# FIELD OBSERVATIONS OF YARDANGS IN THE ARGENTINE PUNA: WHAT DEDOS AND CAP SLOPES REVEAL

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## Introduction:

Yardangs are wind-carved linear ridges that are found selectively on Earth and extensively on Mars and other planets [1-4]. The history of the morphologic development of yardangs is not well known, but is thought to depend on the action of wind on the surface and the material properties of the substrate being acted upon [5-8]. In the Puna high plateau of Argentina there are ignimbrite deposits, many of which have been eroded into yardang fields commonly called fleets. Yardangs fleets are composed of roughly tear-drop shaped, evenly-spaced ridges with noses that to face into the dominate wind, that together resemble a fleet of boats sailing. A prominent fleet, known as Campo de la Piedra Pomez (CCP), was studied during the December 2018 and 2019 field seasons to more fully understand their morphology and formation [6-10].


Field and aerial images of the yardangs of the Puna. The spacing of yardangs is repetitive and even both between the yardangs as seen in image B, as well as from bow to stern as seen in image A. Image C is an aerial view.

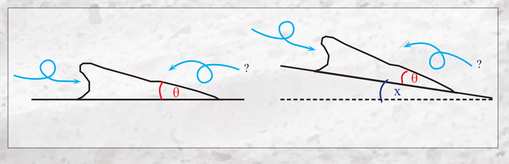
## Conclusions:

We found that the yardangs had increasing numbers of forward dedos toward the front of the fleet, and increasing numbers and lengths of reverse dedos toward the back of the fleet. This indicates a second wind from an opposing direction, rather than wind separation and recirculation. Rose diagrams of dedos show that this opposing wind is coming from a west/-southwest direction, rather than a complete 180° southeast.

Left: Image showing the back of a yardang deflated by an oblique reverse wind (black arrow), forward wind is coming straight out of the page.

## Future Work:

Although the normalized dip of ~10° of the top of yardangs suggests an equilibrium morphology, it is not conclusive what factors could be playing a role in shaping the tops of these yardangs.




Future work will focus on determining what factors play a role in forming this steady state equilibrium angle, and the effects if any of the reverse wind.

## Methods and Results:

**Figure 1.** Dedos on yardangs. A hard lithic inclusion protects the soft ignimbrite from erosion, and causing a finger like protrusion from the yardang pointing toward the direction of erosion like a finger (or "dedo" in Spanish). Using dedo length as a proxy for wind direction and erosive power, dedos on 26 yardangs were measured along a 5.3 km transect (figure 7 for map) for average length of forward and reverse dedos. Forward dedos pointing into the known wind direction, and reverse dedos pointing > 90° from the normal wind direction. Detailed measurements of dedos were measured on 4 yardangs in spatial detail as seen below in figure 2. Scale: 15 cm ruler.

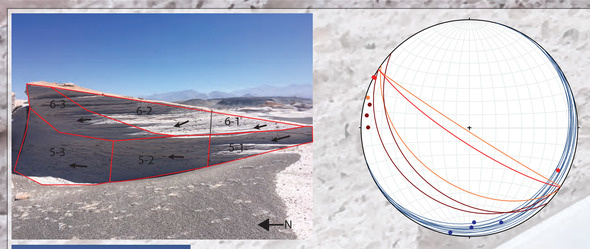




**Figure 2.** Annotated image of 1 of 4 yardangs whose dedos were measured in detail. This yardang was at the front of the CPP fleet (location marked 1 on figures 4 & 7). Facets outlined in red and blue, dedo direction shown by arrows (pointing toward the wind). The spatial direction of dedos as well as the strike and dip of the facet (numbered 6-2, ext) were recorded using the app Clino, by Petroleum experts. The results are graphed in the stereonet above, facets 6-1,2 and 3 are shown in burgundy, orange and red. Facets 4-1 and 2 are shown in blue.

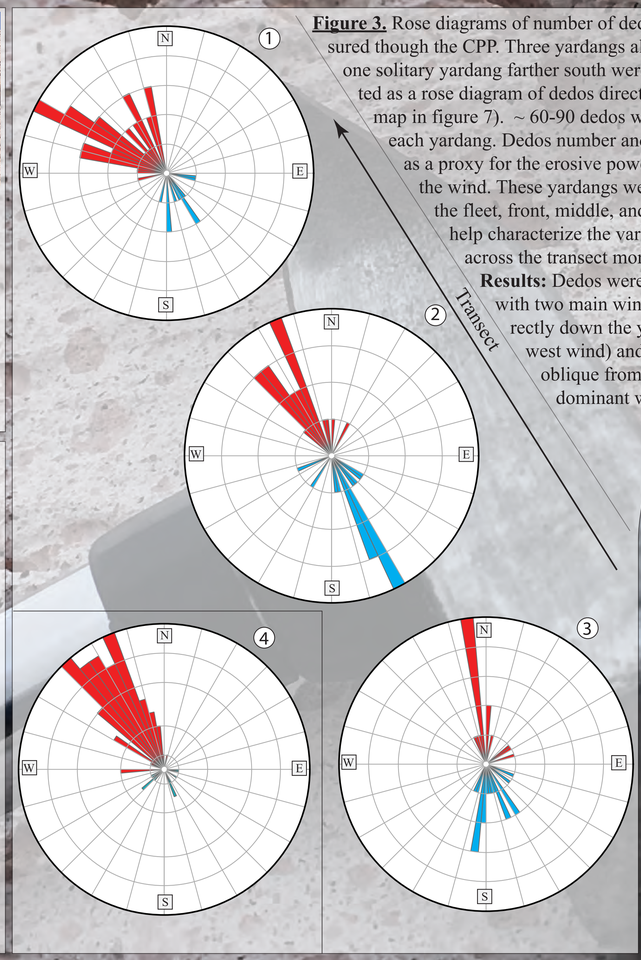
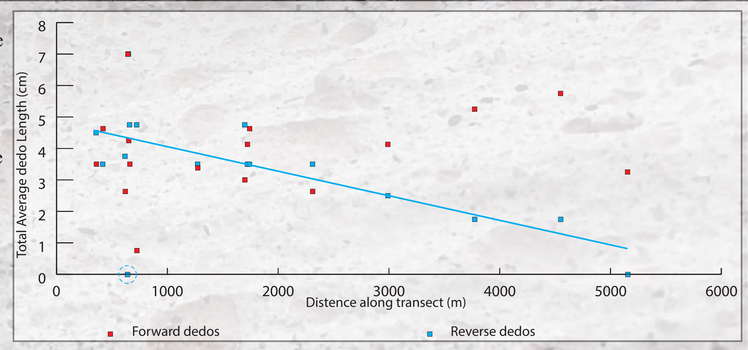



**Figure 3.** Rose diagrams of number of dedos on yardangs measured though the CPP. Three yardangs along the transect and one solitary yardang farther south were measured and plotted as a rose diagram of dedos direction (labeled 1-4 on map in figure 7). ~ 60-90 dedos were measured on each yardang. Dedos number and length being used as a proxy for the erosive power and direction of the wind. These yardangs were selected leading the fleet, front, middle, and back of the fleet to help characterize the variations in the winds across the transect more accurately.

**Results:** Dedos were dominantly aligned with two main wind directions, one directly down the yardang field (Northwest wind) and the other slightly oblique from the dominant wind.

Figure 5. Graph of dedo length across the transect. Although figure 4 shows this more intuitively, this graph shows the average Forward and Reverse dedo length vs distance along the transect. Although there is very low correlation for the Forward dedos, excluding one outlier (circled) there is a correlation in the Reverse dedos of $R^2 = 0.72$, indicating that there is more powerful flow at the back of the fleet. This supports the hypothesis of there being two winds present in the CPP Fleet.



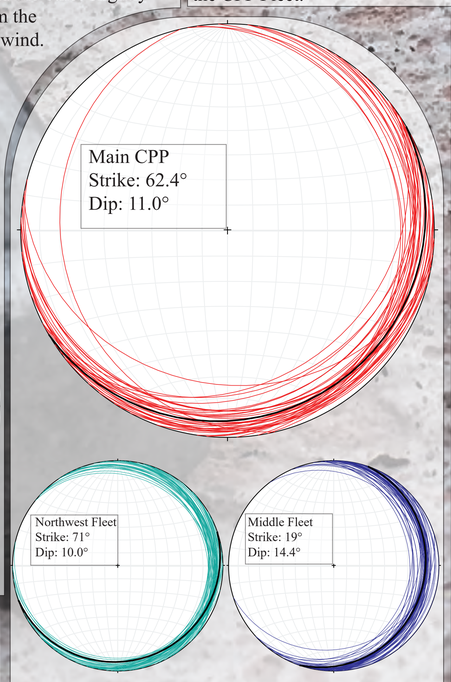




**Figure 6.** Stereographs of strike and dip of the top of yardangs. 137 strike and dip measurements were taken on the tops of yardangs through 3 yardang fleets (figure 7). The average slope of the ground around the yardangs was also measured using DEMs and the data was normalized to the dip of the ground in order to better compare the tops of the yardangs with the angle of incoming wind.

**Result:** The dip of the yardang prow through the CPP and two other nearby yardang fleets was measured to be consistently ~9-13° leeward. The yardang tops had normalized average dips of 10-14° dips depending on the fleet. This consistency suggests an equilibrium morphology, but it is inconclusive of what factors could cause this slope.

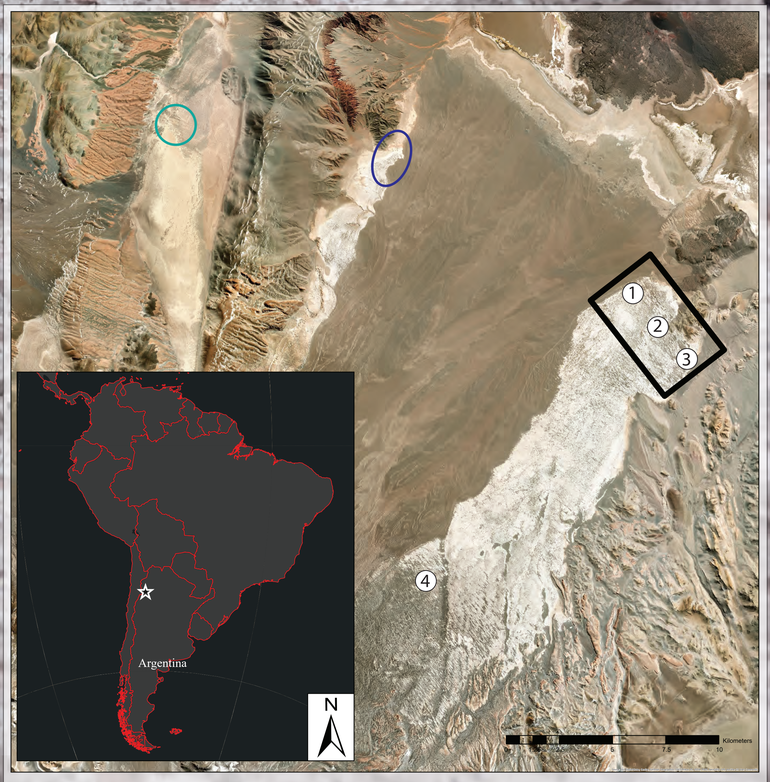



**Figure 7.** Map of Argentina field location. A 5.3 km transect of the Main CPP was chosen to walk through in the northern end of the fleet (inside black box, figure 4&5). Northwest and Middle fleets that were visited are circled in teal and blue respectively (Figure 6). Numbers 1-4 show location of yardangs measured in spatial detail (figures 2&3).

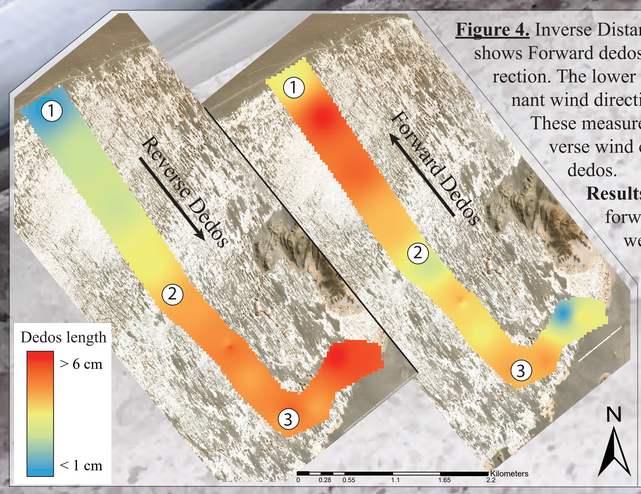



**Figure 4.** Inverse Distance Weighted (IDW) heat map showing length of dedos. The upper right shows Forward dedos, or the dedos that are pointing within 90º of the assumed dominant wind direction. The lower left shows Reverse dedos, or dedos greater that 90º from the assumed dominant wind direction. The dedos were measured from 26 yardangs along the transect (figure 1) These measurements were interpolated in ArcGIS Pro to show the relative forward and reverse wind erosive power though the transect with warmer colors indicating longer dedos.

**Results:** Although dedos stay more or less the same throughout the transect in the forward direction the reverse dedos increase significantly toward the back (southwest) of the fleet. This is likely because there is a secondary wind coming from the back of the fleet causing reverse dedos rather than flow separation.

The image on the right shows forward (top of image) and reverse (bottom of image) dedos on a block fallen off a yardang. Gloved hand for scale.

**Sources:**

[1] Greeley and Iverson (1985). [2] Kerber et al. (2011) Icarus 216, 212-220. [3] Paillou et al. (2016) Icarus 270 211-221. [4] Northrup (2018) BYU MS Thesis. [5] de Silva S. et al. (2010) PSS 58, 459-471. [6] Kerber et al., (2020) LPSC Submitted Abstract; [7] Rabinovitch et al. (2020) this meeting. [8] McDougall et al. (2020) this meeting. [9] Rabinovitch et al., (2019) LPSC Abstract #2250; [10] McDougall et al., (2019) LPSC Abstract #3202.