Geological Survey of Canada
Scientific Presentation 139

REMOTE PERMAFROST TERRAIN MAPPING, GRAYS BAY - YELLOWKNIFE CORRIDOR, NORTHWEST TERRITORIES AND NUNAVUT

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KNOWLEDGE GAP

The proposed Grays Bay – Yellowknife corridor for transportation, energy, and telecommunications through the Slave Geological Province is needed to improve access for exploration and development, reduce operating costs, and open up the vast mineral deposits to existing highway infrastructure in the south and a deep-sea port on the Arctic Ocean (Fig. 1).

In this region, information on potential geohazards to mineral exploration and development, in relation to periglacial features, is relatively sparse. Periglacial features are landforms associated with cold environments and are closely related to permafrost. Permafrost conditions affect terrain sensitivity to climate change and surface disturbance. As air temperature is rising in northern Canada at roughly three times the global mean rate (Bush and Lemmen, 2019), this knowledge of periglacial conditions is needed to inform decisions on adaptation strategies and suitability of terrain for environmentally sustainable and climate change-resilient infrastructure.

Periglacial conditions are often closely related to surficial geology (Fig. 2). These relations are well understood for the southernmost few hundred kilometres within discontinuous permafrost terrain, where bedrock and glaciolacustrine deposits dominate, but are poorly understood for the central and northern regions in continuous permafrost. Here, geological diversity increases with latitude, and it is expected that till, glaciofluvial sediments, and marine deposits likely play a key role in terrain stability.

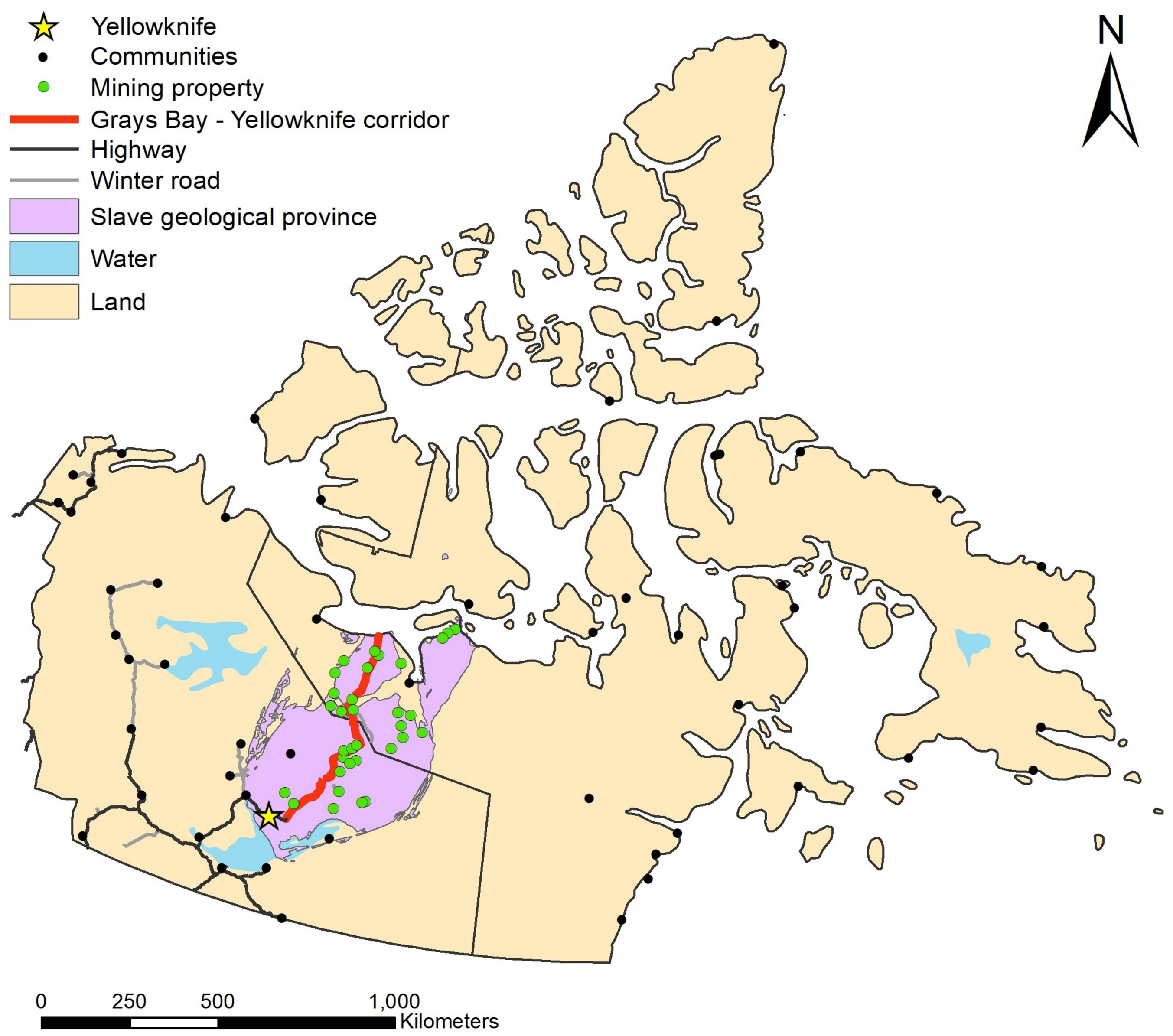

Figure 1. Location of the Grays Bay - Yellowknife Corridor and mining properties within the Slave Geological Province, with respect to northern communities and major transportation infrastructure.

SOLUTION

To fill this regional information gap, we are mapping periglacial terrain features (Fig. 3), compiling related information from historical geotechnical reports, and developing high-resolution models of ground ice potential. This is an activity within GEM GeoNorth, and this poster presents the periglacial feature mapping component. The purpose is to assess current permafrost conditions in relation to surficial sediments, geomorphic processes, and climate. Our objectives are to determine (i) the potential permafrost-related geohazards to mineral exploration and development in the corridor, and (ii) how these terrain features relate to surficial geology.

METHODS

We mapped a 10-km wide swath (8576 km^2) within the Slave Geological Province (Fig. 4), using 39 high-resolution (0.6 m) satellite images together with 2-m resolution ArcticDEM elevation data. Post image processing, we identify and map permafrost and terrain features at a scale of 1:5000, and categorize the features according to a protocol modified from Sladen et al. (2021) to include landforms that were not present in the earlier study. Field validation will be conducted by future aerial photo-surveys.

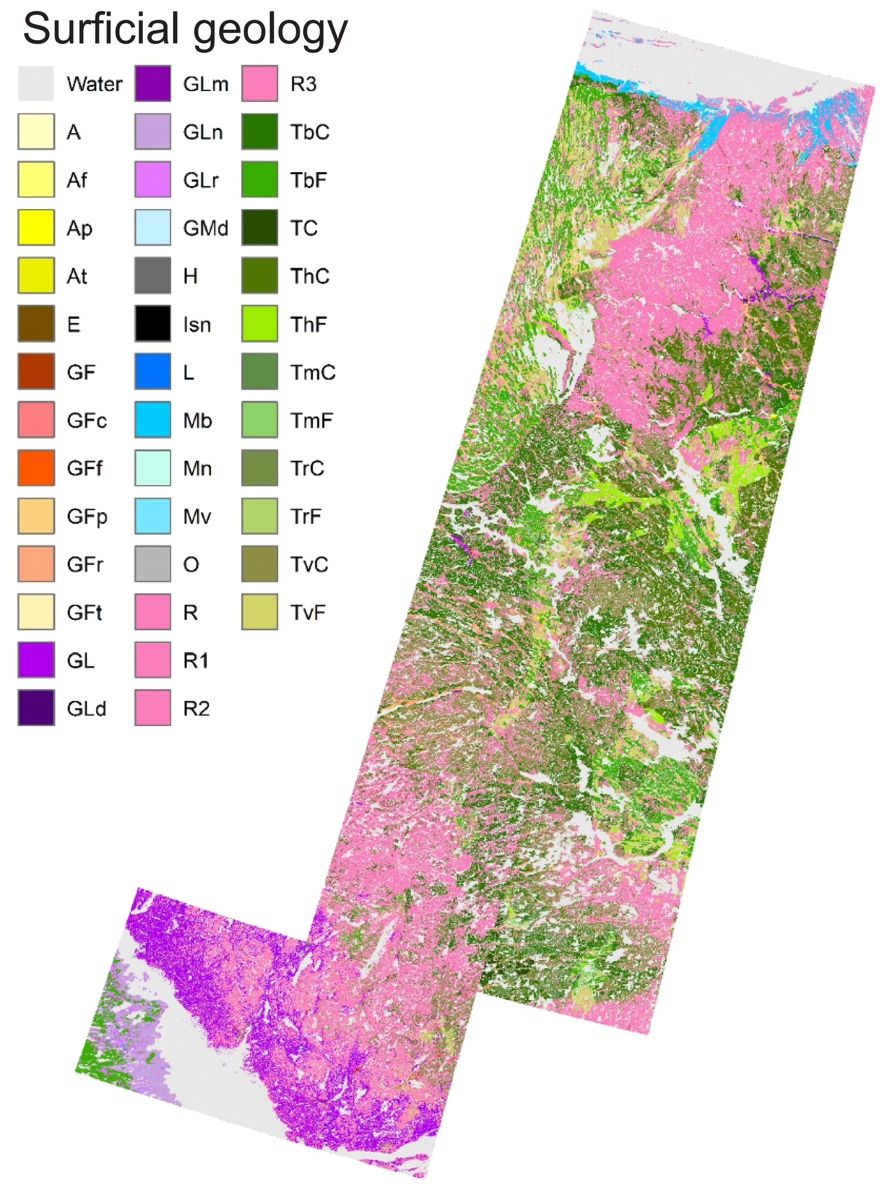

Figure 2. Surficial geology data were compiled from 11 Canada Geoscience Maps generated during previous GEM activities at the Geological Survey of Canada.

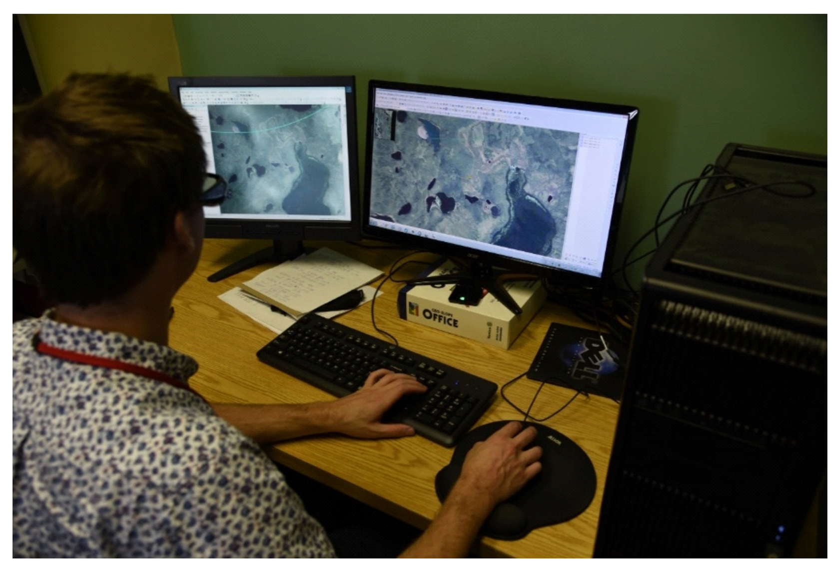

Figure 3. Creep-deformed landforms were not observed in earlier mapping activities, so the protocol developed by Sladen et al. (2021) was consequently modified to include them.

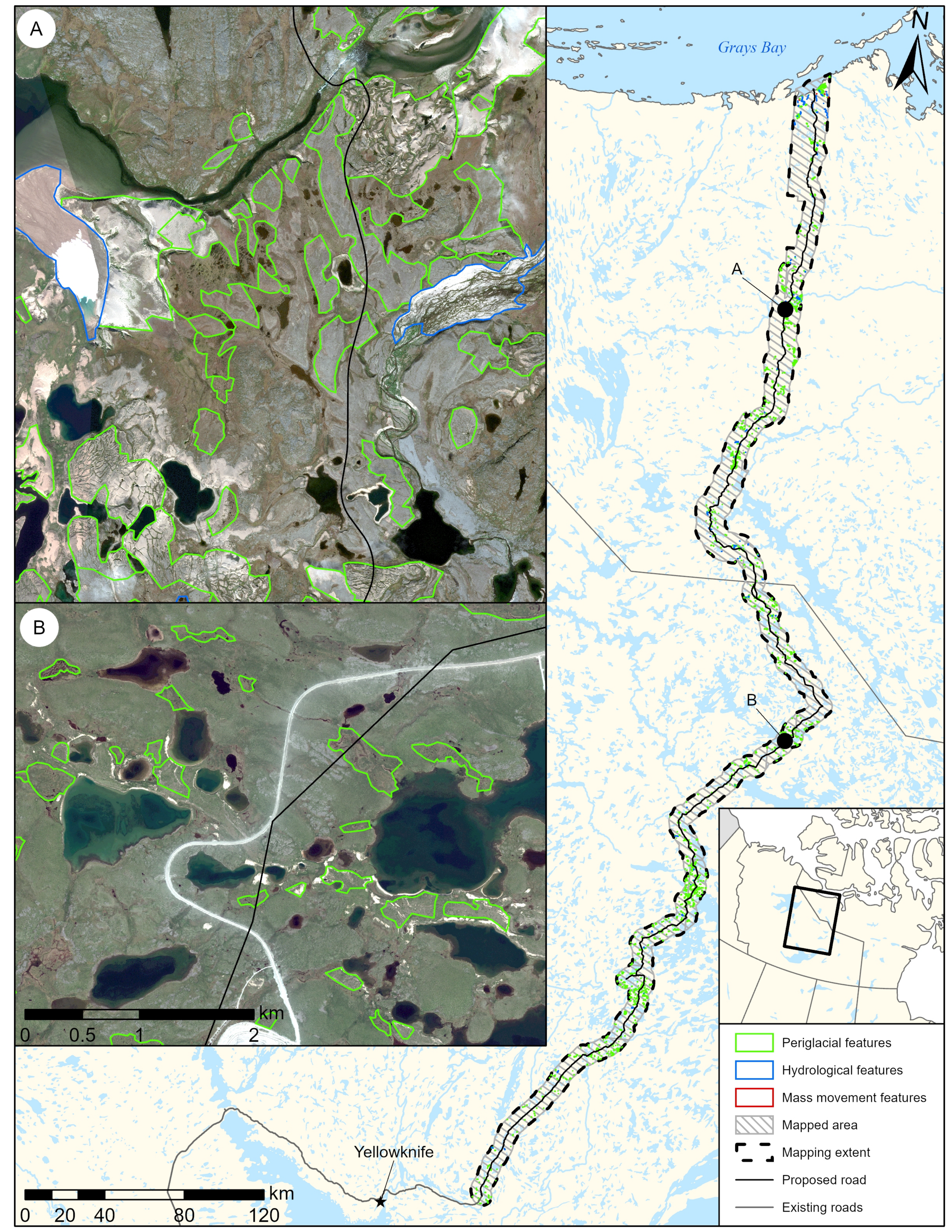

Figure 4. The study area was developed according to a 5-km buffer of the centre lines of the road corridors proposed for the region. We acquired available satellite image and then tasked the satellite constellation to fill in gaps in image coverage.

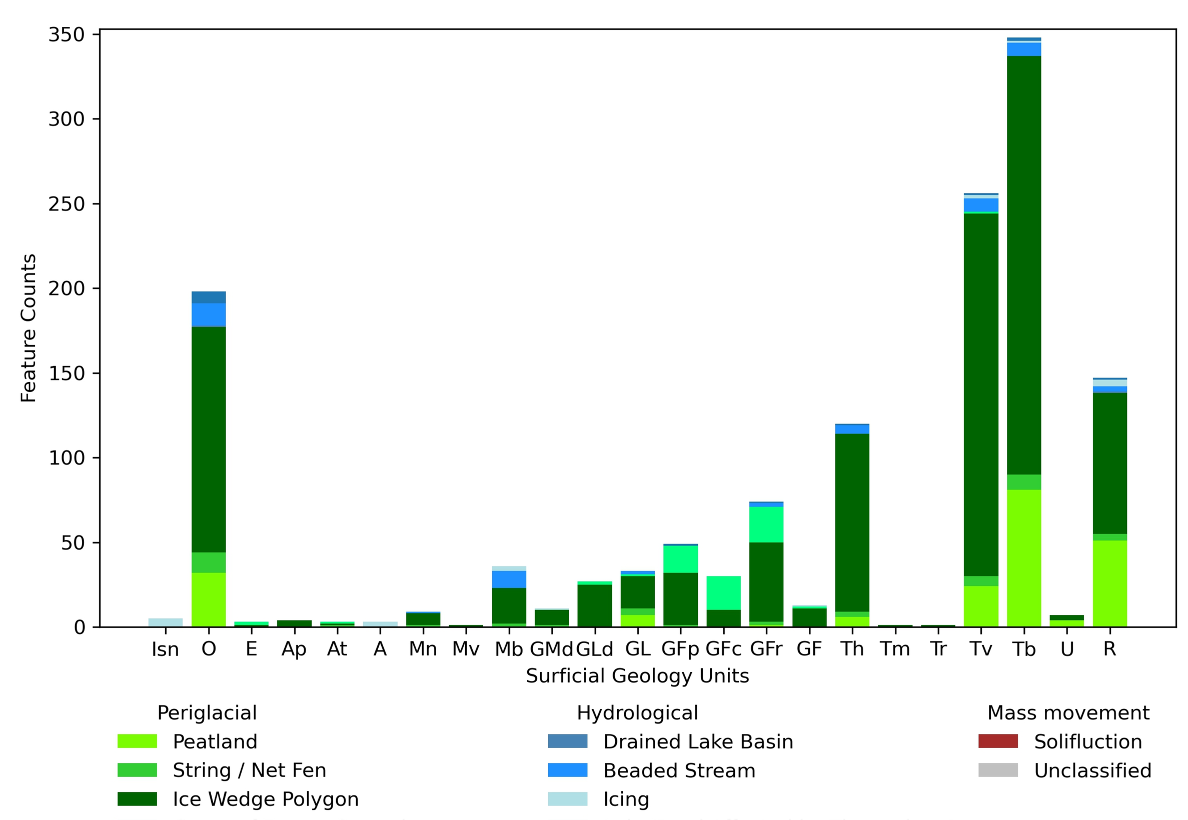

Figure 5. Feature count with respect to surficial geology type. Permafrost features are in green, hydrological features are in blue, and mass movement features are in red.

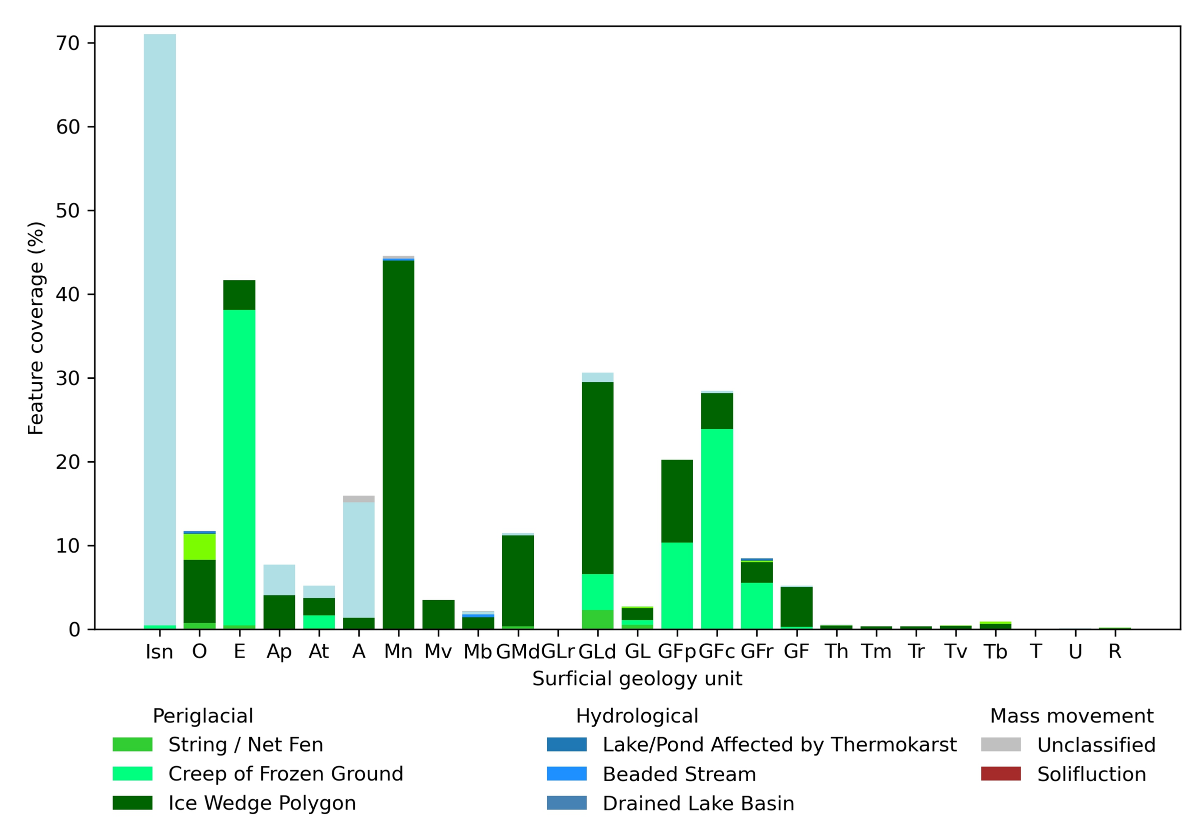

Figure 6. Percent of the surficial geology unit covered by the respective feature. Permafrost features are in green, hydrological features are in blue, and mass movement features are in red.

PRELIMINARY RESULTS

We have so far digitized 1393 features that cover 180 km^2 within the study area (Fig. 4). 93% are permafrost features, and the vast majority are ice-wedge polygon networks, however, creep-deformed landforms and string bogs are common (Figs. 5 and 6). Hydrological features include icings, beaded streams, and thermokarst-affected water bodies. Mass movements include solifluction and unclassified features, which are concentrated. 89% of all mapped features are associated with bedrock and glaciofluvial, till, and organic deposits. However, of these, they are most dense in glaciofluvial deposits. Notably, 87% creep-of-frozen-ground area, which is related to high ground ice contents at depth, occurs within glaciofluvial surficial geology classes (GF, GFp, GFc, and GFr).

Figure 7. Approximately 40% of glaciofluvial deposits have ice-wedge polygons or are associated with thermokarst, slope movement and collapse features that indicate either meltout or creep of large bodies of massive ice. Photograph by P.D. Morse. NRCan photo 2021-709.

IMPLICATIONS

Extent of features and diversity contrasts with western Canadian Arctic where each aspect is greater, but the periglacial landforms present in the Slave Geological Province are no less relevant to understanding potential geohazards, terrain sensitivity to thaw, and landscape evolution.

Periglacial geohazards exist throughout the corridor region. Mapped ice wedge polygon networks and creep-deformed landforms suggest a high potential for thermokarst and terrain instability throughout the region, primarily in association with glaciofluvial, marine, till, and organic deposits. Several icings were mapped, but given the nature of icing dynamics it is likely that we only mapped a minority of the potential population. Mass movements are not common, but occur exclusively in the northern-most region of the mapping area on riverbanks within marine or alluvial deposits.

This contribution to understanding periglacial conditions in the region should make potential geohazards easier to identify and avoid. For example, because eskers are considered to be well-drained and stable landforms suitable for road materials or road base, the 2020 SGP routing analysis was designed to increase suitability as an exponential function of proximity to eskers (Aurora Geosciences, 2020). However, our research and mapping suggest that ground ice is relatively concentrated in glaciofluvial deposits (Fig. 7), which would reduce the long-term stability of the road and aggregate potential and decrease suitability.

SUMMARY

Information on potential geohazards to mineral exploration and development related to periglacial features is relatively sparse for the Grays Bay – Yellowknife corridor. In order to assess current permafrost conditions in relation to surficial sediments, geomorphic processes, and climate, we are determining (i) the potential periglacial geohazards to mineral exploration and development in the corridor, and (ii) how these terrain features relate to surficial geology. Our preliminary mapping results suggest that ground ice and potential periglacial geohazards exist throughout the corridor region, primarily in association with glaciofluvial, marine, till, and organic deposits. Ice wedge polygon networks and creep-deformed landforms suggest a high potential for thermokarst and terrain instability, and such mapping may inform on alignment revision. Icing, which can block culverts and cause washouts or create slippery road conditions, was mapped at several locations, but a multi-temporal approach is needed in order to map the majority of the icing population.

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2022

Publications in this series have not been edited; they are released as submitted by the author.

Permanent link: https://doi.org/10.4095/330206

This publication is available for free download through GEOSCAN (https://geoscan.nrcan.gc.ca/).

Presented at ArcticNet Annual Scientific Meeting 2021
Date presented: December 2021

Recommended citation
Morse, P.D., Parker, R.J.H., Sladen, W.E., Smith, S.L., and O'Neill, H.B., 2022. Remote permafrost terrain mapping, Grays Bay – Yellowknife Corridor, Northwest Territories and Nunavut; Geological Survey of Canada, Scientific Presentation 139, 1 poster. https://doi.org/10.4095/330206

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