GEOMORPHOLOGIC MAP OF TITAN'S POLAR TERRAINS.

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Introduction: Titan's lakes, seas and surrounding hillslopes contain vast amounts of information regarding the history and evolution of Saturn's largest moon. With an atmospheric pressure at the surface of 1.5 bars and a surface temperature of 91-95 K, methane and ethane are both able to condense out of the atmosphere and rain to the surface [1], where the fluid runoff concentrates, incises channels and transports sediment [2]. Landforms common to Earth are found across Titan, and include lakes and seas [3], river valleys [4], fans and deltas [5] and mountains [6]. Yet under Titan conditions, these familiar landforms have all formed and evolved under vastly different environmental and physical conditions from Earth. Of particular interest are the fluvial and lacustrine features clustered in Titan's polar regions, features not found elsewhere in the Solar System. To understand this landscape, we have created a geomorphologic map. We then use the relative elevations of the mapped geomorphological units and their contact relationships to suggest possible stratigraphic relationships that might form the basis for a geological model.

Methodology: Our geomorphologic maps (Figure 1) are centered about Titan's polar regions at latitudes greater than ±60°. We use a combination of the Cassini SAR images along with topographic data in the form of SARTopo [7], altimetry [8] and sparsely distributed Digital Terrain Models [9]. All of our mapping is carried out using the ArcGIS™ cartography software where we were able to combine individual, rasterized SAR swaths with the topographic information, using a polar stereographic projection. Mapping uses the incidence angle corrected SAR swaths so as to minimize any geometric variations, giving us as consistent a dataset as possible. After defining our geomorphologic units, mapping is conducted systematically at a scale of 1:200,000.

Morphological units and interpretation: In areas with a high coverage of topographic data, we define five bulk geomorphologic units as: mountains & SAR-bright dissected terrains, dissected uplands, mottled plains, uniform plains, and superposed units. These units are subdivided according to their morphology, topography, and degree of desiccation

Mountains & SAR-Bright Dissected Terrains: These two units are mapped as distinct units because of their differences in topographic relief. Yet the similarity in morphology, dark appearance in ISS images, and altimetry backscattering suggest a similar formation and water ice-rich composition. Across the poles, we see plains units at higher elevations than the SAR-Bright Dissected Terrains, which suggests a mantling of the plains units on top. In many locations, it appears that the SAR-Bright Dissected Terrains are outcropping from the plains units, appearing as exposed regions of the underlying bedrock

Dissected Uplands: These scarp-bounded units are highly dissected, with a higher channel density than the lower-lying plains. The dissected uplands (both SAR-bright and dark) are topographically emplaced lower than the mountains, though stratigraphically, they are younger, situated above the mountains. The defining characteristic of the dissected uplands is their backscattering behavior at nadir. With altimetry data, we find that the scattering is not dominated by roughness, but instead may be the result of a different composition or subsurface structure that causes absorption at all incidence angles

Mottled Plains: Mottled plains have a radar signature that can be highly variable. Topographically, this unit varies in elevation though always situated below the mountains and the dissected uplands. Most often, these plains are in contact with the dissected uplands.

Uniform Plains: There are four types of plains units in our mapping. Elevated, SAR-dark plains contain the majority of the empty and filled lake depressions on Titan, suggesting that their composition is conducive to the formation of these features. A topographically low counterpart of these dark plains borders the large seas and contains canyons. A third plains unit appears exceptionally dark, interpreted to be locations where liquids are ponded at or near the surface. The fourth plains unit appear SAR-bright. This terrain unit is distinctively SAR-bright, with a uniform radar signature at our mapping resolution, lacking any discernible valley networks.

Superposed Units: Superposed units include filled and empty lakes, alluvial fans, fluvial valleys, and filled and empty seas.

Interpreted geologic history. Despite the difference in the distribution of lake depressions and seas [10], Titan's north and south polar regions have similar morphologies. Accordingly, we propose that the processes that formed their surfaces were similar. Uniform, SAR-dark plains are interpreted as sedimentary deposits that themselves are bounded by moderately dissected uplands. These plains contain the highest density of filled and empty lake depressions, and canyons. These units overlay, unconformably, a basement rock that outcrops as mountains and SAR-bright dissected terrains at various elevations across both poles. All these units are then superposed by surficial plains units that slope towards the seas, suggestive of subsequent overland transport of sediment. From the depths of the embedded empty depressions and canyons, the thicknesses of all of the SAR-dark plains can be up to 600 m. However, the true thickness of these deposits likely varies across the poles. At the lowest elevations of each polar region, there are large seas, which are currently liquid methane/ethane filled at the north and empty at the south. Using the relative elevations of units, we suggest a possible stratigraphic relationship where upon there was sedimentation in putative polar oceans. Sedimentation was subsequently followed by erosion and redistribution of those sediments within the polar regions of Titan. Formed over multiple time scales, the now dissected sedimentary units would have formed as layered sedimentary deposits. Coupled with vertical crustal movements, the resulting layers would be of varying solubilities and rheologies, resulting in the complex landscape that we observe.

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References: [1] Atreya, S.K. et al. (2006) *Planet Space Sci., 54*, 1177-1187. [2] Burr, D.M. et al. (2006) *Icarus*, *281*, 235-242. [3] Hayes, A.G. et al. (2008) *JGR, 35*, L09204. [4] Burr D.M. et al. (2013) *GSA Bulletin*, *125*, 299-321. [4] Birch, S.P.D. et al. (2016) *Icarus*, *270*, 238-247. [6] Radebaugh, J. et al. (2007) *Icarus*, *192*, 77-91. [7] Stiles, B.W. et al. (2009) *Icarus*, *202*, 584-598. [8] Zebker, H.A. et al. (2009) *Icarus*, *200*, 240-255. [9] Kirk, R.L. et al. (2012) *LPSC XLIII, Abstract #2759*. [10] Aharonson, O. et al. (2009) *Nat. Geosci.*, *2*, 851-854.

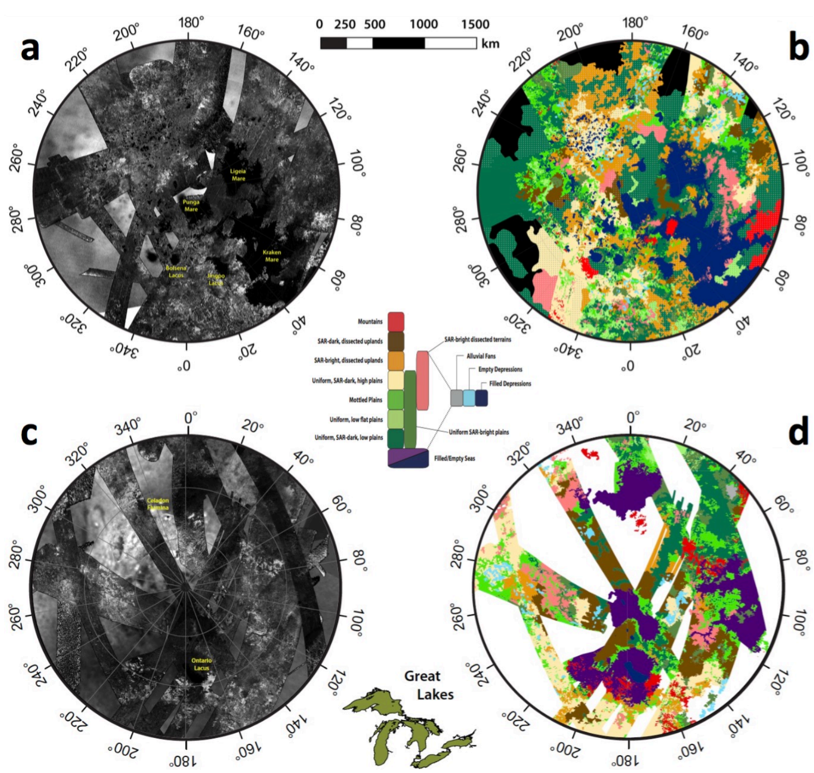

Figure 1 – Image in the center is a topographic legend of our mapped units with their unit names shown. Colors of the units match those shown for the units in the maps (b/d) Units at the top of the column have higher relief. The Great Lakes are also shown for scale; Top (a/b) SAR mosaic centered on the north pole (a) and our corresponding geomorphologic map (b). The five largest liquid bodies in the North are labeled in yellow; Bottom (c/d) SAR mosaic centered on the south pole (c) with the corresponding map on the right (d). Ontario Lacus and Celadon Flumina are labeled.