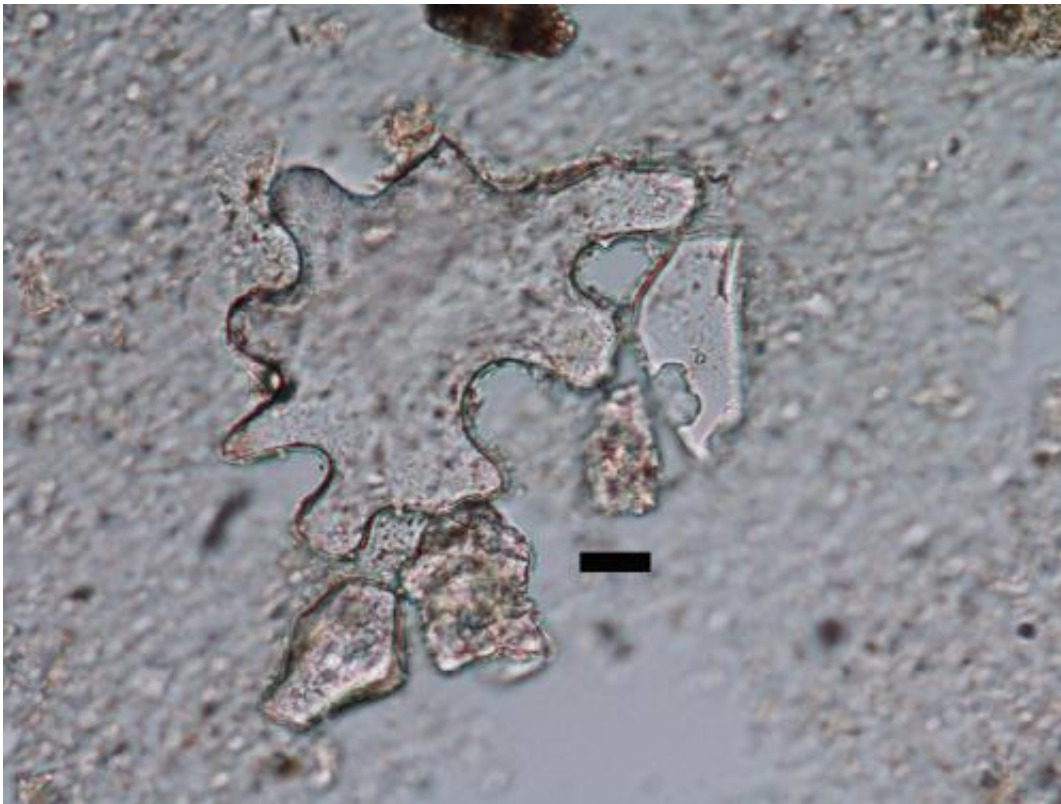


Tiny plant fossils a window into Earth's landscape millions of years ago

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49 million-year-old epidermal phytolith from a fossil soil horizon of the Las Flores Formation. Its curvy and large shape indicate the plant it came from grew in shady conditions. Scale bar = 10 micrometers. Credit: Regan Dunn, U of Washington

Minuscule, fossilized pieces of plants could tell a detailed story of what the Earth looked like 50 million years ago.

An international team led by the University of Washington has discovered a way to determine the [tree cover](#) and density of trees, shrubs and bushes in locations over time based on clues in the cells of plant fossils preserved in rocks and soil. Tree density directly affects precipitation, erosion, animal behavior and a host of other factors in the natural world. Quantifying [vegetation structure](#) throughout time could shed light on how the Earth's ecosystems changed over millions of years.

"Knowing an area's vegetation structure and the arrangement of leaves on the Earth's surface is key for understanding the terrestrial ecosystem. It's the context in which all land-based organisms live, but we didn't have a way to measure it until now," said lead author Regan Dunn, a paleontologist at the UW's Burke Museum of Natural History and Culture. Dunn completed this work as a UW doctoral student in the lab of Caroline Strömberg, the Estella B. Leopold associate professor in biology and curator of paleobotany at the Burke Museum.

The findings are published Jan. 16 in the journal *Science*.

The team focused its fieldwork on several sites in Patagonia, Argentina, which have some of the best-preserved fossils in the world and together represent 38 million years of ecosystem history (49-11 million years ago). Paleontologists have for years painstakingly collected fossils from these sites, and worked to precisely determine their ages using radiometric dating. The new study builds on this growing body of knowledge.

In Patagonia and other places, scientists have some idea based on ancient plant remains such as fossilized pollen and leaves what species of plants were alive at given periods in Earth's history. For example, the team's previous work documented vegetation composition for this area of Patagonia. But there hasn't been a way to precisely quantify vegetation openness, aside from general speculations of open or bare habitats, as

opposed to closed or tree-covered habitats.



Molar tooth of a toxodont, an extinct South American herbivore that evolved high crowned teeth. Colhue-Huapi Member (~20 million years old). Credit: Regan Dunn

"Now we have a tool to go and look at a lot of different important intervals in our history where we don't know what happened to the structure of vegetation," said Dunn, citing the period just after the mass extinction that killed off the dinosaurs.

"The significance of this work cannot be understated," said co-author Strömberg. "Vegetation structure links all aspects of modern ecosystems, from soil moisture to primary productivity to global climate. Using this

method, we can finally quantify in detail how Earth's plant and animal communities have responded to climate change over millions of years, which is vital for forecasting how ecosystems will change under predicted future climate scenarios."

Work by other scientists has shown that the cells found in a plant's outermost layer, called the epidermis, change in size and shape depending on how much sun the plant is exposed to while its leaves develop. For example, the cells of a leaf that grow in deeper shade will be larger and curvier than the cells of leaves that develop in less covered areas.



Richard Madden, Caroline Strömberg and Matthew Kohn work in Miocene-aged deposits near Rio Chico in Chubut Province, Argentina. Credit: Regan Dunn, U of Washington

Dunn and collaborators found that these cell patterns, indicating growth in shade or sun, similarly show up in some plant fossils. When a plant's leaves fall to the ground and decompose, tiny silica particles inside the plants called phytoliths remain as part of the soil layer. The phytoliths were found to perfectly mimic the cell shapes and sizes that indicate whether or not the plant grew in a shady or open area.

The researchers decided to check their hypothesis that fossilized cells could tell a more complete story of vegetation structure by testing it in a modern setting: Costa Rica.

Dunn took soil samples from sites in Costa Rica that varied from covered rainforests to grassy savannahs to woody shrub lands. She also took photos looking directly up at the tree canopy (or lack thereof) at each site, noting the total vegetation coverage.



Tree canopy cover at a site in Santa Rosa National Park, Costa Rica. The corresponding forest profile (modified from Holdridge et al., 1971) gives a side profile of the forest's density. Credit: Regan Dunn, U of Washington

Back in the lab, she extracted the phytoliths from each soil sample and measured them under the microscope. When compared with tree coverage estimated from the corresponding photos, Dunn and co-authors found that the curves and sizes of the cells directly related to the amount of shade in their environments. The researchers characterized the amount of shade as "leaf area index," which is a standard way of measuring vegetation over a specific area.

Testing this relationship between leaf area index and plant cell structures in modern environments allowed the team to develop an equation that can be used to predict vegetation openness at any time in the past, provided there are preserved plant fossils.

"Leaf area index is a well-known variable for ecologists, climate scientists and modelers, but no one's ever been able to imagine how you could reconstruct tree coverage in the past—and now we can," said co-author Richard Madden of the University of Chicago. "We should be able to reconstruct leaf area index by using all kinds of fossil plant preservation, not just phytoliths. Once that is demonstrated, then the places in the world where we can reconstruct this will increase."

When Dunn and co-authors applied their method to 40-million-year-old phytoliths from Patagonia, they found something surprising—habitats lost dense tree cover and opened up much earlier than previously thought based on other paleobotanic studies. This is significant because the decline in vegetation cover occurred during the same period as cooling ocean temperatures and the evolution of animals with the type of teeth

that feed in open, dusty habitats.

The research team plans to test the relationship between vegetation coverage and plant cell structure in other regions around the world. They also hope to find other types of [plant fossils](#) that hold the same information at the cellular level as do phytoliths.

More information: "Linked canopy, climate, and faunal change in the Cenozoic of Patagonia," by R.E. Dunn et al. *Science*,
www.sciencemag.org/lookup/doi/10.1126/science.1260947

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