Volcanic Calderas in the North Polar Region of Titan. C.A. Wood[1], K. L. Mitchell[2], R. M. C. Lopes[2], J. Radebaugh[3], E. Stoffan[4], J. Lunine[5], and the Cassini RADAR Team, [1]Wheeling Jesuit Univ., 316 Washington Ave, Wheeling, WV 26003 and Planetary Science Inst., Tucson, AZ. [2]Jet Propulsion Lab., Pasadena, CA, [3]Brigham Young Univ. Provo, UT, [4]Proxemy Research, Rectortown, VA, [5]Lunar & Planetary Lab, UA, Tucson, AZ.

Introduction: The discovery[1] of lakes poleward of 70° N latitude is a critical clue for understanding the geologic process occuring on Titan. Also of great interest is that the lakes are in a variety of morphologic depressions that appear to be restricted to the polar region. The lakes occur in multiple types of depressions. Some have well-defined circular rims while others are irregular in outline and are bordered by either smooth or rough terrains. The latter appear to be accidental low spots colonized by liquid. The circular features are consistent enough in morphologies that they probably result from a specific process. Here we consider the evidence that at least some of the circular features are volcanic craters; other origins (impact craters, karst) are possible and the structures containing lakes may have multiple origins.

Numbers and Morphologies: We have catalogued 156 lakes in the areas revealed in the T16, T18 & T19 Cassini Radar passes. Of these, ~15 are circular or near-circular and have morphologic characteristics similar to calderas on Earth, Mars and Io. There is no gradation between the roundish structures and the large irregular ones, which we interpret to mean that depressions are not caused by lakes - lakes are opportunistic, occurring in polar depressions of any origin.

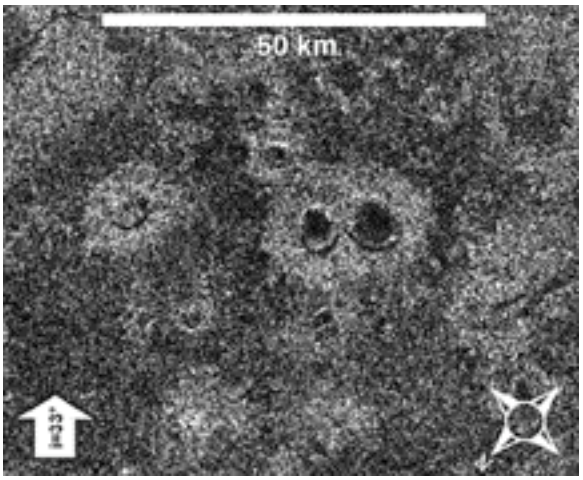

Fig. 1: Circular lakes of possible volcanic origin in 95 km wide piece of T16 swath.

Morphologies of Circular Features: Circular features of possible volcanic origin are illustrated in Fig. 1 from a section of the T16 Radar swath at about 74°N and 119°W. Two roughly circular features, about 8 and 10 km wide, are surrounded by radar bright (rough and/or different composition) halos about as wide as the circular features' diameters. These two structures appear to have rims raised above the surrounding plain, suggesting that they are constructional and not simply collapses.

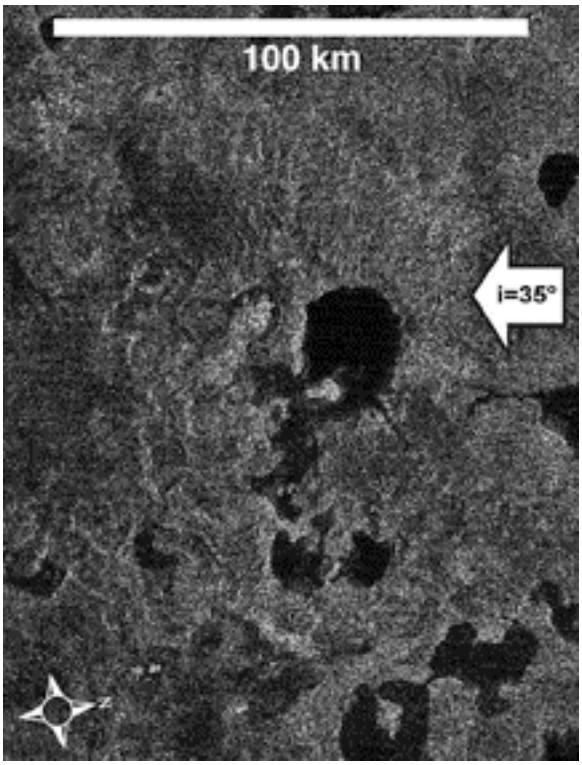

Fig. 2: Circular lakes with radial ridges; smaller circular feature to left contains large bright mountain.

Another circular feature (diameter 30 km; Fig 2) at 73°N and 307°W (T16 swath) appears to have an inner scarp leading from a rim crest to the lake floor. A bright, veri-textured knob on the bottom side of the lake is a high, rough hill. From the rim crest extending ~50 km toward the top of the image is series of radiating ridges. Superimposed on the left flank of this large circular feature is a similar smaller one (10 km) that contains a rough bright central zone that extends beyond the cirucular rim. This dark circular feature is partially surrounded by a ridge-edged deposit. The region around these features includes other circular forms and apparent flow structures. Whatever process formed the features here was very active.

Important evidence relating to the interpretation of circular features is that some are nested, i.e. there are

depressions within depressions. Three dark-floored, roundish features, surrounded by bright halos, occur at 72°N, 353°W (Fig. 3). The left feature is quite circular, includes a bright interior "island" and has a bright, lobe-edged halo. The complex feature at bottom (25 x 15 km) is made up of four to five generally circular, intersecting depressions, with dark lake material partially covering some of their floors. The edge of the lake is very abrupt, suggesting that the liquid is

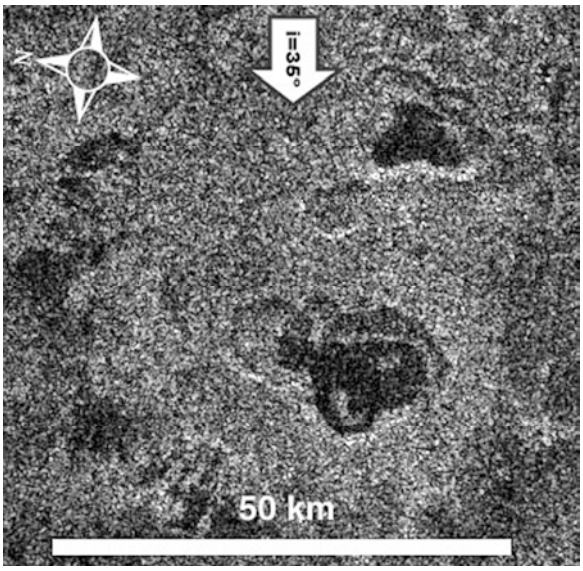

Fig. 3: Circular lakes with nested structure in T16 swath.

constained by topography. The radar illuminated the scene from above and gives the impression of a considerable height difference from the rim to the floor. A second nested structure at top right appears to have resulted from five or more overlapping depressions. Again, a possible radar shadow along the top of the structure demonstrates depth, and a darkening along the structure holding the lake suggests that the lake is contained within another depression.

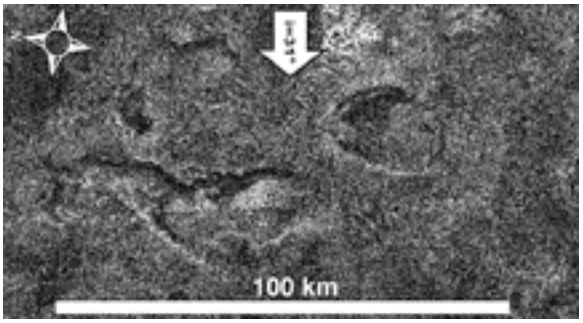

Fig. 4: Irregular and oval depressions in T16.

As these non-circular depressions are often composed of multiple circular elements it is easy to speculate that some of the elongated and less circular features have a similar origin. The area shown in Fig. 4 is adjacent to that of Fig. 3, but one depression has a less regular form and the other is a 27 km long oval. Both appear to have shadow-casting borders.

Discussion: The evidence presented is consistent with these structures being volcanic craters. All are surrounded by bright halos indicating a rough texture, and at least in one case the halo is lobed. These halos could be pyroclastic ejecta or lava flows, the latter interpretation being less likely because of the general evenness of the borders of the halos. It is conceivable that the bright halo is some type of alteration, but that is also unlikely because one halo seems to dam a lake, indicating that it is topographic as well as a brightness boundary. The radial ridges of the feature in Fig 2 also demonstrate both topography and that the ridge material came from the circular area.

The bright (rough) hills within the structures in Fig. 2 – especially the one that extends from the center beyond the rim – may be volcanic flows. Flows associated with two apparent calderas discovered in the Ta Radar swath[2] are also radar bright and have flow morphology.

The two raised rimmed features (Fig. 1) show that in those two cases the circular features are not simply collapses into pre-existing topography. These lips could be constructed of erupted volcanic materials. Most of Titan's circular features do not have observed raised rims, but as they sit at the apex of a bright halo of ejecta which may be the equivalent of a raised rim.

All of these features are depressions, with apparently steep slopes leading from the rims to the floors. This is consistent with volcanic collapse as occurs in calderas and maars.

The nested structures seen in many of the circular features are also characteristic of calderas on Earth, Mars and Io. Each depression represents a separate collapse over a cupola of a magma chamber. As different parts of the chanber rise, ultimately new collapses occur. On Earth, such activity results from the periodic refilling of a chamber from deep source regions. Collapses are caused by eruptions, such as could emplace the bright halos. Nested calderas are indicators of multiple eruptions from a long-lived source region, and are uncommon in landforms other than calderas.

The abundance of likely volcanic calderas in the north polar region of Titan is not matched anywhere else in the 15-20% of Titan seen by Radar. The area of possible calderas is immense and must be due to an unusual tectonic and/or thermal circumstance. Is this region a giant hot spot? And does the presumed volcanism bring abundant volatiles to the surface?

References: [1] Stofan, E. et al. (2007) *Nature, 445, 61-64.* [2] Lopes R.M.C. (in review) *Icarus.*