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Overview of Quaternary research for the Committee Bay Project, central Nunavut[1]

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Abstract: Detailed 1:50 000-scale Quaternary mapping and reconnaissance-scale till geochemistry and kimberlite indicator mineral surveys were carried out within three NTS 1:250 000-scale map areas: Laughland Lake (56 K), the northern half of Walker Lake (56 J), and the southern half of Arrowsmith River (56-O). Quaternary mapping included characterization of surficial geology units, identification of glaciogenic landforms, and the measurement of ice-movement indicators. New data related to the last active ice to occupy areas in NTS 56 K, 56 J, and 56-O suggest divergent ice movement originating from a southward-opening, arcuate ice divide or an ice-centres–saddle scenario. Further investigations will elucidate the complex ice-movement history and test new hypotheses regarding the genesis of some glacial landforms and sediments.

Résumé : La représentation cartographique détaillée des dépôts du Quaternaire à l'échelle de 1/50 000, la géochimie de reconnaissance des tills ainsi que des levés de minéraux indicateurs de kimberlite ont été entrepris dans la région couverte par trois cartes du SNRC à l'échelle de 1/250 000 : Laughland Lake (56K), la moitié nord de la carte de Walker Lake (56J) et la moitié sud de la carte d'Arrowsmith River (56-O). La cartographie des dépôts du Quaternaire comprenait : la caractérisation des unités géologiques des matériaux superficiels, l'identification des formes de terrain glaciogéniques et la mesure d'indicateurs du déplacement des glaces. Les nouvelles données relatives aux dernières glaces actives dans la région des cartes 56K, 56J et 56-O laissent croire à des mouvements glaciaires divergents depuis une ligne de partage glaciaire arquée ouverte vers le sud ou à un scénario d'alternance de centres et de dépressions glaciaires. Des études plus poussées permettront d'éclaircir la complexe histoire des mouvements glaciaires et de vérifier de nouvelles hypothèses relatives à la genèse de certaines formes de terrain et de certains sédiments glaciaires.

[1] Contribution to Targeted Geoscience Initiative

INTRODUCTION

Extensive Quaternary studies are currently being undertaken in the vicinity of the Prince Albert group rocks, approximately 300 km northeast of Baker Lake, central mainland, Nunavut (Fig. 1). This endeavor is in the second year of a three year program and is one component of the multidisciplinary integrated geoscience Committee Bay Project; a collaboration between the Canada-Nunavut Geoscience Office, the Geological Survey of Canada, and several Canadian universities designed to increase the exploration potential in this region. Objectives of the Quaternary component include: 1) compilation of high-resolution (1:50 000 scale) terrain inventories for the Laughland Lake (56 K), Walker Lake (56 J/9–16), Arrowsmith River (56-O/1–8), and Ellice Hills (56 P) map areas; 2) initiation of a reconnaissance-scale drift prospecting program that utilizes both heavy-mineral (e.g. kimberlite-indicator suite, gold and metamorphosed massive suphide indicators) and till geochemical analyses; and, 3) interpretation of the glacial history at local and regional scales.

This paper represents an overview of the field research conducted during the 2001 season and preliminary results derived from field observations. It is to be used in conjunction with more detailed discussions of the Quaternary research and interpretations from the Walker Lake and Arrowsmith River areas presented in Utting et al. (2002), and Ozyer and Hicock (2002) respectively.

REGIONAL SETTING

Physiography

The project area (Fig. 1) is situated in the northern portion of the Wager plateau. It lies within a zone of continuous permafrost (Burgess et al., 2001) and comprises four drainage basins ranging from 181 kha to 1462 kha (Fig. 2, Table 1). The topography is highly variable regionally with elevations ranging from approximately 122 m a.s.l. (NTS 56 K) to 560 m a.s.l. (NTS 56 J). The average elevations for each map area are given in Table 2. The geomorphology of the area includes: large expanses of horizontal to slightly inclined plains; gently

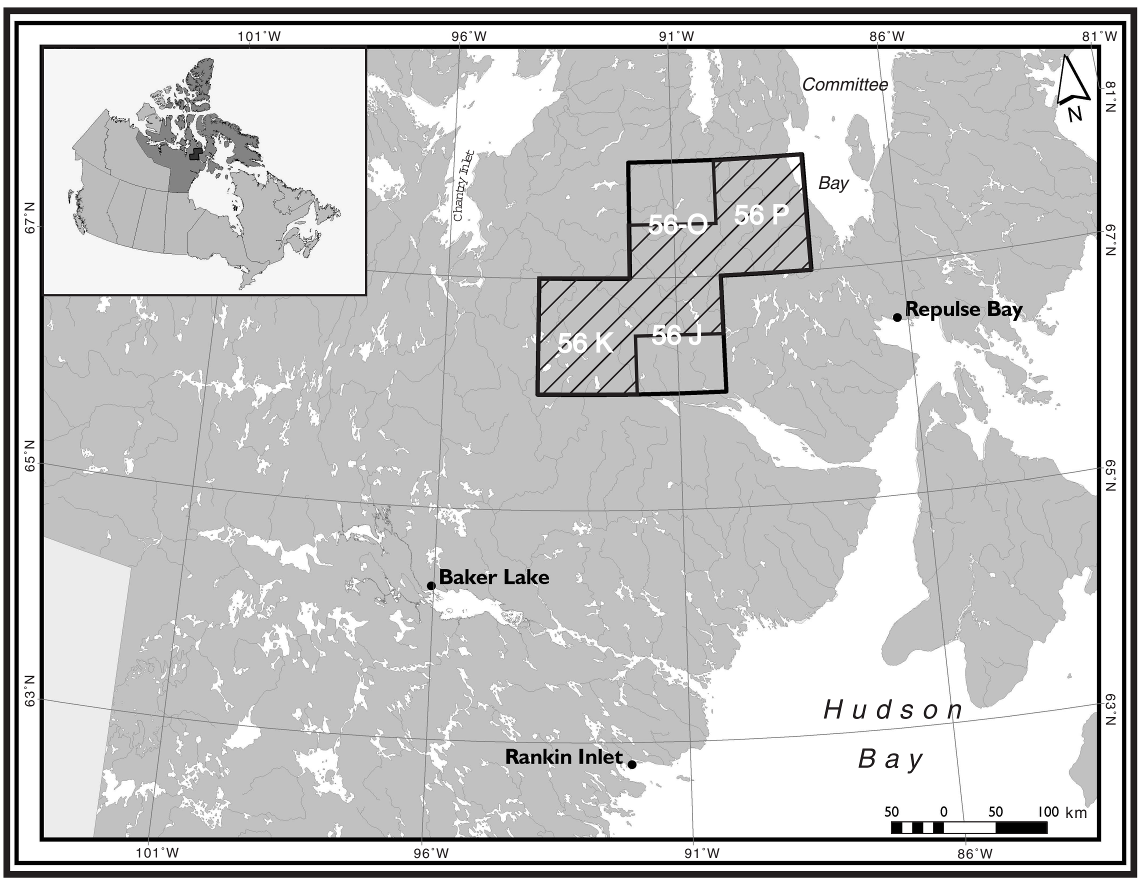

Figure 1. Location of Committee Bay Project field area (hatch pattern). Quaternary-based field work was conducted in 56 K, 56 J/9–16, and 56-O/1–8 in 2000 and 2001.

rolling hills; high-amplitude, hummocky till, and glaciofluvial gravel; broad sweeping valleys; and deep, steep-walled gorges.

Laughland Lake (NTS 56 K), the southwestern most part of the study area (Fig. 1), is dominated by expansive till plains within its north, south, and east-central regions. Some of these plains exhibit extremely well developed streamlined landforms that typically trend north-northwest. Glaciofluvial gravels deposited in meltwater channels, eskers, and kames dominate the southwest and west-central regions as well as isolated pockets in large modern-day valleys (e.g. Hayes

Table 1. Watershed areas for basins within NTS 56 K, J (upper-half), and O (lower-half). This figure complements Figure 2.

Watershed	Total area (kha)	Area within NTS 56 K, J, O (kha)
Gulf of Boothia (west)	6408	1462
Gulf of Boothia (east)	2681	192
Lower Thelon	3204	184
Northwest Hudson	7202	181

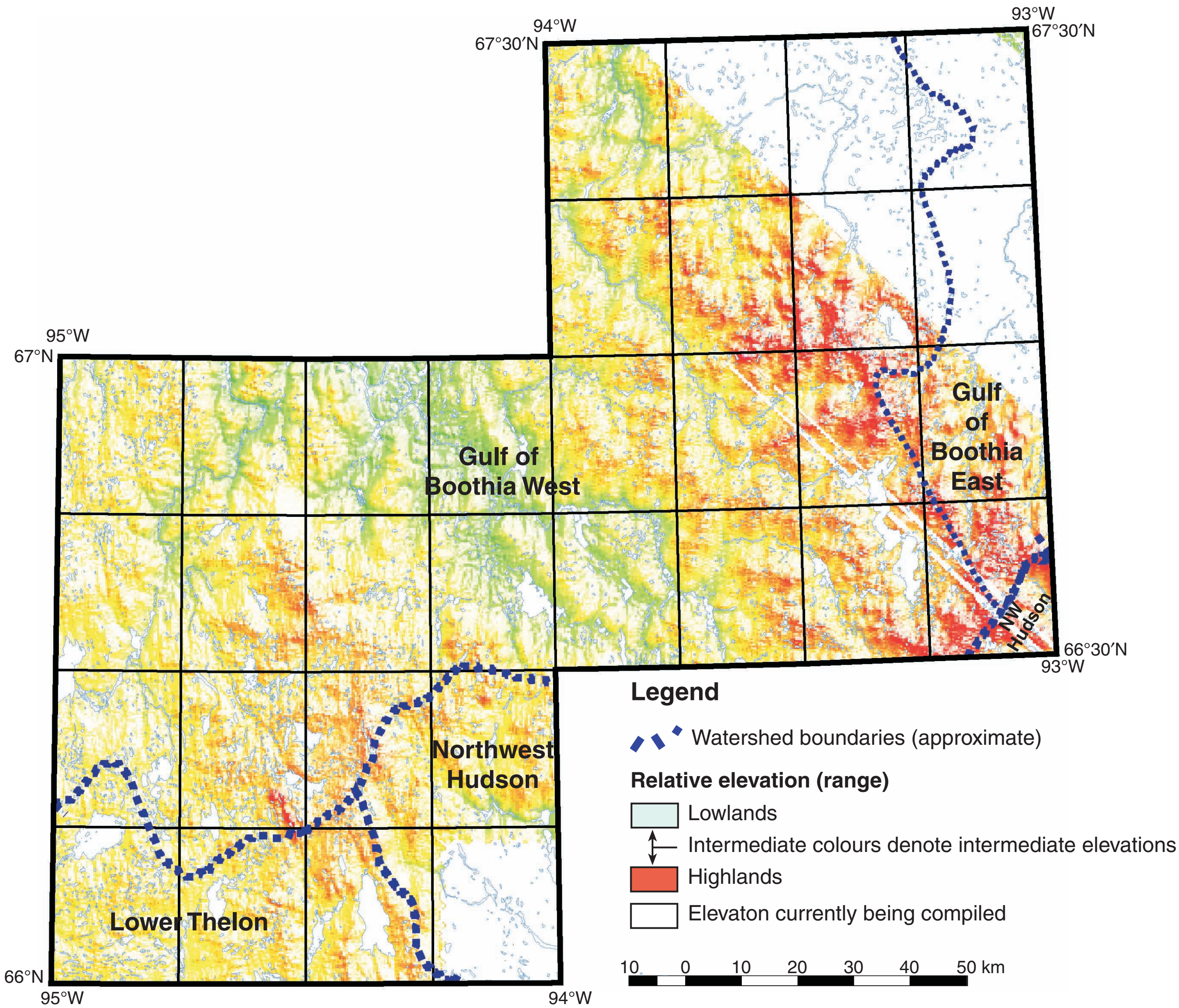

Figure 2. Physiography (including watersheds and relative elevation) for NTS 56 K, J (north-half), and 56-O (south-half). Digital elevation model was created from radar-altimetry data collected during the 2000 and 2001 field seasons.

Table 2. Average elevation and maximum and minimum contours within the study area.

NTS area	Average elevation (m a.s.l.)	Minimum contour (m a.s.l.)	Maximum contour (m a.s.l.)
56 K	312	122	488
56 J/9–16	383	220	560
56-O/1–8	380	200	520

River valley). Till and glaciofluvial veneers dominate the extreme northeast and southwest corners, whereas large moraines truncated by meltwater channels dominate the northwest. The predominant drainage in northern NTS 56 K is from the Hayes River and its tributaries that generally flow northwestward into Chantry Inlet. The Brown River, the dominant drainage of the south, flows into northwestern Hudson Bay. Situated on the periphery of the Lower Thelon watershed, drainage networks of the southeast region of NTS 56 K are not as well developed as those observed within other areas of NTS 56 K.

In the Walker Lake area (NTS 56 J/9–16), two major drainage basins are dominant (Fig. 2): the Hayes River, draining Walker Lake and flowing into Chantrey Inlet; and Pearce Lake, on the east side of the divide, flowing towards Hudson Bay. Surficial materials in the area include till and glaciofluvial and glaciolacustrine sediments. Their distribution appears topographically controlled, which may be a result of deglacial meltwater processes (cf. Utting et al., 2002). Till is the most extensive surficial unit, typically found on local topographic highs. North-trending eskers have been subdivided into those which crosscut topography and those which are predominantly in the preglacial valleys and low areas (Utting et al., 2002). Irregularly shaped mounds and transverse ridges were observed to be associated with the eskers. Glaciofluvial plains are confined to the sides of terraces and along the sides of larger meltwater channels. Ice-dammed lakes and their deltas and raised beaches are localized glaciolacustrine features.

The main drainage system in the Arrowsmith River area (56-O/1–8) is the Arrowsmith River which flows to the north. In the southeast, kame-and-kettle topography dominates with numerous raised shorelines, eskers, and moraines also present. The northeast is extremely rugged, being dominated by bedrock outcrops, till veneers, and glaciofluvial meltwater channels. The southwest manifests a significant number of large meltwater channels and a series of moraines thought to be related to the 'Chantry moraine' system (Ozyer and Hicock, 2002). The northwest is dominated by kilometer-wide sand filled valleys, thermokarst lakes, and eskers. Till veneers and till blankets are also present throughout the northwest.

Bedrock geology

The bedrock mapping component of the Committee Bay Project is currently refining the spatial distribution and relationships of Archean–Proterozoic supercrustal rocks and associated felsic intrusives northeast of the Amer shear zone (*see* Sandeman et al., 2001a, b; Skulski et al, 2002). Exposed bedrock within the study area can be subdivided into three main groups. Forming the main greenstone belt are supracrustal rocks of the Prince Albert group dominated by semipelite and psammite with lesser iron-formation, quartzite, komatiitic basalt, and felsic metavolcanic rocks (Sandeman et al., 2001a, b). To the south and east of this belt are plutonic rocks consisting of quartz diorite, diorite, tonalite, granodiorite, and granite (Sandeman et al. 2001a, b; Skulski et al., 2002). To the west and north of the greenstone belt, increased metamorphism has led to the development of paragneiss and derived peraluminous granitic rocks (Sandeman et al., 2001a, b; Skulski et al., 2002).

PREVIOUS WORK

Regional Quaternary geological studies in or near the current study area (Fig. 1) have proposed numerous paleoglacial characteristics including ice-divide locations, ice-movement chronologies, and general glacial records of ice advance and retreat based on surficial materials distribution and ice-movement indicators (e.g. Wright 1967; Dyke and Prest, 1987; Dyke and Dredge, 1989). Tyrell (1897) was first to suggest ice centres located west of Hudson Bay and south of the Committee Bay study area.

In the early to mid 1950s the Geological Survey of Canada initiated three major field projects covering roughly 480 000 km^2 of central mainland Nunavut (Wright, 1967): Operations Keewatin (in 1952), Baker (in 1954), and Thelon (in 1955). Based on topographic maps, airphotos, and helicopter and/or fixed-wing air support, these projects were able to produce new maps of detailed ice-movement indicators and glaciogenic landforms that ultimately resulted in the recognition of the Keewatin Ice Divide within the Laurentide Ice Sheet, west of Hudson Bay (Lee et al., 1957). Meanwhile, a group of university collaborators utilizing striae data, airphoto interpretation, and compilations of streamlined landforms, came to support the single-ice-dome theory of Flint (1943) for the last glacial maximum of the Laurentide Ice Sheet (e.g. Bird, 1953; Downie et al., 1953). In the ensuing debate, the single-ice-dome theory became generally accepted.

In the 1970s the Geological Survey of Canada initiated another major field project to assist mineral exploration in mainland Nunavut. Ice-movement indicators and dispersal trains identified over the course of this project suggested ice movement into Hudson Bay (e.g. Shilts and Boydell, 1974; Cunningham and Shilts, 1977; Shilts et al., 1979; Shilts, 1980); the concepts put forth by Tyrell (1897) had resurfaced. Subsequent research in central-mainland Nunavut has focused on understanding the complex ice-movement chronology of this region (e.g. McMartin and Henderson, 1999; Little, 2001), and has corroborated and refined the location of the Keewatin Ice Divide (e.g. Nadeau and Schau, 1979; Coker et al., 1992; Klassen, 1995; Little, 2001).

Research endeavours conducted to date within the boundaries of the current study area have been predominately reconnaissance-scale mapping efforts. Craig (1961) covered large portions of NTS 56 K, 56 J, and 56-O during Operation Back River initiated in 1960. Through this field research, he noted an "…orderly retreat of the ice from the sea-coast to…" the 66th parallel based on drumlins, crag-and-tail landforms, striae, eskers, and moraine ridges. Through mapping along coasts and rivers, Craig also was able to identify and ^{14}C date marine strand lines that denoted zones of postglacial submergence. Thomas (1977) briefly discussed the surficial materials observed during further reconnaissance mapping in NTS areas 56 E, F, K, L, M and N, noting that till is the most extensive deposit in that area. This research also lead to the production of the first surficial geology map of NTS 56 K (Thomas and Dyke, 1981).

METHODS

As part of the surficial mapping component of this study, airphoto interpretations were made and field checked with special focus on those areas that were problematic. At each station the following data were gathered: spatial, geomorphic, sedimentological, and terrain inventory information (e.g. map unit). In total, 904 ground-truthing sites were described; at some of these sites drift prospecting samples were also collected (Fig. 3).

Sample media

Basal till and esker sediments were used as sample media for the drift prospecting component of the Committee Bay Project. Various fractions of these media will be used in analytical techniques to determine geochemical and indicator mineral values for eventual release as a GSC Open File. The following is a description of the two sample media, survey design, samples, and data collected during the 2001 field season.

Basal till, a first derivative of bedrock (Shilts, 1993), was sampled from frost boils (cf. mud boils) for the following reasons: 1) frost boils are a product of periglacial processes, bringing relatively unoxidized subsurface (C-horizon) sediment to the surface (Shilts, 1977); 2) frost boils are commonly found within the study area, therefore, in those areas mapped as till, the time required to locate appropriate sites is minimized; 3) geochemical patterns found in basal till produce a regional signature (Levson, 2001); and, 4) the sample material is homogenous at a given sample site giving rise to uniformity of sample material among sample sites (Hornbrook and Allan, 1970).

The relative quality of basal till samples was determined at the time of sampling with each site being placed into one of three classes (based on McMartin (2000)). Class I sample sites were defined as being composed of fresh, light to dark-grey, unoxidized basal till, with the sample itself collected from an active frost boil. Class II sample sites were defined as having weathered surface horizons, or containing oxidized clasts or lenses, and were collected from inactive frost boils. A sample site was placed into Class III if the sample was collected from an inactive frost boil that exhibited oxidation throughout, was very wet, and/or contained organic lenses. Although only a qualitative measure, this information will be useful in interpreting the resulting geochemical data.

Eskers can exhibit anomalous concentrations of representative clasts and indicator minerals that can then be traced upstream to their bedrock source (Lee, 1965; Perttunen, 1989; Korsman and Perttunen, 1989; Perttunen and Vartiainen, 1992). It is for this reason, the ease of sampling the unconsolidated glaciofluvial sediments of eskers, and their common use in diamond exploration, that esker sediments were chosen as a second sample medium for this study.

Survey design

During the 2001 field season, helicopter-supported drift prospecting was conducted in NTS 56 J/9–16, NTS 56 K, and NTS 56-O/1–8. Prior to the 2001 field season, the geological data available for the individual 1:250 000-scale map areas varied; survey design varied accordingly as outlined below.

Survey design for NTS 56 K was guided by five important data sets: preliminary ice-flow history (Little, 2001); 1:250 000-scale map of surficial geology (Thomas and Dyke, 1981); a 1:100 000-scale bedrock geology map (including geochemistry and assay results; Sandeman et al. (2001b)); high-resolution (400 m spacing) aeromagnetic survey; and the NORMIN database (www.inacnt.internorth.ca/normin/). Based on these data, zones with high potential for mineralization were designated as target areas. Within these areas, a sample spacing of 2.5–5 km was applied along traverses perpendicular to ice movement (Fig. 3). At each site within target areas, a 3 kg basal till sample was collected for grain-size analysis, carbonate content, and trace and major element geochemical analyses, and a 10 kg basal till sample was collected for gold-grain counts, pebble lithology, and indicator-mineral analyses. Outside target areas, a reconnaissance-scale approach was utilized and only the 3 kg samples were collected every 5–15 km (Fig. 3). The kimberlite indicator mineral survey in NTS 56 K was designed to sample the largest and most continuous eskers and maximize the sample spatial distribution; the resulting sample spacing is approximately 1 sample per 10 km^2 (Fig. 3).

Within NTS 56 J/9–16 and 56-O/1–8, little geological data was available prior to the 2001 field season. Exceptions to this were locations of known mineral occurrences in NTS

56 J (obtained from NORMIN database), 1:250 000-scale bedrock maps of 56 J (e.g. Fig. 2 *in* Schau (1982)), and a 1:3 500 000-scale bedrock geology map of the 56-O (Wheeler et al., 1997). Due to this lack of geological data, both till geochemistry and kimberlite indicator mineral sample sites were selected with the goal of optimizing the spatial coverage. Where geological and geophysical data were available for identifying target areas, increased sample densities and traverse lines perpendicular to ice movement were utilized.

At all stations, sedimentological data such as sediment type, matrix per cent, texture, colour, sorting, clast size and shape, sample class and depth were collected. In the case of basal till samples, these data were collected to ensure the proper identification of till from other sediment types such as colluvium, earth flows, and glaciolacustrine diamictons. As eskers are geomorphologically unique landforms, these data will be used to characterize the esker site and sediment collected. In order to aid in the terrain inventory and geological

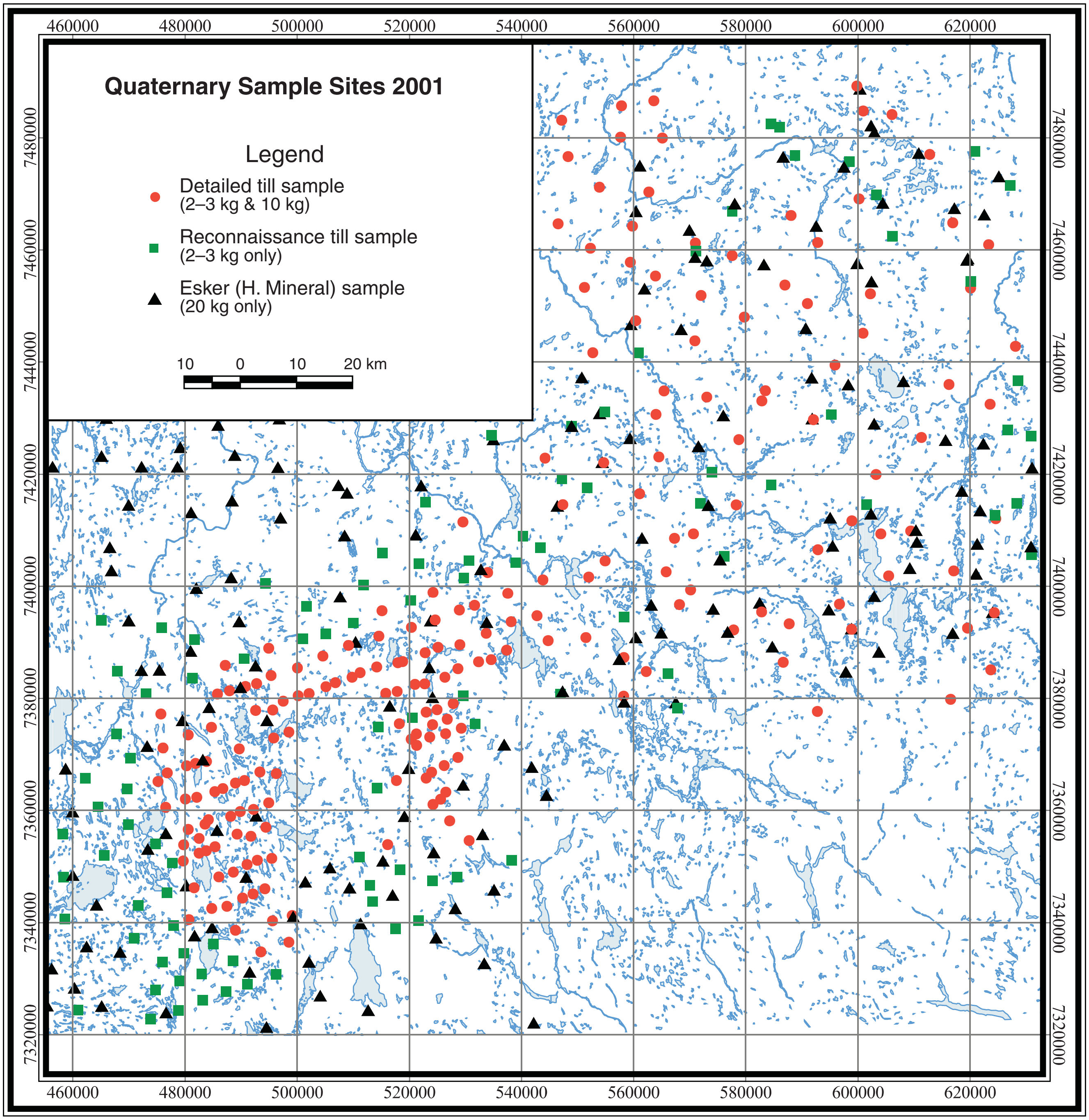

Figure 3. *Sample locations for drift prospecting survey. Samples include detailed (circles) and reconnaissance (squares) till geochemistry samples and kimberlite heavy-mineral samples (triangles).*

interpretations, other descriptions and observations were made regarding map unit, sample site geomorphology, surficial processes (e.g. cryoturbation), whether these processes were active, and assessment as to whether any surficial processes have physically or geochemically altered the sediment.

The samples collected during the 2001 field season (Tables 3, 4) represent only half of the total samples proposed for the drift prospecting component of the Committee Bay Project; all proposed drift samples for NTS 56 K have been collected, whereas only half of those proposed for NTS 56 J/9–16 and 56-O/1–8 have been collected. During the 2002 field season, a reconnaissance scale drift prospecting program will be initiated within NTS 56 P and the remaining proposed samples for NTS 56 J/9–16 and 56-O/1–8 will be collected based on upcoming results from the 2001 field program. Results of the till geochemistry survey conducted in 2001 are planned for release as a GSC Open File in spring 2002 whereas kimberlite heavy-mineral survey data are planned for release in February 2003.

Table 3. Summary of drift samples collected within NTS 56 K.

Sample site type	Number of samples
3 kg basal till* (within target area)	126
10 kg basal till* (within target area)	126
3 kg basal till (outside target area)	67
20 kg esker	91
Total till geochemistry samples	***319***
Total kimberlite heavy-mineral samples	***91***

*At each site within the target area 3 and 10 kg samples were obtained for detailed analyses.

Table 4. Summary of drift samples collected within NTS 56 J (north half) and 56-O (south half).

Sample site type	Number of samples
3 kg basal till* (within target area)	83
10 kg basal till* (within target area)	83
3 kg basal till (outside target area)	33
20 kg esker	74
Total till geochemistry samples	***199***
Total kimberlite heavy-mineral samples	***74***

*At each site within the target area 3 and 10 kg samples were obtained for detailed analyses.

GENERALIZED ICE MOVEMENT IN NTS 56 K, 56 J (north), and 56-O (south)

Within the Committee Bay study area, over 600 measurements at 126 sites have been made on both bidirectional (n=524) and unidirectional (n=79) ice-movement indicators. Together, these data suggest a complicated ice-movement chronology (cf. McMartin and Henderson, 1999; Little, 2001). The following brief discussion presents a preliminary interpretation, and highlights the variation in the last significant ice-movement event to affect the study area.

Little (2001) identified four different ice-flow directions in the southern half of NTS 56 K. Preliminary interpretations of ice-movement data from NTS 56 J and 56-O (Fig. 4) suggest that a wide range of ice-movement directions affected the study area, adding further complexity that was not apparent to Little (2001). Within NTS 56-J, bidirectional indicators span 050° (340°–030°), whereas unidirectional indicators span 190° (290°–120°). Some of these unidirectional indicators may correspond to ice-movement events 3 and 4 of Little (2001) whereas others appear to have parallel trends, but opposite vergences. Similar observations are made regarding ice-movement indicators within NTS 56-O. Bidirectional indicators span 100° (330°–070°), whereas unidirectional data span 120° (300°–060°). Again, some of the data exhibit trends and vergences similar to events presented in Little (2001), whereas other data exhibit parallel trends with opposite vergences. These comparisons may help define the shape, extent, and location of the deglacial and maximum-state ice-divides, and perhaps suggest the presence of an earlier ice divide located between southwestern NTS 56 K and northeastern NTS 56 J and 56-O. Further research in to the validity of these interpretations and correlation between ice-movement indicator data are ongoing (cf. Ozyer and Hicock, 2002).

In order to begin to unravel this apparently complex ice-movement history, our efforts have concentrated on interpretation of the clearly youngest landforms and/or glaciogenic features. New data from NTS 56 J and 56-O now suggest that the late deglacial ice divide did not have a simple linear morphology (cf. Little, 2001) based on the orientation of ice-movement indicators such as striae, grooves, and streamlined landforms.

The unconsolidated, mobile nature of the sediments that comprise morainic landforms such as till flutes and drumlinoids suggest that these features can be extremely short-lived (Sugden and John, 1990). Hence, any subsequent ice movement under warm-based ice conditions would have likely destroyed or re-oriented these landforms. Given the number of eskers and meltwater channels within the study area (cf. Ozyer and Hicock, 2002; Utting et al., 2002) that existed during deglaciation, it is reasonable to assume warm-based ice conditions dominated the final stages of ice movement. Together, these two factors suggest that

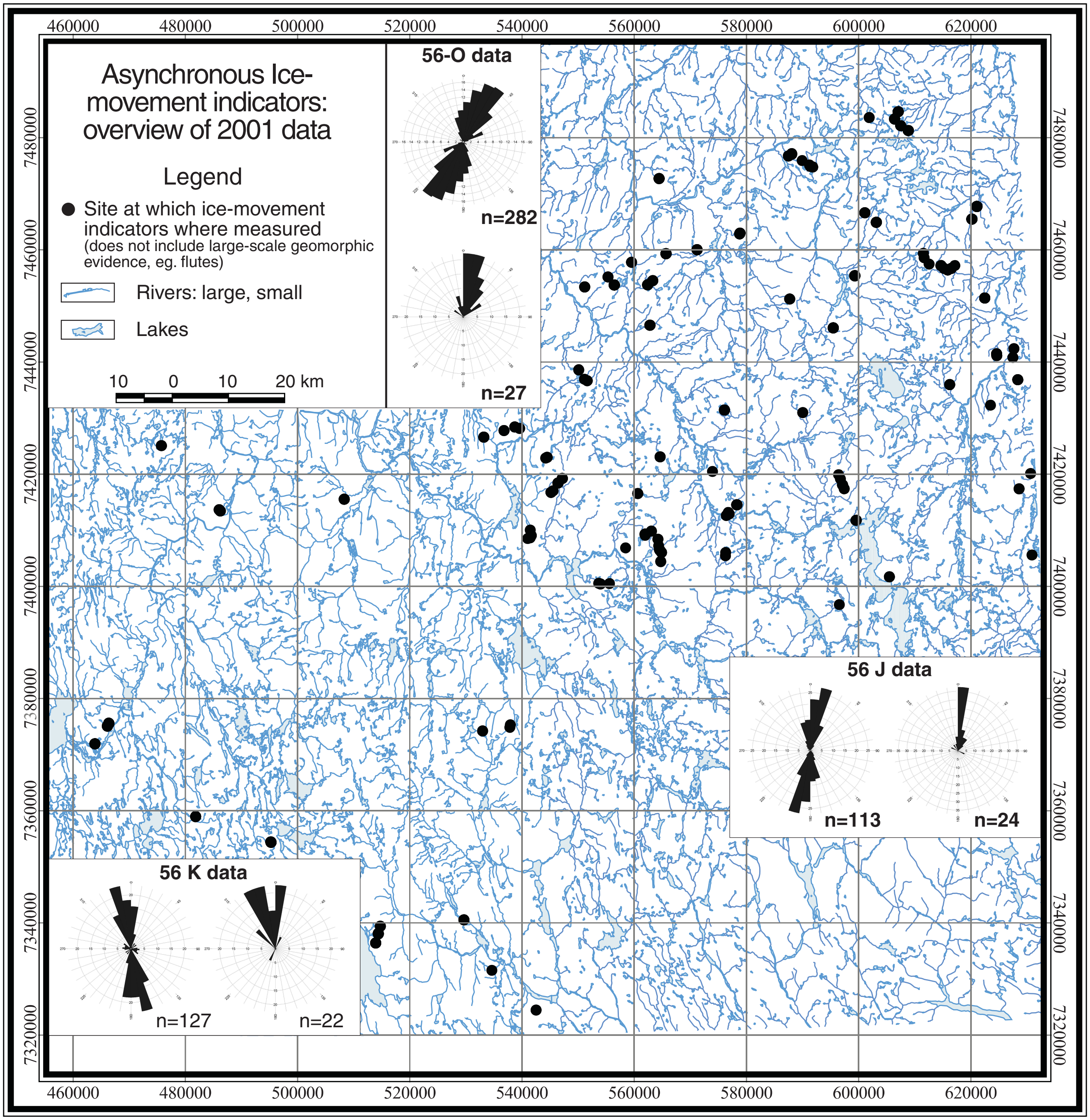

Figure 4. *Asynchronous bi- and unidirectional ice-movement indicators plotted for NTS 56 K, J/9–16, and O/1–8. For detailed discussion of ice-movement within NTS 56 K and 56-O refer to Little (2001) and Ozyer and Hicock (2002), respectively.*

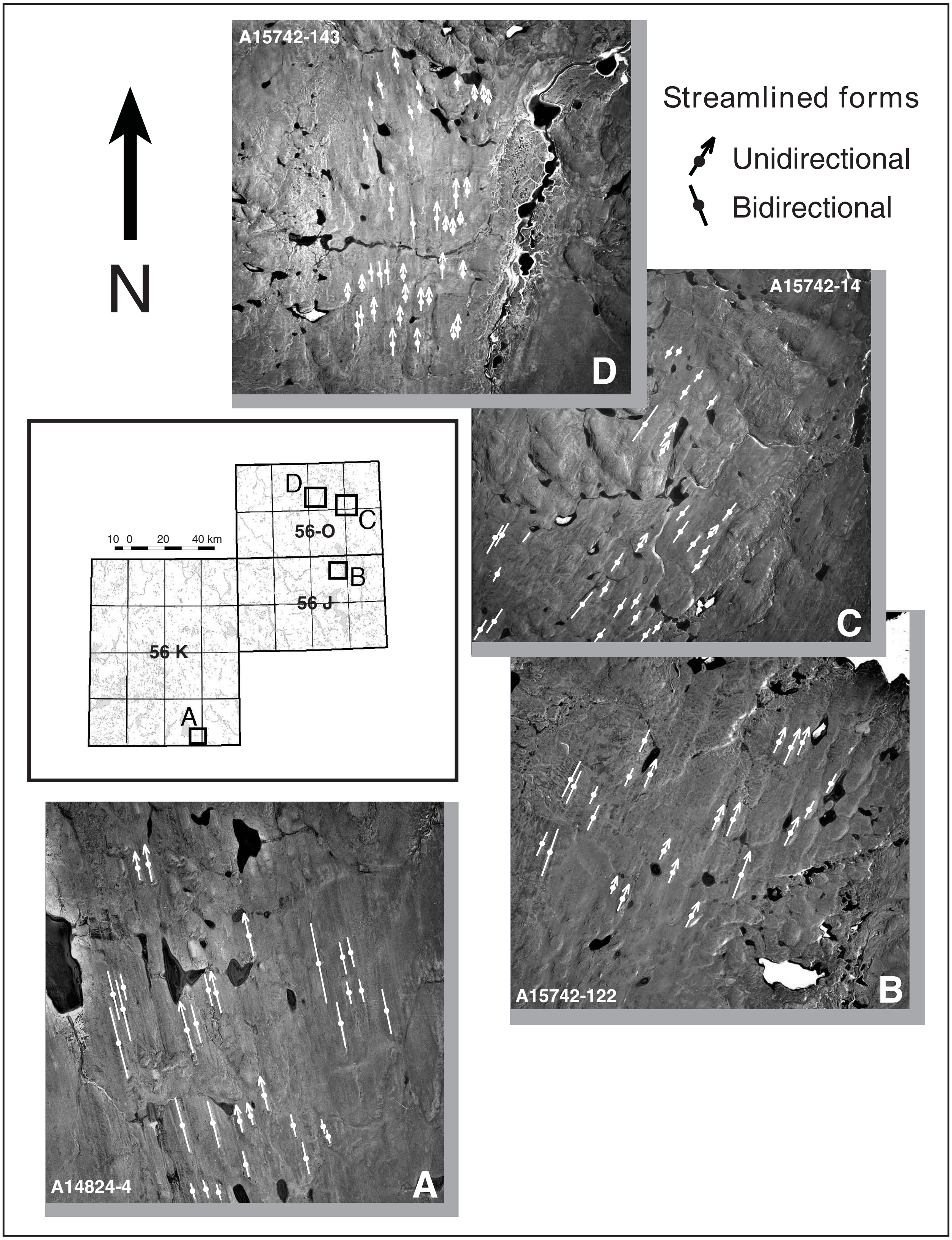

Figure 5. Streamlined glaciogenic landforms composed of till in four different areas within the Committee Bay Study area. See text for detailed discussion. NAPL numbers on each airphoto.

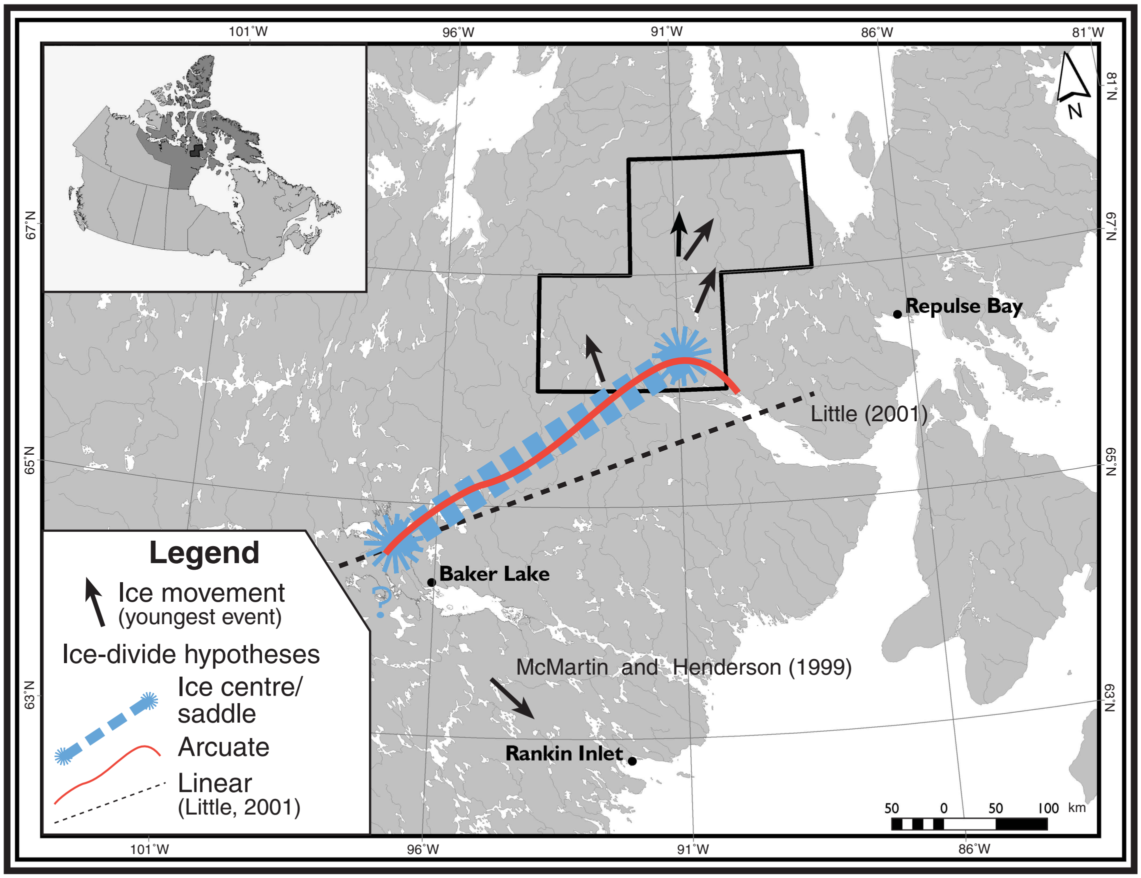

Figure 6. *Schematic diagram of ice-divide hypotheses: ice centres and associated saddle, arcuate divide (cf. Aylsworth and Shilts, 1989a, b; McMartin and Henderson, 1999), and linear ice divide (Little, 2001).*

streamlined landforms in the Committee Bay area likely represent the last ice-movement event to affect the region. Figure 5 illustrates streamlined forms in four different areas within the Committee Bay study area. The westernmost airphoto (Fig. 5A) from NTS 56 K suggests northwest movement of the last active ice in the region (Little (2001), his ice-movement event 4). The easternmost two airphotos (Fig. 5B, C) suggest northeastward ice movement in northwest NTS 56 J and southwest NTS 56-O, respectively. Figure 5D illustrates a northward trend in south-central NTS 56-O that may represent a localized ice-movement event. Collectively, these streamlined landforms portray a divergent fan-shaped ice-movement pattern that, if locally synchronous, would suggest the presence of an arcuate ice-divide located south of study area (cf. Little, 2001) that opened towards the south (cf. Aylsworth and Shilts, 1989a, b; McMartin and Henderson, 1999). Alternatively, an ice-saddle situation could also explain the orientation and distribution of streamlined landforms. In this scenario, ice-movement centres (domes) are connected by a saddle with an axis oriented northeast-southwest. One dome would be located, presumably, south of NTS 56 J/9–12 and the saddle would be southeast of 56 K (Fig. 6). This orientation would produce the consistent northwest ice-movement observed in streamlined landforms within NTS 56 K and also the divergent streamlined landforms observed in NTS 56 J/9–16 and 56-O/1–8.

CONCLUSIONS

During the 2001 field season our efforts focused on: 1) research into the glacial history of the region including the development of an ice-movement chronology (Ozyer and Hicock, 2002) and associated ice-divide reconstruction (this paper), and re-evaluation of the genesis of classical glacial geomorphic features (Utting et al., 2002); and, 2) a drift prospecting program consisting of a reconnaissance-scale till geochemistry survey and a kimberlite heavy-mineral indicator survey.

Upon integration of these two themes, it will be possible to model the mechanical transport of mineralization in basal till by glacial processes within NTS 56 K, thereby investigating the relationships between known mineral occurrences and geochemical and/or mineralogical anomalies in basal till. Future mineral exploration within NTS 56 K (and possibly 56 J, -O, and P) will benefit from this research, as dispersal models developed from these data may provide further insight including 1) determining the characteristics of a geochemical signature within glacial drift from a known mineral occurrence (e.g. length, width, transport distance, pathfinder elements), and 2) the possible identification of new target areas based on a more complete understanding of geochemical anomaly characteristics. Dispersal models could also be applied to the design of drift prospecting programs in areas with similar physical, geomorphological, and geological settings, i.e. NTS 56 J, 56-O, and 56 P.

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