EMBEDDED PHYLLOSILICATES AND SULFATES IN EASTERN MERIDIANI: AN OTHER GALE CRATER?
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Introduction: Remote sensing and *in situ* data from recent European and US Mars orbiter and lander missions have provided extensive evidence for the former presence of water lain sedimentary rocks on Mars [1]. In addition, spectral-imager instruments have detected hydrated minerals such as ancient phyllosilicates and sulfates on the Martian surface. These minerals appear to have formed in two distinct climatic episodes [2]: 1-The early Noachian period (4.2-3.7 Gy), presumably warm and wet, resulted in the formation of clays, whereas 2-The intermediate Hesperian (3.7-3.0 Gy) could mark a transition to a dryer and more acidic climate, resulting in the formation of sulfates. In contrast, Amazonian (3.0 Gy-today) areas lack hydration features, implying that the surface has been dry for at least 3 Gy [2].

The occurrence of a thick sedimentary sequence dominated by phyllosilicates and sulfates at higher elevation in the central mound of Gale Crater [3] has been perceived as a possible record of this climatic transition; therefore Gale crater was chosen as the final landing site for the latest rover mission, Mars Science Laboratory (MSL, NASA). MSL rover, Curiosity, landed in Gale crater in August 2012 and will take about a year to reach the central mound and perform analysis of this sequence. We show here that a similar stratigraphic sequence is present in the etched terrains of eastern Meridiani, with a thicker and larger extent. The etched terrains underlie the hematite plains where another rover, Opportunity (MER, NASA), landed in 2004. The co-occurrence of clays and sulfates, both formed *in situ*, at two different locations on each side of the planet, with different extents, could bring precious clues about the origin of both minerals, and their paleoenvironment(s).

Previous studies*:* The area of Terra Meridiani became of interest after the detection of crystalline gray hematite by TES (MGS) [4] which led to the choice of Meridiani planum as one of the MER landing sites. Previous geological mapping outlined four main units (Fig. 1, [5]), including the hematite-rich plains where Opportunity landed (unit Ph). The first hydrated minerals to be observed lied in the central portion of the 'etched terrains' (unit ET), a few hundreds kilometers to the northeast [6,7]. In addition to this detection of kieserite made by OMEGA (MEx), polyhydrated sulfates (PHS, possibly ferric) and phyllosilicates were observed associated with the etched terrains [8,9], while the remaining units (MCT: mantled cratered terrains; DCT: dissected cratered terrains) seemed dominated by dust and/or mafic minerals signatures.

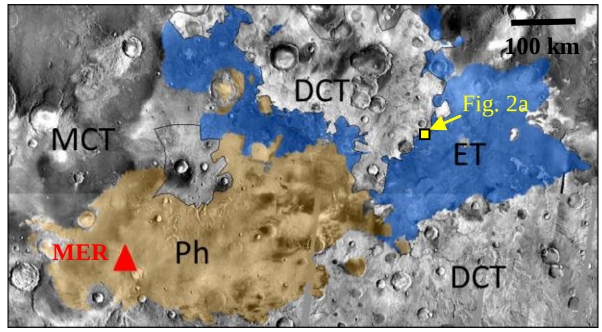
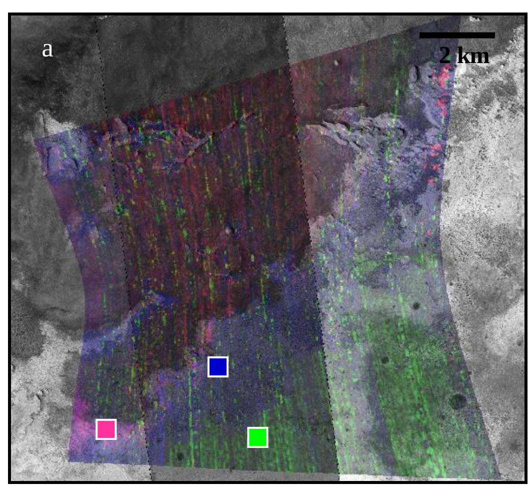


Figure 1: The four main geologic units of eastern Meridiani: see text for details. Adapted from [5, 8].

We review here the precise composition of eastern Meridiani (etched terrains and hematite plains) with both OMEGA and CRISM observations. Data available over the area were processed and analyzed, as described in [8, 10].

Mineralogic analysis: *Etched terrains.* Both clays and sulfates were almost systematically observed with OMEGA over the surface of the etched terrains. Similar observations were made with CRISM at higher resolution, however, only sulfates were observed on the flanks of the etched terrains and in-depth, anytime a cross-section was exposed (Figure 2a, 3). All hydrated mineral detections are associated with high albedo and high thermal inertia outcrops.



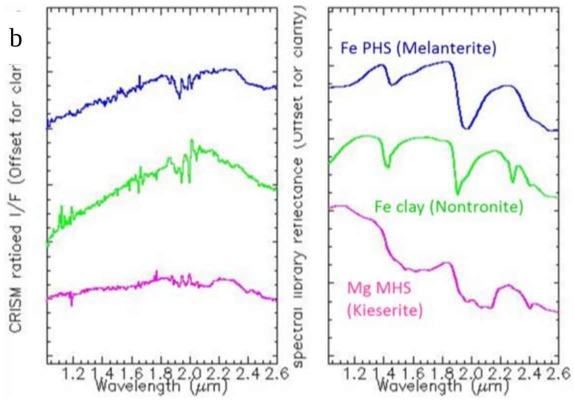


Figure 2: a- RGB composition of CRISM FRT00012FC3 summary parameters (R= BD2100, G= BD2290, B= Sindex) overlain on HiRISE and CTX images. This CRISM observation is taken on the Northern flank of the ET.
b- Associated CRISM spectra vs spectral library.

Sulfates are characterized by the presence of a strong absorption feature at 2.4 µm (blue and magenta spectra on Fig. 2b) [11]. Polyhydrated sulfates are most commonly observed; they present additional water absorption bands at 1.44 and 1.94 µm. However, monohydrated sulfates are sometimes present at the bottom of the flanks of the etched terrains, they are identified thanks to their 2.1 and 2.4 µm set of absorptions [5].

Clay detections present diagnostic absorption features at 1.41, 1.93, 2.30 and 2.4 µm (green spectrum on Fig. 2b). The exact position of the 2.3 µm band at 2.30 µm in CRISM spectra argues in favor of a Fe-smectite such as nontronite rather than a Mg-rich one [12]. However they also present additional absorptions that suggest that they are commonly mixed with PHS, and sometimes, Al-clays. Clays occur in association with a wide range of geomorphological features: ridges, pits and mesas, polygonal structures or massive, smooth deposits.

Hematite plains. A few small craters on the top of the hematite plains expose an intact stratigraphy in their walls. An approximately 50 m-thick PHS-rich layer is observed just below the hematite-rich surface. An additional band at 2.28 µm suggests the presence of other minerals mixed, possibly jarosite or Ca-sulfates. These sulfates likely correspond to the ones analyzed to the west by the Opportunity rover.

This bright, massive layer of PHS is overlying a finely-layered clay and sulfate-rich mixed sequence, similar in aspect and composition to the one observed on the summit of the etched terrains. The contact between the hematite plains and etched terrains is also observed in the central portion of the etched terrains, and backs up these detections, which a thin PHS rich layer overlain over the clay-rich ET top layer.

Conclusions: We do observe a clay-rich layer on the surface of the etched terrains, which are mostly made of sulfates, over an area grater than 100,000 km^2. This clay-rich layer is overlain to the south-west by a layer of sulfates and hematite – those analyzed by Opportunity in Meridiani Planum and forming the hematite plains (Figure 3).

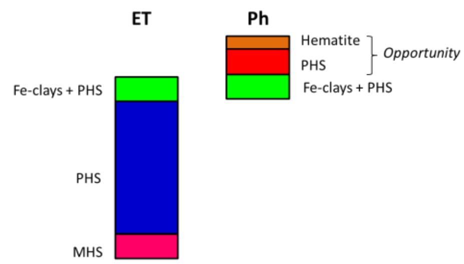


Figure 3: Summary of the mineralogic detection sequences in the etched terrains (ET) and the hematite-rich plains (Ph).

Aforementioned detections should be confronted to Opportunity's finding and recent observations of its next target, Endeavour crater. New results in Endeavour crater indeed show the presence of smectites within the crater, along with sulfates of various compositions [13,14].

These detections also remind of a well-known but rare stratigraphic sequence, observed at a smaller scale, in Gale crater. Similarly the hydrated minerals present in Gale correspond to nontronite and PHS mostly. The similiarities in term of stratigraphy and chemical composition of the two sites could suggest a common formation mechanism for the co-occurrence of clays and sulfates. Possible geochemical environments and formation mechanisms shall be further discussed at the conference time.

References: [1] Carr M.H. and J.W. Head (2010) *Earth Planet. Sci. Letters*, 294, 185–203. [2] Bibring J.-P. et al. (2006) *Science*, 312, 400-404. [3] Milliken R. et al. (2010) *Geophys. Res. Letters*, 37.[4] Christensen, P. R. et al. (2001) *J. Geophys. Res*., 106 (E10), 23,873-23,885. [5] Arvidson R.E. et al. (2003), *J. Geophys. Res*., 108, E12, 8073. [6] Gendrin A. et al. (2005) *Science*, 307, 1587-91. [7] Arvidson R.E. et al. (2005) *Science*, 307, 1591-93. [8] Poulet F. et al. (2008) *Icarus*, 195,106–130. [9] Wiseman S. (2009) *J. Geophys. Res*., 115, E00D18. [10] Murchie S. L., et al. (2009) *J. Geophys. Res*., 114, E00D07. [11] Cloutis E. A. et al. (2006), *Icarus*, 184, 121-157. [12] Poulet F. et al. (2005), *Nature*, 438, 623–627. [13] Wray J. J. et al. (2009), *Geophys. Res. Lett.*, 36, L21201. [14] Noe Dobrea E.Z. et al. (2012), *Geophys. Res. Lett.*, 39, L23201.