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Geological Survey of Canada

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2006-C1

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2006

CURRENT RESEARCH

Natural Resources Canada
Ressources naturelles Canada

Canada

ISSN 1701-4387
Catalogue No. M44-2006/C1E-PDF
ISBN 0-662-42919-2

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Publication approved by Canada–Nunavut Geoscience Office

Original manuscript submitted: 2005-12-14
Final version approved for publication: 2006-02-22

Correction date:

Ice-movement history, drift prospecting, and marine incursion in the Darby Lake and Arrowsmith River map areas, southern Boothia Peninsula, Nunavut.

C.A. Ozyer and S.R. Hicock

Ozyer, C.A. and Hicock, S.R., 2006: Ice-movement history, drift prospecting, and marine incursion in the Darby Lake and Arrowsmith River map areas, southern Boothia Peninsula, Nunavut; Geological Survey of Canada, Current Research 2006-C1, 9 p.

Abstract: study of ice-movement indicators in the Darby Lake (NTS 56 N) and Arrowsmith River (NTS 56-O/9–16) map areas revealed a complex ice-flow history involving four phases. The oldest phase was north-northeastward to northeastward, and likely reflects ice flow during the last glacial maximum. This was followed by divergent flow, where ice in the western 56 N map area flowed north-northwest, and ice in the central to eastern 56 N, and in 56-O (north) map areas, flowed north-northeast. The third phase involved a shift of Darby Lake and western Arrowsmith River ice-flow directions to north-northeast and to the northeast in eastern 56-O (north). The final phase was a late-stage advance into 56 N /1 and 2.

As part of a reconnaissance-scale drift-prospecting program, 92 till samples were collected and analyzed for heavy-mineral content, texture, carbonate content, pebble lithology, and trace/major elements. The study area was subjected to significant marine incursion, particularly in the major river valleys where marine sediments were found at elevations ranging between 92 m to 223 m a.s.l.

Résumé : L'étude des marques d'écoulement glaciaire dans les régions cartographiques du lac Darby (SNRC 56 N) et de la rivière Arrowsmith (SNRC 56 O/9 à O/16) a révélé une histoire complexe d'écoulement glaciaire comportant quatre phases. La phase la plus ancienne a été du nord-nord-est au nord-est et reflète vraisemblablement l'écoulement des glaces durant le dernier maximum glaciaire. Lui a succédé une phase d'écoulement divergent, pendant laquelle les glaces dans la partie occidentale de la région cartographique 56 N se sont déplacées vers le nord-nord-ouest et les glaces dans la partie centrale à orientale des régions cartographiques 56 N et 56 O (nord) se sont écoulées vers le nord-nord-est. Au cours de la troisième phase, les glaces dans la région du lac Darby et dans la partie ouest de la région de la rivière Arrowsmith se sont déplacées vers le nord-nord-est et le nord-est dans la partie orientale de la région cartographique 56 O (nord). La dernière phase a été une avancée tardive des glaces dans les régions cartographiques 56 N/1 et N/2.

Dans le cadre d'un programme de prospection à l'échelle de la reconnaissance, 92 échantillons de till ont été recueillis et analysés afin d'en doser les minéraux lourds et d'en étudier la texture, le contenu en carbonates, la lithologie des cailloux et les éléments traces et majeurs. La région à l'étude a été sujette à une importante transgression marine, notamment dans les principales vallées fluviatiles où des sédiments marins ont été retrouvés à des altitudes allant de 92 à 223 m au-dessus du niveau de la mer.

INTRODUCTION

During the 2004 field season Quaternary studies were carried out in southern Boothia Peninsula, approximately 250 km west-northwest of Repulse Bay (Fig.1). The study was conducted during the first year of the two-year Boothia Peninsula Integrated Geoscience project, a component of the Targeted Geoscience Initiative (TGI-2). This project involves collaboration between the Canada-Nunavut Geoscience Office (C-NGO), the Geological Survey of Canada (GSC), and several Canadian universities. It was designed to explore and evaluate mineral potential in the Darby Lake (56 N) and Arrowsmith River (56-O north) map areas. The objectives of the Quaternary component are to 1) interpret the glacial history at regional and local scales; and, 2) initiate a reconnaissance-scale drift-prospecting program incorporating magmatic/metamorphic massive sulphide indicator mineral (MMSIM), gold grains, texture, pebble lithology, carbonate content, and trace- and major-element geochemical analyses.

This paper presents preliminary interpretations of paleo–ice-movement indicators observed in the Darby Lake (NTS 56 N) and Arrowsmith River (NTS 56-O/9–16) map areas and summarizes the drift-prospecting program. Paleo–marine incursion with implications for drift prospecting in the area is also discussed. Results of till analyses and ice-flow data sets are presented in GSC Open File 5003.

REGIONAL SETTING

The study area is located on the northern periphery of the Wager plateau, within a zone of continuous permafrost (Burgess et al., 2001). Topography in the region is highly variable with elevations ranging from 40 m to 460m a.s.l. in 56 N, and 70 m to 460 m a.s.l. in 56-O (north). Regionally,

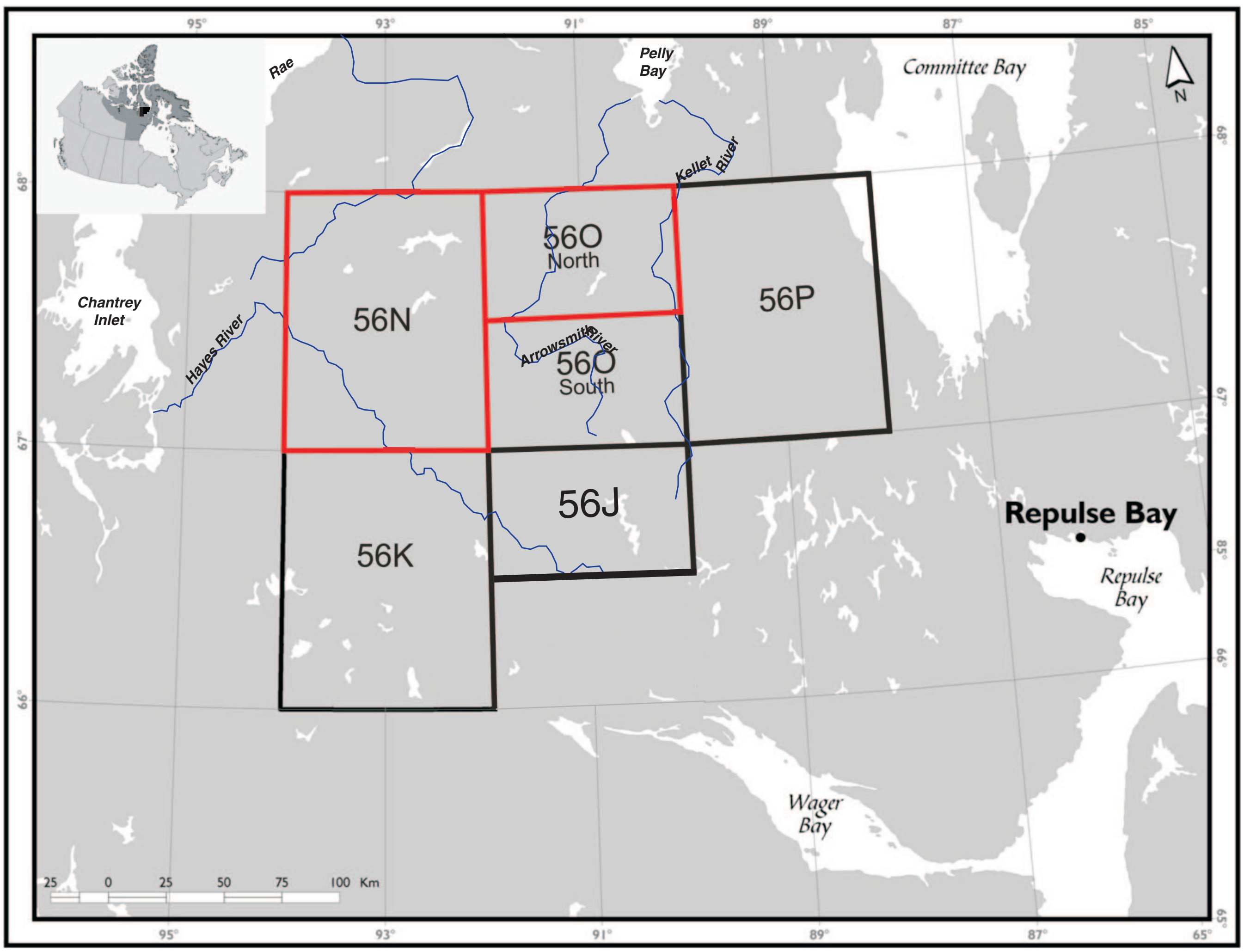

Figure 1. Location of study area in southern Boothia Peninsula, Nunavut (in red). Also shown is the location of the Committee Bay TGI-1 multidisciplinary project (in black).

there are four major drainage basins: the Hayes, Murchison, Arrowsmith, and Kellet rivers. The Hayes River flows northwestward into Chantrey Inlet; the Murchison River flows northeastward before it flows westward into Rae Strait; the Arrowsmith and Kellet rivers drain northward into Pelly Bay. Geomorphic features include considerable felsenmeer, bedrock outcrops, till veneers, and marine-related sediments.

BEDROCK GEOLOGY

The study area is underlain by three northeast-trending lithological subdomains (Fig. 2) comparable to those noted in the Committee Bay belt to the south and east (Sandeman et al., 2001; Skulski et al., 2002). The southern subdomain is correlative with the Prince Albert group subdomain of Skulski et al. (2002), and contains sparse supracrustal rocks of the Prince Albert group (PAg) along with cogenetic, as well as abundant younger, late Neoarchean plutonic units. The central subdomain corresponds to the northern migmatite subdomain of Skulski et al. (2002), but comprises more abundant biotite±garnet±magnetite granodiorite and less common high-grade paragneiss, diatexite, and metasedimentary rocks intruded by garnet-sillimanite-biotite and muscovite-biotite granite plutons. The northwestern subdomain is similar to the Prince Albert group subdomain and is underlain by voluminous biotite±hornblende±magnetite tonalite (with granodiorite and monzogranite) that contains numerous rafts and xenoliths of supracrustal metasedimentary and less common volcanic units. Rocks of the northwestern subdomain are structurally overlain by clastic and less common chemical metasedimentary rocks of the inferred Paleoproterozoic Chantrey Group (Frisch et al., 1985).

PREVIOUS WORK

Previous Quaternary studies were conducted in areas adjacent to this one during the Committee Bay Multidisciplinary Geoscience Project (Fig. 1), a three-year Geological Survey of Canada Targeted Geoscience Initiative (TGI) and a collaboration between the Canada-Nunavut Geoscience Office, the Geological Survey of Canada, and several Canadian universities. For a discussion of the Quaternary history, drift prospecting, and surficial maps of those areas, the reader is directed to Craig (1961a,b), Dyke (1984), Ferbey and Little (2003), Giangioppi et al. (2003), Little (2001, 2004), Little et al. (2002), Little and Ferbey (2003), McMartin et al. (2002, 2003a, b), Ozyer and Hicock (2002), Ozyer (2004), Thomas and Dyke (1982), Utting et al. (2002), and Utting (2004).

METHODS

Ice-flow indicators

Large- and small-scale ice-movement indicators from 150 sites have been recorded to determine the ice-movement history of the area. Large-scale indicators include roches moutonnées, flutes, and crag-and-tail forms. Small-scale bi-directional indicators include striae and grooves; unidirectional indicators include nailhead striae, chattermarks, crescentic gouges, and lunate/crescentic fractures. Crosscutting relations (where available), primarily from striae, were used to determine ice-movement phases. In some cases, crosscutting relations superimposed on large-scale landforms such as roches moutonnées, and the orientation of moraines in relation to large-scale features like flutes, further distinguished phases.

Drift Prospecting

A series of 3 kg and 10 kg till samples were collected from frost boils. Frost boils were chosen because they transport relatively homogeneous (McMartin and McClenaghan, 2001), unoxidized subsurface sediments to the surface (Shilts, 1977; McMartin et al., 2002). Furthermore, till was chosen as a sample medium because 1) it is abundant, and 2) it is a primary glacial deposit, therefore, easier to trace back to source (provenance).

Till sample characteristics recorded in the field include sample depth, texture, pebble morphology (e.g. angularity, size), and frost-boil classification (class I, II, or III). The surficial unit (e.g. till veneer, till blanket, etc., from which the sample was collected) was also recorded, as were digital photos of till samples showing described surficial unit in the background (Fig. 3).

ICE-MOVEMENT HISTORY

Phase I

The oldest phase identified was likely north-northeastward to northeastward (Fig. 4). Large-scale erosional landforms such as large roches moutonnées (Fig. 5) record this phase and were likely formed by dominant, sustained iceflow during the last glacial maximum (LGM). Grooves and striae superimposed on these landforms record subsequent ice-movement phases. However, in central to western 56 N, some large-scale stoss-lee forms are oriented north to north-northwest. It is uncertain whether these forms represent a later phase, or are remnants of earlier phases as McMartin et al. (2003a, b) suggested.

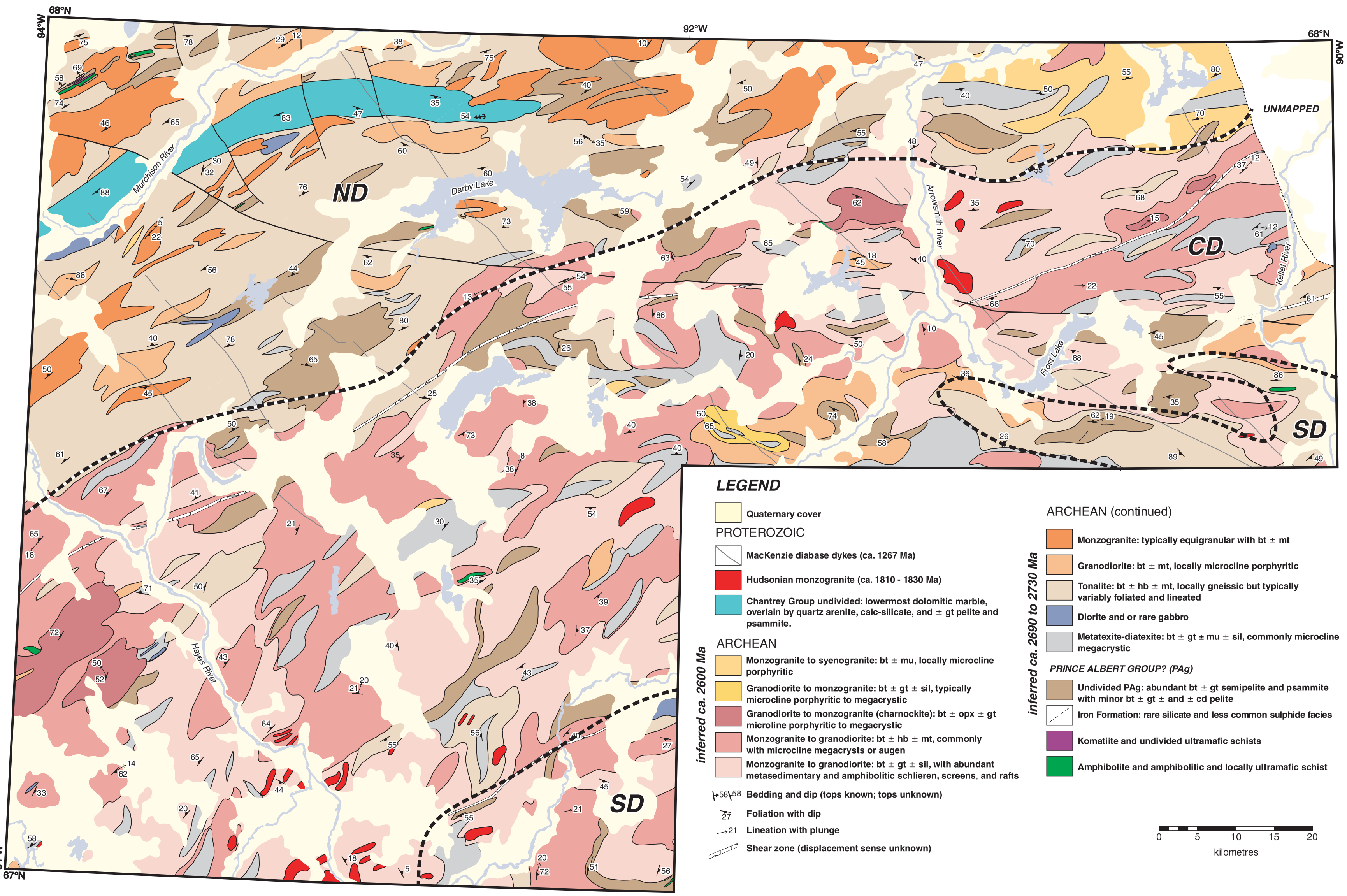

Figure 2. Bedrock geology of the Darby Lake (NTS 56 N) and Arrowsmith River (NTS 56-O north) map areas (*from* Sandeman et al., 2005). Northern Domain (ND), Central Domain (CD), Southern Domain (SD).

Figure 3. Till sample collected from a frost boil, showing landscape from which the sample was collected.

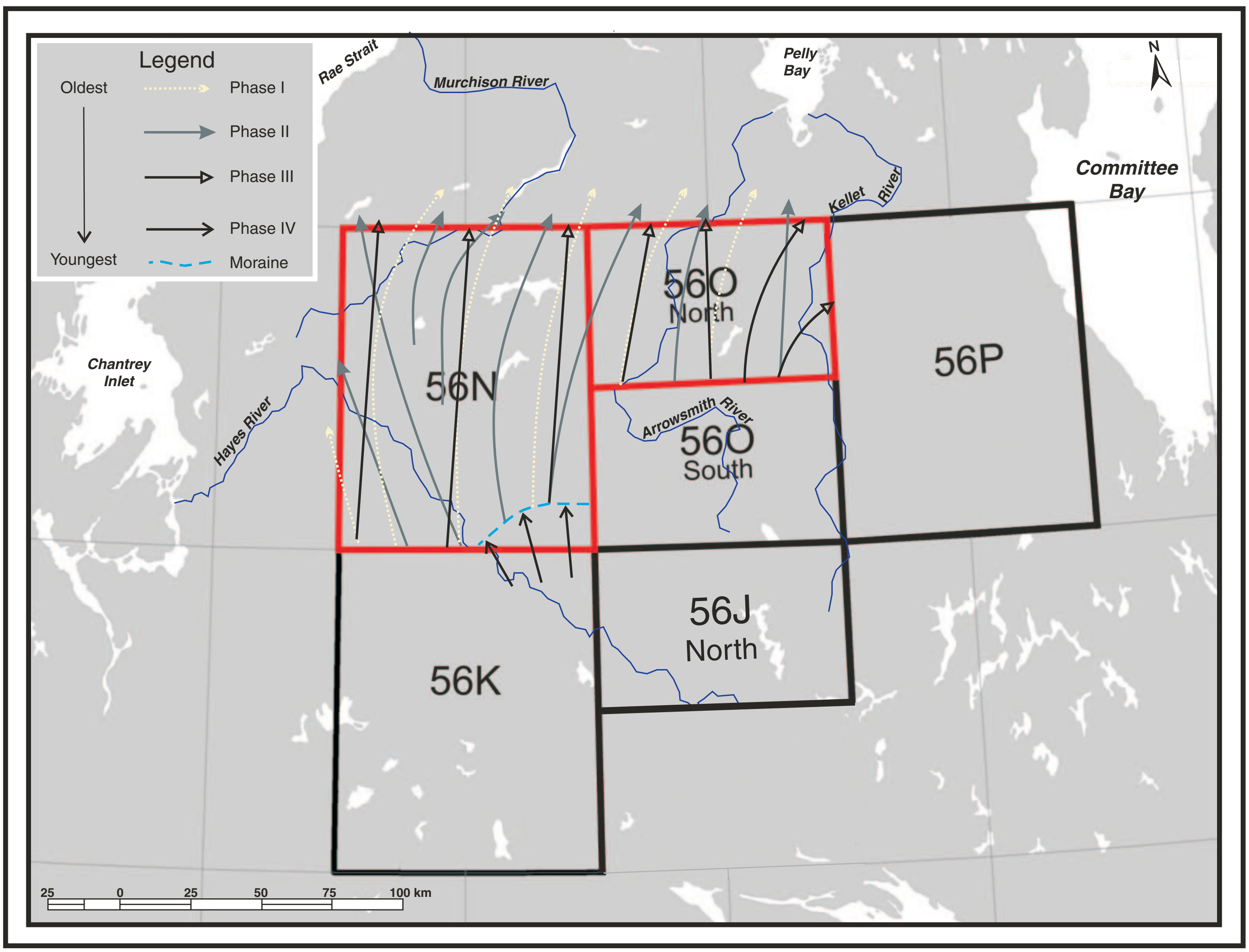

Figure 4. Map showing ice-flow phases the study area (in red), and the TGI-1 study area (black).

Figure 5. Example of a roche moutonnée from 56-O (north) associated with the first phase of ice movement (~250 m in length).

Phase II

Phase I appears to have been followed by divergent flow, where ice in the western third of 56 N flowed north-northwest and north-northeast in the upper central and eastern third of 56 N, and in 56-O (Fig. 4). Ice flow in the western part of the study area may have occurred during early deglaciation when ice from the M'Clintock Ice Divide retreated, possibly allowing ice from the Keewatin Ice Divide to flow toward Chantrey Inlet. This phase is consistent with Phase II West identified by McMartin et al. (2003a, b).

North-northeasterly flow in the eastern section may have occurred during early deglaciation, when Keewatin Sector ice became detached from Baffin Sector ice by the paleo–Gulf of Boothia (McMartin et al. 2003a, b). As Keewatin ice retreated, inlets and bays were accentuated, allowing Keewatin ice to flow north-northeastward toward paleo–Pelly and Committee bays (McMartin et al. 2003a, b). This phase is similar to Phase II East identified McMartin et al. 2003a, b).

Phase III

Phase III involved a shift of ice across the whole Darby Lake area toward the north-northeast, and a variance from north-northeast in the western Arrowsmith River map area to northeast in its eastern part (Fig. 4). This phase may represent a late-stage advance of ice from the M'Clintock Ice divide into the area. Alternatively, the western portion the Keewatin Ice Divide may have shifted and oriented itself northwestward, causing ice to flow northeastward toward Committee Bay. The northeast flow in the Arrowsmith River map area was likely the result of calving-bay effect as ice was pulled into Committee Bay.

Phase IV

The final phase was a late-stage advance into the southwestern the Darby Lake map area (56 N/1 and 2). Ice flow in this discrete section of the map area varied from north-northwest along the 56 N/56-O border, to northwest along the central 56 N/56 K border (Fig.4). This phase is similar to Phase III identified by McMartin et al. (2003a,b). Little (2001) suggested late-stage ice flow in 56 K (south of 56 N) was west-northwestward, and may be associated with flow from the 8.4 ka Keewatin Ice Divide of Dyke and Prest (1987). This advance is represented by northeast segments of the Chantrey Moraine that are aligned with those identified by Ozyer and Hicock (2002) and Figure 2 in McMartin et al. (2003a, b). A section of the moraine in 56 N /1 is oriented 060°and is intersected by a later segment oriented 010° (Fig. 6).

DRIFT PROSPECTING

Prior to the 2004 field season, detailed bedrock maps of the area did not exist, with the exception of the Chantrey Group, located in the northwestern sector of the Darby Lake map area. Therefore, the drift-prospecting program used magnetic-susceptibility maps and observations from the bedrock crew to target suitable sample locations. Magnetic highs, komatiites, and the Paleoproterozoic Chantrey Group were the main targets of the program; however, samples were also collected from locations where none of these targets existed, in order to distribute samples evenly for the reconnaissance-scale program. The program resulted in the collection of 92 till samples from different locations. Three kilogram and 10 kg samples were collected from 66 sites in 56 N, while 3 kg samples were collected at only 3. Three kilogram and 10 kg samples were collected from 23 sites in 56-O (north). Figure 7

Figure 6. Segment of the Chantrey Moraine oriented 060° in 56 N/1. (Note segment oriented 010°.)

shows the distribution of till samples on a magnetic-susceptibility map of the area. Till compositional results are presented in GSC Open File 5003.

MARINE INCURSION

Abundant marine deposits were observed in the area. They consist mainly of marine silts and clays, sometimes stratified (Fig. 8). These marine deposits have experienced considerable post-glacial erosion, giving the appearance of dissected badlands topography. Most marine deposits occur within or along valleys of major rivers and some of their tributaries. The Murchison (Fig. 9) and Hayes river valleys had extensive marine incursion, well into the heart of the study area, whereas marine sediments along the Arrowsmith River are confined mainly to the north-central part of 56-O (north). Marine sediments in the Arrowsmith River area are more extensive than those in the Murchison and Hayes areas. The relatively high altitude in the Arrowsmith River area likely impeded marine incursion.

The elevations of several marine deposits were measured using a hand-held GPS and aircraft altimeter. Marine deposits measured in 56 N ranged from 92 m to 143 m a.s.l. along the Hayes River and 150 m to 202 m a.s.l. along the Murchison River. Marine deposits measured in 56-O (north) ranged from 208 m to 223 m a.s.l. along the Arrowsmith River and 182 m a.s.l. along the Kellet River (only one measurement was taken along the Kellet River). Marine elevations are below the maximum paleo-marine limit of 255 m a.s.l. identified by Giangioppi et al. (2003) who also showed the paleo-marine limit decreased to 180 m in the Kellet River valley. Marine shells were not observed in any of the marine deposits, possibly due to the presence of brackish water far inland from the large bays and inlets in the area. Marine bivalves collected by Giangioppi et al. (2003) were from areas near the present day Committee Bay coast, and from three sites near the Kellet River.

Wave-washed zones were observed below the paleo-marine limit north of the Chantrey Group, and in the north-western section of 56-O (north). These areas can be identified by an abrupt change above the marine limit from bedrock and till veneers to loose sandy till where most of the fines below the marine limit have been washed away by wave action. These zones tend to be water saturated and poorly drained, likely due to permafrost below the active layer and relatively flat topography. These areas contain lush vegetation, compared to sparse vegetation found on the tundra above the marine limit. In some places, extensive areas of ice-wedge polygons were observed from the air (Fig.10). These zones

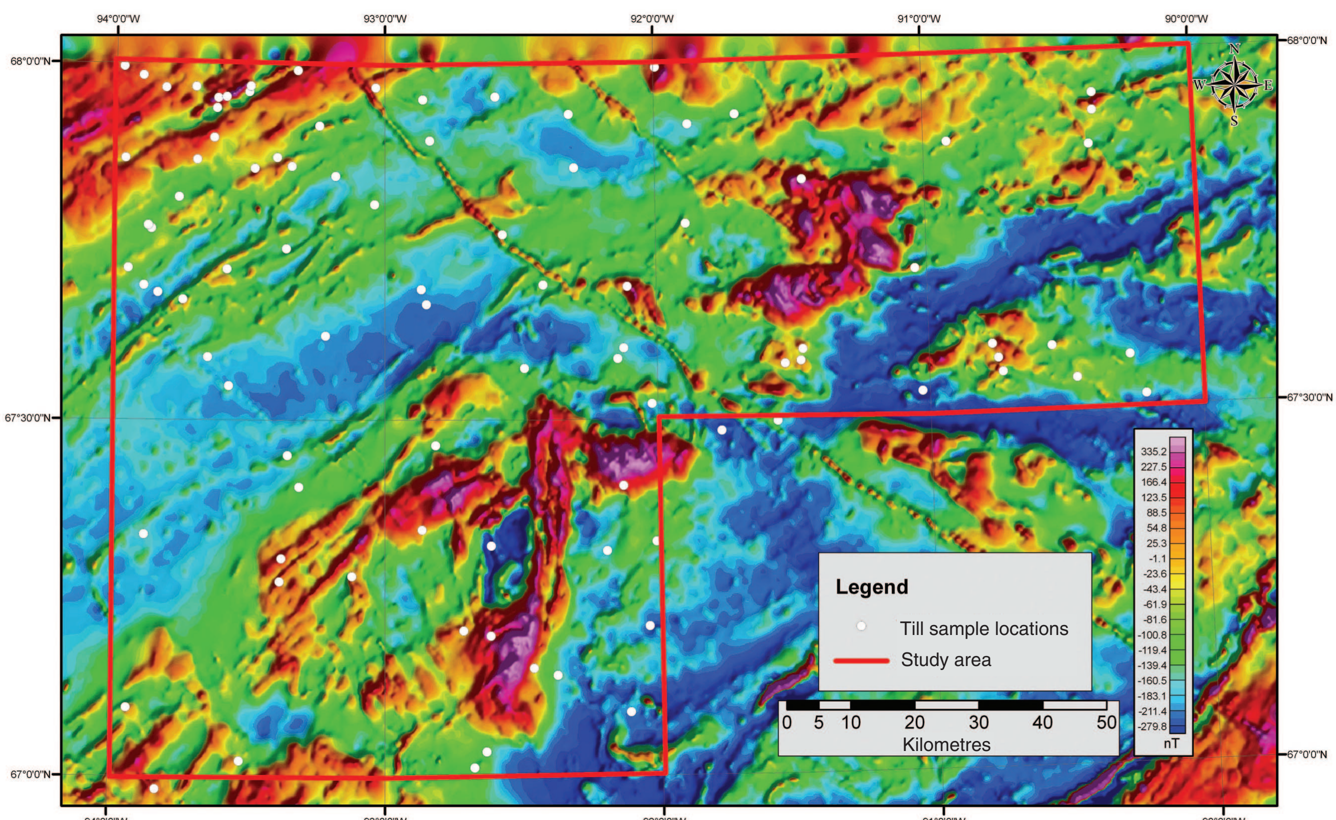

Figure 7. Residual total magnetic field map (800 m line spacing) showing the distribution of till samples (white dots) (after Teskey et al., 1985).

Figure 8. Exposure of horizontally stratified marine silts and clays.

Figure 9. Marine sediments exposed along the Murchison River valley in NTS 56 N.

are not conducive to foot traverses, and contain very few glacial sediments suitable for drift prospecting, although isolated till pockets with frost boils can be located from the air.

SUMMARY

Small- and large-scale paleoflow indicators were recorded at 150 sites during the 2004 field season. These indicators, together with crosscutting relations, suggest the area was subjected to a complex ice-movement history during the Late Wisconsinan. Three regional phases and one local phase of ice movement were identified. Large-scale landforms throughout the area, oriented north-northeast to northeast, are possibly associated with the last glacial maximum (Phase I). Phase II is characterized by divergent flow, where ice flowed north-northwest in the western third of 56 N, and northnortheast in the eastern third of 56 N, and in 56-O. Following Phase II, ice in the Darby Lake map area shifted toward north-northeast, and varied from north-northeast in the western Arrowsmith River map area, to northeast in its eastern part (Phase III). The final phase was a local late-stage north-northwest to northwest advance into the southeastern Darby Lake map area (Phase IV).

A total of 92 till samples were collected, 69 from the Darby Lake area (56 N) and 23 from the Arrowsmith River area (56-O north). The samples are being analysed for MMSIMs, gold grains, texture, pebble lithology, carbonate content, and trace and major elements. Results of the analyses will be presented in a GSC Open File report.

The area experienced considerable post-glacial marine incursions, particularly in the valleys and tributaries of the four main drainage systems. The maximum observed paleo-marine limit is 223 m a.s.l., below the paleo-marine limit of 255 m a.s.l. of the Committee Bay area identified by Giangioppi et al. (2003). These areas contain few glacial sediments suitable for drift propecting.

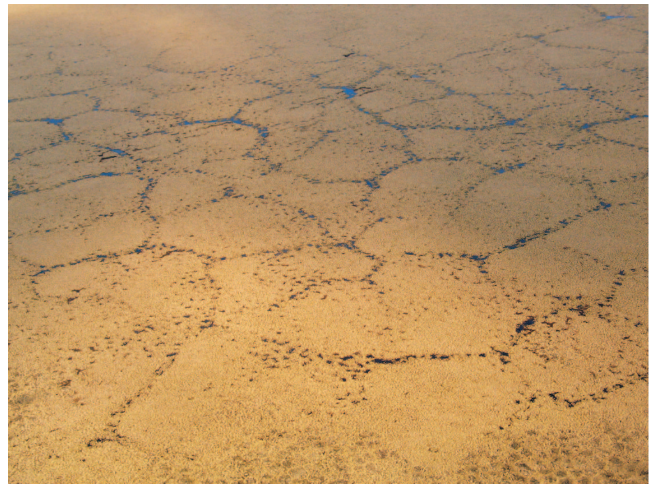

Figure 10. Ice-wedge polygons in water-saturated terrain north of Murchison River. Note frost boils within ice-wedge polygons (bottom).

ACKNOWLEDGEMENTS

Special thanks go to Isabelle McMartin (GSC Ottawa), Don James (C-NGO), and Dan Utting (C-NGO) for critically reviewing the manuscript. We thank Hamish Sandeman (C-NGO) and the entire bedrock crew for sharing their logistics. The Polar Continental Shelf Project, Technical Field Support Service (TFSS), and Charlie Cahill (Gjoa Haven) provided logistical support. Jamie Boles (Custom Helicopters) is thanked for his piloting skills and camaraderie. NSERC and the Northern Scientific Training Program (NSTP) provided funding for fieldwork to Carl Ozyer.

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