

DIAGENETIC FEATURES ANALYZED BY CHEMCAM/CURIOSITY AT PAHRUMP HILLS, GALE CRATER, MARS.

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Introduction : Onboard the Mars Science Laboratory (MSL) Curiosity rover, the ChemCam instrument consists of : (1) a Laser-Induced Breakdown Spectrometer (LIBS) for elemental analysis of targets [1;2] and (2) a Remote Micro Imager (RMI), which provides imaging context for the LIBS [3]. The LIBS/ChemCam performs analysis typically of spot sizes 350-550 μm in diameter, up to 7 m from the rover [1].

Within Gale crater, Curiosity traveled from Bradbury Landing toward the base of Mount Sharp, reaching Pahrump Hills outcrop circa sol 750. This region, as seen from orbit, represents the first exposures of lower Mount Sharp. In this abstract we focus on two types of features present within the Pahrump Hills outcrop : concretion features and light-toned veins.

Concretions : At Pahrump, Curiosity detected a type of cluster-like (sometimes ramified/dendritic) feature that stands out some millimeters from the country rock, but appears to be embedded in it [4;5]. They are the same color as the surrounding sediment and display a very fine-grained texture.

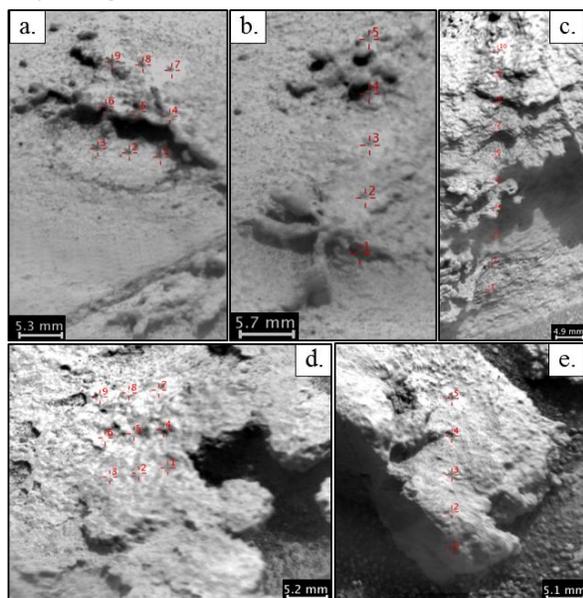


Figure 1 : RMI images of different types of concretion features observed at Pahrump and analyzed by ChemCam (red locations).

ChemCam analyzed several of these millimeter-to-centimeter-long features (Figure 1a,b.). The typical ChemCam analysis of ~ 30 laser shots at the same point allows dust removal and provides “depth-profile” analysis of the underlying target composition. As compared to the surrounding sediments, these features display a clear enhancement in magnesium, that does not appear to correlate with iron content, nor with Si. In terms of minor elements, they display sulfur peaks (Figure 2), and nickel may be above the usual level of detection (~ 1000 ppm), though this is still under investigation. H signal is present, but decreases with depth.

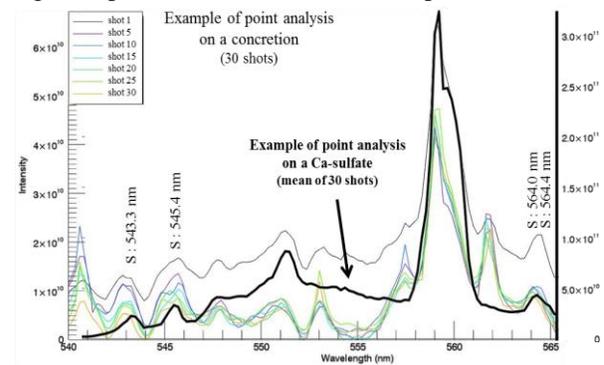


Figure 2: Sulfur detection within the shots of a ChemCam point analysis on a cluster-like resistant feature at Pahrump. The mean spectra (30 shots) of a local light-toned vein is also displayed (with its intensity scale on the right).

Other types of concretion features were analyzed, among which an aggregate feature (Figure 1d) which displays one point with significant iron-enrichment compared to the other points and to the country rock, as well as reduced silicon, magnesium, titanium ; hydrogen signal is present but decreases with depth. Another target (Figure 1a) displays several higher iron points.

Light-toned veins : At Pahrump, multiple light-toned veins, usually millimeter to centimeter in width (Figure 3) and cm to decimeter long, were observed by Curiosity. Their compositional analysis by ChemCam shows a clear detection of sulfur as well as enhanced calcium (Figure 2), compared to the host rock.

One target analyzed by ChemCam (Figure 3c) displays a vein with quite « fibrous » (rectilinear) texture on the top of the RMI image, and more “chicken wire like” (circular) texture on the bottom.

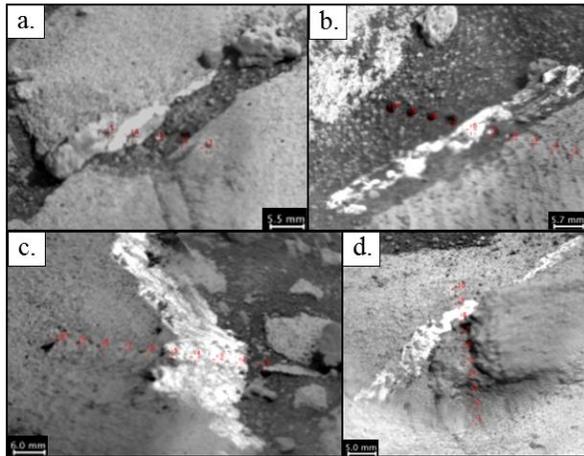


Figure 3 : RMI images of light-toned veins analyzed by ChemCam (red locations) at Pahrump Hills.

Localization and geological settings : The basal fractured platy unit on which Curiosity drove at Pahrump Hills’ entrance displays light-toned veins that crisscross in these mudstones in a variety of orientations ; cluster-like concretions are also present [4;5]. An example target imaged by MAHLI displays a fine light-toned vein criss-crossing a cluster-like resistant feature quite sharply, suggesting (at least in this particular case) that the veins were emplaced after the cluster-like features formed.

Stratigraphically-upper laminated faciès also present light-toned material, in the form of fine veins cutting the stratification, and sometimes present inter-layers. Cluster-like concretions mentioned above are not observed up to now, but more nodular-like features are present, on the top and at the edges of the laminations.

Discussion : Along Curiosity’s ~10 km traverse (Figure 4), the ChemCam instrument analyzed a series of light-toned veins (roughly 30 at Yellowknife Bay [6], 15 up to before Pahrump Hills, and nearly 10 since). It has to be noted that these analyses are a sample of the light-toned veins present and observed [7], since ChemCam did not target every vein. The roughly 100 ChemCam laser points analyses on these veins all display sulfur peaks and calcium enhancement, leading to the interpretation that all of them contain a (more or less pure) calcium sulfate phase. Their more detailed compositional variation is still under investigation.

In terms of concretions, the most detailed observations previously reported at Gale correspond to nodules, hollow nodules [8], and raised-ridges [9], all at Yellowknife Bay [10]. The raised ridges had enhance-

ments in Mg, but showed no presence of S ; this was interpreted to be related to a clay deposit (like smectites) [9]. At Pahrump Hills, within the cluster-like concretions, the S-detection related to the enhanced Mg and associated with the Ni-detection could be related to sulfates or sulfides.

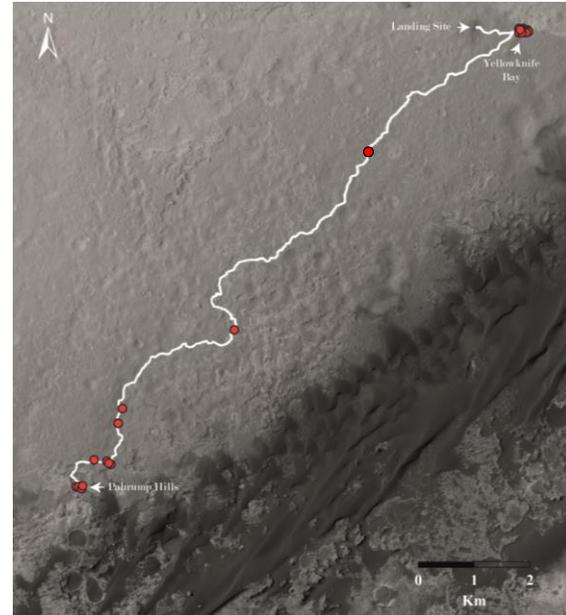


Figure 4 : Curiosity’s route on HiRISE image and localization of light-toned veins analyzed by ChemCam (red dots).

Given the distinct classes of concretions analyzed up to now through the Pahrump Hills stratigraphy, the precise mechanism that led to their formation, as well as their nucleation origin etc, is still under investigation. The distinct compositions analyzed by ChemCam could suggest heterogeneity within the initial deposition of the sediments, or be related to distinct formation events or processes. Further ChemMin drill analysis are expected to constrain the understanding of these features’s mineralogy. Light-toned veins are present within the stratigraphic units analyzed up to now, and appear to record a later event of fluid circulation.

Acknowledgments: the first author acknowledges funding by OSUNA, France.

References : [1] Maurice *et al.*, Space Sci. Rev. 170, 95-166, 2012. [2] Wiens *et al.*, Space Sci. Rev., 170, 167-227, 2012. [3] Le Mouélic *et al.*, Icarus, 2014. [4] Stack *et al.*, this meeting. [5] Kah *et al.*, this meeting. [6] Nachon *et al.*, JGR, 10.1002/2013JE004588, 2014. [7] Rachel *et al.*, this meeting. [8] Stack *et al.*, GSA, 2013. [9] Lèveillé *et al.*, JGR, 119, 2398–2415, 2014. [10] McLennan *et al.*, Science, 2013.