ERCB/AGS Open File Report 2008-02

Surficial Geology of the McLennan Area (NTS 83N/NE), Alberta: Report to Complement Surficial Geology Map 418

Energy Resources Conservation Board

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Surficial Geology of the McLennan Area (NTS 83N/NE), Alberta: Report To Complement Surficial Geology Map 418

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Energy Resources Conservation Board
Alberta Geological Survey

April 2008

ISBN 978-0-7785-6955-8

Fenton, M.M. (2008): Surficial geology of the McLennan area (NTS 83N/NE), Alberta: report to complement surficial geology Map 418; Energy Resources Conservation Board, ERCB/AGS Open File Report 2008-02, 27 p.

Published April 2008 by:
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Acknowledgments

Surficial mapping was completed in 2006. Nigel Atkinson and John Pawlowicz participated in the field mapping, and Scott Botterill and John Jamieson provided field assistance. Manuscript was reviewed by Nigel Atkinson, Roger Paulen, Glen Prior, Gisela Hippolt-Squair and Aimee Maxfield. Maryanne Protz prepared the manuscript for publication.

Abstract

The purpose of this survey was to map the distribution of surficial materials, understand Quaternary history and collect samples to characterize the glacial sediments' geochemistry and indicator mineral content. The McLennan study area (NTS 83N/NE) is west of Lesser Slave Lake and a few kilometres north of the town of High Prairie. The physiography includes the Heart River Upland and the Peace River Lowlands. The Peace River Lowlands, below approximately 680 metres above sea level (asl), include Falher Plain, Bearhead Plain and the High Prairie Plain.

The Heart River Upland is a wooded terrain with abundant wetlands that includes a broad area of glacial sediment—mainly till—in the north-central part with hummocky to flat glaciolacustrine sediment covering much of the remainder. Major meltwater systems include a southwest-trending channel occupied by the South Heart River and a second channel in the west, trending southeastward to form a major glaciofluvial delta on the north side of the South Heart channel. In places, these glaciofluvial sediments have been blown into dunes. The Peace River Lowland is an open, low-relief terrain that is extensively cultivated. The primary surficial material is glaciolacustrine sediment deposited in glacial Lake Peace

There is evidence for three relatively stable lake stages of glacial Lake Peace. A high-level stage at about 680 to 670 m (asl), an intermediate level at about 640 to 630 m (asl), and a final low stage at about 595 to 590 m (asl). Lake sediment above 680 m (asl) may have been deposited as local isolated lakes or during an earlier and higher stage of glacial Lake Peace. Following glacial lake drainage, much of the High Prairie Plain was gradually covered by fluvial sediment from the South Heart River and smaller streams flowing northward from the Swan Hills. A few landslides have occurred in the bedrock exposed in the south flanks of the Heart River Uplands.

The Quaternary stratigraphy and glacial history is poorly understood; only a few deep exposures have been examined in the study area. A section along the South Heart channel exposes about 3 m of pebbly sand over a clay till. One site in the north-central part of the study area exposes a massive grey-brown till overlying a lighter olive-brown till. The uppermost till is correlative with other surface tills in northern Alberta deposited by the Late Wisconsin Laurentide Ice Sheet. The underlying till may be tentatively correlative to other older till units recognized to the north in the Buffalo Head Hills.

1 Introduction

As part of a multi-year initiative, the Alberta Geological Survey (AGS) continued its surficial mapping program focusing on the McLennan map area (NTS 83N/NE), the northeast quadrant of the Winagami map area (NTS 83N). This work was released as AGS surficial geology Map 418 (Fenton 2008).

The survey's objectives were the

a) determination of the distribution of surficial materials, particularly granular resources;

b) determination of the Quaternary and glacial stratigraphy and history; and

c) collection of reconnaissance till samples to document the texture (grain size), matrix carbonate, geochemistry and indicator mineral content.

This report's purpose is to present information and figures to complement the surficial geology map for the McLennan area. The study area is in north-central Alberta (Figure 1), west of the Lesser Slave Lake and a few kilometres north of High Prairie (Figure 2). The town of McLennan is in the west portion of the area (Figure 2).

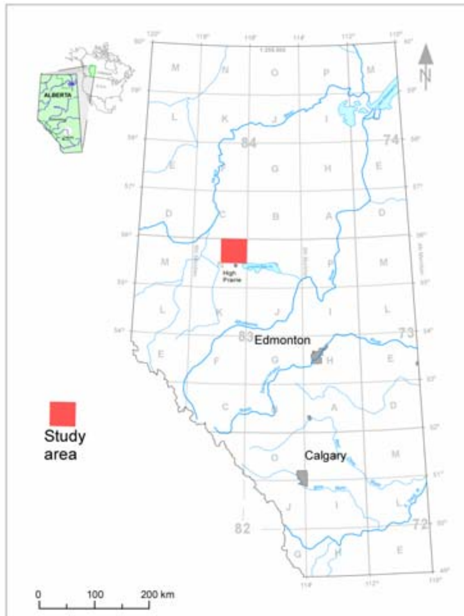

Figure 1. Location of the map area, north-central Alberta.

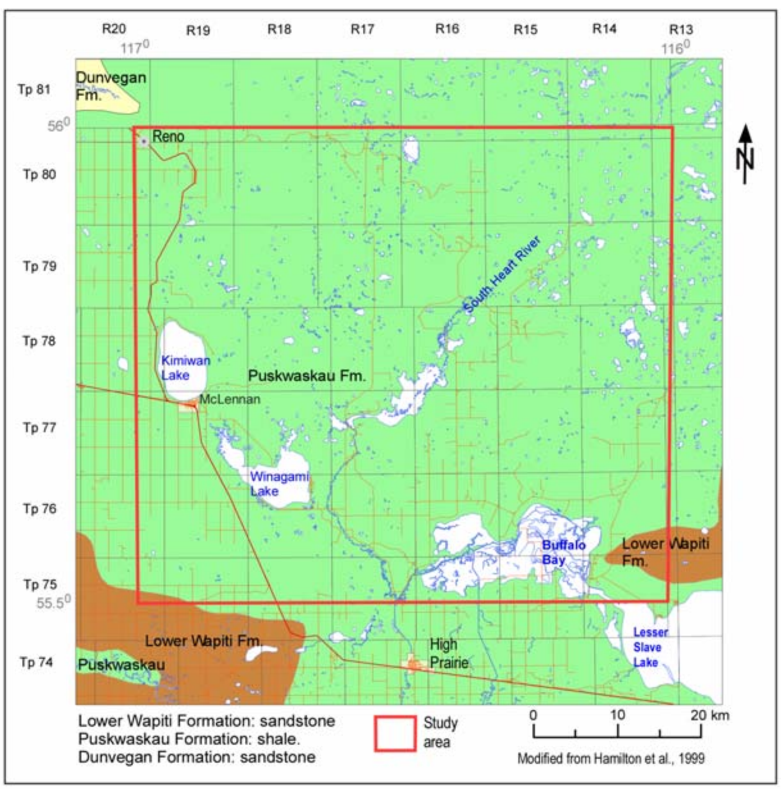

Figure 2. Location and bedrock geology map of the study area.

The McLennan area is underlain by Upper Cretaceous Age clastic bedrock (Figure 2) with the units described by Glass (1990) and Hamilton et al. (1999). The Puskwaskau Formation extends over almost all the area and consists of thinly bedded, dark-grey, fossiliferous marine shale. This formation, the youngest unit of the Smoky Group, is conformably overlain by the Wapiti Formation. The lower part of the Wapiti Formation subcrops in the southeast and in the extreme southwest, and consists primarily of thinly bedded to massive, medium to coarse-grained, calcareous, feldspathic, clayey, fresh-water sandstone. Bentonitic mudstone and bentonite, with scattered clay beds and coal seams may be present. The Dunvegan Formation, underlying the Puskwaskau, subcrops just beyond the study area, northwest of Reno (Figure 2). The unit consists of grey, fine-grained, feldspathic sandstone with thin beds of shale, shelly limestone and coal deposited in a deltaic to shallow-marine environment.

The study area encompasses two major physiographic units: the Heart River Upland in the northeast (a component of the Utikuma Uplands) and the Peace River Lowlands in the west and southeast (Figure 3; Pettapiece, 1986). This lowland unit lies below approximately 680 m (asl), and includes Falher Plain in the west, Bearhead Plain in the west and southwest, and the High Prairie Plain in the southeast. The Natural Regions include the Dry Mixedwood Subregion and the Central Mixedwood Subregion (Downing et al., 2006). The Dry Mixedwood unit corresponds approximately to the Peace River Lowlands and the Central Mixedwood to the Heart River Upland.

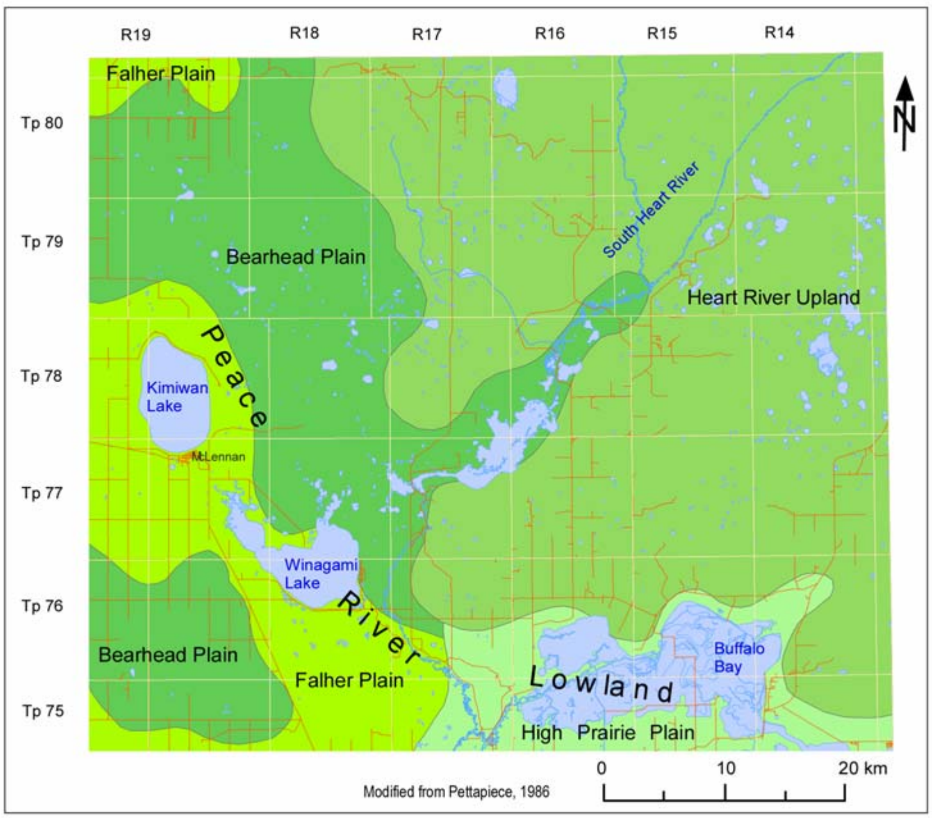

Figure 3. Physiography of the study area.

2 Surficial Geology

Reports containing information pertinent to the surficial geology and the Late Wisconsin glacial history include soil survey reports (Wyatt, 1935; Odynsky and Newton, 1950; Odynsky et al., 1952, 1956). Earlier Quaternary investigations in the Winagami region have been complete to the west of the map area (Henderson, 1959; Liverman, 1989; Balzer, 2000). The hydrogeology of the region was examined by Borneuf (1980a, b).The surficial geology has been mapped to the north (Fenton et al., 2003; Paulen, 2004; Paulen et al., 2004a), east (Paulen et al., 2004b) and south (St-Onge, 1966). Examination of granular aggregate resources in this region has been conducted at the reconnaissance scale, various aspects of which are reported by Edwards and Scafe (1994) and Balzer (2000).

Fieldwork was conducted during late July and early August 2006. Initial preliminary maps were compiled using 1:60 000 scale air photographs flown in 1985, supplemented by LandSat 7 satellite and Shuttle RADAR Topography Mission (SRTM) DEM imagery. After ground truthing, the revised surficial maps were scanned and vectorized using ArcInfo™. Following review and editing, the final map products were prepared.

The Heart River Upland/Central Mixedwood is a wooded terrain (aspen, spruce and pine) with abundant wetlands, primarily bogs and fens. There is extensive energy development and significant aspen and conifer harvesting with only minor agriculture. This upland includes a broad area of moraine in the north-central part (Figure 4). Hummocky to flat glaciolacustrine sediment covers much of the rest of the upland, and varies from massive silty clay to clayey silt to rhythmically laminated clay and silt. At some sites these rhythmites also include interbeds of massive stony to silty clay diamicton. Thickness of this glaciolacustrine cover is variable: in some places it forms a thin and discontinuous veneer, whereas in other regions it is two or more metres thick.

Figure 4. Southward view of a small meltwater channel eroded into low-relief hummocky moraine, north-central portion of Heart River Upland (Approximately Twp. 79, Rge.15 W 5th Mer.).

There are a number of glacial meltwater channels in the Heart River Upland. The largest is a southwest-trending channel occupied by the South Heart River (Figure 5). These channels are cut into the hummocky glacial substrate, typical of Nye or N-channels (Nye, 1973), and possibly initially formed under retreating or stagnating ice. Within the upland there are extensive deposits of glaciofluvial sand and minor gravel. In places, this sand has been remobilised by eolian activity to form dunes (Figure 6). Another channel system trends southward, eastward, and finally, southward in the western portion of the area to form a major glaciofluvial delta on the north side of the South Heart channel (Twp. 78, Rge. 16, W 5th Mer.).

Figure 5. Southward view of the South Heart River meltwater channel. Hummocky glaciolacustrine sediment occurs to the west (right) and low hummocky glaciofluvial sediment occurs to the east (left; approximately Twp. 80, Rge. 14, W 5th Mer.).

Figure 6. Sand dune ridge east of the South Heart River. Approximately one metre of well-sorted, fine grained eolian sand overlies a metre of glaciofluvial pebbly sand which, in turn, overlies glaciolacustrine sediment. (Site MF06-075; Twp. 80, Rge. 14, W 5th Mer.).

The Peace River Lowland/Dry Mixedwood is an open, low-relief terrain consisting primarily of cultivated land (Figure 7). During the last major glaciation, the Laurentide Ice Sheet flowed up the regional slope toward the west and southwest, overriding the entire area. As the Late Wisconsin glaciers retreated, the ice front melted back toward the east and north, damming the meteoric and glacial meltwaters to form glacial Lake Peace (Mathews, 1980). One stage of glacial Lake Peace inundated the lowlands below 680 m (asl), depositing glaciolacustrine silty clay over a broad area and resulting in a relatively flat, stone-free landscape ideal for agriculture. In some places, the glaciolacustrine sediment was deposited over stagnant ice; the subsequent melting of the buried ice produced a hummocky topography. The exact reasons the ice remained submerged and did not float to the surface are uncertain and include the ice being frozen to the underlying land, the ice containing enough debris to counteract its buoyancy and/or the submerging lake being to shallow. The close proximity of the ice margin during the formation of glacial Lake Peace is indicated by the presence of coarser sediment and interbeds of diamicton. In deeper, distal portions of the glacial lake, rhythmites consisting of fine sand, silt and clay laminae formed (Figures 8 and 9a). Stones dropped from floating icebergs are also in the glaciolacustrine sediments (Figure 9b). At surface, the rhythmically bedded sediments form a relatively flat, low-relief plain (Figure 10).

Figure 7. The Peace River Lowland is composed mainly of open, low-relief cultivated terrain underlain by glaciolacustrine sediment. (Near site MF06-067; approximately Twp. 80, Rge.19. W 5th Mer.).

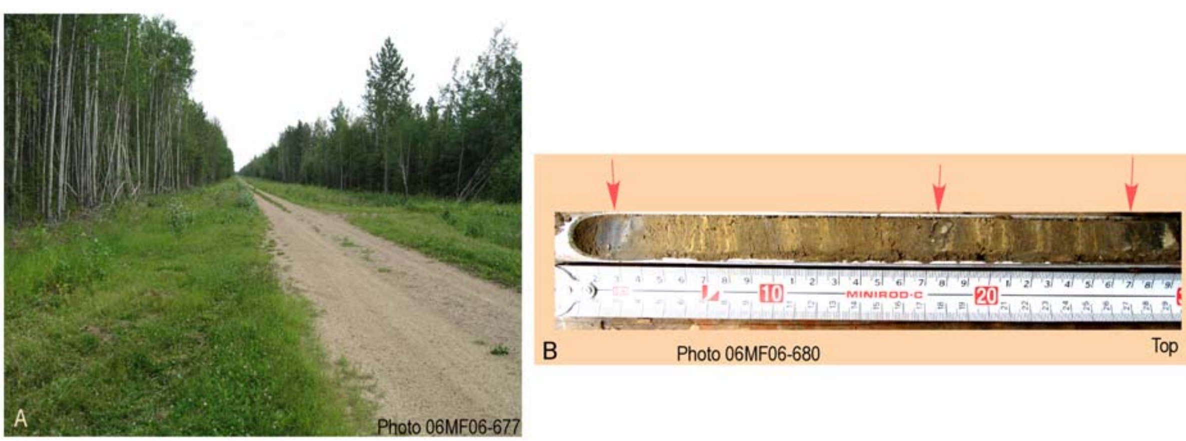

Figure 8. Glaciolacustrine plain northwest of north side of Winagami Lake. A) Flat topography. B) Core in soil probe shows the thinly laminated sediment with three clay laminae (arrows). (Site MF06-034; Twp. 79, Rge.19, W 5th Mer.).

The submergence of the landscape by glacial Lake Peace occurred in several stages. Evidence was observed for one or more early phases of ice-dammed lake(s) forming above 680 m (asl) and three lower and relatively stable glacial lake levels. These three stable glacial lake phases occurred successively, with water planes lowering as the ice margin retreated northward and eastward uncovering successively lower drainage outlets: a high-level lake phase formed at about 680 to 670 m (asl), an intermediate level formed at about 640 to 630 m (asl), and a final low-level phase formed at about 585 to 595 m (Figure 11). The glacial lake sediment lying above 680 m may have been deposited in some places as local isolated lakes and in other places during an earlier and higher stage of glacial Lake Peace (Taylor, 1958, 1960; Henderson, 1959; St-Onge, 1972; Mathews, 1980). Portions of this sediment were deposited over stagnant glacial ice that later melted to produce the current hummock topography.

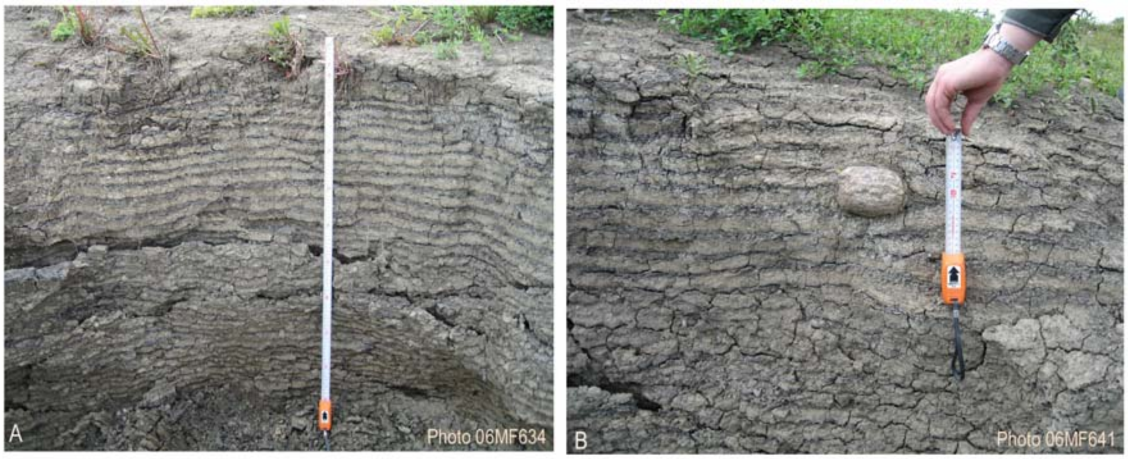

Figure 9. Glaciolacustrine sediment above bedrock scarp west of Buffalo Bay. A) Exposure of glaciolacustrine rhythmites. B) A dropstone impacting and deforming the underlying laminae. Tape measure in left photo is 1 m long. (Site MF06-034; Twp. 79, Rge.19, W 5th Mer.).

Figure 10. Flat landscape typifies the region blanketed by glaciolacustrine sediments. Site is just above pit shown in Figure 9. (Site MF06-016; Twp. 76, Rge. 15, W 5th Mer.).

The high-level lake phase is demarked by a well-developed wave-cut scarp at approximately 680 to 670 m (asl). This scarp is believed to be a continuation of the scarp recognised by Paulen et al. (2004b) along the north side of Lesser Slave Lake. This lake stage would have deposited sediment over all of the Peace River Lowlands and part of Heart River Upland (Figure 11a). The intermediate lake level at about 630 to 640 m (asl) formed beaches and littoral strandlines at a number of sites. A wave-cut scarp formed southeast of Reno (Figures 2 and 12) and lag deposits formed due to winnowing in the northwest part of the map area (Figure 13) and on the flanks of a recently emerged 'island' within glacial Lake Peace (Figure 11b). The lowest and final lake phase at about 595 to 585 m (asl) is documented primarily by a well-developed scarp along portions of the lowest part of the south flank of the Heart River Upland, in many places just above the fluvial plane (Twp. 76, Rge. 16 and 17 W 5th Mer.; Figure 14). This scarp's elevation is low enough that in places the scarp has been eroded into the bedrock (Twp. 76, Rge. 15, W 5th Mer.; Figures 15 and 16).

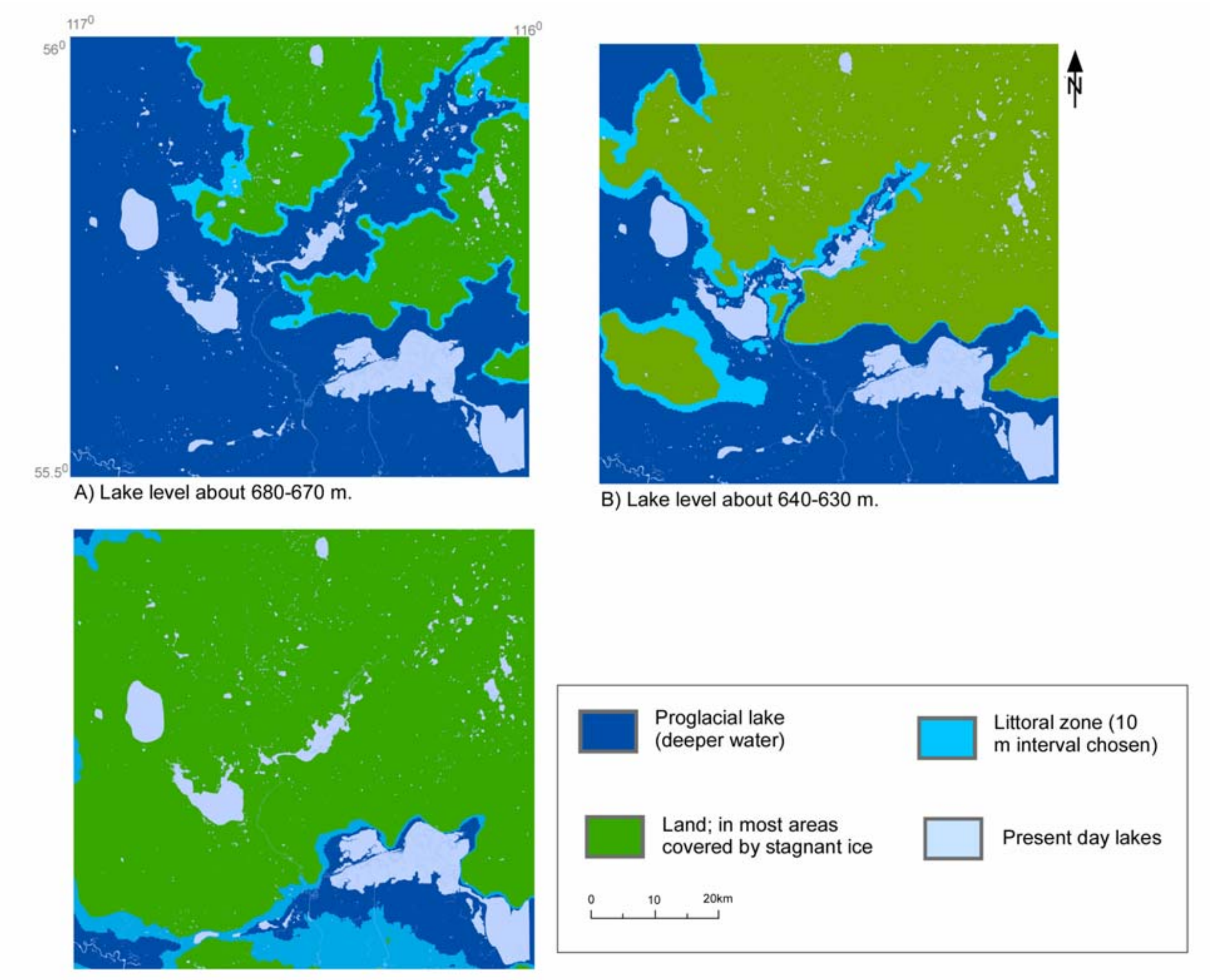

Figure 11. Paleogeographic maps illustrating the three major glacial lake levels of glacial Lake Peace within the McLennan study area. Water levels are approximate based on strandlines, wave-cut scarps and eroded surfaces (lag deposits) and plotted on a modern digital elevation model; isostatic rebound levels remain unknown. A) Glacial lake levels between 670-680 m; B) intermediate glacial lake levels at 630-640 m; and, C) final glacial lake levels at approximately 595-585 m, prior to the abandonment of the eastern drainage outlet of glacial Lake Peace.

The history of glacial Lake Peace in the surrounding regions has been described by Taylor (1958, 1960), Henderson (1959), St-Onge (1972), Mathews (1980), Liverman (1989), Catto et al. (1996), Leslie and Fenton (2001) and Hartman (2005). The elevation of the upper scarp (670–680 m) corresponds to the early Clayhurst stage (Phase 4a) of Mathews (1980), and glacial Lake Falher I of St-Onge (1972) and Henderson (1959). Likewise, the intermediate strandline (630–640 m) likely formed during the late Clayhurst stage of Mathews (1980). The lowest scarp (590 m) could have been formed during the Indian Creek stage (Phase 5) of glacial Lake Peace (c.f., Mathews, 1980, p. 18) and glacial Lake Falher III phase (c.f., Henderson, 1959, p. 77). During this final glaciolacustrine phase, the northeastward retreat of the Laurentide Ice Sheet margin exposed the Lesser Slave Lake—Athabasca River valley depression allowing eastward drainage (c.f., St-Onge, 1972, p. 7). The Indian Creek stage of glacial Lake Peace drained eastward through the Iroquois Lakes spillway into an unnamed glacial lake occupying the Lesser Slave Lake basin to the east (Figure 11c). The subsequent fall in water level resulted in the separation of what had been the eastern arm of glacial Lake Peace into two lakes in the southern portion of the study area. Mathews mentions that St-Onge indicates that the drainage of Lesser Slave valley occurred about 11 000 years ago (Mathews, 1980, p. 19) and Dyke et al. (2003) place the event at about 11 500 years before present.

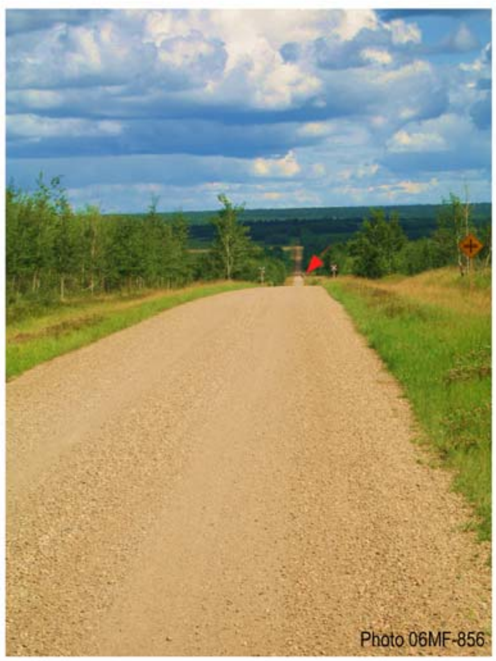

Figure 12. Eastward view from the top of the wave-cut scarp formed on the southern flank of the Heart River Upland, southwest of Reno, during the 630 m (asl) lake level. Local relief here is 10 m between the top of the scarp and the base, where the truck is parked (indicated by arrow). (East of site MF06-071; Twp. 80, Rge.19, W 5th Mer.).

Figure 13. Wave-washed till plain south of Reno where boulders and cobbles, winnowed from the till, are abundant in ploughed fields. A) Farmers pick the cobbles and boulders from their fields and deposit them into large piles (indicated by arrows). B) Close up of one pile; igneous and metamorphic clasts glacially transported southwestward from the Precambrian Shield predominate. (South of site MF06-063; Twp. 80, Rge.19, W 5th Mer.).

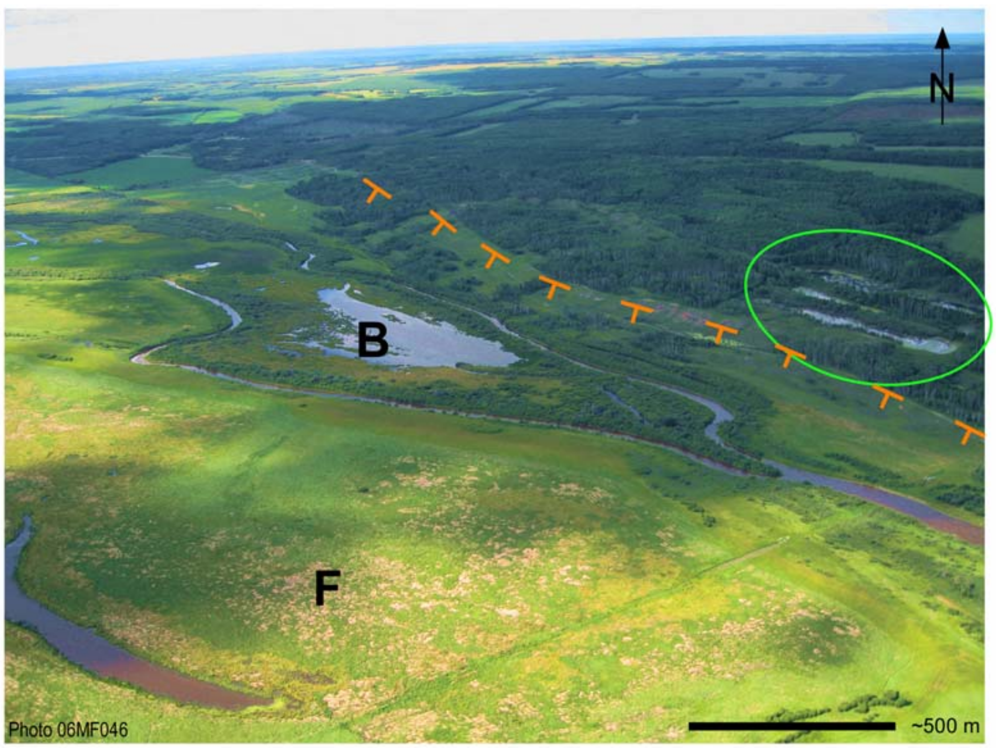

Figure 14. Northward view over southeast part of study area showing the fluvial plain (F) of the South Heart River, the low-level (585–590 m asl) wave-cut scarp (indicated by symbols) and a rotational landslide scar with sag ponds (circled). Note that the landslide is seated within the Mesozoic shale and mudstone (approximately Twp. 76, Rge. 16, W 5th Mer.).

Figure 15. Mesozoic bedrock exposed along the wave-cut scarp, west of Buffalo Bay, formed during the 585 to 595 m (asl) lake level. A) Strong wave erosion has created a scarp several metres high (truck for scale). B) In many places the scarp is covered by thin colluvium. This scarp is below the glaciolacustrine rhythmites deposited at higher elevations (see Figure 8). (Site JP06-014; Twp. 76, Rge.15, W 5th Mer.).

Henderson (1959) mentions Lake Falher II was formed by a southward readvance of the Laurentide Ice Sheet, west of the study area. Evidence to support this readvance in the McLennan area was observed at one section along the southern portion of the South Heart meltwater channel. At this site, an exposure of about 3 m of pebbly sand overlies a clay-rich till (Figure 17). The till is massive, possesses a very high clay content and contains only a small number of granules with, essentially, no larger casts. This is typical of the sediment produced by a glacier advancing into a glacial lake and reincorporating the glaciolacustrine sediments into the basal ice. Surface morphologies show a strong southward-fluted terrain. Mathews (1980) noted that the glacial Lake Peace was probably dammed by a lobate and frequently unstable retreating lobe of ice, defined as the Peace River ice lobe (Mathews) that occupied and fluctuated within the greater Peace River valley.

Figure 16. Recent excavation reveals weathered shale and mudstone in a few places. (Site JP06-015; Twp. 76, Rge.15, W 5th Mer.).

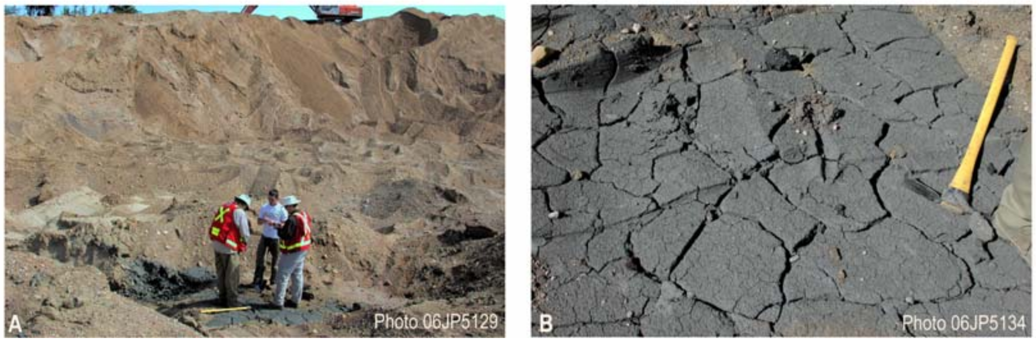

Figure 17. Till exposed below glaciofluvial sediment. A) Recent excavation at a gravel pit along the south Heart River has exposed grey unoxidized till in the base of the pit. B) The till is massive and has a high clay content and contains <2% granules (2 to 4 mm diameter) with essentially no larger clasts. (Site MF06-020; Twp. 76, Rge. 17, W 5th Mer.).

Following the final drainage of glacial Lake Peace from the region, much of the High Prairie Plain was gradually draped by alluvial sediment transported into this area by the South Heart River and smaller streams flowing northward from the Swan Hills Upland south of the study area. Intermittent dendritic drainages to perennial meandering streams have deposited alluvial sediments over significant portions of the High Prairie Plain (Figure 18). The northern portion of this plain south of the Heart River Upland is still subject to periodic flooding and covered by extensive wetlands, primarily marshes (see Figure 14).

The Quaternary stratigraphy and glacial history is poorly understood, as there were only a few deep exposures to allow the examination of the underlying sediment. One aforementioned section along the southern portion of the South Heart River meltwater channel exposes about 3 m of gravely sand over a very clay-rich till (Figure 17). Only one site showing multiple tills was discovered; this site was in the north-central part of the map area. Here a massive grey-brown till overlies a lighter olive-brown till (Figure 19). The uppermost till is correlative with other surface tills mapped in northern Alberta, and deposited by the Late Wisconsin Laurentide Ice Sheet. The underlying till may be tentatively correlative with other possible older tills that were intersected in boreholes to the west (Balzer, 2000) and documented in boreholes to the north in the southern Buffalo Head Hills (Fenton et al., 2005; Pawlowicz et al., 2005).

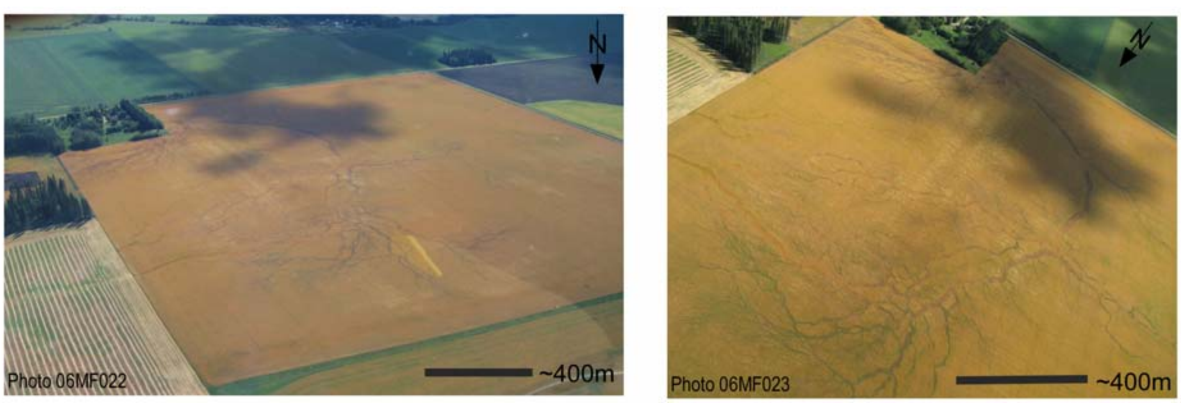

Figure 18. Oblique photographs, taken from the air, of the shallow dendritic drainage patterns developed on the fluvial plain in the southeastern part of the map area (southwest of Buffalo Lake; approximately Twp. 75, Rge.15, W 5th Mer.).

Figure 19. Dark-brown to grey calcareous till deposited over an oxidized, olive-brown till, north-central part of the study area. A) Upper and lower till exposed in a recent pit. B) Oxidation is extensive on fractures and joint surfaces in the lower till. Yellow pick handle is 85 cm long. (Site MF06-003; Twp. 80, Rge. 16, W 5th Mer.).

3 Engineering and Economic Geology

The exposure of the bedrock along the lowest portion of south flanks of the Heart River Upland has resulted in a few landslides (Figure 14). These are the largest failures in the study area; however, deep-seated landslides are common in the Little Smokey River directly west of the map area. Minor failures and colluvium occur along the edges of the meltwater channels in the Heart River Upland, likely a result of glaciolacustrine sediment slumping on the oversteepened erosional boundaries of the meltwater channel.

Nine samples were collected for heavy mineral processing and kimberlite indicator mineral (KIM) identification at a commercial laboratory (Table 1). These include eight samples of till (28.9 kg to 35.8 kg bulk weights) and one sample of glaciofluvial pebbly sand (12.9 kg bulk weight; Figure 20). One till sample from the northwestern part of the area (sample 6505) contained 116 probable olivine grains, based on visual identification: 36 of those grains are in the 0.5–1.0 mm fraction, while 80 are in the 0.25–0.5 mm fraction. Ten of these grains have been confirmed as olivine based upon SEM analyses. The sample was collected from a burrow pit on the north side of a small meltwater channel (Figures 21 and 22). Five other samples in the north-central area contained between one and seven KIM grains. A sample of glaciofluvial sediment from the south-central part of the area contained 24 grains, mainly olivine. The direction of glacial flow is not well understood. Lineaments interpreted to be glacial flutes buried and partially obscured by the glaciolacustrine sediment west of the sample sites, indicate a south to southwest flow. This is supported by Paulen (2004) and Paulen et al. (2004a).

Table 1. Kimberlite indicator mineral grains recovered from bulk samples. Identification based mainly on visual examination. Only a few grains have undergone SEM checks to confirm mineralogy.

	6502 Till	**6503** Till	**6504** Till	**6505** Till	**7401** Glaciofluvial	**7403** Till	**7404** Till	**7406** Till	**7408** Till
Pyrope					1			2	
Chrome Diopside		3	1				2		
Ilmenite		1			2				
Chromite		2		1			1		1
Olivine	1	1		116	21				2
Totals	**1**	**7**	**1**	**117**	**24**	**0**	**3**	**2**	**3**

Previous work on the granular resources of the area consists of a reconnaissance-scale study by Edwards and Scafe (1994). The McLennan surficial geology map illustrates a number of glacial meltwater channels in the Heart River Upland. The largest is a southwest-trending channel occupied by the South Heart River (Figure 5). Another channel system trends southward, eastward, and finally, southward again in the western portion of the area to form a major glaciofluvial delta on the north side of the South Heart channel (Twp. 78, Rge. 16, W 5th Mer.). Sand and gravel extraction pits have been developed in a few places along both these channels (Figure 17); any located in the course of this study are shown on the surficial geology map (Fenton 2008). In general, these pits have a high proportion of sand to gravel. Within the upland, there are other more localized deposits of glaciofluvial sediment, but the proportion of gravel in these areas is unknown.

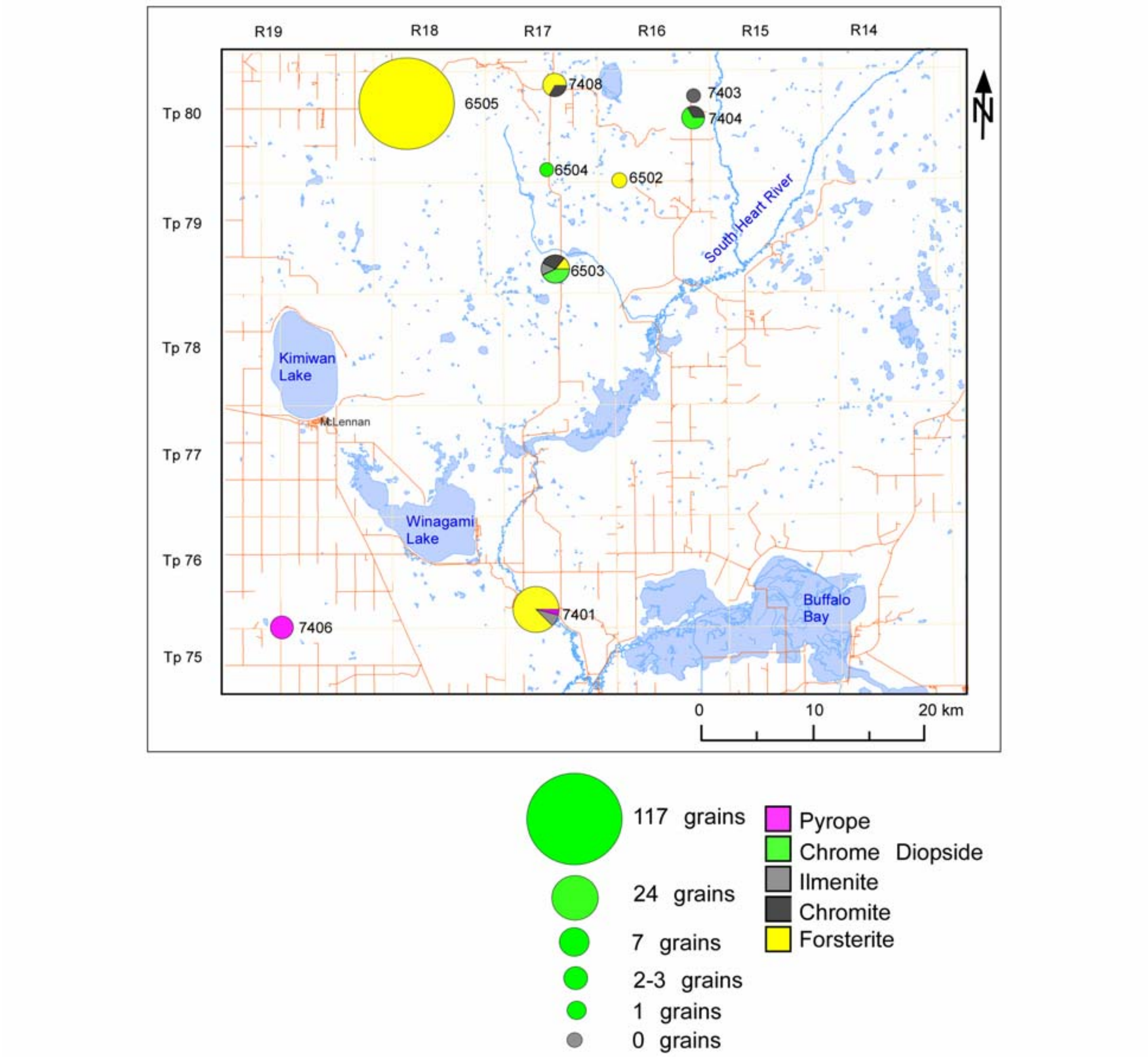

Figure 20. Map showing distribution of samples analyzed for kimberlite indicator minerals.

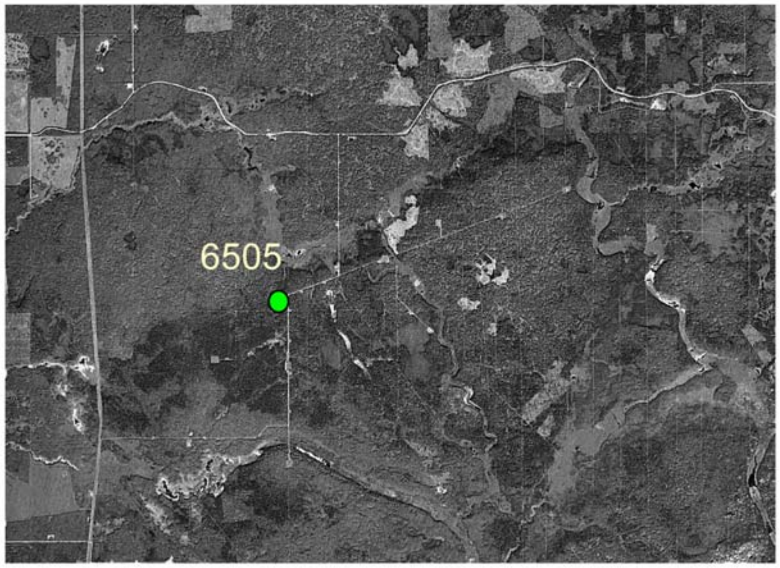

Figure 21. Location of sample site 6505 on the margin of a small meltwater channel.

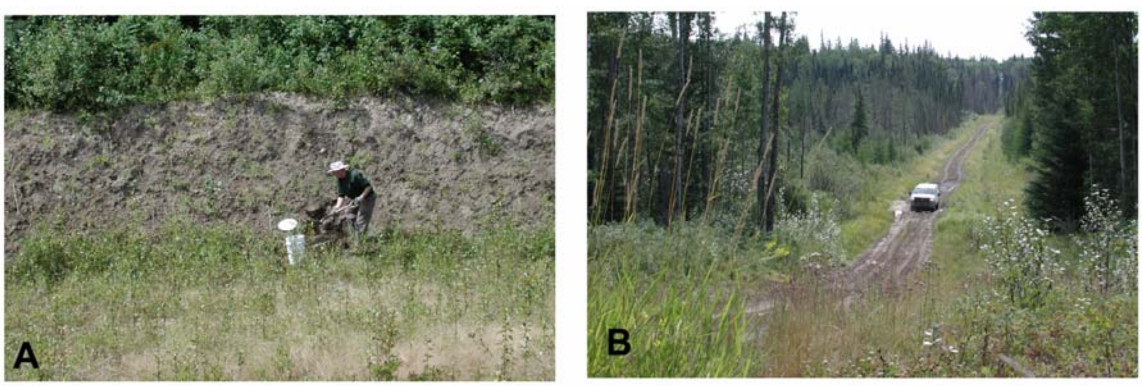

Figure 22. Sample site 6505 (A) on the north margin of a small meltwater channel (B).

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Appendix 1 – Field Site Data

Appendix 1 - Surficial Geology of the McLennan Area (NTS 83N/NE): Field Site Data

August 1, 2006

Location data collected using a Garmin 76CSx

Site_Name	Position: (GPS, NAD1983)	Altitude (GPS)	Unit 1	Unit 2	Unit 3
JP06-001	11 U 548796 6191467	668 m	0 - .7m silt; GF? GL?	.7 - 1.5m sand; GF	
JP06-002	11 U 548535 6190684	653 m	0 - 1.3m sand & silt; GF		
JP06-003	11 U 545304 6188053	646 m	0 - 4.0m sand; GF with some eolian		
JP06-004	11 U 551702 6185314	683 m	0 - 1.2m till with dk gry clay interbeds		
JP06-005	11 U 547074 6185264	668 m	0 - .7m silty clay; GL	.7 - 1.2m till with minor clay beds	
JP06-006	11 U 542129 6177086	675 m	0 - 1.2m till with dk gry clay interbeds		
JP06-007	11 U 537297 6172201	658 m	0 - 1.3m clay; GL		
JP06-008	11 U 537260 6165726	727 m	0 - 1.3m sandy clay till, .3m clay at surface		
JP06-009	11 U 543824 6165776	672 m	0 - 1.8m silty clay; GL		
JP06-010	11 U 542671 6165771	683 m	0 - 1.8m clayey silt; GL		
JP06-011	11 U 538954 6166292	730 m	0 - 1.0m sandy clay till, v. hard		
JP06-012	11 U 538994 6164927	693 m	0 - 1.0m sandy clay till, v. hard		
JP06-013	11 U 540602 6162569	665 m	0 - 1.3m till		
JP06-014	11 U 542262 6158371	590 m	0 - .4m colluvium	.4 - 1.2m mudstone; bedrock	
JP06-015	11 U 543531 6159738	585 m	0 - .5m colluvium	.5 - 1.8m mudstone; bedrock	
JP06-016	11 U 547106 6165035	664 m	0 - 1.3m silty clay bedded diamict; GL?		
JP06-017	11 U 547298 6162853	601 m	0 - 4.0m mudstone; bedrock		
JP06-018	11 U 555243 6165878	668 m	0 - 1.0m sandy clay till, hard		
JP06-019	11 U 530686 6151897	585 m	0 - 1.0m f - mg sand, alluvium?	1.0 - 1.8m clay; GL? Recent lacustrine?	
JP06-020	11 U 529873 6151170	587 m	0 - 1.8m silt; alluvium		
JP06-021	11 U 527593 6157960	612 m	0 - 0.3m fg sand; eolian	.3 - >1.0m mg sand with stones; GF	
JP06-022	11 U 528298 6157524	614 m	0 - 0.5m fg sand; eolian	>.5m sand with stones; GF	
JP06-023	11 U 521533 6160914	632 m	0 - 1.8m sand with silt interbeds; GF		
JP06-024	11 U 524923 6165611	658 m	0 - 1.3m silt; GL		
JP06-025	11 U 532440 6164763	686 m	0 - 1.0m clayey diamicton; GL?	1.0 - 2.5m till	
JP06-026	11 U 539182 6204100	718 m	0 - 2.0m till		
JP06-027	11 U 540169 6200960	676 m	0 - .7m massive clay; GL	.7 - 1.3m bedded silt and clay; GL	
JP06-028	11 U 540867 6198657	670 m	0 - .75m massive clay; GL	.75 - 1.5m bedded silty clay; GL	1.5 - 1.8m massive clay; GL
JP06-029	11 U 540417 6198563	680 m	0 - 1.0m massive clay; GL	1.0 - 1.8m diamciton with 30 cm clay bed; till	
JP06-030	11 U 532625 6195021	728 m	0 - 4.0m clayey silt till; regional till		
JP06-031	11 U 535975 6188436	689 m	0 - .6m massive clay; GL	.6 - 1.3m massive till	
JP06-032	11 U 531865 6187092	701 m	0 - 2.0m till		
JP06-033	11 U 533912 6185414	687 m	0 - 1.2m till with minor dark gray clay beds		
JP06-034	11 U 535369 6182578	629 m	0 - .6m massive mg sand; alluvium	.6 - 1.2m bedded silt; alluvium	1.2 - 1.8m massive oxidized till
JP06-035	11 U 503124 6152937	635 m	0 - .8m clayey diamicton; GL? Till?	.8 - 1.8m till	
JP06-036	11 U 503149 6149901	614 m	0 - 3.2m clay; GL		
JP06-037	11 U 503131 6150043	613 m	0 - 1.5m clay; GL		
JP06-038	11 U 503146 6165488	629 m	0 - 1.8m silty clay; GL		
JP06-039	11 U 515693 6167236	625 m	0 - 1.5m till		
JP06-040	11 U 514660 6168646	636 m	0 - .4m clayey diamicton; GL?	.4 - 1.8m silt; GL	
JP06-041	11 U 522729 6150906	629 m	0 - 1.3m rhythmic bedded silt /clay; GL		
JP06-042	11 U 522819 6148588	603 m	0 - 3.0m silty clay; GL		
JP06-043	11 U 512100 6152605	640 m	0 - .4m silty clay; GL	.4 - 1.8m till	
JP06-044	11 U 520613 6164498	642 m	0 - 1.8m silt; GL		
JP06-045	11 U 513302 6162330	632 m	0 - 1.8m clay; GL		
JP06-046	11 U 515789 6160475	624 m	0 - 1.8m silt; GL		
JP06-047	11 U 512823 6205115	675 m	0 - .75m till	.75 - 1.0 poorly sorted sand and pebbles; GF?	
JP06-048	11 U 509543 6204467	621 m	0 - 2.7m clay; GL	2.7 - 3.3m clay with diamict interbeds; GL	
JP06-049	11 U 507983 6197999	634 m	0 - 1.3m till		
JP06-050	11 U 504790 6198792	656 m	0 - .7m silty clay; GL	.7 - 1.5m till	
JP06-051	11 U 511603 6198070	654 m	0 - .4m silt; GL	.4 - 2.5m clayey diamict; till? GL?	
JP06-052	11 U 527234 6187142	710 m	0 - .4m clay; GL	.4 - 4.0m till	
JP06-053	11 U 527572 6188641	694 m	0 - 1.0m sand and gravel; GF		
JP06-054	11 U 526246 6195836	716 m	0 - .5m silty clay; GL?	.5 - 2.0m till	
JP06-055	11 U 516119 6203030	694 m	0 - 3.5m till		
JP06-056	11 U 507997 6205904	606 m	0 - 1.5m clay; GL	1.5 - 1.8m clay interbedded with diamicton; GL	
JP06-057	11 U 501486 6199122	640 m	0 - 1.3m till		
JP06-058	11 U 503073 6188095	646 m	0 - .9m sandy diamicton; till	.9 - 1.8m silt interbedded with diamicton; GL	
JP06-059	11 U 503933 6186732	638 m	0 - 1.5m clay; GL		
JP06-060	11 U 501501 6185833	637 m	0 - 1.5m clay; GL		
JP06-061	11 U 499904 6184974	643 m	0 - 1.6m peat	1.6 - 1.8m silty clay; GL	
JP06-062	11 U 499850 6187136	655 m	0 - 1.0m silty clay; GL	1.0 - 1.6m diamict; till? GL?	
JP06-063	11 U 499855 6191298	641 m	0 - 2.0m silt & clay; GL		
JP06-064	11 U 499855 6201132	612 m	0 - .8m clayey silt; GL	.8 - 1.8m diamict; till? GL?	
JP06-065	11 U 500493 6204463	600 m	0 - 1.5m clay & silt; GL		
JP06-066	11 U 504762 6201216	642 m	0 - 1.5m till		
JP06-067	11 U 507731 6201187	617 m	0 - 1.0m massive silty clay; GL	1.0 - 1.8m clay, bedded; GL	
MF06-001	11 U 432624 6179181	601 m	0 - 2.0m rubbly Badheart, few quartzite & chert; colluvium?	2.0 - 2.5m silty clay, few clasts; till?	
MF06-002	11 U 438436 6172477	633 m	0 - 4.0m gray mudstone; Wapiti bedrock		
MF06-003	11 U 538985 6201499	701 m	0 - 2.0m calcareous till	2.0 - 3.0m noncalcareous till; (2 till site to be revisited)	
MF06-003a	11 U 539031 6201528	709 m	0 - 2.0m stony silty clay till	2.0 - 3.5m sand; GF	3.5 - 5.0m sandy oxidized till
MF06-004	11 U 525020 6174053	639 m	0 - .9m clayey silt & sand; GF? GL?	.9 - 1.8m massive silty clay; GL?	
MF06-005	11 U 532583 6148676	586 m	0 - .7m silty clay; likely GL	.7 - .8m sand; GL?	.8 - 1.9m claye silt; GL
MF06-006	11 U 537438 6188399	665 m	0 - 4.0m silty clay; GL		
MF06-007	11 U 548556 6191348	648 m	0 - 1.8m clayey silt; GL	1.8 - 1.9m sand; GL?	
MF06-008	11 U 547248 6189986	649 m	0 - 3.0m sand; eolian?		
MF06-009	11 U 551034 6185301	679 m	0 - 3.0m diamicton, silty clay interbeds; GL?	3.0 - 3.5m diamicton; till?	
MF06-010	11 U 550155 6182039	662 m	0 - 2.0m silty clay; GL		
MF06-011	11 U 540661 6172241	677 m	0 - 1.8m diamicton with clay interbeds; GL?		
MF06-012	11 U 542268 6165764	695 m	0 - 1.8m till	1.8 - 1.9m clay; GL?	
MF06-013	11 U 542205 6167293	709 m	0 - 1.7m till		
MF06-014	11 U 540606 6163193	686 m	0 - 2.0m till		
MF06-015	11 U 541772 6161247	641 m	0 - 1.0m diamicton, littoral: GL	1.0 - 1.7m silty clay; GL	
MF06-016	11 U 542884 6158527	602 m	0 - 3.0m rhythmic bedded silt/clay; GL		
MF06-017	11 U 563380 6166034	692 m	0 - 1.2m till		
MF06-018	11 U 531619 6155954	605 m	0 - 1.0m sand; eolian	1.0 - 1.3m clay; GL	1.3 - 2.9m silt & sand; GF?
MF06-019	11 U 524329 6160311	624 m	0 - 2.6m sand; eolian	2.6 - 2.7m silty clay; GL?	2.7 - 3.2m sand; GF?
MF06-020	11 U 525397 6157782	609 m	0 - 12.0m sand &gravel; GF	12 - 13m till	
MF06-021	11 U 524378 6157539	616 m	0 - 2.0m sand; eolian? GF?	2 - m till (see MF field notes)	
MF06-022	11 U 524308 6164090	663 m	0 - 1.7m laminated silt and clay; GL		
MF06-023	11 U 538916 6195011	681 m	0 - 1.7m laminated silt and clay; GL	1.7 - 1.8m diamicton; till?	
MF06-024	11 U 535202 6194885	714 m	0 - 3.5m clayey silty till		
MF06-025	11 U 539034 6193219	693 m	0 - 1.0m till		
MF06-026	11 U 529260 6189715	696 m	0 - 3.4m till		
MF06-027	11 U 532985 6184616	677 m	0 - 5.0m sand and gravel (pit); GF		
MF06-028	11 U 503140 6156039	664 m	0 - .7m sand and gravel; beach	.7 - 4.5m till	
MF06-029	11 U 503140 6157220	667 m	0 - 2.0m organics; wetland		
MF06-030	11 U 503138 6160360	663 m	0 - 1.9m silt and clay; GL		
MF06-031	11 U 503140 6161962	653 m	0 - 1.0m silty clay; GL	1 - 2.5m till	
MF06-032	11 U 504760 6168842	629 m	0 - 1.5m silty clay; GL		
MF06-033	11 U 515302 6166519	622 m	0 - 0.2m sand and gravel; beach	.2 - 1.7m till	
MF06-034	11 U 513321 6170001	637 m	0 - 1.5m laminated silt and clay; GL		
MF06-035	11 U 522742 6154144	623 m	0 - 1.7m laminated silt; GL	1.7 - 1.9m rhythmic bedded silt and clay; GL	
MF06-036	11 U 515004 6152630	637 m	0 - 2.0m silty clay, minor stones; GL? Till?	2.0 - 2.5m till	
MF06-037	11 U 557447 6156565	675 m	0 - 4.0m till hummock		
MF06-038	11 U 557466 6154268	650 m	0 - 1.3m till		
MF06-039	11 U 557460 6155189	669 m	0 - 1.2m till		
MF06-040	11 U 556174 6155204	664 m	0 - 1.3m rhythmic bedded silt and clay	1.3 - 1.5m till	
MF06-041	11 U 556103 6156355	652 m	0 - 1.5m massive silty clay; GL		
MF06-042	11 U 562878 6163866	656 m	0 - 1.0m till		
MF06-043	11 U 555144 6169162	671 m	0 - 1.7m massive clay; GL	1.7 - 1.8m diamicton; till? GL?	
MF06-044	11 U 556903 6169183	684 m	0 - 1.4m massive clay; GL	1.4 - 1.5m silty clay diamicton; till	
MF06-045	11 U 566893 6153618	673 m	0 - 2.0m sand & gravel; Beach?		
MF06-046	11 U 562748 6150888	598 m	0 - .5m quartzite cobbles and sand; Beach?		
MF06-047	11 U 557887 6151520	581 m	0 - 1.0m massive clay; GL	1.0 - 1.5m rhythmic bedded silt & clay; GL	1.5 - 1.8m diamicton; till?
MF06-048	11 U 510479 6165608	631 m	0 - 1.9m silt and clay; GL		
MF06-049	11 U 511267 6165579	624 m	0 - 1.9m silt and clay; GL		

MF06-050	11 U 518553 6161516	630 m	0 - 1.9m silt; GL		
MF06-051	11 U 515068 6204455	696 m	0 - 1.0m till		
MF06-052	11 U 511255 6204461	674 m	0 - 1.8m till		
MF06-053	11 U 509610 6203337	627 m	0 - 1.8m silty clay; GL		
MF06-054	11 U 508004 6195370	664 m	0 - .5m sand; GL	.5 - 1.5m silty clay; GL	1.5 - 1.7m till
MF06-055	11 U 512146 6197261	661 m	0 - 2.4m silty clay; GL	2.4 - 2.8m till	
MF06-056	11 U 527630 6189229	695 m	0 - 1.0m till		
MF06-057	11 U 527593 6188622	691 m	0 - 1.5m sand and gravel; GF		
MF06-058	11 U 528916 6192414	713 m	0 - 2.0m till		
MF06-059	11 U 524249 6195714	687 m	0 - 1.2m till		
MF06-060	11 U 527309 6203356	757 m	0 - 4.0m till		
MF06-061	11 U 516126 6202917	686 m	Probe 1, 1m sand & gravel & till. Probe 2, 2m peat. Probe 3, .3m silt and from .3 - 1.0m till		
MF06-062	11 U 509614 6205927	633 m	0 - .9m silty clay; GL	.9 - 1.7m till	
MF06-063	11 U 501474 6204002	605 m	0 - 1.7m silty clay; GL		
MF06-064	11 U 501498 6188245	664 m	0 - .3m silty clay; GL	.3 - 4m stones; lag	.4 - 1.7m till
MF06-065	11 U 501504 6181785	627 m	0 - 1.8m silty clay; GL		
MF06-066	11 U 500149 6181757	635 m	0 - 1.0m silty clay; GL		
MF06-067	11 U 499844 6194958	638 m	0 - .7m till		
MF06-068	11 U 499841 6197851	625 m	0 - 1.5m silty clay; GL	1.5 - 1.7m bedded diamicton; GL?	
MF06-069	11 U 501493 6201198	626 m	0 - .8m till		
MF06-070	11 U 503061 6201202	629 m	0 - .4m silt and clay; GL	.4 - 1.8m bedded silt and clay; GL	
MF06-071	11 U 506384 6201204	648 m	0 - 1.65m silty clay; GL	1.65 - 1.7m till	
MF06-072	11 U 508004 6193378	660 m	0 - 1.0m clay; GL	1.0 - 1.1m till	
MF06-073	11 U 515423 6188675	643 m	0 - 1.1m silty clay; GL		
MF06-074	11 U 545532 6200791	696 m	0 - 1.0m clay; GL	1.0 - 1.1m till	
MF06-075	11 U 555804 6203324	672 m	0 - 1.0m sand; eolian	1.0 - 2.2m sand; GF	2.2 - 2.25m clayey silt; GL
MF06-076	11 U 554168 6202352	674 m	0 - 1.0m till		
MF06-077	11 U 557658 6200829	693 m	0 - 1.1m till		
MF06-078	11 U 550569 6194395	677 m	0 - 1.1m sand and silt; GF? GL?		
MF06-079	11 U 555465 6194451	655 m	0 - .4m silty clay; GL?	.4 - 1.1m sand GL? GF?	
MF06-080	11 U 561438 6185944	725 m	0 - 1.0m till		
MF06-081	11 U 561634 6182086	732 m	0 - 1.1m till		
MF06-082	11 U 558383 6159927	645 m	0 - 1.1m bedded silty clay; GL		
MF06-083	11 U 547853 6172044	711 m	0 - 1.1m clay; GL		
MF06-084	11 U 553750 6180754	707 m	0 - 1.1m diamict with thin clay interbeds; GL? Till?		
MF06-085	11 U 556674 6189309	680 m	0 - 1.0m bedded silty clay; GL		
MF06-086	11 U 558997 6189714	710 m	0 - 1.1m till		
MF06-087	11 U 540153 6185703	625 m	0 - 1.9m sand with silt layers; GF		
MF06-088	11 U 541306 6184819	630 m	0 - 1.5m silt; GL		
MF06-089	11 U 536864 6177879	649 m	0 - 1.0m massive sand and silt; GL	1.0 - 1.5m bedded sand and silt; GL	1.5 - 1.9m massive silty sand; GL
MF06-090	11 U 536625 6179857	626 m	0 - 1.7m silty clay; GL		
MF06-091	11 U 535811 6162481	598 m	0 - 1.0m silty clay; GL		
MF06-092	11 U 532461 6164570	679 m	0 - .6m sandy diamict; till?	.6 - 1.0m coarse sand	
MF06-093	11 U 532455 6163191	645 m	0 - .3m gritty silty diamict	.3 - 1.0m sily clay; GL	