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The raised ramparts around Titan's northern lakes

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Abstract

We investigate the spectral characteristics of a selection of Titan's small northern lakes that have raised ramparts around their perimeters using Cassini Visual and Infrared Mapping Spectrometer (VIMS) and RADAR data. Ramparts (which are distinct from raised rims) are radar-bright mounds that extend from the shores of some lakes out for up to tens of kilometers. We performed a comparative spectral analysis among the lakes, their ramparts, and the surrounding regions. We overcome the profound difference in spatial resolution between VIMS and SAR data by using a method that provides overlays between the spectral images and SAR, thus enabling the correct selection of VIMS pixels. The surface properties of the selected areas are obtained using a radiative transfer analysis on the selected VIMS pixels, in addition to emissivity obtained from the RADAR in radiometry mode. Analysis of these combined and co-registered data provides new constraints for the formation mechanism(s) of raised ramparts observed around a subset of Titan's northern lakes. The results show that the microwave emissivity of the raised ramparts is close to that of Titan's labyrinthic terrains and to that of empty lake floors in the northern polar regions. The infrared analysis also shows that the spectral response of the raised ramparts is very similar to that of some empty lake floors. This suggests that both areas are made from or are covered by a similar material. In addition, two out of the eight lakes with raised ramparts show spectral differences at three specific wavelengths, 1.6, 2.0, and 5.0 µm, between the ramparts and the surrounding terrain. We hypothesize that this could be due to some component, or mixture of components, in the ramparts that is less absorbent at these specific wavelengths, or it could be an effect of different grain sizes. A number of theories for the formation of the raised ramparts are discussed.

1. Context/Data

Cassini observations of Titan have revealed ~650 polar lakes (lacus) and seas (mare), with more than 200 being empty and more than 300 filled or partially filled [e.g. 1]. Most of Titan's smaller lakes are characterized as sharp-edged depressions (SEDs), which appear either empty or filled, and have been extensively discussed [2;3]. These studies showed that the SEDs have relatively flat floors and significant depths (up to 600 m), and are partly or wholly encircled by narrow (typically ~1 km or less extending from the lake edge), hundred-meter-high rims. A small subset of the north polar SEDs (<10) also show raised rampart features (Fig. 1). Rampart features are defined as SAR-bright, mound-like annuli extending away from the lake for up to tens of kilometers from the shoreline. The formation of the ramparts around a subset of the lakes is similarly unconstrained. As these lakes are unique among Titan's many polar lakes, these ramparts may yield important clues to the formation of Titan's lakes more generally. In this study we focus on eight lakes (5 filled, 3 empty) using both VIMS and RADAR data (Fig. 1).

2. Methods

To maximize the information we can obtain from the Cassini VIMS and SAR data, we overlaid the SAR and VIMS images following a method described in [4]. This allows us to extract the morphological information from SAR images and the spectral information from VIMS data. To derive spectral information for the lakes of interest, we analyzed the VIMS data using specific tools. We use a radiative transfer (RT) code for which the methodology and several applications on VIMS are presented in [4;5;6;7]. In brief, we can estimate the atmospheric contribution to the VIMS data and extract meaningful surface information using Huygens's inputs and other parameters that simulate

Titan's conditions. In addition, when the Cassini RADAR operated as a radiometer at 2.2-cm wavelength [8], it measured the thermal emission from the surface, which depends on the surface's physical temperature and emissivity at 2.2 cm. Here, we took into account the emissivity of four raised rampart areas.

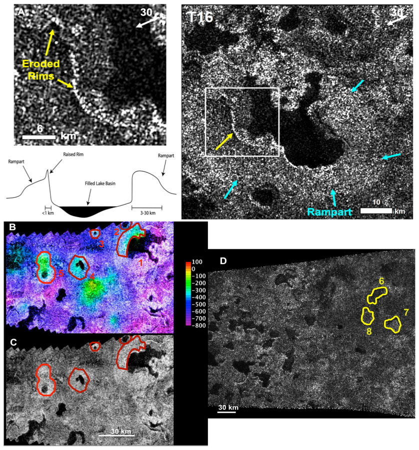

Fig. 1. Filled lakes with a subset that show ramparts and empty lakes: (A) T16 SAR image of Viedma Lacus. Cyan arrows denote the rampart feature, Yellow arrows denote portions of the raised rim. Bottom Left: Conceptual model of a lake with a rampart and rim (not to scale). (B, C) Detailed view of topography and SAR, ramparts marked with red lines; (D) SAR image of empty lakes (marked with yellow).

3. Results

We have investigated five northern filled lake regions with raised ramparts and three empty lakes from a nearby region, extracting spectral and emissivity information from Cassini VIMS and RADAR data.

After radiative transfer analysis of VIMS data, two out of five examined filled lake regions showed spectral differences at specific wavelengths (1.6, 2, and 5μm) between the lakes, their raised ramparts, and their surroundings. This suggests either a compositional or grain size difference between the raised ramparts and their surroundings. Relative differences in dielectric constant were attributed to differences in bulk material composition of the empty lake basin floors and their surroundings, while differences in volumetric scattering behavior were attributed to relative differences in porosity or surface saturation fraction. Furthermore, our analysis of the empty lakes showed that their floors have very similar spectral responses to those of the raised ramparts of the filled lakes, suggesting that both types of feature are made of or coated by similar material.

The emissivity of the raised ramparts is relatively high for Titan and is similar to that of the empty basins. This, combined with the VIMS results, suggests that the ramparts and the empty lake floors may have the same composition. The emissivity of the ramparts is also close to that of the labyrinth terrains and plains which points to a composition enriched in organics rather than water ice, and thus to a photochemical origin of the material the ramparts are made of (rather than derived from the primordial water ice crust).

Currently, a number of plausible theories for the formation of the ramparts have been suggested [e.g. 3;9;10] including: 'Eroded diapirs', 'Eroded spring mounds', 'Maars (calderas)', 'Cryovolcanism', 'Impact Cratering', 'Evaporitive rim stone deposits', and 'Karst-hardened post-deflation remnants'. Two aforementioned hypotheses that might fit the rampart formation include the 'Eroded spring mound' mechanism in which the difference in elevation between the empty lake floors and the filled lakes is suggestive of a subsurface phreatic surface; and the karst-hardening post-deflation remnant hypothesis, where temporal variation of this phreatic surface would be consistent with the results of this current work.

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