

Aqueous Alteration of Glass on the Martian Surface: A Comparison of Remotely-Acquired and Experimental Data Sets. M. H. Yant¹, A.D. Rogers¹, B.H.N. Horgan², and R.J. Smith². ¹Stony Brook University Department of Geosciences, Stony Brook, NY, 11794. ²Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, West Lafayette, IN, 47906. (marcella.yant@stonybrook.edu).

Introduction: A spectral component consistent with high silica amorphous material has been detected across many regions of Mars by the Thermal Emission Spectrometer (TES) in abundances ranging from ~10-40% [1, 2]. This material has been interpreted as unweathered silica-rich volcanic glassy material [e.g., 1] or as weathered basaltic material [e.g., 3]. The regions where this material is observed are typified by Acidalia Planitia (Surface Type 2, ST2) [1]. Based on visible/near-infrared (VNIR) observations in the northern lowlands where ST2 signatures are detected with TES data, the high-silica phases have been interpreted as altered glasses via interpretation of OMEGA data [4].

In order to more reliably interpret remote spectra of terrains on Mars, we focus on comparing laboratory acquired infrared (IR) spectral signatures of altered synthetic Martian basaltic glasses [5] and altered terrestrial analog basaltic glasses [6] with TES and OMEGA data. The laboratory-acquired signatures include basaltic glasses with Martian surface compositions that were altered under controlled, closed-system, acid-sulfate conditions. The terrestrial analog experiments were performed under controlled, open-system, acid-sulfate conditions [6].

Procedures Overview: Here we assess alteration conditions on Mars utilizing TES and OMEGA data sets. First, thermal-infrared (TIR) spectra of laboratory altered glasses were used to model TES surface emissivity data to locate regions that are potential matches. Global abundance maps of the laboratory material were created using linear least squares modeling [e.g., 7] of the TES spectra at a resolution of 1ppd. The modeled fits depend on the spectral library used; the better the library represents Martian phases, the better the model fit will represent the surface mineralogy. Here, a library with the altered spectral data sets previously collected by [5] and [6] are added to the spectral library from [8]. This expands the library previously used by [8] to include unaltered and closed-system altered glass endmembers with measured Martian compositions as well as unaltered and open-system altered glass

endmembers of terrestrial analogs, allowing for improved global mapping. Once regions of interest were identified with TES, higher resolution data sets from OMEGA were used to ascertain the VNIR characteristics of those regions.

Data Sets: Four different synthetic compositions were used, including Irvine (tholeiitic basaltic), Backstay (alkalic basaltic), Pathfinder soil (basaltic andesitic, lower silica), and Pathfinder rock (basaltic andesitic, higher silica) compositions. Sand-sized particles from all glass compositions were altered in various acidic solutions (pH ~0-4) under low fluid-to-rock ratios (1:1, 10:1) for 14 days at ambient temperature and pressure. These materials provide a unique data set for comparison with retrieved Martian spectral data, as they are the first direct IR spectral analyses of Martian basaltic glasses altered under controlled conditions.

The Irvine, Backstay, and Pathfinder soil materials altered in pH \leq 1 conditions exhibited strong 1.4, 1.9, and 2.4 μ m features (indicative of poly-hydrated sulfates) along with negative spectral slopes in the VNIR and well-developed sulfate features in the thermal-infrared (TIR) [5]. Little to no alteration was observed for the composition with the highest silica content, Pathfinder rock.

Additionally, IR spectra of two terrestrial analog glasses from [6] were utilized in this study, a Hawaiian glassy basalt from a subaerial flow (BAS101) and Hawaiian basaltic glass sand (BSB101). These materials were altered under acidic conditions in a simulated open-system environment by repeatedly rinsing and submerging the samples in ~pH1 and ~pH3 acid-sulfate solutions for 220 days. Reaction of the samples and subsequent rinsing lead to the formation of silica-rich leached rinds under the lowest pH condition. As a result, silica absorption features dominate their IR spectra. Whereas, the IR spectra of glasses reacted with more moderate pH solutions show little sign of alteration.

Results: The altered Irvine, Backstay, and Pathfinder Soil glasses are significant components (~20-50%) of the modeled assemblages for TES

pixels throughout the northern lowlands and the southern highlands (**Figure 1A-C**). However, the highest silica glass composition, Pathfinder Rock, is only found in detectable abundances in the northern plains, sparsely contributing to the TES assemblages in the southern regions (**Figure 1D**).

Due to the sulfate-dominated signatures exhibited by the closed-system laboratory spectra, regions of interest for the synthetic compositions are restricted to areas where sulfate features have been previously detected including, Terra Meridiani, Valles Marineris, Mawrth Vallis, and Terra Sirenum [e.g., 9]. Although no sulfate detections have been observed in Acidalia, it is included as a region of interest due to presence of signatures consistent with acid-sulfate leaching.

Altered Irvine provides the highest modeled TES abundances in all of the regions of interest, excluding Acidalia Planitia. For Terra Meridiani, Valles Marineris, Mawrth Vallis, and Sirenum, Irvine glasses altered under pH1-3 conditions are contributing to the modeled assemblages. The Irvine pH1 material is the highest modeled glass for all of these regions, excluding Mawrth Vallis, where pH2 material is the primary modeled glass. The sulfate spectral characteristics, observed for the Irvine pH \leq 1 material, dominate the VNIR signatures in the OMEGA data. This is important

because only glass materials altered in pH \leq 1 conditions exhibited alteration features in the TIR and VNIR wavelength ranges. This suggests acid-sulfate weathering at pH \leq 1 conditions in these widespread locations.

The global TES abundance maps for the open-system, acid-sulfate weathered glasses provided a distribution that was concentrated in the northern lowlands with some isolated fits in the southern regions. The BAS101 glass provides a similar distribution to the closed system composition Pathfinder Rock with detectable abundances in the northern plains and sparse contribution to the TES assemblages in the southern regions. The BSB101 composition is a significant component of the modeled assemblages for TES pixels throughout the northern lowlands, with some concentrated areas in the southern highlands.

References: [1] Bandfield, J. L. *et al.*, (2000), *Science*, 287, 1626–1630. [2] Rogers A.D. and P.R. Christensen, (2007), *JGR.*, 112, E01003. [3] Wyatt, M. B., and H. Y. McSween (2002), *Nature*, 417, 263–266. [4] Horgan, B., and J. F. Bell III (2012), *Geology*, 40(5), 391–394. [5] Yant, M.H. *et al.*, (2016), *JGR-Planets*, 121. [6] Horgan, B.H.N. *et al.*, (accepted manuscript), *JGR.* [7] Ramsey, M.S., P.R. Christensen (1998), *JGR.*, 103 (B1), 577–597. [8] Rogers, A. D., and V. E. Hamilton (2015), *JGR-Planets*, 120, 62–91. [9] Ehlmann, B.L. and C.S. Edwards (2014), *Ann. Rev. Earth Planet. Sci.*, 42, 291–315.

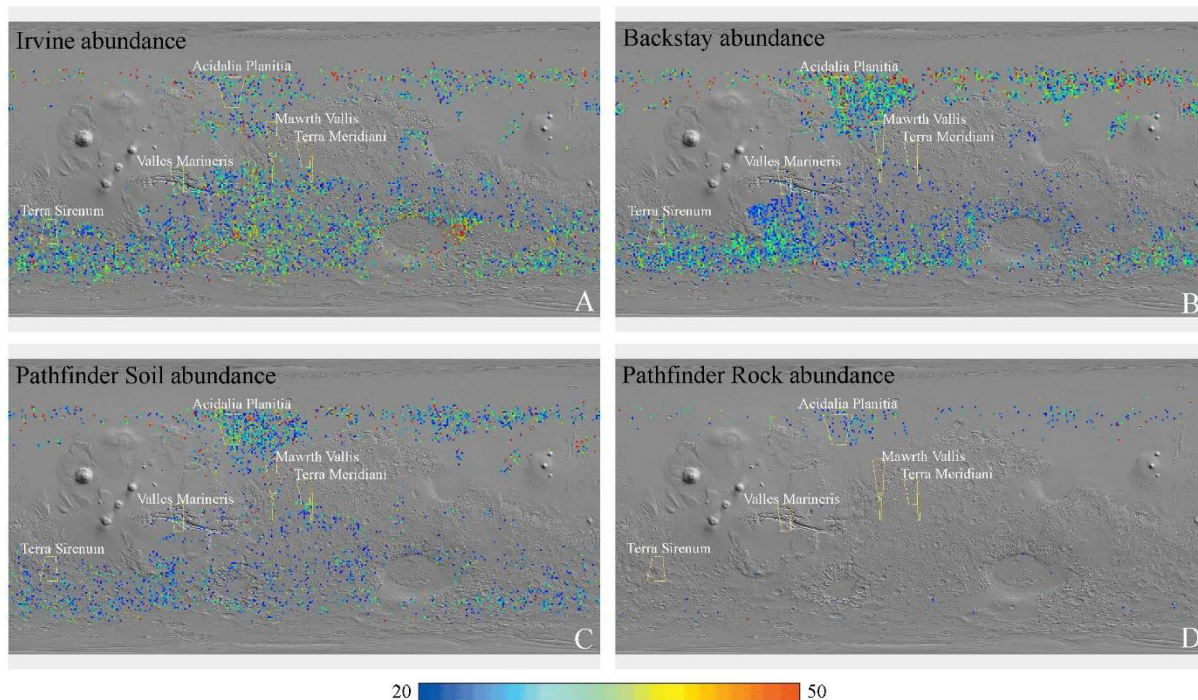


Figure 1: 1ppd binned global TES map showing the abundances of altered glasses ranging from 20-50% for A) Irvine, B) Backstay, C) Pathfinder Soil, and D) Pathfinder Rock. Abundances are the sums of modeled abundances for individual endmembers (e.g. “Irvine” = Irvine altered in pH0 + Irvine altered in pH1 + Irvine altered in pH2, etc.).