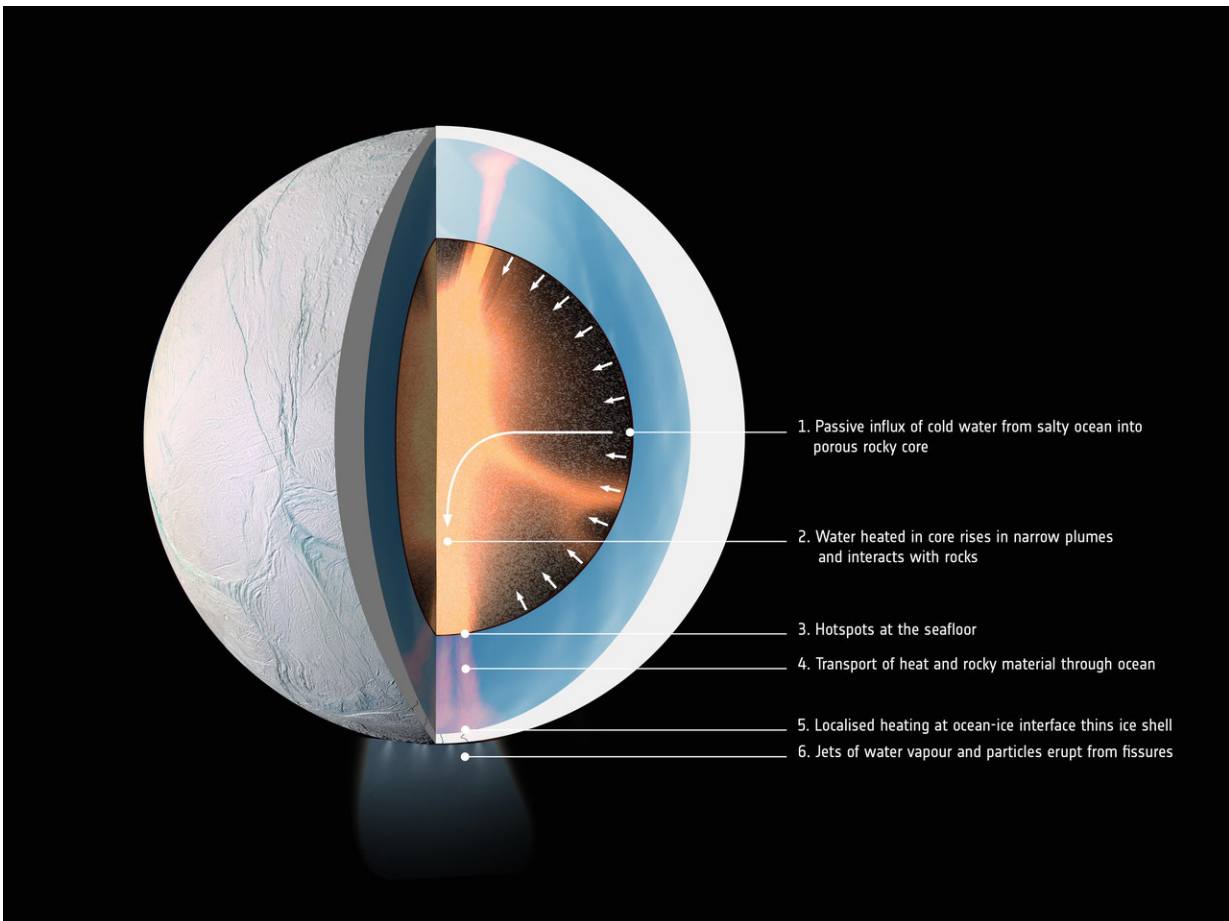


Heating ocean moon Enceladus for billions of years

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Over time, cool ocean water seeps into the moon's porous core. Pockets of water reaching deep into the interior are warmed by contact with rock in the tidally heated interior and subsequently rise owing to the positive buoyancy, leading to further interaction with the rocks. The heat deposited at the boundary between the seafloor and ocean powers hydrothermal vents. Heat and rocky particles are transported through the ocean, triggering localised melting in the icy shell above.

This leads to the formation of fissures, from which jets of water vapour and the rocky particles from the seafloor are ejected into space. In the graphic, the interior 'slice' is an excerpt from a new model that simulated this process. The orange glow represents the parts of the core where temperatures reach at least 90°C. Tidal heating owing to the friction arising between particles in the porous core provides a key source of energy, but is not illustrated in this graphic. The tidal heating results primarily from the gravitational pull from Saturn. Credit: Surface: NASA/JPL-Caltech/Space Science Institute; interior: LPG-CNRS/U. Nantes/U. Angers. Graphic composition: ESA

Enough heat to power hydrothermal activity inside Saturn's ocean moon Enceladus for billions of years could be generated through tidal friction if the moon has a highly porous core, a new study finds, working in favour of the moon as a potentially habitable world.

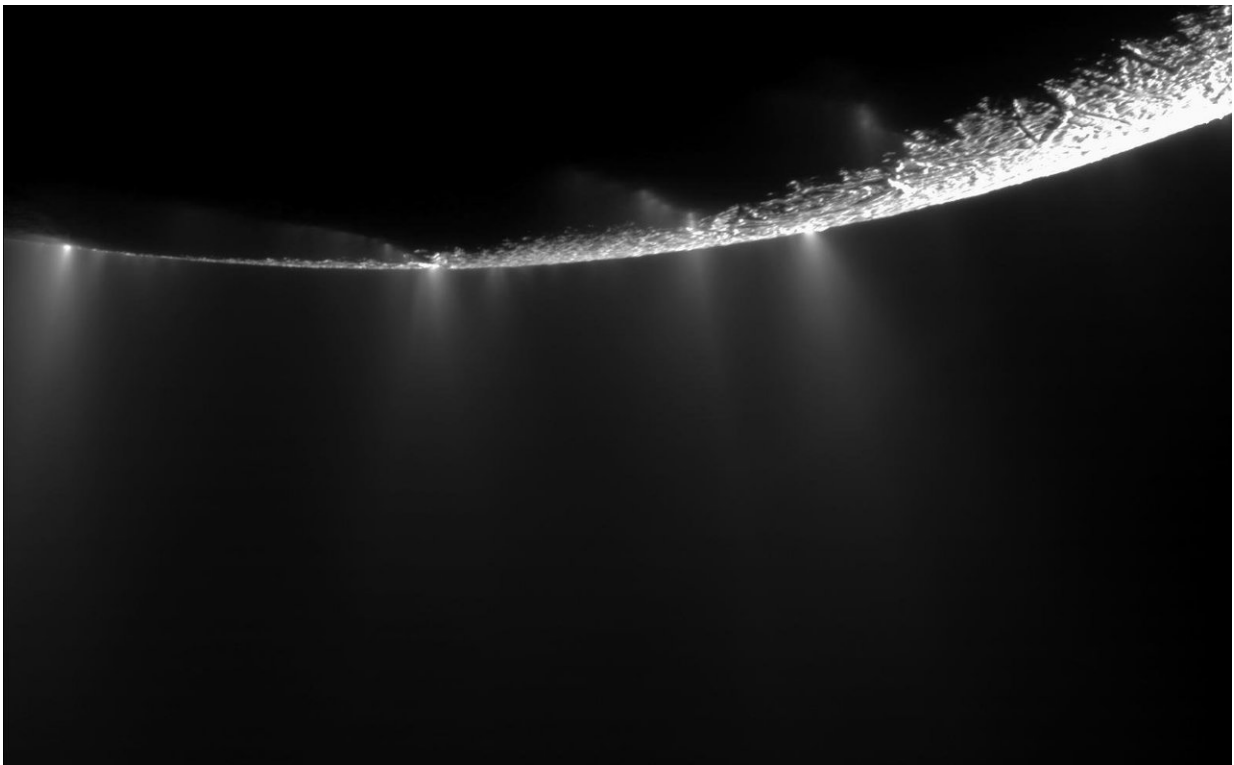
A paper published in *Nature Astronomy* today presents the first concept that explains the key characteristics of 500 km-diameter Enceladus as observed by the international Cassini spacecraft over the course of its mission, which concluded in September.

This includes a global salty ocean below an [ice shell](#) with an average thickness of 20–25 km, thinning to just 1–5 km over the [south polar region](#). There, jets of water vapour and icy grains are launched through fissures in the ice. The composition of the ejected material measured by Cassini included salts and silica dust, suggesting they form through hot water – at least 90°C – interacting with rock in the porous core.

These observations require a huge source of heat, about 100 times more than is expected to be generated by the natural decay of radioactive elements in rocks in its core, as well as a means of focusing activity at the south pole.

The tidal effect from Saturn is thought to be at the origin of the eruptions deforming the icy shell by push-pull motions as the moon follows an elliptical path around the giant planet. But the energy produced by tidal friction in the ice, by itself, would be too weak to counterbalance the heat loss seen from the ocean – the globe would freeze within 30 million years.

As Cassini has shown, the moon is clearly still extremely active, suggesting something else is happening.



Dramatic plumes, both large and small, spray water ice out from many locations along the 'tiger stripes' near the south pole of Saturn's moon Enceladus. The tiger stripes are fissures that spray icy particles, water vapour and organic compounds. More than 30 individual jets of different sizes can be seen in this image, which is a mosaic created from two high-resolution images captured when Cassini flew past Enceladus and through the jets on 21 November 2009. This view was

obtained at a distance of about 14 000 km from Enceladus. Credit: European Space Agency

"Where Enceladus gets the sustained power to remain active has always been a bit of mystery, but we've now considered in greater detail how the structure and composition of the moon's rocky core could play a key role in generating the necessary energy," says lead author Gaël Choblet from the University of Nantes in France.

In the new simulations the core is made of unconsolidated, easily deformable, porous rock that water can easily permeate. As such, cool liquid water from the ocean can seep into the core and gradually heat up through tidal friction between sliding rock fragments, as it gets deeper.

Water circulates in the core and then rises because it is hotter than the surroundings. This process ultimately transfers heat to the base of the ocean in narrow plumes where it interacts strongly with the rocks. At the seafloor, these plumes vent into the cooler ocean.

One seafloor hotspot alone is predicted to release as much as 5 GW of energy, roughly corresponding to the annual geothermal power consumed in Iceland.

Such seafloor hotspots generate ocean plumes rising at a few centimetres per second. Not only do the plumes result in strong melting of the ice crust above, but they can also carry small particles from the seafloor, over weeks to months, which are then released into space by the icy jets.

Moreover, the authors' computer models show that most water should be expelled from the moon's polar regions, with a runaway process leading to hot spots in localised areas, and thus a thinner ice shell directly above,

consistent with what was inferred from Cassini.



This movie sequence of images is from the last dedicated observation of the Enceladus plume by Cassini. The images were obtained over approximately 14 hours as Cassini's cameras stared at the active, icy moon. The view during the entire sequence is of the moon's night side, but Cassini's perspective of Enceladus shifts during the sequence. The movie begins with a view of the part of the surface lit by reflected light from Saturn and transitions to completely unilluminated terrain. The exposure time of the images changes about halfway through the sequence, in order to make fainter details visible. (The change also makes background stars become visible.) The images in this movie sequence were taken on 28 August 2017, using Cassini's narrow-angle camera. The images were acquired at a distance from Enceladus that changed from 1.1 million to 868 000 km. Image scale changes during the sequence, from 7 to 5 km/pixel. The Cassini mission is a cooperative project of NASA, ESA and the Italian Space Agency. Credit: European Space Agency

"Our simulations can simultaneously explain the existence of an ocean at a global scale due to large-scale heat transport between the deep interior and the ice shell, and the concentration of activity in a relatively narrow region around the [south pole](#), thus explaining the main features observed by Cassini," says co-author Gabriel Tobie, also from the University of Nantes.

The scientists say that the efficient rock-water interactions in a porous core massaged by tidal friction could generate up to 30 GW of heat over tens of millions to billions of years.

"Future missions capable of analysing the organic molecules in the Enceladus plume with a higher accuracy than Cassini would be able to tell us if sustained hydrothermal conditions could have allowed life to emerge," says Nicolas Altobelli, ESA's Cassini project scientist.

A future mission equipped with ice-penetrating radar would also be able to constrain the ice thickness, and additional flybys – or an orbiting craft – would improve models of the interior, further verifying the presence of active hydrothermal plumes.

"We'll be flying next-generation instruments, including ground-penetrating radar, to Jupiter's ocean moons in the next decade with ESA's JUICE mission, which is specifically tasked with trying to understand the potential habitability of [ocean](#) worlds in the outer Solar System," adds Nicolas.

More information: Gaël Choblet et al. Powering prolonged hydrothermal activity inside Enceladus, *Nature Astronomy* (2017). [DOI: 10.1038/s41550-017-0289-8](https://doi.org/10.1038/s41550-017-0289-8)

Provided by European Space Agency

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