**LANDSCAPES OF TITAN**

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## 1. INTRODUCTION

The radar on the Cassini spacecraft orbiting Saturn has mapped about 34% of its largest moon Titan since 2004. What has been revealed is a landscape surprisingly similar to Earth's, given the average surface temperature is 93K (Lorenz and Mitton, 2008). Mountain ranges are seen to be eroded by flowing liquid, probably methane, which collects in large lakes. River valleys in some upland areas extend for over 500 km, debouching onto low-lying plains. Some plains exhibit radar-bright lobate forms which are likely produced by some form of cryo-volcanism. While the lakes of Titan appear to occupy preferentially the northern polar region, equatorial regions host large areas of linear dune forms. The orientation of the dunes reflect modeled atmospheric circulation patterns, but is affected by topographic obstacles. As with every other solar-system body, impact craters are also found on Titan. However, like Earth, active geologic processes have erased most so that only a handful have been observed so far.

## 2. MOUNTAINS

High-relief areas are rare on Titan and even so-called mountains have relatively low relief. A group of roughly parallel ranges are so far the highest features at about 2 km. Xanadu, a large equatorial region over 3000 km across, has the appearance of an old, heavily eroded uplift and sports a well-developed drainage net as well as the greatest density of apparent impact craters on Titan (Radebaugh et al., 2007).

## 3. RIVERS

River valleys cut across many types of terrains. The networks are often well-developed implying a long history of erosion. Tributaries extend to the smallest scales observable in radar images (a few 100 m) and were observed in Huygens descent images down to a few m across, indicating rainfall as the origin of the drainages (Lorenz et al., 2008).

## 4. LAKES

Lakes of liquid methane or ethane have been confirmed by both spectral and morphologic means. Most of the lakes occur in the north polar region, but a few have been observed in the south polar region, despite less radar coverage. Lakes occur as isolated small (~100 $km^2$) circular forms, sometimes partially filled or even empty, bright-floored depressions, and as irregular bodies large enough to be called 'seas' (up to $10^5$ $km^2$) which often display drowned shorelines. The observed lakes take up 1.7% of the global coverage area at the end of Cassini's primary mission. Sparse topographic information indicates the lakes may be connected by a subsurface methane aquifer. Repeat observations, planned for the extended mission, may observe lake evolution and help determine how much interaction there is between the subsurface and surface (Hayes et al., 2008).

## 5. VOLCANISM

Evidence for cryo-volcanism is mounting. Several plains areas exhibit a mottled texture in radar images with bright lobate features extending in several directions, but with no obvious connections to the neighboring highlands or river valleys. Recent stereo-photogrammetric work has shown the bright lobate

features to be higher than their surroundings, indicating the flows may be thick. The 'magmas' which could have formed these features could be water-ammonia mixtures which may have enough buoyancy to rise through fractures and erupt on the surface (Lopes et al., 2007).

## 6. DUNES

Dunes are ubiquitous in the equatorial regions of Titan. They are linear, or longitudinal, dunes the orientation of which indicate large-scale near-surface atmospheric circulation that differs from present models, and are affected by local topography as well. Titan's dunes are a couple of 100 m high, a few km apart, and extend for hundreds to over 1000 km long. These dimensions are quite similar to linear dunes in the sand seas of Earth. So far, the nature of the particles which make up the dunes is unclear. Most likely they are either water-ice or organic materials which are resistant and can aggregate to form particles of the size required for saltation (Radebaugh et al., 2008).

## 7. IMPACT CRATERS

Only a few un-ambiguous impact craters have been observed. Many other features have been labeled as possible impacts. Because so few have been observed, it is difficult to derive age-related statistics. There is some indication of non-uniform distribution, e.g. there may be a greater density of craters in Xanadu, but more work needs to be done in mapping and interpretation of possible impact craters on Titan (Lorenz et al., 2007).

## REFERENCES


Hayes, A., O. Aharonson, K. Lewis, K. Mitchell, R. Lorenz, P. Callahan, J. Lunine, R. Lopes, S. Wall, C. Elachi, G. Mitri, R. Kirk, Y. Gim, E. Stofan, and the Cassini RADAR Team, 2008, Hydrocarbon lakes on Titan: Distribution and interaction with a porous regolith, Geophys. Res. Lett., v. 35, p. L09204, doi:10.1029/2008GL033409.

Lopes, R., K.L. Mitchell, E.R. Stofan, J.I. Lunine, R. Lorenz, F. Paganelli, R.L. Kirk, C.A. Wood, S.D. Wall, L.E. Robshaw, A.D. Fortes, C.D. Neish, J. Radebaugh, E. Reffet, S.J. Ostro, C. Elachi, M.D. Allison, Y. Anderson, R. Boehmer, G. Boubin, P. Callahan, P. Encrenaz, E. Flamini, G. Francescetti, Y. Gim, G. Hamilton, S. Hensley, M.A. Janssen, W.T. Johnson, K. Kelleher, D.O. Muhleman, G. Ori, R. Orosei, G. Picardi, F. Posa, L.E. Roth, R. Seu, S. Shaffer, L.A. Soderblom, B. Stiles, S. Vetrella, R.D. West, L. Wye, H.A. Zebker, 2007, Cryovolcanic features on Titan's surface as revealed by the Cassini Titan Radar Mapper, Icarus, v. 186, p. 395-412.

R.D. Lorenz and J. Mitton, 2008, *Titan Unveiled*, Princeton University Press.

Lorenz, R.D., C.A. Wood, J.I. Lunine, S.D. Wall, R.M. Lopes, K. Mitchell, F. Paganelli, Y.Z. Anderson, L. Wye, C. Tsai, H. Zebker, E.R. Stofan and the Cassini RADAR Team, 2007, Titan's young surface: Initial impact crater survey by Cassini RADAR and model comparison, Geophys. Res. Lett., v. 34, p. L07204, doi:10.1029/2006GL028971.

Lorenz, R.D., R. M. Lopes, F. Paganelli, J.I. Lunine, R.L. Kirk, L.A. Soderblom, E. Stofan, G. Ori, M. Myers, H. Miyamoto, B. Stiles, S.D. Wall, C.A. Wood, and the Cassini RADAR Team, Fluvial channels on Titan: Initial Cassini RADAR observations, 2008, Planetary and Space Science, v. 56, p. 1132-1144.

J. Radebaugh, R. Lorenz, R. Kirk, J. Lunine, E. Stofan, R. Lopes, S. Wall, and the Cassini Radar Team, 2007, Mountains on Titan observed by the Cassini RADAR, Icarus v. 192, p. 77-91.

J. Radebaugh, R.D. Lorenz, J.I. Lunine, S.D. Wall, G. Boubin, E. Reffet, R.L. Kirk, R.M. Lopes, E.R. Stofan, L. Soderblom, M. Allison, M. Janssen, P. Paillou, P. Callahan, C. Spencer, and the Cassini Radar Team, 2008, Dunes on Titan observed by Cassini RADAR, Icarus v. 194, p. 690-703.


## ACKNOWLEDGMENT


Part of this work was done under contract with NASA.