

Rise of atmospheric oxygen more complicated than previously thought

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These are rock drill cores removed from the drill hole at the FAR DEEP site in northwestern Russia. Credit: FAR DEEP

The appearance of oxygen in the Earth's atmosphere probably did not occur as a single event, but as a long series of starts and stops, according to an international team of researchers who investigated rock cores from the FAR DEEP project.

The Fennoscandia Arctic Russia - Drilling [Early Earth](#) Project -- FAR DEEP -- took place during the summer of 2007 near Murmansk in the

northwest region of Russia. The project, part of the International Continental Scientific [Drilling Program](#), drilled a series of shallow, two-inch diameter cores and, by overlapping them, created a record representing stone deposited during the Proterozoic Eon -- 2,500 million to 542 million years ago.

"We've always thought that oxygen came into the atmosphere really quickly during an event," said Lee R. Kump, professor and head of [geosciences](#), Penn State. "We are no longer looking for an event. Now we are looking for when and why oxygen became a stable part of the Earth's atmosphere."

The researchers report in today's (Dec. 1) issue of *Science Express* that evaluation of these cores and comparison with cores from Gabon previously analyzed by others, supports the conclusion that the Great [Oxidation](#) Event played out over hundreds of millions of years. Oxygen levels gradually crossed the low [atmospheric oxygen](#) threshold for pyrite -- an iron sulfur mineral -- oxidation by 2,500 million years ago and the loss of any mass-independently fractionated sulfur by 2,400 million years ago. Then oxygen levels rose at an ever-increasing rate through the Paleoproterozoic, achieving about 1 percent of the present atmospheric level.

"The definition of when an oxygen atmosphere occurred depends on which threshold you are looking for," said Kump. "It could be when pyrite becomes oxidized, when sulfur MIF disappears or when deep crustal oxidation occurs."

When the mass-independent fractionated sulfur disappeared, the air on Earth was still not breathable by animal standards. When red rocks containing [iron oxides](#) appeared 2,300 million years ago, the air was still unbreathable.

"At about 1 percent oxygen, the groundwater became strongly oxidized, making it possible for groundwater seeping through rocks to oxidize organic materials," said Kump.

Initially, any oxygen in the atmosphere, produced by the photosynthesis of single-celled organisms, was used up when sulfur, iron and other elements oxidized. When sufficient oxygen accumulated in the atmosphere, it permeated the groundwater and began oxidizing buried organic material, oxidizing carbon to create carbon dioxide.

The cores from the FAR-DEEP project were compared with the Francevillian samples from Gabon using the ratio of carbon isotopes 13 and 12 to see if the evidence for high rates of oxygen accumulation existed worldwide. Both the FAR-DEEP project's cores and the Francevillian cores show large deposits of carbon in the form of fossilized petroleum. Both sets of cores also show similar changes in carbon 13 through time, indicating that the changes in carbon isotopes occurred worldwide and [oxygen levels](#) throughout the atmosphere were high.

"Although others have documented huge [carbon](#) isotope variations at later times in Earth history associated with stepwise increases in atmospheric [oxygen](#), our results are less equivocal because we have many lines of data all pointing to the same thing," said Kump. "These indications include not only carbon13 isotope profiles in organic mater from two widely separated locations, but also supporting profiles in limestones and no indication that processes occurring since that time have altered the signal."

Provided by Pennsylvania State University

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