YARDANG SHAPES AND MATERIAL PROPERTIES IN TERRESTRIAL IGNIMBRITES APPLIED TO THE MEDUSAE FOSSAE FORMATION, MARS. D. McDougall[1], J. Sevy[1], J. Radebaugh[1], L. Kerber[2], J. Rabinovitch[3], E.H Christiansen[1]. [1]Geological Sciences Department, Brigham Young University, Provo, UT (dmcdoug@byu.edu), [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA. [3]Stevens Institute of Technology, Hoboken, NJ, 07030

Introduction: Yardangs on Earth erode via abrasion and/or deflation in some deserts, although the exact conditions of formation are disputed [1,2,3]. This disagreement complicates the definition and identification of yardangs seen in imagery of other planets, where they are helpful for interpreting the wind patterns and bedrock properties that contribute to their formation. To determine the relationship between these factors and the yardang morphology observed on other planets, we apply a series of thresholds to Digital Terrain Models (DTMs) containing thousands of yardangs in the Campo de Piedra Pomez, Argentina (CPP, Fig. 1a) and the Medusae Fossae Formation, Mars (MFF, Fig. 1b). Combined with in-situ and sample data from the CPP, these results indicate that most of the MFF yardangs are probably most similar to the few largest, most porous CPP yardangs.

Geologic Setting: The MFF was deposited over a 2.1 million km^2 equatorial region of Mars during the Hesperian-Amazonian transition [3,4]. This region is characterized by pervasive friable textures and low densities corresponding to a porosity of 51%, assuming a basaltic composition and grain density of 3.0 g/cm^3) [4]. These properties have led to an inferred ignimbrite lithology for the MFF [3]. The CPP is located in the Puna region of northwest Argentina and was deposited as an ignimbrite eruption over 249 km^2 only 70 ka ago. Measurements of the CPP ignimbrite by the authors revealed (coincidentally) an average porosity of 51%, although it differs by having a rhyo-dacitic composition with lower density. While both formations host active eolian erosion, the MFF landforms are extremely extensive across Mars and have undergone ~3 billion years of climate and wind direction changes, while the CPP has existed under more restricted temporal and spatial conditions.

In December 2018 and 2019, we conducted fieldwork in the CPP. We examined a 5 km^2 lee-to-windward transect of the CPP where we gathered in-situ measurements of relative compressive strength with a Schmidt hammer and obtained 2695 drone images to derive a 3cm resolution DTM. We also collected samples for petrographic analysis, porosimetry, and laboratory strength testing.

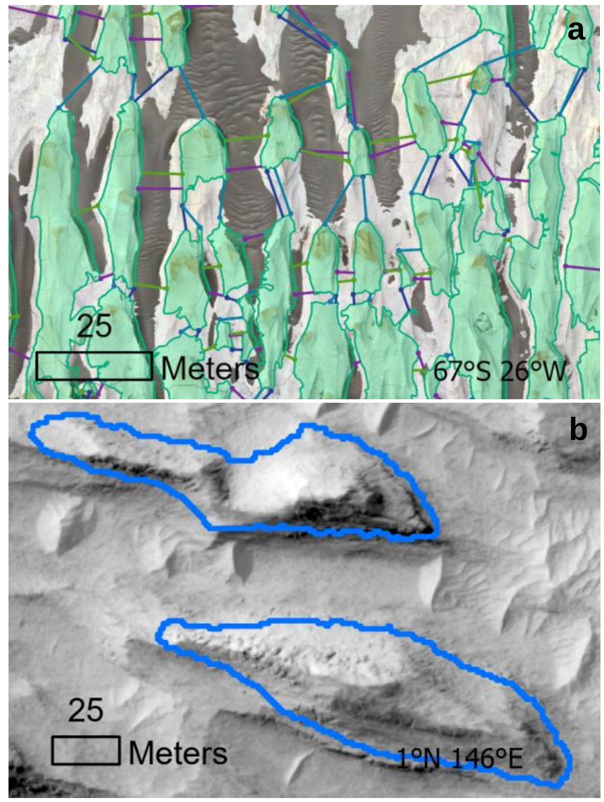

Figure 1. (a) CPP yardangs (highlighted in green) with lines showing automated measurements for their front, back and side spacing. (b) MFF yardangs with identically constructed boundaries.

Methods: Yardangs in our study areas were identified through remote imagery by their steep, convex surfaces, similarly to [5] and [6]. Because slopes necessarily differ between the steep/windward and the shallow/leeward sides of yardangs, and complex yardang fleets can have large networks of convex surfaces, our algorithm starts with a manually chosen threshold for the most convex region around the steepest part of the yardangs and derives a contour approximating the elevation where the surface transitions from convex to concave (Fig. 2).

For yardangs on regional slopes in the CPP DTM, these contours are truncated by topographic saddles to create a bounding polygon for each yardang. A small percentage of these polygons required manual editing due to false positives. For false negatives, a different method will be necessary that dynamically chooses the initial threshold.

For the MFF, we chose a 1m resolution HiRISE DTM made from image PSP_009175_1810. The difference in resolution between the MFF DTM and the 3cm CPP DTM tests the thresholding method. Because of noise in the stereo-derived HiRISE DTM, we use smoothing on the derived curvature image. This greatly improves the final results.

Results: In addition to the conventional metric of aspect ratio (length:width), this dataset allows us to calculate length:width:height for each yardang as well as spacing metrics (front-to-front, front-to-back, and side-to-side) (Fig. 1a). The spacing metrics are enabled by identifying front, back, and side points using the intersections of a bounding box on a convex hull for each yardang.

Due to false positives resulting from intervening sand megaripples, DTM errors, and sloping bedrock, editing the yardang polygons for valid spacing was necessary, especially for features like windward moats and fallen blocks in the CPP, which were less common at the HiRISE scale. Several unique features and terrains were identified in the process of automatically generating the yardang polygons. A few yardangs were associated with formation along fractures in the CPP ignimbrite, and these features were somewhat larger and sheltered the smaller, downwind yardangs. Interactions between yardangs and with other eolian features creates a complicated continuum of terrains that can elongate yardangs into a continuous network where wind may be strongly channelized, as evidenced by deep and narrow interyardang corridors, or shorten them when exposed to multiple wind directions, even creating multiple prows. These features were documented on Mars and Earth, as well as during field campaigns.

The material sampling and spacing metrics allow us to test the assertion from [5,6] that uniform rock strength should create a characteristic side-to-side spacing or width-to spacing ratio. The CPP samples were shown to have a laboratory strength of about 500 Pa, which was validated by uniform Schmidt hammer values (Q=42 +/- 2) and porosities very close to 51%. Preliminary analyses show that spacing is consistent for some regions in the CPP/ MFF where fractures are limited and changing topography enhances wind incision. The largest CPP yardang (Fig.) was shown to be more porous (54%) than average despite vapor phase crystal deposition, but conversely had higher (i.e. strong) Schmidt hammer readings, although laboratory strength was similar to other CPP samples. The unique lithology may affect erosion resistance in a way not described by compressive strength.

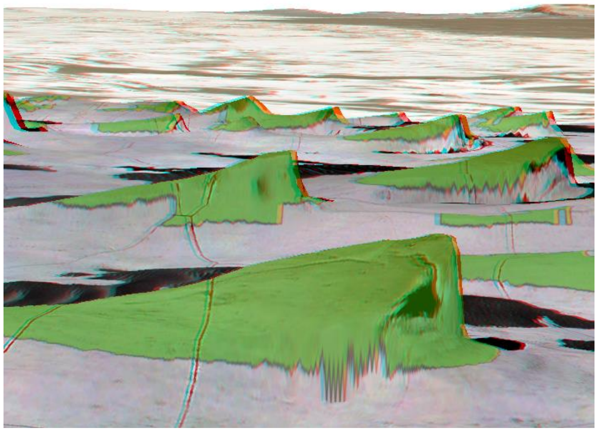

Figure 2. 4 meter tall yardangs in the CPP. The bottom of the region highlighted in green approximates the boundary between the convex topography and the surrounding uncolored concave and flat surfaces. Image constructed by draping yardang shapes and orthophotos over a 3cm resolution DTM. Best viewed with red-blue anaglyph glasses.

Conclusions: As with other studies, this work found that yardang size is generally correlated with hardness. The spacing and size of the large CPP yardangs that are most similar to the ones in the MFF do not reflect the spacing and size of the average yardangs in the CPP. This indicates that the average state of the larger MFF yardangs may be more similar to the local conditions of slope and material properties for the large, crack-controlled CPP yardangs. This initial work with high-resolution DTMs on yardangs opens opportunities for studies using DTMs with other yardang fleets and wind-eroded landscapes. More direct measurements of erosion resistance in yardang materials will help reveal the history of yardangs on Earth and other planets.

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