

MEASUREMENT OF BORON IN GALE CRATER NEAR VERA RUBIN RIDGE. D. Das¹, P. J. Gasda², R. C. Wiens², R. J. Leveille¹, K. Berlo¹ ¹Department of Earth and Planetary Sciences, McGill University, Quebec, Canada H3A 0E8 (debarati.das@mail.mcgill.ca), ²Los Alamos National Laboratory, New Mexico, USA.

Introduction: Boron has been detected on Mars (<0.05 wt.%) by the NASA *Curiosity* rover's ChemCam instrument suite in 43 calcium sulfate (CaSO₄) vein targets between sols 113 and 1537 [1]. Boron is detected in CaSO₄-filled fractures that have been observed throughout the sedimentary strata of Gale crater and have resulted from late-stage groundwater circulation [2]. Boron is a highly water soluble element which makes it useful for gaining insights into surface and subsurface aqueous processes on Mars [3]. Borate anions also act as an important prebiotic component as they have been shown to slow the decomposition of ribose in ribonucleic acid (RNA) in solution [4]. Boron was detected frequently in the lower portions of the Murray and Sinson sedimentary formations, in Gale crater [1]. The observations became sporadic in the mid-Murray section as shown in Fig. 2 (between Old Soaker and the base of Vera Rubin Ridge in Fig. 1) but increased in the upper Murray formation (in Vera Rubin Ridge shown in Fig. 1). The highest elevation Murray member, named Jura, is exposed in the Vera Rubin Ridge (VRR). VRR is a resistant, hematite-enriched ridge that occurs stratigraphically above the rest of the Murray formation in Gale crater [5,6].

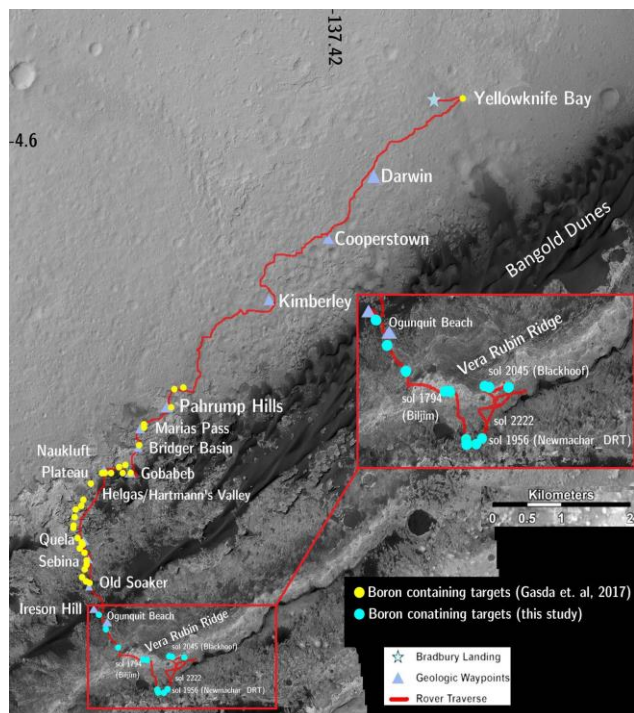


Figure 1. Rover traverse map showing the locations of each boron detection (yellow from [1]; cyan is this work). The inset shows the VRR region.

Methodology: Observations were made using the ChemCam instrument suite. The ChemCam data shows boron emission lines at 249.75 and 249.84 nm [7,1]. The majority of ChemCam targets contain ~18 wt.% FeO_T [8,1]. Interference from an Fe II emission line at 249.96 nm limits boron detection. Hence, B can only be detected in low-Fe targets. i.e., CaSO₄ veins. New targets were selected based on low Fe content of the target (FeO_T < 12 wt%), high total emission of the ChemCam spectra (>10¹³ photons) and targets within 4m. The procedure to fit boron lines is based on [1].

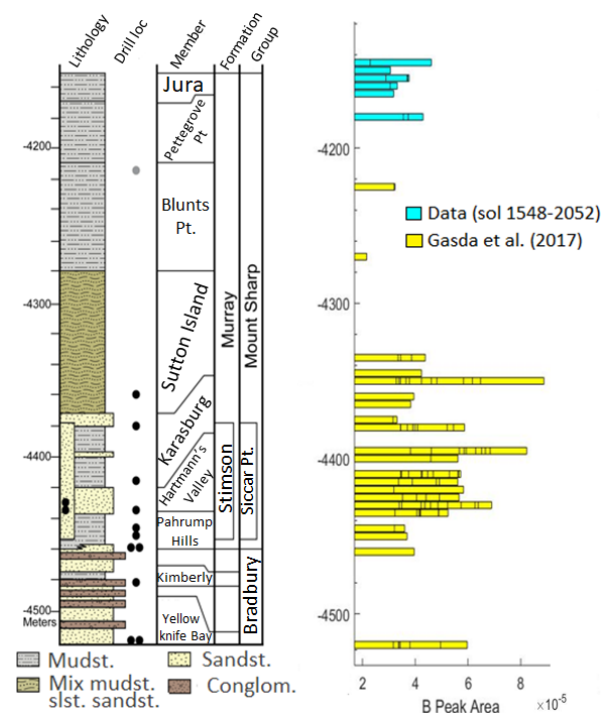


Figure 2. Gale crater stratigraphic column with VNIR normalized boron peak area for each detection plotted versus elevation. Data from [1] is shown in yellow & data for this work in cyan.

Results: Boron is observed in seven new vein targets with a total of 17 point observations (Fig. 2). Three boron observations are in Blunts Point at the upper end this member. On VRR, four observations are in the Petegrove Point near the base of this member and ten observations are in the gray Jura member [5] near the upper portion of this member (Fig. 2). One target called Askival is an altered igneous float rock [9]. Boron is observed in erosionally resistant veins and in veins with nodular texture, with no clear preference for either type. The highest boron concentration is

observed in the target Newmachar (Fig. 3). Concentration of boron for the 17 points shows a weak positive correlation with MgO ($R^2 = 0.47$) and a very weak negative correlation with CaO ($R^2 = 0.21$) (Fig. 4).

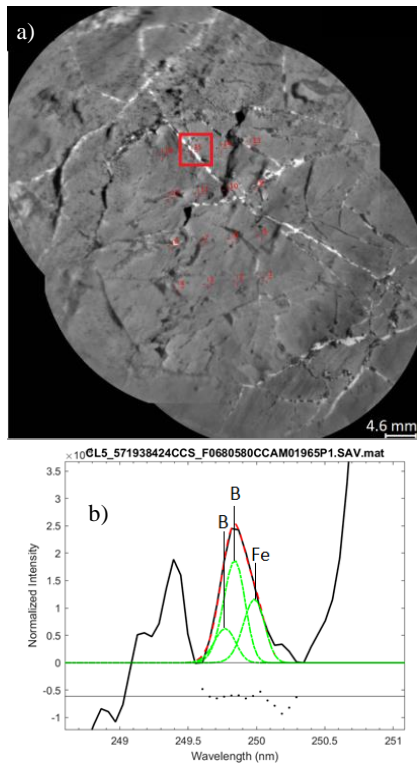


Figure 3. Boron detection in grey Jura member of the VRR bedrock. a) Remote Micro Imager image showing the target Newmachar (sol 1965) where the highest amount of boron is observed (red box) b) ChemCam spectrum showing B and Fe line fits.

Discussion: Altered clays in the upper Murray formation are a result of dehydration, oxidization, elemental mobilization and a drop in Gale Lake's pH [10,11]. With progress in alteration, Mg^{2+} cations are lost from clay minerals [10]. A weak positive correlation between concentration of boron and MgO (Fig. 4 a) may indicate that both boron and MgO were concentrated in the remnant brine and eventually in the groundwater as the lake disappeared.

The boron enrichment locations in the Murray members (Pahrump Hills, Hartmann's Valley, Karasburg and Sutton Island) are close in elevations to detection locations of dehydrated clays (by CheMin), elevated Cl and Na (by ChemCam) and halite (by CheMin) [10,12]. The dehydration of clay in the mid-Murray area is inferred to be caused by shallowing and episodic lake desiccation [10] based on observation of desiccation cracks in mid-Murray formation [13] and comparison with clay minerals on Earth [10]. These observations support the idea that the drying of Gale

lake concentrated boron in the brine. Late stage infiltration [1] of the brine into the Murray formation may have concentrated boron in $CaSO_4$ veins.

Other possible causes of boron enrichment yet to be explored are: 1) adsorption of boron in clay minerals within the Murray host rocks of the sulfate veins where a change in groundwater conditions may have caused desorption of boron into the groundwater [11]; 2) change in origin of the fluids interacting with the groundwater causing enrichment of boron; 3) increased proximity of the rover to the sulphate unit in Gale crater as this unit may better represent dehydration and boron enrichment. Ground water from the sulfate unit may have infiltrated the Murray bedrock at the locations where we observe boron enrichment. Regardless of the path of enrichment, observation of boron in the VRR region expands the spatial window of evidence for dehydration in Gale crater.

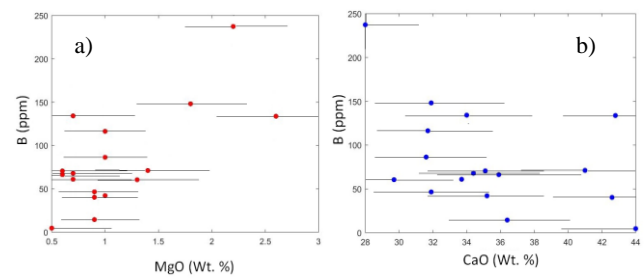


Figure 4. The concentration of boron (ppm) vs a) MgO (wt.%) and b) CaO (wt.%). Instrument precision is shown for MgO & CaO. Uncertainty for quantification of boron is ~100 ppm.

Future work: In order to better understand the behavior of boron with respect to clay minerals and other evaporites, terrestrial analogue studies will be performed in borate-rich playas of Death Valley, CA.

Conclusion: Observation of boron supports other evidence that points towards an onset of dry and more oxidized conditions in Gale crater.

References: [1] Gasda et al. (2017) *Geophysical Research Letters*; [2] Schwenzer et al. (2016) *Meteoritics & Planetary Science*; [3] Spivack et al. (1987) *Geochim. Cosmochim. Acta*; [4] Kim et al. (2011) *J. Am. Chem. Soc.*; [5] Fraeman et al. (2013) *Geology*; [6] Frydenvang et al. (2019) this meeting; [7] Sansonetti and Martin (2005) *J. Phys. Chem. Ref. Data*; [8] Mangold et al. (2017) *Icarus*; [9] Cousin et al. (2019) this meeting; [10] Bristow et al. (2018) *Science advances*; [11] Nellessen et al. (2019) this meeting; [12] Thomas et al. (2018) *Lunar and Planetary Science Conference*; [13] Stein N. et al., (2018) *Geology*.