MINERALOGY OF ALTERED BASALTS USING INFRARED SPECTROSCOPY AT VARYING SPATIAL SCALES. P. Sheevam and W. M. Calvin, Geological Sciences, University of Nevada, Reno, Nevada, psheevam@nevada.unr.edu.

Introduction: We have been studying two continuously cored drill holes from Hawaii (PTA and KMA) as analogs to alteration processes on Mars [1-4]. The PTA and KMA were drilled within 10 km of each other, in the Humu'ula Saddle, between Mauna Kea and Mauna Loa, to assess the groundwater and geothermal resources in the region [e.g. 5]. The PTA core comprised mostly tholeiitic basalts altered to phyllosilicates and zeolites at low to mid temperature, with elemental abundances indicating an isochemical alteration environment [1,2]. The KMA core, although similarly basaltic, experienced an acid sulfate environment, with detections of jarosite, alunite, and hematite [4]. Initial mineral identification and analysis of stratigraphic relationships was determined in the field using a field portable short wave instrument. We subsequently prepared thin sections that were examined using higher resolution spectroscopic methods. This study aims to quantify the abundance of mafic and secondary minerals in the drill core using multiple spectroscopic methods at varying spatial scales.

Field Surveys: Prior work describes field surveys using a visible - shortwave infrared (VSWIR, 0.4 to 2.5 μm) instrument [1,4] and methods from [6]. Based on that data, samples were selected for additional analysis, including bulk long wave infrared (2.5 – 15 μm LWIR) and high resolution spectroscopy in both VSWIR and LWIR.

High Resolution Spectroscopy: A portion of the hand samples were prepped for petrographic analysis. Rectangular sections were embedded in epoxy as billets with a flat exposed surface, and these were used to create polished thin sections. Billets were analyzed in the VSWIR using a hyperspectral imaging spectrometer system at Caltech [7]. Images of the billets obtained spectra at a resolution of ~212 μm/pixel in the SWIR. Thin sections were analyzed using the Nicolet Micro Imaging Spectrometer at Stony Brook, from 2.5 - 15 μm with resolution capabilities as high as 50 μm/pixel [8].

Bulk LWIR: Hand samples were crushed, sorted into fine (<125μm) and coarse (>125μm) grain sizes, and measured from 2.5 – 25 μm using a benchtop Nicolet FTIR. The long wave spectra were analyzed using a spectral unmixing model using singular value decomposition (SVD), as described in [3]. The model compares pure mineral endmembers from USGS, JPL, JHU and other spectral libraries to the collected spectra. The SVD model generates a percent contribution from each end member with an associated RMSE value. The lower the RMSE indicated a better fit, although model fits were also visually inspected.

Validation Data: Select samples were imaged using petrographic and scanning electron microscopes. All hand samples were analyzed for mineralogy using XRD.

SWIR Results: For the PTA core, eight spectral endmembers were identified in the field survey [1,2]. Twelve spectral endmembers were identified using the higher resolution hyperspectral imaging. Similar minerals were identified with both techniques and we were able to discern between epoxy / vug space and mineral spectra in the billet images (e.g. Fig 1). Similar results were encountered in the KMA core with nine spectral endmembers identified using the field survey instrument

and ten identified in the billet scans, with similar mineral compositions.

LWIR Results: The bulk LWIR spectra measure contributions from a mix of individual minerals and although low RMSE values indicate a good fit, we don't believe the abundance values are accurate. For example, the SVD model for an unaltered layer showed that the collected spectra was mostly pyroxene with some small quantity of feldspar. However, petrographic analysis showed equally abundant feldspar to pyroxene.

Identification of minerals using the micro imaging spectrometer led to roughly nineteen endmember spectra in both the KMA and PTA. The diversity in endmembers can be attributed to crystal orientation, and mineral composition and mixtures, especially in feldspars where twinning and zonation of elemental substitutions is common [e.g. 8].

Discussion: The field surveys focused on targeted spectral collection of altered areas of the drill cores. This allowed for quickly gathering high quality spectra and confidence in secondary mineral speciation. Although the spatial resolution is much higher in the hyperspectral scans, the data are noisy. Spectral identification was improved by averaging surrounding pixels. The high resolution SWIR scans found the same minerals as the field data.

High resolution LWIR scans allowed us to identify mafic mineralogy, with some secondary mineral speciation. High resolution imaging using SEM EDS allowed for compositional mineral components at fine scales, as well as secondary mineral associations. LWIR scans were comparable to SEM and allowed determination of the mineralogy of the groundmass, with spectra indicating anorthite, labradorite, diopside and glass. However, even at the highest of resolutions, there were still instances of spectral mixing. Bulk long wave data, though useful in rapid collection and characterization, did not accurately quantify mineral abundance, or secondary mineral associations.

Both SWIR and LWIR bulk and high resolution imaging were useful in characterizing the fine grained mineralogy that composes these basalts. Their alteration environment and lack of exposure to Earth's atmosphere make them an excellent analog for alteration processes on Mars. The field and bulk spectra are analogous to remote spectroscopy, with characterization of major mineral constituents. At higher resolutions, alteration was not found to be as pervasive as suggested by the field and bulk data.

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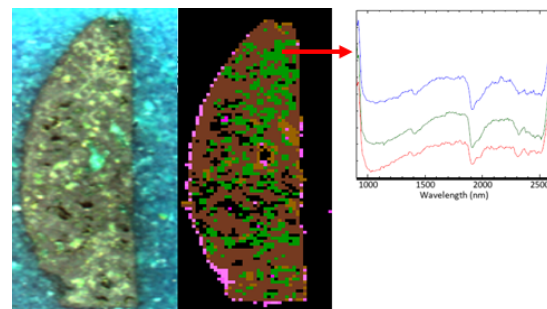

Figure 1: False color composite (left) and SWIR mineral map (center). Minerals are mapped using the following color scheme: green indicates phyllosilicate spectra, browns are mafic minerals, black is vug space or epoxy, and pink is zeolites. Pink shades on edges may be falsely identified due to epoxy and rock spectra mixing. Corresponding spectra are shown on the right to demonstrate feature depth and noise variability.