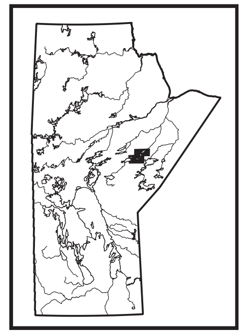
GS-17 Quaternary geology of the Knee Lake area, northeastern Manitoba (NTS 53L14, 15, 53M1, 2)

by M.S. Trommelen



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Summary

Quaternary geology investigations, including 1:50 000 scale mapping of surficial materials and ice-flow indicators, and regional till sampling surveys, were undertaken in the Knee Lake area (NTS 53L14, 15, 53M1, 2) in the summer of 2012. Geological observations, sampling of glacial sediments (till), and/or measurements of ice-flow indicators were recorded at 198 stations within a 3720 km^2 area in central-northeastern Manitoba. These observations will be compiled with data from 695 surficial geology field sites, collected during Manitoba Geological Survey's multimedia and kimberlite-indicator–mineral Operation Superior project, undertaken from 1999 to 2001 in the same area, to produce a series of 1:50 000 scale surficial geology maps, which include till composition. Detailed till geochemistry results from the Operation Superior project identified gold and alteration-type massive sulphide mineralization, as well as scattered kimberlite-indicator minerals. Twenty-three targeted samples of till were collected in 2012, which De Beers Canada Exploration Inc. has graciously accepted for processing and identification of potential kimberlite-indicator minerals.

New collection of ice-flow–indicator data has allowed for recognition of five main ice-flow phases that indicate spatial and temporal variations in ice flow. The oldest flow (Phase I) trends towards the southeast (between 150 and 160°), and is followed by a westward flow (Phase II; between 255 and 280°). Rare but widespread ice-flow indicators then document southward ice flow (Phase III; between 180 and 194°, and towards 200°). This was followed by a strong, fairly erosive, southwestward ice flow (Phase IV; between 230 and 248°). During deglaciation, ice flowed to the south-southwest (Phase V; between 212 and 220°), evidenced by erosional ice-flow indicators. Drumlin formation in most of the area likely occurred during the last two phases, as drumlinoid ridges trend toward 220° in the south and 235° in the northwest.

The Knee Lake area is dominated by thick streamlined till in the north. Rugged terrain is more common in the south, consisting of exposed bedrock outcrop ridges with thin (<1 m) discontinuous till cover on the lower slopes and in low-lying areas. Preliminary results indicate the dominant till is a beige, calcareous, silty clay to silty sand till, though variations in colour, texture and lithology are present. Following the retreat of ice, shallow waters of glacial Lake Agassiz inundated the entire region and deposited clay and silt of variable thickness (10–300 cm). At two sites, thin till overlies glaciolacustrine sediments, which may indicate a resurgence of ice into glacial Lake Agassiz.

Introduction

Quaternary geology studies were conducted in central-northeastern Manitoba, encompassing Knee Lake and the easternmost portion of Oxford Lake (NTS 53L14, 15, 53M1, 2; Figure GS-17-1), in August, 2012. This report presents a summary of fieldwork activities, which included surficial geology mapping at 1:50 000 scale, regional ice-flow indicator analysis and preliminary glacial dispersal analyses based on till composition. This work builds on detailed till geochemistry (including instrumental neutron activation analysis [INAA], carbonate analysis, kimberlite-indicator–mineral [KIM] analysis) data collected at 1 km spacing during Manitoba Geological Survey's (MGS) Operation Superior project undertaken from 1999 to 2001 in the same area (Fedikow et al., 2001, 2002a, 2009).

Physiography

The study area is located in the central-northeastern part of Manitoba (Figure GS-17-1). Elevation varies primarily from 160 to 220 m asl with local relief of up to 10 m.

The Hayes River is the major drainage channel in the study area; it flows northeast and eventually drains into Hudson Bay. Knee Lake and Oxford Lake are both widened expanses of the Hayes River. Numerous small streams flow across the drift plains from one lake to another in an immature drainage network, or flow through the muskeg. The northern part of the map area is characterized by very poor to poorly drained closed coniferous forests (Mills et al., 1978a), underlain by clay-rich till. Most drumlinoid ridges have a crest that sticks out above the thick cover. The remaining area is a mix of till blankets and till veneers over bedrock. Soils are predominately

- eluviated eutric brunisols, developed on well to moderately drained till and glaciolacustrine parent materials,
- rego gleysols, formed on imperfect to poorly drained till and glaciolacustrine parent materials, and
- a mix of cryosols and mesisols (organic surficial materials; Mills et al., 1978a, b).

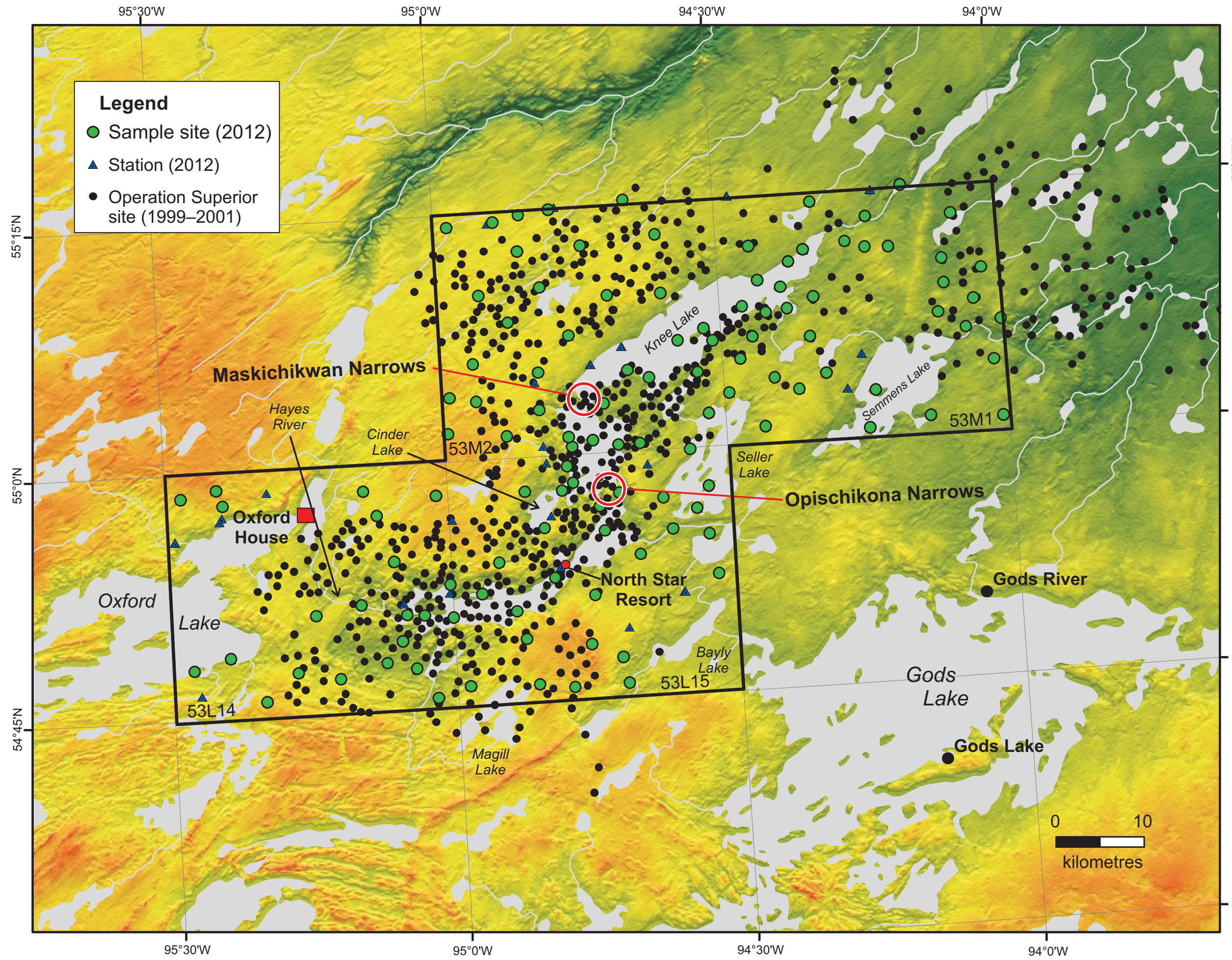

***Figure GS-17-1:** Study area in central-northeastern Manitoba. Field sites include those stations where data was collected as part of this study (green circles and blue triangles), and sites digitized from unpublished Operation Superior data (black circles). Background image was generated using a Shuttle Radar Topography Mission digital elevation model (United States Geological Survey, 2002), draped with a Canadian digital elevation data (GeoBase®, 2007) model.*

Regional glacial history

Surficial geology in the Knee Lake area (NTS 53L14, 15) was first mapped in the late 1950s as part of a bedrock mapping project (Barry, 1959, 1:63 360 scale). The Knee Lake map area (NTS 53M) was then mapped at a reconnaissance scale by Klassen and Netterville (1979) and the surficial geology of the Oxford House map area (NTS 53L) was later published as an "A" series map by Clarke (1988, 1:250 000 scale). Both regions were predominately mapped using aerial photographs, with 'limited ground checking'.

The study area was repeatedly glaciated by the Laurentide ice sheet (LIS; Klassen, 1986; Dredge and Cowan, 1989; Dyke, 2004). Considerable work has been undertaken on till stratigraphy in the Hudson Bay Lowland, but there is limited information on the extent and character of tills that overlie the Superior Province of Manitoba. Across the Hudson Bay Lowland, outlined stratigraphy comprises four tills and two nonglacial sequences, not including the present interglacial (Klassen, 1986; Nielsen et al., 1986; Nielsen, 2001, 2002; Dredge and McMartin, 2011). The three uppermost tills were thought to have been deposited by ice flowing out of Hudson Bay in a southwesterly direction, whereas the lowest till was deposited by southeasterly flowing ice originating in the Nunavut region, north of Manitoba.

During deglaciation, the study area was thought to have been covered by ice flowing southwest from the Hayes lobe (Klassen, 1983; Dredge and Cowan, 1989), originating from the Hudson Bay area of the LIS. Around 8.7 ka ^{14}C BP, a large portion of this lobe was thought to have stagnated over the study area, resulting in the preservation of the streamlined landforms (Klassen, 1983). Klassen (1983) then suggests the study area was inundated by glacial Lake Agassiz by 8.2 ka ^{14}C BP (Ponton level, Thorleifson, 1996). Radiocarbon dates are rare in northeastern Manitoba, but it is thought that this inundation was short-lived (Mills et al., 1978a, b) and absent by around 7.7 ka ^{14}C BP (Fidler level, Thorleifson, 1996; Teller and Leverington, 2004).

Methods

The goal this season was to map the surficial geology of the Knee Lake area, in order to provide a better delineation of the geomorphology, ice-flow history and composition of surficial materials in the region. Helicopter-supported fieldwork was undertaken during a three-week period in August 2012, based out of a fishing lodge at Knee Lake (Figure GS-17-1). A total of 198 field stations was visited, by two field teams, to ground-truth the surficial geology mapping, collect till samples and identify ice-flow indicators. As alluded to in previous geological surveys of the area, the thick vegetation cover makes access difficult. Road and trail networks are limited to small areas surrounding the community of Oxford House and North Star Resort on Knee Lake. Helicopter landings were largely restricted to areas with open untreed fens, which heavily influenced where field stations could be situated. Shutdown areas for a helicopter without floats were rare and thus were limited to portions of the old winter road, the airport at Oxford House, North Star Resort and rare scattered flat bedrock outcrops.

This summer's fieldwork builds on the previous work initiated during the MGS Operation Superior project (Fedikow et al., 2001, 2002b, 2009). Prior to the fieldwork, digital compilation of the unpublished, archived, field site data from the MGS Operation Superior project was completed. Information from the 695 compiled sites, discussed herein, was incorporated into aerial photographic map production and guided sample site selection. The unpublished till geochemistry and carbonate content will be incorporated into final interpretations of the area.

The surficial material at each field station was investigated by means of a hand-dug shovel hole and/or a Dutch auger (1.3 m long). A total of 68 samples, each weighing around 2 kg, was collected from till plains, blankets, veneers and streamlined landforms throughout the area for geochemical and lithological analyses (Figure GS-17-1). An additional 57 till samples were collected for lithological analysis, from areas where geochemical analysis was completed during Operation Superior. As with the Operation Superior project (Fedikow et al., 2002a), an opportunity to further assess the diamond potential of the Knee Lake region has been provided by co-operative efforts with De Beers Canada Exploration Inc. (De Beers). Ten litre pails of till collected at 23 target sites were submitted to De Beers laboratories in September 2012, to have the samples concentrated, mineralogically picked and analyzed by electron microprobe. Sample locations were withheld from De Beers to ensure security and allow equal opportunity for follow-up by all interested parties in the exploration community when locations are released in an open file report. Striations and other ice-flow indicators were measured at 27 sites and combined with data collected at 49 Operation Superior sites.

Results

Surficial geology

Organics

Organic, treed bog deposits (Figure GS-17-2) are common on very poorly drained surfaces in the study area, and are usually underlain by permafrost. Small streams that link the numerous lakes are usually bordered by thick fen deposits (Figure GS-17-2). Organic cover is commonly thin (5–30 cm) where it overlies drumlinoid ridges, and thicker in low-lying areas between drumlins or where the underlying surficial material is finer textured (glaciolacustrine or silty clay till).

Till

The subglacial till in the Knee Lake area is predominately beige, calcareous and consists of a massive silty clay (Figure GS-17-3a) to silty fine sand matrix (Figure GS-17-3b) with 5–15% angular to rounded clasts. A range in till colour was noted, including beige, brown, grey and reddish. At one site, 25 cm of red-brown, noncalcareous, silty fine sand till was encountered overlying 20 cm of beige, calcareous, silty fine sand till (Figure GS-17-3c), overlying bedrock. At eight other sites, the till is also noncalcareous. At 10% of the field sites, the till is mixed with stringers, pockets or beds of glaciolacustrine clay (Figure GS-17-3d). The range in texture and colour of the till suggests there may be more than one kind of till in the study area. The lithology of the till varies greatly, including the proportion of carbonate clasts noted in the field. Clast types encountered include carbonates (beige, grey, black, red, fossiliferous), granitoid and gneissic rocks, metasedimentary rocks (psammite, quartzite), black shale, chert, metavolcanic rocks (basalt, volcaniclastic rocks), Omarolluk erratics (greywacke erratics with hemispherical voids or pits; Prest et al., 2000; Figure GS-17-3e) and rare red porphyritic Dubawnt Supergroup (Peterson, 2006) erratics (Figure GS-17-3f). All of the 2012 field samples will be analyzed for clast lithology, to help ascertain the presence of different till types.

In 2012, ablation till was only encountered at one site, consisting of hummocks, undulations and ridges with no bedrock outcrops.

Washed till, consisting of sand-rich diamict, was present at eight sites between Oxford House and the lower part of Knee Lake. Fine fractions were usually present as clay skins on clasts, but were otherwise absent.

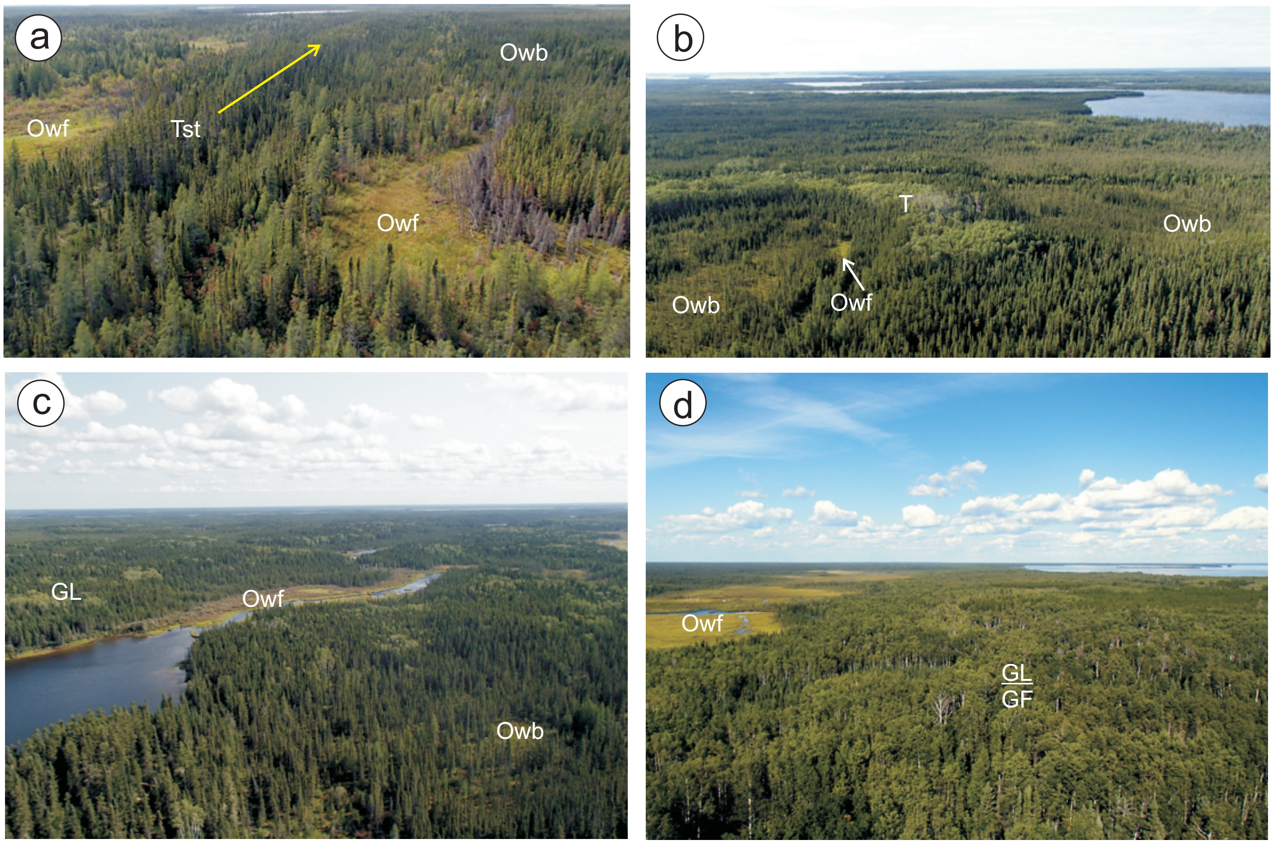

Figure GS-17-2: *Typical vegetation and geomorphology of the Knee Lake area, northeastern Manitoba. Higher, well-drained areas are covered by dense tall aspen (light green) trees, while lower lying, poorly to very poorly drained areas are draped by a mantle of densely treed spruce bogs. Wetter areas with flowing water are lined with fen deposits (bright green). Abbreviations: GF, esker; GL, glaciolacustrine; Owb, bog; Owf, fen; T, till; Tst, drumlinoid till ridge.*

Glaciofluvial sediments

Glaciofluvial ice-contact sediments at surface in the Knee Lake area are rare. Instead, glaciofluvial sands and gravels were encountered at less than one percent of field sites. Where present, they are typically situated below a mantle (30 to >130 cm thick) of glaciolacustrine clay and silt (Figure GS-17-2d).

Esker ridges are the dominant glaciofluvial landform in the region. The four main esker systems consist of large (1–5 m high), long (10–25 km) and regularly spaced (11–17 km) esker segments, with smaller (1–5 m high) and shorter esker ridges found between the large ridges.

Glaciolacustrine sediments

Description

Dense, compact, milk-chocolate brown, generally massive clay was encountered throughout the study area, at elevations that range between 110 and 210 m asl (Figure GS-17-4). All sediments were devoid of organics. Some sites at elevations >200 m asl consisted of massive to interbedded silt and fine sand. The thickness of these sediments is unpredictable at any one site, but generally varies from 5 to 300 cm (averaging ~40 cm). At two sites just east of Oxford House (Figure GS-17-4), glaciolacustrine sediments are not present but the till has been extensively washed and/or winnowed. Glaciolacustrine sediments were absent from some lakeshores, where till and bedrock is exposed, but thicken inland, especially around Knee Lake.

Mixed till and glaciolacustrine clay was encountered at 10% of all field sites (Figure GS-17-4). Mixing occurs as stringers, pockets or beds of one material within the other, usually as clay within till, and decreases with depth. Field notes from both projects described multiple sites where mixing occurred throughout the entire hole (0.8 m deep shovel holes and/or 1.3 m deep auger holes).

Glaciolacustrine sediment is predominately absent at surface northwest of Knee Lake, though is present in some lowland areas between high drumlinoid ridges. At three sites, between Knee Lake and Semmens Lake (Figure GS-17-4), clay was found at depth in auger holes, beneath 40–60 cm of beige, calcareous, silty clay till and sandy silt till.

Figure GS-17-3: *Till and till-derived clasts in the study area:* ***a)*** *typical organically enriched Bh-horizon soil overlying beige, calcareous, silty clay till;* ***b)*** *typical beige, calcareous, sandy silt till;* ***c)*** *red-brown, noncalcareous, silty fine sand till overlying beige, calcareous, silty fine sand till;* ***d)*** *example of till (beige sandy silt diamict) and glaciolacustrine (red-brown clay) mixing, as encountered in an auger hole;* ***e)*** *greywacke with an eroded concretion (Omarolluk erratic);* ***f)*** *red metavolcanic rock with porphyritic feldspar (Dubawnt Supergroup erratic).*

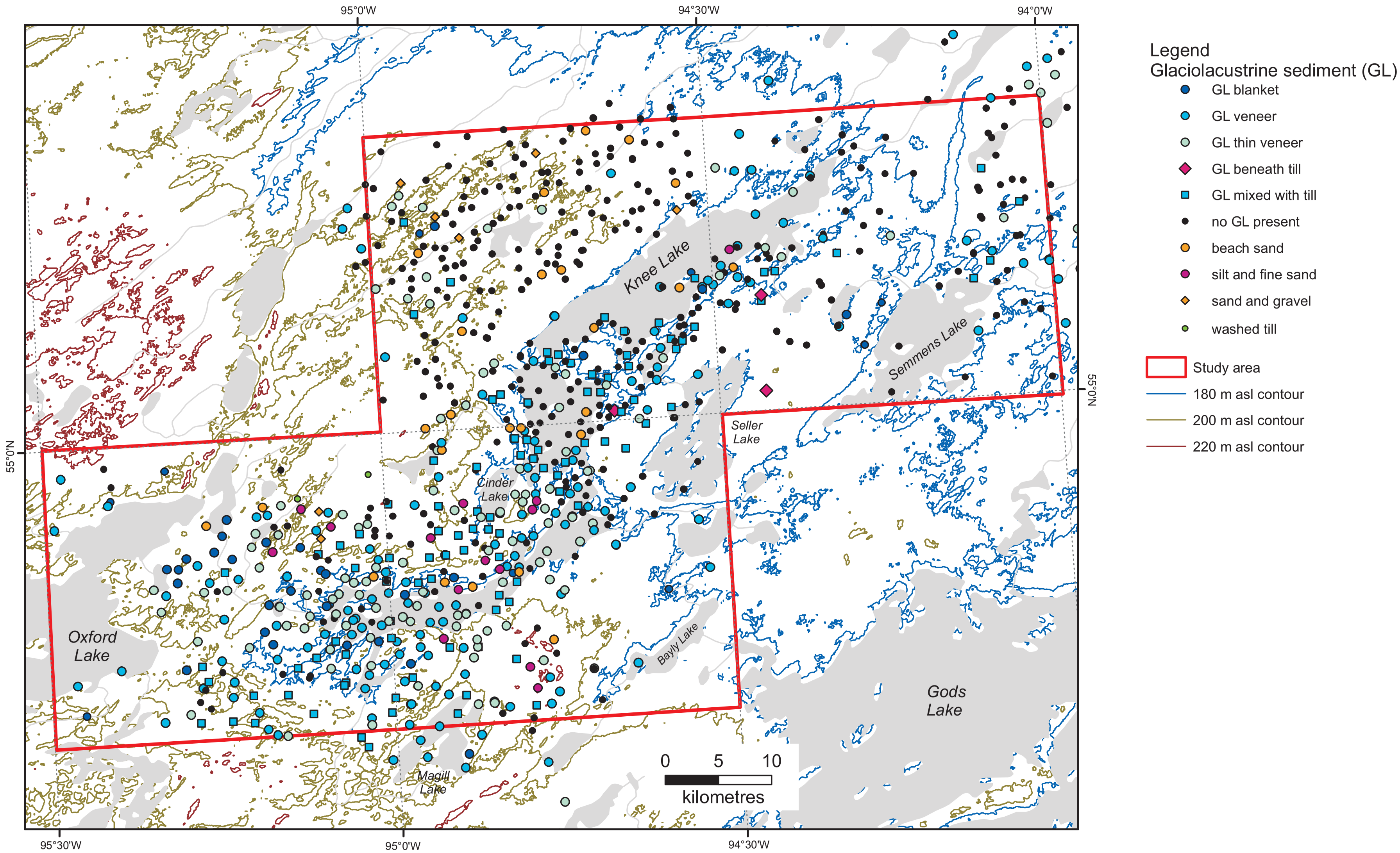

Figure GS-17-4: *The distribution and composition of glaciolacustrine sediments in the Knee Lake area, northeastern Manitoba.*

Preliminary interpretation

The entire study area is thought to have been covered by glacial Lake Agassiz for approximately 300–500 years (Klassen, 1983; Clarke, 1988; Thorleifson, 1996). Because glaciolacustrine sediments are absent in some lowland areas, are of variable thickness and have been washed and eroded from most of the topographic highs, it is likely that the lake was relatively shallow here.

Glaciolacustrine sediments also occur beneath tills or are extensively mixed with till. Mixing was attributed to cryoturbation by the Operation Superior project team (Fedikow et al., 2001, 2002b), but permafrost features are rare at surface and thus the extensive depth of mixing seems unusual. Together with the sites where glaciolacustrine clay was encountered beneath the beige calcareous till, these features indicate there may have been some fluctuation or re-advance of the Hayes lobe during deglaciation.

Ice flow

Evidence from small-scale erosional indicators

New ice-flow measurements were obtained from striations, grooves, chattermarks, crescentic scours and roches moutonnées, and compiled with previously unpublished ice-flow indicator data from Operation Superior (Figure GS-17-5). Striae from Barry's (1959) surficial maps were also included. The 2012 field sites were generally limited to lakeshores, where outcrops are well exposed because till cover has been removed by wave washing. Where crosscutting striae patterns were found, the relative ages of flows were determined when

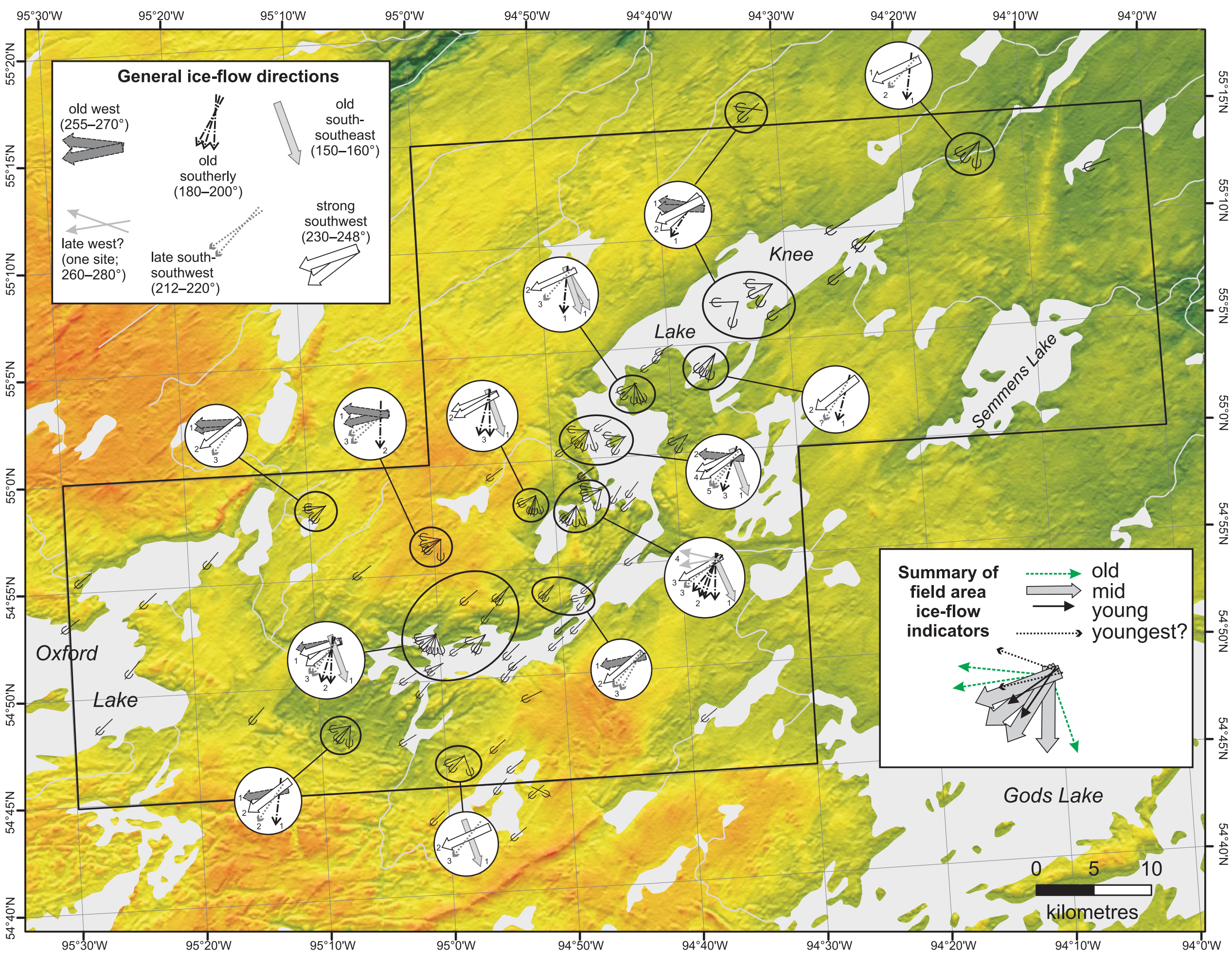

***Figure GS-17-5:** Relative-age ice-flow indicator map, based on striations, grooves, chattermarks, crescentic scours and roche moutonnées in the Knee Lake area, northeastern Manitoba. Direction was not known at every site, but enough sites in the area provided information to consistently assign the directions as shown here. Numbers indicate the relative age of each indicator at a particular site. The five ice-flow phases were recognized based on consistent repetition of relative-ages for similarly oriented ice-flow indicators. Background image was generated using a Shuttle Radar Topography Mission digital elevation model (United States Geological Survey, 2002), draped with a Canadian digital elevation data (GeoBase®, 2007) model.*

possible. Commonly, directional indicators, such as stoss-lee relationships, crescentic scours and chattermarks, were present. The regional field-based ice-flow indicator data (DRI2012004[1]) is complex, and consists of five main ice-flow phases.

Ice-flow indicators document an old, rare, southeasterly trending, ice-flow phase (between 150 and 160° azimuth, Phase I), followed by a widespread old westward-trending ice-flow phase (between 255 and 280°, Phase II). Phase I is evidenced by only rough, deep chattermarks and gouges (Figure GS-17-6a), whereas Phase II evidence consists of grooves, striations, chattermarks and roches moutonnées. Rare, but widespread, intermediate relative-age ('mid' in the Summary of field area ice-flow indicators on Figure GS-17-5) striae and grooves then indicate a southward-trending ice-flow phase (between 180 and 194°, and towards 200°, Phase III). Phase III is recorded as chattermarks, striations and grooves (Figure GS-17-6b) and by roches moutonnées at one site. At almost all sites, intermediate relative-age ice-flow indicators then trend southwest (between 230 and 248°, Phase IV). When present, Phase IV ice-flow indicators are typically the dominant features and consist of roches moutonnées, striations, grooves, chattermarks and crescentic scours (Figure GS-17-6c–e). Outcrop moulding may be more extensive south of the Maskichikwan Narrows (locally called second narrows) on Knee Lake (Figure GS-17-1), as ice flow was subparallel to the pre-existing southwest-trending bedrock structure (schistosity or gneissosity, Barry, 1959) in this area. Young, presumably late deglacial, fine striae and grooves are situated on outcrop tops throughout the study area and are oriented towards south-southwest (between 212 and 220°, Phase V, Figure GS-17-6f). At one site (Figure GS-17-5), a rare young westward ice-flow phase may correlate to the possibly young westward-trending drumlinoid ridges situated between the towns of Thompson and Gillam, approximately 130 km northwest of the study area.

Evidence from large-scale indicators

The majority of drumlinoid ridges in the study area trend southwest between 220 and 235°. These subglacial landforms are situated in the centre of a very large regional flowset of lobate streamlined landforms. This flowset originates from within 100 km of the southwestern shore of Hudson Bay and is approximately 280 km wide and 400 km long (Prest et al., 1968; Klassen, 1983; Dredge and Cowan, 1989).

Preliminary interpretations

Ice-flow indicators in the study area suggest ice has flowed between 150 and 280°. This is considerably more variation in ice-flow orientation than what has been previously published for the area (Barry, 1959; Klassen, 1986; Clarke, 1988; Fedikow et al., 2000, 2001). This new data indicates that the study area has been affected by ice flowing southeast and south from an ice divide situated in central Nunavut (possibly correlative to the Sundance till and a Late Wisconsinan till), as well as by ice flowing southwest from Hudson Bay (Hudson Dome, Dyke et al., 1982; ice saddle, Dyke and Prest, 1987; Trommelen et al., 2012) and west from the Quebec/Labradorean ice sector (possibly correlative to the Amery till and a Late Wisconsinan till).

Mid-aged southwest and south-southwest-trending ice-flow indicators are likely coeval to the streamlined landforms that outline the deglacial Hayes lobe. This work confirms that a confident late deglacial geomorphological and erosional ice-flow indicator record is lacking in the area.

Future work

Ongoing surficial geological analyses focuses on tracing lithological indicators from known bedrock source areas, using clast counts and the major and trace element geochemical composition of the collected till samples. Results of these analyses will

- establish the compositional till characteristics (multiple tills?) and aid investigation of subglacial transport directions and distances, and
- help to determine whether the till composition in the study area relates to the streamlined landform orientations, or whether there is evidence of compositional inheritance (Trommelen et al., in press).

Economic considerations

As bedrock outcrops are rare, a thorough understanding of surficial geology is essential for drift prospecting in Manitoba's northern region. Till geochemistry is commonly used in drift-covered regions, but is more difficult to interpret in palimpsest terrains that have been modified by more than one ice advance and transport direction. Forthcoming results will provide new constraints to drift exploration in this area, applicable to exploration for a variety of commodity types, including diamonds, precious and base metals, including gold, and pegmatite- and carbonatite-hosted rare element deposits (Fedikow et al.,

[1] MGS Data Repository Item DRI2012004, containing the data or other information sources used to compile this report, is available online to download free of charge at http://www2.gov.mb.ca/itm-cat/web/freedownloads.html, or on request from minesinfo@gov.mb.ca or Mineral Resources Library, Manitoba Innovation, Energy and Mines, 360–1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada.

Figure GS-17-6: *Ice-flow indicators in the Knee Lake area, northeastern Manitoba:* ***a)*** *ice-flow indicators on a side of an island protected from younger ice flows (site 12115MT222). An old gouge trending 160° is crosscut by abundant striations (275°), which are then crosscut by rarer deeper striations trending 200°;* ***b)*** *small patch of fine striations (184°) in a hollow protected from ice-flow phases IV and V at this site (12115MT296);* ***c)*** *abundant striations (240°) across the top and down an older face that trends 150° (site 12115MT213);* ***d)*** *common small roches moutonnées trending 245° at the up-ice side of an island (site 12115MT235);* ***e)*** *abundant striations (248°) on the sloping side of this island, which was likely covered by till (vanished protector, Veillette and Roy, 1995) and protected from the Phase V ice flow (218°) recorded on the top of the outcrop (site 12115MT247);* ***f)*** *abundant crescentic scour sets trending 218° on a mafic volcanic outcrop (site 12115MT225).*

2000, 2002a, b). Ongoing surficial geological studies aim to provide

- a detailed framework for the directions, timing and nature (e.g., erosive or depositional) of major and minor ice-flow events in the region, and
- dispersal train patterns as measures for ice transport distances and directions.

The outcomes of these studies are geared toward providing mineral exploration geologists with an up-to-date surficial geology knowledge base and the adequate tools to more accurately locate exploration targets in Manitoba's north.

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