

**FIRST MEASUREMENTS OF THE MSL APXS CALIBRATION TARGET ON MARS.** J.L.Campbell<sup>1</sup>, J.A.Berger<sup>2</sup>, R.Gellert<sup>1</sup>, P.L.King<sup>3</sup>, G.M.Perrett<sup>1</sup>, N.I.Boyd<sup>1</sup>, K.S.Edgett<sup>4</sup>, R.A.Yingst<sup>5</sup> and the MSL Science Team. <sup>1</sup>University of Guelph (Guelph, ON, N1G2W1, Canada; icampbel@uoguelph.ca), <sup>2</sup>University of New Mexico, Albuquerque, NM., <sup>3</sup>Australian National University, Canberra, Australia, <sup>4</sup>Mahlin Space Science Systems, San Diego, CA., <sup>5</sup>University of Wisconsin, Madison, WI.

**Introduction:** A polished slab of the basalt of Broken Tank (BT2) from near Socorro, NM was mounted on Curiosity to transfer the terrestrial calibration of the APXS from the laboratory in Guelph to Gale Crater. The epoxy-free basalt was prepared as a polished disc (to 0.03  $\mu\text{m}$  polish, 4cm diameter, 2mm high) that was set into a Ni holder. The basalt was characterized for its mineral and bulk chemistry [1], micron-scale grain size and surface imperfections.

MAHLI images of the calibration target taken after landing clearly show that it interacted with the dust&stone cloud during landing, raising three questions: (i) what is the nature of the deposited Martian material? (ii) is an adjustment of the instrument calibration parameters required? (iii) do the sources have a similar deposit requiring additional adjustment?



Figure 1. Stretched MAHLI image of the basalt calibration target in its Ni holder

**MAHLI of calibration target:** The MAHLI image (Fig.1) preceding APXS integrations on Sols 34-35 shows dust contamination. Full coverage of dust imparts a dull red reflectance on the highly polished surface; fine dust particles are not resolvable at 32  $\mu\text{m}/\text{pixel}$ . Additionally, wind may have deposited dust on this vertical surface since landing. Many spherical “dust balls”, likely held together by electrostatic forces, have accumulated near the edge of the Ni mount, although the exact boundary is obscured by shadow. In addition, about 25 dust balls (50-155  $\mu\text{m}$ ) are visible in the target interior. Dark marks (<150  $\mu\text{m}$ ), not present before launch are visible. Some of these are due to

blemishes in the MAHLI CCD, but others suggest that the target was struck by flying material.

**APXS cross-calibration:** The BT2 disc was measured with the flight sensorhead, but with laboratory <sup>244</sup>Cm sources at Guelph in 2008 prior to delivery of the APXS to NASA. The actual flight sources were assembled in 2011 close to launch. A selection of powdered geochemical reference materials (GRMs) was analysed with all instrument and source configurations to provide cross-calibration [2]. This suite of samples was supplemented with materials prepared by author King and certified at Activation Laboratories, Ancaster, Canada. This exercise characterized the different <sup>244</sup>Cm source configurations (comprising alpha-emitting and standard X-ray emitting sources) in terms of the intensity ratio between Pu L X-rays and alpha particles. The Si/Fe counts ratio was 12% smaller in the ultimate flight configuration than in the 2008 calibration of the flight unit.

**APXS spectrum changes after landing on Mars:** As seen in Fig. 2, the 2008 and 2012 calibration target spectra exhibit changes in the contributions of several elements; most visible is the appearance of S and Cl peaks, whose concentrations are negligible in the original rock. Note that the laboratory spectrum has significantly wider peaks due to higher temperature.

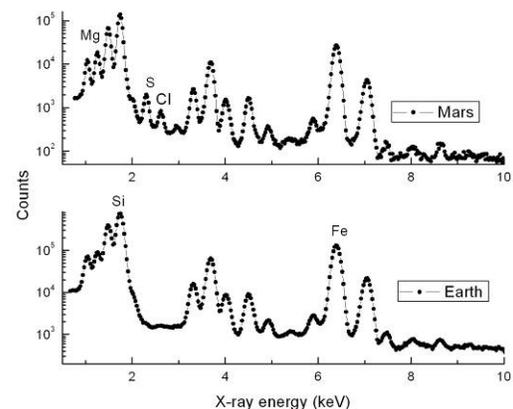


Figure 2. APXS spectra of calibration target

The count rate ratios for the peaks in Fig. 3 quantify the changes. The S:Cl ratio of the contamination on Mars is 3:1, agreeing with the MER soil value [3].

The Martian data were corrected for X-ray absorption in 7 mbar CO<sub>2</sub> atmosphere. The results are normalized to 1 for the four scatter peaks. Besides the 12% drop for light elements, a constant peak area ratio for all elements would have been expected if only geometric differences were in play.

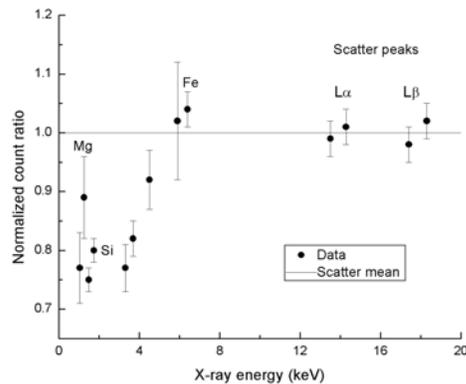


Figure 3. Ratio of element count rates on Sol 34 relative to calibration exercise in 2008

However, three significant differences are visible in the figure: (i) the lightest elements, whose X-rays are induced by alpha particles, are depressed beyond the known 12%; for Si the drop is 20% below the normalized scatter peak value; (ii) Mg is anomalously high among the light elements; (iii) Fe is elevated by ~4%. The largest of these effects arising from the apparent surface dust deposition is the additional 8% drop in Si relative to the scatter peaks (assuming no Si in the deposit).

Overall it appears that on Mars a contaminant layer containing (at least) S, Cl, Mg and Fe is preferentially absorbing light element X-rays from the basalt. Such a layer may also be present on the sources, causing decreased excitation of the light elements through degradation of the alpha particle energy.

**Modelling of the contaminant layer:** Rather than assume the material to be global soil/dust, we proceed on the basis of the main observed changes in the APXS spectra. Both the form and the composition of the deposit are crucial. We initially considered both partial coverage with thick grains and a homogeneous layer over the full slab, and eventually preferred the latter. Due to the different X-ray escape depths depending on atomic number, thin layers will show higher signal from low atomic number elements than from Fe, compared to a thick sample.

The layer composition was modeled using our computer code APX-Yield, which is based upon the physics of XRF and PIXE and predicts the X-ray intensities emitted by both layer and substrate. Just as in our spectrum processing codes [2,3] a homogeneous distribution of atoms on the 1-100  $\mu$ m scale is assumed.

Various models of the deposit, including Gusev soil, were tested. In the model which agreed best with experimental data, Fe<sub>2</sub>O<sub>3</sub> was chosen to represent the iron excess, with the thought that nanophase iron oxide, npOx, [4] could be trapped on the surface along with “sticky” MgSO<sub>4</sub>. However, Mg and SO<sub>4</sub> were taken as separate entities to admit the possibility of some SO<sub>4</sub> adhering to the npOx. Cl was linked to SO<sub>4</sub> to take advantage of the known S/Cl counts ratio. The model that best fitted the APXS results was a ~100 nm layer containing: 45 wt% MgSO<sub>4</sub>, 32 wt% Fe<sub>2</sub>O<sub>3</sub>, 16 wt% SO<sub>4</sub>, 7 wt% Cl. Because H<sub>2</sub>O causes only weak X-ray absorption, the model is not sensitive to inclusion of hydration, and does not differentiate among hydrated phases that have been suggested for Mars. We recognize that adherence may be assisted via jet fuel residue. Given the assumptions made in the modeling and the error bars in our data, this result should be used conservatively.

**Impact on <sup>244</sup>Cm sources:** If the layer characterized above had also been deposited on the <sup>244</sup>Cm sources, the energy loss of the alpha particles traversing it would be ~20 keV. Use of the APX-Yield code shows that this change would have negligible effect on the X-ray intensities excited from the calibration target, reflecting the fact that we are operating in the energy region where the X-ray excitation cross-section has its least energy-dependence. This indicates that the sources have not been significantly contaminated, a result consistent with the fact that the sensorhead is located higher on the rover and was protected behind the contact plate (with main opening only 2.5 cm). We conclude therefore that there is no need to change the pre-existing cross-calibration of laboratory to flight sources.

**References:** [1] Burkemper, L. et al. (2008) EOS Trans AGU, 89(53), P53C-1464, [2] Campbell J.L. et al. (2012) Space Science Reviews 170, 319, [3] Gellert R. et al. (2006) JGR Planets 111, JE002555, [4] Morris, R.V. et al. (2006) JGR: Planets 111, E02S13.

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