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Lakes, Seas, Mountains and Volcanoes on Titan: Implications for Geologic History

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Abstract

The surface of Titan exhibits abundant evidence for erosional and depositional processes, with bodies of liquid hydrocarbons at both poles. While the portion of Titan's geologic history that we can access through its current surface is dominated by exogenic processes, remnant mountains and a few cryovolcanic features hint at a more endogenic past.

1. Introduction

The geologic histories of planets can be described as a combination of exogenic and endogenic processes: tectonism and volcanism driven by interior dynamics combined with atmospheric processes causing surface modification through erosion and deposition. Venus is at the endogenic end of the spectrum with a volcanism-dominated surface with scattered dunes indicating low rates of erosion and re-deposition of material. Mars has had more of an Earth-like history, with a balance of endogenic and exogenic processes, although it is now dominated by aeolian processes. The Cassini mission has revealed Titan to be a world with extensive equatorial dune fields [1], polar lakes and seas [2, 3] and little tectonic or volcanic activity (e.g., 4).

The lakes and seas of Titan allow lacustrine and marine processes to be studied on another world. Our ability to constrain these processes is somewhat limited, given the remote nature of Cassini's observations. The distribution of volcanic and tectonic features and their relative ages are critical to understanding the interior evolution of Titan.

2. Lacustrine and Marine Processes

Lakes on Titan, ranging in size from a few km to tens of kilometers across, occur mostly at the north pole, with only a few found at the south pole. Small lakes have also been possibly detected by the Cassini VIMS in the equatorial region [5]. Most of the lakes are approximately circular, suggesting formation by surface collapse, although a volcanic origin for some lake basins has been suggested [6]. Lakes range from full and fed at least in part by surface runoff to partially filled or empty [3]. Empty lakes are common further from the pole, consistent with the increasing instability of methane at the surface towards the equator. However, no clear example of empty lakes can be seen equator-ward of ~60°. Ontario Lacus (73°S, 175°E) shows evidence of possible shoreline modification by wave action, as well as a modified delta [7]. Debate over whether Ontario exhibits evidence of evaporation over the Cassini mission (e.g., 8) illustrates the limits of current datasets. Microwave absorption indicates that depths of lakes in some places exceeds ~6 m [9, 10], but in other places lakes are shallow or are mudflats [8,10].

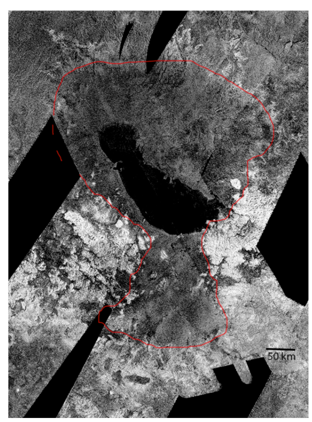

Figure 1. Ontario Lacus with possible remnant shoreline outlined in red.

Titan's three seas (Ligeia, Punga and Kraken Maria) have maximum dimensions in excess of 350 km, and large radar-dark regions indicate depths > 10 m. Waves have yet to be detected in seas on Titan, although changing conditions make them more likely before the end of the Cassini mission [11; Lorenz et al., this meeting]. Shorelines at Ligeia resemble terrestrial ria coastlines, indicating a current high sea level. No evidence of a change in sea level has been observed at the northern seas [10,12]. Possible remnant seas have been identified in the south polar region (Figure 1), consistent with the predicted long-term transfer of methane from pole to pole, in a cycle similar to the Kroll-Milankovich cycle [13]. Examination of these putative empty sea basins suggests that the northern seas are relatively flat floored, less than a few hundred meters deep, and maintain a relatively stable shoreline for a long period of time. Given that Ontario Lacus sits in one of the remnant basins, sea liquids on Titan may persist for hundreds of thousands of years.

3. Endogenic Processes

Lopes et al. [4] described the distribution of a hill unit found in small patches all over Titan, possibly indicating more extensive tectonic activity in the past. No evidence has been found for any recent tectonic activity. However, the identification of rectilinear channel networks near Titan's north pole and equator suggests possible tectonic control [14].

Evidence for volcanism on Titan is best seen at two features: Sotra Facula and Hotei Regio [15]. Most of the likely volcanic features are located in the equatorial region, near Xanadu, although it has been suggested that some lake basins in the north could be cryovolcanic in origin [6]. The origin of the plains that make up much of the surface of Titan, generally broad and featureless [4], is unknown, but could represent extensive cryovolcanic deposits similar to plains on other planets whose surface morphology has been obscured by later erosion and deposition.

4. Summary and Conclusions

Titan is the only body besides Earth in our solar system where active lacustrine and marine processes are observed. The distribution, liquid nature and current calm state of the lakes and seas has been determined with Cassini data. Future in situ missions to these targets are needed, as interchange processes between the atmosphere and lakes and seas cannot be determined remotely, nor can the potential astrobiological implications of these features be assessed**.** Future remote observations can be used to better determine the extent of volcanic processes on Titan.

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