EOLIAN BEDFORMS AND EROSIONAL LANDFORMS AT HIGH ALTITUDES ON THE MARTIAN THARSIS VOLCANOES. K. S. Edgett and M. C. Malin, Malin Space Science Systems, P.O. Box 910148, San Diego, CA 92191-0148, USA.

Introduction: Despite the relatively thin modern atmosphere at the high flanks and summit regions of the four large Tharsis volcanoes—Olympus, Pavonis, Arsia, and Ascraeus—high spatial resolution images from the Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) reveal eolian depositional and erosional landforms in these areas (Figs. 1–5). Each of these volcanoes towers to more than 17 km above the martian datum—thus the modern atmospheric pressures can be as low as 1 mbar. The presence of bedforms at any altitude requires that conditions have occurred in which loose, granular material has been transported in wind via saltation and traction [1]. Erosional forms, such as pedestal craters (Fig. 3), require sufficient winds to strip away surface coverings and move them elsewhere.

Background: Eolian activity—in the form of dust plumes and changes in wind streak patterns—has been known to occur on the four large Tharsis volcanoes since the Mariner 9 mission [2, 3]. Such activity requires that the eolian threshold friction velocity needed to move loose grains must be exceeded. Wind streaks on the volcano surfaces can change in as little as a few weeks or days [2, 3] and are attributed to strong local slope winds (slopes are typically <10°) that blow down off these mountains at night [3, 4]. Prior to MOC, no bedforms had been observed on the volcanoes, although Zimbelman [5] noted Viking images that showed a set of possible dunes near the base of the west flank of Arsia Mons.

Observations: The first hint of eolian bedforms at high altitudes came from MGS MOC image AB1-03308—at the summit of Arsia Mons—acquired in November 1997 and noted by Hartmann *et al*. [6]. The next and most spectacular occurrence of high altitude bedforms was documented in MOC image SP1-20805 on 30 March 1998. Fig. 1 shows part of SP1-20805 in which two types of eolian landform are seen on the high eastern flank of Olympus Mons. Parallel, ripple-like bedforms occur in troughs on the east flank of Olympus (Fig. 1, inset) and also at the base of cliffs in craters and pits (Fig. 5). In addition, nearly crescent-shaped mounds or drifts are dominant in Fig. 1 (right); each is piled in the lee of a very small obstacle and tapers in the down-slope direction. Other tapered ridges also occur on the east Olympus flanks (Fig. 1, lower left) and such features are common throughout the Tharsis region and usually point down-slope. The caldera floors of Olympus and Arsia lack eolian bedforms, while the caldera floor of Ascraeus Mons exhibits a pedestal crater—an indication of deflation of the upper layer of material into which the crater had initially impacted (Fig. 3). Ascraeus also exhibits ripples like those in Fig. 2 which appear to have been covered by a textured mantle and occasional boulders that have rolled down an adjacent slope—these bedforms are interpreted to be inactive because of the materials that superpose them. Bedforms also occur on the high flanks of Arsia Mons (*e.g.,* Fig. 4). Pavonis Mons has a thickly-mantled summit region with very few bedforms, though MOC images M00-02882 and M02-02198 near 0.8°N, 112.0°W both show what appear to be mantled dunes on this volcano.

Discussion: Most bedforms on the Tharsis volcanoes generally appear to be mantled (*e.g.,* Fig. 2). Drifts and tails (as in Fig. 1, right) are common and, like pedestal craters, might represent the stripping of a once more-extensive blanket of material. Mantled bedforms indicate inactivity in the modern environment, but suggest a time in the past when the atmosphere might have been thicker and/or winds stronger. Some bedforms, as on Arsia Mons in Fig. 4, do not appear to be covered by a mantle and could therefore be active today. The pedestal crater in the caldera of Ascraeus Mons (Fig. 3) sets this surface apart from the nearly mantle-free floors of calderae of Olympus and Arsia Mons. Bedforms likely require sand and/or granule-sized materials [1]; possible sources for loose, clastic debris on the high volcano flanks include pyroclastic volcanism, meteorite impact, gravity (mass-wasting of slopes) and perhaps thermally-induced fracturing of rock. The bedforms and erosional features resemble those found elsewhere at lower elevations in Tharsis, including the flanks of the small Tharsis volcanoes (*e.g.,* Jovis Tholus, Biblis Patera, Ceraunius Tholus).

References: [1] Bagnold R. A. (1941) *The Physics of Blown Sand and Desert Dunes*, Methuen, London. [2] Sagan C. *et al*. (1974) *Icarus, 22*, 24–47. [3] Lee S. W. *et al*. (1982) *JGR, 87*, 10025–10041. [4] Magalhães J. and Gierasch P. (1982) *JGR, 87*, 9975–9984. [5] Zimbelman J. R. (1993) *LPS XXIV*, 1575. [6] Hartmann W. K. *et al*. (1999) *Nature, 397*, 586–589.

Figure 1. Eolian bedforms occur in troughs (small box and larger inset) and arcuate drifts are seen in the lee of small obstacles (right half of frame) on the upper east flank of Olympus Mons. Subframe of MOC image SP1-20805 near 19.1°N, 132.4°W, illuminated from lower right.

Figure 2. Eolian bedforms at base of escarpment on upper northwest flank of Ascraeus Mons are mantled by a lumpy-textured mantle. Dark spots are boulders that have rolled down from escarpment. Bedforms predate the deposition of boulders and mantle. Subframe of M03-03306, near 11.5°N, 104.7°W, sun from

left.

Figure 3. Pedestal crater on Ascraeus Mons caldera floor indicates eolian deflation of material that was present when the impact crater formed. Small box shows location, inset shows magnified view. Subframe of M07-03040, near 11.6°N, 104.4°W. Caldera wall visible across middle of frame, sun from lower left.

Figure 4. Eolian bedforms on high southern flank of Arsia Mons, occurring both on the upper shield surface and down in troughs and channels. Subframe of M02-01563, near 8.2°S, 119.6°W, sun from left.

Figure 5. Megaripples (arrow) at contact between floor and wall of pit near impact crater on upper east flank of Olympus Mons near 18.5°N, 131.9°W. Illumination from lower left, subframe of M03-06151.