CHARACTERIZING SHIFTING ANCIENT DEPOSITIONAL ENVIRONMENTS IN THE MURRAY FORMATION, GALE CRATER, MARS FROM CHEMCAM LIBS DATA. F. Rivera-Hernandez[1], D. Y. Sumner[1], N. Mangold[2], K. M. Stack[3], K. Edgett[4], N. Stein[5], E. Heydari[6], C. Fedo[7], S. G. Banham[8], S. Gupta[8], J. Schieber[9], H. Newsom[10], O. Forni[11], A. Yingst[12], M. Nachon[1], J. L'Haridon[2], O. Gasnault[8], R. Wiens[13], S. Maurice[8]
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Introduction: The lower member of the Murray formation in Gale crater, Mars (Fig. 1), the Pahrump Hills member, has been interpreted as an ancient lacustrine environment and was an important sedimentary facies transition traversed by *Curiosity*, the Mars Science Laboratory (MSL) rover [1]. Detailed interpretations of sedimentary facies for the remaining >300-m-thick Murray formation are limited, and thus the extent and duration of this ancient lacustrine environment are poorly constrained. Reconstructing ancient depositional environments and identifying sedimentary facies changes is key to accomplishing the main goal of the MSL mission, which is to characterize habitable environments of early Mars from the sedimentary record in Gale crater [2]. Identifying lacustrine facies is particularly important as lakes commonly preserve biosignatures on Earth [e.g., 3] and provide evidence for sustained liquid water on the martian surface.

The size of sediment grains in rocks constrains depositional processes and provides constraints on ancient environments. This study uses ChemCam Laser Induced Breakdown Spectroscopy (LIBS) data and the Gini Index Mean Score (GIMS) [4] to infer grain sizes and identify facies changes in the Murray formation. Results from this study add to grain size information acquired using image data and provide new insights into the details of the depositional environments preserved in the Murray formation, enhancing our understanding of the habitability of early Mars.

Methods: Grain-size data with almost continuous coverage throughout the *Curiosity* rover traverse can be inferred by quantifying point-to-point chemical variabilities in major-element oxide compositions in ChemCam LIBS data [4, 7]. The diameter of each point vaporized by the ChemCam laser is in the range of medium to coarse sand in size [8, 9]. Thus, rocks with grains smaller than the laser spot size produce bulk rock compositions at all LIBS points and low point-to-point chemical variability [4, 10-13]. In contrast, those with grains about the size of the spot or larger provide contributions from individual grains at each point and often have high point-to-point chemical variability. The presence of sand can be inferred for coarse rocks with non-uniform compositions and grains smaller than granule in size [4].

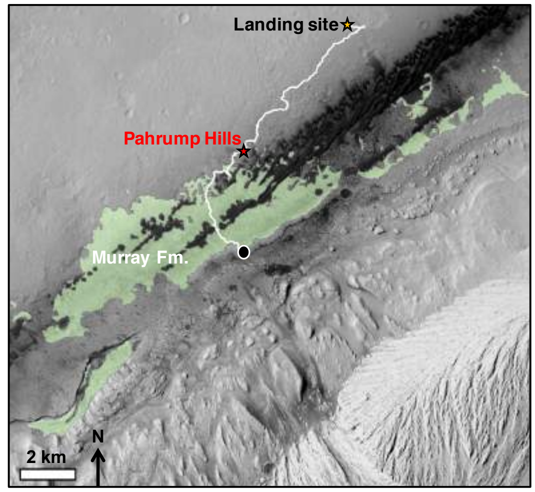

Figure 1. HIRISE image of Gale Crater showing the landing site for *Curiosity* (yellow star) and the rover traverse up to sol 1850 (white line). The green highlighted area is the mapped aerial extent of the Murray formation from [15]. Pahrump Hills is the base of the Murray formation (red star).

The GIMS was used to quantify the chemical variability in the ChemCam LIBS data by implementing the Gini Index [14], a non-dimensional statistical parameter that varies from 0 to 1 [4]. The variability of each major-element oxide was combined to derive a Gini mean score, G_{MEAN}, for each LIBS observation [4]. Finer-grained rocks have smaller G_{MEAN} than coarser-grained rocks [4, 7]. Textural analyses from images taken by the Mars Hand Lens Imager (MAHLI), and the ChemCam Remote Micro Imager (RMI) were used to exclude targets with resolvable diagenetic features from the GIMS analysis. The GIMS was first applied to rocks of known grain size to develop a G_{MEAN} grain size scale. Overall, four different grain size regimes (GSR1-4) were defined for the Murray formation based on correlations between the Wentworth scale and G_{MEAN}: mud (G_{MEAN}=0.00-0.06; GSR1), silt to fine sand (G_{MEAN}=0.07-0.09; GSR2), fine to medium sand (G_{MEAN}=0.10-0.17; GSR3), and medium to coarse sand (G_{MEAN}=0.18-0.34; GSR4). These GSRs were used to predict the grain size of rocks with unknown grain size.

Results: Preliminary results using the GIMS suggest that the Murray formation is dominated by mudstones with grain sizes below the resolution of all imagers on *Curiosity* (Fig. 2). Intervals of fine to coarse sandstones were also detected in GIMS data. The majority of medium to coarse sandstones where verified using grain-size measurements or the presence of cross stratification in images (Fig. 3). The grain size of most fine sandstones identified by GIMS could not be verified due to an absence of sufficiently high-resolution images. However, a few outcrops contained cross stratification, confirming sandstone interpretations.

Discussion: GIMS provides new constraints on grain size variations in the Murray formation, documenting additional diversity of depositional environments and how they changed through time. Specifically, most of the Murray formation consists of mudstone, suggesting low energy depositional environments. However, beds and lenses of cross-bedded sandstone are common in specific intervals, suggesting periods of rapid fluid flow, and the presence of rivers and/or eolian deposits. This is consistent with image based sedimentological studies of the Murray formation [e.g., 5]. At least one interval of sandy mudstone has been identified in the Murray formation, and this may represent lake deposition under an ice-cover. Ice-covered lakes have been proposed for Gale crater by previous studies using orbital datasets [e.g., 16]. While the interstratified mudstones and sandstones indicate that there were changes in sediment deposition in this early martian environment, the persistence of laminated mudstones throughout the >300-m thick Murray formation suggests that liquid water was sustained on the martian surface for tens of thousands to millions of years [e.g., 1, 17].

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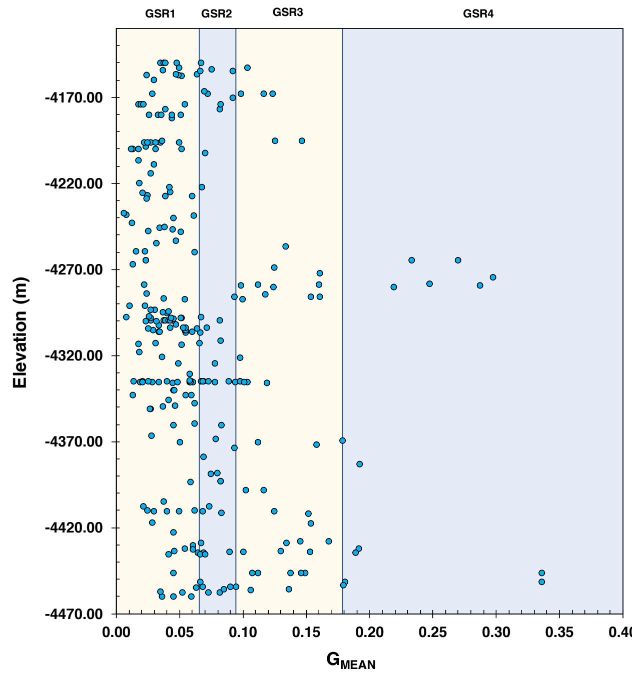

Figure 2. Elevation versus G_{MEAN} for the rocks of the Murray formation derived from the GIMS.

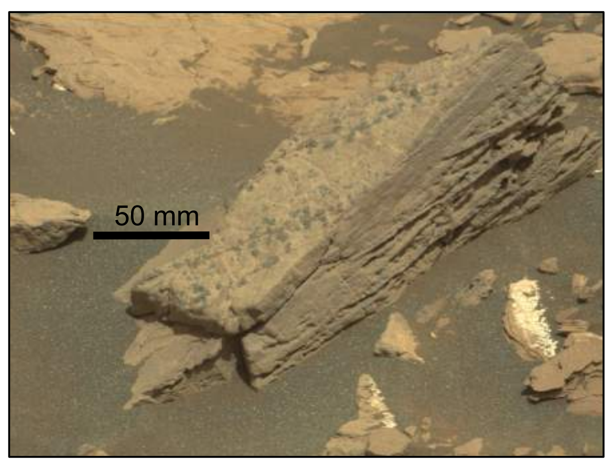

Figure 3. Example of a cross-stratified sandstone in the Murray formation confirming the presence of sand in the rock. Cropped Mastcam image of rock approximately a meter away from the ChemCam LIBS target, Heron_Island, taken on sol 1714 (mcam08947).