

Peter Lake Domain Project: Quaternary Investigations in the Northwest Reindeer Lake Area (parts of NTS 64E-15 and -16)

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Abstract

Quaternary geological investigations in the MacKenzie, Zengle, and Reindeer lakes area involved surficial mapping at 1:50 000 scale, recording ice-flow indicators, and a regional till sampling survey. The dominant ice-flow direction was to the south-southwest (205° to 210°), becoming more southwesterly (215° to 220°) towards the southern boundary of the map area. Two older regional ice-flow directions are oriented at ~188° (175° to 195°) and 228° to 240°. Rare, faint striae sets trending 154° (two sets) and 295° (one set) were also recorded.

Drift cover is variable. The Crane Island area, is dominated by bedrock (approximately 60 to 80%) mantled by less than 2 m of discontinuous drift cover. The present-day landscape is controlled by the bedrock topography with little geomorphic expression of the glacial deposits. Westward, the drift thickens and is more extensive, with less than 10% bedrock exposure. The landscape is more subdued there and reflects both glacial geomorphic features and bedrock topography.

The dominant surficial sediments are till and organic deposits. Sand and gravel deposits are associated with esker systems, minor meltwater drainage channels, stagnant ice hummocky moraines, and glaciolacustrine littoral deposits. Till occurs primarily as ground moraine veneer, less than 2 m thick, and ground moraine plain, greater than 2 m thick, as well as hummocky moraine and stagnant ice moraine. Ridged moraine and streamlined forms such as drumlins and crag and tails are less common. Till composition varies with the type of deposit, thickness, and source rocks from which it is derived. At least four facies were identified: a silty-sand to sandy till, a very sandy till, a silty-sand matrix-rich diamicton, and a gravelly sand diamicton.

Winnowed and reworked sediments and raised strandlines, such as sand and cobble beaches, terraces, wave-cut notches, and ice-contact deltas indicate that glacial Lake Agassiz extended further north and west than previously thought. The highest strandlines were found at about 425 to 430 m asl. Much of the area below ~350 m asl is characterized by exposed outcrop, boulder lags, and winnowed till.

Several large southwest-trending subglacial meltwater drainage systems cross, or terminate, in the map area. These systems consist of subglacial tunnel valleys and/or esker complexes, and associated ice-contact deposits including ice-contact deltas.

A large part of the area is not suitable for drift prospecting, as bedrock, organic, ice marginal, and wave-reworked deposits dominate the terrain. Drift prospecting techniques are more applicable in the MacKenzie-Zengle lakes area where the drift cover is more extensive.

Keywords: surficial geology, Quaternary geology, glacial geology, till geochemistry, drift prospecting, Reindeer Lake, Peter Lake Domain, northern Saskatchewan, glacial Lake Reindeer, Lake Agassiz, ice-flow history.

1. Introduction

Although the economic potential of the Peter Lake Domain in northeastern Saskatchewan (Figure 1) has long been recognized, mineral exploration has been limited, partly due to poor bedrock exposure and the lack of a clear understanding of the regional geological history. In 2002, the Saskatchewan Geological Survey (SGS) launched a multidisciplinary mapping project to enhance our understanding of the geological framework of the Peter Lake Domain, and to further evaluate its economic potential (Maxeiner and Hunter, 2002; Maxeiner and Leatherdale, 2003; Maxeiner *et al.*, this volume). The main focus of this project is the mafic intrusive complexes in the southern and eastern part of the domain, which are perceived to have substantial potential for platinum group elements (PGEs) (Hulbert, 1989).

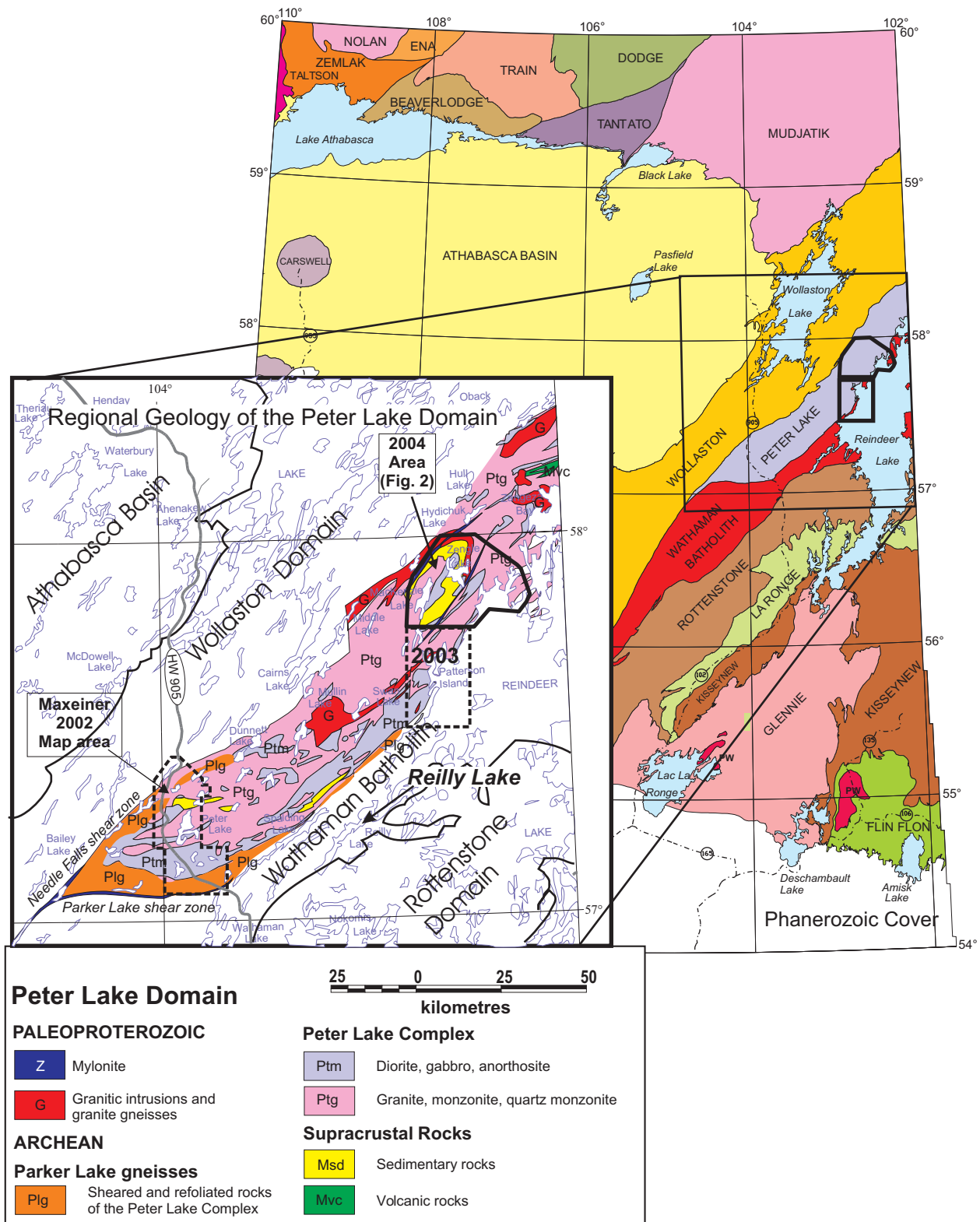


Figure 1 - Location of the northwest (NW) Reindeer Lake map area, eastern Peter Lake Domain, (after Maxeiner et al., this volume).

In conjunction with the bedrock mapping and a multi-parameter airborne geophysical survey, Quaternary geological investigations were initiated in 2003 in the Patterson Island area, Reindeer Lake (parts of NTS 64E-10 and -15) (Campbell, 2003a, 2003b). The primary focus was on the region underlain by the dioritic to gabbroic rocks (unit Ptm, Figure 1) of the Archean Swan River Complex (Corrigan, 2001), and the study involved 1:50 000 scale mapping, recording ice-flow indicators, and a regional till sampling survey. The objectives of this component of the project are to:

- 1) provide a Quaternary geological framework for drift prospecting,
- 2) determine the signatures of precious and base metals in the till down ice from known PGE occurrences,
- 3) determine whether till composition reflects the local bedrock,
- 4) propose a glacial dispersal model for the region,
- 5) provide till geochemical and surficial materials databases to serve as a baseline for mineral exploration and environmental assessment, and
- 6) provide ground truthing for the multi-parameter geophysics survey of the Peter Lake Domain.

Quaternary geological investigations continued in 2004 in the MacKenzie Lake, Zengle Lake, and Crane Island (Reindeer Lake) area immediately north of the Patterson Island map area (Figures 1 and 2), which are collectively referred to as the NW Reindeer Lake area.

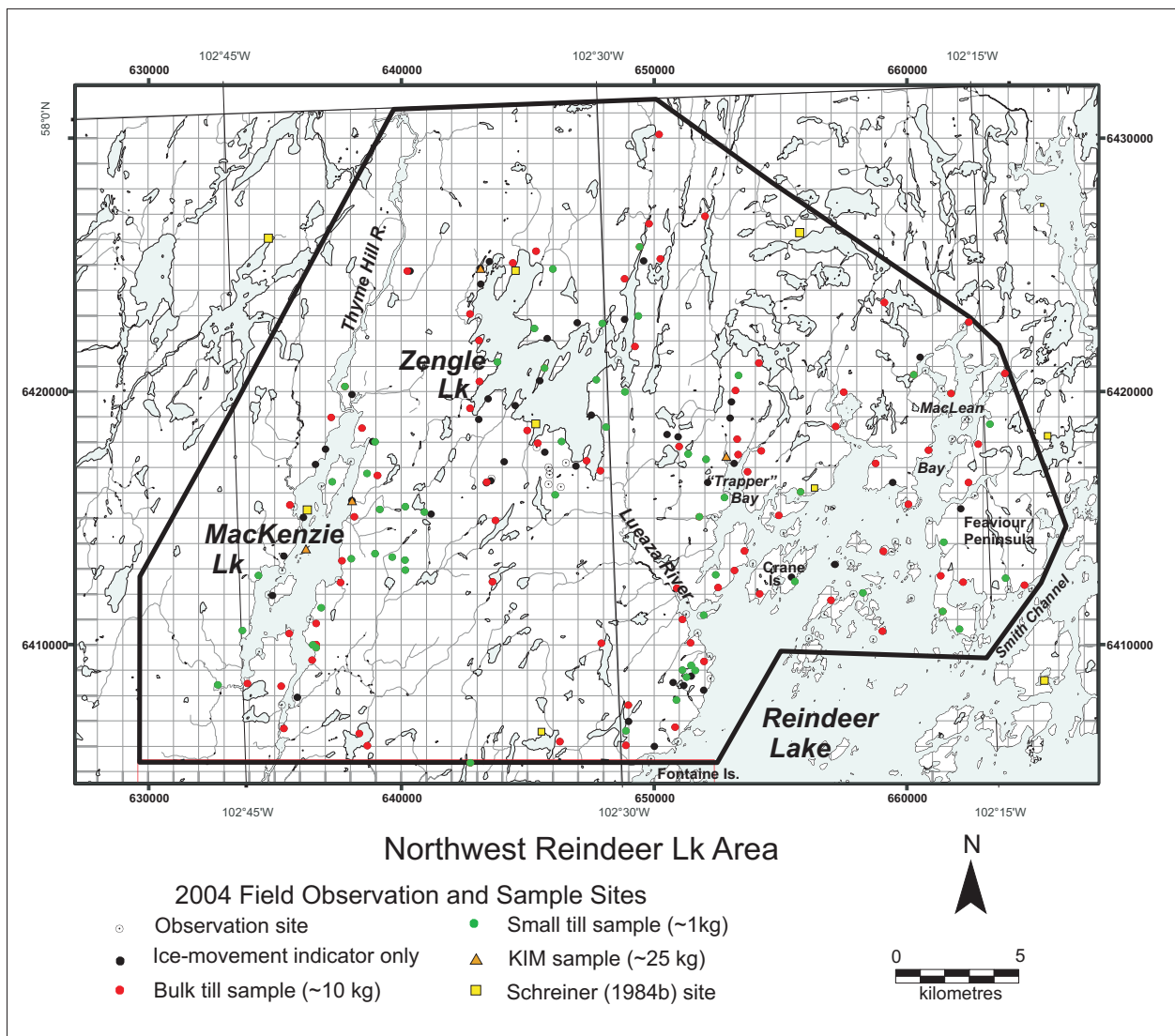


Figure 2 - Detailed location map showing the location of 2004 field and till samples sites. Unofficial names are in quotations.

a) Previous Work

The surficial deposits of the entire Peter Lake Domain were mapped at 1:250 000 scale in the late 1970s (Schreiner, 1984a, 1984b, 1984c). Limited overburden drilling was conducted along Highway 905 as part of that program to gain stratigraphic information.

Campbell (1992) conducted a regional orientation study aimed at determining the applicability of drift prospecting for mineral exploration in the Peter Lake Domain. Selected Saskatchewan Research Council archived till samples collected during the reconnaissance mapping program were analyzed for major and trace elements plus gold. Ten bulk till samples were collected in 1992, primarily along Highway 905, for more detailed studies of till composition. On a regional scale, the composition of the till reflects the local bedrock geology, either underlying or immediately up ice of the sample site (Campbell, 1992; Campbell *et al.*, 1999). The geochemistry of the silt-clay fraction (<0.063 mm) revealed elemental associations characteristic of the metasedimentary, granitic, and mafic source rocks.

Swanson (1996) collected samples from eskers in the Peter Lake Domain as part of a reconnaissance kimberlite indicator minerals (KIM) sampling program in northern Saskatchewan. The data from these samples are included in the Kimberlite Indicator Minerals Digital Database housed on the Saskatchewan Industry and Resources website (www.ir.gov.sk.ca).

b) Current Work

Current surficial geology mapping is based on the interpretation of 1:25 000 and 1:63,360 scale aerial photographs and Landsat 7 imagery with follow-up ground checking. Ground truthing focused on characterization of the various surficial deposits, measurement of ice-flow indicators, collection of till samples, and examination of the surficial sediments and geomorphologic features. No vertical exposures were found to provide stratigraphic information. Field verification was restricted to areas accessible by boat and foot traverse. Limited fixed-wing air support allowed some access to the central and northern parts of the map area.

Till samples were collected at 137 of the 232 field sites (Figure 2). They were spaced 1 to 2 km apart where accessibility allowed. Bulk till samples (~10 kg) were taken, where possible, from the C horizon in pits hand dug to an average depth of 1 m. These samples will be submitted for both kimberlite and base metal(s) indicator mineral analyses, as well as gold (Au) and platinum grain counts. A 1 kg sample was also collected from each pit for determination of 55 major and trace elements plus Au and textural analyses. The pebbles from the 6 to 20 mm fraction will be used to determine the relative abundance of various rock types. The lithological, mineralogical, geochemical, and textural data will be used to define the composition of the till deposits which, in turn, will aid in defining the provenance(s) of the till(s) and the development of a glacial dispersal model for the area. Three 25 kg samples were collected from eskers for kimberlite indicator mineral analyses.

The orientations and relative ages of nearly 500 erosional ice-flow indicators, including striae, microstriae, grooves, crescentic gouges and fractures, chattermarks, roche moutonnées, and other streamline bedforms, were measured at 314 sites. These data include measurements collected by the bedrock mapping crew. Measurements were collected primarily from flat-lying surfaces to avoid the effects of local topography; the majority being from lakeshore outcrops where access and preservation was better than lichen- and moss-covered outcrops found inland. The sense of ice flow was derived from crescentic gouges, and stoss and lee topography landforms such as crag and tails, and roche moutonnées. The relative ages of multiple sets of diverging ice-flow indicators were determined based on the following criteria: a) a set located in a lee position relative to another is older, b) a set preserved only in the depressions is interpreted as older, c) deeper grooves and/or striae cross-cut by a finer set are usually older, and d) a set found only on the top of an outcrop is considered the youngest movement.

2. Regional Setting

The NW Reindeer Lake map area straddles the boundary between the largely Archean Peter Lake Domain of the Hearne Province and the Paleoproterozoic Wathaman Batholith of the Reindeer Zone. The northwestern part of the map area is underlain by syenogranites, megacrystic monzogranites, and dioritic orthogneisses of the Peter Lake Complex (Ray and Wanless, 1980). These rocks are massive to mylonitic and have been metamorphosed under upper amphibolite facies conditions. The central part of the map area is primarily underlain by mafic and alkaline intrusive rocks of the Archean Swan River Complex (Stauffer *et al.*, 1981; Corrigan, 2001) and a subordinate package of mafic volcanic rocks (Corrigan, 2001). The Swan River Complex is composed of massive to layered ultramafic, mafic, and intermediate rocks including pyroxenite, gabbro, leucogabbro, anorthosite, and diorite. It also includes alkaline syenite to monzonite intrusive rocks such as the Patterson Island Pluton (MacDougall, 1988). The eastern part of the area is underlain by megacrystic granitoid rocks of the Paleoproterozoic Wathaman Batholith (Stauffer *et al.*, 1981; Corrigan, 2001). A more comprehensive summary of the regional bedrock geology for the

Peter Lake Domain and its boundaries is provided by Maxeiner and Hunter (2002), Maxeiner and Leatherdale (2003), and Maxeiner *et al.* (this volume).

The NW Reindeer Lake area lies within the Churchill River Upland eco-region and the Hudson Bay drainage basin. The landscape is characterised by bedrock outcrop, glacial deposits, wetlands, and lakes. Local relief is as much as 80 m but rarely exceeds 25 m. The natural vegetation is largely black spruce and jack pine interspersed with white birch. The wetlands are commonly underlain by permafrost and support black spruce and tamarack. The lakes are predominantly southwest trending, parallel to the regional bedrock structure and direction of glacial ice movement.

During the late Wisconsinan glaciation, the Keewatin Lobe of the Laurentide Ice Sheet advanced south-southwestward over the region from a dispersal centre in Nunavut (Prest *et al.*, 1968; Prest, 1984). As the ice retreated from the Reindeer Lake area approximately 8500 to 8200 yrs BP (Schreiner, 1984a), parts of the region were inundated by proglacial Lake Agassiz. Reindeer Lake is a modern remnant of Lake Agassiz, which apparently abandoned the area by 7800 to 8000 yrs BP (Schreiner, 1984a; Teller and Leverington, 2004). Models for deglaciation and the northern extent of the proglacial lakes in Saskatchewan are presented by Schreiner (1983), Teller *et al.* (1983), Dyke and Prest (1987), Dyke and Dredge (1989), Dyke *et al.* (2002), and Dyke *et al.* (2003), Teller and Leverington (2004).

3. Ice-flow Record

Multiple ice-flow directions were documented throughout the map area with the directions and relative ages being similar to those previously found in the Patterson Islands area (Campbell, 2003a). The main ice-flow event during the Late Wisconsinan was to the south-southwest (Figure 3), sub-parallel to the regional bedrock structural grain, which suggests bedrock topographic control. Although the orientation of ice movement indicators ranges from 200° to 214°, most were between 205° and 208°.

As in the Patterson Island area, two older regional ice-flow directions were recognized (Figure 4). Striae and roche moutonnées record more southwestward flows; 230° to 240° (13 sites), and a distinct 220° (21 sites) ice-flow direction. The 220° direction has not previously been recognized as older than the main ice-flow direction and may be a transitional shift in ice flow related to the 230° to 240° event. A southward regional flow direction of about 190° (35 sites) was also documented by striae oriented 175° to 195°. Cross-cutting relationships indicate that the 220° and the 230° to 240° flow directions predated the southward direction.

These flow directions most likely represent shifts in ice-flow direction in response to changing glacial conditions related to the advance and retreat of the Keewatin ice lobe, as well as interaction with the Labradorean ice sheet to the east, during the Late Wisconsinan glaciation. It is proposed that early ice flow was initially to the southwest then swung eastward into Manitoba. This eastward flow is correlated with an early south-southeastward flow from 140° to 170° documented in Manitoba (Kaszycki, 1989a, 1989b). The subsequent swing of the southeastward ice flow towards the south-southwest appears to be transitional as there is a continuum of striae orientation recorded from 175° to 212°. The main regional ice direction to the south-southwest reflects ice flow during deglaciation. Local variations in the striae record reflect topographic deflection of ice flow.

Several rare, faint sets of striae were found on protected surfaces and are cross-cut by the main south-southwest and the south-southeast ice-flow directions. These striae sets have been grouped into two flow directions: one trending southeast from 140° to 150° (three sets); the other flow direction is more east-west trending at 250° to 260°. These striae directions were found in the Patterson Island area (Campbell, 2003a) and northeast quarter of Phelps Lake map sheet (Campbell, 2002a). Schreiner (1984a, 1984b, 1984c) and Campbell (1992) reported a similar southeast (~151°) striae direction in the western part of the Peter Lake Domain. Johnston (1978) and Schreiner (1984d) also reported striae of northwest- to west-trending ice-flow direction around the southern part of Reindeer Lake. Rare due east-west striae were also reported in northwestern Manitoba (Dredge *et al.*, 1986; Kaszycki, 1989a, 1989b).

Extrapolation of these flow directions into other areas is tenuous and their sense of movement is uncertain. Both ice-flow directions have been interpreted as event(s) that predated the main Late Wisconsinan advance. Dredge *et al.* (1986) proposed an eastward flow into northwestern Manitoba north of 58° N, from an initial position of the Keewatin ice divide in the south-central part of the NWT and extended down to at least the Fond du Lac River, Saskatchewan. In contrast, Johnston (1978), Schreiner (1984a), and Kaszycki (1989a, 1989b) suggested that these east-west striae reflected an early westward flow. Kaszycki (1989a, 1989b) suggested the westward striae record may reflect a pre-Late Wisconsinan advance of the Labradorean ice sheet across the Prairies as postulated by Prest and Neilson (1987) and Prest (1990) to account for the distribution of distinctive greywacke erratics derived from eastern Hudson Bay.

Johnston (1978) suggested the southeast striae might be related to westward ice flow and therefore the ice would have flowed to the northwest; however, no evidence was found to support this sense of movement. In fact, an

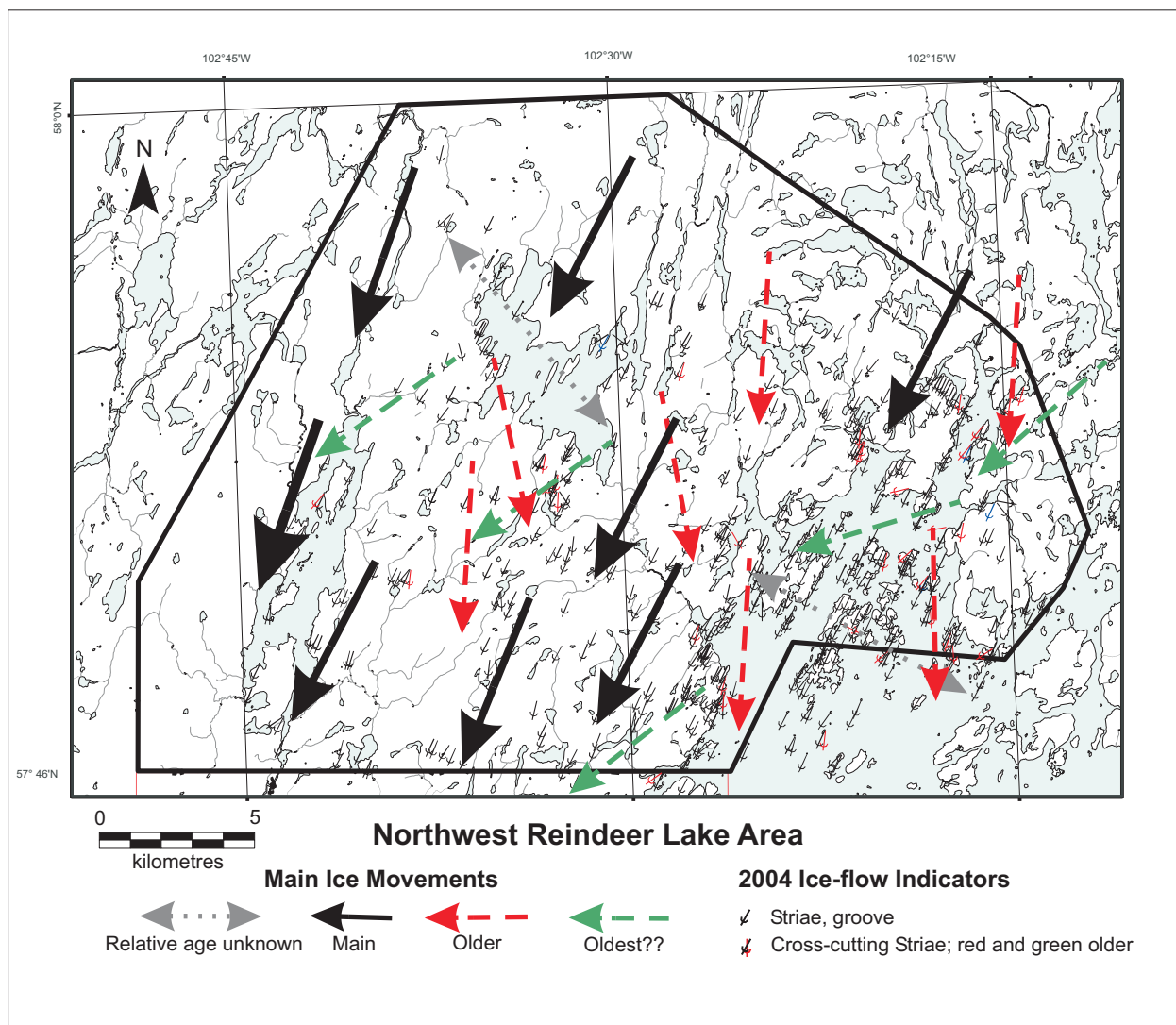


Figure 3 - Regional ice-flow directions compiled from detailed mapping of erosional ice-flow indicators and landform analysis.

Athabasca Group sandstone erratic found this summer in the Crane Island area (Figure 4C) suggests that a southeast ice-flow event transported this cobble from the Athabasca Basin to the NW Reindeer Lake area. The erratic was likely derived from the Manitou Falls D Formation, which lies to the west-northwest of the map area. With the exception of Reilly Lake outlier (Figure 1), which lies south of the Peter Lake Domain, there are no other known Athabasca Group outliers. Although it is probable that the Athabasca Basin extended further east than its present margin prior to glaciation, it likely did not extend far enough east to provide a source for the sandstone detritus to be dispersed south-southwestward into the Reindeer Lake area. Furthermore, a cross-cutting relationship at one site suggests that the southeastward (140° to 150°) ice flow predated the southward (175° to 195°) ice flow.

4. Surficial Geology

Drift cover is variable. There is a relatively sharp break approximately 4 km west of Reindeer Lake between bedrock-dominated terrain and drift-dominated terrain to the west. In the east, the bedrock-dominated terrain is characterized by 60 to 90% outcrop, mantled by thin (less than 2 m thick), discontinuous drift cover, and muskeg occupies the lowlands (Figures 5A and 5B). The majority of the bedrock terrain lies below the 360 m asl elevation contour and thus, below the lower, more sustained water level of glacial Lake Agassiz. This suggests that the abundance of exposed bedrock is, in part, a result of removal of the drift cover by wave action. The present-day landscape in this region is controlled by the bedrock topography with little geomorphic expression of the glacial deposits. Westward, the drift thickens and is more extensive with less than 10% bedrock exposure. The landscape is

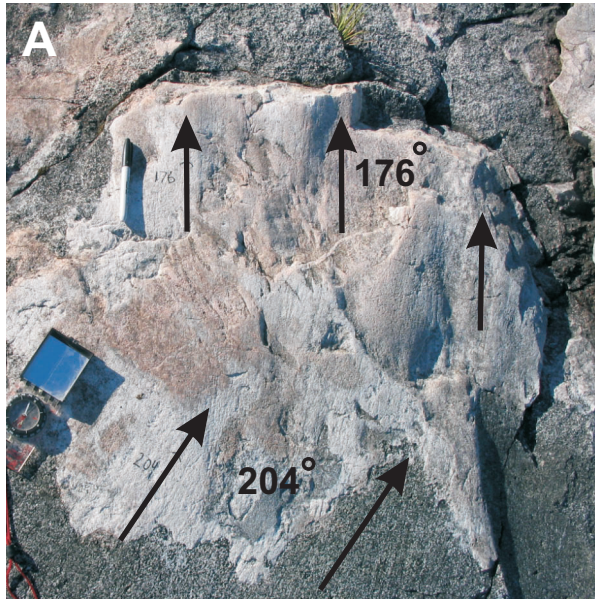


Figure 4 - A) Striae oriented at 176° on protected outcrop surfaces provide evidence of southerly ice flow that predated the main 204° ice-flow direction; B) remolded outcrop records two ice-flow directions; dashed arrow denotes original roche moutonnées oriented at ~240°; subsequent remolding and striae on the surface record the main 204° ice-flow event; and C) cobble-size Athabasca Group sandstone erratic found south of Crane Island, Reindeer Lake.

more subdued and reflects both geomorphic features related to glacial processes and bedrock topography (Figures 5C and 5D).

The depth to bedrock in areas of thick drift is unknown due to the lack of exposed sections and limited drill hole information; however, Schreiner (1984a) and Scott (1970) reported thicknesses of greater than 20 m in the western Peter Lake Domain. Therefore, it is likely that glacial drift associated with streamlined till plains, ice marginal deposits, and esker complexes is more than 20 m thick.

The surficial geology is very similar to that of the Patterson Island area (Campbell, 2003, 2003b). The dominant surficial sediments are till and organic deposits. Most of the significant sand and gravel deposits are part of the major esker systems; however, smaller stratified deposits of these sediments are found throughout the area. These are related to small eskers, meltwater drainage channels, stagnant ice hummocky moraine, and localized glaciolacustrine littoral deposits derived from wave-reworked glacial sediments.



Figure 5 - Bedrock-dominated terrain beside Reindeer Lake is characterized by outcrop ridges with thin, sparse glacial drift cover and interspersed peatlands. A) Aerial view of the terrain west of Crane Island, Reindeer Lake (UTM 651957m E, 66408189m N); B) ground view of the bedrock dominated terrain; C) the landscape to the west, such as south of Zengle Lake, is more subtle due to the thicker and more extensive drift cover; and D) ground view of thick ground moraine typical of the central and western parts of the map area (UTM 640912m E, 6415225m N).

The surficial geology reflects depositional environments of both the advancing and retreating Late Wisconsinan ice sheet. Both ice and water played major roles in sculpting the present-day landscape. Extensive ground moraines were deposited during the main advance and early stages of retreat of the ice sheet. There is abundant evidence that during deglaciation, the ice margin retreated slowly and a proglacial lake inundated the area adjacent to the margin of the retreating ice. Stagnant ice moraines and ice-contact deposits are products of a stagnant ice margin. Channel valleys, esker systems, boulder lags, and fluvial-sculpted ground moraine indicate that large quantities of meltwater drained through subglacial conduits and as sheet flow. Erosional features such as wave-cut notches and extensive wave-winnowed boulder lags are common, particularly below 360 m asl. Further evidence of proglacial lake(s) are sandy to cobbly beaches, bars and spits developed from reworked till, and glaciofluvial deposits.

a) Till Deposits and Associated Landforms

Till occurs primarily as ground moraine, and to a lesser extent, as hummocky moraine, and stagnant ice moraine. Streamlined moraine constitutes a small component of the surficial geology and is primarily restricted to the north and northwest parts of the map area. Other streamlined landforms such as crag and tails are locally present. The composition of the till varies with the type of deposit, thickness, and source rocks.

As in the Patterson Island area, only one till unit composed of several facies was recognized. These surface tills were deposited by the last major Late Wisconsinan glacial event. Schreiner (1984a, 1984b) found two till units in the western Peter Lake Domain where the lower till was preserved in topographic lows. Therefore, in areas where the drift is thick, it is possible that multiple till units exist. At least four till facies were identified: 1) a silty-sand to sandy till, 2) very sandy till, 3) a gravelly sand diamict, and 4) a matrix-rich diamict (Figure 6F). Till veneers

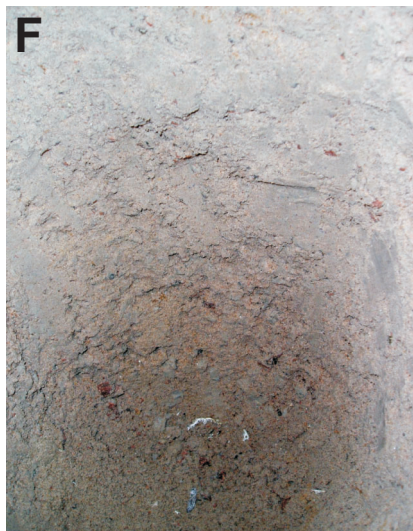


Figure 6 - Till deposits: A) silty-sand to sandy till (UTM 650894m E, 6412225m N); B) hummocky stagnant ice moraine (UTM642796m E, 6423047m N); C) bouldery, sandy till of stagnant ice moraine; D) sand and gravel diamicton terrain (UTM 648097m E, 6418530m N); E) sand and gravel diamicton over silty-sand till; and F) matrix-rich diamicton (UTM 635574m E, 6410427m N).

consist primarily of locally derived material, whereas the thicker till deposits, such as till plains, crag and tails, and stagnant ice deposits, have a higher component of exotic or allogenic debris.

The various till deposits and their associated landforms are described in the following sections. For detailed descriptions of the till deposits refer to Campbell (2003a).

Silty-Sand to Sandy Till

The most common till is the silty-sand to sandy till, the texture of which is dependant on the dominant rock type from which it was derived (Figure 6A). Tills with greyish silty-sand matrix and higher clay content tend to be rich in mafic intrusive, metavolcanic, and/or metasedimentary detritus. Tills derived from felsic intrusive rocks and orthogneisses are brown, sandier, and have a lower clay content. The majority of these deposits are interpreted as subglacial-meltout tills (Shaw, 1979; Campbell, 2001a, 2002a, 2003a).

In the southern and west-central parts of the area, where the drift cover is thick, the surface till tends to be sandier and less compact, with a lower boulder to pebble size content. There is a greater mixture of clast lithologies, including rock types exotic to the area, indicating inclusion of far-traveled detritus.

The silty-sand to sandy till is mainly associated with flat to low-relief till plains and veneers (Figures 5C and 5D). These deposits are associated with the main south-southwest ice-flow direction.

Very Sandy Till

A brown to greyish-brown bouldery, sandy till with a sandy to very sandy matrix is the dominate surface deposit in the Thyme Hill River–MacKenzie Lake area, east and north of Zengle Lake (Figure 2; Figures 6B and 6C). Less extensive deposits of the very sandy till occur elsewhere. Compositionally, this till is highly variable both vertically and laterally. The sandy till is associated with ice marginal deposits, subglacial drainage systems, and hummocky, stagnant ice moraine. The terrain underlain by the very sandy till is typically hummocky, and characterized by gently undulating to high-relief (>10 m) knob and kettle topography (Figure 6B). The surface of the moraine is commonly strewn with boulders of variable size and lithology. This sandy till is differentiated from the previously described silty-sand to sandy till by its lower silt-clay content, bouldery nature, lack of textural mottling, looser compaction, and its landform association (Figure 6C).

Sand and Gravel Diamicton

The sand and gravel diamicton is less common than in the Patterson Island area. The diamicton occurs sporadically as a discontinuous veneer, overlying either bedrock or the silty-sand till, but is most common along the shores of Reindeer Lake and in the vicinity of MacKenzie Lake. It consists of a loose, poorly to moderately sorted, gravelly, medium to coarse sand, which locally contains small amounts of silt and clay (Figures 6D and 6E). The sand and gravel diamicton has no geomorphic expression and its similarity to bouldery till made it difficult to distinguish on aerial photographs and on the ground (Figure 6D). In sample holes it is difficult to distinguish from ice-contact sands and gravels or washed tills. The diamicton is interpreted as an ice marginal ablation till deposited by retreating ice during the final phase of deglaciation.

Matrix-rich Diamicton

A matrix-rich silty-sand diamicton is present north of Zengle Lake and around the south-southeastern part of MacKenzie Lake. The matrix is texturally and structurally very similar to the silty-sand till; however, the clast-size fraction is sorted and constitutes a low percentage of the deposit. Rare to no boulders were noted at the surface. Within the sample hole, all of the clasts were pebble-size, generally less than 20 mm diameter, were uniformly angular to sub-angular, and were generally exotic rock types. The deposits were commonly normally graded. At one site, the deposit consisted of graded matrix-rich diamicton overlying dirty, yet well-sorted gravel. Matrix-rich diamictons have been interpreted as flow tills, most likely deposited in a subaqueous environment (Figure 6F).

Eroded and Washed (Reworked) Tills

Boulder lags commonly armour the surface of the terrain, particularly below 360 m asl (Figure 7A). A coarse-grained, poorly sorted diamicton is commonly associated with the boulder lags. These deposits are generally less than 50 cm thick and grade into the underlying till. They are interpreted to have been produced by winnowing of the fines from the till by wave action when the region was occupied by a proglacial lake. The winnowed material from the till was redistributed to lower elevations as linear, sandy, pebbly glaciolacustrine deposits.

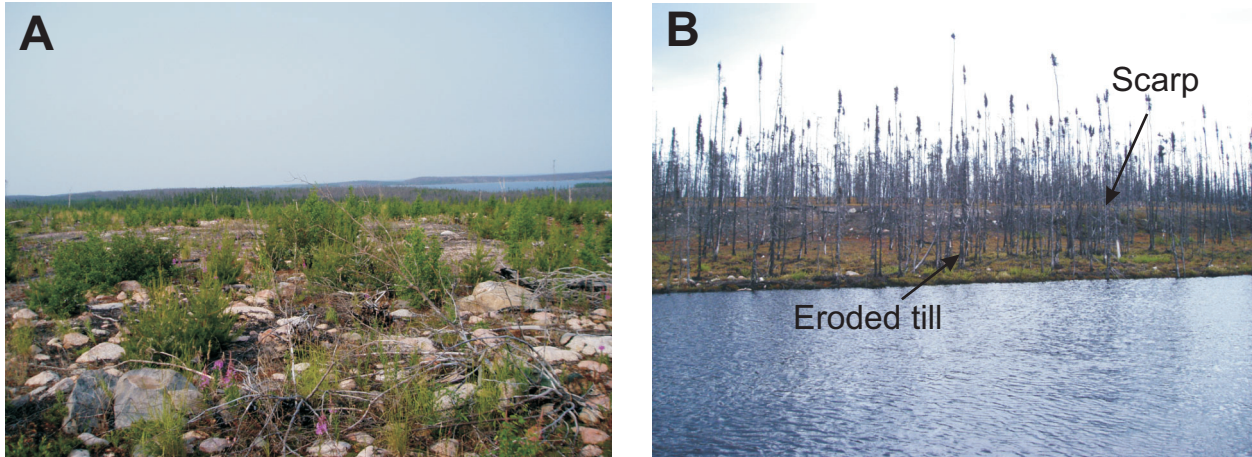


Figure 7 - A) Wave-winnowed boulder lag on ground moraine (UTM 662806m E, 6417905m N); and B) streamlined landforms with steep, eroded sides interpreted to be remnants of a till plain carved by subglacial meltwater (UTM 648572m E, 6421213m N).

It is evident in the digital elevation model (DEM) and air photo mosaics that much of the area was modified by fluvial erosion. Low-lying areas between the uplands channeled meltwater draining from the ice. Localized boulder pavements, boulder fields, and small deposits of modified till also occur in these channels, which were active both beneath (subglacial) and/or in front of the ice (proglacial).

Undulating to flat-topped, streamlined landforms with terraced and/or scarp slopes northeast and west of Zengle Lake and east-southeast of MacKenzie Lake are erosional remnants of till uplands dissected by meltwater flow (Figure 7B). They are similar to those in the northern Phelps Lake map sheet (NTS 64M: Campbell, 2001a, 2001b, 2002a, 2002b), and in the Porter Bay, Reindeer Lake area (Campbell, 2003a), which were interpreted as products of subglacial meltwater erosion.

b) Glaciofluvial Sediments (Stratified Drift) and Associated Landforms

Stratified sand and gravel, and minor silts constitute approximately 30% of the surficial sediments. They are mainly ice-contact deposits associated with esker complexes, subglacial channels, stagnant ice moraine, and ice-margin features, but include small outwash plains and terraces associated with meltwater channels (Figure 8). Numerous isolated, small esker ridges overlying other deposits and following the underlying topography were formed in englacial tunnels and set down on the surface as the ice melted. Eskers on the floor or along the tops of valley side-walls formed at the base of the ice and indicate these valleys were parts of a subglacial meltwater drainage system during deglaciation. Associated deposits and features include exposed bedrock, boulder-armoured eroded surfaces, terraces, and small outwash plains. The majority of these meltwater channels follow bedrock-controlled valleys. Once ice-free, many channeled meltwater away from the ice margin or were flooded by the proglacial lake.

The largest stratified drift deposits are the dendritic esker and/or subglacial meltwater channel systems, some of which are part of larger regional drainage systems. Grain size varies considerably over their length, from sorted sand, to matrix-supported gravels, to cobbles and boulders with no matrix. Other associated deposits that flank the eskers include kames, transverse crevasse fill ridges, ice-contact deltas, and outwash sand plains (Figure 8). Stagnant ice moraine deposits of sandy, gravelly till and sand and gravel commonly border the larger esker systems.

The largest subglacial drainage system is the south-southwestward-trending Thyme Hill River–MacKenzie Lake corridor. The present-day river north of MacKenzie Lake occupies a subglacial meltwater channel that cut between two uplands and eroded into ice-contact and till deposits to produce scarp slopes (Figure 9A). The floor of the valley is characterized by boulder-armoured eroded till, boulder fields, and a small discontinuous esker. Parallel to this subglacial system is a well-developed cobbly to sandy esker complex that starts north of the map sheet and extends to the Zengle Lake area (Figure 8A), where it jogs westward through a valley to MacKenzie Lake where it joins up with the MacKenzie Lake system. It continues southwestward from MacKenzie Lake across the extreme northwest corner of the Patterson Island map sheet as part of a large southwest-trending dendritic esker system that crosses the entire Peter Lake Domain (Campbell, 2003a, 2003b).

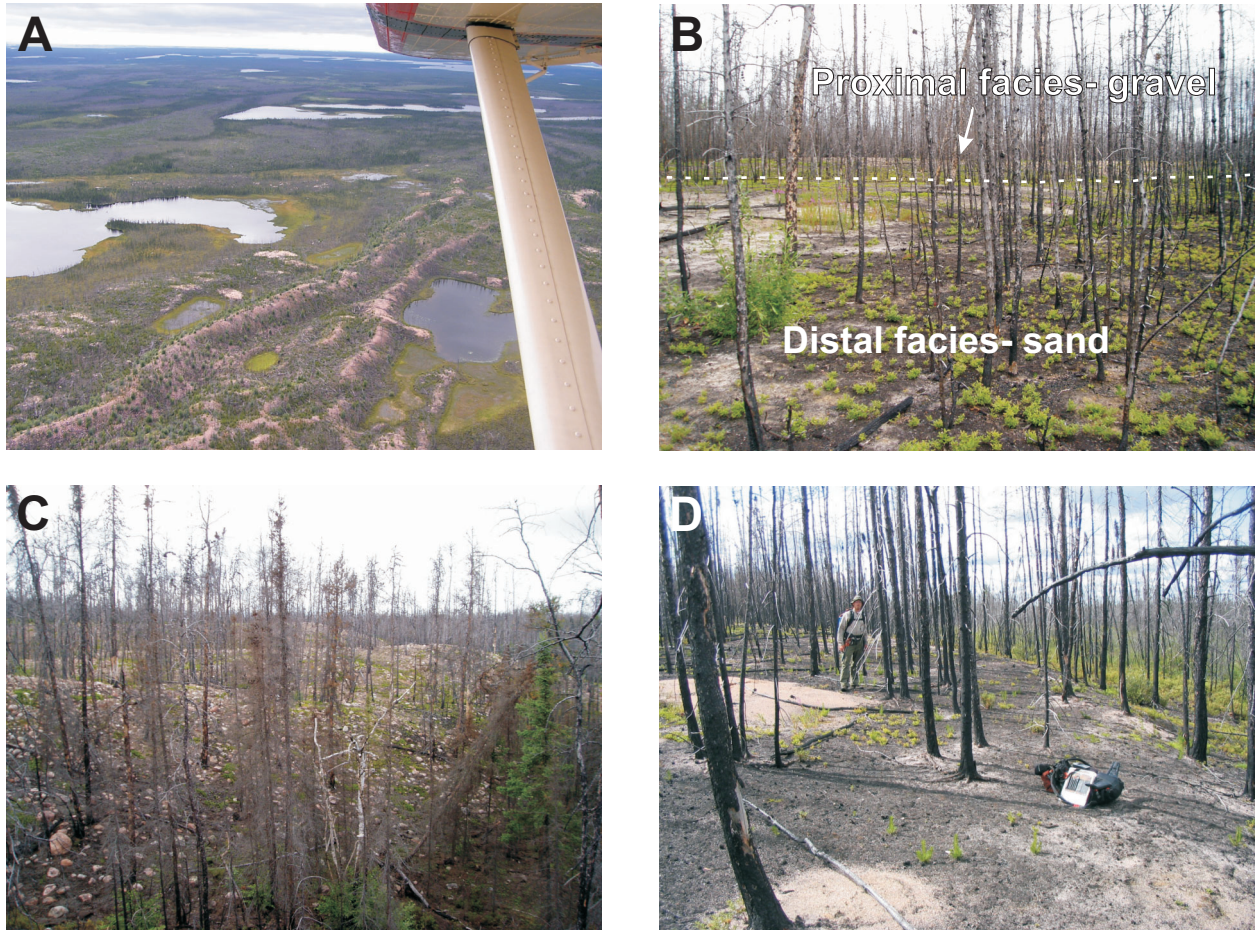


Figure 8 - Ice-contact glaciofluvial deposits in the NW Reindeer Lake area. A) Zengle Lake esker system near north map boundary (UTM 647690m E, 6433119m N). Lueaza River esker system: B) ice-contact delta (UTM 652109m E, 6416395m N); C) hummocky ice-contact drift (UTM 652331m E, 6416618m N) west of Trapper Bay; and D) outwash sand plain in the south-central part of area (UTM 643045m E, 6411482m N).

The landscape in the southwest part of the MacKenzie Lake area is dominated by stagnant ice hummocky moraine composed of very bouldery ice-contact and till deposits interspersed with outcrop and glaciofluvial sands (Figure 9B). The unique characteristics of this landscape are the abundance, size (up to 3 m diameter), and monolithologic composition (megacrystic granite) of the subrounded to rounded boulders that dominate the surface (Figure 9C). This boulder moraine is associated with the subglacial drainage system and indicates high energy and volume of meltwater flow under confined conditions.

Two other major esker systems cross the central part (Lueaza River) and eastern side (Smith Channel) of the map area (Figure 2) and terminate within it. The Lueaza River esker system comprises at least two discontinuous esker tributaries. Northeast of Zengle Lake, the tributaries were subglacial channels with discontinuous sandy esker ridges following two parallel, north-south, fault-controlled bedrock valleys. Southeast of Zengle Lake, the drainage systems cross the drift-covered, low-relief terrain as ice-walled subglacial conduits, resulting in gravelly to sandy esker ridges and associated deposits (Figure 9D) that join just west of the river (Figure 9E). There are several ice-contact deltas and outwash fans along the esker, the largest of which is at its terminus. Southwest from the terminus of the esker, outwash sand plains (Figure 8D) and meltwater channels indicate proglacial meltwater drainage continued beyond the ice margin. The deltas developed in proglacial lakes present at the ice margin and mark successive positions of the retreating ice front. Ice-contact deltas also occur as part of the Zengle Lake esker.

A large sand and gravel esker complex that originates to the northeast in Manitoba terminates along the north shore of Smith Channel. The sandy glaciofluvial sediments have been modified and reworked by wave action into a series of beach ridges and terraces.

Isolated ice-contact ridges and hummocks, too small to map at this scale, are scattered throughout the area (Figure 9F). They range from well-sorted, stratified, clean gravel and sand to coarse cobbly to bouldery debris. These

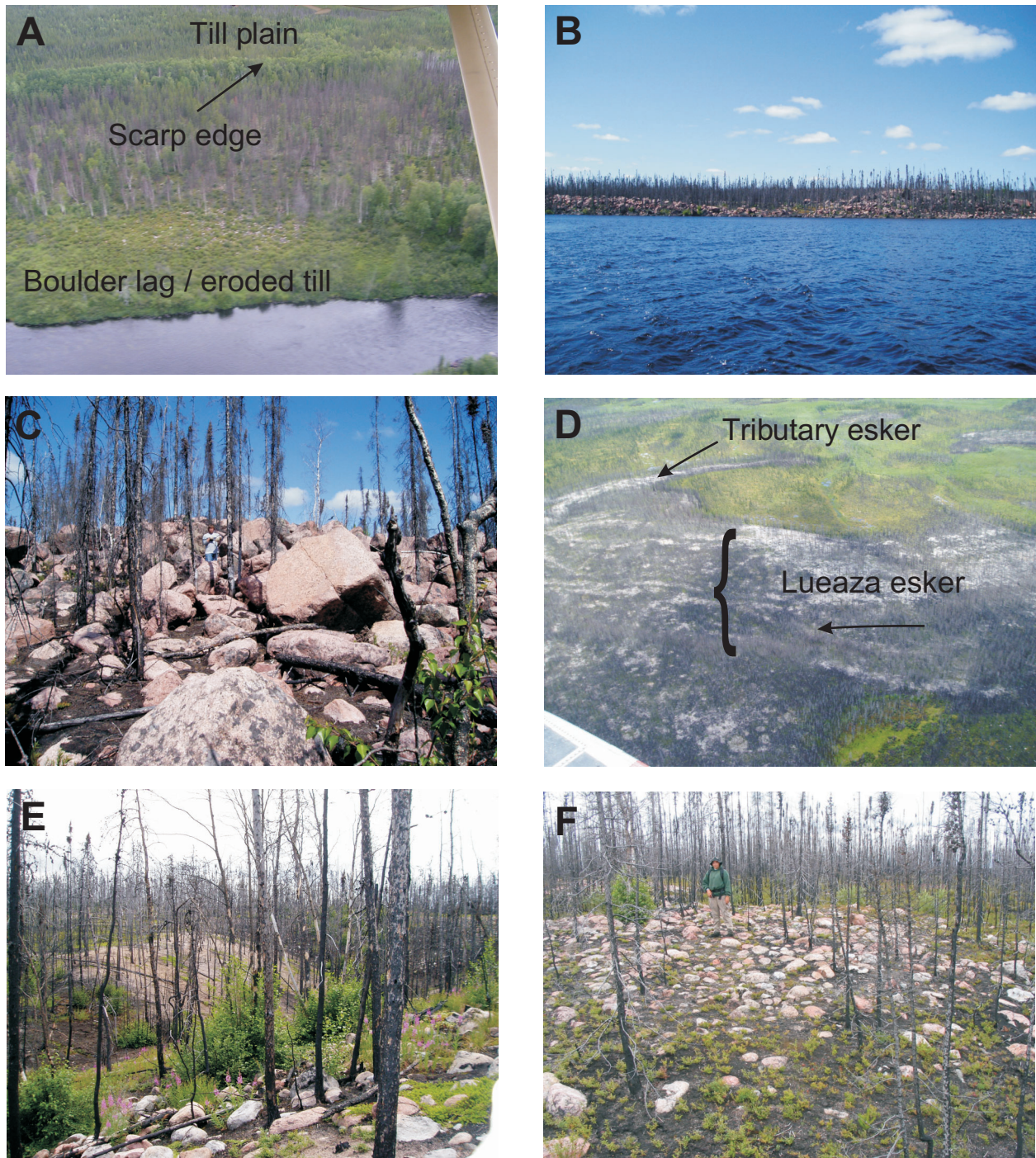


Figure 9 - Thyme Hill River–MacKenzie Lake subglacial drainage system: A) Thyme Hill River occupies a channel eroded into a till plain producing scarp slopes north of MacKenzie Lake (UTM 639208m E, 6423722m N); B) bouldery, hummocky ice-contact deposits along the southwest shore of MacKenzie Lake are dominated by (C) large, subrounded monolithologic boulders (UTM 633714m E, 6410556m N). Lueaza River esker system: D) cobbly esker ridge and adjacent sand plain west of “Trapper Bay” (UTM 652309m E, 6416669m N); E) a tributary esker joins the Lueaza esker southwest of Lueaza River (UTM 648184m E, 6413967m N); and F) ice-contact cobble “hills” in the south-central part of the area (UTM 643313m E, 6413624m N).

deposits are commonly associated with stagnant ice moraine and meltout tills indicative of ice-marginal depositional environments.

Minor, thin discontinuous veneers of well-sorted sands capping till and bedrock are scattered throughout the map area. The sands are associated with nearby eskers, within and adjacent to meltwater channels, or occur as discrete isolated patches on the till plains.

c) Glaciolacustrine Sediments and Associated Features

Campbell (2003a, 2003b) identified sporadic lacustrine deposits and raised strandlines, such as sand and cobble beaches, terraces, and wave-cut notches in the Patterson Island area, indicating that glacial Reindeer Lake and/or glacial Lake Agassiz extended further north and west than previously recognized (Schreiner, 1983; Teller *et al.*, 1983; Teller and Leverington, 2004). The majority of the beaches were formed at approximately 350 ± 5 m asl and were well developed, indicating that the lake level stood at this elevation for some time. Strandlines above 355 m asl are poorly developed and less common, suggesting that these lake levels were short lived, probably before the 350 m asl lake stand. The higher strandlines were interpreted to be those of glacial Reindeer Lake, whereas the lower ones represent the shoreline of glacial Lake Agassiz, which occupied the basin for a longer time (Campbell, 2003a).

This past summer, evidence of a proglacial lake was found at much higher elevations. Sand and cobble beaches were found as high as 425 to 430 m asl at several locations (Figures 10A to 10C). At site PL04-55, located on the crest of the upland above the cobble strandlines shown in Figures 10 A and B, the till surface was winnowed, suggesting that the water level was at a higher elevation and thus covered the entire upland. Several moderately well-developed strandlines were also found between 410 and 370 m asl. Ice-contact deltas occur at elevations ranging from 370 to 405 m asl. The higher elevation strandlines were not observed in the Patterson Island area as most of that area is below 410 m asl. As in the Patterson Lake area, numerous well-developed beaches, wave-cut notches, and terraces are at ~350 to 355 m asl. Much of the area below ~350 m asl is characterized by outcrop, boulder lags, and winnowed till (Figures 5A, 10D, and 10E).

Nearshore and littoral lacustrine sediments constitute less than 5% of the surficial materials. They comprise moderately to well-sorted sand, gravel, and/or cobbles reworked by wave action from the underlying till and glaciofluvial deposits (Figures 10C and 10D). The largest deposit is a sand plain along the northwest shore of Mackenzie Lake. Smaller deposits within the Reindeer Lake basin include raised beaches, bars, and spits. These deposits occur below 360 m asl. Well-sorted sands that occur sporadically within valleys could be either fluvial or littoral deposits.

Kaszycki and Way Nee (1990) mapped strandlines at elevations greater than 400 m asl east of Brochet, Manitoba (NTS map sheet 64F) indicating that this higher water level, proglacial lake also occupied the region to the east of the Reindeer Lake. Based on their regional extent, these high elevation strandlines are more likely related to glacial Lake Agassiz rather than glacial Reindeer Lake, if indeed that lake existed. Therefore, the northwest extent of Lake Agassiz around 8,400 C¹⁴ BP was more extensive than previously reported (Schreiner, 1983, 1984a; Teller *et al.*, 1983; Teller and Leverington, 2004). Although the amount of glacio-isostatic rebound in this region is unknown, the higher elevation strandlines suggest that the water level may also have been higher during this stage of Lake Agassiz.

Note, that the elevations presented here are estimations derived from GPS-determined locations plotted on 1:50 000-scale topographic maps. Many of the strandlines are not visible on the 1:63,360- or 1:25 000-scale aerial photographs. Caution is advised when comparing these elevations with other quantitative paleo-lake elevation data.

d) Organic Terrain

Many of the streams and small lakes are bordered by wetlands. Peatlands commonly occupy low-lying areas between bedrock ridges and uplands. In the north, peatlands are relatively small and shallow. In areas of thicker drift, they are more extensive and commonly thick enough to obscure the underlying topography. Discontinuous permafrost is most commonly found within the peat deposits. Peat plateaus and mounds, and thermokarst features related to the presence of permafrost were observed in bogs and fens.

5. Glacial Dispersal

Glacial dispersal can be mapped at varying scales from regional (hundreds of kilometres), to local (1 to 10 km) to detailed (less than 1 km). While definitive glacial transport distances and directions have not yet been determined, field observations of the pebble to boulder fraction suggest significant variability in dispersal distances depending on the type of till deposit, its thickness, and the resistance of the rock types to comminution and weathering.

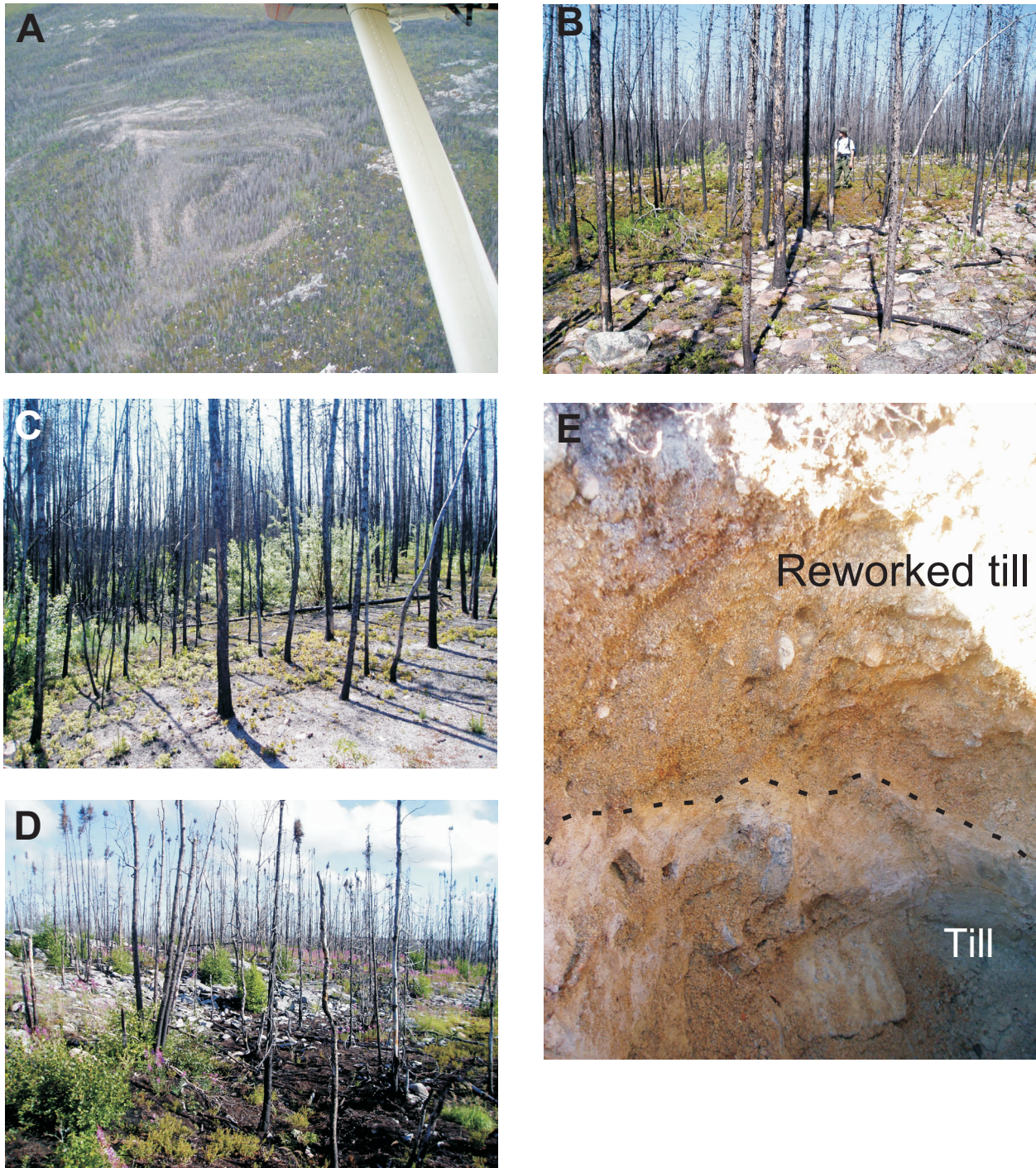


Figure 10 - Raised strandlines of glacial Lake Agassiz. A) Aerial view of well-developed beaches above 410 m asl south of Zengle Lake (UTM 643359m E, 6416389m N); B) ground view of the cobble beaches at about 425 m asl and to the east; C) a sandy beach at about 423 m asl, the proglacial lake was to the left in both (B) and (C) photos; D) wave-winnowed cobble paleoshoreline at ~350 m asl with pebbly sand deposits from reworked till at the base of the cobble slope south of Crane Island, Reindeer Lake (UTM 651958m E, 6409337m N); and E) close-up of the pebbly glaciolacustrine sands (reworked till) overlying unmodified till.

Regional-scale transport of glacial debris is evident. In addition to the Athabasca sandstone cobble mentioned previously, several exotic boulders (erratics), including slightly deformed polymictic conglomerate boulders were found in the Crane Island area (Figures 11A and 11B). A greater abundance of similar conglomerate boulders were found in the northeast quadrant of Phelps Lake map sheet (Campbell, 2002a; Harper *et al.*, 2002), approximately 200 km to the north. These boulders were probably derived from the Hurwitz Group several hundred kilometres to the north in Nunavut. A white mature quartzite boulder, found in the Patterson Island area in 2003, is tentatively attributed to the Kinga Formation, Lower Hurwitz Group (Figure 11C) (Harper, pers. comm., 2004). These boulders are indicators of regional dispersal of glacial debris over distances greater than 250 km from sources to the north-northeast.

During the 2003 field season, a detailed orientation study was done at the Cu-Pt-Pd Antoine Showing to investigate dispersal and detection of Pt-Pd in till (Campbell, 2003a). Neither geochemical nor indicator mineral/ Pt-Au-Cu grain dispersal was detected in the till approximately 450 m down ice from the showing. This was not completely unexpected as the surficial geological conditions in the area surrounding the Antoine Showing are not considered favourable for drift prospecting. Thin drift, the abundance of ice-contact and organic deposits, and a high water table hampered sample collection. Further detailed studies are warranted at other known mineral occurrences to characterize the signatures of platinum group elements and associated base metals in till.

6. Implications for Drift Prospecting

Although the till geochemical, textural, lithological, and mineral indicator data are unavailable for interpretation, a few preliminary comments can be made concerning the application of drift prospecting for mineral exploration in the NW Reindeer Lake area. Surficial conditions are similar to the Patterson Island area, and therefore, many of the implications outlined by Campbell (2003a) apply to this region.

- 1) Much of the area is unsuitable for drift prospecting. In the east, near Reindeer Lake, bedrock with interspersed organic deposits dominates the terrain. Till in this region is commonly very thin, patchy, and wave winnowed. Ice-contact drift and ablation till are common within and adjacent to the subglacial channels and esker systems. This material commonly occurs as a thin veneer and is difficult to distinguish by surface characteristics from the subglacially derived till. Drift prospecting is more suited in the central and western parts where the drift cover is more extensive; however, there are significant expanses of fens and bogs which would inhibit till sampling.
- 2) Although the area has been influenced predominantly by ice flowing to the south-



Figure 11 - Exotic boulders (erratics) in the NW Reindeer Lake area. A) and B) Weakly metamorphosed polymictic conglomerates from the Crane Island area (A: UTM651827m E, 6411138m N; B: UTM 660243m E, 6412485m N); and C) white fine-grained quartzite (Patterson Island area 64E-10; UTM 646375m E, 6396385m N).

southwest, the complex ice-flow history (multiple directions and relative ages) must be taken into account when applying dispersal models to geochemical or indicator-mineral anomalies.

- 3) Soil profiles are well developed, with thick Ae and B horizons, indicating heavy leaching and oxidation of the sediments. Till is oxidized to depths greater than 1 m in some areas. Due diligence is needed when sampling in order to obtain results representative of the metal concentrations in the till and minimize secondary accumulations associated with soil-forming processes.
- 4) Boulder lags and winnowed till are common below 350 m asl elevation. The boulders may hamper till sampling. The upper 40 cm of the till has commonly been affected by wave action, resulting in removal of the fines and natural concentration of heavy minerals. This concentration effect must be taken into account when interpreting grain count data. Till samples should be collected from the underlying, unmodified till.
- 5) Field observations suggest that the silty-sand to sandy till is, for the most part, locally derived and the preferred sampling medium; however, the thickness of the deposits is an important factor in controlling renewal distances (distance from source) of rock detritus and the degree of dilution by exotic material. Consequently, the thicker the deposit, the larger the component of distally derived material.
- 6) Exotic debris derived from outside the Peter Lake Domain, as a result of regional scale dispersal, may hinder interpretation of regional till geochemistry by influencing background element concentrations as well as affecting the resolution of local geochemical anomalies. For instance, the far-traveled debris may be geochemically impoverished with respect to the local bedrock, and therefore, could mask or suppress local mineralization. Alternatively, if the exotic material is geochemically distinctive and dispersed over a large area of metal-poor rock lithologies, false geochemical anomalies may result. Either case would lead to an incorrect assessment of the mineral potential of a region.
- 7) Till composition studies, surficial geological mapping and ice-flow history are crucial components for drift prospecting programs in this region of the Peter Lake Domain.

7. Future Work

Sample analyses and interpretation of the textural, geochemical, and lithological till data is in progress. The focus will be on characterizing the various till deposits, identifying their provenance(s), and developing a glacial dispersal model(s) for the region. Bulk tills will be processed for Au and Pt grain counts, and kimberlite and base metals indicator minerals. All analytical data is slated for release in 2005.

8. Acknowledgments

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