CERES

Ahuna Mons lonely no more

Volcanic domes are common in our Solar System but so far only one has been identified on dwarf planet Ceres. New research suggests that numerous volcanic domes may have formed throughout Ceres's history, indicating that cryovolcanism may have once been more common on the dwarf planet.

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On Earth we are familiar with volcanism, the process by which molten rock from the interior is spewed onto the surface. Volcanic eruptions may be violent, such as the eruptions of Mount St. Helens and Krakatoa, or they may be quiescent, such as the meandering lava flows from Hawaii's Kilauea volcano. Volcanoes are also present on other planets, and may grow to enormous heights, such as Olympus Mons on Mars. On ice-rich bodies in our outer Solar System, instead of manifesting as the extrusion of molten rock, or lava, volcanism is often expressed as the extrusion of low-temperature, liquid solutions containing water, ice crystals and salts. This exotic volcanism, termed cryovolcanism ('cryo' from the ancient Greek word 'kryos', which means 'icy cold'), occurs or has occurred on several icy satellites, including Triton[1], Europa[2], Enceladus[3] and possibly Titan[4]. Dwarf planet Ceres is also a relatively ice-rich body[5]. Its past cryovolcanic activity is evidenced by the heretofore lonely cryovolcanic dome, Ahuna Mons[6] (Fig. 1). Writing in *Nature Astronomy*, Michael Sori and colleagues report the identification of additional domes that may be cryovolcanic in origin. These findings shed new light on the cryovolcanic history of Ceres[7].

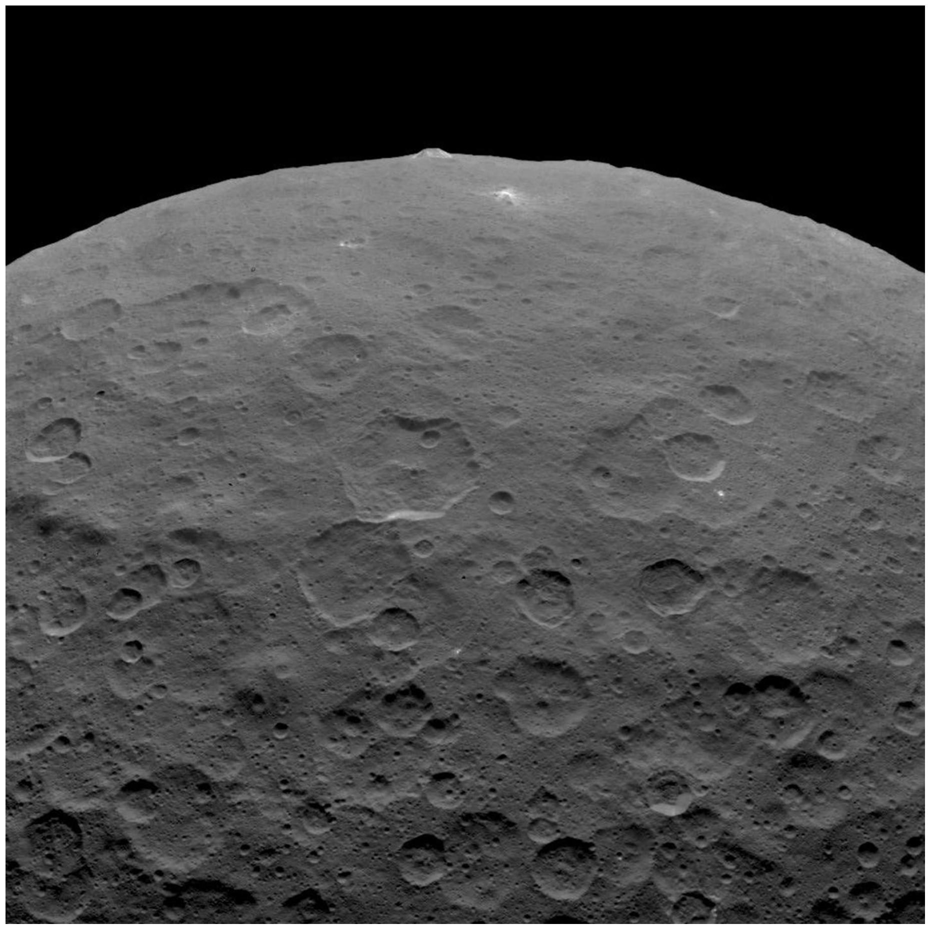

Fig. 1 | Image of Ahuna Mons taken by the Dawn spacecraft's Framing Camera. Ahuna Mons is the mountainous feature with a slightly flat top that protrudes at the centre of the limb. It was the only cryovolcanic construct identified on Ceres before the study presented by Sori and colleagues[7]. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

Clustered volcanic domes can be found elsewhere in the Solar System[8], including ice-rich domes similar to Ahuna Mons[2,9]. Hence, the existence of one solitary cryovolcanic dome on Ceres is puzzling. If cryovolcanic processes were once active on the dwarf planet, we would expect to see numerous cryovolcanic domes at the surface. The reason that past cryovolcanic evidence is not visible at Ceres's surface could boil down to a process called viscous relaxation: warm surface temperatures may have caused ice-rich domes to flatten over time[10]. Viscously relaxed cryovolcanic domes would therefore be unrecognizable today.

Sori et al.[7] utilized observational data from the Dawn spacecraft, in combination with numerical modelling, to test the viscous relaxation hypothesis. They used imagery from Dawn's Framing Camera (FC) to identify domes that may have undergone viscous relaxation. In all, more than 20 large, ice-rich domes, with volumes and morphologies consistent with a cryovolcanic origin, were analysed. Average heights and diameters for these domes were extracted from Dawn FC imagery. From this information, the aspect ratios of the domes were determined. Then, assuming all cryovolcanic domes on Ceres were initially 50% ice by volume and had initial shapes similar to Ahuna Mons, numerical techniques were applied in order to model their viscous relaxation from 1 Gyr ago to the present. Sori et al.'s models[7] assumed that one cryovolcanic dome existed per every five degrees of latitude on Ceres.

When the aspect ratios of the domes imaged by Dawn were compared to those of the viscously relaxed domes in their models, Sori et al. found that of all of the domes analysed, Ahuna Mons and Yamor Mons had the highest aspect ratios. The high aspect ratio of Ahuna Mons can be attributed to it being too young to have undergone extensive viscous relaxation. The high aspect ratio of the much older Yamor Mons is indicative of a lack of viscous relaxation due to its location: Yamor Mons is situated at Ceres's north pole. Here, temperatures are on average less than 100 K, compared to 155 K at the equator. Colder temperatures at the poles allow for the preservation of ice-rich geological constructs.

The results presented by Sori et al. suggest that, statistically, the amount of cryovolcanism that occurred on Ceres is consistent with one cryovolcano forming every 50 Myr for the past 1 Gyr. Estimated rates of cryovolcanism on Ceres, on the order of 10^4 m^3 yr^{-1}, are orders of magnitude lower than the rates of silicic volcanism on the Moon and the terrestrial planets. This study suggests that while cryovolcanism has played a significant role in shaping Ceres, it hasn't played as substantial a role as volcanism has in shaping the terrestrial planets.

The work presented in Sori et al. is limited by the fact that since older domes at warmer latitudes are likely to have undergone viscous relaxation, they are unidentifiable today. In addition, as Yamor Mons is the only polar dome identifiable in the Dawn dataset, it is difficult to judge whether it serves as indirect confirmation of the viscous relaxation hypothesis, or if its presence is solely serendipitous. Moreover, it is possible that not all of the domes analysed by Sori et al. have cryovolcanic origins, or that their initial shapes differed considerably from Ahuna Mons. Nevertheless, this analysis provides a baseline from which the history of cryovolcanism on Ceres can be extrapolated. New, high-resolution data from Dawn's second extended mission are currently being analysed. These data can now be interpreted with the results of Sori et al. in mind. Continued modelling and observation will aid in the unravelling of Ceres's geological history in due time. Understanding the role of cryovolcanism in shaping this enigmatic world is a key piece of the puzzle. ❐

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