LITHOLOGIC CONTROLS ON YARDANG MORPHOLOGY FROM FIELD OBSERVATIONS OF THE CERRO BLANCO IGNIMBRITES OF ARGENTINA. Dylan McDougall[1], Jani Radebaugh[1], Laura Kerber[2], Eric H Christiansen[1], Jonathon Sevy[1], Jason Rabinovitch[2]. [1]Department of Geological Sciences, Brigham Young University, Provo, UT (dmcdoug@byu.edu), [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction: Yardangs are streamlined eolian erosional features found on Earth [1], Mars [2-4], Titan [5], and perhaps Venus [6]. When viewed from above, they are regularly spaced and much longer than they are wide (Fig. 1a), while in profile they have boat-shaped cross sections with prominent, wind-facing prows (Fig. 1b). The yardangs in the ignimbrites of the Puna plateau of Argentina were described by de Silva et al. (2010) with regard to how lithologic variations affect the yardang positions, orientations, and physical dimensions [3]. In this work, we aim to investigate the lithologic variations in ignimbrite from the Cerro Blanco caldera, the material for the Campo de Piedra Pomez (CPP) and related deposits [3], in more detail so as to separate their influence on yardang morphology from the influence of regional aerodynamic forces such as flow separation and erosion by sand suspended in vortices [7].

Background: With more than 3000 meters of elevation, the South American Puna is one of the largest and driest plateaus in the world, owing its aridity to the rain shadow of the Andes to the west. The Cerro Blanco caldera in the southern Puna last erupted about 70 ka, depositing four lobes of ignimbrite to the south, northwest, north, and northeast [8] (Fig. 2). Yardangs are formed in some areas of these units with orientations corresponding to the regional NW-SE wind pattern. The northeastern ignimbrite lobe includes the CPP yardangs. These terrestrial yardangs make exceptional analogs for martian features due to the Puna's arid conditions and because they consist of variably indurated volcaniclastic material [2]. The CPP ignimbrites demonstrate low induration and lack any evidence of fluvial alteration. This provides unique controls on the formation of yardangs in such units, which have been proposed to bear lithologic similarities to the yarding-bearing Medusae Fossae Formation on Mars [4].

Field Observations: During a December 2018 field investigation, we examined yardangs in the Cerro Blanco ignimbrites in the CPP area and in the region to the northwest. The Cerro Blanco ignimbrites exhibit wide variations in ash content, phenocryst abundance and types of lithic fragments, especially when comparing CPP to the much less indurated lithologies in the regions north and northwest of the Cerro Blanco caldera (Fig. 2). The CPP ignimbrite contains a matrix of bright white ash with quartz, feldspar, and biotite phenocrysts and plentiful, hard lithic (Fig. 3a). The northern ignimbrite lobe includes several exposures of tan ignimbrite containing few phenocrysts and forming medium-sized,

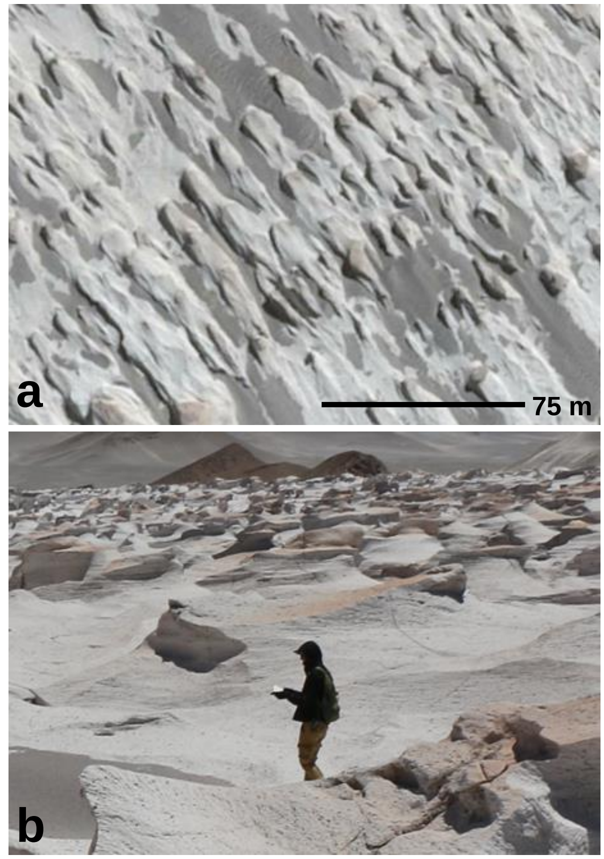

Fig. 1. (a) Map view of yardangs in the Campos de Piedras Pomez. North up. Source: Google Earth
(b) Side view of the same yardangs.

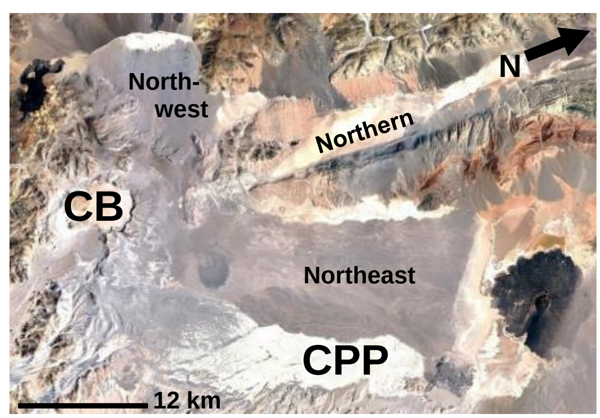

Fig. 2. Cerro Blanco caldera (CB, blue) and associated yardang-bearing ignimbrites (pink), including Los Campos de Piedras Pomez (CPP). The northwest and northeast ignimbrite lobes are mostly covered by dark grey gravels. Southern ignimbrite lobe is not shown here. Source: Landsat/ Google Earth

tan yardangs. These latter ignimbrites were soft enough that the pumice clasts they contained were eroded into positive relief relative to the surrounding and less indurated ash matrix (Fig. 3b).

There are layers in CPP with large pumice clasts. Because the pumice is less indurated than the surrounding matrix, they erode out of the matrix and leave behind gaps that are filled with sand and gravel when at ground level. When the stratigraphic position of the pumice layer is below the more indurated layers, this increases the erodability of yardangs at their base [3].

Alteration: Fumaroles were observed in only a few yardangs, especially near the windward front of the CPP fleet, as in [3]. This may imply that only these forward yardangs are initiated by flow separation around indurated fumarole deposits and that yardangs in the interior of the fleet are most affected by the airflow from the yardangs in front of them.

Cooling joints with individual widths from meters (visible in imagery) to centimeters occur in swarms throughout the CPP. Some yardang arrays are within tens of meters of large joints are observed to have larger, less streamlined shapes (Fig. 4a). This morphological distinction is attributed to induration by devitrification and deposition of vapor-phase alteration products along the pervasive joints in these areas [3]. The orientations of some of these yardangs vary from the regional wind direction, making them analogs of "bidirectional" yardangs in the Medusae Fossae Formation despite the lack of joint control in the Medusae Fossae (Fig. 4b) [4].

Orange weathering was observed on the topmost, case-hardened surfaces of most yardangs and often coincided with fumarolic textures, which are much rarer. Where they did occur, fumaroles were often associated with bicolored banding along fractures where gases had escaped [3]. It is not clear whether this is universally related to the weathered surfaces on most yardangs or with the uniform color variations in some areas of ignimbrites, especially at the rear (eastern) side of CPP. These variations are from orange to tan, in stark contrast to the white ash and ignimbrites but not the pumice clasts within them, which are also orange to tan.

Conclusions: In the CPP area, yardang morphology is partially controlled by substrate hardness. Variations in hardness can come from gas release alteration, primary differences in incorporated pumice sizes, and differences in matrix hardness [3]. Future work will focus on systematically investigating the effects of matrix hardness on yardang morphology by using the contrast between the CPP and northern yardangs fleets.

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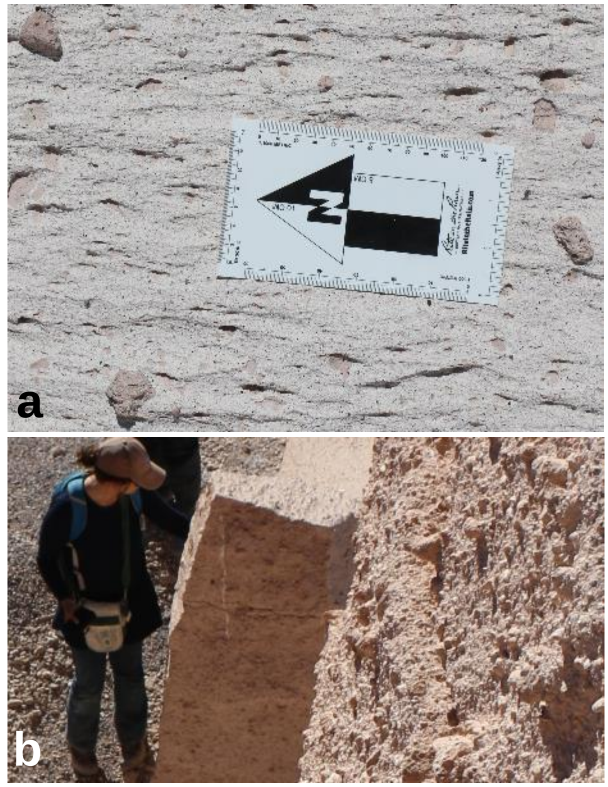

Fig 3. (a) Ignimbrite texture in CPP. Arrow length is 10 cm. (b) Ignimbrites in westernmost yardang fleet. Geologist in background for scale.

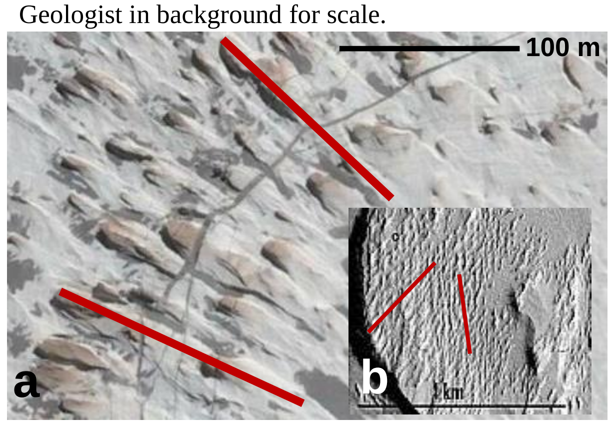

Fig 4. (a) Yardangs in CPP arrayed along joints (gray lines). The local induration causes their variable orientations (red). Source: Google Earth (b) Bidirectional yardangs on Mars. Source: MGS MOC in [4].

[8] Báez, Walter, et al. (2015) *Revista mexicana de ciencias geológicas* 32.1 29-49.

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