EVIDENCE OF SALTY RESIDUES IN LAYERED OUTCROPS AT MAWRTH VALLIS AND IMPLICATIONS FOR EVAPORATIVE ENVIRONMENTS ON EARLY MARS. J. L. Bishop[1], J. J. Wray[2], A. Sessa[2], J. Danielsen[1,3], B. L. Ehlmann[4], S. L. Murchie[5], B. Horgan[6], C. Gross[7], M. Parente[8], and F. P. Seelos[5], [1]SETI Institute (Mountain View, CA; jbishop@seti.org), [2]GeorgiaTech (Atlanta, GA), [3]San Jose State Univ. (San Jose, CA), [4]CalTech (Pasadena, CA), [5]JHU-APL (Laurel, MD), [6]Purdue Univ. (West Lafayette, IN), [7]Freie Univ. Berlin (Berlin, Germany), [8]Univ. of Mass. (Amherst, MA).

Introduction: Evidence for salty environments at Mawrth Vallis, Mars, is present in evaporative residues found in thin horizons between phyllosilicate units. Here we present new observations of mixed sulfate/phyllosilicate deposits including jarosite, alunite, gypsum, bassanite, kaolinite, opal and smectites. We investigated multiple MTRDR versions of CRISM images in the Mawrth Vallis region and were able to resolve sulfates in many small sites. These salty deposits may represent vestiges of ancient salt ponds similar to those found in SW Australia, the Painted Desert, AZ, El Tatio, Chile, or the Antarctic Dry Valleys.

Study Site: Salty outcrops are observed throughout the Mawrth Vallis region where light-toned, layered phyllosilicate units are present [1]. The locations of three images presented here are shown in Fig. 1. Typically this evaporative horizon occurs on top of the thick Fe/Mg-smectite unit. In most cases the salty residues occur as tiny pockets of sulfates intermixed with Al-phyllosilicates and opal. In one region at the edge of the dichotomy boundary more expansive salty deposits are observed (Fig. 2). Transitions in mineralogic units were characterized previously [1] using spectral properties and surface morphology. The observations point to an ancient wet and warm geologic record that formed the thick nontronite unit, a period of wet/dry cycling to create acid alteration, followed by leaching or pedogenesis to result in Al-phyllosilicates, and finally a drier, colder climate that left the altered ash in the form of nanophase aluminosilicates, rather than crystalline clays [2].

Methods: Recently developed CRISM parameters [3] and newly available MTRDR images [4] are enabling refined characterization of the mineralogy at Mawrth Vallis. Distinct phyllosilicate horizons are mapped using HRSC DTMs across 100s of kms and using HiRISE DTMs across 100s of meters. Small outcrops of jarosite, alunite, Ca sulfates and other units having a spectral doublet between 2.2-2.3 µm are observed in several CRISM images (e.g. Figs. 2-4).

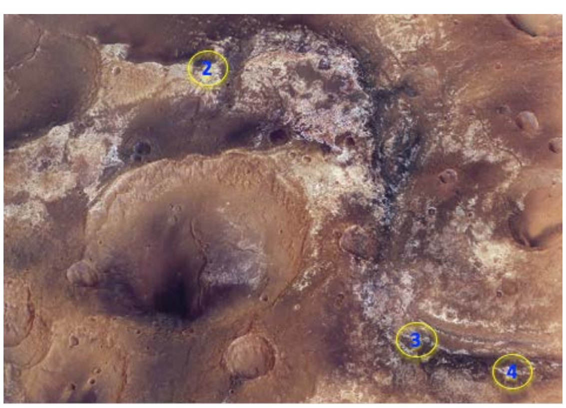

Fig. 1 HRSC view of Mawrth Vallis region with locations marked of images discussed.

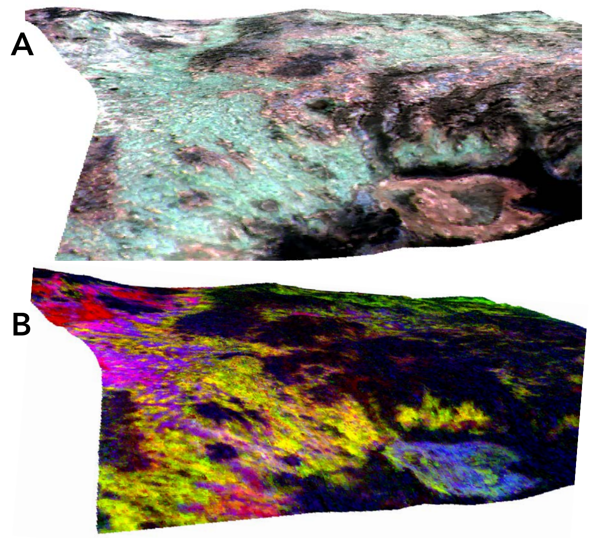

Fig. 2 Views of CRISM image FRT0000A425 with A) RGB as 2.5361, 1.3358, 0.7749 µm, and B) Fe/Mg-smectite in red, sulfates and Al-phyllosilicates in pink-yellow, jarosite in green, and jarosite/phyllosilicate mixtures in light blue.

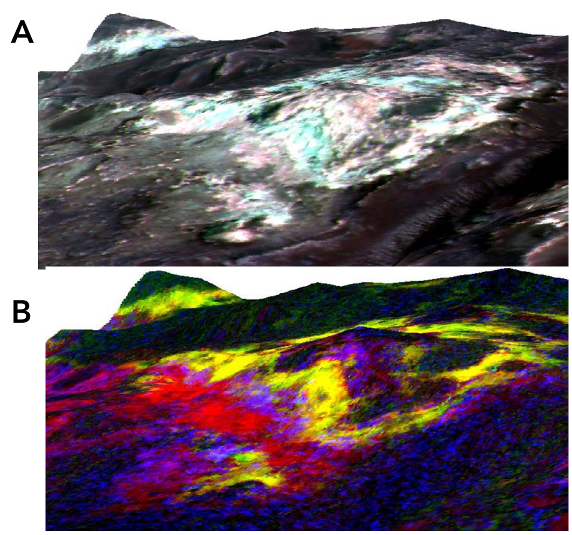

Fig. 3 Views of CRISM image FRT00003BFB with A) RGB as 2.5361, 1.3358, 0.7749 µm, and B) Fe/Mg-smectite in red, sulfates and Al-phyllosilicates in pink-yellow, and jarosite in light green.

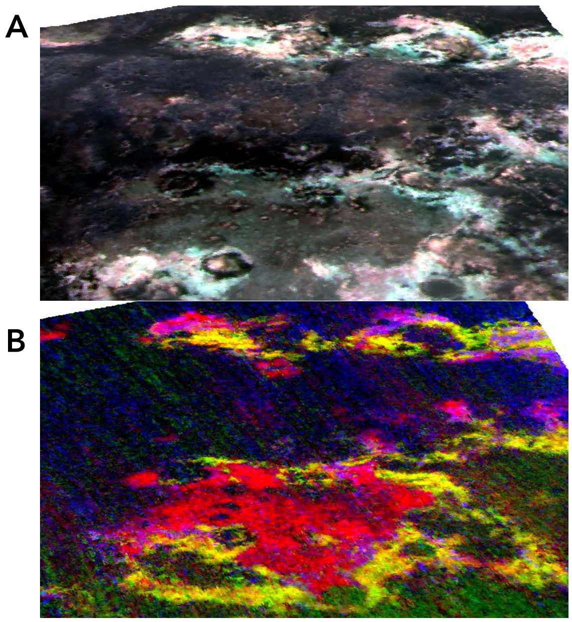

Fig. 4 Views of CRISM image FRT0000C467 with A) RGB as 2.5361, 1.3358, 0.7749 µm, and B) Fe/Mg-smectite in red, sulfates and Al-phyllosilicates in pink-yellow, and jarosite in light green.

Results. This study builds on previous detections of sulfates [5-7] and doublet-type units [1] in Mawrth Vallis. The band centers and relative intensities of the doublet features are highly variable (Fig. 5), which is consistent with mixtures of Ca sulfates, OH-bearing sulfates and clays, or acid alteration of clays [1].

CRISM spectra (Fig. 5) attributed to jarosite include bands at 1.47, 1.86 and 2.27 µm [8] and are found in several tiny outcrops throughout Mawrth Vallis [1,9]. Spectra of jarosite also include a shoulder or weak band near 2.22-2.23 µm. Many of the doublet-type spectra have bands near 2.22-2.23 and 2.26-2.27 µm that are roughly similar to the positions of the jarosite bands, although the relative intensity is inconsistent with jarosite, and other diagnostic jarosite features are missing [9]. Similar acid-alteration processes are likely responsible for the formation of the doublet-type material and jarosite. The small occurrences of jarosite may indicate localities where acidic conditions persisted longer, thus enabling its formation.

Spectra of the Ca sulfates bassanite and gypsum [10] also contain a doublet near 2.22 and 2.26 µm, similar to jarosite features and a band near 1.75 µm, similar to that of alunite. Thus, mixtures of these sulfates can be difficult to sort out. Typically, Ca sulfates are expected in near neutral environments, while jarosite and alunite form in low pH environments. However, in high Cl and S systems, all of these sulfate minerals can form together in mildly acidic conditions. This is observed in salt ponds in SW Australia [11], the Painted Desert [12], and elsewhere.

CRISM spectra attributed to alunite include bands at 1.47, 1.75 and 2.17 µm [8] and a particularly nice outcrop of alunite is observed in FRT0000C467 [13]. The band at 2.17 µm overlaps with the kaolinite doublet, presenting challenges for identification. Mixtures of kaolinite and alunite have been found in salt ponds in SW Australia [11] and may be present on Mars also.

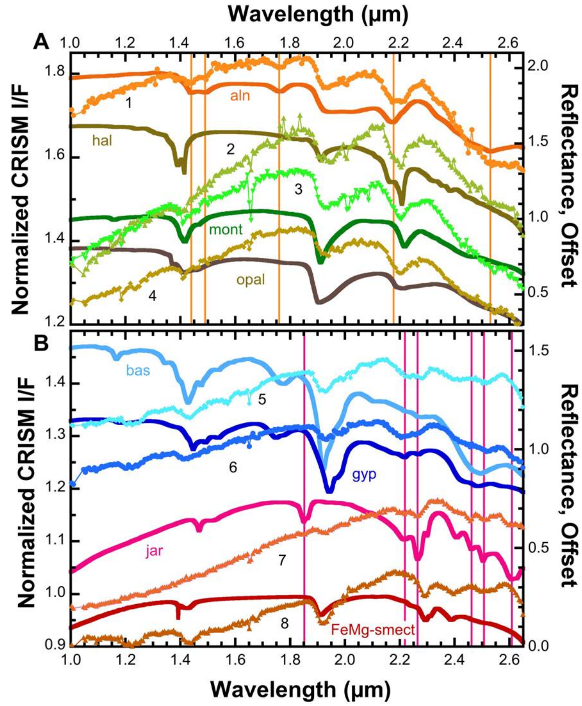

Fig. 5 A VNIR reflectance spectrum of jarosite for comparison with spectra of jarosite-bearing and doublet-type CRISM spectra from image FRT00003BFB.

Summary. Small outcrops of Ca-sulfates, jarosite and alunite are present in pockets between the thick, lower Fe/Mg-smectite unit and the upper Al-phyllosilicate/opal unit. These sulfates likely formed in surface evaporative environments that were later buried. A few isolated regions exhibit spectral properties most consistent with these sulfates, while most occurrences are mixtures with kaolinite or opal. Comparison with terrestrial outcrops bearing Ca-sulfates, jarosite, alunite, kaolinite and opal suggests that these salty units at Mawrth Vallis formed in evaporative environments.

References: [1] Bishop et al. (2016) LPSC #1332. [2] Bishop & Rampe (2016) EPSL, 448, 42-48. [3] Viviano-Beck (2014) JGR, doi: 10.1002/2014JE004627. [4] Seelos, (2012) Planetary Data Workshop. [5] Wray et al. (2010) Icarus, 209, 416-421. [6] Farrand et al. (2009) Icarus, 204, 478-488. [7] Farrand et al. (2014) Icarus, 241, 346-357. [8] Bishop & Murad (2005) Am.Min. [9] Danielson et al. (2018) LPSC. [10] Bishop et al. (2014) Am.Min., 99, 2105-2115. [11] Benison & Bowen (2006) Icarus, 183, 225-229. [12] Perrin et al. (2018) LPSC. [13] Sessa et al. (2018) LPSC.

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