ISMENIUS CAVUS, MARS: A DEEP PALEOLAKE WITH PHYLLOSILICATE-BEARING DEPOSITS.
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Introduction: Hydrated minerals such as phyllosilicates [1-2] and hydrated sulfates [3] have been detected on Mars over the past several years using data acquired by OMEGA and CRISM visible/near-infrared spectrometers [4-5]. The spatial and temporal distribution of phyllosilicates and sulfates have been interpreted to represent a global chemical shift from a wet to a dry environment corresponding roughly to the transition from Noachian to Hesperian, 3.7 Ga ago [6].

Only few phyllosilicate-bearing units were found in connection with lacustrine landforms yet: Jezero and Holden craters are putative paleolakes of Noachian age [8-9], and none have been found in subsequent periods. The interest of the depression studied here is that it shows a combination of Fe/Mg phyllosilicates in sediments outcropping on its floor and evidence for lacustrine activity dated to the Hesperian period, thus later than generally expected for such combined processes.

Main geologic units and landforms: Ismenius Lacus is a region located at the Martian dichotomy, north of Arabia Terra, where fretted channels are frequent. Mamers Vallis is the longest of them (1,200 km long). It displays a meandering course and tributaries typical of fluvial activity. It crosses a series of troughs that are often circular or partly circular in shape, and may consist of ancient craters re-incised by fluvial activity. Our main interest corresponds to a 60 x 90 km crater-like depression (located 33.5°N, 17°E ; Fig. 1) named Ismenius Cavus. Geomorphic analysis of the area was achieved using HRSC, HiRISE and CTX data.

Ismenius Cavus is a basin where six valleys converge into, including Mamers Vallis in the south, which then leaves the basin to the north (Fig. 1). The age of these valleys is constrained to the Hesperian period by superposition relationships mapped in the past [7-8].

Three of the six valleys entering Ismenius Cavus display depositional fans. The first fan, to the northeast, was already interpreted as a Gilbert delta from Viking data [9-10]. A second fan, 20 km to the south, is less obvious in the morphology or in the topography. A third fan 40 x 20 km in size is observed at the connection with Mamers Vallis in the southeast. It shows a plain at nearly constant elevation in between -3,150 and -3,100 m, with local incision by channels. The large volume of material and more complex shape of this fan may be due to Mamers Vallis larger volume of sediments transported compared to the small size of other feeding valleys. The topography and morphology of these fans suggest a deltaic origin and thus a long-term fluvial activity with the occurrence of a lake inside the basin. The elevation difference between the delta plains and the deepest basin floor section implies that this lake was ~600 m deep.

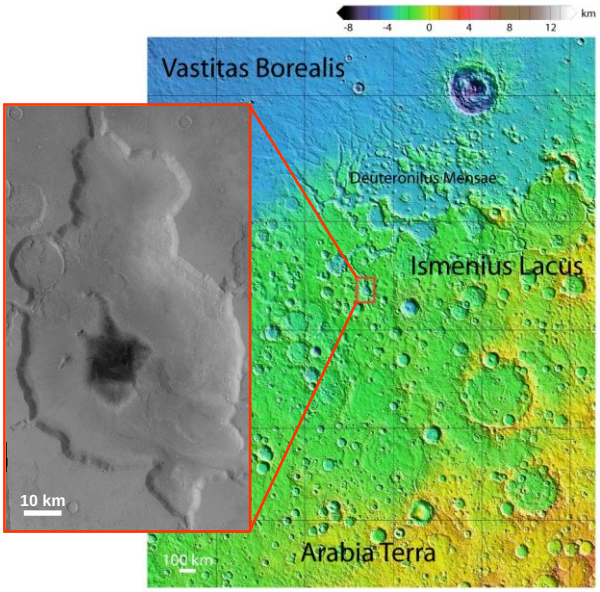

Fig. 1. HRSC image of Ismenius Cavus, and location on the MOLA reference map.

Mineralogy and geology of the crater floor: The crater floor is often smooth and blanketed by bright dust as in many regions of Mars, except in the southern darker part of the floor. Dark material containing pyroxene is identified using CRISM data, as previously seen in OMEGA data [1]. This material consists of dark eolian dunes and a dark mantle that blankets parts of the lows of Ismenius Cavus.

A layered unit is visible east of the pyroxene-bearing material at the foot of the Mamers Vallis delta. Iron-rich smectites were detected at this location by OMEGA [1]. CRISM data display spectra with 1.4 and 1.9 µm absorption bands, due to the presence of water molecules in the minerals, and a 2.3 µm band. Absorptions in the 2.2-2.4 µm wavelength region correspond to metal-OH vibrations, where the precise position of the band is a function of the cation species; Al-OH, Fe-OH and Mg-OH features are centered at 2.20, 2.29, and 2.32 µm, respectively [11]. Possible minerals with

these three bands include Fe/Mg phyllosilicates such as nontronite, saponite or vermiculite. A RGB map (Fig. 2) shows that the 2.3 µm band (in red) and the 1.9 µm band (in blue) are exactly correlated (most pixels appear magenta), therefore confirming the origin as Fe/Mg phyllosilicates. Pyroxenes are not detected together with hydrated minerals precluding a mixing of the two phases in a single rock.

The phyllosilicate-bearing unit shows meters-scale thick layers (Fig. 2c) from -3,400 to -3,600 m. The erosion of this layered unit likely occurred recently (<10 Ma), as deduced from the lack of fresh impact craters. Phyllosilicates are also observed west of the main outcrop on series of layers showing a V-shape in plan view (Fig. 2b).

Synthesis and concluding remarks: Ismenius Cavus displays three fans consistent with the presence of a 600 m deep lake during the Hesperian period, which interior displays sedimentary deposits containing Fe/Mg phyllosilicates. The presence of phyllosilicates, which consist often of clay-sized material, in distal sediments at the foot of the deltaic structure is common in such settings on Earth.

Deltaic deposits and related basin floor sediments in Ismenius Cavus are similar in age to the valleys, therefore constraining this age to the Hesperian period. The age of this paleolake is consistent with other evidences for Hesperian fluvial and lacustrine activity on Mars [9, 12-14].

Phyllosilicates may have formed by two distinct processes: (1) an *in situ* formation during the period of lake activity, or (2) by clastic deposition inside the lake. Both processes were possible, even if the stratigraphic position could favor a deposition. In both cases, the presence of phyllosilicates associated with the lack of hydrated sulfates in this Hesperian paleolake show that Mars, at that period, may have preserved regions for which sustained liquid water existed long enough to built delta fans, preserve a deep lake, and support the presence of hydrated minerals without precipitating sulfates.

References: [1] Poulet, F., et al. (2005), *Nature, 438*, 623–627. [2] Mangold, N., et al. . (2007), *JGR, 112*, E08S04. [3] Gendrin, A., et al. (2005), *Science, 307*, 1587-1591. [4] Bibring, J.-P., et al. (2004), in *Mars Express : the scientific payload*, ESA Publications Division, Noordwijk, 37-49. [5] Murchie, S.M., et al. (2007), *JGR, 112*, E05S03. [6] Bibring, J.-P., et al. (2006), *Science, 312*, 400-404. [7] Greeley, R., & Guest, J. E. (1987), *USGS Map I-1802-B*. [8] Tanaka, K. L., et al. (2005), *USGS Scientific Investigations, Map 2888*. [9] Cabrol, N., & Grin, E. (1999), *Icarus, 142*, 160-172. [10] Ori, G. G., et al. (2000), *JGR, 105*, 17,629-17,641. [11] Clark, R. N., et al. (1993), *USGS Open File Report 93-592*, http://speclab.cr.usgs.gov/. [12] Quantin, C., et al. (2005), *JGR, 110*, E12S19. [13] Mangold, N., & Ansan, V. (2006), *Icarus, 180*, 75-87. [14] Di Achille, G., et al. (2009), *GRL*, doi :10.1029/2009GL038854.

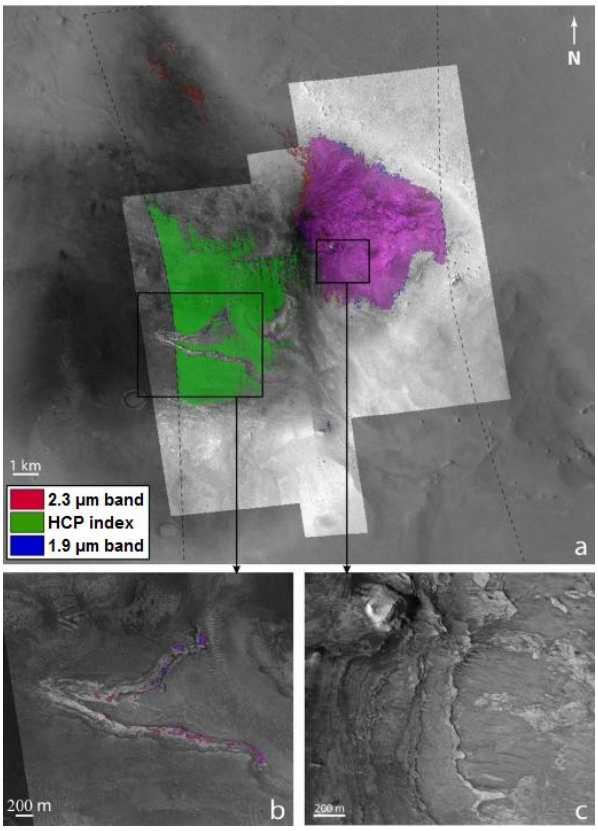

Fig. 2. a, RGB map of the crater floor with 2.3-µm band (red), HCP-band (green), and 1.9-µm band (blue), build using CRISM data ~40 m/px, and displayed over one HRSC and three HiRISE images. The magenta color indicates a one to one correlation between the 1.9 and 2.3 µm bands. **b**, HiRISE close-up on a bright scarp with layering with 1.9 and 2.3 µm bands. **c**, HiRISE close-up on sub-horizontal layered rocks.