BIPOLAR VOLCANISM ON TITAN? C. A. Wood, Planetary Science Institute, Tucson, AZ, and Wheeling Jesuit University, Wheeling, WV; chuckwood@cet.edu.

Introduction: Titan is a difficult world to understand. Because of its dense atmosphere, optical imaging is degraded compared to all the airless worlds of the outer solar system. The Cassini Titan Radar instrument has looked through the haze revealing impact craters, mountains, river channels and dunes, but there is great uncertainty in the geologic interpretation of much of the surface and its landforms. At the 300 to 1500 m resolution of Radar many of the surface units lack diagnostic morphologic features that would allow their processes of origin and modification to be unambiguously identified. And the fact that Titan has the equivalent of a hydrologic cycle, with methane acting as water, there is a possibility – but no certainty – that unusual processes have helped create it surface. As a result of these uncertainities that there is little compelling evidence that Titan is or isn't internally active, rather than simply being surficially modified by atmospheric processes.

Here I present a hypothesis that significant numbers of volcanic craters exist in both the northern and southern polar regions of Titan. Morphologic comparisons are made of fields of round depressions on Titan with known volcanic depressions on Earth. It is currently impossible to prove the origin of these depressions. Part of the reason is that volcanism is largely absent from the smaller icy moons in the outer solar system so there is little knowledge of what such landforms should look like. And even if there were morphologically pristine calderas elsewhere, the influence of Titan' atmosphere and its geologic consequences are not certain. Because the question of whether Titan has been internally active is critical to understanding its history, this exercise is deemed of value.

Outside the polar regions only a few putative volcanic landforms have been proposed [1]. The most likely candidate is Sotra Facula, a likely caldera and associated lava flow that is very similar to terrestrial calderas with viscous domes on the floor and with surrounding flow units [2]. A second possible example of volcanism is a field of apparent lava flows in the Tui Regio area of southern Xanadu [3]. Only possible lava flows are seen there, with no source features. The lack of other proposed caldera and flow features suggests that volcanism may be limited across much of Titan.

Possible Caldera/Maar Fields near Titan's North Pole: The first radar passes of Titan's north polar regions revealed hundreds of lakes [4], most contained within circular depressions, some 200-300 m deep [5]. In initial discussions these depressions were interpreted either as volcanic calderas [6] or karst [7]. The shear abundance of these depressions, and the non-circular outlines of many are consistent with a karst interpretation, although many of the morphologic features are inconsistent with it, and it is not known if the crustal material is dissolvable by methane or ethane liquids.

However, considerable morphological evidence supports a volcanic interpretation for at least some of the features:

Circular outlines – as common for craters and collapse calderas

Raised rims – indicated by radiating drainage, indicative of constructional rather than erosional origin

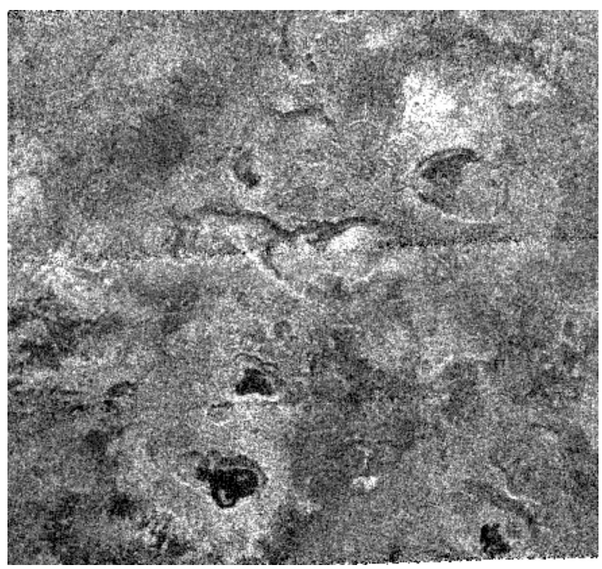
Nested depressions - depressions at different levels with dark fluid only at lowest levels, as common for multi-stage caldera collapses

Bright halo – possible chemical/thermal alteration, could be overflow of lavas, or less likely, ash

Apparent age differences – sharpness, continuity and contrast with surroundings indicate probable features of different ages, with rapid loss of bright halo, morphological degradation and cover by later features.

Clustering – fields of calderas/maars implies near surface magma/hydromagmatic eruptions.

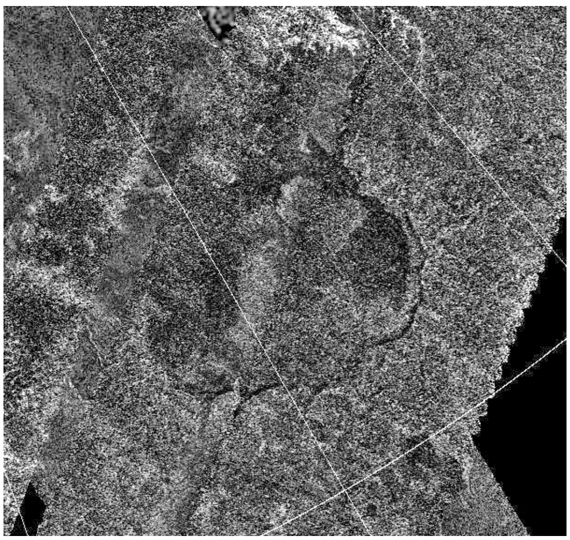
Bright flows – fill some depression centers and occasionally extend beyond rim.



Caldera-like depressions in T16 Radar swath in north polar region. Image width 160 km.

Features like these are familiar in volcanic regions on Earth. But large collections of abutting and overlapping rimmed depressions are most commonly created on Earth by explosive eruptions when rising magma intersects abundant ground water, as in the Katwe-Kikorongo Volcanic Field in the Western Rift Valley of Uganda.

Possible Caldera Fields near Titan's South Pole: Small depressions with or without lakes are rare near Titan's South Pole, but large landforms of possible volcanic origin occur. A wonderful example is a ~100 km wide, rimmed depression at 77°S, 149°W. This feature has an elevated rim as indicated by radial erosion channels that diverge from its rimcrest. The oval but irregular in detail rim outline is exactly what occurs when local geologic stresses control collapse. The feature looks remarkably like the 12 km wide Menengai caldera in Kenya [http://corners-of-a-life.wikispaces.com/Kenya].



Caldera-like rimmed depression at 77°S, 149°W.

Interpretation: The morphological arguments presented here lead to the logical interpretation that volcanism is the most likely origin for these depressions, implying that volcanism was and perhaps still is widespread near Titan's north and south poles. Why should volcanism be dominately, if not only, near the poles? One possible answer relates to the global distribution of elevations. Derivation of elevation profiles along 130,000 km of Radar tracks [8] show that the poles are the lowest extensive areas on the planet; virtually all topo data points within 30° latitude of either pole are lower than -500 m elevation. The temperate and equatorial regions are generally 500 to 1000 m higher. Perhaps, as on Earth's Moon, lower elevations correspond to thinner crusts, which are easier for magma to rise through and erupt on the surface. If so, volcanism would be favored near Titan's poles.

Two other questions are (1) Why are the volcanic features strongly clustered, and (2) Why do they have different diameters and shapes? Clustering of volcanic depressions occurs at two scales on Earth. Maar volcano volcanic fields - typically a few tens of kilometers in diameter – form where a rising dike or sill of magma intersects abundant ground or surface water or permafrost. Because there is a spatially wide source of magma there are many near surface explosions producing maars that abut or overlap. Maar formation also includes landsliding into vent areas to produce flat-floored craters hundreds of meters to a few km wide.

Clustering also occurs in caldera fields that typically span 30-100 km, and mark a near surface batholith. Ash flow calderas above the batholith are generally 3 to 20 km in diameter, their relatively large width compared to maars is due to the greater depth to the magma source/batholith that they collapse into. Overlap of either maars or calderas create irregular shapes with arucate edges, as seen on Titan.

The northern putative volcanics are younger looking – for example, bright halos are rare in the south – suggesting that volcanism is more recent in the north. This is consistent with the proposal [9] that rainfall and lake levels migrate between poles over timescales of tens of thousands of years due to orbital forcing. Does methane/ethane liquid in the porous upper crust of Titan act like water on Earth, causing near-surface maar-type eruptions near the poles where the crust may be thin? If so, the young, bright-haloed craters near the North Pole may have formed during the current orbital wet period there.

Finally, although only a few landforms have been mentioned here, there are hundreds of depressions at each pole that may be of volcanic origin. If many are, then polar volcanism covers tens of percent of Titan's polar regions.

The large and small features in the polar regions described here look more volcanic than like any other type of landform seen elsewhere in the solar system. But because Titan has an exotic methanospheric cycle, and there is uncertainty of the exact composition and characteristics of surface rocks, as well as the moon's thermal history, the existence of volcanism can not yet be confirmed. Nontheless, it is a planetologically reasonable theory to be considered. Confirmation of active volcanism is possible with the IR bands of CIRS and maybe VIMS [10], but thermally equilibrated volcanic deposits can not be uniquely identified with current resolutions – unless a new volcanic feature is imaged where none existed before.

References: [1] Lopes et al. (2007) *Icarus, 186*, 395-412. [2] Stofan et al., in prep. [3] Wall S.D. et al. (2009) *Geophys. Res. Lett., 36*, L4203. [4] Stofan E.R. et al. (2007) *Nature, 445*, 61-64. [5] Hayes, A. et al, (2008) *Geophys. Res. Lett. 35*, L09204. [6] Wood, C. A., et al. (2007), *LPS 38 th*, Abstract #1454. [7] Mitchell, K. et al. (2007) *LPS 38 th*, Abstract #2064. [8] Stiles et al. (2011) this volume. [9] Aharonson, O. et al. (2009) *Nature Geoscience* DOI: 10.1038/NGEO698. [10] Davies, A.G. et al. (2009) *LPS 40th*, Abstract #1906.