GEOMORPHIC FEATURE MAPPING ALONG THE DEMPSTER HIGHWAY AND INUVIK TO TUKTOYAKTUK HIGHWAY CORRIDOR, YUKON AND NORTHWEST TERRITORIES, CANADA

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INTRODUCTION

Thaw of ice-rich permafrost reduces ground stability, modifies terrain, and alters drainage patterns. This affects terrestrial and aquatic ecosystems and the integrity of critical transportation infrastructure. Since the western Canadian Arctic is warming at more than double the global average rate (Bush and Lemmen, 2019), permafrost thaw may present significant societal and economic challenges. Understanding the thaw trajectory of sensitive permafrost terrain requires knowledge of ground ice conditions. Thaw sensitivity can be inferred by the presence of characteristic periglacial landforms.

Here we map the spatial variability in periglacial landscape features using high-resolution satellite imagery along a 10 km-wide corridor centred on the 875 km-long Dempster Highway and Inuvik to Tuktoyaktuk Highway (DH-ITH) (Fig. 3). The road traverses a variety of physiographic terrain types, and though permafrost distribution is continuous, variation in climate, surficial geology, topography, ecology, and disturbance has produced a diverse range of permafrost conditions and landforms (Fig. 1).

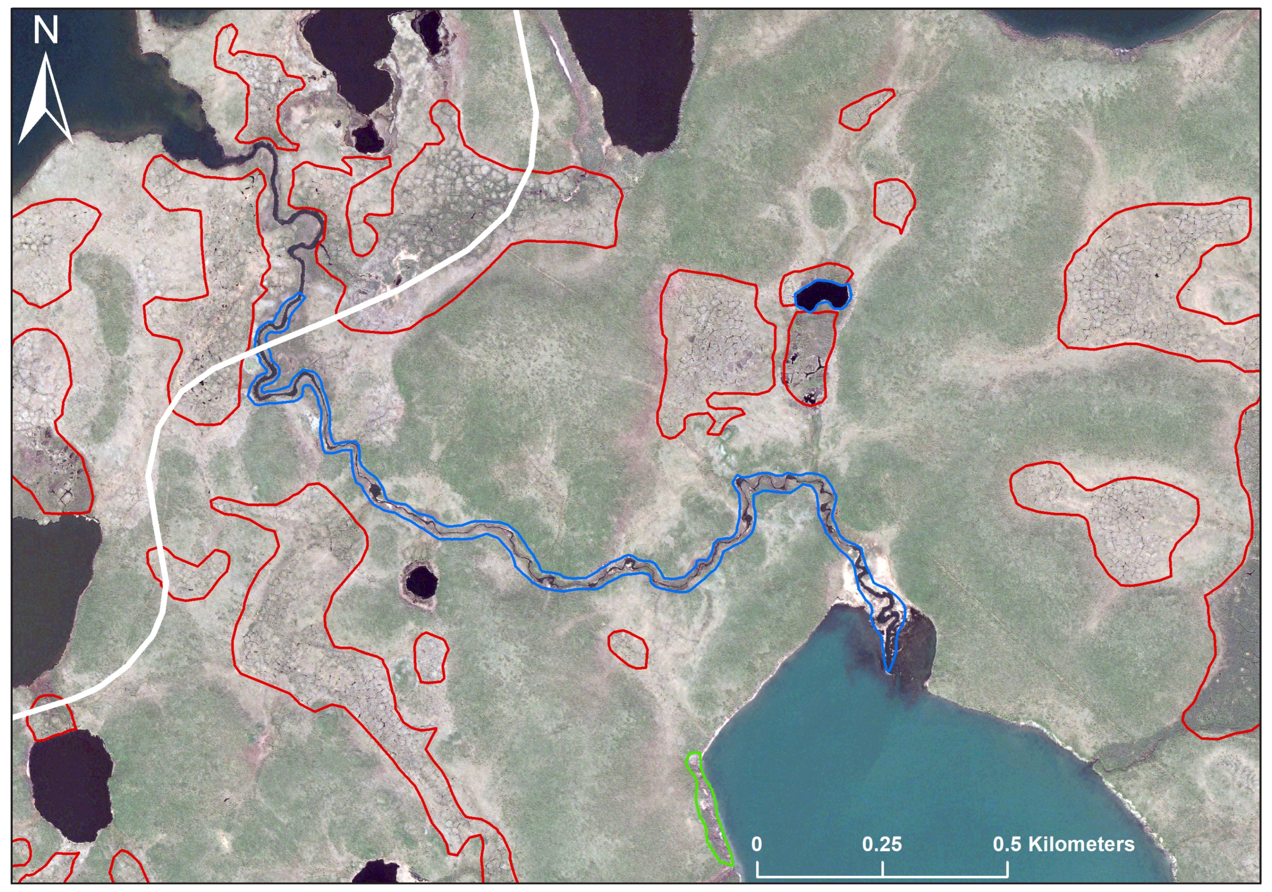

Figure 1. Example of digitized polygons for mass movement (green), periglacial (red), and hydrological (blue) features on the Tuktoyaktuk Coastlands near the ITH (shown in white). Image source: WorldView-2 (copyright 2005 DigitalGlobe, Inc.).

METHODOLOGY

Key landscape features were mapped in 3D using synthetic stereopairs generated from very high-resolution (0.6 m) WorldView-2, WorldView-3, and GeoEye-1 images (Sladen et al., 2021). Features were identified at 1:10 000 scale, and digitized at 1:5000 scale using Summit Evolution™ and ArcMAP™ platforms. Landforms were classified according to main formational process: hydrological, periglacial, and mass movement (Fig. 2). Landform type attribution was semi-automated, and additional attributes were extracted from GIS data layers, such as surficial geology and permafrost conditions.

Mass Movement	Periglacial	Hydrological
Flow	Ice-wedge polygon	Beaded stream
Active-layer detachment	High centre	Drained-lake basin
Debris flow / fan	Low centre	Fully-drained
Solifluction	Undifferentiated	Partially-drained
Rock glacier	String / net fen	Icing
Slide	Palsa	Lake affected by thermokarst
Rotational slide	Peat plateau complex	Thermokarst gully
Translational slide	Thermokarst mounds	
Shoreline slump	Pingo	
Fall	Lithalsa	
Rock fall		
Topple		
Block failure		
Complex failure		

Figure 2. Landscape feature classes based on dominant process and their associated feature types and subtypes digitized in this study.

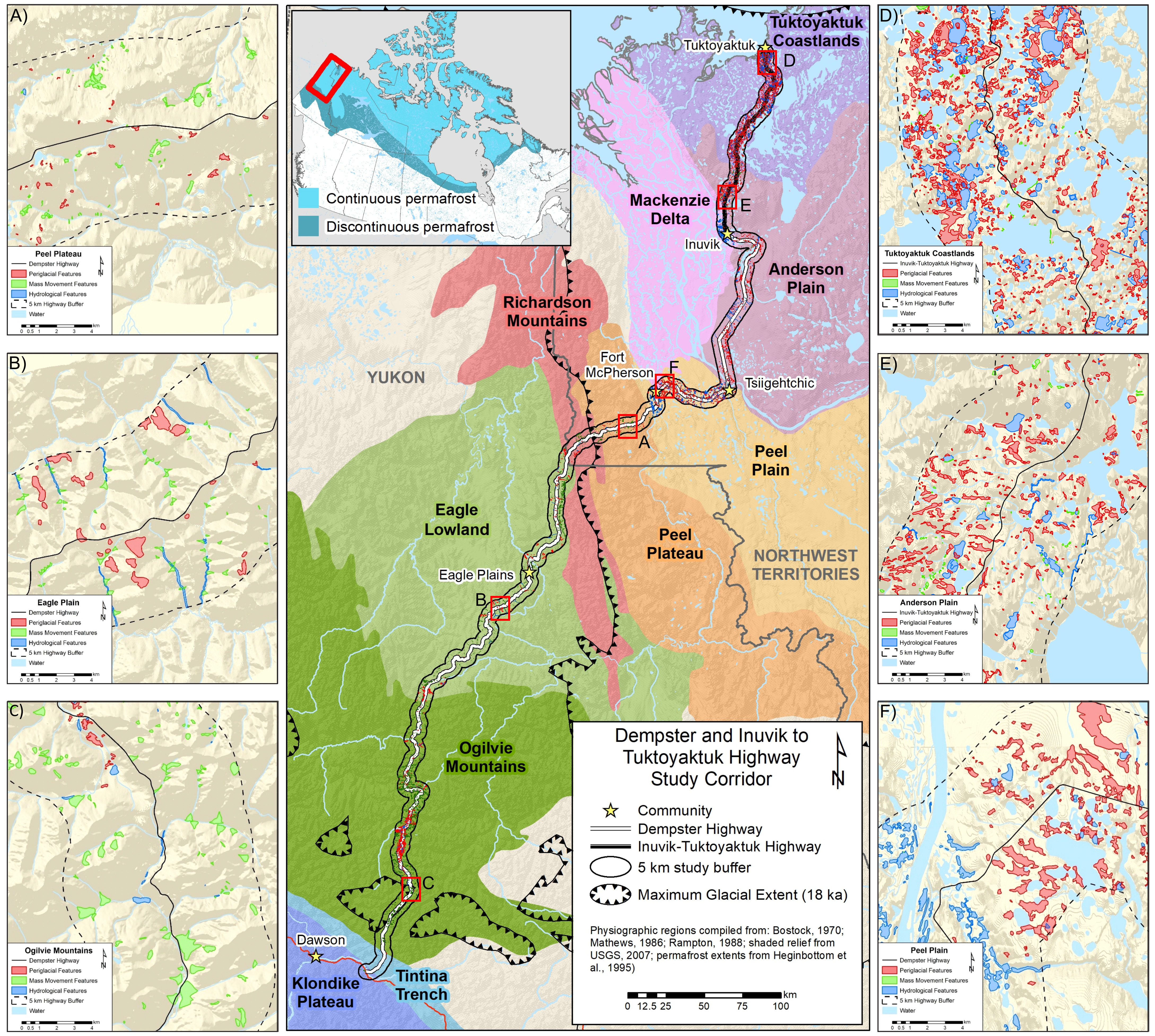

Figure 3. Centre: DH-ITH corridor and physiographic regions, extent of mapping, and locations of images A-F. Inset shows the study area relative to Canada and permafrost zones. A) to F) Feature class distribution in key physiographic regions.

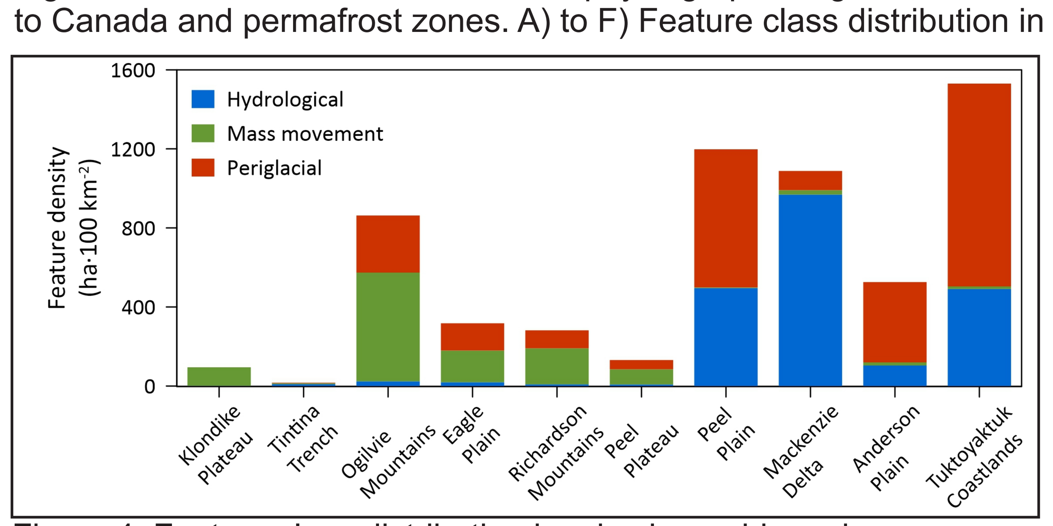

Figure 4. Feature class distribution by physiographic region.

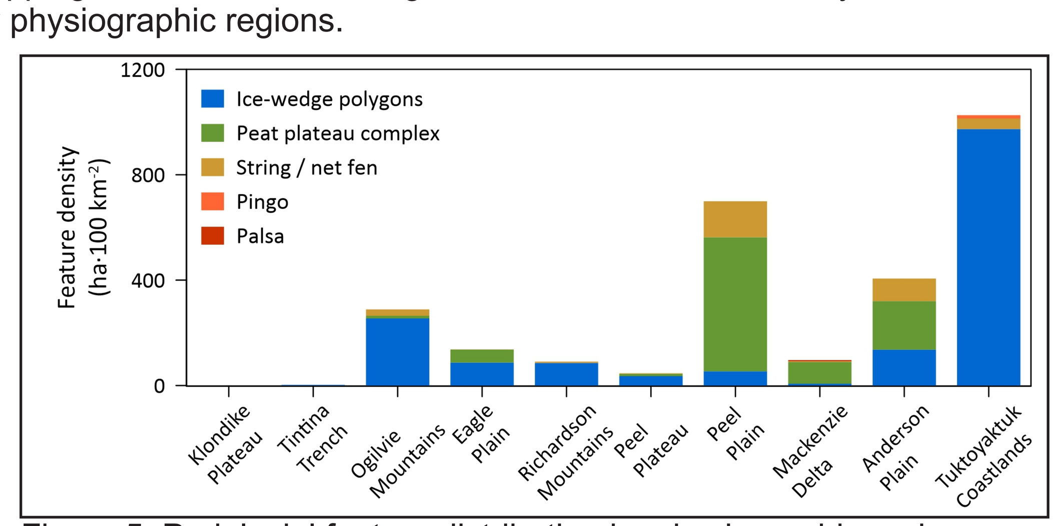

Figure 5. Periglacial feature distribution by physiographic region.

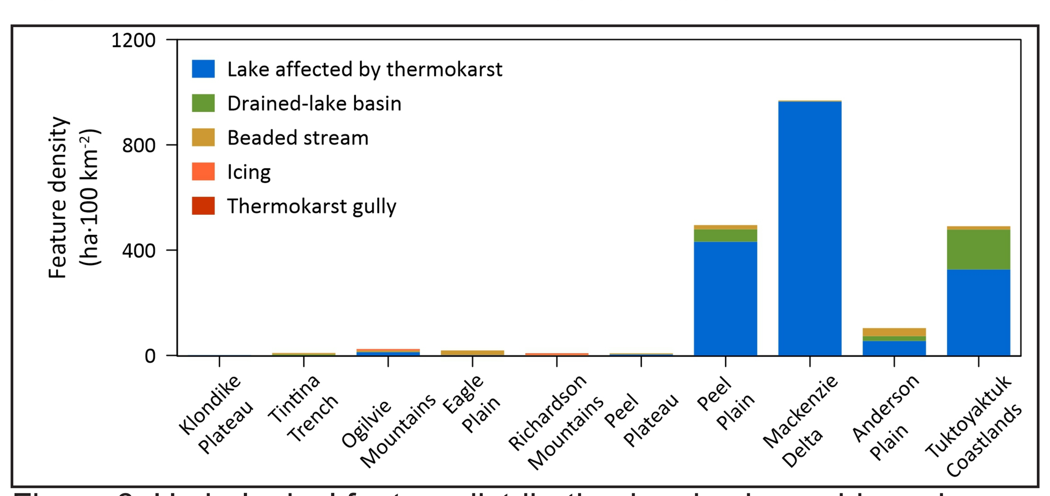

Figure 6. Hydrological feature distribution by physiographic region.

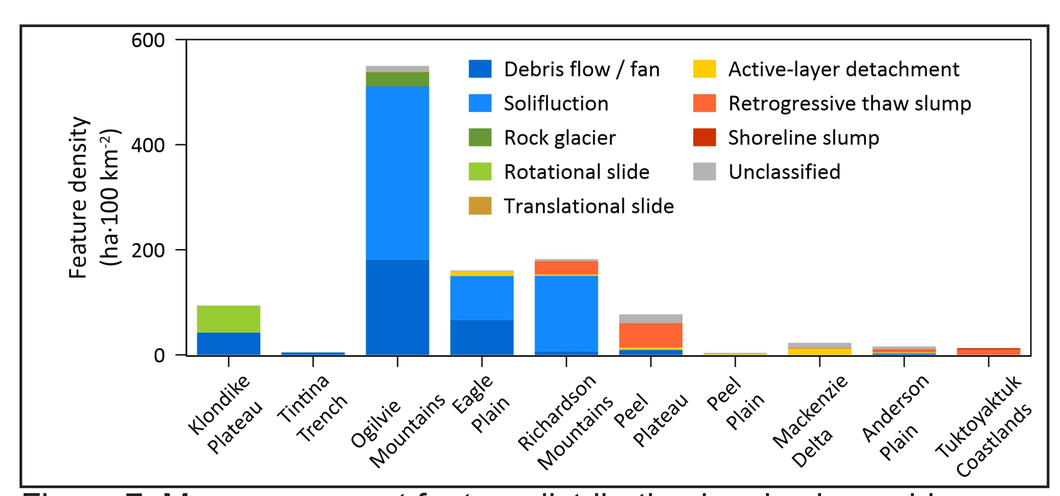

Figure 7. Mass movement feature distribution by physiographic region.

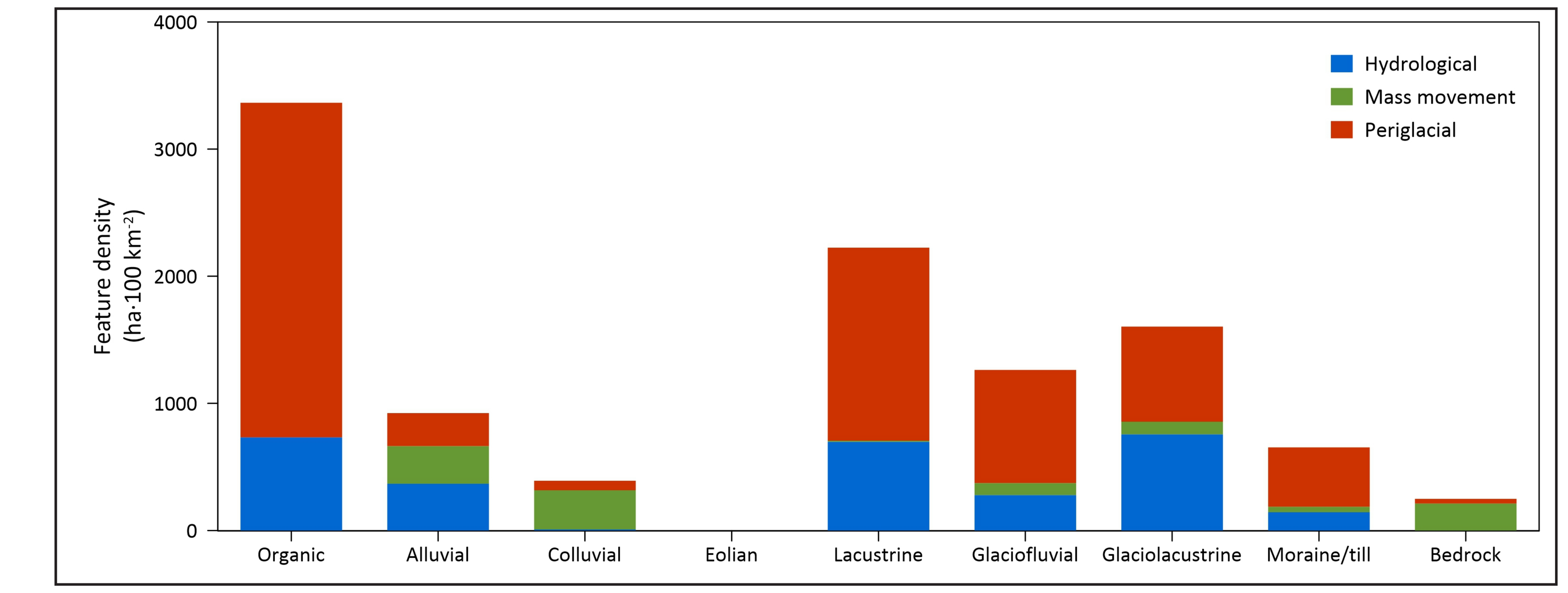

Figure 8. Feature class distribution according to dominant surficial geology unit.

RESULTS

A total of 8793 landforms were mapped within the 8411 km^2 highway corridor, including 5150 mass movement features, 2441 periglacial features, and 1202 hydrological features (Fig. 3). The average density of features is 692 ha·100 km^{-2} for the corridor, but this varies from 17 ha·100 km^{-2} in the Tintina Trench to 1530 ha·100 km^{-2} in the Tuktoyaktuk Coastlands (Fig. 4). Periglacial and hydrological features are concentrated in the northernmost 40% of the corridor, whereas slope and mass wasting features dominate the southern 60% of the corridor, where the physiographic regions have high relative relief. These densities may vary slightly if waterbodies are taken into consideration.

Ice-wedge polygons are the most common periglacial feature throughout the entire corridor, but peat plateau complexes dominate in the Peel Plain, Mackenzie Delta, and Anderson Plain (Fig. 5). Waterbodies affected by thermokarst, the most widespread hydrological feature, are found mainly in the Peel Plain, Mackenzie Delta, and Tuktoyaktuk Coastlands (Fig. 6). Flow-type mass movements, in particular debris flows and solifluction, are the most common mass movement landforms, which are overall most common in the Ogilvie Mountains (Fig. 7). Retrogressive thaw slumps are the dominant mass movement feature on the Peel Plateau.

By an order of magnitude relative to other surficial geology units, the majority of periglacial and hydrological features occur in organic, lacustrine, glaciolacustrine, and glaciofluvial deposits (Fig. 8). Conversely, mass wasting is mostly confined to alluvial and colluvial deposits as well as bedrock, where solifluction dominates in the weathered rock veneer.

DISCUSSION

This dataset provides the basis for establishing relationships between geomorphic landforms and landscape characteristics. The distribution of periglacial and hydrological features indicates the comparatively high extent of ground ice and permafrost thaw sensitivity in the northern regions of the DH-ITH. The high density of lakes affected by thermokarst suggests a high magnitude of contemporary thaw activity, which is expected to continue under a warming climate. The concentration of these features in organic, fine-grained, and glacially-derived sediments highlights the presence of ground ice and thaw-sensitivity of these deposits.

Such permafrost geomorphic feature inventories provide the basis for developing spatial models of landscape-thaw susceptibility, which can inform risk assessment and improve decision making regarding public safety and environmental management (Rudy et al., 2019). The methodology can easily be applied to other areas, such as communities or road corridors, in order to assess ground ice conditions, which is especially useful where sedimentological and cryostratigraphic information is sparse (Morse et al., 2021).

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