

Do Titan's mountains betray the late acquisition of its current atmosphere?

J. M. Moore (1), F. Nimmo (2)

(1) NASA Ames Research Center, Moffett Field, CA, USA (jeff.moore@nasa.gov) Fax: (650) 604-6779 (2) University of California Santa Cruz, Dept. Earth and Planetary Sciences, Santa Cruz, CA, USA (fnimmo@es.ucsc.edu)

1. Introduction

Titan may have acquired its massive atmosphere relatively recently in solar system history [1,2,3,4]. Prior to that time, Titan would have been nearly airless, with its volatiles frozen or sequestered. Present-day Titan experiences only small (~ 4 K) pole-to-equator variations, owing to efficient heat transport via the thick atmosphere [5]; these temperature variations would have been much larger (~ 20 K) in the absence of an atmosphere. If Titan's ice shell is conductive, the change in surface temperature associated with the development of an atmosphere would have led to changes in shell thickness. In particular, the poles would move down (inducing compression) while the equator would move up. Figure 1 shows the predicted change in surface elevation as a result of the change in surface temperature, using the numerical conductive shell thickness model of [6].

2. Model and Analysis

The pattern of elevation change is almost identical to that experienced by a planet during spin-up. For a thin shell body (such as Titan) the equatorial region would have undergone strike-slip faulting (not normal faulting) in a NE-SW or NW-SE orientation, while the polar region would experience E-W thrust faulting [7]. This pattern does not change significantly if shell thickness variations are taken into account [8].

Published mapping shows lineaments with NE-SW or NW-SE orientations in the equatorial region [9]. These faults may have originated as strike-slip faults and then have been reactivated as compressional features as further compressional stresses developed (e.g. due to gradual cooling and contraction of Titan [10]). So the equator would have experienced strike-slip faulting and regional uplift followed by compression, while the poles would have

experienced regional subsidence and compression throughout. Polar compression may have formed the isolated massifs seen there akin to isolated mountains thought to form in compression on Io [11,12]. The development of the atmosphere results in a regional polar strain of order 10^{-4} , but the local strain at isolated mountains could be of order 10^{-3} . The polar massifs are typically ~ 100 km wide, so if they are due to faulting then the predicted topography is roughly 100 m (depending on the angle of the fault), which is approximately what is observed. To accommodate the same strain by folding would require much higher relief. We will present mapping and additional modeling to evaluate the hypothesis that Titan's tectonics reflect the consequences of recently acquiring a thick atmosphere.

3. Figures

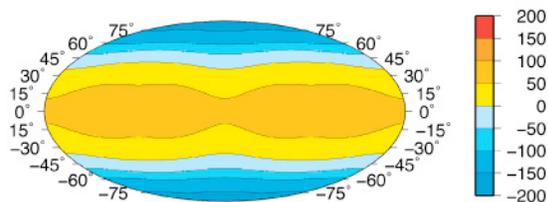


Fig. 1. Change in topography of Titan as a consequence of the change in surface temperature variations due to acquisition of an atmosphere. The poles become warmer, resulting in shell thinning and a reduction in elevation, while the equator becomes colder, resulting in shell thickening and uplift. The minor longitudinal variations arise from the shell thickness variations due to tidal heating (see ref 6 for details on the numerical model employed). Units for scale bar are in meters.

References

- [1] McKay, C.P., Pollack, J.B., Lunine, J.I., and Courtin, R.: Coupled atmosphere-ocean models of Titan's past, *Icarus*, 102, 88-98, 1993.
- [2] Lorenz, R.D., et al.: Titan's inventory of organic surface materials, *Geophys. Res. Lett.*, 35, L02206, doi:10.1029/2007GL032118, 2008.
- [3] Lorenz, R.D., McKay, C.P., and Lunine, J.I.: Photochemically driven collapse of Titan's atmosphere, *Science*, 275, 642-644, 1997.
- [4] Moore, J.M., and Howard, A.D.: Are the basins of Titan's Tui Regio and Hotei Regio sites of former low latitude seas?, *Geophys. Res. Lett.*, 37, L22205, doi:10.1029/2010GL045234, 2010.
- [5] Tokano, T.: Meteorological assessment of the surface temperature on Titan: Constraints on the surface type, *Icarus*, 173, 222-242, 2005.
- [6] Nimmo, F., Bills, B.G.: Shell thickness variations and the long wavelength topography of Titan, *Icarus*, 208, 896-904, 2010.

[7] Melosh, H.J.: Global tectonics of a despun planet. *Icarus*, 31, 221-243. 1977

[8] Beuthe, M.: East-west faults due to planetary contraction, *Icarus*, 209, 795-817, 2010.

[9] Radebaugh, J. et al.: Regional geomorphology and history of Titan's Xanadu province, *Icarus*, 211, 1, 672-685, 2010.

[10] Mitri G. et al.: Mountains on Titan: Modeling and observations, *J. Geophys. Res.*, 115, E10002, 2010.

[11] Schenk, P. M. and M. H. Bulmer: Origin of mountains on Io by thrust faulting and large-scale mass movements, *Science*, 279, 1514, 1998.

[12] McKinnon, W.B., Schenk, P.M., and Dombard, A.J.: Chaos on Io: A model for formation of mountain blocks by crustal heating, melting, and tilting, *Geology*, 29, 103-106, 2001.