Using ChemCam derived geochemistry to identify the paleonet sediment transport direction and source region characteristics of the Stimson formation in Gale crater, Mars.

Conference or Workshop Item

USING CHEMCAM DERIVED GEOCHEMISTRY TO IDENTIFY THE PALEONET SEDIMENT TRANSPORT DIRECTION AND SOURCE REGION CHARACTERISTICS OF THE STIMSON FORMATION IN GALE CRATER, MARS. C. C. Bedford[1], S. P. Schwenzer[1], J. C. Bridges[2], S. Banham[3], R. C. Wiens[4], J. Frydenvang[5], O. Gasnault[6], E. B. Rampe[7], P. J. Gasda[4]. [1]The Open University, Walton Hall Campus, Milton Keynes, UK (Candice.bedford@open.ac.uk). [2]Space Research Centre, University of Leicester, UK. [3]Imperial College London, UK. [4]Los Alamos Laboratory, Los Alamos, USA. [5]Natural History Museum of Denmark, University of Copenhagen, Denmark. [6]IRAP, Toulouse, France. [7] NASA Johnson Space Centre, Houston, USA.

Introduction: The NASA *Curiosity* rover has encountered both ancient and modern dune deposits within Gale crater. The modern dunes are actively migrating across the surface within the Bagnold Dune field of which *Curiosity* conducted analysis campaigns at two different localities [1,2]. Variations in mafic-felsic mineral abundances between these two sites have been related to the aeolian mineral sorting regime for basaltic environments identified on the Earth which become preferentially enriched in olivine relative to plagioclase feldspar with increasing distance from the source [3]. This aeolian mineral sorting regime for basaltic minerals has also been inferred for Mars from orbital data [2,4]. The aim of this study is to investigate whether this aeolian mafic-felsic mineral sorting trend has left a geochemical signature in the ancient dune deposits preserved within the Stimson formation.

The Stimson formation unconformably overlies the Murray formation [5] and consists of thickly laminated, cross-bedded sandstone [6]. Stimson outcrops have a variable thickness up to 5 m covering a total area of 17 km^2 [5,6]. A dry, aeolian origin was determined for this sandstone due to the high sphericity and roundness of the grains, uniform bimodal grain size distribution (250–710 µm), and 1 m thick cross-beds [6]. Identifying the geochemical signature of mineral sorting can provide insights about the paleo-net sediment transport direction of the dunes and prevailing wind direction at the time of deposition.

Methods: We use ChemCam derived major element data for host rock Laser-Induced Breakdown Spectroscopy analyses [7,8]. Observation point compositions are generated by averaging 30–50 spectral analyses for each point within a target raster [7,8]. ChemCam analysed the Stimson formation at the Emerson and Naukluft Plateaus (Fig. 1). We have removed any observation point that has hit an obvious alteration feature, with the exception of concretions that are suggested to have formed isochemically [9]. We also removed points with a major-element total outside the 95–105 wt% range to remove analyses with high volatile contents (i.e., S or H).

ChemCam's small sample footprint (350–550 µm) is compensated by numerous points to represent most of the geochemical variation within a defined stratigraphic group. The alteration- and dust-free bulk rock compositions for key stratigraphic units are estimated using a density contour analysis [11]. We next use a multivariate cluster analysis to identify the main geochemical components of the Stimson sandstone (i.e., mineral proportions and diagenetic cement). Then, average compositions for each cluster are calculated using an ANOVA analysis on cluster memberships to compare with the bulk density contour compositions.

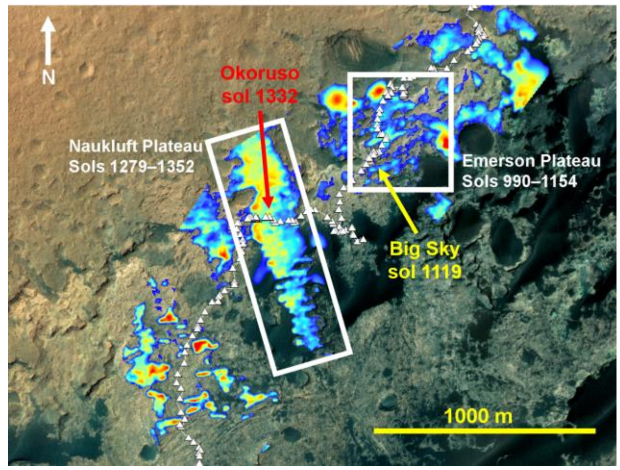

Fig. 1: Isopach map of the Stimson formation (red = thick, blue = thin) generated using data from [5]. Line with triangles shows the Curiosity rover traverse and waypoints. Arrows show the locations of CheMin drilled samples Big Sky and Okoruso that sampled unaltered Stimson bedrock [10].

Results and Discussion: Density contour results show that, geochemically, the bulk Stimson formation is relatively uniform, though subgroups are present for Al_2O_3 and MgO. Contours specific to the Emerson and Naukluft Plateau show that the Emerson Plateau has a higher bulk MgO composition, while the Naukluft Plateau has higher bulk compositions for Al_2O_3, Na_2O and K_2O (Fig. 2). These differences in bulk compositions are statistically significant when taking into account ChemCam instrument precision according to equivalence tests conducted for both localities.

Aside from concretions that likely relate to the isochemical cementation of the bedrock [9], and a few occurrences of Ca-sulfate mineral veins and fractureassociated halos [10,12], Stimson has relatively few alteration features compared to the underlying mudstones [6,10,12]. Additionally, CheMin FULLPAT analyses of the unaltered Big Sky and Okoruso drilled samples (Fig. 1) show that Stimson bedrock is dominated by primary igneous minerals and a secondary magnetite cementing component, has a relatively small amorphous component (<25 wt%) and does not contain phyllosilicates [10]. The lack of evidence that the Stimson formation has experienced substantial open-system alteration makes it likely that any geochemical effect of mineral sorting regimes and sediment source regions have been preserved.

Seven clusters were identified in the constrained Stimson ChemCam dataset using complete linkage and Manhattan distance methods. Clusters 2 (n = 186) and 3 (n = 159) comprise the majority of the ChemCam Stimson observation point analyses and are situated within the low and high Al_2O_3 Stimson bulk focal compositions respectively. Clusters 1, 2, 3, and 6 were shown to lie along a mixing line between CheMin derived mafic and felsic compositions (Fig. 2), with Cluster 1 (n = 24) richer in MgO, and Cluster 6 (n = 10) richer in Al_2O_3, SiO_2, Na_2O and K_2O compared to bulk Stimson. As a result, we interpret Clusters 1 and 2 as relating to ChemCam analyses of Stimson sandstone that have preferentially sampled a high proportion of mafic minerals (pigeonite and orthopyroxene). Consequently, Clusters 3 and 6 have likely analysed a greater proportion of felsic minerals (plagioclase and K-feldspar).

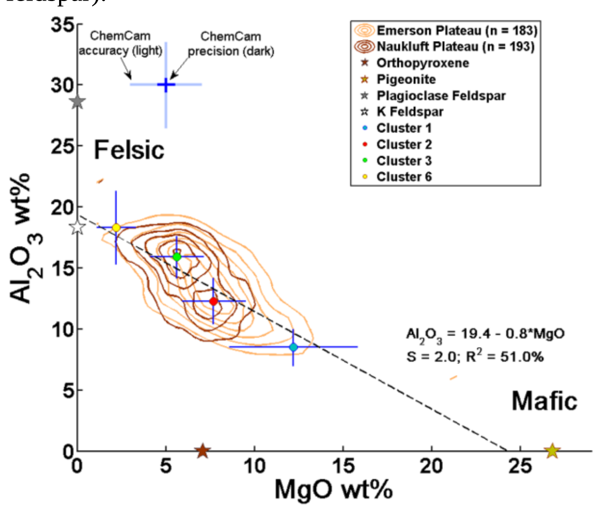

Fig. 2 shows the density contours of the Emerson and Naukluft Plateaus, a linear regression relating to mafic-felsic mineral sorting, and the derived mafic (1 & 2) and felsic (3 & 6) clusters with 1σ error. CheMin mineral compositions for the Big Sky drilled sample are from [13]. S = standard error of the regression. ChemCam 1σ precision and accuracy are shown as dark and light blue crosses respectively.

Relatively few (n <16) observation points comprise Clusters 4, 5, and 7 which are distinguished from bulk Stimson compositions by respective enrichments in TiO_2, CaO and FeO_T. These clusters do not correlate with any trends towards CheMin-derived primary igneous mineral compositions and are therefore classed as outlying compositions, most likely relating to diagenetic cement [9] or a possible enrichment in rare heavy minerals such as ilmenite for Cluster 4.

Mineral sorting trends in the Ancient Stimson Dunes: Generally, the Emerson Plateau Stimson shows a higher proportion of ChemCam observation points with mafic cluster memberships (1 & 2) relative to the Naukluft Plateau which is richer in felsic cluster memberships (3 & 6). This suggests that aeolian mineral sorting may have preferentially enriched the Emerson Plateau Stimson in mafic minerals. Based on previous studies of the mafic-felsic mineral sorting regime in Martian [14] and terrestrial basaltic dune sands, this infers a net sediment transport direction from the Naukluft Plateau in the SW to the Emerson Plateau in the NE.

Conclusions: ChemCam derived bulk compositions of the Stimson formation sandstone show that these ancient aeolian dune deposits are largely uniform in composition, though subtle variations in MgO, Al_2O_3, Na_2O and K_2O occur between localities. A cluster analysis of the constrained Stimson dataset revealed seven clusters, four of which relate to different proportions of mafic and felsic minerals analysed by ChemCam. In general, the Emerson Plateau is shown to possess a greater proportion of mafic mineral clusters relative to the Naukluft Plateau. Based on the aeolian mineral sorting regime for basaltic environments, this suggests a SW to NE paleo-net sediment transport direction, which in turn would indicate a NE prevailing wind direction at the time of deposition. The results of this geochemical study support the sedimentologically derived paleonet sediment transport direction by [6].

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