

BASALT WEATHERING RATES IN A MARS ANALOG ENVIRONMENT: CLUES TO THE DURATION OF WATER ON MARS? E.M. Hausrath¹, S.L. Brantley² and AMASE³ ¹302 Hosler Building, Penn State University, University Park, PA 16802 emh191@psu.edu, ² 2217 Earth and Engineering Building, Penn State University, University Park, PA 16802 brantley@essc.psu.edu, ³ Arctic Mars Analog Svalbard Expedition

Introduction: Extensive evidence, most recently from the Mars Exploration Rovers, documents that liquid water once existed on the surface of Mars [1], [2]. However, significant uncertainty still exists as to the duration of liquid water on the surface of Mars. Mineral dissolution rates may provide information on maximum durations of water on Mars [3],[4].

However, field and laboratory weathering rates on earth differ significantly, by up to 5 orders of magnitude [5]. Few field weathering rates for basalt and olivine have been published. The climate history of Mars is not well-constrained; however, field weathering rates of minerals in Mars-analog environments may provide information on the duration of water on Mars.

Spitsbergen (Norway) provides three examples of basalts weathering in a Mars-analog environment: outcrops of the Quaternary volcano, Sverrefjell, plateau basalt lavas emplaced approximately 10 million years ago [6], and a basalt dike. Sverrefjell has been well documented as a Mars analog containing carbonate globules that are very similar to those found in ALH84001 [7]. These three basalts with different chemistries will allow us to study basalt weathering in a cold, dry climate.

Methods: Basalt samples were collected from each of the three locations as part of AMASE, the Arctic Mars Analog Svalbard Expedition in August of 2004. They were then observed by optical microscopy, backscattered electron microscopy, and energy dispersive x-ray spectroscopy.

Results: *Chemical weathering.* All three basalts are only slightly weathered, as expected from the cold (yearly average temperature approximately -5°C), dry (less than 200 mm precipitation) climate, and the small amount of time since the surfaces were deglaciated (10,000 years) [8].

An altered surface is sometimes observed on samples from each of the locations (Figure 1). However, most surfaces, although exposed to the environment, show little to no evidence for dissolution (Figure 2). In one case, the altered surface layer was 100 μm thick (Figure 1b). Evidence for dissolution includes porosity and preferential loss of minerals (Figure 1); however, some alteration may be related to prior hydrothermal events.

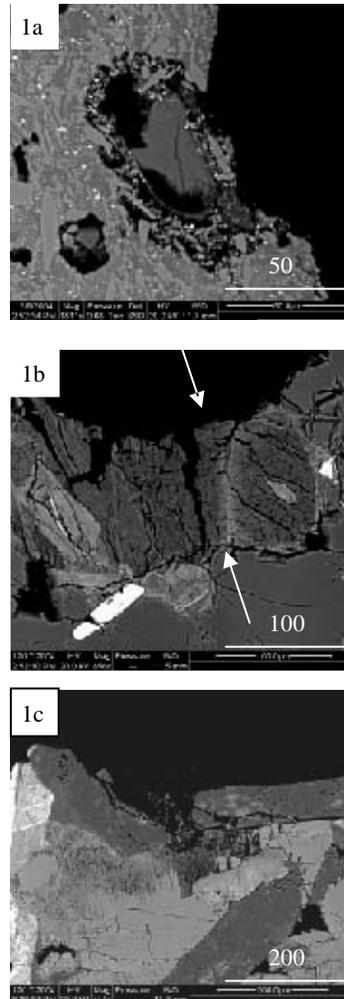


Figure 1. BSEM photomicrographs of a) a potential dissolution feature from a sample from the Sverrefjell volcano. Dark (epoxy) areas indicate porosity, possibly due to dissolution of glass matrix, leaving plagioclase grains; b) a potential dissolution feature from a sample from the plateau basalt lava flows; c) a potential dissolution feature from a lichen-covered sample from the basalt dike. Scale bars are in μm . Arrows indicate the thickness of the altered layer.

Physical weathering. Cracks parallel to the surface indicate the potentially important role of physical weathering in a cold, dry environment. In cold dry regions, thermal fluctuations at the surface may be large [9], and may contribute to such cracking. The potential for artifacts due to preparation is also being investigated (see Figure 2).

Olivine was observed to have physically weathered out of xenoliths at the basalt surfaces (see Figure 3), sometimes forming piles of mm-size olivine grains. We infer that physical disaggregation is as important or more important than chemical weathering in this locality.

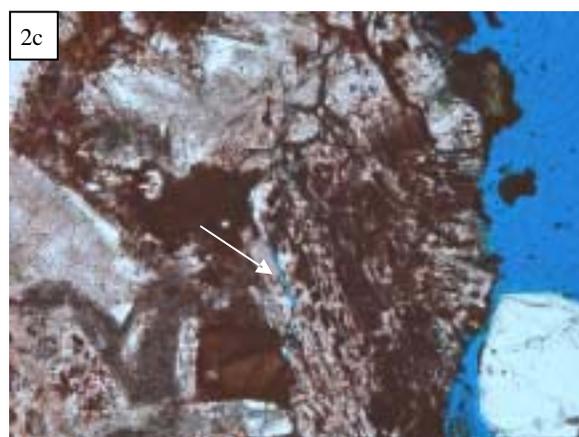
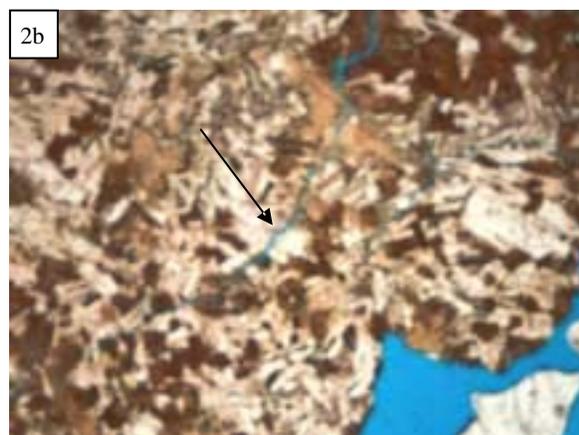
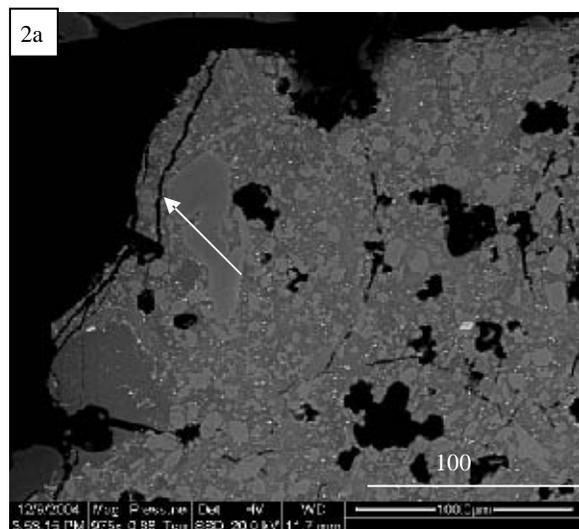


Figure 2. Fractures parallel the exposed basalt surface in samples from Sverrefjell (a), plateau basalts (b), and the basalt dike (c), as imaged under BSEM (2a, scale bar in microns) and optical microscopy. Arrows indicate fractures in all samples.



Figure 3. Olivine-rich xenoliths from the Sverrefjell volcano weathering out of an outcrop leaving large holes.

Discussion and Conclusions: The observation that much of the surface shows little to no alteration, while some samples show loss of material to 100 μm depth is consistent with spalling of outer layers creating relatively pristine surfaces. If some layers (i.e. those with the deepest alteration as shown in Figure 1b) have never spalled in 10 ka, then a dissolution estimate can be made. For example, for the altered layer in Figure 1b, the overall dissolution rate is approximately 10 μm per 1000 years. However, only about 5% of this layer has been removed. Translating this to units of $\text{mole m}^{-2} \text{s}^{-1}$ in order to compare to laboratory rates yields a maximum rate of approximately $10^{-12.4}$.

Such a rate is approximately 4 orders of magnitude slower than glass dissolution rates at 25° C in the laboratory at neutral pH [10]. A slower field rate than laboratory rate is expected [5], especially given the difference in temperature between laboratory and field. In addition, the frequency of spalling is also unknown.

Chemical weathering of basalt in these three locations is minimal, and physical weathering plays a larger role. Field weathering rates of basalt and olivine in a Mars analog setting should provide constraints on the duration of weathering on Mars.

Acknowledgements: Many thanks to D. Egger, R. Fletcher, M. Angelone, J. Cantolina, C. Lopano, and A. Navarre. We acknowledge funding from the Biogeochemical Research Initiative, the World Universities Network, and the Penn State Astrobiology Research Center.

References:

- [1]K. E. Herkenhoff, et al., (2004) *Science*, 306, 1727-1730.
- [2]S. W. Squyres, et al., (2004) *Science*, 306, 1709-1714.
- [3]J. D. Stopar, et al., (2003) SICOM, Abstract #3151.
- [4]N. J. Tosca, et al., (2004) LPS XXXV, Abstract # 1043.
- [5]A. F. White and S. L. Brantley, in *Chemical Weathering Rates of Silicate Minerals* A.F. White and S. L. Brantley, Eds. (Mineralogical Society of America, Washington, D.C., 1995), vol. 31, pp. 1-22. [6]T. Prestvik, (1977) *Norsk Polarinstitutt Arbok*, 1977, 129-143. [7]A. H. Treiman, et al., (2002) *Earth and Planetary Science Letters*, 204, 323-332.
- [8]J. Y. Landvik, et al., (1998) *Quaternary Science Reviews*, 17, 43-75. [9]K. Hall and M.-F. Andre, (2003) *Earth Surface Processes and Landforms*, 28, 823-836. [10]S. R. Gislason and E. H. Oelkers, (2003) *Geochimica et Cosmochimica Acta*, 67, 3817-3832.