

Permafrost and geocryological hazard research trends in Nunatsiavut, northeastern Canada

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ABSTRACT

Climate warming is contributing to permafrost thaw and threatening the structural integrity of northern infrastructure. In Canada, permafrost conditions and geocryological hazards have been extensively researched in Nunavik and the Territories; however, similar work has not yet been undertaken in Nunatsiavut, Labrador, the southernmost portion of Inuit Nunangat. Here we perform a systematic literature review to identify and characterise geocryological conditions and hazards across Labrador with a particular focus on Nunatsiavut. We found a paucity of investigations on regional permafrost conditions generally, and geocryological hazards, specifically. Regional and local descriptions of permafrost conditions are primarily focused on periglacial landforms. Limited descriptions of geocryological hazards are restricted to the community of Nain. This review provides valuable context and recommendations for understanding geocryological hazards in Nunatsiavut, emphasizing the need for targeted research to support climate adaptation in the region.

RÉSUMÉ

Le réchauffement climatique contribue au dégel du pergélisol et menace l'intégrité structurelle des infrastructures à travers le Nord. Au Canada, les conditions du pergélisol et les risques géocryologiques ont fait l'objet de recherches approfondies aux Nunavik et les Territoires; cependant, les recherches similaires n'ont pas encore été entrepris au Nunatsiavut, Labrador, la région la plus méridionale de l'Inuit Nunangat. Ici, nous réalisons une revue systématique visant à identifier et caractériser les conditions et les risques géocryologiques au Labrador, en mettant l'accent sur Nunatsiavut. Notre analyse révèle un manque d'investigations sur le pergélisol en général, et sur les risques géocryologiques en particulier. Les descriptions régionales et locales des conditions du pergélisol se concentrent principalement aux formes périglaciaires. Les rares descriptions des risques géocryologiques se limitent à la communauté de Nain. Cette revue offre un contexte précieux et des recommandations pour mieux comprendre les risques géocryologiques au Nunatsiavut, soulignant la nécessité de recherches ciblées afin de soutenir l'adaptation au changement climatique dans cette région.

1 INTRODUCTION

Climate change is transforming permafrost landscapes across the circumpolar North (Lewkowicz and Way 2019). Since 1980, permafrost temperatures have warmed at a rate of 0.3-1.0°C/decade with increases in active layer thickness and thermokarst development (Smith et al. 2022). Warming ground temperatures have impacted ecological integrity through changes in vegetation (Ogden et al. 2023), wildlife habitats (Berteaux et al. 2017), and hydrological systems (Vonk et al. 2015). Permafrost thaw also poses significant challenges for built infrastructure and future community expansion (Allard et al. 2023; Doré et al. 2016; Smith and Riseborough 2010).

A growing body of literature has emerged on the potential and realized risks of permafrost thaw on development corridors and infrastructure in the Canadian North. Construction is constrained by short summers and high material costs, and geohazards from thawing permafrost pose additional barriers to future infrastructure expansion (Allard et al. 2023; Doré et al. 2016). Over the past decade, assessments of geocryological hazards (i.e., hazards from the thaw of ice-rich terrain, mass wasting, thermal erosion, and frost processes) have been undertaken in Nunavik and the Territorial North (e.g., Allard

et al. 2023; Benkert et al. 2015; Wolfe et al. 2014). This research has been valuable for climate adaptation and community planning (Allard et al. 2023; Benkert et al. 2015; Daly et al. 2022; Wolfe et al. 2014), linear infrastructure adaptation and design (Doré et al. 2016; Smith and Riseborough 2010), and advancing the state of knowledge on permafrost hazards, especially in northwestern Canada (Kokelj et al. 2023; Oldenburger et al. 2022).

In Labrador, there has been much less research on permafrost, generally, and geocryological hazards, specifically, even though discontinuous permafrost can present challenges for development. Synthesizing existing information on potential geocryological hazards is necessary to support ongoing and future development within Nunatsiavut and to summarize the state of regional knowledge prior to future major linear infrastructure projects, such as roads and hydroelectric transmission line corridors.

Here we present a comprehensive literature review of permafrost research in Labrador with a focus on Nunatsiavut (Labrador Inuit Settlement Area) and its five communities: Nain, Hopedale, Makkovik, Postville, and Rigolet. This review brings together historical and current research, as well as information on permafrost conditions from grey literature, technical reports, and environmental

assessments, to generate a synthesis of the existing state of knowledge and literature trends on regional permafrost and geocryological hazards. By identifying key knowledge gaps, this work will contribute to developing permafrost research priorities that align with climate adaptation and infrastructure expansion planning in Nunatsiavut. This literature review also contributes to a broader effort, in collaboration with the Nunatsiavut Government, to identify geocryological hazards in Nunatsiavut.

1.1 Study Area

Labrador is the continental portion of Canada's easternmost province, Newfoundland and Labrador (Figure 1). Geologically, it is part of the Canadian Shield and is mostly characterized by blankets of glacial till over eroded igneous and metamorphic bedrock (Roberts et al. 2006). Thin layers of marine and glaciomarine sediments are found in coastal lowland areas below the marine limit (Fulton 1995). Permafrost distribution in Labrador ranges from continuous at high elevations and high latitudes to isolated patches in the south, with approximately two-thirds of Labrador falling within the isolated patches of permafrost zone (Heginbottom et al. 1995).

Historically, most of the infrastructure development in Labrador has been linked to economic, military, and industrial activities. Fish merchants and whaling stations were the first permanent establishments in Labrador, and in the mid-1800s, Hudson's Bay Company trading posts were established in central coastal Labrador. In northern Labrador, missionaries from the Moravian Church established missions that eventually became larger communities, including Nain and Hopedale (Brice-Bennet et al. 2023). Inland expansion in the 1940s was prompted by military activities, including construction of an air base near Happy Valley-Goose Bay, and industrial activities such as mining operations by the Iron Ore Company of Canada (IOCC) near Schefferville (1954-1983) and Labrador City (1962-present) and hydroelectric operations near Churchill Falls (1974-present). Regional development projects included the construction of the Trans-Labrador Highway (1980s-2022) and the Quebec North Shore-Labrador Railway (1951-1954). Other mining operations include the IOCC dolomite and iron ore mine (1967-present), the Scully iron ore mine (2017-present) near Labrador City, the Voisey's Bay nickel-copper-cobalt mine near Nain (2005-present), and the proposed Strange Lake rare earth mining project on the Quebec-Labrador border.

This review encompasses the entire Labrador region (51.4-60.3°N, 55.7-67.8°W) and focuses on Nunatsiavut (53.8-60.3°N, 57.2-64.1°W). Studies from border regions along the Labrador-Quebec border in Schefferville and Blanc-Sablon were also included.

2 METHODS

2.1 Literature Reviewed

The primary sources of literature were peer-reviewed journal articles and refereed conference proceedings papers. Grey literature, including technical reports and

government statements and reports, was also evaluated. Conference presentations and posters were not included.

A systematic search in Web of Science was completed using a combination of keywords such as "permafrost", "hazards", "ground ice", "frost", "peatlands", and "palsa". Location keywords included "Labrador", "northeastern Canada", "Schefferville", "Blanc-Sablon", "Nunatsiavut". Studies were restricted to Labrador and/or the Labrador-Quebec border region. Other studies in Quebec were not considered. This same exclusionary practice was also applied to larger-scale studies, such as nationwide research. Consequently, most global- and national-scale permafrost modelling research was not considered in this work. This keyword-based initial list of literature was supplemented by a cited reference search, or "citation mining", to find additional relevant studies referenced in the initial literature list. This intermediate list was then evaluated to identify any other peer-reviewed sources that were not previously included. Grey literature, such as reports submitted to government agencies, including for environmental impact assessments and detailed project reports for large-scale projects (Howse Property iron mine project, Nain airport project, Strange Lake rare earth mining project), was also added to the list, where applicable. Finally, a series of unpublished reports relevant to this review was compiled.

Restrictions in accessing older grey literature not publicly available or only available as archived hard copies meant that some research reports could not be reviewed. Further, we evaluated only summary and/or review papers when the primary author had written a series of smaller studies that contributed to these larger works. These limitations were restricted to the Schefferville area; however, the permafrost research program for iron ore mining operations (1954-1983) still featured prominently in our literature review, so we are confident that we included the seminal research works from this region.

In total, 62 English and 7 French peer-reviewed articles or book chapters, grey literature, and technical reports were compiled for further analysis. These studies represent most, if not all, of the key papers that focus on or include discussions on permafrost or periglacial features within the Labrador region. A compiled list of all reviewed and unreviewed literature can be found here: https://84bbf97c-1ba3-4840-8e5a-93b4adf7881f.usrfiles.com/ugd/84bbf9_02dfc4d7eb57460da02fc96a51fe4274.pdf.

2.2 Thematic Analysis

Specific thematic information was extracted from each study, including study location(s), discussion of permafrost and/or seasonally frozen ground, investigated landforms, estimates of ground ice, the use of ground thermal data, and discussion of geocryological hazards. Locations were classified as western, southern, central, eastern, northern, or all of Labrador. Generally, studies within the 'northern', 'eastern', or 'all of Labrador' classifications also overlapped with the Labrador Inuit Settlement Area. We performed a separate count for these studies whose activities, in whole or in part, were undertaken in Nunatsiavut.

All observations and discussions of periglacial landforms were included by the author team. Ground ice

estimates were noted where any quantitative or qualitative description of ice content was contained within the work. Ground thermal data was only indicated when it was collected or where it formed a substantial portion of the discussion. Finally, geocryological hazards were only considered if they were discussed in relation to the specific research undertaken. For example, a brief mention of permafrost-related hazards in the introduction of a study was not considered sufficient for the study to be classified as containing information on geocryological hazards.

After relevant information from all studies was extracted, a thematic analysis was conducted to identify trends, commonalities, and research gaps. Spatial and temporal trends were explored across Labrador, with special attention to Nunatsiavut and the context of permafrost research and geocryological hazard characterisation in this region.

3 RESULTS

3.1 Overall trends in permafrost research in Labrador

A total of 69 studies were identified in the literature, spanning 1939 to 2024. This included 36 peer-reviewed journal articles, 15 conference papers, 10 technical reports, four books/book chapters, two environmental impact statements, and two project reports. The first published study that discussed permafrost in Labrador was by Hustich (1939), followed by Wenner (1947). These studies observed and described a small number of locations with palsas as part of investigations on vegetation and pollen along the Labrador coast. Several studies were later published in the early 1960s, but it was not until 1973 that Labrador permafrost research began to be published regularly following the establishment of permafrost research programs in Schefferville, QC. The later closure of the Schefferville mining operations in 1983 resulted in a reduction of Labrador permafrost research and contributed to a lull in permafrost research from 1988 to 2012. Two to four year-long gaps where no permafrost research in Labrador was published occurred beginning in 1976, 1985, 1995, 2002, and 2019. Since 2012, there has been a surge in permafrost research in Labrador.

In Nunatsiavut (Figure 1), research activity remained minimal until 1979, after which there was a slight increase in research in northern Nunatsiavut. However, over a period spanning just over 20 years, little to no research was conducted in Nunatsiavut until 2011, when permafrost research activity began to increase. Over the 86-year history of permafrost research in Labrador, just more than half of the studies (38 out of 69) have included work in some part of Nunatsiavut.

3.2 Geographic trends in permafrost research in Labrador

Following a reconnaissance-level overview of Labrador permafrost conditions conducted in the 1960s (Brown, 1975), permafrost research activity in Labrador has generally been clustered in a few areas (Figures 1 and 2). The largest concentration of studies ($n=17$) was near

Schefferville, where IOCC mining operations included the development of a permafrost research program from 1954 to 1983. These seminal studies contributed greatly to the early understanding of permafrost in northeast Canada. However, as permafrost research related to Schefferville mining operations slowed in the late 1970s, research trends shifted towards periglacial landform investigations, and the overall number of studies declined (Figure 2).

Other permafrost research clusters, especially in recent years, include southern and eastern Labrador, namely Blanc-Sablon, Red Bay, Cartwright, and Rigolet (Figures 1 and 2). This coincides with increased understanding of the regional distribution of peatland permafrost in coastal Labrador (Way et al 2018; Wang et al. 2023).

Finally, the community of Nain has included five permafrost-related studies within the community limits and another five in the broader vicinity. Research in Nunatsiavut has been mostly limited to the Nain region, the areas surrounding Rigolet, and the Torngat Mountains (Figures 1 and 2). This has left large regions of Nunatsiavut without any field assessment of permafrost conditions, even though modelling has indicated that permafrost is likely to be present (Way and Lewkowicz 2016).

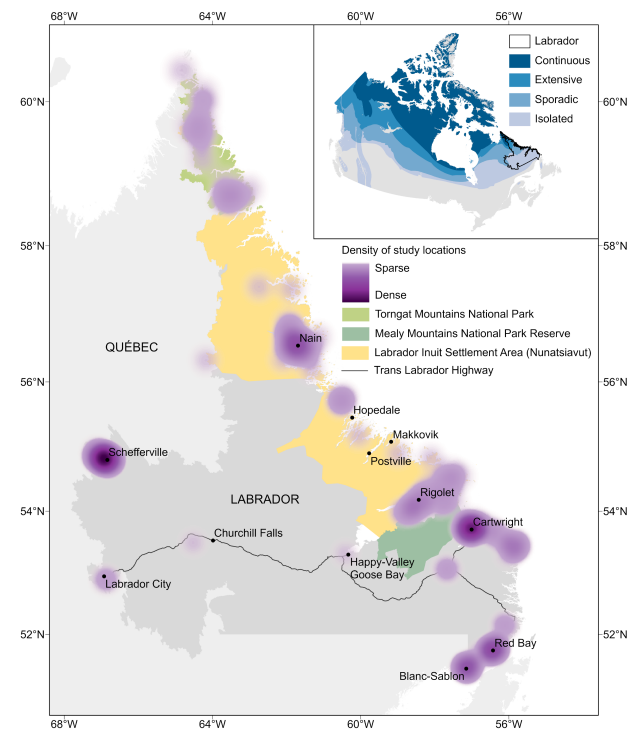


Figure 1. Density of permafrost studies in Labrador. Locations with higher densities of studies, such as in the Schefferville region ($n=17$), are indicated by a dark purple hue, while lighter saturation is used for lower densities. Studies covering multiple research locations are included, but research without discrete study locations (e.g., regional analyses) has been excluded. Landform inventory studies have been condensed to represent one percent of the overall site locations. Inset map shows the location of Labrador relative to permafrost distribution zones in Canada (Heginbottom et al. 1995).

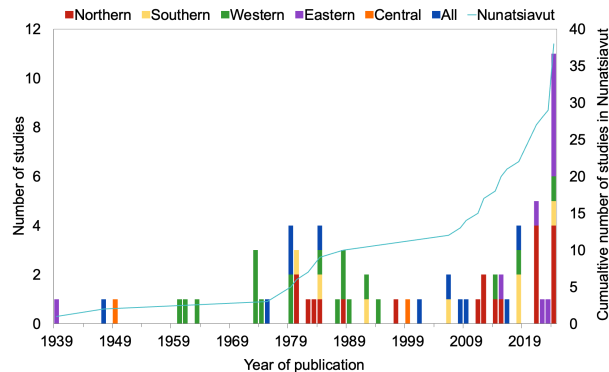


Figure 2. Total annual number of permafrost-related research studies in Labrador stratified by region. Secondary axis shows the cumulative number of permafrost-related research studies (blue line) that included at least one study location in the Labrador Inuit Settlement Area (Nunatsiavut).

3.3 Types of permafrost features studied

Periglacial landform investigations comprise a substantial portion of permafrost research in Labrador ($n=38$) (Table 1). Much of this research has focused on peatland permafrost, including early research studies investigating the southern limit of permafrost (Brown 1975; Dionne 1984), which used palsas and peat plateaus to delimit the isolated patches of permafrost zone (Dionne 1984). Thermokarst features were also often discussed in conjunction with palsas, as climate warming is contributing to increased degradation of these landforms (Beer et al. 2024; Wang et al. 2024a, 2024b).

Wang et al. (2023) later highlighted that palsa distribution extends into far northern Labrador (58.6°N), though most palsa and peat plateau research has been limited to southern Labrador (Anderson et al. 2018; Beer et al. 2024; Wang et al. 2023; Wang et al. 2024a, 2024b; Way et al. 2018). Only 13 studies have discussed peatland permafrost in Nunatsiavut, and a number of these have only broadly discussed palsas across all of Labrador, making it challenging to determine to what degree these findings apply directly to Nunatsiavut.

3.4 Investigations on ground conditions

Ground temperature data have been used in many studies to monitor, model, and validate permafrost conditions. Of the reviewed studies, 35 discussed ground temperature data. Most of these used data from Schefferville, where sensor cables installed in the 1950s allowed early investigations of the ground thermal regime (Desrochers and Granberg, 1984; Garg 1979; Granberg 1973; Ives 1960; Moore 1987; Nicholson 1979; Nicholson and Granberg 1973; Seguin 1974). Recently, ground temperatures have been used to support modelling, such as to predict the spatial distribution of permafrost (Way and Lewkowicz 2016), characterize ground thermal conditions based on snow, vegetation, and soil properties (Forget et al. 2024; Tutton et al. 2021), and examine post-fire permafrost change (Wang et al. 2021).

Twelve studies examined ground ice in Labrador. These ground ice estimates have been derived from drilling ($n=6$), geophysical methods ($n=3$), combined geophysics and geotechnical investigations ($n=1$), UAV-based geomorphometry ($n=1$), and mine pit blasting ($n=1$). Only five of these studies investigated ground ice within Nunatsiavut. Studies noted that ground ice concentrations are generally low except in peatland permafrost features (Beer et al. 2024) and post-glacial marine deposits (Way et al. 2021).

Table 1. Frequency of discussions on periglacial landforms identified in the literature between 1939 to 2024, presented in descending order.

Periglacial Landform	Number of Investigations
Palsa	31
Peat plateau	15
Thermokarst landform (ponds, lakes, depressions, etc.)	11
Polygonal feature	8
Frost feature (mounds, blisters, etc.)	7
Solifluction feature (gelifluction)	5
Sorted patterned ground feature	5
Nonsorted patterned ground feature	3
Thaw slump	2
Lithalsa	2
Rock glaciers	1

3.5 Characterizing geocryological hazards

Discussion of geocryological hazards in Labrador appeared in just 32% of studies ($n=22$) (Table 2). The most common hazard identified was ground subsidence (e.g., Bell et al. 2011; Dionne 1984; Pryer 1963; Seguin and Dionne 1992; Way and Lewkowicz 2015; Way et al. 2018; Way et al. 2021; Wang et al. 2024b). This subsidence can contribute to infrastructure damage but also landscape changes that may alter cultural practices (Wang et al. in review).

Ground subsidence impacts on community infrastructure have only been documented in a few studies ($n=8$). Most of these have focused on a subset of buildings below the marine limit in Nain (Bell et al. 2011; Lewkowicz and Way 2014; Smith and Melendy 2015; Stantec 2015; Way and Lewkowicz 2015; Way et al. 2021). Despite the volume of research conducted in the Schefferville area, discussions on geocryological hazards are limited. Research on industrial and linear geocryological hazards has been conducted in western Labrador in relation to mining (Ives 1960; Garg 1979) and railroads associated with the transport of mining deposits (Pryer 1963).

More recently, some limited discussions of ground subsidence, ground instability, and frost heave occurred in relation to the Voisey's Bay mine (Voisey's Bay Nickel Company Ltd. 1997) and the site of the proposed airport in Nain (Nunatsiavut Government 2024). Across the broader Nunatsiavut region, only 12 studies in total have discussed geocryological hazards.

Table 2. Frequency of studies noting geocryological hazards in Labrador and the context of the discussion of each hazard.

Hazard Type	Periglacial landforms	Community infrastructure	Linear infrastructure	Industrial infrastructure	Archeological sites
Ground subsidence and/or settlement	5	8	1	3	1
Frost heave	—	4	1	2	—
Slope instability	1	2	1	—	—
Thermal erosion	1	2	—	—	1
Icing	—	—	1	—	—
Unspecified hazards	—	2	1	3	—

4 DISCUSSION

4.1 Trends in Labrador permafrost literature

Permafrost research in Labrador has been spatially restricted, temporally sparse, and thematically limited. Though the first mention of permafrost in Labrador was in 1939 by Hustich, there was very little follow-up work on permafrost until the 1960s. The next three decades of permafrost research were then heavily influenced by the interests of the IOCC's mining operations. The establishment of the McGill Sub-Arctic Research Laboratory around the same time (1954) contributed to the strong early research focus on permafrost conditions in the Schefferville region, largely to support mining (Granberg et al. 1984). In 1968, Brown (1975) conducted the first regional survey of the distribution and thermal properties of permafrost landforms in Labrador. These early seminal investigations on permafrost built the foundation for geocryological research in Labrador, but this surge in permafrost research was relatively short-lived, and outputs again declined after the closure of the IOCC mine in 1983.

The two decades that followed included a number of years without any permafrost publications on Labrador in contrast with the concurrent surge of interest in permafrost research in adjacent areas of Nunavik (e.g., Allard et al. 1992; Laberge and Payette 1995; Roche and Allard 1996), Yukon Territory (e.g., Burn 1991; Burn and Smith 1990), and the Northwest Territories (e.g., Mackay 1995; Nixon and Taylor 1998). While these studies across the North built our contemporary understanding of the foundations of the thermal regime, active layer conditions, and permafrost degradation in northern Canada, contributions to this knowledge base from Labrador were nearly non-existent. These gaps would be even more apparent if border regions, such as Schefferville, were excluded.

Compared to northwestern Canada in particular, the lack of research and the limited thematic scope of studies have created knowledge gaps that hinder current and future permafrost research and infrastructure development in Labrador. Following the decline of permafrost research from Schefferville, most studies have investigated peatland permafrost (e.g., Anderson et al. 2018; Andrews 1961; Beer et al. 2024; Brown 1975, 1979; Davis et al. 2020; Dionne 1984; Elias 1982; Hustich 1939; Seguin and Dionne 1992; Way et al. 2018; Wang et al. 2023; Wang et al. 2024a, 2024b). Even with this relative abundance of research, a recent study by Wang et al. (2023) found a significant underestimation of peatland permafrost in

Labrador. This finding calls attention to the large gaps that remain in regional permafrost knowledge, despite recent investigations, and even in more heavily studied areas. This has implications for permafrost distribution modelling, ground ice estimation, and thermokarst prediction, which are likely to be unreliable in poorly studied regions.

4.2 Geocryological hazard research in Nunatsiavut

The paucity of research on permafrost and geocryological hazards in Labrador is even more prominent in Nunatsiavut, where there have been very few investigations of ground ice conditions despite the importance of ground ice for effectively characterizing geocryological hazards and risks (O'Neill et al. 2024). Discussions on geocryological hazards in Nunatsiavut have generally been restricted to the Nain region, although ground subsidence due to permafrost thaw has been noted in other parts of coastal Labrador (Wang et al. 2024b) and cryosphere-influenced mudslides in Nachvak (Torngat Mountains National Park) were described by de Vernal et al. (1983). Nain is near the northern extent of the sporadic discontinuous permafrost zone (Heginbottom et al. 1995) and local infrastructure damage inferred to be caused by permafrost thaw has been documented (Bell et al. 2011; Lewkowicz and Way 2014; Smith and Melendy 2015; Stantec 2015; Way and Lewkowicz 2015; Way et al. 2021). For example, due to inferred thaw subsidence, a caribou processing plant had to be demolished after only five years of operation (Way et al. 2021), while the community church had to be raised by 0.75 m (Smith and Melendy 2015). Despite these well-documented permafrost thaw-related challenges in Nain, previous permafrost research in the area has been mostly restricted to the lower limits of the community or in specific developed areas (Lewkowicz and Way 2014; Stantec 2015; Way and Lewkowicz 2015; Way et al. 2021). Here, ice-rich permafrost has been inferred (Stantec 2015; Way et al. 2021), but community-wide assessments of geocryological hazards have yet to occur.

By contrast, in Nunavik and Yukon Territory, comprehensive community-scale assessments of geocryological hazards have been undertaken to support community planning and climate-adapted development (Allard et al. 2023; Benkert et al. 2015). These assessments have been instrumental in mitigating impacts on infrastructure and developing effective construction adaptation strategies. Geocryological hazard assessments have also been undertaken in some communities in the Northwest Territories (Daly et al. 2022; Wolfe et al. 2014).

In Nunatsiavut, discussions on geocryological hazards have been limited in scope, mainly focusing on small areas of a community and specific buildings, or serving as secondary discussions within studies focused on other primary objectives. Combined with limited information on ground ice conditions, in part due to the lack of high-resolution surficial geology mapping (O'Neill et al. 2024) in Labrador, this has led to significant gaps in our understanding of the distribution of these hazards and the risks to infrastructure and cultural keystone places. Assessments of permafrost conditions are also hindered by a lack of consistent snow cover monitoring and an underestimation of permafrost at low elevations in Nunatsiavut (Wang et al. 2023). Based on this review, it is evident that hazards from thawing permafrost are present in the region; however, there is insufficient research to gauge the risk of these hazards for existing and future infrastructure.

Currently, there are several large-scale development projects proposed in Nunatsiavut. Torngat Metals Ltd. proposed the development of a large-scale rare earth mining operation (Strange Lake mine) on the border of northern Nunatsiavut (Torngat Metals Ltd. 2024). This project would include a 160 km-long access road traversing sporadic and extensive discontinuous permafrost zones (Heginbottom et al. 1995; Torngat Metals Ltd. 2024). A pre-feasibility study has also been completed (but not yet released publicly) to investigate the potential for a highway connecting central Labrador to the six communities in northern Labrador (Government of Newfoundland and Labrador 2023). Finally, in Nain, construction of a new airport with a 1.8 km-long runway is proceeding following environmental review (Nunatsiavut Government 2024). This would include the construction of a 13 km-long access road to connect the community to the airport (Nunatsiavut Government 2024).

All of the above projects face challenges due to insufficient knowledge of regional permafrost conditions, ground ice content, and geocryological hazards, which may lead to slower environmental approval processes and potentially costly structural damage and maintenance. Further research on geocryological hazards in Nunatsiavut is warranted to inform these large-scale projects, as well as to support community expansion in northern Labrador.

5 CONCLUSION

This study conducted a review of all available permafrost research in Labrador to identify spatial and temporal research trends with a particular focus on geocryological hazards in Nunatsiavut. The results generally show that permafrost literature in Labrador is temporally inconsistent with frequent gaps in research outputs until recent years, which is a pattern not observed to the same extent in northwestern Canada. The limited discussion of geocryological hazards is notable, and no studies have directly investigated the distribution and risks of potential geocryological hazards, as has been done in Nunavik and the Territorial North (Allard et al. 2023; Benkert et al. 2015; Wolfe et al. 2014). Together, these findings point to considerable gaps in our understanding of permafrost

hazards throughout Labrador and in Nunatsiavut, specifically. Given ongoing proposals for expanded regional development, information on permafrost conditions and potential hazards will be critical to mitigate and manage future infrastructure damage.

We recommend the development of comprehensive geocryological hazard mapping throughout Nunatsiavut, with specific attention to communities and potential linear infrastructure corridors. This research will support future infrastructure expansion in Nunatsiavut and across Labrador. Further research on permafrost distribution, ground ice content, and geocryological hazards will enable Nunatsiavummiut to better adapt to changing permafrost conditions and increase climate resiliency.

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