WEATHERING PROFILES AT MAWRTH VALLIS YIELD INSIGHT INTO THE AQUEOUS HISTORY AND POTENTIAL HABITABILITY OF MARS. S. R. Gainey[1]; E. M. Hausrath[1]; J. A. Hurowitz[2] [1]Department of Geoscience, University of Nevada, Las Vegas, 4505 S. Maryland Parkway, Las Vegas, NV 98154-4010, USA gaineys@unlv.nevada.edu. [2]Department of Geosciences, Stony Brook University, 255 Earth and Space Building (ESS), Stony Brook, NY 11794-2100, USA.

Introduction: Although abundant evidence exists for liquid water on Mars, the duration and characteristics of that liquid water remain under-constrained. The duration of liquid water, in particular, is important to questions of habitability, as the longer there was liquid water on Mars the more conducive it might have been to habitability. On Earth, thickness of weathering profiles can be quantitatively modeled, with inputs of measured geochemical parameters, and known durations yielding observed profile characteristics [1, 2]. Putative weathering profiles have also been observed on Mars, including Mawrth Vallis [3] and Nili Fossae [4] which may yield information about duration and characteristics of alteration [3,4]. Of these putative weathering profiles on Mars, Mawrth Vallis may represent one of the largest.

The stratigraphy of the Mawrth Vallis region is generally characterized by an Al-rich unit dominated spectrally by kaolinite and/or montmorillonite (Figure 1), overlying a Fe/Mg-rich unit(s) spectrally composed of nontronite and/or saponite [3], a sequence that is also observed broadly across the martian surface [5]. Visible Near Infrared spectroscopy suggest that the lower unit in the Mawrth Vallis region more closely resembles nontronite than saponite [3]. Past work by [6, 7] suggests that the upper Al-rich unit contains between 20 to 40 percent phyllosilicates, and that the Fe, Mg-rich unit is composed of approximately 20 to 65 percent clay minerals [6, 7].

As fluids interact with rock, sediment and/or soil, they may produce changes in chemistry and mineralogy with depth, eventually producing weathering profiles. These profiles can preserve the properties (e.g. pH) and duration of the fluid-rock interaction [8, 9]. Reactive transport modeling is one method used to quantitatively interpret weathering profiles [8]. Kinetics of phyllosilicate dissolution and precipitation have been previously measured and therefore, reactive transport modeling may be a useful quantitative tool to analyze potential weathering profiles on Mars [8].

In order to interpret the potential implications of a weathering profile in the Mawrth Vallis region, we used the reactive transport model CrunchFlow, to forward-model alteration of nontronite and mixed deposits of clay minerals under soil-forming conditions. CrunchFlow has previously been used to model weathering on Costa Rica basalts [2], ocean floor sediments [10], Svalbard basalt and martian rocks [8] at a variety of scales and has been demonstrated to accurately model weathering profiles over a range of conditions.

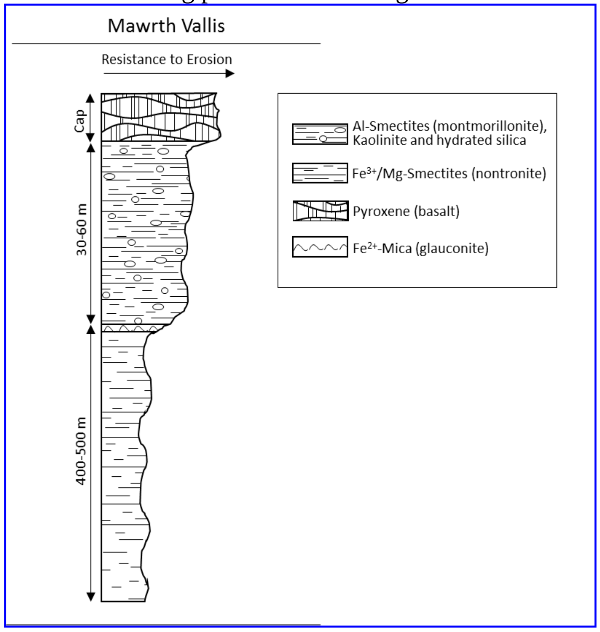

Figure 1: Stratigraphy of the Mawrth Vallis region, constructed from spectra taken by the Mars Reconnaissance and Mars Express Orbiters [3].

Methods: We used the reactive transport code, CrunchFlow, to forward-model alteration of nontronite (scenario 1), mixed nontronite and montmorillonite) (scenario 2), mixed saponite and nontronite (scenario 3) and saponite (scenario 4) under pedogenic conditions such as those that may have potentially formed an alteration front at Mawrth Vallis. CrunchFlow allows fully kinetic mineral dissolution and precipitation reactions; it incorporates advective, diffusive, or dispersive flow, including unsaturated transport with gas-aqueous exchange; and it contains reaction-induced porosity and permeability feedback [11].

In scenario 1, the parent material consisted of 65% nontronite and 35% porosity, which is based on spectral deconvolution models [6, 7]. In scenario 2, the parent material consisted of 55% nontronite and 10% montmorillonite (the amount of montmorillonite which would likely be undetected by VNIR remote observations). Most VNIR observation of the martian surface suggest that Fe/Mg bearing clay minerals, such as nontronite and/or saponite are the most wide spread and therefore, scenario 3 consist of a mixed deposit consisting of 30% nontronite and 30% saponite. Lastly, a deposit of pure saponite was modeled (scenario 4). In each case, the clay minerals nontronite, montmorillonite, kaolinite and saponite were allowed to precipitate, in addition to goethite.

The weathering profile for each scenario consisted of a one-dimensional, 100 cell column, representing a 100 meter stratigraphic column of phyllosilicate-rich rock. Published dissolution rates and solubilities from the literature were used for nontronite [12], saponite [13], montmorillonite [14], and kaolinite [15].

Results and Discussion: The results of these models suggest that the weathering of both saponite and/or nontronite will alter to Al-rich clay minerals (e.g. kaolinite and/or montmorillonite), with the phase depending on the pH of reacting fluids. If Fe is present, it will precipitate as goethite, in agreement with terrestrial and orbital observations [6, 7]. In scenario 1, the dissolution of nontronite leads to oversaturation and precipitation of Al-bearing phases (e.g. kaolinite and montmorillonite), whereas the majority of Fe is incorporated into goethite (Figure 2). In scenario 2, the presence of Al-rich clays increases the amounts of kaolinite and montmorillonite due to the high concentration of Al and lower Fe concentrations. The dissolution of saponite in scenario 3 produced Al-rich clays, however due to the less soluble and more-slowly dissolving nontronite a mixed unit of nontronite and Al-rich clays formed, which eventually produced an Al-rich capping unit. In scenario 4 the dissolution of saponite produced Al-rich clays, producing stratigraphy similar to that in Nili Fossae [4]. In each case, sufficient duration of weathering leads to the eventual sequence from top to bottom of: kaolinite + goethite, montmorillonite + goethite, nontronite and/or saponite.

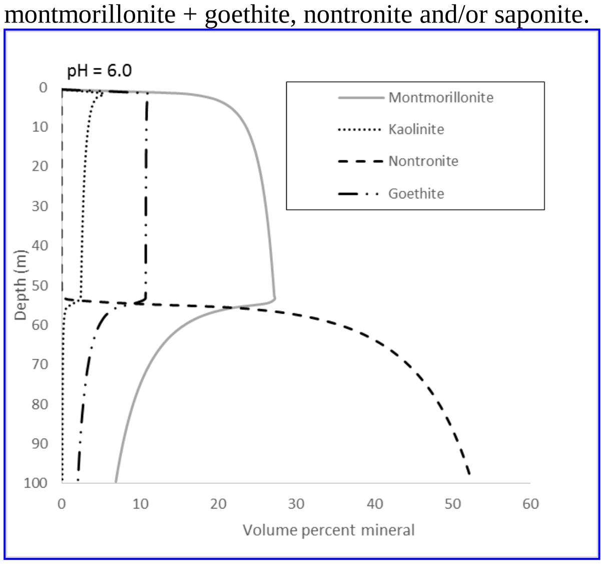

Figure 2: Modeled weathering profile (pH 6) of the Mawrth Vallis region. The overall trend suggests the dissolution of nontronite will precipitate montmorillonite and minor kaolinite, producing a profile similar to that observed in Mawrth Vallis. A similar trend of Al overlying Fe/Mg minerals is observed in all 4 scenarios.

The chemical and mineralogical progression from Mg-rich to Fe-rich to Al-rich minerals is not uncommon on Earth [4]. In addition, the mineralogical transition from smectite to kaolinite through weathering has been previously documented on Earth [16, 17]. Terrestrial observations, therefore, suggest that Fe, Mg-rich smectites may alter to kaolinite and oxides, which has been similarly suggested for Mawrth Vallis and Nili Fossae [3, 4].

Conclusions: These model results suggest that over time the weathering of a nontronite and/or a mixed unit composed of nontronite, montmorillonite, and/or saponite bearing materials will produce stratigraphy similar to that observed in the Mawrth Vallis or Nili Fossae region. The models results observed here are also consistent with observations of natural terrestrial environments. Weathering may therefore be a viable mechanism to produce the transitions in clay mineral chemistry in the Mawrth Vallis region. These results would also suggest that Mawrth Vallis may have been exposed to long term fluid-rock interaction, a key requirement in the search for habitable environments.

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