VQ

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Cover photograph by Sally McCay

Greenland's ice sheet: 1,500 miles long, thousands of feet thick, and melting quickly. Photograph by Joshua Brown

ICE SHEETS ISOTOPES & MUSK-OX PIZZA

A polar scientist's tour of Greenland

Story and photographs by

JOSHUA BROWN

It's getting hot. Paul Bierman takes off his ski hat and wipes his brow. Then he scrambles out of a stream and up a bank of wet snow. Alice Nelson holds open a plastic bag. Bierman carefully empties a brass sieve, filling the bag with sand from the bottom of the stream.

The air temperature feels like it's about fifty degrees Fahrenheit. Chilly for a day in June. Except this is Greenland. We're sixty-two miles from the Arctic Circle. It's supposed to be cold here: most of this not-green island is covered with an ice sheet 1,500 miles long and thousands of feet thick.

Covered, that is, for now—but it's getting hot. That's why Bierman, professor of geology at UVM since 1993, has led a team of scientists to this barren coastline. They're collecting sand and rocks, washing out from the snow and ice, that will help answer a little understood—but most important—question: how fast will Greenland melt in a warming world?

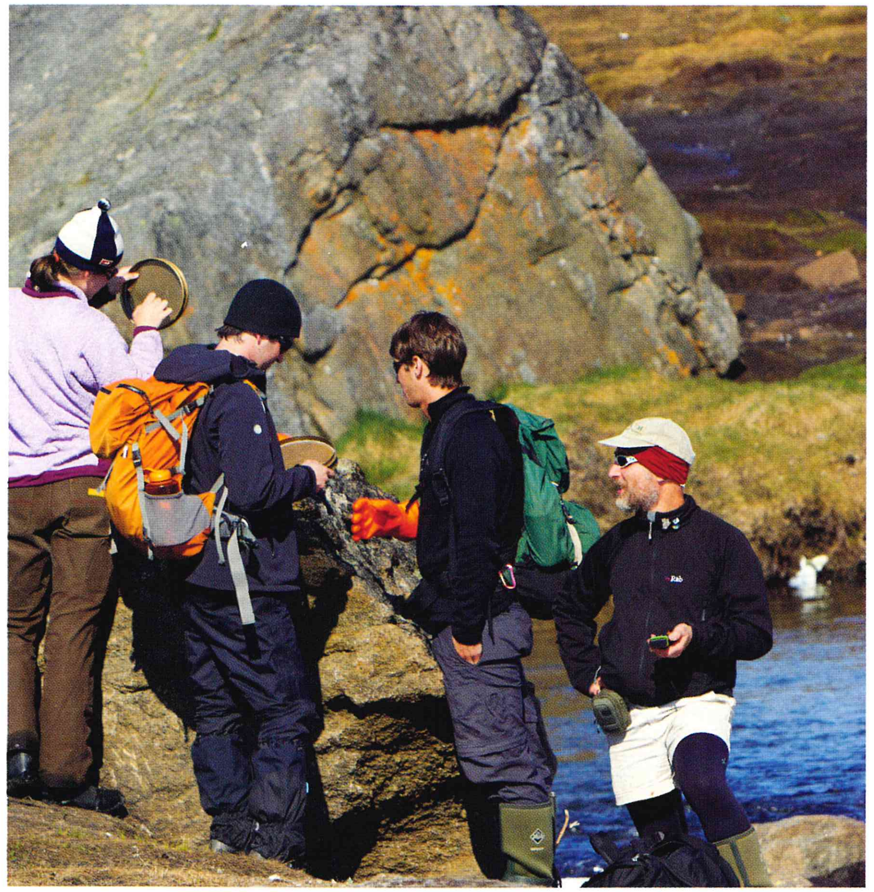
Still standing in the stream, Jeremy Shakun, a researcher from Harvard, stoops to collect more sand. A glinting torrent of ice and water goes rushing past, nearly overtopping his Muck boots. Alice Nelson, Bierman's graduate student, enters our GPS coordinates in a notebook. On the opposite bank, Dylan Rood, a Californian now at the Scottish Universities Environmental Research Centre, arranges black letters on a magnetic

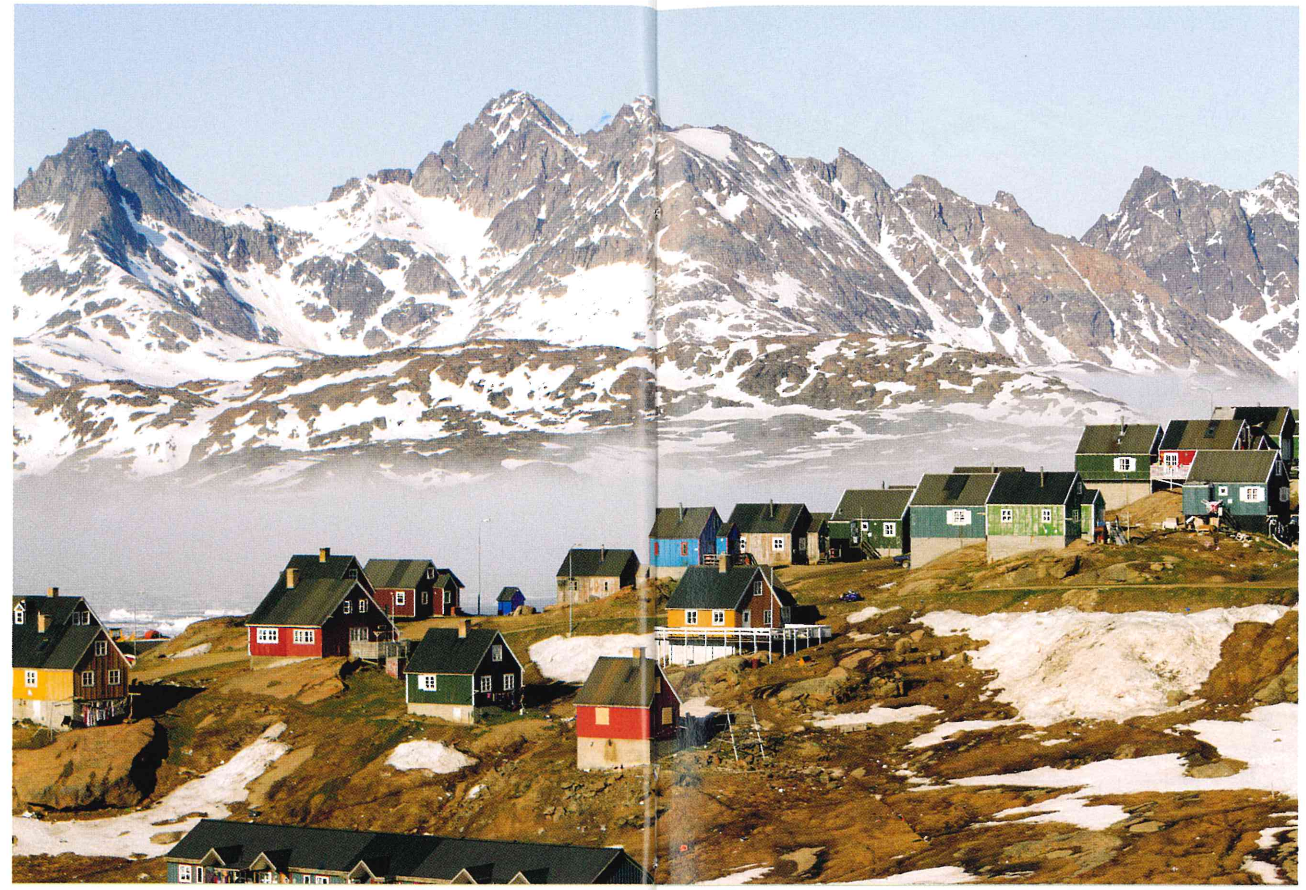
white board. I sit and watch, an embedded science reporter armed with skis and a camera. Rood begins humming snatches of some drinking song or, maybe, it's a sea shanty.

Shakun dunks his hands back into the water. "Yep, thirty-two-point-one degrees," he says and takes another scoop from the streambed. He swears at his numbing fingers. "It hurts worse when you bring 'em out," he says. Nelson laughs. "Well, put 'em back in then," she says.

The stream winds silently down a valley that could be a ski slope on Mars: red boulders and tan gravel punctuate long soggy tongues of snow. At the bottom, the water pours into a still-frozen bay. A thin band of sea fog moves over the salt ice. Behind, mountains remain visible like pencil marks on a white sheet. Their jagged tops stick out of the fog into blue sky, supersaturated in a wash of fierce polar sunlight.

It's our second day above Tasiilaq, the so-called capital of East Greenland, where tiny houses perch in a pleasing jumble on the hills, brightly painted in red, yellow, and electric blue. There are no trees, just earth-tone patches of rock, lichen, snow, and golden grass. It's like the landscape was done by some brooding elemental god and the houses by Crayola. The vast Greenland ice sheet—the "big ice" as locals call it—remains out of sight, several





miles inland, hidden behind rows of mountains.

There are no roads that lead to Tasiilaq—we arrived by helicopter. With one school, one church, two bars, and some 2,000 people—mostly Inuit, who cobble together a livelihood hunting seals, fishing, and serving odd-duck tourists—it seems a vulnerable outpost on the edge of inconsequence. Only 57,000 people live in all of Greenland, an island five times the size of California, and most of them live on the western side. This eastern coast is one of the more remote places on the planet, congenial for polar bears, far from the world's great cities. But, since arriving here, I've been thinking a lot about Manhattan.

If the whole ice sheet—that covers more than 80 percent of Greenland—were to melt, global sea level would rise twenty-three feet, drowning coastal cities on every continent. The dirt tracks through Tasiilaq may drain onto Wall Street.

Bierman and his team want to create a clearer picture of how quickly such a melt-off could happen. Some scientists predict that the ice sheet is at a tipping point where it will begin to melt irreversibly—faster and faster—disappearing in a couple thousand years. In the shorter run, it's likely that global sea level will rise three or four feet this century, if greenhouse gas emissions continue unchecked. And a good bit of that water will wash off Greenland, obliterating coastal wetlands, overrunning highways.

Warm spells are becoming increasingly common in Greenland and this summer the surface of the ice sheet melted over a far greater area than ever before observed. But the deeper details are devilishly important. Exactly how warming will affect ice in Greenland and West Antarctica remains one of the least well-understood variables in global climate models.

"We want to know: how stable is the ice sheet?" Alice Nelson tells me. To augur its future with greater precision, the scientists look to the past, collecting rocks and sand that, back in Bierman's lab at UVM, let them measure how extensive the ice was here over the last ten thousand years as temperatures rose and fell. This relatively short record will, in turn, allow the team to interpret far-more-ancient sediment from the bottom of the ocean. Hidden in this ocean muck, the geologists think they'll be able to uncover the story of Greenland's ice stretching back millions of years.

The next night, at 10:36 p.m., the sky is still bright. The sun has gone behind a mountain, but it is mostly going sideways, sliding not setting. This close to the North Pole, in the height of summer, the sky never gets fully dark. The scientists, still at work in our hotel's dining room, drink tea and study maps. They're preparing to fly in a helicopter tomorrow to the outwash of about a dozen glaciers. The team hunches over their papers trying to decide how many minutes each stop will take. The fuel and money burn rate of a chartered Air Greenland helicopter makes thousands of dollars tied into this five-hour trip.

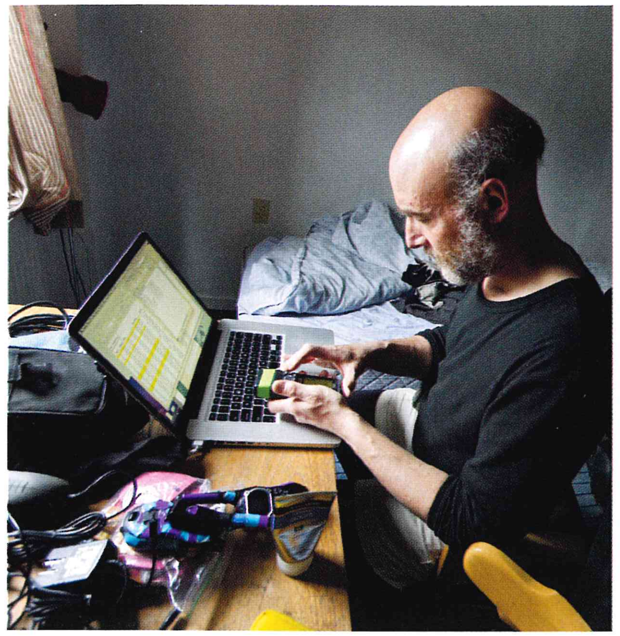
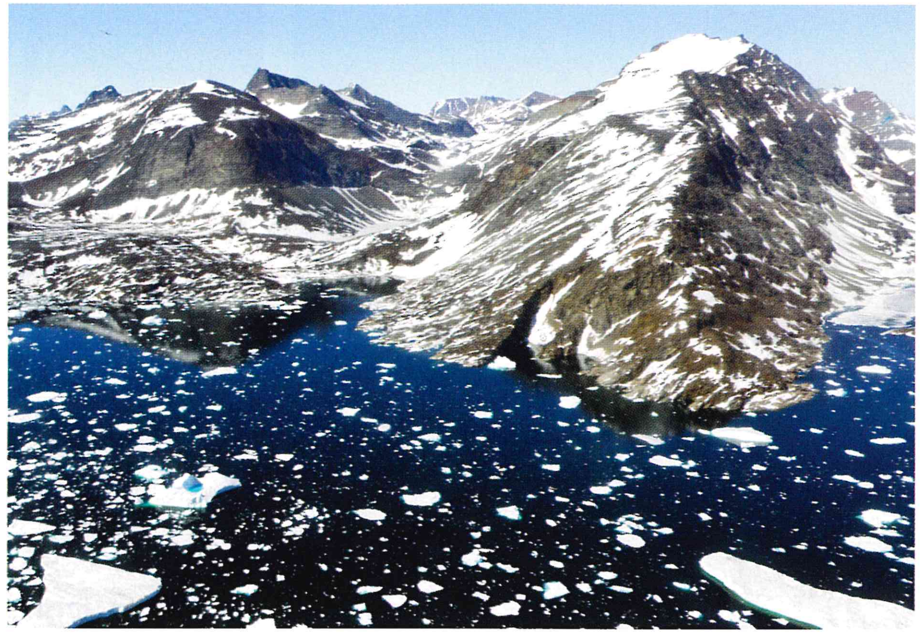
The sand and rock that they collect will travel back to UVM's Delehanty Hall, home of one of the few cosmogenic isotope laboratories in the world, where it will be painstakingly dissolved to yield nearly pure quartz. "I was working on samples for twenty-five straight days," Alice Nelson says, with the rueful head-shaking characteristic of graduate students.

From the quartz, Bierman and his students will extract the element beryllium and then ship it to Scotland, where Rood will test the substance in a specialized mass spectrometer, capable of detecting a single atom out of a million billion atoms. Why, you may be asking, would four geologists—interested in understanding climate change—want to collect bags of sand in order to count the atoms of beryllium in its quartz?

Because of cosmic rays. Really. This radiation, born at the beginning of the universe, rains down on you, me, polar bears, and rocks. It penetrates the top few meters of the Earth's surface. And where it does, ever so rarely, it smashes into oxygen within the quartz, knocking a chunk off. What remains from the busted oxygen is a special form of beryllium, the rare isotope 10Be. The longer the quartz is exposed to the sky, bombarded by cosmic rays, the more 10Be accumulates within its crystals.

But buried under snow and ice—shielded by, say, the Greenland ice sheet—no 10Be accumulates in the quartz. So the amount of beryllium in a grain of sand

Sponsored by the National Science Foundation, the geologists (left: Alice Nelson, Dylan Rood, Jeremy Shakun, and Paul Bierman) traveled the island by helicopter—and skis. "We know surprisingly little about what happened to the ice sheet over the last six million years," UVM graduate student Nelson says. The team's goal: better understand this deep past to better forecast the near future.

North of the Arctic Circle, Paul Bierman enters field data at the Kangerlussuaq International Science Station. Water spilling off Greenland will raise global sea level over the next centuries. How many feet will depend on how fast the ice sheet melts and how much carbon dioxide humanity pumps into the atmosphere.

can reveal how long it was exposed, versus how long buried under ice. Collect enough of these grains, from enough spots in Greenland, and you could begin to sketch a picture of when and where ice rested here in the past.

The next day, the helicopter lifts, thudding and whining, while we all stare out the windows, suddenly ripped from the ground. It is loud—and for twenty minutes we roar over ragged ranges, ten-story icebergs with azure pools on top, and vertiginous peaks that look like a frosted version of Wyoming.

The helicopter banks and all the world is now on its side. We circle, the machine slows, descends, its rotors so powerful that water on the ground sprays like a hurricane and rocks roll away. Down again onto the ice.

Our Norwegian pilot slides open the doors and Bierman leads us over boulders to where a stream slices along a wall of snow. It's old gray below, fresh white above. The scientists quickly dig with a trowel in the sand on the stream edge and fill another bag. We're probably standing where no human has ever stood before, but this is no time to set out a picnic and ponder eternity. We have hours of flying ahead. The team quickly labels the bag, "GLX-63," hoist their packs, and are about to hustle back to the helicopter. Then Bierman stops. "Listen," he says, and we hear the rush of water over rock. "That's the sound of Greenland melting."

We're now near Kulusuk, population three hundred, in a most unlikely hotel: a stronghold of cinderblock and blue paint plunked down on the edge of a fjord full of icebergs. We've woken to bad news. Air Greenland has called to say our flight to Nuuk, the capital, is cancelled. I can see why: white on white, a heavy fog sifts over the snow. I can't see the dirt runway only a few hundred yards from the hotel.

We're stuck in one of the most remote airports in the world, and the next scheduled flight to where we need to go isn't for three more days. This, it seems, is how polar science often works: months of intensive careful planning from the comfort of home, followed by frantic calls on a satellite phone from the field.

Hours later, we still don't know what's going to happen. The fog has cleared—but it's also clear that no trip to Nuuk is happening today. "Let's go skiing," Bierman finally says.

An hour later, we re-gather in Kulusuk. Local people, with coppery Inuit complexions, push their babies in baby joggers. Tuborg beer cans litter the snow and dirt paths that wind between red houses. A dead seal lies in a wheelbarrow. A man and his sled-dog team huff past the grocery store where I just paid about eight dollars for two bananas.

Down the road, the hotel manager pulls up along us in his jeep. Air Greenland called, he says, to tell us our flight to Nuuk has been rescheduled for tomorrow. We're back in business.


Prior to this trip, my sense of Greenland came largely from schoolroom maps of childhood. The traditional Mercator projection stretched Greenland into a huge blank white wedge, larger than Africa—a timeless fortress of ice resting at the top of a rectangular world. But Greenland is smaller, more complex—and its ice more fragile—than those old maps suggest.

The researchers know Greenland has had distinct chapters of melting and ice growth. But how big did the ice sheet get? When did it melt? It may have been totally gone during a warm period 100,000 years ago. "It's really hard to study ice sheets from the past," Alice Nelson told me. "If it melted, it melted."

If past climates—that were three or four degrees warmer than today—didn't have a Greenland ice sheet, there is good reason to think that future ones won't either. Some climate models project that local warming over Greenland will go up five degrees Fahrenheit, and perhaps as much as sixteen degrees, during the next century.

Happily or not, there is only one Earth. N=1, the scientists might say. And so the changes that people have wrought on the planet, pouring out vast quantities of heat-trapping carbon dioxide from our fossil-fuel and jet-plane-loving ways of life represent an experiment with no control group. We can't run it again with a bigger sample. Which is why scientists try to understand how past warm periods affected things—like Greenland's ice sheet—as a way of guessing what will happen next. Based on what we now know, buying real estate on high ground in Greenland might not be such a bad idea.

The next day we land in Nuuk and head out immediately to Kangerlussuaq, a former U.S. military airfield where inbound 757s from Copenhagen touch down. Fat-bellied C-130 U.S. military propeller planes, equipped with skis for landing on the ice sheet, sit in a motionless row on the tarmac.

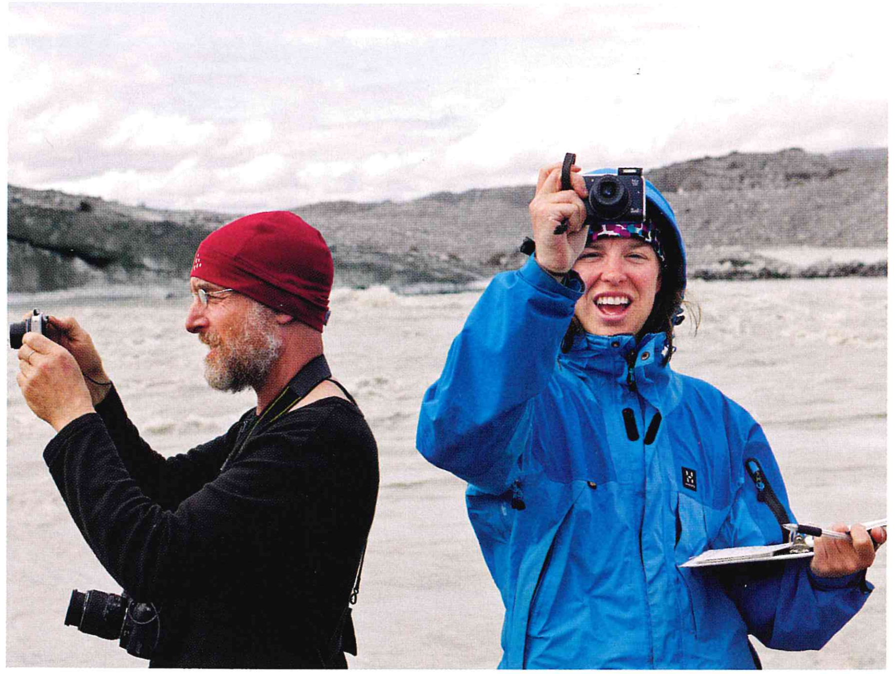
And then there are the mosquitoes. They're big enough to serve an in-flight meal. We drag our train of backpacks and gear—including a cooler nearly full with 150 pounds of rocks and sand—out to the parking lot. The mosquitoes are on us immediately, landing with military precision all over backs, wrists, and Paul Bierman's apparently delicious bald head.

It's dry here on the southwest edge of Greenland. The snow is gone. A silty river sweeps by and the landscape looks more like Afghanistan than a land of ice. But the silt is a clue that, not far from here, the ice sheet remains, melting and calving, pouring down water bound for the sea.

At the Kangerlussuaq International Science Station—an old army barrack identical to the nearby Polar Bear Inn—we dump our gear in dormitory rooms amidst a small stream of wandering American scientists.

But no rest. Still chewing musk-ox pizza, we cram in the back of a small AStar helicopter and float into the air. Our Norwegian pilot, with a chin worthy of Hollywood—and

Traveling with a pilot and mechanic, UVM scientists touch down in a land of glaciers and wandering musk ox. Some of the places they visited have likely never felt human footsteps before. Above: Kulusuk, Greenland



Paul Bierman, UVM professor of geology, and graduate student Alice Nelson.

lium levels—provide a good picture of the recent geologic past, roughly the last 10,000 years. This picture will serve as an analogy to the deeper past, Nelson tells me, guiding interpretation of the samples drawn from far down the ocean core. In short, beryllium concentrations in ocean sediments will be a yardstick of the ice sheet stretching back six million years.

It's a method that has worked for Bierman in studying other landscapes—but has never been tried before on ocean cores, which is a large part of why the National Science Foundation is investing in flying these four geologists all over Greenland.

The helicopter hugs the terrain, roaring through a narrow rock opening.

a job worthy of a marriage proposal, Alice Nelson jokes—listens on his headset to Bierman's directions, trying to match the landscape to a handheld GPS. The Watson River, the color of milky coffee, passes underneath, carrying a load of sediment toward the ocean.

And it's from the ocean that the most important insights of this research project will come. Sediment, washing off Greenland, has sifted to the ocean bottom and piled up, in intact layers, for millions of years. In 1993 and 1995, an international effort collected two long cores of these sediments, drilled from the sea floor, off the southeast coast of Greenland. This year, Jeremy Shakun traveled to Germany to get samples of these cores stored in a huge refrigerated hangar.

In the deepest—and therefore oldest—of these samples, the team expects to find high levels of beryllium in the sediment, revealing a time when much of the bedrock was exposed to cosmic radiation—a time before glaciers had covered Greenland with an ice sheet.

Moving up the core, the scientists expect to find decreasing beryllium concentrations as the ice sheet grew. But, punctuating this big downward trend, they expect to find short up-pulses during brief interglacial periods ("brief" to geologists being in the neighborhood of every 100,000 years) when the ice sheet was reduced.

To make sense of these ocean core data, the team collects samples from today's Greenland. That's what this whole trip is for. Contemporary erosion rates, sediment transportation, ice coverage—and associated beryl-

We turn on a bank of nothingness, and there it is. The Greenland ice sheet. Black and pale gray and brooding and dripping. A wall on a different scale than everything else I've seen here. We stop and collect sand, like lycra-clad ants at its base. Then the helicopter rises again, over the lip, and the ice sheet stretches, white and pocketed, a whole landscape of frozen water, toward an end that can't yet be seen.

The next day, our tenth day of travel, we're heading home. On the runway at Kangerlussuaq, a half-circle of scientists, many bearded and baggy-eyed, gather around a clean-shaven officer from the New York Air National Guard. We're getting final instructions—I guess—about what to do if our transport plane has to ditch over water.

The C-130—flown here to train soldiers in cold-weather combat and to aid scientific expeditions—is dark inside and full of red webbing and plastic-wrapped pallets of gear. Our ears stuffed with plugs, the plane lifts off. Paul Bierman and Dylan Rood work on their laptops, preparing data, and writing each other notes on-screen, tired of shouting over the engines. Alice Nelson reads a novel, her third this week. Jeremy Shakun scrolls through science papers on his iPad.

Inside one of the pallets is a blue cooler, now full with dozens of bags of sand and small rocks from Greenland. They're going to Vermont. And they're quite heavy. These four geologists believe they'll tell us something useful about the ways the ever-so-much-more-heavy ice that rests on this island, now passing away beneath us, is getting lighter—becoming, perhaps, for coastal parts of the world, an unbearable lightness. **VQ**