CRATERIFORM STRUCTURES ON TITAN. C. A. Wood[1], J.I. Lunine[2,3], R.M. Lopes[4], E.R. Stofan[5], K. Mitchell[4]. J. Radebaugh[2]. [1]Planetary Science Institute, 1700 E Ft. Lowell, Tucson, AZ, 85719 and Center for Educational Technologies, Wheeling Jesuit University, Wheeling, WV 26003; chuckwood@cet.edu, [2] Lunar and Planetary Laboratory, University of Arizona, Tucson AZ, 85721. [3]IFSI, INAF, Rome, Italy 00133, [4]Jet Propulsion Laboratory, Pasadena, CA 91109. [5]Proxemy Research, Bowie, MD 20715.

Introduction: Solid bodies in the solar system have surfaces scarred by impact craters unless active processes erase them. The absence of impact craters implies a very youthful and geologically active surface. Applying this standard crater investigation approach to Saturn's moon Titan does not yet yield satisfying results. A major difficulty is that only about 4% of Titan's surface has been revealed by radar's high resolution imaging. Only two impact craters have been convincingly identified, but the fact that these are large raises many questions.

Two Craters: As reported previously [1] the only impact structures convincingly detected on Titan are Sinlap, an 80 km wide crater, lacking central peaks and wall terraces, but having both a dark ejecta wreath and a broader bright zone of possible ejecta. Menrva is a 450 km wide two or more ring impact basin with sharply defined scarps, a smooth inter-ring moat, and a rough central area. Each of these impact structures raises questions. How can Sinlap possess the dark ejecta blanket but have a smooth peak-free floor? Impact craters as large as this have central peaks – or in icy worlds – central pits; why doesn't Sinlap? One possible answer is that it formed with one but the peak/pit has been removed or hidden by erosion or infilling processes. The preservation of the ejecta argues that those processes must have been less effective outside the crater.

Based on experience in the inner solar system the large diameter of Menrva implies that it is ancient. But it is well preserved in places, suggesting that it has somehow been renewed (volcanic resurfacing of moat and recent emplacement of jagged interior?), that erosion is slow on Titan (inconsistent with other evidence), or that Menrva is young – all dubious.

Menrva is large enough that even for a relatively thick 50-km thick crust, breaching and hence some flooding would occur during impact if the mantle immediately under the crust were liquid [2]. The unusual appearance of its floor may be related to this or a subsequent episode of flooding. It is also possible that the odd (and diverse) forms of these craters reflect a non-monotonic variation in the thickness of Titan's rigid crust over time. Recent evolutionary models of the interior predict a crust that thinned early on Titan, becoming thick again only in the last 0.5-1 billion years. [3]. Sinlap might have formed when the crust was thin allowing its central peak to erode, while Menrva may have formed in an ancient thick crust, and was heavily modified as the crust thinned and then rethickened.

Another Impact Crater? On the Ta and T3 radar swaths of Titan there were a handful of small or poorly defined, generally circular objects that might have been formed by impact, but lacked sufficient detail for any meaningful conclusion. The T7 and T8 swaths obtained later in 2005 contain a greater variety of similarly ambiguous crateriform structures, and at least one quite possibly of impact origin.

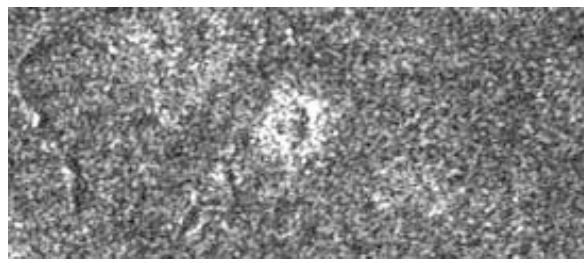
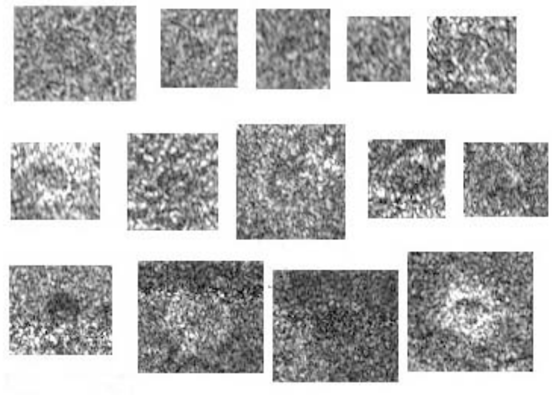


Fig. 1: T7 crater – 3.5 km wide.

The T7 feature shown in fig. 1 is approximately 3.5 km wide with a circular rim - apparently topographically raised - based on its being bright on one side and radar shadow-casting on the opposite. The round feature is surrounded by a radar bright nimbus just as are small youthful impact craters on the Moon. This T7 feature would be interpreted without doubt as an impact crater if it were imaged by radar on Venus or the Moon. The reason for certainty there, but hesitation on Titan, is that those other worlds exhibit a continuum of crater sizes. If one argues that burial by organic aerosols has obscured intermediate-sized craters on Titan (but not Sinlap or Menrva), the T7 feature must be very young (< 1 billion years). It is possible that this feature may have a different origin, but interpretation as an impact crater best matches the morphological evidence.

Dark-Floored Features (DFF): Bright rimmed, dark-floored circular features are common in the T7 swath of Titan (Fig. 2). Their diameters are generally only 5 to 10 km. Each is poorly shown but as a class they are distinctive. The features are quite round and often have narrow bright rims; some have small bright spots on their floors. These may be impact craters that have been weathered. The dark floors (dark = smooth in radar) could be impact melts or volcanic resurfacing. None of the DFF have radiating flow structures expected of volcanoes.

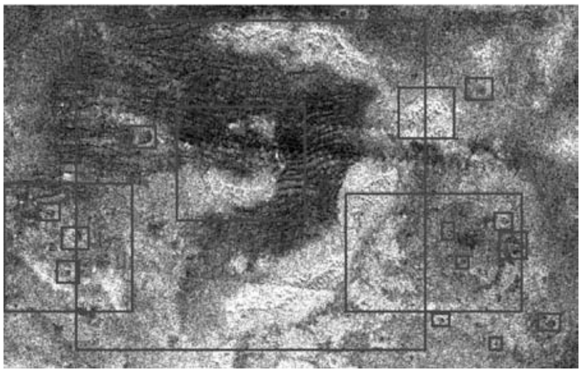
Fig. 2: T7 dark floor features.



Ink Dots: Another class of dark floored rings is abundant in the western end of the T8 swath. These are generally clustered together and are much smaller, typically only 1-2 km wide. Ink Dots appear less likely to be impact craters because of their clustering – they are not secondary craters because there is no apparent primary crater. Ink Dots may be the small end tail of the distribution of DFF.

Bright-Ringed Arcs (BRA): A third type of arcuate to circular feature is common on T8 and other swaths. These typically have broader radar bright rings, often incomplete, and they reach a larger diameter and have a wider range of diameters – 50 to 150 km. The largest square in Fig 3 shows a 140 km wide example with a possible inner ring; the other boxes mark additional circular features of unknown origin. BRA give the impression of being older and more modified than the features in Figure 2. Other than their rough circularity there is little evidence that BRA might be impacts; some may be volcanic calderas.

Fig. 3: Many circular features of unknown origin in T8 including a BRA in the biggest box.



Speculations: Despite the fact that only two impact structures have been convincingly identified on Titan radar images, there is considerable circumstantial evidence for the possible existence of dozens of other impact craters with diameters ranging from one to hundreds of kilometers. Because of the clustering of the Ink Dots they do not seem likely to be of impact origin, but if they (and/or the Dark Floor Features) are impacts their tiny diameters are inconsistent with the theoretical conclusion [ref] that Titan's dense atmosphere would destroy projectiles creating craters smaller than 10-20 km. If they are impacts the theory is flawed or Titan's atmosphere has waxed and waned in density, potentially consistent with an episodic supply of methane to the atmosphere [4].

If the Bright-Ringed Arcs are impact craters why do they look degraded and lack details of impact crater morphology? The answer could be that they are all old and have been significantly eroded or modified. Likewise, if Dark Floor Features are impact craters, why are they limited to diameters < 10 km? Could it be that larger craters present too large a topographic obstruction to the wind-driven deposition of dark sand in the crater floor [5]? And what does a fresh crater look like on Titan, anyway? Or they could be of internal origin. From the existing radar and ISS data we cannot determine their origins.

Even counting all of these suspect features as impact craters Titan has a much younger surface than Rhea - if Titan had the same ancient crater density we should have discovered > 400 in the ~4% imaged by radar. The T7 crater suggests that impact craters are being formed on Titan, but something is destroying or burying them. The existence of two large craters (Sinlap and Menrva) suggests that in some places larger (=older?) craters can be preserved. On Earth we have ancient terrains (shields) that preserve old large craters, and other areas where very dynamic geologic processes rapidly destroy and hide craters. Perhaps Titan is Earth-like in these terms.

References:

[1] Wood, CA. et al. (2005) LPSC XXXVI, abst. 1117. [2] Lunine, J.I. et al. (2005). *LPSC XXXVI*, abst. 1504. [3]. Tobie, G., Lunine, J.I., Sotin, C. (2006). *Nature*, in press. [4] Lorenz, R.D., McKay, C.P. and Lunine, J.I. (1997). *Science 275*, 642-644.
[L4] [5] Lorenz R. et al. (2006), *LPSC XXXVII*, this volume.