**DETECTION OF FLUORINE-RICH PHASES, PHOSPHATES AND HALITE IN THE STIMSON-MURRAY UNITS, GALE CRATER, MARS:** O. Forni^1, P.-Y. Meslin^1, J. L’Haridon^2, W. Rapin^3, M. Nachon^3, H. Newsom^4, N. Mangold^2, O. Gasnault^1, D. E. Anderson^5, R. B. Anderson^4, D. L. Blaney^4, S. M. Clegg^6, A. Cousin^1, E. Dehouck^7, J. R. Johnson^8, N. L. Lanza^2, J. Lasue^1, S. Maurice^4, R. C. Wiens^3^1Institut de Recherches en Astrophysique et Planétologie, Toulouse, France, ^2LPGN, Nantes, France, ^3UCD, Davis, USA, ^4UNM, Albuquerque, USA, ^5Caltech, Pasadena, USA, ^6USGS, Flagstaff, USA, ^7JPL, Pasadena, USA, ^8LANL, Los Alamos, USA, ^9APL, Laurel, USA ; [olivier.forni@irap.omp.eu]

**Introduction:** ChemCam is an active remote sensing instrument suite that has operated successfully on MSL since landing Aug. 7th, 2012 [1, 2]. It uses laser pulses to remove dust and to profile through weathering coatings of rocks up to 7 m away. Laser-induced breakdown spectroscopy (LIBS) obtains emission spectra of materials ablated from the samples in electronically excited states. The intensities of these lines scale with the abundances of the related element. ChemCam is sensitive to most chemical major elements as well as to a set of minor and trace elements such as F, Cl, Li, P, Sr, Ba, and Rb [3]. We report here a summary of the fluorine, phosphorus and chlorine detections [4] occurring in the extensive Murray formation stretching from the Pahrump outcrop until the present, e.g., from Sol 758 to Sol 1550. We identify the F-P-Cl bearing phases and look at the chemical variations related to these phases in relationship with their geological context.

**Geological unit description:** Based on orbital mapping, Pahrump Hills is the first stratigraphic unit of Mt. Sharp that Curiosity has explored. It has distinct albedo and textural appearance in HiRISE imaging (Fig. 1). Curiosity reached Pahrump Hills ca. sol 750 (in September 2014). At Pahrump Hills, the Lower Murray formation consists of finely laminated mudstones, with interstratified cross-bedded basaltic sandstones [5]. ChemCam performed extensive analyses of the material within this Pahrump section, providing chemical compositions both on the host rock/sediment [6, 7] and on post-depositional features. On sol 923, Curiosity left the primary Pahrump Hills locality, through the Artist’s Drive Valley, and encountered a network of prominent veins, termed Garden City, protruding above the host rock. Leaving this area on sol 949, the rover proceeded toward a contact between the Murray Formation and an unconformably overlying eolian deposit, named the Stimson Formation. The rover continued to an area where the contact is fully exposed. ChemCam observations were acquired on the rocks and materials in this area of the contact during two visits, which ended with the departure of Curiosity from the Marias Pass area on Sol 1072. From Sol 1100 to Sol 1400, the rover drove on the Naukluft Plateau which is rugged sandstone region of interspersed Murray and Stimson outcrops crossed by numerous veins.

Finally from Sol 1500 on, the rover entered the Murray buttes region, which belongs to the Murray formation.

![Traverse map of the Curiosity rover with the described locations](image1)

**Fluorine detection and chemical relationships:** More than 600 fluorine detections have been identified (Fig. 2). Up to the Garden City outcrop, fluorine has been very frequent. At Garden City, fluorine contents are very high (up to 10 wt.% for the highest point on the Alvord Mountain target) [10]. After Garden City and up to the departure from Marias Pass there are very few detections. Likewise the Gobabeb region, where the rover analyzed the Bagnold dunes, does not show
fluorine detection. The rate of detection notably increases after Marias Pass especially on the Naukluft Plateau and Murray Buttes area (Fig 3). It is worth noting that all the detections occur in the Murray formation.

Around 280 fluorine detections have been observed in the Pahrump Hills. The majority of the detections occurred in the basal Pahrump Hills outcrop, correlated with silicon probably in phyllosilicates [8] in good agreement with CheMin [9]. In the upper part of the outcrop, fluorine is detected as secondary calcium correlated phases because found in dentritic features and veins. In the Garden city location in the uppermost part of Pahrump Hills, very high fluorine contents were detected in association with Ca (and no other element), thus likely associated with fluorite [10]. Its formation can be structure-related including mineralization in breccia and veins or unconformity-related and may require hot (200°C) hydrothermal and/or acidic fluids [8].

About 60 detections were identified in the Marias Pass-Bridger Basin area. The majority of the detections was made very close the unconformity between the Murray mudstone and the Stimson sandstone and is mainly located in the Stimson unit. The fluorine is generally found in a calcium-correlated phase, either apatites or fluorite. Theses phases are probably indicating fluid circulation at the unconformity [11].

More than 200 detections were made in the Naukluft Plateau and Murray Buttes. These detections are related to calcium bearing phases and mainly found in fractures fills, in the dark-toned veins or maybe in the interstitial space between these veins and the sulphate veins. However, there are some differences between the veins we observe in the Naukluft Plateau and Garden City: fluorine is in apatite and not in fluorite; halite is inferred from simultaneous Na and Cl enrichments to be present in recent veins, near the interface between the Ca-sulfate veins and the bedrock more recently, but was absent at Garden city; hydrated calcium phosphates (enriched in Sr, Cr, Ba), perhaps as brushite, are present in recent veins, as described in greater detail at this meeting in [12], but are absent at Garden City. Finally, in recent observations made in the Murray Buttes area on calcium-sulphate veins presenting dark grey points like the Blue_Hill target (Fig. 4), ChemCam observed a unique assemblage of phases associated with these grey spots. They are characterized by very high MgO (up to 16 wt%), very high FeO and sometimes very high Na₂O and Cl. They also present a unique signature of P which appears to be very high (at least 10 wt. %) as well as relatively high MnO (1.5 wt.%) on some points. A shot-to-shot analysis shows that all these elements are not in silicates: Mg and P are correlated together, implying the presence of a Mg-phosphate. The Mn is apparently associated with the high Fe. Iron oxides are favoured here [13], perhaps magnetite, as suggested by preliminary visible spectral analyses [14]. Finally the high Na is associated with the Cl detection, making halite the most likely phase.

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