PROBABLE CHONDRITIC FRAGMENTS DETECTED BY CHEMCAM IN GALE CRATER. J. Lasue[1], P.-Y. Meslin[1], V. Sautter[2], I. Maroger[1], L. Krämer Ruggiu[3], J.C. Bridges[4], E. Lewin[5], R.C. Wiens[6], P. Beck[7], A. Cousin[1], O. Forni[1], O. Gasnault[1], W. Goetz[8], J.R. Johnson[8], S. Le Mouélic[9], M. Nachon[10], H. Newsom[11], S. Maurice[1], D.F. Wellington[12]
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Introduction: ChemCam is a Laser-Induced Breakdown Spectroscopy (LIBS) instrument on-board the NASA Mars Science Laboratory (MSL) rover that has been exploring Gale Crater, Mars for the past six years. A pulsed infrared laser is focused to the target of interest and heats it up to about 10000 K generating a plasma of electrons, ions and atoms, the light of which is collected by a small telescope and analyzed by spectrometry [1, 2].

Thanks to its ability to analyze the chemical composition of geological targets at a distance from the rover and without sample preparation, ChemCam is an ideal survey instrument to detect changes in composition along the rover's traverse. Over the six years of exploration at Gale, ChemCam has acquired more than 600,000 spectra and analyzed around 20,000 different point locations.

Typically, ChemCam samples several locations per target and probes each location with 30 laser shots. Each shot on a specific point removes a few nanograms of material. The first five shots are contaminated by martian aeolian dust and are systematically removed for data processing and the determination of rock composition [3].

This work reports the potential detection of chondritic material and develops an interpretation of the measurements for the rate of meteorite falls on Mars and their survival in the martian environment.

Meteorite falls on Mars: It is well known that on Earth, the meteorite classes from observed falls correspond to a large fraction of ordinary chondrites (>70%) with H, L and LL chondrites being the major groups represented, while iron meteorites are a small fraction of the flux of meteorites arriving on Earth (~4%) [4]. The MER rovers on Mars have detected iron meteorites on several occasions [5, 6] and stony achondrite meteorites [7], indicating weak alteration of the meteorites mostly due to wind abrasion, coating-forming chemical alteration and possibly aqueous acidic exposure [8].

The MSL rover has also observed a few dozen iron meteorites since the beginning of the mission [9, 10], and ten of them were analyzed by ChemCam in the rover workspace [11]. Assuming that the alteration rate is relatively similar between meteorites, this would translate into ~at least 150 ordinary chondrites and a number of carbonaceous chondrites that could have been detected by MSL in its workspace.

Even when using more realistic alteration estimates for chondrites, between 5 and 5000 chondritic fragments >10g may be expected in the surface area covered by the rover [11, 12]. Identifying such samples would be beneficial to better understand weathering/alteration on Mars, and could prove to be important to constrain the exogenous carbon input [13]. Chondritic impacts on Mars were indirectly demonstrated by the composition of the polymict breccia NWA 7533 [14].

Detection of chondrites with ChemCam: ChemCam allows us to detect elemental compositions of small targets at a distance of <7m from the rover. Among the silicate targets analyzed by ChemCam, two present definitive signatures of nickel content >1wt.% : Normandien (sol 1831) and Omusati (sol 1463) as illustrated in Fig. 1, which is much higher than the typical Mars soil abundances of up to 650ppm Ni [15].

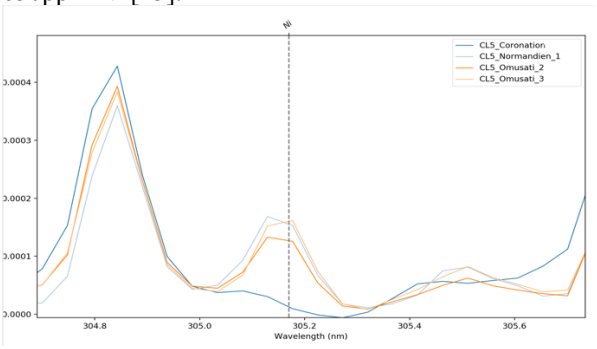

Figure 1: Ni line (305.17nm) of Normandien (sol 1831) and Omusati (sol 1463) as compared to the basaltic target Coronation (sol 13).

These targets also present elevated Mg content unique among Gale samples. The Ni-Mg ratio obtained from those samples is inconsistent with the values obtained from typical Mars rocks and their alteration products as described in [16]. We interpret the association between high Mg and high Ni as a mixture between olivine and a metal phase. Most major elements and trace elements measured by Chem-

Cam fall well outside their typical values measured in Gale crater, making these rocks very unique.

Their composition is different from the stony meteorites analyzed by *Opportunity* at Meridiani Planum [7], in particular with much larger Mg and Ni contents. The Meridiani finds have a composition more similar to howardites and diogenites, but with additional metal.

As illustrated in Fig. 2, the major elements composition of these samples compared to local soil fines analyzed by ChemCam [17] follow trends that are similar to the ones of the major groups of ordinary chondrites : H, L and LL (average composition taken from [18]). Especially, Mg/Si at. ratios of 0.9 are consistent with an origin as an ordinary chondrite. The alkali content is highly variable maybe due to local contributions on specific shots.

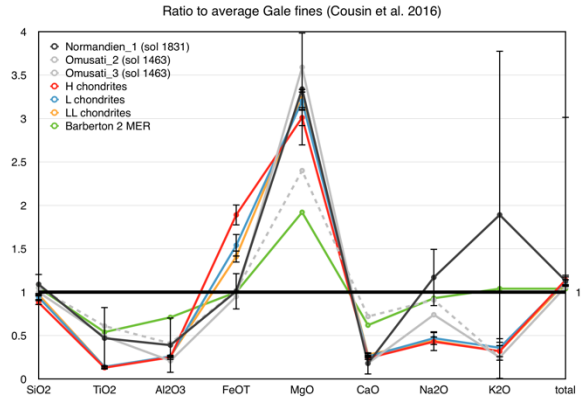

Figure 2: Major elements ratio to Gale fines: Normandien, Omusati, Barberton2 [7] and the main ordinary chondrite groups (H, L, and LL [18]).

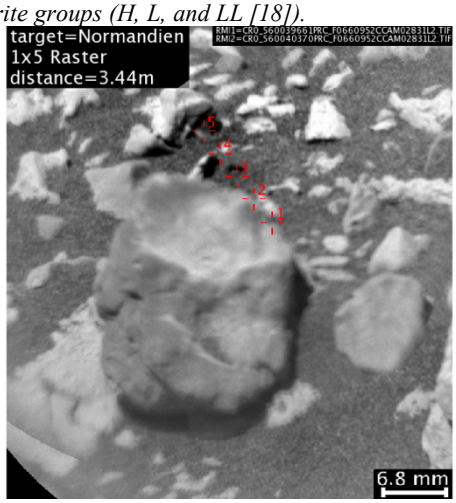

Figure 3: Sol 1831 RMI mosaic of target Normandien, a possible chondritic fragment analyzed by ChemCam (location #1).

Geological context: The outlier targets identified by their elemental composition have also been imaged with the RMI capability of ChemCam as illustrated in Figs. 3 and 4. They correspond to small pebbles 1-2 cm in size with a rocky surface. Normandien shows some fractures (Fig. 3) whereas Omusati presents some angular facets unlike the rounded pebbles surrounding it (Fig. 4). The images of the targets are thus consistent with their possible origin as fragments of ordinary chondrites.

Conclusion: Two possible cm-sized chondritic fragments have been identified by ChemCam onboard MSL. Their chemical composition showing elevated Ni content (>1wt.%) and elevated MgO content (~20-30wt.%), together with Mg/Si ratios and other major and trace elements unlike other martian targets analyzed by ChemCam in Gale crater. Their chemical composition and visual appearance are consistent with an origin as fragments of ordinary chondrites, most likely from the L or LL groups.

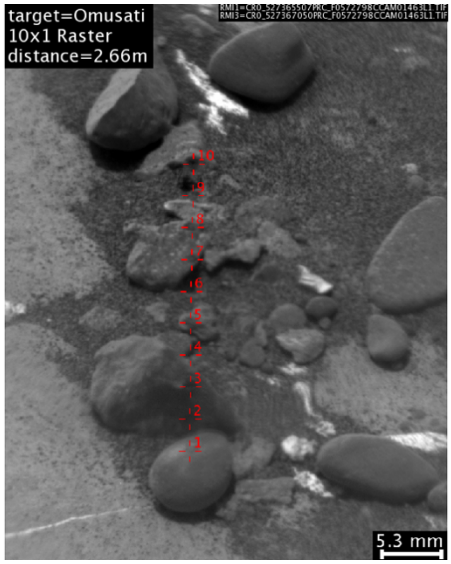

Figure 4: Sol 1467 RMI mosaic of target Omusati, a possible chondritic fragment analyzed by ChemCam (location #2 and #3).

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