DEGRADATION OF ENDEAVOUR CRATER BASED ON ORBITAL AND ROVER-BASED OBSERVATIONS TOGETHER WITH LANDSCAPE EVOLUTION MODELING. M. N. Hughes[1], R. E. Arvidson[1], J. A. Grant[2], S. A. Wilson[2], and A. D. Howard[3], [1]Department of Earth and Planetary Sciences, Washington University in St. Louis, St. Louis, MO (mnhughes@wustl.edu), [2]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC, [3]Department of Environmental Sciences, University of Virginia, Charlottesville, VA

Introduction: The 22 km diameter Noachian Endeavour crater has been the target of many orbital and ground-truth observations, with the Opportunity rover exploring its western rim since August 2011 [1]. Understanding the degradational history of Endeavour can indicate how erosional processes on Mars have changed since the Noachian [2]. In this abstract we use the MARSSIM landscape evolution model [3] to simulate the geomorphic evolution of the crater.

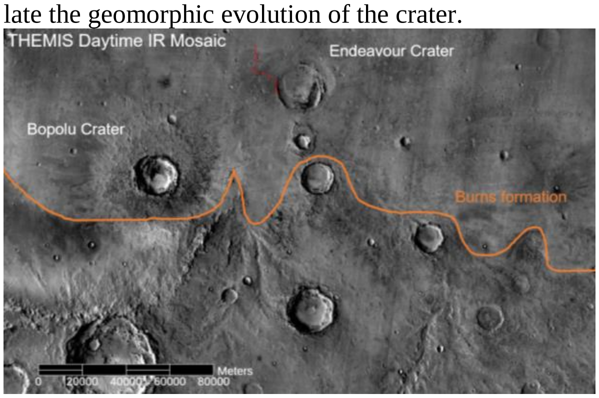

Fig. 1: THEMIS day IR mosaic showing locations of Endeavour and Bopolu craters. The orange line shows the contact between the Burns formation hydrated sandstone deposits and fluvially dissected Noachian terrain to the south.

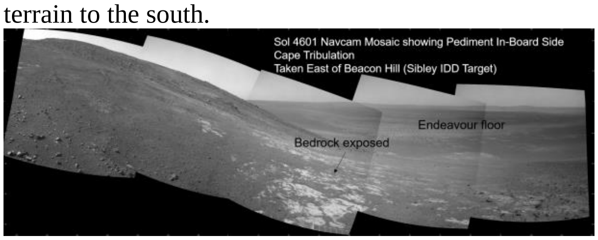

Fig. 2: Opportunity Navcam mosaic (sol 4601) showing a pediment surface sloping toward Endeavour's interior, with a thin regolith cover and a shallow dip.

The Morphology of Endeavour Crater's rim Compared with Bopolu: Endeavour crater is located in the Meridiani Planum and has undergone extensive erosion (Fig. 1). The deposition of the Burns formation sulfate-rich sandstones in the late Noachian to early Hesperian has buried most of Endeavour, however some rim segments are still exposed. Navcam and Pancam images from the Opportunity rover show that there are pediments on both the exterior and interior sides of Cape Tribulation, with little to no regolith cover and bedrock sloping ~6° on the exterior rim and ~10 to 20° on the interior rim (Fig. 2). This is consistent with the morphology, regolith cover, and slopes of terrestrial pediments [4].

The exposed rim morphology of Endeavour can be compared with the nearby fresh-looking Bopolu Crater, which has a diameter of 19 km and formed after the deposition of the Burns formation and cessation of extensive fluvial activity (Fig. 3) [2]. Crater counting indicates it has a formation age of late Hesperian and is at least 0.5 billion years younger than Endeavour [5]. Endeavour has a much more subdued rim morphology compared to Bopolu [6].

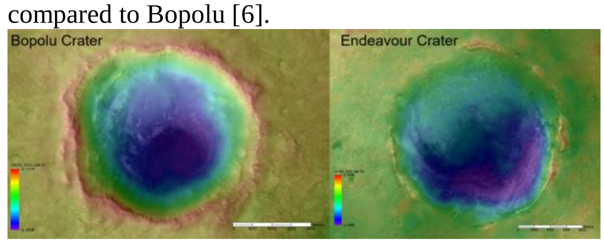

Fig. 3: HRSC images of Bopolu crater (left) and Endeavour crater (right) overlain with the corresponding HRSC DTMs.

Simulating the Evolution of Endeavour's rim: To understand the efficacy and timing of fluvial, weathering, and aeolain activity in shaping Endeavour's rim, degradation of the crater was simulated using the landscape evolution model MARSSIM [3**]**. Parameters in the model were changed as a function of time in a series of forward models to simulate different erosional environments such as varying fluvial or aeolian erosion and deposition.

Bopolu Crater was used as a model for a fresh Endeavour Crater due to the similar diameter, younger age, and relatively fresh appearance. The craters were formed in similar Noachian terrain, however Bopolu was formed after the deposition of the Burns formation, so some Burns is present in the wall and ejecta [2]. A Mars Express HRSC DTM over Bopolu was used as the starting topography for Endeavour (Fig. 4a). To produce the morphological characteristics seen at Endeavour, an initial period of fluvial erosion in a hyper-arid environment is required. In the initial period of degradation, erosion is dominated by weathering, fluvial detachment, sediment diffusion, and mass wasting. Fluvial erosion is sourced from local surface runoff.

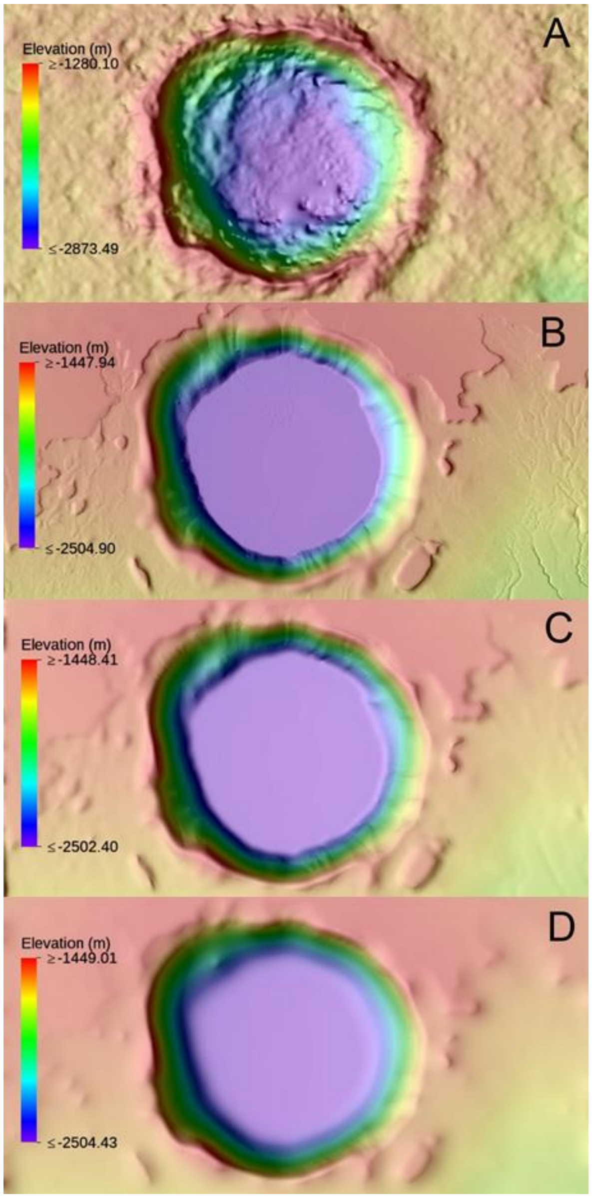

Fig. 4: a) Shaded relief image overlain with color-coded elevation of the starting topography of the simulation. Elevation data was taken from a HRSC DTM over Bopolu Crater (h2075_0000_da4). **b)** Shaded relief image after simulating fluvial erosion of the crater in a hyperarid environment. This would be the appearance of Endeavour crater before emplacement of the Burns formation strata and subsequent mass wasting and aeolian erosion. **c)** Shaded relief image after simulating a period of mass wasting and diffusion in a hypperarid environment with no precipitation. **d)** Shaded relief image after modeling a final period of aeolian erosion and deposition.

This initial erosional environment was modeled using a low rate of weathering (0.0005 m yr^{-1}), regolith that is more erodible than the bedrock, inefficient runoff production, and low bedrock erodibility. A rate scaling parameter was used in modeling fluvial erosion on Mars since absolute rates of precipitation and evaporation are unknown, and it is defined as the ratio of net lake evaporation rate to runoff depth. This ratio used in the initial simulation approaches infinity, similar to hyperarid environments on Earth [7].

The simulations significantly infills the crater interior with sediment sourced from the inner crater wall and erodes the crater rim. The morphology produced is a rounded crater rim with little to no regolith cover and minimal channeling on the crater interior (Fig. 4b).

After the hyperarid fluvial period a hyperarid environment without water was modeled with no presence of standing water, and dominance by low rates of weathering, mass wasting and diffusion. This smooths out the crater walls and fills in the interior of the crater further. It also causes the exposed bedrock on the rim to be more subdued (Fig. 4c).

A subsequent period dominated by aeolian erosion and deposition was then modeled, which simulates either deposition of wind-blown sediment or erosion of positive relief surfaces, e.g., hills and knobs [8]. This smoothed out the rim further, and deposited aeolian sediment in the interior of the crater (Fig. 4d)

Discussion: Similarities between the simulations of Bopolu gradation and the appearance of Endeavour crater show Endeavour's morphology was likely produced during an initial period of fluvial erosion in a hyperarid environment, followed by a drier period of erosion without water dominated by diffusion and mass-wasting, and an ongoing period of aeolian erosion and deposition. Simulations show that the pediment surfaces were created early, through fluvial erosion in a hyperarid environment, when the rate of weathering was slow enough that only thin regolith deposits formed/accumulated on these surfaces. Most of the regolith was transported downhill and is now buried by the embaying Burns formation. We are currently quantifying the intensity and timing of these processes that shaped Endeavour Crater to better understand the degradational history and implications for paleoclimatic conditions.

References: [1] Arvidson R. E. et al. (2014) *Science, 343*, 1248097. [2] Grant J. A. et al. (2016) *Icarus, 280*, 22-36. [3] Howard A. D. (1997) *Earth Surface Processes & Landforms, 22*, 211-227. [4] Strudley M. W. and Murray A. B. (2007) *Geomorph., 88*, 329-351. [5] Hartmann W. K. and Neukum G. (2001) *Space Science Reviews, 96*, 165-194. [6] Hughes M. N. et al. (2017) *LPS XLVIII*, Abstract #1483. [7] Howard A. D. (2007) *Geomorph., 91*, 332-363. [8] Forsberg-Taylor N. K. et al. (2004) *JGR, 109*, E05002.