CHEMCAM INVESTIGATION OF THE LAST FOUR MSL DRILL SITES IN THE MURRAY FORMATION, GALE CRATER, MARS. R. S. Jackson[1], R. C. Wiens[2], L. W. Beegle[3], E. B. Rampe[4], J. R. Johnson[5], O. Forni[6], H. E. Newsom[1] and the MSL Team; [1]Univ. of New Mexico (Albuquerque, NM 87131; rjacks04@unm.edu), [2]Los Alamos National Laboratory, [3]Jet Propulsion Laboratory, [4] Johnson Space Center, [5]Johns Hopkins Univ. Applied Physics Lab [6]Institut de Recherche en Astrophysique et Planetologie.

Introduction: This study utilizes ChemCam data for outcrop surfaces, drill hole walls, tailings, and dump piles in the Middle Murray Formation to investigate chemical variations with depth in the drill holes and possible effects of the drilling and sample processing. This work is a continuation of similar work on drill sites at Yellowknife Bay [1], the Pahrump Hills [2], and the Stimson Formation [3].

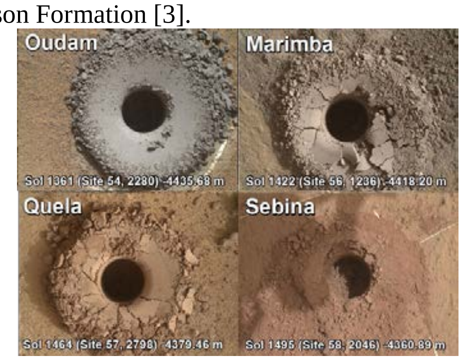

Fig. 1: MAHLI images of the drill sites. NASA/JPL-Caltech/MSSS/F. Calef.

The ChemCam instrument on the Mars Science Laboratory (MSL) rover includes a Laser Induced Breakdown Spectroscopy (LIBS) tool that allows for ~400 µm spot chemical analyses. This microprobe device is designed for rapid remote analyses [4]. These abilities allow the ChemCam instrument to differentiate between the bulk composition of the host rock and composition of chemically distinct diagenetic materials, such as veins [1-3].

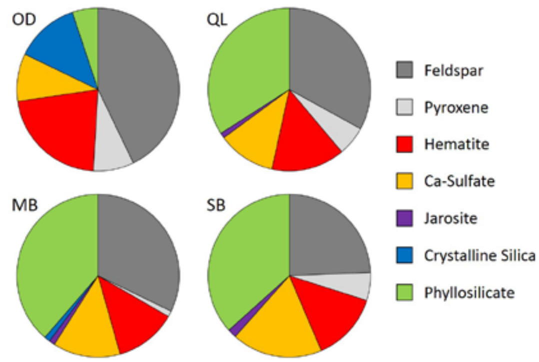

Figure 3: CheMin detected mineralogy at the 4 drill sites [7].

The rover drilled four holes in the Murray Formation after leaving the Stimson Formation and before entering Vera Rubin Ridge, from sols 1361 to 1495. This portion of the Murray Formation is mostly composed of lacustrine mudstones, which the last 3 drill holes sampled; however, Oudam sampled a cross-stratified, possibly fluvial interval. These drill sites continue previous trends in the Murray of decreasing primary mafics upslope and subsequent increase in phyllosilicates. In addition, Ca-sulfates are more common at these 4 sites than previous Murray drill sites [5].

Analytical Details: The LIBS-derived oxide weight percentages of Si, Ti, Al, Fe, Mg, Ca, Na, and K were calculated through a calibration method that combines the PLS1 and ICA algorithms [e.g. 6]. ChemCam analyses are planned and organized by individual sequences usually consisting of a line-scan or grid raster pattern of

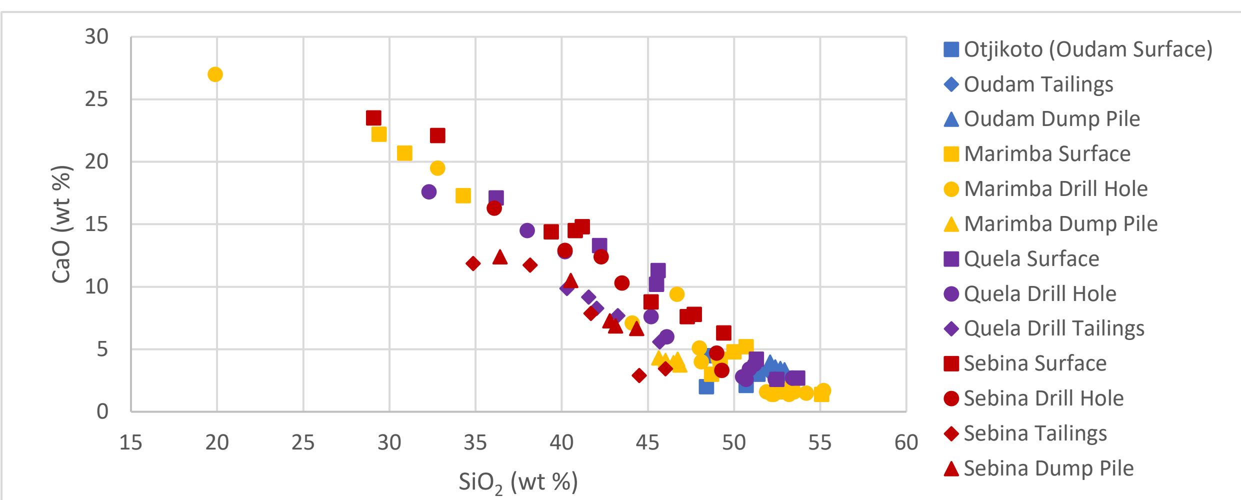

Fig. 2: Averaged ChemCam point data for sequences at the four drill sites with variation in CaO and SiO_2. Points to the top-left are indicative of Ca-sulfate veins.

observation points, where each point is observed with multiple laser shots and where an emission spectrum was recorded for each laser shot. Data in this research use the average of the first 3 single shots for tailings and dump piles and "averaged data" for surface and drill hole data. The "averaged data" is a spectrum created by averaging the spectra of all LIBS shots at each point after the first 5 shots, and then this mean spectrum is used to calculate the oxide abundances.

The rover drill system is a rotary percussion drill head that bores to a depth of 6.5 cm. The drill fines collection system does not engage until a depth of ~2.0 cm is reached; materials from less than 2.0 cm depth are deposited on the surface as tailings. The material collected by the drill system is sieved to <150 μm and delivered to the CheMin and SAM instruments, the material (both sieved and unsieved) is later dumped back to the surface and is referred to as the dump pile. ChemCam also conducted sequences on the drill hole wall, but these sequences were only able to sample from the top third or less of the wall [1].

Results: Fig. 2 displays variations in CaO and SiO_2 for each observation point in each data set. There is a strong anti-correlation between the 2 elements. The Oudam points all cluster at high silica, low CaO values; the other 3 drill sites display a greater range in values with Marimba and Sebina displaying the greatest degree of variation.

Fig. 4 presents the average value for every ChemCam data set at each drill site. Variation is minimal across the data sets for all elements. The alkalis and CaO display some differences at each site, but there are also large standard deviations for these elements as well.

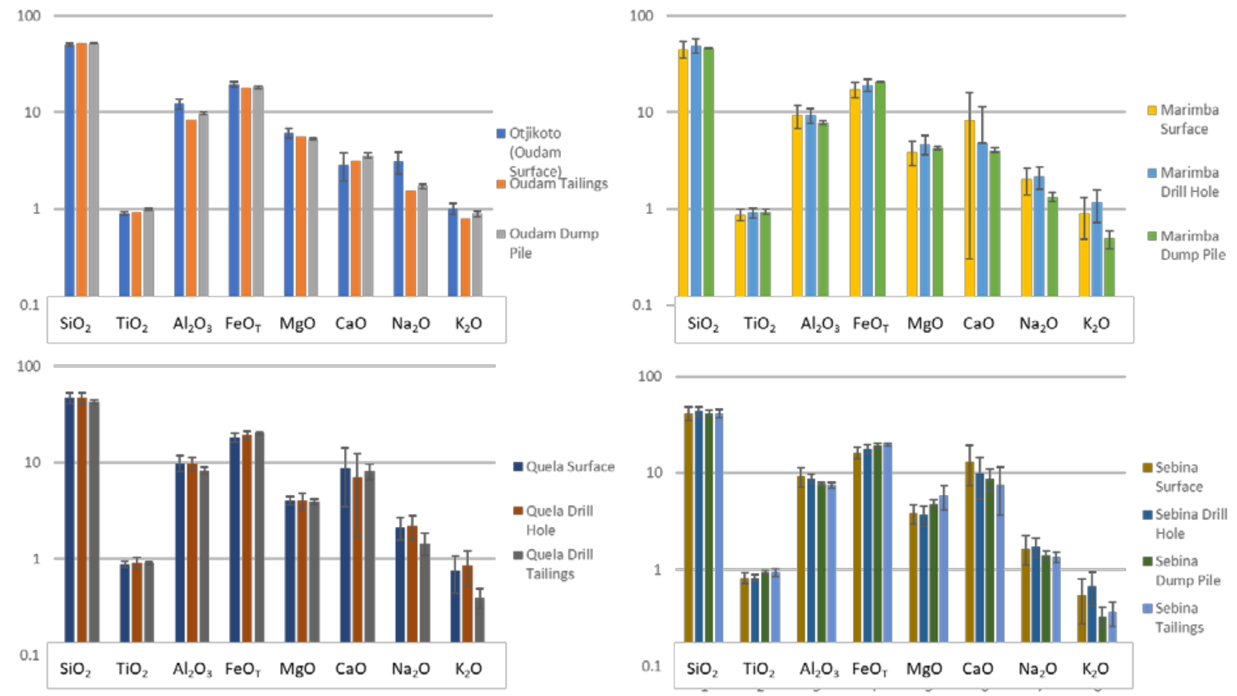

Fig. 4: Semi-log plots of the averages of each data set, separated into each drill site. Clockwise from the top-left, Oudam, Marimba, Sebina, and Quela. Error bars display 1 standard deviation; Oudam tailings has only 1 reliable point so it has no error bars.

Discussion: The minor amount of variations in Fig. 4 and the minimal amount of scattering in Fig. 3 suggests that the major trend at these sites is between Ca-sulfates and silicates, whether primary mafic silicates or diagenetic phyllosilicates. ChemCam data show little evidence for Ca-sulfates in Oudam, whereas there are a few observations at Marimba and Sebina that likely directly sampled at least a portion of a Ca-sulfate vein. The highest silica, lowest CaO point is in the Marimba drill hole; in which a vein can be seen in some of the images of the hole but it is unclear if the vein reaches across to the LIBS observation sites.

Conclusion: Ca-sulfate veins are typical in these sediments, and there is no evidence for significant chemical heterogeneity across the stratigraphy represented by these four sites.

References: [1] Jackson R. S. et al. (2016) *Icarus*, 277, 330-341. [2] Jackson R. S. et al. LPSC XLVII. [3] Jackson R.S. et al. (2017) GSA vol. 49, No. 4. [4] Wiens R. C. et al. (2012) *Space Science Review*, 170, 167, Maurice, S. et al. (2012). *Space Science Review*, 170(1-4), 95-166. [5] Rampe et al., LPSC XLVIII. [6] Clegg S.M. et al. (2017) *Spectochimica Acta Pt. B: Atomic Spect.* 129, 64-84, Anderson, R. B., et al. (2011). *Icarus*, 215(2), 608–627., Forni O. et al. (2013) *Spectrochimica Acta Part B: Atomic Spect.*, *86*, 31-41. [7] Bristow et al., *in revision, Sci Adv.*.