CONTROLS ON THE MORPHOLOGY OF YARDANGS L. Kerber[1] [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109 (kerber@jpl.nasa.gov)

Introduction: Yardangs are wind-eroded ridges common in regions of Mars [1] and in the most arid deserts on Earth. Yardangs have also been documented on both Venus [2] and Titan [3]. Throughout the years, studies of yardangs have concentrated on particular field sites, and therefore conclusions relating to the controlling parameters on yardang morphology have been highly divergent.

Observations:

Many parameters affect yardang morphology. The following list describes the major parameters and how they affect terrestrial yardang fleets.

(1) *Deflation vs. Abrasion*. The wind erodes yardangs both through the abrasion of the yardang head as well as deflation of the yardang flanks, and it is clear that the strength of the substrate plays a large role in determining the relative importance of these two processes. For example, at Roger's Dry Lake, where the yardangs are made of lightly indurated aeolian dune sands, Greeley et al. [1975; 4] observed that yardang heads were undercut, suggesting that particles up to the saltation height were responsible for eroding the yardang, followed by mass wasting of the overhangs. In 2015, the author returned to the same yardangs, and found that while the overhang had indeed collapsed, the entire flank of the yardang next to it was also missing, suggesting a large role for deflation (**Figure 1**).

In the Chinese National Yardang Geopark near Dunhuang [5], where the yardangs are formed of lacustrine sediments, yardangs experience deflation through the pluvial formation of thin, clay flakes that are subsequently plucked from the yardang flanks (**Figure 2-3**). In contrast, the harder ignimbrite substrate of the Campo de Piedra Pomez yardangs in Argentina greatly reduces the possibilities for plucking or deflation.

(2) *Ridges vs. Troughs*. Some yardang fleets are defined by a largely flat plane interrupted by wind-sculpted ridges, while other fleets are defined by unshaped remnant topographic highs interrupted by long, straight troughs filled with sand. In the latter case, it is the presence of the troughs which channel the sand and create the illusion of defined ridges from above (**Figure 4**).

(3) *Pre-existing Shapes vs. Wind-formed shapes*. While many yardangs owe their major relief to the wind, others are simply pre-existing knobs and mesas that have been modified by the wind. In some cases, pre-existing fluvial canyons have been accentuated by the wind, leaving yardang-like features between them [6]; (**Figure 5**).

(4) *Isolated vs. Interfering*. Widely space yardangs achieve a more "perfectly streamlined" appearance than closely spaced yardangs, which cause interference in the incoming wind profile.

(5) *Burial vs. Erosion*. The level of current activity of a yardang fleet is partially controlled by the availability of sediment compared to the wind's ability to move it [7].

(6) *Isotropic Substrate vs. Layered Substrate vs. Fractured Substrate*. Isotropic substrates lead to smooth yardang flanks and evenly spaced yardangs. Strings of yardangs can nucleate along substrate fractures, and fractures can speed yardang erosion through mass wasting. Layered substrates can yield flat-topped "layer-cake" yardangs, and differential erosion of the layers can enhance gravity-driven mass wasting. Resistant, dipping beds can control the locations of yardangs as well, as is the case in the Qaidam Basin of China (**Figure 6**)

(7) *Original flank texture vs. Water-Dominated Texture vs. Wind-Dominated Texture*. In many yardangs original lacustrine bedding and/or aeolian cross-bedding can be seen. In others, a patina of water-deposited clay flakes or a carapace of salt-cement is seen (**Figure 2**). In the windiest, driest places, yardang flanks are dominated by aeolian fluting.

(8) *Water erosion vs. Wind Erosion vs. Mass Wasting*. Many terrestrial yardangs flanks are heavily modified by pluvial gullying. Martian and extremely arid terrestrial yardangs are dominated by aeolian faceting. Periodic flooding of inter-yardang troughs can create crusty salt pans that retard further aeolian downcutting. Occasionally, rivers can cut through a fleet of yardangs, undercutting yardang flanks and accelerating mass wasting.

(9) *Constant Winds vs. Changing Winds*. Yardangs need mostly unidirectional winds to form, but bidirectional winds or slightly shifting winds can create stubby, dual-headed yardangs.

References:

[1] Ward, A.W. (1979) *JGR 84*, B14, 8147–8166. [2] Greeley, R. (1992) *JGR 97*, E8, 13319–13345. [3] Radebaugh, J. et al. (2015) *LPSC 46*, Abs. 2746. [4] Ward, A.W., and Greeley, R. (1984) *GSA Bull. 95*, 7, 829–837. [5] Dong, Z. et al. (2012) *Geomorphology 139-140*, 145-154. [6] Perkins, J.P., et al. (2015) *Nature Geoscience 8*, 305-310. [7] Barchyn, T.E. and Hugenholtz, C.H. (2015) GRL 42, 5865–5871.

Fig 1. Evolution of a yardang over 83 years. Note undercutting of foreground yardang in 1975 and missing yardang flank between 1932 and 2015 (red arrows). The interyardang troughs have been filled in by a significant amount of sand since 1975 [4].

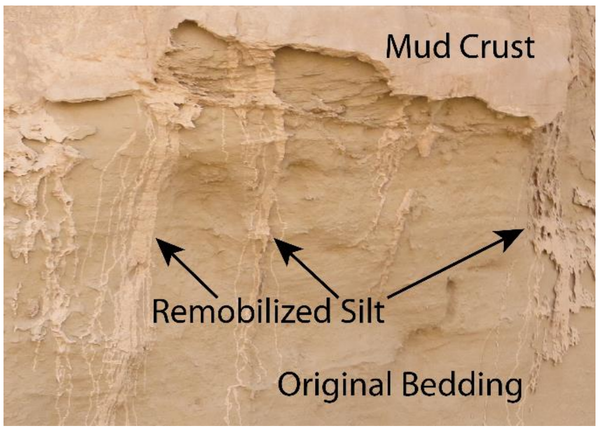

Fig 2. Rain-mobilized clay from higher on the yardang is deposited on the yardang flank. At first, these tendrils are flakey and vulnerable to deflation. If they have a chance to build up, however, they can shield the yardang from further erosion (see mud crust). Kumtagh Desert, China.

Fig 4. The megayardangs of the Lut Desert in Iran grow taller as their interyardang corridors are deepened. The yardangs themselves show little sign of wind erosion.

Acknowledgments:

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Fig 3. Remobilized clay from infrequent rainfall. Lut Desert, Iran.

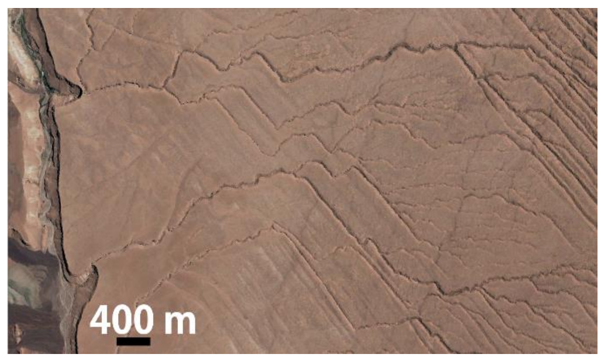

Fig 5. Fluvial canyons in Argentina that have been accentuated by the wind [7]. Image from CNES/Astrium accessed via Google Earth (22.54˚S 68.20˚W).

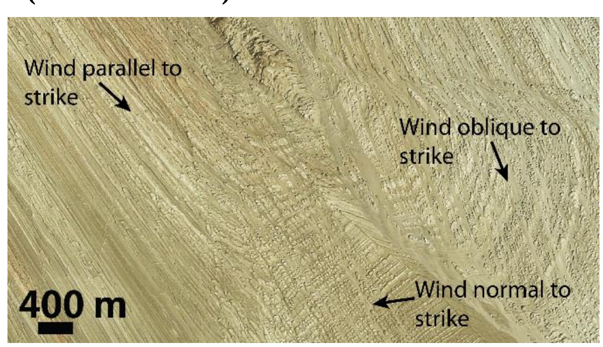

Fig 6. Yardangs in the Qaidam Basin, China, responding to the underlying structure of the substrate. Image from CNES/Spot accessed via Google Earth (38.62˚N 92.84˚E).