PRIMARY AND SECONDARY FEATURES WITHIN THE PAHRUMP HILLS OUTCROP AS SEEN IN THE MARDI SIDEWALK MOSAIC. M.E. Minitti[1], J. Van Beek[2], F.J. Calef III[3], D. Harker[2], K.E. Herkenhoff[4], L.C. Kah[5], M.R. Kennedy[2], G.M. Krezoski[2], L. Lipkaman[2], B. Nixon[2], S.K. Rowland[6], J. Schieber[7], K.M. Stack[3], and R.A. Yingst[8]. [1]Framework, Silver Spring, MD 20902 (minitti@me.com); [2]Malin Space Science Systems, San Diego, CA; [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA; [4]USGS, Flagstaff, AZ; [5]University of Tennessee, Knoxville, TN; [6]University of Hawai‘i at Mānoa, Honolulu, HI, [7]Indiana University, Bloomington, IN. [8]Planetary Science Institute, Tucson, AZ.

Introduction: The Mars Science Laboratory *Curiosity* rover first encountered the basal unit of Aeolis Mons (informally, "Mt. Sharp"), a 5 km layered mound within Gale crater, on Sol 753. The basal unit, the Murray formation [1], is a recessive, mud- to sandstone package that exhibits a variety of primary and secondary features over at least 260 vertical meters from the initial encounter point. *Curiosity* spent several months interrogating the first (accessible) ~13 m of the Murray formation, known as "Pahrump Hills", yielding the first detailed characterization of the Murray formation.

Detailed characterization was accomplished via three campaigns at Pahrump Hills: reconnaissance, contact science, and sampling [1]. The reconnaissance campaign involved driving a loop around the Pahrump Hills with stops at waypoints of interest (Fig. 1). During the drive, the nadir-pointing Mars Descent Imager (MARDI) operated in video mode [2]. The images acquired, when mosaicked together, form a "sidewalk," or a nearly continuous record of the terrain traversed by the rover (Fig. 2).

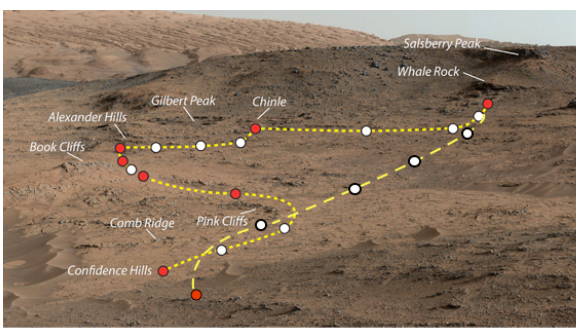

Fig. 1: Reconnaissance campaign path (yellow line) across the recessive bedrock [1] of the Pahrump Hills. Red spots mark locations of end-of-drive imaging or sampling. White spots mark locations of mid-drive imaging. Labels mark prominent outcrops that were the focus of further study. *Image PIA19039 (NASA/JPL/MSSS).*

Observations: The sidewalk path cuts across outcrop strike and up/down outcrop slope in two different places, enabling the search for trends in the spatial distribution of observed features (Figs. 1, 2).

Bedrock laminations. The pale orange to gray, recessive bedrock of Pahrump Hills exhibits flat lying, mm-scale layers, or laminae that fall into three morphological categories. Weakly apparent laminae are defined by muted individual lamina that occur in limited patches (10-30 cm^2) in a span of multiple meters along the sidewalk path. Apparent laminations are distinct, coherent layers that can be traced for 30-40 cm across a single MARDI frame. Strongly apparent laminations are also distinct, coherent layers, but are traceable across most to all of a single MARDI frame (92 cm). Apparent and strongly apparent lamination packages continue for distances ≥1 m along the sidewalk path.

The spatial distribution of weakly apparent, apparent and strongly apparent lamination packages is not random (Fig. 2). Variations in lamination expression occur as zones of weakly apparent, apparent and strongly apparent laminae. These zones are consistent laterally across the Pahrump Hills outcrop.

Resistant features. Resistant features are observed embedded within or along the perimeters of bedrock slabs throughout the Pahrump Hills, standing proud relative to the surrounding bedrock [4]. Resistant features exhibit both compact and platy morphologies. Compact morphologies include dendrites (2-4 mm wide fingers emanating from a central point) [5], globules (spherical to sub-spherical) and flowers (higher aspect ratio than globules). Platy morphologies are flat, resistant layers 1-30 cm wide and ≤1 cm thick that protrude from the surrounding bedrock. In some in-

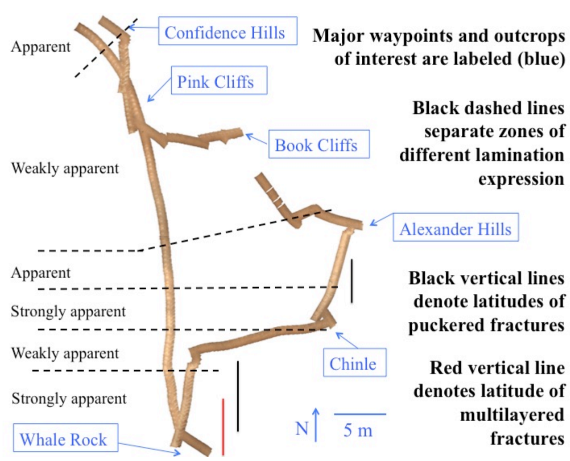

Fig. 2: MARDI sidewalk mosaic acquired over the reconnaissance campaign path at the Pahrump Hills. Features identified to right of figure.

stances, the surrounding bedrock is eroded sufficiently far to leave the platy feature suspended above the bedrock below it.

Resistant features are ubiquitous throughout the Pahrump Hills, with densities varying from 50 to 300+ features/m^2. Globules and flowers are found consistently throughout Pahrump Hills, but dendrites are concentrated north of the "Pink Cliffs" waypoint (Fig. 2), and platy features are more common in areas of apparent and strongly apparent laminae.

Fractures. Fractures cut the Pahrump Hills bedrock into cm^2- to m^2-scale slabs. A subset of these fractures exhibit either fill material or raised edges. Fill materials include single to multiple layers of material with the same color and texture as the surrounding bedrock, and white material revealed as Ca-sulfate by ChemCam [e.g., 4]. Raised edges are expressed multiple ways. Compact resistant features either line fractures or are cut by them, creating raised edges along fractures. Thin (1-2 mm) raised edges are comprised of bedrock material along a fracture. Bedrock adjacent to such thin raised edges displays no deformation. Thick (4-10 mm) or "puckered" raised edges are created by bedrock material rising to meet the fracture edge. Bedrock in areas of puckered fractures appears undulating relative to the flat nature of bedrock slabs throughout the remainder of the Pahrump Hills.

The distribution of fractures with white fill and with thin raised edges exhibit no pattern throughout the Pahrump Hills. Those with raised edges formed by compact resistant features are limited to the area around the "Confidence Hills" waypoint (Fig. 2), mirroring the distribution of dendritic resistant features. Fractures with puckered edges are found in limited zones north of the "Chinle" and "Whale Rock" waypoints (black vertical lines, Fig. 2). Fractures with multilayered fills begin to appear in the latter zone and continue up to Whale Rock (red vertical line, Fig. 2).

Interpretations: The presence of mm-scale laminations is consistent with multiple working hypotheses for formation of the Pahrump Hills bedrock [e.g., 1,3]. The changing expression of laminations could mean a) the laminations themselves are absent in parts of the bedrock, or b) merely their exposure changes. The former scenario has implications for changing depositional conditions. The latter scenario suggests that a bedrock characteristic affects the expression of laminations. We explored the relationship between bedrock slope and degree of expression of the laminations to address this question.

We used JPL's Multi-Mission Geographic Information System [6] to measure slopes of the Pahrump Hills terrain along the drive path, in some cases breaking drive segments into 2-10 parts to measure localized

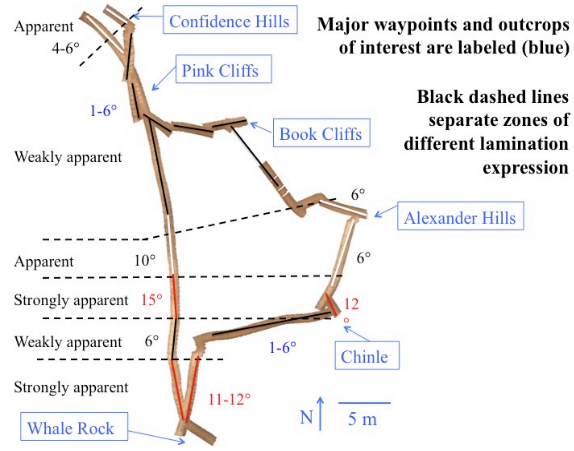

Fig. 3: Distribution of lamination expression and outcrop slopes. Black dashed lines as in Fig. 2. Solid lines along sidewalk path: black = low slopes (1-6°); white = moderate slopes (4-10°); red = high slopes (>11°).

changes in slope. A positive correlation exists between outcrop slope and strength of lamination expression (Fig. 3). This suggests that the Pahrump Hills bedrock is laminated throughout, and a bedrock characteristic controls slope and thus lamination expression.

A likely bedrock characteristic that can explain not only the higher slopes (e.g., zones of strongly apparent lamination) but also the puckered fractures is a greater degree or amount of cementation (Figs. 2,3). Both features are only observed below the sandstone horizons of Chinle and Whale Rock. In the depositional model of [7], the dominant mud- to sandstone grain size of the Pahrump Hills bedrock coarsens approaching these horizons. Coarser grain sizes permit a greater degree or amount of cementation and thus yield more resistant bedrock. Higher slopes, undulatory bedrock, and thick fracture rims are all consistent with greater erosion resistance. More broadly, diagenesis can also explain resistant features and filled fractures, indicating the importance of syn- and post-depositional processes in the development of the Pahrump Hills.

References: [1] Grotzinger J.P. et al. (2015) *Science,* 350, DOI: 10.1126/science.aac7575. [2] Minitti M.E. et al. (2015) *LPSC XLVI,* Abstract #2399. [3] Schieber J. (2015) *LPSC XLVI,* Abstract #2153. [4] Nachon M. et al. (2017) *Icarus*, 281, 121-136. [5] Kah, L.C. et al. (2015) *LPSC XLVI,* Abstract #1901. [6] Calef F.J., III (2017) *LPSC XLVIII,* Abstract #2541. [7] Stack, K.M. et al. (2016) *Geol. Soc. Am. Ab. Prog.*, 48, 7, doi: 10.1130/abs/2016AM-283972.