Geochemical variations observed with the ChemCam instrument on Vera Rubin Ridge in Gale crater, Mars.

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Introduction: On Mars day (sol) 1800 of the Mars Science Laboratory (MSL) mission, the Curiosity rover arrived at the doorstep of the Vera Rubin Ridge (VRR) after traversing more than 17 km from the Bradbury landing site. VRR is a prominent shoulder on Aeolis Mons (Mt. Sharp) displaying a hematite spectral signature from orbit (fig. 1), and represents the first new spectral unit - as mapped from orbit - of the Mt. Sharp Group [1] - overlying ~250 m of vertical exposure of the Murray formation. In-situ rover observations revealed that the Murray fm is a primarily thinly laminated mudstone that was deposited in a long lived lacustrine environment in Gale crater [2].

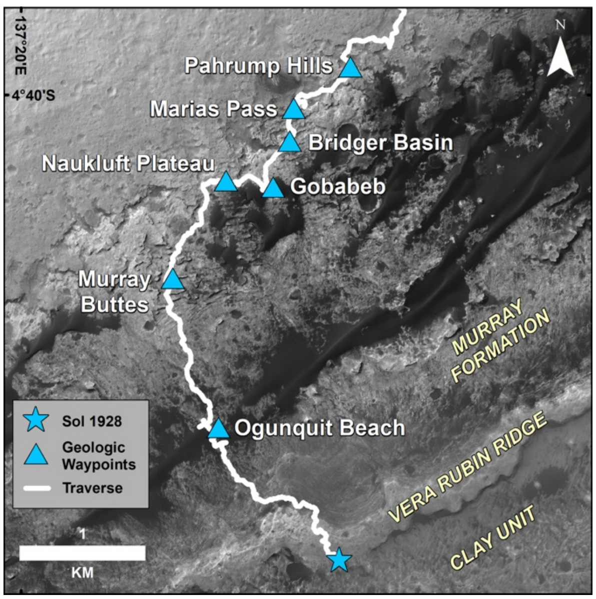

Figure 1: Map showing the traverse of the Curiosity rover from arriving at the Murray fm at the Pahrump Hills location and up Mt. Sharp in Gale crater, Mars.

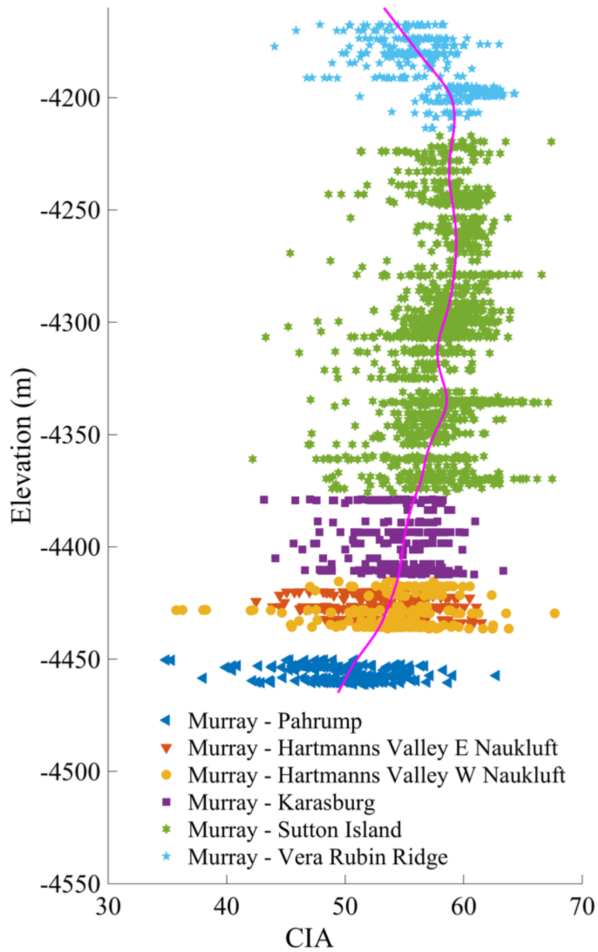

Figure 2: Variation in bedrock Chemical Index of Alteration (CIA) up through the Murray formation and VRR as measured by ChemCam. A notable drop in CIA is observed on VRR. The magenta line represents a smoothing spline fitted to the observation points.

Here, we present results from the ChemCam instrument [3,4] on the bedrock geochemical variations observed on VRR, and hypotheses for their implications on its geological history.

Methods: The ChemCam instrument utilizes Laser-Induced Breakdown Spectroscopy (LIBS) to quantify major [5] and select minor elements [6]. Due to its speed and remote analysis capability, ChemCam provides the largest number of bedrock analyses from the MSL mission, and hence the highest spatial resolution of chemical variations observed in the stratigraphy of Mt. Sharp.

Here we present the bedrock observation points acquired with ChemCam. The ChemCam instrument laser has a spot diameter of 350-550µm on a target [4], which implies that rasters, e.g. a 10x1 line raster, can contain observation points that hit, e.g., Ca-sulfate veins and/or other diagenetic features [7,8]. These points have been excluded from the data presented in figs. 2 and 3. Furthermore, detrital and diagenetic high-silica Murray bedrock in the Marias Pass and Bridger Basin areas (fig. 1) have also been excluded [9, 10]

Results: No major facies differences were observed when ascending from underlying Murray fm bedrock and onto VRR [11,12]. Similar to the Murray fm, VRR bedrock is observed to primarily consist of thinly laminated mudstones interpreted as lacustrine [13]. As the

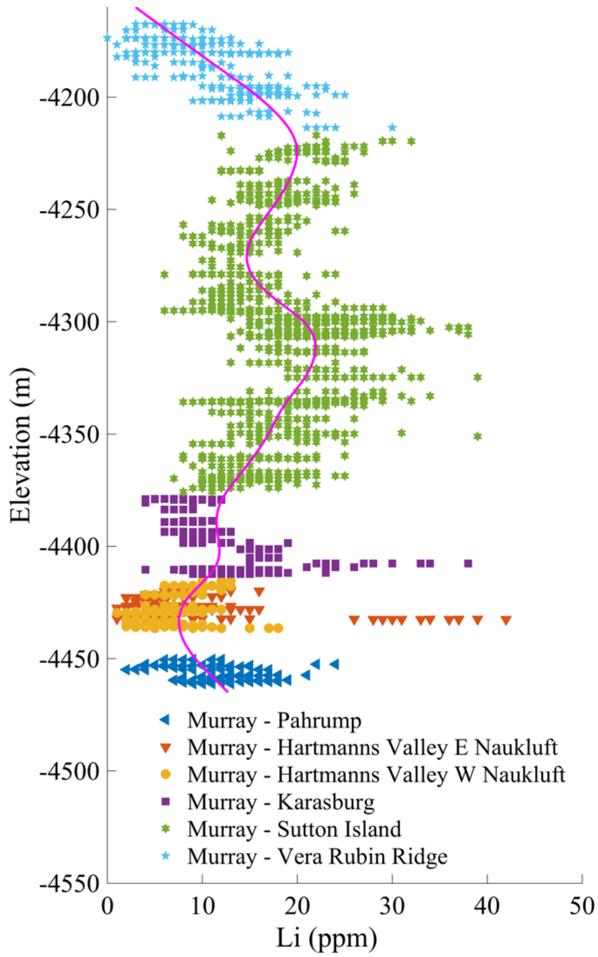

Figure 3: Li bedrock content as measured by ChemCam. The Li-content on VRR shows a noticeable drop on VRR to levels previously observed in the Hartmanns Valley group.

layers of VRR are interpreted as conformable with the underlying Murray fm, VRR is interpreted as an individual group within the lacustrine Murray fm [13]. The Murray fm is an erosionally deflating surface, so VRR is a ridge because of its greater resistance to erosion relative to stratigraphically lower Murray bedrock [13].

No major or minor elements are observed to diverge from the elemental ranges defined by previous Murray bedrock obervations – in particular, despite the clear orbital hematite spectral signatures, VRR bedrock FeO-content is not observed to differ from an overall, but very minor, increasing trend that has been observed up through the Murray fm stratigraphy.

While the absolute content does not differentiate VRR from underlying Murray fm, the relative differences between certain elements show an intriguing change. In particular, an increase in K is observed on VRR, but no corresponding increase is observed for Na, and Al decreases slightly. Combined, these relative variations cause the chemical index of alteration (CIA) [14], which has displayed an increasing trend through the Murray stratigraphy up to VRR [15], to decrease for the first time on the ridge (fig. 2).

While the minor elements quantified by ChemCam are also inside the previously observed range, a noticeable shift is observed for Li up VRR (fig. 3). Li is an easily observable element in LIBS spectra, and displays well resolved spectral lines even for the lowest Li-content observed on the VRR.

Discussion: Neither the observed facies, nor geochemistry suggest that VRR bedrock represent a different depositional environment relative to underlying Murray fm. This implies that the lacustrine stratigraphy is extended further up Mt. Sharp, further expanding the period of a lacustrine environment in Gale crater.

An increase in K was observed previously in the mission at the 'Kimberley' location, where it was identified by CheMin to originate from a sanidine-rich component [16]. At VRR, however, the corresponding drop in Al suggests that the main carrier of the increased K must be a different phase.

Li is a volatile element that is often present in the structural composition of phyllosilicates (e.g., hectorite [17]). The low Li content observed on VRR is thus consistent with a possible drop in clay content that could potentially also explain the increased erosional resistance of VRR. The drop in CIA at VRR may likewise be linked to a decrease in alteration and thus in clay content on VRR. Notably, the Li-content and CIA observed on VRR are comparable to that observed in the Hartmanns Valley group, ~150m below VRR (though the K-content is lower in the Hartmanns Valley Group). Outside two samples containing considerable crystalline silica, drill analysis of the Oudam drill sample from that region displayed the lowest clay content and the highest hematite content observed in Murray bedrock [18]. An explanation to the particularly prominent hematite spectral signatures on VRR observed from orbit remains unclear however.

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