TARGETING AND CLASSIFYING DRILL HOLES ON MARS WITH CHEMCAM. O. Gasnault[1] , P. Pinet[1], R.C. Wiens[2], E. Dehouck[3], P. Gasda[2], O. Forni[1], J. Lasue[1], K. Stack[4], S. Maurice[1], C. Fabre[5], [1]IRAP (Toulouse, France – ogasnault@irap.omp.eu), [2]LANL (Los Alamos, NM, USA), [3]LGLTPE (Lyon, France), [4]JPL (Pasadena, CA, USA), [5]GeoRessources (Nancy, France).

Introduction: One of the major innovations of the Curiosity rover was the capability to drill the surface of Mars [1]. The payload of the rover is then used to characterize the drill areas. Here we discuss some of the ChemCam instrument contribution to these special investigations in which the laser is used to measure the composition variation inside the drill hole.

The characterization of a drill area with ChemCam is made in several steps, including reconnaissance of the local bedrock, measurement at the drill location before the drill, measurement inside the drill, of the tailings, and of the dump, both in active and passive modes [2]. Shooting and focusing inside the 1.6 cm diameter drill hole is quite challenging and may require several attempts. Other instruments are used to document the area, and the collected samples are analyzed by SAM and CheMin, but only ChemCam can make several point measurements inside the drill hole thanks to its fine scale analysis (spot size of ~500 µm).

The processing of these data is based on multivariate techniques [3] and various statistical tools were developed to study this large dataset. A clustering method has already been used in diverse contexts as support to global or local target classifications [4]. Here we used again this same hierarchical divisive method, limited to the 275 points on drill walls between Sols 227 and 2282; Only spectra in good focus were used. The goal is to describe the diversity of the drill locations, and also to evaluate the capability of this approach to link distant targets that may share common sediment sources.

Results: Fig. 1 shows the dendrogram summarizing the clustering steps, starting at the top with all the data points and, after successive divisions into two sub-groups, ending at the bottom with each individual measurement point [5]. The control of clustering quality index (silhouette) suggests that 8 to 13 clusters can be considered; In this abstract we show 11 clusters of points, although the last one is weak. Their Major Oxide Composition (MOC) distribution is given in Fig. 2.

Sampling. The number of points inside a drill hole is quite variable (e.g. 6 points in Mojave and 36 in Duluth), increasing along the mission as we were improving the technique, but with the risk to create a biased sampling. Okuroso and Oudam drill holes were not included because of focus uncertainties. However the sampling per stratigraphic unit [6] is reasonably balanced with 38 points in the Bradbury Group equally distributed between the Yellowknife Bay and Kimberley formations, 49 points in the Siccar Group, and the other distributed between the members of the Murray formation of the Mount Sharp Group: 49 in Parhump Hills, 29 in Karasburg, only 10 in Sutton Islands, 36 in Blunts Point, 25 in Pettegrove Point, and 39 in Jura.

Preliminary discussion. The three drill holes in the Bradbury Group are well clustered together in this analysis, consistent with a composition enriched in feldspar [7], shown as black and gray clusters at the left of the dendrogram (Fig. 1). The median abundance of SiO_2 in clusters 1 and 3 is slightly below the median content of all the drill holes (49 wt.%), and the MgO content of these clusters is double the median abundance of the population (4 wt.%), while quite variable in cluster 1 (John Klein and Cumberland drill holes). Inside the Bradbury Group, the main difference between the Yellowknife Bay and the Kimberley formations is a well-documented excess of potassium in the latter (Windjana drill hole in cluster 3) interpreted as a contribution from a source of alkali sediments [8].

The Parhump Hills member data are also clustered (shown as red in Fig. 1 as a sub-cluster of cluster 4), except for the Buckskin drill hole from the Marias Pass locality, which appears as a separate cluster (5) with much more SiO_2 and TiO_2, and a depletion of FeO_T, in which tridymite was discovered by CheMin [9] and the general silica enrichment in halos in that area was interpreted as late-stage groundwater activity [10].

The data from Siccar Group are also clustered together (clusters 7 to 9 in green on the right of Fig. 1). They present excesses of SiO_2 and TiO_2 compared to the median of all the drill holes (0.9 wt.% for TiO_2), and depleted in Al_2O_3 compared to the population median (9.5 wt.%) and FeO_T (19.5 wt.%), which match the composition of the amorphous component [11]. The Big_Sky drill hole in a sandstone of the Stimson formation, which has less amorphous material and is less altered than its neighbor Greenhorn sample [12], makes an exception as it plots with the Bradbury Group (cluster 1) consistently with a basaltic origin.

The points from the other Murray members are more distributed, which probably reflects more variability in their local compositions, possibly due to variable alteration levels [13] and the contributions from later diagenetic features [14]. The large and diverse cluster 4 can certainly be subdivided since it look or-

ganized between the drill holes in Pahrump Hill, Pettegrove, and Blunts Point members.

Cluster 2 obviously includes mixtures with calcium sulfates (high Ca, low total) that are common at Gale crater, mainly in veins [15] but also occasionally in the bedrock; Some points may also have sampled the tailings and a more rigorous selection of the data may help to focus the analysis on the bedrock only.

Conclusion: Different sedimentary bedrock were sampled by Curiosity along its traverse of various formations, from a rather preserved basaltic composition to a more altered composition [13].

While a clustering method cannot be used alone, it helps to detect commonalities, through identifying similar compositions and highlighting differences from one locality to another. For example, we may want to quantify the overlap between Bradbury and Stimson sandstones, or later in the mission search for a possible link between Greenheugh pediment and Stimson [16].

Sampling objectives will be different on the next rover mission, Mars2020, and measurements inside drill holes with the SuperCam instrument will be an important source of documentation of these samples.

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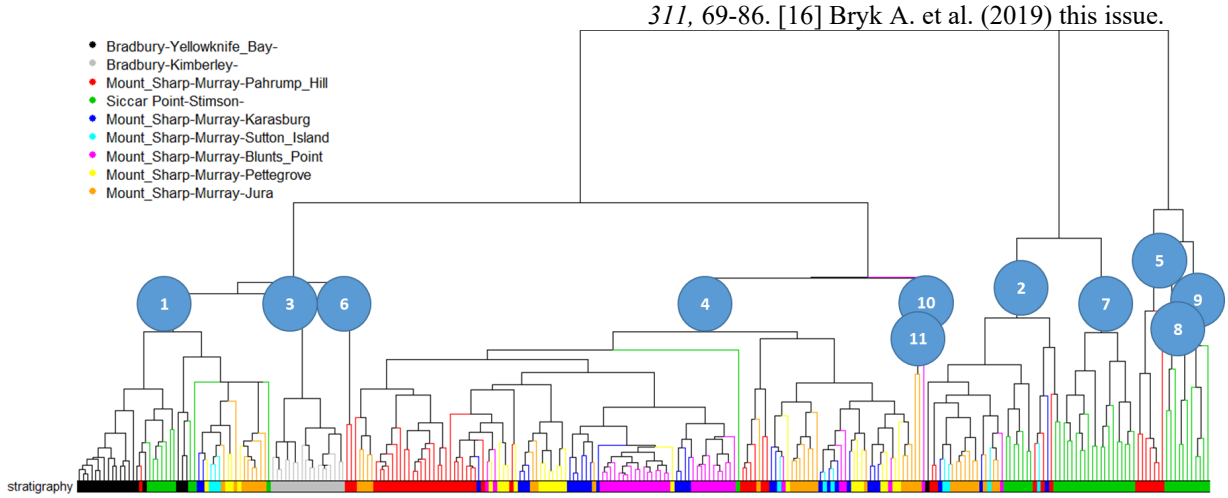

Figure 1: Dendrogram representing the clustering of 275 ChemCam points from drill holes. The division in eleven clusters is shown. The colors represent the stratigraphic units (group-formation-member) of the original data.

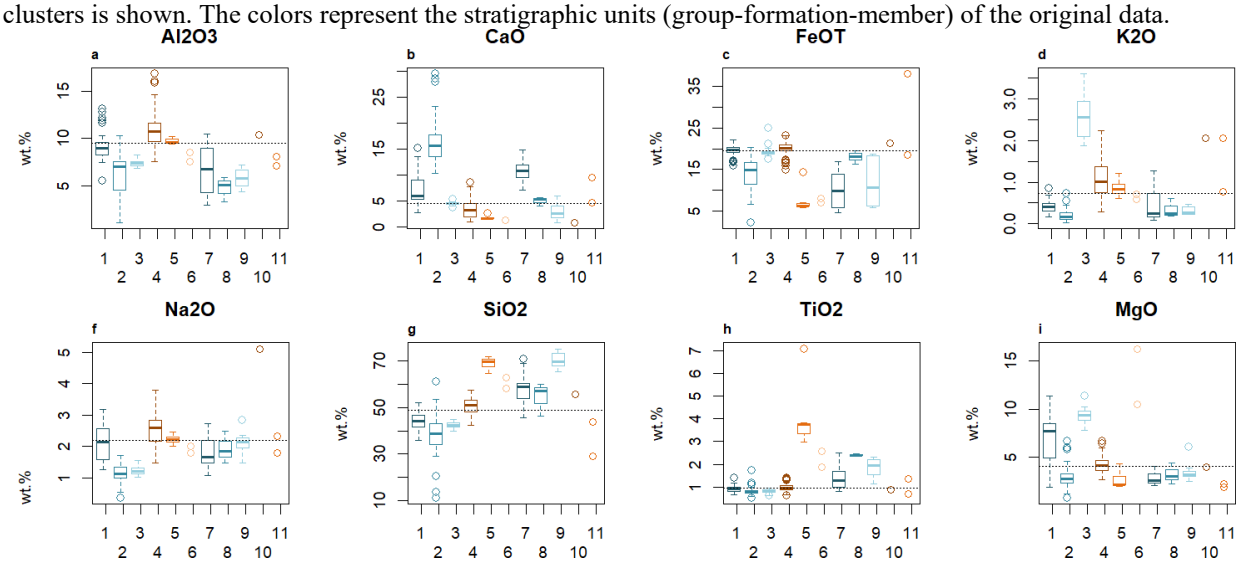

Figure 2: Boxplots showing the composition distribution measured in the eleven clusters described in Fig. 1.