USING WIDTH, SPACING, AND SINUOSITY OF TERRESTRIAL YARDANGS AND DUNES TO CLASSIFY RADAR BRIGHT FEATURES IN TITAN'S NORTHERN MIDLATITUDES. D. Northrup[1], J. Radebaugh[1], E.H. Christiansen[1], [1]Brigham Young University, S-389 ESC, Provo, UT USA 84602,. northrup.dustin@gmail.com.

Introduction: Relatively straight, elongate ridges that form as wind erodes sediment and rock are known as yardangs. These can be found in many deserts on Earth [1], Mars [2,3,4], and perhaps Venus [5] and Titan [6]. They generally form in soft sediments such as lakebed clays [7] and in volcanic ash [8], but can form in resistant layers [9] or crystalline basement rock. Terrestrial yardangs typically form in arid regions that lack vegetation, and have a persistent, unidirectional wind, oriented along the long axes [1].

Methods: Using images acquired from ESRI World Imagery which were taken using IKONOS, with image resolution ~1 m [10], we measured the width, spacing, sinuosity, and the area between the crest line and the straight length of yardangs in China, Argentina, and the radar bright features and dunes in the northern midlatitudes of Titan; in order to understand yardang morphologies (Fig. 1). These Earth analogs may further aid in the understanding the origin of these features on Titan and their material properties.

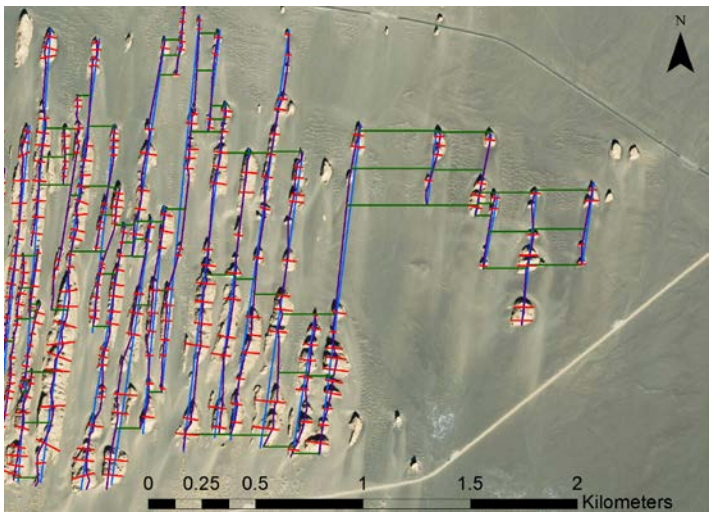

Fig 1. Yardangs found in western China. The dark blue line is the crest length, the lighter blue line is the straight length. The red lines denote the width measurements, and the green is the spacing.

Western China Yardangs: Yardangs in the Dunhuang Yardang field of western China (Fig. 1) formed in erodable lakebed sediments at 40°30' N, 93°06' E. They form a series of discontinuous, linear features that are highly parallel and generally straight [1, 11]. The yardangs display a blunt upwind margin with streamlining downwind around the steep hills. There are as much as 40 m high and they are generally discontinuous. Grey limestone gravels surround the yardangs; the clasts are 0.5-1.0 cm and form large ripples (0.5 m), indicative of high wind speeds or reptation.

Argentinian Puna Yardangs: Yardangs in two separate fields in the Puna high plateau of NW Argentina developed under hyperarid conditions with prevailing NW-SE winds [8, 12]. NW-SE oriented mega- and mesoyardangs form in ignimbrites at 25°39'S, 66°47'W, and 26°36'S, 67°28'W respectively [8, 13].

Mega- and mesoyardangs are differentiated primarily by size. Megayardangs are typically significantly larger in scale than and appear to be typically found in more well-consolidated materials than the mesoyardangs [8].

Similar to the Dunhuang field, both yardang types in Argentina display a blunt morphology on the upwind margin with a streamlined form on the downwind margin. The tops to both the mega and mesoyardangs are somewhat flat. The mesoyardangs display a more discontinuous morphology than the megayardangs and are more closely spaced. Cooling fractures in the young ignimbrite ash that makes up the mesoyardang materials may contribute to yardang formation and overall morphology through mass wasting along the fracture blocks, while extreme fluting and rounded faces evidence high wind speeds and abrasion [8]. Gravel deposits similar to those found in western China are also present, as well as large gravel ripples.

The older and larger megayardangs are in the more coherent Cerro Galan welded ash-flow tuff [8]. Cooling fractures are present and appear to contribute to the morphology. Interyardangs are typically vegetated, sandy, and have some gravel. Fluting is visible, though to a smaller degree than on the mesoyardangs; generally the wind sculpting is present in the large-scale morphology.

Features on Titan: Yardang-like features on Titan are located in the T18, T23, T30, T56, and T64 Cassini SAR swaths in the northern midlatitudes (Fig. 2). Though image resolution (~300 m) is much lower for Titan than imagery of yardangs on Earth, the features are different from other regularly-spaced forms such as dunes and appear less sinuous and SAR bright [6]. All of the features are aligned in a NW to SE orientation and

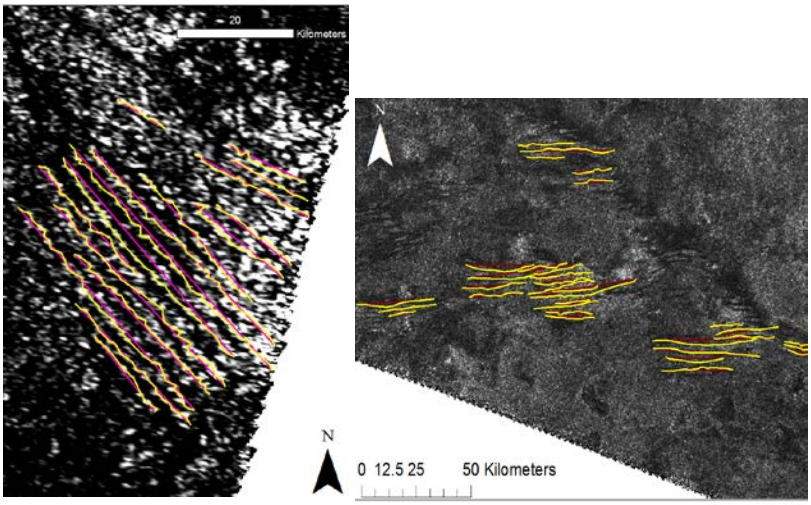

Fig 2. (Left) Radar bright features found in Titan SAR swath T83. The yellow denotes the crest line and the pink the straight length. Note the multiple cross over points between the crest line and straight line. (Right) Dunes found in swath T3. Note the arcuate nature of the crest line and the small number of cross over points between the crest line and straight line.

are highly parallel, as is observed in the Earth yardang fields. The features appear to be is continuous to a small degree at their edges. Dunes in swath T3 are included in this study (Fig. 2).

Discussion: Titan's radar bright features are larger in width and spacing than the currently measured terrestrial fields (Fig. 3). Initial sinuosity measurements show little to no difference between terrestrial yardangs, the radar bright features, and dunes in Titan swath T3. The median sinuosity of the dunes in T3 and features seen in the northern midlatitudes is 1.02 while the terrestrial yardangs is 1.01. Initial meaures of the area between the crest length and the straight length show a median percent of variance toward one side of the features seen in T56 of 76%, in T83 of 56% for T83, and 96% for the dunes on T3 (Fig. 3). Thus, the yardangs are less linear than the dunes.

While the features on Titan, both dunes and putative yardangs, are typically larger than those on Earth, a clear linear trend is readily apparent between width and spacing, indicating that these features are likely formed by processes similar to those that formed terrestrial yardangs (Fig. 3). The difference in scale may be a result of the material properties of the substrate the features are formed in.

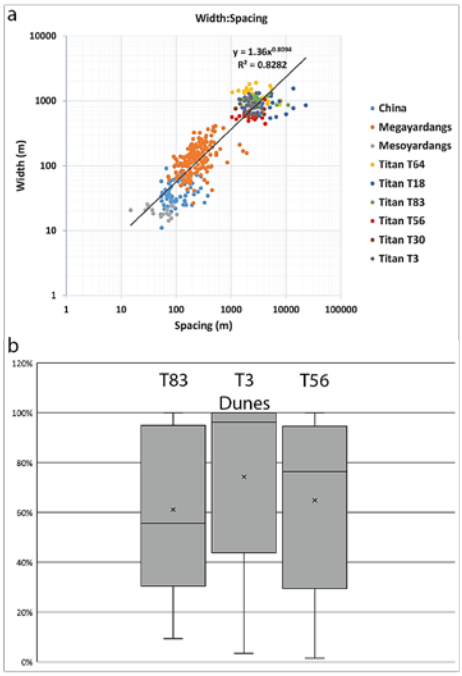

Fig 3. (a) Scatter plot comparing width (m) and spacing (m) across the measured yardang and dune fields. (b) Box and wisker plot of the assemetry of the putative yardangs (T83 and T56) and dunes (T3) on Titan. This is calculated by taking the absolute value of the difference of the area between the crest line and straight line and then dividing it by the total area and converting to a percentage. The x represents the mean.

While sinuosities are nearly identical for dunes and the yardang candidates on Titan and Earth, a marked morphological difference is apparent between the radar bright features and the dunes. The radar bright features crest lines appear more morphologically similar to the crest lines of the terrestrial yardangs than the dunes, due to the larger number of cross over points between the crest line and straight lines (Fig. 1 & 2). This is also quantitatively demonstrated in figure 3. This may indicate that the features seen in swaths T83 and T56 are yardangs. More measurements of the area between the crest length and the straight length across Titan and Earth will test this preliminary conclusion.

Continued remote sensing measurements and field studies of Earth's yardangs and Titan's dunes will yield a greater understanding of classification, formation, and possible Earth analogs for the radar bright features seen on Titan.

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