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Thermal properties of olivine- and diogenite-rich sites on Vesta

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Abstract

Olivine-rich deposits were discovered locally on Vesta's surface. Unexpectedly, these deposits occur far away from the prominent Rheasilvia basin: they were rather found in the northern hemisphere as a layer exposed in walls and in ejecta of two craters, scattered more diffusely over a broad area [1]. Furthermore, while diogenite was firmly identified at southern latitudes [2], mineralogical data acquired by VIR suggest diogenite-rich howardite at equatorial latitudes, namely on the top of Brumalia Tholus hill and in the nearby Teia crater's ejecta, which is consistent with the hill being the surface representation of a magmatic intrusion (dike) [3,4].
Dawn's Visible and Infrared Mapping Spectrometer (VIR) [5] hyperspectral images can be used to retrieve surface temperatures, with high accuracy (< 1 K) as long as temperatures are greater than ~180 K. In this work, we present temperature maps and emissivity spectra of olivine-rich deposits found on Vesta, and temperature maps of crater Teia's ejecta.
Thermal emission, especially when measured at different points in time, can provide clues to the physical structure of such peculiar sites, which complements the mineralogical investigation based on VIR data collected at shorter wavelengths.

1. Introduction

After the initial Survey (11 through 31 August 2011) and High Altitude Mapping Orbit (HAMO-1, 29 September through 1 November 2011), Dawn spiraled down to its 210-km above mean surface Low Altitude Mapping Orbit (LAMO) (12 December 2011 through 30 April 2012). The Dawn spacecraft eventually raised its altitude back to 685 km above mean surface to perform a second High Altitude Mapping Orbit (HAMO-2, 15 June to 25 July 2012).
Low resolution VIR data (~700m/pix), taken during Survey at moderate northern latitudes, showed a possible olivine signature, confirmed later on by higher resolution data (~200 m/pix) that definitely established the presence of olivine in and around a couple of craters, whose diameter is of the order of tens of km [1]. This is believed to be a sample of the vestan mantle or deep pluton. Brumalia Tholus is an elongated hill in Vestalia Terra and was similarly observed by VIR during Survey, but high resolution data acquired in HAMO-2 were crucial to determine its composition to be diogenite-rich howardite [3]. This is particularly evident in the ejecta of Teia crater (6.6 km, Lon 271°, Lat 3.4° S), which impacts the north side of Brumalia and thus is likely sampling its core material [3].
Here we calculate surface temperatures of such features on the basis of VIR data acquired in HAMO-2. On Vesta, the region of the infrared spectrum beyond ~3.5 μm is dominated by thermal emission from the asteroid's surface, which can be used to determine surface temperature by means of temperature-retrieval algorithms. To calculate surface temperatures, we applied a Bayesian approach to nonlinear inversion [6] based on the Kirchhoff law $r_\lambda=1-\varepsilon_\lambda$ and the Planck function. Results were compared with those provided by the application of alternative methods (e.g, [7]). In all cases, the minimum retrievable temperature (~180 K) is set by the Noise Equivalent Spectral Radiance (NESR), i.e. the RMS noise of the in-flight measurements expressed in units of spectral radiance. On the other hand, for a given local solar time (LST), the maximum temperature depends on incidence angle and surface properties such as thermal inertia and albedo.

2. Results

Olivine-rich deposits found on Vesta show a different thermal behaviour compared to the surrounding terrains. Especially in one of these craters, olivine-rich ejecta are significantly cooler (ΔT ~10 K) than the surrounding terrains observed under similar illumination and at the same LST (**Fig. 1**). Because the average emissivity of such features in the thermal range is very similar to that of the surroundings, this is likely related to the physical structure of surface material and may be due to its higher thermal inertia, in turn related to an increased local density (i.e. a reduced local porosity) or to a different thermal conductivity (or both things together). On Mars, olivine-rich dikes were found to be thermophysically distinct, showing higher thermal inertia compared to the surrounding terrains [8]. As far as ejecta are concerned, this evidence might point to a local concentration of coarser regolith, compared to the average fine regolith that mantles most of the asteroid.

The temperature difference between Teia's ejecta and the surrounding terrains observed in similar illumination conditions (**Fig. 2**) tends to increase with time in the vestan morning, reaching the same values (ΔT ~10 K) found for olivine-rich ejecta and in the pitted floor of some craters on Vesta [9,10]. Again, because the spectral emissivity of Teia's ejecta in the thermal range substantially matches that of the surroundings, this seems to be related to the physical structure of the ejecta, namely a local concentration of compact material or coarser regolith.

3. Figures

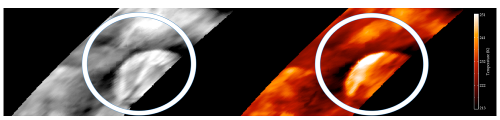

Figure 1. Simple cylindrical projection of a portion of an olivine-rich crater on Vesta, observed by VIR in HAMO-2 (185 m/pixel). The left panel shows the region as seen at the near-infrared wavelength of 1.4 µm (not photometrically corrected). The right panel shows a temperature map of the same area, as derived from VIR infrared spectra in the range longward of 4 µm, where thermal emission is important. The ejecta (highlighted by the circle), observed at approximately 11.6 h LST, have an average temperature of 226±0.4 K and are ~10 degrees cooler than surrounding terrains observed at the same LST and under similar illumination conditions.

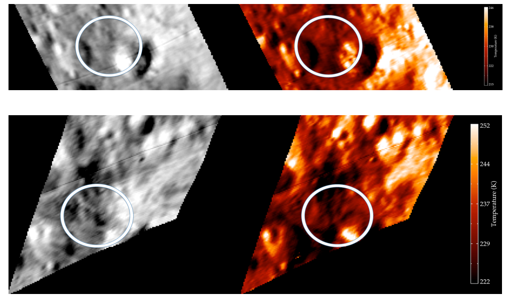

Figure 2. Two views of Teia crater, observed by VIR during the HAMO-2 phase (166 and 163 m/pixel, respectively). In both cases, the left panel shows the region as seen at the near-infrared wavelength of 1.4 µm (not photometrically corrected), while the right panel shows a temperature map of the same area. In the first view (top), spectrally distinct material associated to Teia's ejecta (highlighted by the circle), observed at 9.6 h LST, has an average temperature of 227±0.4 K and is at least 5 degrees cooler than surrounding terrains observed at the same LST and under similar illumination conditions. In the second view (bottom), Teia ejecta are observed at approximately 10.5 h LST and show an average temperature of 229±0.4 K, i.e. 10 K cooler than the surroundings.

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