PLANETARY SCIENCE

Titan's sticky dunes?

Titan's surface is covered by vast fields of linear dunes, probably composed of organic sand-sized particles. The study of linear dunes in China suggests that sediment cohesiveness can be as important as wind direction in the creation of these dune forms.

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Thousands of linear dunes, covering up to 20% of Titan's surface, were one of the greatest surprises uncovered by the Cassini spacecraft[1]. The fact that these dunes have formed, and persisted, suggests that there must be, or have been, sufficient wind, sediment and collection areas at Titan's surface. Wind patterns on Titan have been estimated based on the orientation of the dunes and a formation model derived from observations on Earth, in which linear dunes form in regimes of winds from two alternating directions with a wide angle of separation. This model suggests that the global effective winds (a weighted sum of the present wind directions) go from west to east[2]. On page 653 of this issue, Rubin and Hesp investigate dunes in the Qaidam Basin, China, and propose that the dunes on Titan could equally well have been formed by unidirectional winds blowing over sticky sediments[3].

The wind speeds and directions required to form most dune morphologies are well known. Therefore, many dune shapes can essentially serve as wind vanes in the absence of landed planetary spacecraft. However, giant linear dunes that can reach 1–2 km in width and over 100 km in length, and are found in abundance in most of the large deserts on Earth (Fig. 1), are less well understood. Early on, the giant linear dunes were viewed as either erosional or depositional forms[4], engendering debate regarding the direction and style of regional wind flow. More recent models for linear dune formation are centred on two main scenarios for formation and perpetuation. Winds from two alternating directions, separated by a wide angle, result in the formation of dunes whose long axis falls somewhere between the two wind directions. Alternatively, winds blowing from a single direction along a dune surface that has been stabilized in some way, for example by vegetation, an obstacle or sediment cohesiveness, can produce the same dune form.

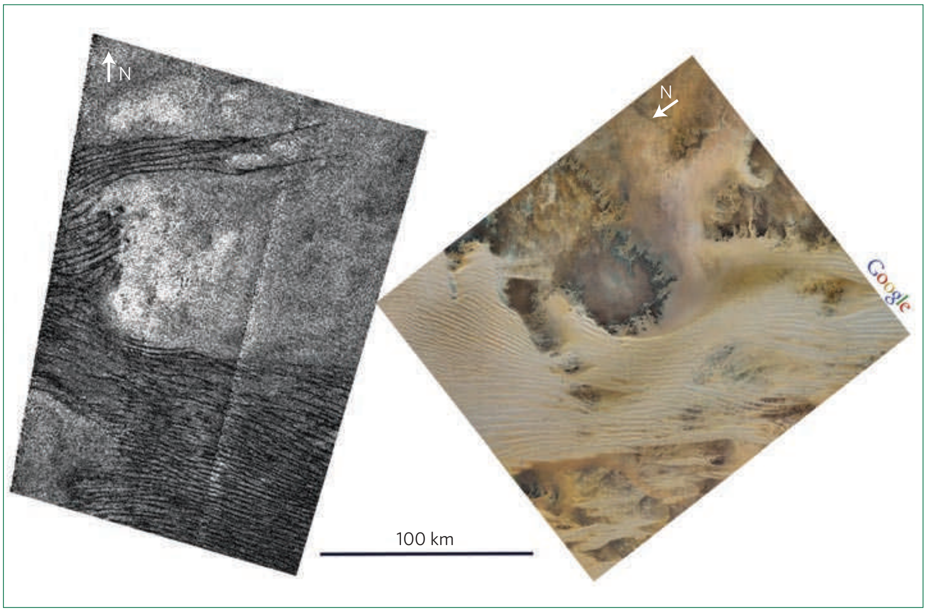

Figure 1 | Linear dunes far and near. **a**, The linear dunes on Titan, occurring near the equator, are imaged by Cassini Radar. The linear forms, which are dark in this image, seem to diverge around the light obstacles. Image courtesy of NASA/Cassini/JPL. **b**, This Landsat image shows light coloured dunes in southwest Libya. Rubin and Hesp propose that some linear dunes on Earth, and by analogy on Titan, form as sticky sediments are carried downwind by single direction winds and are deposited on the lee side of the dune[5]. These dunes would be self-extending, and as such could grow to the massive proportions visible in these images. Image courtesy of Google Earth.

The winds that formed the linear dunes on Titan were probably generated by tidal energy, supplemented by solar energy, in Titan's thick atmosphere — uncannily similar in composition and pressure to that of Earth. However, the source of the requisite sediments is more puzzling. The particles seem to be predominantly composed of organic material from atmospheric fallout[5], with a possible contribution from water ice. However, the materials must have been reworked in some way into particles that can be transported by wind and formed into dunes. The poles of Titan are thought to be humid, with evidence for prevalent lakes[6], but Titan's dune fields occur primarily in the equatorial regions that have been interpreted as deserts, far from the influence of persistent methane rains.

Rubin and Hesp[3] have used a desert setting on Earth, the Qaidam Basin of China, to examine the role of sediment stabilization in linear dune formation. The wind direction in the basin remains steady throughout the year, but the characteristics of the sediments vary across the region. They found that the portion of the basin containing loose, dry sands shows barchan (arc-shaped) dunes, which are typical of single-direction wind regimes. However, closer to ephemeral lake basins, the sediments are cohesive clay particles, and the dunes are linear in form. They argue that the stickiness of the particles causes any blown particles to attach to the downwind side of the existing dune, thus elongating it in the downwind direction. This results in a linear dune with a long axis that is parallel to the wind direction.

Rubin and Hesp argue that if the dune sands of Titan consist of organic material, they could be cohesive in nature, much like the Qaidam Basin clays. Like the clays, organic sands would stick to the lee side of the dune form, elongating the dunes parallel to the direction of the winds. In the absence of vegetation or substantial amounts of methane rain, the presence of cohesive sediments is the only way that would allow formation of stabilized dunes by elongation on Titan.

This hypothesis attractively explains some aspects of Titan's dunes, such as the dominance of linear forms, which make up about 95% of all observed dunes. It also creates a clean picture of Titan's global winds: there is no need to resolve two wind directions, as in this scenario the winds are always simply lined up with the long axis of the dune.

However, much work remains before we have a complete understanding of Titan's dunes, or even linear dunes in general. The Qaidam Basin dunes, having formed by growth through stabilization, may not be typical of Earth's linear dunes. Thus, to apply this exceptional model to all of Titan is risky, as our current understanding of surface processes on Titan is limited. For instance, our knowledge of the composition and behaviours of the sands comes primarily from relatively new laboratory and theoretical models. And indeed, these and earlier observations of linear dune morphologies on Titan predict a global effective wind direction[2,3] exactly opposite to those simulated by circulation models[7]. A straightforward solution to this problem has been elusive, although clues may lie in the consideration of atmospheric boundary layer effects on dune formation (ref. 8 and Lorenz *et al*., manuscript in preparation).

Furthermore, although dunes on Titan appear to superpose nearly all surface features, we do not know if they are active at present. For that matter, we do not know whether the wind conditions observed on Earth today are responsible for its large linear dune forms, or if these features are a remnant of the drier, windier and more sediment-ridden Last Glacial Maximum[9].

The work by Rubin and Hesp[3] uses Earth observations to open up a new possibility for the interpretation of the surface morphology of Titan and its atmospheric dynamics. In turn, if we can discern that the vast sand seas of Titan are active, the linear dunes of Titan may pave the way to understanding the linear desert dunes on our own planet Earth. ❐

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