

WHAT CAN WE LEARN FROM DEPTH PROFILES ON MARS? E.M. Hausrath¹, A.K. Navarre-Sitchler¹, P.B. Sak², and S.L. Brantley¹, ¹Penn State University, University Park, PA, 16802 emh191@psu.edu ²Dickinson College, Carlisle, PA 17013

Introduction:

Exciting new data document the presence of a variety of minerals on the surface of Mars, including primary phases such as olivine [1], pyroxene [2], plagioclase [3], and glass [4] and secondary minerals such as sulfates and clays [5, 6]. Observations of weathering products and the stability or instability of primary minerals with depth may provide interesting new constraints on the aqueous and climate history of Mars.

Although olivine and other primary silicates are readily weathered, they are recognized in terrestrial soils and weathering rinds that are up to millions of years old. On a planet with high water fluxes and erosion rates such as Earth, the time that primary minerals will persist in a soil environment will be shorter than on a planet with lower water fluxes and erosion rates such as Mars. Therefore we predict that mineral persistence times on Mars will be greater than those documented on Earth.

Documented field mineral persistences follow mineral dissolution trends determined in laboratory experiments for near-neutral terrestrial pH values [7]. For example, basalt glass dissolves more quickly than olivine under alkaline conditions in field environments [8, 9]. If we can understand the pH-dependence of relative weathering rates on Earth, we may be able to use phases such as glass and olivine to better interpret past weathering environments on Mars.

Basalt weathering profiles:

Minerals in soils, regolith, and alteration rinds form weathering profiles as parent minerals are increasingly altered. Profiles of chemistry and mineralogy as a function of depth record information about mineral dissolution rates, transport, duration of weathering, erosion, and aeolian deposition. Such profiles are best analyzed after normalization to an assumed immobile element to account for non-isovolumetric weathering and other factors [10]:

$$\tau_{i,j} = \frac{C_{j,w}}{C_{j,p}} \frac{C_{i,p}}{C_{i,w}} - 1 \quad (1)$$

where $\tau_{i,j}$ is the fraction of mobile element or mineral j lost assuming that element or mineral i is immobile (w and p refer to weathered and parent material respectively). Plots of $\tau_{i,j}$ versus depth delineate both the weathering gradient (slope of reaction front) and

weathering advance distance (distance of retreat of original parent surface). For example, depth profiles on a basalt-derived soil in Pennsylvania (Figure 1) document both K and Mg loss at approximately 3.75 meters, and then enrichment of K at the surface which suggests aeolian input or biological cycling.

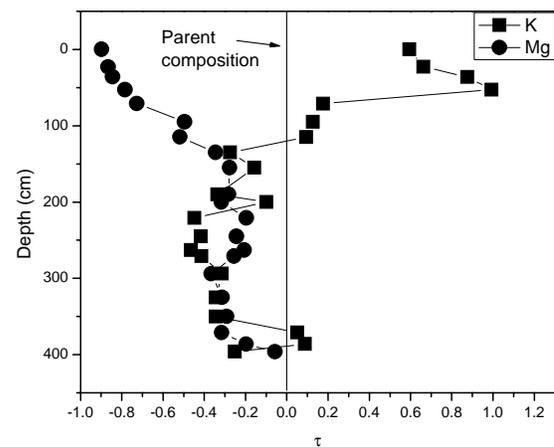


Figure 1. Elemental concentrations with depth for a basalt-derived soil in Pennsylvania document K and Mg loss at approximately 3.75 meters depth, and K enrichment near the surface, possibly due to aeolian input, or biological cycling. When $\tau=0$, the concentration is the same as the parent material, when $\tau=-1$ all of the element or mineral has been lost, and $\tau>0$ indicates that the element or mineral has been enriched.

On a much finer scale, observations of back-scattered electron micrographs of altered basalt rocks from Mars-analog Svalbard (Norway) indicate an altered layer at the rock surface which consists primarily of glass loss. This minimal alteration is consistent with the short duration of time the rock was exposed to weathering and the presence of significant erosion [11]. The loss of primarily glass, with little observed loss of other minerals is consistent with the measured pH range of $\sim 7-9$ for soil pore waters in this environment.

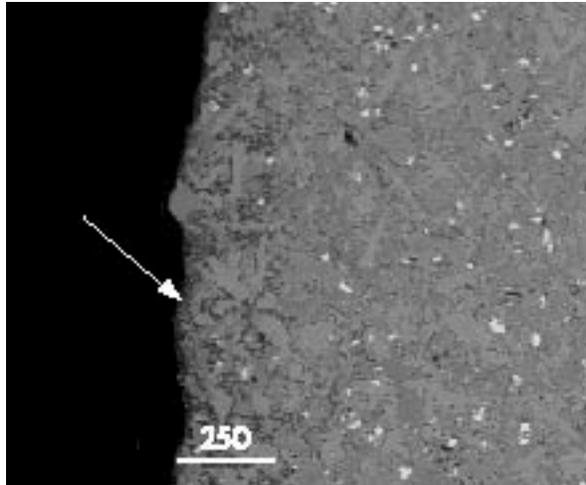


Figure 2. Back-scattered electron micrograph of a thin section through an altered layer that formed on the surface of a basalt rock sample in Svalbard (Norway). Layer has increased porosity relative to bulk material due to glass loss. The arrow indicates the surface of the rock, and the scale bar is 250 μm . Bright areas are Fe-Ti oxides, grayish areas are minerals and interstitial glass (when it is still present at depth), and black areas are pore space.

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Conclusions:

Mineral persistence data on Earth provide minimum persistence times for minerals on Mars, and suggest the importance of pH in terrestrial and Martian weathering. Weathering profiles on Mars record information about the mineral dissolution rates, transport, duration of weathering, erosion, and aeolian deposition in the same way that profiles record this information on Earth. The interpretation of weathering profiles on Mars is therefore a novel approach to study that planet's aqueous history. The utility of depth profiles in documenting the past history of weathering makes it imperative that more depth profiles be measured on Mars and Earth.

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