Distinct thermal appearances on Vesta as inferred from the Dawn/VIR data

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In this paper, we review some of the peculiar thermal appearances that the Dawn spacecraft has observed on Vesta at the local scale: pitted terrains, with an emphasis on the Marcia crater, olivine-rich sites, and diogenite-rich howardite craters. The information derived by the thermal infrared measured by the Visible and InfraRed mapping spectrometer [1] onboard Dawn is fully complementary to mineralogical information inferred by the same instrument at shorter wavelengths, and to geologic and topographic information derived on the basis of optical images acquired by the onboard camera. In particular, the thermal information is crucial to identify local concentrations of coherent material, and thus allow a better understanding of the observed structures.

Pitted terrains were found in a few sites on Vesta [2], and display distinct thermal properties compared to other terrains. They show a reduced thermal emission at infrared wavelengths greater than 4 µm and have distinct margins in the temperature images, being cooler than nearby terrains observed under similar solar illumination conditions. Pitted terrains can be >10 K cooler than the surroundings [3], and even cooler than bright material units found on Vesta, despite their lower albedo [4].

The Marcia crater is the largest location of pitted terrains [2]. The pitted floor of Marcia is distinct in color and albedo from its surroundings, with lower reflectance at visual wavelengths and shallower pyroxene band depths. A prominent difference in temperature is found between the pitted floor (cooler at ∼230 K) and the regions of curvilinear systems in the crater walls (hotter at ∼240–260 K).

The lower temperatures of Marcia's pitted floor, as well as of other pitted sites on Vesta, suggest a higher thermal inertia, i.e., a slower thermal response to changing insolation. This is consistent with an increased local density or a higher thermal conductivity (or both), following an impact [4]: local cavities at micrometer to centimeter scale disappear, leaving a compact layer. The lower albedo of pitted terrain also supports coherent material as opposed to the unconsolidated material widespread on the surface of Vesta. Similar to the origin proposed for numerous martian pitted craters, pits on Vesta may form through degassing of volatile-bearing materials [2], possibly an ice-rich subsurface layer, following an impact.

Olivine-rich deposits found on Vesta [5] show a different thermal behaviour compared to the surrounding terrains. Especially in the vicinity of Arruntia crater, olivine-rich ejecta are significantly cooler ($\Delta T \sim 10$ K) than the surrounding terrains observed under similar illumination conditions and at the same local solar time. 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. On Mars, olivine-rich magmatic intrusions (dikes) were found to be thermophysically distinct, showing higher thermal inertia compared to the surrounding terrains [6]. As far as ejecta are concerned, this evidence might point to a local concentration of roughest material, compared to the average fine regolith that mantles most of the asteroid.

Teia is a diogenite-rich howardite crater on the top of Brumalia Tholus hill. This composition is consistent with the hill being the surface representation of a dike [7,8]. The temperature difference between Teia's ejecta and the surrounding terrains observed in similar illumination conditions tends to increase with time in the Vestan morning, reaching the same values ($\Delta T \sim 10$ K) found for olivine-rich ejecta of Arruntia and in the pitted floors of Cornelia and Marcia [3]. 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 coherent material or coarser regolith.

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