CHEMCAM ANALYSIS OF AQUEOUS PROCESSES ON POLYGONAL CRACKS AT GALE CRATER, MARS.
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Introduction: Since its landing, the Curiosity rover has traversed 15 km towards the layered rocks at Mt. Sharp (also named Aeolis Mons), spending >1572 sols (Martian days) at the surface of Mars. On sol 750, the rover entered into continuous light-toned layers named the Murray Formation marking the base of Mt. Sharp. This formation is dominated by mudstones and fine-grained sandstones, interpreted to be mostly lacustrine deposits that are locally unconformably overlain by dark-toned sandstones of the Stimson Formation (deposited through eolian processes) [1,2]. The Murray formation is on the order of 200 meters thick and is formed predominantly of mudstones. These mudstones record lacustrine deposition; they contain minerals such as clays, and various sulfates found as diagenetic features [1-6]. In the last months, the rover passed along a series of well-organized cracks, forming polygonal networks similar in geometry to desiccation cracks [3] (Fig.1). The rover analyzed this outcrop from sols 1555 to 1571. We report here preliminary results from the ChemCam instrument.

Method: ChemCam is a laser ablation spectrometer that determines the chemistry of rocks over series of points with diameters close to the laser beam, ca. 0.3-0.5 mm. Chemistry is obtained quantitatively for major elements. Several volatiles are detected (H, F, etc.) but some of them only at high abundances, ca. 5-10 el. wt.% for Cl, S and P. A series of 15 targets totalizing 110 individual points were analyzed enabling a detailed assessment of the rock diversity and of the material filling cracks. The ChemCam/Remote Micro-Imager (RMI) enables a detailed image of the target at a scale reaching 40 μm/pixel at 2 m, showing the location of the laser shots, which is an important constraint for the interpretation of the texture.

Results: The polygonal cracks cut a red-toned surface relatively homogeneously with cracks spaced by 1 to 5 cm (Fig. 1). They display a random orthogonal geometry with frequent T-shaped intersection (Fig. 1). Most of the polygons are limited by prominent dark ridges (1-4 mm in width) locally cut in the center by a smaller light-toned vein (right of point 1 in Fig. 1, bottom). Larger cracks are systematically filled by white material (4-10 mm in width).

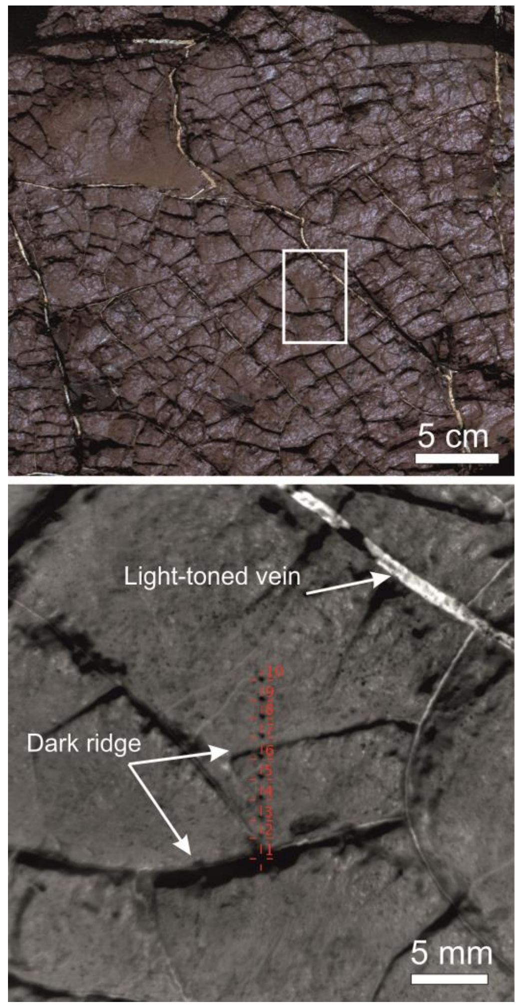


Figure 1: Mastcam image of the polygonal cracks observed on sol 1555 (top). ChemCam/RMI image of the area in white rectangle of the MastCam image (bottom). Red numbers indicate cavities of the ten points ablated by the laser at this location.

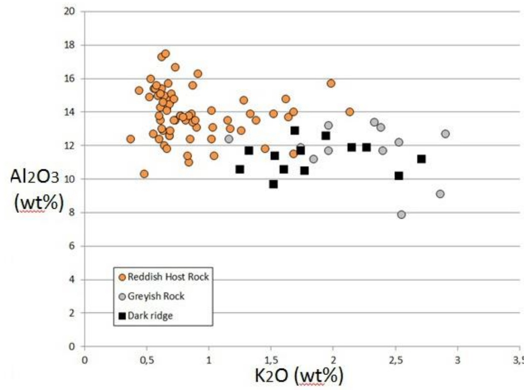
The chemistry of large, light-toned cracks indicates a strong enrichment in Ca, S and H. These characteristics are typical of Ca-sulfates as observed extensively along the rover traverse [5,6,7]. The smaller light-toned veins are also composed of Ca-sulfates. Compared to the red-toned host rock, the dark ridges show a distinct composition, especially an enrichment in K_2O (2-3 wt.%), which is correlated to a depletion of most cations, especially Al_2O_3 and SiO_2. This trend suggests that the enrichment in K_2O is not related to feldspars (Fig. 2). Hydrogen is systematically enhanced on these dark ridges. Other volatiles are not clearly detected but two points on ridges display putative sulfur lines.

The analysis of the bedrock on eroded areas (a few cm of section of subhorizontal layers) enabled identification of three distinct compositions, from bottom to top: (1) The lowermost light-toned layer is enriched in Ca and S, but it does not show any diagenetic features, thus suggesting a cementation by Ca-sulfates as observed in several examples along the rover traverse [8]; (2) The layer above, which is just beneath the surface, is grey-toned and includes higher K_2O (2-2.5 wt.%), as well as high emission lines of H, which are characteristics similar to dark ridges; (3) The red-toned rock at the surface is close to the usual composition of Murray mudstones with slightly higher MgO abundance.

Discussion and conclusion: A main interest of these results is that dark ridges filling cracks and the greyish layer below the surface display similar variations in Al_2O_3 and K_2O (Fig. 2). Both also display a slight increase in FeOT. Assuming sulfur to be present, K-sulfates, including K-jarosite, can reasonably explain the variations observed for both types of material (Fig. 2 bottom). Alternatively, K-chlorides or K-perchlorates could also explain these variations although no Cl was detected by ChemCam. Phyllosilicates, such as illite locally detected by CheMin in Murray mudstones [9,10], are ruled out by this diagram (Fig. 2). The spatial relationships between the K-enriched dark ridges and the layer underlying the reddish surface suggest that the cracks were initially filled by this underlying layer, either physically by fluid injection or chemically by dissolution and precipitation.

In addition, the presence of a Ca-sulfate rich layer immediately below the K-rich rock points towards a strong episode of brine activity. Indeed, jarosite is known to follow Ca-sulfates in the sequence of crystallization of S-rich salts when conditions become more acidic [e.g., 11], and any alternative K-chlorides would also fit this explanation.

Polygonal cracks with the geometry observed are due to the decrease of volume of a given layer. This shrinkage can occur for various reasons: (1) Desiccation of mud at the surface; (2) Subaqueous dehydration of clays (synaeresis); (3) Fluid expulsion during diagenesis. While desiccation cracks are usually filled from above with mud or sand, synaerisis or diagenesis can explain filling from below. Nevertheless, the presence of brines in connection with cracks suggests a genetic link that complicates their relationships. Indeed, crack filling composition may have been modified during fluid circulation and brines precipitation. These results are preliminary constraints toward a more in-depth characterization of the formation of these polygonally fractured rocks similar to terrestrial mud cracks [3]. Whether formed at the surface as mud cracks, below water or during burial, they indicate active aqueous processes during, or shortly after the deposition of the Murray mudstones.



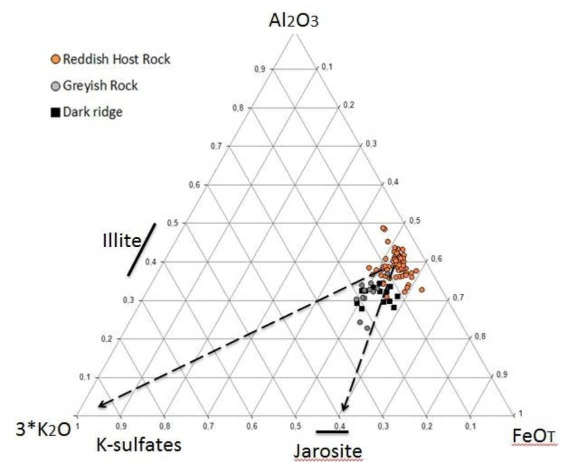


Figure 2: (top) Al_2O_3 vs K_2O on dark ridges filling cracks compared to the reddish surface layer and the underlying greyish layer. (bottom) Al_2O_3-K_2O-FeO ternary diagram with 3 times enhanced K_2O abundance for better visibility.

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