DETECTION OF A MINOR ALTERATION PHASE IN SOILS AT THE PHOENIX LANDING SITE, MARS.

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Introduction: The Phoenix Spacecraft (PHX) carried an Optical Microscope (OM) that returned color images of soil material with a spatial resolution of 4 µm/px. Several hundreds of in-focus color OM images were used to develop a taxonomy of soil particles, to describe their optical and magnetic properties and to assess their relative abundance. The science payload onboard PHX did not allow a (direct) determination of the mineralogy of these grains. Whenever possible, data from other instruments onboard PHX: Wet Chemistry Lab. , Thermal and Evolved Gas Analyzer, Stereo Surface Imager (SSI), and Robotic Arm Camera, and MER: Pancam, and Microscopic Imager) and also from laboratory experiments with Mars analog samples were used to constrain the nature (and the mineralogy in particular) of the these particles [1-3].

The OM consists of a high-resolution imaging system and an active sample illumination system composed of four types of LEDs (Figure 1a): Blue (B, λ ~ 465 nm), Green (G, 524 nm), Red (R, 636 nm), and UV (375 nm)/NIR (705 nm). The last mentioned LED type is truly a UV LED with a very small secondary emission in the NIR (Figure 1b – note the strong amplification of the NIR signal). Filters in the optical path prevent the OM-CCD to detect reflected or scattered UV light. In the absence of strong UV-luminescence the CCD signal recorded during UV/NIR illumination must be caused by reflectance of NIR light. It turns out that this is a very reasonable assumption for virtually all OM soil samples and UV/NIR images. However, caution is required and in each particular case we need to evaluate a potential contribution by UV luminescence.

Analysis: The weak NIR signal has been calibrated with respect to the R signal by comparison to SSI and CRISM data of the PHX landing site (Figure 2). We inferred 4-point reflectance spectra for various OM samples with a fixed set of calibration parameters.

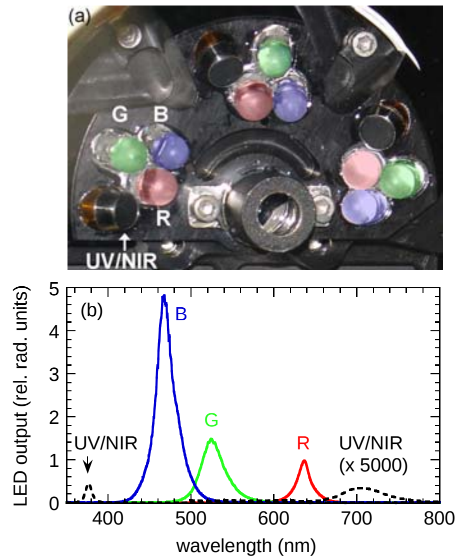

Figure 1 (a) Front side of the OM, as seen from the sample position. A total of 12 LEDs is arranged in three clusters. The red, green, and blue LEDs have been artificially colorized in this figure. (b) Emission spectra of the LEDs.

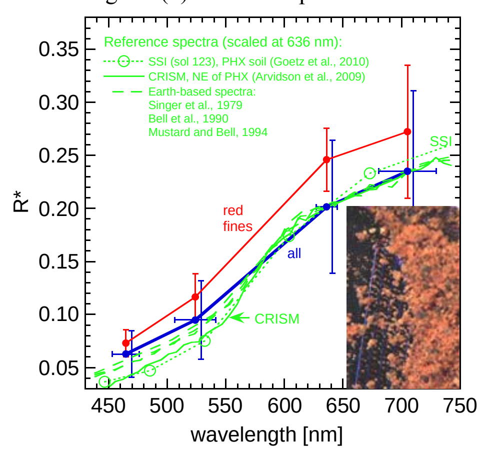

Figure 2 Calibration of the NIR signal by comparison to SSI and CRISM reflectance spectra of the PHX landing site. Result of calibration shown by using the example of Golden Key, sol 99 (inset, ~1 mm across horizontally): Spectra of all pixels within the soil covered area (blue solid line) and of red fines within that area (red solid line). Also comparison with Earth-based spectra.

Results: We found bright particles (bright in the VIS domain) that have a particularly low NIR reflectance (Figure 3). Comparison with spectral libraries such as that maintained by R. Clark, USGS [4] did not provide any plausible match. The spectra do not match laboratory spectra of magnesium perchlorate (at any hydration state) either [5]. Figure 4 compares these spectra to those of almost pure water ice (#0) as well as ice-rich clods (#1, #2, #3) in the Dodo-Goldilocks trench. It can be seen that also water ice does not provide a good spectral match. Hence we are unable to identify the nature of these particles, except stating that they are likely neither water ice nor magnesium perchlorate. The particles appear with similar abundance (~0.1 vol.%) in all OM image sets we have been investigating so far. Some of these images have been acquired on the sample delivery sol, others have been acquired several sols later, suggesting that these particles are non-volatile.

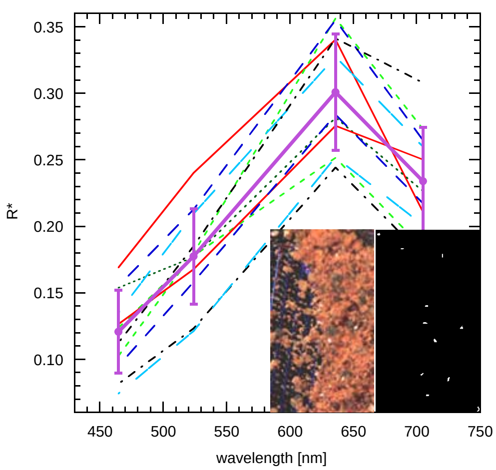

Figure 3 Golden Key, sol 99: Spectra of unusual patches refered to as "particular fines". See the insets (~0.8 mm across) for location of these patches. Thick magenta solid line: average spectrum with error bars.

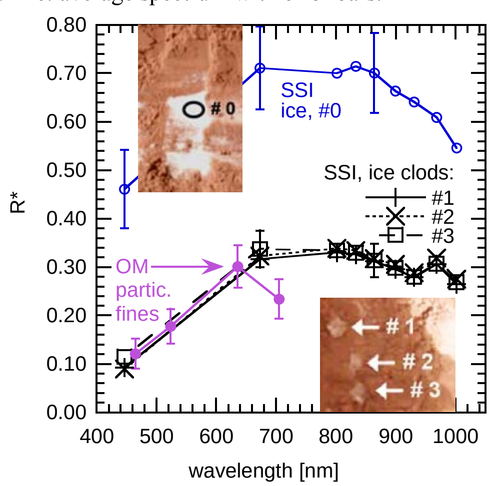

Figure 4 SSI reflectance spectra of Dodo-Goldilocks trench ice and ice clods. The ice clods (#1, #2, #3) are ~1 cm across. The black ellipse (#0) is ~2 cm across. Both insets are part of a single color image acquired by SSI on sol 20. Also shown (filled magenta circles): "Particular fines" as characterized by OM (same data as plotted in Figure 3).

Conclusions: We have reanalyzed microscopic images of soils at the PHX landing site in terms of 4-point reflectance spectra (465 nm, 524 nm, 636 nm, 705 nm). Based on these spectra and by comparison to other data sets (SSI in particular) we propose a new taxonomy of Martian (PHX) soil particles (Figure 5). The red reflectance (λ = 630-710 nm) is found to vary strongly from particle to particle leading to the following classification (components listed according to decreasing abundance (in vol.%), Figure 5): Red fines, brown sand, black sand and a particle type termed "particular fines". The abundance of the latter type of fines is ~0.1 vol.% (0.1 px%), which is likely a lower bound to the actual abundance, as many particles may be masked by the pervasive reddish dust.

As emphasized by [1] the sand particles (both brown and black sand) are very diverse and may well deserve to be distributed among several subclasses. Comparison of OM spectra (Figure 3) to SSI spectra of water-ice rich soil patches and to laboratory spectra suggests that these "particular fines" may represent a non-volatile (perhaps hydrous) alteration phase. With the data in hand we cannot identify this alteration phase, but consider it likely that it is neither water ice nor magnesium perchlorate.

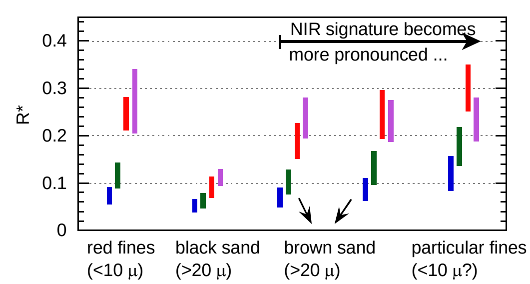

Figure 5 Taxonomy of Martian (PHX) soil particles: Pervasive reddish dust (far left) dominate the soil material. Different types of "sand" refer to silt-/sand-sized particles of diverse color and morphology. "Particular fines" (far right) are an alteration phase making up only ~0.1 vol.% of the PHX soil.

References: [1] Goetz W. et al. (2010) *JGR*, 115, E00E22. [2] Goetz W. et al. (2009) *LPS XL*, Abstract #2425. [3] Goetz W. et al. (2010) *LPS XLI*, Abstract #2738. [4] USGS Spectral Library: http://speclab.cr.usgs.gov/spectral.lib04/spectral-lib.desc+plots.html. [5] Morris R. V. et al. (2009) *LPS XL*, Abstract #2317.