POSSIBLE YARDANGS OF TITAN AND WESTERN CHINA REVEAL WINDS AND SURFACE EROSION. J. Radebaugh[1] R.D. Lorenz[2], P. Paillou[3] and T.G. Farr[4], [1]Brigham Young University, S-389 ESC, Provo, UT USA 84602, janirad@byu.edu, [2]Johns Hopkins Applied Physics Laboratory, Laurel, MD, USA, [3]Universite de Bordeaux, Floirac, France, [4]NASA Jet Propulsion Laboratory, Pasadena, CA, USA.

Introduction: Winds on planetary surfaces can act to construct landforms, such as sand dunes, but they can also act to remove materials, leading to the occurrence of wind-erosional landscapes. The results of such processes can reveal wind direction and strength, the nature and erodability of the substrate and regional climate [1]. Yardangs are one such landform created by the stripping of surface materials by winds. They are long, narrow, parallel ridges having steep slopes, streamlined shapes and blunt upwind margins [2]. They are similar in some ways to linear dunes, though they are generally shorter, straighter, and more discontinuous, with a range of morphologies and sizes [3,4]. They do not have Y-junctions as many linear dunes do. They are found in a variety of locales on Earth [1] and perhaps Venus [5], Mars [6,7] and Titan [8]. Yardangs are not well studied, and thus comparisons using planetary geomorphology and other characteristics, such as radar response, may shed light on the requirements for their formation [7,9]. We describe potential yardangs on Titan seen in Cassini RADAR data and compare them with yardangs on Earth.

Yardangs on Earth: Yardangs are found in many deserts on Earth, such as the Saharan Great Sand Sea, the desert near the Namib Sand Sea, the northern Saudi peninsula, the Central Desert of China, the Lut desert of Iran and the Altiplano of South America [1,9]. They generally form in soft sediments such as lakebed clays [10] and volcanic ash [9] but can form in resistant layers [11] or even microcrystalline basement rock. Of great importance appears to be extreme aridity and lack of vegetation, a persistent, unidirectional wind, and materials such as sand or gravel that can effectively erode the underlying materials [1,12]. The ages of yardangs are not well known [1], though those made of soft materials are likely highly transitory.

Yardangs of Dunhuang, China: Central western China, east of the Taklamikan desert, is home to a collection of yardangs carved into highly erodible lakebed sediments at 40°30' N, 93°06' E (Fig. 1). These features are several tens of meters high, with blunt upwind margins and discontinuous forms from ongoing erosion and destruction (Fig. 2). The yardangs are up to 9 km long and have highly variable widths, with a roughly average length:width relationship of 20:1. This is slightly higher than determined for other regions on Earth [3,10]. There are two sets of yardangs in close proximity, oriented 90° from each other, one set NS, the other EW. This likely reveals two separate wind directions, and is consistent with the NE/SW orientation of linear dunes to the southwest of the yardangs.

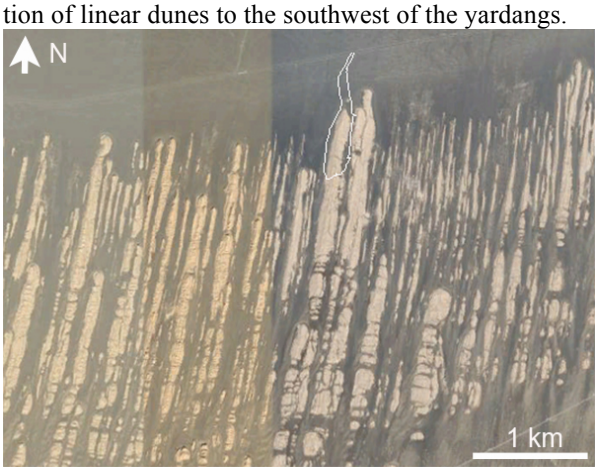

Fig. 1. A portion of the Dunhuang Yardang Park, China. The location of Fig. 2 is 2 km east of the image, and of Fig. 3 is at center top, near the GPS track. The upwind margin (north) is more abrupt than downwind.

Fig. 2. Yardangs of the Dunhuang Yardang Park, viewed from the north. Winds blow to the south, creating blunt upwind noses. Pillars and hoodoos are from differential erosion along their lengths.

The dunes and yardangs all lie in a corridor or basin, which may act to funnel winds. This basin is surrounded by large alluvial fans that serve as a source for a widespread limestone gravel lag deposit surrounding the yardangs. The gravels are 0.5-1.0 cm and form a desert pavement atop fine sands and clays (Fig. 3). The gravels form large ripples (0.5 m), revealing extremely high wind speeds if these form by saltation and if the gravels are lofted to carve the yardangs. The height of

the yardangs, up to 40 m, reveals the ongoing, gradual reduction in base level around the remaining pillars.

Fig. 3. Gravel lag and gravel ripples at Dunhuang Yardang National Park. Camera case is ~5 cm long.

Yardangs of Titan: Titan is well known for its extensive linear dune fields, covering up to 17% of the surface [13,14,15]. Thus it is expected that other desert and wind-related landforms should be present. In a couple of locations, landforms resembling yardangs occur. These features are SAR-bright, or rough, and are in this way different from SAR-dark dunes (Fig. 4).

The features in Fig. 4 are found north of the Belet Sand Sea, from the T64 flyby. They are more short and straight than dunes, having lengths up to 80 km (though the image is cut off on the eastern margin) and a length:width ratio of ~25:1. The variations in RADAR response of these features reveal that they taper and widen while retaining their overall straightness, while the RADAR response of dunes is that of gentle sinuosity along the dune form [7]. They appear to be carved into materials confined to a semi-circular boundary (Fig. 4). There is evidence for fluvial erosion into these materials in deep, badlands-style gullies on the south of the figure. This could be a deposit of highly erodible materials, similar to lakebed clays or ash, that has been eroded by fluvial and eolian processes into gullies and yardangs. These features are 20° north of any dunes; however, their orientation is similar to that of nearby dune-like landforms, possible remnant dunes [16]. They appear to be aligned with some GCMs [17], to be further explored.

Discussion: Yardangs are important planetary desert landforms that can reveal much about regional conditions and erosion. The Dunhuang yardangs exist in generally arid conditions, yet there is extensive vegetal cover in the western portion of the field. Yardangs oriented at different angles in close proximity, such as those in Dunhuang, Titan's yardangs in Fig. 4 and some candidates on Venus, reveal either locally varying winds or progressively deflating layers formed during different wind orientations. Yardangs on Titan may reveal the presence of soft lakebed sediments, and thus a past, wetter climate in that location, or they could reveal volcanic constructs and related ash deposits. They also reveal wind directions at some point in the past or present. The presence of yardangs can help peel back the blanket of our understanding of planetary surface evolution.

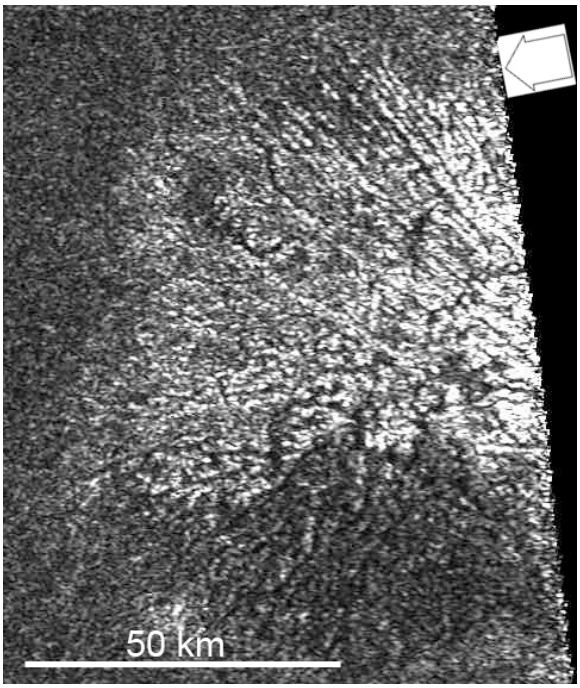

Fig. 4. Possible yardangs on Titan at 41°N, 210°W, north of the Belet Sand Sea. North is up, the white arrow indicates RADAR illumination direction. Orientations are roughly NW/SE (right) and WSE/ENE (left). From Cassini RADAR swath T64, Dec 2009.

References: [1] Goudie A.S. (2007) *Geography Compass 1*, 65-81. [2] Cooke R., Warren A. and Goudie A.S. (1993) *Desert geomorphology*, UCL Press. [3] Goudie A.S. (1999) in *Aeolian Env., Seds Landforms*, 167-180. [4] Mainguet M. (1972) *Le modele des gres*, Paris. [5] Greeley R. (1999) *Tech Rep*, ASU. [6] Ward A.W. (1979) *Jour Geophys Res 84*, 8147-8166. [7] Zimbelman J. et al. (2010) *Icarus 205*, 198-210. [8] Paillou P. and Radebaugh J. (2013). *EPSC Abs*. [9] de Silva S. et al. (2010) *PSS 58*, 459-471. [10] Bristow C. et al. (2009) *Geomorph 105*, 50-58. [11] Bridges N. et al. (2007) GRL. [12] Ward and Greeley (1984) *GSABull 95*, 829-837. [13] Lorenz R. et al. (2006) *Science 312*, 724-727. [14] Rodriguez S. et al. (2014) *Icarus 230*, 168-179. [15] Arnold K. et al. (2014) *MS Thesis*, BYU. [16] Radebaugh J. et al. (2011) *EPSC Abs*. [17] Tokano, T. (2010) *Aeolian Res. 2,* 113-127.