Introduction: The abundance and species of chemical alteration products on planetary surfaces are related to the starting composition of unaltered protolith, the style and duration of alteration processes, the fluid composition, and fluid-to-rock ratio [e.g. 1, 2, 3], and ultimately, the preservation of those products in rocks and soils. Thus detection and interpretation of alteration mineral assemblages on Mars is critical to deciphering the history of the Martian surface. Among the techniques available to detect mineral assemblages on Mars, visible and infrared (IR) spectroscopic remote sensing provides the greatest areal coverage at the highest spatial resolution, allowing for assessment of spatial and/or temporal variability in weathering environment.

However, it is difficult to predict the spectral character of alteration assemblages due to non-linear IR spectral mixing. This can make it difficult to detect certain alteration phases [4, 5] and obtain quantitative abundances [4, 6, 7, 8] of alteration phases using spectroscopy. Thus in order to more reliably interpret remote spectra of altered terrains, we focus on obtaining spectral data of synthetic Martian basaltic glasses, from controlled weathering experiments. By linking geochemical experiments with IR spectral measurements, we can assess the degree to which starting pH and composition influence the spectral signature of acid-altered Martian materials as well as provide insight on the detectability of alteration phases.

Procedures Overview: In this work, we synthesize glass with a Backstay composition and subject the material to acid-sulfate weathering followed by spectral and chemical characterization. We then compare the spectral properties of the unaltered and acid-altered Backstay glass to previously altered synthetic Martian basaltic glass with Irvine, Pathfinder rock, and Pathfinder soil compositions. Irvine and Backstay were measured by the Mars Exploration Rover (MER) Spirit at Gusev Crater [9]. The Pathfinder material was synthesized and altered by Tosca et al. [1] and spectrally analyzed here.

The procedural outline of this experiment was to (1) synthesize basaltic glass with a Backstay composition; (2) react samples (63µm - 400µm grains) with acidic fluids (0-4 pH) and a constant water-to-rock ratio of 1, under ambient temperature and pressure; (3) evaporate the fluids from the basalt after a 14 day reaction period [e.g. 1]; and (4) perform mineralogical and spectral analyses on the unaltered and altered material. A variety of analytical methods including Electron Microprobe, SEM, XRD, Raman, VNIR and TIR spectroscopy were used to examine the unaltered and altered samples. (5) Compare data with previous data from Irvine and Pathfinder samples.

Results: Acid alteration on the Backstay particles resulted in sulfate-dominated spectra in the most acidic solutions (pH≤1). Spectral differences between alteration products from each starting material were present, reflecting strong sensitivity to changes in mineral assemblage. Alteration resulted in well-developed sulfate features in the TIR and well-developed 1.4, 1.9, and 2.4µm features in the VNIR for samples altered under pH≤1 conditions.

Spectral differences can be observed between the four unaltered compositions (Irvine, Backstay, Pathfinder soil, and Pathfinder rock) as well as between altered samples from each starting material in the VNIR (Figure 1A), reflecting changes in the mineral assemblage. Influence from secondary phases are observed for Irvine, Backstay, and Pathfinder soil material altered in pH≤1, however, all of the Pathfinder rock spectra are spectrally consistent with unaltered material. The absorptions associated with alteration material are most consistent with hydrated sulfates, though the exact phases differ for the individual samples.
Figure 1: Comparison of the A) reflectance signatures and B) thermal emission signatures of the unaltered and altered material from the four compositions; Irvine (IRVG, red), Backstay (BKSG, purple), Pathfinder soil (PFSG, blue), and Pathfinder rock (PFRG, green).

Spectral differences can be also observed between the unaltered and altered material from the four starting compositions in the TIR (Figure 1B). Alteration features dominate the spectral signatures for the Irvine material altered in pH≤1, Backstay and Pathfinder soil material altered in pH=0, and for none of the Pathfinder rock spectra. Again the spectral features associated with alteration material are most consistent with hydrated sulfates.

Discussions/Future Work: These experiments illustrate that spectral slopes, contrast, and absorption positions of altered glasses are strongly dependent on the starting composition of the glass (tholeiitic basaltic glass, alkali basaltic glass, basaltic andesite glass) in addition to the pH of the fluid. Spectral signatures of alteration are detectable for the lowest pH fluids (≤1), but for higher pH values, little spectral difference is observed between altered and unaltered surfaces. This is consistent with the low abundance of alteration products observed in SEM/XRD for the pH>1 surfaces. Future work will compare our experimentally altered glasses with spectral data obtained from Mars.