MORPHOLOGIC EVIDENCE THAT TITAN'S SOUTHERN HEMISPHERE BASINS ARE PALEOSEAS.

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Introduction: Titan is the only body in the solar system, besides the Earth, known to currently have standing bodies of liquid on its surface. The distribution of liquids on Titan though is not uniform, as nearly all of these liquids reside in high northern latitude lakes and seas [1]. Croll-Milankovitch cycles, where the apsidal precession of Titan's obliquity over 100,000 year cycles forces liquids from pole-to-pole, have been invoked as a physically plausible mechanism to account for the dichotomy [2]. However, such a model requires the presence of large basins that are able to accommodate ~70,000 km^3 of liquid methane and ethane [3]. Our study identifies four large basins that show evidence for being formerly liquid filled. These basins are also able to accommodate the volume of north polar liquids.

Basin Morphologies: The south polar region of Titan is characterized by four large, SAR-dark basins (Fig. 1). The area of the southern basins is similar to the area of the northern, liquid-filled seas (South: $6{:}26 \times 10^5$ km^2, North: 6.79×10^5 km^2; Hayes 2016 [3]), suggesting that the southern basins may have also been liquid-filled. Below we discuss the morphology of each basin:

Ontario Basin (Fig. 1a): The Ontario basin is the most prominent basin at the south, having the well-studied Ontario Lacus (e.g., [4], [5], [6], [7], [8]) situated at the basin's lowest topographic point. On the southern border of the basin, crenulated terrains show evidence for high levels of fluvial dissection, and sediment transport processes. This perimeter forms an outer ring around the basin. We interpret this ring to be the location of a former shoreline when liquid levels in the past were higher. On the northern half of the border are mountainous terrains that enclose the remainder of the basin. These mountains are likely water-ice rich [1] and they have high relief (~600 m).

Bounded within the crenulated and mountainous perimeter is a SAR-dark, low sloping plain. This plain surrounds the largest south polar lake, Ontario Lacus. The western half of Ontario Lacus itself is much less smooth. This roughness can be attributed to what appears to be a depositional environment. Evidence for deposition occurs in the form of two abandoned deltas [9] and numerous through-flowing channels.

The Ontario basin, however, is not the lowest topographically of the four southern basins. Instead, the lowest point resides in the Romo Basin near the geographic South Pole. To first order, it is expected that we should find the liquids at the lowest elevations, as liquids should migrate to the lowest gravitational potential over geologic time scales. Over shorter time scales, liquids may reside in higher elevations for two reasons. First, an impermeable boundary separating the basins would allow for the collection and sustained presence of liquids in a topographically elevated region. An alternative, yet parallel, scenario can be imagined where the boundary has low permeability and there is a dynamic equilibrium between the rates of recharge and discharge from the basin.

Romo Basin (Fig. 1b): Located around the geographic south pole, Romo Planitia is another prominent feature of Titan's south polar terrain. Romo Planitia is a SAR-dark plain that is enclosed within a topographic low basin, and is bounded by crenulated terrains on nearly all sides. The only region of the basin perimeter that is not crenulated terrain instead has high relief labyrinthic terrain (top of Figure 1b; ~700 m above the surrounding plains) marking the perimeter. Tracing through the labyrinthic terrains are channel features that progress to the lowest point of the basin. At these lowest

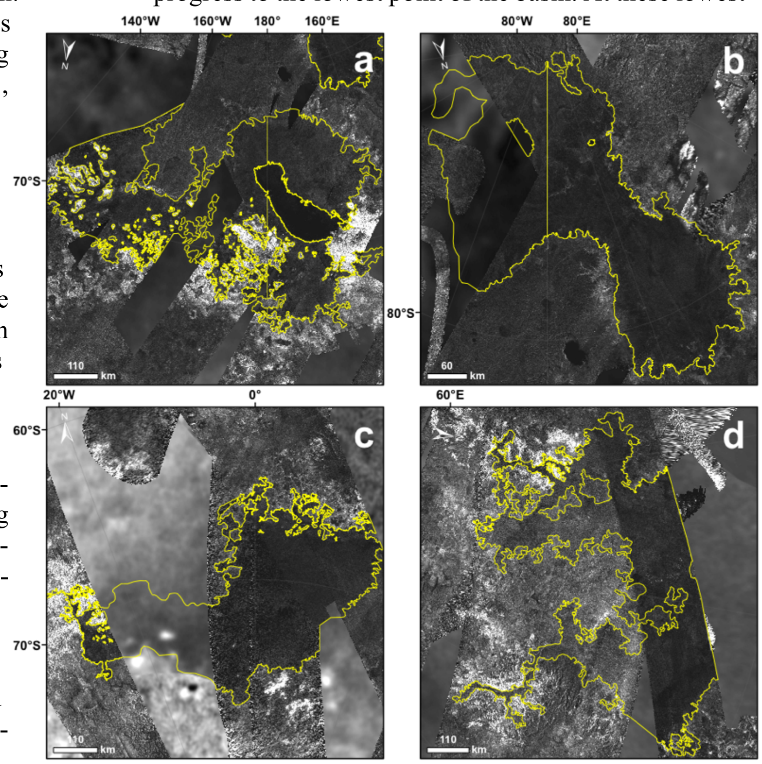

Figure 1 – Four basins, outlined in yellow, in Titan's south polar region we identify as paleoseas. Coordinates range from 180°W to 180°E; a: Ontario Basin; b: Romo Basin; c: Rossak Basin; d: Buzzell Basin.

elevations, two small lake features are found (Tsomgo Lacus & Kayangan Lacus). The Romo basin is the smallest of the four basins that we identify.

Evidence is also found for a lowering liquid levels in the Romo basin along the eastern border. SAR-bright channel features that dissect the surrounding, elevated terrain mark this region. The higher standing terrain also appears tilted away from the basin in topographic data. We interpret these features to represent channels that have incised up an exposed cliff face.

Rossak Basin (Fig. 1c): The Rossak basin is distinctive in that it is floored by both a uniform, SAR-dark plain (named Rossak Planitia) in SAR imagery, and a similarly low-albedo plain in ISS data. Along its borders in SAR data are crenulated and mountainous terrains, much like the Ontario basin. Further, like the other basins, the Rossak basin occupies a topographic low. The basin also has large drainage networks that terminate onto a broad plain, just beyond the crenulated terrain borders. The eastern and western halves of the Rossak basin are well imaged in SAR, while ISS data show that the two halves are clearly connected. On the eastern half of the Rossak basin, the shoreline is also visible in what appears to be previously drowned topography. This shoreline is somewhat dierent from the more crenulated shorelines of the Ontario and Romo basins, but similar to the southern shoreline of Punga Mare at Titan's north pole.

Buzzell Basin (Fig. 1d): The final basin identied in our study is an unnamed region centered at 65^oS that we refer to as Buzzell Basin, after it's defining feature, Buzzell Planitia. This basin is the largest, and most southern of all the basins, though at similar latitudes as the Ontario and Rossak Basins. Like the rest of the basins, Buzzell Basin resides in a topographic low, though unlike the others, we are unable to determine if the basin is completely closed. Only the most southern parts of the basin have been imaged in SAR, while the signature in ISS data is less clear than others like Rossak. We therefore, are unable to constrain the full areal coverage of the basin and how far southward it may extend.

Volumes: For the four features we identify to be paleoseas, there must be sufficient accommodation space for the ~70,000 km^3 volume of northern liquids. As we do not know the volumes of any subsurface liquid reservoirs [10], we use only the measured volumes of the northern seas [3]. With an updated topographic model of Titan (see abstract #2703, this meeting) we filled in the four basins, ignoring any regions outside the basins themselves (Figure 2a). As such regions may also store liquids, by not including them in our calculation, the fractional fill state we calculate is an upper limit.

To calculate the fill state of the four basins, we discretized the topographic data into 1^ox1^o bins and then iteratively filled the basins with 70,000 km^3 of liquids, starting from the lowest data point (until the total volume was reached. This resulted in the liquids filling up 71% of the basins (Figure 2b), implying that there is sufficient space for the northern liquids.

Summary: While morphologic and topographic data support the four basins we identify having been formly filled seas, compositional data suggest otherwise. Specifically, there is no 5 μm-bright material, interpreted as evaporite, identified in the proximity of these basins [10]. If the seas were formerly filled as the northern empty lakes and Tui Regio and Hotei Regio lake basins were interpreted to have been [10], then we should expect to find similar 5 μm-bright deposits in our southern basins. If our analysis is correct, then there must be some mechanism to mask a surficial coating of evaporite material, either by erosional mechanisms or by burial. As the time scale that determines the presence or absence of liquids in a given hemisphere is ~100,000 years, it can thus be expected that significant erosion/deposition of materials has occurred and any large 5 μm-bright deposits are hidden from our view today.

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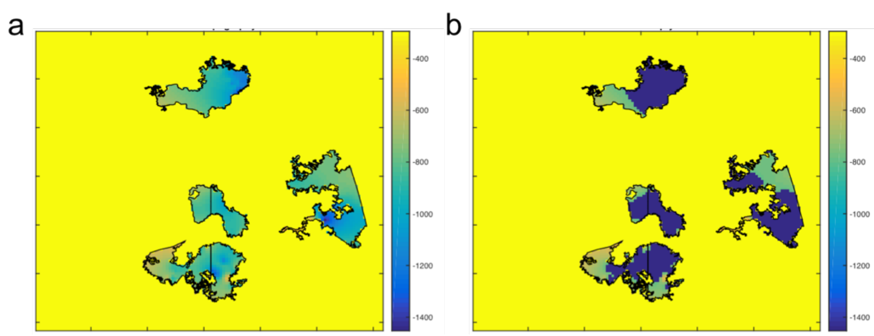

Figure 2 – a: Masked topography where we only consider data inside the four basins; b: Fill state, using 70,000 km^3 of liquids, is 71%. Regions in dark blue represent areas covered by liquids if the volume of the northern seas resided at the south.