MARTIAN CHLORIDE DEPOSITS: THE LAST GASPS OF WIDESPREAD SURFACE WATER. M. M. Osterloo[1] and B. M. Hynek[1, 2], [1]Laboratory for Atmospheric and Space Physics, [2]Dept. of Geological Sciences, University of Colorado-Boulder, Campus Box 600 UCB, Boulder, CO 80303, mikki.osterloo@lasp.colorado.edu

Introduction: Chloride salts have been identified throughout the southern highlands of Mars using data from the Mars Odyssey Thermal Emission Imaging System (THEMIS) [1,2]. Understanding the geologic context of these sites enables a better determination of the degree and duration of habitable conditions and can provide clues regarding the evolution of the regional and global climate. Here, we present our results of geologic characterizations of the 20 largest chloride sites in order to better understand their geologic setting, age, and formation mechanisms.

Datasets and Methods: For each of the 20 chloride sites, we drafted maps at 1:1,000,000 scale to glean the local geologic context for regional to global cross-comparisons. Map regions were defined as 3° × 3° boxes centered on the chloride deposit. This area encompassed the main deposits, and in many locations, a suite of chloride deposits, to allow for investigation of lateral contiguity.

We utilized custom THEMIS decorrelation stretched (DCS) mosaics and band 9 day and night mosaics as our basemaps for each region of interest. We also used the Mars Orbiter Laser Altimeter (MOLA) gridded topography to characterize the regional setting [3]. Where available, we incorporated additional higher resolution visible imagery and topographic data to further elucidate the geology. We used a combination of different criteria, including textural, morphological, topographic, and thermophysical properties to differentiate map units.

Given the small areal extent of the chloride exposures, crater densities are not useful for age estimates. However, through our mapping we were able to define the broader geologic unit in which the chloride salt deposits occur and these units were large enough for crater-age determinations. Combined with stratigraphic relationships we were able to determine minimum or maximum ages for the chloride deposits. We incorporated the global crater database of [4], which is statistically complete down to diameters ≥ 1 km; absolute ages were determined from isochrons of [5] and the production function of [6].

Key Results: In all sites, the chloride deposits are small, scattered, of high albedo and display an indurated appearance suggesting lithification and/or degree of cementation or consolidation, but also appear to be in a state of erosion. The chlorides are located in local topographic lows, often in younger low-lying relatively flat units typically surrounded by older cratered highlands.

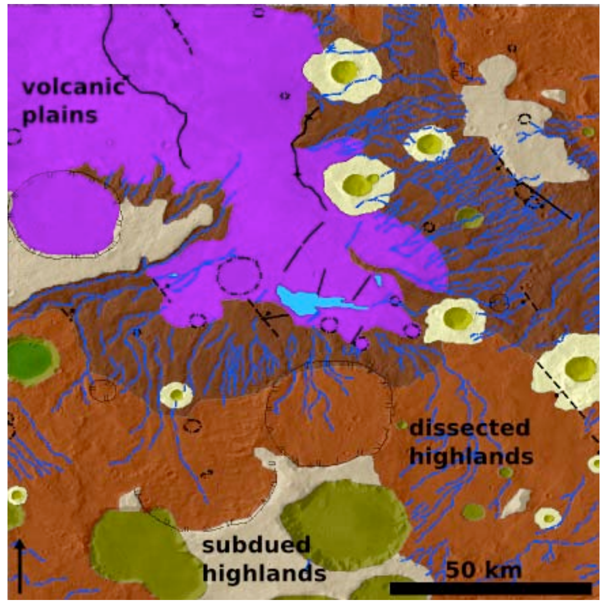

Figure 1. Site #15 (-38.8°N, 205.81°E) is shown as an example of the results of our geologic mapping of the 20 largest chloride deposits on Mars. The chloride deposit is indicated in blue. Here, the highlands were subdivided into two subunits based on the degree of fluvial dissection (darker brown indicates higher dissection). Yellow indicates crater ejecta and craters are subdivided based on degree of degradation.

The chlorides are predominantly located in plains units that are characterized by broad, relatively smooth and flat surfaces where flow lobes and lobate margins are observed in places (Figure 1). These plains units fill in lows and ghost craters are commonly observed on their surfaces. The plains units were likely later modified by contraction or compressional stresses as we commonly observed wrinkle ridges on these units. The above morphologic observations suggest that these plains units are low viscosity lava flows. Chloride deposits occur less commonly within a second type of unit that is also characterized by broad relatively flat surfaces. Ridges and buried craters are less common and we rarely observed flow fronts. Our observations suggested that these units may also be volcanic in origin, but perhaps more thinly bedded and less extensive than the plains units. These units roughly correlate to the previously mapped Hesperian and Noachian ridged plains units and less frequently in terrains previously mapped as Noachian plateau units [7,8].

Understanding the age of the chloride deposits is important to assess the timing of aqueous activity on

Mars. We note that these are minimum ages – the chlorides could have formed at any time after the underlying geologic unit on which we can reliably age-date with craters. However, we utilized HiRISE imagery where available to investigate the local stratigraphy. In some places the chlorides are superimposed (maximum ages possible) and elsewhere they are exhumed or appear to be to exposed due to erosion of overlying basaltic material (minimum ages possible to calculate). In a few sites chlorides are exposed as distinctive layers within craters. A thin to moderate layer of dark toned materials and sediments typically cover the chlorides. Therefore, crater age-dates may represent a minimum age of formation for the chloride deposits in these sites.

Absolute ages of the units that contain chloride deposits range from ~3.5 to ~3.8 Ga, or Early Hesperian to Late Noachian. The highland materials that surround the plains units typically range from ~3.5 to ~4.0 Ga. However, in most sites the surrounding terrain is older than the plains units. Interestingly, the plains units where the chloride deposits occur are constrained to a narrow range of time. The average age of the units where the chloride materials occur is 3.65± 0.09 Ga. Importantly, this crater age-date corresponds to the tail end of significant valley network formation on Mars [9].

Finally, we have observed significantly more evidence of fluvial activity near the chloride deposits than was previously noted in [2]. Detailed investigations of available HiRISE imagery indicate that there is commonly clear evidence of small, sinuous, sometimes inverted topography channels leading into the depressions where the chloride deposits are located (Figure 2). Furthermore, chlorides are often located within the channels themselves. In addition, we commonly observed dissection of the surrounding highland units as well as the plains units in which the chlorides occur. Typically the highlands units showed more extensive dissection than the plains, but we also observed channels crosscutting both units in many areas (Figure 1).

Interpretations: We have established that most of the chloride deposits occur within plains units and many within volcanic plains. We hypothesize that instead of being geologically related to the volcanic processes, the plains represent low points in the topography where ponding of surface runoff occurred. Our geomorphologic evidence of significant fluvial channel development near and within chloride deposits in addition to their geographic location in local topographic lows at the downstream end of fluvial networks supports this hypothesis. Furthermore, our crater age-date averaging 3.65 Ga suggests that the last pulse of widespread surface water activity on Mars spread surface water activity on Mars may have deposited the chloride deposits. We infer that the chloride salts were deposited as evaporites as the ponded surface water dissipated.

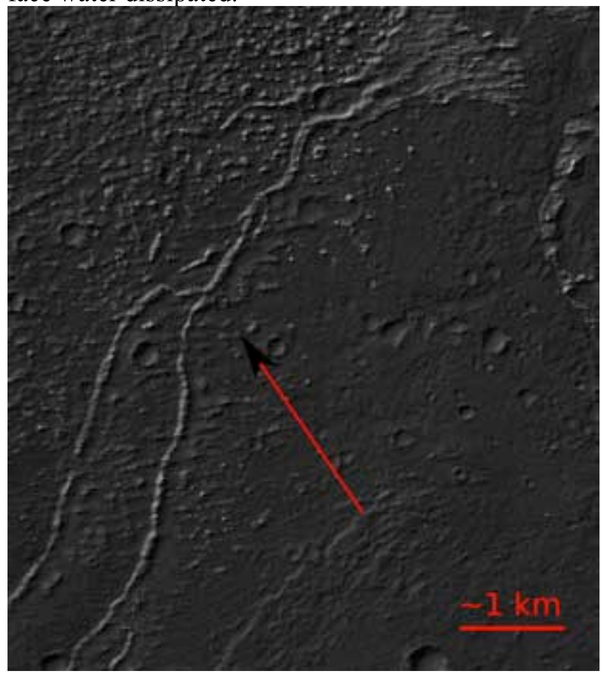

Figure 2. An example of a sinuous, light toned, inverted channel with a chloride spectral signature that empty into a larger fan deposit in HiRISE image PSP_009318_1465.

Conclusions: The results of our work have provided evidence for chloride formation via evaporatic processes from surface runoff given the correlation of chloride deposits with channels and incised valleys. Furthermore, our crater age-dating results suggest that the chloride deposits may represent the last pulse of surface water at the end of the major valley network formation period on Mars. Thus, our geologic analyses definitively links chloride formation with surface runoff and valley formation. This result has broad implications for the global aqueous history of Mars and pinpoints the chlorides as a signature of the last gasps of widespread surface water, making them a key target for future astrobiological investigations of Mars.

References: [1] Osterloo, M. M. et al. (2008) *Science* [2] Osterloo, M. M. et al (2010) *JGR* [3] Smith, D. E. et al. (2001) *JGR*. [4] Robbins, S. J. and B. M. Hynek (2012) *JGR* [5] Hartmann, W.K. and G.Neukum (2001) *Space Sci. Rev*.. [6] Ivanov, B. A (2001) *Space Sci. Rev.* [7] Scott, D.H. and K. L. Tanaka (1986) *U.S. Geol. Surv. Misc. Invest. Ser., Map I-1802-A* [8] Greeley, R. and J. E. Guest (1987) *U.S. Geol. Surv. Misc. Invest. Ser., Map I-1802-B*. [9] Hynek, B. M. et al. (2010) *JGR*.