USE OF MRO CRISM, HIRISE, AND CURIOSITY DATA TO MAP BEDROCK AND SAND COVER PROPERTIES ALONG CURIOSITY'S TRAVERSES IN GALE CRATER, MARS. R. E. Arvidson, Washington University in St. Louis, McDonnell Center for the Space Sciences, Department of Earth and Planetary Sciences, arvidson@wunder.wustl.edu.

Introduction: The Mars Curiosity rover has traversed across extensive Murray formation (Mf) lacustrine exposures [e.g., 1], including hematite bearing outcrops on Vera Rubin Ridge (VRR) [2], and most recently units in Glen Torridon (GT) [3] (Figs. 1,2). In this abstract the spectral signatures for the broad 3.0 μm mineral hydration [4] and 2.3 μm ferric smectite (Fe-OH) absorptions [5] are presented using denoised Mars Reconnaissance Orbiter (MRO) CRISM hyperspectral imaging data (~0.45 to 3.8 μm [6]) that have been modeled for atmospheric aerosols, gases, and thermal emission. Results are compared to MRO HiRISE image data and what has been observed by Curiosity.

Approach: The DISORT radiative transfer code was used with a mildly backscattering Hapke function for the surface boundary condition, together with explicit inclusion of atmospheric dust and ice aerosols, CO_2, H_2O, and CO gases [7]. Additionally, a neural network approach was used to resolve the underdetermined nature of the mixed solar and emission terms for the longer wavelength data, and thus to solve simultaneously for surface kinetic temperatures and single scattering albedo spectra free of thermal effects [8]. A log maximum likelihood regularization with penalty functions was used to denoise and map project the CRISM data [7].

Results and Implications: The Bagnold Dunes are an extensive modern barchan and longitudinal basaltic sand field [9] located to the north of the VRR that Curiosity observations show covers Mf outcrops. The 3.0 μm hydration map shows very low values associated with the field, consistent with Curiosity's observations of the lack of hydrated phases [e.g., 9,10]. Comparison to HiRISE data also shows a strong positive correlation between relatively sand-free Mf outcrops and the depth of the hydration absorption. This indicates ubiquitous and extensive hydration of the outcrops, with spectral variability simply controlled by the areal extent and depth of the modern wind-blown sand cover.

Comparison of the HiRISE and the hydration maps also shows that the VRR has low hydration values, even though Curiosity data show extensive exposures of Mf bedrock. This relationship must be associated with the post-depositional alteration of Mf rocks that produced the hematite evident in both CRISM and Curiosity data [2].

Perhaps the most interesting results are the hydration and the 2.3 μm absorption signature patterns in the Mf rocks within GT, the outcrops that dominate the surface of the Greenheugh pediment (Gp), and the sulfate strata that overlie the Mf rocks (Figs. 1,2).

The Gp surface has a CRISM spectral signature similar to the Stimson formation encountered by Curiosity in the Naukluft hills (Nh) area and inferred to be a wind-blown sandstone deposit that lies unconformably over partially eroded Mf strata. Both the Gp and Nh are interpreted using CRISM spectra to be a mix of basaltic sandstone, modern wind-blown sands, and regolith cover.

The sulfate-bearing strata exposures to be examined by Curiosity during its initial traverses into the kilometers-thick sulfate section have strong hydration signatures, but lack a 2.3 μm signature. This is consistent with the spectral dominance of both mono and polyhdrated magnesium sulfate signatures evident in CRISM spectra. It is also consistent with the lack of sand cover observed in HiRISE data, and the relatively cool temperatures and high thermal inertias retrieved from CRISM data [11].

Various Mf stratigraphic units have been mapped in GT using HiRISE and Curiosity data [3]. The smooth ridged unit [12] is located in the northern portions of GT. This surface is dominated by regolith, with ridges capped by layered outcrops [12]. Exposures of this unit have both elevated hydration and 2.3 μm (and 1.9 μm hydration, not shown) absorption signatures. This unit also has the highest smectite contents encountered by Curiosity, based on CheMin data [13], and high, but variable DAN equivalent H_2O contents [14]. Based on areal extent, and locations with minimal sand cover, this surface is interpreted to be the carrier of the CRISM-based spectral signatures.

There is also a strong positive correlation between the hydration and 2.3 μm absorption signatures within the GT smooth ridged unit, with less correlation to the south, where the overlying GT fractured and intermediate fractured units are exposed [3]. The interpretation of an enhanced 2.3 μm signature with variable hydration is work in progress as Curiosity continues its exploration and characterization of GT. A working hypothesis is that it is due to a combination of varying ferric smectite content and hydration states. The latter is

consistent with retainment of the Fe-OH bonds with decreasing interlayer H_2O during dehydration [15].

References: [1] Grotzinger J. et al. (2015), *Science*, 10.1126/science.aac7575. [2] Fraeman A. et al. (2019), *JGR*, submitted. [3] Fedo C. et al. (2019), AGU Fall Meeting, Abs P22-XXX. [4] Liu, Y. et al. (2016), *JGR*, 10.1002/2016 JE005028. [5] Viviano-Beck C. et al. (2016), *JGR*, 10.1002/ 2014JE004627. [6] Murchie et al. (2006), *JGR*, 10.1029/ 2009JE003344. [7] Kreisch et al. (2016), *Icarus*, 10.1016/j.icarus.2016.09.033. [8] He, L. et al. (2019), *IEEE*, 10.1109/ JSTARS.2019.2900644. [9] Ehlmann, B. et al. (2018), *JGR*, 10.1002/2017JE005267. [10] Rampe et al. (2018), *GRL*, 10.1029/2018GL079073. [11] Christian, J. et al. (2020), *LPS LI*, abs. [12] Stack, K. et al. (2019), AGU Fall Meeting, Abs P33B-02. [13] Bristow, T. et al. (2019), AGU Fall Meeting, Abs P33B-03. [14] Czarnecki, S. (2019), AGU Fall Meeting, Abs P31A-3427. [15] Morris, R. (2019), pers. com..

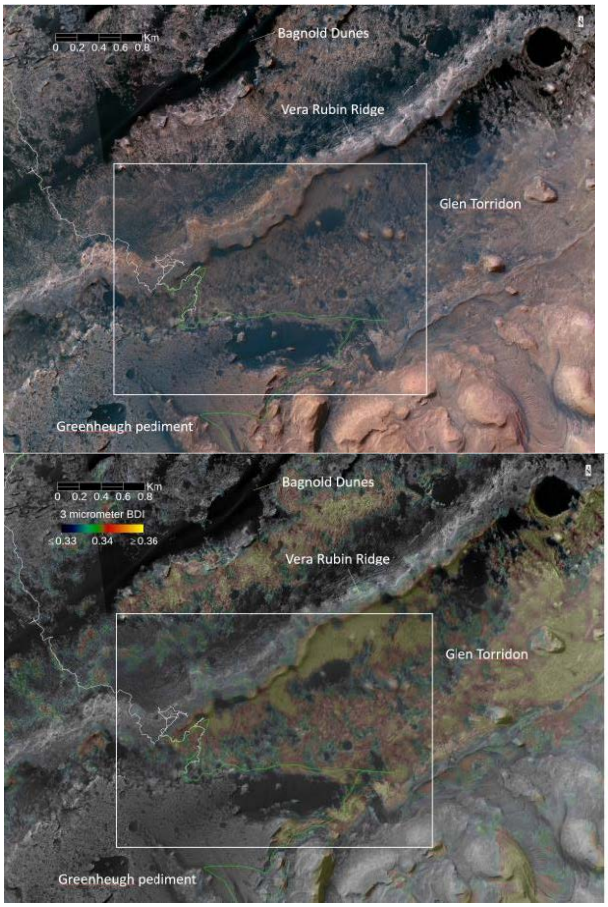

Figure 1*:* Top: HiRISE-based color mosaic. Bottom: Portion of CRISM scene HRL0000BABA-based 3 μm hydration absortion strength map overlain onto a HiRISE-based red mosaic. Murray formation outcrops extend to overlying Greenheugh pediment and the sulfate strata that outcrop as the hills in the lower right portion of the images. White line represents Curiosity's traverses and green line Extended Mission-3 (EM-3) planned traverses. White box delinates areas shown in Fig. 2. Sulfate-bearing hills are located in the lower right-hand portions of the scenes.

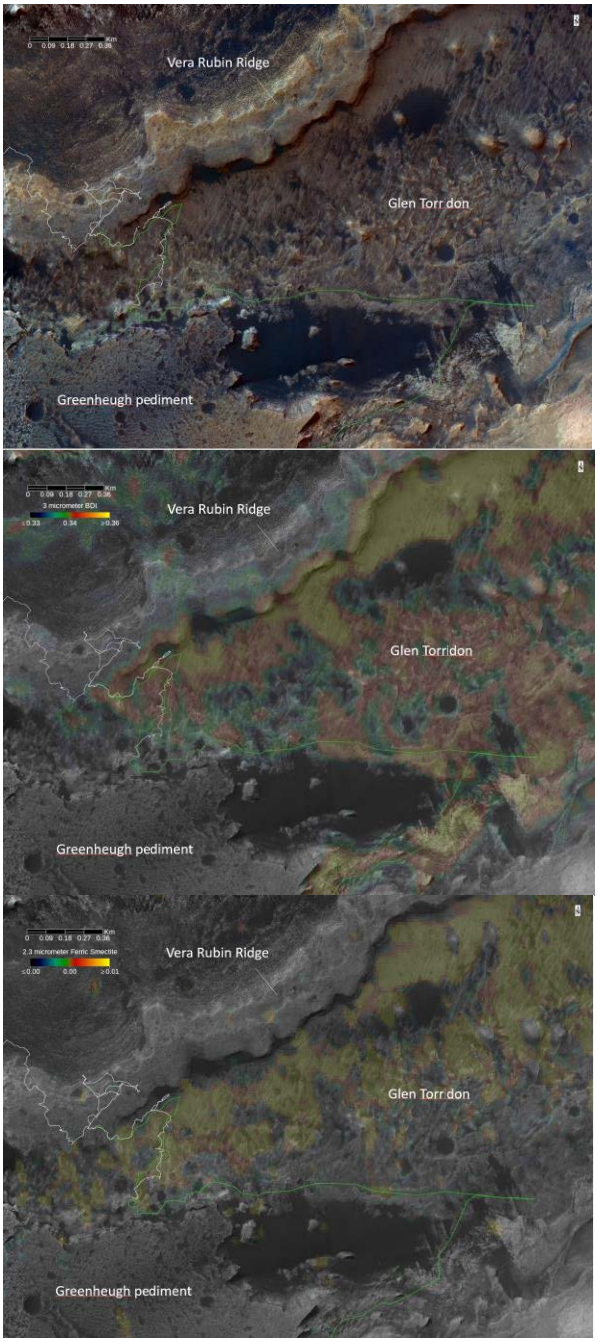

Figure 2: Enlargements for the area shown in Fig. 1 are shown on the top and middle figures, whereas the bottom figure shows the 2.3 μm smectite absorption. Enhanced hydration values immediately adjacent to southern side of the Vera Rubin Ridge are an artifact of using coarsely-spaced elevation data to model the escarpment lighting. Note the enhanced hydration absorption associated with the eastern and southern portions of the EM-3 traverses. These outcrops are the initial sulfate-bearing rocks to be encountered by Curiosity.