



PHOTOGRAPH FOR ONEARTH BY MATTHIEU PALEY

HIMALAYA MELTING

GLACIAL LAKES POSE A NEW
PERIL AS ICE TURNS TO WATER

BY BROUGHTON COBURN

IN THE HEART OF NEPAL'S SAGARMATHA

National Park, I hike above the hamlet of Chukung, 11 miles south of Mount Everest, with Tenzing Sherpa, a former monk in the Tengboche monastery. We wander through lush yak meadows beneath the monolithic Lhotse, the world's fourth-highest mountain peak. Ravens clack and prattle as they wheel above us, and I scan the surrounding peaks, all more than 22,000 feet. Our faces are seared by the high-altitude sun, our backs chilled by the 10-degree air.

We scramble up the flank of a 200-foot-high hill of freshly churned rubble that stretches more than a mile. I reach the ridgeline, peer cautiously over an abrupt edge, then quickly draw back from a precipitous drop to a lake 150 feet below. I crawl again to the edge and watch a skein of late-morning mist rise from the water's surface, like steam from a cup of coffee.

Fifty years ago, Imja Tsho (*tsho* is Tibetan for lake)—now about a mile in length and up to 295 feet deep—did not exist. Instead of looking down at a body of water, we would have looked out at the Imja Glacier, an upended maze of house-size blocks of ice and near-bottomless crevasses. Now, between breaths, Tenzing and I listen as rocks loosened from the gravelly glacial moraine by the morning thaw clatter and plunge to the water.

The rapid melting and recession of the Imja Glacier, and the simultaneous growth of Imja Tsho, have alarmed national park staff and the Sherpas who grow potatoes and run trekking lodges in scattered villages down valley.

Glaciologists are concerned too, for they are seeing glacial lakes forming and filling faster than they can identify and catalog them. Ultimately, they fear, many will simply grow too large and burst through their moraines of unstable ice and rubble—as happened in northern Bhutan in 1994.

The glacial lake
Dig Tsho, in
Nepal, overflowed
when it burst
through its
moraine, visible in
the foreground.

That year, a mile-long glacial lake named Luggye Tsho, near Bhutan's border with Tibet, ruptured catastrophically. Over a period of several hours, the entire lake—more than a billion cubic feet of water—emptied out, sending a rampaging torrent down valley that swept away an artisans' colony near the town of Punakha, killing 23 people. Along Bhutan's border with India, 125 miles away, a hydrograph that measures the level of the nearby Sankosh River broke when the water rose to eight feet above normal. Now two nearby lakes, Thorthormi and Raphstreng, are also poised to overflow.

The Great Himalaya is home to thousands of glacial lakes. In 2001 the United Nations Environment Program identified 44 in Nepal and Bhutan that are at imminent risk of bursting. The task of tracking the growth of all these lakes is immense: The Himalaya contains more than 18,000 glaciers covering an area of 13,000 square miles. Directly to the north on the Qinghai-Tibetan Plateau, according to the Chinese Academy of Sciences, 46,298 glaciers blanket nearly 60,000 square miles. All told, this constitutes the largest area of ice outside the polar regions.

Global warming has forced into retreat virtually all of these glaciers, which are shrinking at a rate of 100 to 230 feet per year. Since the mid-1970s, average air temperatures across the Himalaya have risen by 1 degree centigrade, with higher sites warming twice as much as middle elevations. Glaciers reflect sunlight back into the atmosphere, but as they recede, more heat-absorbing rock and impounded glacial lake water are exposed to the sun, raising ambient temperatures and intensifying the melting process. This phenomenon is similar to what is occurring at the polar ice caps, as dark-colored ocean replaces the reflective ice sheet.

During the Little Ice Age, which ended as recently as 150 years ago, glaciers slowly bulldozed horseshoe-shape moraines of rubble and ice down valley. Now the melting tongues of some glaciers are found several miles up valley from these remnant moraines' farthest reaches. Some of these natural structures act as dams, trapping glacial meltwater. But they are not inviolate; beneath their surface rubble lies a core consisting largely of ice. As this ice melts,

the moraine subsides and the lake fills with meltwater. "Piping," or infiltration of lake water through interstices in the ice and rubble, further weakens the moraine, turning it into the geologic equivalent of Swiss cheese.

The collapse of a moraine dam usually doesn't occur spontaneously. Most outbursts are triggered by a specific event, such as a landslide or an avalanche that sends rock and earth cascading into the water, generating a massive surge wave that can crest at well over 100 feet. These waves easily overtop the retaining moraine, causing a breach.

GLACIAL LAKE OUTBURST FLOODS ARE SUDDEN

and terrifying, as anyone who has seen one can tell you. Heading down valley, Tenzing and I stop in the hamlet of Ghat, along a river named the Dudh Kosi, about five days' walk below the Everest base camp. We park our rucksacks at the lodge of an old friend, Lama Dorje, whom I came to know while working as a UNESCO consultant, nearly 20 years ago. Sweeping a length of robe over his shoulder, Lama Dorje, now 78, emerges from the Buddhist chapel attached to his lodge and summons us into his kitchen. He sets a teakettle over the open hearth and blows on the fire, then recounts the 1985 flood that washed away half of his village.

During the monsoon season, a gargantuan chunk of the Langmoche Glacier, perched above the southwestern end of a lake called Dig Tsho, a day's walk upriver from Ghat, detached and crashed into the lake. The resulting wave hurdled the lake's natural moraine, displacing enough rubble and ice to cause an outburst.

"My wife and I were drinking tea at the hearth of our old house, below here," Lama Dorje says, running his fingers across his head. "We heard a low, whirring rumble that gradually grew in volume, like an approaching helicopter. I scrambled down the stairs, stepped outside, and looked upriver. It was right there, coming toward us—a wall of gray and brown water with what looked like steam or dust swirling crazily around it and above it. The wave itself was filled with boulders, dirt, firewood, and whole trees. The trees would run into an obstacle, be forcefully upended, and be tossed downriver,



MAP BY MIKE REAGAN



Lama Dorje had to rebuild his home and monastery; both were washed away when the glacial lake Dig Tsho overflowed its natural moraine. The pathway scoured by the flood, right, is still visible below Thame village.

over and over again, like a kid kicking a stick down a trail.

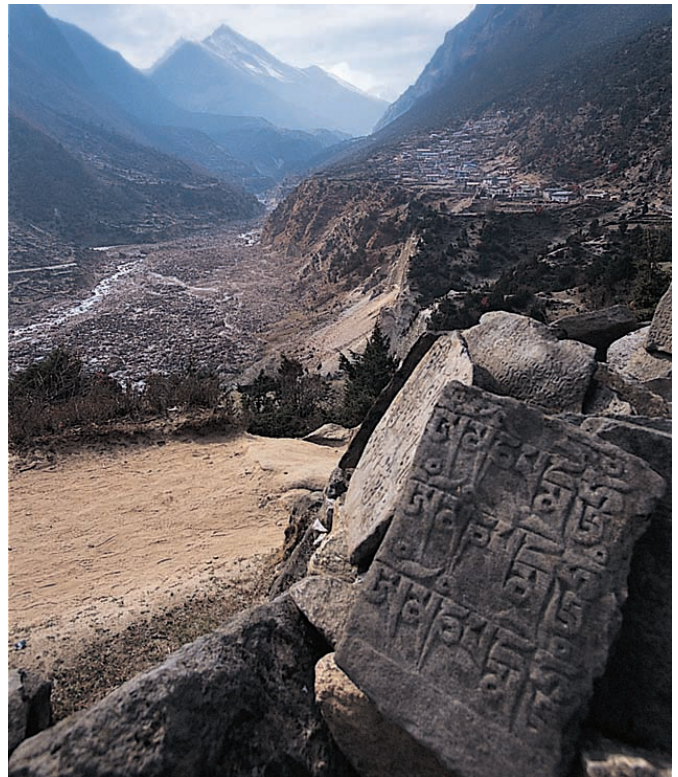
“When the wall of water reached the bridge just downstream from here, it simply picked up the bridge and took it away. Then it carried away four of our livestock, then our neighbors’ livestock. When it reached the houses located below ours, it swept those away too. We could only stand there helplessly.”

Over the next six hours, the entire volume of the mile-long lake careered furiously down the narrow valley, destroying a nearly completed 500-kilowatt hydropower station, sweeping away 14 bridges, and erasing stretches of the Everest trek route. By the time it surged across the Indian border, 100 miles downstream, four people had drowned. The flood occurred during daytime, fortunately, when valley residents could escape to higher ground; otherwise there would almost certainly have been more casualties.

AT TWO MILES LONG AND 100 FEET DEEP

Tsho Rolpa, Nepal’s largest glacial lake, lies menacingly at the head of a quiet valley known as Rolwaling, 40 miles west of Everest. Rolwaling is home to many of the Sherpa youth who work as high-altitude climbing guides. The \$60 million Khimti hydropower project, which supplies electricity to Nepal’s national grid, is also located nearby. In aerial photographs the lake’s narrow, 500-foot-high ice-core dam appears to bulge outward from the water impounded behind it.

At the International Center for Integrated Mountain Development, a research facility on the outskirts of Kathmandu, remote-sensing expert Birendra Bajracharya shows me a computer model of what is likely to happen when Tsho Rolpa bursts. He calmly points to areas where fields and houses would be swept away. I no-



tice a red wash over the village of Beding, just 10 miles below the lake, where the level of the river would climb to more than 50 feet above its present level, flooding the hamlet.

In 1992, after a smaller glacial lake burst nearby, the village’s 300 residents petitioned the government to protect them from the swollen Tsho Rolpa, a far more imposing threat. The Nepalese government, with financial aid from the Netherlands, responded by digging a channel in the lake’s moraine and constructing a 20-foot-wide flood control gate. Engineers lowered Tsho Rolpa by 10 feet, which has reduced water pressure on the moraine. But lowering the lake has also exposed a larger area of the moraine to the rays of the sun and to ambient air temperatures higher than that of the frigid water. This could allow more heat to migrate into the moraine, expediting the melting of its ice-and-rubble core.

John Reynolds, managing director of Reynolds Geo-Sciences, an environmental engineering firm based in Wales that specializes in glacial hazard assessment and remediation projects, remains concerned. “Tsho Rolpa is still at risk,” he says. “To make it truly safe, the level should be drawn down at least another 37 feet”—at a cost of about \$12 million. By contrast, if the lake bursts, the cost in repairs and lost revenue for the Khimti hydropower plant could reach \$22 million, not to mention the loss of property and livestock belonging to the subsistence villagers who live below the lake.

And yet governments and aid agencies are reluctant to finance glacial lake studies or remediation work. It’s a political fact of life: Funds for emergency disaster relief are easier to come by than support for preventive measures. Which means the mountain villagers least responsible for global warming, and least able to affect its outcome, will pay the consequences. 🍂

Broughton Coburn is co-editor of *Himalaya: Personal Stories of Grandeur, Challenge, and Hope* (National Geographic Books).