Decade-long project pushes back the prehistoric timeline in Africa by more than 10 million years

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Artistic rendering of the open woodland habitat reconstruction at Moroto II with Morotopithecus bishopi vertically climbing with infant on back and juvenile below. Active volcano (Mount Moroto) is in background. Fossil relative of an elephant (Prodeinotherium) is foraging in center back. Credit: Corbin Rainbolt

Something as simple as a grass can fundamentally change the understanding of life in the prehistoric world. Studies published in the journal *Science* document the earliest evidence for locally abundant C_4 grasses in eastern Africa and how C_4 grasses and open habitats influenced early ape evolution.

Since 2013, Daniel Peppe, Ph.D., associate professor of geosciences at Baylor University and an international team of researchers have focused their research on understanding how ancient environments influenced the evolution of early apes in eastern Africa.

Researchers have often argued that during the early Miocene, between about 15 and 20 million years ago, equatorial Africa was covered by a semi-continuous forest and that open habitats with C_4 grasses didn't proliferate until about 8 to 10 million years ago. Yet there was some research that showed contradictory evidence to this long held idea. This lone study had evidence of C_4 grasses in East Africa around 15 million years ago. Peppe and the research team set out to find if this study was an anomaly or a clue to the true diversity of ecosystems that occurred during the early Miocene.

Determining whether open habitats and C_4 plants were more prevalent much earlier than originally thought would have important implications for understanding the features and adaptations of early apes and why there are tropical C_4 grasslands and savanna ecosystems in Africa and around the world.

Peppe and a collaborative team of geologists conducted research alongside paleoanthropologists at nine Early Miocene fossil site complexes in the East African Rift of Kenya and Uganda.

Collectively known as the Research on Eastern African Catarrhine and Hominoid Evolution project or REACHE, the team simultaneously

focused on understanding the types of ecosystems that existed in the early Miocene, and particularly the prevalence of open environments and C_4 grasses, and how these different environments could have potentially affected the evolution of early apes, such as Morotopithecus.

The research flourished through the uniqueness of the REACHE project, according to co-author Kieran McNulty, Ph.D., professor of anthropology at the University of Minnesota, who played a central role in organizing the project.

"Working in the fossil record is challenging. We discover hints and clues about past life and need to figure out how to assemble and interpret them across space and time. Any one of the analyses in these papers would have made for an interesting study, and any one of them, alone, would have produced incomplete, inconclusive or incorrect interpretations," McNulty said. "That is the nature of paleontological research: it's like putting together a 4D puzzle, but where each team member can only see some of the pieces. By combining these methods, we leverage the strength of one to shore up weaknesses or validate assumptions of another, resulting in a synthetic approach that challenge well-established theories."

As participants exchanged information and expertise about geological features, isotopes and plant and ape fossils found at the sites, the bigger picture came into focus. The paradigm that during the early Miocene period equatorial Africa was completely forested was wrong.

Further, the result of this decade long research pushes back the oldest evidence of C_4 grass-dominated habitats in Africa—and globally—by more than 10 million years, calling for revised paleoecological interpretations of the development of plants and mammals.

"We suspected that we would find C_4 plants at some sites, but we didn't

expect to find them at as many sites as we did, and in such high abundance," Peppe said. "Multiple lines of evidence show that C_4 grasses and open habitats were important parts of the early Miocene landscape and that early apes lived in a wide variety of habitats, ranging from closed canopy forests to open habitats like scrublands and wooded grasslands with C_4 grasses. It really changes our understanding of what ecosystems looked like when the modern African plant and animal community was evolving."

A critical aspect of this work was that the team combined many different lines of evidence—geology, fossil soils, isotopes and phytoliths, which are plant silica microfossils—to reach their conclusions.

"The history of grassland ecosystem in Africa prior to 10 million years had remained a mystery, in part because there were so few plant fossils, so it was exciting when it became clear that we had phytolith assemblages to add to the other lines of evidence," said co-author Caroline Strömberg, Ph.D., professor of biology at the University of Washington.

"Phytoliths are particularly informative for revealing the history of grassland ecosystems. They can tell us not just that there were grasses, but which grasses were there and how abundant they were on the landscape. What we found was thrilling, and very different from what was the accepted story. We used to think tropical, C_4 dominated grasslands only appeared in the last 8 million years or so, depending on the continent. Instead, both phytolith data and isotopic data showed that C_4 dominated grassy environments appeared over 10 million years earlier, in the early Miocene in eastern Africa."

This much earlier occurrence of C_4 grasses and open habitats found at the same sites as early apes also allowed the researchers to assess the

kinds of environments in which the early apes were living, according to co-author Rahab Kinyanjui Ph.D of the National Museums of Kenya and Max Planck Institute.

"As a paleobotanist, my first task in any fieldwork is to undertake vegetation study of the site in question. Then I collect sediments with known geological age, either absolute or relative dates," Kinyanjui said. "My work gets exciting once I process and extract plant microfossils in the lab to study them through the microscope. This task can take weeks to months depending on the number of samples, abundance and diversity of the plant's microfossils. These are weeks/months spent in the ancient wilderness, habitats that are no longer in existence. Roaming through ecosystems imagining the kind of animals you are likely to encounter in the forests, bushlands and grasslands."

Importantly, one of the most advanced early apes, Morotopithecus, was found to inhabit open woodland environments with abundant grasses and to rely on leaves as an important component of its diet. This contradicts long-standing predictions that the unique features of apes, such as an upright torso, originated in forested environments to enable access to fruit resources. These findings are transformative, said Robin Bernstein, program director for biological anthropology at the U.S. National Science Foundation.

"For the first time, by combining diverse lines of evidence, this collaborative research team tied specific aspects of early ape anatomy to nuanced environmental changes in their habitat in eastern Africa, now revealed as more open and less forested than previously thought. The effort outlines a new framework for future studies regarding ape evolutionary origins," Bernstein said.

More information: Daniel J. Peppe et al, Oldest evidence of abundant C4 grasses and habitat heterogeneity in eastern Africa, *Science* (2023).

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