CHEMCAM CHEMOSTRATRIGRAPHY OF THE PAHRUMP OUTCROP, GALE CRATER. O. Forni[1], N. Mangold[2], D. L. Blaney[3], M. Fisk[4], R.C. Wiens[5], P.-Y. Meslin[1], M. Nachon[2], O. Gasnault[1], S. Maurice[1], A. Cousin[1], S. Le Mouélic[2]. [1]Institut de Recherches en Astrophysique et Planétologie, Toulouse, France, [2]LPGN, Nantes, France, [3]JPL, Pasadena, USA, [4]Oregon State University, Corvallis, USA, [5]LANL, Los Alamos, USA ; [olivier.forni@irap.omp.eu]

Introduction: ChemCam is an active remote sensing instrument suite that has operated successfully on MSL since landing 28 months ago [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 are proportional to the amount 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 Li, Sr, Ba, and Rb. Qualitative and quantitative relationships between elements can be identified using univariate and multivariate techniques [3, 4]. We report here a summary of the chemical variations occurring at the Pahrump waypoint and try to outline some properties of the various facies that belong to it based on the 400 observation points probed by ChemCam from Sol 758 to Sol 801.

Pahrump waypoint description: Based on orbital mapping Pahrump is the first stratigraphic unit of Mt. Sharp that Curiosity has explored. It has distinct albedo and textural appearance in HiRISE color imaging. Pahrump layers are characterized by three main different facies: the first one consists of decimeter-high resistant layers, the second one is characterized by recessive laminated layered terrains and the third one has platy and often fractured slabs [5]. Several outcrops have been analyzed: "Confidence Hills" where a hole was drilled in platy fractured layers, "Pink Cliffs", and "Book Cliffs" which display resistant layers of various thickness separated by recessive layers, "San Gabriel" mainly composed of finely laminated layers, "Carnivore Canyon" and"Alexander Hill", which correspond to massive resistant layers with poorly visible lamination, the laminated layers of "Chinle" and the "Whale Rock" sediments which have a distinct layering with very visible lamination that is more resistant than the underlying Pahrump layers. From the chemical point of view the sediments with the closest composition to the Pahrump waypoint are the conglomerates, especially at the Darwin waypoint [6]. With respect to these conglomerates, Pahrump is only slightly enriched in Mg whereas sandstones found at Yellowknife Bay and elsewhere have higher Mg. This similarity with conglomerates suggests a similar provenance with small variations related to physical sorting or alteration.

Pahrump elemental compositional variations as seen by ChemCam: In the following we study the variations in composition between the different outcrops of the Pahrump waypoint. There is generally a common increase in aluminum and titanium for several layers (San Gabriel", "Carnivore Canyon_Alexander Hill" and "Chinle") whereas as the "Confidence Hill" unit is characterized by low Al (Fig 1.). "Pink Cliffs" and "Book Cliffs" are intermediate and "Whale Rock" is very different from the others units having generally low Al but not following the general observed trend. A comparable trend can be observed with the alkalis, that generally increase from "Confidence Hills" to "Chinle", "Whale Rock" being very low.

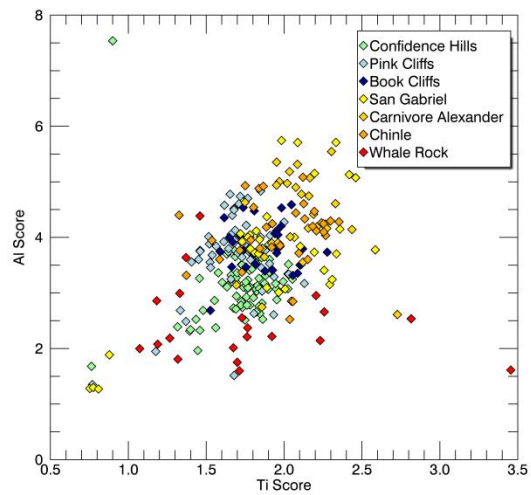

Figure 1: Al ICA score vs. Ti ICA score for the Pahrump waypoint showing the correlation between these elements.

Pahrump is also characterized by an overall high lithium content of about 40 ppm which is much higher than the average Mars Li content of about 5 to 10 ppm. [7]. Li exhibits also a strong correlation with Al; the "Book Cliffs" and "Carnivore Canyon-Alexander Hills" units are the most enriched in Li with a mean value of about 45 ppm (Fig 2.).

From a chemical point of view, two groups of layers appear very different among the units of the outcrop, namely the "Carvivore Canyon_Alexander Hill" unit and the "Whale Rock" unit.

The "Alexander Hill-Carnivore Canyon"section: This unit is characterized by fine laminated indurated

and massive decimeter-high strata. Chemically it is enriched in Al, Mg and H and depleted in Fe with respect to the other surrounding units, the alkalis remaining the same. It is also enriched in Li and Cr, the latter not being correlated with Fe. This unit has also the highest Chemical Index of Alteration (CIA) of about 60 (Fig 3.). The higher Mg and Al are also correlated with higher H, perhaps indicative of Mg-clays.

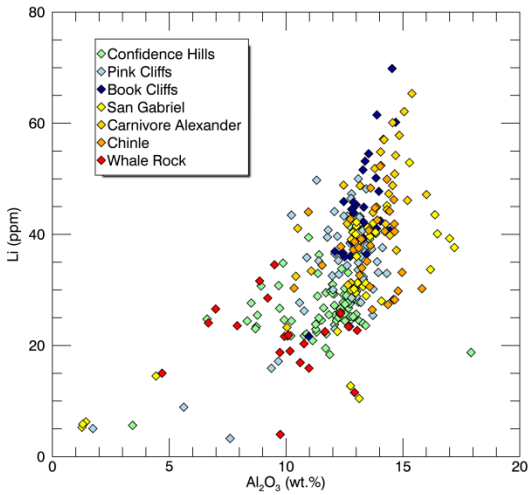

Figure 2: Li content vs. Al_2O_3 content for the Pahrump waypoint showing the correlation between these elements. The mean Li content is about 40 ppm.

The "Whale Rock"section: This unit is very heterogeneous. One of the target Vaqueros is dominated by high Ca content and low major-element totals, suggesting sulphates, although the identification of sulphur lines is unclear. The other target, Orrocopia, contains very high Ti, a property suggesting enhanced ilmenite.

Diagenetic features: Pahrump is characterized by the presence of many diagenetic features, among which white veins filling fractures, interpreted as calcium sulfate veins and dentritic concretions containing high Mg, Ni, and S [8]. Whereas veins are clearly late stage, the role of Mg-rich concretions in early stages of diagenesis may have modified the composition of the host rock since they seem nucleated both within the host mudstone and at the edges of fractures. Some evidences uggest that these diagenetic crystal clusters and dendrites are post-depositional, potentially burial diagenetic features [9].

Discussion and Summary: From all the units composing the Pahrump waypoint, two units appear very different from the other units. Indeed the "Confidence Hills" unit and drill hole is not completely typical of Pahrump average composition. In particular, it looks depleted in Mg, Ti, Al and alkalis and exhibits a large variability in Fe. Secondly, the capping "Whale Rock" unit has somewhat uncommon chemistry, with high Ca and sulfate concentrations as well as elevated content of titano-ferros oxides. Although the different sections appear as different facies [5] some commonalities can be identified between them.

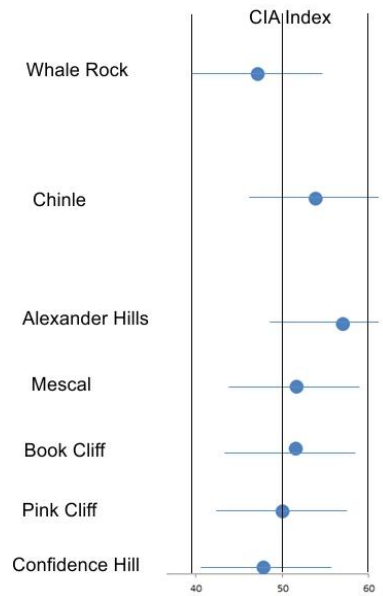

Figure 3: Chemical Index of Alteration (CIA) for the Pahrump waypoint. "Alexander Hills" has the largest value. The two members that have value lower than 50 are "Confidence Hills" and "Whale Rock".

"Pink Cliffs", "Chinle", and "San Gabriel" have relatively homogeneous compositions, although "Pink Cliffs" is enriched in Li.

"Alexander Hills" has very faint laminations. It is enriched in Al, Mg, H, Cr and Li and depleted in Fe. It may contains more clays and forms at deeper levels.

"Pink Cliffs" and part of "Confidence Hills": These sections are characterized by the presence of diagenetic features like the Ca-sulphate veins and the Mg-rich dendritic concretions.

Finally the difference between some of these layers could be partly due to various provenances, especially for the "Whale Rock" section, and partly due to alteration, especially the layers with enhanced Mg and resistant facies, considering their context of lacustrine deposits [10].

References: [1] Maurice S. et al. (2012) *SSR, 170,95-166* [2] Wiens R.C. et al. (2012) *SSR, 170, 167-* [3] Forni O. et al. (2013) SCAB, 61, [4] Wiens R.C. et al. (2013) *SCAB, 82, 1-27* [5] Stack, K. M. (2015) this meeting [6] Mangold N. (2014) AGU Fall meeting. [7] Olllila et al. (2014), 119, 1-31 [8] Nachon et al. (2015) this meeting. [9] Kah L. C. (2015) this meeting [10] Grotzinger J. et al. [2014] AGU Fall meeting.