Probing crystalline and amorphous phases at Yellowknife Bay, Gale crater, Mars: comparison of ChemCam LIBS data with CheMin XRD results

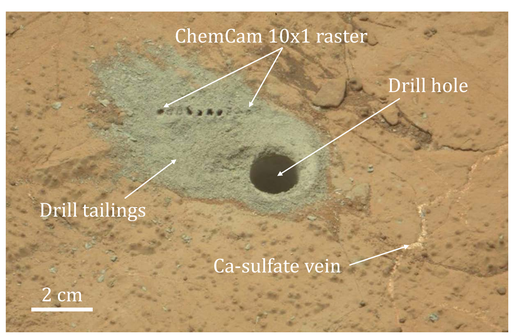
Erwin Dehouck[1], P.-Y. Meslin[1], O. Gasnault[1], A. Cousin[1], O. Forni[1], W. Rapin[1,2], S. Maurice[1], R. C. Wiens[3], M. Salvatore[4]

[1]*Institut de Recherche en Astrophysique et Planétologie (IRAP), Toulouse, France*
[2]*Div. Geological & Planetary Sciences, California Institute of Technology, Pasadena, CA, USA*
[3]*Los Alamos National Laboratory (LANL), Los Alamos, NM, USA*
[4]*University of Michigan-Dearborn, MI, USA*

erwin.dehouck@irap.omp.eu
@ErwinDehouck

Introduction

- The Mars Science Laboratory (MSL) rover *Curiosity* carries a unique suite of scientific instruments capable of characterizing both the chemistry and mineralogy of soils and rocks encountered at Gale crater. This suite includes:
  - the **ChemCam LIBS instrument** [1,2]
  - the Alpha-Particle X-ray Spectrometer (APXS) [3]
  - the CheMin X-ray diffractometer (XRD) [4]
- In this study, we compare chemical trends observed in small-scale (≤500 µm) LIBS measurements from ChemCam with bulk crystalline and amorphous compositions derived from CheMin and APXS data, with the following objectives:
  - to get insights into some **physical properties** of the targets (grain size, homogeneity, coatings, etc.)
  - to identify minor **mineral phases** undetected by XRD
  - to better constrain the chemical composition (and thus the nature and origin) of the **amorphous component**

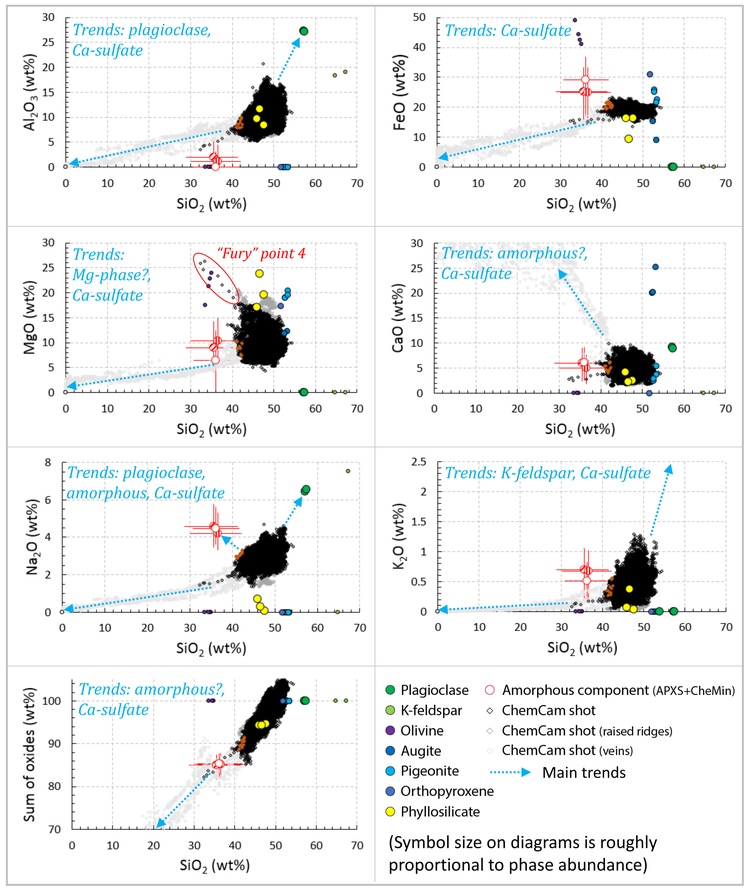


← *MastCam image of the second drill hole (named Cumberland) made by Curiosity into the Sheepbed mudstone*
NASA/JPL-Caltech/MSSS

Data and methods

- Here we present ChemCam shot-to-shot data of all targets from the **Sheepbed and Gillespie Lake members** of the Yellowknife Bay formation (sols ~120 to 300) [5]
- The first 5 shots of each analysis point are ignored in order to remove the contribution from the **dust**; in addition, **Ca-sulfate veins** [6] and **Mg-rich raised ridges** [7] are plotted separately
- The composition in major oxides was calculated for each LIBS spectrum based on a set of known samples [8]
- The mineralogy of the Sheepbed mudstone was determined by CheMin at two drill sites named John Klein and Cumberland [9], and the composition of the amorphous component was estimated through **mass balance calculations** [10]

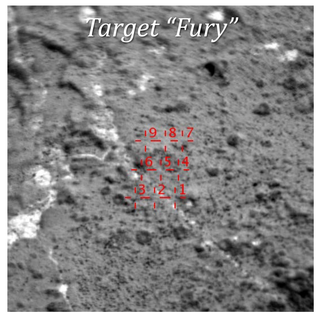
Preliminary results

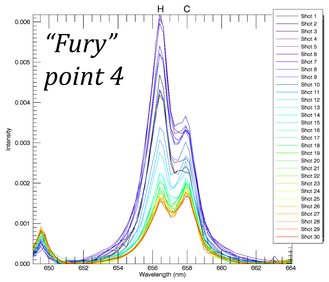


↑ *Oxide vs SiO_2 diagrams showing ChemCam shot-to-shot analyses of all Sheepbed targets [5], compared to crystalline phases identified by CheMin and estimated amorphous compositions (for 3 different smectites) [9,10]*

Comparison with CheMin mineralogy

- Crystalline phases are **intimately mixed** at the LIBS scale (no pure endmember sampled except Ca-sulfate in veins); however, trends are observed towards major mineral phases, mainly plagioclase
- Besides veins [6] and raised ridges [7], very few data points display outside of the point cloud, which suggests the **lack of coarser grains**; one exception is the target "Fury" (sol 188), which displays a series of high-Mg, high-H, low-Si compositions, suggesting the presence of a **Mg-sulfate, Mg-perchlorate or Mg-carbonate** grain



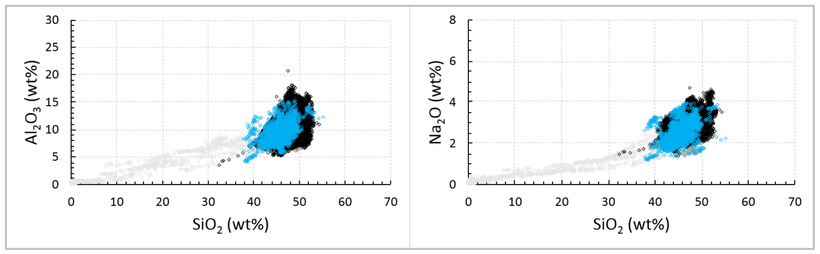


Comparison with estimated amorphous compositions

- Because the amorphous component is at least as abundant as plagioclase [9,10], one might expect to also observe trends towards its composition in ChemCam data (depending on the size of amorphous grains/aggregates)
- The Na_2O vs SiO_2 diagram shows a small trend towards **low-Si, high-Na compositions** that could correspond to the amorphous component; these compositions are also consistent with the amorphous component in other diagrams (brown points)

Comparison between the Sheepbed mudstone and the Gillespie Lake sandstone

- ChemCam shot-to-shot data show a similar dispersion between Sheepbed and Gillespie Lake members, which suggests that even though Gillespie Lake is coarser-grained (fine to medium sandstone), the difference compared to the mudstone is **not significant at the LIBS scale**



↑ *Comparison between ChemCam shot-to-shot analyses of the Sheepbed mudstone (black) and the Gillespie Lake sandstone (light blue)*

Summary and future work

- The systematic comparison between ChemCam shot-to-shot data and CheMin XRD results reveals several **compositional trends** towards major mineral phases (plagioclase, amorphous component)
- This approach also helps highlight **peculiar compositions** within an otherwise homogenous outcrop
- We plan to apply this approach to **other sampling sites at Gale crater**, with a priority to those with a high proportion of amorphous component and/or a coarser grain size

References: [1] Maurice S. et al. (2012) *Space Sci. Rev.*, 170, 95–166. [2] Wiens R. C. et al. (2012) *Space Sci. Rev.*, 170, 167–227. [3] Campbell J. L. et al. (2012) *Space Sci. Rev.*, 170, 319–340. [4] Blake D. F. et al. (2012) *Space Sci. Rev.*, 170, 341–399. [5] Mangold N. et al. (2015) *JGR-Planets*, 120, 452–482. [7] Nachon M. et al. (2014) *JGR-Planets*, 119, 1991–2016. [7] Léveillé R. et al. (2014) *JGR-Planets*, 119, 2398–2415 [8] Clegg S. M. et al. (2017) *Spectrochim. Acta Part B*, 129, 64–85. [9] Vaniman D. T. et al. (2014) *Science*, 343. [10] Dehouck E. et al. (2014) *JGR-Planets*, 119, 358-382.