NEWS

Even in the High Arctic, Nothing Is Permanent

Rising temperatures are thawing vast swaths of northern land that had been frozen for millennia, creating headaches—and hazards—for scores of communities perched above unstable ground

Last spring, residents of a four-story apartment building in Cherskii, a town high above the Arctic Circle in northeastern Siberia, grabbed what few possessions they could carry and ran for their lives. Hours earlier, a huge crack had snaked up the wall of their building after hot water leaking from a pipe began melting the ice-laden ground below. The basement sank abruptly by more than a meter, and within 3 days, whole sections of the building had collapsed. "It seemed like an earthquake had hit," says geophysicist Vladimir Romanovsky of the University of Alaska, Fairbanks, who surveyed the scene last June.

To inhabitants of Russia's High Arctic, such misfortunes are becoming frighteningly familiar. Over the last 4 decades, rising global temperatures have hammered the region, thawing vast swaths of permanently frozen soil, or permafrost. The uppermost layers in some areas are thawing at rates approaching 20 centimeters per year, says geologist Thomas Osterkamp of the University of Alaska, Fairbanks. As a result, life in the harsh subpolar lands is getting harder: Roads are caving in, airport runways are fracturing, and buildings are cracking, tilting, and sometimes falling down. "Thirty years ago," says civil engineer Branko Ladanyi of the Polytechnic Institute of Montreal, "no one ever talked about [climate-induced] changes in ground temperature." As the toll from global warming mounts, that subject has become inescapable.

Early Arctic settlers built their wooden homes directly on permafrost, which covers more than 20% of the world's land surface, including most of Alaska and more than half of Canada and Russia. But the heat radiated by these buildings thawed the ground below, and many sank into dilapidation.

Engineers thought they'd licked this problem in the mid–20th century, when they began perching buildings on pilings driven deep into the permafrost. The meter-or-so gap between a building and the ground helps keep the permafrost cool. For larger structures, pipes channel heat away from the soil. More than 122,000 such pipes prop up a section of the Trans-Alaska Pipeline, adding $800 million to construction costs.

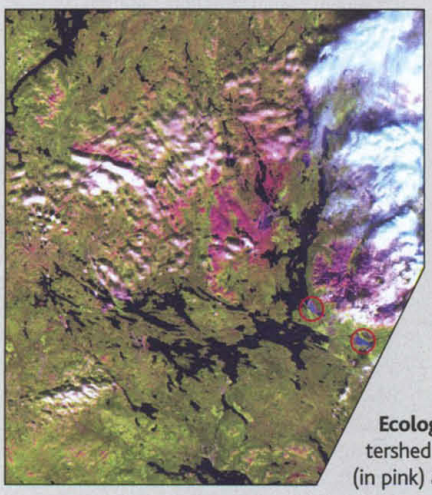
Such engineering fixes assumed that the permafrost would remain frozen if heat did not bleed into the ground. But climate change is beginning to wreak havoc, especially in areas with shoddy construction. "Some of the severest problems have occurred in the Russian Arctic because of the poor quality of the infrastructure and the lack of money to maintain it properly," says Gareth Rees of the Scott Polar Research Institute in Cambridge, U.K.

Russia might be worse off for other rea-

Slip-sliding away. Melting permafrost undercut the foundation of this apartment building in Cherskii, to devastating effect.

Feeling the Pulse of Modern Arctic Life

The tale is sadly familiar in the Russian High Arctic. For centuries, the Sámi worked the Kola Peninsula, breeding reindeer, fishing, and hunting on a frigid land hard up against northern Scandinavia. Then the Soviet industrial machine rolled in and pockmarked the peninsula with mines and military bases.



Ecological abuse. This Landsat image of the Imandra watershed reveals a swath of denuded land 60 kilometers long (in pink) and mine-tailings ponds (indicated by circles).

An innovative project is now attempting to use data on pollution and the environment to create a picture of how the post-communist upheaval is buffeting the Kola region. Although still in the early stages, "it's an interesting approach," says Arctic expert Rasmus Ole Rasmussen, a geographer at Roskilde University in Denmark.

To get a snapshot of regional conditions, the interdisciplinary project, sponsored by the Kola Science Centre of the Russian Academy of Sciences and the American Association for the Advancement of Science (AAAS, publisher of *Science*), is focusing at first on Lake Imandra and its 1379 tributaries. Like much of Kola, the Imandra watershed in Soviet times absorbed heavy pollution from mine tailings and power plant discharges. These days, people are leaving in droves. Imandra's population has shrunk from 362,000 in 1991 to fewer than 300,000 today. Most of the émigrés are "young and able-bodied," says Elizabeth Kirk, project leader for AAAS.

Filling in the details is proving harder than Kirk and others had anticipated. It's not certain, for one, whether a reduction in pollution has occurred in tandem with population decline. For example, although the Severonikel plant near Imandra no longer extracts nickel, it has ramped up its ore processing from other mines. The result, Kirk says, is that the plant might be belching more sulfur dioxide and heavy metals than ever before. Four mines that extract apatite and nephaline are also thriving. But other ecological nightmares have diminished: "The lake is getting a little clearer and fish stocks are on the rise," says Kirk. With the region on the mend, Kirk says, "there's plenty of reason for optimism."

As the 3-year-old project attempts to reconcile conflicting data, it is gearing up next year to address broader questions, such as how global warming might affect Imandra's ecology and economy. And the long-suffering Sámi will at last get their due: The project intends to pull in anthropologists to explore how this culture is coping with change high above the Arctic Circle. —RICHARD STONE

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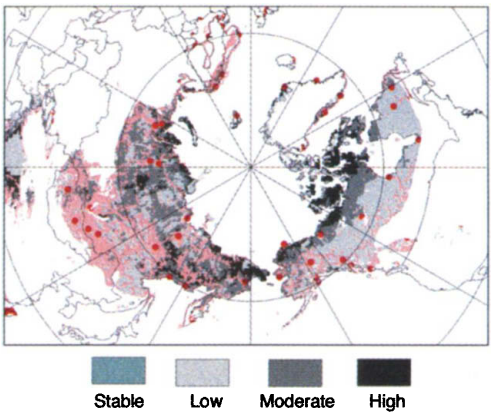
sons. Its Arctic territory supports a much larger population than do other permafrost-laden regions. And whereas Arctic architects in North America have tended to favor wood, their Soviet counterparts generally opted for concrete or brick edifices that pushed pilings to the limit, says geologist Peter Williams of Carleton University in Ottawa. So far, thawing permafrost has damaged roughly 300 apartment buildings in the Siberian cities of Norilsk and Yakutsk alone.

The situation, it appears, will only become direr. Lev Khrustalev, a geocryologist at Moscow State University, analyzed potential failures of five-story apartment buildings in the Russian Arctic as warmer temperatures reduce the ground's ability to bear weight. Assuming that the region continues to warm at the modest rate of 0.075°C per year, Khrustalev estimates that by 2030, *all* five-story structures built between 1950 and 1990 in Yakutsk, a city of 193,000 people, could come crashing down unless steps are taken to strengthen them and preserve the permafrost. Khrustalev has called repeatedly for modifications of Russian building codes to account for warming, to no avail.

The highest priority, experts say, is to come to grips with ice-rich permafrost, which is the type most prone to thawing. One strategy being floated is to preempt nature and thaw patches of this permafrost before construction starts. But this approach is unlikely to be adopted by many builders, Osterkamp says, as it could delay projects by up to 5 years. Some Arctic communities are already implementing less radical solutions, such as putting buildings on screw jacks or latticelike foundations that can be adjusted easily to accommodate shifting ground.



Danger zones. This map shows which towns and centers (red) and smaller settlements (pink) are most threatened by thawing permafrost.

To help planners identify settlements that need urgent action, experts are working up hazard maps based on permafrost type and warming models. "What we see now will only get worse. We need increased vigilance," says geologist Stephen Robinson of St. Lawrence University in Canton, New York. Robinson, Réjean Couture of the Geological Survey of Canada in Ottawa, and colleagues have worked with two Canadian Arctic towns, Norman Wells and Tuktoyaktuk, to tackle current problems and forecast future ones. Other hazard maps developed by Frederick Nelson's group at the University of Delaware, Newark, and Oleg Anisimov of the State Hydrological Institute in St. Petersburg, Russia, warn of trouble for places such as Barrow, Alaska; Inuvik, Northwest Territories; and Yakutsk, Norilsk, and Vorkuta in Russia.

According to geologist Rostislav Kamensky of the Permafrost Institute in Yakutsk, which will host a conference on permafrost engineering next month, sustainable development in the High Arctic depends on finding ways to adapt to thawing permafrost—not to mention shoring up the existing infrastructure before the next collapse catches people unawares. **–ERICA GOLDMAN**

With reporting by Julia Day in Cambridge, U.K.

NEWS

Breaking Up Is Far Too Easy

Spring is in the air on the Antarctic Peninsula, where rising temperatures are eroding ice shelves that have been in place for millennia. Their retreat could augur a far more perilous melting of the mainland ice sheets

MARGUERITE BAY, ANTARCTICA—As freezing rain pelts the deck of the *RRS James Clark Ross*, half a dozen men gather around as a winch hauls a 6-meter-tall, spindly steel contraption from the gray-green swells. A few minutes later the mackintosh-clad figures retrieve a cylinder from the clutches of the orange rig, then use a piston to extrude a clear plastic tube filled with grainy sediment. Two postdocs slice the tube into 1-meter sections, score each lengthwise with a saw, and carry the pieces below deck. There, on a steel workbench, they split the top section's soft mass with a wire, as though cutting cheese.

"This is the last 10,000 years," Cambridge University glaciologist Julian Dowdeswell says, pointing to a top section of oozing, greenish sludge. Delving further back in time, Dowdeswell presses his fingertips into stiff, dark-gray mud lower in the sediment core. It looks and feels like the kind of stuff one might slather on at a spa, but to scientists, it's vastly more precious: The mud is loaded with grains of sand and other glacial debris deposited by an ice sheet that covered this bay 15,000 years ago. These sediments hold clues to the climatic history of Antarctica—and, perhaps, to its future.

Catch of the day. Postdocs Colm O'Cofaigh and Jeffrey Evans split a plug of sediment fresh from the sea floor off the Antarctic Peninsula.

Collecting mud cores in this part of the world is no pleasure cruise. The *James Clark Ross*, a British Antarctic Survey (BAS) ship, spent a nauseating 2 days crossing the stormy Drake Passage that separates the peninsula and Cape Horn at the tip of South America. Here in Marguerite Bay, Dowdeswell, BAS marine geologist Carol Pudsey, and their queasy coring crew are pulling 12-hour shifts under bleak skies, cheered on by a few curious petrels and albatrosses. The discomfort is a small price to pay to gather data that could help unravel the profound environmental changes now transforming the Antarctic Peninsula. "This is a scientific problem that's really relevant to climate change," says Pudsey. "You can only gather the data by going there."

Call it the mystery of the disappearing ice. The past dozen austral summers have witnessed titanic breakups of the peninsula's ice shelves, the massive, floating plates that gird the peninsula's flanks. During the BAS cruise last February, a slab of ice the size of Rhode Island started fissioning into fleets of icebergs. The disintegration of much of the Larsen B ice shelf on the peninsula's east side in a mere 5 weeks was "the largest event of its kind" since satellites began to record the ice shelves breaking up 30 years ago, says glaciologist Ted Scambos of the University of Colorado, Boulder. Warming is clearly the culprit, he and oth-

CREDITS: (TOP TO BOTTOM) F. E. NELSON *ET AL.*, *NATURE* 410, 889 (2001); J. KAISER