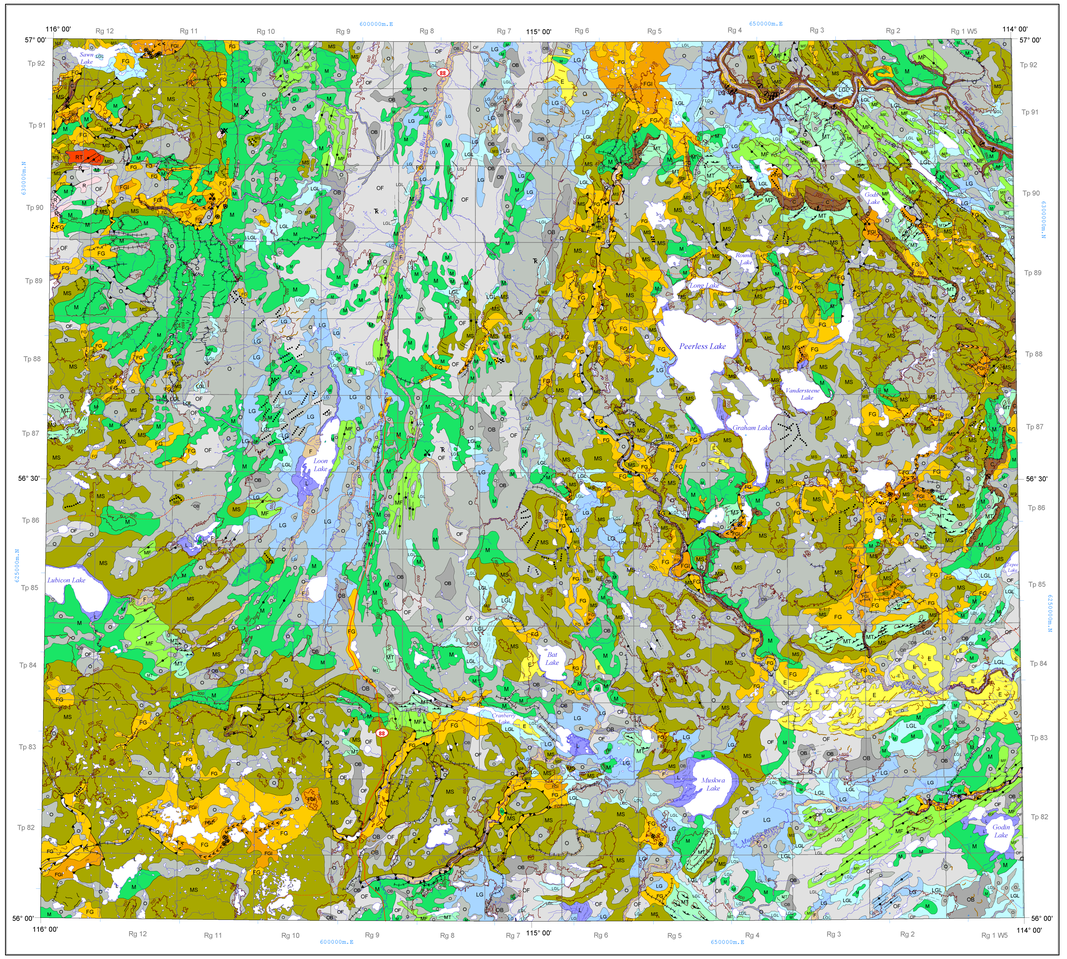
NTS 84B
SURFICIAL GEOLOGY



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Map 269

Surficial Geology of the Peerless Lake Area, Alberta (NTS 84B)

Geology by: R.C. Paulen, M.M. Fenton and J.G. Pawlowicz

Scale 1:250 000

0 2 4 6 8 10 12 kilometres
0 1 2 3 4 5 6 7 8 miles

Projection: Universal Transverse Mercator
Datum: North American Datum, 1983

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UNIT	UNIT NAME	DESCRIPTION AND GENESIS
QUATERNARY		
HOLOCENE		
O		**ORGANIC DEPOSITS:** Undifferentiated peat (woody to fibrous muck) occurring in undifferentiated wetlands; commonly underlain by fine-grained, poorly drained glaciolacustrine deposits; includes marshes, swamps, bogs and fens.
OB		**Bog peat:** Occurs in a peatland with a fluctuating water table and commonly a raised surface; peatland surface is dominated by sphagnum mosses, shrubs and short, stunted trees.
OF		**Fen peat:** Occurs in a peatland with water table at surface and slow internal drainage; peatland surface is dominated by sedges, with grasses and reeds near local pools, sparsely treed.
C		**COLLUVIAL DEPOSITS:** Materials that have reached their present position as a result of direct, gravity-induced movement; commonly occur as slope and slump deposits confined to valley slopes and floors; include pre-existing bedrock, till, glaciolacustrine, glaciofluvial and eolian sediments, generally poorly sorted.
F		**FLUVIAL DEPOSITS:** Sediments transported and deposited by streams and rivers; synonymous with alluvial. Include well-sorted stratified sand, gravel, silt, clay and organic sediments occurring in channel and overbank deposits (e.g., postglacial floodplains, terraces, fans and deltas).
L		**LACUSTRINE DEPOSITS:** Sediments deposited in and adjacent to recent lakes; offshore sand, silt and clay; littoral (nearshore) beaches and bars of sand, silt and minor gravel; minor organic deposits.
E		**EOLIAN DEPOSITS:** Wind-deposited sediments; well-sorted, medium to fine-grained sand and minor silt (loess); generally massive to locally crossbedded or ripple laminated; include both active and vegetated deposits.
PLEISTOCENE		
LG		**GLACIOLACUSTRINE DEPOSITS:** Primarily fine-grained, distal sediments deposited in or along the margins of glacial lakes, including sediments released by the melting of bedding ice. Include laminated (rhythmically bedded) to massive fine-grained sand, silt and clay, and may contain ice-rafted stones.
LGL		**Littoral (nearshore) sediments:** Massive to stratified, well-sorted silty sand, pebbly sand and minor gravel; occur as beaches, bars, spits and forset deltaic sediments deposited during lowering of glacial lakes.
FG		**GLACIOFLUVIAL DEPOSITS:** Sediments deposited by glacial meltwater streams as subaerial or subaqueous outwash. Include sand and gravel, often stratified, minor silt, and may show evidence of ice melting (slumped structures). Features include meltwater channels, kettle holes, terraces and minor ice-contact sediments.
FGI		**Ice-contact sediments:** Sediments deposited by glacial meltwater streams in direct contact with glacial ice, either in front of (kame terraces) or within (eskers, crevasse ridges) glacial ice. Include massive to stratified, poorly to moderately sorted, coarse sediments (gravel/sand) and commonly pebble gravel and coarse sand, locally till) and may show evidence of ice melting (slumped structures).
M		**MORAINE:** Nonsorted diamicton (till) deposited directly by glacial ice, consisting of a mixture of clay, silt, sand and minor pebbles, cobbles and boulders. Locally, this unit may include blocks of bedrock, pre-existing stratified sediment, till and lenses of glaciolacustrine and/or glaciofluvial sediments.
MS		**Stagnant ice moraine:** Material resulting from the collapse and lateral movement of englacial and supraglacial sediment in response to melting (ablation) of stagnant ice at the ice margin; sediment is mainly diamicton, but locally includes stratified sediments of glaciolacustrine or glaciofluvial origin. Characterized by low to high-relief hummocky topography.
MT		**Ice-thrust moraine:** Terrain resulting from glaciotectonic transport of originally subglacial material deposited by the glacier more or less intact; deposits may include pre-syngenetic till, as well as masses of pre-existing till, stratified drift and/or bedrock. Characterized by high to moderate relief, and features include hill-hole pairs and glaciotectonic moraine ridges.
MF		**Fluted moraine:** Glacially streamlined terrain; varies from alternating furrows and ridges to nearly equidimensional smoothed hills; all landforms parallel the local ice-flow direction; includes flutes, drumlins and drumlinoids.
PRE-QUATERNARY		
RT		**UNCONSOLIDATED FLUVIAL GRAVELS:** Fluvial sediments transported and deposited by rivers prior to glaciation; Cordilleran source, Paleogene (Tertiary) to early Quaternary in age; predominantly well-sorted quartzite and chert gravel and cobbles; these deposits are usually overlain by a thin (<1 m) veneer of glacial sediment.
R		**BEDROCK:** Undifferentiated; consists of shale, mudstone, sandstone, coal and/or kimberlite; Cretaceous age. Bedrock regions are commonly overlain by a thin (<1 m) veneer of glacial sediment, except where individual outcrops are indicated.

SYMBOL LEGEND

- Thermokarst depression
- Landslide and active-layer failure scar (small)
- Landslide and active-layer failure scar (large)
- Eolian forms; dune ridges
- Beach or strandline
- Wave-cut bench
- Escarpment
- Meltwater channel (minor)
- Meltwater channel (minor, flow indicated)
- Meltwater channel (major)
- Meltwater channel (major, flow indicated)
- Crevasse filling
- Ice-contact slope
- Kettle
- Esker, direction of paleoflow unknown
- Esker, direction of paleoflow indicated
- Drumlinoid or streamlined landform
- Drumlinoid, down-ice flow indicated
- Buried drumlinoid or streamlined landform
- Minor moraine ridge
- Major moraine ridge
- Iceberg scour
- Ice-thrust ridge
- Striation (direction unknown)
- Striation (direction known)
- Bedrock outcrop
- Gravel and/or sand pit

BASEMAP LEGEND

- Paved highway
- Gravel road - all season
- River
- Lake
- UTM grid, Zone 11 (+ 430000m.E)
- Contour, 50 metre interval

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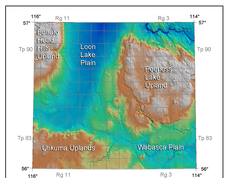
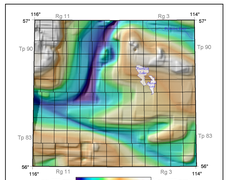
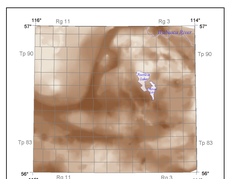


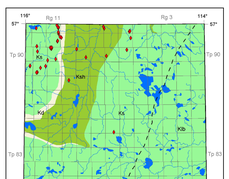
Digital Elevation Model and Physiography (Pettipiece, 1986) of the Peerless Lake Area (NTS 84B)



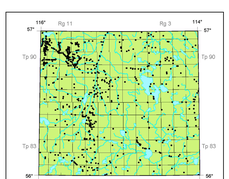
Bedrock Topography of the Peerless Lake Area (NTS 84B) (Pawlowicz and Fenton, 2005a)



Drift Thickness of the Peerless Lake Area (NTS 84B) (Pawlowicz and Fenton, 2005b)



Bedrock Geology of the Peerless Lake Area (NTS 84B) (Green et al., 1970; Hamilton et al., 1999)



Ground-truthing stations (n = 726) within the Peerless Lake Area (NTS 84B), 1999–2003.

Surficial Geology of the Peerless Lake Area (NTS 84B)

INTRODUCTION

The surficial mapping of the Peerless Lake area was completed as a contribution to the Alberta Mineral Strategy, to provide information about the Quaternary geology that will benefit infrastructure development and drift prospecting. Data were obtained through field traverses conducted by the Alberta Geological Survey (formerly Alberta Research Council) and Geological Survey of Canada in the Peerless Lake area from 1999 to 2003. Field activities included terrain mapping, till sampling, measuring of ice-flow indicators and stratigraphic studies. Field traverses and airphoto interpretation provided information on the nature and distribution of surface materials shown on the map. Maps were constructed using 1:40 000 and 1:60 000 scale airphotos compiled onto a 1:60 000 scale base. The surficial maps were constructed and published as 1:100 000 scale maps (Fenton et al., 2003; Paulen et al., 2003a–c). Additional detailed mapping at 1:50 000 scale was conducted in 2003 for the Sawn Lake area (Trommelen, 2004), in the heart of the Buffalo Head Hills kimberlite field.

PHYSIOGRAPHY

The Peerless Lake area is bounded by the Buffalo Head Hills Upland to the west and the Peerless Lake Upland to the east, which are separated by the Loon Lake Plain (Pettapiece, 1986). The highlands are characterized by extensive areas of stagnant ice terrain dissected by multiple meltwater channels. Organic terrain, interspersed with glaciolacustrine and glaciofluvial sediments, occupies the lowlands. Drift thickness is variable, ranging from <2 m in the Buffalo Head Hills to >200 m in the Loon Lake Plain (Pawlowicz and Fenton, 2005a). Elevations in the map area range from approximately 620 m above mean sea level in the Buffalo Head Hills to 540 m in the Wabasca Plain. Local relief is low and some geomorphic features visible on airphotos are negligible at ground level.

BEDROCK GEOLOGY

The Peerless Lake map area is underlain by Cretaceous strata of the Western Canada Sedimentary Basin. The Peerless Lake region is underlain by shale of the Smoky Group, Labiche Formation and Shaftesbury Formation, and sandstone of the Dunvegan Formation (Green et al., 1970; Hamilton et al., 1999). Recent palynological results from outcrops and shallow augerholes indicate that the uppermost bedrock unit in the Buffalo Head Hills is the Puskwaskau Member of the Labiche Formation, not the Smoky Group Formation (Pawlowicz et al., 2005a). Outcrops of kimberlite occur in the Buffalo Head Hills, some of which form small prominences above the surrounding hummocky topography. The majority of the kimberlites in the Buffalo Head Hills occur within the Peerless Lake map area. Kimberlite emplacement occurred between 88.5 ± 5 and 86 ± 3 Ma (Heaman et al., 2003; Skelton et al., 2003).

PREVIOUS WORK

Soil surveys in the Peerless Lake region (Lindsay et al., 1957; Leskiw, 1976) preceded hydrogeology studies by Cerocki (1979) and aggregate resource studies by Scafe et al. (1986, 1987) and aggregate potential mapping (Edwards et al., 2004). McPherson (1974) conducted the first surficial geology mapping in the region, with later mapping at 1:100 000 scale by the Alberta Geological Survey (AGS; Fenton et al., 2003a; Paulen et al., 2003a–c). Detailed surficial mapping and studies of the surface materials were conducted in the Sawn Lake region (Trommelen, 2004). Drift thickness (Pawlowicz and Fenton, 2005a) and bedrock topography (Pawlowicz and Fenton, 2005b) maps of NTS 84B were created from existing well-log information and limited regional drilling by the AGS (Pawlowicz and Fenton, 1995; Pawlowicz et al., 1999, 2005b).

SURFICIAL MATERIALS

The present-day landscape of the Sawn Lake region is a result of preglacial fluvial incision and later multiple glacial and nonglacial events. The landforms and surficial sediments reflect the advance and retreat of the Laurentide Ice Sheet during the last (Late Wisconsin) glaciation and subsequent Holocene fluvial erosion and bog development.

Preglacial (pre-Laurentide) deposits (unit RT)

Exposures of preglacial unconsolidated sediments, as defined by Edwards and Scafe (1996), are found only at the highest elevations within the Buffalo Head Hills and lie beneath a thin veneer of glacial till. Preglacial gravels are characterized by predominantly quartzite, quartz sandstone, chert and minor ironstone clasts. They lack clasts derived from the Canadian Shield, indicating that they predate regional Laurentide glaciation. In the Buffalo Head Hills, these deposits consist of strongly oxidized, overconsolidated, weakly stratified gravel containing coarse sand lenses. The gravel contains approximately 70% clasts by volume, ranging in diameter from 0.2 to 22 cm, with a fine- to medium-grained sand matrix. Preglacial gravels have not been previously documented in the Buffalo Head Hills, but they have been described elsewhere in northern Alberta (Edwards and Scafe, 1996).

Moraine (till) deposits (unit M)

Glacial moraine or till is ubiquitous throughout the region, commonly overlain by thick glaciolacustrine sediments in the lowlands and organic veneers in the uplands. Till occurs at surface on the margins of the Buffalo Head Hills, in the Loon Lake Plain and in the Wabasca Plain. This sediment, commonly deposited directly by ice as basal till, generally occurs as a nonsorted diamicton with a silty clay matrix, commonly fissile and compact, with an average of 1–5% clasts ranging from granules to rare boulders. Areas mapped as unit M commonly form low-relief plains with perched water tables that host numerous holocene fens and peat bogs and may include some low-relief stagnant ice moraine (indistinguishable on airphotos).

On the uplands of the Buffalo Head Hills and Peerless Highlands, the surface moraine is genetically different, yet with similar properties. Mapped as stagnant-ice moraine (subunit MS) and consisting of stratified and/or basal till, it is characterized by diamicton with a matrix ranging from sandy silt to silty clay. The matrix is typically poorly compacted and local sand lenses (medium to coarse grained) are commonly found. Clast lithologies are similar to those found in basal till, and clast content ranges from 1–5% by volume. Although it has the same lithologic composition as basal till, this sediment is generally stratified, likely due to the presence of water during its formation. Topographically, this material is typified by undulating to hummocky terrain consisting of roughly equidimensional hills and depressions. Hummock-relief ranges from 2 to 10 m and is highly variable throughout the region, creating a surface morphology significantly different from that underlain by basal till. This sediment represents glacial sedimentation during ice stagnation and retreat, and consists of a combination of till and glaciofluvial and/or glaciolacustrine sediment. The stagnant-ice moraine commonly forms circular ridges, or doughnuts, consisting of roughly circular till hills and central depressions infilled with remobilized silt and clay deposits.

Ice-thrust moraine (subunit MT) occurs on the northeastern flank of the Peerless Highlands and as small ridges near Muskwa and Lubicon lakes. Thrust moraine or deformation terrain is composed of masses of Cretaceous bedrock or pre-existing unconsolidated Paleogene (Tertiary) and Pleistocene sediment, or both, that have been transported more or less intact by glaciers. The glaciotectonic features that occur on the northeastern flank of the Peerless Highlands are a result of the Laurentide Ice Sheet thrusting rafts of relatively flat-lying Cretaceous bedrock during the Late Wisconsin glacial maximum, when the ice was the most erosive, and flowed in a southwestward direction. Small-scale thrust ridges south of Meadowa Lake are possibly glaciotectonic hill-hole pairs (cf. Moran et al., 1980).

Fluted moraine (subunit MF) is distinguished by prominent glacially streamlined landforms such as flutes and drumlins. The sediment properties of this unit are typical of basal till, having generally good bedrock control with mean vectors parallel to the streamlined terrain. This till subunit often reflects deglacial-phase ice flow, which imparted features from the last flow of surging glacial ice on the landscape, often obliterating regional depositional ice-flow indicators from the glacial maximum. This moraine is common in the lowlands, where tongues of ice readvanced into the proglacial lake basins, deforming and incorporating the clayey glaciolacustrine sediments.

Glaciofluvial deposits (unit FG)

Ice-walled glaciofluvial meltwater channels are found throughout the map area, some of which are over 25 km in length and have formed the deepest valleys, in depths of more than 30 m. The glaciofluvial meltwater channels exhibit a significant negative relief on the landscape, exceeding the local relief of hummocky topography. Series of small, parallel meltwater channels occur on the flanks of uplands. These channels occur perpendicular to the modern drainage (slope) and indicate periodic meltwater flow against a retreating ice margin, although they contain little or no glaciofluvial material. Larger glaciofluvial outwash systems occur from the rapid drainage of water ponded on, under or in front of the ice margin, and contain a variety of sorted glaciofluvial outwash deposits (unit FG). Sediments associated with these glaciofluvial systems occur in the form of small kames, aggraded outwash plains, terrace deposits and overbank material. These deposits consist of poorly sorted, massive to crudely stratified gravel, sand and minor silt. Some of the notable meltwater systems include the Trout River meltwater channel, which occurs near the western edge of the Peerless Highlands, and the Sawn Lake to Haig Lake meltwater channel in the Buffalo Head Hills. Kame complexes are uncommon, but a large kame deposit is currently being exploited adjacent to Goda Lake.

An extensive esker and ice-contact meltwater complex was observed in the southwestern corner of the map area. Smaller isolated eskers occur in the Buffalo Head Hills and on the southeastern flank of the Peerless Highlands. Except at their crests, these eskers and related ice-contact deposits (subunit FGI) are characterized by planar to ripple-laminated, silty, fine-grained sands and sandy gravels. Sediments on the esker crests are typically composed of interbedded sandy pebble to cobble gravel-sand facies that reflect the discharge of sediment-laden meltwaters from confined tunnel channels. The cores of these eskers may provide a large volume of granular aggregate, although they may, in places, be composed only of sand.

Glaciolacustrine deposits (unit LG)

Extensive deposits of massive to rhythmically bedded silt and clay occur in the Loon Lake and Wabasca plains. During deglaciation, proglacial lakes formed in the lowland basins along the retreating ice margins. Blankets of fine-grained glaciolacustrine sediment up to 3 m thick are found along the Loon River and Red Earth Creek, and glaciolacustrine blankets up to 5 m thick occur near the Wabasca River to the northeast. In the Muskwa River region, most of the glaciolacustrine sediments were reworked into a clayey till when a late glacial surge readvanced into the glacial lake basin. Large fens and bogs have formed over these sediments in the lowland regions. Washed till lags and thin (<2 m) deposits of littoral silt and sand mark the former shorelines of the larger glacial lakes (subunit LGL).

Eolian deposits (unit E)

A large dune field lies in the southeastern corner of the map area. Large sand dunes formed near the terminus of the Trout River meltwater channel and near the margin of the glacial lake that occupied the Wabasca Plain. Hairpin and parabolic dune morphologies indicate that postglacial early Holocene wind directions were from the northwest. Occasional longitudinal dunes occur near the Wabasca River, northeast of the Peerless Lake Upland, and rare transverse dunes occur near the former margins of the glacial lakes that once occupied the Loon Lake Plain.

Lacustrine deposits (unit L)

Lacustrine deposits occur mainly along the margins of the larger lakes. These are characterized by Holocene deltaic deposits and raised shorelines that formed during high water stands. These sediments usually consist of well-sorted sand, silt, clay and organic detritus.

Fluvial deposits (unit F)

Modern drainage is poorly developed in the region due to the low topographic gradient and the impermeable nature of the surficial sediments. Commonly, modern drainage occurs as relatively narrow (under10) streams occupying large glacial meltwater channels. In addition, beaver dams are common in the region, blocking streams, often in succession. This has caused widespread erosion and diversion of surface drainage, leading to standing water (bogs) and fens. Modern fluvial sediment is dominantly silt and clay with organic detritus and minor gravel and is more developed streams.

Colluvial deposits (unit C)

Colluvium is defined as sediment displaced due to gravity, and it records various slump and flow processes. Colluvium is found along steeply incised meltwater and fluvial channels where the slopes have become unstable, and also occurs along the northern flank of the Peerless Lake Upland. Colluvium consists of predominately rotational and translational earth-slide deposits derived from bedrock and glacial and nonglacial sediments.

Organic deposits (unit O)

Organic deposits are widespread throughout the map area. They are most abundant overlying the glaciolacustrine sediments but also occur extensively overlying till. Thicknesses of organic materials are variable, but commonly range from 1 to 4 m. They occur as wetlands, including fens, bogs and marshes. Fens are characterized by extensive areas of stagnant ice terrain dissected by multiple meltwater channels. peatlands, with water at the surface and slow internal drainage. They are dominated by sedges, willow and tamarack trees. In contrast, bogs represent acidic, nutrient-deficient peatlands, dominated by sphagnum mosses, bog birch and stunted black spruce trees. They have fluctuating water tables and commonly raised surfaces. The presence of the large expanses of poorly drained organic terrain is due to the shallow gradients and the low permeability of surface sediments.

GLACIAL HISTORY

The history of ice flow in the Peerless Lake area is interpreted from streamlined landforms, glacial thrust ridges and pebble fabric measurements. Early glacial flow was likely dictated by topography but, as ice-sheet thickness increased during the glacial maximum, approximately 21 000 BP (Dyke et al., 2003), ice flow was impeded by local topography and generally flowed to the southwest. Flutes on the Buffalo Head Hills and a sculpted crag and tail feature at the K5 kimberlite support this regional ice-flow interpretation (Skelton Buffalo Head Hills (Paulen and McClenaghan, in press).

Flutings and linear landforms on the northeastern flank of the Peerless Lake Upland indicate a later south-southeasterly ice flow. This indicates that thinning late-stage ice was deflected due to topographic control. Striae measured on the planed tops of boulder pavements in the Loon River valley indicate that the surface till in the Loon Lake Lowland was deposited by ice flowing southward. During early deglaciation, approximately 11 000 BP (Dyke et al., 2003), glacial lakes submerged several areas as the northward-retreating ice blocked meltwater drainage. This created an unstable ice margin, and surging ice lobes advanced and retreated into the proglacial lakes, modifying or obliterating older streamlined landforms and creating strongly fluted terrain in the lowlands. Ice was often confined by topography and streamlined landforms often deviate considerably from glacial-maximum flow directions. Sometime after glacial maximum, southward flowing ice in the northern Peace River valley advanced over the southeastern flank of the Buffalo Head Hills (Mathews, 1980; Paulen and Fenton, 2003). This ice flowed around the northern end of the Buffalo Head Hills and deposited a till that is now exposed in the bed of the Loon River valley. Thinner ice stagnated on top of the uplands, while thicker ice in the valleys continued to actively flow into their proglacial lake settings. Beautifully preserved flutings in the southeastern part of the map area suggest that southwestwardly flowing ice readvanced into a large glaciolacustrine lake that occupied the Wabasca Plain.

A considerable region of hummocky terrain, with circular or 'doughnut' morphology, occurs at higher elevations in the Buffalo Head Hills and the Peerless Lake Upland. These features are mapped as stagnant-ice terrain and are formed, at least in part, by ablation processes (cf. Mollard, 2000).

ENGINEERING GEOLOGY

Identification of surficial materials is important in the Peerless Lake region to meet the continuing needs of the petroleum industry and others for infrastructure development. Till, dug from borrow pits, is the most abundantly used form of material in the study area for subgrade purposes and is employed to build well pads and most petroleum development access roads. The high clay content of local tills presents several problems for the construction of roads and foundations for buildings due to its low shear strength and potential for swelling and/or heaving. When wet, roads constructed from till are treacherously slippery and susceptible to rut formation. Areas of high traffic and other roads of importance are top-dressed with gravel, providing an all-weather surface. In regions lacking granular aggregate resources, geotextiles are often utilized to form road bases. The size and density of borrow pits appears to be largely a function of groundwater seepage (rate of flooding) and logistics (hauling distance). Borrow pits are generally situated proximal to the roads and well pads being constructed.

Granular aggregate for the Peerless Lake map area is primarily derived from ice-contact glaciofluvial sediments (subunit FGI), such as eskers, kames and ice-walled meltwater channel terraces. These aggregate sources are suitable for multiple purposes due to the higher clast content and coarse sand matrix that typically occur within these deposits. Coarser beds of gravel in various sandy glaciofluvial deposits typical of outwash plain sediments (unit FG) are also extracted. A potential deposit of preglacial pebble gravel (unit RT) in the Buffalo Head Hills occurs beneath a thin (<2 m) veneer of till. Its areal extent and thickness and full extent of this deposit are unknown.

Slope stability problems exist in areas where former meltwater and modern fluvial channels have overdeepened slopes. The majority of natural landslides are found along the modern rivers and resulted from downcutting and overdeepening in the glacial sediments. Shallow earth flows may also occur on overdeepened slopes, both natural and anthropogenic, where the surficial weathered zone and near-surface water flow contribute to rapid, small-volume landslides. Potential road instability may occur in areas of poor water drainage and where roads have been constructed on colluvium.

IMPLICATIONS FOR MINERAL EXPLORATION

Since 1997, thirty-eight kimberlite pipes have been discovered within the southern Buffalo Head Hills region by Ashton Mining of Canada Inc. and its partners (Hood and McCandless, 2004). Till and stream sediment sampling surveys for kimberlite indicator minerals have been conducted in the Peerless Lake map area (Eccles et al., 2001; Frake et al., 2003; Prior et al., 2005). For till sampling surveys, delineating suitable sample material for indicator mineral sampling is important, given the sediment and geologic differences in basal till (subunit MF and most of unit M) versus ablation till (subunit MS). Basal till, which may be difficult to identify, is generally fissile, has a massive appearance and has a well-defined clast fabric. It is the most useful material for determining local ice-flow directions and developing dispersal trains (Paulen et al., 2003d). Ablation till, found most commonly within stagnant ice moraine, may result from basal melt-out processes and would be a suitable material for sampling if it has a relatively proximal source. It also may include material carried englacially and may reflect source material of a distal provenance. Samples collected in regions of ice-thrust terrain and recognition of blocks of bedrock and/or intact eolotic stratigraphy within till sequences should be cautiously interpreted (subunit MT). The material is likely derived locally, but ice-reflected blocks of bedrock can also travel hundreds of kilometres (cf. Fenton and Pawlowicz, 2000). For reconnaissance surveys, sampling of ice-contact glaciofluvial sediment may help determine regional kimberlite potential, as the majority of ice-contact material is usually derived from the erosion of the local till.

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