RIM STRUCTURE, STRATIGRAPHY, AND AQUEOUS ALTERATION EXPOSURES ALONG OPPORTUNITY ROVER'S TRAVERSE OF THE NOACHIAN ENDEAVOUR CRATER. Crumpler[1], L. S., R. E. Arvidson, R.E. [2], Golombek, M.[3], Grant, J.A.[4], B. L. Jolliff[2], D.W. Mittlefehldt[5], and the Athena Science Team. [1]New Mexico Museum of Natural History & Science, 1801 Mountain Rd NW Albuquerque, NM, 87104, USA, larry.crumpler@state.nm.us, [2]Dept. Earth & Planetary Sciences, Washington University, St. Louis, MO, [3]JPL, California Institute of Technology, Pasadena, CA, [4]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC, [5]NASA Johnson Space Center, Houston, TX.

Introduction: The Mars Exploration Rover Opportunity has traversed 10.2 km along segments of the west rim of the 22 km-diameter Noachian Endeavour impact crater as of sol 4608 (01/09/17). The stratigraphy, attitude of units, lithology, and degradation state of bedrock outcrops exposed on the crater rim have been examined in situ and placed in geologic context. Structures within the rim and differences in physical properties of the identified lithologies have played important roles in localizing outcrops bearing evidence of aqueous alteration.

In Situ Crater Rim Geologic Exploration. Opportunity visited outboard sides of the crater as well as inboard outcrops at the northern segment Cape York and the southern segments of Cape Tribulation [1]. During its 13th year of operation Opportunity explored exposures within the interior of *Marathon Valley*, focusing on local relatively redder zones and other areas of apparent alteration, and began traverses eastward and southward onto the lower crater walls (Fig. 1**)**

S**tratigraphy & Lithology of the Inner Crater Wall***:* Elongation and aligned trains of clasts analogous to eutaxitic textures, and relief-conformal planar partings or "foliations" in outcrops of the "*Shoemaker fm*" impact breccia, are consistent with an abrupt, but sequential or progressive, style of ejecta emplacement. Vertical variations in clasts and matrix in outcrops likely reflect different arrival times of proximal ejecta and can be likened to depositional planes. *Marathon Valley* is bound on the north and south by vertical, 4±2 m outcrop sections consisting of an *upper Shoemaker fm* of darker clasts up to several centimeters embedded in a matrix of altered fine-grained material and coarse agglomerations of both in contact with a lower Shoemaker fm of clast-poor breccias (Fig. 2). Foliations are unconformable to current outboard slopes, dipping westward at up to 22° on the planar ≤10° slopes of the current crater rim, but dip steeply inward toward the crater on the inboard side of the rim. The lower *Shoemaker fm* accounts for much of the eastward-dipping bedrock exposures flooring *Marathon Valley*, the valley entrance near *Spirit of St. Louis crater*, and the lower crater walls near several knobs visited after departing the valley southward into the "*Bitterroot Valley*." The relatively redder zones appear associated with some vertical joints [1] and the contact between the upper and *lower Shoemaker fm.* A linear zone on the west side of "*Spirit Mound,*" conceivably one of many proposed vertical fault zones, bears significant Ca and S enrichment [1]. Other knobs on the lower crater walls, such as "*Pompy's Tower*" (Fig. 3), consist of steeply-dipping colluvial debris shed from lag-like masses of disaggregated dense rocks of basaltic composition [1,2] on sections of the upper walls and rim. These deposits are eroded, perched masses, implying that backwasting of crater slopes by mass-wasting and aeolian stripping has been persistent even long after early, greater rim degradation [3].

S**tructure of the Inner Crater Wall:** Foliations near the rim are close to horizontal but increase to 14°-18° east on most of the valley floor (Fig. 2,4) and exceed 18° near the -1450 m elevation below which surface slopes exceeded safe rover slope parameters. The unconformity between slope and bedrock dip in the valley floor exposes the interface between a ledge-forming upper zone within the lower *Shoemaker fm* (S_{L2}) and underlying lower unit (S_{L1}). Analysis of outcrops confirms that the local relatively redder zones correspond to sites of alteration, as well as sites of detection of smectites [4]. Smectite appears to be present at the interface between the ledge-forming upper zone and lower unit and redder zones occur at the intersection with some vertical joints within those outcrops. The relatively redder zones *are* enriched in Si and Al, and depleted Fe and Mn [*5,6*]. Other evidence of alteration and oxidation in the host rock exists such as spectral signatures of hematite [*7*].

Summary Discussion: The association of relatively redder alteration zones, joints, and the interface between units of differing petrographic character is evidence for formerly enhanced fluid flow along fractures that leached the *Shoemaker fm* breccias, concentrated immobile ions in the redder zones, and precipitated ions in zones adjacent to fracture walls and along planar zones between units of differing fluid transmission characteristics. The inward-dip of the impact breccias are either (1) the result of post-impact rotation and folding of initially flat to outward dipping breccias, or (2) draping of impact breccia over initially uplifted pre-impact substrate materials. The setting is further complicated by post-impact modification, including slumping and debris slides that provide pathways for fluid migration and interaction in local rock masses within the lower crater walls.

References: [1] Arvidson , R.E.,, et al. (2017), LPSC 48; [2] Bouchard, M., et al. (2017), LPSC 48; [3] Grant, J.A., et al. (2016), *Icarus*, http://dx.doi.org/10.1016/ j.icarus.2015.08.019; [4] Fox, V. et al. (2016) ,GRL, 43, 8 p.; [*5]* Arvidson et al. (2015), AGU; *[6]* Mittlefehldt et al. (2016), *47th LPSC*, [7] Farrand W. H. et al. (2017) *48th LPSC.*

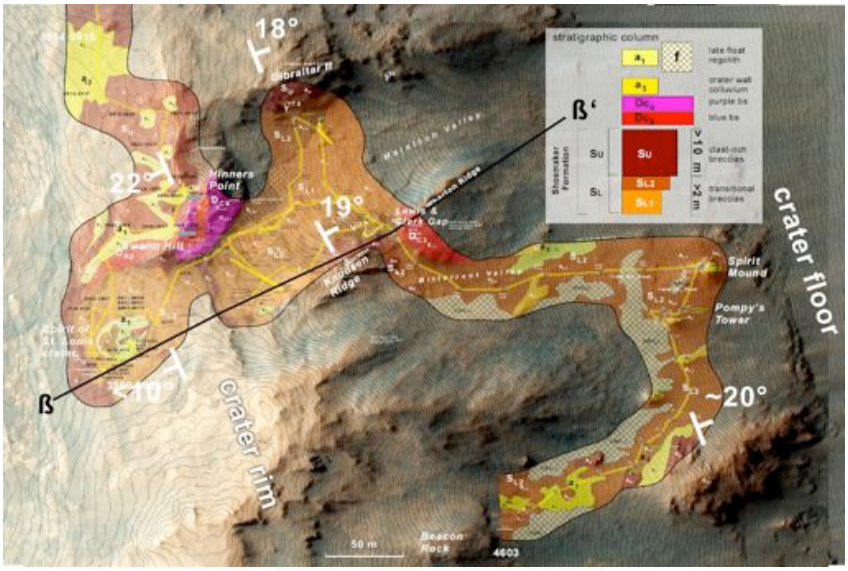
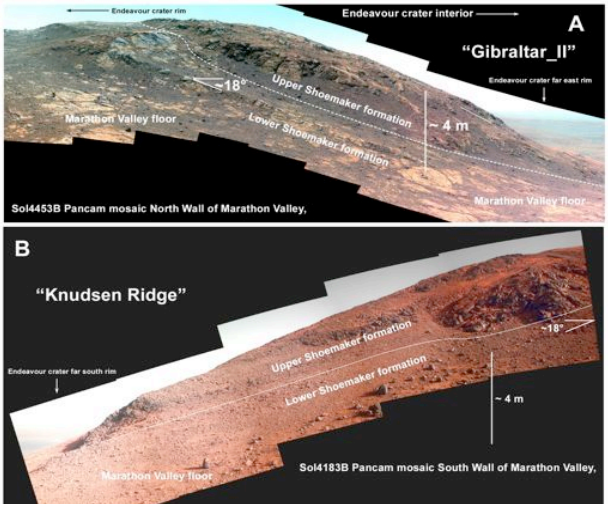


Figure 1. In situ geologic mapping along Opportunity's traverse during Opportunity's 13th year of operations within *Marathon Valley*, traverse to *Spirit Mound*, and climb south and west out of Endeavour crater. The width of the mapping corridor is defined by the distance beyond which resolution of Navcam images is insufficient for lithologic detection, correlation, and identification.



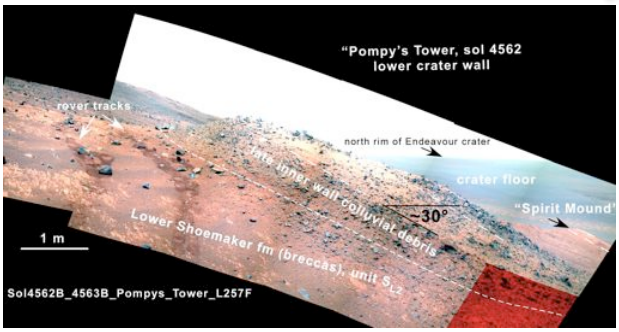


Figure 3. View north along the lower inner crater wall. "*Pompy's Tower*" is an eroded mass of steeply-dipping colluvial, dark, basaltic clasts resting unconformably on bedrock exposures of the lower *Shoemaker fm*. Emplacement and erosion of these types of deposits appear to have been a persistent characteristic of the lower crater walls.

Figure 2. The contact between the upper and lower *Shoemaker fm* exposed in the walls of *Marathon Valley*. The contact and conformal foliations dip steeply (~18°) craterward in both the (A) north wall (*Gibraltar II*) and (B) south wall (*Knudsen Ridge*). A prominent ledge at the top of the lower Shoemaker fm characterizes the contact on both walls.

Figure 4. West-to-east schematic section along the south rim of *Marathon Valley* (ß - ß') from Opportunity's exploration of the valley floor and margins. The structure is broadly arched suggesting that folding accompanied rim slumping. The principal sites of "red alteration zones" and orbital smectite detection were in or near the interface between the lower *Shoemaker fm*, its ledge-forming cap, and pervasive bedrock joints.