STRATIGRAPHIC CORRELATION BETWEEN THE CLAYS OF THE REGION OF MAWRTH VALLIS AS DETECTED BY OMEGA, AND HRSC COLOR IMAGES AND DTM.

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Introduction: The hyperspectral imager OMEGA/Mars Express has discovered a large layered unit rich in phyllosilicates in the region of Mawrth Vallis, Mars (around 20°W, 25°N) [1, 2, 3]. The region is located in Noachian highly cratered terrains, close to the limit of the Martian dichotomy, where the outflow channel Mawrth Vallis cuts the Noachian highlands.

In this work we constrain the geomorphology of the phyllosilicate-rich unit using HRSC color imagery and HRSC DTMs.

OMEGA data: We have examined this region using OMEGA/MEx spectra of the surface from 0.9 µm to 2.6 µm, with spatial sampling from 500 m to 3 km, offering a full coverage of the region. Phyllosilicates have been identified by absorption bands at 1.41 µm, 1.93 µm, and 2.20 or 2.30 µm. The last two bands are respectively due to the Al-OH bond and to the Fe-OH or Mg-OH bonds. Comparison with laboratory spectra reveals similarities with Al-smectites such as montmorillonites, or Fe-smectites smectites such as nontronite, but the presence of other smectites such as Mg-smectites cannot be excluded [3].

A precise location of the phyllosilicate-rich areas on visible HRSC/MEx images indicates that they are placed exclusively on bright outcrops, mostly on the plateaus, dated to the Noachian period [4]. In figure 2, right, all phyllosilicates are displayed in blue. The Al-smectites and Fe- or Mg-smectites are located on distinct outcrops [3]. In figure 2, right, the Al-smectites (detected with the 2.20 µm band) are shown in blue, and the Fe- or Mg-smectites (detected with the 2.30 µm band) are shown in red.

On HRSC/MEx, MOC/MGS narrow angle and HiRISE/MRO images, the phyllosilicate-rich outcrops reveal strong erosional features such as numerous residual buttes composed of a few meters thick layers (see Figure 1). Those outcrops are the exhumed parts of a larger unit partly covered by dust and by a thin pyroxene-rich dark mantle [3].

TES/MGS and THEMIS/Odyssey show a medium thermal inertia (300 to 400 SI [5]) for this phyllosilicate-rich layered unit. This involves relatively indurated rocks or coarse grains different of dust material.

The phyllosilicate-rich unit corresponds to a geological unit more than 100 m thick, over a horizontal extension approximately of 300 km x 400 km. This unit implies a very important volume of altered rocks, either in situ or after transport and deposition, in Noachian terrains, revealing a different climatic and geological environment from the present one [3, 6].

Two hypothesis of formation are put forward: deposition of altered sediments in an aqueous environment, or in situ alteration by liquid water of volcanic ash or wind deposited unit. Contributions of eolian deposition of smectites-rich material, or of accumulation of altered ejectas from the large impacts are also possible[3].

Figure 1: MOC narrow angle image showing concentric layers inside the clay-rich unit (R09_01962), north is at the top, light comes from south.

HRSC color imagery: The high resolution camera HRSC/MEx records color images of the surface in four channels: blue, green, red and near infrared. We computed RGB images by combining the blue, green and red channels, to obtain a ~50 m/pixel resolution color imagery for this region (whereas the HRSC nadir resolution is of 18 m/pix). In this study, we did not try to retrieve true martian colors, but tried to use the color imagery as an additional tool to make the distinction between different geological/mineralogic units.

Concentrating on the bright outcrops of the Noachian plateaus, the HRSC color imagery reveals distinct colors, dividing the bright outcrops into different parts. The HRSC color image, Figure 3B, shows a large reddish outcrop on the southern side, and a whiter outcrop on the northern side. Those differences
are also slightly visible on the HRSC nadir grey scale image (Figure 3A).

Regionally, we can distinguish three different colors: 1. dark red outcrops, 2. light red or orange outcrops, and 3. white outcrops. Contacts between those three terrains are seen in all the large bright outcrops of the region.

**Similarities between OMEGA and HRSC color:**

We see that: a) on OMEGA datasets, the phyllosilicate-rich areas are divided into Al-smectites-rich outcrops and Fe- or Mg-smectites-rich outcrops, b) on HRSC color imagery, the bright outcrops are sorted into at least three different colors.

Comparisons of smectites, mapped with OMEGA, with HRSC color imagery shows a concordance between the two datasets:
- The dark red and light red/orange outcrops always show a 2.30 µm absorption band in OMEGA data, revealing the presence of Fe- or Mg-smectites.
- The white outcrops show a band at 2.20 µm, corresponding to the presence of Al-smectites.

The example area Figure 3, illustrates this concordance: the reddish southern part (fig. 3B) shows the 2.30 µm absorption band (in red, fig. 3D), whereas the white outcrops in the northern part display the 2.20 µm band (in green, fig. 3D).

The Fe-smectites such as nontronite show a strong absorption in the short visible wavelengths, which is due to Fe3+, an absorption that misses in the other smectites [7]. Hence, the presence of Fe-smectites could explain the red color in the HRSC color imagery on outcrops where OMEGA found a 2.30 µm band.

**Contact between red and white outcrops:**

Mapping the bright outcrops with the help of HRSC color imagery provides a high resolution tool to understand the contact between the different smectites identified by OMEGA. Indeed, OMEGA resolution is a strong limit to retrieve the geology of the region, and the detection is too weak for many surfaces to show any of the 2.20 or 2.30 µm bands.

Contacts between the Al-smectites and Fe- or Mg-smectites exist in all the phyllosilicate-rich outcrops. In the example showed in Figure 3, a stratigraphic relation appears between the two: the white surfaces are always located on top of the red outcrops, showing that the difference of colors fits the topography. However, figure 3C shows that the red and white surface are tilted, and a simple horizontal stratigraphic relation cannot be retrieved.

The correlation between HRSC colors and OMEGA data allows us to compare these layers at the 50 m sampling of HRSC color imagery over the whole unit. Our results show that the layering of the material is associated to a layering in the composition, consistent with the two main hypothesis of formation (sedimentary deposition or in situ alteration). However, the irregularity of the bright-red color units relative to topography and layering suggest a complex interaction that might not fit a simple vertical deposition of material of each composition. Either lateral variations in composition or variations in the in situ alteration due to local fluid composition might have modified phyllosilicates from a phase to another.

At smaller scale and higher resolution, CRISM/MRO also showed the presence of Al-smectites and Fe- or Mg-smectites on distinct outcrops [8] respecting the same concordance with HRSC colors, however, CRISM cannot provide the same coverage than OMEGA and HRSC yet.

**Conclusion:**

The high resolution HRSC DTMs, along with the high resolution mineralogical mapping made with HRSC color imagery, allow us to a fine geological mapping over the broad phyllosilicate-rich unit of the Mawrth Vallis region. Understanding the geology of this unit is essential to find clues about the formation of the region and its evolution.

**References:**

Figure 2: left: HRSC mosaic of the region of Mawrth Vallis; right: detection of the 1.93, 2.20 and 2.30 µm bands superimposed on the HRSC mosaic. The white box indicates the close-up presented Figure 3.
Figure 3: Close-up on the western part of the Mawrt Vallis region presenting two large outcrops, which display the 2.20 µm and 2.30 µm absorption bands, corresponding to white and red outcrops respectively.