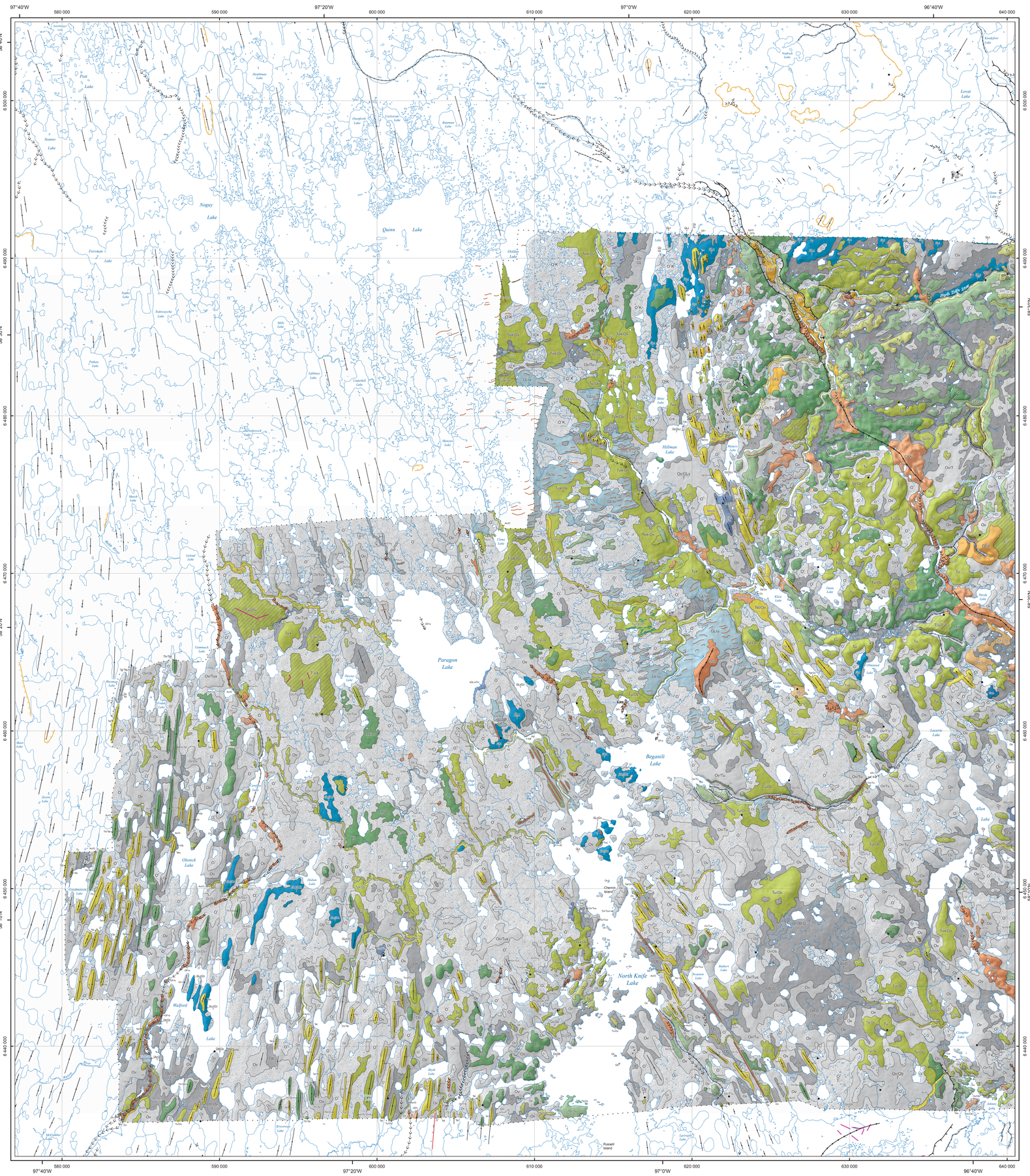
Surficial geology of the North Knife and South Knife lakes area (west half), Manitoba (parts of NTS 64I2–7, 10, 11)



QUATERNARY

HOLOCENE

Nonglacial environments

ALLUVIAL DEPOSITS: sorted sand, silt and clay with minor gravel and organic detritus; commonly stratified; deposited along and/or within all modern rivers and streams

- Av — **Floodplain deposits, thin:** sorted sand, silt, clay, minor gravel and organic detritus, <1 m thick; forming active floodplains close to river and stream level
- Af — **Fluvial fan:** sorted sand, silt, clay, minor gravel and organic detritus; forming a fan deposit where a stream channel enters a larger water body
- Ap — **Floodplain deposits:** sorted sand, silt, clay, minor gravel and organic detritus, >1 m thick; forming active floodplains close to river and stream level; includes terraces too small to show at this map scale
- At — **Fluvial terraces:** inactive terraces above modern floodplain; >2 m thick; consisting of gravel, sand, and overbank silt and organic detritus

ORGANIC DEPOSITS: undifferentiated peat and muck; 1 to >5 m thick; formed by the accumulation of plant material in various stages of decomposition; generally occurs as flat, wet terrain (swamps and bogs) over poorly drained substrates; fibric fens are present along some water channels; permafrost is commonly present underlying/within thick organic deposits, as well as the prevalent raised bogs with ice-wedge polygons; small, unmapped deposits commonly occur in most terrain units; peat mantles most geological units

- Ov — **Veneer:** thin accumulations of peat, 0.3 to <1 m thick, which drape the existing topography
- Ob — **Blanket:** continuous peat between 1 and 2 m thick, which drapes the existing topography; some polygons include hummocky mounds and plateaus underlain by discontinuous permafrost
- Op — **Plain:** flat to gently undulating plain of peat, >2 m thick, that contains numerous small thermokarst ponds and depressions
- Ov° — **Wetland – bog:** flat to gently undulating plain of peat, >2 m thick, that contains hummocky mounds and plateaus underlain by discontinuous permafrost; **Ov°** includes thermokarst areas related to melting ground ice
- Ov° — **Wetland – fen:** flat to gently undulating plain of fibric vegetation, often floating, that masks the underlying topography

COLLUVIAL DEPOSITS: mass-wasting debris; nonsorted to poorly sorted, massive to stratified debris deposited by direct, gravity-induced movement; composition depends on source material

- Ch — **Mass-wasting debris:** sediment moved downslope by active and inactive mass-movement processes; hummocky topography
- Cf — **Landslide and slump debris, toe:** fan-shaped base where sediment derived from mass-movement processes upslope has come to rest.
- Cv — **Veneer:** thin and discontinuous cover of slumped and/or soliflual material; >1 m thick

EOLIAN DEPOSITS: wind-deposited, medium to fine sand; derived from deltaic, esker or glaciolacustrine deposits; in some areas, eolian sediments are thin or absent between dunes

- Ev — **Veneer:** discontinuous veneer of eolian sediments; <1 m thick
- Eb — **Blanket:** 1–3 m thick, continuous cover forming flat to undulating topography that locally obscures underlying geomorphology
- Eu — **Undulating deposits:** forming dunes; generally >2 m thick

MARINE SEDIMENTS: poorly to well-sorted sand and silt with 0–20% pebbles, cobbles and occasional boulders (ice rafted and lags), deposited in the postglacial Tyrrell Sea; clasts are typically subrounded to subangular, occasionally striated and/or faceted/bullet-shaped, derived from the reworking of till; the marine limit is between 140 and 180 m asl, defined by washing limits on eskers and till plains and by the elevations of sand blankets and beaches – the exact elevation is uncertain, owing to the likelihood that glacial Lake Agassiz was coeval with the Tyrrell Sea during deglaciation; near the marine limit, glaciomarine sediments also occur and this sand and silt locally includes pockets of debris-flow sediments; till and/or minor dropstones, deposited from suspension and iceberg rafting

- Mv — **Veneer:** thin, discontinuous silt and/or sand, <1 m thick, that drapes the existing topography; predominantly derived from reworking of till and/or glaciofluvial deposits
- Mn — **Nearshore sediments:** poorly sorted to well-sorted sand, silt and clay; occurs as veneers and blankets of sediment overlying till and/or bedrock; commonly between 1 and 2 m thick, but can be up to 5 m along the North Knife River valley
- Mr — **Littoral sediments:** poorly sorted to well-sorted, stratified sand with 5–20% pebbles and cobbles; typically 1–2 m thick; where eskers occur below marine limit, wave washing has commonly reduced the ridges to a height of 0.25–1 m and redistributed the sand, creating veneers and blankets of light orange, granitic pebbly sand; low-lying regions or depressions often have an organic veneer overlying the sand and silt

LATE WISCONSINAN

Proglacial and glacial environments

GLACIOLACUSTRINE DEPOSITS: massive to laminated (rhythmically bedded) silt, clay and sand, deposited into littoral and deep-water environments of glacial Lake Agassiz; these deposits are of variable thickness (0.2–3 m) and drape both till deposits and bedrock; just north of South Knife Lake, 10–15 m of glaciolacustrine sediments are overlain by a till blanket

GLACIOLACUSTRINE, ICE CONTACT: weakly calcareous to noncalcareous, massive to weakly stratified, fine sand, silt and minor clay, commonly contains ice-rafted stones, diamict beds (massive with 1–5% granules to small pebbles of carbonate and crystalline rock) and stratified water-laid diamict; deposited beneath and/or reworked by ice near the margin at the contact zone between the glacier and glacial Lake Agassiz

GLlu — **Undulating:** 0.2–3 m thick, imperfect to well drained, forms undulations and hummocks that rise up out of the surrounding organic terrain; includes De Geer moraines—minor moraines formed due to subglacial sediment advection to the ice margin during temporary halts in grounding-line retreat

GLACIOLACUSTRINE, LITTORAL: glacial sediments reworked by wave action; forms moderately well sorted isolated ridges or a series of ridges, including beaches, bars and spits; blankets of sand grading basinward into silt and clay, commonly <1 m thick

- sGLr — **Ridged sediments:** 0.5–2 m thick, moderate to well-drained sandy beach ridge
- sGLv — **Veneer:** 0.2–1 m thick, moderate to imperfectly drained blankets of fine sand and silty sand; underlying topography is discernible

GLACIOLACUSTRINE, DEEP-WATER: Calcareous to noncalcareous, massive to rhythmically bedded, well-sorted, moderately dense, milk-chocolate brown clay and rarer silt

- GLv — **Veneer:** 0.2–1 m thick, imperfect to poorly drained; underlying topography is discernible
- GLb — **Blanket:** 1–3 m thick, imperfect to very poorly drained, continuous cover forming flat to undulating topography that locally obscures underlying geomorphology; typically mantled by peat of variable thickness
- GLp — **Plain:** >3 m thick, imperfect to very poorly drained, continuous cover forming flat topography that obscures underlying geomorphology; typically mantled by peat of variable thickness

GLACIOFLUVIAL DEPOSITS: orange to tan, moderately to poorly sorted, silt, sand, gravel and diamicton deposited behind, at or in front of the ice margin by flowing glacial meltwater; where the suffix **x** has been added to the terrain-unit label (i.e., **GFrx**), it indicates that the sediments have had significant surface reworking by glacial Lake Agassiz and/or the Tyrrell Sea

- GFv — **Veneer:** discontinuous sand and gravel cover, <1–2 m thick; underlying topography is discernible
- GFb — **Blanket:** continuous sand cover >2 m thick; forming flat to undulating topography that locally obscures underlying units and associated geomorphic patterns; typically formed by redistribution of glaciofluvial sand in a shallow-water environment
- GFh — **Ice-contact sediments:** undifferentiated deposits; poorly sorted sand and gravel with minor diamicton, deposited by glacial meltwater in direct contact with the glacier; 1 to >10 m thick; forming gently undulating to hummocky topography related to melting of underlying ice; features include kettles, kames and ridges
- GFr — **Eskers, esker systems:** massive to stratified sand and minor gravel, deposited by meltwater flow within tunnels beneath or within the glacier; present as 1–20 m high ridges
- GFd — **Ice-contact delta:** well to moderately stratified sand and gravel deltaic deposit formed where a meltwater channel entered a glacial lake during regression and lowering of lake levels

GLACIAL DEPOSITS: unsorted to poorly sorted diamicton (till) deposited in subglacial environments; wide range in the composition of the till, with significant variable proportions of eastern- and/or northeastern-sourced (Paleozoic and Proterozoic) and regionally to locally sourced (greenstone belt and granitoid rocks) clast concentrations; where the suffix **x** has been added to the terrain label (e.g., **Tvx**, **Tbx**, **Tstx**, **Tux**), it indicates that the sediments have had significant surface reworking by lacustrine, fluvial or marine waters

- T — **KEEWATIN-HUDSONIAN TILL:** calcareous hybrid till, with silty sand to clayey silt matrix, which contains 10–76 ct. % Paleozoic carbonate-bearing clasts mixed with Proterozoic, Precambrian and Archean clasts (granitoid, gneissic and greenstone belt rocks); the matrix is calcareous (3.8–44.6 wt. % total carbonate and 2.1–20.3 wt. % CaO); this till was deposited by ice flowing from the Quebec–Labrador ice sector of the Laurentide Ice Sheet, and later variably reworked by ice flowing southwest and south from the Keewatin sector, or an ice saddle overlying southeastern Hudson Bay
- T — **KEEWATIN-DOMINANT TILL:** weakly calcareous to noncalcareous till, with silty sand to clayey silt matrix, which contains 0–9 ct. % Paleozoic carbonate-bearing clasts, mixed with Precambrian and Archean clasts (granitoid, gneissic and greenstone belt rocks); the matrix may contain up to 19 wt. % total carbonate and 17 wt. % CaO; this till was predominately sourced from ice flowing south, southeast and southwest during the Quinn Lake readvance, and from later reworking by ice flowing southwest from an ice saddle overlying southeastern Hudson Bay; this till type may be more widespread than it appears on the map, as it was only applied to map polygons where supported by till-sample laboratory analyses
- Tv — **Till veneer:** discontinuous till cover 0.2–1 m thick; underlying topography is discernible; where not otherwise noted, bedrock is assumed to be the underlying material
- Tb — **Till blanket:** continuous till cover, 1–3 m thick, forming flat to undulating topography that locally obscures underlying units and associated geomorphic patterns; occasional thinner patches of till may occur
- Tp — **Till plain:** continuous till cover, in places up to 30 m thick, forming flat topography that obscures underlying units and associated geomorphic patterns
- Th — **Hummocky till:** till >2 m thick with hummocky topography (2–5 m swales), either moulded beneath the glacier or as a result of supraglacial meltout (ablation) tills deposited by melting of stagnant ice; loose, texturally variable, sandy to gravelly matrix; some sorting; angular to subangular clasts
- Tu — **Undulating till:** till >2 m thick, moulded beneath the glacier into undulating topography (0.1–2 m swales)
- Tr — **Ridged moraine:** minor lateral and shear moraines associated with the Quinn Lake readvance, 0.3–3.8 km long
- Tst — **Streamlined till:** >2 m thick, subglacial till moulded beneath the glacier into linear ridges and/or furrows parallel to ice flow; drumlins, drumlinoid ridges, flutings; ridges are typically 0.1–1.7 km long and 0.5–5 m high

PRE-QUATERNARY

- R — **Precambrian bedrock:** metasedimentary and metavolcanic rocks and associated intrusive rocks; may be overlain by a thin, discontinuous veneer of sediment

Notes:
This legend is common to MAP2015-1 and -2. Not all units and symbols shown in the legend will appear on this map.

In areas where the surficial cover forms a complex pattern, the area is coloured according to the dominant unit and labelled in descending order of cover (e.g., R/Tv). Where underlying stratigraphic units are known, areas are coloured according to the overlying unit and labelled in the following manner:

GLv / Tst — means glaciolacustrine veneer overlies streamlined till

Multiple modifiers may be combined to clarify the detailed geology (e.g., Tbx, T^{L}_{ux}).

DESCRIPTIVE NOTES

Surficial geology of the North and South Knife lakes area, Manitoba (parts of NTS 54L, 64I)

Methods

The surficial geology of the North Knife and South Knife lakes area was interpreted from 1:60 000 scale black and white airphotos obtained from Natural Resources Canada. Aspects of the regional surficial geology were also gleaned from Shuttle Radar Topography Mission imagery (30 and 90 m resolution; United States Geological Survey, 2002) and SPOT orthoimages (GeoBase®, 2012). Field studies were conducted by helicopter in September 2013, with additional studies along the Churchill River in 2014. This project includes data from 227 field sites, from which 192 till samples were analyzed for geochemical and clast composition. This new mapping builds on previous 1:250 000 scale surficial mapping completed in the late 1980s (Dredge and Nixon, 1981, 1982).

Physiography

This portion of northeastern Manitoba is mantled by glacial and postglacial sediments. Bedrock outcrops are scarce, and generally limited to exposures along creeks and rivers. Elevation varies mainly from 50 to 340 m above sea level (asl) and local relief is up to 30 m.
The region falls within the zone of discontinuous permafrost (Sladen, 2011). Bogs are commonly frozen and ice-rich below 1 m. Periglacial features, such as mud boils, peat plateaus, ice-wedge polygons and frost-shattered rock, are common in all nonforested areas.

Ice-flow history

The Laurentide ice sheet flowed across the study area over a span of 275° (Figure 1), and in the same direction multiple times: from the Keewatin sector to the north, the Quebec–Labrador sector to the east and from an ice saddle over southern Hudson Bay late in deglaciation. Because of this history, the preserved subglacial record reflects a complex erosion, transportation and deposition relationship between inheritance from older ice-flow phases and overprinting during younger ice-flow phases.
Old ice-flow phases were to the west and northwest (270–290°), southwest (230–250°) and southeast (140–160°). Ice then flowed to the south-southwest (180–200°) and southwest to west-southwest (220–250°). During deglaciation, an ice lobe surged south into glacial Lake Agassiz, termed the Quinn Lake readvance, whereas ice sourced from Hudson Bay remained at an ice margin ~10 km north of South Knife Lake. After this surge, retreat proceeded toward the north and northeast, and a major switch in orientation resulted in late phases of ice flow to the east-southeast (110–130°) and southeast (150–170°). Not all of these phases affected the entire study area, but rather the ice-flow history is different in each compositional glacial terrain zone (Figure 2).

Glacial Lake Agassiz and the Tyrrell Sea

As ice retreated, parts of the map area were inundated by the postglacial Tyrrell Sea or glacial Lake Agassiz and/or other smaller ice-marginal lakes. Exposed in a landslide, ~15 m of interbedded silt and fine sand were encountered between two till units just northeast of South Knife Lake. These sediments are capped by a 3 m thick till that contains infinite ^{14}C age marine shell fragments at its base. The extent of this buried lacustrine sediment is unknown.
The maximum surface lake limits are between 140 and 280 m asl. An ice-marginal lake limit of 245 m asl is defined by wave-washing on the South Knife glaciofluvial complex, glaciolacustrine onlap onto the complex, delta and fan formation on the eastern side of the complex, and the elevation of a meltwater spillway at South Knife Lake. This lake represents the northern boundary of glacial Lake Agassiz, but was likely restricted in size, and continually changing configurations along the retreating ice margin.
Radiocarbon ages indicate that the sea and lake(s) were coeval; further work is required to fully reconstruct the deglacial history. The minimum age for deglaciation, based on incursion of the Tyrrell Sea, is 8 821 ±0.17 cal. ka (Beta-338664) in the study area (Figure 1) and 8.26 ±0.15 cal. ka (UCIAMS-149592) further south of the study area at Gillam. There are new glaciolacustrine radiocarbon ages of 8.11 ±0.07 cal. ka (UCIAMS-135236) at 142 m asl elevation, and 8.00 ±0.04 cal. ka (UCIAMS-135233) at 86 m asl elevation (Figure 1). The marine limit in the study area is difficult to determine, but falls between 140 and 180 m asl.

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United States Geological Survey 2002: Shuttle Radar Topography Mission, digital topographic data; United States Geological Survey, URL <http://dds.cr.usgs.gov/srtm/>, 90 m cell, zipped hgt format [December 2011–June 2012].

Symbols

- Beach ridge
- Crevasse ridge
- De Geer moraine
- Drumlin
- Drumlinoid ridge or fluting
- Dune
- Esker, direction known
- Esker, direction unknown
- Esker, washed, direction known
- Esker, washed, direction unknown
- Iceberg scour
- Major moraine
- Minor moraine, undifferentiated
- Meltwater channel
- Meltwater corridor
- Scarp
- Trimline (scarp)
- Limit of mapping
- Field site with sample
- Field site without sample
- Outcrop
- Radiocarbon age
- Mass movement
- Roche moutonnée
- Striae, direction known, well preserved
- Striae, direction known, poorly preserved
- Striae, direction unknown, well preserved

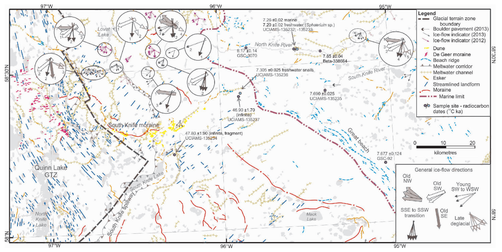


Figure 1: Ice-flow indicators, marine limit and mapped geomorphology in the North Knife and South Knife lakes area of northeastern Manitoba. The orientation and relative ages of erosional ice-flow indicators, including micro-scale nondirectional indicators (striations and grooves) and directional indicators (chattermarks, crescentic gouges and stoss-lee relationships), are shown. Large circles highlight the regionwide relationship between indicators mapped in the field and the relative timing of variously oriented ice-flow phases at each site. The inset with the general ice-flow directions provides a summary of ice-flow orientation for the entire region. Conventional ^{14}C ages for shell samples are also depicted. Abbreviations: Beta, Beta Analytic (Miami, Florida); GSC, Geological Survey of Canada (Ottawa, Ontario); GTZ, glacial terrain zone; NW, northwest; SE, southeast; SSE, south-southeast; SSW, south-southwest; SW, southwest; UCIAMS, University of California, Irvine, Keck Carbon Cycle Accelerator Mass Spectrometer facility (Irvine, California); WSW, west-southwest.

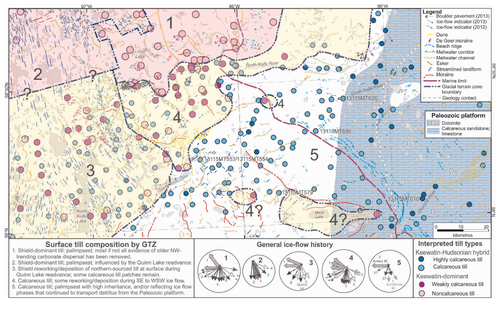
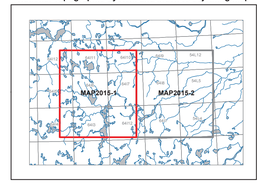
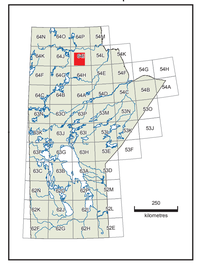


Figure 2: The North Knife River–Churchill River region has been separated into different glacial terrain zones (GTZ) for the purposes of this study. These zones are based primarily on surface till composition, but also include stratigraphy and patterns of field-based (striae) and streamlined-landform flowsets. Interpreted till type, geomorphology, marine limit and stratigraphic field sites (e.g., 13115MT626; M.S. Trommelen, unpublished data, 2014; Gauthier, 2016) are also depicted. The general ice-flow history (inset) is based on data presented in Figure 1, and from interpreted dispersal orientation of till clasts. Abbreviations: NW, northwest; SE, southeast; WSW, west-southwest.

National Topographic System and index to adjoining map



Location Map



Geology by M.S. Gauthier (2013, 2014 field seasons)

Airphoto interpretation onto 1:60 000 scale airphotos by M.S. Gauthier.

Digital cartography by B.K. Lenton, P.G. Lenton and M.E. McFarlane (2014–2016).

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Gauthier, M.S. 2016: Surficial geology of the North Knife and South Knife lakes area (west half), Manitoba (parts of NTS 64I2–7, 10, 11); Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, Geoscientific Map MAP2015-1, scale 1:100 000.

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