Observations of cryovolcanism in the Solar System

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A primary process in the resurfacing of many outer solar system satellites is the eruption of substances that would be solid at terrestrial temperatures, termed cryovolcanism. An astonishing variety of putative cryovolcanic landforms have been observed, but considerable ambiguity exists as to their origins, and the interplay between cryovolcanic and tectonic processes.

The most definitive cryovolcanic features observed to date are the numerous plumes at Enceladus' south pole, which appear to originate in a subsurface liquid reservoir, and which have benefited from study with numerous in-situ and remote sensing instruments on Cassini. Plumes have also been observed on Triton, but these appear to be seasonal in nature suggesting that they may be sublimation features originating from a shallow subsurface layer rather than true cryoclastic eruptions. In addition to the plume deposits, Triton's surface has probably undergone global resurfacing relatively recently, and exhibits a variety of probable endogenic cryovolcanic features, many of which are thus far unique in the solar system, including the cantaloupe terrain, and the mysterious bright and dark guttae. Because Triton and Pluto share similar bulk compositions, and both may have undergone widespread internal disruption, it is possible that features observed on the surface of Triton may also be present on Pluto.

In addition to Enceladus, the Saturnian moons Tethys and Dione show some evidence of resurfacing. Cryovolcanism likely played a role in the formation of surface features of the Uranian moons including Miranda's coronae, and the smooth flows within Ariel's canyons. Titan's surface shows several features that have been interpreted to have a cryovolcanic origin on the basis of their morphology and topography. The most promising candidate is Sotra Facula, a mountainous edifice surrounded by flow-like features and a deep pit. However, the low resolution of Titan imaging data and the relative lack of stereo topography has made interpretation of putative volcanic features on Titan difficult. Several features originally thought to be volcanic in nature – such as Ganesa Macula – subsequently turned out to be inconsistent with volcanism when stereo topography was acquired.

Of the Galilean satellites, Europa's very young surface shows evidence of surface flows, both in the form of frozen pools of low albedo fluid material, and flow associated with higher viscosity chaos. The chaos itself is likely the surface manifestation of compositionally or thermally buoyant diapirs, which may have directly impinged upon the surface, or interacted with brine pockets trapped within the ice. Other cryovolcanic features on Europa include bands, formed when the surface separated long cracks and new material welled up into the gaps. Ganymede's grooved terrain may have formed in a similar manner, but it has not been possible to unambiguously determine whether these bright icy swaths formed from volcanic resurfacing or tectonic resurfacing, or some combination of the two. A number of caldera-like features within the grooved terrain appear similar to terrestrial volcanic vents, but seem to be far too few to have formed the vast resurfaced areas of bright terrain.

In this paper, we review putative cryovolcanic features across the solar system, discuss the uncertainties in their formation models, and make predictions for the likely surface features that will be observed on Pluto by New Horizons.