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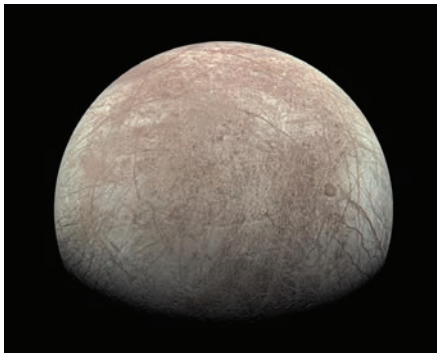
Europa's Ocean Might Lack the Ingredients for Life

Jupiter's moon Europa has long been considered one of the most promising candidates to host extraterrestrial life in our solar system. Under kilometers of ice lies a liquid ocean where living organisms could potentially eke out an existence by exploiting chemical reactions similar to what happens near hydrothermal vents in the dark depths of Earth's oceans.

Two new studies presented at the 2024 Lunar and Planetary Science Conference, however, pour cold water on these expectations.

Researchers have found that the small moon likely lacks the necessary geothermal energy to produce volcanism with enough oomph to reach the surface, and tidal stresses induced by Jupiter and its other moons aren't enough to crack Europa's rocky crust.

Without the interaction between water and newly exposed rock, the oceans are chemically inert, leading to what's been called a "thermodynamics-driven extinction."



Europa may be dead after all, according to two new studies. Credit: NASA

Hard to Break

Though many studies have focused on the icy crust of Europa and the interactions between the ice and the ocean below, few have systematically looked into the crust and mantle. "When we think of icy worlds, generally, we should be thinking of them as rocky worlds as well, because the vast majority of Europa by volume and mass is rock," said Paul Byrne, a planetary geologist at Washington University in St. Louis who presented one of the studies (bit.ly/Europan-seafloor-geology).

Byrne and his coauthors investigated the strength of Europa's lithosphere and the forces that could fracture it.

They modeled its strength with two possible scenarios: a hard-to-break lithosphere, where the rock is unaltered and doesn't have any preexisting cracks, and an easier-to-break one, where the rock has been chemically weakened and previous geological processes have already produced faults and cracks. They also considered different seafloor depths, because a large water column increases pressure and makes the ocean floor more difficult to break.

In the second scenario, relatively weak forces could cause preexisting faults to slip, exposing fresh rock that could chemically react with the ocean.

The researchers looked at the strength of the mechanisms that could break the rock. They considered the tides produced by Jupiter and its other moons, as well as the compression produced by the cooling of the crust over time, and found that they don't come anywhere near the strength needed to break rock or cause preexisting faults to slip.

"I would say there's not much going on there," Byrne said, and if life on Europa depends on chemical reactions, "that becomes an issue."

Not Enough Magma

Another way fresh material could reach the top of Europa's lithosphere is through volcanism. Not only eruptions but also hydrothermal vents could supply chemical reactants, such as hydrogen sulfide, diatomic hydrogen, and methane, to the ocean. Hydrothermal activity doesn't require the magma to reach the seafloor, but it must be close enough to the surface to interact directly with the ocean.

Though the effect of tides and radiogenic elements trapped in the mantle can likely produce magma in the deep interior of Europa, that magma must travel up through the thick lithosphere. To see whether that's possible, the researchers combined existing estimates of Europa's mantle thickness and magma generation with newly developed simulations of the movement of that magma.

The team found that Europa does not produce enough molten rock to break through the lithosphere. In addition, the low gravity on the moon reduces the buoyancy of the magma, making it difficult for dikes to push all the way to the seafloor. The simulations showed that dikes are unlikely to travel beyond 3%–5% of the total lithosphere before cooling down and stopping their ascent.

"This makes present-day volcanism on the seafloor highly unlikely," said Austin Green, a planetary scientist at NASA's Jet Propulsion Laboratory who presented the second study (bit.ly/Europan-seafloor-volcanism). "If this volcanism is necessary for habitability, Europa's ocean is uninhabitable."

On the other hand, if heat builds up in Europa's interior, there must be a way for it to escape eventually, said planetary scientist Gabriel Tobie from Nantes Université in France, who wasn't involved in either study. "Maybe at some point it would lead to episodic volcanism," Tobie said. "If we look at other examples in the solar system, we can see that the Moon has evidence of prolonged volcanism and the tidal heat production inside the Moon is smaller than on Europa."

We must also consider, Tobie said, that the orbit of Europa has likely changed over millions of years, which could have led to periods of extreme heat and magma generation that could have produced volcanism. "It's something we need to model," he said.

Upcoming Exploration

In October 2024, NASA aims to launch the Europa Clipper mission, with the goal of determining whether the small moon harbors conditions suitable for life. The mission will study the composition and properties of Europa's icy crust and the composition of its ocean. The spacecraft might even sample the ocean if plumes of water spew into space, like on Saturn's moon Enceladus.

However, the Clipper mission isn't designed to look into the seafloor, so it's unlikely that it will answer questions about hydrothermal activity or seafloor tectonics.

There are some ways it could do so indirectly, Tobie said, such as by detecting gravitational anomalies that could point to variations in the thickness of the rocky crust. The thickness of the ice cover could also reveal the level of volcanic activity in the interior of the planet, because a warmer interior would lead to a thinner icy crust.

To test their hypothesis, Byrne said, "the only reliable way I can think of is getting down into the ocean and to the ocean floor, and I just don't see that happening for 150 years or so."

By **Javier Barbuzano** (@javibarbuzano), Science Writer