SOURCES OF SAND IN MT. SHARP: POSSIBLE VOLCANIC LAYERS IN GALE CRATER, MARS. A. Rudolph[1], B. Horgan[1], K. Bennett[2], M. Rice[3], [1]Purdue University, West Lafayette, IN (rudolph4@purdue.edu), [2]USGS Astrogeology Science Center, Flagstaff, AZ, [3]Western Washington University, Bellingham, WA.

Introduction: The Murray formation at the base of Mt. Sharp in Gale crater was formed in a lacustrine environment more than three billion years ago, when liquid water flowed on the surface of Mars [1]. The duration of the lake is not fully constrained, and determining the origin of layers higher in Mt. Sharp is a key goal of the Mars Science Laboratory (MSL) mission. Within these higher layers, dark and potentially laterally continuous "marker beds" [2] appear to be composed of unaltered materials, while the surrounding layers both stratigraphically above and below these marker beds are altered sediments. This difference in alteration patterns indicates that the marker beds were deposited by different processes [3]. Similar marker beds in sedimentary sequences on Earth are often ash deposits that can help to date the timing of deposition in the region [i.e., 4]. If this type of marker bed is present in Mt. Sharp, it could place better relative time constraints on geologic events both within Gale crater and at a regional scale, if these beds formed during large-scale volcanic events. The marker beds could also be useful for evaluating the lateral continuity of the Mt. Sharp stratigraphy.

In this study, we seek to determine the mineralogy, transport pathway, and source of mafic sediments in Mt. Sharp. Here we present initial results from the northwestern region, including the dune fields along MSL's traverse, the marker beds, and comparison to other sediment sources stratigraphically higher in Mt. Sharp. Understanding the primary mineralogy of the marker beds and other sediment sources in Mt. Sharp will provide context for results from MSL. MSL determined the mineralogy of active dunes in the northwest region of Mt. Sharp [5,6], but whether or not some of this sand was locally sourced from within Mt. Sharp is unclear [7]. Here we compare the spectral properties and inferred mineralogy of surface sediments to the dunes to determine whether or not the marker beds or other mafic units in the mound could be a sediment source.

Methods: Visible/near-infrared (VNIR) hyperspectral images from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on MRO were used to create mineral maps of Mt. Sharp, starting in the well-understood northwestern region, and extending these maps to the rest of the mound. The CRISM analysis Toolkit (CAT) for ENVI was used to create a map focused on mafic minerals, specifically low-calcium pyroxene (LCPINDEX3), high-calcium pyroxene (HCPINDEX3), and ferrous minerals (OLINDEX3). The mafic mineral map is an RGB band parameter map, where LCPINDEX3 is red, HCPINDEX3 is green, and OLINDEX3 is blue. High-Resolution Imaging Science Experiment (HiRISE) images and terrain models of the region were used to visually relate stratigraphy and geomorphologic features to the mineral maps.

Results: The marker beds have a lower albedo than the surrounding layers with a smoother appearance, and form distinct benches in outcrop (Fig. 1a). We identify at least three distinct marker beds in northwest Mt. Sharp (Fig. 1a/d), and they are continuous to the farthest west portion of Mt. Sharp (Fig. 1d). Further analysis of the elevations and dips of the beds can help confirm the continuity of the marker beds within the western portion of Mt. Sharp and then across the mound. The marker beds are primarily highlighted by the CRISM parameter HCPINDEX3 (Fig. 2). CRISM spectra of the marker beds show a deep, relatively narrow, and slightly asymmetric absorption band centered at 1.02 μm**,** consistent with high-Ca pyroxene (HCP) with some olivine or glass (Fig. 3). A shallow, broad, and slightly asymmetric absorption band is present at 2.10 μm, also consistent with HCP (Fig. 3). All three marker beds exhibit nearly identical spectra, suggesting similar mineralgoies.

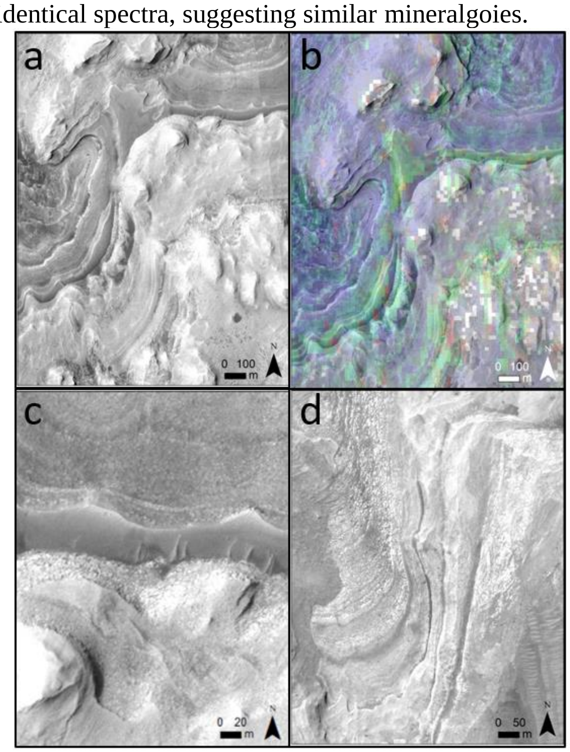

Figure 1: *(a)HiRISE image of marker beds. (b)Fig. 1a overlain with mafic CRISM map (c) Landforms on marker beds (d) Continuation of marker beds seen in W. Mt. Sharp.*

The dunes in the northwest portion of the study region, which were sampled in situ by MSL, have similar spectral properties as the marker beds. The dunes also exhibit a deep, narrow and slightly asymmetric

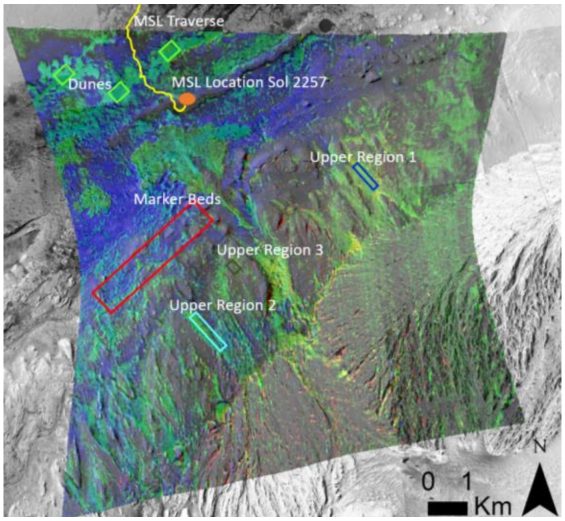

Figure 2: *HiRISE images of study site overlain with CRISM mafic parameter map. Colored boxes indicate where each spectrum was taken and correspond with the colors in the spectra plot in Fig. 3.*

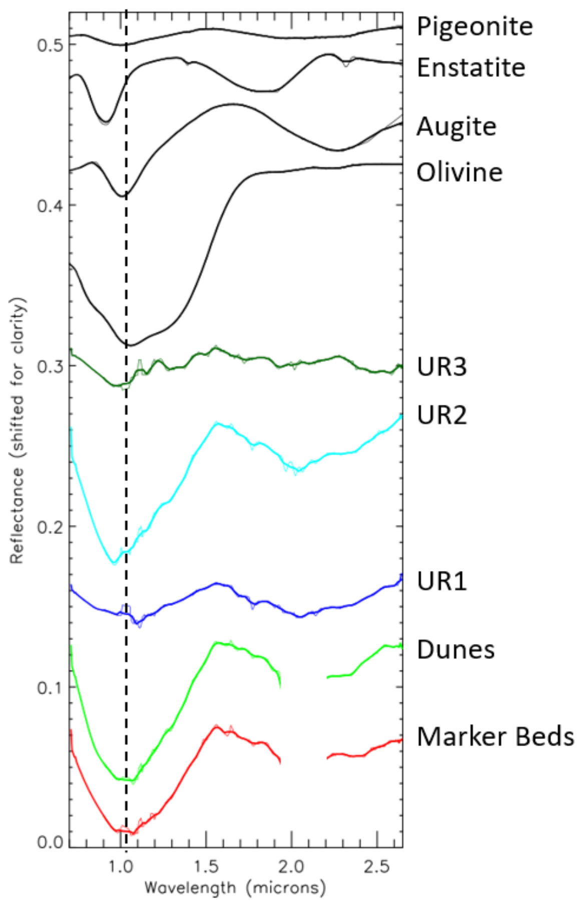

Figure 3: *(left) CRISM spectra: (bottom to top) marker beds, dunes, UR1, UR2, and UR3.(Right) Lab spectra: (bottom to top) olivine, augite, enstatite, and pigeonite. Dashed line at 1.02 microns indicates the band center for the marker beds. Residual atmospheric absorptions near 2 µm have been removed from lower spectra.*

absorption band at 1.02 µm and a shallow, broad, and slightly asymmetric absorption band at 2.08 µm (Fig. 3). Between the dunes and the marker beds, strong OLINDEX3 signatures correspond to parts of the Intermediate Fractured Unit, at similar elevations to the pediment (Fig. 2). At higher stratigraphic levels than the marker beds (the upper region), the spectral shape is distinct from the marker bed spectrum (Fig. 3). A spectrum from sediments mantling surfaces on the upper mound (UR2; cyan) exhibits an asymmetrical band centered near 0.96 µm band and a broad, shallow, and symmetrical 2.12 µm band, consistent with HCP mixed with either low-Ca pyroxene (LCP) or hematite. Similar surficial sediments on the western portion of the upper region (UR1; blue) exhibit two broad, shallow, and symmetrical absorption bands at 1.07 µm and 2.02 µm, consistent with HCP mixed with olivine or glass, but the similar band depth across the two bands may be more consistent with HCP and glass. One location of possible bedrock outcrop on the upper region (UR3; dark green) exhibits weak broad bands near 0.96 and 1.95 µm potentially consistent with HCP or an LCP/HCP mixture.

Discussion: Mafic sediments on the upper region exhibit diverse spectral properties suggesting that a variety of mineral sources are present and actively shedding sand. Our ongoing work aims to determine the full variation in mafic mineralogy across this region the rest of mound. However, our preliminary results show strong similarities between the spectra of the dunes and marker beds, suggesting that some of the dune sediment sampled by MSL could be sourced from the marker beds. MSL data and previous studies indicate the presence of basaltic material in the dunes, primarily composed of olivine, HCP, plagioclase, and amorphous material [5,7], which is consistent with our results.

Because the marker bed spectra are not accompanied by clear alteration signatures, they likely indicate sediments from non-lacustrine processes, like volcanic, impact, or aeolian deposits. This also suggests that the marker beds have not been exposed to strong late diagenetic processes, which may have had a major effect on the mineralogy of lower Mt. Sharp. The multiple repeating layers with nearly identical spectra make three different impact events an unlikely source. But, differentiating whether the marker beds formed through volcanic activity or aeolian deposits requires a visual analysis on smaller scales to look for aeolian bedforms (i.e., cross-bedding). Thus, in situ investigation of the marker beds by MSL may help to constrain the diagenetic history of Mt. Sharp.

References: [1] Grotzinger J. P. et al. (2014) *Science, 343,* 6169. [2] Milliken R. E. et al. (2010) *Geophys. Res. Lett.*, 37. [3] Bennett K. et al. (2017) *GSA, 49*, 4, 5-5. [4] Westgate J. A. and Evans M. E. (1978) *Can. Journ. Ear. Sci., 15*, 1554-1567. [5] Achilles C. N. et al. (2017) *Geophys. Res. Lett. 122*, 2344-2361. [6] Rampe E.B. et al. (2018) *Geophys. Res. Lett., 45*, 9488-9497. [7] Lapotre M. G. A. et al. (2017) J. *Geophys. Res. Planets,* 122, 2489-2509.