A NEW MODEL FOR LINEAR DUNE FORMATION: MERGED BARCHAN CONVOYS ON MARS

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Introduction: Most Martian aeolian dunes seen in Mariner 9 and Viking 1 and 2 orbiter images were identified as barchan, barchanoid, transverse, or complex dunes that combine aspects of these dune types [1-5]. However, examples of linear dunes have also been found [6, 7].

Several models have been proposed to explain the formation of linear dunes. These models include the development of helical vortices in unimodal wind regimes [8, 9], or emphasize the importance of bidirectional wind regimes [10-12]. Some linear dunes are associated modification and extension of existing dune forms [13-15] or undifferentiated mounds of sand [16].

On Mars, linear dunes have been reported to form from secondary flow patterns (essentially Bagnold's Model [12]) [17, 18, 7] and topographically influenced, complex wind patterns [6]. In addition to these observations, linear dunes extend as lee projections from dunes and topographic obstructions [see Fig. 5 and 6 in 19]. This paper describes a new mechanism for the formation of linear dunes that complements the above suite, *i.e.* merged barchan convoys.

Dune morphodynamics on Mars: Observations of dunes in MOC-scale images indicate a wide variety of dune forms. Barchan dunes exhibit asymmetry, display extension by lee projection, show evidence of calving and collision/merging.

Linear extension from a dune. On Mars two types of dune extension are identified. 1. The extension of one arm of a barchan dune leading to dune asymmetry and 2. the development of lee projections from barchan, barchanoid and akle dunes (Fig. 1). The form of the extending limb can be further subdivided into: beaded, linear/seif, hinge, kinked and lateral.

Dune calving. Barchan dunes shed sediment from the tips of their arms. Depending on the sediment flux and wind regime, sediment may be deposited as sand streamers/stringers or, they form dunes in the downwind trajectory of the (extending) arm or projection of the dune (Fig. 1). On Mars, three styles of downwind forms have been observed: 1. Isolated dunes (barchan, dome, linear (incl. Seif), 2. *En echelon* and 3. Dune convoy (barchan, dome).

Dune collision and merging. It has been shown that small barchan dunes move faster than large ones [20]. Similar to Earth, Martian sand dunes display differential migration rates. This is evidenced by dune collision and merging. A range of morphological interactions have been observed between smaller barchan and dome dunes that collide with larger barchan and barchanoid dunes. On reaching another dune, they tend to 'side-swipe', merge, transform (e.g. barchan to dome or linear), coalesce and superimpose.

The Model: The model proposed here essentially involves the collision and merging of a barchan convoy.

There are two prerequisites for the merging of barchans to form a linear dune: First, barchans must migrate in convoy (Fig. 1). This is facilitated by the calving of barchans from a barchan arm or projection. Second, barchans must have differential migration rates. A barchan will merge when a proceeding dune migrates at a lower rate (or is stabilized). The differential migration rate of barchans in convoys is indicated by the variable spacing between dunes (Figs. 1 and 2). This spacing may also be a function of the rate and volume of calving from the limb/projection.

The mechanism of dune merging is predominantly by the extension and thickening of one of the barchan arms. The side of the dune that extends, alternates for each successive dune (Fig. 2). This results in the construction of saddles and peaks, and a beaded linear dune forms (Fig. 2). This sets in place local aerodynamics where a series of converging and diverging wind vortices transport sediment along the extended limbs, connected to the dome-shaped (remnant barchan) segments. This form evolves into a sinuous crest, i.e. a seif dune. If the angle of wind incidence is reduced as a result of the new dune form, a steady state develops [21] and the linear dune may extend downwind (Figs. 1 and 2). However, if the angle of incidence increases, erosion and deposition will be concentrated in the same place and the dune will be broken up by erosion of the saddles and growth of the peaks [22] giving rise to a series of individual or linked barchan and dome dunes.

Conclusion: The collision and merging of barchan and dome dunes to form linear ridges and seif dunes has not been previously reported for dunes on Earth or Mars and represents a new model for the formation of linear dunes.

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References

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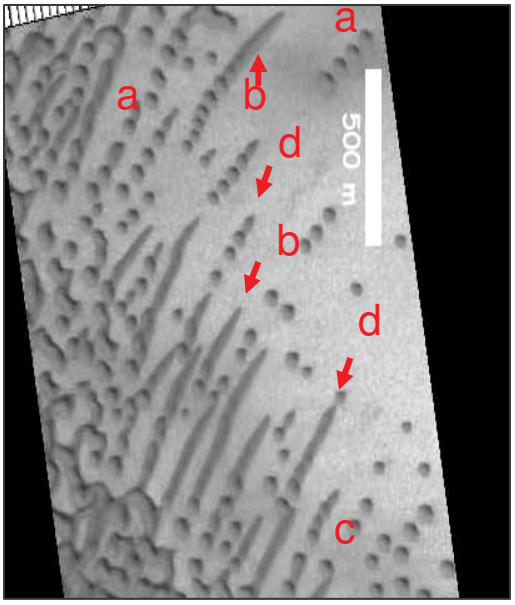

Figure 1: Morphodynamics of dunes in the north polar region of Mars.
a. barchan and dome convoys.
b. linear dune.
c. merging convoy.
MOC image E0200135; 4.85 m/pixel; 272.83°W, 76.11°N

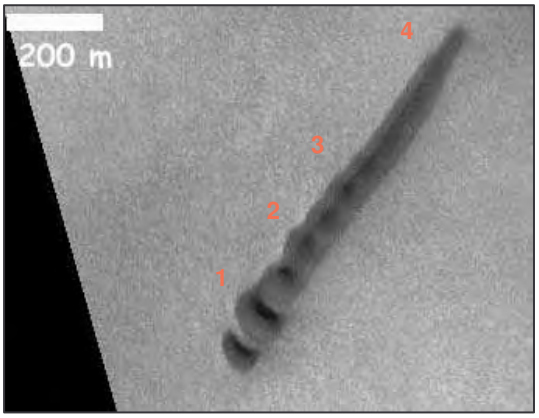

Figure 2: Linear dune in the north polar region of Mars (255.24°W, 78.66°N)
1. Merging barchans by alternate limb extension.
2. beaded linear dune,
3. sinuous crest to linear crest.
4. Linear dune extension.
MOC image M02-02835, 3.22 m/pixel;