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PERIGLACIAL LANDFORMS OF THE GRAYS BAY ROAD CORRIDOR REGION, NUNAVUT, AND IMPLICATIONS FOR CLIMATE-RESILIENT INFRASTRUCTURE

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Introduction

Knowledge of thaw sensitive terrain is required to develop climate-resilient northern infrastructure, identify potential geohazards, inform decisions regarding resource development, and make inferences on past and future landscape evolution. However, little is known about permafrost conditions in the northern Slave Geological Province (Fig. 1a). The region has rich mineral resources and great northern economic development potential, including the proposed Grays Bay Port and Road (Fig. 2). To address this knowledge gap, we use a periglacial landsystems approach to attempt to understand how the region's landscape and thaw-sensitive terrain was formed. Our research considers the relations between sediments and permafrost-related landforms that constitute the landscape of northern Slave Geological Province. Future work will link these assemblages to the processes that form them. The ultimate goal is to enable inferences on past and future landscape evolution supported by process-form models established from present-day conditions. Here we present and discuss preliminary mapping results.

Background

Permafrost is continuous in the region (Heginbottom et al. 1995) and where it occurs in unconsolidated deposits it contributes to landscape stability through ice-bonding of sediments. The stability and integrity of such permafrost are dominantly functions of ground temperature, materials, and ice content, which are a function of landscape history (e.g., O'Neill et al. 2019). Potentially deleterious effects of permafrost thaw include decreased load-bearing capacity, ground surface settlement, and initiation of geomorphic processes from the melt of ground ice that transport sediment and water. In a rapidly changing northern climate, these adjustments to thaw are potentially major geohazards for northern infrastructure, however, differential effects are expected due to the heterogeneous distribution of surficial materials. O'Neill et al. (2020) estimate that ground ice abundance (excess ice volume in the top 5 m of permafrost) in the region ranges from none to high (> 20-30 %), but what little is known about *in situ* permafrost conditions is largely derived from sparse sedimentological and cryostratigraphic records (e.g., Kerr et al. 1996, Wolfe et al. 1997a, 1997b, SRK 2003, BGC 2005, 2006; Fig. 3b). Dredge et al. (1999) related surficial materials and landforms to ground ice conditions where these records were available, and the potential for mapping the presence of massive ice in granular deposits has been assessed with air photos at a limited set of locations (AGRA Earth and Environmental 1998), but there has been no regional landform-sediment assemblage mapping.

Methods

Our mapping zone is the ~1600 km^2 area that is generally within a 5 km buffer of the proposed Grays Bay Road corridor (some image areas extended beyond the buffer, Fig. 1a). Periglacial and hydrological features were mapped using satellite images and a Digital Elevation Model (DEM) and a mapping methodology developed for the Dempster Highway and Inuvik-to-Tuktoyaktuk Highway corridors (Sladen et al. 2021a). The methodology prescribes feature identification at a scale of 1:10000, with digitization at a scale of 1:5000. We modified the methodology to include deposits with depressions and terracing that indicate previous thermokarst activity and slope movement (Dredge et al. 1999), and used available high resolution WorldView-1, -2, and -3 satellite imagery (acquired from Digital Globe, Inc.) and ArcticDEM (Porter et al. 2018) as inputs.

Results and Discussion

The satellite imagery acquired covers 72% of the study corridor (Fig. 1a). We delineated 110 periglacial and 5 hydrological features. Due to widespread bedrock outcropping and low relief with stable slopes in the Grays Bay Road corridor, the density of features is substantially lower than for terrain mapped in the Dempster Highway and Inuvik-to-Tuktoyaktuk Highway corridors where surficial deposits can be comparatively extensive and there is mountainous relief with unstable slopes (Sladen et al. in press).

Mapped periglacial landforms (Fig. 3a), are mostly ice-wedge polygon networks (IPN; ~81%; 15.91 km^2, Fig. 4), and the remainder are irregularly elongated (stretched appearance) ice-wedge polygon networks (EIPN) with depressions and terracing (3.78 km^2). IPN and EIPN occur in 16 types of surficial materials (Fig. 4). IPN are widespread on marine sediments at the coast (Fig. 3a), but are also common on glaciofluvial outwash plain and undifferentiated sediments, organic deposits, glaciolacustrine deltaic sediments, and glacial blanket and hummocky till deposits. EIPN are almost entirely associated with glaciofluvial ice-contact and esker deposits, but also occur in glaciolacustrine undifferentiated and deltaic deposits and in alluvial terrace sediments. Although glacial till veneer and hummocky till are the most widespread sediments in the region, the extent of IPN and EIPN mostly reflect the distribution of the other, less extensive surficial deposits. However, for a given surficial geology type, the extent of these landforms is not equal to the extent of the respective deposit. Instead, the landforms are irregularly distributed throughout the deposit. The few geophysical data available for EIPN in the southern portion of the corridor indicate massive ice at depth (Fig. 3b; Wolfe et al. 1997a, 1997b). A notable landform-sediment assemblage derived from these records and our data is glaciofluvial ice-contact deposits, dissected by extended ice-wedge polygons (Figs. 1c and 5).This assemblage exhibits long-term creep that suggests the presence of icy permafrost at depth, it includes thermokarst depressions due to ice-rich permafrost thaw, and it likely has the highest potential for thermal adjustment in the landscape. Consequently, this assemblage may represent a substantial potential geohazard in this region. However, processes linked to the development of EIPN are not clear (e.g., is the apparent creep real, and is it due to formation of syngenetic or epigenetic ground ice at depth, or is there buried ice?) and require future field work to assess.

Hydrological landforms, shown in Figure 3a and summarized in Figure 4, are comprised of three aufeis-modified flood plains and two beaded streams. Beaded streams, a form of thermokarst, are associated with IPN in glacial veneer and marine blanket, whereas aufeis, a hydrological phenomenon of the freezing season that develops as seasonally thawed ground freezes back, occurs in association with undifferentiated glaciofluvial sediments, marine blanket, and undifferentiated alluvial sediments. Beaded streams are necessarily associated with IPN that occur in these surficial geology units. Conversely, the location and formation of aufeis is a function of broader geological and environmental contexts and not just local surficial geology. Aufeis formation is a potential geohazard and it occurs in the vicinity of the proposed road corridor (Fig. 1b).

Conclusions

This poster presents our initial stage of identifying the relations between periglacial landforms and sediments in the northern Slave Geological Province. Our results demonstrate the highly spatially-heterogeneous nature of ice-rich indicator landforms within surficial deposits, and thus the utility in establishing relations between landforms and sediments to guide the eventual development of process-form models. These early results can be used to identify the locations of thaw-sensitive, potentially geohazardous terrain in the Grays Bay Road corridor region, which needs to be considered when planning climate-resilient infrastructure.

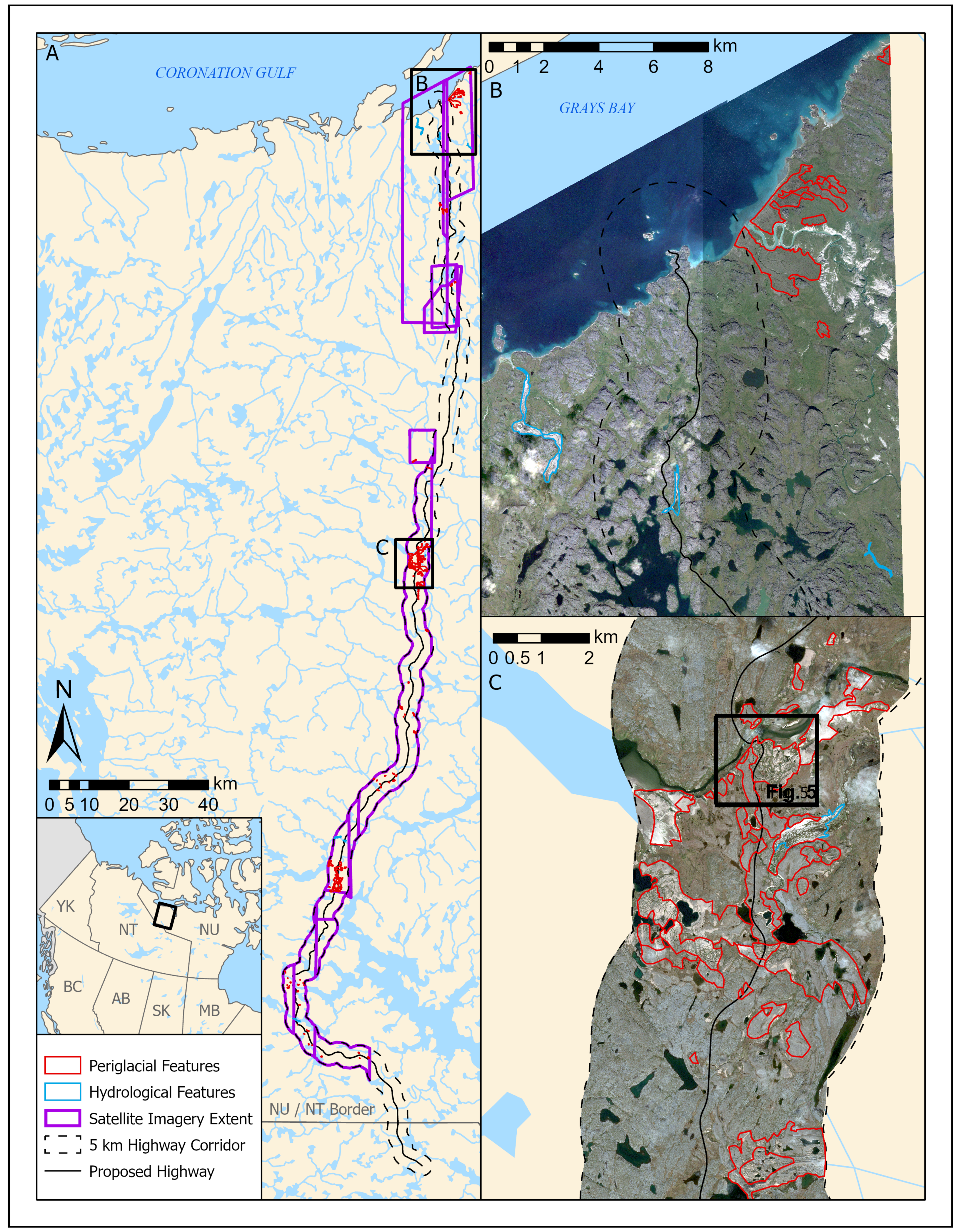

Figure 1. (a) Location of the Grays Bay Road corridor study area within the northern Slave Geological province (inset map), extent of very high-resolution satellite images used for mapping, and the extent of periglacial and hydrological features mapped. The black rectangle indicates the locations of Figure 1b and 1c. (b) An example of features mapped at the northern coastal area with extensive marine sediments. (c) An example of features mapped at a central location within the study area with widespread glaciofluvial deposits. The black rectangle indicates the location of Figure 5.

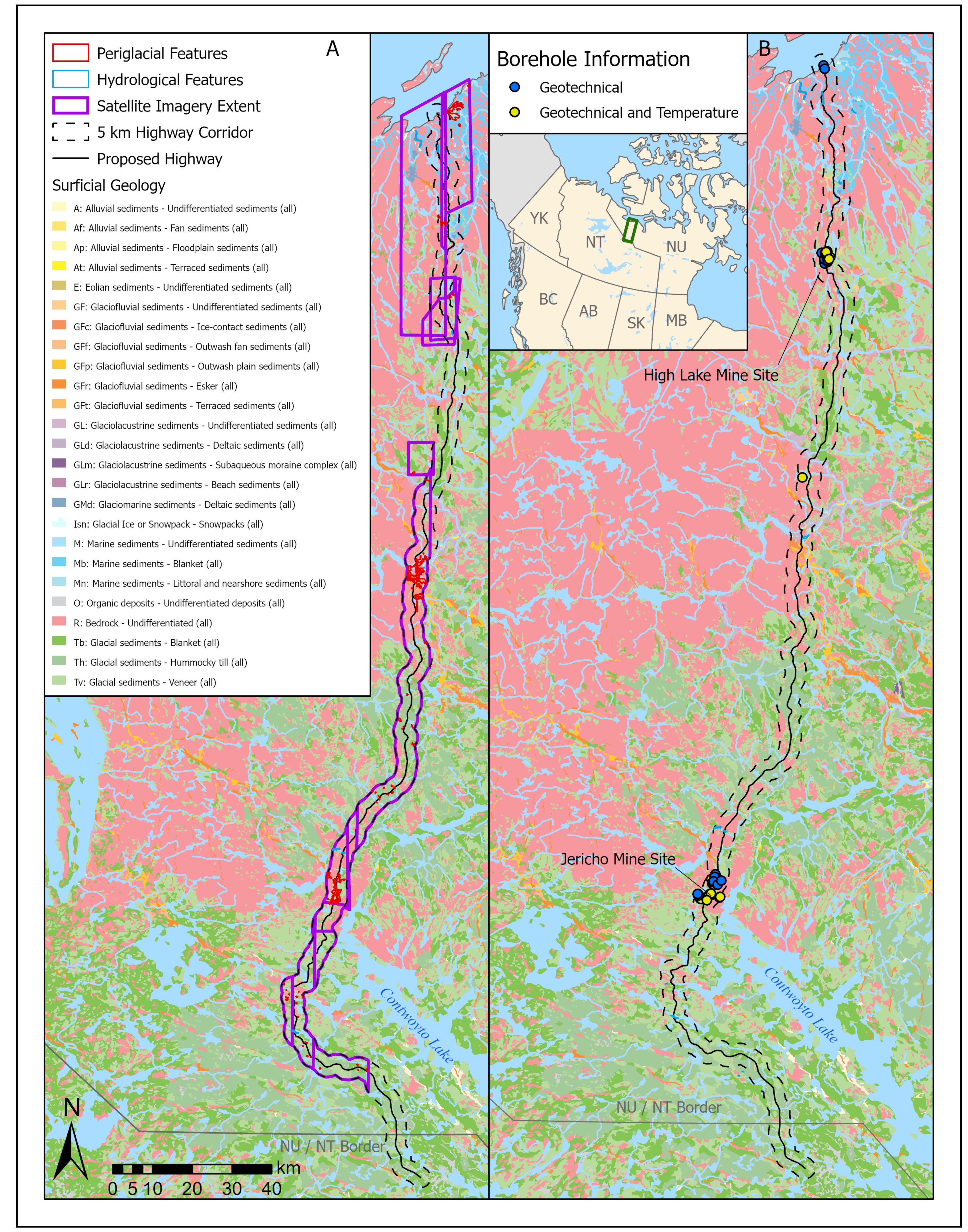

Figure 3. Location of mapped features (a) and boreholes (b) in the study area with respect to surficial geology. Surficial geology data compiled from Canadian Geoscience Maps (GSC 2014, 2016a, 2016b, 2017a, 2017b, 2018). Borehole data are compiled from BGC (2005, 2006), SRK (2003), and Smith et al. (2013).

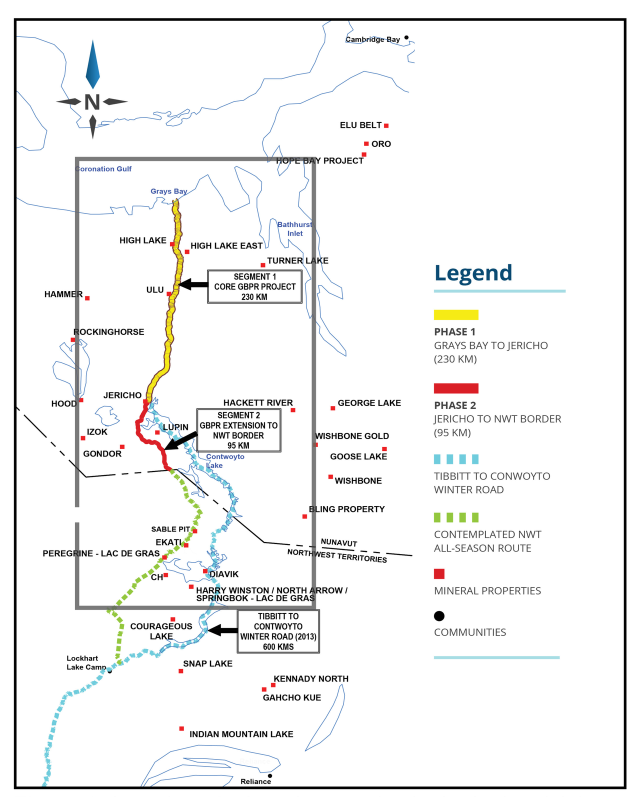

Figure 2. Location of mineral properties in the in the vicinity of the proposed Grays Bay Port and Road project (Source: KIA 2020).

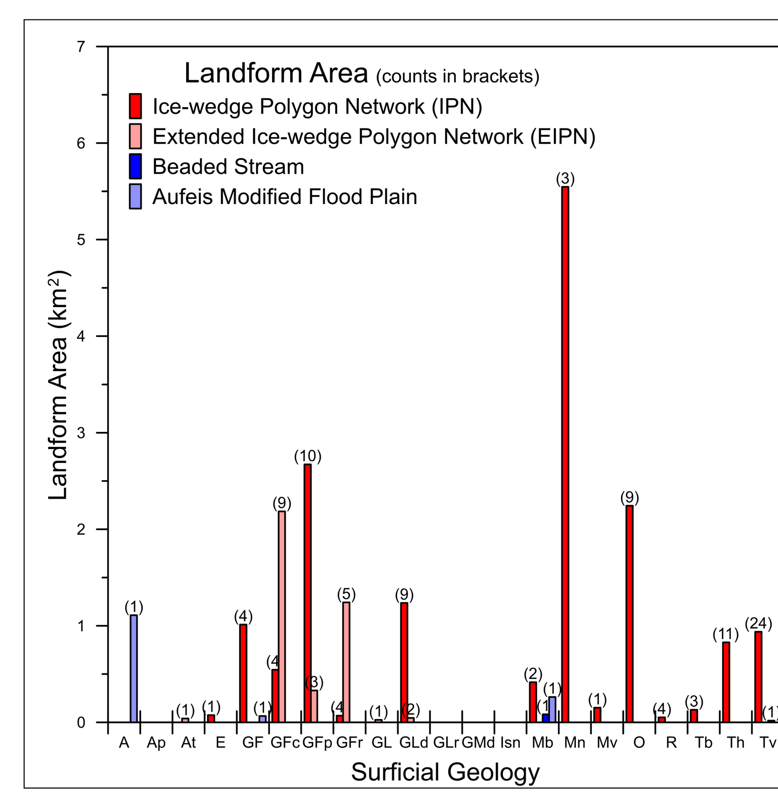

Figure 4. Landform areas summarized according to surficial geology unit. Surficial geology codes are the same as in Figure 3a. Landform counts are labelled within brackets.

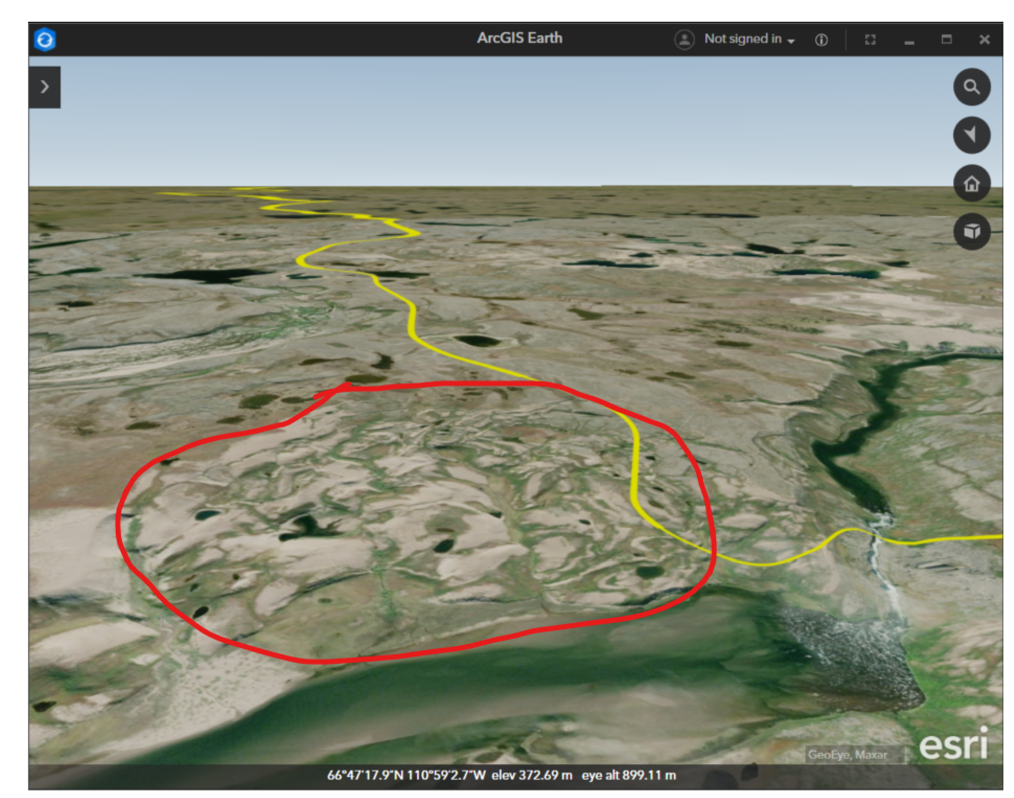

Figure 5. Oblique image of glaciofluvial ice-contact deposits dissected by extended ice-wedge polygons (circled in red), Hood River, Nunavut , approximately 15 km south of the Ulu Mineral Lease (Fig. 2). This southward perspective shows the proposed Grays Bay Road alignment in yellow. The cause of the apparent creep of the ground and extension of the ice-wedge polygon network is unclear, but is likely related to icy permafrost at depth.

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