MGS MOC IMAGES OF SEIF DUNES IN THE NORTH POLAR REGION OF MARS. K. S. Edgett and M. C. Malin, Malin Space Science Systems, P.O. Box 910148, San Diego, CA 92191-0148, USA.

Introduction: Eolian dunes with morphologies that form in multi-directional wind regimes have long been considered to be rare on Mars [1]. This view is largely confirmed by Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) images, except now many more examples of dunes formed in complex localized wind regimes have been revealed, thus allowing potential for better understanding of their occurrence and for comparison with Earth. More than half the surface area covered by dunes on Earth consist of those with linear form that result from an essentially bimodal wind regime [2], but these are so rare on Mars that only a few isolated and putative examples had been identified in Viking orbiter images [3–5]. Local topographic influence in an otherwise unimodal wind regime were invoked to explain these rare occurrences [4–5]. This paper describes several good, unambiguous examples of 'seif' dunes that have been found by MOC.

Background: On Earth there are essentially three types of 'linear' dune: those that form in the lee of an obstacle (lee dunes), those with generally flat or rounded crests that occur in association with vegetation (vegetated-linear dunes), and those with a sharp, almost sword-like crest (seif dunes) [2]. Lee and seif dunes have essentially similar morphology, but lee dunes form on the down-wind side of a non-dune obstacle such as a cliff. Vegetated-linear dunes have long been thought to require the presence of shrubs or grasses to initiate and maintain their forms, while seif dunes are typically thought to form when a transverse dune, such as a barchan, moves into a local or regionally bimodal wind regime. Seif dunes and transverse (*i.e.,* crescentic and barchan) dunes can in fact occur in the same dune field with the same regional wind conditions, particularly if a barchan 'horn' becomes extended in one direction but is locally confined by other dunes or obstacles such that it cannot be affected by winds from different directions [*e.g.,* 6].

Local topographic influence on wind regime is considered to be the lead cause for putative and limited occurrences of linear dunes on Mars. Lee and Thomas [5] and Tsoar *et al.* [3] presented several Viking orbiter images that seemed to indicate the presence of seif dunes in the martian north polar sand sea that had formed by elongation of a barchan horn until, in some cases, the barchan itself had vanished leaving only the linear form. Edgett and Blumberg [4] presented a different form of linear dune in the martian southern hemisphere—a form that essentially resembled lee dunes with the linear features created in the lee of larger semi-crescentic dunes.

MOC Observations: The search for good examples of martian linear dunes focused in 1999 upon the large dune fields of the north polar region. The northern summer season that occurred February–July 1999 presented many opportunities for the MGS MOC to obtain new, high spatial resolution pictures of dunes in the north polar region. The camera was operational almost continuously from early March 1999 onward. No MOC images of the north polar dunes described by Tsoar *et al*. [3] or Lee and Thomas [5] were obtained during 1999, but several MOC images provided new and unequivocal examples of seif dunes in a variety of locations in the north polar region.

MOC examples of seif dunes are shown in Figs. 1–4. Three of the four (Figs. 1, 2, 4) are in the largest trough in the north polar permanent cap, Chasma Boreale. The Boreale dunes are all found in association with barchan dunes. Some of the barchans have elongated horns, others show no elongation, still others have been modified into low, elliptical forms with no slip faces. The Boreale seif dunes commonly appear to have connected one pre-seif barchan to another to form a longer longitudinal dune (*e.g.,* the longest dune in Fig. 1). The dune in Fig. 3 is not in Chasma Boreale, but occurs close to the margin of the permanent north polar cap. In each case, there is a local or regional topographic influence on wind regime that might provide the strongly bimodal setting in which these dunes can form. Other dunes and dune fields in the north polar region exhibit a range of morphologies (*e.g.,* rectilinear), but most are variants of typical transverse forms.

Discussion: Longitudinal dunes are rare on Mars, but they *do* occur, and therefore the same physics and processes that contribute to their genesis and maintenance on Earth [see 3, 7] are at work on Mars. The extension of barchans into seif dunes, and the connection of such barchans to create longer seif dunes (e.g., Fig. 1) are practically "textbook examples" of how such dunes have been thought to form since at least the seminal work of Bagnold (see Fig. 78 in [8]).

References: [1] Greeley R. *et al*. (1992) in *Mars*, p. 730–766, Univ. Arizona Press. [2] Tsoar H. (1989) *Progr. Phys. Geogr., 13,* 507–528. [3] Tsoar H. *et al*. (1979) *JGR, 84,* 8167–8180. [4] Edgett K. S. and D. G. Blumberg (1994) *Icarus, 112*, 448–464. [5] Lee P. and Thomas P. C. (1995) *JGR, 100*, 5381-5395. [6] Tsoar H. (1974) *Zeitschr. Geomorph., 20*, 41–61. [7] Tsoar H. (1983) *Sedimentology, 30*, 567-578. [8] Bagnold R. A. (1941) *The Physics of Blown Sand and Desert Dunes*, Methuen, London.

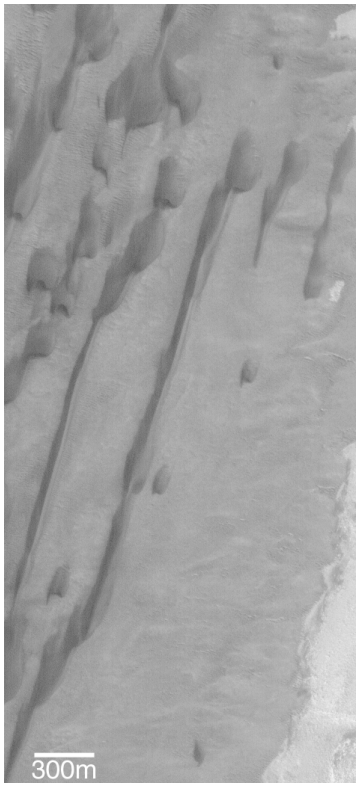

Figure 1. Seif dunes formed from elongated barchans in a trough in southern Chasma Boreale. Illumination is from the lower right. Sub-frame of MOC image M01-00179, near 82.2°N, 76.7°W, taken 6 May 1999.

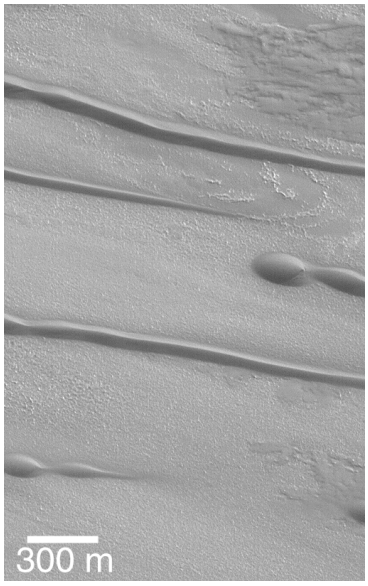

Figure 2. Seif dunes formed and forming from barchan dunes in Chasma Boreale near 84.8°N, 26.2°W. Sub-frame of MOC image M02-00783, illumination from the upper right. Image obtained 8 June 1999.

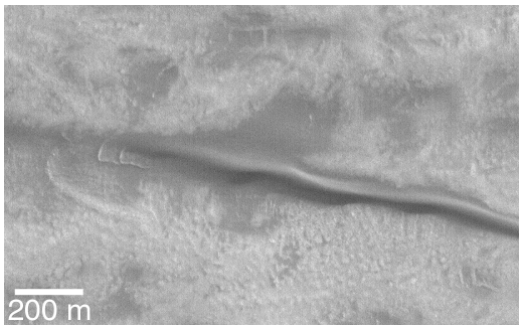

Figure 3. Single, semi-sinuous longitudinal dune near 83.0°N, 204.0°W, close to the margin of the permanent north polar cap. The somewhat sinuous form of this dune resembles the dunes in classic seif dune studies in the Negev Desert by H. Tsoar (see Fig. 1 of [8]). Sub-frame of MOC image M02-01955, illuminated from the upper right, acquired on 15 June 1999.

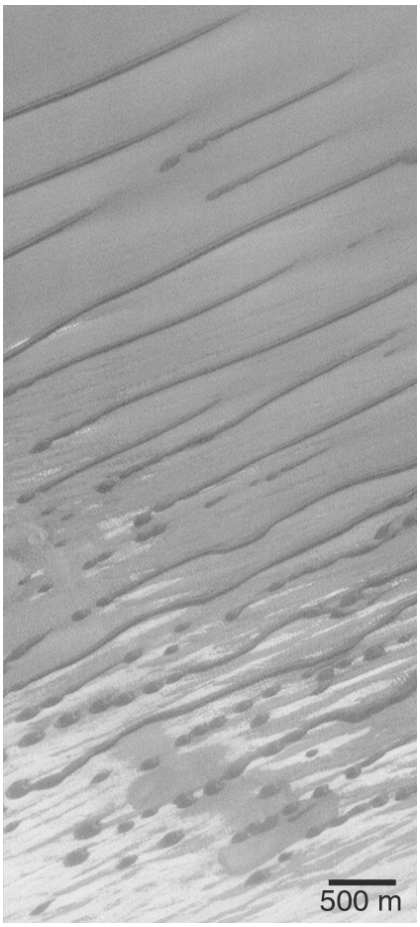

Figure 4. Linear dunes associated with extended barchans in Chasma Boreale near 84.2°N, 37.6°W. Illumination is from the upper left. Bright areas are frost. MOC image M03-07330, taken near the evening terminator in early northern autumn on 7 August 1999.