Study finds forest cover and runoff influenced by freezing temperatures during late Paleozoic ice age

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New research led by Baylor University biology doctoral candidate William J. Matthaeus and professor of biology Joseph White, Ph.D., considers how plant freeze-intolerance affected forest cover and hydrology during the Pennsylvanian period, roughly 340 million to 285 million years ago during the Paleozoic Era, proposing improvements to climate projections for the past and future with plant function data.

This highly interdisciplinary and collaborative project included Baylor geology post-doctoral researcher Jon Richey, as well as climate scientists, geologists and paleobotanists from several other U.S. and European institutions.

The study, published in *Proceedings of the National Academy of Sciences*, suggests that plant freezing would have limited the geographical distribution of forest cover across the supercontinent Pangaea. During this time, there were glacial-interglacial cycles and sustained periods of low temperatures. Depending on the limitations of freeze-tolerant plant physiology, freezing minimum temperatures likely limited the ability of arboreal plants to survive.

"Plants can tell us things about the time and place that they grew because plants have basic needs, kind of like people. But because plants can't move around to get what they need, they have to build their 'bodies' to work well for where they're growing," Matthaeus said. "Because of this, plant fossils contain information about the way those plants functioned, but also the conditions they faced, even 300 million years ago."

Low forest cover increased surface runoff of freshwater and sediment in some regions. The freeze-induced runoff changed considerably between glacial and interglacial periods across Pangaea, and may have driven location-specific differences in mineral, sediment, organic matter and nutrient levels in the freshwater runoff into riverine, riparian and coastal marine environments.

The researchers combined climate modeling and ecosystem process modeling to simulate arboreal vegetation during the late Paleozoic ice age. Because existing global climate modeling projections do not account for differences of plant functional traits between contemporary and Paleozoic plants, the researchers used fossil-derived plant trait data to simulate global ecosystem processes.

"Even with the limited sample of the fossil record used here, hints toward the impact of freezing on 300-million-year-old plant communities are evident. We're combining fossil-based inference about plant function with global climate modeling to bring ancient Earth to life. This is a critical pairing of disciplines for assembling the puzzle of natural history," Matthaeus said.

The global climate modeling showed that freezing temperatures were nearly global in occurrence and likely one limiting factor in forest cover distribution, even in the topics. Less than 25% of unglaciated land that could support vegetation remained above freezing year-round. The researchers suggest that widespread and repeated exposure of plants to freezing temperatures during the Pennsylvanian influenced the evolution of notable aspects of later Paleozoic plant physiology.

"Climate models are typically used to study average temperature trends over monthly or longer time scales in the Earth's past. However, this approach ignores temperature extremes that are known to be critical for plant function and survival today. One novel aspect of this study is that we focus on daily temperature changes simulated by the model that plants likely endured during the Pennsylvanian," said Sophia I. Macarewich, co-author and paleoclimatology and scientific computing doctoral candidate at the University of Michigan.

The incorporation of fossil-derived paleobotanical data into deep-time climate modeling can improve projections and understanding of past Earth systems as well as aid future climate change models, according to the authors.

"Further development of these methods may serve as a bridge for understanding the foundations of global ecosystems across Earth's ancient past. By understanding how things worked throughout natural history, we have a better chance of understanding our own future," Matthaeus said.

White sees the study as bolstering Baylor as a leader in the field, particularly with regard to doctoral studies and academic success.

"Mr. Matthaeus' success can be attributed to his inherently inquisitive mind and outstanding computational skills that, with his academic degrees in evolutionary biology and mathematics, provided him with the prepared mind to succeed in addressing such a difficult question," he said. "He is also extremely well-read and has had the benefit of direct interaction with the discipline experts, many of whom are his co-authors, in addition to mentorship from additional Baylor faculty such as paleobotanist Dr. Dan Peppe, associate professor of geosciences, and Dr. Bernd Zechmann, director and associate research professor for the Center for Microscopy and Imaging."

More information: William J. Matthaeus et al, Freeze tolerance influenced forest cover and hydrology during the Pennsylvanian, *Proceedings of the National Academy of Sciences* (2021). DOI: 10.1073/pnas.2025227118

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