MULTIPLE WORKING HYPOTHESES AT PERSEVERANCE VALLEY: FRACTURE AND AEOLIAN ABRASION.

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Introduction: Understanding the role of water in past Martian environments is the overarching goal of the Mars Exploration Rover (MER) mission. To this end, the rover Opportunity has been exploring the vicinity of Perseverance Valley, a system of troughs extending 190 m down the steep (~15°) interior rim of 22 km diameter Endeavour crater. From orbit, Perseverance Valley is an array of shallow, interleaved troughs reminiscent of anastomosing fluvial systems on Earth. However, no basal deposits are apparent subjacent to the trough system, indicating either post-depositional erosion of materials carried through the troughs, or the trough system never functioned as a conduit for fluid-borne materials.

The MER team has been utilizing a Multiple Working Hypotheses approach [1] during exploration of the Perseverance Valley trough system. As of this writing, the rover has descended through only about one third of the trough system. Multigenetic contributions to trough system morphology are being considered, including potential contributions from erosion by debris flow, groundwater discharge, and fluid flow from lake spillover, as well as the potential effects of periglacial processes, fracturing, faulting, and aeolian abrasion [2-5].

This presentation focuses on only a portion of the overall ongoing MER team effort, discussing potential contributions of fracturing, faulting, and aeolian abrasion to the morphology of Perseverance Valley. The motivation for evaluating these processes involves more than just an attempt at completeness. An outstanding characteristic of the Perseverance Valley trough system is its singularity at Endeavour crater: It is the solitary example of its type, anywhere around the crater rim. This poses important challenges to origins that would require a fluid supply of regional extent, such as perched water tables or, ultimately, precipitation.

Aeolian Abrasion: Wind-driven saltating sand is known to be an effective erosional process of exposed rock on Earth and on Mars [e.g., 6]. From terrestrial experience, both the rate of rock abrasion and the style of erosional surface texture are known to vary greatly, depending on rock hardness and other factors including saltation flux history and grain-surface impact angle [7-9]. Adjacent rocks exposed to the same, potentially abrading, saltation flux can display very different degrees of erosion and erosional texture (including no obvious signs of aeolian abrasion at all), depending on intrinsic differences in rock composition and internal structure, and the possible competing effects of other, more effective weathering processes.

At Meridiani Planum, aeolian abrasion is recognized when a rock surface is exposed to a dominant sand-driving wind direction and includes components of contrasting hardness, so that positive relief "rock tails" or stalks in weaker material extend downwind, protected behind more resistant materials as the rock surface erodes. Rocks with more uniform hardness can develop classic ventifact shapes, as well as textures such as elongation of surface pits. The aeolian abrasion and reduction of ejecta blocks at relatively recent impact sites across the Meridiani plains indicates aeolian abrasion has effectively reduced surface relief at Meridiani Planum over the last half of martian history after the Noachian, and more recently on a timescale comparable with large ripple migration [10-13].

The same timescale of effective erosion is implied for similar aeolian abrasion textures on rocks along the upper interior rim of Endeavour crater, including the Perseverance Valley trough system. In these examples the dominant sand-driving direction of erosion is radially up and out of the crater, inconsistent with erosion from gravitationally-driven fluid or debris flows (Fig. 1). The timing of aeolian abrasion reducing impact crater ejecta on the plains, contemporaneous with large ripple migration there [13], suggests that the low-relief Perseverance Valley trough system survives as a recognizable feature only because it formed relatively late in martian history, after the Noachian.

Fracture and Faulting: On the Meridiani plains, under the thin, discontinuous mantle of rippled basaltic sand (with loose hematite concretions), the Burns formation bedrock of sulfate-enriched sandstone is intricately and pervasively fractured, such that shapes of relatively fresh craters, such as 150-m diameter Endurance, can reflect structural control exerted by the preexisting fracture network [14]. The more ancient Shoemaker breccias of the eroded Endeavour rim are pervasively fractured as well, consistent with impact-related emplacement and structural adjustments. Fractures in both units expressed at the surface generally are nearly filled with sand. It is unclear if fracture widths oriented perpendicular to sand transport directions might have been enhanced by aeolian abrasion compared with other fracture orientations.

Relevance to Perseverance Valley Origins: Rover views from within Perseverance Valley reveal that potential fluvial traces seen from orbit actually are very shallow, soil-filled troughs between similarly low-relief outcrops, therefore sharing characteristics with sand-filled fractures in more level bedrock seen elsewhere along Opportunity's traverse. Outcrops immediately across troughs commonly display dissimilarities with each other in color and erosional texture; these dissimilarities can be interpreted as resulting from fault displacement offsets (Fig. 2).

One working hypothesis for the shallow interleaved trough system of Perseverance Valley involves ancient fractures and faults reactivated after the Noachian, conceivably multiple times with long hiatuses in between. Minor surface relief resulting from each reactivation (i.e., from any upward component of displacement by one block relative to another) would be followed each time by gradual erosion and reduction of the newly-formed relief by aeolian abrasion, as well as crumbling in place due to thermal cycle stresses [15-16].

The solitary nature of the Perseverance Valley trough system at Endeavour crater, mentioned earlier, poses challenges to any proposed origin. The Perseverance Valley troughs are subjacent to a low portion of the Endeavour rim (which might also qualify as a potential lake spill-over feature). This location, between higher rim segments to either side, could be a likely place for stress-adjusting fault reactivation to occur (e.g., as a response to the higher rim segments on either side eroding and unloading mass at different rates). But there are other low points around the Endeavour rim that do not have trough systems like Perseverance Valley. More to the issue: How rare is post-Noachian fault movement at Meridiani Planum? Rare enough (yet not absent) to be a candidate for explaining the solitary nature of Perseverance Valley? It can be difficult to establish any explanation as resulting from a potentially rare phenomenon, but the large collection of Navcam panoramas acquired at each stop along Opportunity's traverse across the plains provides at least an approach to this question. Unambiguous examples of recent displacement offsets of bedrock do exist along Opportunity's traverse, and indeed are rare: Fig. 3 (the best example of the very few known to the authors) demonstrates that displacement fault activation does occur, very rarely, and on the same timescale as ripple migration, therefore comparable with the survival time of minor surface relief (such as recently emplaced impact ejecta blocks [13]) against aeolian abrasion.

Explanations for morphologic observations commonly are multigenetic [1]. Whether the Perseverance Valley trough system can be explained completely without water, or if after further data acquisition and analysis the most likely explanation implicates an essential role for water, the processes of fracture and aeolian abrasion are likely to contribute at least in some way to the continuing development of multiple working hypotheses as Opportunity explores the rest of Perseverance Valley.

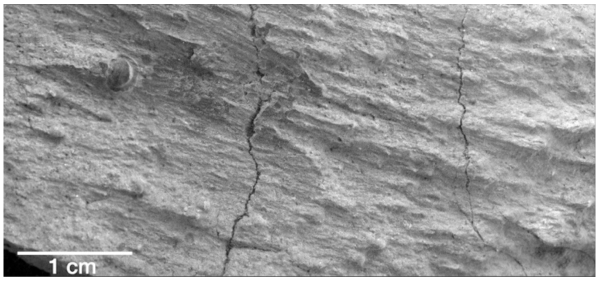

Figure 1. Portion of sol 4900 Microscopic Imager mosaic of aeolian abrasion textures at Perseverance Valley. Rock tail in upper left extends leftward (which is also upslope) from resistant embedded clast.

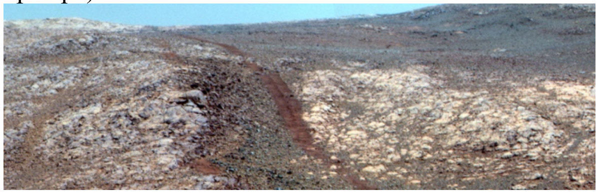

Figure 2. Sol 4859 Pancam enhanced-color view upslope at Perseverance Valley, showing one example of a putative fault offsetting contrasting rock types. Rover tracks span 1.2 m.

Figure 3. Sol 1784 Navcam view showing large ripple disrupted by fault offset in Burns Fm. on the plains NW of the Endeavour crater rim. Ripple width ~2.2 m.

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