“The ice can be conquered”:
Scientific knowledge and mobilizing Arctic gas

by

James Wilt

A Thesis submitted to the Faculty of Graduate Studies of
The University of Manitoba
in partial fulfilment of the requirements of the degree of

MASTER OF ARTS (GEOGRAPHY)

Department of Environment and Geography
Clayton H. Riddell Faculty of Environment, Earth, and Resources
University of Manitoba
Winnipeg

Abstract

This thesis examines the histories of two proposed natural gas transportation projects from the Canadian Arctic Islands in the 1970s and 1980s: the Polar Gas Project and Arctic Pilot Project. Specifically, it analyzes scientific inquiries into the issue of ice by the consortiums, which posed a major obstacle to successfully establishing commodity circulation. In total, more than 80 scientific and technical reports produced by the consortiums and contracted firms about the various challenges of ice facing the two projects were examined for this thesis. These scientific investigations covered an enormous range of focuses about the mechanics and behaviour of ice, including its thickness, coverage, patterns of formation and break-up, and strength. Three categories of theoretical approaches were used to analyze this scientific work: 1) production of cryo-nature; 2) scientific knowledge production; and 3) political ecology of failure. This thesis draws attention to the diverse and often ad-hoc scientific labour that produced Arctic natures as abstracted and exploitable spaces for capital accumulation. It also considers the alternative production of natures by Inuit societies, rooted in relations of kinship and reciprocity. The two case studies demonstrate that scientific inquiries were highly productive despite the eventual failure of the projects, with many of the same issues now resurfacing with the melting of Arctic ice and capitalist ambitions to maximize "accumulation by disappearance."

Acknowledgements

Many thanks for support and assistance to: my supervisor Jonathan Peyton; committee members Mark Hudson and Bruce Erickson; classmates Melissa Davidson, Katherine Aske, and Liam Kennedy-Slaney; unofficial mentor Warren Bernauer; librarians and archivists Lucille Wallace, Robin Lee, and Erin Acland; sister Rachel Wilt; parents Brenda and Garth Wilt; friend Levi Mayerle, partner Emily Leedham—and cats, Stokely and Muggsy.

Table of contents

Chapter 1: Introduction

The two catastrophic natural gas blowouts could not have come at a better time for Panarctic Oils. Since 1961, when Dome Petroleum drilled the first well in the Canadian Arctic Islands, oil and gas companies had been fervently hunting for "elephant" fields like Atlantic Richfield's 1968 discovery of giant oil reserves at Prudhoe Bay, Alaska (Bregha, 1981, p. 9). Exploration in the Arctic Islands was extremely expensive and resource-intensive—and consequently heavily subsidized by the federal government. Panarctic, founded in 1967 by the federal government in partnership with 20 private companies, had received "farmed out" permits from 75 companies and individuals to explore, equivalent to nearly two-thirds of leased acreage in the Arctic Islands region (Perry, 1967). To secure continued confidence from leaseholders and government, Panarctic needed to prove there were sizable reserves beneath the ice and snow. They needed a "win." Nothing could demonstrate the terrific latent potential of the underground resources quite like the pair of spectacular eruptions.

The first, at Drake Point on the Sabine Peninsula of Melville Island, blew in July 1969 for 14 months, eventually plugged with explosives (Kennedy, 1988, p. 18). Partway through the blowout, a *Maclean's* reporter wrote about the consortium's rapidly escalating costs: "Only mammoth low-cost Middle East-type reserves will justify the expense, but the odds are with Panarctic" (Carney, 1969). That prophecy seemed to only be further confirmed with the even more visible blowout on King Christian Island, which blew in October 1970; another journalist dramatically wrote about the initial explosion: "The men were covering their eyes to protect them from the glare, leaving their eardrums exposed to the din of what seemed like a rocket's take-off … The ground shook under their feet with the intensity of a volcanic eruption" (Kennedy, 1988, p. 26). A month after it exploded, the *New York Times* reported that its glow could be seen from 200 miles away and had become "a regular sight seeing feature for passengers on polar-route jets" (Cowan, 1970). The blowout belched an estimated 300 to 400 million cubic feet of gas per day, for 92 consecutive days (Kennedy, 1988, p. 32).

Charles Hetherington, president of Panarctic Oils, did not view this environmental disaster in a particularly negative light. The blowouts were not easy situations to deal with; the King Christian Island (KCI) effort necessitated an "air-lift of war-time proportions" (Kennedy, 1988, p. 12). There were reasonable fears that failing to efficiently plug the wells would jeopardize future support and permits from the federal government (Kennedy, 1988, p. 28).

Despite the potential risks, Hetherington reportedly "hoped to coax it to burn bright enough to be seen all the way from Houston," a vivid representation of his desire to exploit the incident for marketing purposes (Kennedy, 1988, p. 28).

The Panarctic executive transformed the blowout into a promotional opportunity for his company, flying in photographers to document the 200-foot flame and senior gas executives from across North American to view it in an attempt to sign them up for buying contracts (Kennedy, 1988, p. 29). Kennedy (1988) wrote: "Gas traditionally lacked romance. What sold KCI was the spectacle" (p. 63). After the blowout was contained, Hetherington kept the key to the padlock on the wellhead attached to his belt and flared the gas spout when investors and dignitaries visited the site (Kennedy, 1988, p. 54). Journalist Tom Kennedy (1988) later wrote that the well "became his private property, in the only recorded case of a well ever to have been adopted as a pet" and that the flaring "not only impressed the onlookers but would make them part with their money that much easier" (p. 54). Hetherington declared that the largest natural gas field in Canada had been discovered, despite not having any reliable reserve estimations (Kennedy, 1988, p. 38). *Oilweek* reported pipeline engineers "had stars in their eyes at the though[t] of building a pipeline to carry those riches south to market" ("Panarctic lights a fire," 2008). At long last, Arctic exploration efforts had resulted in indicators of large reserves—and buyers. In the years that followed, estimated gas reserves in the Arctic Islands soared in quantity, particularly at the Drake Point and Hecla gas fields off the coast of Melville Island; by the early 1980s, reserves in the Arctic Islands were estimated at a massive 15.7 trillion cubic feet (Tcf) (Kaustinen, 1983). Fossil fuel companies salivated at potential profits buried beneath the ice.

Yet not a single cubic foot of gas was ever shipped out of the Arctic Islands. In fact, with the exception of the small Bent Horn oil field on Cameron Island—which shipped two seasonal tankers of oil per year to a Montreal refinery between 1985 and 1996, equivalent to a "tiny fraction of 1%" of Canada's oil and gas production—no fossil fuels were ever transported from the region (Bernauer, 2018, p. 141; Warde, 2018, p. 23). It certainly was not for a lack of trying. Two large and influential consortiums, the Polar Gas Project and Arctic Pilot Project, spent many years attempting to design and build massive natural gas transportation infrastructure: a lengthy pipeline spanning thousands of kilometers and several wide Arctic channels, and a pair of large liquefied natural gas-carrying icebreakers, respectively. These consortiums were backed by some of the largest fossil fuel companies of the time, including TransCanada, Dome Petroleum, Petro-

Canada, Tenneco, and Alberta Gas Trunk Line. But both failed to get their projects even beyond the regulatory phase. There are a wide range of factors for this, including growing opposition from Inuit communities to proposed transportation projects, discoveries of less costly gas reserves in Alberta, and declining global gas prices that undermined the economic case for multi-billion-dollar Arctic construction.

This thesis will not apportion specific blame for these failures, with the rise and fall of these projects shaped by a countless array of complex factors. Rather, this thesis will examine these industrial failures as producers of capitalist natures, generating enormous amounts of scientific knowledge about the Arctic and specifically ice—which was framed as one of the greatest impediments by fossil fuel companies to establishing commodity circulation to southern markets. Specifically, these new natures were produced by scientific and engineering firms contracted by Polar Gas Project and Arctic Pilot Project. These investigations covered an enormous range of focuses about the mechanics and behaviour of ice, including its thickness, coverage, patterns of formation and break-up, and strength. They also interrogated the properties of many different kinds of ice varying based on age, size, thickness, colour, origin, proximity to land, and structural integrity. These reports rendered ice and Arctic environments knowable and exploitable for capital accumulation, and are worthy of analysis given the ongoing imperative to establish greater commodity circulation throughout the Arctic. However, these reports have not been subject to sustained academic analysis since their publication several decades ago.

This is a missed opportunity for several reasons. Most obviously, elements of the specific natural gas transportation proposals continue to live on in the imaginations of fossil fuel proponents. A 2005 report prepared by the Canadian Energy Research Institute—a research organization funded by Natural Resources Canada, Alberta Energy, and the Canadian Association of Petroleum Producers—examined the economic case for producing and transporting natural gas from the Arctic Islands that relied on "information provided by proponents of the Polar Gas Project and the Arctic Pilot Project" (Chan, Eynon, & McColl, 2005). Information about natural gas reserves and potential costs produced in the 1970s and 1980s was directly harnessed to advance the possibility of future extraction. In 2008, Petro-Canada officially formed a "small team" to again examine the feasibility of developing gas resources on Melville Island, with the company's CEO describing it as "the project to die for" (Lee, 2007). A decade later, in late 2019, *National Post* columnist Terence Corcoran (2019) used

the Arctic Pilot Project as an example of why shipping Alberta oil sands crude through the Hudson Bay is technically feasible. None of these possibilities could have been seriously reconsidered without the production of scientific expertise decades ago.

Analyzing these reports serve another, more general, function. Polar Gas Project and Arctic Pilot Project were far from the first organizations to produce scientific knowledge about Arctic regions; rather, they belonged to a multi-century history of incursions for purposes of establishing capital accumulation and colonial sovereignty, including "explorers," whalers, missionaries, police, military, doctors, and scientists. The consortiums were also not unique in their investigations of ice as an object, with the Royal Canadian Navy starting systematic ice forecasting several decades earlier, in 1958 (Shokr & Sinha, 2015, p. 495). Other extractivist projects had also begun operations in the region by this time, including Rankin Inlet Mine in 1957 and Nanisivik Mine in 1976.

However, the scientific work produced by Polar Gas Project and Arctic Pilot Project offer important insights into the specific practices of how ice became rendered a capitalist nature that was to be alienated and exploited for commodity circulation. The field work, laboratory testing, devising of mathematical formulas, and creation of technical solutions documented in these reports functioned to extend what Richard C. Powell (2017) has described as "scientific sovereignty" over the Arctic Islands, rendering them a geography that could be known, managed, and exploited by capitalist interests. These practices advanced new ways of knowing ice as an object that could be managed. Ice was made scientific by capitalist interests seeking to establish commodity circulation to southern metropoles, whether that meant strengthening the ice to support the weight of vehicles required for pipeline installation, using warm water effluent to prevent its growth, or destroying it with a large icebreaker.

Neil Smith (2007) wrote that scientific labour "serves up" objects like molecules, organisms, and species as "discrete targets of instrumental social labour and simultaneously ratifies this purview of an external, exploitable natural world" (p. 22). This scientific labour produced ice as a "capitalist nature," or what James O'Connor (1998) defined as "everything that is not produced as a commodity but that is treated as if it is a commodity" including labour and land (p. 146). These efforts were far from a cohesive project: many such efforts were messy and rife with failure and iterative experimentation, with the science itself produced in a dialectical process with the ice.

The production of scientific knowledge advanced through these inquiries and reports sought to predict and stabilize ice for capitalist development. This process was also settler-colonial in function, conflicting with Inuit cosmologies and modes of production. Bruce Erickson (2018) explains that "settler colonialism establishes itself in place not through a moment of conquest, but through an invasion that is a continual production of physical and discursive infrastructures that stabilize and secure settler states" (p. 111). Eve Tuck and K. Wayne Yang (2012) write that settler-colonial incursions into Indigenous lands, disrupting existing social relations, "represents a profound epistemic, ontological, cosmological violence" that is structurally reproduced on a constant basis (p. 5). Similarly, Glen Coulthard and Leanne Betasamosake Simpson describe one manifestation of colonial practices as "impeding and systemically regulating the generative relationships and practices that create and maintain Indigenous nationhoods, political practices, sovereignties, and solidarities (p. 254). Scientific knowledge about ice was produced for the explicit purpose of commodity circulation and capital accumulation, implying the dispossession or undermining of Inuit usages of the material.

This thesis is structured around the following questions about the work conducted by the Polar Gas Project and Arctic Pilot Project: 1) How was scientific knowledge produced about ice to render Arctic natures exploitable to capitalist interests?; 2) What questions were asked about ice and how did those questions change over time in response to scientific work?; and 3) How did scientific work produce ice as an object that could be managed with expert control? Firstly, in Chapter 2, I describe the three theoretical approaches used: 1) production of cryo-nature; 2) scientific knowledge production; and 3) political ecology of failure. In Chapter 3, I provide historical context about four related topics: 1) science in the Arctic Islands; 2) oil and gas development in the Canadian Arctic; 3) Polar Gas Project; and 4) Arctic Pilot Project. These brief histories will help position the case studies within a broader, cumulative lineage of development, extraction, and knowledge production. Finally, in Chapters 4 and 5, I apply the theoretical considerations to the case studies of the Polar Gas Project and Arctic Pilot Project.

The methods that I used to collect this information are relevant, as a major focus in this thesis is about how knowledge is produced: in effect, I am producing knowledge about producing knowledge. The research process began with a survey of online databases of libraries and archives across Canada to establish which collections held reports produced by and for Polar Gas Project and Arctic Pilot Project. The University of Calgary possessed many relevant reports,

housed at its Arctic Institute of North America library and Gallagher Library (named after Dome Petroleum founder Jack Gallagher). The archives of the Glenbow Museum also housed relevant materials. I contacted staff at both institutions to schedule appointments in November 2019. I picked up seven boxes of technical reports from the University of Calgary, as well as several additional reports from the Gallagher Library, taking them back to where I was staying in Calgary. In total, there were 82 reports from the libraries.

Over the next several days I took photos of every page of each report with my smartphone, uploading the photos to my laptop, on which I would create a PDF for each report. This process allowed me to collect all potentially relevant information for review at my home in Winnipeg. Additionally, the creation of individual PDFs enabled the application of optical character recognition (OCR) software in order to easily search for keywords. Upon returning to Winnipeg, I spent several weeks carefully reading through each report and taking detailed notes on its approaches and findings, particularly those most relevant to ice studies. To condense the hundreds of pages of notes produced through this process, I wrote brief summaries of each report and assigned general themes such as “ice coring,” “strength testing,” or “laboratory experiments” to allow for referencing.

This process enabled me to establish a timeline of scientific work, as many reports referenced other reports or findings, and identify common themes between them including the types of questions scientists were asking of ice and how they went about trying to produce answers. It provided valuable perspectives on how such scientific knowledge was produced about Arctic ice by and for these firms. Many key questions posed of ice remained largely unresolved despite decades of scientific inquiry and production of expert interpreters. In fact, that is a consistent theme throughout this research: the kind of “certainty” required to know and engineer ice in a way that is legible and exploitable for capital is an immensely difficult task. To this day, ice remains a particularly fickle object to manage and exploit.

Chapter 2: Theoretical considerations

Many environmental factors were of concern to the Polar Gas Project and Arctic Pilot Project, but none as much as the problem of ice in all its forms. Ice posed serious threats to the construction and operation of the infrastructure required by the two projects—including pipelines, docks, and ice-breaking tankers—and needed to be well understood to prove the projects could be safely and efficiently executed for commodity circulation to commence. Writing about the specific issue of ice strength, Polar Gas contractor Banister Technical Services (1975a) explained that "reliable knowledge … become paramount for safety, long term planning, and investment purposes" (p. 5). Scientific knowledge was required to improve perceived viability of the projects to investors, as well as resolve the gaping technical issues that could disrupt or undermine attempted commodity circulation even if investment was secured. This required the production of immense quantities of scientific, environmental and engineering knowledge over the course of many years.

Before proceeding into the historical context and case studies, I will provide an overview of the theoretical considerations guiding this inquiry. These analytical tools provide a framework to "read" the field work, sampling, laboratory studies, and writing of technical reports that sought to make ice a knowable, legible, and exploitable environment. The history of the Arctic Islands has not been the focus of much social science research in recent years. However, research by many scholars working in fields including geography, anthropology, and environmental history provide insights that can be applied, including some focused on other regions of the Arctic and subarctic. These theoretical approaches are organized into three themes: 1) production of cryo-nature; 2) scientific knowledge production; and 3) the political ecology of failure. These related insights provide key analytical methods to make sense of the scientific knowledge production explored in Chapters 4 and 5.

Production of cryo-nature

The bourgeois ideology of nature suggests there is a fundamental divide between humans and the rest of the world, including non-human animals and ecosystems. Under capitalism, in which one class owns the means of production and the other class sells their labour power for wages, nature is rendered a collection of raw materials that can be disaggregated and reassembled either as a commodity such as oil or gas or as a condition of production enabling

commodity circulation (Smith & O'Keefe, 1980, p. 35; O'Connor, 1998, p. 21). Over the last several decades, Marxist geographers have critiqued this ideology by centering labour as the process that produces natures in the form of the prevailing social relations motivating the labour. As James O'Connor (1998) wrote: "Insofar as cultural and natural processes intermesh and interact, labor provides the animation. This is why Marx placed labor or human material at the center of the materialist conception of history" (p. 26). This theoretical approach can be applied to the production of ice, or what we might call "cryo-nature."

Specifically, the production of nature thesis—solidified by Neil Smith in his 1984 book *Uneven Development*—challenged the idea of "pristine" natures untouched by humans and called attention to the economic imperatives motivating this production of nature (Ekers & Loftus, 2012, p. 236). Smith posited that "first nature" ("concrete and material, the nature of use-values in general") had been largely replaced by "second nature" ("abstract, and derivative of the abstraction from use-value that is inherent in exchange-value"), so that what we now think of as untouched natures such as national parks are produced "by and within" second natures (Smith, 2008, p. 78; Smith & O'Keefe, 1980, p. 35).

The resulting totality of nature that is produced under capitalism is not of a physical or biological nature—but "a social unity centered on the production process" (Smith, 2008, p. 81). Under a capitalist mode of production—in which territory is enclosed through dispossession and proletarianization of existing users, and the money-commodity-money (M-C-M') circuit is established for capital accumulation—nature is rendered a "universal means of production in the sense that it not only provides the subjects, objects, and instruments of production, but is also in its totality an appendage to the production process" (Smith, 2008, p. 71). This transformation is not only quantitative but qualitative, as "nature—the varied realm of use values—becomes embroiled in the logic of exchange value on the world market" (Castree, 2000, p. 26).

In the production of commodities, means of production, or conditions of production, social relations are "frozen" in place in the form of "dead labour"—a particularly apt analogy for considering ice (Kirsch & Mitchell, 2004, p. 696). Rosemary-Claire Collard and Jessica Dempsey (2017) identify five types of capitalist natures: 1) officially "valued"; 2) the reserve army (entities with future value); 3) the underground (unvalued ecosystem services and functions); 4) outcast surplus (superfluous natures like extinction and pollution); and 5) threat (natures that can undermine capital accumulation) (p. 79).

According to Marxist scholars, the production of nature is "the goal of capital," a mandate "written into the DNA of capitalist ambition from the start" (Smith, 2008, p. 87; Smith, 2007, p. 22). Writing about capital circulation and accumulation, Noel Castree (2002) argues that "they are necessarily embedded in a qualitatively diverse world of flora, fauna, minerals, bodies and ecologies" but render highly diverse and complex materials under a "qualitatively homogenous and one-eyed imperatives" of capital (pp. 137-138). However, Castree (2002) emphasizes that this does not mean that natural entities are inert and totally compliant to the unrelenting drive by capital to expand and consume (p. 139).

Indeed, all production of nature can have unintended consequences that "may come to dominate the living labor that makes it," such as air pollution and greenhouse gas emissions (Kirsch & Mitchell, 2004, p. 701). It can also enable new opportunities for capitalist development, such as the thawing and melting of Arctic ice through what Klaus Dodds (2019) dubs "accumulation by disappearance" (pp. 3-4). This phrase is derived from David Harvey's concept of "accumulation by dispossession," which he defined as "the continuation and proliferation of accumulation practices which Marx had treated of as 'primitive' or 'original' during the rise of capitalism" (Harvey, 2005, p. 159). The second section of this chapter will discuss the role that scientific production of knowledge plays in this production of cryo-nature.

A key aspect of the production of nature thesis is that all societies produce nature, regardless of dominant mode of production. However, in a non-capitalist society, this is a metabolic process with the labourer appropriating matter to meet needs in a "unity of nature with society" (Smith, 2008, p. 55). This applies to Inuit, whose territories would have been significantly impacted by the Polar Gas Project and Arctic Pilot Project. Inuit have been living and producing natures throughout what is now known as the Canadian Arctic for some 5,000 years (Riewe, 1991, p. 3). Inuit Nunangat, or "homeland" in Inuktitut, is made up of four regions across Canada: the Inuvialuit Settlement Region (the northern parts of Yukon and Northwest Territories), Nunavut, Nunavik (northern part of Quebec), and Nunatsiavut (northern Labrador). In contrast to the "noble savage" myth of Indigenous peoples failing or refusing to cultivate their surroundings in a suitably "productive" manner, Inuit communities have always produced natures through labour, including the hunting of marine mammals using an array of tools and weapons like toggling harpoons, ice picks, hide scrapers, and snow knives (Riewe, 1991, p. 3).

Sea ice is a central dimension of this process. As a report by the Inuit Circumpolar Council (2014) put it: “our entire culture and identity is based on free movement over the sea and sea ice” (p. ii). In the early 20th century, colonial explorer Vilhjalmur Stefansson found a series of large hunting villages constructed on the sea ice, each containing about 50 igloos; these villages melted back into the ocean every spring, so the only evidence that remains of them is oral histories transmitted by elders (Aporta, 2011, p. 10; Riewe, 1991, p. 3). Riewe (1991) also identified several specific technologies that are “remarkable for their efficient designs,” including igloos, a qamutik (traditional Inuit sled), and lightweight sealskin boots (which he wrote “has never been surpassed by modern technology”) (pp. 7-8). The political economy that such a production of nature belongs to is inextricably tied to Inuit knowledge, or Inuit Qaujimajatuqangit (IQ).

Frank Tester and Peter Irniq (2008) argue that rather than being “holistic”—which implies the interconnection of many parts and a whole—IQ is better understood as “seamless,” which indicates “no discernable parts” and “nothing can stand alone, even in the interest of gaining an appreciation of the whole” (pp. 48-49). Sheila Watt-Cloutier, former chair for the Inuit Circumpolar Council, summarizes this paradigm in a 2015 interview: “I'm born into a culture in which environment is all-encompassing. It's not just ‘Let's save the trees,’ or ‘Let's save the seal.’ Everything is interrelated. We are an extension of the land, we are the land, and the land is us. It's what we call ‘sila,’ which is environment, but sila is also consciousness. Sila is wisdom” (Vasil, 2015). The concept of “sila” is described by Rachel A. Qitsualik (2013) as a “super-concept, both immanent and transcendent in scope” that possesses dozens of variant meanings that are “intellectual, biological, psychological, environmental, locational, and geographical” (p. 29). Discussing the significance of “sila,” Emilie Cameron, Rebecca Mearns and Janet Tamalik McGrath (2015) emphasize that Inuit cosmologies are anchored by understandings of the world as uncertain and “in a continual state of flux” (p. 278).

For Inuit hunters and travellers, ice is predictable and knowable to a certain extent. But as Michael Bravo (2010) emphasizes, Inuit risk management and relationship to sea ice in general has been premised on a “capacity to respond flexibly and quickly to changing local conditions” (p. 449). Similarly, Inuit understanding of time and place results from an understanding of cyclical and progressive processes, contained within a “world of possibilities” based in uncertainty (Gombay, 2012, pp. 24-29). Claudio Aporta (2011) writes that sea ice is understood

by Inuit as a "connective geographic entity" that forms seasonally, possesses a unique "social life," and serves as a home (p. 7). For Inuit, sea ice "has a profound social ontology, an existence as a social object by virtue of the deep-seated meanings and relations" (Bravo, 2010, p. 446). Importantly, the formation of sea ice throughout the winter has historically meant temporary access to new regions and settlements for hunting and fishing, with the ice itself allowing for lifeforms to breed and den (Aporta, 2011, p. 9). This ice formation occurred rather predictably, resulting pressure ridges, ice leads, and polynyas that are relied on as recurring landmarks when travelling on trails (Aporta, 2011, p. 9; Aporta, 2010, p. 170). As an Inuit Circumpolar Council (2014) report puts it: "A skilled navigator can use the ridges in the snow like a compass based on which direction the prevailing winds come from at that time of year" (p. 9).

Aporta (2010) observes that mobility and travel are foundational components of Inuit environmental knowledge; networks of trails that have been used for many generations are navigated using "wayfinding" through places of significance, rather than simply travelling through abstract space (p. 172). The trails disappear with their coverage by snow during blizzards and melting of the ice every year. As Aporta (2009) stresses, what makes knowledge and memory of such trails so significant is that they are remembered as a "spatial itinerary" that "materializes again when the next trailbreaker makes the trip" (p. 131). The network of trails in a region are not understood as "isolated and discrete entities" but related to memories and a variety of environmental knowledge (Aporta, 2009, p. 132). The experience of using a trail is "in a sense, lived rather than traveled," with a deeply "physically ephemeral" quality that integrated knowledge and naming of many geographic features such as rivers, valleys, and bays (Aporta, 2009, p. 133). Robertson and Ljubicic (2019) write that Uqsuqtuurmiut (Inuit of Uqsuqtuuq, also known as Gjoa Haven) encounter a sense of freedom and happiness when out on the land results from the "experience of being unified on the land and the spatialization of a distinct political ontology" (p. 545). This way of seeing ice is intertwined with complex social relations.

Within Inuit social relations, ice cannot be isolated from other environment and social factors, including humans and various manifestations of "nature." This paradigm views ice as a highly usable and reliable material within this broader network—but does not treat it as a controllable and exploitable object. The key distinction about such production of nature is that they occur within a context of non-capitalist social relations, rather than primarily for exchange

value from a system of generalized commodity production that is reliant on wage labour, legally enforced private property, and the creation of money capital.

The trails, igloos, and various technologies produced by Inuit were not historically produced as commodities with the end goal of realization of surplus value, but for the purposes of shared use within kinship networks. This production reality fundamentally alters the types of natures that are produced through the labour process. The ancestral production of nature by Inuit is rooted in a metabolic exchange between labourer and external matter, reflective and constitutive of a social ontology that understands human as inseparable from nature. As Nicole Gombay (2012) writes, the Inuit worldview sees well-being as continued reciprocal relations with others: "To the degree that the Inuit economy allows value to be stored for future uses, this process is accomplished reciprocally via social relations established with human and other-than-human beings" (p. 31). This worldview is centrally reflected in Inuit food systems. An Inuit Circumpolar Council (2014) report notes: "The primary resource for Inuit is the animals. Our people have always known how to care for this resource. We live in harmony with the land. When we hunt, we only take what we need and make sure to leave enough of the herd so that it can replenish itself" (p. 24).

In pre-colonial Inuit society, the isumataq, or male group leader of a large extended family, made decisions about resource distribution including food (Harder and Wenzel, 2012, p. 308). Traditionally, in the Iglulik area between Melville Peninsula and Baffin Island, "more successful households did not accumulate surplus for their own use, but shared their production via the concomitants of kinship" (Harder and Wenzel, 2012, p. 309). Meat collected from hunts belonged to the extended family, not the individual (Harder and Wenzel, 2012, p. 309). The collapse of the fox-fur trade following World War II resulted in the federal government structuring mining at Rankin Inlet, Little Cornwallis Island, and Baffin Island as a way to integrate Inuit into the capitalist economy (Tester, Lambert, & Lim, 2013, p. 16). That was by no means a successful project, with very high turnover rates at mines among Inuit workers in large part due to the use of wage labour to support their involvement in the subsistence economy (Tester, Lambert, & Lim, 2013, p. 25). Inuit workers in the mining industry did not only see themselves as "labour" but prioritized a range of other activities including hunting, fishing, and community events (Tester, Lambert, & Lim, 2013, p. 26).

These collective practices have been steadily undermined with the colonization of Arctic regions, included the coerced migration of Inuit into settlements and attempted proletarianization. The relocation of Inuit—first to remote regions to assert sovereignty with the creation of the settlements of Grise Fiord and Resolute, then to more southern permanent settlements in the Arctic to facilitate a transition to wage labour—is described by Bernauer (2018) as a highly significant social and spatial transformation representative of Marx's concept of "primitive accumulation," in which capitalist social relations destroy non-capitalist relations through dispossession and dislocation (p. 39).

However, there remains examples of a distinct production of nature among Inuit societies that result from continually distinct social relations. Harder and Wenzel (2012) describe the ongoing Inuit subsistence economy in Clyde River as a "social economy" as it is structured primarily by kinship, with sharing of resources of both traditional foods and non-traditional resources like money and equipment used for hunting (p. 306). While money plays a significant role in such communities today, Harder and Wenzel (2012) suggest that its value is constantly being reinterpreted and tends to be "valued for its immediate use potential, not for its potential as a storehouse of value" with economic decisions guided by "socio-cultural responsibilities" (p. 309). Food continues to constitute a social currency with greater value than money (Harder and Wenzel, 2012, p. 309). Traditional foods like seal are not commercialized, with the sale of such meat subject to stigmatization (Harder and Wenzel, 2012, p. 315). As a result, the natures produced by Inuit labour remains largely unalienated and in the realm of "first natures."

In a 2009 survey of food transfers in Clyde River, Harder and Wenzel (2012) found that a majority of direct food transfers continued to occur within the ilagiit, or Inuit extended family, with announcements made over the community's radio station for non-ilagiit transfers (Harder and Wenzel, 2012, pp. 309-310). Collective meals serve as another means of sharing resources, including to those with little income, and lending of equipment for traditional resource activities continues to be common (Harder and Wenzel, 2012, pp. 311-312). Another study, this time in the settlement of Kangiqsujuaq in Nunavik, found that "access to country food continues to be primarily mediated by harvesting participation and social relations rather than by markets or formal institutions" (Ready, 2017, p. 8).

There are many nuances to these relations, varying based on what kind of resources and region being considered (Harder and Wenzel, 2012, p. 308). Further, some redistributive efforts

are arguably "tied up with political office and wealth," with Elspeth Ready (2017) arguing the "act of redistribution is in itself a way to create and to legitimate inequality because it reinforces patterns of social distinction in the settlement" (p. 26, 29). However, Pamela Stern (2005) cautions against an overly narrow reading of sharing networks as only an economic practice, suggesting that such systems are instead "a form of Inuit social interaction that both binds people together and acts as a powerful symbol of those ties" (p. 68). Stern (2005) instead identifies an extreme shortage of steady employment accounting for rampant economic disparity, while acknowledging that the nuclearization of the Inuit family through state-built social housing has encouraged households to see themselves as "socially and economically independent units" with greater privacy and self-reliance (pp. 73-78).

The increased melting of ice in the Arctic, which is warming on account of climate change at a rate of twice the average of the rest of the world, is already seriously impacting Inuit communities (Joyce, 2014). Hunting is now more dangerous and difficult due to the unreliability of ice, reduced season, and migration of animals (Mercer, 2018). These shifts are having major mental health impacts on Inuit communities (Mercer, 2018; Albeck-Ripka, 2017). Ashlee Cunsolo of the Labrador Institute of Memorial University collected perspectives from over 120 Inuit from five communities in Nunatsiavut, Labrador, about the impacts of ecological grief (Cunsolo & Ellis, 2018). Community perspectives included: "Inuit are people of the sea ice. If there is no more sea ice, how can we be people of the sea ice?" and "If you don't have it, then that part of your life is gone, and I think that's very depressing" (Cunsolo & Ellis, 2018, pp. 276-277). A key source of grief that Cunsolo and Ellis (2018) identify is the loss of environmental knowledge and identity, with older generations especially impacted due to anxieties about being unable to provide reliable knowledge about travel and weather (p. 277). Cunsolo and Ellis (2018) write: "This caused grief at the loss not only of their own knowledge and identity associated with 'knowing the land', but also with the loss of a cultural system of land-based knowledge that was passed on through generations" (p. 277).

Capitalist interests, including the state, have increasingly been producing their own Arctic natures imbued with logics of potential accumulation. Michael Bravo (2010) argues: "Neoclassical economic theory argues that more efficient delivery of goods to markets presents the owners of infrastructure and commodities with new opportunities, but this thinking reflects the logic of a social ontology that is radically at odds with the way in which indigenous peoples

traditionally value their resources" (p. 450). Gombay (2012) writes the fundamental assumption guiding a capitalist economy is that the future "can and ought to be controlled," a premise that reflects an "existential inauthenticity" elevating future returns over present conditions in a world of unpredictability and change (Gombay, 2012, pp. 27-31). To render the Arctic an increasingly exploitable space—whether for resource extraction, shipping, or military adventurism—such efforts to produce greater certainty and predictability must be made. This capitalist production of ice exists in conflict with Inuit relations with Arctic natures that motivated by very different logics than the imperative of private capital accumulation—and as a result, produce distinct natures. A leading technique of this knowledge production about ice is through scientific research. The next part of this chapter will explore theoretical underpinnings that help us better understand the relationship between capitalist production of cryo-nature and scientific processes.

Scientific knowledge production

Scientific labour plays a driving role in the ever-expanding quest for capital accumulation. This assertion does not mean that scientific inquiry is inescapably capitalist or colonial in orientation: like the production of cryo-nature, scientific work is conducted as part of the dominant mode of production, which guides its priorities and possibilities.

Smith and O'Keefe (1980) argued that natural sciences first emerged "to appropriate nature through industry" and it simultaneously reifies nature as external to society while internalizing it through knowledge production (p. 36). Hilary and Steven Rose (1976)—leading figures in the "radical science" movement starting in the late 1960s—argued that "under capitalism, nature becomes denatured, humanity dehumanised; and science is integral to both processes" (p. 5). Scientific labour becomes a direct force of capitalist production, advancing "mechanical materialism"—or "knowledge of the natural separated from the social"—as the dominant ideology (Rose & Rose, 1976, p. 6). Specifically, "science for the accumulation of capital" concerns itself with developing industrial capacity, exploiting new materials, and increasing profitability (Rose & Rose, 1976, p. 14).

Neil Smith (2004) argued that geographical knowledge (or scientific geography) was "itself a condition of conquest" that "transforms immediate practical questions of environment and resources into manageable scientific and technical problems" (p. 56). Specifically, scientific work remakes land (or in this case, ice) into something abstract and mathematical, invisibilizing

existing social relations and enabling the production of social space as distinct from natural space (Smith, 2008, p. 100-104). As noted by Martín Arboleda (2017), Marx argued for a dialectical understanding of science and technology—rather than a causal one—that develops in relation to "mental conceptions of the world, social relations, and everyday life" (p. 373).

Indigenous societies practice scientific work of their own, often distinct from many of the imperatives driving much of Western science. Inuk scholar Pitseolak Pfeifer (2018) identifies an ongoing "credibility gap" between Western scientific knowledge and Inuit knowledge (p. 29). Pfeifer (2018) emphasizes that Inuit hunters are "Arctic scientists and professors, experienced wildlife, ice, and water researchers, and environmental knowledge keepers" (p. 31). Duane Ninqaqsiq Smith recalls his childhood in an Inuit Circumpolar Council (2014) report: "We studied the ice and predicted weather and animal migration patterns. We did all this by travelling across, and observing, the sea" (p. 1). Similarly, anthropologist Colin Scott (2011) argues that Cree hunters in the James Bay region practice a form of science, if science is defined as "a social activity that draws deductive inferences from first premises, that these inferences are deliberately and systematically verified in relation to experience, and that models of the world are reflexively adjusted to conform to observed regularities in the course of events" (p. 175). However, Scott (2011) emphasizes that Cree knowledge is premised on fundamentally distinct "paradigms and social contexts."

Given these realities, it is important to be clear about what is meant by "science." At the foundation of Western scientific pursuits embedded in a capitalist mode of production is the theoretical approach of positivism, which assumes "natural science is the only foundation for true knowledge" (Chilisa, 2012, p. 26). A positivist approach understands the world as governed by natural, observable laws that can be quantified, measured, and organized (Chilisa, 2012, p. 26). Botswanan post-colonial scholar Bagele Chilisa (2012) suggests there are three categories within all knowledge systems: ontology (the nature of reality), epistemology (the nature of knowledge), and axiology (the nature of values) (Chilisa, 2012, p. 27).

Ontologically, positivism understands reality as objective, universal, independent, and discoverable (Chilisa, 2012, p. 27). Epistemologically, positivists believe objective understandings of the world can be attained or approached through a range of research tools and designs, and axiologically espouses scientific objectivity as a foundational goal of research (Chilisa, 2012, p. 28). These assumptions guide the practicing of the scientific method:

establishing research questions and a hypothesis, defining variables, measuring and observing. Chilisa (2012) argues: “In most cases, research within the positivist/postpositivist paradigm is more about what researchers want to know, and what knowledge and what theory they want to legitimize” (p. 31). Wråkberg and Granqvist (2014) describe “technoscience” as an “intricate combination of logistical methods, observational norms, and knowledge enactments” that is distinct from other knowledge systems (p. 82). Wråkberg and Granqvist (2014) add that “science throughout its modern history has been a sworn enemy of all superstition, including shamanism, holism, sacral phenomena, spirituality, occultism, etc.” (p. 91).

These positivist approaches are contrasted by what Chilisa (2012) describes as “the transformative paradigm,” including critical social scientific methods of Marxism, feminist theories, critical race theories, and postcolonial and Indigenous theories (p. 35). These diverse approaches are united by a set of assumptions that understands reality as historically contingent, with some realities privileged over others and knowledge of such a reality grounded in practice and transformation (Chilisa, 2012, p. 36). A key example of this approach is the work of Donna Haraway (1988) that called for a “feminist objectivity” grounded in “limited location and situated knowledge,” in contrast to the totalizing “god trick” of both objectivity and relativism (p. 583). Research from such a paradigm is explicitly viewed as a moral activity and a tool “to destroy myths, illusions, and false knowledge and therefore empower people to act to transform society” (Chilisa, 2012, p. 36). Smith and O’Keefe (1980) argued positivist science was a distinct logic than the Marxist dialectic that “presupposes (among other things) that nature exists in and for itself, external to human activity” (p. 30).

Shawn Wilson (2001) demarcates an Indigenous paradigm from dominant paradigms including positivist, critical, and constructivist, arguing that Indigenous knowledge is relational and shared with all of creation: “It is not just interpersonal relationships, not just with the research subjects I may be working with, but it is a relationship with all of creation” (p. 176). He writes that the foundation of such an approach is relational accountability, meaning: “You are not answering questions of validity or reliability or making judgments of better or worse. Instead you should be fulfilling your relationships with the world around you” (p. 177). Zoe Todd (2016) echoes this assessment, writing: “Indigenous thinking must be seen as not just a well of ideas to draw from but a body of thinking that is living and practiced by peoples with whom we all share reciprocal duties as citizens of shared territories (be they physical or the ephemeral)” (p. 17).

Vanessa Watts (2013) describes Indigenous understandings of the world as "Place-Thought," "based upon the premise that land is alive and thinking and that humans and non-humans derive agency through the extensions of these thoughts" (p. 21). Theory and praxis are indistinguishable from one another in this framework (Watts, 2013, p. 22). As a result, knowledge production embedded in Indigenous lifeways requires accountability to other people, non-human animals, and land. In Aotearoa (New Zealand), Māori research methodologies explicitly challenge and resist Western scientific research approaches and ground their practices in Māori self-determination (Walker, Eketone, & Gibbs, 2006, pp. 332-333).

More specifically, Inuit scientific knowledge has been produced over the course of many generations of direct usage, observation, and "a long apprenticeship in situ," allowing for safe crossing over it despite its movement (Aporta, 2011, p. 7; Bravo, 2010, pp. 446-447). Inuk author Suzie Napayok-Short (2017) writes: "Inuit had to understand the science of snow and ice—the texture, its mass, the seasons affecting it, the potential (or lack thereof) for purposeful architecture, the safety and danger zones—all by heart." Similarly, Watt-Cloutier emphasizes that much of the wisdom passed on to younger generations is through experiential observations gained while hunting (2015, p. xv). These practices are highly systematic. For example, Inuit continue to use a stick with an iron end to poke thin ice before putting weight on it (Inuit Circumpolar Council, 2014, p. 8).

Inuit historically did not use physical maps to categorize geographic knowledge, meaning expert knowledge has been communicated through repeated stories from elders, which includes highly specific terminology and narratives (Riewe, 1991, p. 6; Aporta, 2009, p. 132). Relations between many factors were combined in these epistemes, including astronomical phenomena such as the phases of the moon, environmental factors like wind direction, tidal currents, topography, temperature, animal behaviour, and behaviour of the ice (Aporta, 2011, p. 9; Riewe, 1991, p. 6). Nicole Gombay (2012) calls this holistic knowledge an "economy of place" that recognizes elements are never static and are constantly changing: "They must not suppose they have authority over time, but are encouraged rather to develop the mental capacity to adjust to the instability and impermanence they witness everyday all around them" (p. 25).

This contrasts sharply with how scientific labour is practiced when motivated by capitalist and colonial interests. As Michel Foucault (1984) argued in his examination of systems of thought and power that developed in modern Europe, knowledge is co-produced with power,

creating new "epistemes" that shape and limit possibilities. What he called "power-knowledge" produces and advances certain ways of relating the world, and in this case, ice. Power, to Foucault (1982), only exists when it acts upon an action, whether in the present or future: "it incites, it induces, it seduces, it makes easier or more difficult; in the extreme it constrains or forbids absolutely; it is nevertheless always a way of acting upon an acting subject or acting subjects by virtue of their acting or being capable of action" (p. 789). Rather than acting directly upon a body or a thing, which Foucault (1982) described as a "relationship of violence," power relationships function "to structure the possible field of action of others" (Foucault, 1982, p. 790). Stephanie Rutherford (2007) emphasizes in her reading of Foucault that power is not held but rather circulates, and is a productive force—not only a force that disciplines (pp. 295-296).

Critically, Foucault (1984) warned against a unilateral association of power with nefariousness or wrong-doing, recommending instead that we acknowledge power relations among everyone and everything: "there is no power relation without the correlative constitution of a field of knowledge, nor any knowledge that does not presuppose and constitute at the same time power relations" (p. 175). That certainly does not mean that power does not consolidate and become "progressively governmentalized"—but that its existence depends on being put into action (Foucault, 1982, p. 788). The "field of knowledge" produced among individuals and organizations is not necessarily oppressive, but necessitates the production of experts who carry or convey both knowledge and power. Further, "discourse" is not restricted to writing and speaking, but shapes and is shaped by "minute material details" (Foucault, 1984, p. 178). This analytical approach can be applied to knowledge of ice, providing insights into how distinct ways of knowing ice have been produced over time.

Edward Said (1977) interrogated the construction of the "Orient" by Western colonial powers through the application of scientific knowledge production about places and people, emphasizing that "Orientalism" was itself a "field of learned study" that is "approached systematically, as a topic of learning, discovery, and practice" (p. 73). Scientific knowledge can produce what Said (1978) called "an increasingly profitable dialectic of information and control" (p. 36). A key example of this in *Orientalism* shows how the production of the publications *Description de l'Égypte*—the "Description of Egypt"—required Napoleon Bonaparte to bring dozens of scientists and scholars on his invasion of Egypt in the final years of the 18th century "to render it completely open, to make it totally accessible to European scrutiny" (p. 83). From

this post-colonial perspective, science was used to produce the very concept of the "Orient," giving it "shape" and legitimizing colonial authority over the country; as Said (1977) put it, Napoleon advanced a "wholly Orientalist engulfment of Egypt by the instruments of Western knowledge and power" (p. 86).

Timothy Mitchell (2002) argues that colonial knowledge production rarely imposed itself as successfully as it imagined that it did, emphasizing about the construction of the Aswan Dam in the 1960s that "science did not direct the engineer's work as a preformed intelligence. The projects themselves formed the science" (p. 37). Further, Mitchell (2002) suggests that ideas and technology were "manufactured in the processes themselves" rather than imposed as "pure forms of thought" (p. 52). With that said, he writes the administration of techno-scientific expertise resulted in the formalization of this knowledge into "scientific journals and irrigation manuals" at the direct expense of local farmers and irrigation experts who had "managed and maintained the earlier hydraulic systems" (Mitchell, 2002, p. 37). This dialectical relationship between nature and knowledge is one that has long been interrogated by Marxist scholars; as Susan W.S. Millar and Don Mitchell (2017) wrote about Neil Smith's approach: "We have no choice but to produce nature, and in so doing, produce our own knowledge of nature. The question becomes: to what end and to whose benefit?" (p. 87).

These scientific practices concerned the establishment of authority and expertise over a territory. At a fundamental level, scientific practices under a capitalist mode of production is a process of producing legibility to capitalist interests, or what Stephen Bocking (2011) calls "annexing territories into imperial forms of political and economic rationality" (p. 40). In other words, it reconstitutes places and people through measurement, calculation, manipulation, and control by outsiders acting on behalf of capitalist interests. These general perspectives about scientific labour within a capitalist mode of production are bolstered by analysis of specific scientific practices and techniques. Bruce Willems-Braun (1997) examines in detail the works of geologist George Dawson, a member of the Geological Survey of Canada working on Vancouver Island in the 1870s and 1880s. Willems-Braun (1997) argues that Dawson's survey reports "brought a particular mode of intelligibility to bear on the landscape," using techniques such as the separation and evaluation of plants, animals, and Indigenous people that allowed for them to be "apprehended entirely apart from their surroundings, displaced and resituating objects within quite specific, but very different, orders of signification" (p. 14). The accuracy of Dawson's

descriptions were not of interest to Willems-Braun (1997)—the focus was rather about how such techniques created an "ordered scene that could be read" (p. 17). A fundamental aspect was the systematic erasure of Indigenous people from natures, enabling settler-colonial claims to "resources" premised on a lack of "proper" use.

This form of dispossession by imposing arbitrary metrics of "proper usage" of land was also unfolding at this time in the Prairies, with colonial land practices justified based on ideas about Indigenous inhabitants not using the land appropriately. Sarah Carter (1993) writes of how colonial institutions attributed a "life of virtue" to "improving the land" through agriculture, while migratory hunting, fishing, and gathering was seen as a backwards "tribal communism" (pp. 27-29). These colonial processes divorced what Willems-Braun (1997) described as "expert cultures from the lifeworld," demarcating areas as inadequately exploited based on techniques including the survey, journal, and map (p. 15). Cole Harris (2004) also identifies the map as a critical tool in producing colonial space and allocating private property, alongside the use of numbers about population that "replaced local knowledge with numbers" (p. 176). Likewise, James C. Scott (1999) uses early German forestry science as a foundational example of how such legibility requires a radical simplification of the world that excluded all natures that did not represent potential profitability (p. 12). Jake Kosek (2006) also discusses how the surveying of timber by the Forest Service in New Mexico—the measuring of trees, defining timber units, creating forest boundaries—transformed natures into "a system of orderly, efficient forests" that could be harvested for profits (Kosek, 2006, pp. 80-81).

Similarly, Nicholas Blomley (2003) writes how the frontier, survey, and grid enacted and disciplined space for capitalist exploitation. The survey was another key tool in establishing foundational logics to colonial occupation, applying fixed boundaries and linearity to diverse landscapes filled with complex social relations (p. 127). In turn, it produced colonial space understood as a "purely abstract and empty site that has meaning only in terms of the logic of private property" (Blomley, 2003, p. 129). This process of rendering land into property and a resource meant that "Indigenous peoples must be erased, must be made into ghosts" (Tuck & Yang, 2012, p. 6).

Another example of this can be found in the life of Sidney Ells of the Geological Survey of Canada, whose extensive surveying work in the early 20th century of Northern Alberta identified bitumen deposits and produced them as capitalist natures (Gismondi & Davidson,

2012, p. 75). Like the actions of Dawson in the analysis by Braun (2000), Ells' reports produced natures as places to facilitate extraction rather than homes to many diverse lifeforms (Gismondi & Davidson, 2012, p. 76). These transformations demonstrate the operationalization of Michel Foucault's power/knowledge configuration, with the production of knowledge about places erasing original claims and authorizing certain voices to speak for new systems of knowledge.

A more recent technique of producing Western scientific knowledge about a place as part of a capitalist mode of production is the environmental assessment (EA) or impact assessment (IA), formally introduced in Canada in 1973 with a federal cabinet decision and in 1993 with environmental impact legislation (Noble, 2011; Sadar and Stolte, 1996, p. 215). This process relies upon the production of scientific knowledge by many actors, including government, corporations, and Indigenous nations. While designed as a means of mitigating environmental damages and evaluating environmental concerns with the same level of considerations as economic and political matters, scholars have argued that EAs serve to advance colonial power/knowledge through the neutralizing of political opposition and authorization of expert voices that speak only in the realm of the technical.

Examining a proposed mining project in Peru, Fabiana Li (2009) writes that both the form and process of environmental impact assessments tend to take precedence over the actual content of the opposition contained in such documents (p. 219). Further, by defining the issues as predominantly technical in nature, they work to undermine community opposition by producing "objective" truths that "implicitly facilitates a project's eventual approval" (Li, 2009, p. 225). Further analysis by Li (2018) demonstrated how another environmental assessment process of a mining project abstracted and delimited glaciers from consideration, with the discourse of environmental management playing into the "company's technocratic solutions and state efforts to monitor glacier retreat and quantify glacial melt" (p. 113). Similarly, Bernauer (2018), writing about the role of hegemony in undermining Inuit resistance to resource extraction in Nunavut, explains that "EA plays an important role in the production of extractive capital's hegemony, in part by imposing concessions and compromises between Indigenous communities and extractive capital" (p. 21). Instead of asking fundamental questions of whether extraction should happen at all, the EA process "renders technical" conflicts over proposed projects that screen out political arguments and reinforces power relations between Western experts about natures and objects of domination (Li, 2011; Bernauer, 2018, p. 90). Writing about small-scale mining in Zimbabwe,

Samuel J. Spiegel (2017) argues that the imposition of environmental assessment regimes belonged to a larger process of bureaucratizing becoming a "legal miner" which resulted in the incarceration, fining, and loss of employment for individual miners, especially women (p. 98). Far from a neutral terrain that balances competing interests, environmental assessments can help to produce and cultivate capitalist natures through the "rendering technical" of dissent and achieving "socio-ecological fixes" that strategically outmanuever other firms (Zalik, 2015, p. 2447).

These scientific processes of surveying, calculating, and assessing territories for potential environmental impacts produce colonial authority and extractive possibilities about a place, displacing previous social relations and ways of knowing. Inuit Qaujimajatuqangit (IQ), or Inuit cosmological and scientific wisdom/knowledge, is described by Pfeifer (2018) as "non-hierarchical, a culture of sharing knowledge by sharing actions, where welcoming and helping represent central societal values" (p. 30). However, Frank Tester and Peter Irniq (2008) cautioned that Inuit Qaujimajatuqangit (IQ) has increasingly become a colonial management strategy through its reduction into biophysical information and integration of it into state processes, which risks neutralizing the radical cosmological critique it poses to Western conceptions of "progress" and "development" (p. 52).

One colonial management technique identified by Tester and Irniq (2008) was a strict localization of biophysical knowledge, precluding intervention in global issues like climate change (p. 56). Paul Nadasdy (1999) identifies a similar issue with "traditional ecological knowledge" (TEK) research, noting that concepts like "environment" and "ecological" are products of Western knowledge systems that reinforce a binary between humans and their surroundings and that "incorporating" TEK into Western management practices "leads inevitably to its compartmentalization and distillation" (p. 4). Tester and Irniq (2008) maintain that "rediscovering and rearticulating that worldview is a task best undertaken by Inuit, and it contains the possibility of rejuvenating and invigorating Inuit culture and relations between youth and elders" (p. 58).

From such a perspective, IQ can become a form of political opposition to capitalist and settler-colonial totalization, which Tester and Irniq (2008) explain as the integration of "frontier" regions into a nation but "affecting the consciousness, beliefs, and behavioural patterns of those seen to be within the state's influence" (p. 51). This scholarship reminds us that Western science

under the capitalist mode of production is not the only possible approach to interacting with, learning from, and producing natures. I use this analytical framing as a tool to "read" the technical reports produced for and by the Polar Gas Project and Arctic Pilot Project in Chapters 4 and 5. Scholarship reviewed in this section provides many examples of this playing out through surveying, mapping, and conducting environmental assessments. The case studies expand on these examples to examine how scientific knowledge was produced in the geographical context of the Arctic Islands to produce ice as knowable and exploitable.

Political ecology of failure

A key analytical tool that interlinks and augments both previous sections—production of cryo-nature, and scientific knowledge—is the relatively new theoretical approach of political ecology of failure. This framework recognizes a wide array of impacts resulting from both "success" and "failure" of resource extraction and infrastructure projects, with failed projects including those that have been "unrealized, partially built, or operated within relatively short time horizons" (Peyton, 2017, p. 9). Many factors can contribute to such failures, including Indigenous resistance, social movements, market forces, and lack of ability to secure necessary capital and state supports.

Scholars using this analytical framing have tended to be less concerned with the direct causes of failure, but rather the impacts of that failure over time and space. This echoes a Foucauldian approach to genealogy, focusing on how discourses are reshaped and reconstituted through a project's failure rather than a technical autopsy of the reasons for the failure itself. From this perspective, failure is itself a highly productive and generative force. That does not mean that it is desirable by its proponent, but that it has many unseen impacts that accrue over time and expand capitalist and colonial possibilities.

This analytical tool is particularly useful given that both Polar Gas Project and Arctic Pilot Project were failures by all conventional standards, never moving beyond the initial regulatory phase. However, it is clear the efforts by the two consortiums had many residual impacts well beyond their lifespans that this tool can help identify and analyze. Generally, productive failure can take many forms: creation of knowledge that can be relied on for future attempts at establishing commodity circulation, the development of new technological and legal frameworks to facilitate "vertical intensification" of an area, or the construction of infrastructure

including roads and pipelines that allow for potential usage in the future (Bennett, 2016, p. 258). Production of nature literature augments this approach in drawing attention to how abstract space is produced as devoid of social relations and remade with the logics of accumulation. Tania Li (2005) complicates that picture by noting that failure can compromise the authority of colonial representatives who claim expertise and authority, with forms of resistance emerging in its wake (p. 391). Rob Nixon (2011) also notes that state failures to respond to the impacts of environmental devastation can stoke "insurrectionary anger" (p. 42).

Jonathan Peyton (2017) writes about the Stikine region of northwest British Columbia: "Development failures produce their own conditions of possibility by creating a perception of the Stikine as a part of the province where resources are located and can be mobilized, with careful planning and initiative" (p. 14). One of the examples provided by Peyton (2017) demonstrates how the Dease Lake Extension, a rail bed abandoned in the late 1970s, has since become a critical line of access and "central axis for manipulation of environment" in the area (p. 64). Jessica Dempsey (2016) argues the entire history of attempts to render nature "enterprising" has been one of failing to become operational as promised—and rather than seriously reflect on such failures, related policies and products are sold through "dramatic performances" based largely on marketing hype that help advance the discourse of capitalist natures (p. 3, 167).

Timothy Mitchell (2002) writes that many attempts to impose techno-scientific solutions in Egypt failed—responding to issues created by the previous techno-scientific solution of Aswan Dam—resulting in improvised repairs, introduced alternatives and reformulated goals (pp. 41-42). Large firms often exploit "failures" such as price crashes and economic recessions to embark on merger and acquisition sprees of smaller or more exposed firms, along with pressuring states to weaken regulations and increase subsidies and tax breaks. For example, Larry Pratt (1976) wrote that Atlantic Richfield's decision to pull out of the original Syncrude oil sands consortium in late 1974 allowed the project to transfer enormous costs and risks onto the public sector (p. 29). Potential failure becomes swiftly weaponized by the ruling class.

A relevant focal point in this literature is failure's production of a "frontier" discourse and future extractive potential. The frontier, famously theorized in Frederick Jackson Turner "frontier thesis" that linked colonial expansions into supposedly undiscovered territories with the emergence of supposedly democratic traditions, has been framed as a means of distinguishing between the realm of private property and legal violence within the frontier from the realm of

communal claims and "savage violence" outside it (Purdy, 2015, p. 33; Blomley, 2003, p. 123-124). Territory outside the frontier represents places of lawlessness and nonproperty, contrasting with the orderly and rational society inside it (Blomley, 2003, p. 124). The discourse of the "frontier" fundamentally relies on a reconstruction of space as empty, or at least inadequately used. Eva Mackey (2016) notes that the doctrine of "terra nullius" ("land belonging to no one") was uniquely applied in the settler-colonial context of Canada, in which it was recognized that Indigenous people existed—but were not possessing land in "specific, culturally recognizable, ways" such as agriculture or urban settlements (p. 47). The same racist fiction has been deployed in cities across North America as well, with scholars referring to this as "urbs nullius" or the idea that cities are void of Indigenous claims and visions (Toews, 2019, p. 22).

This erasure of ancestral and ongoing usage of territory by Indigenous peoples was necessary for the production of new discourses which assert authority over lands, which colonial projects contribute to whether successful or failed. Writings by Edward Said (1977) are instructive here, as the attempted conquest by Napoleon Bonaparte's army of Egypt and Syria addressed in *Orientalism* ended in failure. However, Said (1977) stressed that this failure did not "destroy the fertility of its overall projection for Egypt" but rather "gave birth to the entire modern experience of the Orient as interpreted from within the universe of discourse founded by Napoleon in Egypt, whose agencies of domination and dissemination included the Institut [d'Égypte] and the Description [de l'Égypte]" (p. 87). Similarly, Emilie Cameron (2015) writes that Samuel Hearne's journey to find copper at Kugluk was a failure by all counts that only resulted in the finding of a single piece of copper—but led to the production of histories and settler-colonial relations via the apocryphal story of the Bloody Falls massacre: "It has made legible a distinctly Qablunaaq sense of being innocent witnesses to the suffering of northern Indigenous peoples, it has shaped northern resource extraction and land claims, it interweaves with the production of racialized classificatory schemes, and it helps anchor Qablunaaq claims to the history of the North" (p. 9).

Both Said (1977) and Cameron (2015) demonstrate how failure produces frontier discourses. This framing is further advanced and specified by Mia Bennett (2016), who argues the construction of the Arctic as a "resource frontier" is a "place-based, cumulative process that builds on previous rounds of degradation, extraction, and export of commodities ranging from furs to oil" (p. 258). In a similar analysis to Andrew Stuhl (2016), Bennett (2016) writes that the

discourse of the Arctic as the "last frontier"—particularly within the context of melting ice due to climate change, "opening up" previously impassable channels for shipping—erases multi-century histories of Inuit existence and colonial extraction. This imaginative production of the frontier, or even "the Arctic" as a coherent whole, is the first step to further enclosure and exploitation (Bennett, 2016, p. 261). Such a process is fundamentally dependent on the construction of the territory presently outside the frontier as an unused and ahistorical place, which Bennett (2016) suggests renders the possibility of extraction "more justifiable" as its resources are not being "stolen" from anyone (p. 262). In this reading, extractive possibilities rely on patterns of previous colonial incursions, including failure.

Failure can provide the justification for development in other regions or at different time, be harnessed to "open up" other geographies for capitalist development, or reappear at a later date. Bennett (2016) argues: "Resource frontiers may actually be more likely to regenerate in the same place due to the accumulation of environmental degradation and the seeming legitimization this grants to industry to continue extraction in an area seen as forsaken" (p. 269). Berit Kristoffersen (2014) describes Norway's High North as related to "a series of seascapes in transition" with petroleum development serving as potential stepping stones to future technological interventions that facilitate further development in the future (p. 139). The construction of the Arctic as exceptional, a region that must supposedly develop as a hinterland to serve the southern metropoles with little or no long-term self-sufficiency, has allowed for many such successes and failures of resource projects (Wilson Rowe, 2017, p. 3). Proposals can fail again and again in such a constructed geography, producing ever more knowledge and legitimation of future resource development in a cumulative cycle. These efforts reinforce production of capitalist natures that alienate and exploit environments. While future extractive potential may be advanced by a different formation of capital and state alliances, this analytical tool argues that it could not have happened without previous attempts and failures.

There are several benefits to using this analytical tool alongside insights into production of nature and scientific knowledge. Reading failure as productive helps to attune our senses to important histories and conflicts that may have not received popular or academic attention. It also emphasizes the cumulative nature of social and environmental impacts. This approach can also work to heed the warning issued by Timothy Mitchell (2002) not to ascribe capital or the state "the coherence, energy, and logic they claim for themselves" (p. 14). In other words,

extractive and infrastructure projects never emerge out of thin air due to the innate ingenuity or tenacity of its backers, but result from years and decades of often hidden labouring that frequently ends in failure—at least at the time. These efforts produce and maintain extractive potentials. In February 2020, Alberta Premier Jason Kenney responded to the cancellation of the Teck Frontier oil sands mine by telling the media that the government may directly invest in such projects to ensure their completion (Black, 2020).

As Michael Simpson (2019) writes, the discursive construction of "resources" relies on the framing of future economic value: "It remains in nature, in a state of standing reserve, awaiting circulation. The resource can thus be thought of as a commodity-in-waiting. The key to the resource lies in its potentiality." Using such a perspective, it is clear that resource-making can withstand and even benefit from failure, helping to produce a sense of rising inevitability. Such scholarship will be of considerable use in the analysis of scientific work and technical reports produced for Polar Gas Project and Arctic Pilot Project. Rather than only seeing these failed projects as historical curiosities, the political ecology of failure framing recognizes them as helping to produce capitalist natures in the Arctic.

Conclusion

In this section, I have reviewed the three categories of theoretical considerations that I intend to apply to the case studies: 1) production of cryo-nature; 2) scientific knowledge production; and 3) political ecology of failure. These diverse analytical tools provide a basis for "reading" the case studies described in the next two chapters. Importantly, they help demonstrate how capitalist natures are produced and legitimized through scientific inquiry, even if the project "fails" by conventional standards. These analytical tools centre the fundamental role of scientific labour in producing abstract natures imbued with logics of accumulations, whether the nature is produced as direct value for exchange, non-valued services, or potential threats. They also work to clarify the ways that non-capitalist natures are produced and known by Inuit societies. The next section will provide historical context for the two case studies and their production of cryo-natures through scientific labour.

Chapter 3: Historical context

The incredibly ambitious proposals of Polar Gas Project and Arctic Pilot Project emerged as only the latest iterations of many centuries of capitalist and colonial incursions into the Arctic. Andrew Stuhl (2016) recommends that scholars of Arctic regions seek to "dissolve notions of the place as frozen in time" by anchoring their work in the cumulative histories of such activities.

This analysis is especially useful when considering knowledge production, with the material manifestations of particular ways of knowing often not seen for years or decades after creation; in turn, this production of infrastructure can shape future possibilities. As a result, Polar Gas Project and Arctic Pilot Project cannot be exclusively studied as isolated case studies, but rather belong to a lengthy and concerted effort to produce capitalist natures—and more broadly as a coherent geography that can be understood as "the Arctic" despite its diverse natures and societies; as Todd (2016) notes, "mega-categories" like "the Arctic" can "quickly erase arctic Indigenous peoples and their laws and philosophies from their discourses" (p. 6). This section will briefly review the histories of science in the Arctic Islands, oil and gas exploration in the Arctic, and provide overviews of the Polar Gas Project and Arctic Pilot Project. It will become clear through this overview of how science, fossil fuels, and proposed infrastructure projects relate and accumulate power over time in the service of capital accumulation.

Colonial science in the Arctic Islands

Colonial knowledge production about the Arctic traces back to the earliest expeditions by Martin Frobisher in the late 16th century, which included the "discovery" of lands and attempts to establish a mining colony to exploit hard black rocks thought to contain gold (McGoogan, 2017, pp. 11-12). This knowledge production, particularly mapping, continued through the following decades including by John Davis, Henry Hudson, Robert Bylot, William Baffin, and Jens Munk. William Parry's 1819 expedition in search of the Northwest Passage included the gathering of rocks and fossils for geological data while wintering at Melville Island, knowledge that was later used by Dome Petroleum in its early drilling efforts (Christie & Kerr, 1981, pp. 187-88). Many European explorers ventured into the Arctic Archipelago for the purposes of mapping and scientific observation, particularly following the notorious Franklin expedition of 1846 (Cooke, 1981, p. 52). Attempts to locate the ships led to significant scientific data production, with a

1944 government report describing this process as creating "a great deal of geographic information" (Robinson, 1944, p. 33).

Canada was awarded colonial title to the Arctic Islands in 1880 from Britain (Cooke, 1981, p. 51). Grant (2010) notes that the British claim to the region was on shaky legal grounds and necessitated "effective occupation" to prevent claims from lapsing (p. 21-22). Stuhl (2016) writes that the International Polar Year of 1882 to 1883, with participation from 11 countries including Canada, started a century of science and intervention (p. 27). He argues that this geographic advance of science into the Arctic was far more effective at displacing Inuit than fur traders were: "Now imperial agents used science to effect exploitation within the same territories where Inuit operated—a direct challenge to Inuit authority" (Stuhl, 2016, p. 27).

Concerns about sovereignty challenges from other countries led to the inauguration of dedicated Arctic patrols in the early 20th century. Alan Cooke (1981) writes that the Canadian Arctic Patrols from 1903 to 1911 led to "a vast amount of data valuable to all branches of science and, in many landings, their commanders took formal possession of the Arctic islands for Canada" (p. 55). Many Arctic expeditions continued throughout this era led by colonial explorers including Otto Sverdrup and Vilhjalmur Stefansson, leading to the production of scientific knowledge about Arctic geology, ethnography, and botany (Christie & Kerr, 1981, pp. 191-193). Joseph-Elzéar Bernier captained many voyages with the CGS *Arctic*, later formalized under the Eastern Arctic Patrol in 1922. Sulphide deposits on Baffin Island found by a prospector on Bernier-led CGS *Arctic* expeditions resulted in continued prospecting over the decades and eventually the opening of the Nanisivik Mine in the mid-1970s (Christie & Kerr, 1981, p. 193). R. Quinn Duffy (1988) wrote that these annual Eastern Arctic Patrols were conducted for the purposes of "on-site administration of the Arctic islands and for upholding the precarious prize of Canadian sovereignty" (p. 11).

However, systematized production of scientific and geographic knowledge about the Arctic did not begin in force until the 1940s and 1950s, following the conclusion of World War II and escalating anxieties about the perceived threat posed by the Soviet Union (Farish, 2006, pp. 178-79). As explained by a 1944 federal report: "Geography is the science of organizing and correlating facts about the natural environment and its influence upon the inhabitants. Its function in the present outline of the Eastern Arctic is to bring this information together and show how these various factors have influenced the past and will be influential in the future

development plans for the region" (Robinson, 1944, p. 36). The establishing of the Arctic Institute of North America at McGill University in 1944 helped "strengthen and coordinate research" following World War II (Doel et al., 2014, p. 68).

In 1946, the Canadian Army conducted Operation Muskox, an 81-day military exercise involving 48 men driving snowmobiles from Churchill to Victoria Island and south through Kugluktuk and Fort Nelson before concluding in Edmonton ("The Army Goes North," n.d.). While the priority of the lengthy journey was military in nature—intended to test equipment and skills in the Arctic environment for a potential Soviet invasion—a group of scientists accompanied it and conducted extensive surveying and mapping along the way ("The Army Goes North," n.d.). However, Kevin Thrasher (1998) writes that despite the expedition being described by the military as scientific in nature, it ultimately "produced no significant advancement in understanding the Arctic" (p. 111). Regardless of outcome, such expeditions are consistent with analysis by Matthew Farish (2006), who emphasizes that the geography of the Cold War Arctic must be understood not only geopolitically and scientifically but also through the lens of "military bodies moving across 'hostile' terrain" (p. 177).

Between 1947 and 1950, the U.S. and Canada built five Joint Arctic Weather Stations (JAWS), including a central station in Resolute and smaller stations at Mould Bay on Prince Patrick Island, Isachsen on Ellef Ringnes Island, and Eureka and Alert on Ellesmere Island (Orvig, 1981, p. 136). The "small network of good (and some not so good) airstrips" that were constructed at the weather stations "opened the way to a small influx of scientists and soon to a much larger group of explorers for oil and gas" (Pounder, 1981, p. 164). Similarly, the forced relocations of Inuit families to Resolute and Grise Fiord in the 1950s turned the new settlements into "convenient bases for geological field work" (Christie & Kerr, 1981, p. 197).

The construction of the Distant Early Warning (DEW) Line during the late 1950s to monitor Soviet aircraft concretized scientific and military expertise in many parts of the Arctic. The Defence Research Board of Canada was a leading actor in many of these mid-century efforts, supporting biological investigations of Banks Island in 1952 to 1953 and Operation Hazen and Operation Tanquary in northern Ellesmere Island during and following the International Geophysical Year of 1957 to 1958 (Orvig, 1981, p. 138). The International Geophysical Year has been described as "the largest-ever science program to occur on the planet" and led to the creation of World Data Centres to house data produced during the

program, “a crucial advance in scientific infrastructure that linked national empires of scientific knowledge in a global framework” (Doel et al., 2014, pp. 60, 78). During this time, the U.S. Navy was working to improve its knowledge of below-ice conditions to prepare for potential Soviet submarine activity, including using drifting ice stations that accumulated under-ice acoustic data (Dodds, 2010, p. 65). There was considerable concern that the Soviet Union “knew more about the Arctic” than any other country, threatening sovereignty claims (Doel et al., 2014, p. 63). The Arctic also served as a testing ground for many military technologies and activities, resulting in Inuit organizations increasingly demanding nuclear disarmament and demilitarization of the Arctic (Bernauer, 2018).

The production of expertise in aerial surveying escalated throughout this era, providing new approaches and ways of producing Arctic natures. The Geological Survey of Canada was at the forefront of this, creating an extensive aerial surveying program (Bocking, 2009, p. 273). Starting in 1952, the federal agency mapped over 250,000 square kilometers of territory in the Arctic Archipelago from helicopters (Greenaway & Dunbar, 1981, p. 85). The increased use of aircraft to secure the North from potential invasion evolved into its use as a tool of production of nature, a process that Bocking (2009) says encouraged a perception of the North as “a landscape shorn of mystery” and something that could be surveyed and managed (p. 287). Matt Dyce (2013) similarly argues that “the aerial photograph was a key allowing expert interpreters to read landscapes for their economic potential,” with surveying and mapping serving as its greatest advancement (p. 69). The creation of this massive body of data necessitated the rise in expertise and authority to interpret it for governments and corporations (Dyce, 2013, p. 70).

Another key development in Arctic science was the inauguration of the Polar Continental Shelf Project (PCSP) by the Government of Canada in 1958 to “render cartographically and geophysically the continental shelf to the north and west of the Canadian High Arctic Islands” or, less euphemistically, begin “probing the secrets of the continental shelf, and of the sea and air around and above it, in a large, coordinated assault; (Powell, 2017, p. 5; Orvig, 1981, p. 139). The scientific project was explicitly conceived by Prime Minister John Diefenbaker as part of his “Northern Vision” and worked to establish “scientific sovereignty” in the Arctic (Powell, 2017, pp. 23, 28). Critically, Richard C. Powell (2017) argues: “At the same time as defining national identities, such field practices were also colonial inscriptions of ownership in defiance of both indigenous inhabitants and the competing claims of other European states” (p. 30). That the

PCSP was created in the Department of Mines and Technical Surveys, now the Department of Natural Resources, reveals a great deal about its overarching purposes.

The study of ice emerged as a priority for many expeditions, perhaps unsurprisingly given the multi-century history of ice destroying and impending ships. Powell (2017) writes that a central component of the PCSP's mission was in "deciphering and depicting sovereignty over constantly changing ice regimes" (Powell, 2017, pp. 48-49). Constructing the DEW Line throughout the late 1950s also required considerable ice information for the ships carrying supplies to the sites (Greenaway & Dunbar, 1981, p. 85). Initially conducted by military aircraft, these reconnaissance flights were replaced in 1958 by the Canadian Meteorological Service (Greenaway & Dunbar, 1981, p. 85). By the late 1970s, this service had been institutionalized with specially designed aircraft, with ice observers flying approximately 3,000 hours across the territories in 1979 (Greenaway & Dunbar, 1981, p. 85). Expeditions including Operation Hazen in 1957 and the Jacobsen-McGill Arctic Research Expedition in 1959 included studies of ice islands and glaciological characteristics (Orvig, 1981, pp. 138-39). The production of tools such as current meters and remote sensing greatly assisted with this task (Dunbar, 1981, pp. 151-52).

The Cold War increasingly escalated military incursions in the Arctic, including the visit by *Nautilus*, a U.S. submarine, to the North Pole in 1958 and occupation of ice islands by American and Soviet research stations (Dodds, 2010, p. 65; Grant, 2010, p. 341). Considerable research was also being directed to improving the safety and efficiency of icebreakers for year-round operation, which itself relied heavily on the acquisition of ice data (Pullen, 1981, p. 160). The highly publicized and controversial voyage of the American SS *Manhattan* icebreaker in 1969, which completed the first crossing of the Northwest Passage in anticipation of shipping Alaska oil through the channel, acted as a massive mobile laboratory that collected data on sea ice; the U.S. Coast Guard designated the vessel both a commercial ship and scientific research vessel (Coen, 2012, pp. 4; 120). Rather than seek out the easiest route, the *Manhattan* intentionally voyaged through the thickest ice to collect data necessary to design future icebreakers, using hundreds of pressure sensors built into the hull to record strain (Coen, 2012, pp. 35, 49).

Prior to the construction of the vessel, the U.S. Army Cold Regions Research and Engineering Laboratory provided the company with data on ice thickness, strength, and composition, while the U.S. Navy and Coast Guard contributed proposed routes, aerial

reconnaissance data, and a report with how ice forms (Coen, 2012, p. 31). Yet limitations on available ice data meant the *Manhattan* was required to conduct local analysis of ice conditions to plot courses (Coen, 2012, p. 31). This process included a Coast Guard aircraft based in Thule, Greenland, collecting data on over 5,000 square kilometers of ice every day to airdrop to the Manhattan for navigational planning (Coen, 2012, p. 35).

Alongside icebreaking design, oil and gas companies eagerly studied ice conditions in order to build artificial islands that supported drilling operations, with scientific investigation assessing sea ice, oceanographic phenomena, and meterology (Jones, 1981, p. 226). Rising public pressures concerning potential oil spills in the Arctic—a situation made far harder to clean up due to floating ice and cold water—resulted in the creation of the Arctic Marine Oilspills Program (AMOP) by the federal government in 1976 to test spill response in such conditions (Page, 1981, p. 243). The Baffin Island Oil Spill project was conducted between 1980 and 1983, intentionally spilling 45,000 litres of oil off the northern coast of Baffin Island to study its beahviour in Arctic environments (Sergy & Blackall, 1987). A 2002 study found that "small patches" of oil remained in the environment two decades after the spill (Prince, Owens & Sergy, 2002).

Capitalist natures had been produced in the Arctic over many decades and centuries, seeking answers to a tremendously wide range of issues depending on the particular motivation. These inquiries have been conducted for many purposes, including military, commerical, medical, and transportation (with frequent crossover between such categories). Both the Polar Gas Project and Arctic Pilot Project belonged and contributed to that lengthy history.

Arctic oil and gas

Visions of Arctic resource extraction had been entertained since Frobisher's early mining efforts in the late 16th century on Kodlunarn Island off the southern coast of Baffin Island. Northern oil exploration in the early 20th century led to the creation of the Norman Wells oil field, which received increased attention during World War II with the construction of the Canol pipeline to ship oil to a Whitehorse refinery (the costly and poorly engineered pipeline was abandoned in 1945). It was not until 1955, when the Geological Survey of Canada-led Operation Franklin mapped over 250,000 square kilometers of territory in the Arctic Archipelago, that potential oil and gas deposits in the Arctic islands were identified as worthy of serious

investigation. The Government of Canada has reported: “Geological features discovered and made public from Operation Franklin triggered intense industry interest in northern oil and gas exploration” (“Operation Franklin,” 2017).

A mass sale of leases followed a few years after, with over 160,000 square kilometers leased for oil and gas exploration by mid-1960 (Grant, 2010, p. 345). Dome Petroleum drilled its first well in the Arctic Islands in 1961 at Winter Harbour on Melville Island. Kennedy (1988) speculated that Dome president Jack Gallagher chose the location because of “romantic connotations” resulting from his readings about William Parry’s wintering there in 1819-20, with the company using Parry’s depth soundings that had been recorded in his journal (p. 121). The Canadian government became increasingly concerned about the foreign ownership of many leases in the Arctic Islands. In response, Canada claimed authority over all internal waters, airspace, landfast ice, and seabed in the Arctic Archipelago (Grant, 2010, pp. 13-14). It also created the Task Force on Northern Oil Development and created Panarctic Oils.

Panarctic was founded in 1967 by the federal government in association with 20 resource companies, with Ottawa pledging an initial $9 million and the companies another $11 million to kickstart the process (Perry, 1967). The government’s ownership of 45 percent of Panarctic was described at the time by a reporter as a “radical departure from Canadian tradition” (Perry, 1967). Dome Petroleum—the leading firm in oil and gas exploration in the Canadian Arctic, including in the Beaufort and Arctic Islands—served as the original operator of Panarctic’s activities (Lyon, 1983, p. 92). The discovery of the massive Prudhoe Bay oil field in Alaska in 1968 sent shockwaves throughout the North America fossil fuel industry and triggered a frenzy of exploration in both Alaska and the Canadian Arctic. The first offshore Arctic oil discovery was not made until January 1970, with Imperial Oil’s find at Atkinson Point in the Beaufort Sea. Exploration in the Beaufort and Mackenzie Delta regions—led by Dome Petroleum, Gulf Canada Resources, and Imperial Oil/Esso—relied on brand-new drilling technologies including artificial offshore drilling islands that used dredged sand from the ocean floor or gravel transported from land, large caisson structures and floating ice-reinforced drillships (Callow, 2013).

By the early 1970s, Panarctic was the largest capitalist entity in the Canadian Arctic, with Kennedy (1988) writing that Hetherington “commanded more men and had more equipment and material at his disposal than the generals of the armed forces could have mustered in an

emergency in the North" (p. 56). Panarctic's regional operations became headquartered at Rea Point, on the east shore of Melville Island, requiring a massive annual sealift transporting drilling equipment, fuel, and supplies (Masterson, 2013, p. 2). Along with aforementioned discoveries at Drake Point and King Christian Island, other significant gas finds at Hecla on Melville Island and Kristoffer Bay on the southern edge of Ellef Ringnes Island bolstered the economic case for transporting the fossil fuel to southern markets ("Firms to study Arctic," 1973).

Between 1967 and 1986, Panarctic ran 35,000 kilometers of seismic line throughout the Arctic Islands and drilled a total of 150 wells: 112 onshore, and another 38 offshore on floating ice platforms (Masterson, 2013, p. 2). These efforts came at tremendous cost, totaling $1 billion in spending by the mid-1980s (Newman, 1985). The federal government took an increasingly supportive role throughout the years, increasing its share from 45 percent to 53 percent with the inauguration of Petro-Canada (Newman, 1985). However, this participation was described as "simply a case of the government stepping in to help in a situation where the private sector considered the costs to be too great; in essence, it was a bailout of small private firms in which there was no federal government influence on corporate decision-making" (Fossum, 1997, p. 26).

Efforts to produce and distribute Arctic gas took place within the political context of alleged shortages that would result in supposedly devastated economies and quality of life in the South. In 1970, the National Energy Board and Liberal government had declared that Canada had an entire century's worth of fossil fuel supplies and could easily increase exports to the United States, where there were major fears of shortages (Lewis, 1976, p. 110). Yet by 1973, the NEB had reversed course and determined that Canada was in its own shortage position and could not meet its own demand (Lewis, 1976, p. 111).

Paul Warde (2018) writes that critics of the rapid development of Arctic resources argued that companies had intentionally fostered "highly misleading, if not unsound, methods of potential reserve calculations" (p. 27). This alleged manipulation of reserves arguably helped produce what Bregha (1979) described as a "shortage psychology" or "shortage mentality" (pp. 97-101). Critics argued that this mentality was exploited to justify the construction of resource megaprojects like the Arctic Gas proposal through the Mackenzie Valley, and the rapid expansion of production in the Arctic Islands. This pattern of volatile shifts in supply estimations is consistent with observations by Gavin Bridge (2015) that the discourse of energy security is a "powerful framing device: it constructs worlds, normalises certain practices of resource use, and

establishes grounds for intervention" (Bridge, 2015, pp. 328-329). Looking back at the "energy crisis" of the 1970s that prompted the advancing of many resource projects in the Arctic and elsewhere, Bridge (2015) writes that "energy security" can be read "as an effort to secure the status-quo, locking in historically specific modes of production and social reproduction" (p. 333). Similarly, Carlo Sica and Matthew Huber (2017) argue the rhetoric of "energy independence" in the United States has been used to "rationalize and legitimize the opening up of Pennsylvania's gas reserves to global networks of money and power" (p. 338).

Despite the technical challenges of drilling in Arctic environments, the dominant obstacle facing fossil fuel interests was transportation. That was particularly true in the Arctic Islands. Unlike in the Mackenzie Valley, producers in the Arctic Islands had to plan pipelines across wide Arctic channels between islands in a way that minimized potential damage to the infrastructure from icebergs or other ice formations. While deep-water pipeline installation had been successfully conducted in the North Sea, conditions in the Arctic Islands were of a significantly more difficult nature including the presence of ice, darkness, and cold through much of the year. Many technical solutions to these conditions were imagined by various companies, ranging from a massive 12-engine resource-carrying aircraft, to nuclear-powered submarines, to airships.

This failure clearly did not impact the physical presence of the gas itself. While a five-year federal moratorium on offshore oil and gas exploration continues to delay potential production, with a review scheduled to occur in 2021, there is always the possibility of these resources becoming re-prioritized in the future as sea ice melts and natural gas continues being positioned by the fossil fuel industry as a necessary "bridge fuel" to renewables (Anselmi, 2019; Powell, 2019). The industry lobby group Canadian Association of Petroleum Producers (CAPP) has said that Canada is "falling behind" the United States in extracting its Arctic oil and gas resources, arguing "the ban on development creates uncertainty in the market and means Canada is not able to compete for investment dollars for Arctic drilling or related research" ("Canada 'falling behind' because of Arctic oil," 2019).

In 2019, the federal government refunded $430 million in Arctic exploration licenses to oil and gas companies (Anselmi, 2019). Warren Bernauer (2018) traces how organized Inuit resistance to colonial interventions in Inuit Nunangat have been eroded over the decades through the establishing of "extractive hegemony" by state processes including environmental

assessments, land-use planning, and the discourse of Aboriginal rights. Today, many Inuit governments and organizations are leading proponents of extractive industries, including mining and oil and gas exploration. In 2019, the mayor of Tuktoyaktuk told media: “There's just so many environment regulations. It's just frustrating” (Kyle, 2019). While efforts to produce and transport Arctic oil and gas have largely failed up until this point, there is little reason to assume that this conflict has been resolved.

Polar Gas Project

The Polar Gas Project was a major but often forgotten proposal in this history. The consortium itself was formed in 1972 by four original members: TransCanada, Tenneco, Canadian Pacific Investments, and Panarctic Oils. By this point, several technologies had been floated by various parties to ship natural gas out of the Arctic Islands, perhaps most notably the massive resource-carrying aircraft (dubbed the “RC-1” or “Big Ugly Bird”) designed by the short-lived Great Plains Project.

Despite enormous technical challenges, a conventional natural gas pipeline was selected as the most viable option of the time. The original proposed pipeline route, costing an estimated $5 billion if built, would start on the Sabine Peninsula of Melville Island—where the large Hecla and Drake Point gas fields were located—and make several underwater crossings before reaching the Boothia Peninsula, and running down either the west or east side of Hudson Bay to conclude in Ontario (“Firms join to tap Arctic,” 1973; “New consortium will study,” 1973). The project’s executive team was assembled from the head offices of consortium members, including TransCanada president George Woods and Tenneco vice-president Jack H. Ray (“New consortium will study,” 1973). An early media report about the Polar Gas Project called its tentative plans “crystal clear in comparison with some of the wild ideas advanced for moving Arctic resources south,” contrasting its vision with “unorthodox proposals” including an Arctic railway and the Great Plains Project’s RC-1 (Sellar, 1973).

By the end of its first year, the Polar Gas Project had been joined by the American firms Texas Eastern Transmission and Pacific Lighting Gas Development Company (Nowell, 1973). Later, in mid-1975, various governments expressed interest in joining the Polar Gas consortium as direct investors (Prager, 1974). The exodus of Canadian Pacific Investments from the group in 1975 left an opening for a government’s involvement, which was seized by the newly formed

Ontario Energy Corporation with an initial $10 million investment ("CPI quits Polar Gas," 1975; "Ontario to back polar," 1975).

Polar Gas was largely evading public attention or criticism, with a journalist describing it as "Canada's other Arctic pipeline, a sort of Brand X project in the minds of most residents of Western Canada" and speculating that it may have benefited from the overwhelming attention paid to the Mackenzie Valley Pipeline and Berger Inquiry (Taylor, 1974). *Inuit Today* identified a similar division in attention, noting in 1976: "While Canadians across the country debate whether or not a pipeline should be built down the Mackenzie Valley, Polar Gas is quietly continuing its plans for an Arctic island pipeline…" ("Polar Gas continues to plan," 1976). A later issue of the newsletter included a letter from Resolute resident Simeonie Amagoalik (1977) voicing concern that others in the Qikiqtaaluk Region were not expressing their views often enough about the potential pipeline. Advocates of the Polar Gas proposal routinely argued that a vast majority of territory that would be crossed by the pipeline was sparsely populated and biologically "unproductive," helping justify its construction over other projects ("How Polar Gas proposes to cross deep water," 1975). This rhetoric was similarly reflected in a *New York Times* article, with the journalist claiming, "the land it traverses is almost unpopulated and even animal life on it is meager" (Borders, 1974).

Yet the proposed pipeline was opposed from the very beginning by Inuit communities. In 1972, Inuit Tapirisat of Canada president Tagak Curley toured Panarctic sites, stating: "To me, the most impressive thing was the inevitable mess that is made on the land at one of these sites" ("Polar Gas," 1975). In 1975, James Arvaluk, president of Inuit Tapirisat of Canada—now known as Inuit Tapiriit Kanatami—said at the time: "We oppose the pipeline for selfish reasons, because our ancestors lived there, and we have never wanted waters, animals, or man to be disturbed. We still have to live on the land" (Morehouse III, 1975). Panarctic's personnel representative was criticized by the organization for his response to Inuit opposition, stating: "We are interested in their well being, but our involvement stops after work. We have a job to do up here, and that is to put holes in the ground, and spend money doing that in the best way we can" (Morehouse III, 1975).

In September 1977, Inuit community members of Baker Lake—representing the hamlet council, hunters and trappers association, land claim committee and women's group—delivered a letter to Polar Gas president John Houlding in Toronto demanding that the consortium close its

office and move employees out ("Eskimos want rid," 1977; Bernauer, 2018, p. 129). A resolution passed by Inuit representatives in 1977 condemned the Environmental Assessment and Review Process (EARP), arguing it "consists of civil servants who represent government departments that are promoting large-scale development of the North" and that they did not recognize the process or its activities ("Inuit demand Berger-type inquiry," 1977). Southern church leaders also organized to express their dissent, with the leaders of the Anglican, Roman Catholic, Lutheran and United churches writing to the prime minister demanding a Berger-style inquiry into the pipeline ("Inquiry into Polar Gas urged," 1977). Inuit Tapirisat of Canada explained that this inquiry was needed because: "Polar Gas has been working for five years or more on its plans and giving the public little or no information beyond what the consortium wants the public to know" ("It's official for Polar Gas," 1978).

The project's own environmental statement acknowledged that the pipeline would likely reduce hunting opportunities in Resolute area, force walrus herds to leave the Crozier Strait, impact fishing operations near Baker Lake, and undermine hunting activities in Barrow Strait (Carruthers, 1978). Opposition to the project was formalized at the Inuit Tapirisat of Canada annual general meeting in 1978 (Bernauer, 2018, p. 130). That same year, the two-volume report prepared by Frank Tester on behalf of the Keewatin Inuit Association found that "the vast majority of Inuit who were interviewed, however, clearly stated that they did not want the pipeline to be built" (Bernauer, 2018, p. 131). While concerns from Inuit communities and southern environmentalists had resulted in the consortium's decisions to adjust the route in eight "problem areas" and suggest mitigating measures in eight others, major concerns remained about its overall impacts (Carruthers, 1978). In mid-1979 a working alliance was formed between the Dene Nation, Manitoba Indian Brotherhood, Kitikmeot Inuit Association, Keewatin Inuit Association and Grand Council of Treaty Nine to oppose the Polar Gas pipeline, reiterating their position of "no major development can go ahead on their lands until just settlements are signed and implemented" ("Native groups form alliance," 1979).

The Polar Gas proposal was facing other complications as well. By 1977, talks of the Arctic Pilot Project had started to emerge as a possible contender to the Polar Gas Project. Downgraded gas reserve estimates at Melville Island had resulted in the pipeline proposal reducing its diameter from 48 to 42 inches (Nowell, 1977b). Yet its application the National Energy Board and Indian and Northern Affairs indicated that cost had only continued to increase,

now featuring an estimated price tag of $10 billion, equivalent to $40 billion in today's dollars—making it the longest and most expensive pipeline proposal up to that point in time (Blunn, 1977). Building the pipeline would require a "very significant logistics effort" including the movement of 4.2 million tonnes of equipment and materials through 15 staging sites (Kaustinen, 1983, p. 221).

Increased pressures from the Arctic Pilot Project proposal also spurred a resurrected "Y Line" idea, in which the Polar Gas pipeline would travel to the southwest to join with a spur line from the Mackenzie Delta, and then head south ("Polar Gas has step-by-step," 1977). In a special issue of *Alternatives* about Northern issues, Jan Macpherson and Greg Thompson (1978) identified an array of issues with the ongoing Polar Gas proposal, including conflicts of interest between government proponents and regulators: "Will the government regulatory bodies responsible for evaluating the project be impartial? Will pressures be exerted to approve the project since government funds are involved and since the government would expect to receive a significant portion of the profits which are generated?" (Macpherson & Thompson, 1978, p. 35). By 1980, the Polar Gas Project was in deep trouble. Costs continued to skyrocket and cheaper options including the Arctic Pilot Project undermined its economic case, despite the latter's insistence that the two were complementary projects tapping into different reserves. The Ontario Energy Corporation was also considering exiting the consortium ("Researchers want credit," 1979; "Pulling out," 1980).

After three years of relative silence, Polar Gas re-emerged in 1983 with a new attempt for regulatory approval—but for a pipeline from the Beaufort Sea to Alberta through the Mackenzie Valley, effectively replicating Foothills Pipe Lines' original "Maple Leaf" project of the early 1970s ("Polar Gas project back," 1983). Without the need to cross multiple frozen channels, the project cost descended from $10 billion to $3.3 billion, with the idea of eventually connecting to the Arctic Islands once enough cashflow had been generated (Struzik, 1984). The revised project never got further than the application. Yet the dream persisted for years to come. Houlding, president of Polar Gas, died in 1988 and was replaced by John Beddome, former president of Dome Petroleum ("Beddome heads gas project," 1989). In 2006, an *Edmonton Journal* reporter compared Polar Gas to other failed resource projects of the time such as the Alsands oil sands mine, describing them as "stillborn giants" (Jaremko, 2006). But while the project itself may

have been "stillborn," its attempted creation nevertheless contributed an enormous amount to the production of the Arctic as a capitalist nature.

Arctic Pilot Project

Despite many years of scientific and engineering study, the feasibility of Polar Gas to safely operate pipelines across Arctic channels remained in question for many. The Arctic Pilot Project presented another option for large-scale natural gas transportation that avoided many key problems with the pipeline proposal, and retained its nationalistic objectives through the participation of the newly formed Petro-Canada.

In 1976, Petro-Canada joined forces with Alberta Gas Trunk Line—the proponent of the Foothills Yukon project to ship Prudhoe gas along the Alaska Highway, and previously involved in the Canadian Arctic Gas Pipeline mega-consortium—and Melville Shipping, a firm assembled of four shipbuilding companies on the request of Petro-Canada (Panitch, 1977). Its plan, the Arctic Pilot Project, was described by the Calgary Herald in 1977 as "one of the most ambitious resource developments ever proposed for Northern Canada" (Nowell, 1977a). Specifically, the project proposed the production of 225 to 250 million cubic feet of gas per day and transport it from Melville Island to a regasification facility in either Nova Scotia, New Brunswick, or Quebec using two large Class 7 ice-breaking LNG tankers. The proposed tankers were the largest in the world, with Melville Shipping's Michael Bell describing their 125,000 cubic metre capacity as "awfully big" ("Size of tankers poses," 1977). The two vessels would make between 12 and 14 round trips per year between the Arctic Islands and the regasification facility in the Maritimes or Quebec (Hull, 1979). In total, the project would require offshore wells, a 160-kilometer pipeline from Drake Point to the island's southern coast at Bridport Inlet, a liquefaction facility, and a regasification facility at the other end (Campbell, 1977). The liquefaction plant and storage tanks at Melville Island would be mounted on three barges constructed in the south (Bailey, 1983, p. 263).

Proponents argued that the $1.2 billion price tag would provide immediate cashflow that much larger proposals like the Polar Gas Project could not compete with, which would in turn provide incentives for companies to continue exploration in the Arctic Islands ("Transporting liquid gas," 1977; Arctic Pilot Project Environmental Assessment Panel, 1980, p. 38). Further, the project was heralded for its "relatively small-scale" nature that would allow for opportunities

to collect information about environmental impacts and mitigation (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 4). Further, the Arctic Pilot Project Environmental Assessment Panel recommended that "advantage should be taken of the long lead time required for the project to become operational" to establish a route control authority and an advisory committee to coordinate studies about marine mammals (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 4-5). The argument was that without conducting a pilot project, the firms and state would not know of the effects that such an industrial presence posed, and therefore could not mitigate for its harms. As a result, the pilot project represented a calculated means of introducing large-scale fossil fuel transportation to the region using the discourse of scientific inquiry and environmental protections.

As in the case of the Polar Gas Project, Inuit communities and organizations quickly condemned the concept and called for a full public inquiry to evaluate the impacts of the project, as well as settlement of outstanding land claims (Johnson, 1979). Consultation processes started in 1977, with specific outreach to settlement councillors occurring in the communities of Arctic Bay, Grise Fiord, Pond Inlet, and Resolute (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 13). These meetings were continued in 1979, with settlement representatives also taken on a tour of an LNG plant in Alaska (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 13).

Between April 23 to 29, 1980, general meetings were held by the review panel in Resolute, with representatives from other communities flown in to attend (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 16). In total, 69 oral presentations were delivered to the review panel (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 17). Despite significant criticisms of the project, especially relating to impacts on marine wildlife and hunting practices, the project received approval from the federal environment panel, although it expressed concern about its potential impacts on Parry Channel and recommended further research and monitoring of marine mammals. A separate environmental assessment panel studied the project's impacts on the Lancaster Sound region.

Titus Allooloo, a Pond Inlet resident, was quoted in the EARP report as expressing resignation about the process: "We do not oppose development because we know that such a viewpoint would be unrealistic and nobody would even listen to us. But we must emphasize our deep concern for our land, our animals and our people" (Arctic Pilot Project Environmental

Assessment Panel, 1980, p. 34). Inuit leaders from Canada, Greenland, and Alaska met to form the Inuit Circumpolar Conference, immediately denouncing the project with a resolution ("Greenland Eskimos fight," 1980).

In addition to transporting natural gas to southern markets, the Arctic Pilot Project was heralded as helping to support Canadian sovereignty in the North. In this respect, the proponents framed Arctic gas as a question of geopolitics in a way the other projects did not. Edgar Dosman, author of *The National Interest* about the privatization of the country's Arctic policy, made the case in 1979 that the project would help fend off threats from the Soviet Union and the U.S., while also mitigating the worst harms on Indigenous peoples by a slower pace of development (Ridsdel, 1979b). An ad campaign in mid-1980 by the federal government reiterated this claim, arguing that the Arctic Pilot Project would help get Canada off oil, especially that from unreliable foreign sources: "This is a Canadian project. It uses Canadian money, public and private, and Canadian people. It's on territory administered by the Government of Canada. It uses Canadian skills, Canadian technology. It's a total Canadian commitment" (Government of Canada, 1980). By then, the federal government had come to control a 55 percent stake of Panarctic via Petro-Canada, up from 45 percent at Panarctic's inception in 1966 (Campbell, 1979). Dome Petroleum—the leading firm in the Beaufort, original operator for Panarctic, and part owner of TransCanada—also joined Arctic Pilot Project with a 20 percent stake shared with the pipeline company (Hatter, 1980a).

Exploration levels in the Arctic Islands had declined significantly since the mid-1970s but the project was still attracting potential buyers from suitors like the Southern Natural Gas Company of Georgia and Tenneco (Hatter, 1980a). A tour by Petro-Canada of 10 European countries concluded that a dozen utilities expressed interest in buying Arctic gas (Campbell, 1980). In a complicated swap arrangement resulting from the National Energy Board's requirement for a domestic surplus be proven before further gas exports be allowed, the buyers of Arctic Pilot Project gas would not receive the physical gas from the Arctic Islands but instead use Alberta gas, with Arctic gas being shipped to the Maritimes—but with the Arctic Pilot Project receiving the Canadian gas export price, roughly twice the price of gas sold domestically (Hatter, 1980c). Yet another proposal used to make the economic case for the project included the shipping of Arctic gas to iron ore mines in northern Quebec (Gibbens, 1980).

The emergence of competing projects added to the sense of urgency in attempts to transport Arctic gas. In October 1980, TransCanada—a partner in both Polar Gas, and whose largest owner, Dome Petroleum, was now a participant in the Arctic Pilot Project—announced that it was planning its own LNG project to ship gas out of more northerly reserves at Ellef Ringnes and King Christian Island (Hatter, 1980b). Another project was simultaneously being proposed by Petro-Canada and Westcoast Transmission that would see LNG exported to Japan from northwestern B.C (Hatter, 1980c).

However, the Arctic Pilot Project received an approval from the federal government's interdepartmental review team in October 1981, with the report recommending constant monitoring of ice conditions and consultation with regulatory agencies about emergency response protocol ("Arctic gas plan gets nod," 1981). Resistance efforts continued to mount. Inuit organizations did not buy the review panel's claim that Arctic Pilot Project was "merely a 'pilot' project, and thus experimental in nature" ("Arctic Pilot Project: Another Norman Wells," 1981). The government of Greenland voted unanimously to oppose the project in 1981 due to environmental concerns ("Greenland aims to halt Arctic gas-tanker plan," 1981).

The Inuit Tapirisat of Canada maintained that land claims had to be settled in the eastern Arctic prior to any approval of the project, with president John Amagoalik voicing concern that Arctic Pilot Project was "only the cutting edge to facilitate oil tanker traffic" and that the government was obstructing a settlement by rushing the process (Lewington, 1982). By September of that year, the National Energy Board announced that it was adjourning hearings from the project until the proponents delivered a more specific proposal for exporting gas, with exact markets identified (Hill, 1982). The chair of the French state-owned Gaz de France reiterated his interest in the project that same year, comparing the Canadian Arctic to the deserts of North Africa which "gave up its riches" for exploitation (Lewington, 1983).

But just over a year later, in August of 1984, the project was officially declared dead by the media after the National Energy Board closed its application. A post-mortem written by Lewington (1987) argued that the Arctic Pilot Project was defeated by an absence of "clear and compelling purpose," along with a combination of falling commodity prices and a prolonged recession (p. 163). The Ontario government also saw the Arctic Pilot Project as a threat to the Polar Gas Project—which it had a stake in—and joined with Inuit groups in the court challenge following the private meetings of the National Energy Board with project proponents

(Lewington, 1987, p. 175). The intentions of the private players were also contradictory, with Dome especially pushing for its own dominance over the Northwest Passage (Lewington, 1987, p. 171). Given the "shapeless concept" and extremely high costs—not only financial, but environmental and social—Lewington (1987) concluded that the Arctic Pilot Project was a "downfall of its own making" (p. 178).

Such an account draws too precise a boundary around the effects of the project, given the way the Arctic Pilot Project lived on beyond the drafting table, including the previously mentioned report by the Canadian Energy Research Institute. In 2014, Michael Bell—previously of Melville Shipping—made an appeal to "Arctic sovereignty via LNG," calling on a resuscitation of it as a means of "putting a Canadian sovereignty stamp on the Canadian High Arctic" (Bell, 2014). Most recently, a 2016 paper prepared by several researchers at the University of Lapland argued for a "Melville Island LNG Project" that would ship LNG from the Hecla and Drake point fields to European markets using the exact same technology as the Arctic Pilot Project, including a pipeline to Bridport Inlet and ice-breaking LNG carriers (Davis, Hossain, & Koivurova, 2016, p. 255). The proposal used studies conducted by the Arctic Pilot Project, including its application to the National Energy Board, and expanded its vision to ship triple the amount of gas and added a transit terminal in Greenland (Davis, Hossain, & Koivurova, 2016, p. 255).

Like with the Polar Gas Project, the Arctic Pilot Project was highly productive despite its commercial failings, creating immense amounts of scientific and engineering knowledge about the Arctic and advancing the possibility of extractive potential in the region. Unlike the pipeline proposal, which would have been unalterable once installed, the Arctic Pilot Project uniquely branded itself as a "pilot project" that could actively evaluate environmental and social impacts, factor this data into its activities, and attempt to mitigate its worst harms. Such framing appears indicative of a growing awareness by fossil fuel companies that Indigenous and environmental opposition could disrupt, if not end, the viability of a proposal unless concessions were offered. However, these attempts were evidently far from sufficient, with Inuit organizations and communities asserting their self-determination over Arctic lands.

Conclusion

This section has framed the work of this thesis by providing outlines of the history of science and oil and gas exploration in the Canadian Arctic, alongside summaries of the Polar Gas Project and Arctic Pilot Project. This process had made clear that the work by natural gas transportation consortiums to produce and accumulate scientific knowledge about ice belonged to a long lineage of capitalist and colonial activities in the Arctic region tracing back centuries. The Arctic has represented many things to many different interests: lands to be conquered by the sovereign, a region to be protected from invasion, environments to be known and conserved. The call by Stuhl (2016) to "dissolve notions of the place as frozen in time" requires us to recognize the related and cumulative nature of these interventions (p. 13). Similarly, it helps focus our attention on the residual impacts of such activities well beyond their conventionally understood lifespans, with outcomes often not discernible for years or decades after the fact.

Chapter 4: Polar Gas Project

Introduction

Ice was probed, excavated, and grown in a lab. It was subjected to enormous pressures, catalogued from airplanes and satellites, and trenched through with large machinery. It was experimented on using small model ships and massive real-life icebreakers. The ice was surveyed, defined, and sorted using hyper-specific metrics including age and thickness. It was envisioned as the foundational material for an array of competing pipeline installation methods: should the pipeline be dropped through a wide trench in the ice? Or dragged along the bottom of the sea, guided by cables hung through the ice?

From the very beginning of the consortium's planning, ice was identified as the biggest obstacle necessitating scientific intervention to understand and exploit in order to build the pipeline from Melville Island to Longlac, Ontario. A 1973 presentation to a Polar Gas technical committee explained that impediments like severe cold and darkness had been controlled to some degree but that "sea ice continues to limit our present efforts almost as much as it thwarted the sailing ships used by our predecessors" (Lindsay, 1973, p. i). Another Polar Gas publication in 1978 acknowledged that the installation of pipelines across deep-water channels had "attracted the greatest degree of public attention as the major technological challenge" (Polar Gas Project, 1978, p. 1).

As a result of insufficient knowledge and control over ice, the Polar Gas Project launched a major ice research program in 1973 to collect data, improve technologies, and establish workable designs to strengthen and exploit ice to install the pipeline. These research projects were continued in full force throughout 1974 and 1975, with more sporadic investigations in subsequent years. Topics of interest for the ice research programs ranged considerably in subject, including ice thickness and strength, the impacts of cracks and various loads on the structural integrity of ice, the testing of ice trenching equipment, ice and iceberg movement observations, ice scour, predicted scheduling of construction in ice, and ice break-up patterns in southern rivers. New objects of inquiry emerged as certain experiments or observations failed due to unknown factors warranting investigation. Most of this research work was based out of Rea Point on the eastern side of Melville Island, the headquarters of Panarctic's operations in the Arctic Archipelago. In total, there were five channel crossings between Melville Island and

Somerset Island that the pipeline was required to cross in its original plan, each requiring specific knowledge production and planning to complete installation (Polar Gas Project, 1978, p. 3).

An example of how this power circulated is found in a 1978 letter sent by B.J. McCutcheon, the manager of public affairs for Polar Gas, to a Winnipeg-based nun, Sister M. Beaucage (McCutcheon, 1978). Two months earlier, Beaucage wrote an article critical of Polar Gas in the Catholic publication *Prairie Messenger*. The Polar Gas manager claimed that the article "contained a number of factual errors" and suggested that the nun's concerns about lack of public information was invalid due to the physical presence of corporate documentation in Winnipeg libraries. McCutcheon noted that Polar Gas had also offered to send documentation to Indigenous communities along the proposed route, but that "none of the Chiefs in Manitoba have responded and accepted our offer." To resolve this alleged discrepancy in information, McCutcheon sent Beaucage a Polar Gas promotional booklet, which included claims about how Polar Gas engineers and researchers "assembled a vast body of knowledge on the channels themselves" that has "reduced the challenge to one of manageable proportions" (Polar Gas Project, 1978). The powerful gas consortium appealed to the presence of physical documentation of their plans as evidence of their knowledge and authority to speak about Arctic natures. In this version of the Polar Gas story, expertise was produced by the company, and circulated to the appropriate places and peoples. Knowledge was produced for profit by the individual firms contracted by the consortiums, and was used by the consortiums to support the production of natural gas infrastructure; in this way, knowledge production benefited different firms in different ways, depending on what commodity they were attempting to circulate.

This case study will examine and analyze how exactly capitalist natures were produced: what questions were asked of the ice, what techniques were developed and administered, and how the consortium "reduced the challenge" of building pipelines across deep Arctic channels "to one of manageable proportions." Through this work, many aspects of Arctic ice were transformed from a "threat" to "the underground," establishing the material as an unvalued but reliable surface to install a pipeline from (Collard & Dempsey, 2017).

Laying the icework for a pipeline

The Polar Gas proposal was not the first deep-water pipeline installation to be proposed. By the early 1970s, underwater pipelines had been installed in the United Kingdom's North Sea,

using lay barges to drop the pipe from the surface into the water (Borders, 1974). However, such a technique had never been attempted in the Arctic. This reality required the production of entirely new engineering schemes and collections of scientific knowledge. This knowledge production was conducted and published for Polar Gas by a small group of consulting firms headquartered through Canada and the United States. In addition to Banister Technical Services, these firms included Arctec Canada, Montreal Engineering Company, R.J. Brown and Associates, Brown & Root, and Northwest Hydraulic Consultants.

Many of these companies had lengthy reputations that predated involvement in the Arctic. Montreal Engineering Company was launched in 1907 by the Royal Securities Commission (RSC), becoming a "milestone in Canadian business development" and "systematically collected information from the far-flung utilities [owned by RSC] so that their diverse experiences could be accumulated and general lessons learned" (Marchildon, 1996, p. 115). Arctec Canada was the first company in Canada—and only the fourth in the world—to build a dedicated "Cold Regions Marine Research and Engineering Laboratory," allowing it to produce specific research about ice technologies.

Many of the firms also worked together to produce scientific knowledge, with reports often featuring several corporate authors. In other cases, reports would be produced for one firm by another firm, such as a 1977 report written by California's Offshore Technology Corporation for Canada's Montreal Engineering Company under supervision of Texan Brown & Root (Offshore Technology, 1977). Some research was also conducted directly by the consortiums, as well as through industry collaborations such as the Arctic Petroleum Operators' Association.

The specific challenge for Polar Gas was finding a way to install a pipeline within a severely limited time restriction of ice-free conditions, with differing conditions from channel to channel and the constant threat of ice trapping or damaging the pipeline. Using older methods of pipeline installation, Polar Gas would have only been able to operate a couple of months per year. As a result of this environmental limitation, an assortment of pipeline installation techniques were devised based on a combination of previous efforts, such as in the North Sea, and completely new schemes. The consortium worked to produce capitalist natures that could serve as a reliable condition of production.

Three general categories of pipeline installation were devised over the years by Polar Gas: "on-ice," "in-ice," and "under-ice pull" techniques. Each of these promised to extend the

potential construction window in the Arctic, allowing for the possibility of hundreds of kilometers of under-ice pipeline to be built in just a few short years. The “on-ice” method proposed using a “laybarge,” also known as a pipelaying ship, or “gantry train,” a set of large mobile cranes and support units. The characteristic element of this method was that the pipeline would be installed from the surface through a large open trench in the ice. Laybarges were—and still are—the conventional approach used for offshore pipeline installation. Plans were devised to strengthen laybarges for Arctic conditions, including strengthening the barge’s hull to withstand greater pressures and increasing its boiler size to allow for ice and slush to be blown off the deck with hot water jets (Brown & Root, 1976, pp. 8-3, 8-24).

The “in-ice” technique would have seen the pipeline being pulled across the channel within a trench, also referred to as the “ice envelope,” with the pipeline supported by buoys or support structures (Montreal Engineering Company, & Banister Pipelines, 1976, p. 3-5). However, field studies suggested that there was a “possibility of small movement in the ice sheet” that could collapse the trench and crush the pipeline (Montreal Engineering Company, & Banister Pipelines, 1976, p. 3-5). As a result, this scheme was discarded for most of the lifespan of Polar Gas, although it saw some resurgence in its later years. This process demonstrates that if ice was not used “properly,” it represented a threat to the structural integrity of the pipeline and ability to establish commodity circulation from the Arctic.

The third approach was known as the “under-ice pull method” or “bottom-pull technique.” This category included all approaches in which the pipe would be installed below the ice cover. Rather than the pipeline being lowered from above, the bottom-pull technique would use a variety of cradles, buoys, and cables to pull lengthy stretches of the below-ice pipeline along the direction of the route from the surface (Palmer and Croasdale, 2013, p. 294). The pipeline would then be welded below or near the ice using divers. Unlike the other two approaches, this technique did not require a large trench in the ice as only cables needed to be passed through it. This approach often envisaged the installation of a series of artificial ice platforms or ice islands across the ice cover, with winches installed on the strengthened ice to pull the under-ice string of pipeline (Montreal Engineering Company, & Banister Pipelines, 1975c, p. 2-5).

A variation of this technique, called the “seal hole concept,” was devised for channels with thick multi-year ice and pressure ridges that impeded continuous trenching following

several years of field work that was regularly delayed or halted by these ice formations. This approach proposed the installation of artificial "seal holes" at two-kilometer intervals along the pipeline route, with the pulling unit mounted on the ice at the holes (R.J. Brown and Associates, 1978a). The pipe would then be pulled on the bottom of the channel from the pulling units mounted on the surface, with the seal holes kept open with an insulated liner with cooling pipes that kept the ice around the hole frozen and water in the hole unfrozen using waste heat from the engine pumping coolant (R.J. Brown and Associates, 1978a, p. 2-2).

No single approach won out in the end. The "under-ice pull method" tended to be framed as the best available option for most scenarios due to lighter loads on the ice, narrower trenches, and no requirement to transport or weld pipe on the weather-vulnerable surface (Montreal Engineering Company, 1976, p. ii). However, by 1978, Polar Gas was planning to combine this method with tunnelling efforts in some locations to protect the pipeline, such as under Pullen Strait between Little Cornwallis and Cornwallis Island—and concluded the laybarge method would have application for one of the Arctic channels (Polar Gas Project, 1978, p. 2-3).

In 1978, Panarctic Oil achieved one of its greatest successes by completing a flowline from an offshore gas well at Drake Point to an onshore production facility. The flowline represented the first pipeline constructed under Arctic ice in North America, the first well drilled from the ice to be completed and produced, and was described in a news report as a technological feat akin to "going to the moon" (Palmer and Croasdale, 2013, p. 298; Barrette, 2017, p. 14; "Completion of Arctic well," 1978). This was a critically important demonstration project, showing that ice could be successfully exploited to install a pipeline. As Palmer and Croasdale (2013) write: "There is clearly little point in finding gas if you cannot produce it, and the Panarctic participants wished to be reassured that it would be possible to produce the gas and to pipeline it to shore, without waiting for some future technology that had yet to be developed" (p. 298). Investors need to know that the project was possible.

Despite earlier concerns, it was installed through a trench in the ice using a combination of the "on-ice" and "in-ice" methods, demonstrating the constantly evolving nature of scientific knowledge production and practice. However, while the revolutionary flowline system at Drake Point succeeded, the success was not sustained, duplicated, or monitored over time. The system was not plugged and cleaned up until the mid-1990s. Offshore engineers have since expressed disappointment that the operator and regulator did not analyze the flowline system to evaluate

how ice had impacted it over the years before dismantling it, considering it a lost opportunity for Arctic pipeline engineering (Barrette, 2017).

Understandings of ice and its potential utility varied greatly depending on the engineering method proposed at any given time. The "laybarge" concept viewed ice as something to physically plow through, while the bottom-pull method harnessed the strength of the ice to lower the pipeline into place. In both cases, trenching equipment was necessary to carve through the ice. The "seal hole" concept, an extension of the bottom-pull method, reimagined actual seal holes as something that could be engineered through "difficult" ice channels filled with multi-year ice and pressure ridges to allow for efficient installation.

Each of these iterations of pipeline installation techniques promised to transform the ice into a condition of capitalist production. In a 1978 report, Polar Gas reported that one of the "positive results" of alleged resource scarcity and the ensuing exploration in offshore regions was "the development and use of dependable equipment to permit large diameter pipe to be laid at great depth on the seabed" (Polar Gas Project, 1978, p. 17). As the industry entered more "inhospitable" sections of the globe, "equipment development to perform the task of pipe laying has more than kept pace" (Polar Gas Project, 1978, p. 17). That body of existing knowledge was used by Polar Gas to develop new techniques of pipeline installation in the Arctic.

Producing Arctic natures

Arctic ice had been an object of serious scientific investigation for decades prior to the creation of the Polar Gas consortium. However, the ongoing lack of scientific knowledge about the Arctic Islands and unique engineering ambitions of the proposal meant that Polar Gas had to efficiently produce and distribute knowledge to facilitate pipeline construction and maintain investor confidence.

The first dedicated Polar Gas research program started in March 1973 (Montreal Engineering Company, & Banister Pipelines, 1975d, p. 2). Its initial interest in ice as an object was "to confirm and assess the strength and stability of Arctic ice as a working surface" (Montreal Engineering Company, & Banister Pipelines, 1975d, p. 2). Alongside ice, the 1973 program also conducted research into bathymetry (the depths, currents, and bottom characteristics of Arctic channels), ecology, aerial photography of alternative pipeline routes, and engineering research to design the pipeline across Arctic channels. The ice research program was

explicitly “designed to test its theory that pipe could be laid during a four-month construction season” (Montreal Engineering Company, & Banister Pipelines, 1975d, p. 3). Initial questions asked of the ice related to trenching, load bearing capacity, and the impacts of currents and tides on pipelaying (Montreal Engineering Company, & Banister Pipelines, 1975d, p. 3-4).

The 1973 research program was followed up in 1974 and 1975 with dedicated programs consisting of dozens of studies per year. In 1974, the ice research program was invested in improving ice strength and repairing cracks along the proposed right-of-way, and increasing the scale and design of load-bearing tests (Montreal Engineering Company, & Banister Pipelines, 1975d, p. 7). One of the key objectives of these field experiments was to gather data to design predictive computer programs, as well as test and confirm mathematical formulas used in the programs. Polar Gas reported that as a result of ice research carried out in 1973 and 1974, a computer program was developed to assist researchers evaluating load bearing capacity under a variety of configurations (Montreal Engineering Company, & Banister Pipelines, 1975d, p. 3).

This knowledge production was cumulative, actively identifying missing information and applying knowledge produced from previous efforts to refine and direct approaches. In both 1973 and 1974, much of the scientific research produced for Polar Gas was collected in an annual report of sorts authored by three leading firms: Montreal Engineering Company, Banister Pipelines, and R.J. Brown and Associates. This allowed production of knowledge by various firms and endeavours to be united into a central program and compare successes, failures, and recommendations. Scientific failure was especially integral to this process, producing justification and specificity for future field work, laboratory testing, and predictive modeling.

Much of this knowledge was being produced for the first time with specific application in the Arctic Islands, meaning these were critically important processes to establishing a coherent body of knowledge in order to construct fossil fuel infrastructure to the south. Ice research conducted by Polar Gas over several years can be organized into four general categories of inquiry: 1) ice thickness and electrical properties of ice; 2) load-bearing tests; 3) trenching and penetration of ice; 4) ice movement and scour. These processes were constantly marred with errors, flaws, oversights, and logical leaps.

Ice as a vertical (and electrical) structure

The firms contracted by Polar Gas started their research efforts by producing scientific knowledge about ice thickness throughout the Arctic channels. This work was needed to produce baseline knowledge about ice, understand its variations over time and place, and create technologies to more efficiently survey thickness. Banister Technical Services (1975a), one of the contractors hired by Polar Gas, wrote in a report: "Successful completion of the feasibility studies and the eventual construction of a high Arctic pipeline, proposed by the Polar Gas Project, suggest strongly the need for systems to measure ice strength and thickness with reliability, speed and ease" (p. 5). New knowledge had to be produced, accumulated, and transmitted to achieve these goals.

Many techniques were designed and harnessed for this task. Manual ice augering was initially relied upon by Polar Gas contractors to produce measurements of ice thickness at experimental test sites near Rea Point, with locations "evenly distributed" throughout the area using aerial reconnaissance (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, pp. 3-4, 4-13). A survey rod was used to measure thickness once a hole was dug in the ice (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 4-55). However, this technique of using an ice auger and survey rod was time-consuming and resource intensive. While an effective way of seeing ice, at least in channels free of multi-year ice and pressure ridges that prevented augering, this technique of knowledge production was too slow to effectively capture the range of potential ice thicknesses throughout the channels. As a result, firms contracted by Polar Gas started to design alternative methods of knowledge production allowing for more efficient surveying.

One result of this was the creation of a radar technology called "Electromagnetic Subsurface Profiling" (or ESP, not to be confused with perhaps the most slippery science of extrasensory perception) by the Massachusetts-based company Geophysical Survey Systems (1973). The ESP was originally designed to locate buried pipelines in the ground and was adapted for Arctic use on an "experimental basis" (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 3-2). This technique measured ice thickness by sending out a radar pulse from an antenna that was pulled across several Arctic channels behind a survey vehicle. Unlike with the previously attempted technology of augering, the ESP

technique offered efficiency due to no longer having to reposition technicians and stop for long periods to collect data.

At least, that was the proposed benefit. The testing of the ESP technology sought to acquire thickness data while "defining" any problems that emerged with "successful and efficient acquisition of sea ice thickness data" in order to devise solutions (Geophysical Survey Systems, 1973, p. 1). Prior to official testing, the surveying crew spent a week conducting preliminary profiling and interpretation due to the "unique nature and potential danger" of on-ice operations, concluding the "ice along most of the route posed no danger" (Geophysical Survey Systems, 1973, p. 3). In order to survey the ice, with the eventual goal of building a pipeline, the ice had to be constituted as safe and predictable. However, once surveying started, technicians found that the vehicle frequently had to stop to auger a hole through to ice to "calibrate" the technology. The application of this technique also encountered many problems in the process, including poor weather, extremely rough ice, variability of ice surface conditions, ice polarization, weak reflections from the ice bottom, and equipment issues including a loose bolt shorting out a power supply and an antenna cable breaking when caught on a block of ice. Geophysical Survey Systems (1973) concluded: "All of these problems were due to the hostile arctic environment or to the electrical complexity of sea ice" (p. 1).

Instead of profiling six channels throughout the research season as originally planned, these obstacles meant the surveying team was only able to complete three-and-a-quarter traverses. In some places, the radar burst was not adequately rebounded, and in others large cracks or pressure ridges in ice prevented safe travel. Another approach used in places where poor signals were received was for the survey vehicle to tack back and forth across the intended route to obtain stronger signals. It was also found that the presence of a foot or more of snow resulted in margin of errors of up to 20 percent (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 3-4).

Slower alternative approaches had to be used, including augering holes in the ice or using mathematical calculations in places where an incomplete profile was formed, necessitating interpolation by "an interpreter thoroughly familiar with both sea ice and sea ice profile data" (Geophysical Survey Systems, 1973, p. 25). The process of producing knowledge about ice thickness resulted in new methods of producing capitalist natures such as the use of predictive calculations. Technical failure also resulted in the creation of several recommendations by

Geophysical Survey Systems (1973), including that a "ruggedized system" of surveying be constructed for Arctic environments and an airborne ice thickness profiling system to be used rather than surface methods if possible. The firm also proposed the use of probability analysis based on measured ice thickness data and calculations from meteorological data to predict ice thickness, with the latter process requiring complex mathematical formulas (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, pp. 4-6, 4-11). The process was highly productive despite, and in many ways because of, failure.

The ESP was a technique of scientific knowledge production that emerged in response to the inefficiency of hand-held augering. Rather than physically drilling into the ice to evaluate its thickness—a way of seeing that required direct albeit slow interactions with the object—the firm attempted to devise a method of producing ice thickness data from a survey vehicle. When functional and adequately calibrated, the technique produced a significant amount of data, but such success was frequently undermined by an array of technical difficulties. Even if reliable data was produced, expert interpretation was required to "read" the information in a way that accounted for several complex factors including snow cover and ice polarization, "a phenomenon that is still poorly understood" (Geophysical Survey Systems, 1973, p. 21).

Techniques had to be devised to make this data legible to expert users, including dividing the data into "suitable intervals," overlaying each with a "lucite plate on which horizontal lines have been scribed" to signify depth scales, and eventually presenting the data in graphic and tabular forms (Geophysical Survey Systems, 1973, p. 21). This was a physical reconstitution of knowledge about ice into something that was transportable and legible to capital. The technique produced a new way of seeing ice that defined reliable and unreliable thickness data.

The process of experimenting with a technology imported from non-Arctic conditions also served to identify flaws in the existing system, impediments to data collection such as pressure ridges and ice polarization, and produce recommendations for improving techniques. One of the possibilities that emerged from this was ongoing attempts to design and test technologies to measure ice thickness and quality by "indirect, nondestructive" means. The promise of these approaches was that they would provide a more continuous set of knowledge, rather than only isolated measurements from direct field measurements like augering that "do not guarantee the safety of men and equipment well enough" (Banister Technical Services, 1975a, p. 5).

Following the practices established by Geophysical Survey Systems and their technology, Banister Technical Services worked in 1974 to test and calibrate a "high frequency prototype" ice profiling machine with two distinct designs: an acoustic echo sounding system and a short-pulse radar system (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 2-27). This firm's ice thickness testing was described as a "late and minor addition" to other investigations into bathymetry and sub-bottom profiling, with the ice thickness sensors "crude" and "constructed in the field of various components and material on hand at Rea Point" (Banister Technical Services, 1975a, p. 1). In fact, the entire operation was conducted in a highly ad-hoc fashion, with instrumentation components taken from other systems and the recreation room at Panarctic's Rea Point headquarters serving as the technique's "mobilization facility" due to its "large size" and the fact "metallic reflections" were eliminated during the system testing because the room was "made solely of wood" (Banister Technical Services, 1975a, p. 12). Further, the support vehicles including a Skidozer could only be used when "not required in higher priority programs" (Banister Technical Services, 1975a, p. 12).

Despite its relatively amateur assembly, the firm reported the testing produced "valuable background for a better understanding of problems currently attendant to ice thickness measurements" (Banister Technical Services, 1975a, p. 1). In addition to carrying on the work started by Geophysical Surveys of devising technology to more efficiently survey ice, Banister identified "major boundary conditions" including salinity structure and ice surface conditions that could significantly undermine the "valid results" of ice thickness surveys (Banister Technical Services, 1975a, p. 6).

Salinity, especially, was viewed as a concerning factor that "for reasons not completely understood" acted as a conductor of electricity and produced "frequently inaccurate" measurements requiring a calibration program to rectify (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, 2-28; Banister Technical Services, 1975a, p. 9). In their 1975 report, Banister Technical Services concluded that "more knowledge must be obtained" about the electrical properties of ice in order to build a suitable ice thickness profiling system. Through the production and enclosure of scientific knowledge about ice thickness testing, salinity was advanced as an independent object of inquiry for Polar Gas contractors that expertise could be produced about.

Initial inquiries had been made into salinity in 1973, when sea ice core samples from Byam Channel were shipped to Edmonton for laboratory analysis of salinity content (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 3-4). Coring samples were also extracted during load-bearing field tests conducted by Arctec Canada (1973a), which were then probed with a thermistor and partially melted over hot exhaust from a nearby diesel generator to assess the salinity with an electrical conductivity meter (p. 35). However, these early efforts were largely secondary to other inquiries. The knowledge production by Banister, along with similar research, legitimized the need for more systematic assessments of salinity and advanced the discourse of ice as a container of problematic components requiring scientific reductionism to isolate and control. During ice thickening experiments in 1974, salinity profiles of ice were regularly gathered with an auger to better understand how salt in the ice migrated in response to flooding and freezing (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-10).

In the process, it was found that "smooth humps" formed on the surface of the strengthened ice sheets after flooding it with sea water, then attributed to pockets of high-salinity water (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-11). As a result, salinity profiles were taken in the area on a weekly basis. Full-scale load tests administered the following year, in 1975, found that ice with brine volume of more than 14 percent had excessively low tensile strength (Montreal Engineering Company, 1975b, p. 4-9). Along with ice temperature, the salinity content of ice was produced as an independent variable requiring consistent studying and testing to track and manage. The electrical properties of ice were also identified as in need of greater understanding in order to reliably use technologies to efficiently produce and catalogue ice thickness data (Banister Technical Services, 1975a, p. 9). Failing to produce this particular category of knowledge would mean that ice thickness measurements could include unaccounted distortions and false readings.

Many various factors became understood as having impacts on electrical properties of sea ice, including age, morphology, and the presence of snow on the ice (Banister Technical Services, 1975b, p. 12). Resistive measurements were taken by placing probes in ice, while capacitive measurements were made by placing metal plates on ice and inducing current to flow in the circuit (Banister Technical Services, 1975a, p. 9). However, data and results were

described as “by no means conclusive” and should only be useful to suggest direction of further inquiry (Banister Technical Services, 1975a, p. 4).

By 1976, Polar Gas was shifting into confirming right of way and construction techniques with a new proposed route (Montreal Engineering Company, & Banister Pipelines, 1976). Several years later, in 1979, Polar Gas continued to conduct surveys of ice conditions using ice profilers to produce a supposedly continuous profile of the ice thickness by transmitting short pulses of radar frequencies (Polar Gas Project, 1979b). A “vehicle train concept” was also devised to catalogue physical characteristics of M’Clure Strait, in which all workers and equipment moved in a self-contained “train” including an ice profiler that measured thickness with short radar pulses (Polar Gas Project, 1979b). This technique was very similar in design to previous efforts by both Geophysical Survey Systems and Banister Technical Services. The possibilities advanced through their experiments carried through following years, as did the questions posed of the ice.

To bear the weight of a pipeline

The ice thickness tests—along with the increasingly reductionist inquiries into factors like salinity and electrical properties—were conducted to establish baseline data and limitations of knowledge. However, they largely failed to produce reliable thickness data, which in turn undermined the potential ability to safely operate heavy machinery like ditchers and tractors on the ice that was necessary for all pipeline installation techniques.

This absence of usable data helped necessitate investigation into the adjacent area of load-bearing characteristics of ice, or the amount of weight an ice sheet could withstand before cracking and collapsing under the weight of a vehicle or other loads. These inquiries understood ice as a structural material that could be “improved” or made more “certain” from its existing state of volatility. Failing to do so would allow for excessive risk that could result in inability to construct the pipeline or major structural issues that impeded commodity circulation.

The goal of this knowledge production process was to establish a “rational and systematic approach to the load bearing capacity problem” (Montreal Engineering Company, 1975a, p. ii). One of the main approaches to producing this approach was through simulated field testing, with two main types of strength tests administered to gather information in 1973 and 1974. Both techniques were administered to evaluate the load that ice in various states were able to

withstand before experiencing cracking. The first was large tank tests in which large circular plywood tanks with steel supports were filled with seawater to precisely measure how much weight could be held for a particular length of time. The second was ice cantilever tests in which a large block of ice cut with a ditcher was subjected to various pressures over time.

Most initial tests were executed successfully, with the exception of a tank rupturing while only half-full of sea water and a cantilever test deemed "unsuccessful" for undisclosed reasons (Arctec Canada, 1973a, p. 2). These resulted in estimations that cracks began to form after the application of a "near instantaneous" load of between 115,000 and 212,000 pounds, with variations depending on ice conditions (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 3-14). However, many of the results from the limited load-bearing testing were deemed as largely incomplete and requiring more future study to evaluate performance in a variety of conditions. Arctec Canada (1973a) specifically recommended further field tests, laboratory experiments, and consideration of an "ice bridge" along the pipelaying route to strengthen the material for usage (p. 5).

In addition to the field tests in the 1973 research program, three sets of ice block samples were sent to Laval University for small-scale strength tests, with the results intended to be incorporated in to mathematical formulas to plan out load configurations (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 3-15). To do this, the ice blocks were excavated near Rea Point using a chain saw, with two cubic feet taken from both the top two feet of ice cover and bottom two feet of ice cover. The samples included both first year and multi-year sea ice. They were then catalogued and labelled, wrapped in several layers of garbage bags, and shipped to Montreal via Edmonton in insulated boxes with dry ice to prevent brine drainage that would damage the samples (Arctec Canada, 1974a, p. A-2).

Tests were conducted at the Laval laboratory on cylindrical samples to assess many types of mechanical properties of ice, with the primary intended use as data for a computer program "for predicting response of floating ice sheets to loads of short and long duration" (Arctec Canada, 1974a, p. 1). In total, 84 "short duration tensile tests" were completed, along with another 98 "long-term tensile deformation tests" (Arctec Canada, 1974a, p. 2-3). These tests sought to evaluate the rates of ice deformation under various loads, finding that ice strength "depended strongly" on ice temperature (Arctec Canada, 1974a, p. 2). The tests of elastic modulus, measuring the elastic properties of ice, were compared to seismic tests conducted by

the U.S. Air Force Cambridge Research Center and the Arctic Institute of North America in 1958 and found to "agree well despite the difference in methods of acquisition" (Arctec Canada, 1974a, p. 2).

Salinity once again proved an obstacle and independent variable to scientists, with the report concluding an insufficient range of salinity within samples rendered it "impossible" to produce data about ice elasticity and strength for many ice conditions. This limited range meant a hypothesis relating ice elasticity and strength to salinity could not be validated. Despite efforts to limit it, brine damage was suspected in some of the short-term tests, resulting in lower overall ice strength and the researchers deleting all related data and rerunning analyses to produce what they deemed as more accurate equations (Montreal Engineering Company, 1975a; Arctec Canada, 1974a, p. 21).

The study concluded by acknowledging a lack of data on factors including temperature and salinity of ice, but noted that if future inquiries more accurately accounted for those variables they could be used to predict full-scale sea ice strength. Its authors also argued that establishing a "criteria for failure" for the ice was as important as producing scientific relationships between factors such as creep rate and temperature, but that "this was not possible using the data acquired from the natural sea-ice" (Arctec Canada, 1974a, p. 56). It also deemed it "important and encouraging" that actual Arctic ice "sustains a much more complicated state of stress" than uniaxial loads, suggesting the tests were producing a relatively conservative data set (Arctec Canada, 1974a, p. 4). Shortcomings of testing justified more testing with new inputs and questions.

Further strength testing was conducted with laboratory experiments in a pool by Arctec Canada (1974b), using laboratory-grown ice cover at a $1/50^{th}$ scale with various load configurations designed to simulate trenchers and multiple vehicles. Rather than physically relocate Arctic ice for interrogation in southern laboratories, environmental conditions were circumscribed and artificially produced. While the model ice performed according to theories previously devised to predict collapse loads, Arctec Canada (1974b) concluded the relationship between bearing capacity and ice sheet configuration remained uncertain. Brine drainage was again encountered during the testing, leading the researchers to suggest that ice thickness and bearing capacity be increased in the field by thoroughly flooding compacted snow and potentially mixing and packing it after flooding to remove any air (Arctec Canada, 1974b). The

findings were explicitly intended to be used to help develop layouts for the next season's field tests: in this way, field work and laboratory testing existed in a dialectical relationship that advanced each other's legitimacy and necessity.

Arctec Canada (1974) also re-analyzed data from over 3,700 small-sample tests conducted in the late 1950s and early 1960s by H.R. Peyton of the University of Alaska Geophysical Institute at the Arctic Research Laboratory of the U.S. Navy. The firm extracted original data from reports and punched them onto paper tape to apply linear regression analysis to the results, but determined that Peyton's data on the creep properties of ice was not usable due to lack of sufficient documentation accompanying its collection. However, the firm observed that producing further data about temperature and salinity from Peyton's testing would allow for "valuable results" to be collected (Arctec Canada, 1974c, p. 36). This represented a process of researchers determining what types of knowledge were reliable, along with how to improve the reliability with additional data. "Dead labour" produced a decade-and-a-half prior was salvaged, made legible for new techniques of data processing, and improved through the application of "living labour."

The 1974 field research program focused its attention on the variables of ice strength and increasing ice thickness. These strength tests were designed to test and confirm parameters produced by laboratory testing and mathematical modeling, advancing an internal discourse about Arctic ice that reinforced existing knowledge and authority (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-18). Experiments were hosted on large right-of-way test strips and 16 experimental ice plots, each 100 by 100 feet in size, to study different methods for increasing ice thickness and in turn the ice's productive qualities for pipeline installation.

These experimental methods included keeping an ice sheet cleared of snow to try to grow thicker ice naturally, physically raising the ice surface to keep it snow-free, and thickening ice sheets by flooding the surface with sea water (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-1). The methods tested to evaluate the building up of the ice sheet included adding layers of ice slush, compacted snow, sea water, and scarifying ice (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-14). Many of these plots included combinations of these interventions, like plot C-3 with "scarified ice surface and medium layers of slush" along with two floodings,

or plot D-2 with “ice surface swept and 1.3 cm layers of sea water” along with 10 floodings (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-14).

Another 22 tank tests were conducted between late March and mid-May 1974. This field work aimed to refine knowledge of load-bearing capacity of ice, with a focus on how load capacity shifted with a semi-infinite sheet (after a trench was excavated through an “infinite” ice sheet) and a wedge (after a trench crossed a pre-existing crack) (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-18). The testing became increasingly sophisticated, with the tank tests designed to use fuel oil at their base to prevent freezing, while linear variable differential transducers (LVDTs) were installed for deflection and load measurements (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-20). These LVDTs transported raw data through cables to “instrument shacks,” where they were then recorded using an oscilloscope; this data was used in case there were malfunctions or errors during other kinds of measurements including dial gauges and survey rods (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, pp. 4-20 to 4-21). Thermistor strings and wire ice thickness gauges were also installed throughout the ice sheet to monitor the properties impacting ice thickness during testing, most notably temperature (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-3).

A generalized procedure with 18 steps was devised for tank tests, including clearing an ice sheet of snow, visually assessing it for “aerial homogeneity,” installing the tank and trench, freezing the LVDT into the ice and calibrating the technology, pumping the water into the tank, making observations, and eventually removing the tank after the test was completed by using chain saws and hand jacks to remove it from the ice and transport it to the next test site (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, pp. 4-21 to 4-23). Ice core samples were also taken from tank test sites, with readings made of temperature and salinity. These tests were implemented in many forms that varied in length (short-term and long-term), ice condition (infinite sheet, semi-finite sheet, and wedge), and loads (single and multiple loads).

These tests were also conducted on the experimental plots themselves, such as cantilever tests installed onto swept and scarified plots in order to assess bond strength between natural and

flooded ice (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-16). In total, 89 cantilever beam tests were performed on both natural ice sheets and artificially strengthened sheets using a 12-step sequence of installation (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-37). The cantilever tests also used LVDTs to measure impacts, and collected 37 temperature and salinity profiles. Scientists also conducted "ice anchor" tests to evaluate how much horizontal force an anchor could withstand to pull a pipeline across the bottom of a channel, concluding that a 1.7 meter ice sheet could withstand a 100,000-pound lateral loud for "at least 24 hours" (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-51).

Laboratory testing of ice, including the growing of saline ice, continued concurrently in southern facilities. Such testing processes demonstrated the fundamental alienation of capitalist natures from their contexts. Arctec Canada (1975) acknowledged that previous attempts to collect data from tests conducted on Arctic ice produced results that were "highly scattered, so it became difficult to define a viable mathematical model" (p. 1). In response, the firm opted to investigate whether lab-grown ice would produce "better results." While data produced using lab-grown ice was "slightly less scattered," researchers continued to encounter serious problems with the impacts of brine on testing in the lab, concluding that a technological fix may be required like quick freezing the ice using a cryogenic spray freezing system designed for ship model tests (Arctec Canada, 1975, p. 1). Ice proved to be an ever-fickle object of analysis, even when synthetically produced in a highly controlled laboratory environment.

A computer program using a finite element method—a technique that emerged from the aerospace industry and relies on "discretization" of data to understand and predict complex systems—was designed, integrating previously produced data from small samples of Rea Point ice. The computer program to evaluate short-term loads on ice strength, titled PLATE, rendered ice as a mechanical material, "treated as a plate on elastic foundations," in order to predict stresses, deflections, and load capacity (Montreal Engineering Company, 1975a, pp. v, 3-1). Its base mathematical assumptions were that "the material properties of the ice are completely known and that the ice cover contains no cracks or any other defects" (Montreal Engineering Company, 1975a, pp. v, 3-1).

These varying properties continued to hinder predictive functions: Montreal Engineering Company (1975a) listed "unseen cracks, snow ice layers, brine pockets and air pockets" as

complicating knowledge production, and noted that artificially strengthened ice sheets allowed for greater predictive accuracy as it removed many "undiscovered defects" (p. 2). In response, Montreal Engineering Company (1975a) recommended even more small sample tests, field tests, and laboratory tests to produce "a thorough knowledge" of missing data sets (p. 2).

To be sure, some semi-usable conclusions were being reached. For instance, by 1976, Polar Gas determined that a "minimum thickness" of 1.52 metres of ice was required to ensure that a short-term load like moving equipment or vehicles or long-term loads like stationary support equipment could be safely supported (R.J. Brown and Associates, 1976a; Montreal Engineering Company, 1976, pp. 2-3 to 2-4). However, these kinds of predictive measurements continued to assume the ice was continuous and free of problems like cracks and pressure ridges. This testing in turn became increasingly complex in nature, involving mathematical formulas and technical advances. Multiple years of concerted study had produced countless new objects of inquiry and frustration, necessitating production of further experimentation and expertise to interpret resulting data. Scientific failure only entrenched the need for more scientific inquiry. These practices were not politically neutral: they produced abstracted and exploitable natures.

Entrenching ice

Scientific inquiries into ice thickness and strength were performed to allow for the eventual establishment of construction equipment and infrastructure onto the ice. The first major type of equipment that would be required for pipeline installation was the trenching unit, used for almost all proposed installation methods (with the sole exception of the "seal hole" concept that was engineered later in the project's lifetime, as a direct result of this testing). This trenching equipment was manufactured and designed for application in southern environments, requiring production of new knowledge specific to Arctic environments (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973). This was necessary as all pipeline installation methods required continuous trenching of some kind, with the exception of the "seal hole" concept that emerged later on. In order to safely and efficiently install the pipeline, Polar Gas needed to produce knowledge about the impacts of trenching on the behaviour and strength of ice sheets.

In 1973, over the period of two months, an estimated 55 kilometers of trench was dug across Byam Channel and Austin Channel using a 58,000-lb ditcher equipped with a large

bucketwheel (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. v). The trench was dug to a depth of seven feet, with about 3.2 kilometers of progress made per 24 hours (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. v). The research marked a designated route for the trencher by planting 12-foot high aluminium pipe stakes every 0.3 kilometers that were "easily identified in all weather conditions and proved useful guides for vehicles travelling on the ice during periods of poor visibility" (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 2-1).

One of the key components of trenching experiments was observing the rate of closure, or how quickly the open trench refroze (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, pp. 2-6 to 2-7). Observations found that up to six inches of refreezing occurred in the trench within 12 hours (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 2-5). Experiments were made to prevent the trench from quickly re-freezing, including immediately removing the "slush ice" from the trench, and bubbling compressed air from a submerged hose (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 2-5). The researchers found that removal of slush ice helped, while the use of compressed air actually accelerated the reformation of ice crush "due to buildup of the freezing spray" (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 2-5).

Other efforts were made to impede refreezing by placing 50-foot "plugs" of un-trenched ice in the trench every 1,000 feet: this was found to create a maximum boundary condition of six inches of closure, failing to resolve the issue (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 2-7). In this process, blocks of ice was conceived as a possible impediment to the formation of undesired ice. Critical engineering lessons were learned about the ditching operation, with the vehicle experiencing "excessive wear" due to the harsh conditions and necessitating daily maintenance and repair (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 1-17). Attempts to provide more physical support to the ditching wheel were fruitless, with additions becoming bent and damaged, and the weight of the vehicle itself caused deflection in the ice that resulted in a constant uphill motion. Many other complications were experienced, with weather

and repairs delaying operations considerably (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 2-3).

A 1973 research program had planned to conduct testing "at each stage in the logical expected failure sequence," but mechanical problems with the trencher delayed the testing so significantly that the plans had to be abandoned due to warmer temperatures (Arctec Canada, 1973a, p. 20). However, despite mechanical issues with the ditcher, it was found that its performance had "conclusively substantiated the feasibility of cutting a trench through uniformly thick sea ice" (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. v). Unfortunately for the consortium, sea ice was rarely uniform in its thickness or free of complicating factors like pressure ridges, ice island fragments, and cracks; this meant the engineering process would require a "negotiation" with the ice so the operations could "proceed without interruption" (R.J. Brown and Associates, 1976a, p. 3-3). One technique of "negotiation" was articulated in one of 13 schemes devised by the firm for pipeline installation, in which the load of the pipeline and installation equipment would be transferred to the trench walls, "thus using the ice in its strongest mode, namely compression" (R.J. Brown and Associates, 1976a, p. 4-16). The production of capitalist natures, in the form of the trench, enabled the possible use of the ice in a form more effective than previously available.

This ice trenching itself enabled data collection on a wide range of subjects including ice thickness, movement, and strength (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. vi). As mentioned earlier in this case study, trenching allowed for Geophysical Survey Systems to test its ESP thickness system. Load-bearing experiments were also conducted to specifically simulate trencher loads, with an "end of trench" test added to the 1974 program (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-20). In this way, the excavation of ice produced the possibility for efficient data collection that in turn advanced the possibility of more trenching.

It was also conducted in conjunction with other knowledge production efforts, such as the use of sonar equipment to collect data after the trenching of 3,000 feet adjacent to the shoreline in 1973 (Montreal Engineering Company, & Banister Pipelines, 1975, p. 4). Core sampling of channel bottoms was scheduled to immediately follow behind the trenching machine during its 1973 run (R.J. Brown and Associates, 1973, p. 8). However, the coring operation started 10 days later than expected, requiring the coring group to reopen the trenches at each sampling location

using ice picks and chainsaws. It was also observed that trenching experiments altered wildlife behaviour, with seals using the trench as breathing holes and a polar bear seen hunting along its edge: “Animals appear to have been attracted to the trench in much the same way that they are attracted to a natural lead,” one report concluded (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 3-36).

The “seal hole” concept for bottom-pull pipeline installation was designed as a direct result of these trenching experiments. In its description of the proposed process, R.J. Brown and Associates (1978) argued that ice thickness in some channels are too great for existing trenching techniques, resulting in three potential technical solutions: 1) rerouting the pipeline; 2) building trenchers with the ability to cut to the depths necessary; or 3) inventing a new method of pipe pulling that did not require a continuous trench (R.J. Brown and Associates, 1978, p. 1-1).

Another approach that Polar Gas took to producing scientific knowledge about the trenching of Arctic ice related to the performance of icebreaking vessels in the Arctic, a question that would soon be greatly expanded upon with the emergence of the Arctic Pilot Project. In 1977, Polar Gas participated in a six-week icebreaking experiment with the *Louis S. St. Laurent*, Canada’s largest icebreaker, including 35 representatives of government and industry on board (Polar Gas Project, 1977b). This experiment intended to evaluate if an icebreaker could successfully reach Resolute from Dartmouth several months before the shipping season typically began. Representatives from Polar Gas intended to use the opportunity to conduct a feasibility test of operating a laybarge in East Barrow Strait—one of the many pipeline installation techniques under consideration, with additional application as a supply vessel—with a focus on whether an icebreaker “can initiate an early break up” to facilitate such efforts (Polar Gas Project, 1977b). For Polar Gas, this represented a very large-scale trenching operation to test one of its many pipeline installation methods; far from mere scientific observation, this effort sought to produce extremely dramatic changes in the existing ice regimes for the benefit of pipeline installation efforts. Such efforts were representative of an early understanding of “accumulation by disappearance” that has since found greater support for shipping through the Northwest Passage as climate change reduces ice coverage and density (Dodds, 2019, p. 3-4).

Eventually, the icebreaker—equipped by Arctec Canada with instruments to measure hull strain, torque, horsepower, and observations of ice conditions—became stuck in four-foot ice in Barrow Strait about 80 kilometers away from Resolute (Polar Gas Project, 1977b). While some

passengers on the icebreaker were flown out, scientists remained to conduct ice thickness and salinity tests although "activities on the ice were greatly reduced by the presence of 8 polar bears" (Polar Gas Project, 1977b). Polar Gas (1977b) concluded that the icebreaking experience indicated the shipping season could indeed be extended with larger and highly strengthened ships, with the information deemed useful as a database to both frame regulations for Arctic marine transportation and better designed Arctic vessels. One key takeaway for the consortium was that two icebreaking tugs could be used in tandem to perform the same function as a larger Class 7 icebreaker, with Polar Gas (1977b) reporting they were "considerably encouraged" due to the possibility of reduced costs. While the journey of *Louis S. St. Laurent* did not go completely as planned, failing to reach Resolute or adjacent sites, it was highly productive of capitalist natures.

Unsurprisingly, producing such natures via full-scale icebreaking operations was very costly and resource intensive. Another approach to production of cryo-nature devised by Polar Gas contractor Offshore Technology was to radically reduce the size and scope of the experiment by building a small model of a laybarge out of plywood and plexiglass, at a scale of 1:48, to evaluate factors in a laboratory environment including the impacts of ice on a moored barge and the behaviour of ice floes in the vicinity of a barge (Offshore Technology, 1977, p. 6). Through this technique, Arctic environments and the problems they presented were translocated and miniaturized to produce natures that would eventually return to the original site of study. Writing about the application of modelled experiments to the much larger prototype laybarge, report authors argued: "Measurements of distances, angles, time and acceleration induced forces can be transfered quantitatively to the prototype equivalent without reservation" (Offshore Technology, 1977, p. 4).

The researchers manufactured synthetic ice floes out of a wax base material spanning anywhere between 60 and 300 square feet to simulate the density and strength of Arctic ice. The movement, speed, and concentration of the synthetic ice was altered by using underwater nozzles to create artificial currents (Offshore Technology, 1977, p. 40). The synthetic ice proved a somewhat fickle material to work with: planned dimensions of the ice became "somewhat irregular" due to breaking of the ice during formation and testing, and required "herding" with a floating boom (Offshore Technology, 1977, p. 30). The tests included combinations of many different variables, including the directions and speed of the current, percentage and size of the

ice cover, and the model barge mooring patterns (Offshore Technology, 1977, p. 40). The report did not conclusively resolve design questions about the laybarge, but produced a comprehensive set of knowledge that could be scaled up to construct a laybarge for Arctic operations.

Ice trenching testing and experiments was a process fraught with complications, failures, damaged equipment, and inconclusive results. But while flawed in execution, the material process of trenching in both the Arctic and laboratory environment was highly generative, producing new rights-of-way with aluminium stakes, managing the closure rate through removal of slush ice and using of ice plugs, and advancing conclusions about icebreaker designs. The ice trench itself became an object of inquiry and usage: something to be "negotiated" with, harnessed to access other types of data collection, imagined as a structural material to manage loads, and even an opportunity used by seals and polar bears for breathing and hunting. The failure to trench across thick multi-year ice led to the production of an entirely new pipeline installation technique, named after one of the animals that used Polar Gas trenches. These practices cumulatively produced new natures.

Securing the pipeline

The three fields of analysis explored so far in this case study concerned the rendering of ice as something stable, particularly in its usage as a structural material for engineering ends. The final category of analysis focuses on a more direct perceived threat to long-term pipeline operations: the movement of large masses of ice—particularly icebergs, ice islands, and ice ridges—as well as the behaviour of ice in rivers on the mainland. These objects were identified of great concern to Polar Gas given their potential to seriously damage the pipeline if not properly studied and accounted for in the pipeline design and depth. This perception contrasted with Inuit usages of icebergs, which included relying on their effects on sea ice that created openings in the ice that could be used for hunting seals (Duffy, 1988, p. 20). By examining Polar Gas-commissioned research conducted about the physical creation and movement of icebergs, ice islands, and river ice, it is possible to assess how capitalist natures were produced and moved geographically to encompass new objects of concern.

Ice scour, which occurs when a seabed is gouged by ice, was the most immediate concern for pipeline proponents. In 1975, a representative of Montreal Engineering Company specified in a presentation to the consortium that scour "poses one of the major hazards to bottom-laid

pipelines" and "the data base for the analysis is relatively small" (Montreal Engineering Company, 1975b, p. 2-1). Although little comprehensive knowledge existed about the problem, isolated field observations had been made over the years. Since the 1950s, the federal government had produced weekly data about ice reconnaissance and forecasting in the Arctic region (Montreal Engineering Company, 1975b, p. 3-1). Polar Gas desired more frequent ice observations and commissioned daily ice observations in East Barrow Strait to better predict construction time, which was heavily influenced by the presence of ice masses. The proposed laybarge construction technique required support vessels to keep ice masses cleared from the work area, and for a "suitable sheltered place" for it to be retreated to in case ice masses became too threatening to operations (Brown & Root, 1976, pp. 2-1 and 8-38).

In May 1973, divers working for Polar Gas examined the bottom of Byam and Austin Channels in three locations, locating ice scour at 36 meters of depth while side scan sonar records located frequent bottom scouring at up to 220 meters in depth (Montreal Engineering Company, & Banister Pipelines, 1975b, pp. 2-23 to 2-24). However, Polar Gas concluded that deep scours were of "ancient origins," identified based on their "masked appearance indicating that they have been partly infilled with fine material" (Montreal Engineering Company, & Banister Pipelines, 1975b, p. 2-24). Similar efforts made by the Geological Survey of Canada in 1974 involved dives at 25 locations in Byam Channel, with unpublished results indicating the channel bottom had be "extensively worked by ice scour action" (Montreal Engineering Company, & Banister Pipelines, 1975b, p. 2-24). Side scan sonar records were also imported from Beaufort Sea region, as it was believed that ice masses causing scour had similar keel depths in both locations (Montreal Engineering Company, & Banister Pipelines, 1975b, p. 2-25). These efforts represented a "vertical intensification" of management in response to perception of potential failure (Bennett, 2016, p. 258).

Montreal Engineering Company (1975b) outlined that comprehensive knowledge production about scour would need to include frequency of scouring, depth at which it typically occurs, and the physical size of scours. Two approaches to investigating ice scour were identified by contractors: the dating technique (including isotope, sedimentation, and biological dating) and the mosaic technique (producing annual records of changes to evaluate ice scouring and water depths) (Montreal Engineering Company, & Banister Pipelines, 1975b, p. 1-7). However, both of these approaches, examining the effects of ice scour, were discarded due to technical and time-

based limitations. For example, the sedimentation dating proposal—using measurements of sediment thickness to estimate the date of ice scour—was deemed infeasible as it required "extremely precise techniques" and there was a lack of information on historical deposition rates to compare (Montreal Engineering Company, & Banister Pipelines, 1975b, p. 1-3).

As a result, the firm said that a "deterministic approach" had been harnessed to analyze ice scour, which sought to analyze the cause of ice scour, rather than its effects (Montreal Engineering Company, & Banister Pipelines, 1975b, p. 1-3). This "deterministic" approach required a "thorough knowledge of the origin and movements of ice masses both in the Arctic Islands and outside the Islands" (Montreal Engineering Company, & Banister Pipelines, 1975b, p. 1-7). Rather than seek to produce knowledge about ice scour as an object, a technically and resource-intensive process, the consortium determined that it would more effective to produce knowledge about the ice masses that create ice scour. In this way, production of capitalist natures were extended to new sites.

The firms first had to establish what was known, and not known, about ice masses. A broad literature view on existing knowledge found that no concerted effort has been made to document the occurrence of major ice masses in the Arctic Islands, with studies only carried out on an isolated and effectively random basis by the Polar Continental Shelf Project and Defense Research Board (Montreal Engineering Company, & Banister Pipelines, 1975b, p. 1-8). To compensate for this absence in knowledge, the firms contacted 30 people with knowledge of ice scour, including government, industry, universities, and scientists (Montreal Engineering Company, & Banister Pipelines, 1975b, A1-1 to A1-2). In this way, expertise was actively produced and formalized in writing as a reliable source compensating for lack of direct field data; representatives of the Cold Regions Research and Engineering Laboratory, Atmospheric Environment Service, Geological Survey of Canada, and Gulf Oil were authorized to literally speak about the object of ice masses and scour.

As a result, an episteme about scour was advanced as knowable through the production of a taxonomy of ice masses. The objects of icebergs, ice islands, and ice ridges could be "read" as containing crucial environmental knowledge that would shape pipeline design. In 1974, Polar Gas contractors conducted a week-long field program assessing the height, depth, and bottom profiles of four ice island fragments and a multi-year pressure ridge in Byam Channel, with depth soundings taken through holes augured in the ice (Montreal Engineering Company,

Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-57). These ice masses were described in highly specific detail: regarding the pressure ridge, observers wrote: “Below the ice sheet the ice mass tapered inwards so that its shape resembled an inverted prismoid having dimensions of approximately 29 m by 18 m by 18 m at the sea bed” (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, p. 4-57). While the deterministic approach aimed to understand the ice masses themselves, several scours were identified as directly caused by the ice masses examined. Aerial photographs were also taken of the ice masses. In order to enable photographs of the ice masses taken from helicopters to be properly scaled, and physical dimensions calculated, black paint markings were made at three-meter intervals on two of the ice islands (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, pp. 4-58 to 4-59).

This 1974 winter research program also included measurements of ice movement taken at three sites on West Barrow Strait: three barrels were physically placed on the ice and observed over time. A representative of Montreal Engineering Company warned that an ice mass becoming trapped in pack ice would result in “the severest or deepest scours” (Montreal Engineering Company, 1975b, p. 2-4). However, these results were deemed inconclusive as the observed ice movement of 20 feet or so could not be adequately calibrated with the helicopter-carried system that only had an accuracy of 10 feet (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1974, pp. viii, 4-56). The technologies available for surveying of ice masses remained largely improvised and inadequate for the goals of the consortium, which required greater accuracy and detail.

Investigations concluded that the “maximum probable water depth” of ice scour was 45 meters or so, “provided that large icebergs of glacial origin cannot travel to the pipeline crossings” (Montreal Engineering Company, & Banister Pipelines, 1975b, p. ii). It was estimated that ice conditions would only be ripe for a potentially dangerous ice island or fragment to enter the area once every ten years (Montreal Engineering Company, & Banister Pipelines, 1975b, p. 2-19). However, the authors maintained there was insufficient data available about whether ice masses would pose significant risks to pipelines, despite having produced knowledge used to minimize their threat level. As a result, the report recommended field investigations into the movements and sizes of icebergs, as well as an investigation of sea bottom conditions at

locations of all potential pipeline crossings. The scientific labour of identifying existing gaps in knowledge led to the production of further inquiry.

This report directly led to a field investigation of major ice masses that followed included two key components: 1) measuring icebergs at several locations on Devon Island and Axel Heiberg Island; and 2) measuring ice shelf thickness along the north coast of Ellesmere Island (Montreal Engineering Company, & Banister Pipelines, 1975a, p. 1-3). The inquiry, carried out by a half-dozen people from Banister Technical Services and Memorial University, worked out of Resolute and Eureka. A total of 11 icebergs were identified for study, chosen based on a visual reconnaissance of the area and determination that they had the "largest mass and/or sail height" (Montreal Engineering Company, & Banister Pipelines, 1975a, p. 1-4).

For each of the icebergs, acoustic stations and photographic stations were established near the iceberg to measure its maximum keel depth, underwater profiles, and maximum sail height (Montreal Engineering Company, & Banister Pipelines, 1975a, p. 1-6). Three icebergs were also marked with weighted 10-gallon oil drums to permit visual identification and tracking of the masses at a later date (Montreal Engineering Company, & Banister Pipelines, 1975a, p. 1-7). The acoustic station lowered a sonar device through a small hole in the ice and recorded the echo off the iceberg onto a wet-paper recorder until it no longer received a signal, and the iceberg depth was calculated. Meanwhile, the photographic station took overlapping photos of the iceberg, which was then used to calculate the iceberg height using stereoscopic analysis. The study found that keel depths of the icebergs were significantly greater than expected, leading them to conclude that evaluating iceberg depth could be "significantly in error" (Montreal Engineering Company, & Banister Pipelines, 1975a, p. ii).

The ice shelf measurements were made at Milne Fiord Ice Shelf and Ward Hunt Ice Shelf from a fixed-wing airplane using an echo sounding system and recorded on magnetic tapes (Montreal Engineering Company, & Banister Pipelines, 1975a, p. 1-7). While acknowledging the greatest hazard posed by icebergs would be those originating from Devon Island, the study confirmed the previous study's estimation of the risk of an ice mass scouring at depths of 45 metres and below as a remote possibility. However, the report only cited the beliefs of "some researchers" and acknowledged that "this belief is one which may well be impossible to substantiate as the grounds for such a belief are primarily of a subjective nature" (Montreal Engineering Company, & Banister Pipelines, 1975a, p. 2-6). Production of capitalist natures

continued the more general trend of leveraging scientific failure into legitimizing a discourse predicated on expertise, even when that expertise was explicitly "subjective" in nature.

A 1978 report by Polar Gas concluded that its studies had "defined and categorized this ice scour phenomenon and determined that it will not pose an insurmountable barrier to pipeline construction" (Polar Gas Project, 1978, p. 14). The so-called "tunnel riser approach" was designed to help alleviate possible scour conditions close to the shore, although contractor Pentzien (1978) noted that there had to be a "careful balance" struck between protecting the pipeline from scour and controlling for "valuable construction time and additional project costs" (p. 52). While the possibility of ice islands and ice ridges in the region remained, the consortium had devised technical solutions such as tunnelling and risk calculations that allegedly guaranteed that "the security of the pipeline system against ice scour is assured" (Polar Gas Project, 1978, p. 14).

At the same time, production of cryo-nature spread southward from the Arctic Islands in anticipation of the pipeline route, which proposed to run down the western side of Hudson Bay. Contractors hired by Polar Gas interrogated the behaviour of ice at rivers where the pipeline would have to cross, as there were concerns that scour could occur against the river bed and cause bank erosion. In 1976, Northwest Hydraulic Consultants conducted aerial surveys using helicopters and airplanes of dozens of rivers where the proposed pipeline would cross. These observations produced data about ice break-up patterns, ice jams, and bank erosion, with "engineering judgement" appealed to in order to determine the location and design of a buried pipeline (Northwest Hydraulic Consultants, 1976a, p. 3). The next year, in 1977, further studies were conducted of ice conditions and runoff patterns in rivers. Several rocks were painted before break-up in order to observe their movements over time, with only a few moving for distances less than 3 meters (Northwest Hydraulic Consultants, 1977, p. 32). Willow shrub samples were also collected at two sites to assess the impacts of ice action by evaluating their annual growth rings and approximate ages (Northwest Hydraulic Consultants, 1977, p. 32). Rocks and shrubs were conceived as objects containing environmental information that could be interpreted to produce predictable and exploitable natures.

Previous inquiries had identified ice as a material that could be strengthened and improved for the purposes of pipeline installation. This set of scientific questions and practices expanded that scope to assess the dangers of both concentrated and mobile ice masses with the

potential to cause substantial physical damage to a pipeline once installed, or to a laybarge installing or repairing a pipeline. These practices included a literature review of existing knowledge, contacting experts, and deciding on a "deterministic" approach of knowledge production. These inquiries extended vertical legibility of ice masses and movements, including aerial surveys of icebergs and diving to observe scour on channel bottoms.

Many of the efforts were very ad-hoc in execution, including observing the movement of barrels and boulders as representative of potential risk levels. Polar Gas' interrogation of ice masses including icebergs and ice islands framed them as something dangerous but potentially manageable if adequately known and planned for. These inquiries expanded the scope of capitalist natures geographically both north and south and produced increasingly focused scientific discourses about the behaviours and characteristics of glaciers, ice masses, and break-up patterns in rivers. Much of this process involved the identification of existing gaps and failures in knowledge, along with techniques of knowledge production that were "significantly in error" and "impossible to substantiate." These efforts advanced technical knowledge of the Arctic as a site of capitalist production.

Conclusion

Over a few short years, the Polar Gas Project and its network of contracted firms produced an enormous quantity of scientific knowledge about ice. This knowledge was collected and distributed through written reports for use by the consortium, and its private and state members, for decision-making in southern metropoles. This chapter has described the four general categories of inquiry into ice: 1) ice thickness and surveying; 2) load-bearing capacity of ice; 3) ice trenching techniques; and 4) ice scour and ice masses. However, this research did not proceed in such a strictly coherent fashion, with significant crossover between inquiries (such as ice trenching allowed for testing of a thickness surveying system) and knowledge accumulating over time in a way that produced new objects of study (such as thickness measurements being impeded by salinity). These studies frequently ended in failure, technological breakdowns, or lack of reliable data—but these failings were highly productive, resulting in refining of focuses for future studies, identification of methodological and technical flaws, and creation of new engineering designs like the "seal hole" pipeline installation technique.

These practices rarely involved or implicated Inuit in significant ways. Part of that was because there were not many Inuit communities in the Arctic Islands, where most of this scientific knowledge production took place, with Panarctic's chosen headquarters of Melville Island uninhabited by humans. Advocates of the project frequently used frontier discourses to describe the region as "unproductive" and "unpopulated," helping justify colonial incursions. However, that was far from true for the entirety of the pipeline route, with sizable environmental impacts anticipated to manifest near settlements like Resolute and Baker Lake and resulting in organized opposition to the project by many Inuit organizations including the Inuit Tapirisat of Canada (Carruthers, 1978). These scientific efforts occurred without any attempt to gain consent from Inuit: land-use permits for the programs were made by Panarctic on behalf of Polar Gas to federal departments (Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates, 1973, p. 1-3). The next case study, concerning the Arctic Pilot Project, delves deeper into the perceived relationship between ice science and Inuit usage.

Polar Gas and its contractors were far from the first institutions to produce capitalist natures and practice scientific labour in the Arctic Islands; that history traces back centuries, involving colonial explorers, military, and dedicated scientific research. Despite its eventual failure, the pipeline consortium expanded capitalist nature, rendering ice as something exploitable and enabling commodity circulation. These efforts to survey, experiment, extract, probe, trench, and synthetically grow ice were circulations of capitalist and colonial power that produced new possibilities for capital accumulation while foreclosing more liberatory alternatives. For the most part, Polar Gas and its contractors produced ice as what Collard and Dempsey (2017) describe as "the underground" nature, or the unvalued services provided by environments, along with unwaged labour by women throughout history (pp. 89-91). Ice needed to be rendered stable and predictable for commodity circulation to occur. The seals and polar bears that appeared in the newly formed trenches produced by the scientific inquiries can be understood as the "outcast surplus," or "those whose presences do not even register to capitalism" (p. 91). However, there was an ever-present production of ice as a "threat," particularly in the form of unaccounted icebergs and other ice masses that could create devastating scour (Collard and Dempsey, 2017, p. 93).

In 1978, during the waning years of the project, Polar Gas published a promotional booklet boasting of the scientific and technological advances resulting from these processes. In a

rousing conclusion, Polar Gas declared: “In short, technology is in hand. Research has proven up practical channel crossing methods. Economic and environmental concerns can be satisfied. The challenge posed by the ice can be conquered” (Polar Gas, 1978, p. 19). This final sentence was in many ways the foundational ambition and outcome of the consortium’s scientific work: to conquer the ice, not only for a pipeline but for capital accumulation.

Chapter 5: Arctic Pilot Project

Introduction

In October 1978, William Sidjak, a project manager for Petro-Canada, presented on the Arctic Pilot Project to the 28th Canadian Chemical Engineering Conference in Halifax. The proposal of transporting natural gas out of the Arctic using liquefied natural gas (LNG) tankers had been in the works for two years by that point and was accruing ever-increasing public attention. Although he did not explicitly identify the competing Polar Gas Project by name, Sidjak (1978) noted that other proposals to transport Arctic gas had been hindered by their "inherent large size" and "have suffered long delays in obtaining regulatory approvals and in completing construction with consequent large cost over-runs" (p. 1). The solution to this identified problem, Sidjak (1978) argued, was beginning production with a "reduced scale pilot projects" and increasing capacity over time. While the Polar Gas Project was still afloat at the time of Sidjak's presentation, abandoning its previous routing for a combined pipeline system integrating Beaufort Sea gas, the Arctic Pilot Project was overtaking it as the most viable option on the table.

Rather than laying thousands of kilometers of pipeline across a variety of terrains like Polar Gas proposed, Arctic Pilot sought to build a port on the southeast shore of Melville Island to liquify and export natural gas using large icebreakers through Davis Strait to Eastern Canada. Upon reaching its destination in either Nova Scotia or Quebec, the liquefied gas would be regasified and shipped to consumers. Despite its smaller scale, many outstanding questions remained about the technical feasibility of the plan. In his presentation, Sidjak (1978) said: "The study of the marine portion of the project revolves around one important and basic question: Can large icebreaking carriers operate all year round in the Arctic waters leading to Bridport Inlet?" (p. 6). Unsurprisingly, ice was again identified as the material to be rendered predictable; Sidjak (1978) specifically named "7 ft. level ice, rubble ice fields, up to 5 ice ridges per miles, high winds, and cold temperatures" as environmental conditions that made the Arctic Pilot Project "an exacting proposition." The Environmental Assessment and Review Process (EARP) report observed that ice conditions along the route "vary considerably" in coverage, thickness, and type; winds and currents formed large pressure ridges; and Davis Strait was rife with icebergs and other ice masses (Arctic Pilot Project Environmental Assessment Panel, 1980, pp. 30-32).

Many similar techniques were used to produce knowledge about ice as in the Polar Gas case. But there were also key differences between the two projects in how they confronted the problem of ice. The routing itself of the project was distinct in geographic location: while Polar Gas proposed traversing Bathurst Island, Cornwallis Island, Somerset Island, and the Boothia Peninsula, the Arctic Pilot Project extended far more eastward. This scope required entirely new knowledge production about ice mechanics and behaviour in Lancaster Sound and Davis Strait, as well as evaluating potential impacts on Inuit communities of Pond Inlet and Arctic Bay.

The geographic extension of the project's scope from what was proposed by Polar Gas resulted in additional attention and criticism from potentially impacted groups, including Inuit hunters in Resolute and the government of Greenland. In turn, this necessitated the production of new objects of knowledge by the consortium in order to manage and reduce social and environmental impacts. While some efforts were made by Polar Gas, resulting in the rerouting of parts of the proposed pipeline, the sites of intervention were greatly expanded and intensified through the Arctic Pilot Project and environmental assessment processes.

This case study organizes the consortium's inquiries into four main categories: 1) ice management at Melville Island; 2) ice conditions along the shipping route; 3) icebreaker vessel design; and 4) mitigating impacts of icebreaking. While scientific investigations did not proceed in such a coherent and organized fashion as suggested by these categories, this approach allows for more systematic exploration of how ice types and impacts were identified as objects of concern that in turn warranted interventions. The Arctic Pilot Project was sold as a large-scale scientific experiment that would produce knowledge about its own impacts through the course of its lifespan and improve extractive potential throughout the Arctic.

Imagining a new icebreaker

Unlike the complex pipeline installation proposals produced by the Polar Gas Project, the Arctic Pilot Project did not require entirely new engineering schemes to implement. Rather, the central technical question facing the consortium concerned the nature of the icebreaking tankers. The theoretical basis for icebreaking ships already existed; icebreakers had long operated in the Canadian Arctic, including the Coast Guard's *Louis S. St. Laurent* used in the 1977 trenching experiments and Dome Petroleum's *Kigoriak* that delivered supplies to drilling operations in the Beaufort Sea.

The Arctic Pilot Project took direct inspiration from these vessels. A 1983 journal article by Petro-Canada's Ricard A. Bailey, manager of planning for the Arctic Pilot Project, wrote that many design features "are based on refinements of the design" of the *Kigoriak* (p. 264). Bailey (1983) wrote: "As a consequence of the ice conditions, the Arctic Pilot Project has undertaken to design the largest and most powerful ice-breaking vessels ever envisioned" (p. 259). The Arctic Pilot Project (1979b) wrote in an application to the federal Department of Transport that "their design and operation by Canadians will move Canada to the forefront of world ice-breaking technology" (p. 10). The largest ships built in Canada up until that point had been two 80,000-ton tankers constructed by Davie Shipbuilding in Lauzon, Quebec: the Arctic Pilot Project vessels were equivalent to 180,000 tons, more than twice the size ("Size of tankers," 1977). Each would be 370 meters long by 43 meters wide, carrying up to 140,000 cubic meters of LNG (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 30). Their 180,000-shaft horsepower would represent more than four times the power of *Manhattan* (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 59).

While the Arctic Pilot Project was originally marketed as something that would greatly boost shipbuilding capacity in Canada, it was soon realized that the LNG tankers would have to be built outside of the country due to the sheer size of the operation. Upgrading Canadian dockyards with enlarged infrastructure and equipment to construct the tankers could total $70 million, which Melville Shipping's Michael Bell suggested would not be viable due to the limited number of tankers required by the project and global depression reducing construction prices abroad ("Size of tankers poses problem," 1977). Jennifer Lewington (1988) estimated that only 36 percent of the value derived from tanker construction would originate in Canada, with the remainder benefiting foreign manufacturers (p. 169).

Bailey (1983) described some of the key design features that the project's tankers would include: a "spoon-shaped bow with reaming flanges" to break ice in a downward direction; a "water deluge system" that would pump warm water onto the ice in front of the ship to reduce friction; gas-turbine engines that would run on vapours boiled off from the LNG cargo; and power that made them "amongst the most powerful non-military vessels in the world" (pp. 14-15). These icebreakers would be classified as Class 7 vessels, meaning they could operate in seven feet of level first-year ice (Bailey, 1983, p. 14). There were also strict requirements of the LNG storage techniques, requiring all related equipment to be capable of operations at cryogenic

temperatures and preventing contact between air and LNG (Arctic Pilot Project, 1978, p. vii). These complex technical advances reflect the assessment made by Gavin Bridge (2004), writing that gas is an "uncooperative commodity: it may have use-value and be in plentiful supply, but producing its exchange value requires the labours of science, capital and law" (p. 396).

But the icebreakers represented far more than simply unprecedented size and strength in shipbuilding and natural gas transportation: they were constituted by the consortium as embodiments of scientific knowledge production about a wide range of unknowns, integrating concerns about social and environmental impacts into the physical design of the ship itself. This vision continued the legacies of previous icebreaking voyages including the *Manhattan* in 1969 and *Louis S. St-Laurent* in 1977 that used the ships as giant mobile laboratories to gather environmental data. In 1983, Petro-Canada estimated that the project would spend $220 million—equivalent to just under $520 million in 2020 dollars—over the 20-year lifespan of the pilot project on research and development, into "environmental, socio-economic and technical questions" (Bailey, 1983, p. 17). This data from the 15 round trips per year would then be integrated into future vessel designs in an attempt to mitigate impacts and criticism that could impede extraction. The Environmental Assessment and Review Process (EARP) concluded in its report that "the relatively small-scale shipping proposal by the Arctic Pilot Project would permit further study and allow more accurate assessment of potential impacts and ways to minimize or determine more fully the effects of large scale shipping" (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 4).

Such an approach became increasingly necessary following the EARP that saw Inuit communities articulate many serious concerns about the project's impacts, alongside rising political organization by the Inuit Circumpolar Council and government of Greenland. The pilot project was marketed as a means of resolving concerns about social and environmental impacts by producing knowledge through the process itself.

While only part of this process involved environmental assessment reviews, the Arctic Pilot Project integrated the broader motivation of such logics embedded in environmental assessments that "implicitly facilitates a project's eventual approval" (Li, 2009, p. 225). In this way, the consortium created vessel designs and focused experiments that became new sites of knowledge production and advanced a discourse of more "responsible" Arctic extraction; the EARP report, for instance, identified an advantage of the proposal: "it would permit future

enlargement of the Arctic Pilot Project if proven successful, and if unsuccessful could be discontinued and removed with minimal disturbance" (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 37). The Arctic Pilot Project never made it to the stage of commercialization, yet these efforts of knowledge production and transmission expanded the scope, scale, and type of natures in the Arctic.

Managing ice at Melville Island

While Arctic Pilot Project was predominantly an icebreaking project spanning thousands of kilometers of ice and water, the consortium argued that "most of the environmental interactions" would occur on Melville Island itself (1978, p. 1-1). This assessment was the result of a program of environmental studies of the island, where the Drake Point gas field is located, in 1977. Later studies and organized resistance expanded the scope of the consortium's concern, but Melville Island represented the dominant site of knowledge production at the project's inception.

One of the most pressing questions concerning Melville Island was the siting of where the pipeline from the gas field would end and the liquefaction plant and storage facility would be constructed. This resulted in the hiring of "specialist consultants" to produce a variety of studies into many environmental aspects of Melville Island, including meteorology, geology and vegetation, mammals and birds, and freshwater resources (Arctic Pilot Project, 1978, p. v). Previous studies and data production were also leveraged for this investigation, such as using weather records previously collected by petroleum exploration companies in order to produce a "reasonably complete picture" of atmospheric conditions (Arctic Pilot Project, 1978, p. 3-1).

A survey of the waters near Melville Island led to the conclusion that "unsuitable ice conditions" in nearby channels eliminated the possibility of placing the port on the northern or eastern shores of the island (Arctic Pilot Project, 1978, p. 1-3). Conversely, Bridport Inlet—on the southern shore of the island—offered "good shelter" with a narrow entrance that protected the site from pack ice. Further environmental studies were intended to assist with narrowing in on specifics and implementing measures to "minimize adverse environmental impact and maximize project acceptability" (Arctic Pilot Project, 1978, p. 2-1). Through these studies, Bridport Inlet became produced as a site of capitalist natures facilitating large-scale exports. Oceanographic studies conducted in Bridport Inlet advanced knowledge about the inlet's marine

ecosystems and devised techniques to maintain access to the shipping terminal year-round, including cataloguing patterns of ocean circulation in the inlet and coming up with techniques to control ice (Arctic Pilot Project, 1978, p. 2-6).

Without intervention, Bridport Inlet was projected to remain ice free from mid-August to mid-September (Sidjak, 1978, p. 3). An "ice management system" was deemed necessary to keep the inlet ice-free for year-round operations, reducing costs and potential risks of berthing and loading ships in thick ice (Sidjak, 1978, p. 4-5). A study of possible solutions determined the best way to do this was using warm salt water effluent from the liquefaction process to limit ice growth in the inlet, resulting in an average temperature rise in the inlet's water of 3 degrees Celsius (Sidjak, 1978, p. 5; Arctic Pilot Project, 1978, p. 5-6). The goal of this approach was to keep the ice in the inlet at a thickness of about 20 centimeters between arrivals of the icebreakers (Sidjak, 1978, p. 5).

Studies warned against attempting to melt the ice completely as it would produce ice fog, when ice crystals form suspended in the air in extremely cold temperatures. Ice fog was specifically identified by Arctic Pilot Project studies (1979a) as the result of the newly polluted air, with water droplets in the air freezing at approximately -35 degrees rather than -40 degrees (p. 128). Studies also suggested that warm effluent could undermine soil strength in the inlet that would in turn have to be factored in during the design of storage tank foundations in order to prevent collapse (Arctic Pilot Project, 1979a). The average temperature of the inlet's water was also expected to rise by an estimated 3 degrees Celsius, and the salinity of the water would "increase more rapidly" than outside of the inlet. Yet another projected side-effect of the use of effluent to reduce ice in the inlet was that the effluent may freeze between the remaining ice and seawater and be released "rather suddenly" in the spring (Arctic Pilot Project, 1978, p. 6-44).

Writing about the impacts of icebreaking on the inlet's ice cover, the consortium's technicians acknowledged: "These changes could have a variety of biological effects, none of which are well understood" (Arctic Pilot Project, 1978, p. 6-45). The EARP report took a similar approach to the question of the ice management intervention's impacts, writing that "the thermal regimes of the water and seabed are being studied in a competent manner and that with proper engineering, it does not appear that any exceptional problems will arise" (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 53). Through the process of environmental review, the production of capitalist natures was legitimized. Analysis by Bernauer (2018) also helps to

understand this process as one that works to establish consent through the awarding of minor concessions to concerned parties, such as a commitment to further study and monitoring.

The proposal to reduce ice thickness in the inlet also necessitated the design of several oil spill containment strategies, with floating booms expected to be "regularly deployed" during periods of ice-free conditions to contain leaked oil and absorbents used if ice was present (Arctic Pilot Project, 1979a). The channel created by the LNG tanker through the remaining ice was also expected to help physically contain any oil that spilled (Arctic Pilot Project, 1978, p. 6-56). Studies by the consortium also suggested that the currents in the inlet were not strong enough to drive oil under the ice, making the oil relatively easy to clean up (Arctic Pilot Project, 1978, p. 6-56).

Another anticipated impact of the ice management system was on species residing in the inlet. An Arctic Pilot Project (1979a) report acknowledged a lack of existing data about algae and Arctic mammals. The undersurface of the ice in Bridport Inlet was investigated in 1977 by divers, finding a three cm brownish layer of single-celled algae comprised 50 different species representing a complex food web: "It is evident that ice biota is important to the local ecology of Bridport Inlet; however, its significance cannot be determined at this time" (Arctic Pilot Project, 1978, p. 3-82). By 1979, the consortium had concluded that the ice algae would be eliminated in the inlet altogether. Birds and polar bears were also expected to be impacted by the industrial activity and ice management regime. Meanwhile, ringed seals were expected to continue using breathing holes in sites of reduced ice thickness, and could possibly benefit from the creation of pressure ridges "artificially produced" by icebreaking that allow for "suitable habitat" for birth lairs (Arctic Pilot Project, 1978, p. 6-46).

Concerns were raised by government departments including the Department of Indian and Northern Affairs and Department of Environment about the lack of attention that Arctic Pilot Project had paid to the impacts of marine ecology of Bridport Inlet (Arctic Pilot Project, 1979a, pp. 117-118). However, the consortium argued that was not the intent: "Studies were designed to identify any components of the marine ecosystem that were of such importance that they could potentially preclude the proposed development" (Arctic Pilot Project, 1979a). Further, in response to concerns voiced by federal departments that the ice management may introduce parasitic organisms into the inlet, the consortium argued that the potential for "colonization" of

the Canadian Arctic by plants and animals has long existed and could not be directly attributed to capitalist activities (Arctic Pilot Project, 1979a).

These represented processes of "rendering technical" impacts of capitalist development, reconstituting them within an episteme of environmental management. This applied to social and cultural history of the area too: the EARP report identified one historical site and five "known archeological sites" in the area requiring management, with protection extending to "any new ones revealed during the course of construction" (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 55). Any resulting problems could then be managed within the newly produced nature, abstracted from social relations.

Ice conditions along shipping route

For obvious reasons, the Arctic Pilot Project was interested in ice conditions well outside Bridport Inlet as well. Marine traffic had long travelled through parts of the proposed tanker route, but the consortium had many remaining questions that had to be resolved prior to planning and starting the pilot project. Scientific work about the route and its impacts took place within the broader production of an "integrated route analysis" that divided the tanker path into eight geographic areas that ranged from Viscount Melville Sound to the East Coast of Canada (Arctic Pilot Project, 1981b). While the project had been concerned about the routing since its inception, the EARP process in 1980 resulted in major revisions from a route that only prioritized "ease of transit" to one that included factors like safety, "biological and physical aspects," resource harvesting, and existing marine traffic (Arctic Pilot Project, 1981b). The outcome of this process was an exhaustive production of environmental knowledge for the purposes of capitalist exploitation. Critiques of environmental assessments by Fabiana Li (2009) and Warren Bernauer (2020) can be applied to this knowledge production, demonstrating how the process itself allowed firms to advance projects to completion while circumventing more radical critiques of their existence.

A key method relied on by the Arctic Pilot Project was the creation of a mathematical formula to help predict ice thickness and growth over time across the route. The proposed equation was originally developed in 1961 using ice growth data collected from various sites in Resolute, Alert, Eureka, and Mould Bay (Arctic Pilot Project, 1981b, p. 2-14). However, the formula was rendered invalid if the ice thickness in question was less than 20 centimetres, with

the thickness of first-year ice estimated at 25 centimetres and multi-year ice estimated at 2.5 meters: a number based on under-ice profiling conducted in 1976 in Viscount Melville Sound (Arctic Pilot Project, 1981b, p. 2-15).

The first testing of the algorithm used "real weather data and the snow depth from Resolute Bay" and found that the formula "agreed well" with more recent meteorological data when first tested but produced "less acceptable" results once a survey was conducted of ice thickness and it was found that ice was considerably thicker than assumed (Arctic Pilot Project, 1981b, p. 2-15). Meanwhile, the snow in Resolute during testing was far deeper than in Viscount Melville Sound, where the calculations were being applied. This discrepancy required technicians to multiply the Resolute snow depth by 0.4, and re-execute the algorithm to try produce more accurate predictions. Through this iterative process of corrections and calibrations, scientific inputs from one part of the Arctic were successfully relocated to another: the consortium concluded "the results were in close concurrence with the field observations" (Arctic Pilot Project, 1981b, p. 2-15). While the objective of the algorithm was to eliminate the need for direct field observations, its creation required technicians to validate its results from field work.

The predictive algorithm was also calibrated based on data produced by the *Manhattan* in 1969 and *Louis S. St. Laurent* in 1977. This process allowed the researchers to compare the accuracy of the algorithm to real-world measurements; while calculations deviated by almost a meter in Lancaster Sound compared to the 1977 data, they were near identical in Baffin Bay (Arctic Pilot Project, 1981b, p. 2-18). The two icebreaking voyages failed to achieve their original mandates in full, but the environmental knowledge produced during their trips proved extremely useful in attempting to generate a predictive approach to ice thickness. However, there were significant gaps in existing data in many relevant regions including Davis Strait and much of the Arctic, rendering it impossible to calibrate throughout the entire route (Arctic Pilot Project, 1981b, p. 2-18). The scope and range of scientific knowledge required to predict ice thickness and improve tanker route planning remained inadequate.

In addition to devising a predictive algorithm for ice thickness, the consortium sought to produce knowledge about the physical impediments and impacts of icebreaking. Pressure ridges were rendered an object of scientific knowledge production. The consortium cross-sectioned 40 ice ridges in Viscount Melville Sound to establish the amount of energy required by the icebreakers to carve a path, "provided ground truthing of over-flights" (Sidjak, 1978, p. 8).

Scientific knowledge produced through aerial observation was confirmed through direct field studies. These efforts were followed in 1978 with another on-ice survey that examined 1,300 ice ridges with a towed impulse radar, with calibration ensured by drilling boreholes into the ice (Arctic Pilot Project, 1981b).

The *Louis S. St. Laurent* trip in 1977 also produced imagery that could be used in the planning process for the Arctic Pilot Project. The consortium gathered satellite photographs taken during the several days that the icebreaker was attempting to penetrate ice near Prince Leopold Island (Arctic Pilot Project, 1979a, p. 228). Upon enlarging the satellite imagery by two times, the researchers concluded there was no major disruption of the ice sheet edge (Arctic Pilot Project, 1979a). By observing infrared satellite imagery, it was found that a rapid "healing" of the ship track occurred through refreezing and reconsolidation. The researchers also sought to compare impacts of an icebreaker traveling through "natural faults" in the ice, compared to a ship penetrating consolidated ice. Through the process, they concluded it would be best if the icebreaking tankers followed "existing leads, open or refrozen" in the ice that had been produced by previous trips (Arctic Pilot Project, 1979a, p. 233). "Natural faults" in the ice became identified as the best route for the icebreaker, that would solidify over time due to continued usage.

The *Louis S. St. Laurent* was again used for scientific production of knowledge when it embarked on a trip in July 1979—accompanied by the MV *Arctic*—into Admiralty Inlet on the western shore of Baffin Island, where information about its impacts on ice sheets and break-up patters were gathered. This voyage included a "biologist observer" to observe on behalf of the consortium about the impacts of icebreaking on whales. However, the project argued that a "major monitoring program" of impacts on whales could not be undertaken until the project itself was underway—as existing icebreakers could not penetrate the ice at the times needed, thus impeding the potential for knowledge production (Arctic Pilot Project, 1979a, p. 221). As was the case with the entirety of the proposed project, sufficient knowledge could not be produced until the project itself proceeded, creating a logical imperative that undermined all other ways of knowing and using the Arctic, and producing the conditions of feasibility of the project itself.

The consortium frequently appealed to expertise due to the overall lack of quantitative data about year-round icebreaking; its environmental statement represented "the subjective judgements of the specialist consultants and the proponent" (Arctic Pilot Project, 1979a, p. 216).

The experiences of captains of icebreaking vessels was called upon to confirm the knowledge produced through these scientific trips. For instance, “their collective experience says that when there is a wind towards the ice cover, there is no success in operating icebreakers to break that cover” (Arctic Pilot Project, 1979a, p. 234). Expertise about the behaviour of ice held by ship captains was legitimized through this process and Arctic natures were produced as exploitable.

This approach was built upon in a similar investigation the year after, with imagery from various satellites including Landsat used to prepare mosaics of several adjacent frames. The charts were printed on a clear acetate sheet at the scale of 1:1,000,000, with consecutive frames joined and attached to a cardboard base. Six categories of ice concentrations were catalogued, defined as the ratio in tenths of the sea surface area actually covered by ice to total sea area (Arctic Pilot Project, 1981b, p. 2-9). Augmenting these efforts were a collection of primary sources including ship records and coastal studies conducted between 1952 and 1972 (Arctic Pilot Project, 1981b, p. 2-10). The researchers noted that such observations featured a wide range in quality, from “subjective generalities to rigorous measurement,” and that attempts were made to standardize the observations: “All data judged to be repetitive, questionable or contradictory were rejected. Historical observations were included if judged reliable” (Arctic Pilot Project, 1981b, p. 2-11). Combining these sources, information was digitized for a 50-kilometer by 95-kilometer grid, with each area subdivided into marine grid elements and the ice cover fractions determined by average conditions.

An adjacent investigation was started in 1981 into the “ice crack morphology” in Parry Channel and Barrow Strait, an area where ice cracking often occurred; this area was known as being particularly prone to ice cracking due to a stress analysis test that had been previously conducted, as well as observations made by Inuit in Resolute identified during hunting trips (Acres Consulting Services, 1981, p. 1). Greater knowledge production was necessary in order to properly plot the tanker route and take advantage of existing cracking in the region, especially important due to the incredible thickness of ice during the coldest months in the Arctic Islands that could result in an icebreaker getting stuck and requiring rescue.

The researchers first worked to collect all existing data on ice cracking to understand their environmental impact, with a specific focus on the formation and characteristics of cracking in Parry Channel and Barrow Strait. They contacted organizations including the University of Calgary’s Arctic Institute, the Cold Regions Research and Engineering Laboratory, and several

universities (Acres Consulting Services, 1981, p. 2). Additionally, online databases, conference proceedings, and reports by the Arctic Petroleum Operators Association (APOA) were reviewed (Acres Consulting Services, 1981, p. 2).

Despite this outreach and production of expertise, little information was collected about the specific ice crack process encountered in the area, which the researchers described as "disappointing" in outcome (Acres Consulting Services, 1981, p. 2). The process did identify lessons from other regions that the researchers deemed applicable to Parry Channel and Barrow Strait: that major cracks are caused by thermal effects; the thermal cracks are an important factor in the behaviour of adjacent sea ice due to their impacts on the creation of ice ridges and ice break-up; and that most thermal cracks occur in predictable patterns (Acres Consulting Services, 1981, p. 4-5). However, there was no published data on profiles of thermal ice cracks or standardized terminology and classification of ice cracks. This necessitated more research into formation mechanisms and crack characteristics (Acres Consulting Services, 1981, p. 6-7).

As a result, the firm concluded that there was still little evidence about identifying where cracks would appear and when, and recommended a field study near Resolute to improve this knowledge, potentially to be "conducted by Resolute Inuit, with very simple mechanical equipment" (Acres Consulting Services, 1981, p. 35). This failure also resulted in the creation of a "simple numerical model" that would integrate temperature and salinity data to try predicting ice crack formation; these efforts were similar in nature to those by Polar Gas to interrogate the characteristics of ice.

This process identified the "development of an individual ice crack" as the object of study (Acres Consulting Services, 1981, p. III-1). By using published data about factors including average temperature and ice thickness, the firm wrote it was a "simple step to calculate the coefficient of linear expansion" of an ice crack (Acres Consulting Services, 1981, p. III-7). These attempts proved to be less straightforward than anticipated given that the calculation relied on a base assumption about the length of ice cover in question—which could range from 200 meters to 12 kilometers. The firm settled on an "effective cover length" of 3 kilometers for the purposes of its calculations, in turn producing an estimated ice crack width of 3.13 meters (Acres Consulting Services, 1981, p. III-21). In its conclusion about the formula, the firm admitted that "it must be emphasized that the model makes many simplifying assumptions" and "seems to agree with observations in the Resolute area" (Acres Consulting Services, 1981, p. III-25).

As with the Polar Gas Project, icebergs and other ice masses posed serious concerns to the proponents. There was a large quantity of existing data on icebergs, with the catastrophic failure of the *Titanic* disaster in 1912 leading to the U.S. Coast Guard starting data collection of "iceberg-infested waters" in the region (Arctic Pilot Project, 1981b, p. 2-22). The first "iceberg census" in the Baffin Bay area occurred in 1940 by a U.S. Coast Guard ship (Arctic Pilot Project, 1981b, p. 2-22). These icebergs surveys continued on and off through the 1950s and 1960s.

In 1975, survey flights across Baffin Bay were sent out on a monthly basis, with trained observers manually counting icebergs (Arctic Pilot Project, 1981b, p. 2-24). Aerial surveys using side looking airborne radar had been deemed high priority to chart the concentration, size, and distribution of icebergs in the area; Davis Strait was deemed the "main gateway" to the Eastern Arctic and required close investigation of its ice regime (Arctic Pilot Project, 1981b, pp. 2-14, 2-197). While the method was deemed acceptable to establish the overall count and geographical distribution of the icebergs, the consortium critiqued a "definitely psychological tendency" for the observer to miss counting smaller-sized icebergs due to the presence of larger icebergs nearby. Near Greenland, the density of icebergs meant that "visual estimates, either by observation or photography, can easily be off by 100% or more" (Arctic Pilot Project, 1981b, p. 2-24). This discrepancy was partly managed through the usage of additional overflight programs with radar technologies, and integration of data about "iceberg production" from the Danish Hydraulic Institute (Arctic Pilot Project, 1981b, p. 2-25). The proposed solution to incomplete production of capitalist natures was simply to produce more information.

In 1979, the EARP requested more specific information about the project's proposed iceberg warning system and pack ice reconnaissance system (Arctic Pilot Project, 1979a, p. 166). In response, the consortium detailed a detection system including sonar, radar, and infrared systems that could spot ice pieces from 2.5 kilometers away, integrating real-time data in a central processing facility. If two or more sensors detected a "target," alarms would be triggered. The system had not yet been tested and the consortium could only assure that "theoretically all these instruments are capable of detecting the ice target under certain conditions" (Arctic Pilot Project, 1979a, p. 167). The consortium proposed that a test vessel would be deployed with the iceberg detection system equipped to identify any problems before installation on the LNG tanker, and that "specific equipment may be modified to improve its performance after these tests" (Arctic Pilot Project, 1979a, p. 167). Meanwhile, the project admitted that it would not be

maintaining a full-time renaissance system for pack ice, despite its clear potential impacts on tanker safety and scheduling. Instead, it would actively produce environmental data about pack ice through an array of technologies, including information collected by the vessel's "sister ship" travelling in the opposite direction, satellite imagery, surveys by helicopters and airplanes, and on-board technologies (Arctic Pilot Project, 1979a, pp. 168-69).

This commitment by the Arctic Pilot Project to real-time monitoring and adjustment of tanker routing based on that knowledge production is emblematic of how capitalist natures were produced dialectically rather than causally through interactions with natures, especially through the burgeoning field of environmental assessments. Pressure ridges and ice cracks continued to be identified as objects of concern requiring further study in order to manage through proper routing, but new objects of study were also coming into view as the result of the EARP process including the impacts of icebreaking on whales and the danger of icebergs and pack ice to tanker safety. These inquiries would lead to the production of practices including the management of underwater noise and ice channels.

While efforts were made to reduce costs and accelerate data collection via simplifying techniques like predictive algorithms and satellite imagery, researchers constantly returned to the source material of ice for calibration and direct observation. Charting the tanker routes also involved the production of particular perspectives as experts, including captains of other icebreaking vessels and institutions headquartered in southern cities. The eventual approval of the pilot project by the EARP despite many residual unknowns—unknowns that could only be made known through the implementation of the project itself—demonstrates how natures imbued with logics of accumulation were produced through uncertainty.

Vessel design

This dialectical process between science and nature, in which project specifications and research evolved in response to processes of knowledge production like environmental assessments, soon expanded to how the icebreaking vessel was to be planned and designed. While icebreakers had been used in the Arctic before, none had been carrying liquefied natural gas, nor were they operating on a year-round basis that would subject them to difficult navigation conditions. Nothing like it had ever been tried before and performance could not be evaluated

until the pilot project embarked, meaning the consortium had to come up with a range of methods to conduct tests.

One approach taken to the question was to run testing in small-scale lab experiments using ship models. Early testing was performed in tanks at Arctec Canada facilities in Columbia, Maryland, and Montreal, Quebec, to try predicting vessel speed and maneuverability in ice. As with Polar Gas tank tests, synthetic ice was produced on a wax base to simulate varying conditions, ranging from level first-year ice to multi-year ice floes (Sidjak, 1978, p. 8). A "Vessel Hull Optimization Program" was conducted in Arctec facilities to determine the "most efficient hull form" (Sidjak, 1978, p. 8). As with other scientific inquiries, the end goal of this testing was to establish mathematical equations and computer simulation programs to predict full-scale ship performance and enable capital accumulation.

This method of testing was continued throughout the following years. Further small-scale experimentation was conducted by Vancouver-based Offshore Research (1982) in late 1981 with a testing program that used six ice sheets and a wooden ship model at the scale of 1:47,567 to continue evaluating factors including hull and ice friction. Many highly specific conditions were simulated, including "tests in 1.6m level ice at one draft and two friction levels" and "tests into rubble at two displacements and friction levels" (Offshore Research, 1982, p. 9). The testing proved labour-intensive to prepare, requiring over three days to produce and arrange the full-scale ice to adequate strength and thickness. Even then, initial testing found the model ice was far too strong for experimentation and had to be reduced with thawing, while the use of air bubbling had to be specifically calibrated to properly simulate resistance; attempts to produce knowledge through experimentation were haphazard and uncertain. Data from the testing was digitized onto floppy disks and stored on magnetic tapes (Offshore Research, 1982, p. 3). Colour video tapes were also made of each test run, with cameras placed alongside and underneath the basin (Offshore Research, 1982, p. 8). The tapes were spliced together at the end of each day, and a 25-minute documentary was produced about the testing. These processes rendered testing results legible to capital for future usage.

Computer programs also played a significant role in advancing the feasibility of the pilot project, with the hull design optimization and simulation program called OPTISIM used to assess the performance of LNG carriers through a proposed alternative route from Bridport Inlet to Longridge Point on the south shore of James Bay. (Arctic Pilot Project, 1980). The computer

program allowed for the evaluation of multiyear ice and ice floes across a proposed route via the Fury and Hecla Strait, which would be approximately 1,500 kilometers shorter than another route via Baffin Bay (Arctic Pilot Project, 1980, p. 16). This modelling concluded that vessel performance was far more favourable via the Baffin Bay route, despite its distance.

Similar modelling efforts were conducted by the Tokyo-based Mitsui Engineering & Shipbuilding (1982) to confirm that the Arctic Pilot Project's conceptual design was "sound and feasible" and whether it could be materialized as a "safe, reliable and efficient working vessel" (Mitsui Engineering & Shipbuilding, 1982, p. 1). After reviewing proposed design information and running a technical meeting, a computer program called ICEREM was applied to assess the propulsion performance of the vessel using a mathematical model. Data for the resistance modelling was collected from *Kigoriak*, Dome Petroleum's icebreaking vessel (Mitsui Engineering & Shipbuilding, 1982, pp. 4-5 to 4-6). The firm simulated many different ice collision results and concluded that the tankers were adequately designed for usage with only a few minor recommendations made.

While the ice-breaking tankers were clearly the signature vessel of the Arctic Pilot Project, the consortium was also working on other vessel designs that would assist the project in various ways. One of these proposed vessels was the creation of an "Archimedean screw tractor" (AST) to serve as an ice management vehicle, personnel and cargo carrier, rescue craft, and general work vehicle (Arctec Canada, 1982). Development of the first idea started in 1972, including computer studies and prototypes (Arctec Canada, 1982). The vehicle, which used twin rotating Archimedean screws for propulsion, had been tested in northern Japan and the Alaskan North Slope but required further testing to evaluate the suitability for Arctic conditions (Arctec Canada, 1982). However, testing by the consortium was not applied in the Arctic but at a port in Thunder Bay, Ontario, where ice management problems were deemed as similar to Arctic contexts: "Similar ice management problems to those in Thunder Bay are likely to occur in Arctic situations during extended season shipping from ice bound ports" (Arctec Canada, 1982). "Practical ice management experiments" were conducted on the lake ice in the port area, with experimental plots set up and individually treated using the AST itself and other methods to test out various way of enhancing ice deterioration; as with Polar Gas experiments, ice deterioration was desirable to test as conclusions could be drawn about the best conditions to weaken or strengthen ice for improved access (Arctec Canada, 1982).

The AST was used to produce distinct ice management plots on the Thunder Bay ice, including scarification of the ice and dusting of its surface with grain dust from nearby grain elevator operations (Arctec Canada, 1982). This process allowed for the production of knowledge about both the operation of the AST and the behaviour of ice in different conditions; for example, it was found that melted ice is greatly strengthened when refrozen, for example. Researchers also reported that they listened to the cracking of the ice as the AST passed over it to allow for a rough estimation of how many passes of the vessel were required to fatigue the ice sheet (Arctec Canada, 1982). The expansion of knowledge about ice behaviour and vessel design necessitated the usage of new approaches to data collection, including through the use of senses such as sound.

However, interpretation of the resulting data from the field testing was impeded due to rainfall and coolness present at the Thunder Bay port during testing: "The results of the techniques applied to the ice and snow surfaces should not be considered conclusive." The report concluded by speculating that the AST may be of use to Inuit hunters seeking safe passage across icebreaking tracks, and recommended testing of the vessel in other locations—including in the Arctic. These recommendations were directly applied to future studies.

Managing impacts of icebreaking

While the Polar Gas Project made nominal efforts to account for social and environmental impacts of its proposed pipeline, including rerouting the pipeline in several areas of concern, the Arctic Pilot Project was required to exert considerably more attention to the subject. This was the result of several factors, including growing Inuit and settler resistance in not only Canada but Greenland, and the more visibly destructive nature of the project given it sought to physically break ice rather than solidify it for the purposes of pipeline installation. In response, the consortium undertook a series of studies to ascertain potential impacts and try to mitigate them through a variety of proposals, including re-routing the shipping corridor farther from the Greenland coast—and others that were considerably more ambitious in scope.

Underwater noise generated by the movements of the LNG tankers and their collision with ice had been identified as one of the Arctic Pilot Project's many unknown impacts. In a 1979 environmental statement, the consortium claimed that noise resulting from icebreaking would be similar to noise from "natural processes of fracturing and cracking" and that

icebreaking-related noise would "probably not seriously disturb" the marine mammals as they are "presumably adapted" to existing noise resulting from wind-induced water motion (Arctic Pilot Project, 1978, pp. 236-237). However, the proponents acknowledged that noise generated by the proposed LNG tankers were "not known" and recommended the creation of a "reliable data base" of impacts once the pilot project was underway, "so that the potential effects of future increases in ship traffic could be assessed" (Arctic Pilot Project, 1979a, pp. 236-246).

Concerns about the impacts of noise from LNG tankers were solidified through the EARP process in 1979 and 1980. Simon Akpaleapik of Grise Fiord was quoted in the EARP report as arguing the year-round travel by tankers would mean "the combination of the noise caused by the engines and the ice that the tanker will be breaking, will affect the sea mammals" (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 60). Ringed seals were identified as a population that may be especially impacted by noise given their extreme sensitivity to "unfamiliar sounds," which could result in seal deaths or abandonment of regions where Inuit hunters had historically hunted them (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 70). It was also feared that whales, belugas, and narwhals could be deterred from habitats due to the new noise source (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 72). However, the EARP report concluded that major impacts of tanker noise could be impacted by taking advance of the five years of "lead time" prior to tanker operation to "carry out an experimental investigation of the effects of underwater noise and icebreaking noise," particularly in terms of its impacts on whales and seals (Arctic Pilot Project Environmental Assessment Panel, 1980, pp. 73, 102). In this manner, the EARP process helped advance the discourse of "responsible extraction," with harmful impacts mitigated through specific and long-term research.

In response to these concerns documented in the EARP report, along with interventions made by the Danish Ministry for Greenland that resulted in the formation of a working group with Petro-Canada, a workshop was hosted in a Toronto hotel in February 1981 specifically concerning the impacts of noise from icebreaking and its impacts on marine mammals (Arctic Pilot Project, 1981c). To produce a body of knowledge about ship noise, the workshop brought together people representing a "spectrum of expertise" with the goal of arriving at a consensus about potential impacts on marine mammals in Baffin Bay and Lancaster Sound (Arctic Pilot Project, 1981c, p. 5). These experts included representatives from Petro-Canada, the Greenland

Technical Organization, the San Diego-based Naval Ocean Systems Centre, the Santa Barbara-based Polar Research Laboratory, Denmark's University of Aarhus, and several Canadian universities including the University of British Columbia and the University of New Brunswick.

The workshop sought to produce an estimate of expected tanker noise based on existing vessel design data, to review background noise levels in Davis Straight and Baffin Bay, and assess the behaviour of Arctic marine mammals in the presence of noise (Arctic Pilot Project, 1981c, p. 3). Many sources of underwater sound were identified, including from the ship propeller, the breaking of ice, wind, precipitation, and seismic activities (Arctic Pilot Project, 1981c, p. 2). Routing once again became a key site of inquiry, resulting in discussion that only one-third of the tanker voyage would be spent in ice and the corridor would operate in a way that takes advantage of existing ice cracks to minimize disturbance (Arctic Pilot Project, 1981c, p. 16). However, the ongoing lack of data about ice thickness proved to be an impediment to noise-related planning, with conventional approaches including an ice growth algorithm and satellite imagery appealed to as assisting in this task (Arctic Pilot Project, 1981c, pp. 26, 92).

Some specific conclusions were drawn during the workshop, such as 80 to 85 percent of ship-related noise coming from the propeller cavitation and thus requiring "judicious attention" to hull form and propeller design (Arctic Pilot Project., 1981c, pp. 100, 116). A wide range of data inputs were integrated into the workshop's analysis, such as acoustic measurements made by the Defense Research Board by dropping explosives along routes, establishing portable stations on the ice to measure ship-radiated noise, and usage of "data buoys." An enormous amount of this knowledge was also communicated through maps and charts that were packaged into a 350-page book of conference proceedings that was then distributed by Arctic Pilot Project.

Despite the input of many experts, there was little progress made during the workshop to establishing a coherent understanding about the impacts of noise. It was admitted during the conclusion of the workshop that "there are admittedly very large data gaps" and that a lack of information about marine mammal communication and vocalization functions hampered discussions (Arctic Pilot Project., 1981c, pp. 330-337). As with other objects of knowledge production, these gaps were leveraged to advance the interests of the project itself, with the workshop chair stating: "Only with the LNG carriers in the water can we better understand the effects of underwater noise from these ships" (Arctic Pilot Project., 1981c, p. 332). The object of

scientific study was always seen as ultimately resolvable with more knowledge production. Capitalist natures were to increasingly be produced underwater, to new depths.

Another major concern identified by Inuit was the impacts of large channels in the ice created by icebreakers. Previous studies had indicated that ice broken by a ship would likely not refreeze during the warm summer months, making hunting far more difficult and dangerous. George Eckalook of Resolute told the federal environmental review panel that ships "will be breaking a big distance of ice and it's going to be very wide. The hunters in Resolute are afraid about that" (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 60). As with its approach to the issue of underwater noise, the EARP panel emphasized the need for ongoing monitoring programs throughout the lifetime of the project, requiring close cooperation with government information producers including the Atmsopheric Environment Service and further study (Arctic Pilot Project Environmental Assessment Panel, 1980, p. 62).

As a result, Acres Consulting Services (1982) was commissioned to conduct a study of ship track crossing methods to devise methods of Inuit hunters from Resolute traversing icebreaker-caused channels in Barrow Strait safely and efficiently. The study was explicitly concerned only with technical feasibility, noting that "discussions with the Inuit are planned to ensure that any method chosen must also be culturally acceptable" (Acres Consulting Services, 1982, p. 2). To start, a literature review was conducted in libraries and computer databases and brochures solicited from vehicle and portable bridge manufacturers across North America to create a list of possible technical solutions (Acres Consulting Services, 1982, pp. 5-8). Two organizations were identified as being "particularly helpful" in this inquiry: the Centre for Northern Studies at McGill University and the Alberta Research Council and the University of Alberta (Acres Consulting Services, 1982, pp. 6-7). Inuit hunting activities were also analyzed and "traditional methods" of crossing open water documented through a literature review, with results including waiting for the gap to refreeze, improvising a raft, or carrying a boat on a sled (Acres Consulting Services, 1982, p. 23). New natures were produced through identification of technical experts in southern institutions and reliance on existing observations.

The firm led a "brainstorming" session with its own staff and "other interested parties" to come up with technical solutions to crossing channels. While the study reported that "this particular method of group creativity resulted in a significant number of potential solutions," it added that a problem with the technique was the "natural tendency for engineers and other

experts to criticize suggestions, instead of generating new concepts" (Acres Consulting Services, 1982, p. 10). Through the contentious process of knowledge production, a total of 72 potential strategies lumped into four general categories of alternative crossing methods were devised (Acres Consulting Services, 1982, p. 10).

The four categories of proposed technical solutions were: 1) "problem elimination" (changing the behaviour of hunters, compensating for lost income, altering the shipping or hunting schedule, relocating the terminal, or conducting game management such as "caribou farming"); 2) track consolidation (restoring ship tracks to their original state by spraying the area with liquefied natural gas, engaging in ship maneuvering to organize the ice to aid refreezing, or creating an ice bridge from the broken ice; 3) vehicular crossing (using airplanes, helicopters, submarines, and the Archimedean screw tractor to transport Inuit hunters across the channel); and 4) bridge crossing (with technologies including floating bridges, permanent bridges, inflatable bridges, and bridges made of biodegradable foam) (Acres Consulting Services, 1982, p. 42).

The 72 brainstormed proposals were then evaluated with a "binary elimination method" with nine critical criteria chosen: 1) community acceptability; 2) hunter acceptability; 3) safety; 4) performance; 5) environmental effects; 6) terminal/pipeline operations; 7) ship operations; 8) Arctic Pilot Project economics; and 9) system costs (Acres Consulting Services, 1982, pp. 89-90). Only 11 of the original proposed solutions achieved "minimum acceptability" as outlined by these metrics (Acres Consulting Services, 1982, p. 91). This narrowing down of options was followed by a second round of screening using a "weighted decision matrix" that graded each proposal out of five and then adjusted its score with a weighted value corresponding with its perceived significance (Acres Consulting Services, 1982, p. 98). This process of knowledge production was arbitrary, premised on the expertise of southern engineers applying a series of supposedly neutral methods of evaluation to arrive at a viable technical solution that would enable the project to proceed.

The highest scoring methods according to this process were chartering an aircraft and pilot to fly hunters over the channel, using an Archimedean screw tractor (AST) as tested at Thunder Bay, or a modified canoe, folding boat, or ice boat (Acres Consulting Services, 1982, pp. 151-153). The study also recommended the testing of ship maneuvering to jam broken ice back together and the spraying of dry ice from the ship into the newly formed channel as a lack

of information impeded the evaluation of "realistic scores" (Acres Consulting Services, 1982, p. 153). For the dry ice method, the study recommended testing in a small laboratory model situation rather than from a full-scale icebreaker. The question posed of the ice was once again not resolved, but used to justify more knowledge production.

The question of crossing ship tracks continued to be a problem for the consortium. In late 1981, the Arctic Pilot Project partnered with Dome Petroleum, Gulf Canada, and Esso Resources on a field investigation conducted on ship tracks left in McKinley Bay near Tuktoyaktuk and the Beaufort Sea. Specifically, the inquiry sought to produce knowledge about the ease and safety of crossing icebreaker tracks on both foot and snowmobile—as well as establishing the rate of channel refreezing—to address the issue that icebreaking could "isolate hunting and trapping areas from Inuit communities" (Danielewicz, Pessah & Cornett, 1983, p. 1).

The research program worked in collaboration with hunters and trappers from four nearby communities—Tuktoyaktuk, Paulatuk, Sachs Harbour, and Holman Island—to actually carry out the investigations, alongside observers from Grise Fjord, Arctic Bay, and Pond Inlet (Danielewicz, Pessah & Cornett, 1983, p. 1). The field trials were coordinated by Don McWatt of the Aklavik-based Beaufort Environmental Support Services, who wrote about the collaboration with Inuit: "This approach to field work where industry and the local population have a vested interest is obviously the way to go and hopefully, future projects can use this experience as a measuring stick" (Danielewicz, Pessah & Cornett, 1983, p. 20).

McKinley Bay was the main winter harbour for Canadian Marine Drilling (Canmar), Dome's marine subsidiary, and was chosen as the test site for the three sets of investigations: one in November 1981 when level ice was first deemed safe for travel, the second in March 1982 when ice had further thickened, and the third in July 1982 when ice had started to melt (Danielewicz, Pessah & Cornett, 1983, p. 2). Canmar's *Kigoriak*, a vessel that was being used by Arctic Pilot Project as an inspiration for tanker designs, left the tracks from its offshore resupplying operations.

The study's methodology was extremely ad-hoc in nature. Participants arrived at the site of ship crossings by snowmobile or helicopter and watched the icebreaker passage, taking down visual observations about the residual track. If the crossing was considered safe, the researchers would walk out onto the ice (Danielewicz, Pessah & Cornett, 1983, p. 3). Once understood as stabilized, a snowmobile route was selected and ice blocks in the path of the route were chipped

down with an axe until passable for the snowmobile. The snowmobile was then driven across the newly constructed track several times, followed by a qamutiik (Inuit sled) loaded with ice blocks for weight. Additional observations were conducted over a month after the icebreaker had passed through the area, resulting in "completely reconsolidated" ice (Danielewicz, Pessah & Cornett, 1983, p. 8).

The inquiry featured a great deal of speculation and potentially dangerous experimentation. During the first trial, researchers stepped out onto the fresh track only a half hour after its crossing (Danielewicz, Pessah & Cornett, 1983, p. 5). Based on the number of intact blocks in the channel, the report concluded: "Their behaviour suggested that a person stepping directly into the slush would probably not sink into it above his knees. Because waterproof footwear had not been taken along, this test was not attempted" (Danielewicz, Pessah & Cornett, 1983, p. 5). The investigation also suggested that one could hop across the track from ice block to ice block, but "this test was not carried out" (Danielewicz, Pessah & Cornett, 1983, p. 5). After the passage of a sled during one test, the refrozen crust was weakened and gave way when stepped on; the driver of the snowmobile dragging the sled reported he had not noticed any ice failure (Danielewicz, Pessah & Cornett, 1983, p. 6).

Ice thickness measurements were made of the newly formed ice by drilling through it at five-meter intervals, although slush was found on the bottom of the ice and impeded accurate measurements due to the "unconsolidated nature" (Danielewicz, Pessah & Cornett, 1983, p. 8). Another trial involved researchers walking onto the track directly behind the icebreaking vessel, reporting that the residual ice blocks left in its wake were so tightly packed together than they did not move when stepped on (Danielewicz, Pessah & Cornett, 1983, p. 10). As with the first trial, the investigators hauled a 600-kilogram sled with ice blocks, harnessed ice data, and attempted to drill through the ice—but the auger became lodged in the ice and was reported as lost (Danielewicz, Pessah & Cornett, 1983, pp. 11-13). However, the investigators did not try crossing the track "as the melt pools on the level ice made travel difficult," which also made ice thickness measurements impractical (Danielewicz, Pessah & Cornett, 1983, p. 15).

The report concluded that icebreaker-caused tracks would not pose serious obstacles to travel for Inuit hunters but noted that similar trials would have to be conducted in new locations under different conditions as well as the possible use of warning systems: "The overall conclusion from these tests were that crossing a ship track in the ice is less of a problem than

first imagined" (Danielewicz, Pessah & Cornett, 1983, p. 22). However, serious doubts were expressed by community members about the safety of crossing tracks, including during bad visibility and lack of current in bay where testing occurred. Recommendations devised by the company in response included sounding a fog horn in bad weather to alert hunters, performing helicopter reconnaissance of the channel, conducting further tests in areas of traditional use, and issuing community radio messages to inform local residents of changing conditions.

Despite ongoing concerns from Inuit communities about the effectiveness of this testing, Danielewicz, Pessah & Cornett (1983) concluded: "This approach of jointly having local involvement in both the planning and implementation stage is a sign of recognition of local knowledge and duly respected by the participants and their respective communities" (p. 23). This early iteration of attempting to integrate Indigenous participants in the research project and acknowledging their knowledge of the region resulted in Inuit hunters walking or sledding out onto extremely precarious ice conditions for the purposes of knowledge production by a capitalist consortium.

Through workshops, brainstorming sessions, and field testing, the impacts of underwater noise on marine mammals and Inuit hunters crossing icebreaking tracks helped produce capitalist natures in the Arctic, with potential harms ostensibly mitigated by application of expertise and improved knowledge. When large gaps in knowledge were identified, such as marine mammal vocalization patterns or the application of ad-hoc findings from McKinley Bay to other locations in the Arctic, the proposed solution was simply more studies and expanded knowledge through the process of commodity circulation. Inuit concerns were increasingly prioritized by the consortium in response to the EARP process, but the resulting conclusions were suspiciously inconclusive and failed to account for the possibility that the project should not proceed. In this way, capitalist natures were produced despite—and arguably because of—uncertainty, making a case for capital accumulation in order to collect scientific knowledge.

Conclusion

The Arctic Pilot Project icebreakers would have been some of the largest and most powerful vessels built up until that point: so large that Canadian dockyards would not have had the capacity to construct them. At the same time, the icebreakers were explicitly planned and advanced as inherently small vessels, offering capacity for real-time monitoring and adjustments

to mitigate the most extreme harms caused by their presence. In this way, the vessels were constituted as material embodiments of a more refined capitalist natures premised on environmental assessments and greater consultation with impacted communities.

The production and distribution of scientific knowledge about ice was a central part of this process. The consortium greatly expanded the geographic scope of capitalist natures throughout the Arctic Islands, extending the range of ice inquiries as far as Lancaster Sound and Davis Strait and specifying it in locations such as Bridport Inlet. An extremely wide range of scientific inquiries was conducted, including the devising of an "ice management system" and management of resulting problems such as ice biota disappearance, the production of an "integrated route analysis" relying on predictive algorithms and satellite imagery, the collection of expertise from authorities like icebreaker captains and underwater noise researchers, and the identification of new objects of knowledge such as ice crack morphology. The consortium commissioned small-scale lab experiments to test vessel design, prototyped new vehicles like the Archimedean screw tractor, and integrated data collected from full-scale icebreakers.

As with the Polar Gas Project, the Arctic Pilot Project died out long before its planned infrastructure was ever actualized. But its failure was nevertheless highly productive in expanding and legitimizing capitalist natures throughout the Arctic, with ice rendered something that could be predictably exploited. Specifically, scientific efforts increasingly produced ice as a possible "threat" to capitalist production, with failure to adequately account for impacts on Inuit hunters and marine mammals potentially resulting in organized resistance. In this way, scientific labour was highly productive in advance capitalist and colonial natures in the Arctic, remaking the ice as an abstract and exploitable nature.

Chapter 6: Conclusion

To capitalist and colonial interests, ice had long represented an obstacle to be overcome, trapping explorers searching for the fabled Northwest Passage, concealing Soviet submarines during the Cold War, and—once tamed—serving as the foundation for remote airstrips and weather stations. This production of ice as an abstract and exploitable material as part of a broader attempt to control Arctic natures sharply diverged from Inuit production of ice.

This thesis analyzed more than 80 technical reports produced by both an assortment of private firms contracted by Polar Gas Project and Arctic Pilot Project about the seemingly mundane subject of ice science. While the two projects were far from the first entities to produce natures in the Arctic Islands, this thesis has demonstrated how their scientific labour motivated by logics of accumulation throughout the 1970s and 1980s greatly broadened the scope and scale of this quest. While augering a hole in the ice to collect thickness data, cataloguing iceberg size and movement, or subjecting laboratory-grown ice to experimentation may not appear as viscerally impactful as other interventions, they nonetheless produced new natures as something that stripped the ice of its social relations that reconfigured it as a plaything for capital.

This scientific labour was rarely executed as envisioned. Rather than easily quantifying or cataloguing materiality of ice—whether it was its thickness, strength, movement, or underwater noise—the inquiries frequently ended in technical failure and poor results. Conventional wisdom may suggest that the failure of a proposed project like Polar Gas Project or the Arctic Pilot Project was the end of their respective influence, or a representation that their knowledge production was not accurate enough. But this failure was highly productive, identifying new objects—such as ice salinity or the crossing of channels in the ice by Inuit hunters—as part of Arctic natures to be produced. The eventual collapse of the consortiums under the pressure of changing resource prices, global demands, and organized resistance was certainly not the preferred conclusion for the many personnel who worked to advance their extractive potentials. Scientific failure also produced the technical parameters and discursive imperative to conduct further knowledge production. This process was an iterative “rendering technical” of issues including environmental and social concerns, with the dominant concern being lack of sufficient knowledge to manage ice rather than a fundamental questioning of whether such institutions had the authority to be asserting such control in the first place.

Inuit perspectives were included in the environmental assessment processes for both projects, but these approaches only sought to minimize the most excessive harms rather than reject the project altogether. Non-capitalist production of natures by Inuit were completely ignored by the consortiums. Scientific knowledge about ice was critical to this process, regardless of its failures or conclusions; in the case of the Arctic Pilot Project, it was recommended that many of these scientific insights be produced during its actual operations. Through these processes, natures were transformed and the ice abstracted.

This intelligibility, rooted in scientific principles motivated by capitalist imperatives that contrast sharply with Inuit Qaujimajatuqangit, has been further expanded in the decades since. Many extractive projects have proceeded, including Baffinland's Mary River Mine on Baffin Island and a second push for a Mackenzie Valley pipeline from the Beaufort Sea. This thesis has demonstrated that extraction not only occurs when a cubic metre of natural gas is transported through a pipeline or icebreaking tanker but also when natures are produced through scientific inquiry and reports. Like with a tailings lake or abandoned wellhead, this extraction also leaves permanent marks on the landscapes that shape future decisions and possibilities. This does not mean that people and decisions are forever locked into such a pathway: only that these natures must be clearly acknowledged in origin and impact. As Neil Smith (2008) argued: "This is precisely Marx's point when he says that the defeat of capitalism makes possible the end of the natural history of human beings and the beginning of true history, the end of societal laws experienced in the form of natural laws, and the beginning of truly social control over history" (p. 82).

These questions about production of cryo-nature will only become more pressing in the decades ahead as permanent ice continues to recede in the Arctic. Environmental organizations have started to mobilize around the protection of the "Last Ice Area" in the Far North of the Canadian Arctic (Ferreria, 2019). Marine traffic in the Arctic is expected to continue increasing as ice cover diminishes, necessitating expanded surveying and oil spill response strategies (Boyd, 2020). While these efforts are ostensibly intended to help undo some of the harmful impacts of fossil fuel extraction over previous years, many of these scientific inquiries are motivated by the same processes of capital accumulation propelling climate and environmental crises. As a result, the imperative by Polar Gas Project (1978) that "the challenge posed by the ice can be conquered" has likely not ended—merely updated for a new era of capitalist exploitation.

References

Acres Consulting Services. (1981). *Ice crack morphology in Barrow Strait*. Calgary, Canada: Petro-Canada & Arctic Pilot Project.

Acres Consulting Services Limited. (1982). *Study of ship track crossing methods.* Calgary, Canada: Petro-Canada & Arctic Pilot Project.

Albeck-Ripka, L. (2017, November 25). Why lost ice means lost hope for an Inuit village. *New York Times*. https://www.nytimes.com/interactive/2017/11/25/climate/arctic-climate-change.html

Amagoalik, S. (1977, September). [Letter to the editor]. *Inuit Today, 6*(7), 6.

Anselmi, E. (2019, August 2). Extend offshore oil and gas moratorium, says Nunavut review board. *Nunatsiaq News*. https://nunatsiaqnews.canadalocal.media/news/extend-offshore-oil-and-gas-moratorium-says-nunavut-review-board-4d61fa5a37fabde7d4ed201fcd5adca4

Aporta, C. (2009). The trail as home: Inuit and their pan-Arctic network of routes. *Human Ecology, 37*(2), 131-146. https://doi.org/10.1007/s10745-009-9213-x

Aporta, C. (2010). The sea, the land, the coast, and the winds: Understanding Inuit sea ice use in context. In I. Krupnik, C. Aporta, S. Gearheard, G. J. Laidler, & L. K. Holm, *SIKU: Knowing our ice* (pp. 163-180). Springer.

Aporta, C. (2011). Shifting perspectives on shifting ice: documenting and representing Inuit use of the sea ice. *The Canadian Geographer, 55*(1), 6-19. https://doi.org/10.1111/j.1541-0064.2010.00340.x

Arboleda, M. (2017). Revitalizing science and technology studies: A Marxian critique of more-than-human geographies. *Environment and Planning D: Society and Space, 35*(2), 360-378. https://doi.org/10.1177/0263775816664099

Arctec Canada. (1973a). *Summary and analysis of ice cover bearing capacity tests*. Montreal, Canada: Author.

Arctec Canada. (1973b). *Test plan for Arctic pipelaying studies (ice studies)*. Montreal, Canada: Author.

Arctec Canada. (1974a). *The bearing capacity of sea ice (results of small sample tests)*. Montreal, Canada: Author.

Arctec Canada. (1974b). *Modeling the bearing capacity of sea ice effects of cracks, trenches, and multiple loads*. Montreal, Canada: Author.

Arctec Canada. (1974c). *Reanalysis of data collected by Dr. H. R. Peyton on sea ice strength*. Montreal, Canada: Author.

Arctec Canada. (1974d). *Testing the properties of laboratory grown built-up sea ice*. Montreal, Canada: Author.

Arctec Canada. (1975). *Preliminary creep tests (laboratory grown saline ice)*. Montreal, Canada: Author.

Arctec Canada. (1982). *Evaluation of Archimedean screw tractor for ice management*. Montreal, Canada: Author.

Arctic gas plan gets nod. (1981, October 24). *Edmonton Journal*, H1.

Arctic Pilot Project. (1978). *Draft environmental Statement - Melville Island components volume V, part B, book 2*. Calgary, Canada: Author.

Arctic Pilot Project. (1979a). *Arctic Pilot Project environment statement supplementary information*. Calgary, Canada: Author.

Arctic Pilot Project. (1979b). *Volume 1 Application to the Department of Transport*. Calgary, Canada: Author.

Arctic Pilot Project. (1980). *Ship performance evaluation Bridport Inlet-Longridge Point via Fury and Hecla Strait*. Calgary, Canada: Author.

Arctic Pilot Project: Another Norman Wells. (1981, September/October). *Inuit Today, 9*, 8.

Arctic Pilot Project. (1981a). *Before the National Energy Board in the matter of application by Arctic Pilot Project*, Phase II. Calgary, Canada: Author.

Arctic Pilot Project. (1981b). *Integrated route analysis volume 1*. Calgary, Canada: Author.

Arctic Pilot Project. (1981c). *The question of sound from icebreaker operations: Proceedings of a workshop*. Calgary, Canada: Author.

Arctic Pilot Project Environmental Assessment Panel. (1980). *Arctic Pilot Project (Northern component): Report of the Environmental Assessment Panel.* Ottawa, Canada: Federal Environmental Assessment Review Office.

Bailey, R.A. (1983). The Arctic Pilot Project. *Cold Regions Science and Technology*, 7, 259-272. https://doi-org.uml.idm.oclc.org/10.1177/014459878300200102

Banister Technical Services. (1974). *Comparison of direct marine profiling with through-the-ice profiling Rea Point, Northwest Territories*. Edmonton, Canada: Author.

Banister Technical Services. (1975a). *Ice thickness measurements Polar Gas 1974 winter research program, Volume 1 data acquisition, data reduction and calibration*. Edmonton, Canada: Author.

Banister Technical Services. (1975b). *Ice thickness measurements Polar Gas 1974 winter research program, Volume II analytical discussions and recommendations*. Edmonton, Canada: Author.

Barrette, P.D. (2017). *Feasibility of field investigations to evaluate ice action on the Drake subsea pipeline.* Ottawa, Canada: National Research Council of Canada Ocean, Coastal and River Engineering. https://nrc-publications.canada.ca/eng/view/ft/?id=c911ab71-6baa-45c1-912d-e11820d53aa8

Beddome heads gas project. (1989, August 23). *Calgary Herald*, F2.

Bell, M.H. (2014, January 29). Rather than lay claim to the North Pole, the federal government should tap gas in our Arctic islands. *Financial Post.* https://financialpost.com/uncategorized/rather-than-lay-claim-to-the-north-pole-the-federal-government-should-tap-gas-in-our-arctic-islands

Bennett, M. M. (2016). Discursive, material, vertical, and extensive dimensions of post-Cold War Arctic resource extraction. *Polar Geography*, 39(4), 258-273. https://doi.org/10.1080/1088937X.2016.1234517

Bernauer, W. (2018). *Extractive hegemony in the Arctic: Energy resources and political conflict in Nunavut, 1970-2017* (Doctoral dissertation, York University, Toronto, Canada).

Bernauer, W. (2020). Producing consent: How environmental assessment enabled oil and gas extraction in the Qikiqtani region of Nunavut. *The Canadian Geographer.* Advance online publication. https://doi.org/10.1111/cag.12611

Black, M. (2020, February 24). Kenney seeks to boost investor confidence after Teck mine project shelved. *CTV News Edmonton.* https://edmonton.ctvnews.ca/kenney-seeks-to-boost-investor-confidence-after-teck-mine-project-shelved-1.4825739

Blomley, N. (2003). Law, property, and the geography of violence: The frontier, the survey, and the grid. *Annals of the Association of American Geographers*, *93*(1), 121-141. https://doi-org.uml.idm.oclc.org/10.1111/1467-8306.93109

Blunn, R. (1977, December 22). Consortium unveils plans to construct $10-billion pipeline. *Ottawa Citizen*, 1.

Bocking, S. (2009). A disciplined geography: Aviation, science, and the Cold War in Northern Canada, 1945-1960. *Technology and Culture, 50*(2), 265-290. https://doi.org/10.1353/tech.0.0286

Bocking, S. (2011). Indigenous knowledge and the history of science, race, and colonial authority in Northern Canada. In A. Baldwin, L. Cameron, & A. Kobayashi (Eds.), *Rethinking the Great White North: Race, nature, and the historical geographies of whiteness in Canada* (pp. 39-61). UBC Press.

Boyd, A. (2020). Charting a new course in a melting Arctic: Why the northern shipping debate is heating up. *The Star*. https://www.thestar.com/news/canada/2020/01/18/companies-are-pledging-to-avoid-arctic-shipping-routes-some-residents-say-thats-not-necessary.html

Braun, B. (2000). Producing vertical territory: Geology and governmentality in late Victorian Canada. *Ecumene, 7*(1), 7-46. https://doi-org.uml.idm.oclc.org/10.1177/096746080000700102

Bravo, M. T. (2010). Epilogue: The humanism of sea ice. In I. Krupnik, C. Aporta, S. Gearheard, G. J. Laidler, & L. K. Holm (Eds.), *SIKU: Knowing our ice* (pp. 445-452). Springer.

Bregha, F. (1981). *Bob Blair's pipeline: The business and politics of Northern energy development projects.* Lorimer.

Bridge, G. (2004). Gas and how to get it. *Geoforum, 35*(4), 395-397. DOI: 10.1016/j.geoforum.2004.05.002

Bridge, G. (2015). Energy (in)security : world-making in an age of scarcity. *Geographical journal, 181*(4), 328-339. http://dx.doi.org/10.1111/geoj.12114

Brown & Root. (1976). *Engineering study laybarge installation of a pipeline across the East Barrow Strait*. Houston, TX: Author.

Brown & Root. (1977). *Polar Gas Project engineering study model testing of a laybarge in synthetic ice*. Houston, TX: Author.

Callow L. (2013, March). *Beaufort regional environment assessment oil and gas exploration & development activity forecast: Canadian Beaufort Sea 2013-2028*. Ottawa, Canada: Aboriginal Affairs and Northern Development Canada. https://www.beaufortrea.ca/wp-content/uploads/2012/03/ncr-5358624-v4-brea_-_final_update_-_exploration_and_activity_forecast-__may_2013.pdf

Campbell, T. (1975, March 21). Engineers coping with development problems. *Edmonton Journal*, 83.

Campbell, T. (1977, November 1). Two tankers proposed to haul gas from Arctic. *Edmonton Journal*, 104.

Campbell, T. (1979, April 5). High Arctic venture: energy for tomorrow. *Edmonton Journal*, A5.

Campbell, T. (1980, November 20). Europe interested in gas from Arctic. *Edmonton Journal*, H1.

Cameron, E. (2015). *Far off Metal River: Inuit lands, settler stories, and the making of the contemporary Arctic*. UBC Press.

Cameron, E., Mearns, R., & McGrath, J.T. (2015). Translating climate change: adaptation, resilience, and climate politics in Nunavut, Canada. *Annals of the Association of American Geographers, 105*(2), 274-283. https://doi-org.uml.idm.oclc.org/10.1080/00045608.2014.973006

Canada 'falling behind' because of Arctic oil drilling moratorium: CAPP. (2019, March 14). *The Canadian Press*. https://www.cbc.ca/news/canada/calgary/capp-arctic-moratorium-falling-behind-1.5057214

Carney, P. (1969, November 1). The 'black gold' rush of '69. *Maclean's*, 16-21.

Carruthers, J. (1977, May 25). Panarctic lowers its natural gas outlook. *Vancouver Sun*, 36.

Carruthers, J. (1978, March 22). Polar Gas maintains cautious approach. *The Ottawa Journal*, 32.

Carter, S. (1993). *Lost harvests: Prairie Indian reserve farmers and government policy.* McGill-Queen's University Press.

Castree, N. (2000). Marxism and the production of nature. *Capital & Class, 24*(3), 5-36. https://doi-org.uml.idm.oclc.org/10.1177/030981680007200102

Castree, N. (2002). False antitheses? Marxism, nature and actor-networks. *Antipode, 34*(1), 111-146. https://doi-org.uml.idm.oclc.org/10.1111/1467-8330.00228

Chan, L., Eynon, G., & McColl, D. (2005). *The economics of High Arctic gas development: expanded sensitivity analysis*. Calgary, Canada: Canadian Energy Research Institute. http://library.arcticportal.org/1562/1/HighArcticGasReport.pdf

Chemical Engineering Research Consultants Ltd. (1975). *Preliminary report on heat transfer from pipelines in Arctic waters for Polar Gas Project*. Toronto, Canada: Author.

Chemical Engineering Research Consultants Ltd. (1975). *Polar Gas Project heat transfer from pipelines in Arctic waters*. Toronto, Canada: Author.

Chilisa, B. (2012). *Indigenous research methodologies*. SAGE Publications.

Christie, R. L., & Kerr, J. W. (1981). Geological exploration of the Canadian Arctic Islands. In M. Zaslow (Ed.), *A century of Canada's Arctic Islands* (pp. 187-202). Royal Institute of Canada.

Coen, R. (2012). *Breaking ice for Arctic oil: The epic voyage of the SS Manhattan through the Northwest Passage.* University of Alaska Press.

Collard, R., & Dempsey, J. (2017). Capitalist Natures in Five Orientations. *Capitalism Nature Socialism*, *28*(1), 78-97. http://dx.doi.org/10.1080/10455752.2016.1202294

Cooke, A. (1981). A gift outright: The exploration of the Canadian Arctic Islands After 1880. In M. Zaslow (Ed.), *A century of Canada's Arctic Islands* (pp. 51-60). Royal Society of Canada.

Corcoran, T. (2019, November 6). The West doesn't need Quebec to get its oil flowing East. There is another way. *Financial Post.* https://financialpost.com/opinion/terence-corcoran-the-west-doesnt-need-quebec-to-get-its-oil-flowing-east-there-is-another-way

Coulthard, G., & Simpson, L. (2016). Grounded normativity / place-based solidarity. *American Quarterly, 68*(2), 249-255. DOI: 10.1353/aq.2016.0038

Cowan, E. (1970, November 30). Hopes for a vast oil pool blaze in Canadian Arctic. *The New York Times*, 79.

CPI quits Polar Gas as objectives met. (1975, April 21). *Calgary Herald*, 22.

Cunsolo, A., & Ellis, N.R. (2018). Ecological grief as a mental health response to climate change-related loss. *Nature Climate Change, 8*, 275-281. https://doi.org/10.1038/s41558-018-0092-2

Danielewicz, B., Pessah, E., & Cornett, S. (1983). *Field investigation of tracks left by ice breaking vessels*. Calgary, Canada: Dome Petroleum/Canmar.

Davis, J. D., Hossain, K., & Koivurova, T. (2016). Canadian Arctic offshore oil and natural gas and European Union energy diversification: towards a new perspective? *SSRN*, 227-264. https://dx.doi.org/10.2139/ssrn.2801978

Dempsey, J. (2016). *Enterprising nature: economics, markets and finance in global biodiversity politics*. Wiley-Blackwell.

Dodds, K. (2010). Flag planting and finger pointing: the Law of the Sea, the Arctic and the political geographies of the outer continental shelf. *Political Geography, 29*(2), 63-73. https://doi.org/10.1016/j.polgeo.2010.02.004

Dodds, K. (2019). Geopolitics and ice humanities: Elemental, metaphorical and volumetric reverberations. *Geopolitics.* https://doi-org.uml.idm.oclc.org/10.1080/14650045.2019.1697240

Doel, R.E., Friedman, R.M., Lajus, J., Sorlin, S., & Wrakberg, U. (2014). Strategic Arctic science: national interests in building natural knowledge - interwar era through the Cold War. *Journal of Historical Geography, 44*, 60-80. https://doi.org/10.1016/j.jhg.2013.12.004

Duffy, R.Q. (1988). *Road to Nunavut: The progress of the Eastern Arctic Inuit since the Second World War*. McGill-Queen's University Press.

Dunbar, M. (1981). The history of oceanographic research in the waters of the Canadian Arctic Islands. In M. Zaslow (Ed.), *A century of Canada's Arctic Islands* (pp. 141-152). Royal Institute of Canada.

Dyce, M. (2013). Canada between the photograph and the map: Aerial photography, geographical vision and the state. *Journal of Historical Geography*, *39*, 69-84. https://doi.org/10.1016/j.jhg.2012.07.002

Ekers, M., & Loftus, A. (2012). Revitalizing the production of nature thesis: A Gramscian turn? *Progress in Human Geography*, *37*(2), 234-252. https://doi.org/10.1177/0309132512448831

Erickson, B. (2018). Anthropocene futures: Linking colonialism and environmentalism in an age of crisis. *Environment and Planning D: Society and Space, 38*(1), 111-128. https://doi-org.uml.idm.oclc.org/10.1177/0263775818806514

Eskimos want rid of pipeline plans. (1977, September 30). *Calgary Herald*, A19.

Farish, M. (2006). Frontier engineering: from the globe to the body in the Cold War Arctic. *The Canadian Geographer, 50*(2), 177-196. https://doi-org.uml.idm.oclc.org/10.1111/j.0008-3658.2006.00134.x

Ferreira, B. (2019, August 12). Saving the Arctic's 'last ice area' is a race against time. *Motherboard*. https://www.vice.com/en_us/article/pa7ym7/saving-the-arctics-last-ice-area-is-a-race-against-time

Firms to study Arctic pipeline. (1973, February 2). *The Gazette*, 18.

Foucault, M. (1982). The subject and power. *Critical Inquiry, 8*(4), 777-795.

Foucault, M. (1984). *The Foucault reader.* Vintage Books.

Fossum, J.E. (1997). *Oil, the state, and federalism: The rise and demise of Petro-Canada as a statist impulse*. University of Toronto Press.

Geophysical Survey Systems. (1973). *Sea ice thickness profiling in selected areas of the Canadian Arctic*. North Billerica, MA: Author.

Gibbens, R. (1980, February 7). Arctic gas may play role in development of major iron ore deposits in Ungava. *The Globe and Mail*, B15.

Gismondi, M., & Davidson, D. J. (2012). Imagining the tar sands 1880-1967 and beyond. *Imaginations, 3*(2), 68-102. DOI: 10.17742/IMAGE.sightoil.3-2.6

Gombay, N. (2012). Placing economies: lessons from the Inuit about economics, time, and existence. *Journal of Cultural Geography, 29*(1), 19-38. https://doi.org/10.1080/08873631.2012.646889

Government of Canada. (1980, July 31). [Advertisement for Arctic Pilot Project]. *The Windsor Star*, 7.

Grant, S. D. (2010). *Polar imperative: A history of Arctic sovereignty in North America.* Vancouver: Douglas & McIntyre.

Greenaway, K. R., & Dunbar, M. (1981). Aviation in the Arctic Islands. In M. Zaslow (Ed.), *A century of Canada's Arctic Islands* (pp. 79-92). Royal Society of Canada.

Greenland aims to halt Arctic gas-tanker plan. (1981, October 19). *The Globe and Mail*, 2.

Greenland Eskimos fight to keep Canadian gas tankers from shore. (1980, October 14). *Asbury Park Press*, B3.

Haraway, D. (1988). Situated knowledges: The science question in feminism and the privilege of partial perspective. *Feminist Studies, 14*(3), 575-599. DOI: 10.2307/3178066

Harder, M. T., & Wenzel, G. W. (2012). Inuit subsistence, social economy and food security in Clyde River, Nunavut. *Arctic, 65*(3), 305-318. https://doi.org/10.14430/arctic4218

Harris, C. (2004). How did colonialism dispossess? Comments from an edge of empire. *Annals of the Association of American Geographers, 94*(1), 165-182. https://doi-org.uml.idm.oclc.org/10.1111/j.1467-8306.2004.09401009.x

Harvey, D. (2005). *A brief history of neoliberalism.* Oxford University Press.

Hatter, D. (1980a, April 24). LNG group feels market may be close at hand. *Calgary Herald*, D1.

Hatter, D. (1980b, October 11). TransCanada plans Arctic LNG project. *Calgary Herald*, D1.

Hatter, D. (1980c, October 14). Gas producers may have broken Arctic ice. *Calgary Herald*, D1.

Hill, D. (1982, September 2). NEB halts Arctic project hearings. *Calgary Herald*, C5.

Hull, K. (1979, August 29). Super tankers 'best solution.' *Calgary Herald*, C13.

Inquiry into Polar Gas urged. (1977, November). *Project North*, *1*(11), 1

International Pipeline Engineers, Inc. (1977). *Polar Gas Project river crossing design*. Houston, TX: Author.

Intertech Remote Sensing Ltd. (1980). *Ice feature mapping in Resolute Passage*. Calgary, Canada: Author.

Inuit Circumpolar Council - Canada. (2014). *The sea ice never stops: Circumpolar Inuit reflections on sea ice use and shipping in Inuit Nunaat.* Ottawa, Canada: Inuit Circumpolar Council Canada. https://www.inuitcircumpolar.com/project/the-sea-ice-never-stops-circumpolar-inuit-reflections-on-sea-ice-use-and-shipping-in-inuit-nunaat/

Inuit demand Berger-type inquiry into Polar Gas pipeline proposal. (1977, September). *ITC News*, 1-2.

It's official for Polar Gas. (1978, January). *Project North, 1*(13), 2.

J. D. Mollard & Associates. (1973). *Small-scale maps, mosaics, and charts to be used as background data for airphoto interpretation studies Melville Island to Boothia Peninsula*. Regina, Canada: Author.

Jaremko, G. (2008, January 7). Northern reserves look tempting. *Edmonton Journal*, A12.

Johnson, H. (1979, January 24). Arctic gas proposal premature, Inuit warn. *Edmonton Journal*, E1.

Jones, G. H. (1981). Economic development - oil and gas. In M. Zaslow (Ed.), *A century of Canada's Arctic Islands* (pp. 221-230). Royal Institute of Canada.

Joyce, C. (2014, December 18). Arctic is warming twice as fast as world average. *NPR*. https://www.npr.org/2014/12/18/371438087/arctic-is-warming-twice-as-fast-as-world-average

Kaustinen, O. M. (1983). A Polar Gas pipeline for the Canadian Arctic. *Cold Regions Science and Technology*, 217-226.

Kennedy, T. (1988). *Quest: Canada's search for Arctic Oil.* Reidmore Books.

Kenting Exploration Services. (1977). *Operations report Arctic Islands marine survey, 1977*. Calgary, Canada: Author.

Kirsch, S., & Mitchell, D. (2004). The nature of things: Dead labor, nonhuman actors, and the persistence of Marxism. *Antipode, 36*(4). 687-705. https://doi-org.uml.idm.oclc.org/10.1111/j.1467-8330.2004.00443.x

Kosek, J. (2006). *Understories: The political life of forests in Northern New Mexico.* Duke University Press.

Kristoffersen, B. (2014). 'Securing' geography: Framings, logics and strategies in the Norwegian High North. In R. Powell & K. Dodds (Eds.), *Polar geopolitics? Knowledges, resources and legal regimes* (pp. 131-148). Edward Elgar.

Kyle, K. (2019, December 18). Feds return $430M to oil and gas companies ahead of Arctic offshore exploration ban. *CBC News*. https://www.cbc.ca/news/canada/north/beaufort-sea-moratorium-deposits-nwt-1.5399157

Lajeunesse, A. (2016). *Lock, stock, and icebergs: A history of Canada's Arctic maritime sovereignty.* UBC Press.

Lee, H.Y. (2007, November 29). Petro-Canada CEO: Arctic LNG would be a project 'to die for'. *Dow Jones Newswires*. https://www.rigzone.com/news/oil_gas/a/53475/petrocanada_ceo_arctic_lng_would_be_a_project_to_die_for/

Lewington, J. (1982, March 9). Inuit want claims settled before projects started. *The Globe and Mail*, B9.

Lewington, J. (1983, July 4). Chairman of Gaz de France has faith in Arctic Pilot Project. *The Globe and Mail*, B3.

Lewington, J. (1987). Lessons of the Arctic Pilot Project. In F. Griffiths (Ed.), *Politics of the Northwest Passage* (pp. 174-191). McGill-Queen's University Press.

Lewis, D. (1976). Canadian energy policy: The collapse of credibility. In J. Laxer & A. Martin (Eds.), *The big tough expensive job: Imperial Oil and the Canadian economy*. Press Porcepic.

LGL Limited. (1977). *Marine ecology of fast-ice-edges in Wellington Channel and Resolute passage, N.W.T*. Toronto, Canada: Author.

Li, F. (2009). Documenting accountability: Environmental impact assessment in a Peruvian mining project. *PoLAR*, *32*(2), 218-236. https://doi-org.uml.idm.oclc.org/10.1111/j.1555-2934.2009.01042.x

Li, F. (2018). Moving glaciers: Remaking nature and mineral extraction in Chile. *Latin American Perspectives, 45*(5), 102-119. https://doi-org.uml.idm.oclc.org/10.1177/0094582X17713757

Li, T.M. (2005). Beyond "the state" and failed schemes. *American Anthropologist, 107*(3), 383-394. https://doi-org.uml.idm.oclc.org/10.1525/aa.2005.107.3.383

Lindsay, D. (1973, August 15). *Sea ice in the Canadian Archipelago*. Technical Committee of the Polar Gas Group.

Lyon, J. (1983). *Dome Petroleum: The inside story of its rise and fall.* Beaufort Books.
Mackey, E. (2016). *Unsettled expectations: Uncertainty, land and settler decolonization.* Fernwood Publishing.
Macpherson, J., & Thompson, G. (1978). Polar Gas: A premature pipeline? *Alternatives: Perspectives on Society, Technology and Environment, 7*(4), 34-39.
Marchildon, G. P. (1996). *Profits and politics: Beaverbrook and the gilded age of Canadian finance.* University of Toronto Press.
Masterson, D.M. (2013). The Arctic Islands adventure and Panarctic Oils Ltd. *Cold Regions Science and Technology*, 85, 1-14. https://doi.org/10.1016/j.coldregions.2012.06.008
McCutcheon, B.J. (1978, April 13). *Correspondence from B.J. McCutcheon to Sister M. Beaucage.* Manitoba and Northwestern Ontario fonds (512/3/8). United Church of Canada Archives MNWO/ANCC, Winnipeg, Manitoba, Canada.
McGoogan, K. (2017). *Dead reckoning: The untold story of the Northwest Passage*. Patrick Crean Editions.
Mercer, G. (2018, May 30). 'Sea, ice, snow ... it's all changing': Inuit struggle with warming world. *The Guardian*. https://www.theguardian.com/world/2018/may/30/canada-inuits-climate-change-impact-global-warming-melting-ice
Millar, S.W.S., & Mitchell, D. (2017). The tight dialectic: The Anthropocene and the capitalist production of nature. *Antipode, 49*(S1), 75-93. https://doi.org/10.1111/anti.12188
Mitchell, T. (2002). *Rule of experts: Egypt, techno-politics, modernity.* University of California Press.
Mitsui Engineering & Shipbuilding. (1982). *Design check on Arctic LNG carrier for Arctic Pilot Project*. Tokyo, Japan: Author.
Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates. (1973). *Report on ice research program 1973*. Montreal, Canada: Author.
Montreal Engineering Company, Banister Pipelines, & R.J. Brown and Associates. (1974). *Report on winter research program 1974*. Calgary, Canada: Polar Gas Project.
Montreal Engineering Company. (1975a). *Load bearing capacity of sea ice*. Calgary, Canada: Polar Gas Project.
Montreal Engineering Company. (1975b). *Presentation to Polar Gas technical committee*. Montreal, Canada: Author.
Montreal Engineering Company. (1975c). *Short term load capacity of sea ice*. Calgary, Canada: Polar Gas Project.
Montreal Engineering Company. (1976). *Sea ice bearing capacity studies status report*. Calgary, Canada: Polar Gas Project.
Montreal Engineering Company, & Banister Pipelines. (1975a). *Field investigations of major ice masses*. Calgary, Canada: Polar Gas Project.
Montreal Engineering Company, & Banister Pipelines. (1975b). *Ice scour in the Canadian Arctic Islands*. Calgary, Canada: Polar Gas Project.
Montreal Engineering Company, & Banister Pipelines. (1975c). *Preliminary project description marine pipeline crossings Melville Island to Somerset Island*. Calgary, Canada: Polar Gas Project.
Montreal Engineering Company, & Banister Pipelines. (1975d). *Visit by selected contractors to the Canadian Arctic Islands*. Calgary, Canada: Polar Gas Project.

Montreal Engineering Company, & Banister Pipelines. (1976). *Byam Channel technical assessment by on-ice surface pull method*. Montreal, Canada: Montreal Engineering Company.

Montreal Engineering Company, Banister Pipelines, R.J. Brown and Associates, & German and Milne. (1975). *Conceptual study of installing pipe in Arctic water crossings using pipe pulling vessel*. Calgary, Canada: Polar Gas Project.

Morehouse III, W. (1975, September 22). Eskimos fight pipeline plan. *The Oil City Derrick*, 19.

Nadasdy, P. (1999). The politics of TEK: Power and the "integration" of knowledge. *Arctic Anthropology*, *36*(1/2), 1-18.

Napayok-Short, S. (2017, April 17). *Inuit, capitalism, and colonization: A foreign affair*. https://worldpolicy.org/2017/04/17/inuit-capitalism-and-colonization-a-foreign-affair/

Native groups form alliance to fight Polar Gas. (1979, June-July). *Project North*, *3*(6), 1.

New consortium will study the movement of Arctic gas. (1973, February 3). *Edmonton Journal*, 59.

Newman, P.C. (1985, November 11). A man for most seasons. *Maclean's.* https://archive.macleans.ca/article/1985/11/11/a-man-for-most-seasons

Niiler, E. (2019, March 27). When the Pentagon dug secret Cold War ice tunnels to hide nukes. *History*. https://www.history.com/news/project-iceworm-cold-war-nuclear-weapons-greenland

Nixon, R. (2013). *Slow violence and the environmentalism of the poor*. Harvard University Press.

Noble, B. F. (2011, March 2). *Environmental impact assessment*. https://www.thecanadianencyclopedia.ca/en/article/environmental-impact-assessment

Northwest Hydraulic Consultants Ltd. (1976a). *River break-up observations, Spring 1976, West Hudson Bay Route*. Calgary, Canada: Polar Gas Project.

Northwest Hydraulic Consultants Ltd. (1976b). *River ice and flow conditions, April 1976, West Hudson Bay Route*. Calgary, Canada: Polar Gas Project.

Northwest Hydraulic Consultants Ltd. (1977). *1977 river ice and break up studies*. Calgary, Canada: Polar Gas Project.

Nowell, R. (1973, November 15). Trenches at Pole may lead gas south. *Calgary Herald*, 36.

Nowell, R. (1977a, July 23). Proposals would extend gas links to Maritimes. *Calgary Herald*, 30.

Nowell, R. (1977b, August 30). Polar Gas delays filing pipe application. *Calgary Herald*, 33.

O'Connor, J. (1998). *Natural causes: Essays in ecological Marxism.* Guilford Press.

Offshore Research. (1982). *Ice model tests of an ice breaking LNG vessel for the Arctic Pilot Project*. Vancouver, Canada: Offshore Research Ltd.

Offshore Research. (1983). *Preliminary report: Calm water maneuvering tests of an icebreaking LNG vessel for the Arctic Pilot Project*. Vancouver, Canada: Author.

Offshore Technology. (1977). *Model tests of a laybarge, BAR-347 subjected to ice floes and current*. Montreal, Canada: Montreal Engineering Company.

Ontario to back polar gas project. (1975, July 31). *Nanaimo Daily Free Press*, 4.

Operation Franklin. (2017). https://www.science.gc.ca/eic/site/063.nsf/eng/97263.html

Orvig, S. (1981). A century of Arctic meteorology: From discovery to science. In M. Zaslow (Ed.), *A century of Canada's Arctic Islands* (pp. 131-140). Royal Society of Canada.

Page, R. (1981). The High Arctic: Environmental concerns, government controls and economic development. In M. Zaslow (Ed.), *A century of Canada's Arctic Islands* (pp. 231-244). Royal Institute of Canada.

Palmer, A., & Croasdale, K. (2012). *Arctic offshore engineering*. World Scientific.

Panarctic lights a fire under northern exploration. (2008). *Oilweek, 59*(6), 79.
Panitch, M. (1977, June 1). Alcan route gains support in Canada. *Fairbanks Daily News-Miner*, A11.
Peister, K.S., & Lindsay, D.G. (1974). *Sea ice reconnaissance program summer 1973*. Calgary, Canada: Polar Gas Project.
Pentzien. (1975). *Investigation of bottom pull methods in the Canadian Arctic waters for the Polar Gas Project*. Omaha, Nebraska: Author.
Pentzien. (1978). R*eview of selected Canadian Arctic Straits crossings for the Polar Gas Project*. Omaha, Nebraska: Author.
Perry, F. (1967, December 12). Arctic oil search joined by Ottawa. *Calgary Herald*, 2.
Peyton, J. (2017). *Unbuilt environments: Tracing postwar development in Northwest British Columbia.* UBC Press.
Pfeifer, P. (2018). From the credibility gap to capacity building: An Inuit critique of Canadian Arctic research. *Northern Public Affairs*, 29-34. http://www.northernpublicaffairs.ca/index/wp-content/uploads/2018/07/NPA_6_1_2018_Web_pg29-34.pdf
Phoenix Ventures Ltd. (1977). *Operations report of an on-ice survey conducted March 1977-June 1977*. Calgary, Canada: Phoenix Ventures Ltd.
Polar Gas. (1975, May). *Inuit Today, 4*(5), 45-46.
Polar Gas continues to plan pipeline. (1976, October). *Inuit Today, 5*(5), 16.
Polar Gas has step-by-step strategy to deal with NEB. (1977, November 11). *Edmonton Journal*, 50.
Polar Gas Project. (1977a). *Distribution of birds and marine mammals along fast ice edges in Barrow Strait, N.W.T.* Calgary, Canada: Author.
Polar Gas Project. (1977b). *Early season probe to the Arctic Islands by the icebreaker Louis S. St. Laurent*. Calgary, Canada: Author.
Polar Gas Project (1978). *Natural gas from the Arctic Islands*. Manitoba and Northwestern Ontario fonds (512/3/8). United Church of Canada Archives MNWO/ANCC, Winnipeg, Canada.
Polar Gas Project. (1979a). *Combined pipeline system for connecting Arctic frontiers*. Calgary, Canada: Author.
Polar Gas Project. (1979b). *M'Clure Strait marine geophysical investigation*. Calgary, Canada: Author.
Polar Gas Project. (1979c). *Tour of M'Clure Strait field survey*. Calgary, Canada: Author.
Polar Gas Project. (1981). *Combined pipeline system for connecting Arctic frontier gas phase II: Comparison of alternative routes*. Calgary, Canada: Author.
Polar Gas project back in limelight. (1983, March 18). *Calgary Herald*, D1.
Pounder, E. (1981). Ice, snow and permafrost research. In M. Zaslow (Ed.), *A century of Canada's Arctic Islands* (pp. 163-170). Royal Institute of Canada.
Powell, R. C. (2017). *Studying Arctic fields: Cultures, practices, and environmental sciences.* McGill-Queen's University Press.
Powell, T. (2019, February 12). Calling natural gas a 'bridge fuel' is alarmingly deceptive. https://www.sightline.org/2019/02/12/calling-natural-gas-a-bridge-fuel-is-alarmingly-deceptive/
Prager, B. (1974, March 6). Ontario looks to the North. *The Windsor Star*, 31.
Pratt, L. (1976). *The tar sands: Syncrude and the politics of oil*. Hurtig Publishers.

Prince, R.C., Owens, E.H., Sergy, G.A. (2002). Weathering of an Arctic oil spill over 20 years: The BIOS experiment revisited. *Marine Pollution Bulletin, 44*(11), 1236-1242. https://doi.org/10.1016/S0025-326X(02)00214-X

Pullen, T. C. (1981). *Sea ice and navigation studies in support of logistics plans*. Calgary, Canada: Author.

Pulling out of Polar Gas? (1980, October 18). *National Post*, 7.

Purdy, J. (2015). *After nature: A politics for the Anthropocene*. Harvard University Press.

Qitsualik, R. (2013). Inummarik: Self-sovereignty in classic Inuit thought. In S. Nickels (Ed.), *Nilliajut: Inuit perspectives on security, patriotism, and sovereignty* (pp. 23-34). Inuit Qaujisarvingat.

Ready, E. (2018). Sharing-based social capital associated with harvest production and wealth in the Canadian Arctic. *PLoS One, 13*(3). https://doi.org/10.1371/journal.pone.0193759

Researchers want credit. (1979, September 24). *The Vancouver Sun*, D2.

Ridsdel, J. (1979a, March 6). Arctic Pilot Project 'almost perfect.' *Calgary Herald*, D6.

Ridsdel, J. (1979b, March 15). Northern affairs specialist favors Arctic Pilot Project. *Calgary Herald*, C3.

Riewe, R. (1991). Inuit use of the sea ice. *Arctic and Alpine Research, 23*(1), 3-10.

R.J. Brown and Associates. (1973). *Phase I of marine survey for Byam Channel and Austin Channel, N.W. Territories of Canada*. Montreal, Canada: Montreal Engineering Company.

R.J. Brown and Associates. (1975a). *Byam Channel technical assessment by bottom pull ice island method*. Calgary, Canada: Polar Gas Project.

R.J. Brown and Associates. (1975b). *Report on 1975 marine survey program in the Arctic Islands*. Calgary, Canada: Polar Gas Project.

R.J. Brown and Associates. (1975c). *Summary report on status of survey and data reduction for marine crossings from Queen Elizabeth Islands to Boothia Peninsula*. Calgary, Canada: Polar Gas Project.

R.J. Brown and Associates. (1975d). *Technical assessment of bottom tie-ins for submarine pipelines in the Arctic*. Calgary, Canada: Polar Gas Project.

R.J. Brown and Associates. (1975e). *Technical and cost assessment of Hudson Bay submarine pipeline crossing.* Calgary, Canada: Polar Gas Project.

R.J. Brown and Associates. (1976a). *Assessment of submarine pipeline installation from ice by lower-in techniques*. Calgary, Canada: Polar Gas Project.

R.J. Brown and Associates. (1976b). *Preliminary assessment of inspection, maintenance and repair procedures for submarine pipelines in the Arctic*. Calgary, Canada: Polar Gas Project.

R.J. Brown and Associates. (1976c). *Technical assessment of tow ship and pull ship installation techniques for East Barrow submarine crossing*. Calgary, Canada: Polar Gas Project.

R.J. Brown and Associates. (1978a). *Feasibility study of seal hole concept for ice based pipeline bottom pull without a continuous ice trench*. Calgary, Canada: Polar Gas Project.

R.J. Brown and Associates. (1978b). *Preliminary appraisal of M'Clure Strait and Dolphin and Union Strait Crossings*. Calgary, Canada: Polar Gas Project.

Robertson, S., & Ljubicic, G. (2019). Nunamii'luni quvianaqtuq (It is a happy moment to be on the land): Feelings, freedom and the spatial political ontology of well-being in Gjoa Haven and Tikiranajuk, Nunavut. *Environment and Planning D: Society and Space, 37*(3), 542-560. https://doi-org.uml.idm.oclc.org/10.1177%2F0263775818821129

Robinson, J. L. (1944). *An outline of the Canadian Eastern Arctic: Its geography, peoples and problems*. Ottawa, Canada: Bureau of Northwest Territories and Yukon Affairs, Lands, Parks and Forests Branch.

Rose, H., & Rose, S. (1976). *The political economy of science: Ideology of/in the natural sciences*. Macmillan Press.

Rutherford, S. (2007). Green governmentality: insights and opportunities in the study of nature's rule. *Progress in Human Geography, 31*(3), 291-307. https://doi-org.uml.idm.oclc.org/10.1177/0309132507077080

Sadar, M.H., & Stolte, W.J. (1996). An overview of the Canadian experience in Environmental Impact Assessment (EIA). *Impact Assessment, 14*(2), 215-228. https://doi.org/10.1080/07349165.1996.9725897

Said, E. (1978). *Orientalism*. Pantheon Books.

Scott, C. (2011). Science for the West, myth for the rest?: The case of James Bay Cree knowledge construction. In S. Harding (Ed.), *The Postcolonial Science and Technology Studies Reader* (pp. 175-197). Duke University Press.

Scott, J.C. (1999). *Seeing like a state: How certain schemes to improve the human condition have failed.* Yale University Press.

Sellar, D. (1973, February 13). Key to ending energy crisis still pipelines. *Calgary Herald*, 13.

Sergy. G.A., & Blackall, P.J. (1987). Design and conclusions of the Baffin Island Oil Spill Project. *Arctic, 40*(Supp. 1), 1-9. https://doi.org/10.14430/arctic1797

Shokr, M., & Sinha. N. (2015). *Sea ice: Physics and remote sensing*. American Geophysical Union.

Sica, C., & Huber, M. (2017). "We can't be dependent on anybody": The rhetoric of "Energy Independence" and the legitimation of fracking in Pennsylvania. *The Extractive Industries and Society, 4*(2), 337-343. https://doi.org/10.1016/j.exis.2017.02.003

Sidjak, W. (1978). *The Arctic Pilot Project*. Chemical Engineering Conference. Calgary, Canada: Arctic Pilot Project.

Simpson, M. (2019). Resource desiring machines: The production of settler colonial space, violence, and the making of a resource in the Athabasca tar sands. *Political Geography, 74*, 1-12. https://doi.org/10.1016/j.polgeo.2019.102044

Size of tankers poses problem. (1977, August 17). *The Star-Phoenix*, 43.

Smith, N., & O'Keefe, P. (1980). Geography, Marx and the Concept of Nature. *Antipode, 12*(2), 30-39. https://doi-org.uml.idm.oclc.org/10.1111/j.1467-8330.1980.tb00647.x

Smith, N. (2004). *American empire: Roosevelt's geographer and the prelude to globalization*. University of California Press.

Smith, N. (2007). Nature as accumulation strategy. *Socialist Register, 43*, 16-36.

Smith, N. (2008). *Uneven development: Nature, capital, and the production of space* (3rd ed.). University of Georgia Press.

Spiegel, S.J. (2017). EIAs, power and political ecology: Situating resource struggles and the techno-politics of small-scale mining. *Geoforum, 87*, 95-107. https://doi.org/10.1016/j.geoforum.2017.10.010

Stern, P. 2005. Wage labour, housing policy and the nucleation of Inuit households. *Arctic Anthropology*, *42*(2). 66-81. DOI: 10.1353/arc.2011.0054

Struzik, E. (1984, July 20). Ottawa pondering Polar pipeline. *Edmonton Journal*, E12.

Stuhl, A. (2016). *Unfreezing the Arctic: Science, colonialism, and the transformation of Inuit lands.* University of Chicago Press.

Taylor, L. (1974, April 24). Heat...from the frozen desert. *The Province*, 5.

Tester, F.J., & Irniq, P. (2008). Inuit Qaujimajatuqangit: Social history, politics and the practice of resistance. *Arctic, 61*(Suppl. 1), 48-61. DOI: 10.14430/arctic101

Tester, F.J., Lambert, D.E.J., & Lim, T.W. (2013). Wistful thinking: Making Inuit labour and the Nanisivik mine near Ikpiarjuk (Arctic Bay), northern Baffin Island. *Études inuit. Inuit studies*, *37*(2), 15-36. DOI: 10.7202/1025708ar

The Army Goes North: Operation Muskox. (n.d.). https://www.ucalgary.ca/arcticexpedition/map-home/army-goes-north-operation-muskox

Thrasher, K. (1998). *Exercise Musk Ox: Lost opportunities* (Master's thesis, Carleton University, Ottawa, Canada).

Todd, Z. (2016). An Indigenous feminist's take on the ontological turn: 'Ontology' is just another word for colonialism. *Journal of Historical Sociology, 29*(1), 4-22. https://doi-org.uml.idm.oclc.org/10.1111/johs.12124

Toews, O. (2018). *Stolen city: Racial capitalism and the making of Winnipeg.* Arbeiter Ring Publishing.

Transporting liquid gas 'alternative to pipeline.' (1977, October 27). *Calgary Herald*, C3.

Tuck, E., & Yang, K.W. (2012). Decolonization is not a metaphor. *Decolonization: Indigeneity, Education & Society, 1*(1), 1-40. https://jps.library.utoronto.ca/index.php/des/article/view/18630

Vasil, A. (2015, April 2015). *Fighting for the right to be cold*. https://nowtoronto.com/news/if-we-cannot-save-the-frozen-arctic-how-can-we-save-the-re/

Walker, S., Eketone, A., & Gibbs, A. (2006). An exploration of kaupapa Maori research, its principles, processes and applications. *International Journal of Social Research Methodology, 9*(4), 331-344. DOI: 10.1080/13645570600916049

Warde, P. (2018). Constructing Arctic energy resources: The case of the Canadian North, 1921-1980. In N. Wormbs (Ed.), *Competing Arctic Futures* (pp. 19-46). Palgrave.

Watt-Cloutier, S. (2015). *The right to be cold: One woman's story of protecting her culture, the Arctic and the whole planet*. Allen Lane.

Watts, V. (2013). Indigenous place-thought and agency amongst humans and non humans (First Woman and Sky Woman go on a European world tour!). *Decolonization: Indigeneity, Education & Society*, *2*(1), 20-34. https://jps.library.utoronto.ca/index.php/des/article/view/19145

Willems-Braun, B. (1997). Buried epistemologies: the politics of nature in (post) colonial British Columbia. *Annals of the Association of American Geographers, 87*(1), 3-31. https://doi-org.uml.idm.oclc.org/10.1111/0004-5608.00039

Wilson, S. (2001). What is an Indigenous research methodology? *Canadian Journal of Native Education, 25*(2), 175-179.

Wilson Rowe, E. (2017). Promises, promises: The unbuilt petroleum environment in Murmansk. *Arctic Review on Law and Politics*, 8, 1-14. https://doi.org/10.23865/arctic.v8.504

Wråkberg, U., & Granqvist, K. (2014). Decolonizing technoscience in northern Scandinavia: The role of scholarship in Sámi emancipation and the indigenization of Western science. *Journal of Historical Geography, 44*, 81-92. https://doi.org/10.1016/j.jhg.2013.12.005

Zalik, A. (2015). Resource sterilization: reserve replacement, financial risk, and environmental review in Canada's tar sands. *Environment and Planning A*, 47, 2446-2464. https://doi-org.uml.idm.oclc.org/10.1177%2F0308518X15609218