

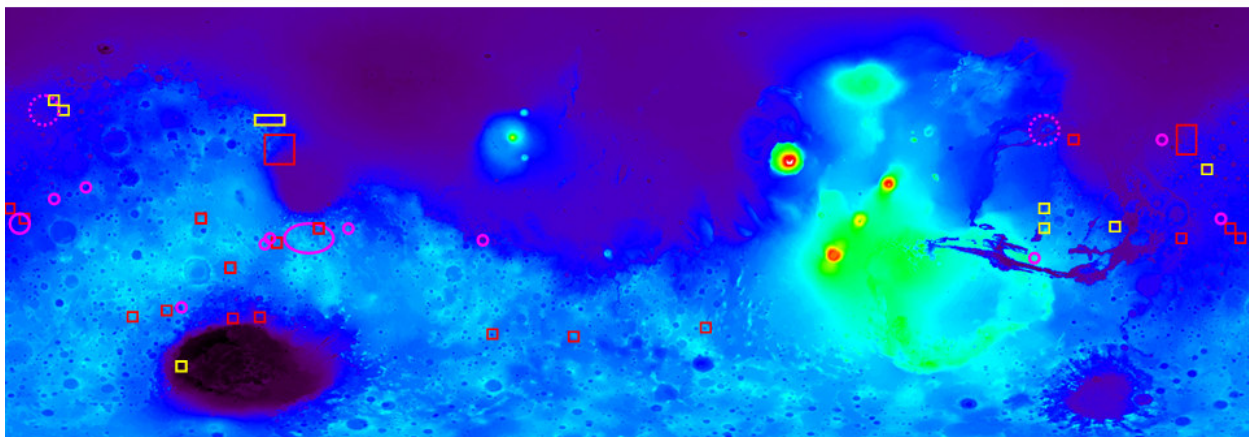
THE DISTRIBUTION OF PHYLLOSILICATES ON MARS FROM THE OMEGA-MEX IMAGING SPECTROMETER. F. Poulet¹, J.-P. Bibring¹, Y. Langevin¹, B. Gondet¹, J. Mustard², A. Gendrin², N. Mangold³, D. Loizeau³, R. Arvidson⁴, V. Chevrier⁵, and the OMEGA Team.¹IAS, CNRS/Université Paris-Sud, 91405 Orsay, France (francois.poulet@ias.fr), ²Brown University, Providence, USA, ³IDES, Université Paris 11, Orsay, France, ⁴Washington University, St Louis, USA, ⁵Arkansas center for Space and Planetary Sciences, Fayetteville, USA.

Introduction: One of the primary objectives of the OMEGA instrument on the Mars Express spacecraft is to determine and map the mineralogic composition of the Martian surface. Of particular interest is the identification of minerals formed through interaction with liquid water. Data from the recent Mars missions show that the Ca-Mg-Fe sulfates have been identified as the best and most common water-bearing minerals on Mars [1,2,3,4]. More recently, unambiguous detection of phyllosilicates has been reported over large areas [1,5]. Here, new identifications by OMEGA of phyllosilicate minerals are presented and discussed, along with new evidence for regions containing hydrated minerals.

Mineral identification: Phyllosilicates are uniquely identified by the presence of absorption features centered at 1.4 μm , 1.9 μm and in the 2.15-2.40 μm wavelength region. The latter is due to metal-OH vibrations. OMEGA observations indicate that diverse phyllosilicates (Fe, Mg and Al-bearing phyllosilicates with Fe and Mg-smectites as the most common) are present on Mars. Spectra with a 1.9 μm band, exhibiting no feature in the 2.15-2.40 μm interval have been

also identified and are also considered in the present study.

Spatial distribution: Fig. 1 presents the global distribution of clays and hydrated minerals (sulfates excluded) on Mars and shows many more areas as compared to what was shown with initial data [5]. Phyllosilicates are identified in two large areas of several square degrees (Mawrth Vallis and Nili-Syrtis regions represented as the two large red rectangles on Fig. 1). In these two regions, the signatures are associated with the Noachian basement [5,6,7]. For example, light-toned outcrops at the mouth of Mawrth Vallis were cut by the valley-forming process. The other spots (red squares on Fig. 1) are in general much smaller (a few square kilometres), but also located in Noachian cratered regions. They correspond to terrains of medium albedo (0.2-0.25) with rough textures such as scarps, crater ejecta, crater floors and eroded outcrops. Of particular interest is the presence of layers in some deposits [7]. Several accumulations (pink circle on Fig.1) of hydrated minerals showing no significant metal-OH absorption except for a few pixels have been also found in some crater ejecta deposits [8] and



- Phyllosilicates (light toned rough terrains)
- Phyllosilicates (dark deposits)
- Hydrated minerals (phyllosilicates?)
- Hydrated minerals (small signatures)

Figure 1: Location of the water-bearing mineral deposits (sulfates excluded) identified by OMEGA over the MOLA altimetry from 60°S to 60°N. Most of the deposits are small (a few square kilometers).

scarps of Noachian units. The spatial distribution and the morphology of the hydrated and phyllosilicates deposits are distinct of those of the sulfate-rich ter-

rains (note that in a few cases such as in Terra Meridiani sulfates and phyllosilicates are mixed).

Another type of phyllosilicate-bearing terrain corresponds to dark deposits (yellow squares on Fig. 1) inside depressions and craters mainly located in the northern hemisphere. Thermal properties and MOC/HRSC images suggest that these dark deposits consist of a thin surface layer. Most of these dark coatings are adjacent to dark terrains rich in unaltered mafic materials and in regions where there are strong evidences for past flooding activity. The phyllosilicate-rich dark material could be either (1) the result of erosion of dark layers cut by the depression or the crater, or (2) distributed by aeolian processes and then trapped inside depressions. Given the few occurrences and nonuniform spatial distribution as well as the presence of dark layers in the vicinity, the first possibility is more likely. The low albedo could be explained by a mixture with relatively unaltered mafic materials, or it could indicate that the primary and mafic material has been only partly altered due to a low rock/water abundance. Finally, we also show a couple of regions (pink dashed circles) where hydrated minerals and possibly phyllosilicates might be present but their detections need to be confirmed.

Implications for stable, liquid water: The presence of clay and hydrated minerals in several rough, eroded and excavated terrains (outcrops, scarps and crater ejecta) of Noachian units strongly supports the following conclusions: (1) large-scale water-rock interactions occurred during the Noachian period; the formation may have continued into later periods but in this case, it occurred at depth; (2) the water-bearing minerals are a bulk component rather than a soil surface coating, and the crust has been altered to depth; (3) the phyllosilicates tend to indicate an environment different of that responsible for the formation of the sulfates; in particular, the formation of Fe- and Al-phyllosilicates require abundant water and near neutral or higher pH; on the other hand, the non-detection of gibbsite could put some limits on the available quantity of water [9]; (4) the presence of nontronite-like mineral suggests oxidizing conditions in the early history of Mars [9].

Different alteration models of mafic-ultramafic rocks can be proposed: (1) *gas-solid reactions* [10], but such a process is unlikely to contribute to a major fraction of clays on Mars [10,11]; (2) *weathering of the martian crust below an ice-water interface* [12]; the altered product could be released by channel formation or by erosion; however, the degree of alteration in this environment is unknown and the OMEGA observations do not favor this scenario because (a)

the sediments and the beds of the outflow channels are depleted in hydrated minerals, (b) it is hard to explain the presence of layers in phyllosilicate-rich deposits by such a process; (3) *impact into volatile-rich targets rocks, weathering with hot volatiles* [13]; although volatiles might be enriched toward the outer layer of a growing planet, it is not clear that phyllosilicates could be formed because they require long periods of alteration whereas impact-related processes are a very fast and hot process; (4) *hydrothermal alteration of basaltic crust* [14] either by crater impact [15] or by eruption through ground ice [16]; although these processes are not well constrained, they could perhaps explain the presence of clays at least locally. However, it is important to note that no serpentine has been detected so far, suggesting a low-temperature process rather than high-T hydrothermal alteration; (5) *cooling of a magma enriched in volatile compounds* [17]; (6) *alteration by leaching under ambient conditions*; this process of formation is probably the most efficient. However, further works need to be done to better constrain the process of phyllosilicate formation which occurred on Mars.

Future landing sites: The phyllosilicates-rich regions identified by OMEGA are ideal candidates for future landed missions searching for biotic and prebiotic environments. The physical characteristics of these sites (especially Mawrth Vallis and Nili-Syrtis regions) may satisfy the engineering requirements for the futures missions.

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