Ancient volcanic activity reveals climate threshold for ocean deoxygenation

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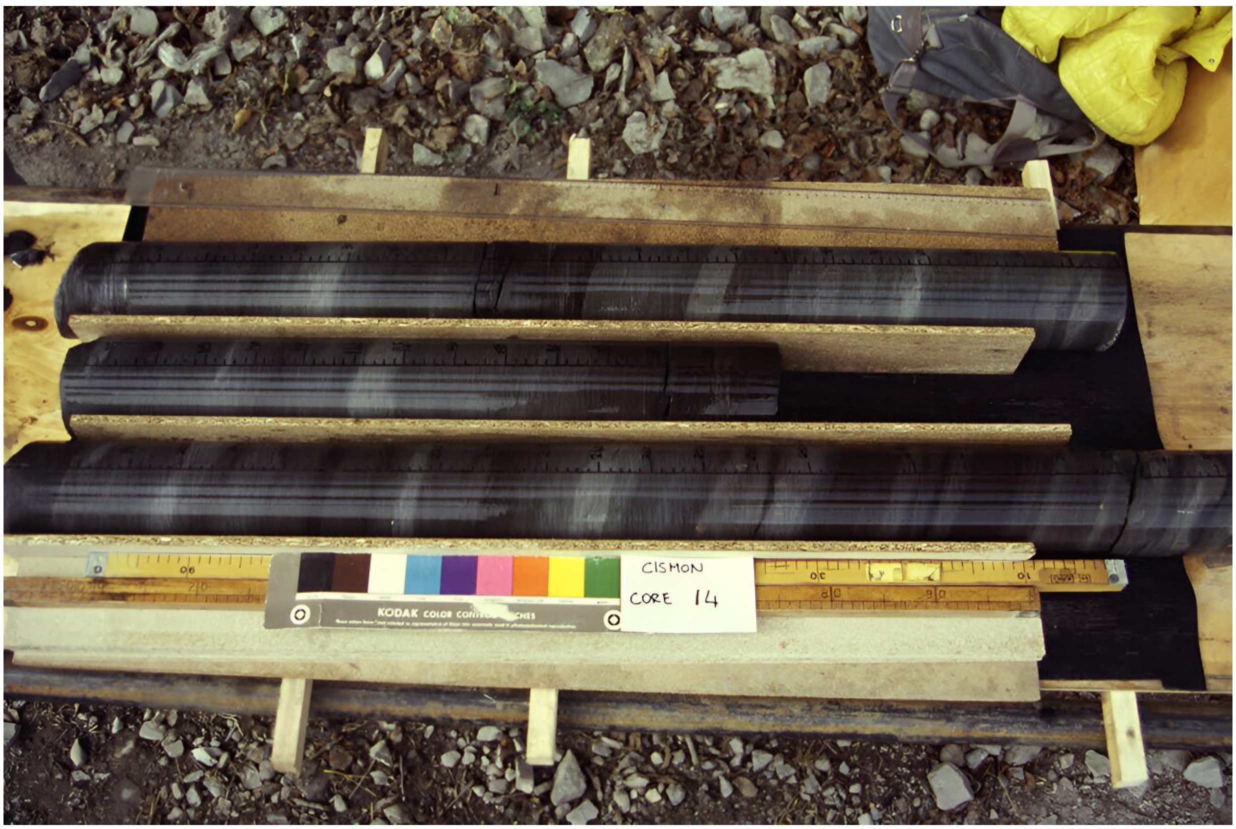

Core sediment samples from the Early Cretaceous. Credit: Elisabetta Erba

Massive volcanic carbon dioxide (CO_2) emissions contributing to an extreme global ocean deoxygenation event over 120 million years ago has modern day implications for understanding a climate warming "tipping point," according to new research published in *Nature*, led by a scientist at Ocean Networks Canada, a University of Victoria initiative.

The paper, titled "A climate threshold for ocean deoxygenation during the Early Cretaceous," reconstructs historical Earth-system processes to establish a climate warming threshold that, when crossed, leads to widespread and persistent ocean deoxygenation.

Led by Kohen Bauer, director of science at ONC, the research team reconstructed environmental conditions using rock samples from the University of Milan archive. The sedimentary rocks studied date back between 115 and 130 million years and were originally deposited in the ancient oceans. By measuring the geochemical composition of the rocks, the team produced a unique high-resolution record of environmental change.

"Our work shows that massive volcanic carbon emissions led to a rapid increase in atmospheric CO_2 concentrations and the crossing of a climate-warming threshold, or tipping point, that resulted in widespread ocean deoxygenation. Following this, Earth's climate system then remained in a warmed state for over two million years," says Bauer, who began the work while at Hong Kong University's Department of Earth Sciences and completed it at UVic.

Forecasted climate scenarios for the next few hundred years suggest that significant warming may emerge as a result of rising human-generated CO_2 emissions. Today, widespread climate warming-induced deoxygenation of the oceans is already being observed and is expected to intensify in the absence of climate change mitigation solutions.

"If current CO_2 emissions cause the climate system to approach and cross the threshold for ocean deoxygenation, we may expect the severity of global ocean anoxia to have huge implications for species, ecosystem and human health," says Bauer.

"While atmospheric CO_2 concentrations today are lower than the Early Cretaceous, anthropogenic CO_2 emissions are being emitted into the atmosphere at a much faster rate than all of the catastrophic volcanic eruptions in the last 500 million years of Earth's history," says Kohen Bauer, director of science, Ocean Networks Canada.

The research team noted that it was a natural process that eventually restored oxygen to Earth's ancient oceans—but the recovery took over a million years.

"We see that reoxygenation of the oceans was only possible once CO_2 concentrations were drawn back down below this critical threshold, due to a natural climate feedback—silicate rock weathering, Earth's main mechanism for stabilizing climate over longer periods of time," says Bauer.

The rock weathering feedback is a key component of the Earth's long-term carbon cycle, and stabilizes the climate by regulating atmospheric CO_2 levels. The paper concludes that this natural mechanism eventually lowered atmospheric carbon levels below the tipping point, resulting in rapid reoxygenation of the oceans after the prolonged period of sustained warming.

"Empirical constraints from Earth's past provide important context through which the relationships between climate warming, ocean deoxygenation, and the broader impacts on the biosphere can be explored," says Sean Crowe, a senior author on the research paper and professor in the departments of Microbiology and Immunology and Earth, Ocean, and Atmospheric Sciences at the University of British Columbia.

Related work published in *Nature Ecology and Evolution* similarly argues that aquatic deoxygenation represents a critical planetary boundary and is a key regulator of current and future Earth system stability with thresholds that should not be crossed. More information on ocean deoxygenation and its impacts can be found through the UNESCO Global Ocean Oxygen Network (GO2NE).

Real-time oxygen concentrations in the Northeast Pacific Ocean can be accessed through Ocean Networks Canada's data portal system, Ocean 3.0.

More information: Kohen W. Bauer et al, A climate threshold for ocean deoxygenation during the Early Cretaceous, *Nature* (2024). DOI: 10.1038/s41586-024-07876-1

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