

APXS determined chemistry of the Vera Rubin (Hematite) Ridge, Gale Crater, Mars: Implications for hematite signature origin. L. M. Thompson¹, A.A. Fraeman², J. A. Berger³, N. I. Boyd³, E. Desouza³, R. Gellert³, C. O'Connell-Cooper¹, J. G. Spray¹, A. Yen² ¹Planetary and Space Science Centre, University of New Brunswick, Canada (lthomps@unb.ca), ²Jet Propulsion Laboratory, ³University of Guelph.

Introduction: The Vera Rubin Ridge (VRR), Gale crater, Mars (formerly Hematite Ridge), is a resistant ridge identified from orbit as having a hematite spectral signature [1]. It occurs within the lowermost strata of Mount Sharp (Mnt Sharp, official name Aeolis Mons), stratigraphically above the Murray formation (fm) over which the Curiosity rover has been driving and exploring since arriving at the base of Mnt Sharp at Pahrump Hills (Fig 1).

The detection of hematite indicates that the ridge was a site of active oxidation, and formed in one of

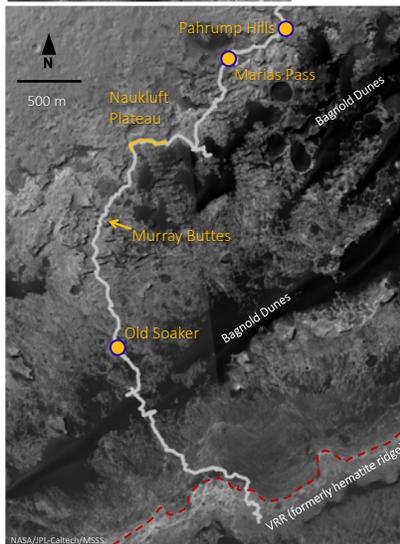
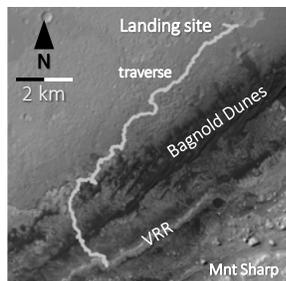


Fig. 1. Top: Curiosity's traverse overlain on HiRise image. Bottom: Curiosity's traverse through the Murray fm and on to the VRR.

two geochemical environments. The hematite could have formed at a redox interface. Fe^{2+} would have been oxidized, and insoluble Fe^{3+} precipitated. An alternative hypothesis is that the hematite precipitated

from an acidic solution [2]. We report the compositional data acquired by the Alpha Particle X-ray Spectrometer since climbing onto the ridge. How does the composition of the ridge compare with the underlying Murray fm and other rocks encountered within Gale crater?

Alpha Particle X-ray Spectrometer: The Mars Science Laboratory Curiosity rover is equipped with a Canadian-built Alpha Particle X-ray Spectrometer (APXS), utilized to obtain quantitative major, minor and trace element compositional data for rocks and

soils. APXS combines PIXE and XRF, which produce characteristic wavelength X-rays of the constituent elements. The field of view (FOV) is 1.5 cm when in contact with a rock or soil. APXS has acquired +500 rock and 47 soil/sand/regolith analyses up to Sol 1889, recording a diversity of rock compositions.

Chemistry of the VRR: APXS has analyzed 45 bedrock targets since climbing on to the ridge on Sol 1810. VRR targets analyzed to date indicate that the ridge strata fall within the compositional range of the underlying Murray fm, encountered from Pahrump Hills to the base of the ridge. Some VRR targets trend to elevated Na and Cl and the ridge shows a wide range of Mn concentrations, from soil- and sand-like (0.4%) to among the lowest at Gale crater (0.07%) (Fig. 2).

Select elements show relatively sharp contrasts in concentration with the immediately underlying Murray

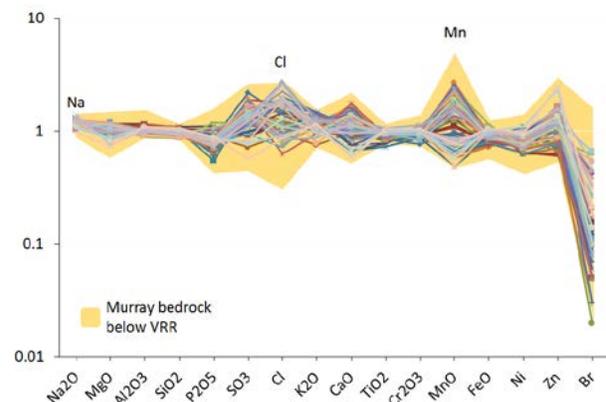


Fig. 2. VRR (lines) and Murray fm (shaded) bedrock targets ratioed to Ganda APXS target (~average Murray composition). VRR bedrock falls within the compositional range of Murray fm bedrock encountered below the ridge. Some VRR targets trend to high Na and Cl concentrations and the ridge exhibits a divergence in MnO content.

fm. Mn, Mg, Ca and S decreased as we climbed onto the ridge whilst certain targets exhibited elevated Si, Zn and Cl (Fig. 3).

In general, VRR rocks trend to relatively high K and Cl, and low Ni, Zn, and Fe concentrations compared to the Murray Fm below the ridge. Mn ranges from very low concentrations as we climbed onto the ridge, followed by a trend to higher concentrations as we gained in elevation. More recent grey targets within a region identified as "blue" in HiRise have relatively low Mn. This variation in Mn results in divergent FeO/MnO ratios for the VRR and very high FeO/MnO at the base. See Figure 3.

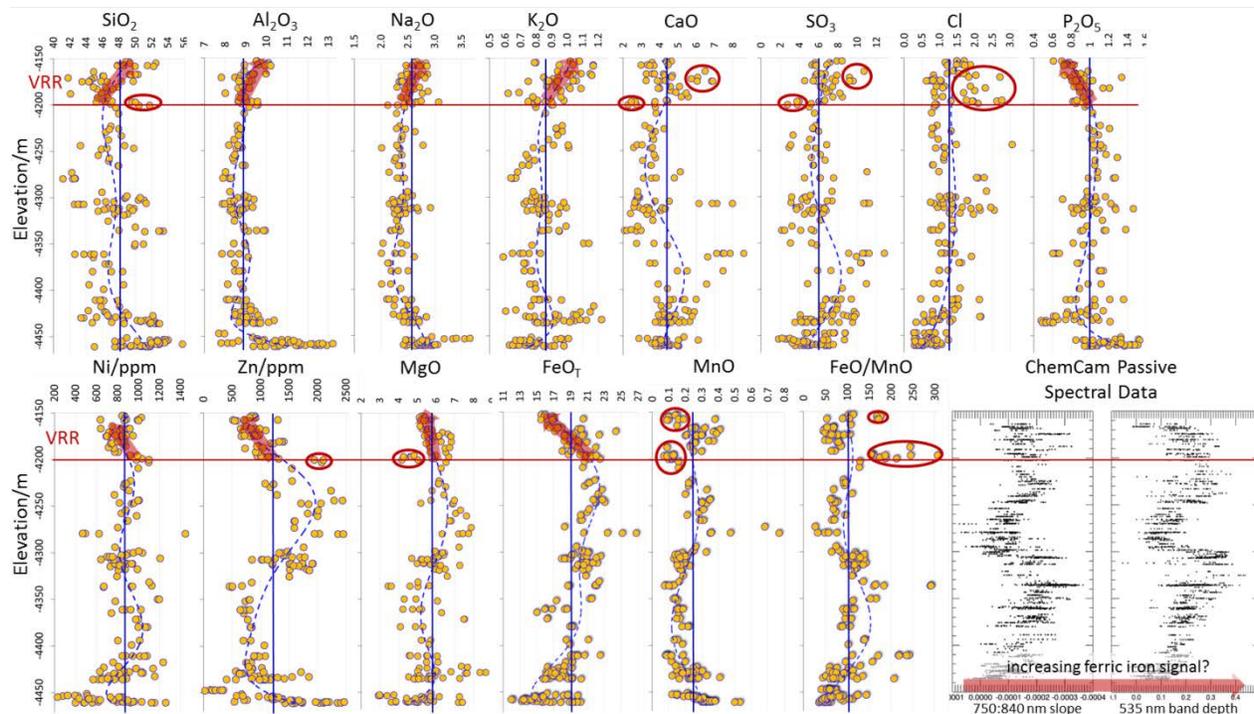


Fig. 3. Variation in chemistry and 750/840 nm slope and 535 nm band depth from ChemCam passive spectra throughout the Murray fm and the VRR with elevation. Dashed blue lines are polynomial trend lines, the solid blue lines are average Murray fm.

Discussion: VRR bedrock compositions fall within the range of the underlying Murray indicating that the rocks that comprise the ridge are a continuation of the underlying Murray indicating that the rocks comprising the ridge are a continuation of the Murray fm depositional sequence. This is also supported by the sedimentology [3] [4]. If there is no change in depositional facies, the VRR is likely recording a change in lake water chemistry and redox conditions at the sediment/water interface, or post-depositional fluid chemistry within the sediment, which resulted in preferential cementation/diagenesis and/or alteration of the ridge rocks.

FeO/MnO: Fe^{2+} and Mn^{2+} have the same charge and similar ionic radii, and occur in similar sites in ferromagnesian minerals. They maintain a fairly constant FeO/MnO ratio of ~ 50 for Mars if present in primary igneous minerals. Deviations from the average martian FeO/MnO ratio indicate alteration of the primary igneous minerals. Upon exposure to oxidizing environments, Fe^{3+} and Mn^{4+} are the common by products, which can, depending on the conditions present, result in fractionation, thereby changing the FeO/MnO ratio. The relatively high FeO/MnO for the Murray fm as a whole (avg ~ 100) is primarily the result of relatively low MnO concentrations. Variations in the FeO/MnO ratio throughout the Murray generally mimic the trends observed in ferric absorption bands from

passive ChemCam spectra (Fig. 3.). This suggests that the FeO/MnO is broadly tracking changes in the abundance of ferric iron and that the Murray fm (~ 100) is enriched in ferric iron relative to average Mars (~ 50). This is supported by the CheMin XRD detection of hematite in drilled targets [5]. The widely divergent FeO/MnO encountered on the VRR suggests variable concentrations of ferric versus ferrous iron within the ridge strata and not a uniformly hematite-rich ridge.

The very high FeO/MnO of targets analyzed at the base of the ridge, also exhibit strong ferric absorption features in both MastCam multispectral and ChemCam passive spectral data [4], perhaps consistent with more hematite than in the immediately overlying and underlying stratigraphy. The concentration and depletion of certain elements within the same targets at this elevation indicate that the processes responsible for the high FeO/MnO and ferric spectral signatures at the base of the ridge, may have varied throughout the VRR.

References: [1] Fraeman, A. A., et al. (2013), *Geology*, 41(10), 1103–1106. [2] Fraeman, A. A., et al. (2016) *JGR Planets*, 121, 1713-1736. [3] Edgar, L. A., et al. *this conference* [4] Fraeman, A. A., et al., *this conference* [5] Rampe, E. B., et al., (2017) *48th LPSC*, 2821.pdf.

Acknowledgements: The MSL APXS is managed and financed by the Canadian Space Agency. We appreciate and acknowledge the support of engineers at JPL during operations.