

**INVESTIGATING MARS EARLY CLIMATE THROUGH STRATIGRAPHY, COMPOSITION AND MORPHOLOGY AT THE NOACHIAN-HESPERIAN BOUNDARY IN NORTHERN MERIDIANI PLANUM.** B. Baschetti<sup>1,2</sup>, M. Massironi<sup>1</sup>, C. Carli<sup>2</sup>, F. Altieri<sup>2</sup>, A. Frigeri<sup>2</sup>, <sup>1</sup> University of Padua, Department of Geosciences, Via G. Gradenigo n.6, 35131, Padova, Italy (beatrice.baschetti@phd.unipd.it), <sup>2</sup>INAF-IAPS, Via del Fosso del Cavaliere n.100, 00133, Roma, Italy.

**Introduction:** The characteristics of Mars early climate and the aspects and timing of the climatic transition that occurred on the planet between the Noachian and the Hesperian epochs are still widely debated. The area of Meridiani Planum (MP), located SW of Arabia Terra, is well known for retaining multiple evidence of past aqueous activity [1] and a variegated hydrated mineralogy [2], with most of the terrains exposed dating around the Noachian-Hesperian (NH) boundary [3]. Constraining the potential water environment at the NH boundary is fundamental to understand Mars early climate and its evolution.

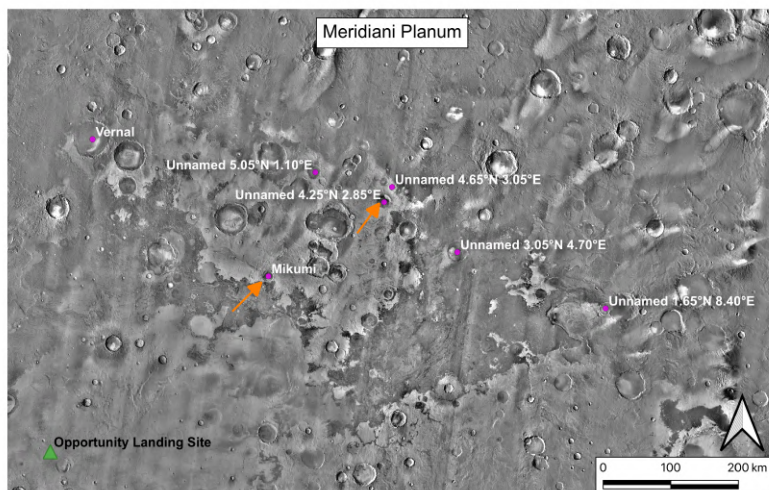
We select 7 craters in Northern MP (figure 1) showing evidence of NH sediment infillings with hydrated materials (e.g., clays and sulfates) to assess in detail the stratigraphic sequence of the units and understand their origin and diagenetic history. The craters are roughly aligned SE to NW following the general slope of the area from the highlands to the lowlands. Assuming a “warm and wet” early climate, MP represents a transition zone between the subaerial alteration environment of the highlands and the subaqueous environment of the Martian ocean. Therefore, MP would be easily affected by climatic changes whose evidence should be retained in MP sedimentary sequences.

We show here some preliminary results from 2 of the 7 craters selected for the study: 1) a 15-km-wide crater named Mikumi and centered at Lat. 2.45°N, Lon. 359.96°E; 2) an 18-km-wide unnamed crater centered at Lat. 4.25°N, Lon. 2.85°E.

**Datasets and Methods:** *Hyperspectral data analysis.* We investigate the mineralogy of the craters' terrains through CRISM [4] hyperspectral data cubes in the range 1.0-2.6  $\mu\text{m}$ . This interval retains part of the key spectral features of primary rock-forming minerals, which constitute the Martian crust, and of most minerals produced by secondary processes such as aqueous circulation and alteration (e.g., clays and sulfates). The mineralogy is first investigated with the aid of some of the RGB browse products defined in [5], mean spectra are then extracted from areas which show strong signals, especially when indicative of hydrated materials.

*Stratigraphy and morphology.* MOLA, THEMIS, CTX and HiRISE data are used for morpho-stratigraphy and camera imaging.

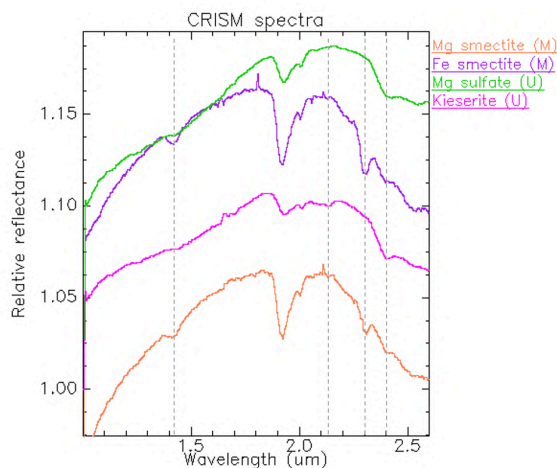
**Results:** *Mikumi crater.* Two types of clays (smectites) with different Fe/Mg content, polyhydrated sulfates and monohydrated sulfates are observed. Fe/Mg-clay spectra (e.g., nontronite and saponite) show absorptions at around 1.4, 1.9 and 2.3  $\mu\text{m}$  with additional overtones at 2.4  $\mu\text{m}$  (figure 2). The exact position of the 2.3  $\mu\text{m}$  feature depends on the relative Fe/Mg content in the clay mineral. We find here some areas with clays richer in iron (e.g., nontronite), showing this feature centered at 2.305  $\mu\text{m}$ , and clays richer in magnesium (e.g., saponite) where the absorption is centered at 2.310-2.315  $\mu\text{m}$ . Polyhydrated sulfates (Mg sulfate) and monohydrated sulfates (kieserite) are detected stratigraphically below the clay-bearing layer. Polyhydrated sulfates display an



**Figure 1.** THEMIS daytime image of Meridiani Planum. Selected craters are evidenced with points. Name and coordinates of the center for each crater are also indicated with a label. Most of the craters are unnamed. The two arrows indicate the craters described in this abstract.

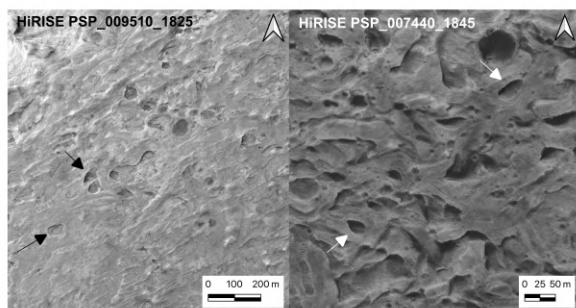
absorption at 1.9  $\mu\text{m}$  whereas monohydrated sulfates have an absorption around 2.1  $\mu\text{m}$ . Both minerals also have a 2.4  $\mu\text{m}$  overtone.

*Unnamed crater, centered at Lat. 4.25°N, Lon. 2.85°E.* Similarly to the previous case, Fe/Mg clays, polyhydrated sulfates and monohydrated sulfates (figure 2) are observed. In this case, we are still investigating the details of the stratigraphic relationships of the units.



**Figure 2.** Example of CRISM mean spectra of clays and sulfates: Fe/Mg clays (smectites) from Mikumi crater (M), mono and polyhydrated sulfates from the Unnamed crater (U). The spectra are extracted from CRISM FRT0000BEF5 and FRT00009B5A datasets respectively.

The deposits inside the two craters do not only share comparable compositional properties but also show similarities in morphology. Small depressions with irregular shapes and different sizes are observed in some areas. These landforms are too irregular to be impact craters and may be related to karst processes (figure 3). Similar landforms were observed in other areas of MP which are also associated with mono and polyhydrated sulfates detection [6].



**Figure 3.** Example of possible karst features formed on the deposits inside Mikumi (left) and the unnamed crater (right).

**Discussion and conclusions:** Clays and sulfates on Mars appear to have formed at different times and under different climatic conditions [7]. Clays are usually associated to Noachian terrains and may have formed under alkaline conditions in a “warm and wet” ancient Mars, whereas sulfates are typically associated to Hesperian surfaces and may have formed under a dryer and more acidic environment. Therefore, sulfates are expected to be found stratigraphically on top of clays, as they should have formed later in the Martian history. However, this distinction between a clay-rich Noachian and a sulfate-rich Hesperian oversimplifies the history of the aqueous chemistry and climate of Mars especially near the NH boundary.

Our analysis suggests a stratigraphic sequence with interleaving clays and sulfates at the NH boundary. Similar stratigraphic sequences have also been observed in other areas of MP (Southern MP) by [2]. In the case of [2], a clay-bearing layer is overlain by other sulfates, generating a sulfate/clay/sulfate stratigraphic sequence. All this argues is in favor of several distinct climatic episodes pacing the NH climatic transition.

Finally, the morphological features, combined with our stratigraphic and compositional observations, help improving our knowledge on the aqueous processes that took place in the area after the sediment deposition: karst landforms are indicative of past surface water percolating underground and possibly giving rise to caves and groundwater aquifers.

The results obtained so far will be enriched by further analysis of these areas along with a thorough investigation of the remaining 5 craters selected.

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**References:** [1] R. M. E. Williams et al. (2017) *GRL*, 44, 1669-1678. [2] Flahaut J. et al. (2015) *Icarus*, 248, 269-288. [3] Hynek B. M. et al. (2002) *JGR*, 107 (E10), 5088. [4] S. Murchie et al. (2007) *JGR*, 112 (E5), E05S03. [5] C. E. Viviano-Beck et al. (2014) *JGR Planets*, 119, 1403-1431. [6] D. Baioni and M. Sgavetti (2013) *P&SS*, 75, 173-181. [7] J. P. Bibring et al. (2006) *Science*, 312, 400-404.