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New paleoaltimetry research questions assumptions about the formation of the Himalayas

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Mountain ranges play a key role in global climate, altering weather and shaping the flora and fauna that inhabit their slopes and the valleys below. As warm air rises windward grades and cools, moisture condenses into rain and snow. On the leeward side, it's quite the opposite. Deserts prevail, a phenomenon known as rain shadow. Thus, the way mountain ranges form is a matter of intense interest among those who study and model climates of the past.

That debate will soon grow more heated with a new paper in the journal *Nature Geoscience*. A team of researchers at the Stanford Doerr School of Sustainability has adapted a technique used to study meteorites to measure historic altitudes in sedimentary rocks to show that one of the world's most familiar mountain ranges, the Himalayas, did not form as experts have long assumed.

"The controversy rests mainly in what existed 'before' the Himalayas were there," explains Page Chamberlain, professor of Earth and planetary sciences and of Earth system science at the Doerr School of Sustainability, and senior author of the study. "Our study shows for the first time that the edges of the two tectonic plates were already quite high prior to the collision that created the Himalayas—about 3.5 kilometers on average."

"That's more than 60% of their present height," added Daniel Ibarra, Ph.D., a postdoctoral researcher from Chamberlain's lab, first author of the paper, and now an assistant professor at Brown University. "That's a lot higher than many thought and this new understanding could reshape theories about past climate and biodiversity."

At the very least, the findings mean that ancient climate models will have to be recalibrated, and it will likely lead to new paleoclimatic assumptions about the Himalayan region of Southern Tibet, an area known as the Gangdese Arc. It could also beget closer scrutiny of other key mountain ranges, such as the Andes and the Sierra Nevada.

Old technique, new insight

Why this longstanding debate is suddenly roiling has much to do with the challenges of measuring topographic altitudes of the past—a field known as paleoaltimetry. It is extremely challenging work, the researchers say. There are not many proxies for altitude in the geologic record, but the Stanford team found one in collaboration with study authors from China University of Geosciences (Beijing).

Not only do rains fall more heavily on windward slopes, but the chemical composition of the precipitation changes as the air rises toward the peaks. Heavier isotopes tend to drop out first; lighter ones nearer the peaks. Thus, by analyzing the isotopic makeup of the rocks, experts can find the telltale signs of the altitude at which they were laid down.

In the sedimentary record, oxygen exists in three stable isotopes: oxygen 16, 17, 18. Dauntingly, the key isotope, oxygen 17, is extremely rare. It comprises just 0.04% of the oxygen on Earth. That means, in a sample containing a million atoms of oxygen, just four atoms are oxygen 17.

"There are maybe eight labs in the world that can do this analysis," said Chamberlain, who helped process samples at the Terrestrial Paleoclimate lab at Stanford. "Still, it took us three years to get numbers that made some sense and that were working every day."

Tectonic shifts

That explains why triple oxygen analysis had been overlooked—or perhaps too easily dismissed—as a proxy for ancient altitude. But Chamberlain and his colleagues saw an opportunity. Using a grant from the Heising-Simons Foundation, the team adapted the technique to paleoaltimetry and used the mountains of Sun Valley, Idaho, for a proof-of-concept paper in 2020. With the science established, they then turned their sights higher—to the Himalayas.

Sampling quartz veins from lower altitudes in southern Tibet and using triple oxygen analysis, the team showed that the foundations of the Gangdese Arc were already much higher than anticipated, long before any tectonic collision occurred.

"Experts have long thought that it takes a massive tectonic collision, on the order of continent-to-continent scale, to produce the sort of uplift required to produce Himalaya-scale elevations," Ibarra said. "This study disproves that and sends the field in some interesting new directions."

Contributing authors include Yuan Gao, Jingen Dai, and Chengshan Wang at China University of Geosciences (Beijing). Chamberlain is also a member of Bio-X and an affiliate with the Stanford Woods Institute for the Environment.

More information: High-elevation Tibetan Plateau before India–Eurasia collision recorded by triple oxygen isotopes, *Nature Geoscience* (2023). DOI: 10.1038/s41561-023-01243-x , www.nature.com/articles/s41561-023-01243-x

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