Subterranean Bodies: Mining the Large Lakes of North-west Canada, 1921–1960

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ABSTRACT

This paper examines the history of hard rock mining on the large lakes of north-west Canada (Athabasca, Great Slave and Great Bear) from 1921 to 1960. It is based on the records of the three largest mining companies, Eldorado Mining and Refining, Cominco, and Giant Mines as well as government documents, oral histories and published geological and technical reports. The paper opens by assessing the historiography of mines in relation to nature and presents an overview of the regional geology and mine operations. The analysis considers the character of 'subterranean bodies' and how they reveal the physical engagement of miners with nature. It assesses how geology in conjunction with the creation of habitable mine environments animated these bodies. The final section moves into the surface mills where ores were metaphorically and physically digested as part of a larger metabolic process. The manuscript argues that the perception of subterranean bodies masked the negative consequences of mine operations by presenting minerals as renewable resources, by presenting the large lakes as physical rather than cultural landscapes, and by separating ores from their larger environmental contexts even as miners integrated industrial operations into the large lake ecosystems.

KEYWORDS

Mining, language, geology, uranium

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Prior to the 1920s, the Mackenzie River basin remained a frontier of Canadian society populated by indigenous northerners, fur traders and missionaries and occasionally visited by scientists, explorers and tourists. Only the southernmost reaches of the basin, the Peace River district of northern Alberta, allowed viable agriculture anywhere other than small pockets of moderate climate on the shores of lakes and rivers. The limited agricultural potential kept settlers out of the basin, although growing numbers of itinerant trappers and traders had travelled north along the Mackenzie River in the closing decades of the nineteenth century. Canada's Dominion government had little interest in the Mackenzie District, however, until the discovery of oil near Fort Norman in 1920, leading to a prompt treaty settlement, Treaty 11, with the indigenous Dene in 1921. The discovery of oil was significant not just in its own right, but also because of its potential to provide a strategic fuel supply for industrial development in the north-west. This potential was realised with the identification and rapid development of radium and gold mines on the large lakes of the Mackenzie basin in the 1930s.

Located close in time and space to the world-famous Klondike gold rush, and sharing the inhospitable subarctic environment as both stage and main actor, the Mackenzie district mining boom was nevertheless of an entirely different character than its predecessor to the west. If the Klondike was one of the last 'poor man's' mining rushes, the Mackenzie mining developments quickly co-opted individual efforts into large corporate structures that characterised mine and mill operations on the north-west large lakes.[1] The Klondike rush had demonstrated that isolation and a harsh climate were obstacles that could be overcome with the right motivation. But the gold and even more precious radium on the Mackenzie lakes was locked up in hard rocks, not dispersed in streams and gravel. Even the most motivated individuals could only prospect for these minerals, they could not hope to extract them. By the 1940s, when uranium replaced radium production in the region, the military applications of radioactive minerals brought the Canadian government into the north-west mining industry through the formation of the federal crown corporation, Eldorado Mining and Refining, Ltd., to mine, process and market uranium found on the large lakes. Between 1920 and 1960, environment and geography combined with the nature of the mineral formations and their market and military significance to create a new kind of northern mining industry and new relationships to northern environments.

This paper considers the languages and practices of the individuals and companies involved in the north-west mining industry as evidence of their relationships to the rest of nature. The perspectives of managers, engineers and geologists predominate in this analysis, reflecting their more influential role in shaping mine and mill operations and practices in this context from within the corporate structures of the principal mining companies: Eldorado Mining and Refining, Cominco, and Giant Mines. Company directors also figure in this analysis as they were often geologists, engineers or prospectors who had spent significant time on the Mackenzie lakes prior to their promotion into the ranks of corporate executives and were much closer to mine operations than their counterparts in other mining districts. The language and practices of miners, millers and prospectors are examined not only as they are preserved within corporate and government records, but also significantly from their own oral and written records. Collectively I refer to this category of sojourning representatives of southern industrial societies as mining men.

The paper argues that these mining men valued their exploitation of subarctic natural resources as a creative engagement that extended the possibilities for life and work into hostile surface and sub-surface places. This argument stands in contrast to prevailing interpretations within environmental historiography which emphasise the malignance of mining operations, the pollution and disfigured surfaces that mines leave behind, and the social and political responses to the environmental crises created by these operations.[2] Historians Richard Francaviglia and Duane Smith, seek explanations for the destructive character of mining in Western cultural justifications that set forth the right to dominate the natural world and transform the land.[3] Kathryn Morse's environmental history of the Klondike gold rush turns sympathetic attention to miners' work in nature and recognises their 'intense physical and mental contact with the earth'. Morse nevertheless argues that miners were, in the end, 'interested only in gold'.[4] Environmental historians see capitalist greed and the abstraction of the natural world into commodities as the motivation and mechanism that drove mining men and allowed their transformation of living nature into dead and mechanical industry.[5] This interpretation draws upon much older perceptions of mines as dead and degraded places. There is no shortage of admonitions against miners in the ancient and early-modern worlds for the damage their work did to nature.[6]

In combination with this deeply rooted critique of mining's assaults upon natural systems there exists an historical mining language that evokes underground ore deposits as subterranean bodies replete with veins, heads and tails. This paper describes how, in the Mackenzie district hard rock mines, this particular mining language flourished and evolved, detailing subterranean bodies that animated mines and mills in early-twentieth-century subarctic Canada. Mining men expanded upon this language in response to changed hard rock mining practices. But subterranean bodies constituted more than an industrial tool, they also reveal the complex symbolic relationships that existed between mining men and the environments they exploited. Daniel Philippon demonstrates how metaphors reveal the values that people read into nature and which in turn affect their interactions with the natural world.[7] Metaphors represent how people understand and experience one thing in terms of another and we can use the presuppositions that make the metaphors work to explore the values and ethics that encourage their collective adoption.[8] When practice correlates to metaphor, as we see mining men remaking nature in the Canadian Subarctic by constructing extractive systems that modelled the human body, this strengthens the interpretative significance of the metaphorical language of subterranean bodies and what it can tell us about the industrial transformation of the large lakes.

By assessing the creative practices of the early twentieth-century mining industry as a specific manifestation of capitalist relations to natural resources, this paper builds upon Andrew Isenberg's argument in *Mining California*, that we have to recognise the systematising and conservative character of capitalism.[9] Extractive industrial systems such as the gold and uranium mines, depended upon locally available resources to subordinate both living and non-living nature to produce simplified goods for international markets. This paper thus provides an illustration of Marina Fischer-Kowalski and Helmut Haberl's argument that, whereas pre-industrial economic activity harnessed other living things to human ends, industry extended this manipulation to the non-living or long-dead parts of nature.[10] The persistent emphasis by mining men upon notions of living mine environments ultimately encouraged environmentally unconstrained mining practices with enduring harmful impacts on local ecosystems. We need to look beneath the earth's surface through the eyes of those who pursued mineral riches there. Otherwise, we underestimate the complex rationale that buttressed decisions with wide-reaching negative environmental effects.

The western subarctic, reaching from the southern tip of Lake Winnipeg to the Arctic Circle as it rings the Northwest Territories, remained remote from industrial society until the combined stimuli of rich oil and mineral finds, economic depression and new transportation technologies bridged the distance between this vast territory and metropolitan centres to the south.[11] After 1930, gold, radium and uranium mines dominated the new industrial landscape laid down on the shores of Lake Athabasca, Great Slave Lake and Great Bear Lake.[12] These three lakes formed with the retreat of the Laurentide ice sheet and are the most spectacular remnants of glaciation across a landscape submerged in a 'patternless profusion' of lakes and ponds.[13] Great Slave and Great Bear lakes are among the largest in the world. Bottoming out at 614 metres, Great Slave Lake is the deepest lake in North America and is exceeded in depth only by ancient tectonic lakes such as Lake Baikal in Siberia, or Lake Tanganyika in the African Rift Valley. Between 1921 and 1960 the Canadian state and private enterprise looked to these freshwaters as openings in an extreme environment, necessary to extend industry into the north-west (see Figure 1).

The aquatic bridge created by the large lakes bound mineral-rich Precambrian rocks in the north-west to the oil-rich Paleozoic formations to the east that would ultimately fuel their extraction. Uniformly old, otherwise Precambrian shorelines along the large lakes expressed considerable variety. On Great Bear and Athabasca, granites intruded, deformed and metamorphosed older sedimentary rocks creating the principal host environments for economic uranium deposits. The Archean Slave province (or Slave craton) that borders Great Slave Lake

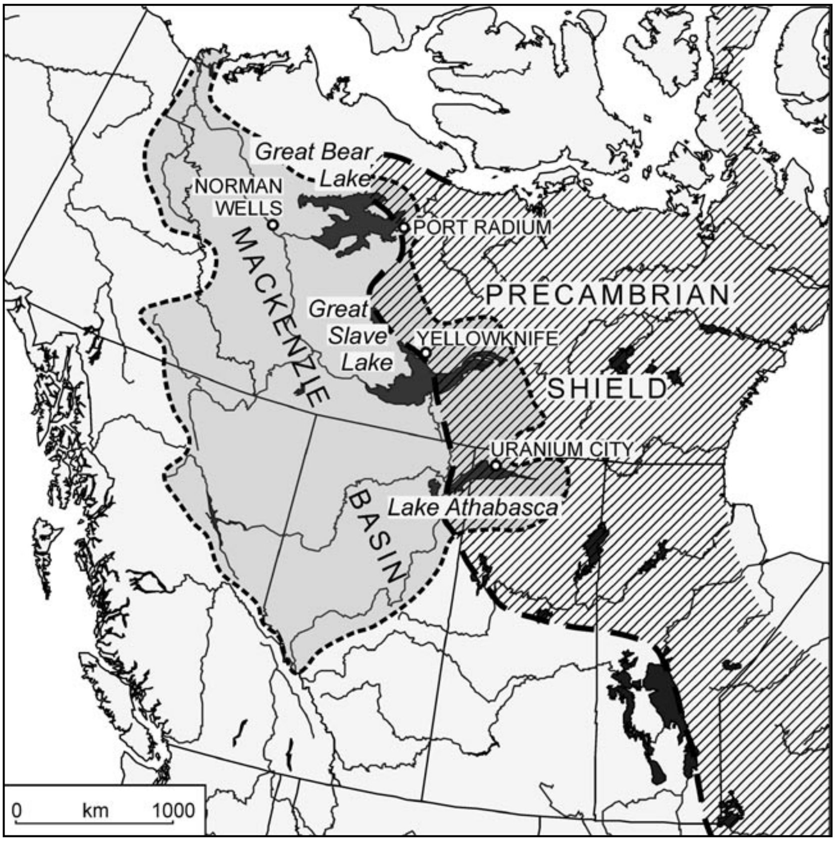

FIGURE 1. The large lakes of north-west Canada

represents the ancient nucleus of a proto-continent with rocks in the Acasta gneiss north of Yellowknife dating back four billion years. Gold was found in a greenstone belt made up of volcanic rocks set down in a marine environment overlain by sedimentary rocks, all of which were subsequently altered and intruded by granites and granodiorites. From the north shore of Lake Athabasca to the Arctic Ocean a great system of north-easterly trending faults and shear zones, dipping vertically to steeply north-west, imposed a regional structural orientation. The diverse origins, ancient age and multiple phases of deformation of the Precambrian rocks produced complicated geologies and striking landscapes. The geologist Mackintosh Bell in his 1900 survey of Great Bear Lake described thousand-foot cliffs at the water's edge with rocks that 'weather to beautiful shades of purple, red, and brown, and the reflections of the coloured precipitous cliffs in the clear northern waters, with the brilliant arctic sunlight were singularly beautiful'.[14]

To the south-west, the younger Interior Platform included Palaeozoic and Mesozoic sedimentary sequences set down overtop of Precambrian rocks when, around half a billion years ago, the Shield was mostly covered by warm and shallow seas. These sedimentary sequences hosted rich oil and gas deposits and some coal. It was in Palaeozoic formations that workers with Imperial struck oil in 1920. At the time, indigenous peoples retained title over the land along the Mackenzie River. From the Department of the Interior, F.H. Kitto advised the Dominion Government that 'the recent discoveries of oil at Norman have been made on lands virtually belonging to those tribes'.[15] A treaty party sent north the following year obtained signatures to Treaty 11 from the Dene resident along the Mackenzie River, Great Slave Lake and Great Bear Lake.[16] The character of the oil field combined with the costs of resource development in such a remote location remained prohibitive and Imperial Oil capped the main well at Norman in 1925. Exploration nevertheless continued apace across the Mackenzie basin, with prospectors and companies secure in the knowledge that oil at Norman Wells could fuel future operations.

The identification of pitchblende on the wave-cleared shores of Great Bear Lake in 1930 and gold on Great Slave Lake and Lake Athabasca after 1933, stimulated the rise of a mining industry and sustained this industry up to 1960. Gold is one of the few commodities that benefits from general economic depression. The value of gold rises during economic downswings; it was a secure commodity much sought after by shaky national economies, particularly those that in the 1930s had retained the gold standard.[17] Radium (produced from pitchblende) likewise remained a profitable commodity during the Great Depression. The value of radium was inelastic as world reserves were so small and the demand for its use in hospitals to treat cancers and for research continuously exceeded supply.[18] Simultaneous to the increase in the value of gold, the costs of exploration and production fell along with other goods and services in the depressed Canadian economy. As Prairie farms failed, more men were willing to work on a distant lake shore in a severe climate. In June 1935 the Saskatchewan Attorney General, T.C. Davis remarked on the 'influx into [the Athabasca] territory of a large number of people from all over Canada … they are drifting in from everywhere'.[19] The combination of available labour, lowered costs and high value for the end products meant that potential profits rose dramatically.[20]

In the early 1930s, hundreds of men and women travelled north to Great Bear Lake to prospect for pitchblende or work in one of the three operating mines.[21] The largest operation, the Port Radium mine on the shores of Echo Bay, went underground in 1932, installed a gravity mill in 1933, and was in continuous operation employing between seventy and one hundred men until wartime labour and material shortages closed it down in 1940. Other newcomers picked up jobs in the burgeoning service industry working on the boats that ferried goods and people, or in administrative offices located at Cameron Bay. The gold rushes onto Lake Athabasca and Great Slave Lake took off in 1934.[22] The Athona and Box mines on Lake Athabasca employed forty and thirty men respectively, who helped populate the village of Goldfields. Prospectors located larger and richer deposits on Great Slave Lake. A new mining community, Yellowknife, was founded in 1938 at the site of the Con and Giant mines. Consolidated Mining and Smelting (hereafter Cominco) operated both the Con and the Box mines as the largest company in the subarctic gold industry.[23] Gold mining operations contracted sharply with the arrival of World War Two. The mines on Lake Athabasca closed permanently, the Con mine ceased production for the duration of the war, and the Giant mine delayed production until 1945.

Port Radium closed in 1940 but secretly reopened in 1942, now under the auspices of the federal crown corporation Eldorado Mining and Refining (hereafter Eldorado). The new operation mined uranium as a continental supplier of high grade material to the American Manhattan Project. After the war and into the 1950s the gold and uranium mines each expanded their operations; the workforce at Port Radium alone tripled to around 250 men.[24] Eldorado opened the Beaverlodge mine, the largest of several mines including as well the Nesbitt-LaBine, Nicholson, Lorado and Gunnar operations sunk into the low-grade uranium deposits on the north shore of Lake Athabasca. Residents abandoned the older village of Goldfields and dragged the school-house, hotel and private residences across the ice to the new site of Uranium City. The contracts between the Canadian federal government and the United States Atomic Energy Commission (USAEC) expired in 1962 as the United States completed its stockpile of nuclear warheads. Having exhausted the most profitable pitchblende seams, Port Radium closed in 1960 and activity in the gold and uranium fields on Great Slave Lake and Lake Athabasca faltered.

THE LANGUAGE OF MINING

Hard rock mining in the Canadian Subarctic did not follow upon previous industrial activities but rather supplanted an earlier mercantile fur trade economy. Eldorado, Cominco, Giant and the many smaller companies imported men to the north-west to operate the mines and mills. Although employed in surface operations and auxiliary industries, as transportation workers in particular, no local Metis or Native workers were employed underground prior to 1958. Native involvement in the Mackenzie mines was even more circumscribed than in the Yukon gold district where many Natives found employment as packers, prospectors, provisioners and woodcutters. These forms of employment were available to Mackenzie Natives but the mining companies closely regulated who would work not only underground but also in auxiliary employment.[25] Mining operations likewise excluded women, although there were a handful of women prospectors including most notably Viola MacMillan who operated Gulch Mines, a small mining company on Lake Athabasca in the 1950s, and served as president of the Prospectors and Developers Association for 13 years beginning in 1943. The majority of workers above and below ground were Canadian-born or otherwise white British men who commonly stayed on only a year (the length of their first contract) and then moved on. A large minority was made up of European immigrants to Canada. Swedes and Norwegians frequently found work as hand-steelers, 'they were shaft sinkers and they drove drifts and cross-cuts underground'.[26] Many eastern and southern European immigrants who came to the mine fields without such specific skills were put to surface work initially, while they learned English, and only later employed underground. Prospectors, miners and mill workers arrived as skilled and unskilled workers, those with experience in similar kinds of environments and those completely new to the subarctic. The majority of workers were sojourners and all found themselves in an unfamiliar environment, segregated physically and socially from the long-term, predominantly Native residents of the region.

Those employed as managers, engineers, geologists and company directors brought specific training and experience to the north-west mines and the degree of specialisation increased towards mid-century. At Port Radium in the 1930s, there was no resident geologist and the superintendent Emil Walli relied on his experience from mines in northern Ontario and a basic knowledge of geological principles to guide development underground.[27] Walli later went on to direct the Nesbitt-LaBine operations on Lake Athabasca. In 1937, Neil Campbell, a graduate from the University of Alberta came to work at the Con mine, which became the subject of his doctoral dissertation. In his doctoral research, Campbell discerned a new gold-rich shear zone, named the Campbell shear, which supplied much of the gold ore to the mine from the 1940s through the 1960s. At Eldorado, Dr E.B. (Gil) Gillanders replaced Ed Bolger as mine manager at Port Radium in 1947 and later took over the Beaverlodge operations. Gillanders had a doctorate in geology, although his thesis area was in north-east Rhodesia.[28] He was a prime example of the new corporate executives at Eldorado and Cominco who used their training as well as field and practical experience in mining, engineering or geology to rise through the corporate ranks. From the outset, mine managers, geologists and superintendents were permitted to bring their families north and their commitment to a particular operation typically spanned several years or even decades. Nevertheless, they too eventually left the subarctic for jobs in the south or elsewhere in the Canadian mining fields.

George Findlay, a prospector who worked in the Yellowknife and Uranium City districts, insisted that 'a mining man without imagination, well he isn't a mining man'.[29] Findlay thus summed up the basic challenge of mineral exploration and development in the north-west: miners, engineers, geologists and company directors had to be able to discuss the physical properties of mostly hidden masses. A highly technical language, inherited from past mining practice and further developed in twentieth-century hard rock operations, contributed concepts such as cobbing, stopes, adits, drifts and raises to describe operations and structures that lacked surface counterparts.[30] Mining's unique technical language pointed to the exceptional character of subterranean primary production.[31] There was another language, however, that coexisted with the technical language but rather than describing mines as alien places, drew instead on familiar organic metaphors and metaphors of the human body. There were ore *bodies* and ore concentrated in *veins*. Miners 'cut' and 'open[ed] up' the veins by drilling and blasting to expose mineralisation.[32] Emil Walli, the superintendent at Port Radium, directed his workers to 'follow the veins' which appeared as 'branching vein system[s]' or 'vein structures' where veins swelled or pinched or were elsewhere 'sinuous' (see Figure 2).[33] Underground, limbs, tongues and noses manifested as exten-

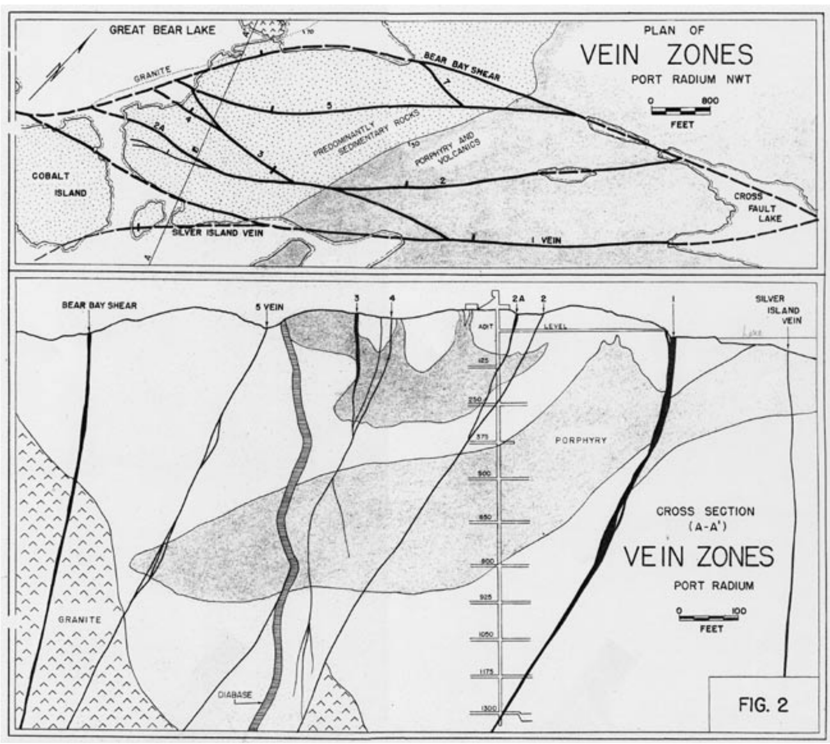

FIGURE 2. Vein zones at Port Radium

sions of larger ore bodies. As W.F. James and B.S.W. Buffam wrote in 1949, 'In addition to the main granite mass plunging east, there is some evidence to indicate that a tongue of granite extends southeast from the main mass.'[34] The limbs and noses were found in structures like veins or other distinguishable formations that curved and folded.[35]

This language evoked a subterranean world modelled on the human body and hearkened back to the descriptions of an alive earth that preceded the modern dead and mechanical nature.[36] Descriptions of veins and bodies were part of the older heritage of mining operations as such language had long been employed in subterranean environments.[37] But beneath the shores of the Canadian large lakes in the early twentieth century mining men set forth much more detailed descriptions of subterranean bodies that reflected hard rock mining's changed relationships to nature in the twentieth-century subarctic.

GEOLOGY

In the early twentieth century geologists became vital to profitable hard rock mine operations. The federal Geological Survey of Canada (GSC) retreated from mapping in the north-west after 1929 and mine geologists played a greater role than ever before in articulating the general geology of the large lake region. Industry geologists focused their attention on the immediate vicinity of mine sites to the extent that C.S. Lord, in his 1951 synthesis of the *Mineral Industry of the Northwest Territories*, remarked how 'the best known parts of the Canadian Shield [geology] lie within 200 miles of its western border' where the mining operations were all found.[38] As changes in technology and processing made exploitation of lower-grade ores more feasible, host rocks generally had a more complex mineralogy which placed greater demand on scientific expertise for its efficient extraction. Mine geologists became fixtures at mine operations on the lakes. By the 1950s, each of the major mine sites employed several geologists. At the Giant mine four men worked under the direction of the Chief Geologist. They visited each working place daily and mapped the geology of a stope 'from the time stope preparation is started until the mining is completed'.[39] Mine directors expected geological staff to regularly examine the rocks exposed during the course of mine work in order to guide operations most efficiently.[40]

As mine science and practice became increasingly specialised, geological visions of subterranean environments exerted greater influence over mine operations than they had in the past. Where other observers saw rocks as static and inanimate objects, geologists saw the lithosphere in motion over time. This motion manifested when geologists imagined ore deposits in the form of their precursor fluids, interpreted regional structural features related to the former location of rocks at or near the edges of continental plates, and assessed how increased pressure and temperature at depth caused solid rocks to fold and fault.[41] In composing regional geological accounts, the geologists working at the Con mine focused on the north-easterly trending fault system, which included the Campbell shear zone. Movement along the fault released pressure and created channels through which ore-bearing solutions moved and in which they ultimately petrified. These ore-bearing solutions originated in the chemical soups that comprised particular rocks.[42] Geologists sought out the source of mineralisation at each site, the 'parent' material from which the mineral-rich hydrothermal solutions descended. The originating granites and granodiorites were readily apparent at Port Radium. On Lake Athabasca, however, multiple events had led to the formation of uranium-bearing rocks and A.W. Joliffe with Gunnar abandoned his efforts to compose a straightforward history.[43]

Matthew Eddy discusses how, in Enlightenment Scotland, geological sciences used medical concepts about the human body as analogies to describe the structure of the earth.[44] Geological accounts from the large lake mines furthered this conceptual relationship by animating subterranean bodies. Geologists saw how veins and bodies 'plunged' and could 'turn the other way and then back again'.[45] These veins were the remnant structures through which the hydrothermal solutions, from which mineral deposits originated, had 'circulated'.[46] Circulating mineral solutions penetrated and impregnated rocks. Ores straddled boundaries and encroached upon other formations. Geologists were concerned to describe the 'habit and character' and the 'behaviour' of structures relevant to the mine operations.[47] Geologists also closely dissected the bodies they encountered. In just one report, the mine geologists at Beaverlodge, B.S.W. Buffam, Douglas Campbell and E.E.N. Smith, described 'hairlike threads of pitchblende', and identified the minerals that entered 'hairline fractures' and the fractures filled with 'bone-white' quartz.[48] The closest detailing of ore bodies appeared in mining reports composed by geologists but produced for managers and engineers. The exclusively geological reports used much more highly technical and specific language. Geologists adapted subterranean bodies to convey notions of an animate lithosphere to other mining men. In this fashion the use of these metaphors shaped a particular human understanding of the material world and reflected the increased prominence of geology in interpreting the structures and rocks exploited in hard rock mines.

EXTENDING HABITABLE ENVIRONMENTS

In the early twentieth century, from the Mike Horse mine in Montana to the Rand gold mines in South Africa, as the richest and most readily accessible ore seams were mined out operators moved further down and exploited ever more marginal deposits.[49] These circumstances were most pronounced in frontier areas like the Canadian Subarctic where the distance from industrial centres required the construction of extensive plants and transportation networks to exploit mineral deposits. Once in place, mine operators preferred to maximise their production in the immediate region before abandoning an investment and moving on. The Con, Giant and Port Radium operations each deepened their shafts in the post-war period and the same rationale guided decisions to mine the low-grade deposits on Lake Athabasca and tailings waste on Great Bear Lake. To intensify operations rather than to exploit more extensively the rich mineral resources of the Canadian Shield meant the construction of ever more complicated subterranean support systems for miners that substituted for the elaboration of transportation networks or the creation of new industrial communities. Mines and mills became more profoundly integrated into local ecosystems, with mine operators drawing on principles of industrial engineering that systematised not only the disparate parts of the natural world (water, air, rocks, ore) but also human relations to different materials and fuels. In this context, mine engineers and operators used descriptions of subterranean bodies to emphasise the place of people in their new industrialised systems.

Sojourning workers in the north-west found conditions at the earth's surface extreme, unaccustomed as they were to the long, cold, dark winters and the blazing hot, mosquito and black-fly-infested summers; conditions above ground were nevertheless quite amenable to human habitation. Below ground was another matter. A mine was only possible if it was habitable. Humans had to survive underground in order to create a mine. Mines were like buildings in reverse, constructed downwards by removing material, rather than upwards with the addition of material. They demanded the same basic flows of air, heat and water and the same, general structural soundness because mines did not exist in the absence of human activity.[50] These elements essential for life had to be brought below ground as inextricable parts of the mines themselves.

Articulating the presence of subterranean ore bodies emphasised that much of what miners did underground was necessary to create space for human bodies and highlighted the physical and tactile relations between mine work and underground nature. Arne Lahti, a manager at Port Radium in the early 1930s, regularly described the makeup of the ore 'face' specifically whether pitchblende showed or not.[51] Miners used figurative 'fingers' and 'toes' to penetrate into the walls of the shaft or the face from which they were working and set powder for blasting.[52] Miners exposed faces, backs and breasts underground.[53] The superintendent at the Giant mine, D.C. McDonald, described how 'breasts are carried 8 ft. high and stope backs are arched where necessary'. McDonald also detailed the 'rib pillars' that provided support along the stopes.[54] This use of language expressed how miners physically engaged underground environments and described alien subterranean places using human bodies as a scale, because it was these bodies that would take the subterranean environments apart. Egan Sorensen, a miner at Beaverlodge, broke his back blasting a breast underground. While scaling the back, a piece of loose rock weighing approximately 1,000 pounds fell from above and crushed his spine.[55] Miners' bodies were necessary to extract ores and the dangers that mine work posed to human life evidenced an intimate physical engagement.

As hard rock mines extended further beneath the surface to access diffused minerals, mines demanded a degree of stability that had not been necessary in more shallow operations. Miners maintained structural stability down shafts and along drifts by timbering, rock bolting and leaving in place pillars of ore, like the ribs in the Giant mine, to act as supports.[56] By the 1940s, cut and fill methods prevailed in the large lake mines and provided stability by using waste material as fill. The barren rock broken up to access the ore, in this system, was redistributed into areas that had been mined out. The Con and Beaverlodge mines used mill tailings to fill in the cavities created by mining.[57] At Beaverlodge water and pipes conveyed the tailings underground as hydraulic fill, which penetrated the interstices between mined-out areas filling in more irregularities and offering better support. These methods contrasted with the short-lived low-grade Box mine in the 1930s, which employed a forced caving system. Here, miners blasted out the supports that held ore bodies allowing the ore to cave, fall and shatter facilitating subsequent handling. The miners retreated parallel to the direction of the ore body, allowing the roof over mined-out areas to subside to restore stability.

Hard rock mines deepened human ties to nature by extending the human experience into ever more alien and previously inaccessible places. This required that mine engineers sustain human bodies beneath the earth and protect them from the unique hazards of these environments. Airflow had to be established and regulated in mines, it also had to account for the additional hazards produced by diesel-powered equipment and the dust created by shattering rocks for ore.[58] As mines extended deeper beneath the surface, the provision of fresh air to workers became increasingly complicated. As one observer noted, deeper mining operations at mid-century were made possible 'by a revolution in methods to produce a lot of muck and move it quickly ... which in turn has meant the creation of more dust. The problem therefore has been to get rid of it.'[59]

Ventilation was necessary to limit the concentrations of silica particles and radioactive dust that were the major health hazards within the north-west mining industry.[60] Wherever hard-rock miners broke apart silica-bearing rocks they inhaled silica-rich dust leading to silicosis, a wasting and fatal lung disease. The hazards of mining radioactive ores were not as well understood as silicosis but drilling, blasting and milling produced dust particles and water droplets to which the solid decay products of radon attached.[61] Inhaling uranium dust brought these radioactive particles inside human bodies, intensifying individual exposure to harmful radiation.[62] Union representatives and Eldorado officials disputed the standards of acceptable daily exposure and most mines simply relied on improved ventilation to minimise exposure to both radioactive and silica-bearing dust. In these ventilation systems, a combination of natural drafts and fans circulated and forced the air through the shafts. To reach the farthest most isolated parts of mines, ten to fifteen inch ventilation pipes and fans were used. Nevertheless, a team that surveyed the Beaverlodge site in the summer of 1954 noted 'active dead ends at the mine with no ventilation': some of these were almost a kilometre long.[63] Invisible radiation hazards undermined workers' efforts to create habitable environments.

Cold posed the greatest hazards to human life and efficient mining in the Canadian north-west. At Port Radium, the farthest north of the mines, permafrost reached 100 metres below the surface. The mine shaft extended to 240 metres by 1940 and the final depth reached in 1953 was 743 metres. In the top permafrost zone, drill machines and water lines froze and haulageways and ditches had to be kept clear of ice. In each of the large lake mines it was necessary to supply warm air to the underground workings. This was accomplished in part by passing air currents through the old workings in upper levels. These 'natural facilities', as ventilation specialist C.S. Gibson of Ontario put it, sufficed in some mines.[64] Elsewhere mine operators relied on the excess heat produced by machines that worked at and below the surface to help keep spaces at working temperature.[65] Bunker heating oil was burned to provide additional warmth and fans directed warm air into the workings.[66]

Industrial operations employed high-energy fuels that generated heat that could be captured to keep workers warm, but which at times was also sufficient to melt and damage the machinery itself. Water was needed to cool machines as well as to keep workers going. This basic dependence explains in part why industries situated initially on the lakes, which provided reliable and massive supplies of freshwater. Under the Dominion Quartz Mining Regulations, mining companies lifted water to satisfy machines and workers directly from the large lakes, pumping this water on-shore and then underground.[67] Gunnar estimated their daily consumption of lake water, including water chlorinated for domestic use, at four million gallons. The Con operations provide an approximation of relative consumption. There the mine and mill were supplied by two 200 gallon-per-minute pumps that directed the flow to 45,000 gallon storage tanks. Two 100 gallon-per-minute pumps and a 20,000 gallon storage tank were required for human consumption.[68]

At each of the mines, controlling water was more important than ensuring adequate supply. As miners blasted and extracted rocks underground they freed up new pathways for water found in the pores, cracks and fissures of the country rock. Water seeped out of the walls and accumulated in the drifts and shafts threatening to flood the mine. Over time, as a mine aged, water and ice problems eased as ground waters disappeared from the shafts closest to the surface, providing more space through which to circulate and warm air. Mine operators recognised the significance of the 'age and probable life' of a given operation, and these notions were part of the larger discourse about mines as living places.[69] Each mine also had unique water problems. Secondary faulting in the gold-rich Campbell shear zone created watercourses in the mine workings. At Port Radium, Great Bear Lake breached the mine in 1936. To remove the water required constant pumping and in 1940 this flow amounted to 300 gallons per minute.[70] In addition to pumping the water out of the mine, workers annually drilled and grouted several thousand metres in the mine walls. A combination of sumps and pumps carried water to the surface for reuse in mill and dredging operations.[71] At Port Radium, Eldorado initiated a major dredging programme to recover quantities of uranium-rich tailings dumped into Great Bear Lake in the 1930s and 1940s. The dredge contributed thousands of tons of tailings to the mill operations monthly and required a constant flow of water to keep the tailings sands moving. Overflow water from the mine and mill initially supplied the dredge; by 1953 these were insufficient and engineers incorporated lake water into the flow. Workers redirected the water that seeped into the mine outwards to combine with lake and mill water, to send tailings sand from the lake bed up a pipe into the mill for processing.[72]

The Port Radium dredge exemplified the interconnected systems erected by mine engineers across the north-west that bound the new extractive operations to local air, water, fuel and rocks. These interconnections signalled the widespread adoption of industrial engineering techniques within Canadian hard rock mines. Industrial engineering integrated people, material, machines and energy and guided decisions to recycle and reuse energy and material flows. In deploying the language of subterranean bodies, engineers like McDonald at the Giant mine expressed how they were creating extractive systems to extend habitable environments beneath the large lakes. Industrial engineering also involved the substitution of mechanical for human labour in the hard rock mines. William Cronon and Richard White have argued that thus industrialisation weakened links between human work and nature's work.[73] As the following section makes clear, in the north-west mining industry mechanical artifice substituted for human or natural processes, most strikingly in the mills and refineries which metamorphosed ores into finished products for sale on international markets. Yet the mills and refineries were only surface extensions of the integrated systems that bound industrial operations, and the people who worked them, to local nature. More importantly, the persistence of figurative living and organic bodies reveal how mining men adopted metaphors not only to articulate the integrated and human character of mining's relationship to its environment, but also used the human body to remodel nature on the large lakes.

MECHANISATION AND MILLING

Machines, powered by fossil fuels, and explosives had always done much of the necessary work underground in breaking up rock. Now machines were adapted to all phases of mine and mill operations from prospecting and drilling to ore handling and mill circuits. Machines provided new information; the increased availability and more precise calibration of Geiger and scintillation counters (scintillometers), which measured radioactivity, meant that by the mid-1950s Geiger counters were used most in most stages of exploration and mine development including airborne geophysical investigations.[74] Geiger counters and airborne geophysical surveys changed relationships between geologists, prospectors and the environment. These technologies substituted for close attention to the appearance, contours and textures of the land. Underground, workers increasingly relied on automated technologies to protect them from the specific hazards of mine environments. In the Fay Shaft at the Beaverlodge mine site, for example, automatic electrical controls kept water levels between two and four feet above the drift bottom.[75] New technologies also facilitated the deeper interpenetration of human and natural systems in mines and mills. Lowered costs of diamond drilling made for its ubiquitous application in prospecting and underground development. Mine operators could thus look ever deeper into the earth, and set their explosive blasts farther inside mine walls. Skilled miners continued to be needed, not only for their abilities to plan and execute mine development, but also for their flexibility and reach in scaling stopes and drifts and selectively mining. But in the post-World War Two period, the acute labour shortages of the war period led to increased mechanical handling of broken ore which allowed further for intensified production.[76]

Mills and refineries used mechanical, chemical and metallurgical treatments to wrest apart the matrices that held the desired elements fast, and then to reconstitute these elements into transportable and saleable forms. At times this process resembled a recipe: add a bit of mercury, some cyanide, some water, and cook to 650°C, stirring constantly to produce a nice, clean, bar of gold. The equipment needed to complete this recipe and the toxic chemicals and hard rocks that made up the ingredient list, necessitated the construction of enormous industrial complexes fitted to cook and mix slurries largely independent from human intervention. The gold mines and mills on Great Slave Lake and Lake Athabasca completed the entire circuit of production and processing on location to produce finished gold bars destined for the Royal Mint in Ottawa. The uranium ores mined from the shores of Great Bear Lake and Lake Athabasca, by contrast, required processing on site to extract much of the waste rock and prepare uranium concentrates (yellowcake) for transportation to Port Hope on Lake Ontario. Eldorado initially constructed the Port Hope Refinery to produce radium but after 1948 the end goal instead was uranium black oxide (U_3O_8), a dense orange powder grading approximately 96 per cent, packed into five-tonne steel containers and shipped to the USAEC.[77] The plant at Port Hope intensified, through repetition and augmentation, the procedures from the on-site mills. Production at Port Hope and on the large lakes was directed to meet the standards set by the USAEC and the Royal Mint.

The earliest mill on the large lakes was the gravity concentration plant constructed in 1933 at Port Radium, which relied on the greater density of radium and uranium to separate out rich pieces of ore from the lighter unmetamorphosed sedimentary host rocks.[78] These gravity concentrates constituted the earliest products shipped south from the Great Bear Lake mine. As the richest pitchblende seams were mined out and demand shifted from radium to uranium, Eldorado turned to more complex processing techniques that combined mechanical and chemical treatments. In the new uranium mills, as in the gold mills on Great Slave Lake and Lake Athabasca, the first stage crushed the ores into manageable and uniformly-sized pieces. In the Con mill these pieces were then directed through ball mills: large, rotating cylinders filled with steel balls. Several hours in these mills pulverised the ore to the consistency of sand.

To squeeze as much value from the large lake ores as possible, intensive processing required the chemical separation of minerals which amplified the physical work done on the ores by penetrating their molecular structure to extract gold and uranium at a microscopic level. The Port Radium, Lorado and Gunnar mills used acid-leaching processes to produce uranium oxide concentrates (yellowcake). The Beaverlodge mill used an alkali-leaching process on its carbonate-rich ores.[79] Acid leaching took place in giant vats kept in constant motion at a low temperature for between 24 and 36 hours to circulate the solution. The chemical treatment of gold ores involved amalgamation: mixing gold with mercury to extract about 60 per cent of the gold. Mercury did not amalgamate with quartz or sulphides and the gold that remained attached to these was dissolved in a dilute cyanide solution, stirred in huge vats for a day or two. Until the fall of 1940, the 100 tons-per-day Con mill recovered 90 to 92 percent of the gold in ores using amalgamation and cyanidation. After 1940 the Con mill, as well as the 500 tons-per-day Giant mill on Great Slave Lake, and the Box mine on Lake Athabasca treated refractory ores, where the gold values were tightly caught up in the crystalline structure of sulphide minerals. Refractory ores required additional processing using flotation to concentrate the gold and roasting to release arsenic (As) and sulphur (S), leaving behind a red oxide – haematite (Fe_2O_3) – with exposed gold particles more susceptible to cyanidation.[80] The gold recovered at each different stage of the milling process, on the jig, from the amalgam and using cyanide, was melted back together, poured into gold bars and stamped for identification.[81]

Representations of living bodies travelled with the ores to the earth's surface and into the mills demonstrating how these metaphors not only expressed particular relationships to subterranean environments, but also to the rocks themselves. In surface plants where mill managers applied mechanical and chemical technologies to transform complex ores into simple end products the metaphors shifted, away from an emphasis on form and movement, to instead present ores as living material that would be consumed and digested. Ore bodies at the surface were referred to as *feed*. Once inside, the feed was conveyed through the mill on belts at constant rates and into bins, cells and ovens. Machines broke down larger pieces of ore rock into fine sands from which the valuable minerals could be more easily extracted. The machines used to pulverise the ores included jaw crushers, that mimicked the levered operation of a jaw. In setting up treatment circuits to break down the ores, samples were assayed to determine their grade and composition; but testing ores also involved evaluating their consistency. Jack Woodward, with Eldorado's Research and Development Division, described custom ore samples as '"tough" to crush, but "medium soft" to grind', evoking the texture of foods ingested for nutrition.[82] Poorer quality ores were hoisted to the surface from older workings, as these had been exposed to the weathering elements that reached underground with the extension of habitable environments. The foremost problem was oxygen itself, brought underground in air and water, and which triggered the oxidation of ores. Henry Howard directed mill operations at Port Radium in December 1942 when he observed 'less slime present due to nearly all ore coming from fresh workings instead of from old stopes. This old ore apparently has disintegrated and creates [the] slime problem.'[83] The mill operators wanted fresh materials, not stale and decayed ores less suitable for processing.

Mill operations modelled the human digestive tract in language and process: the ore that came into the mills as feed *consumed* quantities of chemicals and acids depending on its composition, and the combined chemical and mechanical treatment of feed was termed *digestion*.[84] The sequence of processing strengthened the digestive analogy, for the mechanical separation of ores preceded their chemical processing in various solutions. The mills on Great Bear and Lake Athabasca were the first set of stomachs and the Port Hope Refinery was the second digestive system that transformed the uranium-bearing ores. The Con mill superintendent R.H. Ross and Arvid Thunaes, the metallurgist who headed the Eldorado Project charged with maximising production from the Eldorado ores, used flow diagrams to model mill and refinery circuits. These diagrams represented applied systems thinking, which modelled feedbacks and flows between disparate parts of a given entity and derived from early-twentieth-century explorations into living systems.[85] The flow charts also highlighted the integrated models that guided sub-surface and surface operations used to produce gold and uranium concentrates, simpler compounds than the original ores from which they were extracted and specific products ready to be incorporated into the broader industrial metabolism.[86] Mining men clearly understood milling as a form of digestion that allowed larger industrial entities to feed off subterranean bodies.

MASKING NEGATIVE CONSEQUENCES

Mine operators extended the earth's life-sustaining envelope into their underground workings to sustain human bodies and more intensively exploit ores. Air lines, water lines, electrical lines and lines (hoists or tracks) that allowed for the movement of miners and ore, entered the adit to each mine from the outside. These life-lines established and regulated material and energy flows between the surface and below. Material flows included the movement of air for ventilation and water for cooling, drinking and movement. Energy flows included compressed air, heat and electricity. Engineers designed the mines to recycle and reuse material and energy, such as the waste rock used to provide stability, the waters that moved tailings through the dredge, or the excess heat generated by engines and also used to provide warmth. Surface operations at mine sites employed the same principles of reuse and recycling to send water, heat, mercury and sulphides through different mill operations or multiple cycles. Mill engineers set formulas to minimise chemical waste. In this fashion, mining men used the feedbacks, flows and waste minimisation that characterise natural living systems as an ideal model from which to re-engineer the large lakes towards their own industrial ends.

Through these ties industrial operations embedded in the large lake ecosystems to exploit not isolated resources but rather resource complexes: locally available water, wind, timber, fuel, ice and gravel all necessary to profitable and successful production of specialised goods. These ties also created the wider ecological consequences of mine operations as toxins coursed through waterways, or uranium emitted radioactivity through the steel drums lifted by workers from the shores of the lakes into planes and railcars en route to Port Hope.[87] From the foregoing discussion it is clear that those who designed and implemented these extractive systems saw the hard rock environments in which they worked as animate and even organic places. They attributed living characteristics to the ore bodies they exploited. Mining men sought to deepen human engagements with alien environments and assimilate human, mechanical and natural work. The presence of animate subterranean bodies complicates the prevailing interpretation that mining men satisfied their basic greed and desires for control by exploiting dead nature. Mining men also saw themselves as engaged in a revolutionary and creative process that brought life to mine shafts, nourished industrial communities and produced end products, such as radium, that could be used to save human lives.

The language that likened industrial operations to human bodies and bodily functions illuminates how and why mining men harnessed specific ore bodies to the wider industrial networks that allowed for them to operate efficiently and profit from subarctic nature. But the same metaphors that illuminate this relationship also made it easier for mining men to ignore the negative consequences of mining operations. Metaphors worked to detach subterranean bodies from the large lakes and obscure the negative consequences of these mining operations. Looking at bodies kept miners from seeing the bigger picture.

The suggestion that rocks had organic qualities equated mines with renewable resource harvesting operations. The living attributes of rocks emphasised either the ways that they moved or their capacity for regeneration. Setting aside the animated features of rocks for the time being, their capacity for regeneration was clearly an illusion. The geologist who, for example, described a 'self-regenerating' stope did not actually believe that old ores could grow new ores, but rather employed a figurative extension of a living rock to obscure his own role in discovering new ore and displace the sustainability of mine operations onto the natural environment.[88] In this imagined world, miners did not renew ore reserves underground but rather the rocks renewed themselves. Such a figurative elaboration drew on accounts of underground development and rocks that made reference to 'circulating' ore solutions that 'penetrated' and 'impregnated' rocks. It emphasised the natural resource wealth of the large lake region and reinforced notions of the Canadian Shield, in which these rocks were found, as a storehouse of hidden wealth.[89] In the paradigm presented by subterranean bodies nature provided wealth, mining men did not create it.

After World War Two, mining surpassed agriculture in importance to the Canadian economy. The previously barren north now figured in Canadian imaginations and aspirations as the staging ground for future mine development and the source of mineral wealth.[90] Mine company directors, acutely conscious of the limited life of a mine as it affected financial planning and the amortisation of capital investments, nevertheless shared federal and provincial government ambitions for the long-term viability of mining in the north-west. They allowed notions of impregnated rocks and the elaborate descriptions of renewable mineral resources in combination with the suggestion that ore bodies provided food for digestion and consumption to infiltrate planning discussions for north-western industry. A 1956 report from Lake Athabasca identified uranium ore production as the 'only sound index of population growth' for the surrounding region and specifically, for the new community of Uranium City.[91] This report presented the capacity to sustain a community on the north shore of the lake as a function of mine output and linked people to the land in the way an agricultural community would be tied to soil fertility. Here and elsewhere mining men distinguished mineral-rich locations from the surrounding 'barren ground'.[92] The Uranium City report made no reference to the limited possibilities of growth for a community dependent upon finite resources. The agricultural allusions were intentional. Family farms were seen as the ideal foundation for new settlements in frontier regions such as the adjacent Peace River district to the west of Lake Athabasca. Mine operators evoked the language of agriculture to suggest how their operations could sustain and nourish workers, their families and ultimately new northern settlements. The shared language and concepts that made agricultural allusions possible failed to acknowledge the ways in which mineral deposits were, unlike grains, wholly unsustainable. They actively denied the ephemerality of mining operations and forestalled any effective analysis of short-term gains versus long-term ecological consequences.

Mining men described exclusively physical bodies to populate what they perceived as an otherwise isolated and empty landscape. The majority of mining men, sojourners to the north-west, reacted to the large lakes as untouched 'wilderness', commenting on its beauty and severity but rarely upon its history. This reflected their experiences in mining communities where Native and Metis residents of the region visited, but did not live because of the exclusionary policies of companies that saw them as unsuited to industrial labour. Sojourning workers had no sense of the human history of the large lakes, whereas for the Dene the large lakes were living historical places. Landscape features marked sites where their families, ancestors and mythical heroes had walked, slept, fished, hunted and fought. Bear Rock, for example, a striking promontory along the Mackenzie River at the mouth of the Bear River travelled by workers, oil and uranium products en route to and from the Port Radium mine, figured prominently in the Dene Yamoria legends.[93] Mining men knew the geological history of the large lakes, the 'parentage' of individual deposits, but this was not confused with a human history. Mining men did not translate the uniqueness of a particular geological formation into the value attributed to human-built structures. The large lakes manifested only physical, not cultural landscapes to sojourning industrial workers who in turn felt no cultural inhibitions about taking these landscapes apart.[94]

The absence of emotional bonds to subarctic landscapes highlights how subterranean bodies may have had organic or animate features but nevertheless lacked connections to wider ecosystems. Miners and millers saw how they themselves built such connections with the systems they constructed that recycled water, waste or air but they did not articulate any pre-existing relationships between bodies and the nature in which they were found. In this respect we can see how this particular industrial capitalist engagement with nature made natural resources extractable and isolated in more complex ways than just by their transformation into commodities – drums of yellowcake, needles of radium or bars of gold. Mining men prepared the ground, so to speak, by understanding rocks as discrete units, as vulnerable bodies. Ore bodies worked for miners because they kept underground operations at a human scale even in the context of increased mechanisation at and below the earth's surface. Subterranean veins and ribs and limbs emphasised the place and significance of human bodies. But just as workers' bodies were vulnerable to capitalist depredations, so too rock bodies could be extracted and transformed and disseminated; they were isolated and interchangeable.

It was this process of disassembly and dissemination that created the negative impacts of mine operations. It produced the silica-rich and radioactive dust that was in turn inhaled by miners themselves. Miners acted as geological agents by moving and reconstituting rocks and redistributing radioactive and toxic waste materials, including the concentrated arsenic left over from gold milling used for construction and fill. As miners blasted and extracted rocks underground they created conduits along which waste materials would disseminate and map the distribution of toxins through local ecosystems. In 1954 the team surveying dust hazards reported to Eldorado officials that a muddy, discoloured stream flowed from Tailings Lake into Beaverlodge Lake, used for the community water supply. The hazard team analysed the water and recorded, '9 micrograms of uranium per litre. To the best of our knowledge no standard has been set concerning the safe limit for uranium in potable water, but the report of this analysis is included here for record purposes.'[95] Earl Shannon, a field officer with the Saskatchewan Government, also reported the pollution to Eldorado managers but the stream continued to flow all winter and into the following spring.[96] Binding subterranean bodies through material flows to the surrounding environment ensured the negative consequences of mine operations. Breaking up underground ores led to the dissemination of radionuclides and toxins through the large lake environments. Miners and company directors ignored these consequences even at a direct cost to their own health.

CONCLUSIONS

Looking closely at the initial stages of the industrial transformation that occurred on the large lakes of Canada's Subarctic after 1921 illuminates the relationship between industrial capitalist approaches to natural resources and the changes that affected natural systems. What mining men saw in and did to rocks provides a lens through which to explore what these same people thought about the subarctic nature they encountered and altered. This lens does not reveal a dead and mechanical nature easily torn apart to satisfy base desires, but rather exposes subterranean environments populated and animated by miners, machines and metaphors. Where they saw subterranean bodies, mining men humanised mine and mill environments. Engineers and workers simultaneously built mines and mills as systems that used feedback relationships and energy and material flows to embed extractive operations in the resource complexes available on the large lakes of the Mackenzie basin. These integrated systems drew upon the human digestive tract and other living models to extend the possibilities for life further beneath the earth's surface while more intensively exploiting hard rock ores. The emphasis upon the creative, living and human character of their relationship to nature encouraged the intensification of mining activities across the subarctic and helped to obscure the enduring negative impacts of hard rock mining on the north-west large lakes.

NOTES

Comments from Ryan Arcand, Matthew Evenden, Tina Loo and three anonymous reviewers helped me to sharpen the arguments and clarify the writing in this paper.

[1] Jeremy Mouat cites descriptions of placer mining as 'poor man's mining' in *Roaring Days: Rossland's Mines and the History of British Columbia* (Vancouver: UBC Press, 1995), 8. See also Kathryn Morse, *The Nature of Gold: An Environmental History of the Klondike Gold Rush* (Seattle: University of Washington Press, 2003), 41, 43 for descriptions of the 'poor man's routes' into the Klondike. By the 1920s, however, the Klondike gold fields had likewise ceased to be poor man's mines and instead dredges owned by larger companies extracted much of the gold.

[2] Timothy LeCain, 'The Limits of "Eco-Efficiency": Arsenic Pollution and the Cottrell Electrical Precipitator in the U.S. Copper Smelting Industry', *Environmental History* 5.3 (2000): 336–51; David Rosner and Gerald Markowitz, *Deadly Dust: Silicosis and the Politics of Occupational Disease in Twentieth-Century America* (Princeton: Princeton University Press, 1991); Chad Montrie, *To Save the Land and People: A History of Opposition to Surface Coal Mining in Appalachia* (Chapel Hill: University of North Carolina Press, 2003); Duane Smith, *Mining America: The Industry and the Environment, 1800–1980* (Niwot: University Press of Colorado, 1993); David Stiller, *Wounding the West: Montana, Mining, and the Environment* (Lincoln and London: University of Nebraska Press, 2000).

[3] Richard Francaviglia, 'Hardrock Mining's Effects on the Visual Environment of the West', *Journal of the West* 43.1 (Winter 2004), 40; Smith, *Mining America*, 5, 24; Thomas G. Andrews, 'The Road to Ludlow: Work, Environment, and Industrialization, 1870–1915', (Ph.D. diss., U. of Wisconsin-Madison, 2003), 292.

[4] Morse, *The Nature of Gold*, 94, 112.

[5] See for example J.R. McNeill, *Something New Under the Sun: An Environmental History of the Twentieth-Century World* (New York: W.W. Norton & Co., 2000), esp. 32, 33. For capitalist motivations more broadly see William Cronon, *Changes in the Land: Indians, Colonists, and the Ecology of New England* (New York: Hill and Wang, 1983), 21.

[6] See Clarence Glacken, *Traces on the Rhodian Shore: Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century* (Berkeley: University of California Press, 1967), 61; J. Donald Hughes, *Pan's Travail: Environmental Problems of the Ancient Greeks and Romans* (Baltimore and London: The Johns Hopkins University Press, 1994), 112–120; Carolyn Merchant, *The Death of Nature: Women, Ecology, and the Scientific Revolution* (San Francisco: Harper & Row, 1980), 30–33; Georgius Agricola, *De Re Metallica*, translated from the first Latin ed. of 1556, with biographical introd., annotations and appendices upon the development of mining methods, metallurgical processes, geology, mineralogy and mining law from the earliest times to the 16th century, by Herbert Clark Hoover and Lou Henry Hoover (New York: Dover Publications, 1950), 9.

[7] Daniel J. Philippon's *Conserving Words: How American Nature Writers Shaped the Environmental Movement* (Athens: University of Georgia Press, 2004); See also Edmund P. Russell III, '"Speaking of Annihilation": Mobilizing for War against Human and Insect Enemies, 1914–1945', *Journal of American History* 82 (March 1996), 1510.

[8] For significance of metaphors in understanding indigenous people's relationships to their environments as a model for thinking about the importance of place in environmental history see Julie Cruikshank in collaboration with Angela Sidney, Kitty Smith and Annie Ned, *Life Lived Like a Story: Life Stories of Three Yukon Elders* (Lincoln and London: University of Nebraska Press, 1990), esp. 'Cultural Constructions of Individual Experience', 339–56; Keith H. Basso, '"Stalking with Stories": Names, Places, and Moral

Narratives among the Western Apache', in *Text, Play and Story: The Construction and Reconstruction of Self and Society*, ed. Stuart Plattner (Washington, DC: Proceedings of the American Ethnological Society, 1984), 48–51; George Lakoff and Mark Johnson, *Metaphors We Live By* (Chicago: University of Chicago Press, 1980), 1.

[9] Andrew Isenberg, *Mining California: An Ecological History* (New York: Hill and Wang, 2005), 19.

[10] Marina Fischer-Kowalski and Helmut Haberl, 'Metabolism and Colonization. Modes of Production and the Physical Exchange between Societies and Nature', *Innovation: The European Journal of Social Sciences* 6.4 (December 1993): 415–42.

[11] For descriptions of pre-industrial knowledge and exploitation of mineral deposits in the Mackenzie basin see Christopher C. Hanks, 'Ancient Knowledge of Ancient Sites: Tracing Dene Identity from the Late Pleistocene and Holocene', in *At a Crossroads: Archaeology and First Peoples in Canada*, ed. George P. Nicholas and Thomas D. Andrews, Archaeology Press Publication No. 24 (Burnaby: Department of Archaeology, Simon Fraser University, 1997), 184. René Fumoleau, *As Long as this Land Shall Last: A History of Treaty 8 and Treaty 11, 1870–1939* (Toronto: McClelland and Stewart, 1975), 194; British Columbia Archives [hereafter BCA], MS 2500, Cominco Fonds, Box 429, File 8, Copy of letter from Ed. Nagle to his son E.H. (Ted) Nagle prior to his trip into the Mackenzie River, 15 Apr. 192?; Cominco Fonds, Box 417, File 20, W.G. Jewitt, 'Pine Point – From Prospect to Production', Victoria, BC, 21 Dec. 1965.

[12] Using political boundaries: Great Slave and Great Bear Lakes both lie within the present-day Northwest Territories; Lake Athabasca straddles the northern boundary between the provinces of Saskatchewan and Alberta.

[13] Northwest Territories Archives [hereafter NWTA], Canada. Department of National Defence, Acc.# N-1989-026, Margaret R. Montgomery, 'A Geographical Survey of the Port Radium Area', May 1953, 2.

[14] J.M. Bell, 'Explorations in the Great Bear Lake Region', *The Geographical Journal* 18.3 (September 1901), 256.

[15] Fumoleau, *As Long as this Land Shall Last*, 153, 159.

[16] Treaty 11 was the last and most hurried of the numbered treaties. It did not adequately extinguish aboriginal title to the Mackenzie basin lands as the government failed to meet treaty provisions in later decades. For detailed discussion of this history see Kerry Abel, *Drum Songs: Glimpses of Dene History* (Montréal: McGill-Queen's University Press, 1993); Fumoleau, *As Long as this Land Shall Last*; Mark O. Dickerson, *Whose North? Political Change, Political Development, and Self-Government in the Northwest Territories* (Vancouver: UBC Press; Edmonton: Arctic Institute of North America, 1992); Daniel Richard, 'The Spirit and Terms of Treaty Eight', in *The Spirit of the Alberta Treaties*, ed. Richard Price (Edmonton: University of Alberta Press, 1999), 47–100; Donald G. Wetherell and Irene R.A. Kmet, *Alberta's North: A History, 1890 to 1950* (Edmonton: Canadian Circumpolar Institute Press; University of Alberta Press; Alberta Community Development, 2000).

[17] A.E. Safarian, *The Canadian Economy in the Great Depression* (Toronto: McClelland and Stewart, 1970), 121–2, 163. Safarian writes, 'Gold contributed a further increase of $105 million in this period [to exports up to 1937], or about 250 per cent; furthermore, unlike the other non-ferrous metal exports, this increase had been persistent and rapid

in every year since 1929.' See also Morse, *Nature of Gold*, chapter one, 'The Culture of Gold', 16–39.

[18] K.J. Rea, *The Political Economy of the Canadian North: An Interpretation of the Course of Development in the Northern Territories of Canada to the early 1960's* (Toronto: University of Toronto Press, 1968), 117; Robert Bothwell, *Eldorado: Canada's National Uranium Company* (Toronto : University of Toronto Press, 1984), 7–9.

[19] Saskatchewan Archives Board, Saskatoon [hereafter SABS], NR 1/1 D-101-FR/DO, T.C. Davis, Attorney General to Col. S.T. Wood, Assistant Commissioner, R.C.M. Police, 18 Jun. 1935.

[20] Rea, *Political Economy of the Canadian North*, 112–13; Kenneth Norrie and Doug Owram, *A History of the Canadian Economy*, 2nd edn (Toronto: Harcourt Brace, 1996), 494.

[21] LAC, Irene Spry fonds, File 29-2: Field Research, NWT, notes on interview with M. Gavereaux, Superintendent El Bonanza, Mill Lake, Great Bear Lake, 4 Jul. 1935; Library and Archives Canada [hereafter LAC], RG 134, Eldorado Nuclear Ltd, Series 2-b-i, Vol. 105, File 'Bennett – Balance Sheets', El Bonanza, 1944–1958.

[22] Ray Price, *Yellowknife* (Markham: Simon & Schuster Canada, 1967), 85–98. Many made their way north through Saskatchewan: see Anthony G. Gulig, '"Determined to Burn off the Entire Country": Prospectors, Caribou, and the Denesuliné in Northern Saskatchewan, 1900–1940', *The American Indian Quarterly* 26.3 (2002), 337, 342–444. Saskatchewan Archives Board, Regina [hereafter SABR], Mineral Industry in Saskatchewan – Oral History Project – Tape R-A900, Jock Mackinnon interview with Berry Richards, Uranium City, SK, 24 Jul. 1975.

[23] Consolidated Mining and Smelting was initially abbreviated as CM&S and only later called Cominco. Cominco had lead-zinc holdings at Pine Point on the south shore of Great Slave Lake. Cominco explored and developed these deposits in the 1920s but ceased work in the 1930s. They held on to the deposits until more favourable prices and transportation facilities arrived in 1963.

[24] For more on the uranium boom in Canada and the United States see Bothwell, *Eldorado*, 277–350; Eric Mogren, *Warm Sands: Uranium Mill Tailings Policy in the Atomic West* (Albuquerque: University of New Mexico Press, 2002); Michael A. Amundson, *Yellowcake Towns: Uranium Mining Communities in the American West* (Boulder: University of Colorado, 2002).

[25] University of Alberta Archives [hereafter UAA], James M. Parker fonds, Acc.# 82-46, Box 2, File 66, Noel MacKay interview with James Parker, Fort Chipewyan Alberta, 20 Sept. 1978. NWTA N-1992-267; N-1980-002, Cominco, File 7: Dominion Government Training Scheme, 1958–1960, T.H. Taylor, Supt, Vocational Education Department of Northern Affairs and National Resources to Cominco, 12 Mar. 1958. See also Abel, *Drum Songs*, 212–14. For the role of Native workers in the Yukon gold fields see Ken Coates, *Best Left As Indians: Native–White Relations in the Yukon Territories, 1840–1973*, (Montréal: McGill-Queen's University Press, 1991), 32–46.

[26] SABR, Findlay interview with Richards, 25 Jun. 1976.

[27] Bothwell, *Eldorado*, 45; Walli was close to Gilbert LaBine and he worked for Nesbitt-LaBine on Lake Athabasca until he died in 1953.

[28] Neil Campbell, 'The Geology of the Con-Rycon Mines', (Ph.D. diss., Massachusetts Institute of Technology, 1943); Earle Burdette Gillanders, 'An outline of the general

geology and physiography of the western part of North Eastern Rhodesia: with notes on correlation and Rift Valleys', (Ph.D. diss., Princeton University, 1932).

[29] SABR, Mineral Industry in Saskatchewan – Oral History Project – Tape R-A962, George T. Findlay interview with Berry Richards, Prince Albert, SK, 25 Jun. 1976.

[30] Cobbing separated ore from waste rock, usually by hand and with a hammer. A stope was the ore surface being worked; an adit a horizontal passage driven from the surface for working or dewatering a mine; drifts were the mined out areas that ran horizontal and parallel to ore deposits; while a raise was a vertical or inclined opening driven upward from one level to connect to the level above. From the level above this connecting passage was called a winze.

[31] This technical language did share certain roots with agriculture. Mucking, for example, referred to gathering and carrying away broken ores in a mine and moving and spreading manure on farms. The churn drill, used for development work in deep or wet ground, was so-called because of its original functional and physical resemblance to a butter churn. J.A. Simpson and E.S.C. Weiner, *Oxford English Dictionary*, 2nd edn (Oxford: Clarendon Press; New York: Oxford University Press, 1989) and American Geological Institute, *Dictionary of Mining, Mineral, and Related Terms* (Alexandria: American Geological Institute in cooperation with the Society for Mining, Metallurgy, and Exploration, Inc., 1997).

[32] NWTA, N-1993-012, Robert Coutts fonds, Diary, Friday, 12 Aug. 1932.

[33] LAC, Spry fonds, Eldorado: Mr. Wall[i], 1 Jul. 1935; LAC, RG 134, Eldorado Nuclear Ltd, Series 1-a, Vol. 55, File 5-O – Miscellaneous – Beaverlodge Operation – Ore Reserves, B.S.W. Buffam, D. Campbell and E.E.N. Smith 'Beaverlodge mines', c. 1956; W.G. Jewitt and Stanley Gray, 'The Box Mine of the CM&S Co. of Canada, Ltd', *Canadian Institute of Mining and Metallurgy Transactions* vol XLIII (1940), 448; J.P. Ryan, Asst. Supt., 'Geology and Mining Practice at the Eldorado Radium mine', *Canadian Institute of Mining and Metallurgy Transactions* 41 (1938), 65; LAC, RG 134, Eldorado Nuclear Ltd, Series 2-b-i, Vol. 107, File 'Bennett – Port Radium – Operations and Development', B.S.W. Buffam, Annual Report on Development Work, 1952; D.D. Campbell, 'Structural Control of Orebodies', c. 1951–53.

[34] LAC, RG 134, Eldorado Nuclear Ltd, File 'Port Radium – Operations and Development', W.F. James and B.S.W. Buffam, Toronto, Ontario, 'Report on Eldorado Mine Port Radium', 13 May 1949.

[35] 'Easterly and westerly dipping limbs' in Lower Orebody in NWTA, Giant Mine fonds, A.K. Muir, Report on Operations to 30 Jun. 1950.

[36] Merchant, *Death of Nature*, 24–9.

[37] See for example, Agricola, *De Re Metallica*, 60–72, in particular p. 69 which discuses the 'head' and 'tail' of a vein.

[38] C.S. Lord, *Mineral Industry of District of Mackenzie, Northwest Territories,* GSC Memoir 261 (Ottawa: E. Cloutier, King's Printer, 1951), 148.

[39] D.C. McDonald, Mine Superintendent, 'Mining at Giant Yellowknife', *Canadian Institute of Mining and Metallurgy Transactions* 56 (1953), 95.

[40] Geologists were sharply rebuked when they failed in these tasks. See LAC, RG 134, Eldorado Nuclear Ltd, File 5-O – Miscellaneous – Beaverlodge Operation – Ore Reserves, Letter from R. Henry to W. Gilchrist, 4 Feb. 1957; ccd. to Buffam, Campbell, Bennett;

University of British Columbia Archives [hereafter UBCA], Henry Howard Papers, Box 1, File 10, Technical Diary, 19 Mar. 1943.

[41] These precursor fluids included lavas, hydrothermal fluids and hypabyssal fluids. One good example of minerals imagined as fluids in motion: 'The mineral solutions evidently ascended through the fractures caused by the folding and could penetrate without difficulty, the porous dolomite.' BCA, Cominco fonds, Box A 1616, W.J. Bill McDonald, 'Report: Lead-zinc deposit at Pine Point', 1928.

[42] This refutes Vladimir Vernadsky's distinction between living natural bodies that have genetic connections to one another in the course of geological time and 'inert natural bodies [that] are extremely diverse and have no common structural or genetic connections'. Vernadsky 1945, 2 as cited in Vaclav Smil, *The Earth's Biosphere: Evolution, Dynamics, and Change* (Cambridge: MIT Press, 2002), 12.

[43] A.W. Joliffe, 'The Gunnar 'A' Orebody', *Canadian Institute of Mining and Metallurgy Transactions* 59 (1956): 181–5.

[44] Matthew Eddy, 'Set in Stone: The Medical Language of Mineralogy in Scotland', *Science and Beliefs: From Natural Philosophy to Natural Science,* ed. David Knight and M.D. Eddy (Aldershot: Ashgate, 2005), 77–94.

[45] LAC, Spry fonds, Field Research, NWT, Hal M. Powell, CM&S, Great Bear Lake, 2 Jul. 1935; LAC, RG 134, Eldorado Nuclear Ltd, Series 2-b-i, Vol. 108, File 'Port Radium – Ore Reserves', Kenneth G. Donald, Chief Geologist, Summary Ore Reserves, 31 Dec. 1954; NWTA, Giant Mine fonds, A.K. Muir, Report on Operations to 30 Jun. 1947.

[46] Buffam, Campbell, Smith, 'Beaverlodge Mines', c. 1956; C.E. White, R.H. Ross and N. Campbell, 'The Con-Rycon mine, Yellowknife NWT', *Canadian Mining and Metallurgical Bulletin* (June 1949); NWTA, Giant Mine fonds, A.K. Muir, Report on Operations to 30 Jun. 1945.

[47] BCA, Cominco fonds, A 1616, W.M. Archibald, Manager of Mines to J.J. Warren, President CM&S, 23 Nov. 1928; Buffam, Campbell, Smith, 'Beaverlodge Mines', c. 1956; LAC, RG 134, Eldorado Nuclear Ltd, Series 1-a, Vol. 32, File 2-1-5 R, Radiore Uranium Mines Ltd, Executive Engineer's Report, 21 Mar. 1956; Eldorado Nuclear Ltd, File 5-O – Miscellaneous – Beaverlodge Operation – Ore Reserves, D.D. Campbell, 'Beaverlodge Geology – Intersection of St. Louis and ABC Faults', Jan. 1957; D.D. Campbell, 'Trace of gneiss contact on footwall of St. Louis fault in Fay mine', Jan. 1957; Jewitt and Gray, 'The Box Mine', 454. Also concerned with 'deportment' of minerals once in the mill. See BCA, Cominco fonds, Box A 1616, Arthur Turner to J.R.M. Chairman of Research Board, 20 May 1952.

[48] Buffam, Campbell and Smith 'Beaverlodge mines', c. 1956.

[49] Stiller, *Wounding the West*; Gordon Pirie, 'Railways and Labour Migration to the Rand Mines: Constraints and Significance', *Journal of Southern African Studies* 19.4 (December 1993): 713–30; Francaviglia, 'Hardrock Mining's Effects on the Visual Environment;' Homer Aschmann, 'The Natural History of a Mine', *Economic Geography* 46.2 (1970), 173–4.

[50] Urban ecology, particularly where it has modelled inputs of food and energy, flows of water and outputs of waste, provides an excellent model for understanding mines as built environments. For elaboration on the urban setting see Martin V. Melosi, *The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present* (Baltimore: Johns Hopkins University Press, 2000); J. Galloway, D. Keene and M. Murphy, 'Fuel-

ling the City: Production and Distribution of Firewood and Fuel in London's Region, 1290–1400', *Economic History Review* 49 (1996): 155–96. See also discussions of urban metabolism, Stephen Boyden, 'Nature, Society, History, and Social Change', *Innovation* 14.2 (2001): 103–16; J. Donald Hughes, 'Ripples in Clio's Pond: the Pre-Industrial City as Ecosystem', *Capitalism, Nature, Socialism* 9 (March 1998): 105–10; Joel A. Tarr, 'The Metabolism of the Industrial City: The Case of Pittsburgh', *Journal of Urban History* 28.5 (2002): 511–45. See also Andrews discussion of workscapes in 'The Road to Ludlow' and Craig Heron, 'The Second Industrial Revolution in Canada, 1890–1930', in *Class, Community and the Labour Movement: Wales and Canada, 1850–1930,* ed. Deian R. Hopkin and Gregory S. Kealey (St. John's: LLAFUR/CCLH, 1989), 53

[51] See for examples NWTA, Lahti fonds, Diaries Eldorado Gold mines Ltd Great Bear Lake, 1932–36; NWTA, Coutts fonds, 1932–34; LAC, RG 134, Eldorado Nuclear Ltd, File 'Port Radium – Operations and Development', B.S.W. Buffam, Development Progress Report – Ventures Claims, 18 Aug. 1951; LAC, RG 134, Eldorado Nuclear Ltd, Series 1-d, Vol. 83, File BL 1-7-M [1], R. Hamilton Mine Supt to Dave Smith, Chief Inspector of Mines, 15 Sept 1954; BCA, Cominco fonds, Box 1 & 2, Annual Reports CM&S 1937–1976.

[52] See for example, White, Ross and Campbell, 'The Con-Rycon mine', 294; Jewitt and Gray, 'The Box Mine', 454. See also geological 'fingers' in LAC, RG 134, Eldorado Nuclear Ltd, File 5-O – Miscellaneous – Beaverlodge Operation – Ore Reserves Lisle Jory to W. Gilchrist, 'Verna Quarterly Geology Report', 15 Feb. 1958.

[53] Buffam, Development Progress Report – Ventures Claims, 18 Aug. 1951.

[54] McDonald, 'Mining at Giant Yellowknife', 88–90.

[55] LAC, RG 134, Eldorado Nuclear Ltd, Series 1-a Vol 30 File 2-2-M – Beaverlodge – Medical, H. Bloy, Accident Investigation of E. Sorensen, 24 Aug. 1958, 28 Aug. 1958.

[56] LAC, RG 134, Eldorado Nuclear Ltd, File 5-O – Miscellaneous – Beaverlodge Operation – Ore Reserves, 1957–1967, D.D. Campbell, 'Summary of Ore Reserves', 1951; Buffam, 'Summary of Proposed Development Work and Ore Reserves' 1 Nov. 1956; LAC, RG 134, Eldorado Nuclear Ltd, File 'Port Radium – Operations and Development', Buffam, 'Annual Report on Development Work', 1952.

[57] Deslimed mill tailings referred to tailings after moisture was extracted to create solid waste. NWTA, Cominco fonds, Box 1, File 5: Publicity Brochures, 'Employment with Cominco, Con Operations', 1948.

[58] LAC, RG 134, Eldorado Nuclear Ltd, File BL – 2-1-S [1] Safety, G.R. Yourt, 'Maintenance of Good Air Conditions at Uranium mines', paper presented at the Beaverlodge District Branch Meeting of the CIMM, 3 Aug. 1956; Eldorado Nuclear Ltd, File 'Hazards – radioactive dust and processing radioactivity', C.R. Ross, Industrial Hygiene Engineer and J.P. Windish, Industrial Hygienist, Survey of Dust Hazards at Eldorado Mining and Refining Limited Eldorado, Saskatchewan, 1–21 Apr. 1954.

[59] C.S. Gibson, 'Ventilation Practices in Canadian Mines', in *Mining in Canada*, Proceedings of the 6th Commonwealth Mining and Metallurgical Congress, Canada (1957), 393–4.

[60] LAC, RG 134, Eldorado Nuclear Ltd, Series 1-a Vol 30 File 2-2-M – Beaverlodge – Medical, Dr J.C. Gray, Health Report, Beaverlodge. In this report Gray noted the most man-hours of work were lost to respiratory illnesses.

[61] LAC, RG 134, Eldorado Nuclear Ltd, Series 1-a, Vol. 12, File 1-5-S, 'Submission to the Special Committee on Mine Safety in the Elliott Lake area, Ontario' by the Interna-

tional Mine, Mill, and Smelter Workers, Mar. 1959; Ross and Windish, Survey of Dust Hazards, 1–21 Apr. 1954.

[62] 'There are three forms of radiation from radioactive substances. Alpha particles do not penetrate the skin, although they can produce serious damage if ingested, inhaled, or absorbed through open wounds. Beta particles can sometimes penetrate the protective layer of skin, or damage the skin or eyes, although they usually do not reach deeper organs. They, too, are more important in terms of inhalation or ingestion. Gamma rays are short-way rays of energy, having effects like those of x-rays; they are penetrating and can pose an external hazard.' Heather Myers, *Uranium Mining in Port Radium, NWT: Old Wastes, New Concerns*, Working Paper No. 4, (Prepared for the Native Women's Association of the NWT and the Canadian Arctic Resources Committee, August 1982), 12.

[63] Ross and Windish, Survey of Dust Hazards, 1–21 Apr. 1954.

[64] Gibson, 'Ventilation Practices in Canadian Mines', 395.

[65] N.A. Grant, 'Open Pit Mining at Gunnar Lake, Athabaska', *Canadian Institute of Mining and Metallurgy Transactions* 60 (1957), 58; 'Gunnar Mines Limited', 17–20, quote 19–20.

[66] LAC, RG 134, Eldorado Nuclear Ltd, File 'Bennett – NTCL Reports', Giant Yellowknife Gold mines Limited, 'Brief on Tolls and Practices of Water Carrier Licensees in the Mackenzie River Watershed'. Submitted to the Board of Transport Commissioners for Canada, 1949.

[67] Department of Mines and Resources, *Regulations for the Disposal of Quartz Mining Claims on Dominion Lands in the Northwest Territories, effective 2nd April 1932* (Ottawa, 1946), Section 72 under 'What Entry or Lease Conveys', 26.

[68] White, Ross and Campbell, 'The Con-Rycon mine', 292.

[69] See for example, LAC, RG 134, Eldorado Nuclear Ltd, Series 2-b-i, Vol. 107, File 'W.J. Bennett – Port Radium – Annual Reports', Port Radium Annual Report 1956; Gibson, 'Ventilation Practices in Canadian Mines', 395. Aschmann, 'The Natural History of a Mine', 172–89.

[70] A lot of work went into pumping water out of the mine beginning as early as 1932. See NWTA, Lahti fonds, Diary, 9, 16, 23 Jul., 18 Aug. 1933; 3 Jul., 21 Nov. 1936 for examples. Bothwell, *Eldorado*, 51–2.

[71] During sinking operations at the Gunnar mine, 'a total of 10,712 buckets of water were hoisted for an average of 15.6 buckets per shift'. 'Gunnar Mines Limited', c. 1956, 35.

[72] LAC, RG 134, Eldorado Nuclear Ltd, Series 2-b-i, Vol. 108, File 'Bennett- Port Radium, Progress II, II', Port Radium Monthly and Year End Reports 1953–1959.

[73] See William Cronon, *Nature's Metropolis: Chicago and the Great West* (New York: W.W. Norton, 1991), especially where he outlines his use of first and second nature, xix; Richard White, *The Organic Machine: The Remaking of the Columbia River* (New York: Hill and Wang, 1995), 4, 30.

[74] Ground geophysical surveys dated from the 1920s. Provincial Archives of Alberta [hereafter PAA], A.M. (Matt) Berry fonds, Acc.# 72.295, Box 1, Duncan to Berry, 19 Jan. 1932.

[75] LAC, RG 134, Eldorado Nuclear Ltd, File BL 1-7-M [1], J.M. Douglas, mine Supt. to R.L. McPherson, Acting Chief Inspector of mines, 10 Dec. 1955.

[76] H.R. Rice, 'Introduction to Mining Methods in Canadian Mines', in *Mining in Canada* (1957), 44–5.

[77] Modest radium production continued into the 1950s. It was not possible to extract radium economically from a grade of concentrate lower than 12%. After 1948 Eldorado used a Lapointe picker to segregate all of the high grade concentrate and thus build up an inventory of radium which was processed once a year. In 1950 they obtained 11.5 grams by this method. There was also ongoing experimental work at the Port Hope Refinery on polonium, actinium and other radioactive products. The grade demanded by the USAEC compared to the approximately 70% uranium grade of the chemical precipitates sent south from the large lakes. See LAC, RG 134, Eldorado Nuclear Ltd, Series 1-a, Vol. 67, File 10-U, Table 1 'Analysis of Chemical Precipitates used as feed materials at Port Hope in 1956', attachment to memo from J. McN. Jardine to J.C. Burger, 18 Jan. 1957.

[78] D.A.G. Smith, 'Concentration of the Pitchblende-Silver Ore – The Eldorado Radium mine', *Canadian Institute of Mining and Metallurgy Transactions* 41 (1938), 70–76; Bothwell, *Eldorado*, 46, 207. Gravity concentrates were also referred to as jig concentrates.

[79] The description of the uranium mill circuits is principally drawn from LAC, RG 134, Eldorado Nuclear Ltd, Series 2-b-i, Vol. 109, File 'Bennett – A. Thunaes', Arvid Thunaes, 'Canadian Practice in Uranium Recovery Plants', 24 Apr. 1956.Ores consumed varying quantities of acid largely dependent on their carbonate content. The estimate given was that 1% CO_2 required roughly 50 pounds of sulphuric acid. Nicholson ores tested in Ottawa in 1951 had prohibitively high CO_2 content, at between 9.92% and 27.2% which would have required between 500 and 1500 pounds of sulphuric acid per ton of ore milled. LAC, RG 134, Eldorado Nuclear Ltd, Series 1-c, Vol. 76, File 'Beaverlodge – Custom Ore Vol. 2', Jack R. Woodward, Research and Development Division to J.M. Douglas, re: Nicholson Ore, 2 Feb. 1960.

[80] R.H. Ross, Mill Superintendent, 'Con Milling Operation Yellowknife N.W.T. Canada' Denver Equipment Company Bulletin No. M3-B10 Mills, Cyanide, 5–12; See also K.C. Grogan, 'Treatment Plant Operation at Giant Yellowknife', *Canadian Institute of Mining and Metallurgy Transactions* 56 (1953), 99–101. In contrast to the Con mill, where ores were pre-treated before roasting, the Giant mill used jigs to mechanically concentrate the arsenopyritic ores and then sent the concentrates directly through a two-stage roaster. NWTA, Giant Mine fonds, A.K. Muir, Report of the General Manager, 1 Aug. 1951.

[81] The description of the Con milling process draws from Ross, 'Con Milling Operation', 1–16; R.N. Lauer, 'Con mine', *The Milling of Canadian Ores*, 1957 both found in BCA, Cominco fonds, Box 422 File# 23, File #47; See also CM&S Annual Reports, 1937–38, 1940, 1950, 1958–60.

[82] LAC, RG 134, Eldorado Nuclear Ltd, Series 1-c, Vol. 76, File 'Beaverlodge – Custom Ore Vol. 2', Jack R. Woodward to H.E. Lake, Re: Custom Ore, 15 Oct. 1959.

[83] UBCA, Howard Papers, Box 1, File 9, Technical Diary 1942, 14 Dec. 1942.

[84] These terms are used repeatedly in documents related to milling and refining. For examples see LAC, RG 134, Eldorado Nuclear Ltd, Series 1-a, Vol. 35, File 3-10-P 'Production', J.C. Burger to R.J. Henry 13 Oct. 1955; Series 2-b-i, Vol. 107, File 'Port Hope Reports', 'Calculations made at Port Radium 5–12 Jan. 1949 on mine Metallurgy'; E.B. Gillanders to W.J. Bennett, 9 Apr. 1951; 'Chemical Consumption Estimates [Beaverlodge] 1953'; 'Port Hope Refinery Flow Sheet'; Series 1-c, Vol. 76, File 'Beaverlodge – Custom Ores

Vol. 1', Correspondence Mar. 1956; BCA, Cominco fonds, File 7, Radiograms detailing weekly statistics from Con Property, 1938–1939.

[85] Marina Fischer-Kowalski, 'Society's Metabolism: The Intellectual History of Materials Flow Analysis, Part I, 1860–1970', *Journal of Industrial Ecology* 2.1 (1998): 61–78; Fritjof Capra, *The Web of Life: A New Scientific Understanding of Living Systems* (New York: Anchor Books, 1996) 15–71, 75–77.

[86] For discussions of industrial metabolism see Fischer-Kowalski and Haberl, 'Metabolism and Colonization'; Boyden, 'Nature, Society, History, and Social Change', and Richard C. Hoffmann, 'A Longer View: Is Industrial Metabolism Really the Problem?' in *Nature, Society and History: Long Term Dynamics of Social Metabolism,* ed. M. Fischer-Kowalski, E. Rosa, R.P. Sieferle and B. Smetschka, *Innovation: The European Journal of Social Sciences* 14:2 (2001), 143–55.

[87] See R.C. Powell's correspondence regarding labelling yellowcake drums: LAC, RG 134, Eldorado Nuclear Ltd, File 10-W, Weighing and Sampling Procedure, Pt. 2, R.C. Powell to A. Thunaes, 25 Feb. 1957.

[88] LAC, RG 134, Eldorado Nuclear Ltd, Series 2-b-i, Vol. 108, File 'Port Radium – Ore Reserves', Lisle T. Jory, Summary of Ore Reserves, 31 Dec. 1953.

[89] For discussions of the perceived and realised wealth of the Canadian Shield in Ontario and Quebec see H.V. Nelles, *The Politics of Development: Forests, Mines, and Hydro-electric Power in Ontario, 1849–1941* (Toronto: Macmillan, 1974); Yves Roby, *Les Québécois et les investissements Américains (1918–1929)* (Québec: Les Presses de l'Université Laval, 1976), esp. 15–17; Ian Radforth, *Bushworkers and Bosses: Logging in Northern Ontario, 1900–1980* (Toronto: University of Toronto Press, 1987); Jean Manore, *Cross-Currents: Hydroelectricity and the Engineering of Northern Ontario* (Waterloo: Wilfrid Laurier University Press, 1999).

[90] One classic example is D.M. LeBourdais, *Canada's Century*, (Toronto: McClelland and Stewart, 1956). A.Y. Jackson's 1938 painting *Radium Mine, Great Bear Lake* appeared on the dust jacket of the original publication.

[91] LAC, RG 134, Eldorado Nuclear Ltd, Series 1-c, Vol. 81, File 'Beaverlodge – Uranium City planning and development', K. Izumi and F.R. Arnott, Planning Consultants, *A Guide for Development Uranium City and District* (In Cooperation with Community Planning Branch, Department of Municipal Affairs. May 1956), 5.

[92] Pitchblende at Port Radium occurred in shoots, 'that is, local concentrations and that these recur at intervals laterally and downward'. Prof. J.E. Gill as cited in Thomson Report (1945); NWTA, Giant Yellowknife Gold mines Ltd, Annual Reports, 1944–1952; 'Gunnar Mines Limited', c. 1956, 13; McDonald, 'Mining at Giant Yellowknife', 90.

[93] George Blondin, *When the World Was New: Stories of the Sahtu Dene* (Yellowknife: Outcrop, the Northern Publisher, 1990); Hanks, 'Ancient Knowledge of Ancient Sites', 186.

[94] The impact of industrial mining operations upon Native peoples was greater than the destruction of cultural and historic landscapes and also, in combination with other industrial activities and new interventions by the federal state, significantly undermined subsistence economies. For further discussion of these impacts see Abel, *Drum Songs*, esp. 211–14; Morris Zaslow, *The Northward Expansion of Canada 1914–1967* (Toronto: McClelland and Stewart, 1988), 130–50, 271–305; John Sandlos, 'From the Outside

Looking In: Aesthetics, Politics, and Wildlife Conservation in the Canadian North', *Environmental History* 6.1 (2001): 6–31.

[95] Ross and Windish, Survey of Dust Hazards, 1–21 Apr. 1954, 31.

[96] SABS, NR 1/4, File 821 D, 'Eldorado Mining & Refining', E.N. Shannon to C.S. Brown, Northern Administrator, 26 Aug. 1954; E.N. Shannon to C.S. Brown, Re: Beaverlodge Lake Pollution, 19 Apr. 1955. For problems with arsenic from gold operations see D.A. Gemmill, ed. *Technical Data Summary Arsenic in the Yellowknife Environment,* prepared by the Ad Hoc Standing Committee on Arsenic, D. Billing, Chairman, rev. edn (Yellowknife: Government of NWT, July 1977), 4.