MORPHOMETRY AND SAMPLING OF TERRESTRIAL YARDANGS TO AID GEOLOGIC MAPPING OF MARTIAN YARDANG REGIONS.

D. McDougall[1], J. Radebaugh[1], L. Kerber[2], J. Sevy[1], J. Rabinovitch[2], 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.

Introduction: Yardangs are streamlined eolian erosional landforms that form in consolidated substrates on rocky planets with atmospheres [1, 2] (Fig. 1). Their occurrence indicates a balance of several factors, including the intensity, direction, and sediment load of winds as well as the yardang material's erosion resistance [3]. Recent observers have noted the apparent trend of increasing yardang size with the hardness of the ignimbrites hosting them at a Mars analog site in the Altiplano-Puna region of Argentina [2]. This work seeks to quantify the relationship between yardang size and material properties in order to develop an additional dataset useful for geologic mapping within yardang regions on Mars.

The 249 km^2 Campo de Piedra Pomez (CPP) unwelded ignimbrite in the arid Puna region of Argentina was deposited at 70 ka and has since eroded into numerous meter-scale mesoyardangs [4]. Elsewhere in the region, kilometer-scale megayardangs have formed in harder, welded ignimbrites. The high altitude, low rainfall, and range of yardang sizes makes this region an ideal analog laboratory for investigating yardang formation in similar areas on Mars, such as in the 2.1 million km^2 Medusae Fossae Formation (MFF), which is likely an ignimbrite deposited in the late Hesperian and early Amazonian [5]. Although very large yardangs are known to exist on Mars, HiRISE imagery shows that the range of yardang sizes overlaps with that in the CPP, especially for the MFF where small-scale textures attest to the friable lithology [5].

Methods: Manual measurement of yardangs in imagery or in-situ is complicated by highly variable morphology, complex shadows, and yardangs having dimensions on the same scale as the imagery spatial resolution. For these reasons we chose to derive a 5 km^2, 3 cm resolution digital terrain model (DTM) from drone imagery collected by the authors in 2019 across a leeward to windward transect of yardangs in the CPP, as well as DTMs of other areas in the region having different sizes of yardangs. For the MFF, we have chosen HiRISE DTM DTEEC_009175_1810_009808_1810_A01 from the northwest part of the MFF with ~1 m resolution and 30 km^2 covered by mega- and meso-yardangs. From these DTMs we derive yardang boundaries composed of elevation contours and topographic saddles identified in association with pixels having highly convex curvature.

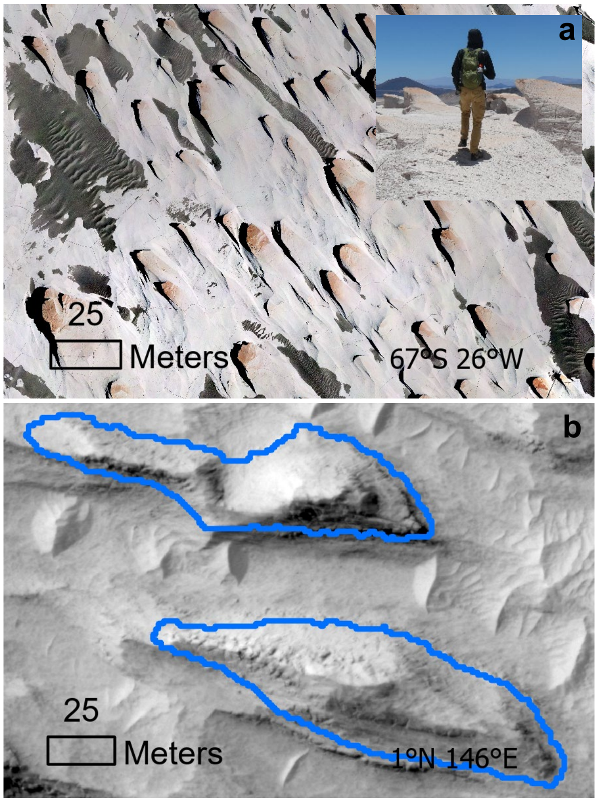

Fig. 1. Automatically delineated mesoyardangs in (a) the Campo de Piedra Pomez, Argentina and (b) the Medusae Fossae Formation, Mars. North is up.

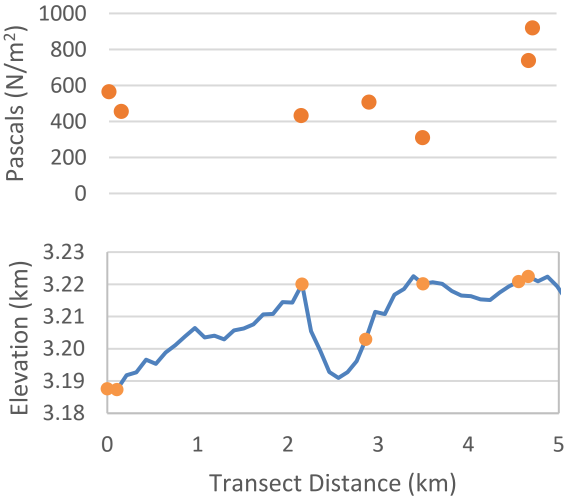

Fig. 2. Compressive strength of CPP yardang samples compared to their elevation and distance from the windward edge of the yardang fleet.

To evaluate the role of material properties in yardang formation, we made in-situ measurements and collected samples along our transect of the CPP and at other yardang localities in the region. In the lab, we processed the samples into cores used for measuring density, porosity, and compressive strength of the ignimbrite. These properties contribute to the material's abrasion resistance, with compressive strength and density serving as direct proxies [6]. Compressive strength should also contribute to the resistance to mass wasting by block collapse which controls yardang height [3], however, the exact relationships between material properties and yardang dimensions are disputed in the literature [2,3].

Results: The mean compressive strength observed for yardangs in the CPP is about 538 Pa (Fig. 2), while in the Rosada it is 1576 Pa. The median aspect ratio (length:width) for both the CPP and MFF yardangs are about 3, while in megayardangs near the CPP such as in the Rosada ignimbrite, the aspect ratio is at least 4. However, the size distributions for each yardang dimension (length, width, height, and area) are more right-skewed in the MFF and Rosada than in the CPP, meaning that there are more similarities in morphology of the largest and smallest yardangs in the MFF and Rosada compared to the those in the CPP. This is also true for qualitative features such as "whaleback" medial ridges (in the Rosada and MFF) as well as reentrant prows, which occur on the windward ends of yardangs in the CPP but not in the other regions (Fig. 1a).

Conclusions: The similarities in detailed morphometric statistics indicate that the MFF yardangs weather most similarly to the terrestrial megayardangs in the Rosada welded ignimbrite. Although a welded ignimbrite would be consistent with the enormous volume of the MFF, the MFF has been shown to have very low density consistent with a porous, unwelded ignimbrite [7]. For this reason, it is likely that the MFF lithology is more similar to the largest mesoyardangs in the CPP, which have unusually high porosity (~50%) and lack reentrant prows. This may also explain the similarity in aspect ratios between the MFF and CPP.

Using these techniques to compare other yardang regions on Earth and Mars will aid the mapping of yardangs and lithological units in combination with other products depicting material properties, such as radar and nighttime infrared imagery.

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