

## Diagenetic features analysed by ChemCam/Curiosity at Pahrump Hills, Gale crater, Mars

M. Nachon(1) N. Mangold(1) A. Cousin(2) O. Forni(2) R. B. Anderson(3) J.G. Blank(4) F. Calef(5) S. Clegg(6) C. Fabre(7) M. Fisk(8) O. Gasnault(2) L.C. Kah(9) R. Kronyak(9) J. Lasue(2) P.-Y. Meslin(2) S. Le Mouélic(1) S. Maurice(2) D.Z. Oehler(10) V. Payre(7) W. Rapin(2) D. Sumner(11) K. Stack(5) S. Schröder(2) R.C. Wiens(6) and the ChemCam Team. (1) LPGNantes, Univ. Nantes/CNRS, France, [marion.nachon@univ-nantes.fr](mailto:marion.nachon@univ-nantes.fr) (2)IRAP, Toulouse, France (3)USGS, Flagstaff, USA (4)Space Inst. of Sci. & Ames Res. Cent., USA (5)JPL, Caltech, USA (6)LANL, USA (7) GeoRessources, Nancy, France (8)Oregon St., USA (9)Uni. of Tennessee, USA, (10)Johnson Sp. Cent., TX, USA (11)Uni. of California, Davis, USA.

### Abstract

At Pahrump Hills, the ChemCam instrument observed unique chemical signatures on a diversity of diagenetic features.

### 1. Introduction

Onboard the Mars Science Laboratory (MSL) Curiosity rover, the ChemCam instrument suite consists of : (1) the first Laser-Induced Breakdown Spectrometer (LIBS) flown on a planetary mission, which provides elemental composition of targets up to 7 m from the rover [1;2] and (2) a Remote Micro-Imager (RMI) for grayscale imaging context of the small (350-550  $\mu\text{m}$  diameter) LIBS points [3]. Within Gale crater, Curiosity traveled from Bradbury Landing toward the base of Mount Sharp, reaching the Pahrump Hills outcrop circa sol 750. This area, as seen from orbit, seems to represent the first exposures of lower Mount Sharp [4].

### 2. Observations

Here we report analyses on features present at Pahrump Hills outcrop : (1) cluster-like/dendritic features and (2) light-toned veins.

#### 2.1 Cluster-like/dendritic features

At Pahrump, Curiosity observed a type of cluster-like (sometimes ramified/dendritic) feature, protruding several millimeters from the country rock, but appearing to be embedded in it [4;5]. They are the same color as the surrounding sediment (confirmed by MastCam and MAHLI imagers) and display a very fine-grained texture. ChemCam analysed four 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 cluster-like features display a clear enhancement in Mg that does not appear to correlate with Fe content, nor with Si. They display sulfur peaks (Figure 2), and nickel may be above the usual level of detection, though this is still under investigation.

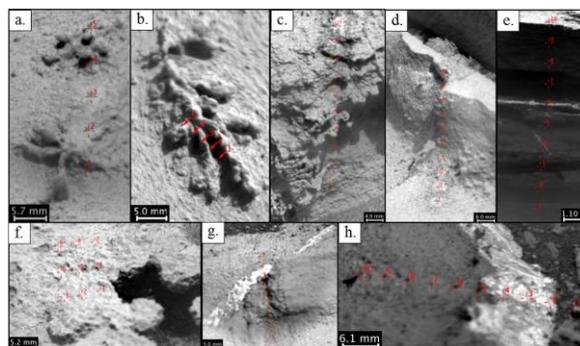


Figure 1 : ChemCam/RMI images of different types of diagenetic features observed at Pahrump and analyzed by ChemCam/LIBS (red locations).

#### 2.2 Other diagenetic features

Other types of features embedded in the local host rock were analysed by ChemCam : (a) Nodular/globular surface exposure (b) A raised feature (Figure 1c) that shows Fe-enhancement. (c) Resistant structures (Figure 1d) that could represent fracture fills. (d) An aggregate feature (Figure 1f) which displays one point with significant Fe-enrichment compared to the other points and to the country rock, as well as weaker Si, Mg, Ti ; the presence of S and Na suggests Na-jarosite, or Fe-sulfates mixed with a Na phase.

## 2.3 Light-toned veins

At Pahrump Hills, multiple light-toned veins, usually millimeter to centimeter in width (Figure 1e,g,h) and cm to decimeter long, were observed. Their compositional analysis by ChemCam shows a clear detection of sulfur (Figure 2) as well as enhanced calcium, compared to the host rock.

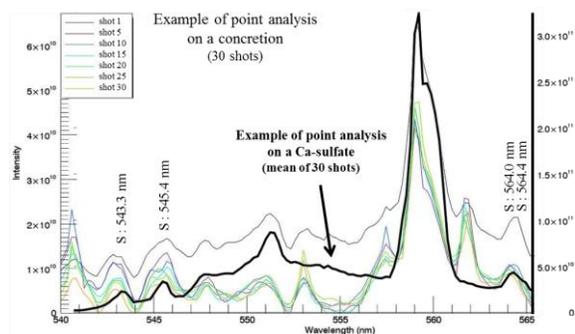


Figure 2: Sulfur detection within the shots of a ChemCam point analysis on a cluster-like resistant feature at Pahrump. The mean spectra (30 shots) of a local light-toned vein is also displayed (with its intensity scale on the right).

One Ca-rich vein (Figure 1h) displays a « fibrous » (rectilinear) texture in the upper portion of the RMI image, and more “chicken wire like” (circular) texture on the bottom. One analysis on a vein displays low Si, clear S peaks, stronger Ca and Mg signal, as well as strong H signal, suggesting the presence of both Mg- and Ca-sulfates.

## 2.4 Localization and geological settings

The basal fractured platy unit on which Curiosity drove at Pahrump Hills’ entrance displays light-toned veins that crisscross the 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 clearly criss-crossing a cluster-like resistant feature, suggesting (at least in this particular case) that the veins were emplaced after the cluster-like features formed.

Laminated faciès located in one of the higher stratigraphic units of Pahrump Hills also present light-toned material, in the form of fine veins cutting the stratification, and sometimes present inter-layers. Cluster-like concretions mentioned above were not observed up at this location, but more nodular-like

features were present, on the top and at the edges of the laminations.

## 3. Discussion

In terms of diagenetic features, the most detailed observations previously reported at Gale correspond to nodules, hollow nodules [6], raised-ridges [7], and light-toned veins [8], all at Yellowknife Bay [9]. The raised ridges had enhancements in Mg, but sulfur was not detected; this was interpreted to be related to a smectite-clay deposit [7].

At Pahrump Hills, within the cluster-like features, the S-detection related to the enhanced Mg and associated with the Ni-detection could be related to sulfates or sulfides. Given the diversity of other diagenetic features (nodular/globular, aggregates) analysed by ChemCam through the Pahrump Hills stratigraphy, and given their distinct compositions, the precise mechanism(s) that led to their formation is still under investigation.

Along Curiosity’s ~10 km traverse from Bradbury Landing towards Yellowknife Bay [8] and up to Pahrump Hills, ChemCam has analysed more than 50 light-toned veins. All display calcium enhancement and sulfur, 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. Light-toned veins appear to record a later event of fluid circulation.

## Acknowledgements

We acknowledge the MSL and ChemCam engineering and scientific Team. The first author acknowledges PhD 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, 249, 93-107, 2015.
- [4] Stack *et al.*, LPSC 2015.
- [5] Kah *et al.*, LPSC 2015.
- [6] Stack *et al.*, GSA, 2013.
- [7] Lévillé *et al.*, JGR, 119, 2398–2415, 2014.
- [8] Nachon *et al.*, JGR, 10.1002/2013JE004588, 2014.
- [9] McLennan *et al.*, Science, 2013.