Cryovolcanism on Titan

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Volcanism is a fundamental geologic process in the solar system, as it has occurred on most solid planetary bodies. Planetary volcanism is manifested across a range of morphologies, driving conditions, and compositions, including ices (cryovolcanism). Understanding volcanism in space and time on a planet provides vital constraints on the transfer of heat and mass from the interior, and can also provide insights into the composition of a planet or moon. Comparing eruption and emplacement mechanisms on other planets to those on Earth better constrains how terrestrial magmatism behaves under present and past conditions. Planetary volcanism has been defined as an eruption from an opening on a planetary surface from which magma, defined for that body as a partial melt product of mantle or crustal material, is erupted. Volcanism that occurs on the satellites of the outer solar system, sometimes known as cryovolcanism, is primarily the eruption of aqueous or non-polar molecular solutions or partly crystallized slurries, derived from partial melting of ice-bearing materials. Observations from the Cassini mission have revealed that the moon Titan is a complex world in which interior, surface and atmospheric processes interact to create and modify geologic features. In terms of active or recent surface-shaping processes, Titan is one of the most Earthlike worlds in the Solar System. 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 (fluvial, aeolian, cryovolcanic, or other). 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 the geology of Titan and in particular stresses the value of topographic data.