Researchers use ancient plant leaf wax to reconstruct the history of Taiwan's mountains

June 26 2023, by Elaina Hancock

Taiwan has some of the world's fastest rates of mountain building. Studying the mountains of Taiwan provides insight into how the mountains are formed and grow. This view is st Hualien, Taiwan. Credit: Queenie Chang

When it comes to studying certain geological processes, you can't get much closer to studying them in real-time than in Taiwan.

Taiwan experiences some of the world's fastest rates of mountain building—they are growing at a faster rate than our fingernails grow in a year. The mountains also see frequent and significant earthquakes, the region experiences about four typhoons per year on average, and in some places, it receives upwards of several meters of rain annually, says UConn Associate Professor in the Department of Earth Sciences, Michael Hren.

These conditions are all due to Taiwan's location at the convergence of the Eurasian and Philippine Sea plates, which leads to a landscape of extremes where you can see the mountains growing, falling, and weathering, all on a human timescale. Hren's team and their collaborators from the University of Oregon have applied novel techniques to understand this changeable mountain range's past. Their findings are published in *Science Advances*.

"For decades Taiwan has been a place where people study the processes of how the earth works because everything is sped up a little bit. It's also an archetypal example of an arc-continent collision, so it's a model for the world, yet we know very little about the height of those mountains through time," says Hren.

Knowing the height of mountains through time is important because the topography, or physical features, of a mountain, are the result of a balance between mountain building and erosion.

Hren explains, "The height of mountains tells us about how or what the feedbacks are between processes in the atmosphere, climate, weathering, biology, and processes that are occurring deep in the earth. If we know the topography, and the height of mountains through time, and we also know what's going on underneath the surface, then we can figure out how these things influence one another."

These ancient events can also help us better understand how the process of mountain uplift impacts the global carbon cycle. For instance, as silicate minerals in mountains are weathered, carbon dioxide from the atmosphere can ultimately become stored in marine carbonate rocks. Similarly, organic carbon produced on land is exported to the sea, says Hren, storing carbon in the deep ocean. Both of these processes can impact long-term atmospheric carbon dioxide levels.

"If we don't understand mountain evolution, then we don't understand how tectonic processes are linked to the atmosphere and global climate," Hren says. "Reconstructing the paleoelevation history of tropical mountain belts such as Taiwan has proved difficult because it is hot, it is wet, things erode quickly and most sediment is dumped into the ocean. There's not a lot of the record left to study on land."

With the shortage of tools for quantifying the paleoelevation of Taiwan, Hren's research group, including Queenie Chang Ph.D., has taken a novel approach to looking back at the history of Taiwan's mountains. The researchers collected 39 samples of ancient sediment transported by water racing down rivers, carrying sediments away from the mountains, from several sections across the Taiwan mountain belt.

3-million-year and younger sedimentary rocks are well preserved and exposed in eastern Taiwan. By analyzing the isotope chemistry of these rocks the researchers are able to reconstruct the paleoelevation of the mountains. Credit: Queenie Chang

"Sediments derived from the mountain were transported and accumulated on the river floodplains and deep marine basin. They were lithified into sedimentary rocks after millions of years," says Chang. "Thanks to the rapid uplift rate in Taiwan, these layers of rock now are exposed on the surface for us to study and collect."

They measured the isotope chemistry of the organic matter in these sedimentary rocks from throughout the ancient river system, which holds details about the elevation at which ancient plants grew, yielding evidence of the history of the entire river network.

"We're essentially trying to relate the chemistry of sedimentary organic matter to where the materials came from in this journey. These sediments are anywhere from three million years old to more recent and the chemistry can tell us about mountain evolution," says Hren.

The researchers measure hydrogen isotopes stored in leaf waxes, which record the water that fell across the landscape before being taken up by plants and other primary producers. The records reveal a fundamental shift in the chemistry of the sediments over time, reflecting changes to the landscape and showing how the mountain belts on the eastern side of Taiwan evolved and grew. Namely, they saw a rapid upshift in elevation of about two kilometers (roughly 1.2 miles) from about 1.3 to 1.5 million years ago to the present.

"Much previous geological evidence has shown a significant transition of tectonic activity in Taiwan at this time—increasing sedimentation rate in the ocean, increasing rock exhumation rate, and a change in plate convergence orientation. Our findings show how these changes in tectonic activities influence the Earth's surface landscape and the height of the mountains rapidly," says Chang.

Hren says this approach yields the first real data for quantifying the evolution of how high the mountains were in Taiwan, and the technique can be applied to any tropical mountain belt.

This research will help dispel uncertainty about Taiwan's paleotopographic history, and Hren explains that much of the debate surrounded the age of the mountains and when they developed. The isotope data provides constraints that can be built upon to reveal further insights into the history and processes of the mountain range.

"There have been long-standing debates about not just when exactly the mountains went up, but also how they went up," Hren says. "One traditional view has been that there was a southward migration of mountain building, then effectively, it started in the north and then continues to grow to the south. This is a part of addressing that question. The other part is about the timing, where some would argue for an older development, and some believe it just popped up in the last million years."

Hren notes that this research is an international effort and was made possible because of a collaborative project with multiple students from Taiwanese universities and faculty members from across the U.S. With the constraints the data applies, the researchers are continuing their work to reconstruct the past and gain a better understanding of these geological phenomena that have so much bearing on how the rest of the planet functions.

"When you grow a mountain, much of the organic matter gets eroded and carried into the ocean and has big implications for the global carbon cycle," says Hren. "We're working on further constraining that process in Taiwan, we're also looking at basins or sediments throughout the island to develop a comprehensive picture of the entire island system to try and answer these questions. Was there a spatial gradient in the timing of uplift? Are there differences in the records between the east sides and the west sides as we think about different mountain systems there? That's part of an ongoing project that we're continuing in Taiwan."

More information: Queenie Chang et al, Rapid topographic growth of the Taiwan orogen since ~1.3–1.5 Ma, *Science Advances* (2023). DOI: 10.1126/sciadv.ade6415

Provided by University of Connecticut