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Earth Desert Analogues for Titan's Large, Linear Dunes

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Abstract

Large seas of linear dunes on Titan have analogues in the Saharan, SW African, Australian and Arabian deserts of Earth. Analogue field studies of these more accessible terrestrial locations can provide insight into the formation of linear dunes in general and of surface, wind and climate conditions on Titan. Initial studies in these remote desert regions using various methods have revealed that linear dune systems have dynamic surfaces subject to continual reworking by recent winds. Given similar morphologies on Titan, similar conditions may prevail.

1. Linear dunes on Titan reveal surface conditions and winds

Sand dunes are prominent across the surface of Titan, found dominantly in the equatorial deserts [1,2]. They are linear or longitudinal in form at the best Cassini SAR (Synthetic Aperture RADAR) and VIMS (Visual and Infrared Mapping Spectrometer) resolutions, with nearly identical morphologies to the large, linear dunes of the big Saharan, Namibian and Arabian deserts [3,4]. Dunes can reveal many aspects of surface conditions, such as the presence of sand and its transport and accumulation, topographic variations, and climate. Currently, dunes on Titan serve as a primary indicator of wind directions [5], though the question remains if the dunes reflect the present wind conditions.

2. Analogue field methods

Analogue comparisons using more accessible and better-studied dunes on Earth, as well as dunes on Mars and Venus, can help further the understanding of dune formation and evolution and relationship to past and present wind conditions. Large linear dunes of Earth's big deserts have been difficult to study because of their sizes and long reaction times and the logistical difficulties of detailed studies in areas hard to access. However, we have undertaken studies that build on previous work in these locations. Methods include use of GPS and laser range finding to determine detailed profiles of dune surfaces, to reveal the most recent winds and to find the direction of dune migration, GPR (ground penetrating RADAR) to reveal internal layering, which is related to wind conditions and changes in materials, and OSL (optically stimulated luminescence) dating to find the most recent exposure ages, related to vigor of dune migration and summit reworking.

3. Egypt, UAE, Namibia studies

Field studies of linear dunes in Egypt, both in the Qattaniya dune field west of Cairo and in the Sand Sea, on the border between Egypt and Libya, include GPS, GPR and OSL studies. GPS traces of the profiles of simple linear dunes in the Qattaniya dune field, a good analogue for the sparse sand conditions of the northern regions of Titan's dune fields, reveal alternating winds across the summit, revealed by a change in the location of the slip face, or steepest part of the summit (Fig. 1), dominantly from the NNE (onto a NNE-trending crestline) and likely also from the NNW. The dune has a broader western plinth, indicating the NNE winds are dominant, and that migration may be happening toward the west (Fig. 1).

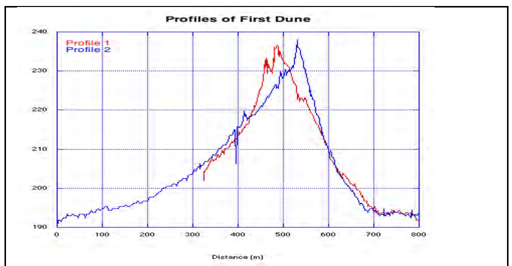

Fig. 1. Profiles of two proximal dunes, Egypt's Qattaniya field, showing alternating winds and dominant W (left) transport.

A GPR profile with a 100 MHz antenna across the northern terminus of the dune clearly shows the underlying substrate and interdune as distinct from the dune, indicating the dune sands are effectively swept into dunes, and are thus actively moving [4]. OSL dates of samples taken down to 30 cm depth on the Qattaniya dunes, and larger, complex dunes in the Sand Sea, yield ages essentially modern, which indicates the upper portions of the dune are being actively reworked. This compares well with a similar study in the Namib Sand Sea that found young ages at the dune summit on top of an older core [6]. Future studies will obtain sands from deeper in the dune to discern between surface reworking and core dune formation.

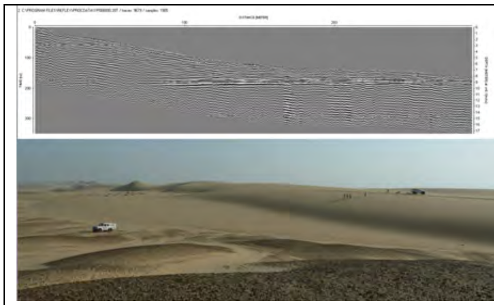

Fig. 2. GPR (top) of Qattaniya dune (bottom), looking south. Strong reflector is rocky substrate.

Studies in the United Arab Emirates portion of the Rub al Khali desert contains large, complex linear dunes that have smaller, secondary linear and barchanoid forms on their flanks and in the interdunes. A GPS trace of the dune summit on top of older imagery (Fig. 3, white line) reveals the dune crest has shifted to the NE. Other features, such as the abrupt SE dune terminus and broad stoss (NW) slope and barchanoid forms in that location also show evidence for SE migration.

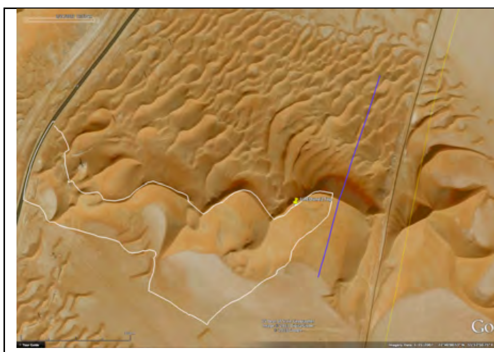

Fig. 3. Portion of linear dune in Rub al Khali, UAE. Road (L) and border fence (R) for scale. White is hiked trace, note summit shift since imagery. Blue is approximate cross section from laser range finder.

A cross section of the dune was obtained (Fig. 3; blue line) using a TruPulse 360B laser range finder, and demonstrates that the steepest face is on the ESE, consistent with the predicted transportation direction, and that large, flanking features upwind of the crest can be seen in the profile. Further study in the area could reveal if the linear forms are stable but moving, or if the sand transportation is acting to destroy the large, linear forms and replacing them with smaller barchans.

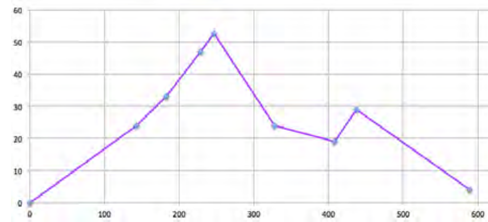

Fig. 4. Profile of linear dune in Fig. 3, purple line. Crest is blade-like, though overall slope is steeper on the SW (left), and flanking feature is visible in NE (right) of the profile.

The Namib Sand Sea in SW Africa has a range of linear forms, from simple to compound and complex dunes and in some locations sandy interdunes [7]. Sands interact with topographic obstacles, making this region a good analogue for dunes in Titan's Belet Sand Sea, where sand volumes are high and inselbergs jut up above the dunes [4]. We will report on initial field studies undertaken there in August 2013.

4. Conclusions

Dunes in Earth's big deserts can provide insights into the conditions on Titan affecting the dunes. The systems under study on Earth show signs of activity, especially on their summits and interdunes, and appear to reflect the current winds. Were this not the case, erosion would likely lower the dune summits and redistribute sand into the interdunes. Given Titan retains high dune summits and sand-free interdunes, similar levels of activity may prevail on Titan's dunes.

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