EXPERIMENTAL EVIDENCE SUGGESTS SIGNIFICANT AQUEOUS ALTERATION AND ABUNDANT PHOSPHORUS RELEASE ON MARS. E.M. Hausrath[1], C.T. Adcock[1], S.R. Gainey[1], M.H. Steiner[1], and V.M. Tu[1] [1]Department of Geoscience, University of Nevada, Las Vegas, 4505 S. Maryland Pkwy, Las Vegas, NV 89154 Elisabeth.Hausrath@unlv.edu

Introduction: In the search for possible life on Mars, the identification of habitable environments is an essential step. Habitability has generally been considered to be an intersection of aqueous conditions, energy, the chemistry needed for life, and sufficiently clement conditions [1, 2]. Observing and interpreting evidence of these conditions in rocks, soils or sediments can help identify the potential presence of habitable environments. Here, in order to help interpret observations from Mars, we present results of experiments to interpret the possible role of aqueous alteration at Mawrth Vallis, as well as experiments and modeling interpreting P mobility on Mars.

Experiments to interpret aqueous alteration: Mawrth Vallis represents one of the largest exposures of phyllosilicates on Mars, and is characterized by Al-rich clay minerals (potentially kaolinite and montmorillonite) mixed with hydrated silica (potentially opal), overlying an Fe, Mg-rich clay (potentially nontronite and/or saponite) [3-9]. Several hypotheses address the origin of the Mawrth Vallis stratigraphy, including deposition of volcanic materials of different compositions, changes due to different oxidation states, and formation due to weathering processes [10, 7, 8]. In order to test these different models for the formation of Mawrth Vallis, we are performing dissolution experiments of the clay mineral nontronite in both dilute and brine solutions, as well as mineral synthesis experiments and reactive transport modeling. We have measured the dissolution rate of the ferric smectite nontronite and calculated a dissolution rate law [11]. Nontronite dissolves more rapidly than the Al-rich phyllosilicates montmorillonite and kaolinite under these conditions, suggesting that a mixture of nontronite, montmorillonite and kaolinite would, after chemical weathering over geological timescales, become enriched in montmorillonite and kaolinite [11]. Increasing evidence suggests the possible importance of brines on Mars [12], and we are therefore also conducting dissolution experiments of nontronite in the presence of $CaCl_2$- and NaCl-containing brines [13]. Results suggest that dissolution in the presence of brines will occur much more slowly than in the presence of dilute solutions [13]. Ongoing reactive transport modeling will also help further constrain the implications of a potential weathering environment at Mawrth Vallis.

In order to interpret the potential effects of different parent materials and different oxidation states on secondary clay mineral formation, with implications for Mawrth Vallis, we are reacting basalt, diabase, andesite and granodiorite under both oxidizing and reducing conditions [14]. Experiments are ongoing, and results suggest the importance of parent material as well as open versus closed weathering conditions in formation of different secondary phyllosilicates and zeolites.

Experiments suggesting abundant release of phosphate under Mars-relevant conditions: Phosphorus is among the elements considered essential for life, important in DNA, RNA, ATP, and phospholipid membranes [15]. In addition, phosphorus, either as phosphate [16], or a more reduced species [17], was likely important in the prebiotic reactions leading to life, with low phosphate concentrations and reactivity considered the "phosphate problem" [18]. In order to understand phosphate mobility from the dominant P-containing minerals in martian meteorites, and therefore presumably on Mars, we synthesized merrillite and Cl-apatite [19, 20].

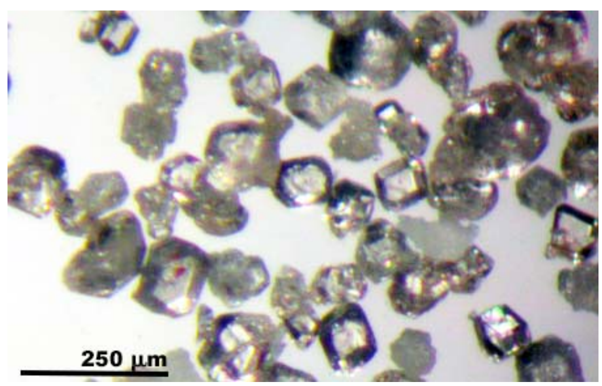

Figure 1. Synthetic Fe-containing merrillite, synthesized as described in [21].

We then dissolved the merrillite and Cl-bearing apatite, measuring mineral dissolution rates and steady state concentrations [19]. Results suggest that the phosphate concentrations of early martian environments may have been more than twice those of Earth, with release rates from water-rock interactions on Mars releasing P at > 45 x higher than on Earth [19]. These results have significant implications for the origin and persistence of life on Mars, suggesting that the "phosphate problem" that the evolution of life on Earth potentially encountered may be less important on Mars.

To further investigate the behavior of phosphate in environments relevant to understanding martian soils such as Paso Robles, we examined the mobility of phosphate under both high temperature, fumarolic conditions, as well as low-temperature, soil-forming conditions. Under high-temperature conditions in acid-vapor and acid-fluid experiments in the laboratory, the soluble Ca-phosphate phase monocalcium phosphate formed, and under acid-fluid alteration conditions, the Fe-phosphate ferrian giniite formed [21]. In *in situ* mineral alteration experiments at a natural fumarole, fluorapatite was found to alter to hydroxyl- and carbonate-bearing fluorapatite [22].

In acidic low-temperature environments, in contrast, amorphous Al- and Fe-phosphates are likely to form [23], and at least some terrestrial waters are likely controlled by equilibrium with amorphous Al-phosphates [24]. In order to interpret phosphate release in such low-temperature soil-forming environments, we synthesized amorphous Al- and Fe-phosphates, and then dissolved them in flow-through reactors [25]. Results indicate increased phosphate release from amorphous Al-phosphates relative to the crystalline Al-phosphate variscite, suggesting abundant phosphate release in such environments.

To place these experimental results into a specifically martian context, we examined phosphate mobility at the Mars-analog environment Craters of the Moon, Idaho [26], and performed reactive transport modeling of the P-rich martian rock, Wishstone [27]. Results suggest the release of P from Wishstone into a near-neutral environment, with positive implications for habitability [27].

Conclusions: Experimental results presented here suggest the potential importance of chemical weathering at Mawrth Vallis, although experimental and modeling work is ongoing to further interpret observations from Mawrth Vallis. Experimental and modeling work suggests the abundant release of phosphate on Mars, as well as its release into near-neutral pH environments. Both significant aqueous alteration and phosphate release have important implications for the habitability of Mars.

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