Linking APXS Compositions to MAHLI Images Collected by the Curiosity Rover in Gale Crater

Rebekka E.H. Lee and Mariek Schmidt (Department of Earth Science at Brock University)

Introduction

The Mars Science Laboratory (MSL) Curiosity rover landed in Gale crater, Mars on August 6, 2012. The MSL payload includes the Mars Hand Lense Imager (MAHLI) for microscopic imaging and the Alpha Particle X-ray Spectrometer (APXS) for determining elemental compositions of rock surfaces and soils. The MAHLI was designed to take the place of a hand lens which geologists use in the field to identify geological features. Using a 2-megapixel colour camera, the MAHLI observes the geological features of the Martian surface by taking images at 2, 5, 10, and 25 cm standoff (Edgett et al., 2012). The MAHLI images are put into a focus stack, which is a compilation of several images taken at the same standoff distance in order to produce a best-focus product.

The APXS instrument examines a 1.7cm diameter area, when in contact with the sample, in order to analyze the elemental composition including the major, minor and some trace elements of the target through the use of curium-244 sources (Gellert et al., 2009).

Gale crater is a 155km in diameter impact structure that was formed approximately 3.8 billion years ago. Within the landing ellipse the rover encountered several different geological terrains as well as rocks; volcanic float, conglomerates, and sedimentary bedrock (Grotzinger et al., 2012). Also encountered by the rover was the Peace Vallis alluvial fan (Anderson & Bell., 2009). Here the rover saw a transition between the high thermal inertia rocks, Sheepbed unit, and the low thermal inertia rocks. A shallow depression known as Yellowknife Bay is also present in the landing ellipse. The surface of this region is different from the rest of Gale, as seen so far by the rover, as it is lighter toned and flatter (Webster, G. 2013).

The surface environment of Gale Crater is dusty relative to other regions explored by rovers on Mars. This is important because dust coverage can affect the elemental concentrations determined by the APXS. The Curiosity rover has a brush (called the Dust Removal Tool, DRT) with the intended use of clearing surface dust off of rock targets before APXS analysis. The DRT was not used until sol 150, well into the mission however. In addition, operational constraints greatly limit use of the DRT and to date, only two rock targets have been brushed.

The purpose of this research was to use MAHLI images to determine the extent of dust coverage on APXS rock targets in order to better constrain its effects on APXS analyses. Other geologic features such as veins and nodules are also taken into account by this study, but due to the MSL Rules of the Road I am limited to what I can disclose in this report.

Methods

To analyze the MAHLI images for their dust coverage, the best images being a 2.5cm standoff merge, the programs ImageJ and Adobe Photoshop were used. Through ImageJ, particle counting can be accomplished and thus a percent areal coverage can be determined. In order for ImageJ to count the dust particles several steps had be to taken to make the dust particles stand out. Once these steps have been taken, ImageJ can then analyze the particles.

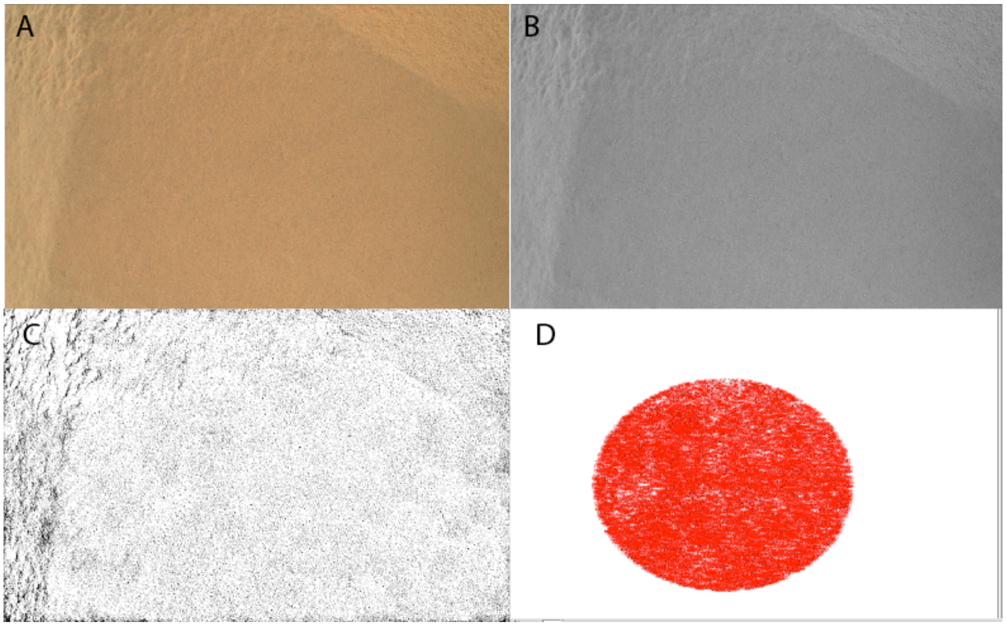

Figure 1: A) The original MAHLI image of Bathurst Inlet _ For Real.
B) The original image converted into 8-bit in ImageJ
C) Black dots represent dust particles
D) APXS field of view, red dots represent what particles were analyzed by ImageJ

A similar approach was taken to analyze the veins and nodules, however, due to the dust coverage on these features it was necessary to colour the features white. By doing so, the dust is eliminated and the full coverage of the nodules and veins can be calculated by ImageJ.

Results

The first two rock targets analyzed were Jake Matijevic and Bathrust Inlet. Jake Matijevic is a vuggy, dark coloured rock with grain sizes ranging from fine to medium and is thought to be volcanic in origin. Bathurst Inlet is light grey in colour, fine grained, and has a relatively smooth surface texture and is likely part of the surrounding bedrock (Schmidt et al., 2013).

Once a percent areal coverage for dust, nodules, and veins were obtained the next step was to plot the values against APXS data to see if any trends appeared. By looking at two ends of the dust coverage spectrum it is possible to see a likely correlation between the elemental concentration of the light elements and dust cover. Jake Matijevic, imaged on Sol 46 and 47, is approximately 10% dust covered whereas Bathurst Inlet, imaged on Sol 54, is approximately 60% dust covered. The graphs presented in figure 2 show the correlation between dust coverage and elemental weight percent. The SO_3 wt% increases with increasing dust cover whereas Cl wt% decreases with increasing dust cover.

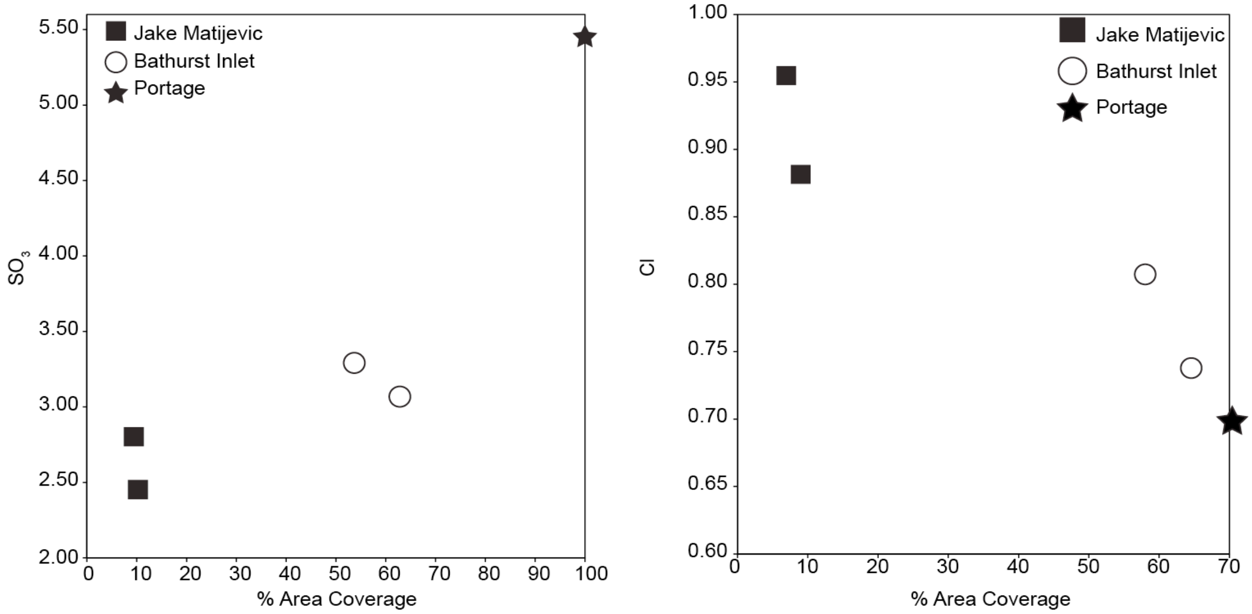

Figure 2: Graphs showing the correlation between chemical wt% and dust coverage.

Discussion

The APXS uses curium-244 to produce X-rays with which it determines elemental chemistry. However, for low atomic numbered elements these X-rays only penetrate the first 5 microns. The higher atomic numbered elements are penetrated to the first 50 microns (Gellert et al., 2009; Schmidt et al., 2013; Campbell et al., 2012). Therefore, the dust coverage on a target will affect, to some degree, the elemental concentrations of the lighter elements. For this reason, it is also important to take into account nodules and/or veins visible on the surface of the targets because these will also affect the composition readings by the APXS.

Since SO_3 wt% increases with dust cover it is likely that SO_3 is mostly contained within the dust rather than the rock. Cl wt% decreases with increasing dust coverage in this case but it does not always follow this trend making it more difficult to interpret.

Conclusion

The purpose of this research was to determine if there was any correlation between dust coverage and APXS elemental analyses of rock targets. Through the use of MAHLI images and ImageJ software a methodology was developed to determine total dust coverage on the rock targets. Comparing these dust coverage results to the chemical data, obtained by APXS analysis, correlations were determined which provide evidence that the APXS analysis, of primarily the lighter elements, is affected by dust coverage.

References

Anderson & Bell (2009). *Geologic Mapping and Characterization of Gale Crater and Implications for its Potential as a Mars Science Laboratory Landing Site.* Retrieved 09/11, 2013, from http://adsabs.harvard.edu/abs/2009AGUFM.P43D1459A

Campbell, J., et al (2012) Calibration of the Mars Science Laboratory Alpha Particle X-ray Spectometer. *Space Science Reviews,* 319.

Edgett, K., et al. (2012). Curiosity's Mars Hand Lens Imager (MAHLI) Investigation. *Space Science Reviews* , 259.

Gellert, R. et al., (2009). *The Alpha Particle X-ray Spectrometer (APXS) for the Mars Science Laboratory (MSL) Rover Mission.* 40th Lunar and Planetary Science Conference, 2364.

Grotzinger, J. et al., (2013). *Mars Science Laboratory: First 100 sols of Geologic and Geochemical Exploration from Bradbury Landing to Glenelg.* 44th Lunar and Planetary Science Conference, 1259.

Schmidt, M. et al., (2013). *APXS of First Rocks Encountered by Curiosity in Gale Crater: Geochemical Diversity and Volatile Element (K and Zn) Enrichment.* 44th Lunar and Planetary Science Conference, 1278.

Webster, G. (2013). *Curiosity Rover Explores 'Yellowknife Bay'.* Retrieved 08/26, 2013, from http://mars.jpl.nasa.gov/msl/news/whatsnew/index.cfm?FuseAction=ShowNews&NewsID=1407