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Constraining the Evolution of Titan's North Polar Landscape

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Abstract

The longevity of the Cassini mission, which has been orbiting the Saturn system since 2004, has started to permit the generation of novel data products that utilize overlapping radar observations of Titan. Repeat observations allow investigations of temporal change, surface properties via microwave backscatter modelling at SAR resolution, and the generation of digital terrain models (DTMs). We will utilize these capabilities to discuss constraints on the evolution of Titan's North Polar Landscape. Discussion will include (1) implications of the absence of observed temporal change in Northern lakes, (2) morphologic evidence for dynamic base level changes separated by intermittent periods of quiescence, (3) topographically closed depressions that imply karstic collapse and/or dissolution processes, and (4) the identification of a regionally common elevation amongst the floors of paleolake basins and shorelines of Kraken, Ligeia, and Punga Mare.

1. Absence of Observed Change

Titan's Lakes [1,2] are found poleward of ~60° latitude and encompass 1.2% of Titan's surface that has been observed by Cassini SAR [3]. Lacustrine features are predominantly found in the North, encompassing 11% vs. 0.5% of the observed area poleward of 55°, respectively. This asymmetry has been attributed to the eccentricity and longitude of perihelion of Saturn's orbit, which results in higher peak solar insolation during Southern vs. Northern summer [4]. North Polar Lakes have been observed in SAR passes acquired between July 2006 (T16) and Sep. 2012 (T86). This dataset includes repeat observations of individual lakes with baselines of up to 5.6 years. Thus far, this dataset has shown no evidence for unambiguous surface change (Fig.1) [5,6], consistent with GCM predictions of little precipitation and/or evaporation in the north during fall and winter [7,8]. These same models, however, predict an increase in precipitation as Titan enters northern spring and summer [7,8]. If correct, polar observations acquired during Cassini's solstice mission, such as T91 & T92 in summer 2013, may observe temporal change in the north.

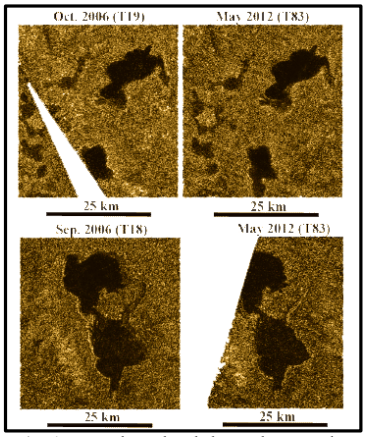

Fig 1: North polar lakes observed in SAR passes acquired in Sep/Oct. 2006 (T18/T19) and May 2012

2. Drowned River Valleys

The largest lakes, or seas, in the north, consisting of Ligeia, Kraken and Punga Mare, have shorelines that include shallow bays with well-developed drowned river valleys (Fig. 2) [1]. Such drowned valleys indicate that once well-drained upland landscapes have become swamped by rising fluid levels where sedimentation is not keeping pace with a rising base level. These features also imply that liquid levels were previously lower and stable long enough to allow the currently drowned networks to be incised into the terrain. In contrast the largest southern lake, Ontario Lacus, expresses depositional morphologies along its western shoreline that include lobate structures interpreted as abandoned deltas [9,10].

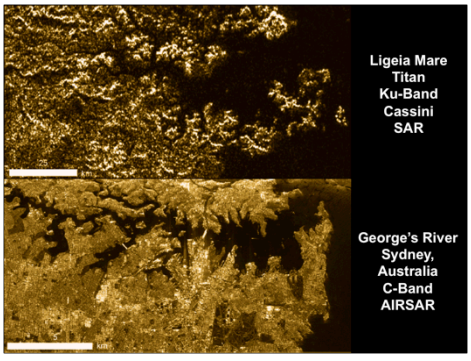

Fig 2: Drowned river valleys on Titan and Earth.

3. Closed Depressions

North Polar DTMs reveal a landscape dominated by variously shaped closed depressions or valleys bordered by uplands that include seemingly planar plateaus (Fig. 3). These closed-form depressions lack the outflow channels required of fluvial activity, requiring alternative erosional mechanisms. The depressions are conical and suggest removal of material by collapse or dissolution (e.g., karstic processes).

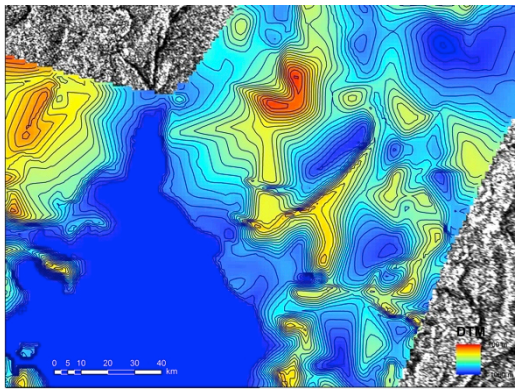

Fig 3: DTM showing region adjacent to the south eastern shore of Ligeia Mare. Contours represent 50 m elevation internavals. Note the closed-form depressions.

4. Paleolake basin elevations

The bright lake features identified by Hayes et al. 2008 are relatively steep-sided, flat-floored, basins hundreds of meters in depth [3] with compositionally distinct floor deposits interpreted by Barnes et al. 2011 as hydrocarbon evaporites. These features have been interpreted as paleolake basins [3]. Twelve of these paleolakes are found within the confines of the current topographic coverage near Titan's large seas (Fig 4). Initial topographic analysis indicates that, while the relative depth of these feature ranges from 250 – 850 m, the absolute elevation of their floors are consistent with the shoreline elevations of Kraken, Ligeia, and Punga Mare. This suggests the presence of a boundary, such as an impermeably stratum or subsurface alkanofer, that governs absolute basin depth. The absence of shallower paleobasins in this region implies that the dissection mechanisms that expose these depressions operate on faster timescales than the changes in boundary level (e.g., liquid level if the boundary is a subsurface alkanofer).

References

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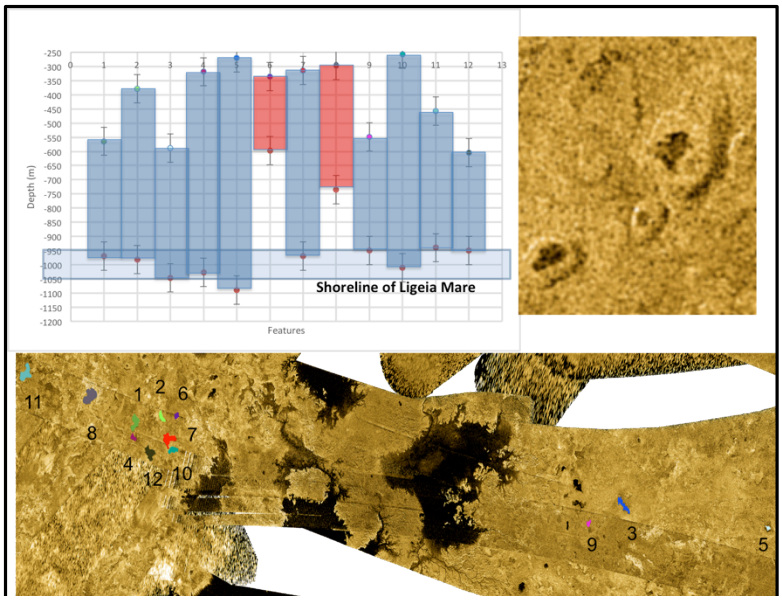

Fig 4: Topographic analysis of paleolake basins on Titan.

Upper Left: Rim and floor elevations for 12 paleolake features within available north polar DTMs. Rim elevations and depths vary by hundreds of meters while the floor elevations are within 100 m of Ligeia Mare's shoreline elevation. The two red outliers are at the edge of DTM coverage. One may also not represent a paleolake basin, as it is nestled within mountainous terrain.

Upper Right: Example of three paleolake basins with potential liquid deposits in their deepest parts, consistent with the idea that deeper basins represent current lakes.

Bottom: Polar map showing the location of investigated features.