BARCHAN DUNE ASYMMETRY: OBSERVATIONS FROM MARS. Mary C. Bourke, Planetary Science Institute, 1700 E. Ft. Lowell, #106, Tucson, Arizona 85719, USA mbourke@psi.edu

Introduction: Barchan asymmetry refers to the preferential extension of one barchan limb downwind. It is found at many locations on Mars. Although several sites exhibit unidirectional limb orientations, others show that limbs may extend in multiple directions even leading to superimposition. Resultant dune field ridge patterns can be highly complex suggesting that there may be several causes of dune asymmetry on Mars.

On Earth, four triggers of dune asymmetry are identified: 1. bi-directional winds [1-7], 2. local topography [8, 9] 3. dune collision [11, 12] and 4. asymmetry in sediment supply [13, 14]. This paper describes limb morphology and uses this to infer triggers of barchan asymmetry on Mars.

Asymmetric limb morphology on Mars: Asymmetry is found on both barchan and barchanoid dunes. Associated limb morphologies are categorized as linear, beaded and kinked (Fig.1). <u>Linear limbs</u> are generally straight, but may have seif-like form. They can taper downwind or assume a more rounded end (Fig. 1a). Some have well developed crestlines and/or slipfaces on the inner side of the limb. <u>Beaded limbs</u> have broad, high sections that alternate with narrow, low sections and resemble a string of beads (Fig. 1 b). For some, the broadest section occurs at the tip of the limb and may produce small domes by calving [15]. <u>Kinked limbs</u> have distinct, often angular changes in downwind alignment followed by straight sections of variable length (Fig.1 c). The apex of the kink may have a well developed (remnant) slipface. Some limbs have several kinks resulting in a seif-like morphology.

Barchan asymmetry models: <u>Bi-directional wind:</u> In Bagnold's model [1, pg. 223] asymmetry is initiated by storm events that are oriented oblique to the dune. Asymmetry develops on the windward barchan limb and is sustained and enhanced by gentler winds that parallel the barchan form (Fig. 2 a). In Tsoar's model [7] there are important differences in the inferred wind direction and the limb that adjusts. The dune is oriented parallel to the stronger winds and modified by gentler winds that trend oblique to the barchan (Fig. 2b). The limb furthest from the approaching gentle wind is extended and the closest limb is eroded.

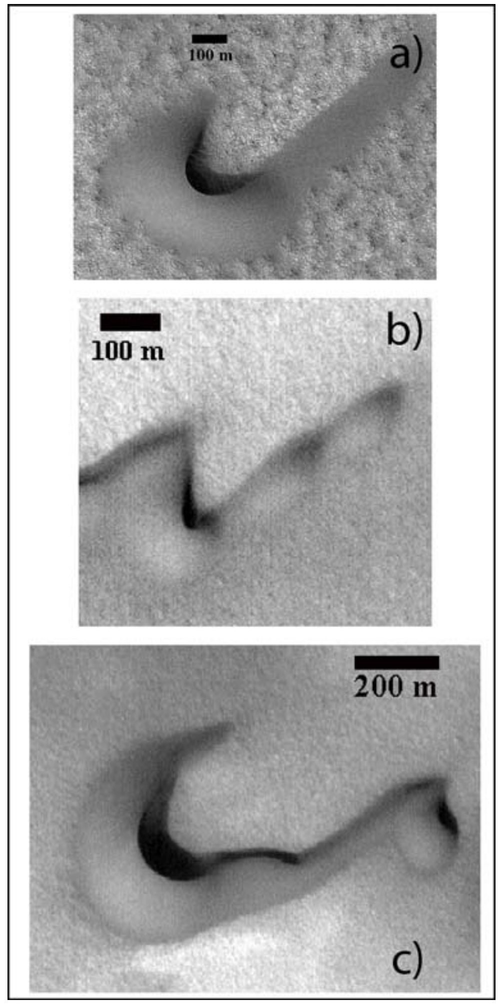

Figure 1: Asymmetric limb styles. a) Linear. HiRISE image PSP_001660_2570,76.7°N; 109.6°E, 50 cm/pixel. b) Beaded. MOC narrow angle image M0202629, 240.67°W; 76.70°N, 3.22 m/pixel. c) Kinked. M0204193, 239.61°W; 76.72°N, 3.22 m/pixel.

The morphology and placement of the asymmetric limb may enable a differentiation between these two models. In Bagnold's model (*sensu stricto*), the growing limb migrates across the front of the dune. Once it enters the sand stream from the opposite barchan limb, it grows more rapidly than the connecting limb and a new dune (or bead) is formed. Resultant limb morphologies would therefore include: variable width, development of a lee side slip face and/or new dune formation coupled with an limb that crosses the path of the barchan dune. In Tsoar's model [7] the limb would have a seif form, variable width, and importantly, would extend away from the barchan (~ 120° angle) [examples are given in 16].

Unidirectional wind: *Dune collisions* distort dune morphology and can cause asymmetry. The collisions reported on here are assumed to occur in unidirectional winds that trend parallel to the dune orientation. It is noted that barchans can form in uni, bi- and multi-modal wind regimes.

Flume studies of two moving barchans under unidirectional flow show that absorption of the smaller impacting barchan by the larger barchan leads to asymmetry [10] (Fig. 1 c). This was also observed in Antarctic barchans [17].

The proximity of dunes, prior to collision, may also trigger asymmetry [18]. A second study [11] found that the back slope of the down-flow dune was eroded by the advancing smaller dune, triggering asymmetry (Fig. 1 d).

Asymmetry on Mars is associated with the lateral merging of smaller barchans and the direct collision of dunes on the windward slope. Dune and limb morphologies that suggest collision as the trigger for the development of asymmetry include a distinctive kink(s) in the asymmetric limb or the vestiges of the impactor dune on the windward slope. Dune collisions explain the asymmetric extension of different limbs within a given dune field [16].

Topography: Local topography (*e.g.*, gullies, bedrock exposures and inclined slopes) distort dune shape [8, 9]. On Mars asymmetric dunes occur on declining and inclining slopes and in locations of confining topography [examples are given in 16].

Conclusion: Barchan dune asymmetry is prevalent on Mars and is triggered in bi-directional wind regimes, in certain topographies and by dune collisions. Limb morphology may help differentiate between these triggers. Seif-like morphologies that trend across the barchan path or away from the barchan suggest bi-directional winds; distinctive kinks in the limb and vestiges of dunes on the windward slope suggest collision; finally topographic obstructions or clearly dipping underlying slopes may induce asymmetry, however the influence of bi-directional winds cannot be excluded.

Dune asymmetry on Mars represents a morphological adjustment to environmental changes such as variable wind direction, enhanced sediment supply through dune collision and variable local topography. There is potential to use asymmetry as a proxy for wind direction and relative strength. However, given the range of potential triggers, attention should be paid to morphological indices outlined here that will allow a more confidently assessment of the wind regime.

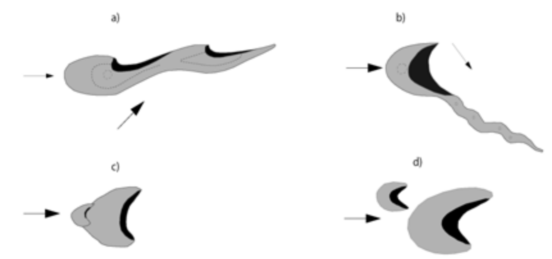

Figure 2: Schematic of models of dune asymmetry. a) Bagnold [1] b) Tsoar [7] c) dune collision (absorption) [10]. d) dune collision (impending) [11] . Arrow indicate wind direction, size indicates relative strengths.

Acknowledgement: This work is funded by NASA MDAP NNX07AV36G

References:[1] Bagnold, R. A., *The Physics of Blown Sand and Desert Dunes*. (Methuen, London, 1941), pp. 265. [2] King, W. H. J., *Geography Journal* **51**, 16-33 (1918). [3] Melton, F. A., *Journal of Geology* **48**, 113-174 (1940). [4] Holm, D. A., *Science* **132**, 1329-1379 (1960). [5] McKee, E. D., *Sedimentology* **7**, 1-60 (1966). [6] Norris, R. M., *Journal of Geology* **74**, 292-306 (1966). [7] Tsoar, H., *Zeitschrift fur Geomorphologie* **28**, 99-103 (1984). [8] Long, J. T. *et al.*, *Geological Society of America Bulletin* **75**, 149-156 (1964). [9] Finkel, H. J., *Journal of Geology* **67**, 614-647 (1959). [10] Endo, N. *et al.*, *Geophysical Research Letters* **31**, 12503 (2004). [11] Hersen, P. *et al.*, *Geophysical Research Letters* **32**, 1-5 (2005). [12] Close-Arceduc, A., Institut Geographique National, 1969. [13] Rim, M., *Bulletin of the Research Council of Israel* **7-G**, 123-137 (1958). [14] Lancaster, N., *Earth Surface Processes and Landforms* **7**, 575-587 (1982). [15] Bourke, M. C., *Geomorphology*, (submitted). [16] Bourke, M. C., *Icarus*, (submitted). [17] Bourke, M. C. *et al.*, *Permafrost and Periglacial Processes*, (submitted). [18] Shehata, W. *et al.*, *Journal of Arid Environments* **23**, 1-17 (1992).