

SERPENTINITE WEATHERING AND IMPLICATIONS FOR MARS. V. Tu¹, J. Baumeister¹, R. Metcalf¹, A. Olsen², E. Hausrath¹ ¹University of Nevada, Las Vegas 4505 S. Maryland Pkwy., Las Vegas, NV 89154-4010 chavezv4@nevada.unlv.edu, baumeis5@unlv.nevada.edu, Rod.Metcalf@unlv.edu, elisabeth.hausrath@unlv.edu. ²Department of Earth Sciences, University of Maine, 5790 Bryand Global Sciences Center, Orono, Maine, 04469 Amanda.Olsen@umit.maine.edu.

Introduction: In the search for life on Mars near-surface soil environments may be important habitats for life accessible to future missions. Serpentinite rocks have been documented on Mars [1], as well as other clay minerals including smectite and kaolinites [2, 3]. Previous studies of soils formed on serpentinites on Earth have documented the formation of extensive clays, including smectite [4-9], vermiculite [7-10], chlorite [11], inter-layered chlorite-vermiculite [6], and kaolinite [5]. Serpentinites are additionally of interest as habitats for life such as methanogens [12]. Here we examine weathering of serpentinites from bedrock to soil surface, as a potential route for the formation of clay minerals on Mars from abundant ultramafic minerals.

We additionally test for the presence of Fe-oxidizing bacteria in weathered serpentinite rocks. Fe-oxidizing bacteria have been previously demonstrated to affect dissolution rates of ultra-mafic minerals [13], and may produce important biosignatures [14].

Methods:

Sample collection

Weathered serpentinites were sampled from ridge-tops in the Trinity Alps, Klamath Mountains, California. Samples were collected from soil pits, and parent bed-rock using a 1" handheld drill (Shaw Backpack Drill). Samples were stored in sterile Whirlpak bags and refrigerated.

Sample analysis

X-Ray Fluorescence (XRF) and X-Ray Diffraction (XRD) were completed at the UNLV XXL: XRF/XRD lab. Samples were powdered and analyzed for bulk composition, major and trace elements using XRF and bulk mineralogy using XRD. Weathered grains were embedded in epoxy, polished, and analyzed using Backscattered Electron Microscopy (BSEM) and Energy Dispersive X-ray Spectroscopy (EDS) for characterization of weathering rinds. Subsets of sample were mixed with a phosphate-buffered saline solution adjusted to the pH of the pore waters and added to Biological Activity Reaction Tests (BARTSTM) which were observed for growth of Fe-related bacteria.

Calculations

Elemental compositions measured in the samples as described above were normalized to an immobile element to account for non-isovolumetric weathering,

or mobility of multiple elements [15,16] (Equation 1, Figure 1).

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

Here, $\tau_{i,j}$ is the fraction of mobile element or mineral j lost or gained. Element or mineral i is assumed to be immobile, w and p refer to weathered and parent material respectively, and C is the concentration of the immobile and mobile elements in the parent and weathered materials. $\tau_{i,j} > 0$ indicates enrichment relative to parent, $\tau_{i,j} < 0$ indicates depletion relative to parent ($\tau_{i,j} = -1$ indicates that the element is completely depleted), and $\tau_{i,j} = 0$ indicates that the element is immobile. The assumed immobile element was Ti, and parent concentrations were estimated from elemental concentrations measured in outcrop samples.

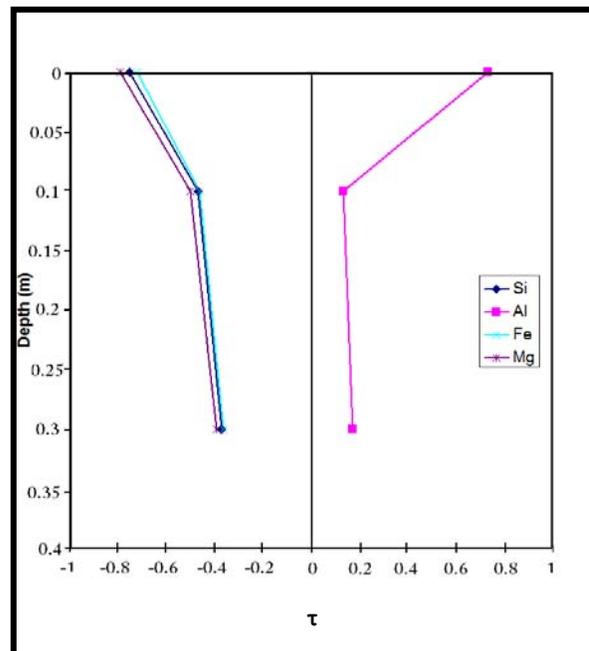


Figure 1 Normalized concentrations, τ vs. depth for the weathering profiles developed on serpentinite.

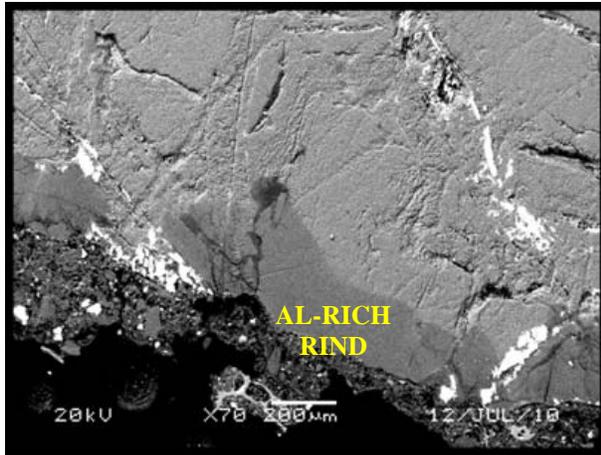


Figure 2 Backscattered electron micrograph of a cross-section through the weathered surface of serpentinite rock. The interior consists of the serpentine mineral lizardite, and the darker surface is an Al-rich secondary rind.

Results and Discussion: Plots of normalized concentrations (Figure 1) indicate the loss of Mg, Si and Fe, and the addition of Al. From the dissolution profiles of Mg and Si, dissolution rates of serpentine minerals have also been calculated [17]. Consistent with the addition of Al near soil surfaces, XRD analyses indicate the presence of smectites as well as the parent mineral lizardite in the weathered soils. Backscattered electron micrographs and EDS chemical analyses indicate a lighter colored serpentinite core altered to a darker, more Al-rich weathered surface (Figure 2). Al enrichment may be important on Mars, as previous work has suggested that Al may be much more mobile on Mars [18].

Observations of the BARTS™ indicate the formation of black clouds and brown rings which represent the growth of Fe-related bacteria. These results indicate that weathering serpentinites may result in a habitable environment, and future work is needed to determine whether important biosignatures may be preserved.

Conclusions and Future Work: Field observations and analyses made on serpentinite rocks and soil from the Klamath Mountains, California indicate the formation of Al-rich weathered surfaces on serpentinites as observed by BSEM/EDS, and the formation of smectites by XRD. In addition, BARTS™ tests indicate the presence of Fe-oxidizing bacteria. More work is needed to further constrain alteration of serpentinite minerals under Mars-analog environments, and the potential for presence and preservation of biosignatures.

Acknowledgements: Brad Rust, Racheal Johnson, Sean Mulcahy, Christopher Adcock, Brian Hedlund, Jason Cornell, and the UNLV Geoscience Department,

Geological Society of Nevada, National Science Foundation, and the UNLV Graduate and Professional Student Association.

References: [1] Ehlmann B.L., Mustard J.F., Murchie S.L. (2010), *Geophysical Research Letters*, Vol. 37, L06201, doi:10.1029/2010GL042596. [2] Bibring, J.P. (2005), *Science*, 1108806. [3] Mustard, J.F. (2008), 454 (7202), 305-309. [4] Dirven J.M.C., van Schuylenborgh J., van Breeman N. (1976), *Soil Sci. Soc. Am. J.* 40:901-907. [5] Ducloux J., Meunier A., Velde B. (1976), *Clay Minerals* 11: 121-135. [6] Graham, R.C. (1990), *Soil Science America*, J. 54: 1682-1690. [7] Burt R., Fillmore M., Wilson M.A., Gross E.R., Langridge R.W., Lammers D.A. (2001), *Communications in Soil Science and Plant Analysis* 32, pp. 2145-2175. [8] Lee B. D., Sears S. K., Graham R. C., Amrhein C., and Vali H., (2003), *Soil Science Society of America Journal* 67, 1309-1317. [9] Oze C., Fendorf S., Bird D.K., Coleman R.G. (2004), *American Journal of Science*, 304: 67-101. [10] Rabenhorst M.C., Foss J.E., Fanning D.S. (1982), *Soil Science Society American Journal*, 46: 607-616. [11] Wildman, W.E. (1968), *Soil Sci. Soc. Am. Proc.*, 32: 787-794. [12] Schulte M., Blake D., Hoehler T., McCollom T. (2006), *Astrobiology*, 6(2): 364-376. doi:10.1089/ast.2006.6.364. [13] Santelli, C.M., et al., (2001) *Chemical Geology*, 180 99-115. [14] Banfield, J.F., et al., (2001) *Astrobiology*, 1 447-465. [15] Brimhall G.H., Dietrich W.A. (1987), *Geochim. Cosmochim. Acta* 51, 567-587. [16] Anderson S.P., Dietrich W.E., Brimhall G.H., Jr., (2002), *Geological Society of America Bulletin*, v. 114, p. 1143-11. [17] Baumeister, J.L., Tu, V., Olsen, A.A., and Hausrath, E. M. (2010), GSA Annual Meeting, Denver, Colorado [18] Hurowitz, J.A., et al., (2006) *Journal of Geophysical Research*, 11.