IMPACT CRATERING ON TITAN – CASSINI RADAR RESULTS

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Summary: As Cassini SAR imaging coverage of Titan approaches ~20%, a general picture of Titan's cratering style is emerging. Significant differences in style from craters in other satellites are noted in this progress report.

Introduction – Crater Density: If Titan were cratered to the same extent as some other Saturnian satellites (or Ganymede and Callisto), it would have >10,000 impact craters [1] with diameter 20km or more (above the atmospheric shielding threshold below which the differential density would decline). However, even the earliest Cassini data showed a lack of observable craters overall [2,3]. A survey [4] of the first ~10% of Titan's surface imaged by Cassini RADAR finds that the large-crater (>300km) population may be consistent with other Saturnian satellites (figure 1), but there is a striking dearth of medium-sized impacts (e.g. 30-100km dia). Indeed, the slope of the size-frequency distribution is very shallow (~0.5), much like the Earth, suggesting that similar processes may be responsible for the obliteration of the craters. A crater retention age of several hundred Myr (roughly the same as Earth or Venus) is indicated [3,4]. Most impacts and candidate impacts have been observed on the leading face (consistent with synchronous rotation and a leading/trailing asymmetry of impact rate in accordance with models) but sampling bias is present and obvious terrain type differences may yield a longitudinal variation in crater preservation.

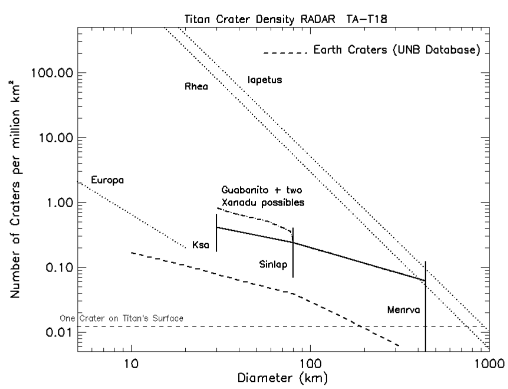

Fig.1 *Titan cumulative size-frequency plot (thick solid line with bars) for TA-T18, compared with Earth, Rhea/Iapetus, and Europa [7]. Some uncertainty (factor ~2) pertains to a number of structures which may or may not be of impact origin, but even taking these into accout, medium-sized craters are a factor of ~100-1000 depleted from what one would expect in the Saturn system.*

So far only 3 impact structures are securely-enough identified to have IAU-approved names (see figure 2) – we discuss these in turn.

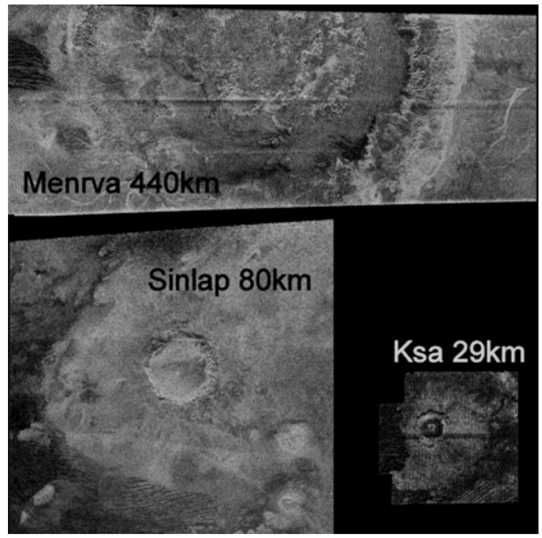

Fig.2 *Montage at same scale of Titan craters . North is up – note the tendency of fluvial channels and Aeolian features to trend eastwards and the better-preserved Eastern rim of Menrva. Near-horizontal stripes across the whole images are radar imaging artifacts. Radar illumination is from above with approximate incidence angles of 21°, 14° and 34° respectively.*

Menrva: This impact basin is centered near 87° W, 19° N and had been noted as a dark annular feature in near-IR imaging [2]. RADAR shows the crater morphology clearly. The outermost edge is 440km in diameter, The steep inner wall is bright, exhibiting numerous radial grooves and chutes, but does not obviously suggest a 'multi-ring impact basin' of the type seen on Ganymede and Callisto for craters of this size. The southern and western regions of the floor are relatively bland, suggesting it may have been flooded. The center of the basin appears elevated and is rough-textured, with bright hummocky hills defining an inner ring about 100 km in diameter. The western rim shows more signs of erosion than the eastern rim. Fluvial features appear to be associated with the basin, but small-scale features in the crater rim and in the central hills are preserved, suggesting that erosion has been rather limited since crater formation. The Cassini RADAR team is presently exploring ways of measuring the topography of Menrva to constrain post-impact modification such as viscous relaxation.

Sinlap : This 80-km crater, at 16° W, 11° N shows no evidence of a raised rim. It appears to be flat-floored, yet craters on Ganymede of this size [5] have domed floors due to viscous relaxation, and central pits, perhaps indicating that their transient cavity came close to a subsurface layer of lower viscosity. There is no indication of such features, nor of a central peak or peak ring. The floor seems flat, similar to some lunar lava-flooded craters or to craters with lacustrine deposits on Mars. Radar geometry gives [6] a crater depth of 1300 ± 200 m for a depth/diameter ratio of ~0.016. This shallowness may be due to the crater being significantly modified by infilling. The crater is asymmetrically surrounded by a blanket of SAR-bright material biased toward the eastern side : the inner part of this blanket has some radial striation. In places it extends more than two crater radii beyond the rim.

Ksa : The T17 flyby in August 2006 showed a 29km diameter crater named Ksa not far from Menrva. Again, this structure shows the recurring pattern of 'intrusion' of aeolian material from the West. A large and sharp-edged ejecta blanket is reminiscent of the fluidized ejecta around many Martian craters, suggesting a significant influence of the atmosphere in constraining the ejecta plume expansion, and the possibility of surface volatiles. In terms of its floor, Ksa is interesting in having a central structure suggestive of a peak ring : evidently 29km is above the transition diameter

Suspiciously-Circular Features and other potential impact structures : A number of circular or near-circular features form bright rings in both radar and optical data – many of these may have an impact origin (e.g. figure 3). The dark floors suggest infilling, perhaps by aeolian sediment – in the case of Guabonito, duneforms are evident.

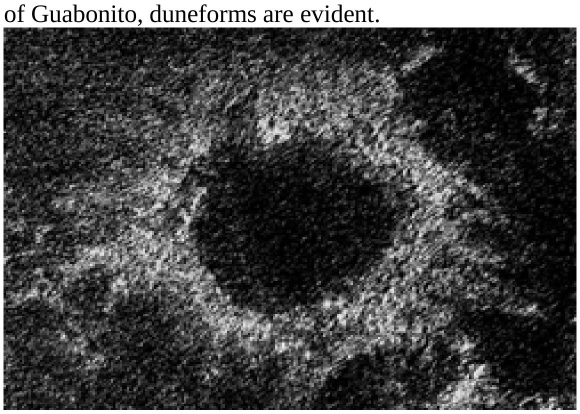

Fig 3. *Unnamed feature, possibly an oblique impact structure observed on T16 – inner part is 65km across, a typical size for 'suspiciously circular features' on Titan.*

The large leading-face bright region Xanadu appears geologically distinct and has a number of likely (but highly degraded) impact structures. Further study of these, and their implications for the age of Xanadu, are under way.

As coverage builds up, a few more 'conventional-looking' impact structures have turned up (e.g. figure 4). The modest resolution of Cassini SAR (300-1000m) makes detailed characterization of small structures difficult, however.

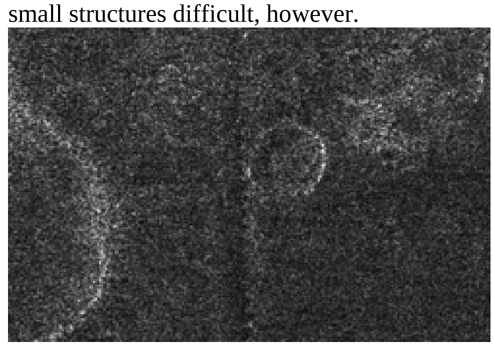

Fig.4 *Unnamed 14km diameter feature, evidently a depression (radar illumination from left) observed on T29.*

Conclusions and Comparisons : As on other bodies, impact craters provide a window into the crustal properties of Titan. Titan's craters are quite distinctive, sometimes having a 'soft' appearance and in many ways, notably in their ejecta and post-impact modification, are more comparable with craters on the terrestrial planets than on other icy satellites.

The lack of observed multi-ring impact structures places some constraint on crustal thickness (i.e. when Menrva formed, the lithosphere was evidently ~50km or more thick). Ongoing Cassini data may shed light on the geographical distribution of craters, and any large-scale variations in crater density or style (e.g. the older but unburied structures seen in Xanadu). Investigations on a future mission might include higher-resolution optical and radar imaging data to permit identification and analysis of smaller craters, together with altimetry to constrain relaxation and subsurface radar sounding to probe structures presently hidden by burial (e.g. does Sinlap have a buried central peak or peak ring?). Such subsurface sounding, as on Mars, may reveal entirely new impact structures beneath the surface of Titan's hydrocarbon lakes and sand seas.

References: [1] Lorenz, R., Planetary and Space Science 45, 1009-1019, 1997 [2] Elachi, C. et al,, Science, 308, 970-974, 2005. [3] Porco, C.C., et al, Nature 434, 159–168, 2005. [4].Lorenz R. D. et al., Geophys. Res. Lett., 34, L07204, doi:10.1029/2006GL028971, 2007. [5] Schenk, P., Journal of Geophysical Research 98, 7475-7498, 1993 [6] Elachi, C., et al., Nature, 441, 709– 713, 2006 [7] Schenk, P. et al., 427-453 in F. Bagenal et al. (eds) Jupiter, CUP, 2004.