Life in Earth's primordial sea was starved for sulfate

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Research vessel on Lake Matano, Indonesia. Sean Crowe, University of British Columbia.

The Earth's ancient oceans held much lower concentrations of sulfate—a key biological nutrient—than previously recognized, according to research published this week in *Science*.

The findings paint a new portrait of our planet's early biosphere and primitive marine life. Organisms require sulfur as a nutrient, and it plays a central role in regulating atmospheric chemistry and global climate.

"Our findings are a fraction of previous estimates, and thousands of time lower than current seawater levels," says Sean Crowe, a lead author of the study and an assistant professor in the Departments of Microbiology and Immunology, and Earth, Ocean and Atmospheric Sciences at the University of British Columbia.

"At these trace amounts, sulfate would have been poorly mixed and short-lived in the oceans—and this sulfate scarcity would have shaped the nature, activity and evolution of early life on Earth."

UBC, University of Southern Denmark, CalTech, University of Minnesota Duluth, and University of Maryland researchers used new techniques and models to calibrate fingerprints of bacterial sulfur metabolisms in Lake Matano, Indonesia—a modern lake with chemistry similar to Earth's early oceans.

Measuring these fingerprints in rocks older than 2.5 billion years, they discovered sulfate 80 times lower than previously thought.

Lake Matano, Indonesia — a modern lake with chemistry similar to Earth's early oceans. Credit: Sean Crowe, University of British Columbia.

The more sensitive fingerprinting provides a powerful tool to search for sulfur metabolisms deep in Earth's history or on other planets like Mars.

Findings

Previous research has suggested that Archean sulfate levels were as low as 200 micromolar— concentrations at which sulfur would still have been abundantly available to early marine life.

The new results indicate levels were likely less than 2.5 micromolar, thousands of times lower than today.

What the researchers did

Researchers used state-of-the-art mass spectrometric approaches developed at California Institute of Technology to demonstrate that microorganisms fractionate sulfur isotopes at concentrations orders of magnitude lower than previously recognized.

They found that microbial sulfur metabolisms impart large fingerprints even when sulfate is scarce.

The team used the techniques on samples from Lake Matano, Indonesia—a sulfate-poor modern analogue for the Earth's Archean oceans.

"New measurements in these unique modern environments allow us to use numerical models to reconstruct ancient ocean chemistry with unprecedented resolution" says Sergei Katsev an Associate Professor at the Large Lakes Observatory, University of Minnesota Duluth.

Using models informed by sulfate isotope fractionation in Lake Matano, they established a new calibration for sulfate isotope fractionation that is extensible to the Earth's oceans throughout history. The researchers then reconstructed Archean seawater sulfate concentrations using these models and an exhaustive compilation of sulfur isotope data from Archean sedimentary rocks.

More information: "Sulfate was a trace constituent of Archean seawater." *Science* 7 November 2014: Vol. 346 no. 6210 pp. 735-739. DOI: 10.1126/science.1258966

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