAMO-2 covered much of the Northern hemisphere that had been in shadow earlier. The nominal VIR pixel resolution ranges from 1.3 km (Approach phase) to 0.18-0.07 km (LAMO). High quality spectra, from 0.2 to 5 µm in 864 spectral channels have been acquired.VIR spectra of Vesta are characterized by pyroxene absorptions at 0.9 and 1.9 µm. Several different regions of Vesta have been identified. They are characterized by distinctly different band depths, widths, shapes and centers [3,4], suggestive of different HED lithologies. A special place is Rheasilvia basin that exposes diogenitic rich material in the deeply excavated southern hemisphere [5,6]. Early in the mission, a specific search was made for olivine in this basin; however no olivine-rich regions were identified. This is attributable to the difficulty of distinguishing olivine spectrally in concentrations <25% in the presence of abundant orthopyroxene [7], due to the lower absorption coefficient of olivine relative to that of pyroxene.

2. Olivine

Olivine spectra are dominated by a diagnostic, broad, complex absorption centered near 1 µm, which varies in width, position, and shape. Unlike pyroxene, olivine lacks a 2 µm band. The search for olivine continued using the latest VIR data acquired during HAMO-2. The spatial resolution of these data are about 200 m and cover from the South Pole to the Northern hemisphere. The analysis of some specific areas in the Northern hemisphere indicates the presence of olivine.

Fig. 1 reports a representative spectrum from the olivine-rich area (green) and a nearby region with a typical average vestan spectrum (black). The two spectra clearly differ in overall shape. In particular, the spectrum of the olivine-rich area shows the 1 µm band center at slightly longer wavelengths with respect to average Vesta, while the 2 µm band center remains the same. The shape of the 1 µm band is also asymmetric, as expected for pyroxenes-olivine mixture.

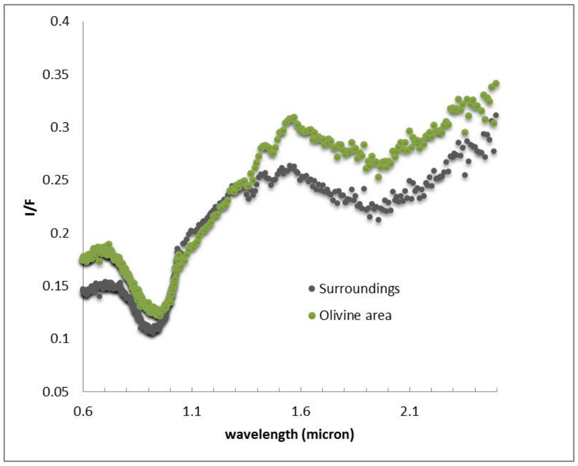

Fig.1: Green curve: spectrum of olivine-rich area. Black curve: average spectrum of a region near the olivine-rich area; The small bands around 1.4 and 1.5 µm are calibration artifacts. No smoothing has been applied to the data.

The olivine-rich areas occur over a broad 100 km size region, located in the northern hemisphere. Olivine is exposed inside craters walls and ejecta. Olivine is in the form of numerous distinct patches hundreds meters across associated with relatively higher albedo materials. Several small craters emplaced in ejecta have high albedo annuli with olivine spectral signatures.

The olivine-rich deposits seem to occur as layered material that is partially obscured by slump deposits and gardening of the surface. Spectrally, the olivine rich areas appear to consist of large amount of olivine mixed with average surface material (howardites). This is in contrast to meteoritical evidence, where olivine mainly occurs in low modal percentage and typically in association with diogenites.

3. Clues on the interior

The identification of olivine-rich lithologies on Vesta can constrain different petrologic scenarios, each of which predicts different abundances and distributions of olivine.

The two main petrogenetic models for Vesta are: 1) magma ocean models [8,9], which invoke widespread crystallization of olivine, and 2) fractionation in multiple crustal plutons [10,11]. The magma-ocean models of Vesta predict an olivine-dominated mantle below an orthopyroxene (diogenitic) lower crust, and a basaltic upper crust. This model, with olivine well below the crust, predicts that olivine-rich material would only be excavated by large, basin-forming impacts. The alternative model considers that some diogenites and harzburgites (diogenites with olivine) may have formed at the base of, or within, the vestan basaltic crust. Both the scenarios are compatible with the distribution and the type of olivine mixing observed on Vesta. Nevertheless, some factors, such as the association with howardites, could favour the hypothesis of olivine excavated from a deep source.

Acknowledgments

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