

Strontium in Ca-Sulfate Veins and Cements at Gale Crater, Mars. R. S. Jackson¹, A. M. Ollila², M. A. Nellesen¹, A. M. Baker¹, R. C. Wiens², O. Forni³, A. L. Reyes-Newell², N. Mangold⁴, A. Cousin³, J. Frydenvang⁵, S. Clegg², and H. E. Newsom¹ ¹Univ. of New Mexico (Albuquerque, NM 87131; rjacks04@unm.edu), ²Los Alamos Nat. Lab., ³IRAP/CNES, ⁴Univ. de Nantes, ⁵Univ. of Copenhagen.

Introduction: The ChemCam instrument on the Curiosity rover uses Laser Induced Breakdown Spectroscopy which provides observations of Martian materials with a footprint of $\sim 400 \mu\text{m}$ [1, 2]. The ChemCam instrument is designed for rapid remote analyses with this micro-probe device. These abilities allow the ChemCam instrument to differentiate between the bulk composition of the host rock and composition of chemically distinct diagenetic materials, like veins [3].

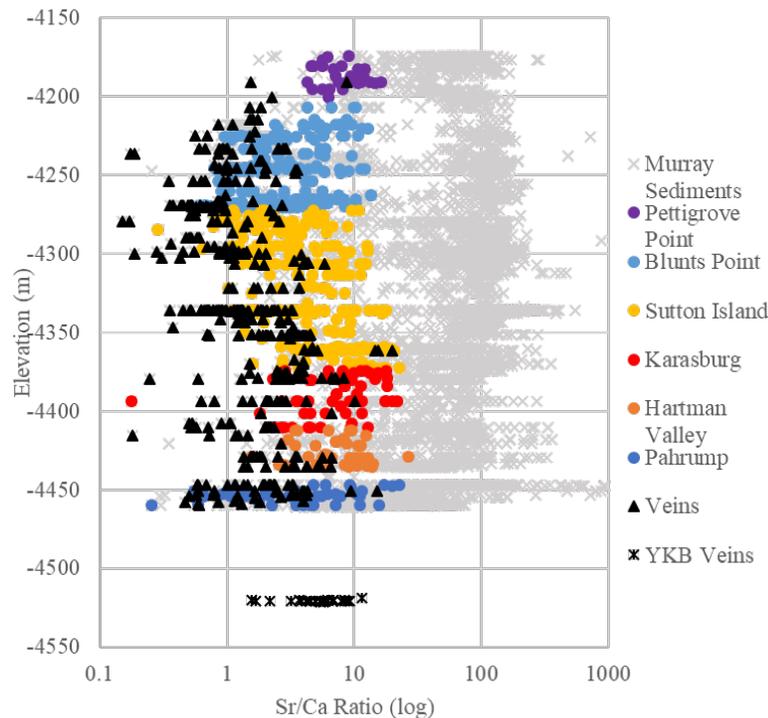


Figure 1: Variation in the Sr (ppm) to Ca (wt. %) ratio with elevation across the Murray Formation for Ca-sulfate veins, cements, and sediments (triangles, colored circles, and grey 'x's respectively) and at the Yellowknife Bay (YKB) location (asterisks). Stratigraphy in the Murray formation is divided into geologic members which are color coded for cement data (10-30 wt. % CaO). Geologic members of veins (black symbols) can be determined by color-coded data. Higher Sr/Ca ratios in veins and cements suggest deposition from a more saline fluid.

The rover has sampled Ca-sulfate veins since entering Yellowknife Bay, during the earliest part of the mission, up until the current drive through the Murray formation, which makes up the lower portion of Mount Sharp [4, 5]. In addition, Ca-sulfate cements were previously identified in the Murray and reported by Nellesen et al. [6].

Sr^{2+} can substitute for Ca^{2+} in the structure of several minerals – including Ca-sulfates. At higher brine concentrations, Sr will coprecipitate at higher concen-

trations relative to Ca [7]. Previous work in the Nijar Basin of Spain was able to differentiate between diagenetic veins and gypsum bearing units, one deposited in a marine environment and one deposited from mixed marine and non-marine fluids. Much of that work was based on the variations in the Sr/Ca ratio and confirmed by other stratigraphic and geochemical methods [8].

Methods: This study currently uses the Sr and Ca abundances reported by the ChemCam team, including previously developed univariate calibration curves for quantitative analysis of Sr (and other trace alkalis) using >400 quantitative standards [9, 10]. The Mars data consists of cemented bedrock – from the list generated by Nellesen et al. [6] – and veins – determined by selecting points with >25% CaO. The data in this abstract were collected through sol 1865. The data were separated into the appropriate stratigraphic members and the ratio between Sr ppm and CaO wt. % was computed. The standard deviation divided by mean (σ/μ) was calculated for targets with at least four Ca-sulfate cement bearing points to investigate spatial variability in Sr.

Results: Sr/Ca ratios vary throughout the Murray formation (Fig. 1), with values from all stratigraphic members stretching from ~ 0 to >10 and a few members with values above 20. The lower members tend to contain the highest Sr/Ca. In Pettigrove Point, which is the lowest member of Vera Rubin Ridge, the minimum values rise gently with elevation, but the maximum values are not much greater than at Blunts Point, the member immediately below (Fig. 1). The median value

of Pettigrove Point is noticeably greater than Blunts point (Fig. 2). The points on rock grains without identified cements have a large amount of variation but tend to have higher ratio values than the cements.

Veins mostly have low ratios (<5) but show higher ratios at the base of Sutton Island and in Pahrump Hills. The four vein points with high ratios are in the targets Hoskinnini in Pahrump Hills and Palapye in Sutton Island (Fig. 1).

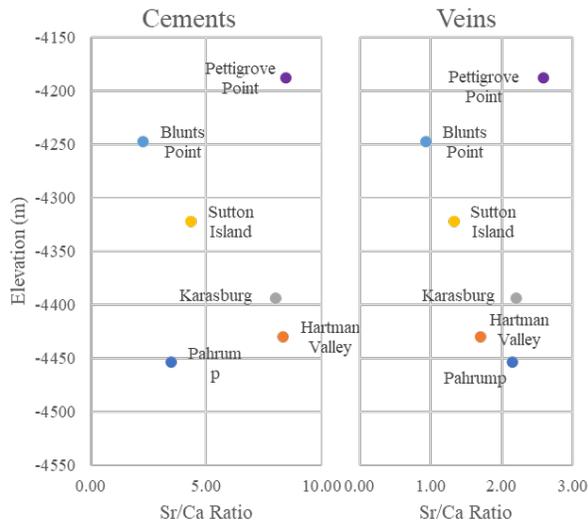


Figure 2: Median values of cements and veins for each unit in the Murray formation.

ChemCam’s small spot size and use of multi-point rasters allow it to sample the spatial variations of Sr that occurs due to the low abundance of trace elements in the fluids that formed the cements. Cements within the Murray formation have Sr standard deviations within each target above 0.5 of the mean with some targets having standard deviations >0.7 of the mean (Fig. 3).

Discussion: Due to the limitations between Martian data and terrestrial data, and the potential that much of the Ca sulfates were deposited during diagenesis, it is not possible to quantitatively determine the paleosalinity of the lake during the deposition of each stratigraphic member [6]. Qualitatively, this method suggests that the lower members were deposited in more saline groundwater than the upper members with the transition occurring in the lower portion of the Sutton Island member. (Figs. 1, 2). The variation observed in ratios may have many causes, including increasing salinity as water is lost from the system or multiple pulses

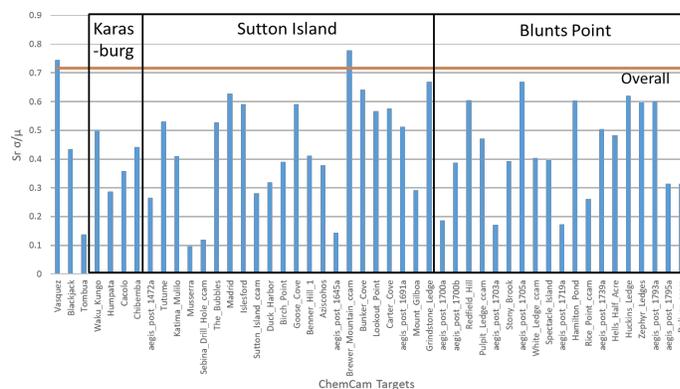


Figure 3: Blue bars: the σ of Sr (ppm) for every ChemCam target with ≥ 4 points containing Ca-sulfate cements. Red line: the overall σ for all individual points containing Ca-sulfate cement through sol 1865.

of fluids. Fig. 3 shows a large amount of variation on the scale of individual ChemCam points within the same target. Indicating that some of the variability in the Sr/Ca ratio is due to spatial variation at the scale of individual targets. The high Sr/Ca values are not uniquely diagnostic of any geologic processes. Sr is present in both primary igneous materials and in many alteration minerals [11]. The Sr/Ca ratio was designed to investigate processes relating to the deposition of Ca-sulfates and is likely not meaningful for the deposition of primary and secondary silicates [7, 8]. The high values of the Sr/Ca ratio in the sediments may be the result of low Ca in secondary minerals but the cements have on average a few 10’s of ppm less Sr than proximal sediments. It is possible that the cements’ Sr abundances have been influenced by the silicates, either by incorporation of sediments with higher Sr abundances into the LIBS analysis or due to pore fluids leaching Sr from sediments during early diagenesis. Either instance would increase the Sr/Ca ratio; however, there is no evidence to support leaching.

Future Work: Laser Induced Breakdown Spectroscopy can be sensitive to materials with different physical and optical properties [12]. To test our calibrations for Li, Ba, Rb, and Sr we plan to check peak areas from emission lines of these elements in >20 terrestrial Ca-sulfate samples of known trace-element compositions. For this, 14 gypsum samples have been provided from a study in the Society Cliffs Formation (Bylot Supergroup, northern Baffin Island) [13]. The rest are Ca-sulfate standards that were used as part of the ChemCam calibration [1, 9, 10]. The optical properties of pure or nearly pure Ca-sulfates may frustrate attempts to develop trace element calibrations for veins; however, it is more likely that Ca-sulfate cements will couple with LIBS laser pulses similarly as with other rocks [12]. This would still be beneficial as the composition of the cement should relate more closely to the processes of deposition, burial, and lithification of the sediment [14].

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