

EXPERIMENTAL ASSESSMENT OF THE HIGH REFLECTANCE PITTED TERRAINS ON VESTA.

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Introduction: Pitted terrains on Vesta occur in and/or around relatively young craters and due to their geomorphological appearance and similarity with Martian pitted terrains [1,2], they have been linked to volatile loss [3]. The surface regolith in the broad region of Marcia crater and its surrounding is characterized by a high amount of OH-bearing materials [4] and by a generally lower reflectance and diminished absorption features (likely due to chondritic contamination [e.g. 5,6]).

Within this region, pitted terrains distributed around Marcia crater show a higher reflectance and stronger pyroxene absorptions with respect to their immediate surrounding (Fig. 1), which was previously described in [7] and [8]. The spectral properties match those of pure eucrites which are members of the endogenic HED meteorite group and some of the pitted terrains also exhibit a local depletion in OH (Fig. 1, lower right panel), as revealed by the 2.8 μm distribution map generated in [9]. The upper panel in Figure 1 shows stronger pyroxene absorptions as greenish colors.

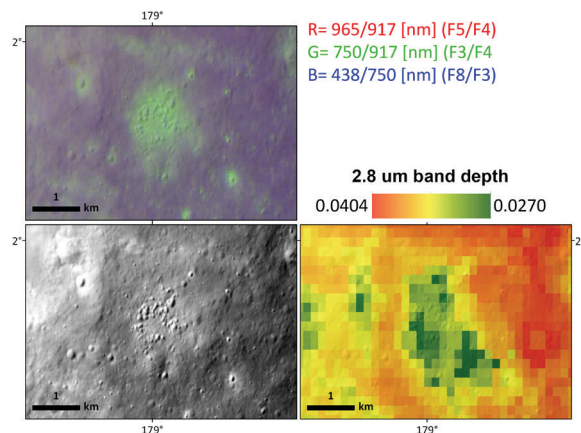


Fig. 1: Pitted terrain SW of Marcia. All three panels show the same locality. The lower left panel is a clearfilter Framing camera image on FC LAMO resolution (~ 16 m/px). The RGB in the upper panel was generated with FC HAMO data (~ 60 m/px). Lower right panel was generated by [9] with VIR data.

Interestingly, volatile loss is generally not linked to an increased reflectance and enhanced absorption features [10,11] and has not been observed on Mars or Ceres. However, several processes might be able to create the observed features on Vesta: (1) particle size segregation, (2) removal of darkening agent, (3) com-

positional differences due to endogenic or impact related processes.

Here, we present results of our first laboratory experiments (structural and spectral), conducted to elucidate the process creating these enhanced spectral features.

Experimental approach: All experiments were conducted in the Planetary Spectroscopy Laboratory (PSL) at DLR in Berlin [12,13]. The reflectance was measured with two different detectors from 0.4 to 1.1 μm and from 1 to 16 μm in an evacuated Bruker 80V spectrometer and by means of a Bruker A513 reflectance unit.

We used three different grain size ranges of hypersthene (from <63 up to 250 μm) as well as fine grained montmorillonite and carbon black (both < 50 μm) as a terrestrial analogue for what is assumed for the Vestan regolith (howardite, phyllosilicates and organic darkening agents, respectively, e.g. [4,5]). The samples were mixed with the following proportions: hypersthene ~ 71 wt%, montmorillonite ~ 28 wt%, carbon black ~ 1 wt%. The mixtures were then either mixed with liquid distilled water and frozen or put on top of a distilled water ice layer (freezing occurred down to ~ -80 $^{\circ}\text{C}$) in a cylindrical sample container with a diameter of 50 mm. Mixtures without any sort of water were also prepared in the same way (frozen to about -80 $^{\circ}\text{C}$) in order to compare the results.

An emissivity chamber was used to let the samples degas under vacuum ($\sim 10^{-5}$ bar) and, in one case, to heat the sample in vacuum to a temperature of approximately 200 $^{\circ}\text{C}$. After the samples degassed for several hours (~ 20 h), a microscopic structural and compositional analysis was followed by reflectance measurements.

Results: The samples that were mixed with liquid water show very subtle signs of devolatilization and did not produce morphologic features.

The experiments with the layering setup produced pronounced morphologic features like cracks and pits as well as evidence for volatile loss indicated by dust emerging from the samples which was retained and measured as well.

In all of the experiments, the microscopic analyses revealed that the darkening agent (carbon black) remained closely bonded with the hypersthene grains after degassing (probably due to fine particle cohesion)

and hence providing a lower reflectance with respect to the pure hypersthene (Figs. 2 and 3).

In the residual samples after degassing (yellow, dark blue and red line in Figs. 2 and 3), we observed no separation of grain sizes; large hypersthene grain sizes (~250 μm) were still visible on the surface and closely bonded with fine-grained hypersthene, montmorillonite and carbon black particles. However, the ejected dust particles were exclusively very fine-grained (in the range of <63 μm); but still contained carbon black particles. Hence, the ejected material (light blue line) exhibits a higher reflectance with respect to the residual material on the ground, but still a lower reflectance and strongly diminished absorption features with respect to the pure hypersthene and the dry mixture (green line).

Figure 3, normalized to a reflectance of 1 at 0.75 μm , displays the different visible slopes of the spectra which decrease strongly from the pure hypersthene (yellow line) to the ejected dust (light blue line) as well as the differences in band depth. None of the altered spectra reaches the band depth of the pure hypersthene. The band depth even decreases slightly after degassing with respect to the dry mixture (green line).

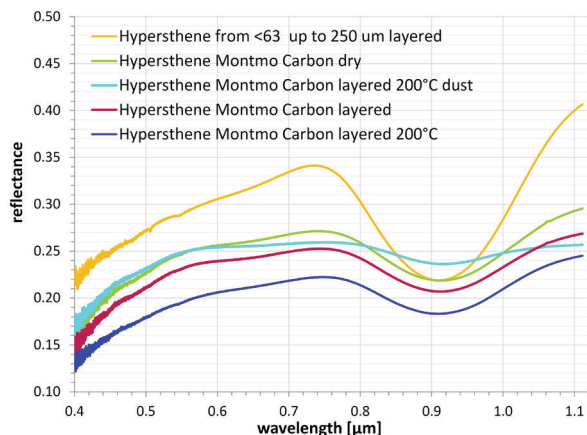


Fig. 2: Examples of analogue material reflectances. Yellow line: hypersthene with mixed grain sizes from <63 up to 250 μm , after freezing on top of a water ice layer and vacuum degassing. Green line: mixture of hypersthene (from <63 up to 250 μm), montmorillonite (<50 μm) and carbon (<50 μm), after freezing and vacuum degassing (no water ice used). Light blue line: ejected material from dark blue line sample. Red line: mixture of hypersthene (from <63 up to 250 μm), montmorillonite (<50 μm) and carbon (<50 μm), after freezing on top of a water ice layer and vacuum degassing. Dark blue line: same mixture and procedure as red line, but with heating to ~200 $^{\circ}\text{C}$ in vacuum.

Montmorillonite behaves very volatile (mixtures with montmorillonite become partly ejected from spectrometer sample holders under vacuum) and could be

the main phase in the ejected dust fraction (could not be distinguished visually from hypersthene at this particle size) and thus be the reason for the very diminished pyroxene absorption feature (light blue line). In conclusion, we observed a particle size segregation with respect to the ejected material. We could not observe the loss of the darkening agent by degassing.

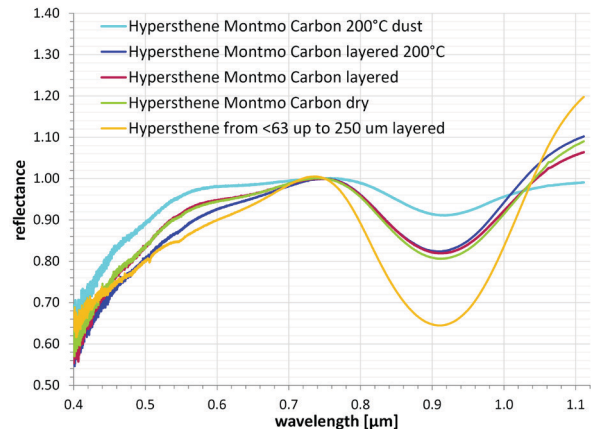


Fig. 3: Spectra of Figure 2 normalized to a reflectance of 1. The different band depths and slopes are clearly visible. None of the setups generated deeper band depths (as observed on Vesta).

Discussion: Our experiments showed that the process of degassing causes the preferred removal of smaller particles from a set of mixed-size samples, however the increase of reflectance due to the observed particle size segregation is not strong enough to produce the observed spectral features on Vesta (based on the given experimental setup). The particle size segregation foremost created a higher reflectance (light blue vs. dark blue line), but not a stronger pyroxene absorption (the opposite instead). Band depths decreased which is the opposite of what we observe on Vesta. We will conduct other setups in the future to further investigate this phenomenon.

References:

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