Surficial geology of central Hall Peninsula, Baffin Island, Nunavut: summary of the 2013 field season

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This work was part of the 2012–2014 Hall Peninsula Integrated Geoscience Program (HPIGP), led by the Canada-Nunavut Geoscience Office (CNGO) in collaboration with the Government of Nunavut, Aboriginal Affairs and Northern Development Canada, and the Geological Survey of Canada. It involved strong contributions from the universities of Alberta, Dalhousie, Laval, Manitoba, Ottawa and Saskatchewan, and the Nunavut Arctic College. It has benefited from support by local and Inuit-owned businesses and the Polar Continental Shelf Program. The focus is on bedrock (1:250 000 scale) and surficial (1:100 000 scale) geology mapping. In addition, a range of thematic studies is being conducted that includes Archean and Paleoproterozoic tectonics, geochronology, landscape uplift and exhumation, microdiamonds, sedimentary-rock xenoliths and permafrost. The goal is to increase the level of geological knowledge and better evaluate the natural-resource potential in this frontier area.

Abstract

This study is part of the Canada-Nunavut Geoscience Office’s Hall Peninsula Integrated Geoscience Program, a multiyear bedrock and surficial geology mapping program. This paper presents the surficial geology component of the program conducted during the 2013 field season, completing a two-year program covering NTS map areas 25I, J, O, P, 26A and B at a scale of 1:100 000. A 1:50 000 scale segment of the surficial geology map for the peninsula, containing all key material types, is presented in this paper. Till and glaciofluvial sediment samples were collected to help understand regional mineral potential. Till geochemistry and heavy mineral results from summer 2012 are briefly presented, the full dataset is available in a separate publication. Glaciodynamic indicators were mapped to provide a regional understanding of ice-flow history on Hall Peninsula. Cold-based (limited glacial erosion, regolith material is present), intermediate cold-based (weak to moderate glacial erosion, a mix of till and regolith is dominant) and warm-based zones (moderate to strong glacial erosion, till and bedrock outcrops are abundant) are the principal glaciodynamic zones mapped. Along the coast, areas with linear selective erosion were also mapped, where fiords and U-shaped valleys are common features.

Résumé

La présente étude s’inscrit dans le cadre du Projet géoscientifique intégré de la péninsule Hall, un programme pluriannuel dirigé par le Bureau géoscientifique Canada-Nunavut mettant l’accent sur la cartographie du substratum rocheux et de la géologie de surface. Ce rapport fait état des aspects de ce projet liés à la géologie de surface réalisés au cours de la saison de terrain 2013, clôturant ainsi ce programme de deux ans dont l’objet était de porter sur les feuilles de carte 25I, J, O, P, 26A et B du SNRC la géologie de la région à l’échelle de 1/1 000 000. Sui la description d’une section de la carte de la géologie de surface de la péninsule dressée à l’échelle de 1/50 000, et des principaux types de matériaux qui s’y trouvent. Des échantillons de till et de sédiments fluvioglaciaires ont été recueillis en vue de fournir des renseignements susceptibles d’aider à mieux cerner le potentiel minéral de la région. Les résultats provenant de l’analyse géochimique du till et des minéraux lourds effectuée en 2012 font l’objet d’une brève description et l’ensemble de données complet fait partie d’une publication connexe. La carte de la répartition des indicateurs de l’activité glaciodynamique a été dressée afin de reconstituer l’histoire de l’écoulement glaciaire à l’échelle régionale dans la péninsule Hall. Les principales zones glaciodynamiques cartographiées sont les zones à base froide (peu d’érosion, présence de matériaux issus du régolithe), à base froide intermédiaires (degré d’érosion glaciaire faible à modéré, prédominance d’un mélange de till et de régolithe) et à base tempérée (degré d’érosion modéré à élevé, nombreux affleurements de till et de substratum rocheux). Le long des côtes, aux endroits où les fjords et les vallées en auge sont des formes de relief très répandues, les zones touchées par l’érosion sélective linéaire ont également été portées sur la carte.

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the Canada-Nunavut Geoscience Office website: http://cngo.ca/summary-of-activities/2013/.
Introduction

Reconnaissance fieldwork began in the summer of 2011 followed by two full field seasons undertaken in the summers of 2012 and 2013 (Figure 1; Tremblay et al., 2013; Leblanc-Dumas et al., 2013). The objective of this work is to produce framework surficial geology maps at a scale of 1:100 000 for Hall Peninsula (NTS 25I, J, O, P, 26A, B). Permafrost studies (LeBlanc et al., 2013; Leblanc-Dumas et al., 2013) are also part of the surficial research program. The surficial geology program encompasses a range of components that include surficial geology mapping; surficial materials characterization; ice-flow indicators; chronology and dynamics; traditional place names; and permafrost studies.

The project was conducted in a region where no surficial maps existed, except at a national scale (Fulton, 1995). Glacial geomorphology on southern Baffin Island has been the subject of much research (Andrews and Sim, 1964; Matthews, 1967; Miller, 1980; Dyke et al., 1982; Andrews et al., 1985; Stravers et al., 1992; Kaplan and Miller, 2003; Hodgson, 2005; Fréchette et al., 2006; Utting et al., 2007; Briner et al., 2009; Clements et al., 2009; Johnson et al., 2013). However, previous research did not completely address the diversity of polythermal glacial bed conditions and juxtaposition of alpine and ice-sheet glaciodynamics, which imparted the Quaternary geology observed on Hall Peninsula.

Surficial geology mapping

Surficial geology mapping at the scale of 1:100 000 was conducted across Hall Peninsula with helicopter support and foot traverses. Field observations, including landforms, surficial cover composition and ice-flow indicators, were compiled using the GanFeld application (Shimamura et al., 2008) developed by the Geological Survey of Canada (GSC). The office-based mapping procedure included an all-digital approach combining a mosaic of airphotos in an on-screen stereoscopic view, using Summit Evolution software (DAT/EM Systems International, 2012) and ArcGIS (Esri, 2012). Mapping was completed using the new GSC surficial geology integrated legend (Deblonde et al., 2012). Landsat, RapidEye, SPOT and WorldView-2 satellite imagery and a DEM (Gilbert, 2012) from CanVec 1:50 000 data (Natural Resources Canada, 2012; Figure 1) were also used in the mapping process. The area covered in 2013 was approximately 17 000 km², in addition to about 21 000 km² mapped in 2012. A preliminary and simplified version of the surficial geology from a portion of this area (covering 2100 km²), which contains all of the key material types, is presented on Figure 2. Surficial material composition includes bedrock, mainly Precambrian granitic rocks and gneiss (Steenkamp and St-Onge, 2014), preglacial (?) weathered material (felsenmeer and regolith), till, glacio-fluvial sediments, glaciolacustrine and marine sediments, colluvium, alluvium and coastal deposits.

In the central part of Hall Peninsula plateau, weathered bedrock material (regolith) is mapped as Wv (<1 m thick) or W (<3 m thick; Figure 3a). The material is a residual of in situ chemical alteration of the bedrock identified as a garnet granite and paragneiss, which probably occurred during the preglacial and interglacial periods. The occurrence of deeply weathered material is mapped with the stippled overlay pattern. The region of deeply weathered material is surrounded by a transition zone where the diamictic surficial material is composed of a mixture of regolith (often iron-stained an orange colour) and glacial sediment, mapped as Tb_Wv (>1 m thick) and Tv_Wv (<1 m thick). The consistent lithology of the material and the locally sharp lithological transitions of the sediment suggests that this material was not glacially transported, but the presence of rare erratics overlying the regolith indicates that the region was covered by glacial ice.

The glacial sediment (Tv, Tb) is a diamict composed of sand, silt and pebbles of different lithologies. This material is associated with late glacial readvances of the Laurentide Ice Sheet. A moraine till (Tm), forming parallel, pronounced crests >100 m high, exists in the study area and is part of the Frobisher moraine complex (Miller, 1980). Hummocky till (Th) is associated with the ice-retreat moraine complex, such as the Hall and Frobisher moraines. Numerous kettles are found on the moraines, indicating the former presence of buried ice. Figure 1 illustrates the location of the known moraines in the area.

The moraine ridges and sediments are directly in contact with proglacial lacustrine and deltaic sediments (GLb, GLv and GLd; Figure 3b). Glaciolacustrine veneer (GLv) represents a thin and discontinuous deposit of fine, well-sorted glacial sediments, and the glaciolacustrine blanket (GLb) represents a thicker (1 m) continuous deposit. These sediments are composed of fine sand, silt and rare pebbles and were deposited during a period of postglacial flooding. Beach crests and terrace scarps are also found, forming small deposits, often too small to map individually. The glaciolacustrine deltas (GLd) are sometimes 25 m high, and are composed of stratified and sorted sand and silt with few pebbles. This unit was deposited by glacial meltwater in proglacial lakes during ice retreat. The dip direction of the foreset beds indicates that meltwater was draining toward the south and southeast. Accumulations of hummocky glaciofluvial sediments (GFh, Figure 3c, d), are generally composed of well-sorted to poorly sorted sand and gravel, which are found near the moraines and the glaciolacustrine sediments. Finally, recent accumulations of river alluvium (blankets as Ab and veneers as Av) are found within river valleys. The river alluvium is stratified and composed of sorted sand, silt and pebbles.
Figure 1: Location map displaying sample locations, principal moraines and carbonate till limit, Hall Peninsula, Baffin Island, Nunavut. Digital elevation model (Gilbert, 2012) derived from CanVec 1:50,000 data (Natural Resources Canada, 2012). The 2013 study area is outlined in blue, the 2012 study area is outlined in grey and the area of the 1:50,000 surficial map segment is outlined in black.
Figure 2: Preliminary map of the surficial geology and geomorphology of central Hall Peninsula, Nunavut.
Surficial geochemistry

A till sampling program was also completed as part of surficial mapping on Hall Peninsula (Figure 1). In 2013, 109 till (or regolith) samples (2 kg each) were collected from the central part of Hall Peninsula with a spacing of 5–20 km between samples. A total of 115 heavy mineral samples (~10 kg bags) were collected to provide information on the potential for kimberlites, massive sulphides, gold, gemstones and other commodities. Ninety-three heavy mineral samples were collected from till and 22 heavy mineral samples were collected from glaciofluvial sediments. These sediments will be analyzed for geochemistry of the <63 µm fraction, heavy mineral content, grain size, carbonate content and mineralogy (X-ray diffraction). Seven mineralized boulders containing sulphides were also sampled. These datasets will be released in future reports.

From the 2012 survey, a total of 144 till matrix geochemistry samples (2 kg) were processed at the GSC Sedimentology Laboratory (Ottawa, Ontario; Tremblay and Leblanc-Dumas, 2014). A portion of the matrix (<2 mm) of each sample was wet-sieved to 63 µm for geochemical analysis. Another <2 mm portion was sent for grain-size analysis and carbonate content analysis. Lastly, a portion was saved for archival purposes. A split of each 2 kg sample was dried and sieved at the GSC Sedimentology Laboratory and then submitted to Acme Analytical Laboratories Ltd. (Vancouver, British Columbia) for analysis of the <0.063 mm fraction (till matrix). A 30 g split was digested by aqua regia and analyzed by inductively coupled plasma–mass spectrometry (ICP-MS) for 72 elements, including gold, base metals, platinum and rare-earth elements. Another 2 g split was digested with lithium metaborate/lithium tetraborate fusion and then analyzed by inductively coupled plasma–emission spectrometry (ICP-ES) for 11 major elements. Analytical accuracy and precision was monitored by including GSC blind CANMET standards in the analytical analysis. Preparation laboratory duplicates of samples, Acme Analytical Laboratories Ltd. blanks, reference standards and analytical duplicates were also analyzed.

A total of 87 bulk samples (~10 kg) collected in 2012 were sent to Overburden Drilling Management Limited (Nepean, Ontario; Tremblay and Leblanc-Dumas, 2014) for heavy mineral analysis (cf. McClenaghan et al., 2012). The standard pre-analysis treatment was applied to all samples, which first included sieving of pebbles (>2 mm; the 4–8 mm fraction were separated for lithological counting) and preconcentration of heavy minerals by shaking table. Field sample duplicates and GSC blanks from granite grus and other information sources used to compile this paper, is available online to download free of charge at http://cngo.ca/summary-of-activities/2013/.
till were inserted for quality control and quality assurance (Plouffe et al., in press). The gold grains from a panning concentrate were counted, described and replaced in the same fraction. The heavy mineral preconcentrate was then submitted for heavy liquid separation (methylene iodide, specific gravity=3.2) and ferromagnetic separation. The >0.25 mm fraction of nonferromagnetic heavy mineral concentrate (NFHMC) was examined by binocular microscope for the identification of various distinctive mineral species, namely, kimberlite-indicator minerals (KIMs) and metamorphic massive-sulphide–indicator minerals (MMSIMs), which notably include gahnite, red rutile, pyrite, chalcopyrite and arsenopyrite (Averill, 2001). The mineralogical picking was performed on three different size fractions (0.25–0.5 mm, 0.5–1 mm, 1–2 mm) of NFHMC. Following further preparation, binocular identifications of MMSIMs and KIMs were undertaken and supported in some cases by scanning electron microscope (SEM) analysis.

Preliminary results for gold (and gold grains) and platinum (and grains of sperrylite, a platinum-bearing mineral) are illustrated on Figure 4. Anomalies of up to 118 grains for gold (per 10 kg of table feed) and 41 ppb gold in the till <63 µm fraction occur in the 2012 study area. Platinum anomalies of up to 3.5 grains for sperrylite (per 10 kg of table feed) and 8 ppb platinum in the till <63 µm fraction also occur in the 2012 samples. In addition, two sapphire grains were found in the till heavy mineral fraction.

**Ice-flow indicators and chronology**

Preliminary ice-flow directions and chronology were established using striations, glacial landforms (macroforms, including ice-moulded bedrock forms and subglacial lineations observed on satellite images) and glacial sedimentology (Figure 5). Different phases of ice flow were recognized in the field by crosscutting relationships between striations and ice-retreat geochronology. Interpretation of this ice-flow history is in part based on previous work (Miller, 1980; Dyke and Prest, 1987; Stravers et al., 1992; Dyke et al., 2003; Johnson et al., 2013). The relative ice-flow chronology is based on the estimated time from the beginning of each phase and not the entire duration of the events, therefore chronological overlap is possible between phases.

**Phase 1 ice flow**

Last glacial maximum(?), main recorded ice-flow direction

This important ice-flow phase radiated from an ice divide located across the cold-based zone on the central plateau on Hall Peninsula (Figure 5). It is inferred that this phase occurred during the last glacial maximum (LGM). During that phase, Hall Peninsula was covered by ice, as were significant portions of the mountainous area of Baffin Island.

Figure 4: a) Distribution of gold (in ppb) and gold grains in till heavy mineral fraction (normalized to 10 kg table feed); b) Distribution of platinum (in ppb) and sperrylite (platinum-bearing mineral) grains in till heavy mineral fraction (normalized to 10 kg table feed). Till samples from central Hall Peninsula, Nunavut.
Figure 5: Preliminary ice flow and glaciodynamic setting in central Hall Peninsula, Nunavut. Digital elevation model (Gilbert, 2012) derived from CanVec 1:50 000 data (Natural Resources Canada, 2012). Abbreviations: CB, cold-based area; IB, intermediate cold-based area; WB/L, mix of warm-based and linear selective glacial erosion areas; L, linear selective glacial erosion area; WB, warm-based area; LGM, late glacial maximum.
(Marsella et al., 2000; Staiger et al., 2006). The ice was stagnant (cold-based) under the ice divide area, and became progressively more active toward Cumberland Sound. The ice flowed uniformly toward the northeast in the northern part of study area, whereas in the south, flow was more channelized in the valleys between highlands on the plateau and the outer rim of islands. Cold-based conditions protected the highlands as ‘sticky spots’ from glacial erosion, at least during the last glaciation. The northern portion of the highlands on the plateau bears striations, roches moutonnées and other marks of glacial erosion (Johnson et al., 2013), and this is not observed farther south on the highlands.

Last glacial maximum(?), ice stream in Cumberland Sound

High velocity zones of glacial flow, or ice streams, moved southeast along the main axis of Cumberland Sound (Dyke and Prest, 1987; De Angelis and Kleman, 2007; Johnson et al., 2013), to drain into Baffin Bay or into an ice shelf in Cumberland Sound (Jennings, 1993). The ice on the northeastern side of Hall Peninsula drained toward the Cumberland Sound ice stream, which likely caused considerable ice surface drawdown along the coast and toward the south.

Phase 2 ice flow

Late glacial, channelized ice flow in U-shaped valleys

It is inferred that this ice flow phase occurred from the late glacial period to the late Holocene and developed as a result of ice sheet thinning in the area, which made the subglacial topography increasingly important in controlling ice-flow direction. It is characterized by convergent patterns of ice flow into long U-shaped valleys located between highlands. As the ice thinned, presumably the conditions became cold-based adjacent to the U-shaped valleys, especially toward the coast into fiords (Johnson et al., 2013). Cirques commonly occurred adjacent to the major U-shaped valleys. Although it is possible that glacial advance and retreat occurred from the late glacial period to the present, the majority of ice flow was probably during the Holocene. Recently deglaciated, neoglacials tills and moraines are found at the margins of several modern glaciers.

On the plateau, phase 2 ice flow is marked by distinct inflexions of ice flows converging toward the main late-glacial valleys, especially toward Ptarmigan Fiord in the north (Johnson et al., 2013). Phase 2 ice flow is chronologically constrained by several later, crosscutting striae, relative to phase 1 ice flow.

Phase 3 ice flow

The three distinct events compiled under phase 3 ice flow share commonalities. They were all south- to southeast-trending flows, and left blankets of till on the plateau. These tills were often deposited over cold-based terrain, at least marginally, where a nonerosive thin lobate margin advanced partly over a landscape characterized by non-glacial features.

Deglacial, unnamed glacial readvance

This readvance represents localized southward ice flow related to a minor standstill of the ice-sheet margin or smaller alpine glaciers and is best characterized by nested recessional moraines. Ice was at least slightly sliding on its base. This warm-based ice transported sediment, deposited a blanket of till and constructed a subdued moraine made of hummocky, slightly thicker till. Evidence of glacial scouring and polish is found on outcrops throughout the landscape (e.g., lakes, bare outcrops and frequent fine striations on uppermost exposed bedrock surfaces).

Deglacial, Hall moraine readvance

The Hall moraine ice (Miller, 1980) was a local event that crosscut regolith and presumably former glacial and glaciolacustrine sediments, and deposited a blanket of till and scoured and exposed bedrock outcrops. This ice generally flowed toward the southeast. South of the large lake at the head of McKeand River some of this exceptionally fine, boulder-poor, thick and drumlinized till blanket may consist of re-entrained former glacial lake sediments. The Hall moraine itself consists of a 5 km wide swath of hummocky till, and occasionally hummocky ice-contact glaciolfluvial sediments. Glacial lake sediments, littoral features (beaches and trim lines) and meltwater channels adjacent to the Hall moraine (Miller, 1985) provide evidence of a glacial stillstand. A few glacial lakes were dammed by the ice in some small valleys adjacent to this ice position (Miller, 1985).

Deglacial, Frobisher Bay moraine readvance

The Frobisher Bay moraine (dated to 9–8 ka14C BP; Blake, 1966; Miller, 1980; Hodgson, 2005) is a major regional feature consisting of several tracts of large push moraines, smaller recessional moraines, hummocky till and glacio-fluvial ice-contact deposits, left by southeast-trending ice flow. It extends hundreds of kilometres to the south across Frobisher Bay onto Meta Incognita Peninsula, and to the north it seems to vanish a few tens of kilometres outside of the study area. On the Hall Peninsula plateau, this moraine contained several glacial lakes, marked by well-defined littoral features (beaches and trim lines), deltas and blankets of fine sediment (Figure 2). Behind the moraine, a thick blanket of till was deposited, sometimes streamlined or hummocky. Locally, the moraine crosscuts cold-based zones, and corresponds to a younger glacial re-advance episode.

Phase 4 ice flow

Modern ice cap flows

During the Holocene, the remaining ice cap located on the Hall Peninsula highlands flowed radially. It flowed west to-
ward the Hall Peninsula plateau, where it marked an ice flow reversal compared to phase 2 ice flow. On this western, land-based part of the local paleo-ice cap, the basal glaciodynamics were probably quite reduced due to cold-based conditions and relatively flat terrain. It is therefore rare to observe well-defined striae; but occasionally rockes moutonnées, grooves, displaced boulders and erratics indicate ice flow reversal toward the west. Hummocky moraines consisting of bouldery till may also have been left by the west-flowing mountain glaciers. This late ice cap also flowed east toward Cumberland Sound, where it is parallel and therefore amalgamated to phase 2 ice flow.

Glaciodynamic zones

Building on work undertaken earlier on Hall Peninsula (Sugden, 1978; Hodder, 2012; Johnson et al., 2013; Tremblay et al., 2013), the mapping of glaciodynamic zones is based on an interpretation of the geomorphology, glacial erosion and glacial sediment in the area (Figure 5). It may help resolve enigmatic ice-flow histories at local scales, and provide first-order estimates of glacial sediment transport distances, which are useful to discover buried mineral deposits.

The geomorphological indicators of glacial erosion are summarized as a broad classification of terrain types. The observations are primarily based on field observations and interpretation of digital elevation models, satellite imagery and airphotos. The presence of numerous small lakes, glacially eroded bare outcrops and streamlined hills are interpreted to represent erosive conditions (warm-based ice), whereas the persistence of a mix of thick nonglacial regolith, felsenmeer and till suggest cover by predominantly weakly erosive (cold-based) ice (Sugden, 1978; Miller, 1980; Dyke, 1993; Dredge, 2000; Tremblay et al., 2011; Hodder, 2012). The dynamic character of the former ice sheet (cold- versus warm-based) can thus be inferred from this classification, and can therefore help understand and outline the nature of glacial transport. The mapping includes theoretical and methodological elements from the central Canadian Arctic (Dyke, 1993), Melville Peninsula (Dredge, 2000; Tremblay et al., 2011; Tremblay and Paulen, 2012) and from Baffin Island (Miller, 1980; Andrews et al., 1985; Marsella et al., 2000; Staiger et al., 2006; Johnson et al., 2013). Hodder (2012) established criteria for a spatial assessment of subglacial dynamics on the Hall Peninsula plateau, and produced a map showing a glacial erosion index by using lake density, elevation and streamlined hill density with elongation ratios. The resulting maps illustrate important glacial erosion near the coast, and progressively less important glacial erosion toward the plateau. As a complement to Johnson et al.’s (2013) studies on northern Hall Peninsula, till geochemistry and cosmogenic isotopes on bedrock outcrops and tills will be used to assess the spatial distribution of glacial erosion during the late Quaternary on Hall Peninsula.

Cold-based area (CB)

Within this zone, the glacier was frozen on its base and little or no basal sliding occurred. On the Hall Peninsula plateau, this area coincides with the location of the main ice divide during the LGM (Figure 5). The landscape is not glacially scoured, as observed by the general absence of ice-scoured lakes and the rarity or absence of bedrock outcrops, and glacial sediments have been transported for short or negligible distances. Locally, a regolith is observed at surface, whereby the host rock was intensely chemically weathered to a thick, orange (iron-stained), clayey-sandy diamicton. Sharp lateral lithological boundaries are observed in the regolith content and correspond to underlying bedrock units, which eliminates a dominantly glacial origin for this material type (Leblanc-Dumas et al., 2013; Tremblay, 2013). Elsewhere in the cold-based zone, the ground cover is composed of in situ material that is reduced to fine material by the action of seasonal frost or chemical weathering (Figure 6a). Coverage by ice sheet during the Quaternary is indicated by abundant glaciofluvial channels and the presence of rare glacial erratics, some of those also intensively weathered (Miller, 1980).

Along the outer rim of islands on the Cumberland Sound coast, cold-based conditions occurred at least since the last interglacial, and allowed the preservation of flat surfaces covered with felsenmeer and displaying well-formed tors. The glacial erosion level was therefore much lower in elevation (200–400 m asl) than inland (600–700 m asl). The abrupt lowering of the paleoglacial profile toward the Cumberland Sound ice stream explains the preservation of these paleosurfaces on the outer rim of the islands.

Intermediate cold-based area (IB)

This glaciodynamic zone is transitional between cold- and warm-based terrains, and shares geomorphological and sedimentological characteristics of both. The cumulative effect of multiple glacial events (switching between cold- and warm-based conditions) has progressively affected the regolith terrains to expose more bedrock outcrops and deposit till (Figure 6b). The glacier was frozen at its base for long periods in this zone while warm-based erosion occasionally occurred with relatively restrained intensity. Scouring of the landscape gradually increases from the cold-based area toward warm-based zones and ice-scoured lakes and fresh bedrock outcrops are increasingly common. Within the intermediate cold-based area, field evidence shows that glacial sediments were transported for short to moderate distances (cf. Tremblay and Paulen, 2012). Some areas around the highest existing glaciers are considered to have been cold-based during the last glaciation, as no striae or glacial polish were found, and moderate chemical weathering occurs. However, outcrops are frequent indicating ear-
lier glacial erosion, therefore they have been classified as intermediate cold-based zones.

**Mix of warm-based and linear selective glacial erosion areas (WB/L)**

In this zone, glacial thermal patterns were mixed, with extensive warm-based areas (and sparse intermediate cold-based areas) on plateaus, and linear glacial erosion in U-shaped valleys or fiords (Sugden, 1978; Johnson et al., 2013). Spatial and temporal variations in ice-flow velocity are implied by this complex glaciodynamic pattern, with ice flow in the U-shaped valleys being generally younger than the warm-based ice flow on the plateau.

**Linear selective glacial erosion (L)**

This is a landscape zone affected by patchy warm-based conditions in the numerous glacial valleys, juxtaposed with cold-based and intermediate cold-based zones on the plateaus and mountain tops (Sugden and Watts, 1977), where no evidence of strong regional glacial erosion is observed. The result was the generation of accentuated relief, caused by the deepening of glacial erosion and the preservation of adjacent summit felsenmeer, where ice was kept relatively thin by dynamic and efficient drainage through the glacial valleys.

**Warm-based area (WB)**

This geomorphological landscape type reflects important glacial activity related to warm-based basal ice conditions, where ice melted at the base of the glacier, and sliding and deformation occurred at the bed. As observed in Figure 6c, glacial scouring is significant, as seen by the numerous lakes, polished or striated outcrops, and streamlined depositional or erosional landforms. Glacial transport distances are generally relatively long and glacial sediment thickness is variable.

**Economic considerations**

The surficial maps and geomorphological studies (glaciodynamic mapping, permafrost, satellite images and uplift history) will help to minimize risk associated with mineral exploration and optimize the design of infrastructure projects on Hall Peninsula. The surficial maps will also...
help identify new sources of granular material, useful for road building and general construction. Zones of silty glaciolacustrine sediments have been mapped, which may contain ice lenses and represent challenges for infrastructure development. Till geochemical and mineralogical data will contribute to more efficient mineral exploration and assessment of environmental and geotechnical characteristics of soil. Gold and platinum mineral potential is present in the study area, and other elements might also be of interest for mineral exploration. Two sapphire grains were also found in the till heavy mineral fraction. Data from the 2012 field season can be downloaded online (Tremblay and Leblanc-Dumas, 2014), and all results will be analyzed and interpreted in future publications.

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