

ACID ALTERATION OF BASALTS: THERMAL-IR SPECTRA AND IMPLICATIONS FOR HIGH-SILICA PHASES ON MARS. R. J. Smith¹, B. Horgan², P. R. Christensen¹, P. Mann³ and E. A. Cloutis³,
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Introduction: Acid-sulfate weathering of mafic rock can generate a variety of secondary mineral assemblages, some of which have been observed on the Martian surface via surface and orbital investigations [1-4]. Therefore, it is commonly thought that localized regions of the mostly basaltic martian surface have been exposed to acidic and oxidative environments throughout the past several billion years [e.g., 1,2]. Mafic minerals weather at different rates due to differences in solubilities [5], and some phases, like glasses, produce spectrally unique leaching rinds [6-8] that may be present on the martian surface [9]. Thus, laboratory studies of primary and secondary mineral assemblages and weathering rinds can perhaps be used to constrain alteration processes occurring on Mars [10,11]. Here we investigate the effects of acid alteration on the abundance and the thermal infrared (TIR) spectral character of the primary minerals found in two terrestrial basalts as proxies for acidic alteration of the martian surface.

The acid leached basalt samples from this study were previously investigated in the near-IR (NIR; Fig 3) [12-14], and the spectra of leached glasses are consistent with OMEGA data from northern Aciadalia Planitia on Mars [9]. Here we do an in-depth TIR spectral analysis of the evolution of the samples with increasing leaching. We compare our results to the NIR, and ultimately to the martian surface. This, and previous investigations in the TIR [13], show considerable agreement with the hotly debated high-silica component of the martian TES Surface Type 2 (ST2) [15,16].

Methods: To investigate the leaching process, rock samples were exposed to frequently refreshed acidic solutions for up to 220 days [12]. Rock samples were crushed and dry sieved to a grain size of 500-1000 μm . Two stock acid solutions were made using concentrated H_2SO_4 and distilled H_2O : Acid A (pH 1) and Acid B (pH 3). Approximately 7 g of each of the crushed samples were placed in separate Teflon vessels with 30 mL of each stock acid solution and 10 mL of 30% H_2O_2 (a candidate for the oxidant in martian surface materials [10,17]). Leaching experiments were sampled every few days until the end of the experiments at 220 days. At each time step, samples were rinsed with distilled H_2O and dried at 80°C for two hours. The remaining sample was placed in a fresh acid solution to mimic an open hydrologic system.

Here we focus on two of the sand-size samples from this study, BAS101, a glassy Hawaiian basalt,

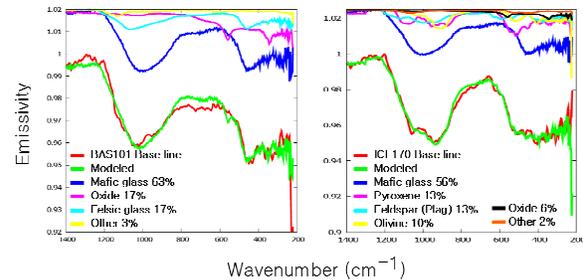


Figure 1: TIR spectral unmixing results for BAS101 (left) and ICE170 (right) starting material.

and ICE170, a somewhat glassy and olivine-rich Icelandic pillow basalt. **Both samples were subjected to both types of acid solutions (A and B).** TIR spectra of samples from different stages of the experiment were collected using the ASU Mars Space Flight Facility Nicolet Nexus 670 spectrometer configured to measure emission spectra from 4000–200 cm^{-1} with a spectral sampling of 2 cm^{-1} [18].

Results: BAS101 is initially spectrally consistent with mafic to intermediate glass in the TIR (Fig 1). Similarly, this sample was designated an iron-bearing glass in the NIR. When BAS101 is exposed to acid A, the TIR emissivity minimum rapidly shifts to $\sim 1100 \text{ cm}^{-1}$, in between that of obsidian and opal-A, and consistent with the minimum of the high-silica component of TES ST2 (Fig 2a). This shift indicates the removal of iron and other network-modifying cations from the surface of the grains [11,16]. In the NIR, the spectrum takes on a shape consistent with a leached glassy rind (concave up slope from 0.7-1.5 μm) [9], and exhibits an absorption band consistent with hydrated silica or glass at 2.2 μm [19] (Fig 3). The TIR spectral shape of BAS101 exposed to acid B resembles a mafic glass throughout the experiment (Fig 2b), which is consistent with minimal spectral change in the NIR (Fig 3).

The initial spectral shape of ICE170 is modeled best with a mix of basaltic glass and more mafic crystalline phases (Fig 1), which is consistent with observations of olivine absorption bands in the NIR. ICE170 exposed to acid A shows increased spectral contrast $\sim 1095 \text{ cm}^{-1}$ consistent with an increase in a high silica phase similar to obsidian, and the spectral unmixing includes a high-Si glass (Fig 2c). This supports the NIR interpretation of hydrated silica or glass based on bands near 1.9 and 2.2 μm . Additionally, the TIR feature around 900 cm^{-1} is maintained, suggesting retention of pyroxene. This is also consistent with NIR observations that show a narrowing of the 1 μm band, and loss of the 0.9 μm and 1.25 μm bands consistent

with preferential dissolution of olivine and enhanced exposure of pyroxene (Fig 3). At the end of the experiment, ICE170 exposed to acid B is most spectrally similar to basalt glass, possibly with increased olivine content (Fig 2d). Once again, these results are similar to the findings in the NIR, which show relatively little change in the spectral shape (Fig 3).

Conclusions: TIR and NIR studies of acid leached basalts both show evidence for the formation of silica-enriched, leached glassy rinds on glass-rich and glass-bearing basalts, as well as preferential removal of olivine. Additionally, TIR results support NIR evidence that the high-silica component of ST2 in the northern plains of Mars is spectrally consistent with weathered glass-rich volcanoclastic or impact sediments [9,12-14].

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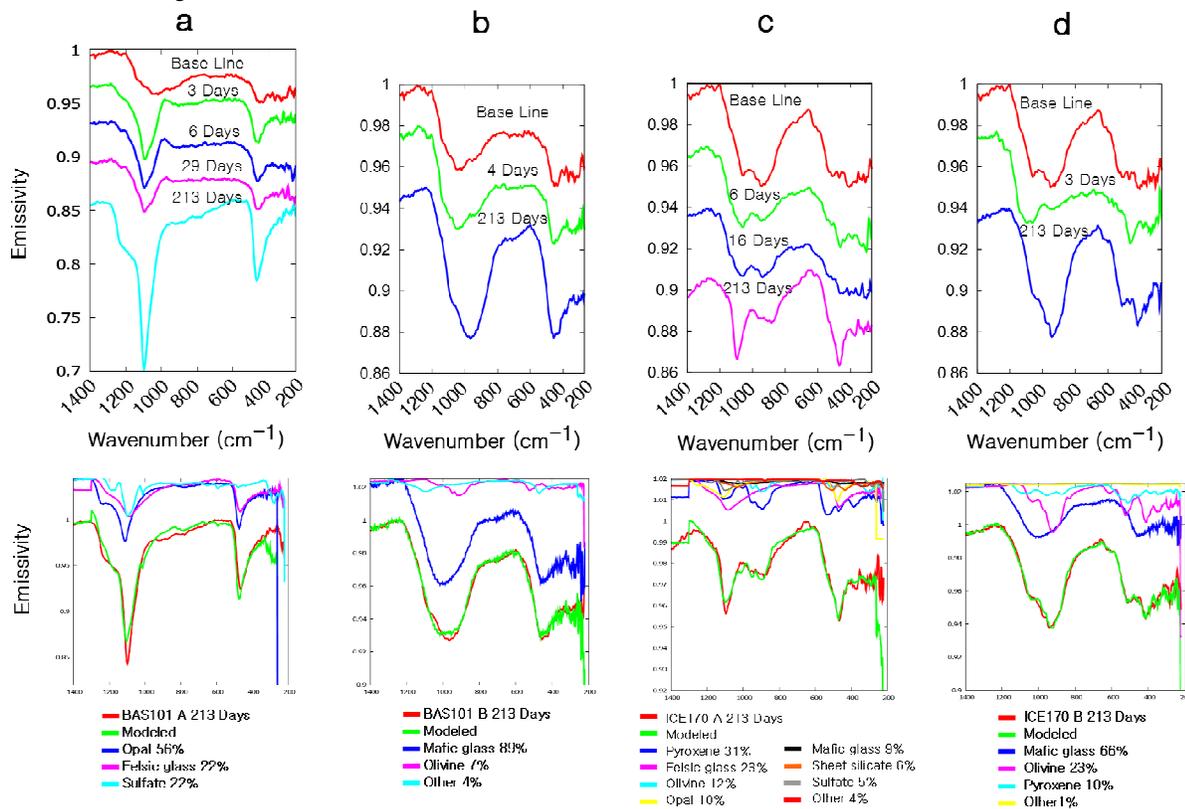


Figure 2: TIR spectra of acid leached samples. Time lapse plots (top) of (a) BAS101 exposed to acid A, (b) BAS101 exposed to acid B, (c) ICE170 exposed to acid A, and (d) ICE170 exposed to acid B. Bottom plots show spectral unmixing results for each respective sample after 213 days of exposure to acid solution.

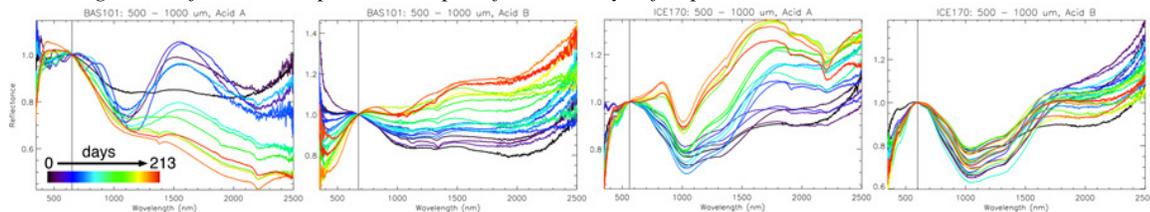


Figure 3: Near-IR spectra of leached samples. Time lapse plots show changes from 0 (black) – 213 (red) days. Left to right: BAS101 acid A, BAS101 acid B, ICE170 acid A, ICE170 acid B.