MER Opportunity at Perseverance Valley: Evaluation of Multiple Working Hypotheses for Valley Formation


1. Introduction

MER Opportunity explored Perseverance Valley, a feature identified from orbit as potentially possessing downslope fluid flow, until a major dust storm ended communications with the rover in 2008. Perseverance Valley originates at a low area between two higher-standing degraded rim segments of the Noachian-age, 23-km-diameter Endeavour Crater. The valley system extends downslope toward the crater interior along a ~37° gradient for ~180 m, spanning 19-20 m.

An important working hypothesis for Perseverance Valley, suggested by its orbital appearance and location, is that the terrain was carved by spillflow from a body of water pushed up the flanks of the rim towards the center, emptying down and across the center. The MER team has been considering multiple working hypotheses for valley origins, including possible contributions from dry mass wasting, aeolian flow in various forms (including debris flows), periglacial processes, faulting/fracturing, and aqueous processes.

2. Rover Observations at Perseverance Valley

(1) Potential fluvial traces seen from orbit are nearly flat areas of soil with little relief, lying only centimeters below adjacent arctic slopes.
(2) Rock weathering by fracturing, possible due to thermal cyclic stresses, is pervasive.
(3) Oriented and isolated blocks within the trough system exhibit an ‘alluvial’ gradation ~<2 cm, and in many cases display surface textures of aeolian abrasion from wind blowing off-limb of the center, rather than textures indicating fluid flow downslope.
(4) Within the area of the high-relief middle section of the trough, rock features resembling streamlined “clasts” within the trough system are revealed at mosaic scale to have crescentic rims defined by stream segments suggestive of spill flow.
(5) Evidence of prominent color and/or morphology between adjacent rock units along linear trends suggest embankment alternations along each flank.
(6) In other places narrow bands of soil separate linear arrays of rock and rubble that contrast in color and/or texture.

3. Analogs from Marathon Valley

Marathon Valley, another relatively low area of the Noachian crater rim explored by the rover in 2005, has features indicating comparisons with Perseverance Valley, but is emerging with much less evidence.

Most of the floor of upper Marathon Valley displays complex fracture patterns in which touching polygons of blocks are separated by narrow bands of soil-filled fractures. Despite the complex structural hierarchy implied by these blocky patterns likely related to the Endurance impact and post-impact structural adjustments, overall surface relief is minimal, being here planarized by aeolian abrasion after any possible residual vertical movements along fractures had occurred. Lowering of ground level by aeolian abrasion is also evidenced by rock tails extending updip behind unconsolidated breccia that herniated out on the valley floor.

Bedrock polygons on the floor of Marathon Valley thought to be carved from the surface by spill flow have fractures closely resembling those found in the trough system in Perseverance Valley. Evidence of structural deformations is abundant in Marathon Valley rocks, but not clearly visible in the Perseverance Valley rocks.

Larger troughs in lower Marathon Valley [1] with abrupt floor-contacting surfaces in Marathon Valley have an alluvial-type fill.

4. Assessing Multiple Working Hypotheses for Perseverance Valley

Pending/Spill-Over. The long-term effectiveness of erosional processes at Marathon Planum [1, 2, 3] made it unlikely that the Perseverance trough system represents a low-relief; non-erosion surface feature. Aerial images of Marathon Planum suggest spill-overflow, i.e., a surface feature not preserved from its original high-relief, high-gradient surface, but rather buried by the continuing mound of aeolian material.

Fracture/Weathering with Aeolian Abrasion. Along with dry mass-wasting and other erosional processes, another concept under consideration interprets the Perseverance Valley trough system as a complex fracture/weather zone that has served as a conduit for aqueous/marine flow. In this concept, compositional changes along fractures/fracture planes from ancient groundwater interactions resulted much later as shallow troughs at the surface due to thermal/marine calcification being more readily dissipated.

Acknowledgements. This work was supported by the MER Project. The exploration of Perseverance Valley, on the Mars Opportunity’s landing site, was conducted by JPL/Caltech engineering during MER hardware and software development many years ago to produce such durable vehicles, and subsequently by 15 years of engineering support dedicated to enable science activities such as those reported here.