ASSESSMENTS OF POTENTIAL ROCK COATINGS AT ROCKNEST, GALE CRATER WITH CHEMCAM.

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Introduction: Many locations on Mars have low color contrast between the rocks and soils due to the rocks being "dusty"—basically having a surface that is spectrally similar to Martian soil. In general this has been interpreted as soil and/or dust clinging to the rock though either mechanical or electrostic processes. However, given the apparent mobility of thin films of water forming cemented soils on Mars and at Gale Crater [e.g. 1,2], the possibility exists that some of these "dusty" surfaces may actually be coatings formed by thin films of water locally mobilizing soil/air fall material at the rock interface. This type of coating was observed by Spirit during an investigation of the rock Mazatzal which showed enhanced salts above "normal soil" [3] and an enhancement of nano phase iron oxide that was ~ 10 μm thick [4]. We decided to use ChemCam to investigate the possibility of similar rock coatings forming at the Rocknest site at Gale Crater.

ChemCam is a Laser Induced Breakdown Spectrometer (LIBS) with an integrated Remote Microscopic Imager (RMI) to provide context of where each LIBS spectra is collected. ChemCam LIBS works by firing a laser focused to a 350 and 550 μm diameter spot that produces plasma from the rock. Spectra of elemental emission lines are recorded from 240-850 nm and used to determine the elemental composition of the rock [5,6] for more details on ChemCam and data analysis].

Table 1: ChemCam Observations (Sol acquired is the last two digits of the sequence number).

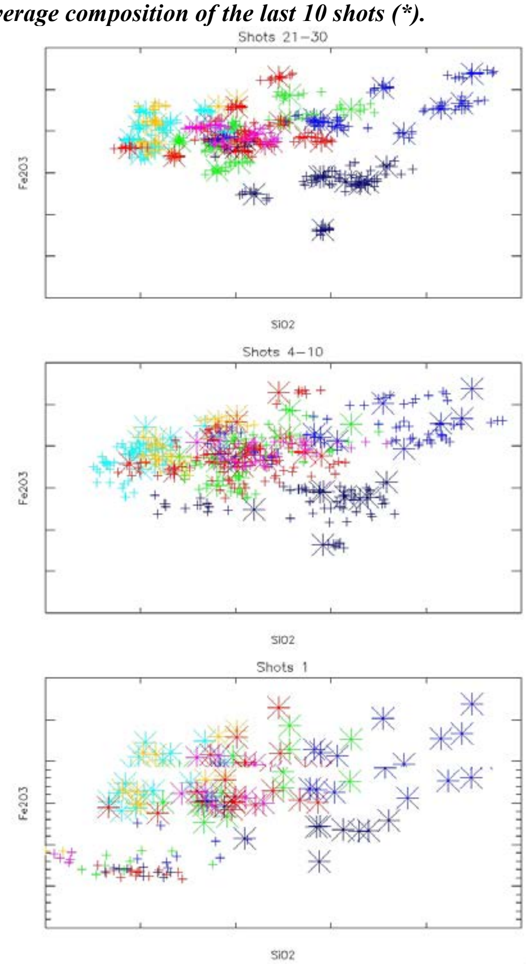
Target	Sequence	Raster Size
Peg	ccam03071	3x3
Rocknest 6	ccam01071	3x3
Rocknest 6a	ccam04087	3x3 (only 7 of 9 used in study)
Rocknest 6b	ccam05087	3x3 (8 of 9 used in this study)
Rocknest 3 Top	ccam01088	5x5 (only 1-15 used in study)
Snare	ccam01069	1x5
Walsh	ccam03079	3x3

Data Utilized: While at Rocknest, ChemCam collected elemental data on a variety of rock by collecting rasters of various sizes across rock faces. At each location a spectrum was collected for each of the 30 laser shots fired at the rock. For instance, the Peg observation consists of 270 spectra (30 shots at 9 different locations on the rock). In general, the first LIBS spectra are excluded from the averages to avoid including dust and the remaining spectra are averaged together to get a rock composition. However for this study, each individual LIBS spectrum was processed. In all 62 chemical depth profiles of 30 shots were examined in detail to determine if there was evidence for rock coatings (Table 1). Spectra with high CaO abundances are covered in depth in other papers [7] and analyses that hit soil rather than rock were are also excluded.

A chemical composition was generated from each individual spectrum using the ChemCam team standard Partial Least Squares analysis to produce an elemental oxide abundance for SiO_2 Fe_2O_3, CaO, MgO, Al_2O3, TiO_2, Na2O, K_2O, and MnO [8].

Analysis: To search for potential coatings, at each of the 62 Rocknest LIBS locations studied, the compositional average of the last 10 laser shots was calculated. To look for coatings, the averages of the Last 10 Shot Average (L10SA) was compared to: a) last 10 shots, b) shots 4-10 and c) the first shot. Figure 1 shows the results for iron and silica, which had the greatest magnitude of elemental differences between the first and last 10 shots. In general, the compositions of the last 10 shots tightly cluster around the L10SA although there is some dispersion that can be inferred as the expected variability in the rock composition or the LIBS spectra generation or in the PLS analysis. For the first shots lie significantly offset from the L10SA. While the Fe_2O_3 is relatively constant, the first shots don't cluster at a single SiO_2 composition. There is also a slight correlation with first shot silica content and average 10 shot silica content—i.e. if the average silica content is higher then the first shot silica content is higher. As would be expected, the situation for shots 4-10 is much more complex with many observations being tightly clustered around the L10SA with other offset from it. There is no uniform clustering indicating that a coating of uniform composition is present in the observations. In general the rock targets selected were chosen to have the cleanest surfaces to maximize texture information from the RMI so there may be a selection bias for rocks least likely to have coatings in the data set.

Figure 1. Variability of iron and silica at Rocknest: Peg (navy), Rocknest (green), Rocknest 6a (cyan), Rocknest 6b (gold), Rocknest 3Top (red), Snare (magenta), and Walsh (blue). Individual shot analysis (+) are compared to the average composition of the last 10 shots (*).

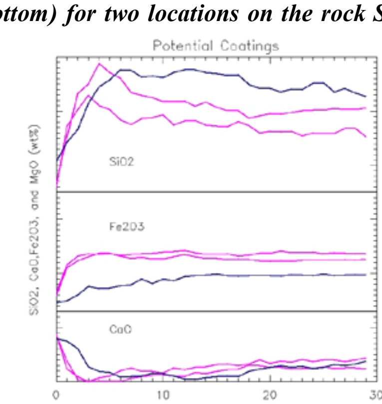


In addition to using the difference between the first and last 10 shots compositions to search for coatings, the elemental profiles were inspected individually and were classified to search for isolated example of coatings. In general, the bulk of the elemental depth profiles follow a similar pattern. The composition of the first shot differs from the bulk of the rock. This is the reason for first shots clustering off the L10SA in Figure 1. However after generally 1-3 shots, the composition approximated the L10SA. This pattern is repeated for 43 of the 62 observations. Looking at the SiO_2 trends in the rest of the observations, 11 observations had a similar shape but the number of shots required to reach the rock bulk compositions was >3, indicating a thicker layer of material covering the rock (see Figure 2, Peg). The other 8 observations showed distinctive elemental profiles that were either flat indicating uniform composition (2 observations), increased monotonically (2 observations), or showed a rise in SiO_2 content well above the L10SA before decreasing to L10SA (4 observations) (See Figure 2, Snare).

Identification of Potential Coatings: The elemental profiles in Figure 2 are consistent with thin coatings formed by localized mobilization of water near the rock surface. In the Peg example CaO and SiO_2 are anti-correlated perhaps indicating some mobile calcium phase being concentrated on the surface. This would not be surprising given the much higher CaO content found on other nearby rock surfaces and in the soil [7]. The Snare examples are consistent with a coating that has a higher Ca content in the uppermost layer (again showing a Ca and Si anti-correlation) followed by silica-rich layer. Similar trends were observed at other locations besides Rocknest [9].

These preliminary results while intriguing are not definitive evidence for coatings. The small size of the LIBS spot introduces sampling variability on a shot to shot basis as particular mineral grains can occupy a substantial fraction of the vaporized volume. Systematic issues in the data reduction such as distance corrections, baseline removal, normalization, and library choices may also affect the results. More analyses, including customized processing of observations, the examination of trace elements, identification of systematic biases, and examining other data sets to identify additional examples are being undertaken to refine / confirm these results.

Figure 2. Elemental depth profiles (SiO_2-top, Fe_2O_3-middle, CaO-bottom) for two locations on the rock Snare



(magenta) and 1 location on the rock Peg (navy) that <u>may</u> be coatings.

References: [1] Meslin this volume, [2] Goetz this volume, [3] Gellert et al, Science, 305, 2004, [4] Fleisher et al, Hyperfine Interactions, 193-198 2008, [5] Wiens et al. this volume?, [6]Maurice et al. this volume, [7] Clegg et al this volume [8] Forni et al. this volume?, [9] Lanza et al. this volume. **Acknowledgements:** This work has been conducted at the Jet Propulsion Laboratory, California Institute of Technology under a contract with the National Aeronautics and Space Administration.