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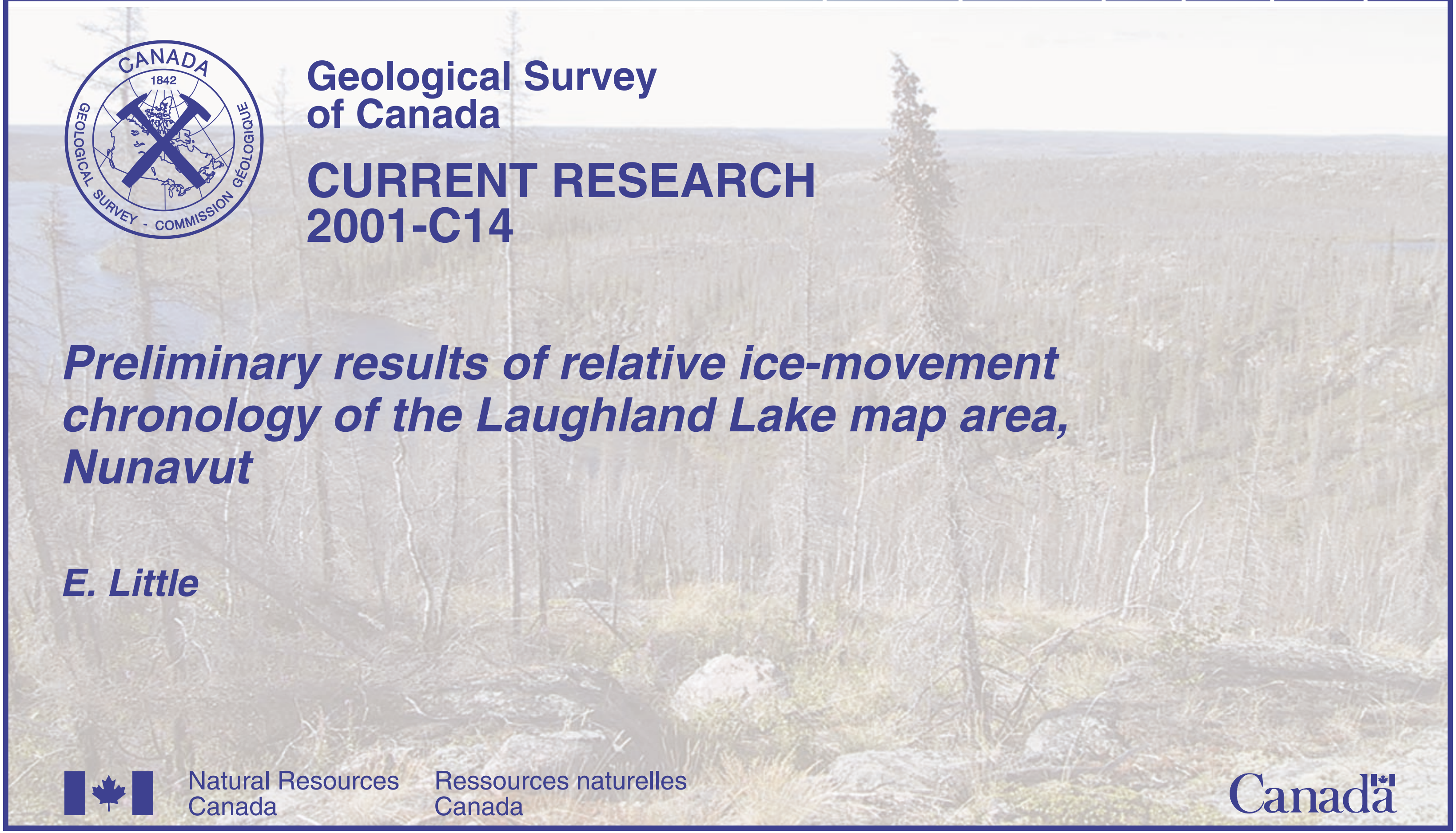

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Preliminary results of relative ice-movement chronology of the Laughland Lake map area, Nunavut

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Abstract

Preliminary surficial materials mapping at a 1:100 000 scale within the Laughland Lake (NTS 56 K) map area has 1) refined the previously mapped distribution and abundance of glacial sediments, and 2) elucidated at least four different episodes of ice movement. The oldest of the ice-movement sequences appears to have originated from an ice divide located northeast of the study area; this particular episode most likely predates the last glacial maximum, possibly related to early Wisconsinan (δ^{18}O stage 4) or penultimate glacial (δ^{18}O stage 6) ice dynamics. The younger ice-movement indicators are related to last glacial maximum and post-last glacial maximum events. Ice-movement indicators associated with the last glacial maximum sensu stricto generally scatter about due north (~355°–005°), whereas those related to post-last glacial maximum events suggest west-northwest followed by north-northwest ice movements. These data also have implications pertaining to the evolution of last glacial maximum and post-last glacial maximum ice divides.

Résumé :

La cartographie préliminaire des matériaux de surface à l'échelle de 1/100 000 réalisée dans la région cartographique du lac Laughland (SNRC 56 K) a permis 1) de perfectionner la répartition et l'abondance des sédiments glaciaires antérieurement cartographiés et 2) de mettre en lumière au moins quatre épisodes différents d'écoulement glaciaire. Le plus ancien de ces écoulements semblent avoir pris naissance sur une ligne de partage glaciaire située au nord-est de la zone étudiée. Il est fort probable que cet épisode particulier se soit produit avant le dernier pléniglaciaire, sans doute associé au Wisconsinien inférieur (δ^{18}O étage 4) ou à la dynamique des glaces de l'avant-dernier événement glaciaire (δ^{18}O étage 6). Les marques d'écoulement glaciaire plus récentes sont associées à des événements qui ont eu lieu durant et après le dernier pléniglaciaire. Les marques d'écoulement glaciaire associées au dernier pléniglaciaire sensu stricto sont dispersées généralement à peu près plein nord (~355°–005°), alors que les marques associées aux événements postérieurs au dernier pléniglaciaire laissent supposer que le sens d'écoulement était ouest-nord-ouest puis nord-nord-ouest. Ces données ont également des répercussions pour l'évolution des lignes de partage glaciaires pendant ou après le dernier pléniglaciaire.

INTRODUCTION

Preliminary Quaternary geological studies of the Laughland Lake map area (NTS 56 K, **Fig. 1**) were initiated during the 2000 field season, and represent the first phase of Quaternary research for the Committee Bay Mapping Project. The Quaternary research objectives are 1) to compile terrain inventories for the Laughland Lake (NTS 56 K), Walker Lake (NTS 56 J), Arrowsmith River (NTS 56-O), and Ellice Hills (NTS 56 P) map areas (Fig. 1) at a resolution useful to academic, government, and industry clients; 2) to initiate a reconnaissance-scale drift prospecting program that will involve both heavy-mineral (e.g. kimberlite-indicator minerals) and geochemical analyses within the aforementioned map areas; and 3) interpret the isostacy record (where applicable) and glacial history at local and regional scales.

PREVIOUS WORK

Regional Quaternary geological studies in the vicinity of the Laughland Lake map area have previously defined a number of late glacial characteristics, including the dominant surficial materials, and location of the last glacial maximum and deglacial phase ice divides for the Keewatin sector of the Laurentide Ice Sheet (e.g. Dyke and Prest, 1987; Dyke and Dredge, 1989). Many of these large-scale regional studies are based on 1:250 000 scale mapping.

The surficial geology of the Laughland Lake map area was originally mapped (1:250 000 scale) by Thomas and Dyke (1981). They recorded a general ice-movement direction from the south-southeast towards the north-northwest, and a landscape dominated by till veneers (<1 m thick) and till blankets (7–20 m thick). Other researchers working in the area have reported basic observations (e.g. paleoflow of eskers), and in some cases, contradictory interpretations regarding the genesis of these deposits (cf. Jefferson and Schau, 1992; Chandler et al., 1993).

Recent preliminary mapping, however, has helped refine the glacial geology and elucidate controversial problems by 1) refining the relative distribution and abundance of surficial deposits; 2) identifying regions of active and stagnant ice bodies; 3) developing a new relative ice-movement chronology; and 4) refining the location of the last glacial maximum and post-last glacial maximum ice divides.

QUATERNARY GEOLOGY OF THE LAUGHLAND LAKE MAP AREA

Terrain inventory

Two types of glacial deposits dominate the landscape within the Laughland Lake map area: glaciofluvial sediments and till. The thicknesses of these deposits vary from thin veneers (0–1 m thick) up to thick esker and ice-contact deposits (>50 m) and till blankets (>20 m). The distribution of these two deposits appears to be inter-related; generally, till flute fields are spatially punctuated by esker complexes, ice-contact deposits, and glaciofluvially scoured bedrock. This implies a first-order interpretation that north-northwest–south-southeast linear regions of active, and possibly streaming ice were separated by large regions of stagnant (or relatively slower moving and/or deforming) ice bodies. In these stagnant-ice areas, eskers and ice-contact sediments were deposited in conjunction with periodic glaciofluvial meltwater scouring and erosion to bedrock. The relationship and genesis of these deposits will be examined in detail over the course of the project.

The distribution and relative abundance of surficial materials observed during the 2000 field season differs from the surficial deposits mapped by Thomas and Dyke (1981); the current study ranks till and glaciofluvial deposits as the most abundant sediment types within the Laughland Lake map area. This difference is due to the larger scale of mapping (1:100 000) used in the present project compared with the reconnaissance (1:250 000) scale employed by Thomas and Dyke (1981).

Ice-movement indicators

Previous researchers have identified till flutes, bedrock flutes, crag-and-tail features, and striae which collectively suggested a north-northwest direction for the last episode of ice-movement in the Laughland Lake region. Detailed work conducted during the 2000 field season has yielded new information about ice-movement directions; as outlined below, these data have allowed the development of a hypothesis encompassing at least four principal ice-movement events and one transitional phase (**Fig. 2**).

The most recent of these ice-movement indicators (set 4, **Fig. 2B**) were observed on numerous bedrock outcrops in the form of nail-head striae, chattermarks, and bidirectional striae (**Fig. 3A**). Fields of till flutes, and crag-and-tail features (Fig. 3B) parallel to these striae were only evident from the air (helicopter or air photographs). All of the above ice-movement indicators suggest a primary ice-movement direction between about 330° and 350°. The relative freshness of the landscape and the prominence of the associated abraded striae and chattermarks suggest formation during the last phase of ice movement to occur in this region; the timing of this event may be associated with the 8.4 ka Keewatin Ice Divide of Dyke and Prest (1987).

A less prominent set of striations (set 3, Fig. 2B) is crosscut by ice-movement indicator set 4; the angle between the two sets is between 30°-60°. This earlier set typically ranges between about 280°–300° (Fig. 3A). Between ice-movement indicator sets 4 and 3, there is a weakly defined suite of ice-movement indicators that fall between about 290°–330°. These may reflect a transitional phase when ice-movement was shifting from ice-movement indicator set 3 to ice-movement indicator set 4 events.

During the oldest phase of north-oriented ice movement, correlated indicators were scattered about due north (~355°–005°; **Fig. 2B**). The only manifestations of this ice-movement event are roches moutonnées (**Fig. 4**), bedrock flutings, and extremely rare striae. The robust nature of the former two may also suggest that this set of indicators formed during the last glacial maximum (*see* 'Discussion').

The oldest set of directional indicators is oriented southwest-northeast (bidirectional data, **Fig. 2**), tentatively suggesting ice movement to the southwest (unidirectional data, Fig. 2). These data, which consist of extremely rare striae and stoss-lee relationships developed on oriented bedrock ridges, are difficult to interpret due to the poor quality of the preserved features. The first-order relative age of this ice-movement sequence (ice-movement indicator set 1, Fig. 2B) in the Laughland Lake chronology is pre-ice-movement indicator set 3. Two hypotheses can be presented to explain and refine the timing of ice-movement indicator set 1. 1) If the unidirectional component is here misidentified, then the bidirectional component matches well with ice-movement directions and the last glacial maximum Keewatin Ice Divide of Dyke and Prest (1987). This hypothesis also requires that post-ice-movement indicator set 1 sequences be correlated with relatively younger phases of ice movement (i.e. ice-movement indicator set 2, 3, and 4 are related to the deglacial phase). 2) Alternatively, if the interpretation of the unidirectional component is correct, then there significant implications for the regional picture.

South of the present study area, in the vicinity of Rankin Inlet (**Fig. 1**), McMartin and Henderson (1999) interpreted very similar ice-movement trends during their systematic ice-movement indicator mapping.

DISCUSSION

Systematic ice-flow-indicator mapping conducted by McMartin and Henderson (1999) in the vicinity of Rankin Inlet (**Fig. 1**) advanced the understanding of the history of ice-movement in that region. This allowed them to refine the location of the Keewatin Ice Divide to a region northwest of Rankin Inlet. They also identified at least four different southerly directed ice-movement phases and one ancient northerly directed phase. From these data they deduced the following ice-movement sequence: 1) to the southwest from an ice centre north and east of the region; 2) south from an undetermined position; 3) east-southeast; and, 4) southeast. In one area (NTS 65-I), an ice-movement interpreted to be older than their southerly directed movement phases was identified.

Considering the present data and interpreting them with respect to those of McMartin and Henderson (1999) two important relationships can be recognized: 1) the oldest southwest-oriented ice-movement phase is identified in both regions, and 2) three younger phases have similar orientations, but opposite vergences (**Fig. 5**). Collectively, the relative timing of all ice-movement indicator sets give rise to consistent interpretations. Given the similarity of ice-movement trends between the Laughland Lake and Rankin Inlet regional data sets, the first hypothesis presented for the relative timing of the southwest-trending ice-movement indicators (i.e. last glacial maximum) is rejected. The alternative, therefore, is the current working hypothesis that states the southwest-trending ice-movement sequence is pre-last glacial maximum and thus the oldest observed in the Laughland Lake ice-movement record.

The recognition and correlation of Laughland Lake ice-movement indicator data to that of McMartin and Henderson (1999) advances our understanding of regional Keewatin ice dynamics during the late Wisconsinan glacial interval, and possibly during early Wisconsinan or the penultimate glacial intervals. Although the absolute ages of the combined ice-movement indicator set data sets are difficult to ascertain, the following interpretation is proposed.

1. Given the relatively fresh topography and well developed crag-and-tail features, striae sets, and till flutes in the Laughland Lake region, ice-movement indicator set 4 most likely represents a late deglacial phase (Holocene) ice-movement event which may correlate to the 8.4 ka event of Dyke and Prest (1987).
2. Striae crosscutting relationships indicate that ice-movement indicator set 3 is older than ice-movement indicator set 4, but younger than ice-movement indicator set 2 and set 1. These striae may be related to the initial (early) deglacial phase of the last glacial interval.
3. A relatively weak striae set (~290°–330°) that occurs between ice-movement indicator sets 3 and 4 may represent a transitional phase of ice-movement between two more persistent ice-movement phases. This may suggest that ice-movement indicator sets 3 and 4 are closely related (i.e. both created by ice-movement events under deglaciation conditions).
4. Crosscutting relationships between ice-movement indicator sets 2, 3, and 4, in conjunction with the rare occurrence of ice-movement indicator set 2 striae, suggests that ice-movement indicator set 2 predates ice-movement indicator sets 3 and 4. The robust nature of the majority of ice-movement indicator set 2 indicators (i.e. roches moutonnées and bedrock ridges with preserved stoss-lee relationships) in conjunction with points 1 through 3, suggests that the ice movement that created these features was itself robust and persistent. In addition, the drastic change of ice-movement direction from north (ice-movement indicator set 2) to west-northwest (ice-movement indicator set 3, **Fig. 5**) may have been due to corresponding shifts in the position of the ice divide. These drastic changes in the orientation of the ice divide may have been brought about by abrupt changes in mass balance (i.e. transition from the last glacial maximum to the deglaciation conditions). The foregoing observations and interpretations suggest a last glacial maximum timing for ice-movement indicator set 2.

5. Given the similarity of data in Laughland Lake and the Rankin Inlet regions, ice-movement indicator set 1 is interpreted as the oldest ice-movement event. If point 4 is correct, then the absolute age of ice-movement indicator set 1 must predate the last glacial maximum. Since the inferred ice divide is drastically different than that interpreted for the last glacial maximum and post-last glacial maximum deglacial phases, the timing of this event could be potentially early Wisconsinan (δ^{18}O stage 4) or perhaps even the penultimate glacial (δ^{18}O stage 6).

The foregoing interpretations of the Laughland Lake ice-movement data set also have significant implications for the locations of the Keewatin ice divides. Firstly, the oldest ice divide in the region appears to have been located northeast of both the Laughland Lake and the Rankin Inlet regions (inferred from Fig. 5). Secondly, McMartin and Henderson (1999, p. 129) stated that the Keewatin Ice "...divide axis may lie slightly further to the northwest than originally thought." The present work in the Laughland Lake map area provides a northern limit for the location of this divide (last glacial maximum ice divide, Fig. 5).

The combined ice-movement data sets illustrate how the Keewatin ice divides have evolved from the last glacial maximum through the deglaciation phases (early and late post-last glacial maximum ice divides, Fig. 5). During the last glacial maximum, the west-trending ice divide was apparently located between the Rankin Inlet region and the Laughland Lake map area. Once the Laurentide Ice Sheet entered the deglaciation phase, the orientation of the ice divide shifted dramatically from west-east during the last glacial maximum to the early deglacial south-southwest–north-northeast orientation (Fig. 5). Then gradually it shifted back towards a west-southwest–east-northeast orientation. These deglacial shifts in orientation of the Keewatin Ice Divide may have occurred in response to a re-equilibration of the ice sheet to a new 'deglacial' ice mass balance.

CONCLUSIONS

Preliminary field mapping has resulted in the discovery of at least four ice-movement sequences in the Laughland Lake map area. Considered with similar data from the Rankin Inlet region, these indicators have significant implications for Keewatin ice dynamics during the late glacial maximum, the deglaciation phase, and the transition between last glacial maximum and deglaciation phases.

Drastic changes in ice movement following the last glacial maximum were inferred from an average northward ice movement to an average west-northwestward ice movement. These are interpreted to be the result of the Keewatin ice sheet disequilibrium during the initial phases of deglaciation. The subsequent shift of the ice divide back towards a west-dominated trend is interpreted as the response of the ice sheet attempting to reach a steady-state under deglacial conditions.

The oldest ice-movement indicators interpreted in both the Laughland Lake and Rankin Inlet regions suggest that a pre-last glacial maximum ice divide existed to the northeast of both regions. The drastic differences in the inferred locations of the last glacial maximum (and associated) ice divides, and the pre-last glacial maximum ice divide may suggest an entirely different set of ice dynamics, and thus perhaps a much earlier timing for this event — perhaps even early Wisconsinan or penultimate glacials.

The improved understanding of ice-movement sequences outlined here provides a foundation for the interpretation of till geochemical information applied to mineral exploration in the Kivalliq region.

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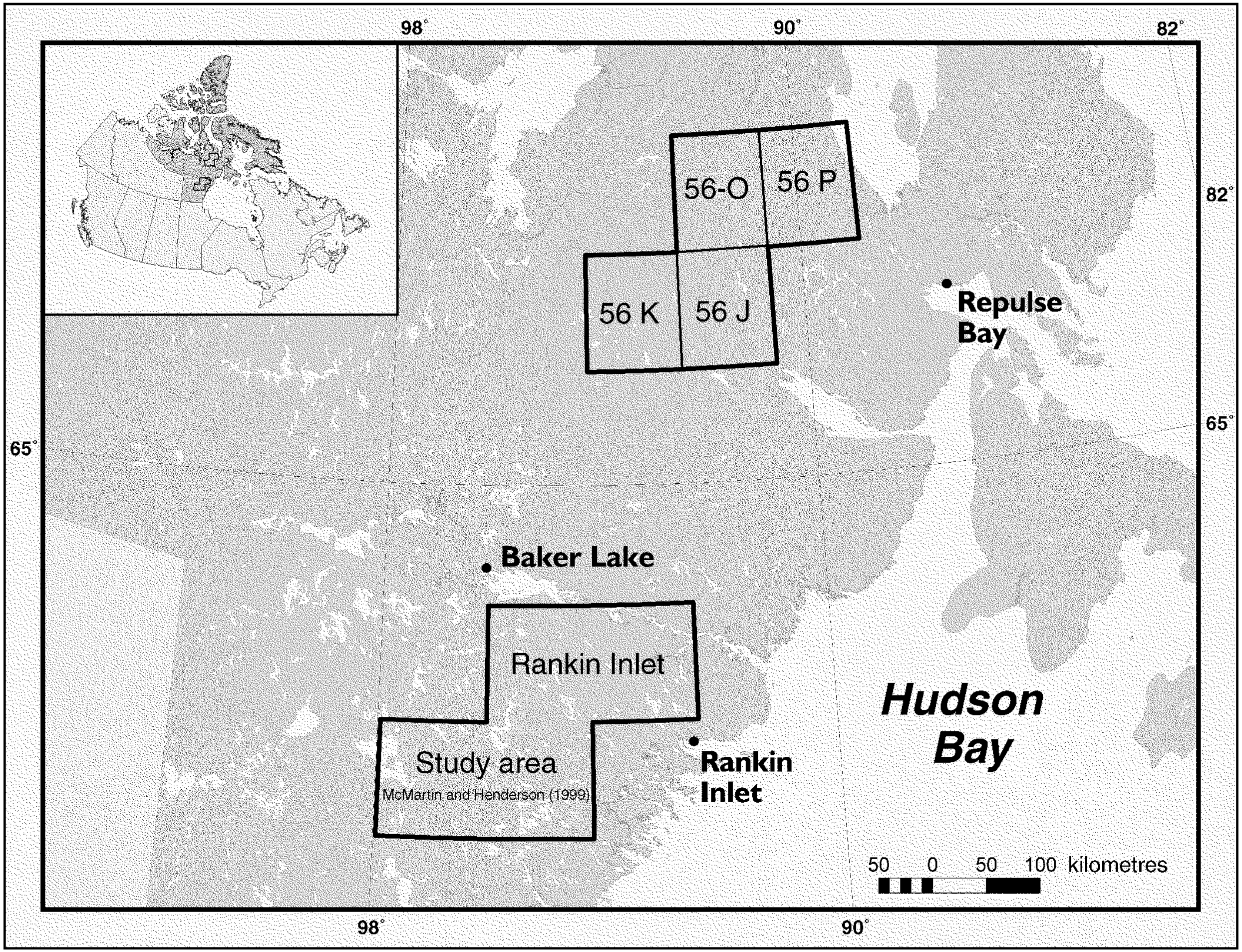

Figure 1. Location map showing the entire Committee Bay study area. The focus of this paper is on work that was conducted during the 2000 field season within the NTS 56 K map area.

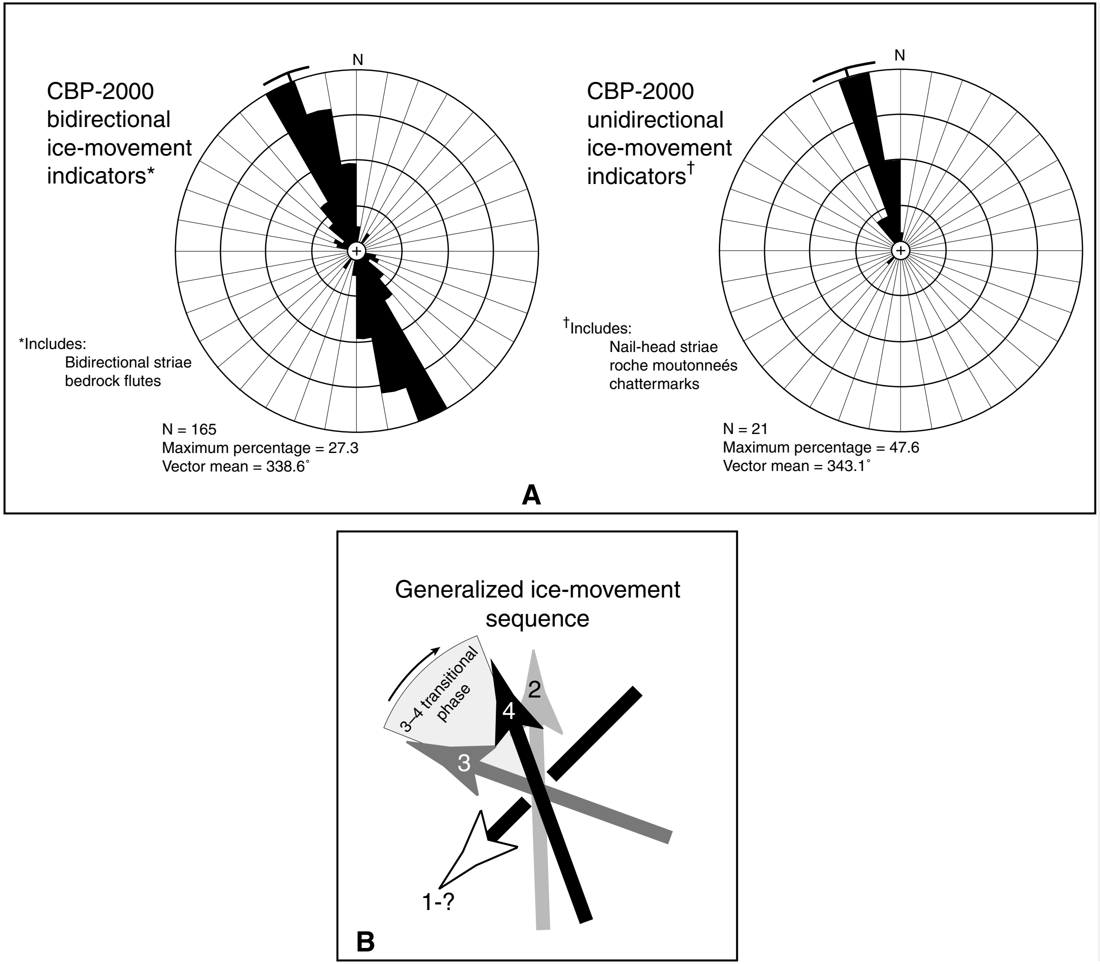

Figure 2. A) Rose diagrams compiling all bidirection (left) and unidirectional (right) ice-movement indicators. **B)** Generalized ice-movement sequence for the Laughland Lake data set. Sequences are numbered from 1 (oldest) to 4 (youngest; cf. McMartin and Henderson, 1999). These interpretations are based on discreet ice-movement indicators (corrected for declination) in addition to the rose-diagram compilations.

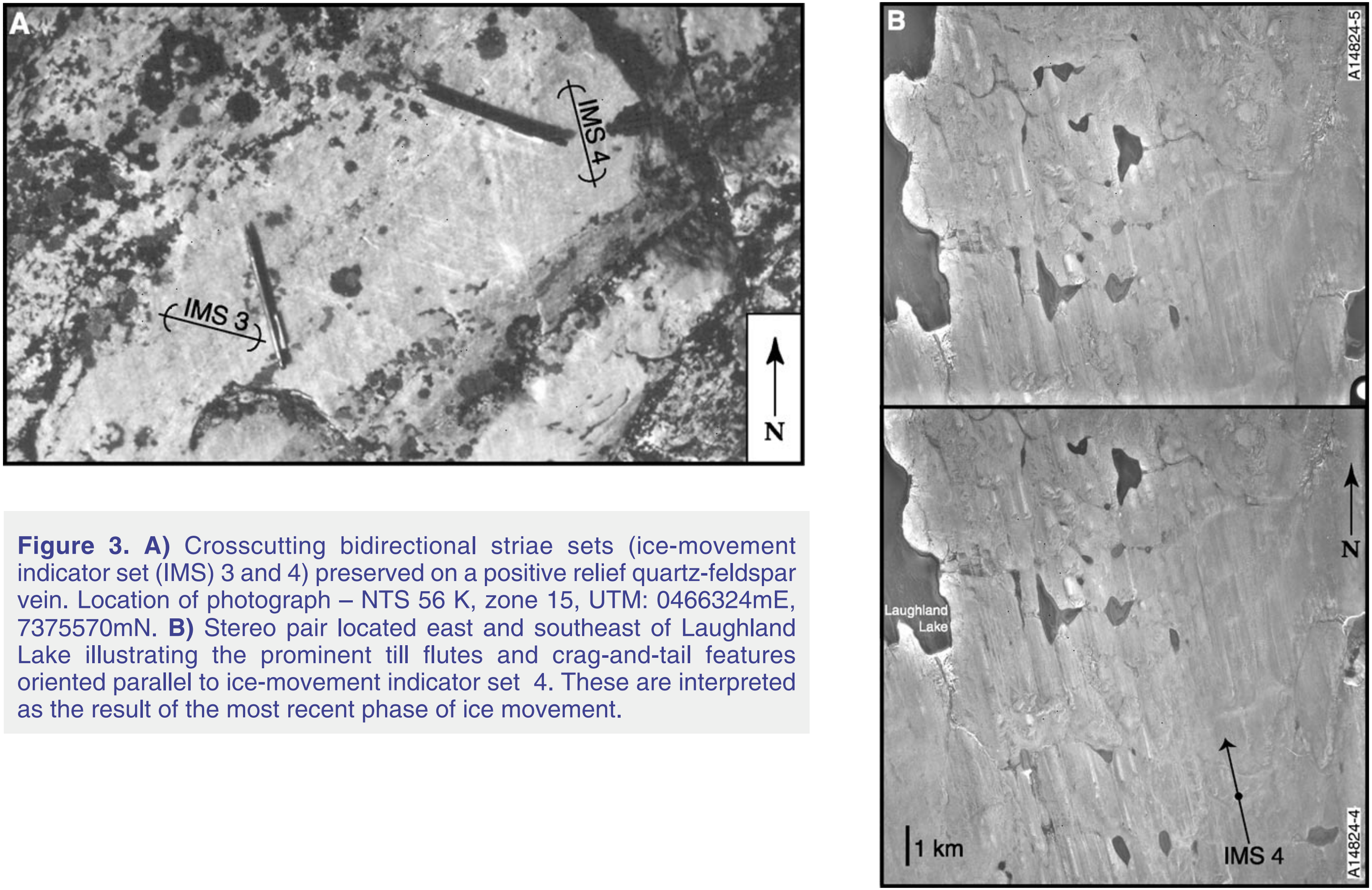

Figure 3. A) Crosscutting bidirectional striae sets (ice-movement indicator set (IMS) 3 and 4) preserved on a positive relief quartz-feldspar vein. Location of photograph – NTS 56 K, zone 15, UTM: 0466324mE, 7375570mN. **B)** Stereo pair located east and southeast of Laughland Lake illustrating the prominent till flutes and crag-and-tail features oriented parallel to ice-movement indicator set 4. These are interpreted as the result of the most recent phase of ice movement.

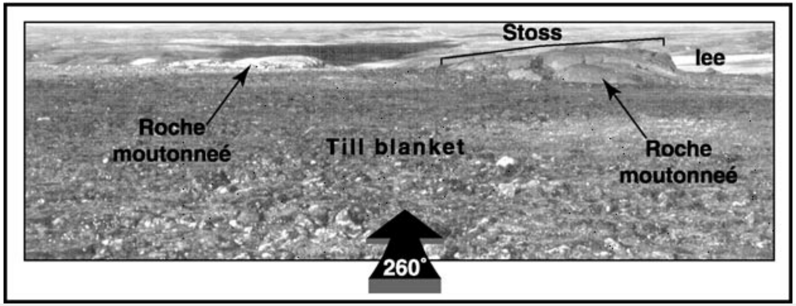

Figure 4. Roches moutonnées formed from komatiite outcrops protruding through a till blanket. Plucked lee surfaces are oriented towards north. Location of photograph – NTS 56 K, zone 15, UTM: 0523100mE, 7365071mN.

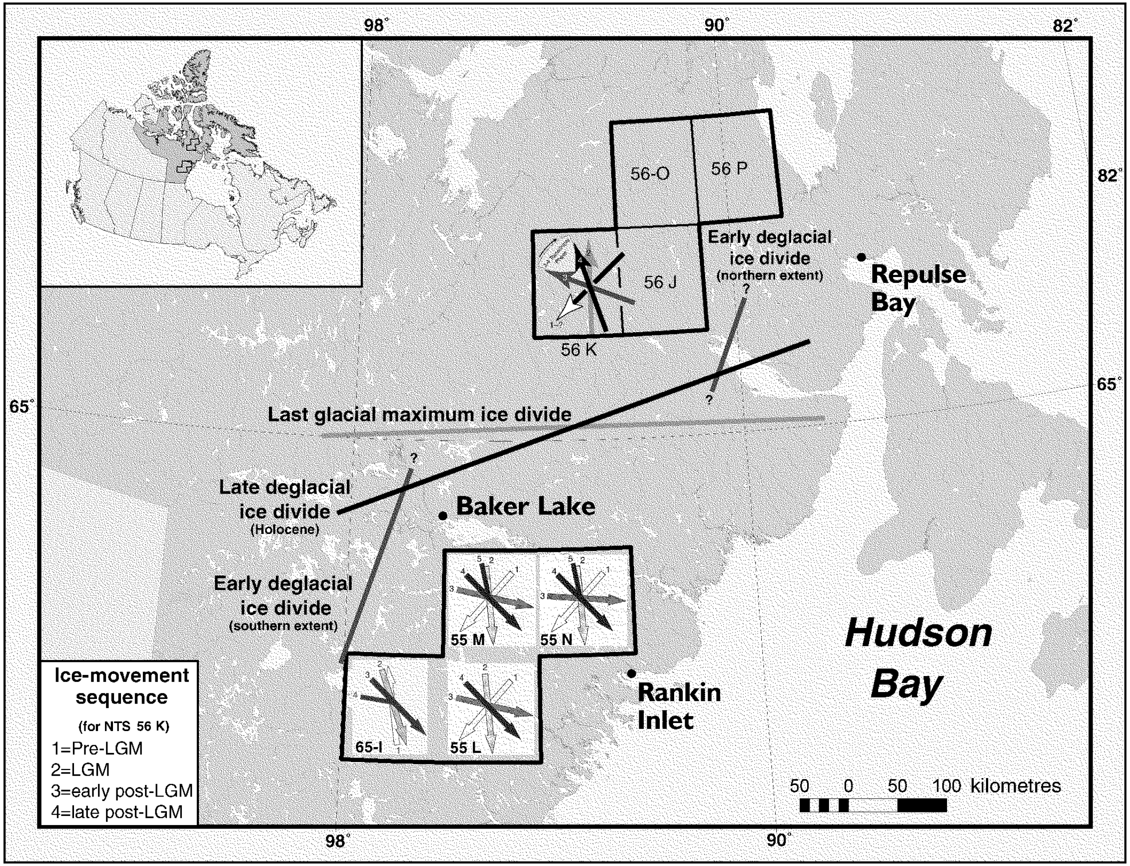

Figure 5. General ice-movement sequence diagrams for NTS 56 K (Laughland Lake; for larger diagram *see* Fig. 2) and 65-I, 55 L, 55 M, and 55 N. From these data sets, northern limits can be placed on the ice divides relating to ice-movement indicator sets 2, 3, and 4 (this paper). Also, ice-movement indicator set 1 in NTS 56 K, 55 L, 55 M, and 55 N suggest the presence of a pre-last glacial maximum ice divide northeast of both study areas. Given the significant difference between last glacial maximum (LGM) and last-deglacial phase indicators and ice-movement indicator set 1, this pre-last glacial maximum ice divide may have been related to early Wisconsinan or penultimate ice-sheet dynamics. Uncertainties with respect to the positioning of the 'early deglacial ice divide' may reflect complex ice dynamics and associated complex ice-divide morphology during the initial deglacial ice dynamics disequilibrium. All ice-divide representations are approximate. General ice-movement sequence diagrams for NTS 65-I, 55 L, 55 M, and 55 N *modified after* McMartin and Henderson (1999).