EXTENSIVE EXPOSURE OF CLAY-BEARING NOACHIAN TERRAIN IN MARGARITIFER TERRA, MARS. Rebecca. J. Thomas[1], Brian. M. Hynek[1,2], Mikki M. Osterloo[1] and Kathryn S. Kierein-Young[3]. [1] LASP, University of Colorado, Boulder, CO 80309, USA, rebecca.thomas@lasp.colorado.edu, [2] Department of Geological Sciences, University of Colorado, 399 UCB, Boulder, CO 80309, USA. [3] Sapphire LLC 7834 Fairview Rd, Boulder, CO 80303, USA

Introduction: The best locations at which to detect evidence for early life on Mars are in material deriving from surface/near-surface aqueous environments, particularly where this resulted in the deposition of minerals, such as clays, that are favorable to preservation of organics [1]. The geological history of the Margaritifer region has resulted in exceptional potential to preserve such deposits and to render them discoverable. Due to its topographic setting, Margaritifer was a major sink for water and sediments in the early, Noachian period, potentially creating habitable environments conducive to clay-formation [2]. Subsequently, during the Late Hesperian to Amazonian periods, the surface was extensively disrupted by geologic activity associated with chaos-formation [e.g., 3,4,5], which could potentially expose these earlier units at the surface. We used orbital imagery, spectral, and topographic data to investigate the exposure of early clay-bearing deposits across the region and found that Hesperian and Amazonian activity did indeed expose extensive clay-bearing terrains, and that the setting and character of many of these clays is consistent with in situ formation in a stagnant groundwater setting.

Margaritifer Terra (-23.6 to 19.7°N, 320.5 to 350.6° E) lies south of the boundary between Mars' southern highlands and northern lowlands, east of Valles Marineris. Our study area (Figure 1) encompasses a broad region along the Uzboi-Ladon-Morava (ULM) Late Noachian to Hesperian outflow system, including Ladon and Margaritifer basins, surrounding uplands, and cross-cutting chaos regions. It excludes Holden and Eberswalde basins to the south and Aram chaos in the north, where localized fluvial activity has been and is being extensively studied by other workers [e.g., 6,7,8], though this study is expected to have relevance to work within these regions.

Identifying clay-bearing units: To detect clays, we conducted spectral analysis on 176 targeted observations from the L-detector of the Mars Reconnaissance Orbiter (MRO) CRISM spectrometer [9], which captures data in an infrared range (1.0-4.0 μm) within which hydrated minerals display diagnostic spectral absorptions. This comprises all images within the study area that are free from excessive atmospheric interference and are spatially-distinct. These were corrected photometrically and for atmospheric gas using standard CRISM CAT tools, and denoised using a custom algorithm to average spectral reflectance across potential band spikes. We ratioed all spectra to those in a user-defined spectrally neutral area, on a column by column basis where possible, and used these values to produce standard [10] spectral summary products. Where these summary products indicated the presence of a unit containing hydrated minerals, we extracted an average spectrum over > 100 pixels and assessed the best spectral match (and thus potential mineralogy) by comparison with the CRISM spectral library.

Mapping clay-bearing units: Spectral analysis combined with inspection of MRO CTX [13] and HiRISE images [14], indicates that clays commonly occur in light-toned material that is densely brecciated on multiple scales, as reported previously for Noachian clay-bearing units in the Margaritifer region [15] and across the highlands [16]. We therefore used visual identification of light-toned material, especially where HiRISE images show it to be densely brecciated (LTBr), to map the probable extent of clays, using a grid mapping approach [17]. To place unit detections within their tectonic/hydrological context, we created regional maps of large-scale fractures and channels, and to investigate the physical properties of the units, we utilized global quantitative thermal inertia (TI) maps [18] based on Mars Odyssey THEMIS nighttime infrared data.

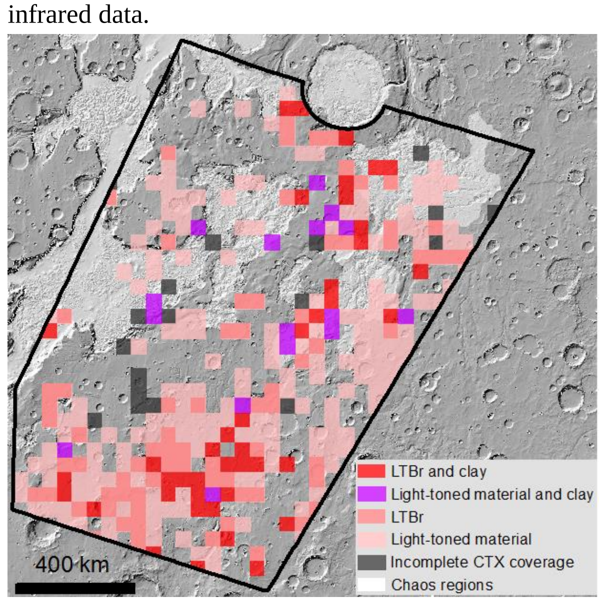

Figure 1. Extent of probable clay-bearing units in Margaritifer Terra. Study area: black polygon, legend in order of confidence. Chaos extent from [11], base: MOLA hillshade [12].

Results and interpretations: Spectral analysis indicated the presence of Fe/Mg-phyllosilicates in 83 CRISM scenes, all associated with basins and uplands outside chaos regions or erosional debris at chaos margins. These detections are widespread, and mapping of the morphological unit (LTBr) within which they consistently occur, indicates that they are also areally-extensive (Figure 1). At a subset of locations in southern Margaritifer, clays occur in layered units along channels. These units may have formed by deposition of detrital clays during ponding in a fluvial system [2,19]. However, elsewhere clay-bearing units occur at a range of elevations in Noachian terrains, both within and outside topographic lows, including those distal from the ULM channel system. This is more consistent with in situ clay-formation by a regional process. Cross-sections through upland areas show that clays occur to the top of the light-toned unit and do not show any compositional layering. This indicates that they formed near the surface but not from top-down weathering [20], most probably by alteration of basaltic material in a stagnant near-neutral pH groundwater-saturated environment [21]. We do not find evidence for sulfates within the clay-bearing terrains, indicating that contrary to some hypotheses for the Meridiani Terra region immediately to the east [22], later acidic upwelling, which could be damaging to biosignature preservation [1], did not occur.

Exposure of light-toned clay-bearing material consistently occurs in the scarps of or on the terrain surrounding Late Hesperian to Amazonian surface fractures. Where exposure is over an area surrounding a fracture, it is clearly centered on the fracture and occurs by removal of a lower-TI (and so less competent) dark-toned capping unit (Figure 2). The geometry of exposure is indicative of removal of the capping material by fluid emitted from the fractures, indicating that exposure occurred in the same period as fracture-formation and owes this exposure to fluid upwelling from the fractures.

Conclusion: We find that clay-bearing Noachian sediments are exposed over a very wide area in Margaritifer, and that their mineralogy is most consistent with clay-formation in a low energy near-neutral pH groundwater environment. We additionally find that evidence for subsequent acidic groundwater activity is absent, indicating that biosignature preservation in these sediments is favored, perhaps to a greater degree than for similar deposits in the surrounding region. Further, we find that, due to intense Hesperian-Amazonian geologic activity, early clay-bearing units are exposed here to a far greater degree than achievable in regions with more localized erosive mechanisms.

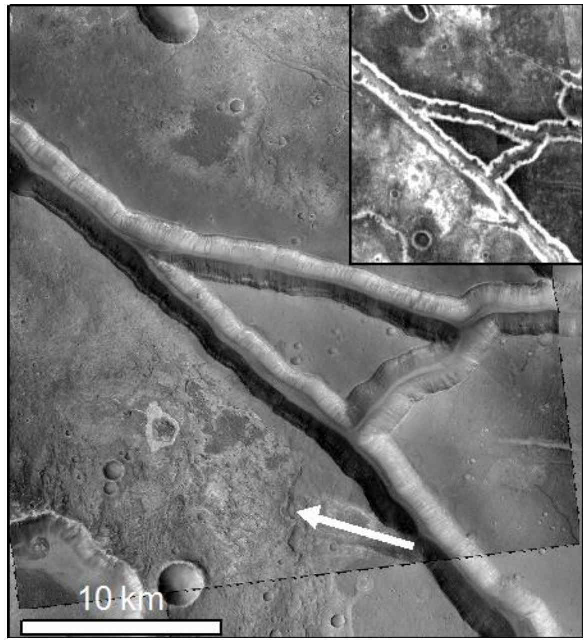

Figure 2. Exposure of clay-bearing light-toned brecciated material at an upland circum-chaos fracture in Margaritifer Terra (CTX G10_022130, B03_010803, B07_012359). White arrow: inferred direction of fracture-sourced erosive fluid flow. Inset: excerpt covering the same extent from global TI map [17].

References: [1] Ehlmann B. L. et al. (2008) *Nat. Geosci., 1*, 355–358. [2] Milliken R. E. and Bish D. L. (2010), *Philos. Mag. 90*, 2293–2308. [3] Carr M. H. (1979) *J. Geophys. Res., 84,* 2995–3007. [4] Grant J. A. and Parker, T. J. (2002), *J. Geophys. Res., 107*. [5] Warner N. H. et al. (2011) *J. Geophys. Res. Planets, 116*. [6] Rice, M.S. (2005) *Mars, 1*. [7] Glotch T.D. and Christensen P.R. (2005) *J. Geophys. Res. Planets, 110*. [8] Grant J.A. et al. (2008) *Geology, 36*, 195-198. [9] Murchie S. et al. (2007) *J. Geophys. Res. Planets*, 112. [10] Viviano-Beck C. et al. (2014) *J. Geophys. Res. Planets, 119*. [11] Tanaka K.L. et al. (2014) *Planet. Space Sci., 95*, 11–24. [12] Smith D.E. et al. (1999) *Science, 284*, 1495–1503. [13] Malin M. C. et al. (2007) *J. Geophys. Res. Planets,112.* [14] McEwen A.S. et al. (2007) *J. Geophys. Res., 112.* [15] Salvatore M.R. et al. (2016) *J. Geophys. Res. Planets, 121.* [16] Mustard J.F. et al. (2008) *Nature, 454*, 305-309. [17] Ramsdale, J.D. et al. (2015) Lunar Planet. Sci. Conf., 46,1339. [18] Fergason R.L. et al. (2006) *J. Geophys. Res. Planets, 111.* [19] Grant J.A. et al. (2011) [20] Gaudin A. (2011) *Icarus, 216,* 257–268. [21] Catalano J. G. (2013) *J. Geophys. Res. Planets, 118*, 2124–2136. [22] Squyres S. W. and Knoll A. H. (2005) *Earth Planet. Sci. Lett., 240*, 1–10.