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Cryovolcanic Features on Titan

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Abstract

We present evidence to support the cryovolcanic origin of some features, which includes the deepest pit known on Titan (Sotra Patera) and some of the highest mountains (Doom and Erebor Montes). We interpret this region to be a cryovolcanic complex of multiple cones, craters, and flows. Elsewhere, a circular feature, approximately 100 km across, is morphologically similar to a laccolith, showing a cross pattern interpreted to be extensional fractures. However, we find that some other previously supposed cryovolcanic features were likely formed by other processes. We discuss implications for eruption style and composition of cryovolcanism on Titan. Our analysis shows the great value of combining data sets when interpreting Titan's geology and in particular stresses the value of topographic data

1. Introduction

Observations from the Cassini mission have revealed that Saturn's moon Titan is a complex world in which interior, surface and atmospheric processes interact to create and modify geologic features. Among the varied surface features observed by Cassini instruments are vast dune fields, lakes of liquid methane and ethane, fluvial channels, and mountains. However, the existence of features formed by cryovolcanic activity has been the subject of controversy. Here we use observations from the Cassini RADAR, including SAR imaging, radiometry, and topography data, plus compositional data from the Visible and Infrared Spectrometer (VIMS) to re-examine several putative cryovolcanic features on Titan in terms of likely processes of origin.

2. Data

Our interpretations of cryovolcanic features on Titan rely on data from Cassini RADAR (including SAR, stereogrammetry, SARTopo, and radiometry) which, where available, are combined with data from VIMS. Interpretations rely on morphology and, in some cases, differences in composition from surrounding terrain as shown by VIMS. To date, no hot spot has been identified on Titan, however, the detection of thermal activity at Titan's surface using radiometry data is not straightforward [1].

3. The Sotra Patera region

The topography, combined with SAR imaging and VIMS data, strongly suggests that the Sotra patera, Mohini Fluctus, Doom and Erebor Montes region is an area of multiple cryovolcanic features: two volcanic mountains (Doom and Erebor Montes), a deep non-circular depression (Sotra patera), which we interpret to be a collapse feature, a flow (Mohini Fluctus) that appears to emerge from Doom Mons, other non-circular depressions interpreted as collapse features between the two Montes, and a series of flows surrounding Erebor Mons. Of particular interest is the fact that the area is totally devoid of fluvial channels, making a fluvial origin for the flows unlikely. Moreover, the dune field that lies between Doom and Erebor Montes indicates that this is a dry region. The fact that the depressions, including Sotra patera, are not circular makes an impact origin unlikely for these features, furthermore, there is no evidence of any impact ejecta blanket surrounding the depressions. Furthermore, the occurrence of Titan's deepest known depression and several lesser depressions in such close proximity to some of the most substantial mountains on Titan make it unlikely that impacts—so rare elsewhere on Titan— could explain these features. We conclude that Sotra patera, Doom and Erebor Montes, and Mohini Fluctus were likely formed by cryovolcanic processes.

4. Hotei Regio

Hotei Regio had been interpreted as an area of cryovolcanic flows [3,4] and even the site of possible activity or degassing [5,6]. Moore and Pappalardo [7] argue that the flow-like features were likely depositional features associated with fluvial channels. Topographic results show that the tops of the flow deposits are substantially higher than the fluvial channels and therefore that interpretation is unlikely. Also, flow deposits are thick (~200 m), a characteristic more consistent with the complex rheology of cryovolcanic flows than sedimentary deposits. Our conclusion is that the Hotei flows are more likely cryovolcanic than fluvial in origin.

4. Titan's "Hot Cross Bun"

A circular, dome-like feature centered at ~38.5N, 203W that resembles a "hot cross bun" was imaged using SAR. The feature, approximately 100 km across, is mostly radar bright but the cross pattern, interpreted to be extensional fractures, located roughly at the center of the brighter area, appears darker at radar wavelengths. Radar illumination of the image indicates that the fractures are lower in elevation than the surrounding bright region. The morphology of the region is markedly similar to that of a 30-km dome-shaped feature on Venus that lies at the summit of the Kunapipi volcano. The Venus feature is interpreted to be the result of intrusion of magma at the summit of the volcano [8]. No topographic data for this feature on Titan are available at this time, but the morphology seen by the SAR data suggests that the feature may have been formed by material pushing up from below. This previously unknown type of structure on Titan may be yet another indication of cryovolcanism.

5. Summary

Topographic data, and DTMs from stereogrammetry in particular, have revealed that two candidate cryovolcanic regions, Hotei Regio and the region of Sotra patera, Mohini Fluctus, Doom and Erebor Montes, are the most likely to have been formed by cryovolcanism. The "hot cross bun" is an intriguing feature which, along with others for which topographic data are not yet available, remains a candidate cryovolcanic feature. It is clear, however, that if the style of cryovolcanism in the Sotra patera region was a major contributor to Titan's resurfacing and relatively young age, edifices like Doom and Erebor Montes should be much more common on Titan's surface than has been observed. If cryovolcanism played an important role in Titan resurfacing, the paucity of features similar to the Montes and the patera points to another style of volcanism being far more common, possibly effusive volcanism forming thin flows that may have been partly buried or totally buried by the accumulation of photolysis products created in the upper atmosphere or wind-blown materials.

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