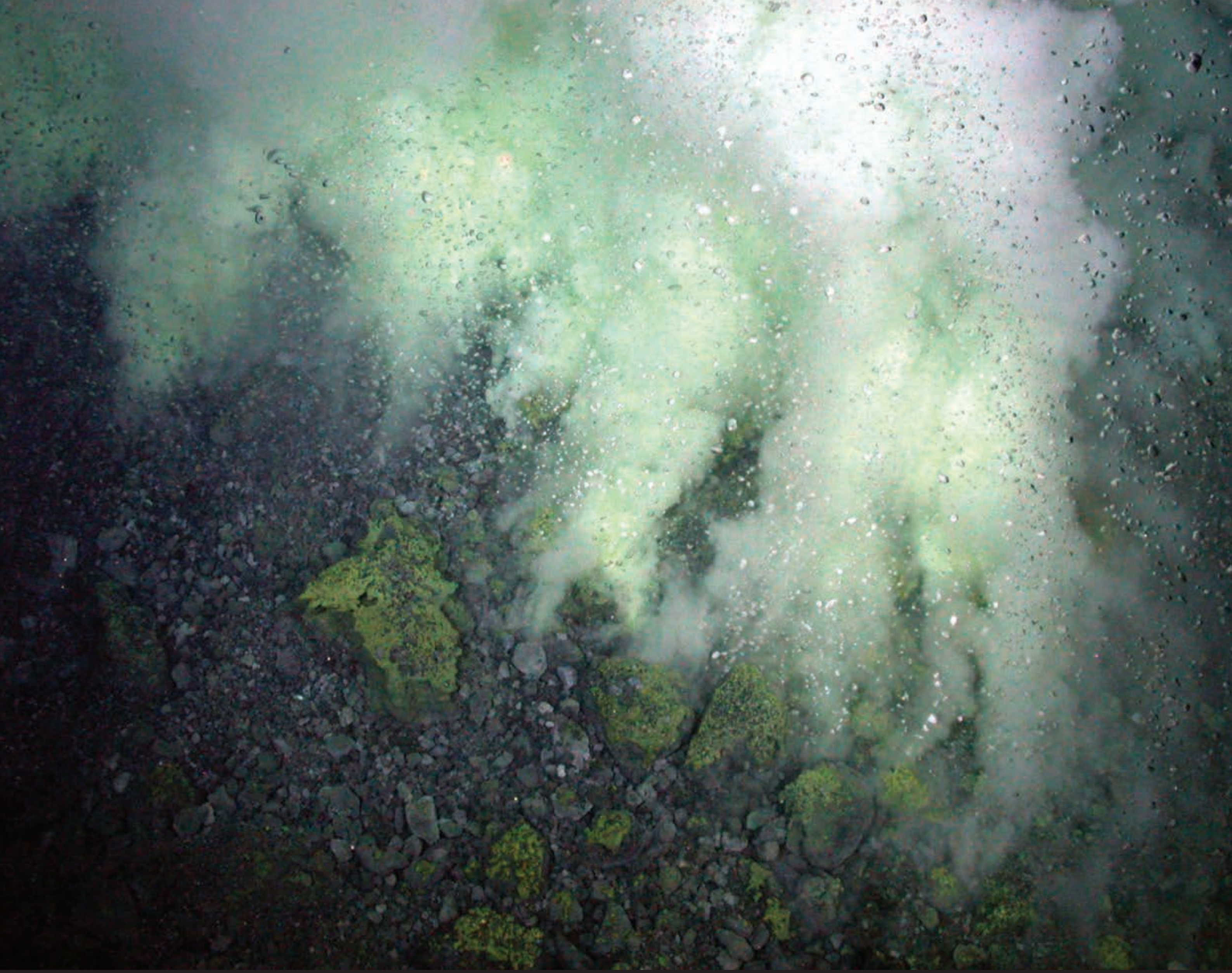

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MYSTERIES OF THE DEEP
Nanostructures similar to molecules that are thought to have enabled the first life have been discovered by RIKEN researchers near deep-sea hydrothermal vents in the Mariana Trench (*see page 18*).

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DEEP-SEA HYDROTHERMAL VENTS

Nanostructures on the deep ocean floor hint at life's origin

A mechanism that powers many biological processes has been found in inorganic minerals six kilometers under the sea

Inorganic nanostructures that are strikingly similar to molecules that enable life have been discovered by RIKEN researchers near deep-sea hydrothermal vents[1]. They shed light on how life began and have implications for the harvesting of blue energy.

When seawater seeps into the Earth's crust through cracks in the ocean floor, it is heated by magma, rises to the surface, and is released back into the ocean through fissures called hydrothermal vents. The rising hot water contains dissolved minerals, which form solid structures around vents called precipitates when the hot water encounters the cool ocean water.

Hydrothermal vents are thought to be the birthplace of life on Earth because they are stable, rich in minerals, and contain energy sources.

Much of life on Earth relies on osmotic energy, which is created by ion gradients—differences in salt and proton concentrations—between the inside and outside of living cells.

A team led by Ryuhei Nakamura at the RIKEN Center for Sustainable Resource Science has been studying special hydrothermal vents that have mineral precipitates with highly complex structures formed from layers of metal oxides, hydroxides and carbonates.

"Unexpectedly, we discovered that osmotic energy conversion—a vital function in modern plant, animal, and microbial life—can occur abiotically in a geological environment," says Nakamura.

The researchers studied samples from the Shinkai Seep Field in the Pacific Ocean's Mariana Trench at a depth of 5,743 meters. The key sample was an 84-centimeter piece composed mostly of brucite crystals arranged in continuous columns, which acted as nanochannels for the vent fluid.

The precipitate surface was electrically charged, and the size and polarity of the charge varied across the surface.

> **"This has direct implications for the origin of life on Earth and beyond."**

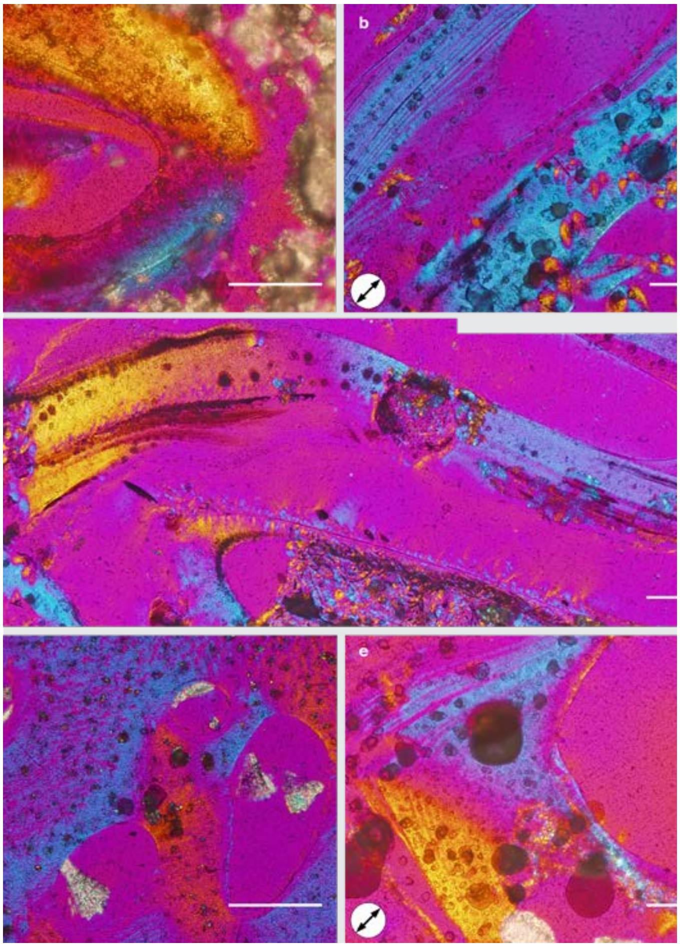
Since structured nanopores with variable charge are signatures of osmotic energy conversion, the team tested whether osmotic energy conversion was occurring naturally in the inorganic deep-sea rock.

The team found ion transport governed by charge that was very similar to voltage-gated ion channels observed in living cells like neurons.

They also discovered that the nanopores act as selective ion channels: nanopores with carbonate on their surfaces only allowed positive sodium ions to flow through, whereas nanopores with calcium on their surfaces only allowed negative chloride ions to pass through.

"The spontaneous formation of ion channels discovered in deep-sea hydrothermal vents has direct implications for the origin of life on Earth and beyond," notes Nakamura.

Industrial power plants use salinity gradients between seawater and river water to generate energy, a process called blue-energy harvesting. Understanding how nanopore structure is spontaneously generated in the hydrothermal vents could help engineers devise better synthetic methods for generating electrical energy from osmotic conversion, Nakamura says. ●



Polarized optical microscopy images showing inorganic nanostructures in thin-section samples obtained near a hydrothermal vent.

Reference

1. Lee, H.-E., Okumura, T., Ooka, H., Adachi, K., Hikima, T., Hirata, K., Kawano, Y., Matsuura, H., Yamamoto, M., Yamamoto, M. *et al.* Osmotic energy conversion in serpentinite-hosted deep-sea hydrothermal vents. *Nature Communications* **15,** 8193 (2024).