CHARACTERIZATION OF BT-2: CALIBRATION TARGET FOR MARS SCIENCE LABORATORY ALPHA PARTICLE X-RAY SPECTROMETER.

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Introduction: Broken Tank is an alkali basalt lava flow from New Mexico [1], and BT-2 (Broken Tank 2) is the 4.2 cm diameter, 2.9 ± 0.1 mm thick disc selected as the calibration target for the Canadian-built Alpha Particle X-ray Spectrometer (APXS) instrument on the Mars Science Laboratory (MSL) Curiosity Rover, due to land on Mars in August of 2012. This work describes the ongoing effort to thoroughly characterize BT-2 using a variety of techniques and instrumentation to aid in the interpretation of APXS data. We also compare different analytical techniques with a view to assessing possible instrument payloads for future planetary missions.

Methodology: The bulk chemistry of BT-2 was previously determined by Albert Yen and Penny King via Inductively Coupled Plasma Mass Spectrometry (ICPMS) and X-ray Fluorescence (XRF) on various powdered rock samples [2]. The aim of this study is to compare this bulk chemistry with compositions obtained from other techniques on a more local, in situ scale, more akin to the scale of an APXS analysis.

The mineralogy of BT-2 has been investigated via the petrographic microscope coupled with point counting and image analysis. Specific mineral compositions were determined via wavelength dispersive spectrometry at the University of New Mexico (UNM) [2].

Two 30 μm thick, approximately 2.5 x 4 cm, polished thin sections were prepared at the University of New Brunswick (UNB) from a sample of BT-2. Thin sections were examined using a petrographic microscope to determine mineralogy and texture. One thin section was then selected for a comparative study utilizing the Field Emission Scanning Electron Microscope (FE-SEM) and Raman Spectrometer at UNB, as well as the Fourier Transform Infrared Spectrometer (FTIR) at UNM.

Two ~1 mm^2 areas were selected and mapped at 3 different orientations using FTIR (Figure 1). Maps of the dominant mineral phases were produced for each area at each orientation by selecting infrared absorption peaks specific to that mineral. Mineral abundances were then estimated using image analysis software. The same two areas were then analyzed via the FE-SEM at UNB for the exact mineral compositions of the constituent phases, and for the bulk chemistry of those areas.

The bulk chemistry of the areas investigated by FTIR were determined by rastering (or scanning) the electron beam of the FE-SEM over approximately twelve 400 x 400 μm areas (Figure 2) and averaging the composition of these areas to obtain a bulk composition for each of the FTIR mapped areas. Further raster analyses (~120) were performed in different areas of the thin section to obtain a more accurate bulk composition for the whole thin section sample (Figure 2). The bulk chemical composition of the thin section was then compared with that obtained by ICPMS and XRF techniques and CIPW Norms computed for the various bulk compositions to give an idealized bulk mineralogy of the sample.
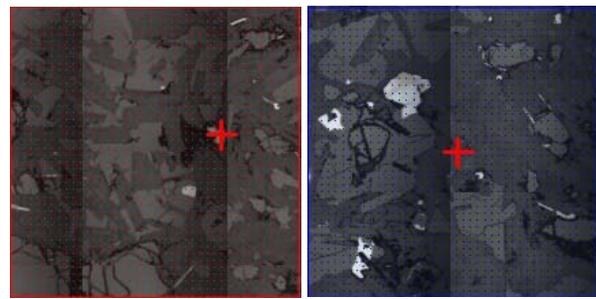

Figure 1: Two ~1 mm^2 areas analyzed by FTIR Spectroscopy (reflected light images)
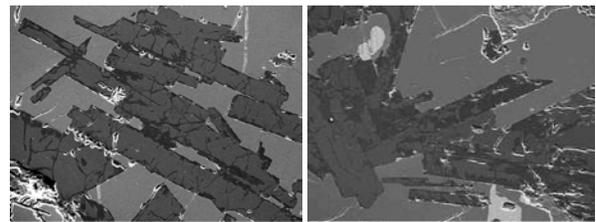

Figure 2: Back scattered electron images of typical raster areas (scale bars 200μm)

Results: FTIR maps of the dominant mineral phases reveal olivine, augite clinopyroxene, feldspar and oxides (e.g., Figure 3). Mineral abundances estimated from these maps range from 4-9 % olivine, ~1% oxides, 35-60% feldspar and 35-40% augite pyroxene. Different orientations of the same area did not reveal any major differences in the phases mapped by FTIR.

FE-SEM energy dispersive spectrometery (EDS) analysis of individual minerals from within the same areas mapped by FTIR reveals magnesium-rich olivine (forsterite), magnesium- and calcium-rich augite pyroxene with a minor sodic component, calcium-rich plagioclase feldspar (labradorite) intergrown with potassium/sodium alkali feldspar (anorthoclase),

iron/titanium oxides (ilmenite) and apatite (calcium phosphate). Interstitial matrices and altered feldspar areas are dominated by a low total sodium-rich phase. Olivine is locally altered to a mixture of clay minerals.
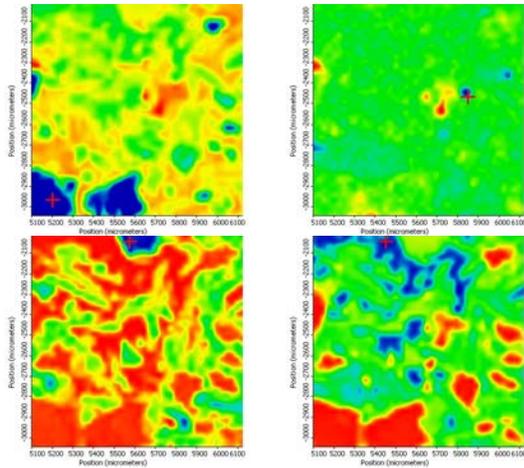

Figure 3: FTIR maps of olivine (top left, blue), oxides (top right, blue), feldsapr (bottom left, blue and green) and augite clinopyroxene (bottom right, blue). Blue/green colours indicate the presence of specific IR absorption peaks associated with that mineral.

FE-SEM raster analyses of the sample indicate a bulk composition similar to that obtained by other techniques (ICPMS, XRF and preliminary APXS analyses). CIPW normative calculations determined from the bulk FE-SEM raster analyses compare well with those calculated from the bulk compositions derived by ICPMS analyses, and these results reflect the mineralogy of the sample as observed petrographically.

Preliminary Raman Spectroscopy of the same areas analyzed by FTIR and FESEM indicates the same mineralogy as determined by those techniques, but has allowed more precise identification of the alteration phases present. The altered feldspar and interstitial matrices are dominated by analcite and the olivine is altered to a mixture of clay minerals (smectites and vermiculite) and chlorite (collectively referred to as iddingsite). Work is ongoing to produce higher resolution Raman maps.

Furture Work: Continued FE-SEM analysis will be performed including rastering larger areas for comparison with bulk compositions derived by other techniques, including existing and upcoming APXS analyses. Further mineral, matrix and alteration phase characterization will be conducted.

It is also planned to compare BT-2 mineralogy and composition with various Martian basalts and perform similar analyses on Martian basalt meteorite samples.

ChemCam analyses have been performed on a sample of BT-2 [3]. We plan to compare these and any other MSL instrument analyses of BT-2 with our data in order to maximize the interpretation of APXS results to aid in cross-calibration efforts.

References: [1] Chamberlain R. M. (2011) *New Mexico Geology, 33, #2*, 40-41. [2] Burkemper L. et al. (2008) *AGU Fall meeting*, Abstract P53C-1464. [3] Cousin A. et al. (2011) *42nd LPSC*, Abstract 1973.pdf.