BT-2 CALIBRATION TARGET FOR MARS SCIENCE LABORATORY ALPHA PARTICLE X-RAY SPECTROMETER: CHARACTERIZATION AND ALKALI BASALT MARTIAN ANALOGUE.
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Introduction: BT-2 (Broken Tank 2) is the 4.2 cm diameter, 2.9 ± 0.1 mm thick alkali basalt disc prepared as the calibration target for the Canadian-built Alpha Particle X-ray Spectrometer (APXS) instrument (Figure 1) on the Mars Science Laboratory (MSL) Curiosity Rover [1]; the latest mission to directly explore the surface of Mars. This work describes the selection, geological context and characterization of BT-2. We also discuss BT-2 as an analogue for similar basalt-like lithologies encountered during the initial stages of our exploration of Gale Crater.

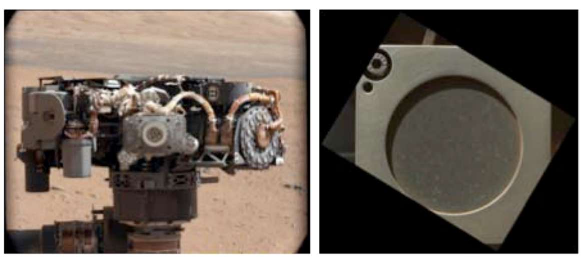

Figure 1: Left – MastCam image of APXS on sol 32; Right – Mars Hand Lens Imager image of BT-2 in a Ni holder after landing on sol 34.

Rationale for Sample Selection: A calibration target for the APXS instrument is required to facilitate the in situ analysis on Mars of a well characterized sample with a known chemical composition. The calibration target is used to check the performance of the APXS on Mars throughout the lifetime of the mission. Ideally, a homogenous glass sample would have been selected, but the engineers required a sample that could withstand the forces during takeoff and landing of the spacecraft. It was determined that a fine grained, relatively homogenous basalt lithology would be the ideal candidate, preferably with a composition similar to the Gusev basalts. A survey of >200 potential basalts was undertaken, with the requirement that the sample not only be relatively fine grained and homogenous, but also free of vesicles, amygdales, cracks and other imperfections, as well as obvious, extensive alteration effects that would weaken the sample; features present in many natural terrestrial basalts [1].

Choice of BT-2 and Geological Context: The basalt of Broken Tank is so called because it flowed into the Broken Tank basin of the southern section of the Rio Grande continental rift. The basalt is exposed in the Socorro area of New Mexico. It is one of a series of intercalated lava flows (^{40}Ar/^{39}Ar age of ~8.4 Ma), with individual flows reaching up to 30 m in thickness, within a Miocene formation age of volcaniclastic conglomerates, sandstones and debris flows, and playa mudstones, preserved within tilt-block rift basins [2]. It flowed over slope gravels onto playa muds within the Broken Tank basin [2]. The cores of these lava flows typically exhibit fine grained, ophitic to subophitic textures, resulting in a strong, interlocking texture of the constituent minerals, as well as a lack of extensive alteration or vesiculation. For this reason, the centre of the basalt flow of Broken Tank was selected as the APXS calibration target. The 2 denotes the fact that the disc mounted onboard the Curiosity rover was the second one made; the first was rejected due to difficulties in polishing.

Methodology: The mineralogy and texture of BT-2 have been investigated via the petrographic microscope, Field Emission Scanning Electron Microscope (FE-SEM) and Raman Spectrometer at the University of New Brunswick; petrographic microscope, electron microprobe, SEM (including X-ray maps and BSE images of the entire BT-2 disc) and Fourier Transform Infrared (FTIR) spectroscopic mapping at the University of New Mexico; and QEMSCAN by Digitalcore.

The bulk chemistry of associated basalts of Broken Tank were previously determined by XRF [3]. The bulk chemistry of a BT-2 sample was determined via Inductively Coupled Plasma Mass Spectrometry (ICPMS) on powdered rock samples [1, 4]. The same powdered samples were analyzed via APXS as pressed pellets and powders, as well as the calibration target disc [4]. Thin section samples were analyzed by rastering the electron beam of the FE-SEM over ~65, 400 x 400 μm areas (Fig. 2). The compositions of individual areas were averaged to obtain a bulk composition of an ~ 6.8 cm^2 area, comparable to the ~ 2 cm diameter APXS field of view. The QEMSCAN results (3 μm step X-ray maps over ~4000 x4000 mm) were used in a similar manner to determine modal mineralogy. The bulk-derived chemical composition of the thin sections via FE-SEM and QEM-SCAN were compared to those from other techniques (XRF, ICPMS and APXS), and

CIPW Norms computed to yield an idealized bulk mineralogy of the sample.

Mineralogy and Composition: The dominant mineralogy (Figs. 2, 3) is magnesium-rich olivine (forsteritic), magnesium- and calcium-rich (augite) pyroxene with a minor sodic component, calcium-rich plagioclase (labradorite) intergrown with potassium/sodium alkali feldspar (anorthoclase), iron/titanium oxides (ilmenite), rare chromite, and apatite. Interstitial matrices and altered feldspar areas are dominated by a low total sodium-rich phase, identified as analcime by Raman spectroscopy. Olivine is locally altered to a mixture of clay and chlorite minerals.

Figure 2: Photomicrograph, under crossed polars, showing the ophitic/subophitic texture of clinopyroxene (cpx) and plagioclase (plg). ol – olivine, o – oxide. Scale bar 1mm.

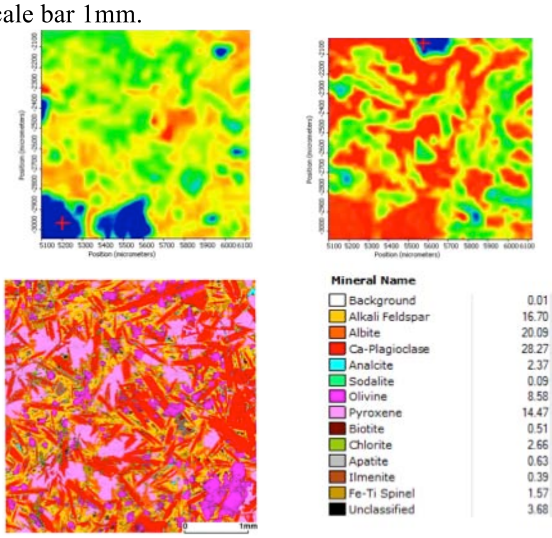

Figure 3: FTIR maps (top) of olivine (left, blue) and feldspar (right, blue and green). Blue/green colours indicates presence of specific IR absorption peaks associated with that mineral. QEMSCAN X-ray map of BT-2 with legend (bottom).

The basalt of Broken Tank and all analyses of BT-2 show it to be alkaline. CIPW normative calculations determined from the compositions derived from the various analytical techniques compare well with each other, and generally reflect the mineralogy of the sample, with the exception of nepheline, which is manifest as analcime in the rock.

Discussion: BT-2 plots as an alkali basalt on an alkali versus silica diagram (Fig. 4). Wishstone and Backstay rocks from the MER mission also plot in this field with similar alkali/silica ratios to BT-2, which are all distinct from the majority of the lithologies analyzed to date during the MER mission, and also from Shergottitic meteorites (Fig. 4). However, analyses of a variety of rocks encountered during the early stages of the MSL mission indicate that there may be significant alkali basalt and associated lithologies present within the Gale Crater [5, 6]. The selection of BT-2 as the calibration target for the APXS instrumentlp may have fortuitously resulted in a calibration standard similar in composition to some of the lithologies we are encountering during our exploration of Gale. The geological setting of the BT-2 basalt, as a flow, down a gravelly slope onto playa lake deposits, may also represent a similar scenario to one that may have existed, in the past, within Gale Crater on Mars.

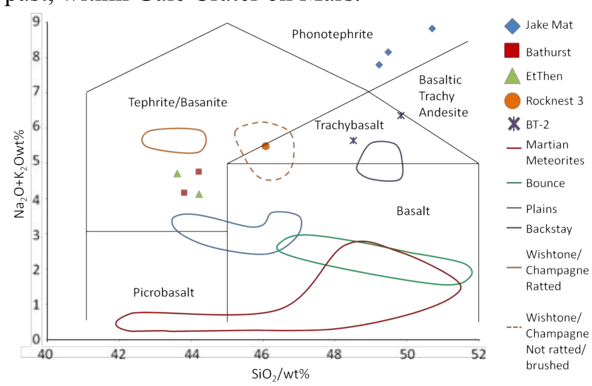

Figure 4: Total alkali versus silica plot for MER basalts, Martian Shergottites, MSL APXS analysed rocks (up to sol 102, Jake Mat – Jake Matijevic) and BT-2.

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