How plants drove animals to the land

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Artistic depiction of early Devonian land-flora. Image: Eduard Riou (1838-1900) from The World Before the Deluge 1872, United States.

(PhysOrg.com) -- A new study of ancient oxygen levels presents the first concrete evidence that after aquatic plants evolved and boosted the levels of oxygen aquatic life exploded, leading to fierce competition that eventually led some fish to try to survive on land.

Evolutionary biologist Tais Dahl and colleague Donald Canfield, of the Nordic Center for Earth Evolution with the University of Southern Denmark in Odense, analyzed ancient sea bed samples from around the globe, and dated between 400 million and 1.7 billion years old. They looked particularly at molybdenum, which is common in the soil and

swept by erosion into the sea, where it circulates for around a million years before settling in the sediment on the sea bed.

The ratios of molybdenum isotopes change subtly in response to oxygen levels, and the stratified layers of deposits therefore present a record of the Earth's oxygen levels. In oxygenated sea water the lighter isotopes ^{95}Mo and ^{98}Mo are absorbed into the sea bed, leaving the heavier isotopes in solution. The patterns of light and heavy isotopes are deposited as striations in rocks called shales, and the strata can be used to chart periods of low and high oxygen levels.

Dahl said the record is much more detailed than information gleaned from the more traditionally studied carbon deposits, and that "indeterminate" carbon records have led to two different theories of the ancient oxygen concentrations and hence the evolution of life on Earth. The uncertainty of the models increase the farther back in time you go, but each of the two models accepts that oxygen levels first spiked around 550 million years ago, which coincides with the appearance of the first symmetrical, mobile forms of life. After that time the two theories diverge.

The first theory is more accepted, and holds that oxygen levels continued to rise and reached levels close to current day levels well before life diversified again about 400 million years ago. According to this theory life in shallow waters such as lagoons began to venture onto the land about 50 million years later. In this view plants provided more atmospheric oxygen but were not essential.

Dunkleosteus terreli, a placoderm from the Devonian. Image: Nobu Tamura / Wikimedia Commons.

The second theory has oxygen levels remaining steady from the Ediacaran period 560-550 million years ago to the Devonian period some 400 million years ago. At that time the ancestors of the modern vascular plants had evolved and flourished, leading to another spike in oxygen levels, which allowed fish to become larger, more numerous, and more predatory in nature.

Dahl and Canfield's findings support the second theory, and provide the first empirical evidence in support of this interpretation. Dahl said the oxygen levels remained steady after 550 million years ago and this limited fish evolution, but after the second dramatic increase about 400 million years ago caused by plants releasing oxygen, fish were able to grow larger — up to 10 meters long — and more predatory, and it was this flourishing of large predators that led other creatures onto the land to escape the predation.

The paper was published in the 28 September edition of the journal

Proceedings of the National Academy of Sciences (*PNAS*). Dahl said further analyses are needed to confirm the findings, but it "looks very promising at this stage."

More information: Dahl, T, W. et al. Devonian rise in atmospheric oxygen correlated to the radiations of terrestrial plants and large predatory fish. *PNAS Early Edition*, September 2010. doi:10.1073/pnas.1011287107