

Plants kick-start evolutionary drama of Earth's oxygenation

October 8 2010, by Jenny Green



A panser shark (predatory fish greater than 30 feet long) is a consequence of the Earth's oxygenation event of 400 million years ago. Credit: Staffan Waerndt/ Swedish Museum of Natural History

An international team of scientists, exploiting pioneering techniques at Arizona State University, has taken a significant step toward unlocking the secrets of oxygenation of the Earth's oceans and atmosphere.

Evolution of the Earth's multitude of organisms is intimately linked to the rise of oxygen in the oceans and atmosphere. The new research indicates that the appearance of large predatory fish as well as vascular plants approximately 400 million years ago coincided with an increase in oxygen, to levels comparable to those we experience today. If so, then animals from before that time appeared and evolved under markedly lower oxygen conditions than previously thought.

The researchers, including collaborators from Harvard, Denmark, Sweden and the United Kingdom, made use of a method developed at ASU by Ariel Anbar, a professor in the department of chemistry and biochemistry and the School of Earth and Space Exploration in the College of Liberal Arts and Sciences, and his research group. The method can be used to estimate global [oxygen levels](#) in ancient oceans from the [chemical composition](#) of ancient seafloor sediments.

Their important findings are presented in a paper published in this week's online Early Edition of the [Proceedings of the National Academy of Sciences](#) (*PNAS*), titled "Devonian rise in atmospheric oxygen correlated to radiations of terrestrial plants and large predatory fish."

"There has been a lot of speculation over the years about whether or not oxygen in the atmosphere was steady or variable over the last 500 million years," explained Anbar, who leads ASU's Astrobiology Program. "This is the era during which animals and land plants emerged and flourished. So it's a profound question in understanding the history of life. These new findings not only suggest that oxygen levels varied, but also that the variation had direct consequences for the evolution of complex life."

The Earth is 4,500 million years old. [Microbial life](#) has probably thrived in the oceans for most of that time. However, until about 2,300 million years ago, the atmosphere contained only traces of oxygen. During that time, some microbes in the oceans likely produced oxygen as a byproduct of photosynthesis. But the quantities they produced were insufficient to accumulate much in the atmosphere and oceans. The situation changed with the "Great Oxidation Event", 2,300 million years ago. Oxygen levels rose again around 550 million years ago. The first animals appear in the [fossil record](#) at this time, marking the beginning of an era that geologists call the "Phanerozoic" – a Greek word meaning "evident animals". This new work explores how oxygen levels changed

during the Phanerozoic.

The new study was led by Tais W. Dahl while he was a postdoctoral scholar at Harvard. Dahl spent several months in Anbar's lab at ASU during his graduate research learning how to make the necessary measurements from Gwyneth Gordon, Ph.D., who is also an author of this paper. Other authors include geochemist Don Canfield, Dahl's Ph.D. mentor at the University of Southern Denmark, and paleontologist Andrew Knoll, Dahl's postdoctoral mentor at Harvard.

Dahl returned to ASU to perform the measurements for this study, which involved measuring the relative amounts of different isotopes of the element molybdenum in rocks called "black shales". These rocks are formed from ancient ocean sediments.

Isotopes are atoms of an element, in this case molybdenum, that differ only in their mass and therefore can be easily distinguished from one another. Molybdenum has seven stable isotopes. Chemical reactions fractionate heavy from light isotopes. For example, carbon 12 is enriched by three percent in plants relative to the carbon in carbon dioxide in the atmosphere. Similarly, molybdenum isotopes are fractionated during their removal from seawater into ocean sediments. The magnitude of this fractionation is sensitive to the presence of oxygen.

The data Dahl obtained at ASU reveal that there were at least two stages of oxygenation during the Phanerozoic, separated by the oxygenation event 400 million years ago. This inference from molybdenum isotopes is corroborated by the appearance of large (up to 30 feet long) predatory fish in the fossil record 400 million years ago, coincident with the rise in oxygen. Animals of that size consume energy rapidly, requiring high levels of oxygen for their metabolism. "Tais's data indicate that early animals evolved in an environment with less oxygen than today," said

Anbar. The newly discovered oxygenation event therefore explains the puzzling appearance of these fish in the fossil record. "It's always satisfying when we can demonstrate how an environmental change drove biological evolution," Anbar explained.

"But the real kicker is that these data also show us the reverse - that biological innovation can drive environmental change" continued Anbar. He points to the fact that vascular plants also appear in the fossil record around 400 million years ago. The bodies of such plants decompose with difficulty, making it easier for organic carbon to be buried in sediments. When that happens, the organic carbon – produced by photosynthesis – is not available for reaction with oxygen. The consequence is a rise in the amount of oxygen in the environment.

"It's a push-me-pull-you situation," explained Anbar. The biological innovation of vascular plants led to more carbon burial, and therefore to more oxygen. Then, the rise in [oxygen](#) made it possible for larger animals to evolve. "This is a great example of what we call the "co evolution" of life and the environment", enthused Anbar "Geoscientists talk about this idea a lot, but we rarely find such nice examples."

Provided by Arizona State University

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