REVISITING THE ALKALINE VOLCANIC ROCKS OF GUSEV CRATER WITH MINI-TES.
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Introduction: The Spirit rover was equipped with an instrument suite tailored to thoroughly characterize the mineralogy and chemisty of the rocks, regolith and dust encountered along its traverse [1]. During its ascent of Husband Hill, Spirit encountered several unique classes of rock based upon their Mini-TES spectra [2]. Upon further investigation with the full suite of contact instruments, these rocks were determined to be alkaline volcanic rocks [3]. This is the first observation of alkaline volcanic rocks on Mars and indicates that the modes of Martian magmatic evolution provide more diversity than previously thought.

Determination of the chemistry and mineralogy of these rocks was restricted to observations using the Alpha Particle X-ray Spectrometer (APXS) and Mössbauer spectrometer [4]. Robust determinations of mineralogy using Mini-TES observations were complicated owing to an aeolian event that deposited dust in the Pancam Mast Assembly (PMA) where the Mini-TES pointing and fold mirrors are located. A rigorous correction for the spectral contribution of this thin coating of mirror dust was not produced and applied to surface observations until years later [5]. Reanalyzing Mini-TES observations of these alkaline volcanic rocks can yield valuable information about the modal proportions and compositions of their constituent minerals.

Previous investigations used a Mössbauer-modified CIPW normative calculation derived mineralogy (mmCIPW) to synthesize infrared spectra for each rock then visually compared the synthetic spectrum to the dust-contaminated spectrum [3,4]. The intent of this study is to build upon the work of [3,4] by determining mineralogy directly from mirror-dust corrected Mini-TES observations.

Methods:

Mirror dust correction. Methods for modeling and removing the radiance contribution of a thin layer of dust on the Mini-TES fore-optics have been successfully implemented for atmospheric observations [6]. We take a similar approach to [6], though modified for surface observations.

Linear least squares regression. A non-negative linear least squares fitting algorithm used with a library of spectral endmembers is employed to determine mineralogy [8; fig 1]. For this study, we used a library composed solely of primary igneous phases. Low Mössbauer-determined mineral alteration index (MAI) values reveal the unaltered nature of the rocks examined in this study [4]. These low values and the apparent tendency to over-estimate sulfate minerals leads to the decision to exclude secondary phases from the library (with the exception of Gusev surface dust).

Sulfate in the library. Previous investigations have noted unexpectedly high abundances of sulfate when modeling Mini-TES spectra of Adirondack-class plains basalt of Gusev crater [7]. To investigate the accuracy of results using a sulfate-populated library, lab spectra of well characterized, minimally weathered terrestrial basalt samples were resampled to Mini-TES spectral resolution and analyzed in the same manner as Mini-TES spectra. The results of this test were similar to those of the Adirondack class basalts; high abundances of sulfate minerals were modeled at the expense of feldspar, pyroxene, and olivine.

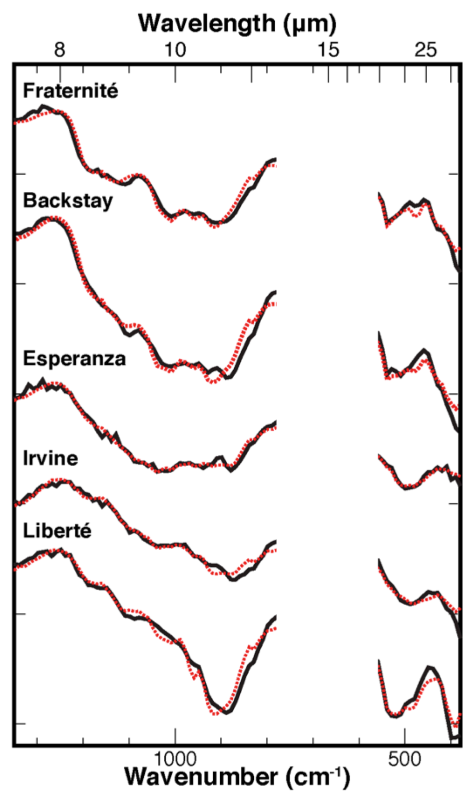

Figure 1: Mirror dust corrected (black) and modeled (dashed red) Mini-TES observations for the alkaline volcanic rocks discussed in text. Results shown in figure 2.

Optically thin dust and environmental artifacts. At thermal infrared wavelengths (6-25μm), thin deposits of dust on rock surfaces contribute emission features when warmer than the target substrate and absorption features when cooler than the target substrate [5,9,10]. In order to account and correct for this behavior, two spectral endmembers (MER-A mirror dust and average sky dust) are allowed to be modeled as positive or negative concentrations. Additionally, thermal gradients within the observation can introduce a continuum slope in the resultant emissivity spectrum. To account for this, a slope derived from the ratio of a 250 K and a 247 K blackbody curve is included in the endmember library following [2].

CIPW and Mini-TES mineralogy:

Adirondack-class basalt. Mini-TES modeled mineralogy for the Adirondack class basalt (Liberté; fig 1) reveals abundant olivine with lesser feldspar and pyroxene, consistent with the results from [7]. Contrastingly, CIPW and mmCIPW derived mineralogy shows pyroxene as the dominant mafic phase with more abundant feldspar.

Irvine-class alkali-basalt. Irvine (type-specimen) and Esperanza are located in different portions of the Columbia Hills but are grouped within the same class owing to their geochemical similarities. Spectra from both show abundant olivine with ~20% glass and lesser feldspar and pyroxene. The Mini-TES modeled mineralogy for both are consistent with one another, which gives us confidence in the results. CIPW and mmCIPW results model pyroxene and feldspar as the dominant phases, again in contrast with the Mini-TES derived assemblage.

Backstay-class trachy-basalt. Mini-TES observations indicate that backstay is a feldspar rich lithology in agreement with CIPW and mmCIPW abundances. However, Mini-TES results suggest olivine as the dominant mafic phase over pyroxene.

Wishstone-class tephrite. All three models are consistent with the Wishstone class being feldspar rich. Mini-TES observations (Fraternité; fig 1) reveal abundant olivine where CIPW and mmCIPW reveal little to no olivine owing to quartz being normative. The Mini-TES modeled mineralogy is noticeably lacking a phosphate mineral to account for the ~5 wt.% P_2O_5 detected by APXS.

Discussion: Mini-TES observations, CIPW and Mössbauer-modified CIPW norm calculations show some agreement between the derived mineral assemblages, notably feldspar. However, the relative proportions of olivine and pyroxene are in disagreement for every rock class examined here. A potential cause for this is that the CIPW norm was designed to predict idealized mineralogy given a whole-rock geochemical analysis and making sound geochemical assumptions. This calculation does not consider depth of crystallization, non-equilibrium crystallization conditions or allow for the presence of glass and as such it will not always accurately predict the true mineral assemblage. Another potential source of the mineralogical discrepancies may lie with the poor representation of pigeonite in the spectral library. Pigeonite is a Mars relevant mineral and having more than one spectrum in the library could improve model fits and increase the proportion of pyroxene relative to olivine.

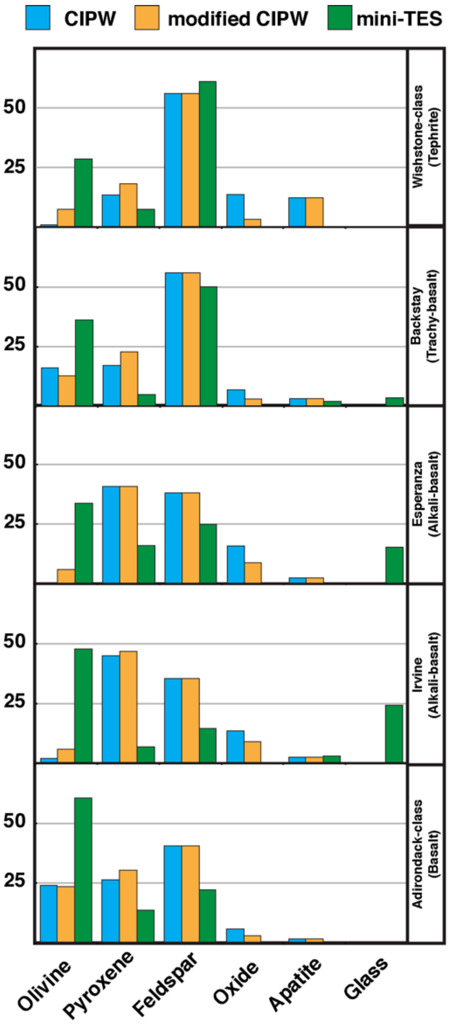

Figure 2: Modal mineralogy determined from CIPW normative calculations (blue), Mössbauer-modified CIPW calculations (orange) and linear least squares modeling of Mini-TES spectra (green). CIPW and mmCIPW data from [4].

References:

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