MARS WAS WARM AND WET, BUT NOT FOR LONG? TWELVE YEARS OF FIELD GEOMORPHOLOGY AT MERIDIANI PLANUM.

T. J. Parker[1] and R. C. Anderson[1], [1]Jet Propulsion Laboratory, Caltech, Pasadena, CA (timothy.j.parker@jpl.nasa.gov)

Introduction: Several distinct morphologies visited by Opportunity suggest a short-lived transgressive marine environment that was likely a direct result of the LHB.

Observations/Interpretations: Several unique morphologies have been identified by the Opportunity rover since it began observations 12 years ago.

1. The bright outcrop is finely laminated, often including aqueous ripple forms in section [1,2]. The outcrop surface exhibits polygonal cracking from centimeter to hundreds of meter scales that suggests volume-loss cracking resembling desiccation of a thick homogeneous deposit (Fig1).

Fig 1: Polygonal cracks on rim of Erebus Crater. Largest polygons in this scene are several meters across.

2. Craters on the outcrop exhibit a range of degradation states to very fresh (prominent, “perched” ejecta) to highly degraded (bright ringed, shallow depressions). Small craters (less than a few tens of meters) visited by opportunity are usually clearly post outcrop in age, and often exhibit perched ejecta blocks in varying stages of destruction by saltating sand and migrating ripples [3]. On the rims of larger craters where the outcrop is exposed, it is either expressed as “flagstones” of randomly-oriented laminated blocks (e.g., Endurance, Victoria) that appear planed off by saltating sand (Fig2), or as a continuation of the polygonally cracked outrop surface, uninterrupted by the presenece of the crater’s rim (e.g., the “dimple craters” Erebus, Nimrod). We propose that the polygonally cracked rims indicate craters subjected to degradation in a playa or shallow marine setting, whereas the randomly-oriented laminations in flagstone ejecta indicates aeolian erosion of crater ejecta in a subaerial environment.

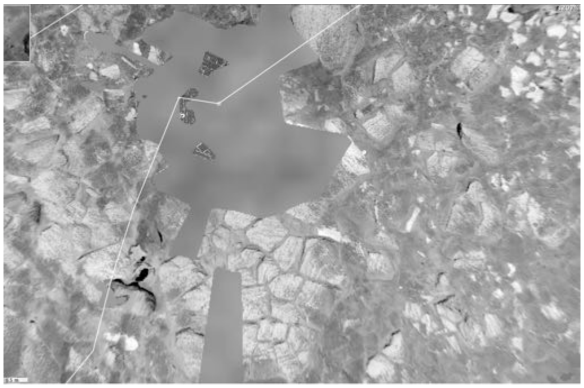

Fig 2: Eroded “flagstones” on rim of Endurance crater, with laminations within blocks in all orientations.

3. The cumulative crater population, including all degraded, but still recognizable craters, is late Noachian to early Hesperian [4-6], and likely related to the end of the Late Heavy Bombardment. These craters are too small to be protruding from beneath the Meridiani Planum Burns Formation, so they date the emplacement of the deposits.

4. Endeavour crater formed in the materials subjacent to the Meridiani Planum deposts and before formation of the present surface, as there are no ejecta materials from Endeavour present on the Burns formation [7].

5. While Opportunity was at Endurance crater, it was predicted that the presence of finely laminated and rippled outcrop and large-scale cross-bedded strata derived from it suggested a sabkha environment, with contemporaneous dunes and playas separated spatially across the plains [2]. However, as Opportunity traversed to Endeavour, we instead saw polygonally cracked outcrop overlying cross-bedded outcrop (Endurance, Victoria, as well as probable aqeous cross bedding at Erebus), suggesting subaerial and subaqueous settings were separated temporally rather than spatially. We suggest that this indicates a shallow marine setting, with perhaps multiple transgressions and regressions from subaqueous to subaerial environments, and that the fine-scale laminations and aqueous ripples formed during ocean transgressions.

6. Because the laminations appear rhythmic, but ripples cross multiple laminations, it seems unlikely that the laminations represent very long cycles (previous ripples might be destroyed in a later flow regime) so perhaps they indicate diurnal cycles of local wind and gravity tides in shallow water across the region. If the laminations are indeed diurnal, and are typically less than a few millimeters thick, in a simple scenario of uninterrupted monotonic marine transgression, the Meridiani deposits could have been implaced in as little as a few hundred thousand years' time.

7. The Burns and Grasberg formations around the base of the Endeavour rim are aqueous coastal deposits (Fig3) that have been tilted into the crater by dewatering, compaction, and/or dissolution of subsurface materials locally [8].

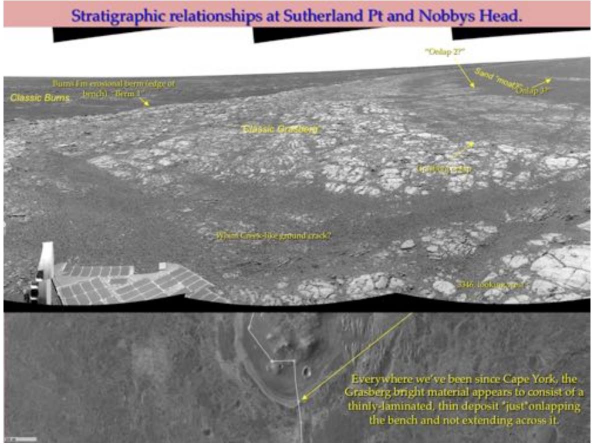

Fig 3: Multiple onlaps of Grasberg and Burns Fm materials at Nobbys Head, Endeavour crater rim.

8. Striations, ridges and grooves, block trains trending roughly east-west across the Endeavour rim (Fig 4) are ice-pushing morphology indicative of a shallow marine "arctic" environment with pack ice driven by winds across the rim of the crater [9].

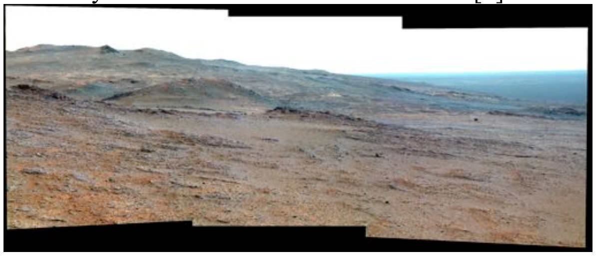

Fig 4: Striations across scene are ridges and grooves of coarse material oriented E-W on west side of Endeavour rim. Pancam from Sol 3921, looking south on approach to Marathon Valley. Scene ~45° Wide.

Preliminary Conclusions: We suggest that Mars had an ocean that extended up to the elevations of the Meridiani Planum during the LHB. The sulfate-rich Meridiani Planum deposits likely accumulated in a shallow water setting (where evaporation across a broad shallow platform could oversaturate the water and enhance sulfate precipitation). It was likely introduced exogenically to Mars during the LHB. Mars was 'warm and wet' during this time. After the LHB, Mars' ocean regressed to lower elevations and higher latitudes [10], where it eventually froze. Proposed shorelines identified in the west Deuteronilus region [11], are likely Hesperian to early Amazonian.

References: [1] Squyres S. W. et al. (2005) Earth and Planet. Sci. Lett., 240, 1-10. [2] Grotzinger J. P. et al., (2005) Earth and planet. Sci. Lett., 240, 11-72. [3] Golombek M. P. et al. (2014) JGR 119, doi:10.1002. [4] Hynek B. M. et al. (2002) JGR 107, 5088. [5] Lane et al. (2003) GRL 30, 1770 [6] Arvidson R. E. et al. (2006) JGR 111, E12508. [7] Grant J. A. et al. (2015) Icarus doi: 10.1016. [8] Parker T. J. and Grant J. A. (2014) GSANo. 329-15. [9] Parker and Anderson, R. C. (2015) GSA No. 234-7. [10] Parker T. J. et al. (2010) in Lakes on Mars, Cabrol, and Grin, eds., Elsevier, 249. [11]Parker T. J. et al. (1989) Icarus 82, 111-145.