Surficial geology of southern Hall Peninsula, Baffin Island, Nunavut: summary of the 2012 field season

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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 with associated thematic studies. This summary presents the surficial geology component of the program conducted during the 2012 field season, along with a summary of future work and a preliminary overview of the Quaternary geology of the area. The emphasis of this study is placed on 1:100 000 surficial geology mapping (NTS 025I, J, O, P, 026A, B), till sampling, glaciodynamic setting and ice-flow history of the area. A traditional place names geological study will aim at describing how the geological landscape is linked with Inuit traditional activities and landmarks.

Résumé

Cette étude fait partie du Programme géoscientifique intégré de la péninsule Hall, du Bureau géoscientifique Canada-Nunavut, un programme pluriannuel de cartographie du substratum rocheux et de la géologie de surface accompagnée d’études thématiques connexes. Le présent article décrit la composante « géologie de surface » du programme mené au cours de la campagne d’exploration de 2012, et résume les travaux futurs qui doivent avoir lieu, tout en présentant un aperçu préliminaire de la géologie du Quaternaire de la région. Cette étude met l’accent sur la cartographie de la géologie de surface à l’échelle de 1/100 000 (SNRC 025I, J, O, P, 026A, B), l’échantillonnage de till, le contexte glacio-dynamique et l’historique des écoulements glaciaires de la région. Une étude géologique des toponymes traditionnels cherchera à décrire la manière dont le paysage géologique est lié aux activités et aux repères traditionnels des Inuits.

Introduction

The Hall Peninsula Integrated Geoscience Program (HPIGP) is being led by the Canada-Nunavut Geoscience Office in collaboration with the Government of Nunavut, Aboriginal Affairs and Northern Development Canada, Dalhousie University, University of Alberta, Université Laval, University of Manitoba, University of Ottawa, University of Saskatchewan, Nunavut Arctic College and the Geological Survey of Canada. It is supported logistically by several local, Inuit-owned businesses. The study area comprises all or parts of six 1:250 000 scale National Topographic System map areas north and east of Iqaluit (NTS 026A, B, 025I, J, O, P; Figure 1).

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/.
Figure 1: Location map displaying till 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).
In the summer of 2012, fieldwork was conducted in the southern half of the peninsula (NTS 025 I, J, O, P) between June 22 and August 8. Fieldwork was supported by a 20–25 person camp located approximately 130 km southeast of Iqaluit. The focus was on bedrock mapping at a scale of 1:250 000 and surficial-sediment mapping at a scale of 1:100 000. A range of thematic studies was also supported. This included Archean and Paleoproterozoic tectonics, geochronology, landscape uplift and exhumation, detailed mapping in mineralized areas, microdiamonds, sedimentary rock xenoliths and permafrost. Summaries and preliminary observations for all of these studies can be found in this volume.

Mineral exploration, geotechnical and aggregate resources studies require accurate surficial geology maps and glaciodynamic interpretations. 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., in press). However, there are currently no surficial geology maps for Hall Peninsula, except national-scale compilations (1:5 000 000 scale map). Ice-flow models for Hall Peninsula at a resolution suitable for drift exploration cannot be developed because publicly available databases are inadequate or non-existent. Thus, due to limited previous research, a mixture of polythermal glacial bed conditions, and juxtaposition of extant. Thus, due to limited previous research, a mixture of polythermal glacial bed conditions, and juxtaposition of

This surficial geology mapping component of the HPIGP encompasses surficial materials characterization, ice-flow indicators, chronology and dynamics, permafrost studies, remote sensing as an aid to surficial mapping and traditional place name research. Fieldwork began in the summer of 2011 (preliminary overview of the study area), was continued in 2012 (Figure 2) and will end in 2013.

Preliminary surficial geology results

Surficial geology mapping

Surficial geology mapping at the scale of 1:100 000 commenced during the summer of 2012 with helicopter and foot traverses. Field observations, including landforms, surficial cover composition and ice-flow indicators, were compiled with ArcGIS (Esri, 2012) using the GSC-developed GanFeld application. 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. An extensive set of field photographs were geolocated using GPS, thus optimizing their desktop mapping usefulness. Mapping features were captured according to the new GSC surficial geology integrated legend. 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 2012 was approximately 21 000 km² and about 17 000 km² are expected to be mapped in 2013.

Surficial cover composition includes bedrock (mainly Precambrian granitoid rocks and gneiss), regolith, till, glacio-fluvial sediments, glaciolacustrine and marine sediments, colluvial, alluvial and coastal deposits, and hydrological elements include streams, lakes and glaciers. Figure 1 depicts the location of the principal moraines currently mapped and the extent of carbonate till transported from Frobisher Bay towards the north (compiled from field data and Stravers et al., 1992). To improve the deglacial chronology, support the ice-flow history interpretations and establish limits on Quaternary erosion history, targeted and opportunistic samples are being collected for radiocarbon dating, optically stimulated luminescence (OSL) dating and cosmogenic nuclide dating.

Surficial material characterization (geochemistry, sedimentology, mineralogy)

A regional coverage of glacial sediments is a major component of surficial studies on Hall Peninsula. So far, 136 geochemistry samples (2 kg each; an additional 14 were sampled in 2011) have been collected from the southern half of Hall Peninsula and selected locations in the northern half, with an average spacing of 10–20 km between samples (Figure 1). The spacing is about 5–10 km in areas of elevated mineral potential (i.e., close to known deposits and volcano-sedimentary belts) and up to 20–30 km in remote islands to the northeast, underlain by metatonical basement. Specific geotechnical studies conducted in the northern area required a higher density of geochemical samples, with a spacing around 5 km between samples. Ninety heavy mineral samples were taken (10 kg bags) to provide information on kimberlites, massive sulphides, gold, gems and many other commodities. Additionally, seven mineralized boulders containing sulphides and one soapstone boulder were sampled.

Ice-flow indicators and chronology

Ice-flow directions and chronology are being established using striations, glacial landforms, glacial sedimentology and multiple geochronological approaches (Figure 2). The occurrence of different phases of ice were observed in the field by crosscutting relationships between striations, stratigraphic relationships and ice-retreat geochronology. Interpretation of this ice-flow history is in part based on the work of previous workers (Miller, 1980; Dyke and Prest, 1987; Stravers et al., 1992; Dyke et al., 2003; Johnson et al.,
in press). The relative chronology of the ice-flow phases is based solely on the estimated time of the beginning of each phase and not the entire duration of the events, therefore chronological overlap is possible between phases.

**Ice flow 1**

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

This important ice-flow phase radiated from an ice divide located on Hall Peninsula, possible during the last glacial maximum (LGM). During that time, Hall Peninsula was probably entirely covered by ice, as was a major part of the mountainous area of Baffin Island (Marsella et al., 2000; Stuiger et al., 2006).

LGM(?), ice stream in Frobisher Bay and Cumberland Sound

Ice flows in these regions are important because they persisted for some time as high velocity zones of flows known as ice streams (Dyke and Morris, 1988), draining ice through major topographic axes in Frobisher Bay and Cumberland Sound. This ice flow may have influenced the velocity of adjacent ice.

LGM(?), radial ice flow, presumed only, no record from striation or macroforms

Sheetlike ice flow possibly occurred across the mountainous area, although no landform or glacial direction indicators in the study area directly support this theory, contrary
to the northern Hall Peninsula area (as described in Johnson et al. [in press]). Alternatively, during the LGM, ice flow might also have been topographically controlled to a certain extent, especially close to the Cumberland Sound ice stream.

**Ice flow 2**

Late glacial, ice flow in U-shaped valleys

This ice flow phase, comprising glacial advance and retreat, occurred from the late glacial period to the Late Holocene. It is characterized by convergent patterns of ice movements that drained ice from topographic highs, including the centre of the peninsula. Glacial erosion was apparently concentrated in topographic lows (deep U-shaped valleys are evident throughout the peninsula). Fjords are commonly located at the down-ice section of the ice flows (Johnson et al., in press).

Late glacial, affluent ice in smaller glacial valleys

This ice-flow episode is directly connected to the extant mountain glaciers. 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, neoglacial tills and moraines are found at the margins of several modern glaciers. Similar to ice flow in U-shaped valleys, this episode is characterized by convergent patterns of ice flow draining ice from the topographic highs to offshore, but these flows are located in smaller alpine valleys and cirques in Hall Peninsula.

**Ice flow 3**

Deglacial, Gold Cove readvance

This flow represents a limited, northward, carbonate-bearing glacial readvance at the southern tip of Hall Peninsula. This ice flow is thought to have been influenced by ice burst episodes of the Hudson Strait and Ungava Bay ice streams (Stravers et al., 1992). This ice-flow phase was probably short-lived and appears to have occurred after ice flow 1, during a part of the longer lasting ice flow 2 phase, which was affecting the rest of Hall Peninsula.

**Ice flow 4**

Deglacial, toward land-based margin

This phase represents localized ice flows related to a minor standstill of the ice sheet margin or smaller alpine glaciers. The flow is best depicted by nested recessional moraines. Ice was at least slightly sliding on its base. This warm-based ice transported sediment to construct the moraines, and evidence of glacial scouring and polish is found throughout the landscape (lakes, bare outcrop and frequent fine striations on uppermost exposed bedrock surfaces).

**Glaciodynamic zones**

The mapping of glaciodynamic zones represents an interpretation of the geomorphological and geochemical results indicating the probable amount of glacial erosion and glacial sediment transport in a particular region (Figure 2). It may help resolve enigmatic ice-flow histories at local scales, or explain unsuccessful attempts to use glacial sediment transport as a means to establish ore sources.

The geomorphological indicators of glacial erosion are summarized as a broad classification of terrain types. The observations are primarily based on numerous field observations and interpretation of DEMs, satellite imagery and airphotos. For instance, glacial scouring as evident from the presence of numerous small lakes and glacially eroded bare outcrops is interpreted to represent erosive conditions (warm-based ice), whereas the persistence of a mix of thick nonglacial regolith, felsenmeer and till would 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 to understand and outline the nature of glacial transport. The mapping includes 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; Johnson et al., in press). As a complement to Johnson et al.’s (in press) 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)**

In this zone, the glacier was frozen at its base and little or no sliding occurred on the glacier bed. This area coincides with the location of the main ice divide during the LGM. The landscape is not glacially scoured (Figure 3a; this is indicated by the general absence of ice-scoured lakes and the rarity of fresh bedrock outcrops) and glacial sediments have been transported for short or negligible distances, probably as englacial load (example on Melville Peninsula [Tremblay and Paulen, 2012]). Coverage by ice sheet during the Quaternary is indicated by abundant glaciofluvial channels and the presence of rare glacial erratics, some of them intensively weathered (Miller, 1980). A few cold-based alpine glaciers are included in this area, and little or no glacial scouring is observed around them.

**Intermediate-based area (IB)**

The glacier was frozen at its base for long periods in this zone, and occasionally warm-based erosion occurred, but with relatively restrained intensity (example on Melville Peninsula...
Scouring of the landscape is gradually more evident compared to the cold-based area (ice-scoured lakes are present and fresh bedrock outcrops are common). This zone is often in contact with the warm-based (WB) zones. Glacial sediments were transported for short to moderate distances.

Mix of intermediate-based and linear selective glacial erosion areas (IB/L)

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

Linear selective glacial erosion (L)

This is a landscape of patchy warm-based conditions in the numerous glacial valleys, juxtaposed with CB and IB zones on the plateaus and mountain tops (Sugden and Watts, 1977). The result is the generation of accentuated relief, caused by the deepening glacial erosion and the preservation of adjacent summit felsenmeer, where ice is kept relatively thin by the dynamic and efficient drainage through the glacial valleys. Small ice caps and valley glaciers are still present on some of the highest mountains, generally over 1000 m asl.

Warm-based area (WB)

This geomorphological landscape type reflects important glacial activity related to warm-based ice conditions, where ice is melting at the base of the glacier and sliding occurs at the bed. Glacial scouring is important and is observed by...
the presence of numerous lakes, polished or striated outcrops, and streamlined depositional or erosional landforms. Glacial transport distances are generally relatively long (example on Melville Peninsula [Tremblay and Paulen, 2012]) and glacial sediment thickness is variable.

**Traditional place names project**

Visits were made to assemble geological information about the sites with traditional place names on Hall Peninsula (Inuit Heritage Trust Inc., 2009). These names are the original place names used by the Inuit people and transmitted through oral tradition and recently mapped from interviews with elders that lived in the specific areas.

During summer 2012, several sites located along the Hall Peninsula southern coast were photographed from the helicopter (Figure 3b). The sites were selected when their descriptive place names related to geology or geomorphology, or involved a specific activity that was controlled by the local geomorphological setting. The photographic surveys were conducted by geologists, geomorphologists and co-author, P. Peyton. Information, co-ordinates and photographs related to the sites will be compiled into a format compatible with other Inuit Heritage Trust Inc. products (notably Google Earth™-based maps).

**Economic considerations**

The scientific results stemming from the surficial geology studies of CNGO’s HPIGP will contribute to helping Canadians make better decisions concerning the management of their natural resources. The surficial maps and geomorphological studies (glaciodynamic mapping, permafrost, satellite images and uplift history) will help to minimize risk associated with mineral exploration in glaciated terrain and optimize the design of infrastructure projects. Till geochemical and mineralogical data will contribute to more efficient mineral exploration and assessment of environmental and geotechnical characteristics of soil.

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