EPSC Abstracts
Vol. 9, EPSC2014-316, 2014
European Planetary Science Congress 2014

Two years of ChemCam exploration at Gale Crater, Mars.

J. Lasue (1), O. Gasnault (1), S. Maurice (1), R.C. Wiens (2), the ChemCam Team and the MSL Science Team
(1) IRAP-OMP, CNRS-UPS, Toulouse, France (jlasue@irap.omp.eu / Fax: +33-561-558692), (2) LANL, NM 87544 USA.

Abstract

Gale crater exploration with MSL and ChemCam has revealed many new findings on Mars' igneous diversity, on the sources and history of sedimentary rocks, and on Mars soils and weathering.

1. Introduction

Gale crater was selected as the Mars Science Laboratory (MSL) landing site based on the orbital detection of a variety of fluvial and alteration features (alluvial fan, flow channels, sulfates, phyllosilicate and hematite spectral signatures), the combination of which strongly indicates the presence of a potentially previous habitable environment. The sedimentary chemistry on Mars show little major element mobility, allowing Curiosity's chemical measurements to reflect the precursor igneous materials which are very different from previous landing sites, as witnessed by float rocks along the traverse. Curiosity's sensitivity to light elements such as H, Li, and F provide important insights into primary source rocks, alteration, and habitability.

ChemCam is a Laser-Induced Breakdown Spectroscopy (LIBS) instrument accompanied by a Remote Micro-Imager (RMI). This enables the MSL team to measure the chemical composition of geological targets without preparation, on a very fine scale (350 to 550 µm) and at a distance from the rover (2 to 7 m) [9, 16]. Since the beginning of the mission, ChemCam has analyzed >130,000 spectra on > 4,000 observation points, supported by > 2,000 RMI images, and APXS obtained a significant number of observations. This work reviews the geochemistry observed over the first two years of exploration and its implications for martian igneous and sedimentary processes and potential habitability.

2. Igneous precursors at Gale

The first measurements, made directly at the landing site, clearly showed coarse-grained igneous rocks unlike any seen before on Mars (*e.g.* Peacock Hill, sol 19; also Fig. 1 and [13]). The mean ChemCam compositions for Bradbury Rise dust-free rocks and pebbles (62 locations) give SiO_2 = 56%, FeO_T = 16% and show high alkalis consistent with Jake Matijevic (sol ~47) APXS Na_2O ~6.6 wt.%. ChemCam measured Rb > 150 ppm and Sr > 1500 ppm on the conglomerate Link (sol 27) [12], while spectra indicated plagioclase grains [1]. These observations imply the presence of abundant alkali feldspars in the lower parts of Gale crater. They are generally consistent with the more feldspar-rich SNC meteorites but show a radical departure from larger scale orbital observations.

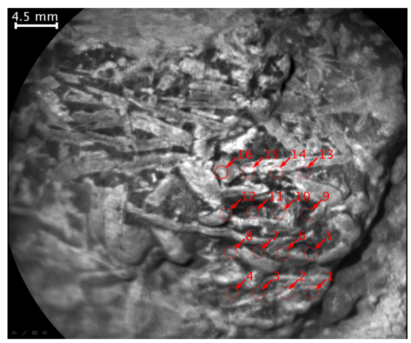

Figure 1: Harrison (sol 514), fluorine-bearing feldspar-rich clast embedded in conglomerate representative of evolved martian magma (CR0_443119527_CCAM02514).

The primary mafic minerals are pyroxenes; olivine being uncharacteristically low relative to previous landing sites and no individual olivine were clearly observed so far. The RMI has imaged impressive feldspar cumulates (Fig. 1), originating either from very thick lava flows or more likely from a magma chamber. Fluorine-bearing minerals detected in > 60 ChemCam observations provides further evidence for evolved magmas [4]. No supporting high Cl was detected with F, and the overall compositions strongly imply fluorapatite and fluorite.

The overall understanding of Mars has been that it had a largely mafic, minimally evolved crust. The current Gale findings strongly suggest otherwise, but the extent of evolved magmas is still unknown.

3. Sedimentary materials analyses

Sediments in Gale appear to originate from two sources: coarse-grained pebbles and clasts in conglomerates have the same evolved-magma upstream sources as the float rocks, while the finestgrained sedimentary rocks seem influenced by ancient aeolian dust. The composition of the mudstone at Yellowknife Bay (YKB [7]) is more similar to the current global average martian soil without the salt component. CheMin results on YKB mudstones indicate ~20% phyllosilicate contents, likely authigenic, with relatively little alteration [15]. LIBS revealed low hydration levels. Sandstones, like Shaler [1], carry the Sheepbed mudstone signature with additional variable alkali, Al, and Si, consistent with comminution of a plagioclase-rich component.

Several outcrops show considerable enrichment in Fe. This is moderate at Bathurst_Inlet, but higher at nearby Rocknest with FeO_T from 19 to 27 wt. % [2]. Increased Fe does not correlate with other elements, suggesting a hematite-rich cement, also observed in some conglomerates. Early diagenetic cracks filled with Mg- and Fe-rich clays are evidenced by the presence of erosion-resistant raised ridges in the lower unit [6]. Calcium sulfate veins (with varying hydration indicating gypsum and bassanite) are found all across the deposit and must have formed last [11].

The YKB formation deposits testify of prolonged aqueous activities relatively late in the history of early Mars, possibly in a series of episodes: transport and sedimentation with little alteration, diagenesis partially into clays, and fluids circulation all along the unit formation through fractures with a more or less limited water activity [8].

4. Coatings, soils and hydration

ChemCam's analysis of depth-correlated spectra provides a third dimension to probe surfaces. The large majority of rocks and coarse gravels analyzed by Curiosity show little or no surface coatings. However, water-rock interactions are evidenced by the discovery with ChemCam of three rocks with Mn-enriched coatings (up to ~60 wt. % MnO) [5]. This may involve hydrothermal systems, the existence of freshwater lakes, or alteration by thin intermittent films of water. Li and F were detected for the first time on Mars by ChemCam. They indicate a low level aqueous alteration pulling the alkalis to the surface [12]. The influx of subsurface water must have been limited, otherwise Li should have higher concentrations in the soils than ChemCam detects.

At the sub-mm scale, ChemCam identifies two major soil types: a fine-grained mafic type and a coarse-grained type of diverse compositions [10]. The mafic component is similar to soils found at other landing sites, and may constitute a global reservoir. It shows ubiquitous hydration [14] in its amorphous phase, which may account for a significant fraction of the global hydration seen from orbit. The second component (coarse grains and pebbles) represents the diversity of chemical compositions of local sources: mafic, felsic, and Fe-rich rocks [3].

Acknowledgements

We thank the Mars Program Office and CNES for funding, and JPL for operating this excellent mission.

References

[1] Anderson, R., et al.: ChemCam Results from the Shaler Outcrop in Gale Crater, Mars. Icarus, 2014.
[2] Blaney, D., et al.: Chemistry and texture of rocks at Rocknest, JGR, 2014, in preparation.
[3] Cousin A., et al.: Compositions of sub-millimeter size clasts and fine particles in the Martian soils at Gale: A window into the production of soils. Icarus, 2014.
[4] Forni, O., et al.: First detection of fluorine on Mars: implications for Gale crater's geochemistry, Nature Geosciences, submitted, 2014.
[5] Lanza, N., et al.: Manganese trends with depth on rock surfaces in Gale crater, Science, submitted, 2014.
[6] Leveille, R., et al.: Chemistry of fracture-filling raised ridges in Yellowknife Bay, Gale crater: Windows in to past aqueous activity and habitability on Mars. Icarus, 2014.
[7] McLennan S., et al.: Elemental geochemistry of sedimentary rocks in Yellowknife Bay, Gale Crater, Mars. Science Express, 2013, DOI:10.1126/science.124473.
[8] Mangold N., et al.: Chemical variations in Yellowknife Bay Formation sediments analyzed by the Curiosity rover on Mars. JGR, 2014, submitted.
[9] Maurice, S., et al.: The ChemCam instrument suite on the Mars Science Laboratory (MSL) rover: science objectives and mast unit description, SSR, 170, 95-166, 2012.
[10] Meslin, P-Y., et al.: Soil diversity and hydration as observed by ChemCam at Gale crater, Mars. Science 341, DOI: 10.1126/science.1238670.
[11] Nachon, M., et al.: Calcium sulfate veins characterized by ChemCam, JGR, 2014, accepted.
[12] Ollila, A., et al.: Trace Element Geochemistry (Li, Ba, Sr, and Rb) using *Curiosity's* ChemCam: Early Results for Gale Crater from Bradbury Landing Site to Rocknest, JGR, 119,255, 2014.
[13] Sautter, V., et al.: Igneous mineralogy at Bradbury rise: The first ChemCam campaign, JGR, accepted, 2013.
[14] Schröder, S., et al.: First analysis of the hydrogen signal in ChemCam LIBS spectra, Icarus, 2014, submitted.
[15] Vaniman, D., et al.: Mineralogy of a Mudstone at Yellowknife Bay, Gale Crater, Mars, Science, 2013, DOI: 10.1126/science.1243480
[16] Wiens, R., et al.: The ChemCam instrument suite on the Mars Science Laboratory (MSL) rover: Body unit and combined system tests, SSR, 170, 167-227, 2012.