

YARDANG SHAPES REVEAL SUBSTRATE LITHOLOGY AND MATERIAL PROPERTIES IN THE ARGENTINIAN PUNA. D. McDougall¹, J. Radebaugh¹, L. Kerber², J. Sevy¹, J. Rabinovitch², E.H Christiansen¹. ¹Geological Sciences Department, Brigham Young University, Provo, UT (dmcdoug@byu.edu), ²Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction: Yardangs are eolian erosional landforms with regular spacing and long, streamlined profiles [1, 2] (Fig. 1). While found primarily in deserts on Earth, they are also prominent on Mars and other planetary bodies [1, 2]. Yardang dimensions are thought to vary with the intensity, direction, and sediment load of the wind [1], and initial work into the effects of substrate properties on yardang shape reveals that larger yardangs form in more indurated materials [2]. However, detailed relationships between yardang shape, wind, and substrate properties have not been established. This study seeks to quantify these associations.

Field Area: The 70 ka Campo de Piedra Pomez (CPP) ignimbrite in the hyperarid Puna region of Argentina (Fig. 2) hosts spectacular yardangs, making it an ideal analog to yardangs in the martian Medusae Fossae Formation [1-4]. The small size of the CPP “mesoyardangs” (1-20 m long and up to 10 m tall) contrasts greatly with the larger “megayardangs” (tens of meters tall and hundreds of meters long) in other ignimbrites found throughout the region (Fig. 1). During December 2018 and 2019, we visited several localities in the CPP to evaluate their shapes and sizes and to assess material properties (Fig. 2).

Yardang Aspect Ratios: Yardang aspect ratios are the measurement of the length to width (Fig. 3), used commonly in yardang studies from early on [1, 2, 5]. Those with a lower aspect ratio are generally mesoyardangs while those with a larger one are megayardangs [5], though we seek to quantify that relationship and to relate it to material properties. In addition, we seek to know the variation in aspect ratio in yardangs across Mars, and to understand how that may be related to material properties. Initial evaluation of yardang morphology was conducted using the approximately 30 cm resolution color imagery in ArcGIS Pro. Yardangs shapes were outlined to compute their length, width, and aspect ratios (length:width). In each locality, yardangs with a median aspect ratio were targeted for in-situ measurements.

White Yardangs (cppi/w, lcpw): The largest area of the CPP ignimbrite is a zone of porous white material. Pumice clasts are eroded into negative relief against the friable matrix. In contrast, lithic clasts in this zone are more resistant than the matrix such that they protrude in finger-like “dedos” pointing into the dominant wind direction for that point on the yardang [6, 7].

Orange Yardangs (cpp*o, lcpo): The white zone is mantled in many areas by orange material [8]. Although

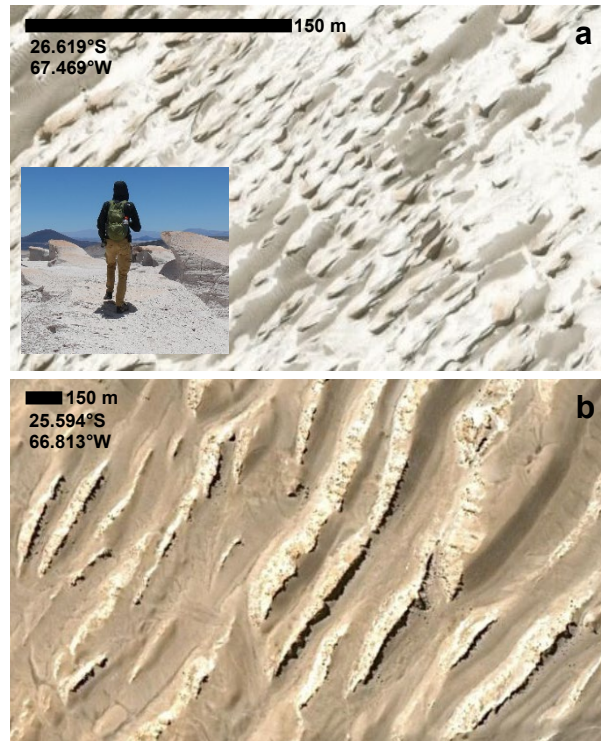


Fig. 1. (a) Mesoyardangs in the Campo de Piedra Pomez and (b) megayardangs in the Cerro Galan Ignimbrite. North to the right. Sources: Google Earth

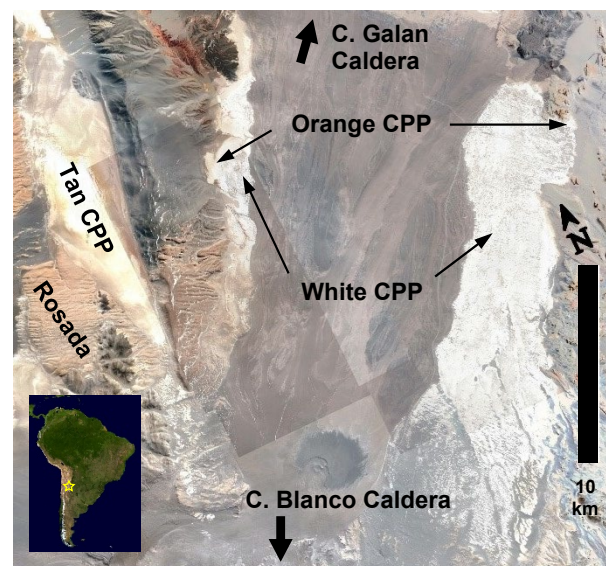


Fig. 2. Map of yardang-bearing ignimbrites in the southern Puna. Cerro Galan and Cerro Blanco are outside the map area in the directions indicated by thick arrows. Sources: Google Earth, Wikimedia

slight compression and sintering of ash is noted in thin section, glassy pumice clasts are intact and resistant.

Tan Yardangs (tan): Yardangs also occur in an adjacent valley where the CPP ignimbrite occurs as a tan-colored facies. Here, the pumice clasts form dedos due to being more resistant than the ash matrix, in contrast to the opposite condition in the white yardangs.

Rosada Yardangs (rosada): The 6.3 Ma Rosada ignimbrite [3] is the most indurated yardang-forming material we studied. Intense welding is evidenced by flat pumice fiamme and alignment of phyllosilicates, indicating high depositional temperatures.

Cerro Galan Yardangs (galan): 100 km north of the CPP, the large volume and low porosity of the Cerro Galan approaches that of the Rosada. The Cerro Galan ignimbrite contains abundant phenocrysts and shards but no fiamme [4].

Yardang Hardness: The compressive strength (a proxy for erosion resistance [9]) of yardang materials was measured using a Proceq Silverschmidt rebound hammer. The measured results varied greatly, from 14 MPa for the tan yardangs to 56 MPa for the Rosada ignimbrite. Yardangs in the white and orange ignimbrite zones had values from 25-30 MPa while the Cerro Galan ignimbrite was 39 MPa. When plotted against the median aspect ratio of yardangs in each area, a rough positive correlation is evident (Fig. 4).

The aspect ratio also correlates with other yardang material properties. The CPP ignimbrite has been previously characterized as having 50% porosity and a density of 1.25 g/cm³ while welded ignimbrites have lower porosity and higher densities, such as 15% and 2.19 g/cm³ for the Rosada [10]. Hence, higher porosity and lower density are associated with lower strengths and shorter aspect ratios.

Discussion: Even with the limited number of characterized areas, the trend in Fig. 4 is useful for placing each yardang area on a continuum. High median aspect ratios is typical for megayardangs. This could be related to unusual stratigraphy in the tan yardangs and possibly to fluvial activity in the Galan yardangs. High aspect ratio yardangs positioned on the upwind margin of the CPP field are likely protected from minor winds by yardangs in the interior of the field, which have lower aspect ratios due to erosion from multiple wind directions [10]. The configuration of strata within a yardang is also seen to have an effect on yardang morphology. Some large yardangs (e.g. in the tan area) are underlain by a soft, thick layer of large pumice clasts which is preferentially eroded by the saltation load in winds from the downslope direction but protected by harder surfaces facing winds from upslope directions.

These findings can be used to infer the properties of extraterrestrial yardangs with similar morphologies

after applying scaling laws for differences in eolian abrasive forces. Yardangs in volcanic tuffs of the Medusae Fossae Formation on Mars have been proposed as human landing sites due to their potential for in-situ resource utilization as habitations and building materials [11]. This work helps with targeting specific yardang areas for these purposes.

Conclusions: Yardang morphology is affected by the hardness and lithology of a substrate according to its abrasion resistance, among other factors. This establishes a firm basis for further studies of yardang morphologies and substrate properties.

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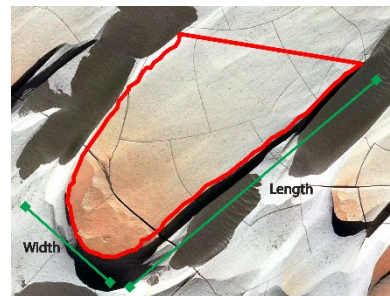


Fig. 3. Automatically generated yardang outline in red with yardang dimensions in green. Aspect ratio (length/width) is about 2.5 here.

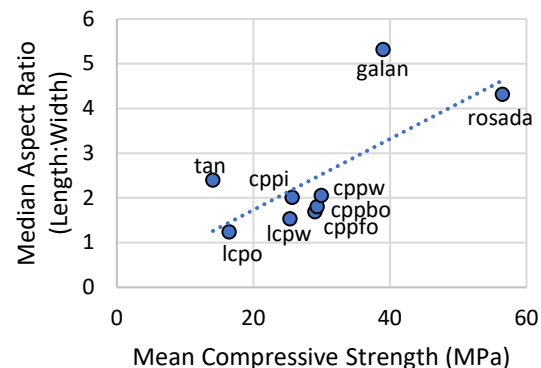


Fig. 4. Aspect ratio plotted against compressive strength for various yardang areas. Linear trendline is dotted in blue. See text for data label descriptions.