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Diagenetic Processes in Sedimentary Rocks At Gale Crater, Mars, Using Chemcam, Curiosity Rover

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Abstract

After > 17 km of traverse, the Curiosity rover reached a local topographic high named Vera Rubin ridge (VRR). VRR is characterized by a hematite signature in orbital spectra [1]. We describe the chemistry of diagenetic features using the ChemCam instrument to understand the post-depositional history of aqueous sedimentary rocks. These new observations display the significant role played by ground water circulation and diagenesis in the mobility and distribution of iron in the Vera Rubin Ridge, highlighted here by reducing fluids observed late in the sequence of diagenesis.

1. Introduction

The Curiosity rover has traversed 20 km from its landing to the layered rocks of Mt. Sharp (formally named Aeolis Mons), spending >2400 sols (Martian days) at the surface of Mars. The Murray formation, a >300 m-thick pile of sedimentary rocks present at the base of Mt. Sharp, is dominated by mudstones and fine-grained sandstones interpreted predominantly as lacustrine deposits [2]. On sol 1800, after > 17 km of traverse, the Curiosity rover reached a local topographic high named Vera Rubin ridge (VRR). VRR is characterized by a hematite signature in orbital spectra [1].

2. Dataset

The ChemCam instrument is a laser ablation spectrometer capable of measuring local chemistry (scale of ~0.3-0.5 mm), thus powerful for identifying the composition of diagenetic features such as veins and concretions. Chemical quantifications for major elements are obtained using a multivariate analysis technique, which compares Mars spectra to those a laboratory database obtained on 450 rocks and minerals [3-4]. As volatiles (H, S, Cl, C, P, etc.) are not quantified, a systematic inspection of spectra of diagenetic targets is needed to identify the presence of volatiles.

3. Results

Within the Murray formation, diagenetic features encountered included pervasive assemblages of mm- to cm- wide, light-toned veins, and local presence of bleached haloes along fracture zones, dark veins and concretions. While light-toned veins are systematically composed of Ca-sulfates such as bassanite [5-6], more local features include composition as Mg- and Fe-sulfates, silica, fluorite-rich veins, P-rich concretions, Fe-oxides, indicative of multiple episodes of fluid circulation [5-7], indicating local variations in fluid chemistry. At VRR, Anomalously high Fe detections were observed on local dark-toned features (Fig. 1).

Figure 1: Fe relative content (red lines) for each ChemCam sample location at the target Rhynie, a dark feature illustrating associations of high Fe with low Fe in the surrounding bleached, light-toned halos.

The chemical compositions of all these dark-toned diagenetic features are summarized in ternary diagrams in Fig. 2 (in molar percentages, based on quantified oxide weight percent reported by ChemCam). Dark-toned features, including dark-toned material within crystal-shaped features, show a composition dominated by an enrichment in Fe to the detriment of other major elements (notably Si, Al, Mg, K and Na) compared to the host rock compositions. High-Fe observations are not associated with detection of volatile content (S, Cl, P or C). The H emission line is also very low, thus pointing toward poorly hydrated Fe-oxide mineralogy, such as crystalline hematite. In contrast, the bleached halo has a very low FeO abundance (6-10 wt.%) compared to other VRR host rock observations (18-22 wt.%). Interestingly, lower Fe abundances are not correlated with depletion in any other major elements, which preserve the same relative abundances, except for MnO which is also strongly depleted.

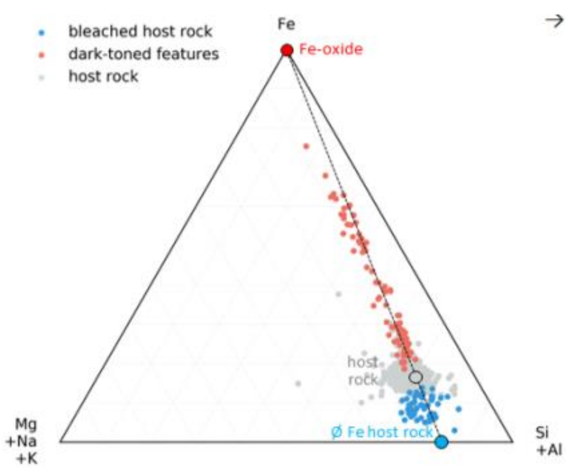

Figure 2: Ternary diagrams showing ChemCam quantified abundances (molar percentages) for major elements: dark-toned features (in red) are associated with very high Fe content, trending toward a pure Fe composition, contrasting with low-Fe observations on bleached light-toned halos such as that observed around Rhynie (Fig. 1).

4. Discussion and Conclusion

Associations of high FeOT abundances and Ca-sulfates were previously observed by ChemCam at several locations along the rover traverse [8]. Here, the Fe enrichments in the VRR are also encountered alongside light-toned Ca-sulfate veins, but they are connected to locations depleted in FeOT and MnO abundances without depletions of other major elements, suggesting reducing fluids. These new observations highlight the significant role played by ground water circulation and diagenesis in the mobility and distribution of Fe in the Vera Rubin Ridge, highlighted here by reducing fluids observed late in the sequence of diagenesis. In this context, the presence of hematite in the “red outcrops” presumably preceded this reducing phase, but its formation by depositional or early diagenetic processes remains unknown.

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