STORY *John Fleischman*

Freezing point

This frame: Melt water lake at base of Quelccaya ice cap in the Peruvian Andes. **Below:** *Distichia muscoides*, a wetland native snap-frozen by a swiftly advancing glacier 5,200 years ago.

Clues to a sudden, unexplained climatic shift 5,200 years ago are being unmasked by the retreat of the world's tropical glaciers. Could it happen again?

Thirty years ago, Lonnie Thompson's interest in tropical glaciers was thought odd enough, but his grant proposals to backpack solar-powered ice-coring drills to the top of the Andes were taken for madness.

"In the early days, no one would fund this work," Thompson recalls. "Their first reaction was, 'What are you doing in the tropics?' Then they said this was the craziest proposal they'd ever seen. They'd never seen a line item for 45 mules before."

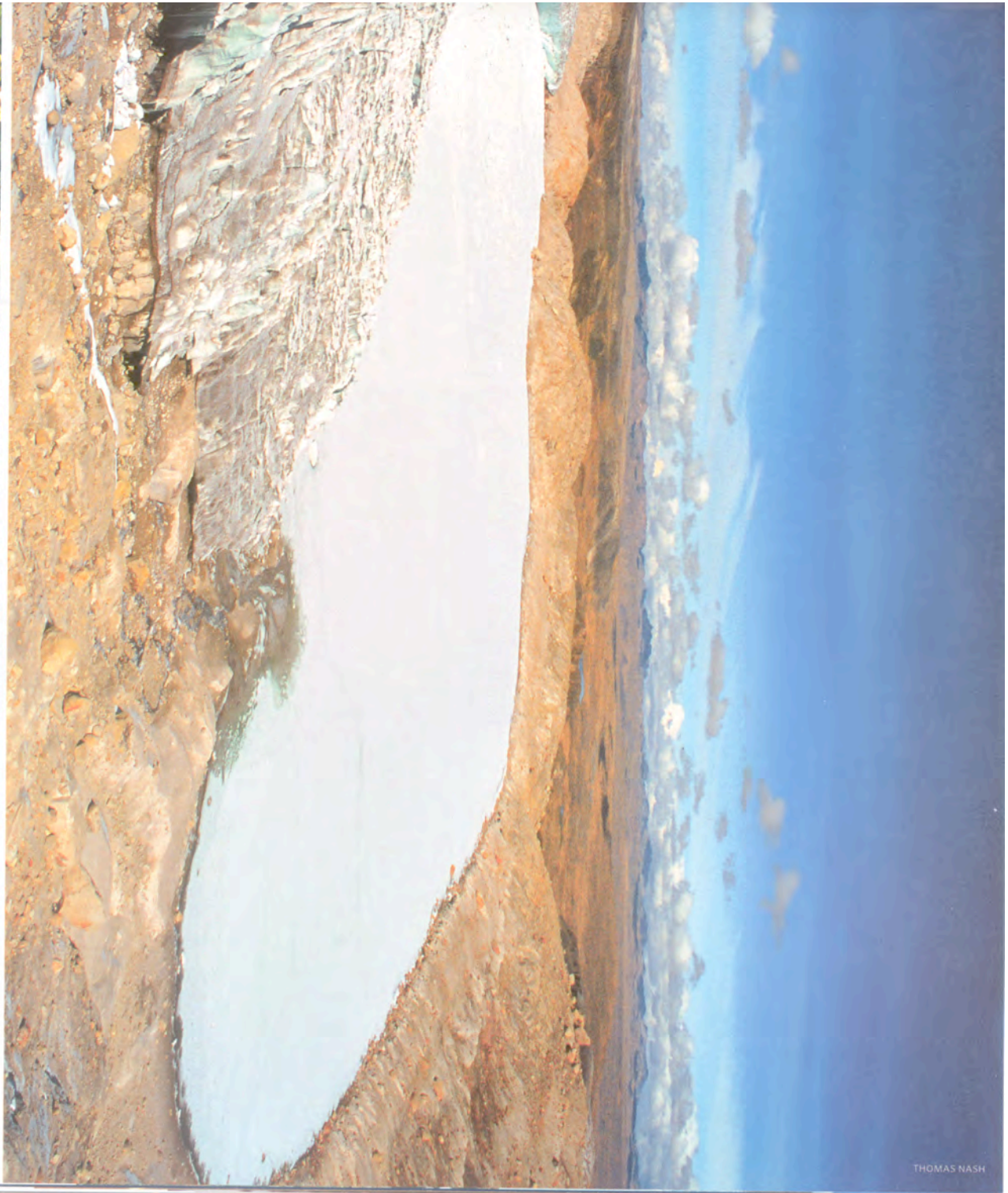
But then nobody had ever drilled a high-altitude, tropical-latitude glacier to bedrock. That was until Thompson finally rounded up the methodology, the money and the mules in 1983 to core the Quelccaya ice cap at 5,800 metres above sea level in southern Peru. From dust and oxygen isotopes trapped in the ice, Thompson made a highly detailed 1,500-year climate history of Quelccaya, the first of hundreds he would pull from high-altitude drilling in South America, Africa and Asia.

From this library of ice cores, Thompson compiled a climate history that now extends deep into the Pleistocene, 130,000 years ago. Today, Thompson's world-renowned ice library is safeguarded inside -35°C archival freezer rooms in the Byrd Polar Research Centre at Ohio State University.

The irony is that outside the archive, Thompson's field is melting. From the slush of Mount Kilimanjaro to the rapid retreat of Quelccaya, the world's ancient tropical glaciers are disappearing at an exponentially increasing rate, says Thompson. Based on measurements he made in 2000 and updated on a return last December, Thompson has calculated that Kilimanjaro, Africa's only glacier, will likely disappear within 15 years.

Along with depriving Australia of its distinction as the only continent on Earth without a glacier, Kilimanjaro's demise could signal more unpredictable climate change to come. The newest evidence is coming out of the ice. Consider a specimen of alpaca moss Thompson gathered at Quelccaya in 2002 at the face of the retreating glacier. It wasn't growing and it wasn't fossilised.

BLANCA LEÓN



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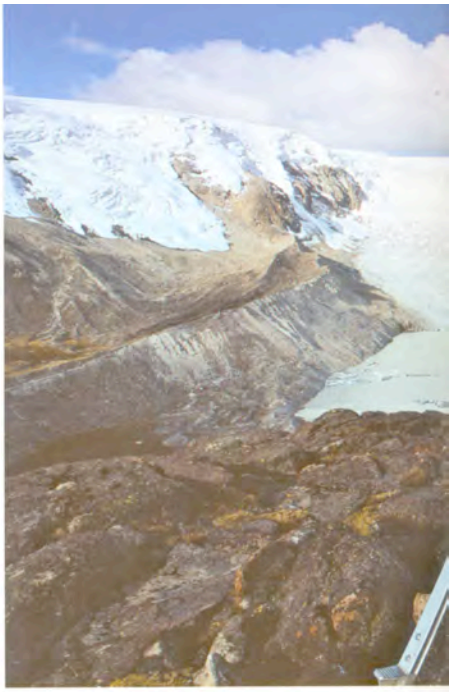
Bruce Koci and Lonnie Thompson (at right) at the summit of Quelccaya in 1983 with a piece of the first tropical ice core ever recovered.

LONNIE THOMPSON



It was flash-frozen, most likely captured by a sudden, out-of-season snowfall, and sealed in place until modern warming released it. Radioactive carbon dating by the Lawrence Livermore National Laboratory in California and the Woods Hole Oceanographic Institute in Massachusetts were in close agreement: these plants lived 5,200 years ago.

Thompson found this frozen cushion of alpaca moss behind the string of ponds that have sprung up along the glacial margin. When he first scouted Quelccaya 30 years ago, there was no open water anywhere near the glacier. By 2002, one of these ponds had become a lake covering 1,277 square kilometres.

"I'm a glaciologist by training, but all this new land is being exposed as the ice retreats, so I've been wondering how quickly plants can re-establish themselves on new ground," says Thompson. "So I went way to the back of one of these new lakes, right under a 30-metre-high ice wall – and there, at the base of the wall, about two metres from the ice, was this plant deposit. I took a pocket knife and cut out a little piece. It was perfectly preserved. I figured that anyone who knew what they were looking at – which I didn't – could identify this plant."

To find someone who could, Thompson contacted Blanca Leon, a Peruvian-born botanist and Andean 'altoplano' expert who is a research fellow at the Plant Resources Centre of the University of Texas in Austin. Leon recalls her first glimpse of the dated but still unidentified Quelccaya specimen.

"First, Lonnie sent me an image by e-mail but when I opened it, I only saw grey blobs," Leon remembers. Thompson followed it up with a cryo-packed specimen by air express. "It was very dry material, so first I had to rehydrate it by soaking," Leon recalls. "But when I began to clean the leaves, I said, 'Oh, my goodness. I know you.' This is a very common plant today in the Andes. So I knew right away what it was, but I had to be sure. So I cleaned some more leaves, peeled away part of the epidermal tissue and put it under the microscope to look at the pattern of the stomata. It was definitely *Distichia muscoides*. So I wrote to Lonnie that it was like running into a very old friend."

"From the slush of Kilimanjaro to the rapid retreat of Quelccaya, the world's ancient tropical glaciers are disappearing at an exponentially increasing rate."

Distichia muscoides is not a moss but a member of the rush family, Juncacae. Unlike a moss, Distichia has tiny, tiny flowers, says Leon, between its evergreen leaves. It's common today in the Andes from Ecuador to northern Argentina at elevations above 3,800 metres – but it grows nowhere near the 5,800 metres where Thompson discovered his frozen specimen. Most importantly, Leon says that Distichia is a wetland plant that requires liquid rainfall and is an unlikely pioneer species onto newly exposed glacial moraine (the accumulated boulders and other debris carried by glaciers).

Even today, with all the melt water at Quelccaya, Distichia is not a living presence. The frozen Distichia Thompson discovered flourished at Quelccaya in a warmer, wetter climate as part of an established wetland ecology. That climate and that ecology ended abruptly at Quelccaya 5,200 years ago – possibly in a matter of days.

It had to have been fast, says Thompson – perhaps an epic blizzard that buried the still-growing plants in place and never melted. The glacier advanced down the valley later as the cold intensified. High-altitude glaciers such as Quelccaya are 'cold-based'. Frozen to their beds and with little or no internal melt water, cold-based glaciers don't flow above a watery base layer but move by internal slippage of the accumulating ice. Cold-based glaciers deform around obstacles instead of bulldozing them. When Quelccaya's advancing ice wall struck a bedrock outcrop just above the little plain where the snow-buried Distichia waited, the ice arced up and over the outcrop, leaving an ice cavern in its lee. Distichia spent the last 5,200 years encased in ice, but not crushed by it.

"Whatever happened 5,200 years ago was so abrupt, so sudden that these plants were captured and preserved in a perfect state," says Thompson. "That shows an abrupt change in a warm climate. The Greenland

THOMAS NASH

Henry Brecher measures ice volume loss at the Qori Kalís glacier, Quelccaya ice cap.

THOMAS NASH

Lonnie Thompson with the Quelccaya ice cap in the background. On Thompson's early visits, around 1976, the boulder was being moved by the ice. In 2000, when this photo was taken, it had receded hundreds of metres.

ice cores show huge variations in temperature over short periods of time – but that was in a cold climate. Here is a sudden change in a warm climate period such as that we are in now. These plants can give us perspective on the current warming."

The Quelccaya date of 5,200 years ago for this abrupt climate reversal ties in with other evidence coming out of the ice in a warming world, according to Thompson – including Ötzi the iceman whose perfectly preserved body was spotted by climbers in 1991, melted part-way out of a glacier near the Austrian-Italian border. The iceman met a similar fate as the frozen Distichia, says Thompson. "Here was a human being who was shot in the back with an arrow but managed to escape his pursuers. He hid behind a rock where he bled to death in a snow event that buried him so deep he never decayed or was found by scavengers. He is so well preserved that we know from looking at the pollen in his lungs what valley he was walking in eight hours before he died." Date of death? You guessed it: 5,200 years ago.

Ötzi the iceman's death fits into a chain of other evidence for an abrupt climate change at about the same time. It matches the samples from Thompson's Kilimanjaro ice cores that show their biggest 'isotope event' – a change in the ratio of two oxygen isotopes that mark major humidity and temperature shifts 5,200 years ago. It matches a 5,200-year date for a sudden warm-to-cold change documented by uranium-thorium dating in Israel. And it matches 'dendochronologies', or tree ring series, which have been painstakingly assembled in Ireland and England.

"If you look at them, the narrowest ring until the 'Little Ice Age' (from 1450 A.D. to 1880) was 5,194 years before the present," says Thompson. The date matches evidence from marine cores taken off the East African coast, from the disappearance of massive lakes in the Sahara Desert, and from trees rising out of melting glaciers in the Cascade Mountains of the Pacific Northwest of the United States. This climate flip 5,200 years ago has no name yet, says Thompson. "Maybe we should name it."

Call it the Quelccaya Crash. In June 2005, Thompson went back to Peru with six tonnes of equipment to redrill Quelccaya before its zero isothermal line disappears altogether, turning its ice archive into a soggy blur. Leon and her husband and collaborator, Kenneth Young, a geographer at the University of Texas, went along. While Thompson's team drilled on the ice fields above, the couple roamed the new margin lands, collecting 20 new 'melt-out' plants in two different valleys.

Life at 5,800 metres is not easy on plants, nor is it easy on botanists, says Leon with some chagrin. "It was so funny. My family is from the Andes and I grew up in Peru, but here I was [at Quelccaya], and I was so very sick. I've been to high altitudes before but never at this altitude in my own country."

Leon was astounded by the rate of glacial retreat. "Lonnie has a photographic dating series for this area, so we knew at what distance from the glacier these plants were found in 2002, and where the glacier was this summer." Quelccaya had lost 30 metres in three years. "It was mind boggling," Leon recalls.

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