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Sulfate calcium veins observed by the ChemCam instrument onboard Curiosity

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1. Introduction

The ChemCam (Chemistry and Camera) instrument suite onboard the Mars Science Laboratory (MSL) rover, Curiosity, consists of a Laser-Induced Breakdown Spectroscopy (LIBS) instrument, which provides punctual elemental composition information at the scale of grains (the ablation cavity is typically around ½ mm), and an imager (Remote Micro-Imager, RMI), which provides context imaging [1,2]. This instrument performed remote elemental and imaging analyses of rocks and soils along the route, from Bradbury landing site to Glenelg, through the hummocky terrain. The following work focuses on observations made at Yellowknife Bay, located at the lowermost point of the alluvial fan accumulated downstream of Peace Vallis.

2. High calcium phase with ChemCam LIBS data

ChemCam is able to detect a series of 20 to 30 distinct elements including all major and several trace elements, such as metals (Fe, Ti, Mn, etc.), alkaline and subalkaline elements (Na, K, Ca, Mg), and volatiles (H, C, S, Cl). However, the detection of salts anions (such as S, Cl) is difficult with LIBS unless the material is strongly enriched in these elements.

At Rocknest, an eolian bedform located at the edge of the hummocky terrain, several points rich in calcium were observed in local rocks. Calcium was anti-correlated with other cations and also silica, showing the presence of a non-silicates phase [3]. As no carbon enhancement was detected, the presence of carbonates was discarded. The calcium rich phase was nevertheless not pure, and the detection of sulphur and chlorine lines initially unclear for a final conclusion. In the absence of definitive detection of these elements, this material was interpreted as possible anhydrite ($CaSO_4$), with apatite and perchlorate as possible calcium bearing material alternatives. This material was not hydrated.

Arriving at Yellowknife Bay, ChemCam has detected material with relative uniform composition and strong enrichment in calcium (30wt% CaO or more). Careful inspection of the spectra shows the presence of weak peaks of sulfur, correlated to the increase in calcium. Several spectra are almost devoid of any other elements pointing toward pure calcium sulfates as an explanation for this unique composition. On the other hand, hydrogen is found to be present on several of these spectra, suggesting hydrated calcium sulfates, such as gypsum ($CaSO_4.2H_2O$) and/or bassanite ($CaSO_4.1/2H_2O$).

3. RMI observations

RMI observations of these LIBS points are fundamental for the understanding of the context of formation of this material. These images show that most of the sulfates correspond to thin light-toned veins crisscrossing into the sediment. Veins are typically several mm to 1 cm thick and display lengths of several tens of cm. No sulfates were detected in the surrounding sediments.

4. Context and implications

On Earth, veins filled by sulfates are typical of sediments crossed by fractures filled by fluid flows. Fractures are then filled with precipitating salts. This phase is usually observed in late stages of deposition or diagenetic processes during burial. The fact that veins cut most of the sediments shows that they are not directly associated with a depositional layer, but with fluid flows during diagenesis (burial). In contrast to the Fe- and Mg-rich sulfates observed extensively in the equatorial regions [4], and especially at Meridiani Planum [5], calcium sulfates form in relatively mild water and dilute flow. These observations demonstrate that the sediments at Yellowknife Bay were submitted to strong aqueous circulation in the close subsurface and in relatively neutral pH conditions.

References

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