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Titan's Global Geology from Cassini: implications for the geologic history

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Abstract

We investigate the geologic history of Titan through mapping and analyzing the distribution of observed geomorphologic features using a combination of Cassini data collected by RADAR, VIMS (Visual and Infrared Mapping Spectrometer), and ISS (Imaging Science Subsystem). Determining the spatial and superposition relations between geomorphologic units on Titan leads to an understanding of the likely time evolution of the landscape and gives insight into the process interactions that drove its geologic history. We have used all available datasets to extend the mapping initially done by Lopes et al. (2010) and Birch et al. (2017) to a global map at 1:800,000 scale in all areas covered by the RADAR Synthetic Aperture Radar (SAR). We show how we are extending the map to regions not covered by SAR, to produce a 1:1,500,000 scale map compatible with USGS standards. We use the map to infer the stratigraphic relations among Titan's different terrain types, which in turn allows us to establish the sequence of geologic processes that have shaped the satellite's surface.

1. Introduction

The Cassini spacecraft has been orbiting Saturn since July 2004. Cassini made 127 close encounters with Titan during these last 13 years, gathering an unprecedented data set collected by 12 instruments. Of particular relevance to geologic studies are the datasets collected by the RADAR, the Visual and Infrared Mapping Spectrometer (VIMS), and the Imaging Science Subsystem (ISS) instruments. The Synthetic Aperture Radar (SAR) mode on the RADAR can to penetrate clouds and organic haze layers to provide high resolution (~350 m spatial resolution at best) views of the surface geology. We used SAR data as the base for mapping, but the RADAR's other modes (altimetry, scatterometry, radiometry) also provide valuable supplementary data for interpreting the geology.

Titan has an icy crust, but water ice signatures are not easily detected due to atmospheric scattering and absorption, hampering observations of complex organic molecules on the surface. The extended, dense, and hazy N_2-CH_4 dominated atmosphere shields the surface from direct optical observations, except at certain frequencies where the methane absorption is weak. These "atmospheric windows" are exploited by VIMS. In particular, VIMS spectro-imaging near-infrared data, after the removal of atmospheric contributions, is capable of providing valuable compositional constraints (Solomonidou et al. 2016; this meeting). Cassini's ISS is equipped with a 0.938 μm narrow band pass filter and infrared polarizing filters that also take advantage of a window in the methane's absorption spectrum. Base maps obtained by ISS were used to obtain overall correlations with the terrain units mapped from SAR. Data from ISS, VIMS, and radiometry were used to extend the mapping in areas not covered by SAR during the mission, using correlations between SAR and these data sets.

2. Methods and Results

Continuing the initial work described in Lopes et al. (2010) and the detailed mapping of the Afekan region by Malaska et al. (2016) and of the polar regions by Birch et al. (2017), we have established the major geomorphologic unit classes on Titan. These broad classes are: hummocky/mountainous terrains, labyrinth terrains, dunes, plains, craters, and lakes. We have also mapped individual features such as craters, channels nd their deposits, and candidate cryovolcanic features. We have found that the hummocky/mountainous terrains are the oldest units on the surface and appear radiometrically cold, indicating icy materials [7]. The labyrinth terrains consist of highly incised dissected plateaux with medium radar backscatter and appear radiometrically warm, indicating organic materials. Dunes are the youngest units and appear radiometrically warm, indicating organic sediments (Janssen et al. 2016). The plains are younger than both the mountainous/hummocky and the labyrinth unit classes. Undifferentiated Plains form the most widespread unit on Titan and are interpreted as aeolian deposits that also appear radiometrically warm (Lopes et al. 2016). Dunes and lakes are the youngest unit classes on Titan; it is likely that the processes forming them are still active. Characterization and comparison of the properties of the unit classes and the individual features with data from radiometry, ISS, and VIMS provide information on their composition and possible provenance. VIMS analysis shows that compositional variations can also exist within the same class of unit (Lopes et al. 2016; Solomonidou et al. 2016). For example, undifferentiated plains located closer to the equatorial dunes appear to be contaminated by dune materials. The correlations among the data sets not only aid in the interpretation of their origin, but also allow us to infer global distributions within regions not covered by SAR. This is particularly important as SAR data did not provide complete coverage of Titan during the Cassini mission.

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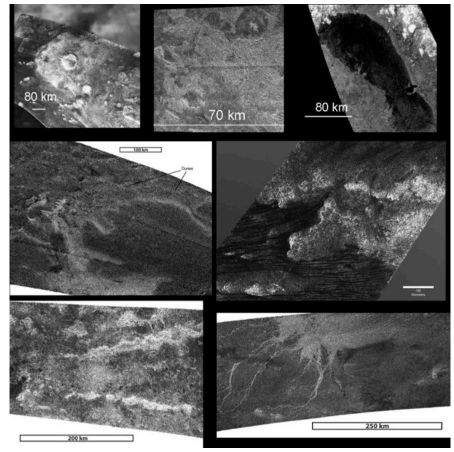

Figure 1. Examples of geologic features on Titan: Top row from left: Sinlap crater with its well-defined ejecta blanket. Middle: Craterform structure (suspected impact crater) in the Xanadu region. Right: Ontario Lacus near Titan's south pole. Middle row, left: Bright (high radar backscatter) deposit Winia Fluctus abutting against darker undifferentiated plains, dunes indicated overlaying part of deposit. Middle row, right: Dunes abutting against hummocky and mountainous terrain. Bottom left: mountains (radar bright) in the equatorial region. Right: Elivagar Flumina, interpreted as a large fluvial deposit, showing braided radar-bright channels. Deposits overlay radar-dark undifferentiated plains.