GS2022-11

Surficial geology mapping and till composition of the western Fox River greenstone belt area, northeastern Manitoba (NTS 53M15, 16, parts of 53N13, 54C4, 54D1): year two

by M.S. Gauthier and T.J. Hodder

In Brief:

- Surficial mapping in NTS 53M15 and 53M16, year 2
- Collection of till samples to determine provenance and drift-exploration potential, including for diamonds—includes release of year 1 KIM analyses
- Collection of ice-flow data to reconstruct the glacial history and aid drift exploration

Citation:

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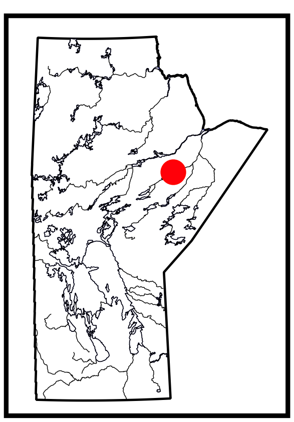


Summary

Quaternary geology fieldwork, including till sampling and ice-flow–indicator mapping, was conducted over a portion of the buried Fox River greenstone belt in northeastern Manitoba (NTS 53M15, 16; parts of 53N13, 54C4, 54D1). This follow-up to 2020 fieldwork included visits to 143 field sites to ground-truth the surficial geology mapping, collect till samples and identify ice-flow indicators. Sixty-five 2 kg till samples were collected for geochemical (<63 µm size fraction) and clast-lithology (2–8 mm size fraction) analyses in 2022. At 40 of these sample sites, an additional 11.4 L was collected for heavy mineral analysis (magmatic or metamorphosed massive-sulphide–indicator minerals, kimberlite-indicator minerals and visible gold).

Sediment cover in the area varies from 0 m, along some river beds, to at least 60 m, as indicated by drillholes in the study area. The study area is draped by a light-coloured diamict with a sandy-silt or silty-sand matrix. A darker-coloured and finer-textured diamict, with a crumbly or blocky texture, can also be found at surface. At six mapping sites, older buried tills, which are denser than the overlying diamicts, blocky with oxidation rinds on joints, darker-coloured and usually finer-grained, were also identified.

Most parts of the study area are covered by a veneer of glaciolacustrine clay or silt (0.1 to ~1.0 m thick), though thicker glaciolacustrine deposits were observed (up to 1.5 m). A proglacial lake washed the existing substrate, commonly to depths of 0.6 m. Consequently, till samples collected for drift exploration purposes must be taken at depth to avoid sampling till that has been washed of fines and/or leached of water-soluble elements and/or sampling displaced material.

Paleo-ice flow was interpreted from both erosional field-based ice-flow indicators (total of seven sites) and till fabrics (total of 13 sites). The till-fabric interpretations suggest young south- to south-southwest-trending ice flow (170–215°), west-trending ice flow (283°) and either a northwest- or southeast-trending ice flow (300–334° or 120–154°). Older ice-flow phases were oriented to the northwest-southeast (bimodal, twice), west (twice), southwest, south-southwest and south. The study area is covered by erosional streamlined landforms, which trend toward the southwest (215–245°) and were formed by the deglacial Hayes Lobe of the Laurentide Ice Sheet.

Introduction

Quaternary geology fieldwork, including till sampling and ice-flow–indicator mapping, was conducted for 21 days in August 2022, over a portion of the buried Fox River greenstone belt in northeastern Manitoba (NTS 53M15, 16; parts of 53N13, 54C4, 54D1). This complements work done in 2020 (Gauthier and Hodder, 2020, 2021). The goals of this project are to

- conduct 1:50 000 scale mapping;
- sample till to assess the till composition of the area;
- sample till to analyze for heavy minerals (magmatic or metamorphosed massive-sulphide–indicator minerals [MMSIMs®], kimberlite-indicator minerals [KIMs], visible gold); and
- conduct paleo–ice-flow mapping to assist reconstructions of the glacial dynamics of the area, which in turn guide drift exploration studies in northeastern Manitoba.

Bedrock geology

The study area is underlain by rocks of the Fox River greenstone belt, which is part of the circum-Superior belt in northeastern Manitoba (Figure GS2022-11-1). The Fox River belt demonstrates potential to host nickel±copper and platinum-group-element (PGE) mineralization (Rinne, 2018, 2020). The belt consists of Paleoproterozoic metamorphosed sedimentary rocks (mudstone, sandstone, minor

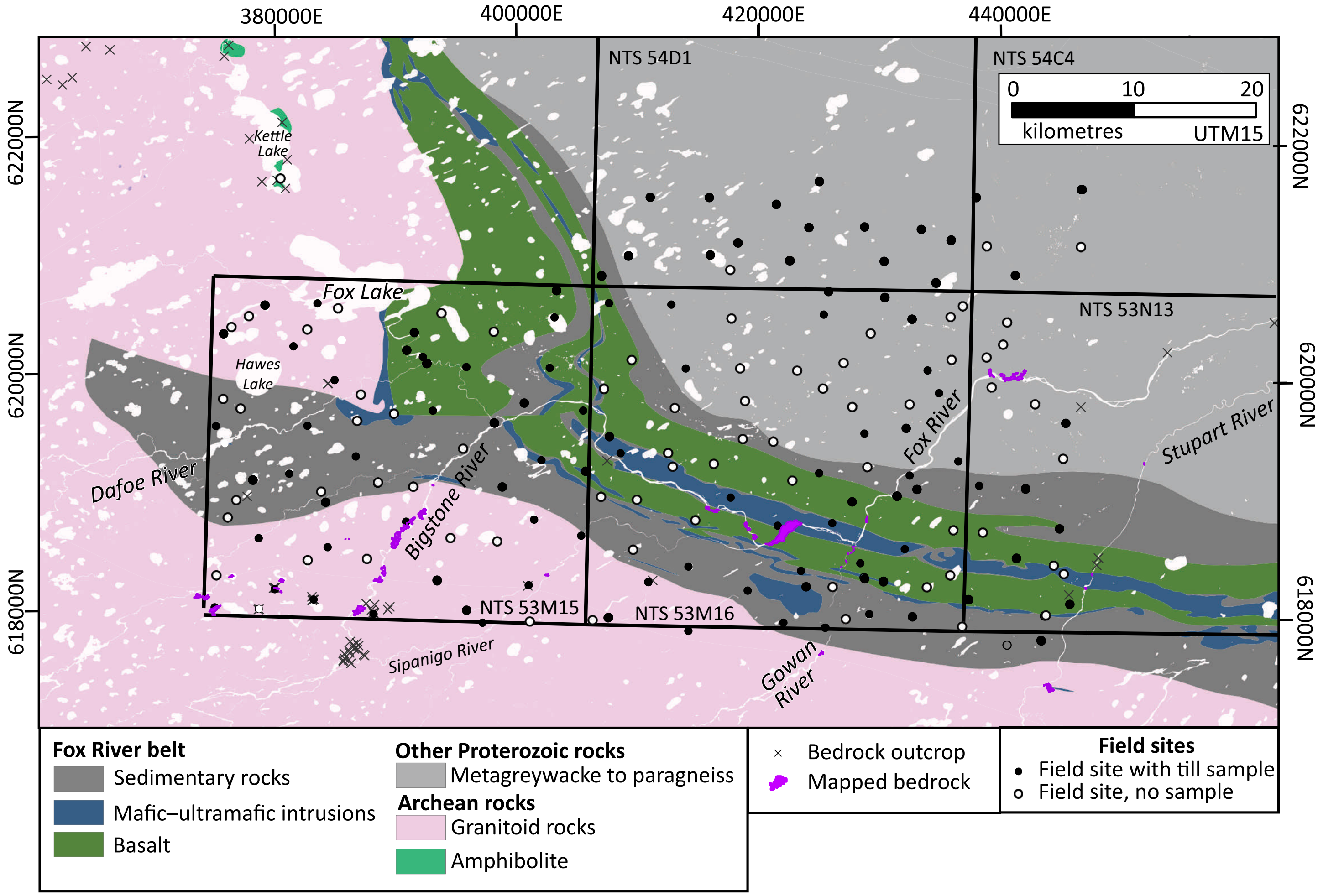


Figure GS2022-11-1: *Field sites and till sample sites overlying a portion of the Fox River greenstone belt, northeastern Manitoba. Bedrock geology is from Rinne (2018, 2020). All co-ordinates are in UTM Zone 15, NAD83.*

iron formation and calcareous beds), mafic to ultramafic rocks (basalt to komatiitic basalt with minor interflow mudstones) and mafic to ultramafic intrusions (serpentinized peridotite, pyroxenite, gabbro and minor leucogabbro). Archean granitoid rocks of the Superior province border the western and southern parts of the Fox River belt, whereas the area north of the belt is dominated by Paleoproterozoic metagreywacke and derived gneiss of the Trans-Hudson orogen (eastern Kisseynew belt).

Quaternary history

The study area was previously mapped in the late 1970s, using aerial photographs at 1:250 000 scale with limited to no ground-truthing (Klassen and Netterville, 1979). More recent work has been conducted to the north and south of the study area (Trommelen, 2015; Gauthier et al., 2019). These areas are dominated by gently sloping, moderately to very poorly drained topography. Stunted spruce bogs and forests drape most areas and surface permafrost is common beneath blankets of organic deposits. Elevation varies between 68 and 198 metres above sea level (m asl). Local relief is typically 1 to 30 m, generated by smooth, bare to thinly drift-covered outcrops separated by low ground.

The study area was glaciated by ice flowing from multiple migratory domes of the Laurentide Ice Sheet during the last glacial cycle, comprising marine isotope stages (MISs) 2–5 (Klassen, 1986; Gauthier et al., 2019). At some point during MIS 2 a thick ice ridge, the Hudson Bay Ice Saddle, formed between two main domes (Dyke and Prest, 1987; Thorleifson et al., 1993). During deglaciation, the lobate Hayes Lobe ice stream flowed southwest from this saddle, and across the study area (Dredge and Cowan, 1989; Gauthier et al., 2021). In an area 55 km to the south, the Hayes Lobe is interpreted as a late-stage erosional event (Trommelen and Ross, 2014), which did not affect the composition of the underlying till(s). The results from this study will determine whether that interpretation holds true for this area as well.

Methods

Helicopter-supported fieldwork was undertaken over 21 days in August 2022, based out of the town of Gillam, which is located 40 km north of the study area. The Bell Jet Ranger helicopter was equipped with floats, as the area is forested and landing is limited to fens. A total of 143 field sites were visited to ground-truth the surficial geology mapping, collect till samples and identify ice-flow indicators (Figure GS2022-11-1). The surficial material at each field station was investigated by means of a hand-dug shovel hole, a Dutch auger (1.2 m long) hole and/or a natural sediment exposure.

In 2022, sixty-five 2 kg till samples were collected for geochemical analysis by partial and total digestion of the silt and clay size fraction (<63 µm) and clast-lithology (2–8 mm size fraction) analysis. Till samples were collected from the C-horizon soil, both at surface and at depths of up to 14 m. At 40 of these sample sites, an additional 11.4 L was collected for heavy mineral analysis (MMSIMs, KIMs, visible gold).

For the 80 till samples collected in 2020, results from till geochemistry and heavy mineral analyses were released in Gauthier and Hodder (2021). Kimberlite-indicator-mineral counts with microprobe results from 2020 were released in Hodder and Gauthier (2022)[1].

2020 indicator mineral processing

During the 2020 field program, 59 till samples were collected for heavy mineral analysis. These till samples were initially processed by the De Beers Group of Companies (De Beers; Sudbury, Ontario). The KIM sample locations were withheld from De Beers to allow equal opportunity for follow-up by all interested parties. Heavy mineral concentrate from the <0.5 mm size fraction of the till sample was passed over a 0.3 mm aperture sieve and the <0.3 mm size fraction was discarded, leaving the 0.3–0.5 mm size fraction. The remaining heavy mineral concentrate was shipped to Overburden Drilling Management (ODM; Ottawa, Ontario) where it was recombined and reprocessed. Suspected KIM grains from both labs were visually selected, and then analyzed by electron microprobe. The resultant KIM grains were initially classified using electron microprobe results, following the methodology outlined in the Manitoba KIM database (Keller, 2019). The chemistry of certain KIM grain types was then further investigated with bivariate plots.

Results

Surficial geology

Organics

Organic, treed bog deposits are common on very poorly drained surfaces in the study area, and are usually underlain by permafrost (Figure GS2022-11-2a). Other flat-lying areas are draped by thick fen deposits (Figure GS2022-11-2b). 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 (Figure GS2022-11-2c). In some areas, permafrost mudboils (frost boils) are visible from the air and indicative of thin organic cover (Figure GS2022-11-2d).

Glaciomarine and glaciolacustrine sediments

Glaciolacustrine sediments

Massive glaciolacustrine clay and/or silt drapes most of the study area (Figure GS2022-11-3a, b). These sediments are thickest (>1.2 m depth) near the esker-meltwater corridor system (Figure GS2022-11-4), and thin to absent overlying drumlinoid ridges. Wave-washed till was observed at elevations between 120 and 175 m asl. Wave-washing was particularly strong in the southwestern portion of the study area, where low-lying bedrock is exposed between 170 and 185 m asl (Figure GS2022-11-3c).

Beaches and trimlines

Southwest-trending beaches formed around a small esker (northeasternmost study area) and along a topographic high (southeastern study area) at ~131 m asl (Figure GS2022-11-4). In the southeast, several trimlines (wave-washed scarps) were mapped at 136 m asl (Figure GS2022-11-3d). Above the scarps are unwashed tills, whereas below the scarps are massive brown clay or washed tills. Nonetheless, given that the marine limit was mapped at 135 m asl in the Gillam area, 35 km to the north (Gauthier et al., 2020), these are tentative marine features.

Glaciomarine sediments

Significant beach development, subparallel to the modern ocean shoreline, occurred at 120 m asl, just east and northeast of the study area. Possible glaciomarine sediments include 1.5 m of interbedded brown clay, light brown fine to medium sand and brown diamict at 121 m asl, in the eastern half of the study area along the Fox River (Figure GS2022-11-5). Silt (0.4 m) over clay (0.2 m) over moderately to poorly sorted, medium to coarse sand (0.5 m) was encountered at 122 m asl near the southeasternmost part of the study area. On the other hand, thick (>1.2 m) massive brown clay was encountered at two separate locations around 122 m asl. This clay is identical to glaciolacustrine clay mapped throughout the study area. As such, it was noted that the marine limit is at least 120 m asl, and also that glaciolacustrine sediments may have been deposited below marine limit. In areas to the north and northeast, glaciolacustrine sediments were mapped as low as 100 m asl (Gauthier et al., 2020).

[1] MGS Data Repository Item DRI2022010, containing the data or other information sources used to compile this report, is available online to download free of charge at https://manitoba.ca/iem/info/library/downloads/index.html, or on request from minesinfo@gov.mb.ca, or by contacting the Resource Centre, Manitoba Natural Resources and Northern Development, 360-1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada

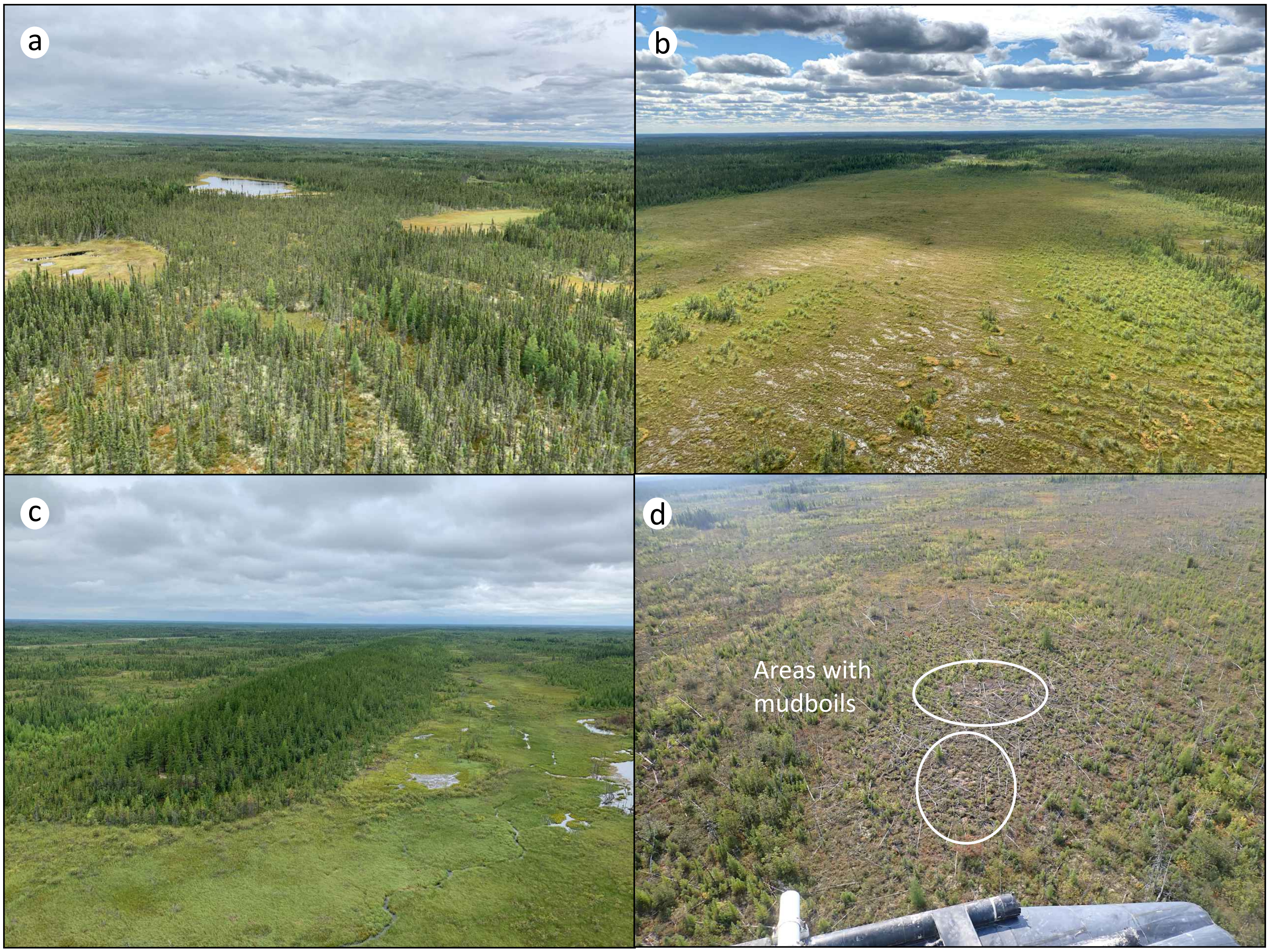


Figure GS2022-11-2: *The majority of the study area is draped by* ***a)*** *organic bogs and* ***b)*** *fens. Organic cover is thin* ***c)*** *where it overlies long linear drumlinoid ridges or* ***d)*** *in better-drained elevated areas, the site of permafrost mudboils.*

Glaciofluvial sediments

The study area is crossed by a large esker-meltwater corridor system, up to 2.5 km wide, that initiates near the confluence of the Stupart and Fox rivers (Figure GS2022-11-4), and extends at least 190 km towards the west-southwest. The corridor has been infilled by at least 11 m of silt and sand, which may relate to the esker, or to later infill by glaciolacustrine and/or glaciomarine sediment. Near the east end of Fox Lake, the surface of the esker is cut by iceberg scours between 170 and 185 m asl. This is the height of land in the study area, and the only place with mapped iceberg scours.

Numerous meltwater channels crosscut the area, including the channels now occupied by the northeast-flowing Bigstone, Fox, Sipanigo and Gowan rivers. These meltwater channels cut down into bedrock (Figures GS2022-11-1, -6a, b), and flowed to the southwest beneath the Hayes Lobe.

Tills

The study area is draped by a light-coloured diamict with a sandy-silt or silty-sand matrix (Figure GS2022-11-7a, b). A rarer darker-coloured and/or finer-textured diamict, with a crumbly or blocky texture, was found below that till at three sections (Figure GS2022-11-7a, c). Both diamicts are loose to crumbly, and interpreted to have been deposited during the last glaciation.

Six sections also exposed underlying older tills that are denser than the upper diamicts, blocky with oxidation staining on joints, darker coloured and usually finer grained (Figure GS2022-11-7d, e). The blocky and relatively dense nature suggests that these tills are significantly older, and that any potential overlying sorted sediments, deposited during an ice-free period, are missing from the area (eroded or not deposited).

Data from the 2020 till samples show that both younger and older tills contain ~65% carbonate clasts (2–8 mm size fraction) and 45% total carbonate in the till matrix (<63 um size fraction), with variable concentrations of greenstone, greywacke and granitoid clasts. A full examination of till composition will occur once the 2022 till sample results are obtained.

Figure GS2022-11-3: *Glaciolacustrine sediments deposited within glacial Lake Agassiz include* ***a)*** *massive brown clay and* ***b)*** *light brown silt. Lowering of lake levels resulted in* ***c)*** *rare removal of Quaternary sediment overlying bedrock and* ***d)*** *the formation of wave-washed scarps (trimline denoted by arrows).*

Washed tills

Drift exploration programs using till samples must be wary of what material to sample. Till in the study area was commonly washed by glacial Lake Agassiz waves, which may have caused removal of the fine-textured size fraction at depths up to 0.6 m, or remobilization and partial sorting of the surface sediments. Wave-washing can leach the water-soluble elements from the sediments and hence lead to a decreased elemental concentration compared to what might have been there originally. Alternatively, if sampling the sand size fraction for heavy mineral analysis, the concentration of indicator minerals within a sample volume may be increased.

In areas of washed till, sediment sampled at depth is usually finer textured, less sorted and denser than the upper washed sediments (Figure GS2022-11-8a–d). Clasts that are clean on one side and have a 'clay skin' adhering to the other side are also indicative of washing and fines removal (Figure GS2022-11-8e, f). In other areas, perhaps due to permafrost mixing, brown clay can be mixed in with beige diamict at depths up to 0.8 m (Figure GS2022-11-8g, h).

Ice-flow history

Erosional field-based ice-flow indicators

Bedrock outcrops are rare in the study area, and new erosional ice-flow measurements were obtained from striations, grooves, chattermarks, crescentic gouges and fractures at just two field sites in 2022 and five field sites in 2020 (Figure GS2022-11-9c; Gauthier and Hodder, 2022)[2]. Based on

[2] MGS Data Repository Item DRI2022009, containing the data or other information sources used to compile this report, is available online to download free of charge at https://manitoba.ca/iem/info/library/downloads/index.html, or on request from minesinfo@gov.mb.ca, or by contacting the Resource Centre, Manitoba Natural Resources and Northern Development, 360-1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada

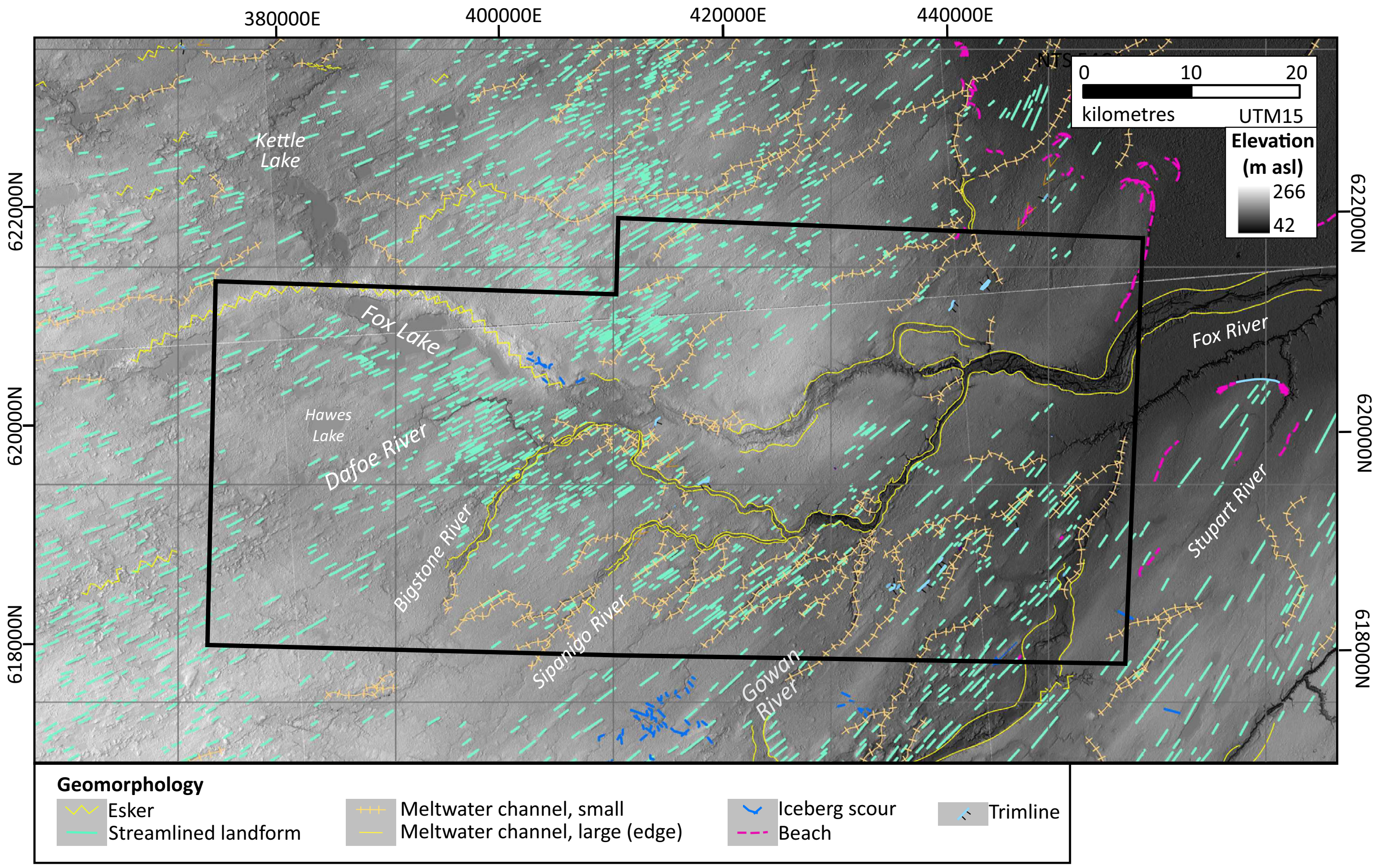


***Figure GS2022-11-4:** Surface geomorphology in the study area is dominated by southwest-trending streamlined landforms, which are accompanied by subparallel meltwater channels. A larger esker-meltwater corridor system crosses the area, and was likely active during formation of the Hayes Lobe. During deglaciation, iceberg scours formed on the bed of glacial Lake Agassiz. Final deglaciation resulted in incursion of the Tyrrell Sea, which formed beaches and trimlines between 131 and 136 m asl. Background imagery is a hillshade created from data provided by Earth Observation Research Center and Japanese Aerospace Exploration Agency (2022). All co-ordinates are in UTM Zone 15, NAD83.*

these erosional field-based ice-flow indicators, paleo-ice flow was to the northwest (308–310°), then west (270°, 286°) and then southwest (235–258°). Ice flowed to the south before the southwest, as demarcated by a protected crescentic fracture to 176° at one site.

Streamlined landforms

Streamlined landforms were mapped across the study area, at a variety of resolutions from remotely sensed imagery (Figure GS2022-11-4). All streamlined landforms trend toward the southwest in the study area, in a fan shape spread toward ~215° in the east and 245° in the northwest, and were formed by the Hayes Lobe ice stream (Dredge and Cowan, 1989; Gauthier et al., 2021).

Till-fabric analyses

Till-fabric analyses were conducted on the surface till at seven sample sites, and on the subsurface till at an additional 13 sample sites. Separating the tills based on presumed relative age (see also Gauthier et al., 2022), the till fabrics suggest that ice during previous glacial cycle(s) flowed to the northwest-southeast twice (direction undetermined), west twice, southwest, south-southwest and south (Figure GS2022-11-9b). The relatively less dense surface till was deposited and/or deformed by south- to south-southwest-trending ice flow, west-trending ice flow and either a northwest- or southeast-trending ice-flow (Figure GS2022-11-9a). The order of these ice-flow phases is unknown, though it is noted that most areas of till were later eroded into southwest-trending streamlined landforms.

Till-fabric analyses are particularly useful in areas where bedrock outcrops are scarce. However, given that the orientations of the surface till fabrics contradict the orientation of streamlined landforms, this study highlights the importance of conducting till-fabric analyses in all areas. The mismatch of orientations between different types of ice-flow indicators likely means that the streamlined landforms are erosional, and have exposed till(s) unrelated to the young southwest-trending ice-flow direction. Although forthcoming till-composition studies will assess this hypothesis, it should be noted that erosional streamlined-landform genesis is confirmed in the Knee Lake area, 55 km to the south (Trommelen and Ross, 2014).

***Figure GS2022-11-5:** Interbedded brown clay, light brown fine to medium sand and brown diamict, interpreted as glaciomarine deposits at the top of a section along the Fox River, northeastern Manitoba.*

2020 kimberlite indicator mineral results

A total of 193 KIM grains were recovered from the 59 samples collected in 2020, averaging 1.7 KIM recovered per 10 kg of till processed. The KIM chemistry and sample abundances are provided in Hodder and Gauthier (2022). The KIM grains include 26 kimberlitic garnets, which are further classified as two G1 garnets, two G11 garnets, two G3 garnets and 20 G9 garnets based on the criteria set out in Grütter et al. (2004; Figure GS2022-11-10a). A single Cr-diopside grain was recovered and plots within the diamond inclusion and intergrowth field defined by Nimis (2002; Figure GS2022-11-10b). A total of 14 kimberlitic Mg-ilmenite grains were recovered (Figure GS2022-11-10c, d). The 19 forsterite grains that were recovered have Mg numbers that range from 0.88 to 0.96 and some grains have detectable concentrations of chromium. Three of the grains fall within and two lie on the border of the diamond inclusion and intergrowth field defined by Fipke et al. (1995; Figure GS2022-11-10e).

The majority of the KIMs recovered are chromite and Cr-spinel grains (69%; n = 133). Of these grains, 54.9% are Mg-chromite (n = 73 of 133), 39.8% are chromite (n = 53 of 133), 3.8% are Ti-chromite (n = 5 of 133) and 1.5% are spinel (n = 2 of 133) based on the criteria used in Smith et al. (2021). Chromite grains are grouped with Cr-spinel herein and in Hodder and Gauthier (2022), in accordance with the terminology established in the Manitoba KIM database (Keller, 2019). One Cr-spinel grain plots within the diamond inclusion and intergrowth field based on two indices (Figure GS2022-11-11a, c), and is interpreted to be a Di-Cr-spinel. Two other grains plot within the diamond inclusion and intergrowth field of one index and are interpreted as possible Di-Cr-spinel grains (Figure GS2022-11-11a).

Importantly, chromite grains are not exclusive to kimberlites and their interpretation as a KIM needs to be approached cautiously. Locally, the Fox River sill contains chromite in concentrations of more than 4% (Scoates, 1990). Even grains that plot within the diamond inclusion and intergrowth fields are also not restricted to kimberlites (Figure GS2022-11-11), as chromite with this composition has been documented from chromite deposits

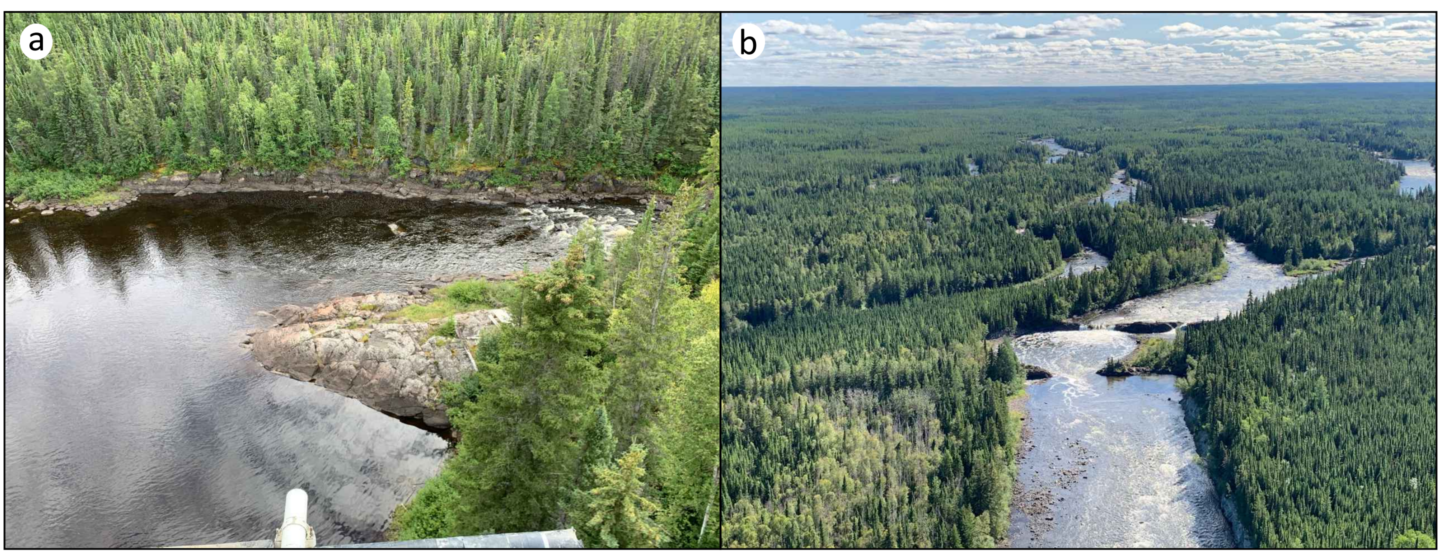


***Figure GS2022-11-6:** Glacial waters flowing beneath the Hayes Lobe cut down through Quaternary sediments into bedrock along multiple rivers in the study area, including at the confluence of the Gowan River with the Fox River **(a)** and just downstream of the confluence of the Sipanigo and Fox rivers **(b)**.*

Figure GS2022-11-7: *The surface till in the study area is light coloured and coarse textured* ***(a, b)****, and overlies either bedrock or older darker-coloured and finer-textured* ***(a, c)*** *tills. Some river sections expose even older dense, blocky diamicts with oxidation rind on joint surfaces* ***(d, e)****.*

in the McFaulds Lake ('Ring of Fire') area of northern Ontario (Gao and Crabtree, 2016). Chromite grains from the Fox River sill have Cr_2O_3 concentrations that range from 25.3 to 46.5 wt. % (n = 73; Turnock et al., 2005). Relationships between grains recovered from till samples and those from in situ bedrock will be more thoroughly analyzed following receipt of the 2022 sampling results.

Spatial trends

On Figure GS2022-11-12a, the spatial distribution of KIM grains is plotted as towers that are proportional in height to the total number of KIMs recovered, normalized to 10 kg of till processed. These towers are then broken down according to the type of KIMs recovered. Since chromite grains can be locally sourced from mafic to ultramafic rocks, the spatial distribution of KIMs without Cr-spinel is plotted separately (Figure GS2022-11-12b).

The distribution of kimberlitic garnet grains is not even across the survey area (Figure GS2022-11-12b). There are two spatial patches with relatively elevated concentrations of garnet. The first patch ('patch 1') is situated in the southeastern corner of the NTS 53M16 map area and the second patch ('patch 2') is

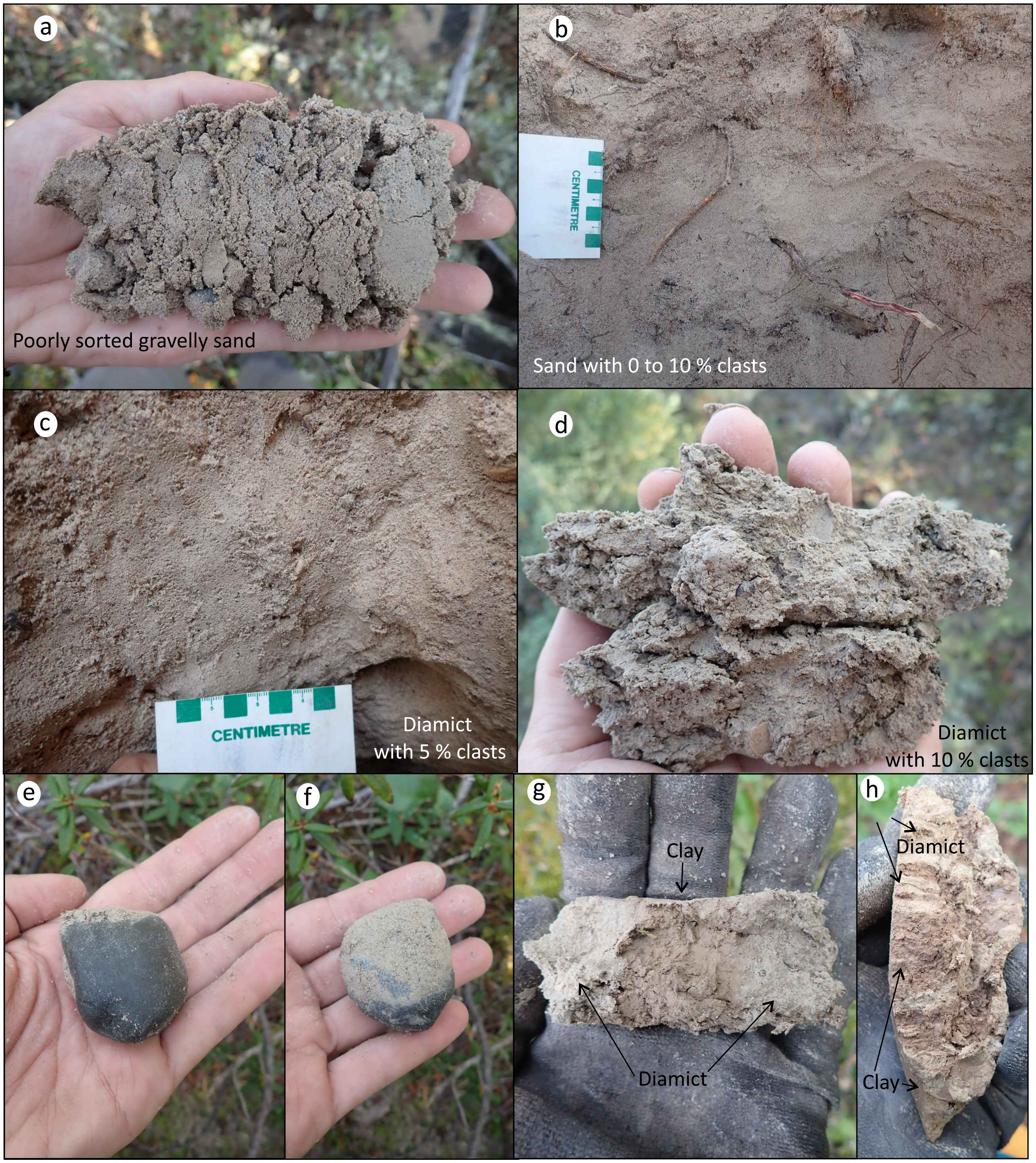


***Figure GS2022-11-8:** Wave-washing at a site can lead to the removal of fines **(a)** or sorting of sediment **(b)** from the diamict parent material **(c, d)**. Clasts that are clean on one side **(e)** and have a 'clay skin' adhering to the other side **(f)** are also indicative of washing and fines removal. In other cases, remobilized till becomes interbedded with clay **(g, h)**.*

situated in the central region of the NTS 53M15 map area (Figure GS2022-11-12b). The spatial distribution of Mg-ilmenite and forsterite is largely restricted to these two patches as well.

Dispersal patterns will be further analyzed following receipt of the 2022 indicator-mineral sample results and in consultation with till clast-lithology and matrix geochemistry provenance analysis. The 2022 sampling occurred within and amongst the samples shown in Figure GS2022-11-12, as well as to the east and northeast (Figure GS2022-11-1). The western boundary of patch 1 is oriented to the southwest, which aligns with the streamlined landform orientation in that area (Figure GS2022-11-9a). Only one site in patch 1 has measured till-fabric orien-

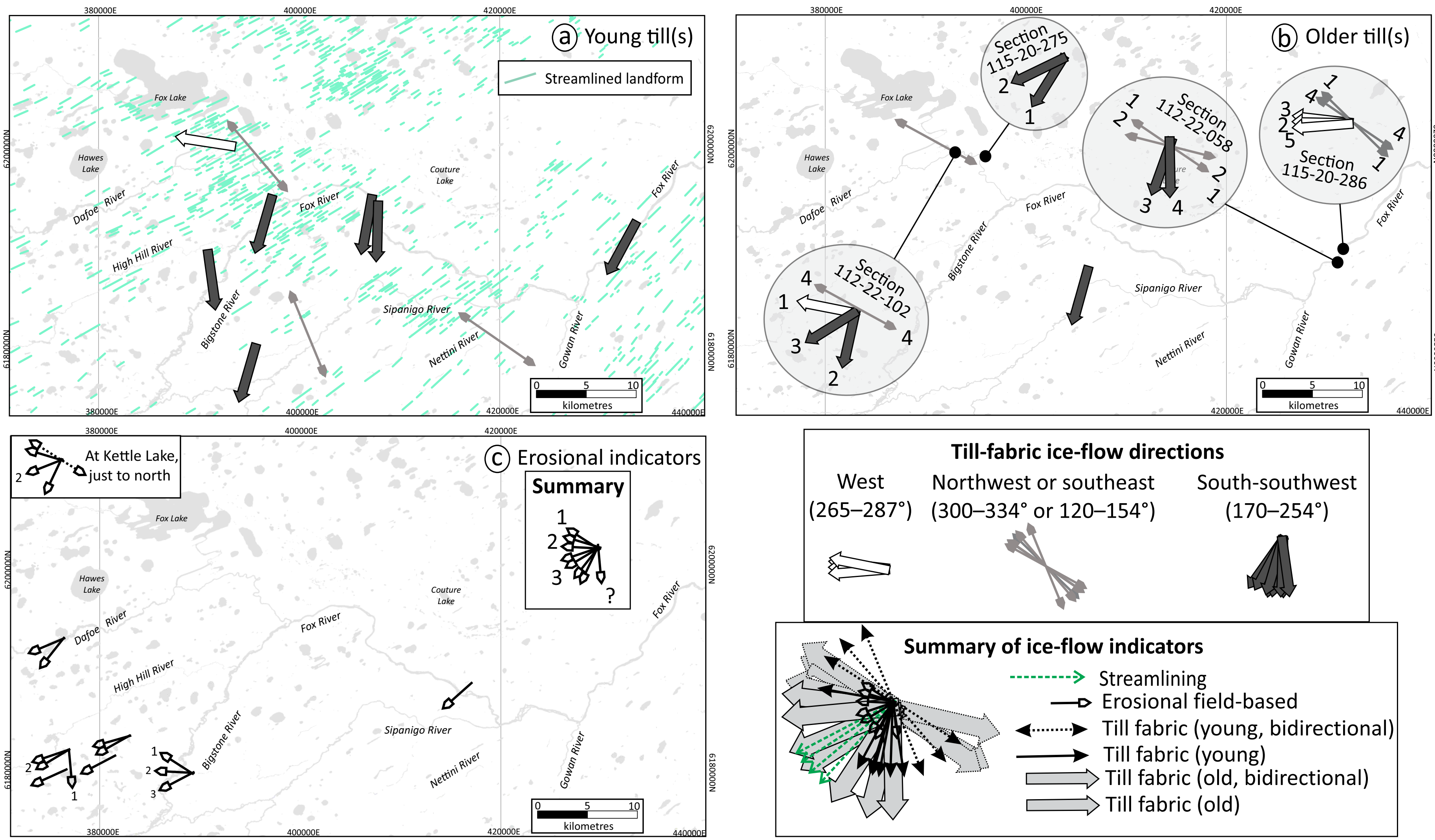
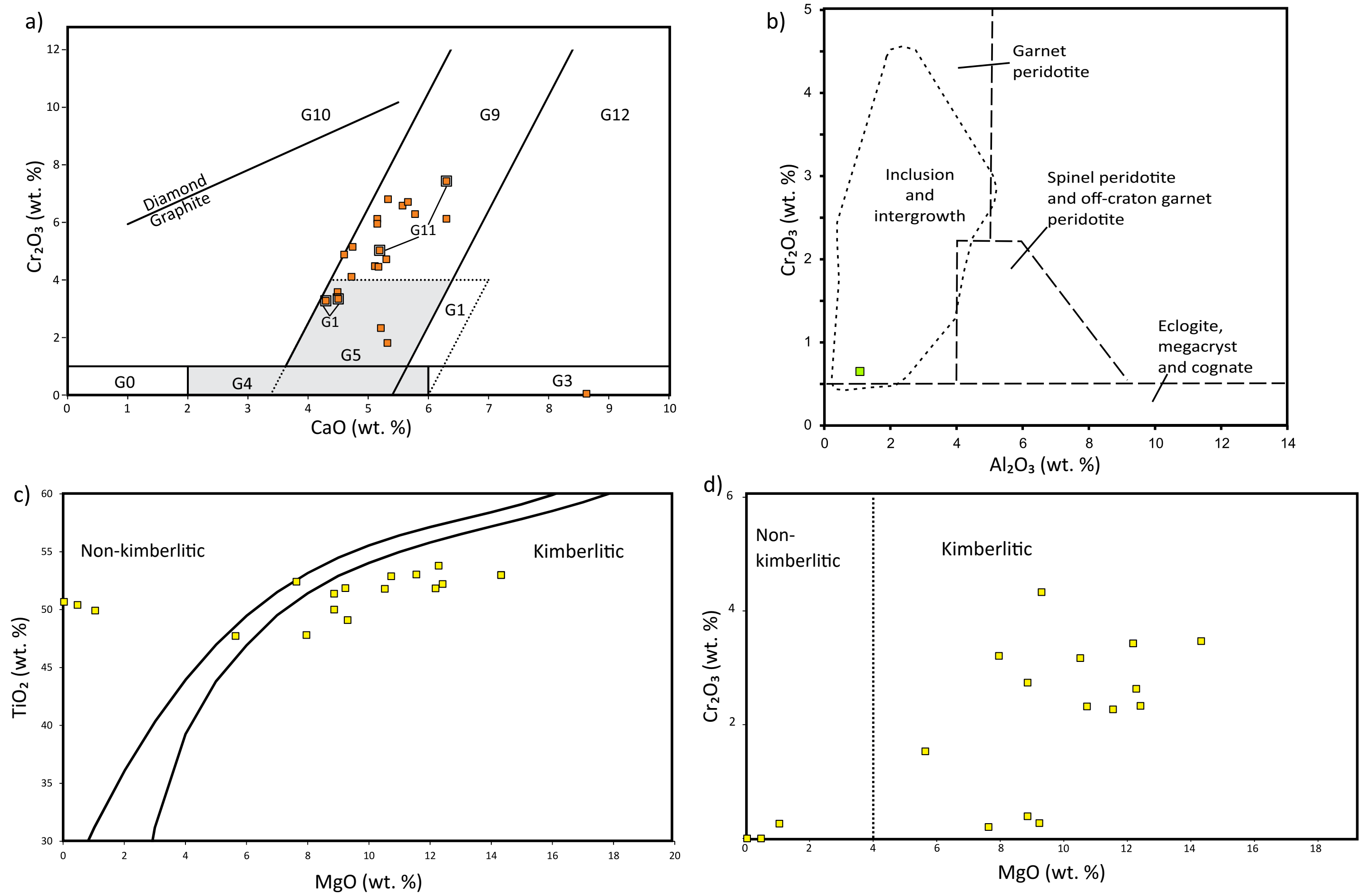


Figure GS2022-11-9: *Ice-flow indicators for the Fox River belt study area, separated into* ***a)*** *a young phase (from till-fabric and landform analyses),* ***b)*** *a presumed old phase (from till-fabric analysis) and* ***c)*** *erosional field-based. Indicators are denoted by relative age when observed either up-section (till fabrics) or by cross-cutting relationships (erosional field-based ice-flow indicators). All co-ordinates are in UTM Zone 15, NAD83.*



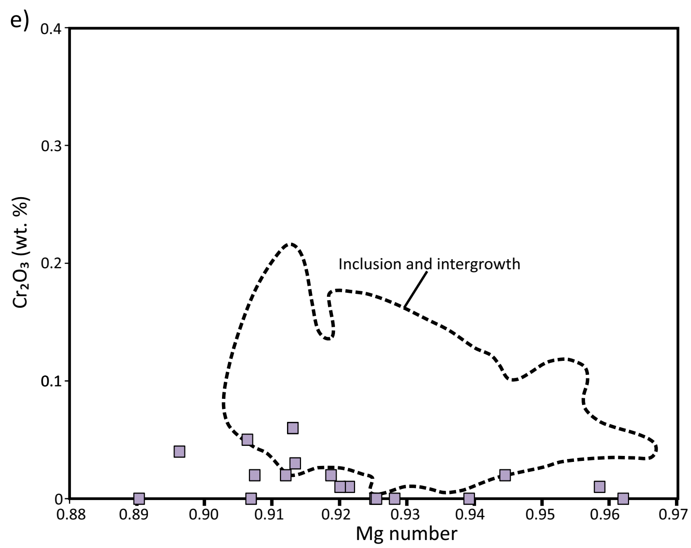
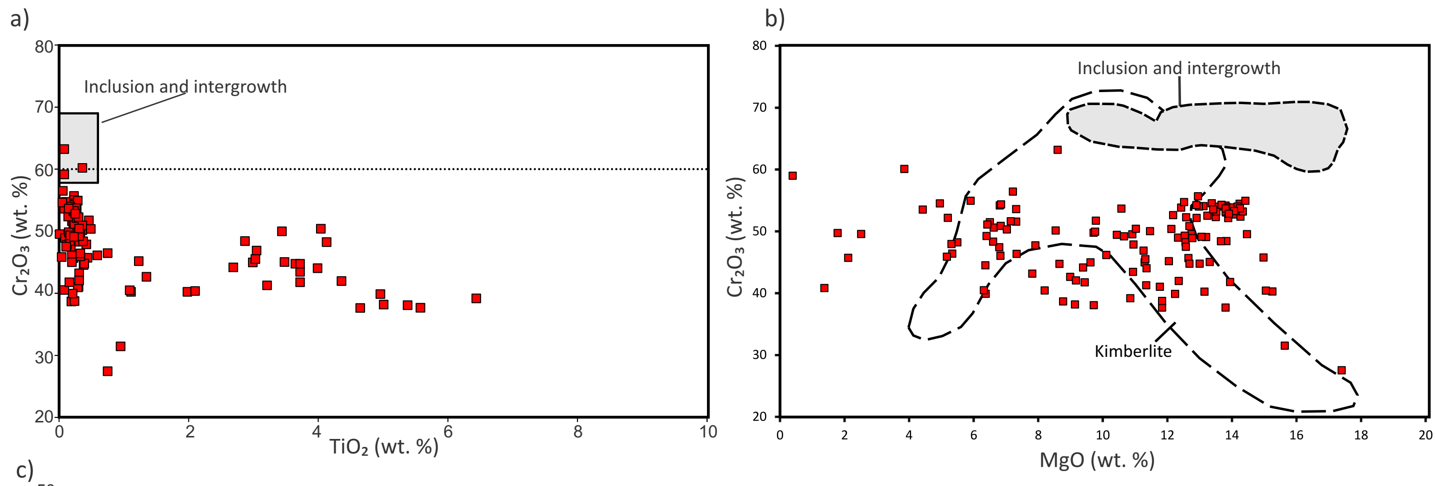


Figure GS2022-11-10: *Bivariate plots of compositional data for garnet, Mg-ilmenite and Cr-diopside kimberlite-indicator minerals:* ***a)*** *Cr_2O_3 versus CaO for garnet grains; garnet classification fields after Grütter et al. (2004); the G5 and G4 classifications indicated by the light grey fill pattern are distinguished by Mg number; the stippled outline of the G1 group does not overlap G4, G5, G9 or G12 categories as G1 garnet grains are distinguished by a higher TiO_2 content; G11 garnets are also classified based on a higher TiO_2 content and are differentiated from G1 garnets by a higher Cr_2O_3 content; two G11 garnets classified from this study are highlighted;* ***b)*** *Cr_2O_3 versus Al_2O_3 for Cr-diopside grains; compositional field for diamond inclusion and intergrowth is from Nimis (2002); other compositional fields are from Ramsay and Tompkins (1994);* ***c)*** *TiO_2 versus MgO discriminate for ilmenite grains; compositional field for kimberlite after Wyatt et al. (2004);* ***d)*** *Cr_2O_3 versus MgO discriminate for ilmenite grains with the distinction between Mg-ilmenite grains drawn at 4 wt. %;* ***e)*** *Cr_2O_3 versus Mg number for forsterite grains; compositional field for diamond inclusion and intergrowth is from Fipke et al. (1995).*

tations; at site 115-20-286, sample B01 has a strong till fabric toward 215°, sample F02 has a moderate till fabric oriented to 308° or 128°, sample H01 has a strong till fabric oriented to 270°, and sample I02 has a very strong till fabric oriented to 315° or 135° (Gauthier and Hodder, 2022). In patch 2, eight of the KIM till samples have associated till-fabric measurements (Gauthier and Hodder, 2022). Those with nonchromite KIMs include young tills with interpreted ice flow to the south-southwest (201°) and northwest or southeast (334 or 154°), as well as a possibly older till with interpreted ice flow to the southwest (254°).

Future work

Ongoing surficial geology analyses will focus on 1:50 000 scale surficial mapping, as well as tracing lithological indicators from known bedrock source areas. The latter will be conducted by clast-lithology counts, indicator-mineral counts and analyzing the geochemical composition of the collected till samples.



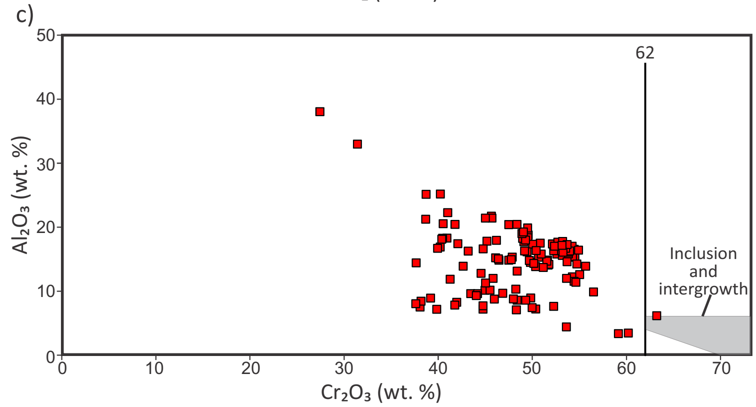


Figure GS2022-11-11*: Bivariate plots of compositional data for chromite and Cr-spinel grains:* ***a)*** *Cr_2O_3 versus TiO_2; compositional field for diamond inclusion and intergrowth field modified after Fipke et al. (1995); a dashed line representing 60 wt. % Cr_2O_3 is shown for visual reference;* ***b)*** *Cr_2O_3 versus MgO; compositional field for diamond inclusion and intergrowth after Fipke et al. (1995);* ***c)*** *Al_2O_3 versus Cr_2O_3; compositional field for diamond inclusion and intergrowth after Sobolev (1977).*

Economic considerations

As bedrock outcrops are rare in much of Manitoba's northern region, a thorough understanding of surficial geology is essential for drift prospecting. Till-sample analysis is commonly used in drift-covered regions to help determine the source area for mineralized erratics and boulder trains, but is more difficult to interpret in palimpsest terrains such as in this study area. Ongoing surficial geology 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. 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 drift-covered areas. More specifically, the results of this study may inform drift exploration for nickel, copper and platinum-group-element mineralization in the Fox River belt, and new KIM results will help assess the regional-scale diamond potential of the study area.

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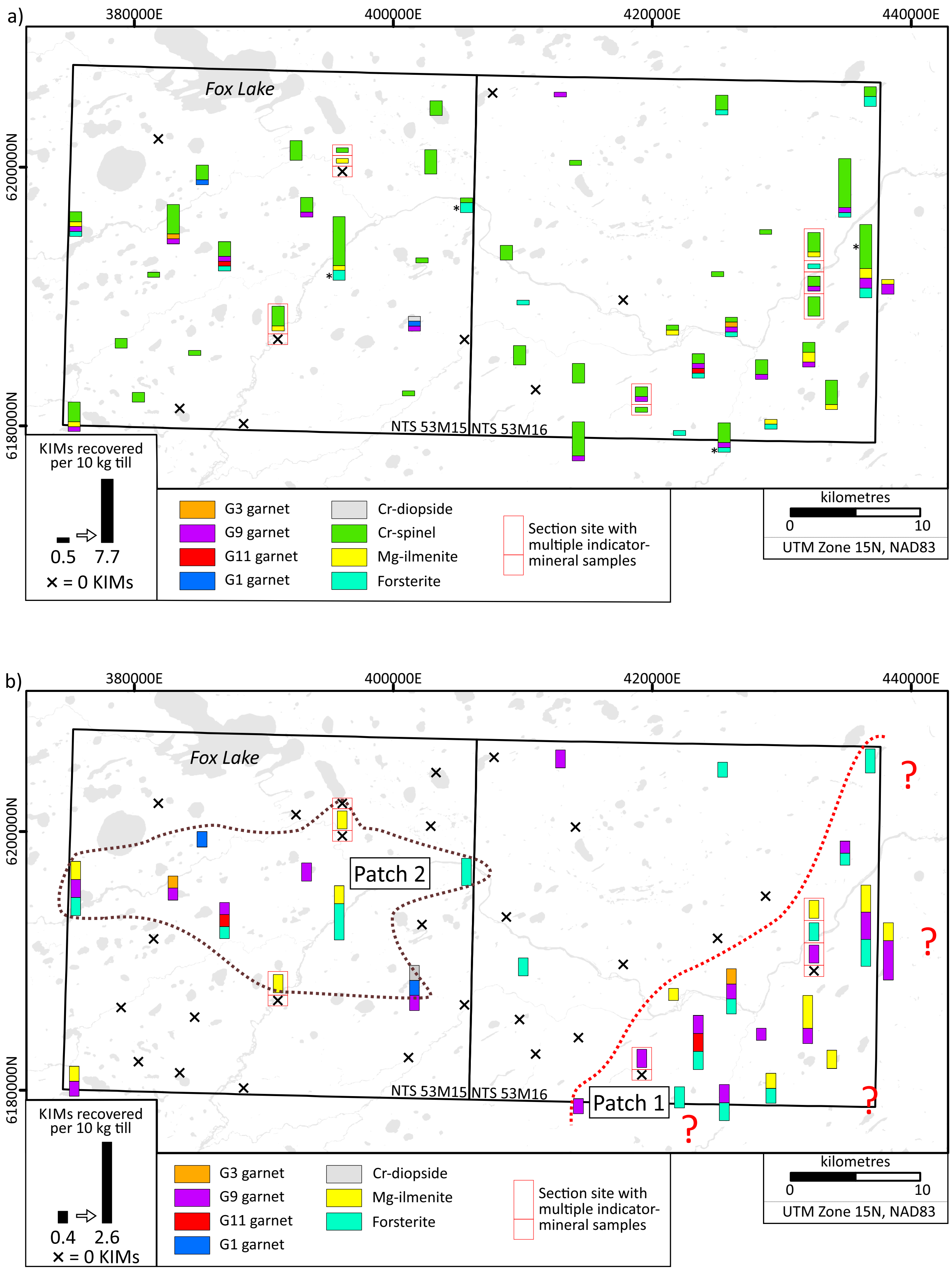

Figure GS2022-11-12: *Spatial distribution of kimberlite-indicator-mineral (KIM) grains recovered from till presented as towers that are proportional in height to the number of KIMs recovered, normalized to 10 kg of till processed:* ***a)*** *all KIMs as defined by the Manitoba KIM database (Keller, 2019); the asterisk denotes samples with either a Di-forsterite (n = 3) or a Di-Cr-spinel (n = 1) recovered, see text for details;* ***b)*** *KIM grains recovered with Cr-spinel removed, since these grains can be locally sourced from mafic to ultramafic rocks in the Fox River sill.*

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