OPPORTUNITY'S EXPLORATION OF PERSEVERANCE VALLEY S. W. Squyres[1] R. E. Arvidson[2], M. Golombek[3], A. Freaman[3], M. Lamb[4], M. Palucis[4], T. J. Parker[3], and the Athena Science Team. [1]Department of Astronomy, Cornell University, Ithaca NY 14853, squyres@astro.cornell.edu; [2]Washington University in St. Louis, Department of Earth and Planetary Sciences, arvidson@wunder.wustl.edu; [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA; Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA.

Introduction: The Opportunity [1] rover has recently been exploring Perseverance Valley on the Cape Byron rim segment of Endeavour Crater (Figure 1). The intent is to acquire imaging and compositional data to test whether or not Perseverance Valley formed by fluvial activity, debris flows, dry mass flows, and/or wind action, and to understand the roles of water and ice in the valley's formation and modification.

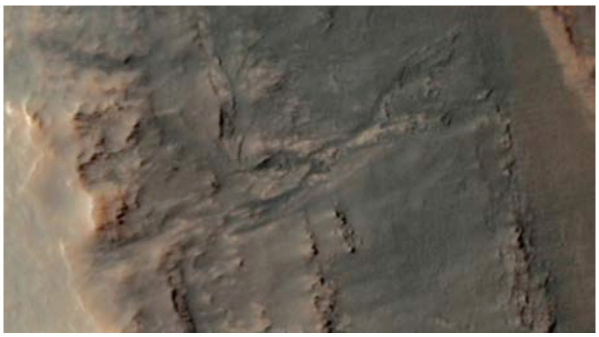

Figure 1: MRO HiRISE image of Perseverance Valley. Length of the valley from top to bottom is about 200 m. Illumination from left.

Large-Scale Morphology: Perseverance Valley is less than 200 meters in length and at most a few tens of meters in width. Individual incised channels just a few meters wide form an anastomosing pattern. The channels appear to arise fully formed from an abrupt break in slope on the plains outside Endeavour crater. They diverge downhill around streamlined "islands", converge again, and then diverge once more to form an apparent distributary system, although no fan or delta is observed.

Perseverance Valley did not form recently. It lacks the crisp topography of recent gullies observed elsewhere on the planet. Small impact craters are superimposed on it, and it terminates abruptly at its lower end, suggesting post-formation truncation. While its age cannot be determined precisely, small valleys with similar states of preservation are common on Noachian surfaces throughout the region, so an origin during a period of extensive denudation and valley network formation during the Late Noachian seems likely.

Formation Hypotheses: We examine three primary hypotheses for formation of Perseverance Valley:

Hypothesis 1: A fluid was involved in cutting Perseverance Valley. The null hypothesis is that dry avalanching processes were responsible. The current gradient along most of the valley's length is approximately 15°, which suggests it formed by fluid-rich flows rather than dry avalanching. Initiation of avalanching on Earth is exclusive to >30° for natural materials, and could be a viable mechanism only if a steeper initiation area at the former top of the valley once existed and has since been eroded away.

Hypothesis 2: Fluvial processes cut Perseverance Valley. The null hypothesis is that it was incised through repeated debris flow events. Fluvial processes are defined here as erosion and deposition of alluvium by fluid flows with low to modest sediment concentrations (<10%). They tend to dominate at lower channel bed slopes (up to 20°). Debris flows, in contrast, have much higher sediment to water ratios (>50%) and dominate on steeper channel bed slopes (>10°).

If Perseverance Valley was carved by fluvial processes, there must have been large amounts of a flowing fluid relative to its volume, and flow events lasting possibly for days or longer. The most thermodynamically plausible fluid is water or brines. Debris flows, on the other hand, can carve gullies in brief surges that may only last for short periods of time. In this case, the fluid could be CO_2, water, or brines. In addition to determining the type of fluid, distinguishing between fluvial and debris flow processes implies different fluid volumes, which is important for understanding Mars's past climate and hydrologic cycle.

Hypothesis 3: The fluid supply was from lake spillover. The null hypothesis is that the fluid supply was sourced either from precipitation (e.g., rainfall or snowmelt) or groundwater. In order to constrain the source of fluid that created Perseverance Valley, an estimate for discharge is required. Given the small upslope drainage area available on the crater walls and rim, precipitation would generate comparatively low discharge flows through the valley. In contrast, if a lake breached the crater rim, discharges could be much larger. As fluvial and debris flow processes require water-to-rock ratios that differ by several orders of magnitude, being able to identify which process dominated constrains water discharges to first order.

Observations and Interpretations: Perseverance Valley cuts into the inner, eastern Cape Byron rim on a ~10 to 15˚ slope, and starts at a local low area on the rim crest. A set of shallow channels, some lined with perimeter rocks, extends from the west to meet the entrance to the valley. The western rim tilts to the west a few degrees and thus these shallow channels tilt away from the valley entrance.

Drawing upon Hypothesis 3, we have considered a fluvial origin for the channels on the plains to the west of Perseverance Valley. Overflow of an ancient lake could have generated the western channels and spilled water into the eastern side of Cape Byron to carve the valley proper. The observation that the western channels meet the channels of Perseverence Valley at the lowest elevation point of the rim is consistent with spillover from a standing body of water. However, a significant complicating factor is the local topography associated with these channels, which tilts to the west, away from the crater rim. We have considered a scenario in which a western lake was present when the Burns formation deposits were being emplaced, followed by self-compaction of these sediments that tilted the western plains away from the rim crest. Calculations to date suggest, however, that it is difficult to achieve the amount of rotation necessary (~0.8˚) to form a western catcment, assuming it was a consequence of topography before compaction of Burns sediments. The notion of a large western catchment that fed Perseverance Valley by overflow at the valley head (Hypothesis 3) is therfore not supported by these calculations.

Within Perseverance Valley, regolith and eolian sands fill in the valley floors, implying lack of any water activity or other channel-carving erosional processes for an extended period. Some valley floor materials are characterized by parallell linear “stone stripes” that could be a result of periglacial or eolian processes [2] postdating valley formation.

Bedrock is exposed in the walls of the Perseverance Valley channels. Imaging shows that many bedrock outcrops consist of impact breccias, with clasts of varying sizes embedded in a finer-grained matrix. APXS data reveal a composition generally consistent with that of the Shoemaker Formation breccias common elsewhere along the rim of Endeavour Crater.

A distinctive characteristic of some bedrock outcrops within Perseverance Valley is a linear texture suggesting some type of scouring process (Figure 2).

We initially considered the hypothesis that the scouring resulted from the erosional processes that initially carved Perseverance Valley. However, high-resolution imaging with the Microscopic Imager (Figure 3) shows that much of the linear texture results from erosional “tails” extending in one direction from resistant breccia clasts. Notably, these tails consistently point uphill, inconsistent with water flow. We therefore conclude that they result from erosional processes, probably eolian, that have shaped outcrop exposures at centimeter to decimeter scales in more recent times.

At the time of this writing, Opportunity is, about to enter its most deeply eroded section of the valley. Near future work will focus on creating a detailed digital elevation model, and high resolution imaging of channel floor and wall materials to test Hypotheses 1 and 2.

Figure 2: Bedrock outcrop in Perseverance Valley, showing lineations interpreted as scour features. Scale across the image is ~1 meter.

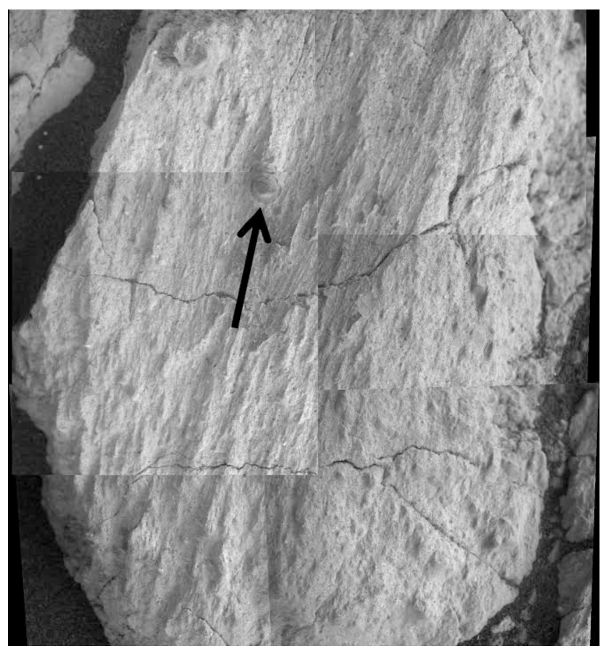

Figure 3: Microscopic Imager mosaic of scour features, taken in full shadow. Arrow indicates a resistant breccia clast with an erosional tail on one side. Uphill is toward the top of the image, indicating uphill erosional flow. Scale across the image is ~5 cm.

References: [1] Squyres, S.W. et al. (2003) JGR doi:10.0129/2003JE002121. [2] Arvidson, R.E. et al., LPSC 2018.