HYDRATED SULFATE MINERALS IN GALE CRATER OBSERVED FROM CRISM AND HIRISE IMAGERY I.E. Ettenborough[1] B.J. Thomson[1], C.M. Weitz[2], J.L. Bishop, K.D. Seelos[4], [1]Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN (iettenb1@vols.utk.edu) [2]Planetary Science Institute, Tucson, AZ, 85719; [3]SETI Institute, Mountain View; [4]JHU Applied Physics Laboratory 11100, Johns Hopkins Rd., Laurel, MD 21043

Introduction: Gale crater is a 154 km-diameter impact crater located astride the global martian topographic dichotomy where the *Curiosity* rover is currently exploring [e.g., 1-4]. Gale crater has been an area of continuous scientific interest due to orbital detections of hydrated secondary alteration minerals, including clays and hydrated sulfates, that suggest past aqueous activity was once present; this hypothesis is further supported by in situ rover evidence that details sedimentary structures indicative of a past lacustrine environment [3]. Within Gale crater lies the 5-km high central mound, Aeolis Mons, which is composed of layered sedimentary rock [e.g., 1-6]. Gale crater is hypothesized to be approximately 3.6 to 3.8 Ga, with the sedimentary strata of Aeolis Mons deposited after this time [2]. Aeolis Mons consists of a thick sequence of sedimentary deposits, where the lowermost units are majorly fluvial-lacustrine in origin and sulfates lie above and are interfingered with a phyllosilicate-bearing strata [e.g., 5-7]. Clay mineral contributions decrease stratigraphically upward, transitioning to a sulfate bearing unit that is capped by a spectrally bland deposit lacking hydrated mineral signatures [10]. This change in mineralogy is thought to record a transition in the martian climate, from a wetter, circum-neutral environment supporting the formation of clay minerals to a drier, more acidic environment supporting sulfate formation [e.g., 11].

This climatic shift, from a wetter, circumneutral environment to a more arid, acidic environment coincides with the Bibring et al. [11] model of global climatic evolution for Mars and was a motivating factor in choosing Gale crater for the landing site of *Curiosity*. As the MSL mission progressed, interpretations based on orbital observations were often challenged and reevaluated where in situ evidence became available. Orbital observations are constrained by their resolution and in situ observations offer new evidence that is often higher in resolution and can provide a more detailed context for interpretation. Therefore, continuing rover research revealed what processes can and cannot be confidently inferred via orbital data alone, but it has been found that high-resolution imagery can be used to extrapolate relationships where units are distinct [e.g., 10-13]. The ability to extrapolate interpretations where imagery resolution is sufficient offers the opportunity to investigate sulfate mineral distribution throughout all of Aeolis Mons. By investigating what the surface sulfate mineral distribution is in the current environment with the Compact Reconnaissance Infrared Spectrometer for Mars (CRISM) and High Resolution Imaging Science Experiment (HiRISE) imagery, interpretations regarding sulfate formation can be constrained and informed. Preliminary results thus far indicate sulfate occurrence in Gale is more complex than previously thought, likely being both heterogeneous and not laterally contiguous [13]. Past literature has shown that for other sulfate rich locations on Mars, monohydrated sulfates (MHS) are preferentially found on more eroded surfaces and steep slopes, whereas polyhydrated sulfates (PHS) are found on less eroded surfaces and show no preference for slope [19-20]. Using CRISM and HiRISE data (Figure 1) to map the distribution of MHS and PHS along with HiRISE digital terrain maps (HiRISE DTMs) to elucidate elevation relationships, this study seeks to characterize the sulfate composition and occurrence throughout all of Aeolis Mons.

Global, orbital observations revealed the presence of abundant sulfate minerals on the surface of Mars but their origins are not well understood [e.g., 9, 16] Chemical weathering has been proposed as an explanation for sulfate mineral occurrences elsewhere on Mars such as in Valles Marineris based on Earth analog studies [14]. In Aram Chaos, a crater located to the west of Valles Marineris, similar spatial heterogeneity of hydrated sulfates was observed; MHS were found to be laterally extensive and

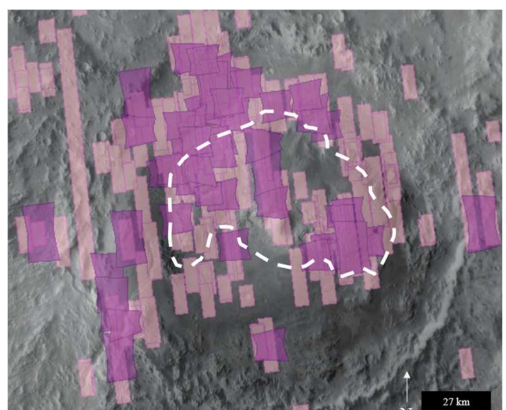

Figure 1. Dark purple denotes CRISM coverage and light pink boxes show HiRISE coverage for Gale. Aeolis mons is outlined in white dashed line. Note the more extensive coverage of HiRISE data that allows for extrapolation of CRISM data.

heterogeneously distributed and PHS were preferentially noted on smoother, darker, and more indurated surfaces. Here, heterogeneity of MHS is attributed to preferential erosion and exposure, and MHS are thought to be even more extensive than what is observable [11]. On Earth, heterogeneous sulfate mineral distribution can be attributed to chemical weathering, in some environments meteoric precipitation mobilizes and oxidizes sulfate and sulfide minerals present in the bedrock, subsequently reprecipitating them on the surface via capillary action [16-18]. Therefore, the spatial distribution of surface sulfate minerals can be tied to the distribution of sulfate/sulfide minerals in situ.

Methods: By combining spectral and spatial data, relationships regarding the spatial distribution and occurrence of sulfates in Gale were able to be distinguished. This was combined with past literature to further evaluate if the sulfates observed in Gale are like those observed in other places on Mars, including West Candor Chasma and Aram Chaos [17-19]. We mapped using the 6 m/pixel CTX mosaic as the basemap and to delineate units [2]. The CRISM scenes used were georeferenced to align with the CTX basemap. Using CRISM coverage, the spatial distribution of MHS was mapped in yellow, PHS in pink, and other, spectrally mixed hydrated minerals are shown in light purple (Fig. 2). HiRISE images and the DTMs produced from available stereo pairs were used to characterize the morphology of the observed sulfates and their relationship to elevation, respectively. While mapping the limitations associated with orbital imagery must be considered. Multiple recent studies have illustrated the complexity involved in making process-based interpretations based significantly on geomorphologic evidence, which was considered while mapping [10-13].

Results: Previous interpretations of CRISM images in Gale have invoked a layer-cake stratigraphy to explain layered sulfate compositions, but this hypothesis has since been challenged based on improved in-situ data [e.g., 10, 22, 25-26]. The distribution of sulfate minerals in Gale where CRISM coverage is available and in areas where it can be confidently extrapolated indicate their spatial distribution is more complex than previously observed. HiRISE imagery made extrapolation possible where CRISM coverage lacked, but it should be noted that interpretations based on extrapolation are not definitive. Results thus far show MHS and PHS to be spatially heterogeneous throughout Aeolis Mons and that units are not always laterally contiguous. This suggests that the presence of hydrated sulfates observed via CRISM may be tied to secondary alteration processes rather than primary depositional features, if formed via a similar process as seen for Earth-based surface sulfate minerals. Additionally, if the observed hydrated sulfate minerals are sourced via chemical weathering of in-situ sulfur minerals, this requires less groundwater to produce what the secondary sulfate minerals observed, requiring a more arid environment that potentially experienced intermittent wet periods during their formation. Continuing exploration of the sulfates by the Curiosity rover will help clarify how the sulfates formed and why orbital data detect changes in the MHS and PHS within the stratigraphy.

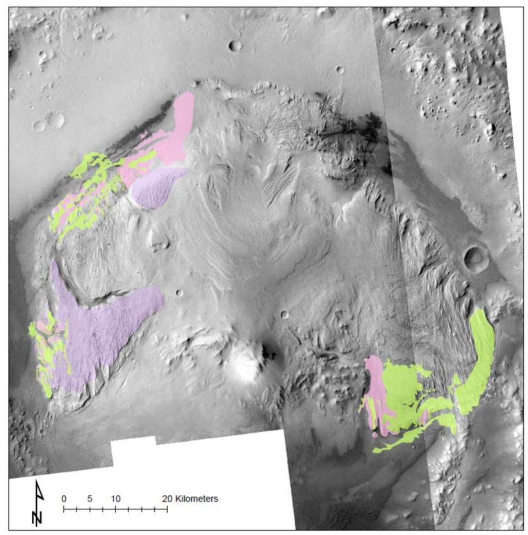

Figure 2. Light purple denotes spectrally mixed compositions, pink represents PHS, and yellow represents MHS.

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