CRATER TOPOGRAPHY ON TITAN: IMPLICATIONS FOR LANDSCAPE EVOLUTION. C. D. Neish[1], R. L. Kirk[2], R. D. Lorenz[1], V. J. Bray[3], P. Schenk[4], B. Stiles[5], E. Turtle[1], and the Cassini RADAR Team, [1]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, 20723 (catherine.neish@jhuapl.edu), [2]Astrogeology Science Center, U.S. Geological Survey, Flagstaff, AZ, 86001, [3]The University of Arizona, Tucson, AZ, 85721, [4]Lunar and Planetary Institute, Houston, TX, 77058, [5]Jet Propulsion Laboratory, Pasadena, CA, 91109.

Introduction: Unique among the icy satellites, Titan's surface shows evidence for extensive modification by fluvial and aeolian erosion [1,2,3]. These processes act to change the topography of its surface over time, through fluvial erosion, mass wasting, burial by dunes and submergence in seas. Quantifying the extent of this landscape evolution is difficult, since the original, 'non-eroded' surface topography is generally unknown. However, fresh craters on icy satellites have a well-known shape and morphology, which has been determined from extensive studies on the airless worlds of the outer solar system [4]. By comparing the topography of craters on Titan to similarly sized, pristine analogues on airless bodies, we can obtain one of the few direct measures of the amount of erosion that has occurred on Titan.

Cassini RADAR has imaged > 30% of the surface of Titan at resolutions as high as 350 m. In this data set, more than 60 potential craters have been identified [5,6]. Topographic information for these craters can be obtained from a technique known as 'SARTopo' [7], which estimates surface heights by comparing the calibration of overlapping SAR beams. In a few special cases, depths can also be determined by comparing the foreshortening of the near and far walls, in a technique known as 'autostereo'.

In this work, we present topography data for several craters on Titan. We compare this topography to similarly sized craters on Ganymede, for which topography has been extracted from stereo-derived digital elevation models [8]. Finally, we make inferences regarding the relative amount of landscape degradation that has occurred on Titan due to erosion and infill.

Observations: We plotted the position of the SARTopo data over SAR images of every known crater on Titan with D > 20 km (models predict that these craters will be only minimally disrupted by Titan's thick atmosphere). Of these, six 'certain' or 'nearly certain' craters had overlapping SARTopo coverage. Of the six 'certain' craters, five had topographic profiles broadly consistent with craters of their size on other icy worlds (Fig. 1), including a near-flat profile for the 450 km diameter Menrva. Only Crater #4 from [5] lacked any noticeable topography.

For those craters with recognizable topographic expressions, we calculated the depth of the crater by taking the difference between the highest point on the crater rim and the lowest point on the crater floor. In the case of Crater #4, no obvious craterform was visible in the SARtopo data, although one candidate craterform of depth 280 ± 100 m deep is observed, offset from the crater walls by a few tenths of a degree in the Cassini RADAR image. If this is not the topographic expression of Crater #4, the crater depth appears to be relatively flat, with a depth approaching zero. Given this uncertainty, we assign a depth of 150 ± 150 m to Crater #4.

We also estimated the depth of a ~40 km diameter crater recently discovered in the Titan flyby T77 using the autostereo technique. This crater, recently named Momoy by the IAU WGPSN, has a depth of 680 m, somewhat shallower than the smaller Ksa crater, even though our experience with craters on Ganymede suggests a trend of increasing depth with increasing diameter in this range [8].

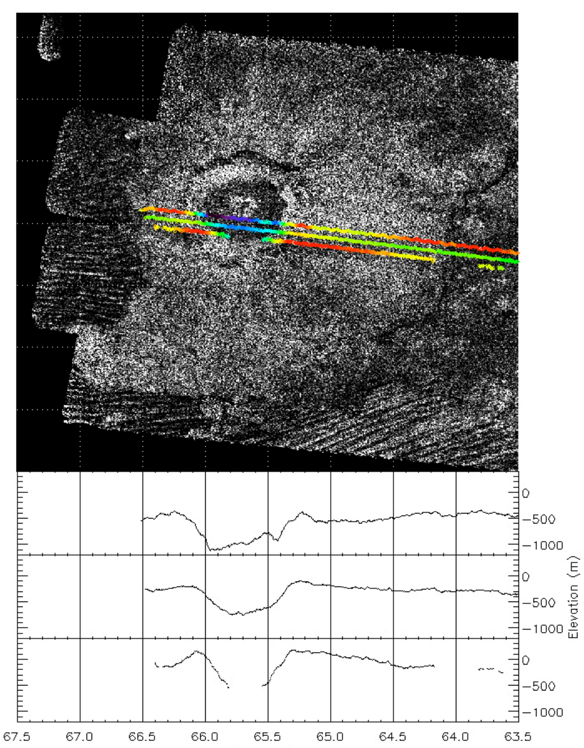

Figure 1: (top) Ksa crater (D ~ 30 km), as viewed by Cassini RADAR. (bottom) Three SARTopo profiles through Ksa crater. The position of the profile is shown in the RADAR image above.

Discussion: Topography data was acquired for seven craters on Titan. We compared these depths to similarly sized craters on Ganymede, and found that the depths of Titan craters are generally within the range observed on Ganymede, but several hundreds of meters shallower than the average depth (Fig. 2).

Given this data, we evaluated the likelihood that the crater depths on Titan represent fresh Ganymede craters that have been altered by erosional infilling using the Anderson-Darling goodness-of-fit technique. Using this method, we evaluated two different null hypotheses. Hypothesis 1 states that Titan craters were selected from the depth distribution of fresh craters on Ganymede. This hypothesis has a significance of only P = 0.029 if you consider the five craters with 'recognizable' craterforms; this significance drops to zero if we include Crater #4 (since no known fresh crater on Ganymede with D > 20 km has a depth less than ~ 500 m). Hypothesis 2 states that the relative depths of Titan craters are uniformly distributed between 0 (fresh) and 1 (completely infilled). Here, the relative depth, R, is given by $R(D) = 1 - d_t(D)/d_g(D)$, where $d_t(D)$ is the depth of a diameter D crater on Titan, and $d_g(D)$ is the depth of a diameter D crater on Ganymede, calculated from the empirical relation for d/D determined by [8]. This hypothesis has a much higher significance than Hypothesis 1, P = 0.83. Note that a high P value means that it is not unexpected to get the observed result if the null hypothesis is true, and a low P value means that the data indicate a significant contradiction to the null hypothesis being tested.

Given this information, we judge that it is quite unlikely that Titan craters come from the same depth population as fresh Ganymede craters. Furthermore, a uniform distribution of relative depths between 0 and 1 suggests an infilling process that varies linearly with time. Forsberg-Taylor *et al*. [9] studied landscape evolution on Mars, and found that aeolian infill varies linearly with time, whereas fluvial modification has an infilling rate that diminishes with time.

We cannot discount the possibility that the craters on Titan have been subject to some amount of viscous relaxation that has reduced their depths. Viscous relaxation is a process that has shaped crater topography on Ganymede, as well as other icy satellites [10]. Craters > 10 km in diameter on Ganymede show a range of relaxation states, from fresh craters to craters with more subdued topography and upbowed floors. However, given its lower surface temperature (95 K vs. 120 K), viscous relaxation is predicted to cause less than a 1% change in topography for craters with D < 100 km on Titan [11]. This would suggest that viscous relaxation is not an important mechanism for modification of most craters on Titan. However, these models assume a water ice rheologic law and thus could be irrelevant if the crustal rheology is significantly different because of the presence of other materials such as organic compounds.

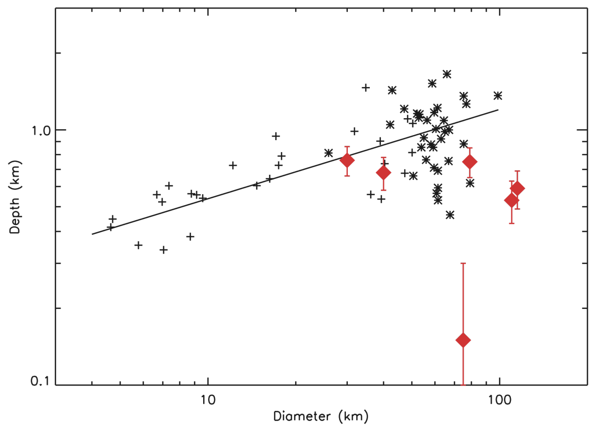

Figure 2: Depth of craters on Titan (red diamonds) compared to similarly sized, fresh craters on Ganymede (central peaks, +; central pits, *) from [8].

Summary: We present the most up-to-date set of topography measurements for craters on Titan. In general, the depths of Titan craters are within the range of crater depths observed on Ganymede, but several hundreds of meters shallower than the average depth. We find that it is extremely unlikely that Titan's craters were selected from the depth distribution of fresh craters on Ganymede, and that it is much more probable that the relative depths of Titan's craters are uniformly distributed between 0 (fresh) and 1 (completely infilled). This is consistent with an infilling process that varies linearly with time, such as aeolian infilling. Assuming that Ganymede represents a close 'airless' analogue to Titan, the difference in depths represents the first quantitative measure of the amount of infill that has shaped Titan's surface, the only body in the outer solar system with extensive surface-atmosphere exchange.

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