Martian surface aqueous alteration from the study of the combined evolution of the 1.9 and 3 microns band with OMEGA

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Introduction: The OMEGA experiment onboard the ESA Mars Express orbiter [1] had observed the Martian surface in the 0.38 – 5.1 µm spectral range from 2004 to 2010. Additional observations with a limited spectral coverage are still ongoing. The dataset contains thousands of hyperspectral cubes covering most of the Martian surface with a typical spatial sampling of 1 km. Repeated observations of the same region have been frequently obtained over the mission, in particular in the high latitudes where time sampling can be about 10° of Ls over most of the year [2]. This spectral range covers water-related spectral signatures of the surface, the most prominent being located at 1.9 and 3 µm [3-6]. Previous studies of the water content derived from the 3 µm band have shown an overall increase of water hydration in the polar regions, with a modeled weight% increased by a factor greater than two in the northern polar latitudes, which presents the highest hydration state levels [5, 6].

The origin of this latitudinal trend is not yet fully understood, although two main hypotheses have been previously suggested and discussed: adsorption of water molecules at the surface (e.g. [5]) and chemical alteration from water molecules deeply bound into minerals or amorphous materials at the surface [6, 7]. We e.g. know that northern polar regions harbor salts, either in the form of large localized deposits of sulfates [8] or at low level in soils [9], as revealed in particular by the in-situ detection of low amount of perchlorates and carbonates from Phoenix [10, 11] not yet identified with orbital observations [12].

In addition, the presence of a significant amount of sub-pixels water ice patches in the polar regions may also result in an average increase of the 3 µm feature when observed at OMEGA resolution. Indeed, recent studies have shown that erosion can create scarps that expose the perennial near-surface water ice contained in the permafrost at latitudes about 55°N [13]. Permafrost depth decreases to a few centimeters at high latitudes while exposed ice stability increases [14], so such subpixels outcrops may be more frequent and could participate to the apparent increase of the 3 µm band depth with latitude.

Results: We have conducted a study of the joint variations of the 1.9 and 3 µm bands in the northern polar regions. Figure 1 shows the latitudinal variations of near-IR "albedo" (reflectance factor at 2.5 µm), 1.9 and 3 µm band depths from an OMEGA orbit during the northern summer. To minimize the impact of the well-established dependence of the 3 µm feature on albedo [3, 5, 15],
we first focus on a limited albedo range $\geq 0.3$. In agreement with previous studies [3,5,6], we observe that the 3 µm band depth continuously increases from 45% to 55% between 50°N and 70°N. We also observe a similar trend for the 1.9 µm band depth that goes from 2% to 4%. Thus, there seems to be a correlation between the latitude dependence of these two bands at global scale. This co-evolution is notably expected in the case of adsorbed water [4]. It may also results from an increase in the amount of trace minerals in soils, like hydrated sulfates that contains a 1.9 µm band, that may be also widespread at polar latitudes [9]. Investigations are ongoing to favor one of these two possible explanations.

On the other hand, we can also observe some regional differences of the co-evolution of these two bands, for areas at the same latitude and that presents similar albedo values like in the northern latitudes of Acidalia Planitia. Indeed, we can see on figure 2 that at ~ 75°N, there is a darker region between 290°E and 350°E (a). This region is associated with high and stable values of the 1.9 µm band (d). On the other hand, the 3 µm band changes significantly with longitude over the region (c), from 46% at 300°E to 52% at 340°E. The blue and red spectra on figure 2(b) show averaged spectra from two spots in this darker region, and the black spectrum is the ratio between the red (high 3 µm) and the blue (low 3 µm) spectra. We observe with this ratio that there is actually no 1.9 µm band variations between this two spots, whereas variations are notable for the 3 µm band.

Figure 1. Latitudinal evolution of the reflectance at $\lambda = 2.26$ µm (a), the 3 µm integrated band depth (b) and the 1.9 µm band depth (c), from OMEGA observations (#2-4) of orbit 041 ($L_s = 100.2^\circ$, longitude $\sim 5^E - 15^E$). To minimize albedo dependency effects, only pixels with albedo $\geq 0.3$ are considered here.
Conclusion: These first investigations have highlighted the multiplicity of evolution behavior of the 1.9 µm and 3 µm band for different scales. Further work will be dedicated to deeper investigations of the co-evolution of the two bands at a regional scale, and their possible link with other spectral signatures. Our objective is to extend the amount of observational constraints related to the polar increase of the surface hydration observed in the 3 µm spectral range, to bring new constraints about the plausibility of the main two considered hypotheses: adsorbed water versus chemical alteration.

Acknowledgments: The OMEGA/MEx data are freely available on the ESA PSA at https://archives.esa.int/psa/#!Table%20View/OMEGA=instrument.

References: