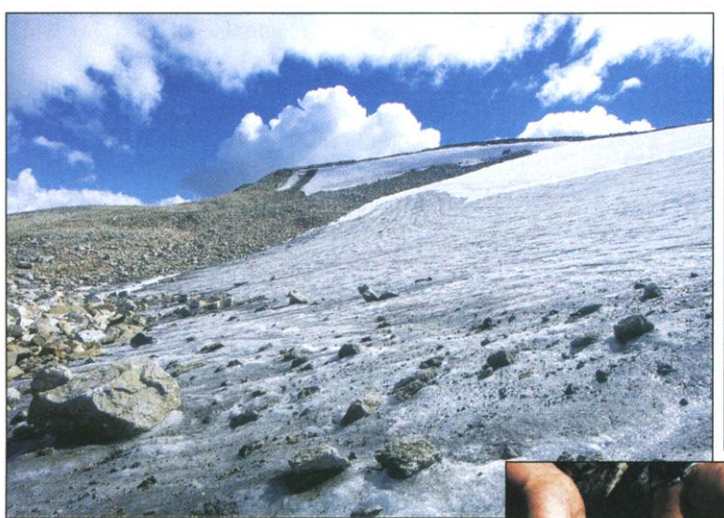
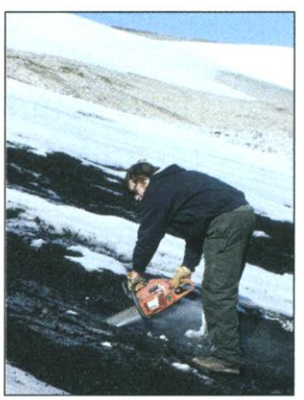
Animal and human remains frozen for thousands of years are melting out of glacial ice—and scientists are rushing to capture them before they decay

# Melting Glaciers Release Ancient Relics

Gerald Kuzyk was hiking on a snowy Yukon peak in summer 1997 when the wind lashed an unexpected barnyard stench his way. He followed his nose to a square kilometer of fresh, ankle-deep caribou dung melting from a perennial ice bank—but caribou had not been seen there for generations. Kuzyk, a wildlife technician for the Yukon Department of Renewable Resources, had stumbled on the alpine equivalent of King Tut's tomb:





**Following the ice.** Scientists retrieve objects, such as this 7080-year-old spear tip still lashed with sinew (*bottom right*), from receding Yukon ice patches; to date the finds, researchers slice out samples (*top right*).

Melting ice was releasing a treasure trove of ancient relics. During a few summer weeks of working at this spot and nearby ones like it, Kuzyk and colleagues found not only rivers of dung but also remains of large mammals, whole freeze-dried birds and rodents, and human artifacts including a long wooden projectile shaft complete with sinews, feathers, and ochre paint. Radiocarbon dating showed that the ice held a more or less continuous biologic record for 8300 years, reaching almost to the present.

As alpine glaciers around the world succumb to warming, scientists are reaping grand harvests of frozen organic objects—and with them previously unavailable information on past wildlife, human culture, genetics, climate, and more. Tissues with intact DNA and archaeological objects of wood and bone provide pictures that stone tools only hint at, and because they can all be radiocarbon dated, there is little guessing about chronology. Up to now, such well-preserved objects from the last 10,000 years—after the retreat of the last great ice sheets—had been vanishingly rare in most parts of the world.

Because the frozen objects are so valuable—and decay so fast once exposed—a growing cadre of scientists is trying to predict and comb fertile spots. "The potential for discovery in many fields is tremendous," says Yukon Territory wildlife biologist Rick Farnell, who is based in Whitehorse and heads an interdisciplinary team that now regularly harvests Yukon ice. "It's one of the few positive things to climate change."

### Vanishing ice

Glaciers have been thinning and retreating since the mid–19th century—Switzerland's have declined a third in volume since 1860—but now the pace is accelerating and with it the urgency to collect stranded perishables. Many regions have not been this warm for 8000 years or more, and so some frozen objects may be at least that old. In March, the University of Colorado published a report by glaciologist Mark Dyurgerov estimating that mountain glaciers worldwide are losing 90 cubic kilometers of ice a year, with those in Alaska, the Andes, and central Asia dwindling particularly fast. Glaciologist Lonnie Thompson of Ohio State University, Columbus, says that the Qori Kalis glacier in the Peruvian Andes, which has retreated by 4.7 meters a year since the 1960s, has suddenly started wasting that much in a week and that the famous snows of Kenya's Mount Kilimanjaro may be completely gone by 2015 (*Science*, 2 March 2001, p. 1690). "This is a really good time to expand the search for any kind of objects," says Dyurgerov.

Until now, scientists assumed that just ice, snow, and plowed-up rocks collect in glaciers, but clearly animals, plants, and people do, too. David Hik, a wildlife biologist at the University of Alberta in Edmonton, has studied the 40,000 square kilometers of mountain ice fields linking the Yukon with coastal Alaska—North America's largest glacial expanse—and says that many animals stray there, including wolves, bears, mountain goats, and especially rabbitlike pikas, which live on rock islands in the ice kilometers from other land. Many eventually end up in the deep freeze. Dozens of bird species migrate over the ice fields and surprisingly often crash by the flockful, later to turn up in snowbanks like raisins in a fruitcake. Even whole forests are sometimes encased by advancing ice, as shown by largely intact ancient trees washing out of glaciers in Alaska and Switzerland. "Ice is a gold mine of dead stuff," says Hik.

Humans have also crossed glaciers far more often than previously thought. In recent years ethnographers and aboriginal elders of the interior Southern Tutchone and coastal Tlingit tribes have drawn maps showing the seemingly impassable Yukon-Alaska ice fields crisscrossed with once-

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lively trade routes. Some natives and later travelers—including countless 19th century gold prospectors—starved, froze, or plunged down the emerald-shaded depths of crevasses. "Some of these people have a long way to go, but we'll see them again," says Gerry Holdsworth, a glaciologist at the University of Calgary, Alberta.

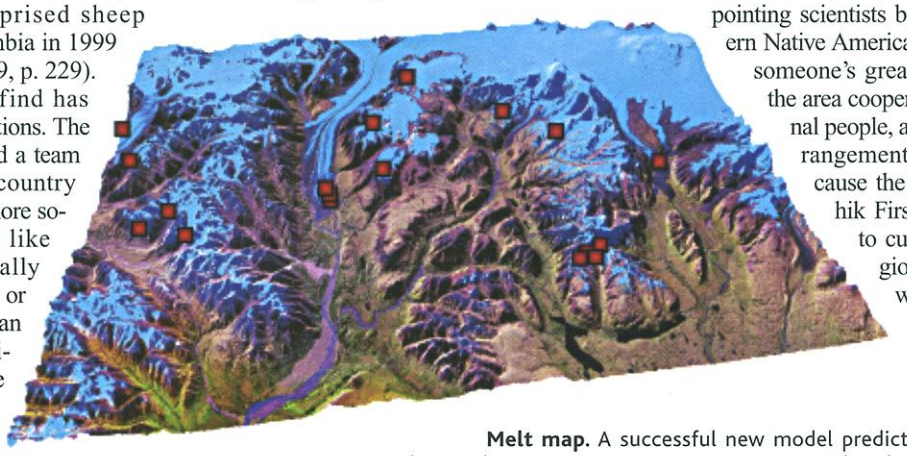
Until now most finds have been accidents, such as the 5300-year-old "Iceman of the Alps" (*Science*, 28 September 2001, p. 2373), spotted by European hikers in 1991 and still under study. Another, much younger ice man surprised sheep hunters in British Columbia in 1999 (*Science*, 8 October 1999, p. 229).

But Kuzyk's 1997 find has spawned sustained operations. The following year Farnell led a team that combed the high country west of Whitehorse for more so-called "ice patches" like Kuzyk's, which generally cover a square kilometer or less and are no more than 50 meters deep—technically too small to be called glaciers, but perfect for artifact hunting because they are susceptible to fast annual melting. So far the team has visited two dozen patches by helicopter during summer melt season, and in more than half team members have found bones, animal tissues, human artifacts, and, everywhere, lots of dung. (Not all animals died in the ice, but many left calling cards.) Farnell says in retrospect it's no mystery why the patches hold such riches: Today, wherever caribou are found, they can be seen wallowing in similar perennial ice to escape summer heat and insects. "Hunters, I'm sure, knew this," he says, and they killed prey in these dependable spots for thousands of years.

Practically every ice-preserved object has scientific value. The humble dung contains not only pollen but large chunks of undigested plants and lichens easily identifiable by species, revealing what was growing and therefore the climate during various periods. Wood also provides climate clues; last year in the journal *Holocene*, a Swiss group reported a highly detailed 9000-year chronology of climate based on tree trunks and peat salvaged from melt streams in the Alps.

Farnell's group is still unraveling the chronology of the Yukon finds, but he says that ancient caribou ate more shrubs and mosses than caribou consume today, an indication of drier, colder times. Other Yukon animal remains include Dall sheep; mountain goats; elk; about 60 largely intact shrews, voles, and birds; and a 4000-year-old lemming. And Darlene Balkwill, a zooarchaeologist at the Canadian Museum of Nature in Ottawa, got a big surprise when analyzing the team's harvest: the horns, teeth, and dung of bison, suspected but never proven to have lived at high altitudes.

Alan Cooper, director of the Ancient Biomolecules Center at Oxford University, plans to analyze the DNA of the caribou and compare them with modern ones in other parts of the mountains. This, he says, will tell him whether today's animals are descended from the frozen ones or, as he suspects, caribou have been periodically extinguished from the region by climate change or humans and later replaced by outsiders. Previously Cooper has been able to study DNA from animals 15,000 to 60,000 years old preserved in permafrost (*Science*, 22 March, p. 2267). But until now, the warmer period of the past 10,000 years has yielded few remains. "The ice patches give us a DNA window into a period rarely seen," he says.



**Melt map.** A successful new model predicts Alaskan sites (squares) where objects melt out from glaciers (blue).

CREDIT: WILLIAM MANLEY AND E. JAMES DIXON/UNIVERSITY OF COLORADO

### Long Ago Person Found

The more recent record is doubly important, says Cooper, because that's when humans probably entered the region. Frozen objects may help resolve many questions about them and their interactions with animals. So far, the artifacts are stunning. There are wooden weapon shafts of birch, spruce, and willow up to 2 meters long, some with antler projectile points attached. One point still has caribou blood on it. There is a finely serrated ivory blade of unknown purpose. "This is unique," says Yukon government archaeologist Greg Hare. "Usually we get just stone points and try guessing what they mean. Now we have the whole thing." He says radiocarbon dating on the wood proves that hunters used the patches from at least 7300 years ago right into the mid–19th century, when the first Europeans arrived.

The weapons also help address a long-running debate about when bows and arrows appeared in the Americas. Some argue that they were used as far back as 10,000 years ago, but Hare says the shafts show that in this locale, until 1300 years ago the weapons were all spears designed to be thrown with a device called an atlatl; only the younger ones are arrows. The group has even found two bows of maple, apparently carried over the glaciers 80 kilometers from Alaska, where maples grow.

The Canadian iceman himself, found just south of the Yukon, wore a squirrel-fur cloak and finely woven hat much like those seen in the region today and carried a bone-and-metal knife, a spear, and a snack of dried fish in a leather bag. About 20 when he died, he was dated to "only" about 550 years ago—disappointing scientists but delighting northwestern Native Americans, because he could be someone's great-ancestor. Scientists in the area cooperate closely with aboriginal people, an unusually amicable arrangement that comes partly because the Champagne and Aishihik First Nations control rights to cultural artifacts in the region, and nothing gets done without their assent.

The Native Americans dubbed the frozen mummy *Kwaday Dan Ts'inchi*—Long Ago Person Found—and started their own DNA analysis project to see to whom he might be related. Says Diane Strand, heritage officer for the Champagne-Aishihik: "We want to know as much about him as we can. That's what science is for, right?"

Maria Victoria Monsalve, a pathologist at the University of British Columbia in Vancouver, is running separate DNA tests and says the iceman is tied to far-flung living native people, including the Haida off the British Columbia coast, the Quecha of Guatemala, and the Amerindians of Brazil. "His lineage is all over [today]," she says. "It bolsters the idea that humans [originally] came from Asia." Some moved south, whereas the ancestors of the Long Ago Person Found stayed up north. Her results are in press in the *American Journal of Physical Anthropology*.

The only thing missing: the Long Ago Person Found himself. After making sure scientists had enough samples, in July 2001 Indians held a potlatch, cremated him, and had his ashes airlifted by helicopter close to where he died. Archaeologist Al Mackie of the Royal British Columbia Museum in Victoria says that return visits to the vicinity have continued to yield objects apparently from other travelers, including notched sticks, a leather thong, and fragments of an atlatl, as well as insects, birds, and a moose.

### Ice spotting

No one knows exactly how old the rich ice patches may be, nor how much longer they

**Long Ago pocketknife.** The 550-year-old Canadian iceman kept his knife in this pouch.

will last. "We should be out there with 10 helicopters every summer, because these places may go fast," says Gordon Jarrell, curator of the frozen-tissue collection at the University of Alaska, Fairbanks, where many of the Yukon finds are stored. He says that flesh starts rotting within hours of exposure—and ravens and other alert scavengers may not mind eating even 8000-year-old meat.

To get ahead of the curve, scientists are now trying to pinpoint good prospecting spots. "We know things melt out, but the real problem is predicting exactly where they'll appear," says archaeologist James Dixon of the University of Colorado Institute of Arctic and Alpine Research (INSTAAR).

Dixon and glaciologist William Manley, also of INSTAAR, have spent the last 3 years assembling a Global Information System model to map potentially fruitful areas in Alaska, which they hope to apply to other areas of the world. Their charts overlay glaciologic data, such as the altitudes below which particular glaciers are melting, with information such as trade routes, ancient stone quarries, mineral licks, and other places where people and animals may have been.

Last summer Dixon and Manley tested their model in Alaska's Wrangell-St. Elias Park—and hit the jackpot. Landing by helicopter and ski plane, they found 36 sites with a mind-boggling array of melted-out material. In addition to the ever-present feces, they found fleshy remains of Dall sheep, caribou, assorted carnivores, many birds, and even a complete, perfectly preserved fish, perhaps hauled in by a human. Other leavings of people included an antler projectile lying near a punctured caribou scapula, a piece of cut wood, and a pile of horse-hoof rinds (the part of the toenail cut off to reshoe the horse) with rusty nails still attached. Dixon assumes these last are from a 1902 gold rush in which prospectors foolishly tried crossing the glaciers.

"The organic content of glaciers is amazing, and it has profound implications for everything from paleontology to water quality," says Dixon. Water quality? "Yes," he says, pointing out that many glaciers provide drinking water. One small example: A hotel near his Colorado home has a drinking fountain labeled: PURE WATER DIRECTLY FROM ARAPAHOE GLACIER. "I wince, thinking about what's probably in there."

–KEVIN KRAJICK

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IMMUNOLOGY

# Gently Soothing a Savage Immune System

**Autoimmune disease and transplant researchers are teaming up in their search for ways to make the immune system tolerate tissue it's attacking**

The immune system is a shifty character, displaying the faces of Dr. Jekyll and Mr. Hyde. Most people encounter only its benevolent side, charged with protecting against disease. But in others, the immune system bares its teeth. For organ transplant recipients, efforts to quash a beastly, overactive immune system have defined treatment for a generation. That may be about to change, as researchers search for ways to tame the immune system without obstructing it entirely.

The new approach, called immune tolerance as opposed to immune suppression, is driven by work in the transplant field, but experts in autoimmune diseases such as multiple sclerosis (MS) and type I diabetes are also getting into the game—in their case to modulate attacks on the patient's own tissue. Results from animal studies have generated promising findings, such as mice cured of diabetes and off all medication and monkeys with new kidneys who don't need immunosuppressants. Spurred on by such successes, dozens of clinical trials are now under way or gearing up.

"I'm very optimistic that [immune tolerance] is going to be a big step forward," says Fritz Bach, a transplant surgeon at Harvard Medical School in Boston. "I've been in this a long time, [and] I've never taken this view before."

But in humans, the work remains highly experimental. Along with some promising preliminary results, a handful of trials have screeched to a halt due to deadly adverse effects—a reminder of how exquisitely sensitive the immune system can be, and how much about it is left to learn.

### Friendly fire

Transplant surgeons have been battling host rejection for decades with drugs such as cyclosporine, which massively suppresses the immune system. This approach has allowed an impressive 90% to 95% of organ transplant recipients to retain their new organ for at least 1 year. But rejection numbers rise sharply with time. Despite continued use of immunosuppressants—patients must take them for life—by 10 years after transplant, the immune systems of roughly 50% of patients have rejected the organ. Even when

**Mix and match.** Immunologist Megan Sykes adds elements of an organ donor's immune system to a recipient's, aiming to overcome the need for immunosuppressants.

CREDITS: (TOP TO BOTTOM) CORBIS; M. SYKES