DUST MODELLING ON MARTIAN ROCK SURFACES STUDIED BY THE MARS SCIENCE LABORATORY ALPHA PARTICLE X-RAY SPECTROMETER.

G. M. Perrett[1,4], M. E. Schmidt[2], N. Bradley[2], S. Bray[2], J. L. Campbell[3], C. Ly[1], S. Squyres[1], D. W. Tesselaar[3] [1]Astronomy Department, Cornell University, Ithaca, NY, [2]Department of Earth Sciences, Brock University, St. Catharines, ON, Canada [3]Department of Physics, University of Guelph, Guelph, ON, Canada, [4] gmp74@cornell.edu

Introduction: The alpha particle X-ray spectrometer (APXS) is a lightweight instrument located on the arm of both the Mars Exploration Rover (MER) and Mars Science Laboratory (MSL) rovers, which measures the bulk chemistry of selected rocks and soils[1,2]. It uses radioactive ^{244}Cm sources that, upon decay, emit ^{240}Pu X-rays and alpha particles. The alpha particles excite the sample via particle induced X-ray emission (PIXE), which preferentially excites the lightest elements (Na-Ca) and interrogates the very near surface down to depths of about 10 microns. The Pu X-rays preferentially excite the heavier elements (Ca-Y) via X-ray fluorescence (XRF) and can detect elements down to depths of a couple hundred microns. This depth dependence of the two excitation methods is not an issue when the sample is relatively homogeneous with depth; however, the majority of targets on Mars are dust covered and/or coated. In such cases, if the covering material is not removed, the covering material contributes the majority of the measured light elements, while the heavier elements are measured from the underlying substrate. The goal of this work is to model the dust coverage parameters (thickness and dust composition; area coverage is provided independently[3,4]) on rocks studied by the MSL APXS. Through modelling we hope to further refine the dust composition beyond work done by Berger et al.[5], as well as identify any systematic geochemical trends with dust thickness and area coverage.

Methodology: Both MER and MSL rover missions are equipped with a brush that is capable of removing the majority of unconsolidated dust and soil on rock surfaces[6,7]. In several instances, the MSL APXS has measured rock targets both before and after brushing took place and was accompanied by MArs Hand Lens Imager (MAHLI)[8] images of both scenarios. The area fractions of the dust coverage in the as-is and brushed images have been previously determined[3,4] and these values are input to the APX-Yield program.

The APX-Yield program is derived from the GUYLS utility in the GUPIX package[9] that has the capability to calculate theoretical peak areas for layered targets. It has previously been used to model the coating on the MSL APXS calibration target that developed on landing[10], the dust composition on the MSL observation tray[5], and a coating on the rock Mazatzal studied by the MER APXS[11]. It allows the area coverage, layer thickness, and layer composition to vary, and thus be determined for, as in our case, a set of dusty and brushed measurements. We must first make a few assumptions: the dust layer is of uniform thickness and homogeneous composition, and the geometry between observations is consistent. APX-Yield is not capable of providing uncertainties for the modelled dust concentrations so the uncertainties are assumed to be the accuracies determined for the APXS calibration[1,2]. Dust/substrate theoretical peak area ratios from APX-Yield are then matched to the dusty/brushed experimental peak area ratios for each element by varying the dust thickness and composition. Experimental peak areas are obtained from spectrum fitting with GUAPX[2]. The area coverage is predetermined and fixed to allow for a unique solution[3,4]. The starting dust composition is that found by Berger et al.[5] on the MSL observation tray, which is in overall agreement with previous dust measurements made by the MER APXS[12,13,14].

Sol	Target	Surface Treatment
149	Ekwir_1	RU
150	Ekwir_1_postbrush	RB
168	Wernecke	RU
169	Wernecke_brushed	RB
173	Wernecke_3_brushed	RB
612	Windjana_center_preDRT	RU
612	Windjana_Center_postDRT	RB
805	Ricardo_raster1	RU
806	Ricardo_raster1_DRT	RB
1253	Bergsig	RU
1251	Kuiseb_DRT	RB
1266	Waterberg	RU
1266	Stockdale_DRT	RB
1318	Cangulo	RU
1318	Lubango_potential_drill	RU
1318	Lubango_DRT	RB
1416	Dondo	RU
1416	Chibia	RB

Table 1. List of the MSL APXS unbrushed (RU) and brushed (RB) rock target pairs used in this study.

Table 1 lists the eight MSL APXS as-is (dusty) and brushed target pairs up to sol 1417. In most cases the same location was examined under both conditions (e.g. Wernecke, Figure 1). Some cases (e.g. Dondo and Chibia, Figure 2) studied the same rock surface but the target pairs were on two different locations. For these cases the target pairs were found to have similar APXS bulk chemistry (excepting elevated S and Cl in the dusty target.

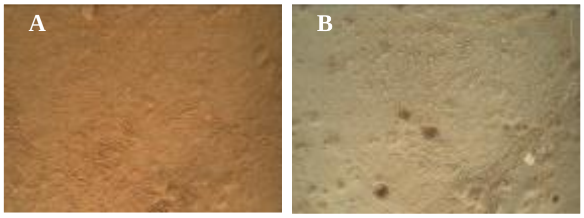

Figure 1. A. Sol 168 MAHLI focus merge of Wernecke as-is. B. Sol 169 MAHLI focus merge of Wernecke_brushed. Each image diameter is approximately 2.5 cm. (NASA/JPL-Caltech/MSSS)

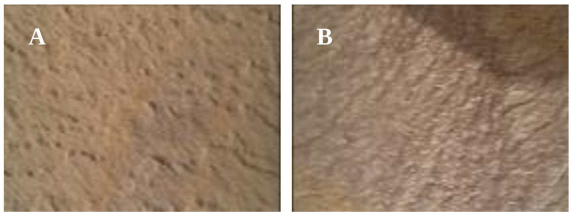

Figure 2. A. Sol 1416 MAHLI focus merge of Dondo (as-is). B. Sol 1416 MAHLI focus merge of Chibia (brushed). Each image diameter is approximately 4 cm. (NASA/JPL-Caltech/MSSS)

Results: Preliminary modelling results indicate that the dust composition found by Berger et al.[5] is a reliable starting point for the model. These concentrations have been adjusted slightly, but agree within uncertainty in most cases. Figure 3 shows an example of Na_2O from modelling of the Wernecke target pair compared to dust, soil, brushed, and as-is pairs at Gale Crater. The modelled Na_2O concentration is lower than previous measurements but agrees within error. It is important to note that various rock classes are represented by the as-is and brushed pairs; the large range in concentrations, particularly for the brushed points, simply reflect the various rock types studied[15]. Figure 3 also plots the SO_3/Cl ratio for the Wernecke modelled dust compared to other Gale Crater observations. The SO_3/Cl ratio is a good proxy for dust coverage because this ratio has been shown consistent in various dust and soil measurements across all rover landing sites[5,13,14]. The modelled ratio is higher than previous measurements but agrees within error.

This method has also made it possible to determine the concentrations of select minor elements that could not be determined via observation tray measurements (e.g. P, Ti). For the eight targets studied, dust thicknesses are on the order of 10 µm.

Conclusions: Modelling of dust parameters on as-is and brushed rock pairs analyzed by the MSL APXS improves our understanding of the dust composition and nature of dust coverage on martian rocks at Gale Crater. With this improved understanding of the dust thickness, composition, and area coverage,

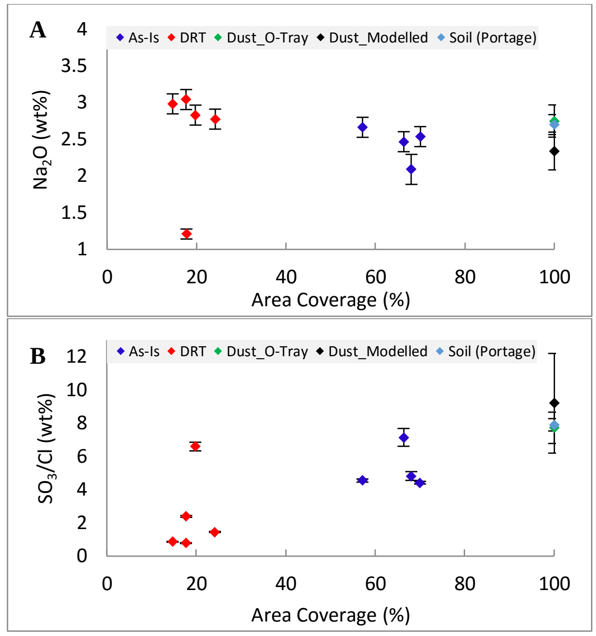

Figure 3. A. Na_2O concentrations and B. SO_3/Cl ratios for as-is and brushed (DRT) pairs plotted by their dust fractions determined by Bradley et al. [3] and Bray et al. [4]. The observation tray (O-tray), standard Gale Crater soil (Portage) and modelled dust concentrations from Wernecke are plotted at 100% area coverage.

geochemical trends are observed. Given enough data points of dusty/brushed rock pairs we may eventually be able to back out rock target compositions in cases where brushing cannot be performed or was not able to entirely remove the dust before use of the APXS.

Acknowledgements: The authors would like to thank the MSL science, engineering, and tactical teams for making the existence of this data possible. We acknowledge the Canadian Space Agency for providing grants that allowed for the development of the APX-Yield program and the APXS itself.

References: [1]Gellert, R. et al. (2006) *J. Geophys. Res.*, 111. [2]Campbell, J.L. et al. (2012) *Space Sci. Rev.*, 170, 319-340. [3]Bradley, N.J. et al. (2017) LPSC 48. [4]Bray, S.L. et al. (2017) LPSC 48. [5]Berger J.A. et al. (2016) *Geophys. Res. Lett.*, 43, 67-75. [6]Gorevan, S.P. et al. (2003) *J. Geophys. Res.*, 108. [7]Anderson, R.C. (2012) *Space Sci. Rev.*, 170, 57-75. [8]Edgett, K.S. et al. (2012) *Space Sci. Rev.*, 170, 259-317. [9]Maxwell J.A. et al. (1995) *Nucl. Instrum. Methods Phys. Res., Sec B.*, 95, 407-421. [10]Campbell, J.L. et al. (2014) *Nucl. Instrum. Methods Phys. Res., Sec B.*, 323, 49-58. [11]Perrett, G.M. et al. (2016) AGU, P21C-2137. [12]Foley, C.N. et al. (2003) *J. Geophys. Res.*, 108. [13]Goetz, W. (2005) *Nature*, 436, 62-65. [14]Yen, A. (2005) *Nature*, 436, 49-54. [15]Schmidt, M.E. et al. (2016) LPSC 47, 2043