Early forests did not significantly change the atmospheric CO2, finds paleoclimate modeling study

December 20 2022

Close up of fossil and Lycophyte. Credit: M.A.R Harding

Scientists have discovered that the atmosphere contained far less CO_2 than previously thought when forests emerged on our planet, the new study has important implications for understanding how land plants affect the climate.

The research has been led by the University of Copenhagen in collaboration with the University of Nottingham and alters 30 years of previous understanding. The study is published in *Nature Communications*.

Earth's continents were colonized by tall trees and forests about 385 million years ago. Before then, shallow shrub-like plants with vascular tissue, stems, shallow roots, and no flowers had invaded the land. Textbooks tell us that the atmosphere at that time had far higher CO_2 levels than today and that an intense greenhouse effect led to a much warmer climate. The emergence of forests was previously thought to promote CO_2 removal from the atmosphere, driving the Earth into a long cool period with ice cover at the poles.

Reconstructing atmospheric CO_2 levels in the geological past is difficult and has previously relied on proxies that also depend on parameters that had to be assumed. Climate scientists agree that CO_2 plays a crucial role in shaping Earth's climate both today and in the past. Therefore, a grand challenge for Earth scientist is to understand what has controlled the abundance CO_2 in the atmosphere.

"We calibrated a mechanistic model for the gas-exchange between plant leaves and the ambient air to the oldest lineage of vascular land plants, namely clubmosses. With this approach, we could calculate the CO_2 level in the air solely from observations made on the plant material," says associate professor Tais W. Dahl from the Globe institute at University of Copenhagen, who led the study in collaboration with an international team of researchers from Germany, Saudi Arabia, the U.K., and the U.S.

The new method builds on three observations that can be made both in living plants and fossil plant tissue, including the ratio of two stable carbon isotopes and the size and density of stomata (pore openings) through which CO_2 is taken up by the plant. The researchers calibrated the method in living clubmosses and found that this approach can accurately reproduce ambient CO_2 levels in the greenhouse.

"The newly calibrated method to study CO_2 levels from the geological record is superior to previous approaches that produce estimates with unbound error bars simply because they depend on parameters that cannot be independently constrained in the geological record," says Barry Lomax Professor at University of Nottingham and a co-author on the study.

The research team applied the method to some of the oldest vascular plant fossils that lived before and after trees evolved on our planet and discovered that the ratio of the two stable carbon isotopes, carbon-13 and carbon-12, is very similar to that of modern plants. Further, the stomata density and size were also very similar to that observed in their living descendants. These observations kickstarted a more thorough investigation of the early CO_2 record.

Dahl and colleagues collected data from 66 fossils of three distinct species of club mosses found in nine different localities worldwide 410 to 380 million years in age. In all cases, the atmospheric CO_2 levels were only 30–70% higher (~525–715 ppm) than today (~415 ppm). This is far lower than previously thought (2,000–8,000 ppm). Ppm stands for parts-per-million and is the unit used to measure carbon dioxide concentrations in air.

The team utilized a paleoclimate model to show that Earth was a temperate planet with mean tropical surface air temperatures of 24.1–24.6°C.

"We used a fully coupled atmosphere-ocean model to find that Earth had ice-covered poles when forests emerged. Yet, land plants could thrive in the tropical, subtropical and temperate zones," explains Georg Feulner from the Potsdam Institute for Climate in Germany, who co-authored the study.

The new study suggest that trees actually play an insignificant role on atmospheric CO_2 levels over longer time scales because early trees had deeper root systems and produced more developed soils that are associated with lower nutrient loss. With more efficient nutrient recycling in soils, trees actually have a smaller weathering demand than the shallow shrub-like vegetation that came before them. This idea goes against previous thinking that trees with deeper root system promoted CO_2 removal through enhanced chemical weathering and dissolution of silicate rocks.

Dahl and colleagues used Earth system models to show that primitive shrub-like vascular plants could have caused a massive decline in atmospheric CO_2 earlier in history, when they first spread on the continents. The model shows that vascular ecosystem would have simultaneously led to a rise in atmospheric O_2 levels.

More information: Tais Dahl, Low atmospheric CO2 levels before the rise of forested ecosystems, *Nature Communications* (2022). DOI: 10.1038/s41467-022-35085-9.
www.nature.com/articles/s41467-022-35085-9

Provided by University of Nottingham

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