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Overview of recent ChemCam Findings after 2000 sols at Gale Crater, Mars

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Abstract

NASA's Mars Science Laboratory (MSL) rover Curiosity landed at Gale crater, Mars, in August 2012. Since then the rover has driven more than 19 km, and climbed 375 m, from the Bradbury landing site southwest over fluvio-deltaic strata, traversing the dark Bagnold Dunes, and is now ascending Mt. Sharp (formally Aeolis Mons). MSL carries aboard the first extraterrestrially employed LIBS (laser-induced breakdown spectroscopy) instrument ChemCam [1-3] that provides the elemental composition of rocks and soils. Here, we summarize the findings from lower Mt. Sharp, starting from Pahrump Hills to the current location of the rover at the Vera Rubin Ridge (VRR) with a focus on the geochemical stratigraphy as seen by ChemCam.

1. Introduction

ChemCam is composed of two instruments: a LIBS instrument for assessing the chemistry of targets in distances of up to 7 m and a Remote Micro-Imager (RMI) [4] that provides high resolution context images. ChemCam collects data nearly every sol, allowing variations in composition to be uniquely tracked at the submillimeter scale [3].

2. Recent Findings of ChemCam

With now over 2000 sols of the mission completed, more than 570,000 ChemCam LIBS spectra of soils and rocks have been recorded, analyzing over 2400 targets. Additionally, many ChemCam passive spectra (i.e. without lasing) have been recorded and analyzed [5-8]. The numerous analyses revealed the compositional diversity of the igneous rocks, the sedimentary rocks, and the diagenetic features.

2.1 Pahrump Hills and Marias Pass

On sol 750, MSL arrived at the light-toned layers of Pahrump Hills. The Pahrump outcrop corresponds to the first observed material at Mt. Sharp's base and is part of the Murray Formation, mainly constituted of mudstones [9]. It has been interpreted as an ancient lacustrine environment. The compositional diversity observed by ChemCam in the diagenetic features suggests a complex history of the sediments [10]. Its facies suggest a stronger alteration, with presence of minor F-bearing materials such as apatite, fluorite, and phyllosilicates [11]. The Stimson unit, which is unconformably overlying the Murray formation, is composed of eolian cross-bedded sandstones possibly evolved from ancient dunes. Both Murray and Stimson formations are highly enriched in SiO2 (>80 wt. %) locally at Marias Pass and Bridger Basin [9,12,13]. The Murray enrichment may be from a pulse of volcanic ash, as it contains tridymite, with subsequent mobilization to fractures in the Stimson.

Moreover, boron was detected in-situ for the first time on Mars by ChemCam at levels <0.05 wt.% in calcium sulfate filled fractures in the Murray mudstone and the Stimson sandstone as well as early in the mission at Yellowknife Bay [14].

2.2 Naukluft Plateau to Sutton Island

Ca-sulfate veins with Fe and Fe+Mg enrichment have been observed in the vicinity of the Naukluft Plateau and near the Old Soaker outcrop in the Sutton Island member implying changing pH and redox conditions in the groundwater [15].

Manganese and iron have shown strong increases with variable amounts of P and Mg in dark surface features [16]. These were found in several regions distributed ~160 m below the Vera Rubin Ridge, mostly in the Sutton Island member of the Murray formation. Mn oxide abundances have risen to >10 wt. % in some dark nodules and laminae. Iron, Mg, and P appear

correlated in high-P observations, with the highest values associated with vein-related inclusions. These findings provide additional evidence for the presence of a more shallow, oxidizing and weakly acidic to circumneutral lacustrine environment.

2.3 Vera Rubin Ridge (VRR)

On sol 1800, MSL arrived at the Vera Rubin Ridge, a ~6.5 km long and ~200 m wide topographic high [17] where relatively strong hematite signals were observed from orbit. ChemCam passive reflectance spectra and Mastcam multispectral data exhibited variable strengths of absorption bands near 535 nm and 860 nm along the traverse that corresponded well to the orbital maps. In ChemCam LIBS data no significantly increased Fe in the host rock was seen, but instead local high Fe detections (nearly pure FeO_T) associated with elongated and polygonal dark-toned clasts along light-toned Ca-sulfate veins were found [18]. These presumably diagenetic features showed lower abundances in all other major and minor elements suggesting a pure FeO mineral phase such as Fe-oxide. ChemCam passive reflectance spectra do not (or only weakly) show ferric absorptions associated with these features, contrasting with typical spectra associated with VRR host rocks.

2.4 Latest chemostratigraphy

The abundant data taken by the ChemCam instrument allows us to track changes in bedrock composition. Average bulk chemistry composition can be obtained by averaging all positions of a given target (ignoring locations on soil and diagenetic targets). Murray bedrock is enhanced in Si and alkali elements relative to usual Martian rocks while Ca is less abundant. Upon approach of the VRR, the Murray formation displayed increasing chemical index of alteration (CIA) that was anticorrelated with Ca, suggesting increasing weathering, especially leaching due to dissolution of either clinopyroxene or plagioclase [19]. These observations indicate weathering in an open system with liquid water, at or near the surface. The rover's cameras observed indications of periodic desiccation in the sediments, including putative mud cracks at Old Soaker at sol 1550 [20,21].

The VRR consists of laminated mudstones thought to be lacustrine in origin similar to the Murray formation and is interpreted as an individual group within the latter. The variation of the major and minor elements at the VRR does not extend the ranges defined by the previously investigated Murray bedrock and the absolute content is similar. However, relative differences between certain elements were found such as an increase in K in VRR but no corresponding increase in Na and a slightly increasing Al, resulting in a decreasing CIA in the VRR after the rising trend when approaching it. The observed reduced Li in the VRR could indicate lower clay content in the VRR and explain the higher erosional resistance [22].

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All Mars LIBS spectra and derived elemental compositions are available at *http://pds-geosciences.wustl.edu/missions/msl/chemcam.htm* and are described in > 40 peer-reviewed papers.

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] Maurice S. et al. 2016. J. Anal. At. Spectrom. 31 :863.
[4] Le Mouélic S. et al. 2015. Icarus 249:93-107.
[5] Johnson J.R. et al. 2015. Icarus 249:74-92.
[6] Johnson, J.R. et al. 2016. Amer. Min., 101, 1501-14.
[7] Johnson, J.R. et al. 2017. JGR 122, 2655-2684.
[8] McConnochie T.H. et al. 2017. Icarus 307 :294-326.
[9] Grotzinger J. et al. 2015. Science, 350:625.
[10] Nachon M. 2017. Icarus 281 :121-136.
[11 Forni O. et al. 2016. LPSC XLVII #1990.
[12] Frydenvang J. et al. 2017. GRL 44:4716-4724.
[13] Morris R.V. et al. 2016. PNAS 113 26 :7071-7076.
[14] Gasda P.J. et al. 2017. GRL 44 : 8739-8748.
[15] L'Haridon J. et al. 2018. Icarus 311:69-86.
[16] Meslin P.-Y. et al. 2018. LPSC XLVIX #1447.
[17] Fraeman A.A. et al. 2018. LPSC XLVIX #1557.
[18] L'Haridon J. et al. 2018. LPSC XLVIX #1333.
[19] Mangold N. et al. 2017. LPSC XLVIII #1894 and submitted paper.
[20] Stein N. et al. 2017. Geology, doi:10.1130/G40005.1.
[21] Mangold N. et al. 2017. LPSC XLVIII #1908.
[22] Frydenvang J. et al. 2018. LPSC XLVIX #2310