COMPARISONS OF YARDANGS ON TITAN WITH MEGA AND MESOYARDANGS IN ARGENTINA AND CHINA. D. Northrup[1], J. Radebaugh[1], B. Fowler[1], E. H Christiansen[1], L. Kerber[2] and R.D. Lorenz[3], [1]Brigham Young University, S-389 ESC, Provo, UT USA 84602, [2]Jet Propulsion Laboratory, Pasadena, CA USA 91109, [3]Johns Hopkins Applied Physics Laboratory, Laurel, MD, USA. northrup.dustin@gmail.com.

Introduction: Relatively straight, elongate ridges that form as wind erodes unconsolidated sediment or 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 lake-bed clays [7] and nonwelded volcanic ash [8], but they can form in resistant layers [9] or microcrystalline basement rock [1]. These features typically form in regions characterized by arid conditions, lack of vegetation, and a persistent, unidirectional wind, oriented along the long axis of the yardang [1].

We describe crest length, width, and spacing of yardangs in fields in Argentina and China in order to understand their morphologies and possible controls on their formation. We then compare them to features found in the northern midlatitudes of Titan. These Earth analogs may further aid in the understanding of Titan's material properties, wind, and climatic conditions at the time of formation of the observed features.

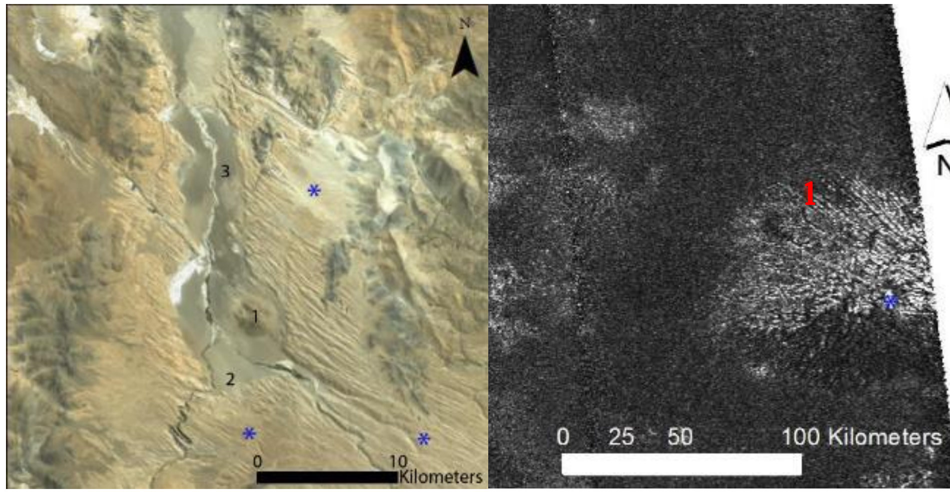

Fig 1. (Left) Satellite imagery of the megayardangs in the Argentinian Puna. The yardangs developed in light colored moderately welded Cerro Galan ash-flow tuff that is approximately 6 Ma in age. The blue stars denote locations of fluvial activity within the yardang field, the 1 denotes a cinder cone, 2 denotes an alluvial fan, and 3 denotes a relict alluvial fan. (Right) Satellite image from Titan. The red 1 denotes possible yardangs. The blue star denotes fluvial channels.

Western China Yardangs: We studied yardangs in the Dunhuang Yardang field of western China. Erodable lakebed sediments at 40°30' N, 93°06' E form a series of linear features that are highly parallel and generally straight. The yardangs display a blunt upwind margin with streamlining downwind around the steep hills, up to 40 m high, and they are generally discontinuous. They have a mean length of 1.2 km and mean spacing of 875 m. Grey limestone gravels surround the yardangs; these are 0.5-1.0 cm and form large ripples (0.5 m), indicative of high wind speeds or reptation. Some evidence of fluvial erosion is present in the form of dry stream channels and cut banks [10].

Argentinian Puna Yardangs: We studied yardangs in two separate fields in the Puna high plateau of NW Argentina. The region is characterized as hyper-arid with prevailing NW-SE winds [8, 11]. NW-SE oriented mega- and mesoyardangs form in ignimbrites located at 25°39'S, 66°47'W, and 26°36'S, 67°28'W respectively (Fig. 2) [8].

Mega- and mesoyardangs are differentiated primarily by size. While no definitive cutoff exists, megayardangs are typically significantly larger than mesoyardangs and were considered to be greater than 1 km for our purposes [12]. It also appears that megayardangs are typically found in more well-consolidated materials than the mesoyardangs, which may be a factor that helps them to grow in size [8].

Similar to the Dunhuang field, both kinds of yardangs in Argentina display a blunt morphology on the upwind margin with a streamlined form on the downwind margin (Fig. 2). The tops of both the mega and mesoyardangs are somewhat flat. The mesoyardangs (Fig. 2; adjacent to Campo Piedra Pomez) display a much more discontinuous morphology than the megayardangs and are much more closely spaced with a mean spacing of 57 m and average length of 509 m. Cooling fractures in the young 70 Ka nonwelded ignimbrite 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 (Fig. 2). Gravel deposits similar to those found in western China are also present, as well as large gravel ripples composed of lithic inclusions weathered from the tuffs (Fig. 2). There is no evidence for fluvial activity in the mesoyardang field.

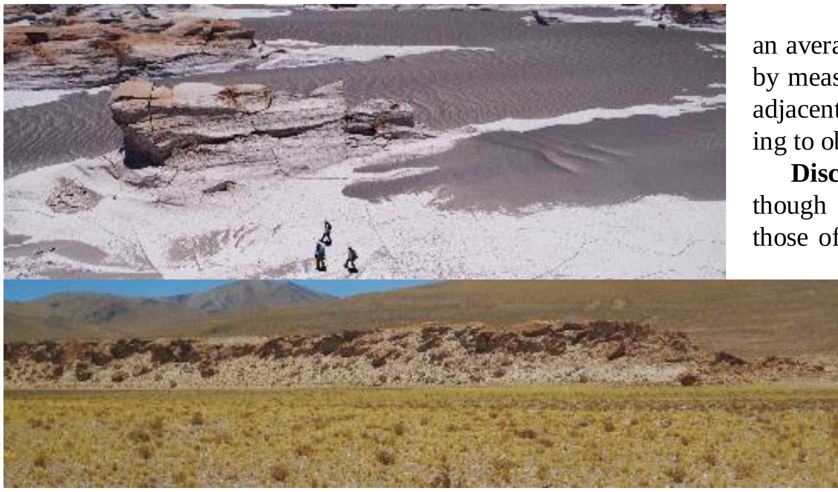

Fig 2. (Upper) Mesoyardangs (~5m high) in the Argentinian Puna. Note their discontinuity, blunt upwind (to the left) margins and the grey gravel ripples. (Lower) Megayardang in the Argentinian Puna. Note the interyardang area and the yardang's continuity.

The older megayardangs, which are significantly larger with a mean length of 2.4 km and mean spacing of 251 m (Fig. 1 & 2), are in the more coherent Cerro Galan ash-flow tuff [8]. Cooling fractures are present and, similar to the mesoyardangs, appear to contribute to the morphology. Inter-yardangs are typically vegetated and sandy and have some gravel, though not as abundant or uniform in size as the mesoyardangs. Fluting is visible, though to a smaller degree than on the mesoyardangs; generally the wind sculpting is present in the large-scale morphology. Some evidence of fluvial activity, such as interyardang channels, is present in certain areas of the megayardang field (Fig. 1).

Features on Titan: Yardang-like features on Titan are located in the T64, T83 and T21 Cassini SAR swaths in the northern midlatitudes. Though image resolution (~300 m) is much lower for Titan than satellite imagery of yardangs on Earth (Fig. 1), the features are different from other regularly-spaced forms such as dunes in that they appear less sinuous and are SAR bright [6] (Fig 1). All of the features are aligned in a NW to SE orientation and are highly parallel, as is observed in the Earth yardang fields. They have a mean length and spacing of 28 km and 1600 m respectively. The features appear to be discontinuous to a small degree at their edges, and evidence of fluvial erosion in the same materials is visible nearby (Fig. 1).

Yardang Measurement Methods: Measurements of the yardangs were made using images acquired from ESRI World Imagery which were taken using IKONOS, with image resolution ~1 m. Yardang crest length was measured as a line, not necessarily straight, down the main crest of each yardang. Width was obtained with straight lines digitized across the yardang at regular intervals and then averaged down the yardang length for an average width. Yardang spacing was obtained by measuring from crest line to crest line of the adjacent yardang at regular intervals, and averaging to obtain the spacing of the yardangs.

Discussion: The megayardangs in Argentina, though significantly smaller, are most similar to those of Titan in their general, more continuous morphology. Many planetary features are larger than their terrestrial counterparts, and it is still possible that Titan's features formed by the same processes as those in Argentina. This may argue for similarities between them as far as wind and environmental conditions and perhaps material properties.

Modeled winds on Titan at those latitudes broadly correspond to the yardangs' NW-SE orientation. Given that dunes and other wind-related landforms are more rare at these latitudes, the presence of yardangs indicate there must have been strong winds at high latitudes either now or in the past.

The lack of fluvial features in the mesoyardangs of Argentina stands in contrast to their presence in the megayardangs to the north. This may indicate a climatic change from wetter to drier regional conditions which is further evidenced by the relict alluvial fan (Fig. 1). Titan may have undergone a similar climatic change with an initial hyperarid climate in the region during yardang formation followed by a wetter period that produced the fluvial valleys that cut through yardang materials (Fig. 1). However, yardangs and fluvial channels have been observed in the same climate when the wind has sufficient strength to overwhelm the effects of a weak fluvial system.

Continued remote sensing measurements and field studies of Earth's yardangs will yield a greater understanding of their formation as well as the formation of Titan's yardangs.

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