IMPLICATION ON AQUEOUS HISTORY OF MARS AS REVEALED BY HYDROUS MINERALS IN SOUTHWEST MELAS CHASMA. Yang Liu and Timothy D. Glotch. Department of Geociences, Stony Brook University, Stony Brook, NY11794 (yang.liu.8@stonybrook.edu).

Introduction: Melas Chasma is the widest segment of the Valles Marineris on Mars and is located in the center of this canyon system. Extensive valley networks, alluvial fans, light-toned materials, and interior layered deposits (ILDs) were identified within the basin and along the wallrock of Melas Chasma [1, 2]. Clinoforms and possible sublacustrine fans were also observed, which suggest the presence of liquid water and a potentially deep lake in the basin [2, 3]. High spatial and spectral resolution orbital visible-near infrared spectroscopy from OMEGA and CRISM has revealed the presence of hydrated sulfates in Melas Chasma [4, 5]. In this study, we report the new detections of hydrated phases from analysis of CRISM data in southwest Melas Chasma and discuss their possible formation processes and implications for Martian aqueous history (Figure 1).

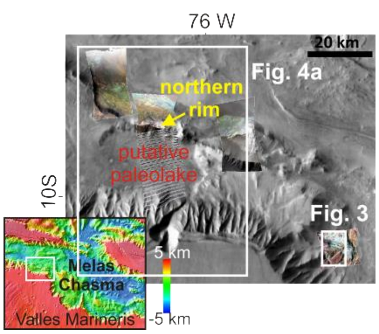

Figure 1. Southwest Melas Chasma basin. White boxes indicate the locations for DTMs in Figure 3 and Figure 4a.

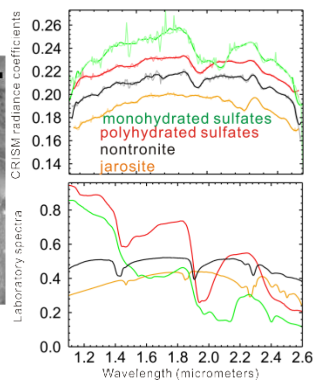

Figure 2. Retrieved CRISM radiance coefficient spectra using DISORT [6, 7] compared with spectra from RELAB.

Hydrous Minerals in Southwest Melas Chasma: In the southern wall and nearby floor of Melas Chasma, a sequence of light-toned materials associated with IDLs were observed. CRISM hyperspectral data show the presence of poly- and mono-hydrated sulfates and jarosite (Figure 2). A CRISM spectral parameter map that differentiates mineralogies by color was then co-registered and overlain on the DTM to aid in defining stratigraphic orders (Figure 3). The ILDs have been eroded into a ~500 m deep bowl shape bounded by a capping, bench-like unit with a jarosite spectral signature. Hydrated sulfates were identified immediately downslope of the cap unit. Within the bowl, interbedded monohydrated and polyhydrated sulfate-bearing layers are exposed.

To the west of the ILDs where hydrated sulfates and jarosite are exposed, a distinct light-toned zone is exposed near the northern rim of a putative paleolake proposed by Quantin et al. [2], as observed by HRSC DTM (Figure 4a). The exposed materials show signatures of monohydrated sulfates, polyhydrated sulfates, and Fe/Mg smectites. Specifically, detailed spectral analyses over a portion of the east part of light-toned zone show that Fe/Mg smectites and hydrated sulfates are interbedded. The HiRISE subset image shows that the interbedded smectite-sulfate units have been highly deformed to produce horse-shoe-shaped folded strata (Figure 4b), where the brighter materials have hydrated sulfate signatures and the relatively darker materials have Fe/Mg smectite signatures.

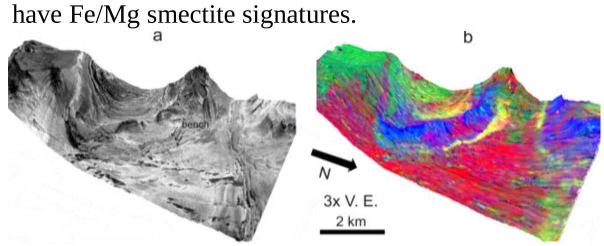

Figure 3. (a) HiRISE DTM and CRISM FRT00013F5B spectral parameter map draped on the HiRISE DEM. Polyhydrated sulfates are displayed in red, monohydrated sulfates are displayed in yellow, and jarosite is displayed in blue to purple.

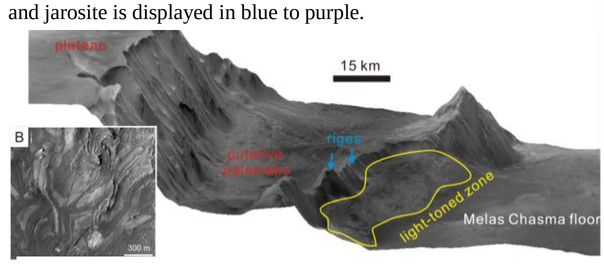

Figure 4. (a) HRSC Digital Terrain Model of a portion of southwest Melas Chasma showing the light-toned zone where hydrated sulfates and smectites were identified. (b) The HiRISE subset image of interbedded hydrated sulfate and Fe/Mg smectite units.

Spectral Mixture Analysis Results: Single-scattering albedo for surface materials is dependent on the real and imaginary indices of refraction of constituent grains as well as the grain sizes [8]. Because mineral SSAs add linearly, a library of mineral SSAs (generated using mineral optical constants and an assumed mineral grain size) can be used for linear spectral unmixing of CRISM SSAs retrieved using the DISORT radiative transfer model. Our initial spectral unmixing results are shown in Figure 5. The jarosite-bearing unit has a abundance of 32% jarosite mixed with ferrihy-

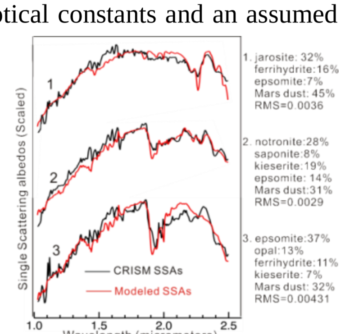

Figure 5. Spectral mixture analysis results.

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drite and epsomite. The best fit of the spectra extracted from clay-bearing region is obtained using nontronite and saponite (total 36% abundance) mixed with kieserite and epsomite. The sulfate-bearing region shows that epsomite has a bundance of 37%, and addition of opal significantly improves the fit. The derived mineral abundances can help us to better assess their formation environment, which will be conducted in future study.

Formation of Hydrated Sulfate and Jarosite-Bearing Minerals: One distinct feature observed in the ILDs is that the poly- and mono-hydrated sulfates are interbedded. Thermodynamic models of evaporation of mixed SO_4-Cl fluids suggest that polyhydrated sulfates could have precipitated when the water-to-rock ratios were high, while monohydrated sulfates could have precipitated during the periods of low water-to-rock ratios with more chloride in the brine [9]. Thus, a cyclic evaporation of upwelling groundwater may explain the interbedded deposits. However, the groundwater upwelling model is questionable because it requires that the canyon was filled with sediments to a significant level (which is apparently not consistent with remote sensing observations) to enable the ground water activity. Also, laboratory experiments have not found any evidence for the direct precipitation of kiesertite at T<50˚C from evaporation of the brines with vey high Cl-concentration as predicted by geochemical models [10]. Rather, kiesertite could have formed through dehydration of polyhydrated Mg sulfates mixed with other sulfates and chlorides, where polyhydrated sulfates likely formed from the top-down processes as suggested by *Michalski and Niles* [11]. Thus, the formation of interbedded layers of poly- and monohydrated sulfates may have been induced by episodic changes of brine chemistry, where dehydration of polyhydrated sulfates have occurred periodically. Jarosite probably formed by evaporation and oxidation of a fluid containing Fe(II), Mg, and SO_4.

Formation of Interbedded Fe/Mg Smectites and Sulfates: Several hypotheses are proposed to explain the formation mechanism of interbedded smectite-sulfate deposits. One hypothesis is that the smectite-hydrated sulfate deposits formed through repeated transport and deposition of detrital clays by a neutral fluid containing Mg and SO_4 and subsequent evaporation. Alternatively, equilibrium thermodynamic calculations show that the interbedded smectite-sulfate deposits can form through coupled basalt weathering and fluid evaporation [12]. One issue about these two models, however, is that they could not explain the observed geological setting in which the light-toned zone deposits are more likely occur with talus or glacial deposits adjacent to the ridge (Figure 4a). Thus, we proposed an alternative model that could explain both the mineralogy and the geological features of the study area. This model is based on a possible genetic link between the putative paleolake [2] and the light-toned deposits near its northern rim, and the growing evidence for glaciation in Valles Marineris [13, 14]. A warmer and wetter climate may have enabled the presence of the paleolake in Melas Chasma before transiting to a cold climate when glaciation was prevalent. The putative paleolake may have provided environmental conditions that were favorable to the formation of the interbedded smectite-sulfate deposits. The study of terrestrial analogs at acid saline lakes in Western Australia have shown evidence for phylloslicate and sulfate layering in interplaya dunes [15], where the interbedded phyllosilicate and sulfate layers were interpreted to have formed through cemetation of clays by sulfates driven by pH and salinity variations in the lake. Thus, it is possible that similar formation process of interbedded smectite-sulfate deposits has occured within the putative paleolake in Melas Chasma. During the past periods of high obliquity, these deposits were then transported to where they are now during glaciation process.

Conclusions: The identification of Fe/Mg smectites, hydrated sulfates, and jarosite in southwest Melas Chasma reveals a complex aqueous history of the study area in the acient time. In the early Hesperian when Valles Marineris formed, the climate was likely warmer and wetter and a paleolake probably has emerged where interbedded smetite-sulfate deposits formed within the lake. During past periods of high obliquity, water ice was accumulated in Valles Marineris, and glaciation process may have played a role to transport the interbedded smectite-sulfate deposit to the northern rim outside the paleolake to form a talus structure. Also in this period, hydrated sulfates accumulated through acid weathering of dust and sand captured in massive ice deposits along with large amounts of volcanic aerosols. Occasional melting of water ice that trapped more SO_2 gases may have produced high acidic fluids to form jarosite-bearing deposits observed in southwest Melas Chasma.

References: [1] Weitz C.M. et al. (2003) *JGR, 108(E12)*, 8082. [2] Quantin C. et al. (2005) *JGR, 110*, E12S19. [3] Metz j.j. et al. (2009) *JGR, 114*, E10002. [4] Gendrin et al. (2005) *Science, 307*, 1587-1591. [5] Weitz C.M. et al. (2012) *LPSC*, abstract 2304. [6] Stamnes et al. (1988) *Appl. Opt., 27*, 2502-2509. [7] Wolff et al. (2007) *Seventh International Conference on Mars*, Abstract 3121. [8] Hapke, B. (1993), *Theory of Reflectance and Emittance Spectroscopy*, 455 pp., Cambridge Univ. Press, NY. [9] Catalano J.G. et al. (2012) *Third Conference on Early Mars*, abstract 7010. [10] Connor and Wang (2014), *LPSC*, abstract 2750. [11] Michalski J.R. and Niles P.B. (2012) *Geology, 40*, 419-422. [12] Liu Y. et al. (2014), submitted. [13] Mege D. and Bourgeois O. (2011) *EPSL, 310*,182-191. [14] Gourronc M. et al. (2014) *Geomorphology, 204*, 235-255. [15] Baldridge A.M. et al. (2010), *LPSC*, abstract 2268.