

PERSISTENT AEOLIAN ACTIVITY AT ENDEAVOUR CRATER, MERIDIANI PLANUM, MARS; NEW OBSERVATIONS FROM ORBIT AND THE SURFACE. M. Chojnacki¹, J. Johnson², T. Michaels³, L. Fenton³, and J. Moersch⁴, ¹Lunar and Planetary Lab, U.A., Tucson, AZ (chojan1@pirl.lpl.arizona.edu), ²Johns Hopkins University Applied Physics Laboratory, Laurel, MD, ³Carl Sagan Center at the SETI Institute, Mountain View, CA, ⁴Department of Earth and Planetary Sciences, U.T., Knoxville, TN.

Introduction and Motivation: Aeolian-driven bedform activity is now known to occur in many regions of Mars, based on surface and orbital observation of contemporary martian ripple and dune mobility events [see 1 for a review]. However, the timing (season and time of day) and duration of sand movement are poorly constrained due to the infrequent temporal coverage of observations. Many of these known sites of activity have only been monitored for the last few Mars years, beginning when the High Resolution Imaging Science Experiment (HiRISE) [2] began taking images of Mars. One exception is Endeavour crater in Meridiani Planum, which was one of the first known sites of unambiguous dune activity (based on pre-HiRISE observations) [3]. Herein, we revisit Endeavour crater with new high-resolution orbital views, historic albedo measurements, and surface observations.

Data Sets: To assess dune activity, we used repeated high-resolution (25 cm/pix) images from HiRISE [2]. Lambert albedo from the THEMIS VIS camera (18 m/pix) [4] was estimated based on the systematic relationship between TES broadband albedo ($\sim 0.4\text{--}2.7\ \mu\text{m}$) and the THEMIS VIS band 3 ($0.654\ \mu\text{m}$) in coincident THEMIS/TES observations [5]. Surface observations from the Opportunity rover, situated on the NE rim of Endeavour (Cape York), include Pancam images [6] of adjacent surfaces [7], the crater interior, and dunes. Additionally, five 360° “albedo pans” were acquired every ~ 30 sols using the broadband L1 filter on Pancam and compared for changes [6,7].

Results - Eastern Dune Field: The smallest dome dunes in the eastern portion of the crater that were earlier found to have a large degree of aeolian activity (between Mars year (MY) 25 and MY29) [3] were reexamined with HiRISE data. The new images reinforce earlier lower-resolution MOC-CTX observational inter-

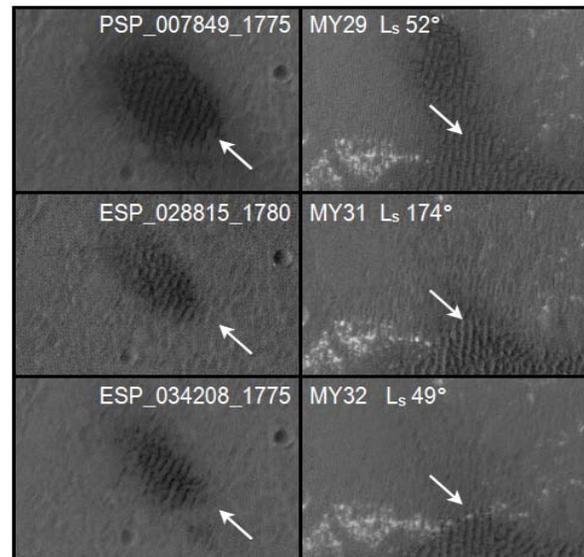


Fig. 1. Deflation of eastern dune field bedforms over three time steps. Dune iii (left), earlier documented to deflate $\sim 45\%$ between MY25 and 28 [3], continued to lose area with $\sim 24\%$ in 2.4 Mars years then another $\sim 38\%$ two seasons later. Other duneforms (left) show similar surface change. Each insets have ~ 100 m FOV.

pretations, showing clear evidence for sand deflation between seasonal and annual time steps (Fig. 1–2). Dunes in these images frequently occupy less area (25%–100%) than in earlier MY29 or 31 images (Fig. 1).

One surprising result of earlier analysis of this dune field was a measured dome dune translation of 10–20 m [3] resulting in some of the fastest known migration rates on Mars (4–9 m per Mars year) when compared with global studies of active bedforms [1]. Reimaging shows that some of these dome dunes migrated 2–6 m within the most recent time step of ~ 0.5 Mars year (Fig. 2), indicating a pulse of activity and high rates of transport (4–12 m per Mars year).

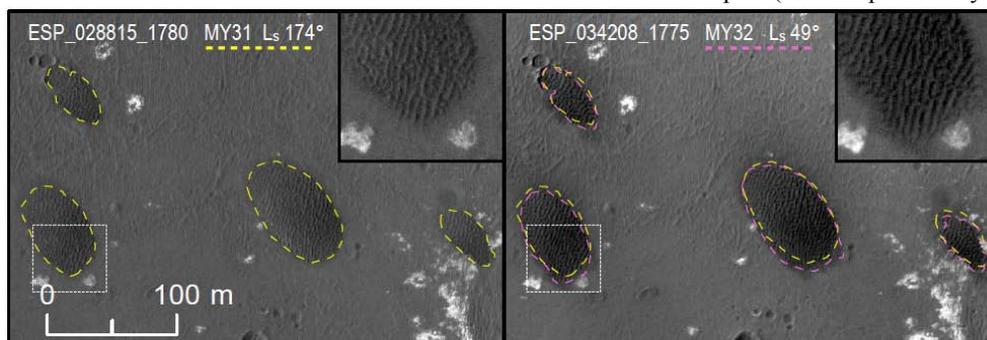


Fig. 2. Several small dome dunes gained or lost surface area, in addition to rapidly migrating (4–9 m per Mars year) to the SE in the half Mars year between images. Insets have ~ 50 m FOV.

Western Dune Field: The western dune field was also reimaged to test whether bedforms were active in this portion of Endeavour. Paired images taken three Mars years apart show clear evidence for dune migration and modification (Fig. 3). Dune slip face movement is evident for most dunes, where crests and aprons advanced (to the SSE) at rates of 0.7–2.3 m per Mars year (average of 1.1 m per Mars year). Smaller dunes had higher rates of transport. Superposed dark-toned ripples were also detected to be migrating, particularly on edges of dunes that are atop light-toned bedrock, which provides adequate contrast for change detection.

Albedo Variations: A sharp increase (~8%) in THEMIS albedo of Endeavour dune fields occurred between MY27 and 28 (Fig. 4a). Similar albedo brightening events (+30%) appeared at the end of MY25 (> L_s 269°) in TES data [8]. These increases in albedo almost certainly occurred in response to the 2001 (MY25, L_s ~180°) and 2007 (MY28, L_s ~260°) global dust storms (Fig. 4a, gray bar). Following the MY28 storm albedo progressively decreased ~17% between MY29 and 32. The persistent deflation of Endeavour bedforms described above likely disseminates dark sand, erodes bright dust, and contributes to the crater's episodic decreases in albedo (Fig. 4b).

Surface Observations at Cape York: The Opportunity rover detected several types of surface changes in the surrounding area while parked at its winter-spring location at Cape York. Observations include the brightening and darkening of adjacent bedforms, soils, and rover tracks in ratios of Pancam albedo pans [7]. Reimaging of adjacent disturbed areas near rover tracks revealed sub-meter movement of variable-sized sediment, which is attributed to the aeolian removal of sand and spherules. Pancam detected far-field surface changes, such as shifting barchan dune dark streaks and an intracrater dust-entraining wind event [9].

Discussion and Summary: Migration rates of barchans are near the averages from global studies, but the rates of smaller dome dunes are the fastest yet documented. The turnover time of aeolian bedforms is defined as the time a dune takes to travel its own stoss-to-

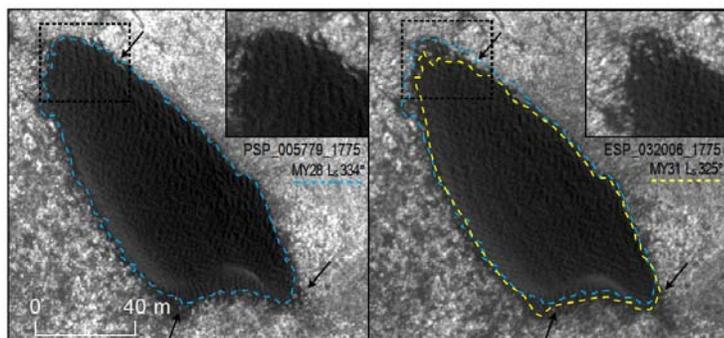


Fig. 3. HiRISE images of a western barchan dune migrating. Dune edge modification includes removal (stoss-side) and deposition (lee-side) of sand (black arrows). Insets have ~30 m FOV

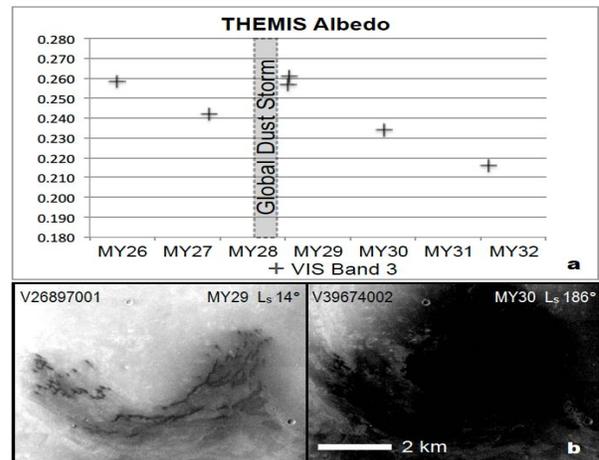


Fig. 4. (a) THEMIS VIS band 3 albedo (MY26–MY32) of Endeavour dune fields (gray bar indicates the 2007 global dust storm). (b) VIS albedo images of the dune fields with approximately the same histograms, showing the relative darkening over the ~1.5 Mars years between images.

lee length in the downwind direction [10] and is therefore a measure of how long it takes to respond to major (~90°) changes in wind patterns. Estimated dune turnover times (using migration rates and dune lengths) here and at other sites [1] are significantly shorter than martian obliquity cycles, implying that it is not necessary to invoke paleoclimate wind regimes to explain the observed dune morphologies.

Dunes, ripples, and dark streaks in Endeavour are now known to be periodically active from over a decade of orbital observations (MY25 to MY32 or 2007–2013) and over a time span of a few seasons to several Mars years. Located on the crater rim, the Opportunity rover detected evidence for near- and far-field aeolian-driven changes. Larger-scale fluctuations in albedo are detected from orbit in response to global dust storms and dune-related activity. Sites like Endeavour crater with a large temporal baseline of observed aeolian activity show that Mars is a dynamic planet where eroded sediment frequently and regularly interacts with the atmosphere in the current epoch. Full results have been submitted to the Icarus Dynamic Mars Special Issue [11].

References: [1] Bridges et al. (2013) *Aeolian Research*, 9, 133–151 [2] McEwen et al. (2007) *JGR*, 112, E05S02. [3] Chojnacki et al. (2011) *JGR*, 116, E003675. [4] Christensen et al. (2004) *Space Sci. Reviews*, 110, 85–130. [5] Edwards et al. (2011) *JGR*, 116, E003857. [6] Bell et al. (2006) *JGR*, 108, E002444. [7] Johnson J. (2011) *EPSC-DPS*, Abstract #1205. [8] Chojnacki et al. (2013) *Icarus*, in print. [9] Chojnacki et al. (2012) *Plant. Dune Workshop*, Abstract #7040. [10] Allen J (1974) *Earth Sci. Reviews*, 10, 263–342. [11] Chojnacki et al. (2014) *Icarus*, in review.