EVIDENCES OF POSSIBLE HYDROTHERMAL ALTERATION IN XANTHE TERRA: IMPLICATIONS FOR SURFACE WATER ON EARLY MARS.

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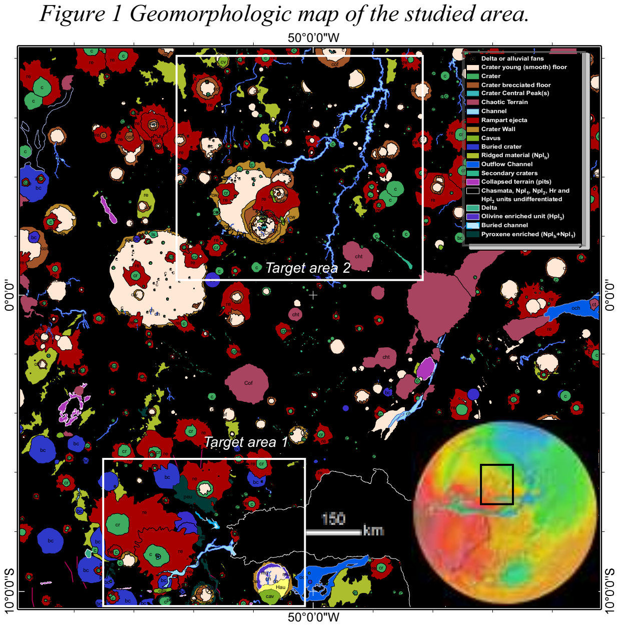
Introduction: The western part of Xanthe Terra (Mars) offers numerous examples of small to medium sized fluvial-like systems that interact with a geologic bedrock characterized by old Martian material mostly of Noachian age and compositionally defined by pyroxene-rich units [1]. The units are consistent with the extension of the previously defined Npl_h unit [2]. Hesperian units (Hpl_3) consist of olivine-rich lava flows [1,2] which outcrop along Ganges Chasma upper walls and culminate at the Morella's crater floor [1]. These geologic units are carved by channels that form hydrographic systems represented by delta and/or fan delta deposits [2, 3]. Mineral alterations are associated with the presence of mafic-rich rocks along these channels, dissected crater rims, and deltaic deposits. Our study suggests that the alterations are most likely a result of hydrothermal processes most likely related to impact crater formation. We use these mineral assemblages to put constraints on the duration and extent of water-rock interactions during early Noachian-Hesperian [1].

Data and methods: The geomorphologic map was digitized using THEMIS day global mosaic. The compositional units in Figure 1 were identified via OMEGA mapping. MRO-CRISM observations were used for detailed studies of the target areas. Laboratory measurements with analogue (natural and/or synthetic opal A and opal CT) materials were done to record the spectral response in NIR for comparison reasons.

Figure 1 Geomorphologic map of the studied area.



Results and discussion: We individuated 2 areas of interest within the survey area tracking the presence of alteration products identified via MRO-CRISM observations. The alteration acted upon Npl_h and Hpl_3 units in target area 1 and is characterized by the presence of phyllosilicates, while target area 2 is characterized by minor phyllosilicates with abundant silica in sinter like deposits in the distal part of a fan delta (Figure 1 and 2) already identified from its morphology by [4].

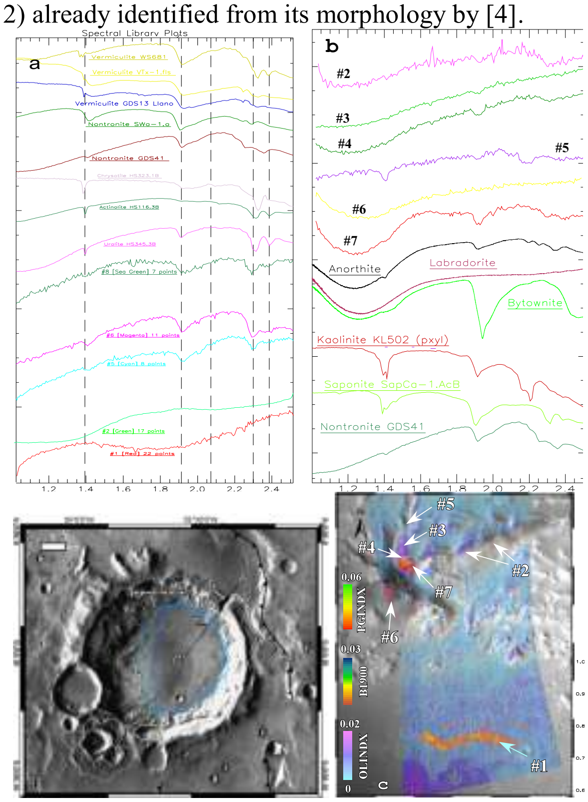


Figure 2 Alteration recorded at target area 1 (a) [5] and area 2, with corresponding locations below each spectra collection.

Given the current data coverage, we were unable to identify obvious phyllosilicate alteration outside the channel areas, where the bulk of the mafic rich Noachian units outcrop. The alteration recorded on target area 1 is Hesperian. In fact, the channel cuts through the Hpl_3 unit constraining the oldest possible age for the alteration to the Hesperian (Figure 2c). This fact suggests that dry atmospheric conditions were dominant from the Npl_h unit deposition up to the channel forming event, implying the lack of enough alteration during the early Noachian to support the idea of an extensive presence of liquid water.

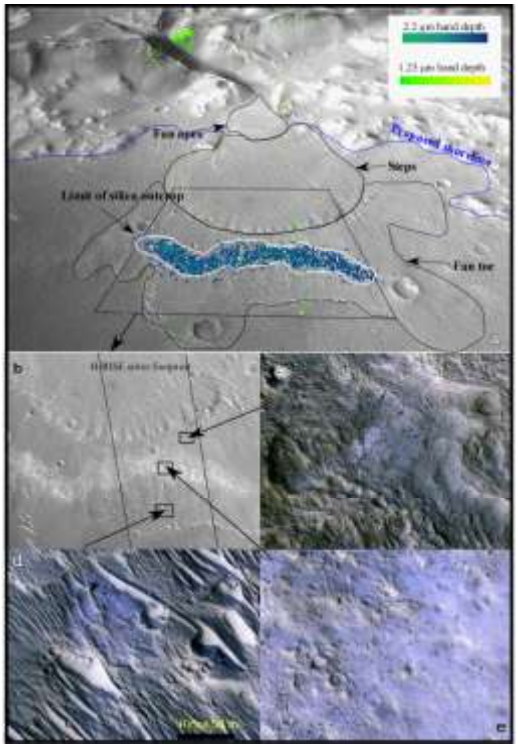


Figure 3 (above) Extent of siliceous sinter deposited in the distal part of the fan delta. The amorphous silica extends further from the outcrop area in the area below the sediment cover.

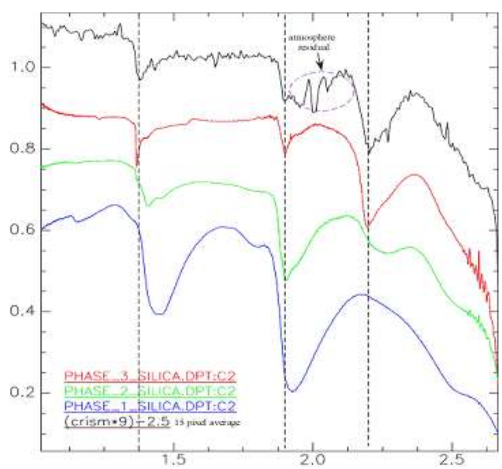


Figure 4 Time series spectral measurements depicting various water content in amorphous opal. Spectra: blue is the most hydrated phase after the generation of synthetic silica; green is the range of water content in most opal A and opal CT samples from Earth, either sedimentary or hydrothermal (e.g. chalcedony, flint, agate, etc); red – synthetic Martian sinter; black CRISM measurement over silica outcrop in the distal part of fan delta from Figure 3

In target area 2 there is a distinct water related event connected to an unnamed 60 km diameter crater that hosts a fan delta deposit (Figure 3). The water that fed this deposit is generated via crater impact melt expressed by rampart ejecta morphology north of the target. We suggest that this rampart generating event fed the western tributary of Nanedi Valles, as well as the small channel that provided the silica rich water for the sinter formation in the fan delta distal part (Figure 3). Similar systems are present to the north, although there are no alteration traces (e.g. Tyras, Drillon).

Laboratory analysis was done in order to explain the observed mineralogy. Synthetic opal was precipitated from silica rich water, then the material was measured in the NIR spectral range in a purged atmosphere (Figure 4). These measurements show that after deposition in the distal part the water was soon lost from the deposit, suggesting a water poor atmosphere.

Conclusions: The distribution of mineral assemblages produced by water interacting with mafic Noachian outcrops in western Xanthe Terra suggests the occurrence of episodic alteration events most likely related to underground water releases associated to rampart impact craters [6, 7, 8]. Most of the alterations seems concentrated between the late Noachian and during the Hesperian. This is not consistent with the hypothesis of an extended period of widespread surface aqueous alteration during the Noachian (i.e. the Phyllosian) [9].

The target area 2 can be used to place constraints on the time span of such events. In fact, a 50-km diameter crater could sustain hydrological activity for as long as 10^4 years [10,11]. The siliceous deposit in target area 2 is dehydrated (Fig. 3-4), which points to immediate exposure to dry atmosphere (with composition close to the present one), suggesting a different process of siliceous sinter deposition with respect to those in terrestrial atmosphere [12]. This process suggests the presence of a silica rich source material which could be possibly represented by the presence of granophyre (eutectic between feldspar and quartz) as suggested by the study of terrestrial analogues (e.g. Sudbury basin) [13].

References: [1] Popa C. et al. submitted. [2] Witbeck, N. E. et al. (1991) Atlas of Mars 1:2k Geologic Series. [3] Di Achille G. et al. (2007) J. Geophys. Res. 112. [4] Hauber E. et al. (2009). Planetary and Space Science 57(8-9): 944-957. [5] Komatsu G. et al. (2009) Icarus 201(2): 474-491. [6] Newsom H. E. et al. (1990) J. Geophys. Res. [7] Brakenridge et al. (1985) Geology 13, 859-862 [8] Ehlmann B. L. et al. (2011) Nature 479, 53-60 [9] Bibring et al. (2006) Science 312. [10] Marzo, G. A. et al. (2010) Icarus 208(2): 667-683. [11] Rathbun J.A. and Squyres S. W. (2002) Icarus 157(2), 362-372 [12] Day and Jones (2008) J. of Sed. Research 78(4): 301-315. [13] Therriault A. M. et al. (2002) Economic Geology, 97(7): 1521-1540.