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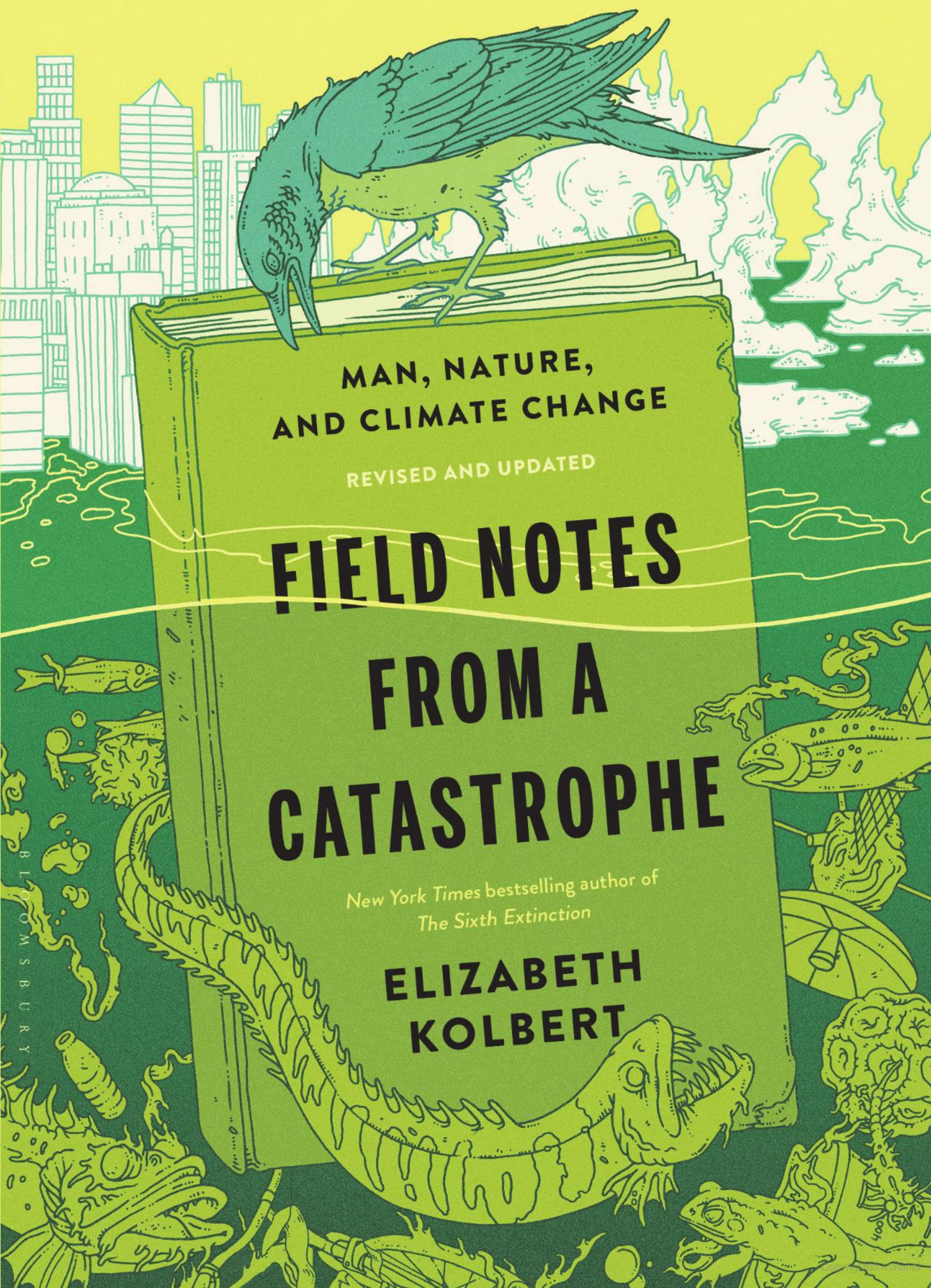

FIELD NOTES
from a
CATASTROPHE

MAN, NATURE, AND CLIMATE CHANGE

Elizabeth Kolbert

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PREFACE

THERE ISN'T MUCH to do at the Hotel Arctic except watch the icebergs flow by. The hotel is located in the town of Ilulissat, on the west coast of Greenland, four degrees north of the Arctic Circle. The icebergs originate some fifty miles away, at the end of a long and fast-moving ice stream known as the Jakobshavn Isbrae. They drift down a fjord and through a wide-mouthed bay, and, if they last long enough, end up in the North Atlantic. (It is likely that the iceberg encountered by the *Titanic* followed this route.)

To the tourists who visit the Hotel Arctic, the icebergs are a thrilling sight: beautiful and terrible in equal measure. They are a reminder of the immensity of nature and the smallness of man. To the people who spend more time in Ilulissat—native Greenlanders, European tour guides, American scientists—the icebergs have come to acquire a different significance. Since the late 1990s, the Jakobshavn Isbrae has doubled its speed. In the process, the height of the ice stream has been dropping by up to fifty feet a year and the calving front has retreated by several

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miles. What locals now notice about the icebergs is not their power or immensity—though they are still powerful and immense—but a disquieting diminishment.

"You don't get the big icebergs anymore," an Ilulissat town councilman named Jeremias Jensen told me. We were having coffee on a late-spring afternoon in the Hotel Arctic lobby. Outside, it was foggy and the icebergs seemed to be rising up out of the mist. "It's very strange the last few years; you can see a lot of strange changes."

This is a book about watching the world change. It grew out of three articles that I wrote for the *New Yorker* magazine, which ran in the spring of 2005, and its goal remains much the same as that of the original series: to convey, as vividly as possible, the reality of global warming. The opening chapters are set near or above the Arctic Circle—in Deadhorse, Alaska; in the countryside outside of Reykjavík; at Swiss Camp, a research station on the Greenland ice sheet. I went to these particular places for all the usual journalistic reasons—because someone invited me to tag along on an expedition, because someone let me hitch a ride on a helicopter, because someone sounded interesting over the telephone. The same is true of the choices that were made in subsequent chapters, whether it was a decision to track butterflies in northern England or to visit floating houses in the Netherlands. Such is the impact of global warming that I could have gone to hundreds if not thousands of other places—from Siberia to the Austrian Alps to the Great Barrier Reef to the South African fynbos—to document its effects. These alternate choices

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would have resulted in an account very different in its details, but not in its conclusions.

Humans aren't the first species to alter the atmosphere; that distinction belongs to early bacteria, which, some two billion years ago, invented photosynthesis. But we are the first species to be in a position to understand what we are doing. Computer models of the earth's climate suggest that a critical threshold is approaching. Crossing over it will be easy, crossing back quite likely impossible. The second part of this book explores the complicated relationship between the science and the politics of global warming, between what we know and what we refuse to know.

My hope is that this book will be read by everyone, by which I mean not only those who follow the latest news about the climate but also those who prefer to skip over it. For better or (mostly) for worse, global warming is all about scale, and the sheer number of figures involved can be daunting. I've tried to offer what is essential without oversimplifying. Similarly, I have tried to keep the discussion of scientific theory to a minimum while offering a full-enough account to convey what is truly at stake.

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Part I

NATURE

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Chapter 1

SHISHMAREF, ALASKA

THE ALASKAN VILLAGE of Shishmaref sits on an island known as Sarichef, five miles off the coast of the Seward Peninsula. Sarichef is a small island—no more than a quarter of a mile across and two and a half miles long—and Shishmaref is basically the only thing on it. To the north is the Chukchi Sea, and in every other direction lies the Bering Land Bridge National Preserve, which probably ranks as one of the least visited national parks in the country. During the last ice age, the land bridge—exposed by a drop in sea levels of more than three hundred feet—grew to be nearly a thousand miles wide. The preserve occupies that part of it which, after more than ten thousand years of warmth, still remains above water.

Shishmaref (population 591) is an Inupiat village, and it has been inhabited, at least on a seasonal basis, for several centuries. As in many native villages in Alaska, life there combines—often disconcertingly—the very ancient and the totally modern. Almost everyone in Shishmaref still lives off subsistence hunting, primarily for bearded seals but also for walrus, moose, rabbits, and migrating birds. When

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I visited the village one day in April, the spring thaw was under way, and the seal-hunting season was about to begin. (Wandering around, I almost tripped over the remnants of the previous year's catch emerging from storage under the snow.) At noon, the village's transportation planner, Tony Weyiouanna, invited me to his house for lunch. In the living room, an enormous television set tuned to the local public-access station was playing a rock soundtrack. Messages like "Happy Birthday to the following elders . . ." kept scrolling across the screen.

Traditionally, the men in Shishmaref hunted for seals by driving out over the sea ice with dogsleds or, more recently, on snowmobiles. After they hauled the seals back to the village, the women would skin and cure them, a process that takes several weeks. In the early 1990s, the hunters began to notice that the sea ice was changing. (Although the claim that the Eskimos have hundreds of words for snow is an exaggeration, the Inupiat make distinctions among many different types of ice, including *sikuliaq*, "young ice," *sarri*, "pack ice," and *tuvaq*, "landlocked ice.") The ice was starting to form later in the fall, and also to break up earlier in the spring. Once, it had been possible to drive out twenty miles; now, by the time the seals arrived, the ice was mushy half that distance from shore. Weyiouanna described it as having the consistency of a "slush puppy." When you encounter it, he said, "your hair starts sticking up. Your eyes are wide open. You can't even blink." It became too dangerous to hunt using snowmobiles, and the men switched to boats.

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Soon, the changes in the sea ice brought other problems. At its highest point, Shishmaref is only twenty-two feet above sea level, and the houses, most of which were built by the U.S. government, are small, boxy, and not particularly sturdy-looking. When the Chukchi Sea froze early, the layer of ice protected the village, the way a tarp prevents a swimming pool from getting roiled by the wind. When the sea started to freeze later, Shishmaref became more vulnerable to storm surges. A storm in October 1997 scoured away a hundred-and-twenty-five-foot-wide strip from the town's northern edge; several houses were destroyed, and more than a dozen had to be relocated. During another storm, in October 2001, the village was threatened by twelve-foot waves. In the summer of 2002, residents of Shishmaref voted, a hundred and sixty-one to twenty, to move the entire village to the mainland. In 2004, the U.S. Army Corps of Engineers completed a survey of possible sites. Most of the spots that are being considered for a new village are in areas nearly as remote as Sarichef, with no roads or nearby cities or even settlements. It is estimated that a full relocation would cost the U.S. government $180 million.

People I spoke to in Shishmaref expressed divided emotions about the proposed move. Some worried that, by leaving the tiny island, they would give up their connection to the sea and become lost. "It makes me feel lonely," one woman said. Others seemed excited by the prospect of gaining certain conveniences, like running water, that Shishmaref lacks. Everyone seemed to agree,

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though, that the village's situation, already dire, was only going to get worse.

Morris Kiyutelluk, who is sixty-five, has lived in Shishmaref almost all his life. (His last name, he told me, means "without a wooden spoon.") I spoke to him while I was hanging around the basement of the village church, which also serves as the unofficial headquarters for a group called the Shishmaref Erosion and Relocation Coalition. "The first time I heard about global warming, I thought, I don't believe those Japanese," Kiyutelluk told me. "Well, they had some good scientists, and it's become true."

The National Academy of Sciences undertook its first major study of global warming in 1979. At that point, climate modeling was still in its infancy, and only a few groups, one led by Syukuro Manabe at the National Oceanic and Atmospheric Administration and another by James Hansen at NASA's Goddard Institute for Space Studies, had considered in any detail the effects of adding carbon dioxide to the atmosphere. Still, the results of their work were alarming enough that President Jimmy Carter called on the academy to investigate. A nine-member panel was appointed. It was led by the distinguished meteorologist Jule Charney, of MIT, who, in the 1940s, had been the first meteorologist to demonstrate that numerical weather forecasting was feasible.

The Ad Hoc Study Group on Carbon Dioxide and Climate, or the Charney panel, as it became known, met for five days at the National Academy of Sciences' summer

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study center, in Woods Hole, Massachusetts. Its conclusions were unequivocal. Panel members had looked for flaws in the modelers' work but had been unable to find any. "If carbon dioxide continues to increase, the study group finds no reason to doubt that climate changes will result and no reason to believe that these changes will be negligible," the scientists wrote. For a doubling of CO_2 from preindustrial levels, they put the likely global temperature rise at between two and a half and eight degrees Fahrenheit. The panel members weren't sure how long it would take for changes already set in motion to become manifest, mainly because the climate system has a built-in time delay. The effect of adding CO_2 to the atmosphere is to throw the earth out of "energy balance." In order for balance to be restored—as, according to the laws of physics, it eventually must be—the entire planet has to heat up, including the oceans, a process, the Charney panel noted, that could take "several decades." Thus, what might seem like the most conservative approach—waiting for evidence of warming to make sure the models were accurate—actually amounted to the riskiest possible strategy: "We may not be given a warning until the CO_2 loading is such that an appreciable climate change is inevitable."

It is now more than twenty-five years since the Charney panel issued its report, and, in that period, Americans have been alerted to the dangers of global warming so many times that reproducing even a small fraction of these warnings would fill several volumes;

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indeed, entire books have been written just on the history of efforts to draw attention to the problem. (Since the Charney report, the National Academy of Sciences alone has produced nearly two hundred more studies on the subject, including, to name just a few, "Radiative Forcing of Climate Change," "Understanding Climate Change Feedbacks," and "Policy Implications of Greenhouse Warming.") During this same period, worldwide carbon-dioxide emissions have continued to increase, from five billion to seven billion metric tons a year, and the earth's temperature, much as predicted by Manabe's and Hansen's models, has steadily risen. The year 1990 was the warmest year on record until 1991, which was equally hot. Almost every subsequent year has been warmer still. As of this writing, 1998 ranks as the hottest year since the instrumental temperature record began, but it is closely followed by 2002 and 2003, which are tied for second; 2001, which is third; and 2004, which is fourth. Since climate is innately changeable, it's difficult to say when, exactly, in this sequence natural variation could be ruled out as the sole cause. The American Geophysical Union, one of the nation's largest and most respected scientific organizations, decided in 2003 that the matter had been settled. At the group's annual meeting that year, it issued a consensus statement declaring, "Natural influences cannot explain the rapid increase in global near-surface temperatures." As best as can be determined, the world is now warmer than it has been at any point in the last two millennia, and, if current trends continue, by

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the end of the century it will likely be hotter than at any point in the last two million years.

In the same way that global warming has gradually ceased to be merely a theory, so, too, its impacts are no longer just hypothetical. Nearly every major glacier in the world is shrinking; those in Glacier National Park are retreating so quickly it has been estimated that they will vanish entirely by 2030. The oceans are becoming not just warmer but more acidic; the difference between daytime and nighttime temperatures is diminishing; animals are shifting their ranges poleward; and plants are blooming days, and in some cases weeks, earlier than they used to. These are the warning signs that the Charney panel cautioned against waiting for, and while in many parts of the globe they are still subtle enough to be overlooked, in others they can no longer be ignored. As it happens, the most dramatic changes are occurring in those places, like Shishmaref, where the fewest people tend to live. This disproportionate effect of global warming in the far north was also predicted by early climate models, which forecast, in column after column of FORTRAN-generated figures, what today can be measured and observed directly: the Arctic is melting.

Most of the land in the Arctic, and nearly a quarter of all the land in the Northern Hemisphere—some five and a half billion acres—is underlaid by zones of permafrost. A few months after I visited Shishmaref, I went back to Alaska to take a trip through the interior of the state with

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Vladimir Romanovsky, a geophysicist and permafrost expert. I flew into Fairbanks—Romanovsky teaches at the University of Alaska, which has its main campus there—and when I arrived, the whole city was enveloped in a dense haze that looked like fog but smelled like burning rubber. People kept telling me that I was lucky I hadn't come a couple of weeks earlier, when it had been much worse. "Even the dogs were wearing masks," one woman I met said. I must have smiled. "I am not joking," she told me.

Fairbanks, Alaska's second-largest city, is surrounded on all sides by forest, and virtually every summer lightning sets off fires in these forests, which fill the air with smoke for a few days or, in bad years, weeks. In the summer of 2004, the fires started early, in June, and were still burning two and a half months later; by the time of my visit, in late August, a record 6.3 million acres—an area roughly the size of New Hampshire—had been incinerated. The severity of the fires was clearly linked to the weather, which had been exceptionally hot and dry; the average summertime temperature in Fairbanks was the highest on record, and the amount of rainfall was the third lowest.

On my second day in Fairbanks, Romanovsky picked me up at my hotel for an underground tour of the city. Like most permafrost experts, he is from Russia. (The Soviets more or less invented the study of permafrost when they decided to build their gulags in Siberia.) A broad man with shaggy brown hair and a square jaw, Romanovsky as a student had had to choose between playing professional

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hockey and becoming a geophysicist. He had opted for the latter, he told me, because "I was little bit better scientist than hockey player." He went on to earn two master's degrees and two Ph.D.s. Romanovsky came to get me at ten A.M.; owing to all the smoke, it looked like dawn.

Any piece of ground that has remained frozen for at least two years is, by definition, permafrost. In some places, like eastern Siberia, permafrost runs nearly a mile deep; in Alaska, it varies from a couple of hundred feet to a couple of thousand feet deep. Fairbanks, which is just below the Arctic Circle, is situated in a region of discontinuous permafrost, meaning that the city is pocked with regions of frozen ground. One of the first stops on Romanovsky's tour was a hole that had opened up in a patch of permafrost not far from his house. It was about six feet wide and five feet deep. Nearby were the outlines of other, even bigger holes, which, Romanovsky told me, had been filled with gravel by the local public-works department. The holes, known as thermokarsts, had appeared suddenly when the permafrost gave way, like a rotting floorboard. (The technical term for thawed permafrost is "talik," from a Russian word meaning "not frozen.") Across the road, Romanovsky pointed out a long trench running into the woods. The trench, he explained, had been formed when a wedge of underground ice had melted. The spruce trees that had been growing next to it, or perhaps on top of it, were now listing at odd angles, as if in a gale. Locally, such trees are called "drunken." A few of the spruces had fallen over. "These are very drunk," Romanovsky said.

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In Alaska, the ground is riddled with ice wedges that were created during the last glaciation, when the cold earth cracked and the cracks filled with water. The wedges, which can be dozens or even hundreds of feet deep, tended to form in networks, so when they melt, they leave behind connecting diamond- or hexagon-shaped depressions. A few blocks beyond the drunken forest, we came to a house where the front yard showed clear signs of ice-wedge melt-off. The owner, trying to make the best of things, had turned the yard into a miniature-golf course. Around the corner, Romanovsky pointed out a house—no longer occupied—that basically had split in two; the main part was leaning to the right and the garage toward the left. The house had been built in the sixties or early seventies; it had survived until almost a decade ago, when the permafrost under it started to degrade. Romanovsky's mother-in-law used to own two houses on the same block. He had urged her to sell them both. He pointed out one, now under new ownership; its roof had developed an ominous-looking ripple. (When Romanovsky went to buy his own house, he looked only in permafrost-free areas.)

"Ten years ago, nobody cared about permafrost," he told me. "Now everybody wants to know." Measurements that Romanovsky and his colleagues at the University of Alaska have made around Fairbanks show that the temperature of the permafrost in many places has risen to the point where it is now less than one degree below freezing. In places where the permafrost has been disturbed, by roads or houses or lawns, much of it is already

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thawing. Romanovsky has also been monitoring the permafrost on the North Slope and has found that there, too, are regions where the permafrost is very nearly thirty-two degrees Fahrenheit. While thermokarsts in the roadbeds and talik under the basement are the sort of problems that really only affect the people right near—or above—them, warming permafrost is significant in ways that go far beyond local real estate losses. For one thing, permafrost represents a unique record of long-term temperature trends. For another, it acts, in effect, as a repository for greenhouse gases. As the climate warms, there is a good chance that these gases will be released into the atmosphere, further contributing to global warming. Although the age of permafrost is difficult to determine, Romanovsky estimates that most of it in Alaska probably dates back to the beginning of the last glacial cycle. This means that if it thaws, it will be doing so for the first time in more than a hundred and twenty thousand years. "It's really a very interesting time," Romanovsky told me.

The next morning, Romanovsky picked me up at seven. We were going to drive from Fairbanks nearly five hundred miles north to the town of Deadhorse, on Prudhoe Bay. Romanovsky makes the trip at least once a year, to collect data from the many electronic monitoring stations he has set up. Since the way was largely unpaved, he had rented a truck for the occasion. Its windshield was cracked in several places. When I suggested this could be a problem, Romanovsky assured me that it was "typical

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Alaska." For provisions, he had brought along an oversize bag of Tostitos.

The road that we traveled along—the Dalton Highway—had been built for Alaskan oil, and the pipeline followed it, sometimes to the left, sometimes to the right. (Because of the permafrost, the pipeline runs mostly aboveground, on pilings that contain ammonia, which acts as a refrigerant). Trucks kept passing us, some with severed caribou heads strapped to their roofs, others belonging to the Alyeska Pipeline Service Company. The Alyeska trucks were painted with the disconcerting motto "Nobody Gets Hurt." About two hours outside Fairbanks, we started to pass through tracts of forest that had recently burned, then tracts that were still smoldering, and, finally, tracts that were still, intermittently, in flames. The scene was part Dante, part *Apocalypse Now.* We crawled along through the smoke. After another few hours, we reached Coldfoot, named, supposedly, for some gold prospectors who arrived at the spot in 1900, then got "cold feet" and turned around. We stopped to have lunch at a truck stop, which made up pretty much the entire town. Just beyond Coldfoot, we passed the tree line. An evergreen was marked with a plaque that read "Farthest North Spruce Tree on the Alaska Pipeline: Do Not Cut." Predictably, someone had taken a knife to it. A deep gouge around the trunk was bound with duct tape. "I think it will die," Romanovsky told me.

Finally, at around five P.M., we reached the turnoff for the first monitoring station. By now we were traveling

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along the edge of the Brooks Range and the mountains were purple in the afternoon light. Because one of Romanovsky's colleagues had nursed dreams—never realized—of traveling to the station by plane, it was situated near a small airstrip, on the far side of a quickly flowing river. We pulled on rubber boots and forded the river, which, owing to the lack of rain, was running low. The site consisted of a few posts sunk into the tundra, a solar panel, a two-hundred-foot-deep borehole with heavy-gauge wire sticking out of it, and a white container, resembling an ice chest, that held computer equipment. The solar panel, which the previous summer had been mounted a few feet off the ground, was now resting on the scrub. At first, Romanovsky speculated that this was a result of vandalism, but after inspecting things more closely, he decided that it was the work of a bear. While he hooked up a laptop computer to one of the monitors inside the white container, my job was to keep an eye out for wildlife.

For the same reason that it is sweaty in a coal mine—heat flux from the center of the earth—permafrost gets warmer the farther down you go. Under equilibrium conditions—which is to say, when the climate is stable—the very warmest temperatures in a borehole will be found at the bottom and temperatures will decrease steadily as you go higher. In these circumstances, the lowest temperature will be found at the permafrost's surface, so that, plotted on a graph, the results will be a tilted line. In recent decades, though, the temperature profile of

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Alaska's permafrost has drooped. Now, instead of a straight line, what you get is shaped more like a sickle. The permafrost is still warmest at the very bottom, but instead of being coldest at the top, it is coldest somewhere in the middle, and warmer again toward the surface. This is a sign—and an unambiguous one—that the climate is heating up.

"It's very difficult to look at trends in air temperature, because it's so variable," Romanovsky explained after we were back in the truck, bouncing along toward Deadhorse. It turned out that he had brought the Tostitos to stave off not hunger but fatigue—the crunching, he said, kept him awake—and by now the enormous bag was more than half empty. "So one year you have around Fairbanks a mean annual temperature of zero"—thirty-two degrees Fahrenheit—"and you say, 'Oh yeah, it's warming,' and other years you have mean annual temperature of minus six"—twenty-one degrees Fahrenheit—"and everybody says, 'Where? Where is your global warming?' In the air temperature, the signal is very small compared to noise. What permafrost does is it works as low-pass filter. That's why we can see trends much easier in permafrost temperatures than we can see them in atmosphere." In most parts of Alaska, the permafrost has warmed by three degrees since the early 1980s. In some parts of the state, it has warmed by nearly six degrees.

When you walk around in the Arctic, you are stepping not on permafrost but on something called the "active layer."

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The active layer, which can be anywhere from a few inches to a few feet deep, freezes in the winter but thaws over the summer, and it is what supports the growth of plants—large spruce trees in places where conditions are favorable enough and, where they aren't, shrubs and, finally, just lichen. Life in the active layer proceeds much as it does in more temperate regions, with one critical difference. Temperatures are so low that when trees and grasses die they do not fully decompose. New plants grow on top of the half-rotted old ones, and when these plants die the same thing happens all over again. Eventually, through a process known as cryoturbation, organic matter is pushed down beneath the active layer into the permafrost, where it can sit for thousands of years in a botanical version of suspended animation. (In Fairbanks, grass that is still green has been found in permafrost dating back to the middle of the last ice age.) This is the reason that permafrost, much like a peat bog or, for that matter, a coal deposit, acts as a storage unit for accumulated carbon.

One of the risks of rising temperatures is that the storage process can start to run in reverse. Under the right conditions, organic material that has been frozen for millennia will begin to break down, giving off carbon dioxide or methane, which is an even more powerful (though more short-lived) greenhouse gas. In parts of the Arctic, this process is already under way. Researchers in Sweden, for example, have been measuring the methane output of a bog known as the Stordalen mire, near the town of Abisko, nine hundred miles north of Stockholm, for

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almost thirty-five years. As the permafrost in the area has warmed, methane releases have increased, in some spots by as much as 60 percent. Thawing permafrost could make the active layer more hospitable to plants, which are a sink for carbon. Even this, though, wouldn't be enough to offset the release of greenhouse gases. No one knows exactly how much carbon is stored in the world's permafrost, but estimates run as high as 450 billion metric tons.

"It's like ready-use mix—just a little heat, and it will start cooking," Romanovsky told me. It was the day after we had arrived in Deadhorse, and we were driving through a steady drizzle out to another monitoring site. "I think it's just a time bomb, just waiting for a little warmer conditions." Romanovsky was wearing a rain suit over his canvas work clothes. I put on a rain suit that he had brought along for me. He pulled a tarp out of the back of the truck.

Whenever he has had funding, Romanovsky has added new monitoring sites to his network. There are now sixty of them, and while we were on the North Slope he spent all day and also part of the night—it stayed light until nearly eleven—rushing from one to the next. At each site, the routine was more or less the same. First, Romanovsky would hook up his computer to the data logger, which had been recording permafrost temperatures on an hourly basis since the previous summer. When it was raining, Romanovsky would perform this first step hunched under the tarp. Then he would take out a metal probe shaped like a "T" and poke it into the ground at regular intervals,

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measuring the depth of the active layer. The probe was a meter long, which, it turned out, was no longer quite long enough. The summer had been so warm that almost everywhere the active layer had grown deeper, in some spots by just a few centimeters, in other spots by more than that. In places where the active layer was particularly deep, Romanovsky had had to work out a new way of measuring it using the probe and a wooden ruler. (I helped out by recording the results of this exercise in his waterproof field notebook.) Eventually, he explained, the heat that had gone into increasing the depth of the active layer would work its way downward, bringing the permafrost that much closer to the thawing point. "Come back next year," he advised me.

On the last day I spent on the North Slope, a friend of Romanovsky's, Nicolai Panikov, a microbiologist at the Stevens Institute of Technology, in New Jersey, arrived. He was planning on collecting cold-loving microorganisms known as psychrophiles, which he would take back to New Jersey to study. Panikov's goal was to determine whether the organisms could have functioned in the sort of conditions that, it is believed, were once found on Mars. He told me that he was quite convinced that Martian life existed—or, at least, had existed. Romanovsky expressed his opinion on this by rolling his eyes; nevertheless, he had agreed to help Panikov dig up some permafrost.

That same day, I flew with Romanovsky by helicopter to a small island in the Arctic Ocean, where he had set up yet another monitoring site. The island, just north of the

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seventieth parallel, was a bleak expanse of mud dotted with little clumps of yellowing vegetation. It was filled with ice wedges that were starting to melt, creating a network of polygonal depressions. The weather was cold and wet, so while Romanovsky hunched under his tarp I stayed in the helicopter and chatted with the pilot. He had lived in Alaska since 1967. "It's definitely gotten warmer since I've been here," he told me. "I have really noticed that."

When Romanovsky emerged, we took a walk around the island. Apparently, in the spring it had been a nesting site for birds, because everywhere we went there were bits of eggshell and piles of droppings. The island was only about ten feet above sea level, and at the edges it dropped off sharply into the water. Romanovsky pointed out a spot along the shore where the previous summer a series of ice wedges had been exposed. They had since melted, and the ground behind them had given way in a cascade of black mud. In a few years, he said, he expected more ice wedges would be exposed, and then these would melt, causing further erosion. Although the process was different in its mechanics from what was going on in Shishmaref, it had much the same cause and, according to Romanovsky, was likely to have the same result. "Another disappearing island," he said, gesturing toward some freshly exposed bluffs. "It's moving very, very fast."

On September 18, 1997, the *Des Groseilliers*, a three-hundred-and-eighteen-foot-long icebreaker with a bright-red hull, set out from the town of Tuktoyaktuk, on the

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