

THE ORIENTATION OF THE BLADED TERRAIN FEATURE IN TARTURUS DORSA, PLUTO AND POSSIBLE REORIENTATION OF PLUTO N. L. Wagner¹, J. P. Kay², and P. M. Schenk², ¹Colorado School of Mines, 1500 Illinois St, Golden, CO, 80401(nlwagner@mines.edu), ²Lunar and Planetary Institute, 3600 Bay Area Blvd, Houston, TX, 77058

Introduction: During the New Horizons flyby of Pluto in 2015, numerous interesting and puzzling features were observed on the dwarf planet. One such feature called bladed terrain is located in the Tarturus Dorsa region of Pluto covering roughly 200,000 km^2 . It extends from 10°S to 40°N in latitude and is considered an uplands area, with elevations around 3 to 4 kilometers above the mean elevation of Pluto [1]. With little to no cratering observed the age of this feature is believed to be on the order of tens of millions of years [2]. The bladed terrain sits on a plateau with a surface consisting of individual ridges, or blades, which are a few hundred meters in height and stretch anywhere from 2 to 14 kilometers in length [1]. Through spectroscopy it is likely that these blades are comprised of methane (CH₄) ice, and it is argued that they are formed through sublimation in a nature similar to penitentes on Earth, where they follow the arc of the sun and their trend is E-W [2,3].

Penitentes form on Earth at high altitudes and low latitudes similar to where the bladed terrain occurs on Pluto. Some regions of the snow melt/sublimate faster than others, creating divots in the snow. These divots then melt faster due to sunlight reflecting off the sides, creating a positive feedback. As the divot becomes deeper the sunlight reflects and bounces off the side of the divot, eventually creating the penitentes observed [3]. On Earth penitentes only rise a few meters above the ground and have an annual life cycle.

Penitentes on Pluto may form in a similar manner as they do on Earth with a preferred orientation. Based on how penitentes form on Earth and Pluto's orbital parameters we expect them to form generally northeast/east to southwest/west [2]. Like other outer solar system icy bodies Pluto is hypothesized to hold an internal ocean of water [4]. Any evidence that Pluto has become re-oriented would help support this theory. Given the fact that the blades form in a preferred orientation any deviation from that would help provide insight into the degree to which Pluto may have been reoriented. There is possible evidence of reorientation from the large fractures around Sputnik Planitia that have been suggested to be caused from reorientation, but this work could place further constraints on the timing of that reorientation given the youngish age of the penitentes [4,5].

Therefore, we mapped the orientation of the bladed terrain in order to determine if this is the preferred formation or if reorientation might have occurred. The average elevation, average longitude, average latitude, and length of each individual blade was also calculated

using respective functions in ArcGIS in an attempt to determine if the blades indicated correlations between those parameters. If reorientation is possible, next steps will include using the Python program SatStressGUI to estimate the direction and magnitude of the reorientation. We also looked for any defining characteristics that may help determine how and why these features form.

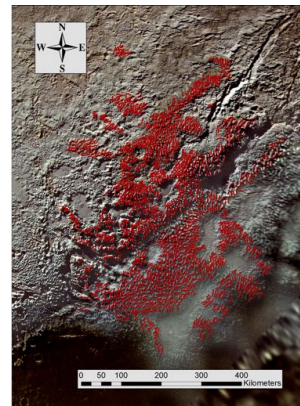


Figure 1: Total extent of the blades in Tarturus Dorsa. 2382 blades in total drawn in red.

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Procedure: We used ArcMap 10.3.1 and a global basemap of Pluto with a 300m/pixel resolution. The blades were traced as polylines along their highest extent using color, elevation, slope, and stereo data. The elevation data has a resolution of 315m/pixel. Sharp changes in the stereo data from light to dark were used to resolve a majority of the blades with color and elevation used to

confine them to certain areas and elevations. Around the terminator in the Southeast region of the blades the elevation and slope data helped to resolve the blades. Once the blades were mapped the length of each one was calculated using one of ArcMaps built in functions for finding the length of a polyline. The orientations were found by calculation through a Python function. Orientations from 0° to 360° were generated based on which direction the line started and ended. 180 was subtracted for each measurement that was over 180° to negate this preference for which direction the line was drawn. Using two more built in functions in ArcMaps, the X and Y coordinates of the midpoint of the blade were calculated.

Results: In total we mapped 2382 individual blades (Figure 1). The blades range in length from 2 to 20 kilometers with an average length of 8 kilometers. There was a general trend of northeast to southwest or around 35° to 45° from North taken from figure 2. A majority of the blades are within 15 degrees of this preferred orientation. They range in latitude from 10°S to 40°N and in longitude from 215° to 240°. There appears to be no indication of multiple sequences of these features and detailed analysis does not show much, if any, degra-

dation or variation in the morphology of these features.

Discussion: In determining the preferred orientation of the blades we looked at as many of the available characteristics as possible. Specifically, we looked at how the orientation of the blades changed as a function of latitude, longitude, elevation, and length. We also looked at how these other factors correlated with each other, however no significant correlation was detected. We have an example below in figure 3 where we attempted to correlate the orientation with the blades latitude.

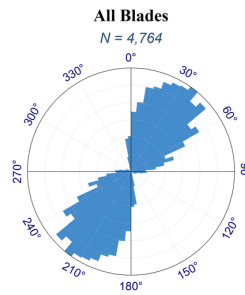


Figure 2: Rose diagram of all the blades, plotted with reverse azimuths for symmetry.. Binned at 5° with 0° as north.

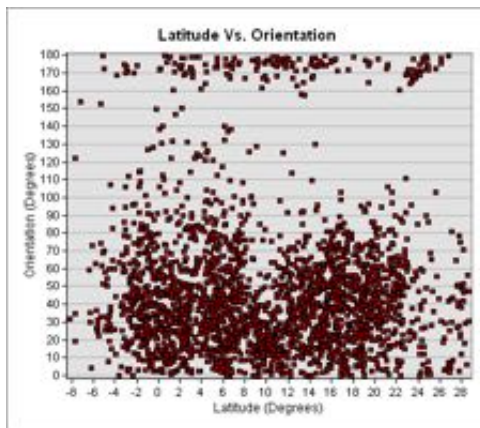


Figure 3: Orientation of the plots plotted as a function of latitude. Blades around 180° are in the same direction as those at 0° except taking magnitude into effect.

We also looked at the morphological shape of the penitentes. Using elevation data, we found the shape of them to be almost symmetric across one wavelength, tending to lean towards the west slightly. Four elevation profiles are and plotted in figure 4. We confirmed the average height of the blades to be around 400 to 500 meters. However, we noticed significant variance in the sizes of the blades, the smallest of them being about 100 meters in height to just over a kilometer. This could be due to the initial parabolic shape of the blades; as more sublimation occurs, the blades become distinct from each other and can be interpreted as separate blades. This variation could also arise from the elevation profiles being relatively near each other along the length of the blades. This causes the same blade showing up in both the red and blue profile and the green and mahogany profile but at different heights. More analysis should be conducted

on the variation of the symmetries of the blades and if there is any correlation between elevation, length, location, or orientation.

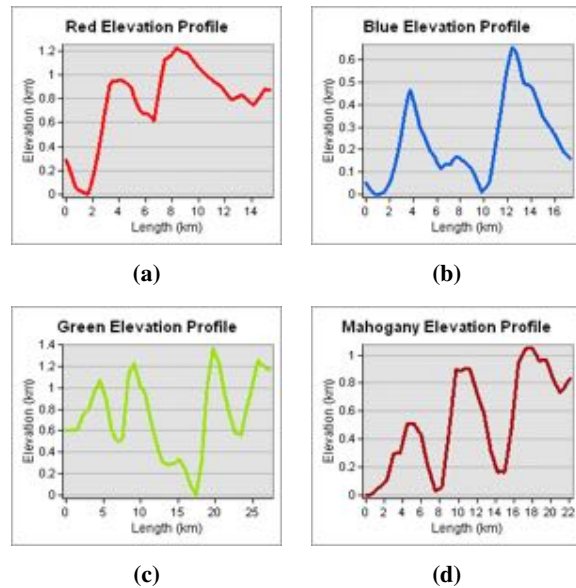


Figure 4: Elevation profiles of the blades.

Conclusion: We did not observe any statistically significant change in the orientation of the penitentes with respect to any observational parameter. Therefore we think that it is unlikely that Pluto has reoriented significantly in the past tens of millions of years. We also did not find any correlations between elevation, orientation, and latitude that would lead us to suggest that reorientation occurred while these features were forming. This study does not preclude that Pluto reoriented, simply that it did not happen while these features were forming. Further work should include deeper analysis into the optimal formation periods of penitentes in Pluto's orbit and how the expected blade morphology changes over tens of millions of years.

References: [1] Jeffrey M. Moore, et al. Bladed Terrain on Pluto: Possible origins and evolution. *Icarus*, 300:129 – 144, 2018. ISSN 0019-1035. [2] John E. Moores, et al. Penitentes as the origin of the bladed terrain of Tartarus Dorsa on Pluto. *Nature*, 541:188, 2017. [3] L. MacLagan Cathles, et al. Intra-surface radiative transfer limits the geographic extent of snow penitents on horizontal snowfields. *Journal of Glaciology*, 60(219):147154, 2014. [4] F. Nimmo, et al. Reorientation of Sputnik Planitia implies a subsurface ocean on Pluto. *Nature*, 540:94, 2016. [5] James T. Keane, et al. Reorientation and faulting of Pluto due to volatile loading within Sputnik Planitia. *Nature*, 540(7631):90–93, 2016. ISSN 1476-4687.