DEPOSITIONAL HISTORY OF THE HARTMANN'S VALLEY MEMBER, MURRAY FORMATION, GALE CRATER, MARS. S. Gwizd[1] (sgwizd@vols.utk.edu), C. Fedo[1], J. Grotzinger[2], K. Edgett[3], F. Rivera-Hernandez[4], N. Stein[2], [1]Department of Earth & Planetary Sciences, University of Tennessee, Knoxville, TN, [2]California Institute of Technology, Pasadena, CA, [3]Malin Space Science Systems, San Diego, CA, [4]University of California, Davis, Davis, CA

Introduction: Based on remote and in situ analyses using the Mars Science Laboratory (MSL) Curiosity Rover in Gale crater, fluvial-deltaic and lacustrine deposits of the Bradbury group and the Murray formation are interpreted to reflect progradation in a lake basin with standing water [1,2]. The MSL science team collected data from the ~25-meter thick Hartmann's Valley member (HVM) of the Murray formation to the east (sols ~1157-1202) and west (sols ~1355-1420) of the Naukluft Plateau (**Fig. 1**). Rover images reveal meter-scale trough cross-bedding, abrupt stratal truncations, and concave-curvilinear features indicative of large-scale dune bedforms. Preliminary investigation indicates that the bedrock in the HVM consists of clastic sedimentary rocks with a dominantly fine grain size, generally too fine to resolve in routinely acquired Mars Hand Lens Imager (MAHLI) images (17-100 µm/pixel; **Fig. 2**).

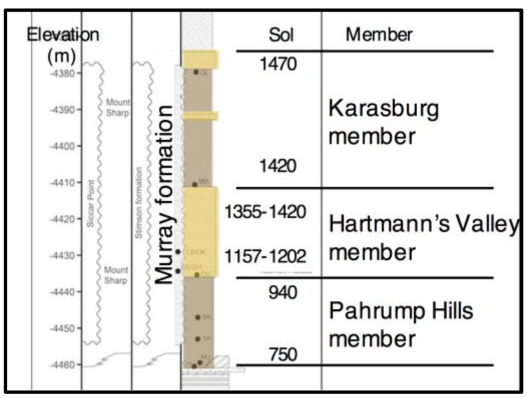

Figure 1. MSL team summary stratigraphic column of a portion of the Murray formation showing the Pahrump Hills through Karasburg members [3].

One interpretation is that the HVM represents lithified aeolian dunes [1]; however, the preliminary MAHLI image analyses as well as grain size interpreted from Chemistry & Camera Laser-Induced Breakdown Spectrometer (ChemCam LIBS) analyses indicate a grain-size distribution inconsistent with that of Martian dune sands [4]. In numerous cases, the HVM grains are finer than those measured in modern-Martian dunes [5].

As the sedimentary structures seen in the HVM can also form from fluvial processes [6], parameters such as grain size become especially important in differentiating between depositional environments. An examination of grain-size characteristics from MAHLI images could help to establish whether HVM strata were deposited by subaerial (aeolian) or subaqueous (fluvial) processes. It is also important to consider secondary effects on grain-size measurements such as diagenesis, compaction, and/or abrasion.

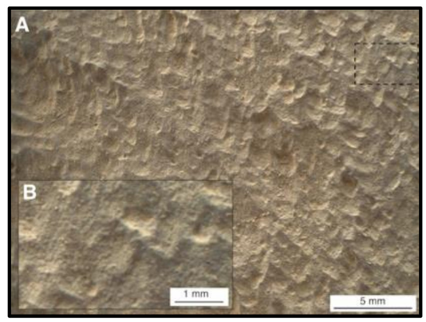

Figure 2. Target *Inamagando* (17 µm/pixel) field of view (A) with highlighted region (B) showing measurable grains (MAHLI 1355MH0004260010502003C00).

Methods: We first identified the presence or absence of grains large enough to resolve in MAHLI images of rock targets examined during the Sol 1355-1420 period. Previous studies (e.g. [7]) show that grain size can be accurately measured in 2D images and grain-size distributions are determined via point counting at least 400 spots on an image. It is notable that the highest-resolution images (17 µm/pixel) prohibit resolution of grains smaller than 5Φ-6Φ (medium-fine silt) depending on the contrast of the grain with the surrounding bedrock. Additionally, grain size can only be measured incrementally with pixel size.

Grain-size results: Out of the 15 targets investigated during Sols 1355-1420, we identified apparent grains in just 4 MAHLI targets. In the other 11 images, the resolution is not sufficient enough to resolve any grains. Target *Inamagando* has the greatest number of resolvable grains (**Fig. 3**), and we find that, with the exception of 3 grains, grains smaller than coarse silt are not resolvable at the highest resolution of 17 µm/pixel. *Inamagando* also contains circular pits (n = 25) with diameters of 0.1 mm to 0.5 mm (very fine to medium sand) that might be sockets from which detrital clasts were eroded. If so, these regions could be an upper limit on the grain size within this rock. Of all points counted, 17% contain resolvable grains, 75% contain grains or features below the resolution of the image, and 8% are surface dust. Seventy-one percent of grains in *Inamagando* are coarse silt, 25% of grains are very fine sand, and 4% of grains are medium silt. Targets *Aubures* and *Koes*, have so few resolvable grains (ranging from medium sand to very fine sand) that point counting did not yield a viable grain-size distribution; however, it is worth noting that both targets contain apparent light-colored, sand-sized clasts with varying degrees of relief. Target *Oudam* has few resolvable grains that range from medium silt to very fine sand. Overall, grain size variability measured from the MAHLI images correlates with variability previously inferred in the HVM [4]; however, the majority of the points analyzed contain grains that are below the resolution of the MAHLI images (plotted at the lower bound of 5Φ in **Fig. 3**).

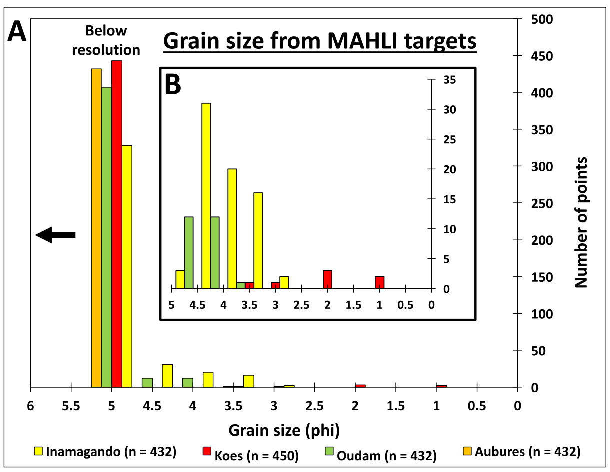

Figure 3. (A) Grain size histogram for the 4 targets analyzed in this study. (B) Histogram from 0 to 5Φ, excluding grains below resolution.

Assessment of an aeolian origin: Resolvable grains within the Hartmann's Valley member are generally smaller than grains that saltate under Martian conditions (very fine to fine sand) [8]. Studies have identified aeolian ripples of very fine sand in Meridiani Planum and Gale crater [5], but the targets observed using MAHLI and ChemCam [4] in the HVM are dominated by silt and sub-silt-sized grains. Some of the rocks examined via MAHLI images contain coarser sand grains, yet grains of this size are not observed throughout the region. Thus, there remains a discrepancy between sand grains in modern Martian aeolian dunes and the dominant grain sizes observable in the HVM. If grain entrainment and transport dynamics at the time of HVM deposition were similar to conditions on the Martian surface today, the bedrock grain size should be dominated by sand. Additionally, aeolian facies are not commonly associated with the current interpretation of the lake basin history for Gale crater strata.

Assessment of a fluvial origin: Models of fluvial dune formation on Mars indicate that dunes that formed in pure water or in a viscous brine would contain grains coarser than silt [8]. This interpretation does not fit with the observations of coarse silt and the inference of even smaller grains within the HVM. Although there is a disagreement between apparent grain size and identified HVM bedforms, a fluvial interpretation would reconcile with the current lake model for deposition at Gale crater [1, 2].

Discussion: Assessment of aeolian and fluvial depositional models do not completely fit with the HVM grain-size results. The trough cross-bedding observed in the HVM does not correlate with grain sizes, although the inferred size at the finer end of the sand range fits closer to aeolian. Additionally, analogous dune environments on Earth contain coarser grains than the grains in the HVM [e.g. 6, 9], whereas studies show that aeolian and fluvial Martian environments transport and deposit coarser grain sizes than Earth due to gravitational and atmospheric differences [8].

It is possible that compaction and diagenesis coupled with aeolian abrasion obscured grain boundaries and fragmented grains within the HVM, making it difficult to assess grain size in this region or biasing grains towards smaller sizes. Cementation during burial and diagenesis would homogenize the color of grains and precipitate nodules with a granular appearance. Upon exhumation, grains would be susceptible to fragmentation during abrasion of the rock surface.

The observations from this study support previous studies inferring grain-size variability in the HVM [4]. Continued image analyses of grain size and bedform in the HVM will enhance our understanding of the HVM depositional history and spatial range as well as the utility of HVM images for grain-size analyses.

References: [1] Fedo, C.M., et al. (2017) *GSA* Abstracts with Programs, Abstract #232-8 [2] Bohacs, K.M., et al. (2000) *AAPG Studies in Geo.*, 46, 3-34. [3] Fedo, C.M., et al. (2018) *LPSC XLIX* [4] Rivera-Hernandez, F., et al. (2018) *LPSC XLIX* [5] Sullivan, R. & Kok, J.F. (2017) *LPSC XLVIII*, Abstract #2422. [6] Lebeau, L.E., & Ielpi, A. (2017) *Sed. Geo.*, 357, 53-71. [7] Eibl, M.A. (2016) *M.S thesis, U Tenn*. [8] Grotzinger J.P., et al. (2013) *Comparative Climatology of Terrestrial Planets*, 439-472. [9] Dade, W.B., & Friend, P.F. (1998) *Journal of Geo.*, 106, 661-676.