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Multidisciplinary Reflections on an Active Layer/Permafrost Core in Boreal Alaska

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INTRODUCTION

In late May/early June of 2022, a group of multidisciplinary academicians from the University of Virginia travelled along the Dalton Highway from Fairbanks to Prudhoe Bay, Alaska, then flew to Utqiaġvik, Alaska. Identified as the Sanctuary Lab, the group of professors and postdocs (funded by the University of Virginia's Environmental Institute, Center for Global Inquiry and Innovation, and Environmental Humanities Lab) study areas around the globe that people might consider to be sanctuaries in the broadest sense of the word. Prior trips of the Sanctuary Lab were to Bhutan and to Yellowstone National Park, Montana. The Lab has core members with others joining depending on the destination. The roster on the Alaska trip consisted of people from the departments of Environmental Sciences (two people), Religious Studies (three people), and one person each from Music, Astronomy, and English.

During the first part of our trip, which began in Fairbanks, we visited the Bonanza Creek Experimental Forest, led by Michelle Mack (Professor of Ecosystem Ecology at Northern Arizona University and Principal Investigator of the Bonanza Creek Long Term Ecological Research [BNZ LTER] program) and Jamie Hollingsworth (site manager for the Experimental Forest). During the visit, within a flat, lowland stand of black spruce, Jamie treated us to the spectacle of extracting a soil core using a 7.4 cm (3 inch) diameter, 91.44 cm (36 inch) long auger. Given the time of year, not much of the active layer had thawed, so Jamie removed a core of largely frozen ground; some of it had already thawed, more would thaw and add to the active layer, and the remainder at the bottom was permafrost. For simplicity, we are going to refer to this as the "permafrost core," knowing, however, that not all of the core was actual permafrost—it included unfrozen and frozen parts of the active layer.

Those who were not environmental scientists made a general observation that the core was not actually ice but more a cylinder of gritty frozen mineral soil and peat in various textures and dark hues, with a few scattered lenses of actual ice. Beyond this, our perceptions of this cylinder of Arctic ground varied widely. We all watched and held the core as it began to thaw in front of us.

The following are writings and other creations from each member of the group, derived from their thoughts of our permafrost core. Our later tour of the Permafrost Tunnel Research Facility near Fairbanks is also mentioned in the essays.

HOWARD EPSTEIN, ENVIRONMENTAL SCIENCES (TERRESTRIAL ECOLOGY)

It was early in the thaw season, not even June yet, so the thaw probe, wielded by Willis (Jenkins), hit frozen ground pretty quickly, within 20–30 cm. You could easily reach through the mossy vegetation and touch the top of the frozen ground layer. I explained that just because the ground was frozen didn't mean that it was permafrost; there were still maybe three months of warm summer temperatures before the active layer would completely thaw down to the top of the permafrost layer (the ground that would not thaw at all that year). Surrounding and above the spot where the core would be extracted were mosses, dwarf birch, and tussock sedges, with black spruce comprising the sparse overstory canopy. Jamie (Hollingsworth) augured down probably a little over a metre and pulled out several intact sections of the core.

Again, most of the active layer was still frozen; the entirety of it would probably not thaw until late August. The core was almost wholly composed of dead organic matter with some mineral soil content. The organic matter represents a huge quantity of carbon, mostly dead vegetation and microorganisms; some of it is vulnerable to rapid decay, some of it has been stored potentially for centuries to millennia. Jamie scraped off some of the now rapidly thawing material on the side of the core, newly exposed to the warm air, to reveal a few additional occupants of the core. We could see a few small sections of ice, which looked white, and also live (I guess now dead) roots, which were orange and rust coloured. Although there was certainly some frozen water in this core, I reminded my multidisciplinary colleagues that permafrost is often not ice—it's whatever stays below 0°C in the ground continuously for multiple years. As the core was exposed to the warm air, the ice in it started to melt and cold, slick mud formed on its surface, showcasing at high speed the vulnerability of permafrost landscapes and their stored carbon.

As an Arctic ecologist, I wondered how deep the active layer would go this year. Would a warm summer extend the active layer beyond its typical depth, into the historical permafrost? How much carbon might be in that layer of ground that was previously permafrost? How much of that would end up as either carbon dioxide or methane in our atmosphere? Would plants be able to access any of the newly available nitrogen in that additional thawed layer?

Jamie and others estimated that by going deeper into the core, we were going back in time a few thousand years. Not nearly as far back as we would see the next day, tens of metres deep in the Permafrost Tunnel Research Facility near Fairbanks, but still enough to make you think about what was going on around the world when the vegetation that would ultimately become stored carbon in this core was alive, exchanging water and oxygen for atmospheric carbon dioxide. I'd seen permafrost cores drilled before, even assisted with drilling deep boreholes in the Arctic ground, but never before had I viewed them with religious scholars, astronomers, and musicians, each providing a completely different perspective … the theologians thinking about ecosystem processes pre-Christ, the astronomer sensing that the core represented temporal minutiae in the context of our galactic history, and the musician pondering ways to sonify the patterns visible in the core.

After spending quite a long time with the core, we put the pieces back into the ground, but I don't think we put them back in the correct order. Did we somehow alter the past, or just the future? Given the sometimes destructive nature of our field research, environmental scientists do have a way of potentially messing with their subjects.

KAREN MCGLATHERY
ENVIRONMENTAL SCIENCES
(AQUATIC ECOLOGY)

Three feet deep into the earth equals three thousand years. We are in the tundra at the BNZ LTER site south of Fairbanks. Our host, Jamie, augers into the frozen ground just below a carpet of grasses, mosses, sedges, and lichens and pulls out a core three feet long and a few inches wide. Layers of frozen earth holding the fragments of organic matter—once living plants now frozen in the permafrost—give us a glimpse into the past. An almost imperceptible amount of matter is laid down each year and buried, leaving a record of what this place was like and how it has changed over time.

Jamie reminds us that each core tells a different story: fires, droughts, floods, freezes, and thaws. Pieces of root tell us how the landscape has changed, which plants were dominant and for how long. Pieces of charcoal tell us when fire ravaged through this place. Tiny ice wedges contain bubbles of ancient air.

As an ecologist, I am focused on the natural history stories that are captured in the permafrost core. I try to imagine the landscape in this part of the Tanana Valley over the last few millennia, and I wonder how stable it has been compared to how fast it is changing now. We are a group of scholars thinking about the intersection of climate change and sanctuaries from different perspectives—ecology, religious studies, astronomy, and music. We are excited when we find charcoal from a fire long ago, and we want to capture the essence of it—I make marks on my hand—but it disappears almost immediately. One of my colleagues looks at the cylinder of brown earth and estimates that halfway down the core is material from her period of religious study.

This is permafrost. It is a physical legacy of place and time. But it is not really *perma*frost. The climate is changing faster than at any other time in human history, and the peat is thawing. The Arctic is warming at a rate four times that of any place on Earth; as we work with the core, it is melting, ephemeral. We scrape the muddy melting exterior to see what is beneath. We are seeing these same changes in our lifetime as the permafrost melts. We are on a pathway of losing this legacy, this memory of the past.

Melting permafrost is not just important for this particular place in Alaska but for the entire planet. Permafrost has helped keep Earth in balance for millennia. Plants take carbon dioxide out of the atmosphere through photosynthesis—one of the most fundamental processes of life—and turn it into carbon-rich living material, some of which gets buried in the permafrost soils as they build up over time. That carbon is locked up in the frozen soils—one of nature's great solutions for regulating Earth's climate.

But now we are reaching a tipping point, as the permafrost thaws more rapidly in a warming climate. The northern permafrost region holds almost twice as much carbon as is currently in the atmosphere. As the permafrost warms, microbes break down the organic carbon at faster rates, releasing carbon dioxide and methane into the atmosphere and accelerating climate change. Seeing this melting core in our hands, how can we not also see the urgency of climate action? Just as we have accelerated the pace of climate warming, we can slow and even reverse it. Doing so requires that we reckon with our moral responsibility to value, respect, and protect the natural processes that keep the Earth in balance.

MARTIEN HALVORSON-TAYLOR
(RELIGIOUS STUDIES)

Can one feel the past? Reach back in time and feel history? What would it feel like if I could touch it, physically touch it with my hands, probe it with my fingers? For as much as I have thought about the past, investigated it, read up on, about, and into it, I have not thought much about the feel of it. And if I have, it has been more about the smell of decaying pages, of the dust motes that arise from them in the library, and concern for the fragility of an archive many years on. I have worried about the letters on a scroll that are disappearing from view. But here in Alaska, I am reaching out my hand greedily, graspingly, to feel the past.

And it is cold, jarring to the senses. I know the smell of the past, have imagined the sounds of the past—but not its feel, this cold contact. It is cold as only something hidden in a deep, dark place can be. Oddly cold—with life. The long thin permafrost core, peaty on top of the cylinder, colder as it descends, muddy in the hands of the scientist who has drilled it. As we inspect it, it begins to melt from our contact, the hands that hold it, our breath slowly smudging its edges. Though it's still cold to its core.

This strange object should be more familiar, I think. It so happens that the core has been drilled, our scientist Hollingsworth, explains, to a layer that dates from "two to three thousand years ago." The scientists, I have noticed, measure time in years back from the present time. My own sense of time follows a different accounting, with the chronological rupturing claimed by followers of a certain Jewish-Palestinian figure. Scholars of the ancient world adopt this but with the preferred and more neutral language of the Common Era. Aligning these various ways of calculating time means that the bottom of the permafrost core contains the physical indications of sometime during the first millennium before the Common Era—which, as it happens, includes the period that has captured my imagination for most of my career. That era, a continent away, is also known as the Second Temple Period. These are some of the many human ways of reckoning with time—all stuff in our heads, none of them accounting for how cold that core feels in the palm of my hand. Or how to make sense of it. How does one account for the past that is buried in permafrost? Is this a new form of archaeology, one not tied to pottery, burial grounds, or texts? I have plumbed texts to imagine answers to these questions, but this permafrost core speaks in a different language. Time, it turns out, does not tell. Or not readily.

This unusual contact is unfathomable—or at least confounding. For one, what are we to do with the mud that has slowly seeped onto our hands? Some of us wipe our fingers along the rough bark of the spruce that live in this harsh climate and that surround us like witnesses to our pilgrimage to the past. A film of mud still remains, and I hope that it will dissolve into my skin, which is becoming papery with age. There is a brief respite when a sliver of charcoal begins to reveal itself. The scholars bow their heads over the core to extract the sliver. We could write something! Make something! Save something!

I still feel the wet mud on my hands, the past inscribed upon my papery palms. I cannot grasp this, understand it, or reconcile it. It may be enough to let it seep into me, like letters on a scroll that are disappearing.

KELSEY JOHNSON (ASTRONOMY)

The surface of the tundra seems serene and uniform despite its heterogeneity. I am puzzled about how we will choose where to drill and extract a cylinder of frozen earth that has been left untampered for millennia. Our guide takes us into the scrubby tundra brush and selects a specific location that seems to have no substantive difference from any of the other virtually infinite possible coffee-cup-sized patches of earth we could choose, at least not to my untrained eye. I cannot help but wonder if there is something special about this particular spot that the trained eye of our guide can see, but I am at a loss, given that the Earth's secrets are buried and invisible under the ground.

The location our guide selects to put down the auger strikes me as entirely arbitrary, but is it really? I would like to know what was going through his mind when he thought, "This is the spot," instead of a location a little bit to the left or right. Was it instinct? Wisdom? Experience? As an astrophysicist, I am mindful of the famous butterfly effect and the nature of chaos. All these seemingly arbitrary choices that feel utterly insignificant have the power to change the future in radical ways, but the Earth system is far too complex for us to begin to predict how this one tiny decision might play out over the long arc of time. Still, I wonder about the possibilities.

I am full of cognitive dissonance when the drilling starts. The act of drilling is violent and bone-jarringly loud, which is especially unsettling in contrast to the pure, unprocessed landscape devoid of human sounds. The drilling itself is more difficult than I expected, and I cannot help but feel as though Earth is trying to protect itself from our violation. I am a dyed-in-the-wool scientist, and I try to check myself against objective and rational knowledge, yet my intuition is saturated with a feeling of unease and shadows of colonialism. We were not given permission yet we believe we are justified in taking a biopsy of Earth to satisfy our curiosity. Are we? How is this manifestly different from eminent domain? With my astrophysicist hat on, I think a lot about the ethics of space—what role and rights do we have as humans to explore, sample, pollute, populate, and transform? This act of drilling is suggestive of telescoping in time and space to human colonization of Mars. I am not a fan of private industry ripping through the solar system unchecked.

When the drill stops, our anticipation is palpable, and our curiosity takes over. We are about to glimpse what happened at this very particular 7.4 cm (three-inch) diameter column in space over the last several millennia. Once extracted, the core immediately begins to melt, and it is impossible to ignore the fragility of the ground we stand on. The core is covered in a rich chocolate-brown sludge that obscures the secrets within. As soon as the newly melted permafrost sludge is scraped away, we can see the interior of the core; a new layer of muddy melt forms just as we get glimpses of ice, fibre, and charcoal. The charcoal grabs our collective attention immediately, perhaps because it is something familiar that we can put in a modern context. Matthew (Burtner) will sketch something with it.

The bottom of the core is bitterly cold to the touch, and I do not understand how our guide holds it with gloveless hands. This intense cold harboured by Earth seems alien to those of us accustomed to more temperate latitudes, but the reality is that these unwelcoming temperatures are the norm in the universe; our thin little band of hospitable climates on this tiny little speck of a planet are—by far—the exception. The existence of temperate sanctuaries is an exception in both space and time. We humans can be so very myopic and laser-focused on the scope of one generation—it is so easy to think of anything longer than a typical human lifetime as permanent. I often wonder whether we might have a slightly more visceral understanding of how transient our universal environment is if our lifetimes were longer. Instead, the shifting baselines easily go unnoted in any given generation. In time, everything around us will be hidden in some arbitrary layer of permafrost on a cold and dead planet. Maybe we would want someone to drill, just so the atoms of our cells could feel seen and acknowledged?

All this ground beneath us is history solidified and entombed, and I get a sense of temporal vertigo. History is happening now, too. What would a scientist think after taking a core from this very location in a thousand years? Never mind—as soon as I have that thought, I remember that, by then, it is probable that there will be no frozen landscapes on Earth, just a sludge of mud with its secrets lost to the unrelenting power of entropy. What will our legacy be?

WILLIS JENKINS (RELIGIOUS STUDIES)

The cultural archive in which I read is about as old as the length of biological memory represented by this frozen cylinder. Someone points out a smear of ash from what must have been a large fire many centuries ago. I wonder which people witnessed the fire, what stories were subsequently told about it, and where that narrative memory may perdure. While impossible to date by sight, I calibrate the permafrost core to my own archive by imagining that the fire perhaps happened about the time Augustine of Hippo was interpreting the decay of the Roman Empire.

As the core begins to thaw in my hands, millennium-old soil turning to mud between my fingers, I wonder about interactions between cultural archives and thawing permafrost. What cultural legacies represented by that permafrost core are needed to make sense of the great subterranean thaw happening across the planet? What texts or narratives could better help us understand the rapid shifts happening beneath boreal forests? What art or ideas could help us imagine ways to live in new conditions?

That is a version of the challenge the forest itself has. Michelle Mack, lead scientist of the BNZ LTER, describes the team's work on forest succession dynamics as an investigation into the way ecological memory interacts with shifting conditions. A spruce-dominant forest typically regenerates after fire through a remembered pattern of succession resident in its seedbed. As a warming climate encourages fires that burn hotter and deeper, however, the fires consume the seedbed, erasing those biological legacies. New kinds of forest communities (more deciduous, less coniferous) emerge as different possibilities from ecological memory are tried and then shaped by relations with intensified fire.

I consider the biological archive now dripping down my arms. How warm can temperatures go while still harbouring possibilities for creating new kinds of forest? For there is a worrisome feedback connection between permafrost thaw and global warming. As the soil thaws, long-frozen microbes start digesting biological material again, metabolizing ancient carbon into the atmosphere as carbon dioxide and methane, which intensifies the warming trend. At some point, I suppose, the scale of change must exceed the range of ecological memory—must exceed the possibility of forest.

Yet that pace of warming is not inexorable. Insofar as societies can understand the relations through which they force warming, they can take responsibility for them and alter course. Responsibility for the drivers of permafrost thaw requires daunting feats of political organization and social transformation. It also requires, as precondition, ways of imagining relations with carbon and permafrost, with forests and fires, as part of social life. That is to say, moral imagination seems prerequisite for political responsibility.

Imagination is conditioned by memory. There is no cultural blank slate from which to start anew, just as there is no zero condition for creating new ecosystems. Like all life, humans make worlds from inherited legacies. Cultural archives are seedbeds in that sense, conditions of constraint and possibility, from which to interpret changes in our lifeworld and fashion new forms of relation within it.

Augustine refashioned Platonist and Christian legacies into a worldview that made sense of what was, for him, a destabilizing and fearful event. By interpreting the rapid diminishment of Rome by a two-cities schema that relativized earthly political disappointment to a divine order, Augustine tried to parse moral imaginations into the relations that matter. That schema and its orientation of moral responsibilities influenced North Atlantic political organization through to the founding of settler states in North America. It endures still in subterranean form, a usually invisible foundation lying just beneath the surface.

Permafrost thaw exerts stress on that worldview because the dynamics responsible for the warming seem to elude the moral imagination cultivated by the Augustinian legacy. Insofar as relations with nonhuman creatures or multispecies communities do not seem to matter to politics, Anthropocene relations challenge the capacity of this body of memory to make sense of the destabilizing, fearful disordering in our time. Perhaps it is time to reimagine political relations by listening to other archives of cultural memory.

After the somewhat diminished cylinder was returned to the shaft from which it was drawn and covered over again with an insulating plug of sedge, we left Bonanza Creek and joined a symposium of artists from the In a Time of Change program, which is supported by the BNZ LTER. Informed by what the LTER scientists are discovering, these poets and visual artists experiment with forms of expression capable of making sense of the rapid shifts occurring beneath their feet. Their creativity is one example of the much broader cultural experimentation needed to reassess archives and memory banks and to develop new possibilities of imagination.

ADRIENNE GHALY (ENGLISH)

It is a powerful experience to be able to hold in one's hand planetary dynamics in the process of acceleration. A permafrost core extracted on a hot day in an Alaskan boreal forest is immediately subject to a much warmer atmosphere than its underground environment. Lifting the springy moss and thrusting a hand into the active layer up to the elbow one hits an unyielding frozen layer less than eighteen inches below the surface. The cylinder pulled out of the ground is composed of soil, rocks, sand, carbon from very old plant and animal matter, and ice, all fused together. It is weighty and very cold. The frozen water it contains immediately begins to change state when exposed to this rapid change in temperature.

Permafrost scientists use the term thaw, not melt—but the core is quickly and palpably melting. Rivulets of muddy water run down its icy sides and drip onto the spongy understory. Repeatedly scraping its sides with a knife temporarily clears away the liquifying matter that obscures the dully glittering shards of ice and the irregular black carbon deposits running down its length; carbon laid down over the last two to three thousand years. The black deposits smudge under the pressure of a finger, and the glints of ice disappear as the core warms, a process not just of change but of rapid disintegration.

I am using the language of sensory experience because feeling the permafrost core's instability is to feel a fast-moving and large-scale process—subjecting ground that has been continuously frozen to above-freezing temperatures—at the scale of my too-human sensory perception. This densely frozen composite material is part of the dynamics of forces and relationships in the boreal forest and its adjacent ecosystems, across the global cryosphere, and through connecting layers of time from the relatively immediate past in geological timescales to probable near futures. Holding the thawing, melting core in my hand is to feel this process condensed into a matter of minutes.

Permafrost, as very recent work in the environmental humanities (Heyes and Pratt, 2022; Sokolíčková, 2023; Wrigley 2023) shows, is nodal, a subsurface layer where complex historical (human) and geological (nonhuman) relations intersect in processes that produce climate futures. But as Leena Cho (2021:26) has pointed out, there are few theoretical reflections on permafrost itself as the materiality of "foundational environmental processes that animate the socioecological landscapes of cold regions."

In environmental humanities, two major theoretical strands—concerning the failure of the human sensory field and its newly urgent possibilities in the face of new climate realities—pull in opposing directions. Traditionally, Western materialist thinking formed assumptions about the material world based on how humans perceived it; a strong corrective has now overturned the legacies of empiricism, phenomenology, and older materialisms. The presence of a perceiving human—long the focus of philosophical inquiry—is a scale of inquiry that appears increasingly untenable for addressing human impacts on a planetary scale. At the same time, the physical feelings of a warming climate are widely, if unevenly, felt across different ecosystems and locales through extreme weather, heatwaves, flooding, and the thick smoke of wildfires. Many communities in both the global South and global North are experiencing an alarming array of a warming climate's physical sensations. The reality of the effects of climate change becoming widely and increasingly perceivable—sometimes catastrophically so—has revived questions of where and how the complexity of the human sensory field in all its cultural and historical specificity can be thought anew by environmental humanities.

A permafrost core falling apart on a warm day reconfigures these strands into a dialectical relation. A permafrost core is a particularly potent example of what I would term materials of planetary acceleration at bodily scale. These are palpable phenomena that condense complex planetary dynamics to human scale. Consequently, materials of planetary acceleration at bodily scale are materials about which collective understanding of a warming climate for those living far from the socio-ecological landscapes of cold regions can fruitfully coalesce. In a rapidly warming world, attempts to convey the far-reaching scale of climate effects often utilize images of calving glaciers, the timelapse retreat of ice, or the aftermath of wildfire. Yet to understand planetary processes bound up with probable climate futures, materials of planetary acceleration at bodily scale—holding climate change in the palm of a hand—may be the better access point to collective understanding.

KURTIS R. SCHAEFFER (RELIGIOUS STUDIES)

In his 1937 novel *Star Maker*, British science fiction author Olaf Stapledon sought to describe a feeling of being rooted in a spot upon a landscape while looking up and out to the near-endless points dotting the night sky. Stapledon's protagonist has taken a nighttime walk from his house in rural England to a nearby hill so that he can sit in the heather and watch the stars. The immensity of sky in relation to the singular minuteness of Earth at this spot carries him to a heightened state of observation as he looks from single planets and stars to clusters of bright lights beyond them and, finally, to the thick swaths of layered light that make up the Milky Way. As he looks to the stars, his observations quickly become suffused with imagination, enabling him to see more detail, more movement, more life than his eyes alone allow. He struggles to name this moment of looking from hill to cosmos: "Gazing at the faintest and remotest of all the swarm of universes, I seemed, by hyper-telescopic imagination, to see it as a population of suns; and near one of those suns was a planet, and on that planet's dark side a hill, and on that hill myself" (Stapledon, 2011:12). Stapledon's science fiction term for this particular form of imagination-powered observation-in-place—the hyper-telescopic imagination—is rich with potential for envisioning the value of dark skies, skies in which we are able to behold the vastness of the galaxies that make up the Milky Way, and thus to place the unique particulars of our life experiences in discrete places on Earth in relation to near-infinite other places, spaces, and potential minds on a cosmic scale.

The hyper-telescopic imagination is also a valuable practice to bring to the observation of geologic or environmental features that belie easy consideration. Hyper-telescopic imagination, a sort of creative effort that synthesizes inspection and scrutiny with introspection and visualization, could help to make sense of environmental phenomena whose surface features may not reveal what is most interesting or important about them. A permafrost core is one such phenomenon.

It's been a long time since this piece of earth has seen the sun. Three thousand years? Four thousand? I'm holding it in my hands like a small piece of firewood, ready to toss it into the flames. But it's wet and cold. And much older than a branch of hardwood, or so I am told. This cylinder, almost 7.5 cm in diameter and as long as my forearm, is a section of a longer cylinder just extracted from the ground. A permafrost core. Jamie (Hollingsworth) has just pulled it from the ground, extracted it with a gas-powered drill powering a purpose-built bit used for coring the permafrost. The bit is just over a metre long. Jamie sank the drill into the ground as far as it would go, with the gas engine partially submerged in the low-lying plants on which we all are standing.

The ground is composed of two main layers: tundra vegetation and permafrost (soil that remains below freezing for at least several continuous years). Where we are standing today, in the Experimental Forest of the BNZ LTER site, about a half mile from the northern bank of the Tanana River, the tundra is about 30 cm deep, so Jamie pulled up about a metre of ground. I am holding approximately the upper third of this tube of frozen water, soil, minerals, and plant debris. The ecologists I am with estimate that this upper portion is several thousand years old. The deeper portions would be older than that. Without either extensive data collection and comparison, or reference to the research literature, it is difficult to be precise about its age. For me, it is old—or, rather, one of the many versions of old to be encountered within the frozen regions of the North.

Before I held this core extracted from the frozen ground just below the surface, permafrost was an abstraction for me. Permafrost is permanent in the sense that it remains frozen for a long time. Not forever, but for a long enough time that the "perma" in permafrost makes good rough and ready sense. Early researchers called it eternal ice. That's strictly inaccurate, but it's evocative of the sense of wonder that even this Tanana Plains permafrost evokes for me, young as it is at a mere three or four millennia old. Deep permafrost under Prudhoe Bay, by contrast, is half-a-million years old.

As soon as this core comes out of the ground, it is no longer permanent. It is a hot day in the Tanana Valley, with temperatures reaching 26.6˚C (about 80˚F) along the river. Millennia-old ice instantly starts to melt, turning the cylinder dark and muddy. Jamie scrapes its surface with a knife like he is skinning a cucumber. He peels the muddy surface away to reveal the more solid contents of the core. Rocks, plant roots, and parts of plants I can't identify. Charcoal indicates a fire from thousands of years ago, probably natural, but possibly from human action. And the ice that binds these contents together into a single entity, permafrost, glitters in the sun for brief moments until the heat melts it. We've brought up a piece of times long gone. It is here with us, held in our hands for a moment before the ice turns to water and the core dissolves into a more permanent past.

The core is at once in my hands, in our hands, and at the mercy of our tools, and it is also a part of a deep past that is teeming with life. Direct evidence of sentient life is scant in the core itself. Plants are directly apparent (once they are pointed out to me by the ecologists) while animals are not. Yet the plant life was part of an ecosystem complete with flora, fauna, stone and dirt, atmosphere and weather. What is in the permafrost now, below ground, was living above ground in times past. Here the imagination must take over from observation. The core makes this possible; it is surprisingly effortless to conjure up a vision of life coursing through the Tanana Valley from this single cylinder of frozen time/earth. And more, the visceral experience of touching—feeling the roots, rocks, and ice within the core—encourages reflection on the value of the visions of life and lives past that it evokes. What does this underground evidence of life above ground mean? How do we best relate to it? The hyperchronoscopic experience of a distant, permanent past fused with one that is intensified and fleeting (melting) now compels this questioning.

Buddhists, to name one group of thinkers and dreamers who considered these questions along the same lines as Stapledon, had an answer to this question: we relate to it with wonder and reverence. In a classic Indian story from the early centuries of the first millennium, the Buddha casts his food bowl to the ground and challenges his disciples to find the bowl. But it is no simple task, for he has cast the bowl through the ground of the Earth and on through countless worlds until it lands on the ground of a world in a different galaxy. None of his disciples are able to find the bowl until Manjushri, never leaving his seat next to the Buddha, stretches his arm and extends his hand through the ground, through countless worlds toward the exact spot on the exact world upon which the bowl had landed. His hand is seen by inestimable living beings as it descends through these worlds and ascends back to the place where the Buddha sat. In every world his hand passes through on its way to the bowl, each pore of his arm emits endless rays of light, upon which ride other Buddhas from different times and places throughout the cosmos. And as Manjushri's hand passes below the spot on Earth where he and the Buddha sat to travel through these myriad worlds, his presence inspires countless beings to become like the Buddha, to become enlightened. When this display of cosmic interconnection is complete, Manjushri draws his arm back through the cosmos to hand the simple wooden bowl to the Buddha, never having left his seat.

Such a sense of wonder we shared on the Tanana Valley floor looking at the permafrost core. The cylinder (Yes, the Buddha's bowl. Yes, Stapledon's stars.) is both of this time and time past. It is simple now: dirt, ice, water, wood. But the subterranean journey it has made over four or more millennia is rich, complex with interconnections to life past and future. The permafrost core we held on that day was wondrous, but it was also connected. It connected us, here and now, to life past, and evoked images of life millennia from now when we are part of the permafrost core that a future being pulls from the ground.

MATTHEW BURTNER (MUSIC)

Sound is a property of motion, the compression and rarefaction of molecules in an elastic medium caused by some impulse. In a closed tube such as the ice core or the Permafrost Tunnel in Fairbanks, Alaska, a standing longitudinal wave may form in which the wavelength and its reflection overlap perfectly in the physical space. The waveform appears to be fixed in space, but this phenomenon is caused by two waveforms superimposed over one another such that the crests and troughs of the wave (really the compressions and rarefactions, since it's a longitudinal wave) align closely, giving the property of standing. In fact, the waves are in a dynamic interaction of interference, and we can read their resonance through microtonal differences. Moving along a standing wave, for example by walking slowly along the tunnel, a listener can move through the pressure variations and the sound will appear to amplify and disappear, depending on where in the waveform the listener orients to. This phenomenon is a consistent characteristic of the closed tube and is common in musical instruments and in ice cores. Perceiving the differences in the standing wave by measuring waves sent through the permafrost ice core might be a way of understanding the spatiotemporal structure of the thing, a way of reading the time we can't read.

In the permafrost tunnel, we are inside the resonant column of air within the closed tube. Here, a standing wave will create nodes of low pressure—places where the molecules are thin. Conversely, in other places, the air molecules are compressed, creating a higher concentration of air particles. At either of these nodal points, one might feel strange because of the low or high pressure and the change of sound. At places inside the permafrost tunnel, I feel slightly ill, and I wonder if it's a property of the unique resonance of this place.

On the tundra, I cannot hear into the permafrost core as I hold it in my hands, but even so I know the sound propagating through that tube of frozen earth is moving in a highly unpredictable and variable manner. A standing wave inside the core would be susceptible to innumerable distortions, sounds determined by slight differences in the material composition of the ice. This composition is also directly related to the temporal record, meaning that the distortions of the standing wave could be heard as a way of listening through the deep past. The hole left by the removal of the core is also a closed tube, and I try threading a small microphone down it, wondering what we might hear, but the vacated space only reveals the present: just the slight settling of the earth as it begins to melt into and retake this new void.

In "Spectral Arctic Ice Triangulations" (Burtner, 2009), two performers play tubes lowered into tubs of water. A hydrophone inside the tubs picks up the underwater reverberation while an air microphone above water picks up sound in the air. At some points during the performance, as a tube is lowered into the water, its length effectively changes. When it is struck above the water, the air column creates a resonant waveform, closed on one end by the water, which defines the frequency of the closed tube. However, the water end is not entirely closed and air molecules from the waveform transfer some of their energy into the water, which then creates a standing waveform underwater at the point of medium change. The tube thus has two resonant frequencies, both articulated by the performers and amplified through microphones designed for the mediums of air or water.

As the tube lowers into the water, the water below the surface fills the tube, dampening it and effectively closing off the tube at a shorter length, raising the pitch. Some of the resonance is transferred into the water and it propagates down through the water-filled tube and out into the tub. At any given moment, the different tones produced by the resonating water column and the resonating air column offer a sound signature of that particular physical configuration. No two depths will be the same; each one is unique and in constant fluctuation.

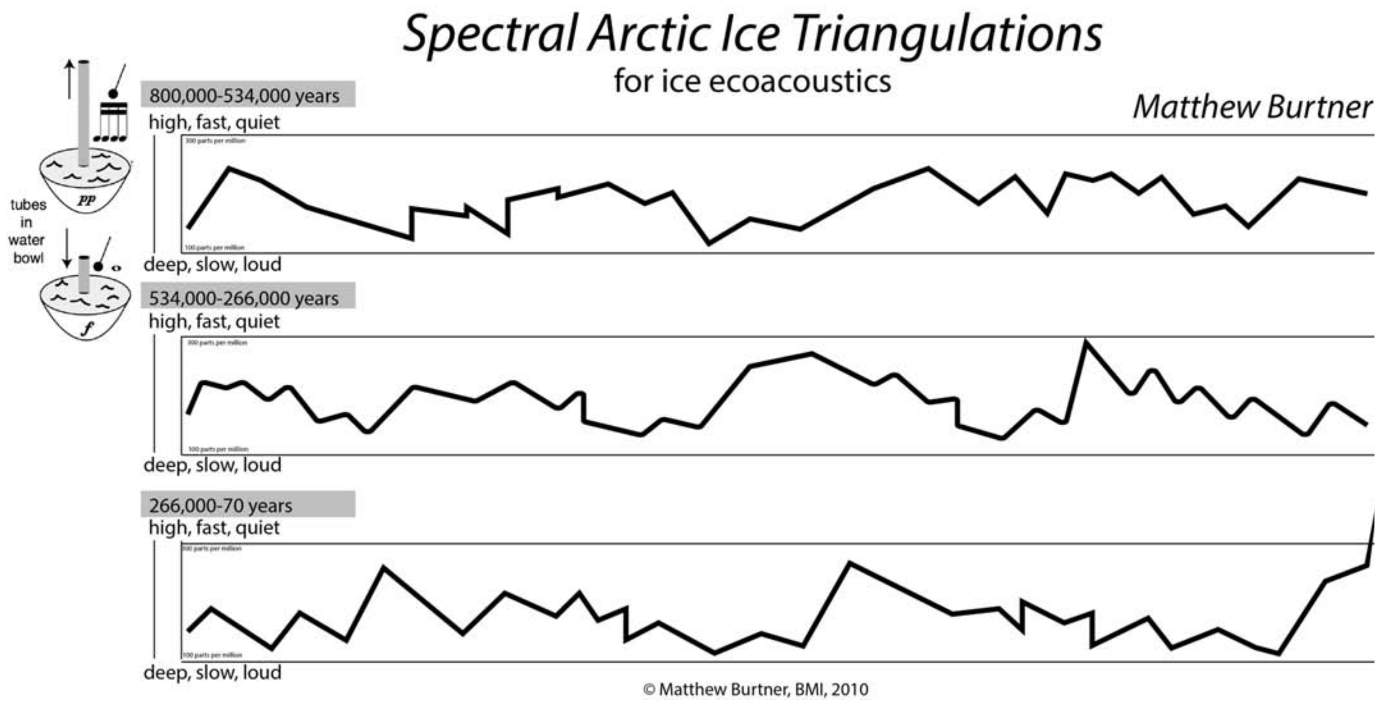

FIG. 1. The "Spectral Arctic Ice Triangulations" notation for playing amplified tubes in water. Photo credit: Matthew Burtner.

The instrument for performing "Spectral Arctic Ice Triangulation" was inspired by ice core samples that use frozen deposits of compressed snow or water, frozen in time, to discover what happened in the past. The chemical composition of the ice at any given depth reveals atmospheric and water conditions from a specific point in time. Just as the ice core allows scientists to discover atmospheric and oceanic phenomena of precise points in time, "Spectral Arctic Ice Triangulation" allows musicians to read the physical properties of the system across time. In the musical score, this action is linked to a climate time model of carbon dioxide levels in the atmosphere going back 800,000 years. The ice cores in Greenland contain ice over 100,000 years old. Antarctic ice cores date back much further, to approximately 800,000 years. The musical score sonifies the temporal record written in ice by having the performers navigate the depth of the tube in water according to a time/depth axis (Fig. 1).

The score sets the Y axis position as the depth of the tube, which would normally be the temporal depth of the core. The performers read the atmospheric conditions by lowering or raising the tube in the water and striking it to sound the differential resonance. As they raise and lower the tube, they are navigating the data set as a function of high and low, while time becomes an absolute function of the passing of the moment in the concert hall, as experienced by a listener. The score links tempo and amplitude with depth: as the musician lowers the tube into the water the pitch rises and they play faster and quieter; as they raise the tube out of the water the pitch lowers and they play slower and louder. In this way, the musicians sonify a data archive of atmospheric conditions created from analysis of ice core drilling samples.

The permafrost core we hold in our hands in Alaska contains streaks of charcoal, a record of past fires. I pocket some on a whim, intending to write something with it later. I consider this ashy evidence of an ancient fire—the fire that burned. I also consider the charcoal in relation to tunnelling, mining, the combustion engine we used to drill the core, … the trucks we used to get there, … the airplanes, the Trans-Alaska Pipeline, … global warming—the fire that burns. Later, I composed an atonal melody and a few words to go with it. I used the pieces of charcoal from the permafrost core to write the melody.

The circles on the paper are pressings from the permafrost core itself, made as it melted. Ten slices of the muddy peat were pressed onto the art paper. I also used the charcoal to highlight features of the mud from the permafrost. The music and text were written using that same ash, then I burned the edges of the paper with a lighter (Fig. 2).

The Fire That Burned Is Not the Fire That Burns

That one is already permafrost for millennia,
a peaty biotic core.
But this fire has no body in the environment.
Yet it remakes ocean currents, stills winds,
Drains lakes, and collapses cities.
The fire that disturbed is not the fire that disturbs.
That one is a thermal legacy,
Now too cold to handle.
But this fire tips continental plates, melts mountains,
Releases anthrax, and starves moose.
The fire that burned is not the fire that burns.

FIG. 2. "The Fire That Burned Is Not the Fire That Burns." Melody written in charcoal and permafrost core pressings on burned paper. Photo credit: Matthew Burtner.

Later I worked with those notes and words to compose a song (Fig. 3). "The Fire That Burned Is Not the Fire That Burns" was motivated from one small slice of the permafrost core, one season out of thousands of years of time contained in that tube of ground. The imaginative response spins out of a reading of ice temporality, like a resonant node along the standing wave, into a feedback loop in the imagination space. The mind's ear permutates and distorts the experience of the core and the tunnel into song. That song is not itself a property of the permafrost core, and yet this human distortion originates within it. The standing wave offers a possible way of acoustically reading the past we cannot read. The creative resonance suggests non-linear pathways from that material-temporal analysis of the core into the imagination, into other ways of knowing.

CONCLUSION

Are we more surprised by the differences or by the similarities in these perceptions of the permafrost core and the feelings that it elicited? Common threads are clearly, and maybe not surprisingly, space and time. The core is effectively a point in space, particularly from the astronomer's point of view, three inches in diameter and just over one metre in length; yet it is representative of a much greater spatial extent, the degree to which might vary depending on each individual biotic or physical component of the core. And the collection of material frozen in that piece of ground certainly did not originate just from what existed within and above it. From where did it all originate? From how far away?

Whereas the collection of material toward a point in space may not be very intuitive, it is quite apparent that the permafrost core embodies the cumulative effects of millennia—migrations in, transformations, storage, migrations out—with rates of different processes varying by orders of magnitude. Knowing the age of some of the

FIG. 3. "The Fire That Burned Is Not the Fire That Burns" song expanded from the original poem and charcoal atonal melody. Photo credit: Matthew Burtner.

material deeper in the core solicits thoughts of earthly geomorphological and societal time, thousands of years of changes, some continuing in the same direction, others moving forward and backward. Another common theme is disturbance and vulnerability—as material that may have been frozen in state for years, decades, centuries, or longer is exposed to us, to other elements, and is literally thawing and melting away in our hands. We watch as this happens in front of our eyes—some of us make drawings, writings, or music with exposed pieces of charcoal, creating anew as the millennium-old ice turns to water again.

REFERENCES

Burtner, M. 2009. Spectral Arctic ice triangulations. https://www.youtube.com/watch?v=SiCbPzqh6ok

Cho, L. 2021. Permafrost politics: Toward a relational materiality and design of Arctic ground. Landscape Research 46(1):25–35. https://ideas.repec.org/a/taf/clarxx/v46y2021i1p25-35.html

Heyes, S.A., and Pratt, K.L. 2022. Memory and landscape: Indigenous responses to a changing north. Athabasca: Athabasca University Press.

Sokolíčková, Z. 2023. The paradox of Svalbard: Climate change and globalisation in the Arctic. London: Pluto Press.

Stapledon, O. 2011 (1937). Star maker. London: Gollancz.

Wrigley, C. 2023. Earth, ice, bone, blood: Permafrost and extinction in the Russian Arctic. Minneapolis: University of Minnesota Press.

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