ANALYSIS OF MARTIAN DUST COVERAGE AND CORRELATIONS WITH APXS OF BEDROCK TARGETS EXAMINED BY THE OPPORTUNITY MARS EXPLORATION ROVER.

N.J. Bradley[1], M.E. Schmidt[1], S.L. Bray[1]. [1]Earth Sci, Brock Univ, St. Catharines, On L2S 3A1, Canada, nb13qa@brocku.ca, mschmidt2@brocku.ca, sb13yz@brocku.ca

Introduction: A thin veneer of airfall dust covers the rocks analyzed by the Opportunity rover. This layer of dust skews textural and geochemical interpretation of bedrock surfaces Microscopic images received via the Microscopic Imager (MI) onboard the Mars Exploration Rover (MER) provide close-up views of the Martian surface in grayscale and are a means to conduct dust analysis. Accompanying the MI is the Rock Abrasion Tool (RAT), which includes a brush to remove much of the dust from the MI's field of view as well as a grinder to remove the outermost 1-2 mm of the rock surface [1]. The Alpha Particle X-ray Spectrometer (APXS) measures elemental abundances in the dust and bedrock surface [2]. The goal of this study is to analyze dust coverage using microscopic imagery and to then compare dust coverage values to APXS data to constrain bedrock composition.

Methodology: In total 24 'as is' and RAT-brushed targets were analyzed for dust coverage using a methodology first developed by Lee et al. [3] for the Mars Science Laboratory (MSL) landing site. Opportunity MI images are taken in greyscale, therefore colour analysis procedures, such as those by Bradley et al. [4] are not possible. The freeware software ImageJ [5] was used to analyze particles in the images. Raw images were obtained by the Planetary Data System [6]. Dust coverages are determined for the entire raw MI image, as the APXS field of view (FOV; 3.8 cm diameter) exceeds the size of the MI images (FOV; 3.2 cm diameter).

Using ImageJ, the MI image is sharpened to differentiate the dust from the visible bedrock surface. Any uncertainties that may skew the analysis (e.g., shadows, vein material, or reflective surfaces) are considered by phasing out areas affected by discrepancies. Pixels representing exposed bedrock material are documented by noting the grayscale range (0-255). The upper and lower thresholds of the image are then adjusted so that only the dust is selected (Figure 1), making note to exclude the bedrock and any uncertainties. The percentage of the image that has been turned red represents the amount of dust in the image, therefore dust coverage percentage can be determined for each target.

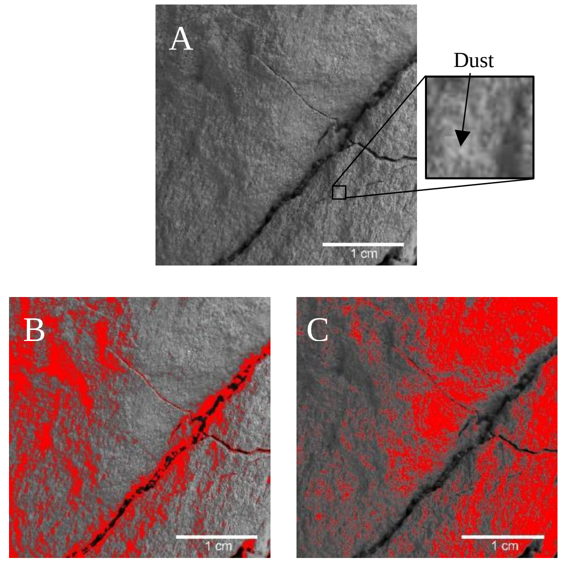

Figure 1: Dust coverage analyses for 'as is' APXS target Cercedilla (sol 1176); A: Unedited, shows dust at pixel scale; B: Lower threshold (22.88%); C: Upper threshold (32.85%).

Image Analysis Results: Our analysis included 12 'as is' (unbrushed) targets and corresponding 12 RAT-brushed targets. Rock surfaces were generally flat, vuggy, sandstone, and mudstone with some surfaces having exposed vein material. Shadows and solar glare were excluded from the analyses, 'As is' surfaces had higher dust coverages than the RAT-brushed targets; 'as is' targets range between 34.7-67.0% dust coverage and RAT brushed targets range 24.6-47.6%. RAT-Brushed surfaces do not represent dust-free rock surfaces. The average difference between paired 'as is' and RAT-brushed is 15.8% (Table 1).

Table 1. Dust coverages and differences between 'as is' and brushed target pairs

Sol	Target	Type	Dust Coverage (%)	Dust Coverage Diff. (%)
679	Ted	As Is	59.29	31.76
680	Ted	Brushed	27.53	
1176	Cercedilla	As Is	55.73	15.92
1182	Cercedilla	Brushed	39.81	
2713	Salisbury1	As Is	34.72	8.76
2717	Salisbury1	Brushed	25.96	
3809	Margarete	As Is	61.17	13.57
3812	Margarete	Brushed	47.60	

Comparison with APXS: Figure 2 presents Opportunity paired targets dust coverages plotted against CaO (wt%) and SO_3/Cl. The data are separated on the basis of sol number to denote any major change in bedrock composition. From sol 400 to 1332, Opportunity traversed sulfate-rich sediments of Meridiani Planum. APXS compositions changed drastically when Opportunity reached Endeavour Crater (sol 2713). In particular, 'as is' targets examined over sols 400-1332 have increasing CaO (r = 0.6104) and decreasing SO_3/Cl (r = 0.587) with increasing dust coverage. From sol 2712 to 3809, 'as is' targets have an increase in CaO (r = 0.2649) and an increase in SO_3/Cl (r = 0.5838) with increasing dust coverage. SO_3/Cl was found to be the most useful proxy for surface dust coverage. Positive linear variations with dust coverage also exist for SiO_2, SO_3, and Na_2O for all sol ranges.

Scattering of APXS data for RAT-brushed targets is common in most APXS proxies. RAT-brushed targets from sol 400 to 2486 show decreasing CaO (r = 0.0191) and decreasing SO_3/Cl (r = 0.3051) with increasing dust coverage. From sol 2712 to 3812, RAT brushed targets have an increase in CaO (r = 0.2919) and an increase in SO_3/Cl (r = 0.356) with increasing dust coverage.

Both sol ranges trend toward a modelled composition for airfall dust on a piece of MSL rover hardware (O-Tray) in Gale Crater [7] with increasing dust coverage. Sulfur-rich bedrock of the Meridiani Planum decreases in SO_3/Cl, while SO_3/Cl of Endeavour Crater bedrock increases toward the O-Tray with increasing dust coverage. A dust composition with SO_3/Cl of ~9.33 at Meridiani Planum was also determined by [8]. The O-Tray [7] represents a better dust estimate on the basis of linear mixing trends between bedrock and dust with our dust coverages.

Conclusions: Comparisons between dust coverage and element composition are a valuable tool in forming assumptions about the overall composition of the bedrock. Results of dust coverage analysis are consistent and provide plausible ranges of dust coverage for Opportunity APXS targets. Each image must be examined individually to assess variations in lighting, shadows, and bedrock type. RAT brushed targets are not pristine, but do provide a better window into interpretation of bedrock composition than dusty 'as is' rock surfaces. Nevertheless, good agreement with APXS determined elemental concentrations lends confidence to the approach.

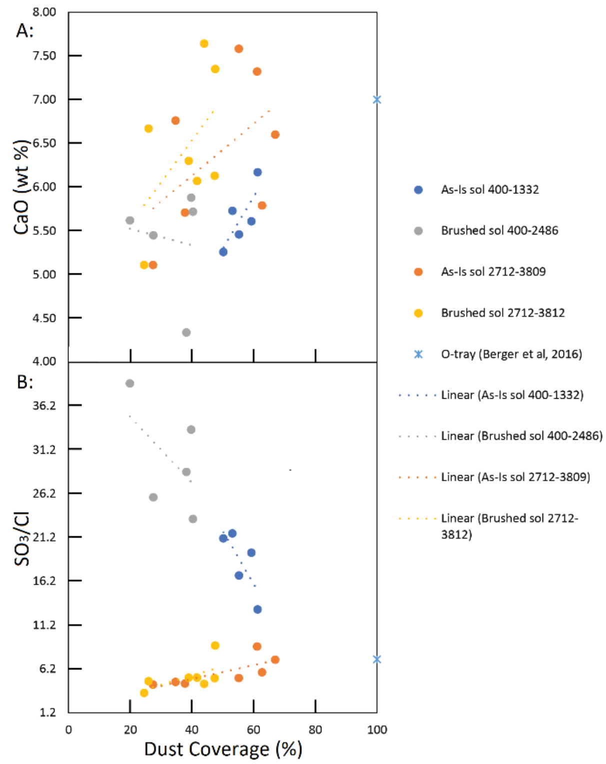

Figure 2: Plots of APXS compositions vs. determined dust coverage. A: CaO (wt%); B: O-Tray represents 100% dust composition determined at the MSL Gale landing site [7].

Acknowledgements: This work was supported by a Canadian Space Agency MSL Participating Scientist grant to Mariek Schmidt.

References: [1] Bartlett, P. et al. (2005) LPSC 35, 2292. [2] Gellert, R et al. (2009), LPSC 40, 2364. [3] Lee, R.E. et al. (2014) LPSC 2144. [4] Bradley, N. et al. (2017) LPSC 48, 1662. [5] ImageJ https://imagej.nih.gov/ij/. [6] NASA PDS https://pds.nasa.gov/. [7] Berger et al. (2013) LPSC 44, 1321. [8] Morris, R et al. (2006), J. Geophys. Res., 111, E12S15, doi:10.1029/2006JE002791.