Scientists discover clue to 2 billion year delay of life on Earth

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Scientists from around the world have reconstructed changes in Earth's ancient ocean chemistry during a broad sweep of geological time, from about 2.5 to 0.5 billion years ago. They have discovered that a deficiency of oxygen and the heavy metal molybdenum in the ancient deep ocean may have delayed the evolution of animal life on Earth for nearly 2 billion years.

The findings, which appear in the March 27 issue of *Nature*, come as no surprise to Ariel Anbar, one of the authors of the study and an associate professor at Arizona State University with joint appointments in the Department of Chemistry and Biochemistry and the School of Earth and Space Exploration in the College of Liberal Arts and Sciences.

The study was led by Clint Scott, a graduate student at University of California Riverside. Scott works with Timothy Lyons, a professor of biogeochemistry at UCR who is a long-time collaborator of Anbar's and also an author of the paper.

"Clint's data are an important new piece in a puzzle we've been trying to solve for many years," says Anbar. "Tim and I have suspected for a while that if the oceans at that time were oxygen deficient they should also have been deficient in molybdenum. We've found evidence of that deficiency before, at a couple of particular points in time. The new data are important because they confirm that those points were typical for their era."

Molybdenum is of interest to Anbar and others because it is used by some bacteria to convert the element nitrogen from a gas in the atmosphere to a form useful for living things – a process known as "nitrogen fixation." Bacteria cannot fix nitrogen efficiently when they are deprived of molybdenum. And if bacteria can't fix nitrogen fast enough then eukaryotes – a kind of organism that includes plants, pachyderms and people – are in trouble because eukaryotes cannot fix nitrogen themselves at all.

"If molybdenum was scarce, bacteria would have had the upper hand," continues Anbar. "Eukaryotes depend on bacteria having an easy enough time fixing nitrogen that there's enough to go around. So if bacteria were struggling to get enough molybdenum, there probably wouldn't have been enough fixed nitrogen for eukaryotes to flourish."

"These molybdenum depletions may have retarded the development of complex life such as animals for almost two billion years of Earth history," says Lyons. "The amount of molybdenum in the ocean probably played a major role in the development of early life."

This research was motivated by a review article published in Science in 2002 by Anbar and Andy Knoll, a colleague at Harvard University. Knoll was perplexed by the fact that eukaryotes didn't dominate the world until around 0.7 billion years ago, even though they seemed to have evolved before 2.7 billion years ago. Together, Anbar and Knoll postulated that molybdenum deficiency was the key, arguing that the metal should have been scarce in ancient oceans because there was so little oxygen in the atmosphere in those times.

In today's high-oxygen world, molybdenum is the most abundant transition metal in the oceans. That is because the primary source of molybdenum to the ocean is the reaction of oxygen with molybdenum-bearing minerals in rocks. So the hypotheses rode on the idea that the amount of molybdenum in the oceans should track the amount of oxygen.

To test that idea, Scott, Lyons and Anbar examined rock samples from ancient seafloors by dissolving them in a cocktail of acids and analyzing the rock for molybdenum content using a mass spectrometer. Many of these analyses were carried out using state-of-the art instrumentation in the W. M. Keck Foundation Laboratory for Environmental Biogeochemistry at Arizona State University. The scientists found significant evidence for a molybdenum-depleted ocean relative to the high levels measured in modern, oxygen-rich seawater.

By studying Earth's ancient oceans, atmosphere and biology we can test how well we understand the modern environment, according to Anbar. "Our molybdenum hypothesis was inspired by the theory that biology in the oceans today is often starved for a different metal – iron – and that the lack of iron in parts of the oceans affects the transfer of the greenhouse gas carbon dioxide from the atmosphere to the ocean" he says. "The idea that metal deficiency in the oceans can affect the entire planet is very powerful. Here, we are exploring the limits of that idea by seeing if it can solve ancient puzzles. These new findings strengthen our confidence that it can."

Source: Arizona State University

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