Models explain canyons on Pluto's large moon Charon

February 7 2023

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In 2015, when NASA's New Horizons spacecraft encountered the Pluto-Charon system, the Southwest Research Institute-led science team discovered interesting, geologically active objects instead of the inert icy orbs previously envisioned.

An SwRI scientist has revisited the data to explore the source of cryovolcanic flows and an obvious belt of fractures on Pluto's large moon Charon. These new models suggest that when the moon's internal ocean froze, it may have formed the deep, elongated depressions along its girth but was less likely to lead to cryovolcanoes erupting with ice, water and other materials in its northern hemisphere.

"A combination of geological interpretations and thermal-orbital evolution models implies that Charon had a subsurface liquid ocean that eventually froze," said SwRI's Dr. Alyssa Rhoden, a specialist in the geophysics of icy satellites, particularly those containing oceans, and the evolution of giant planet satellite systems. She authored a new paper on the source of Charon's surface features in Icarus.

"When an internal ocean freezes, it expands, creating large stresses in its icy shell and pressurizing the water below. We suspected this was the source of Charon's large canyons and cryovolcanic flows."

New ice forming on the inner layer of the existing ice shell can also stress the surface structure. To better understand the evolution of the moon's interior and surface, Rhoden modeled how fractures formed in Charon's ice shell as the ocean beneath it froze. The team modeled oceans of water, ammonia or a mixture of the two based on questions about the makeup. Ammonia can act as antifreeze and prolong the life of the ocean; however, results did not differ substantially.

When fractures penetrate the entire ice shell and tap the subsurface ocean, the liquid, pressurized by the increase in volume of the newly frozen ice, can be pushed through the fractures to erupt onto the surface. Models sought to identify the conditions that could create fractures that fully penetrate Charon's icy shell, linking its surface and subsurface water to allow ocean-sourced cryovolcanism. However, based on current models of Charon's interior evolution, ice shells were far too thick to be fully cracked by the stresses associated with ocean freezing.

The timing of the ocean freeze is also important. The synchronous and circular orbits of Pluto and Charon stabilized relatively early, so tidal heating only occurred during the first million years.

"Either Charon's ice shell was less than 6 miles (10 km) thick when the flows occurred, as opposed to the more than 60 miles or 100 km indicated, or the surface was not in direct communication with the ocean as part of the eruptive process," Rhoden said. "If Charon's ice shell had been thin enough to be fully cracked, it would imply substantially more ocean freezing than is indicated by the canyons identified on Charon's encounter hemisphere."

Fractures in the ice shell may be the initiation points of these canyons along the global tectonic belt of ridges that traverse the face of Charon, separating the northern and southern geological regions of the moon. If additional large extensional features were identified on the hemisphere not imaged by New Horizons, or compositional analysis could prove that Charon's cryovolcanism originated from the ocean, it would support the idea that its ocean was substantially thicker than expected.

"Ocean freezing also predicts a sequence of geologic activity, in which ocean-sourced cryovolcanism ceases before strain-created tectonism," Rhoden said. "A more detailed analysis of Charon's geologic record could help determine whether such a scenario is viable."

The work is published in the journal *Icarus*.

More information: Alyssa Rose Rhoden et al, The challenges of driving Charon's cryovolcanism from a freezing ocean, *Icarus* (2022). DOI: 10.1016/j.icarus.2022.115391

Provided by Southwest Research Institute

Citation: Models explain canyons on Pluto's large moon Charon (2023, February 7) retrieved 11 May 2024 from https://phys.org/news/2023-02-canyons-pluto-large-moon-charon.html

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