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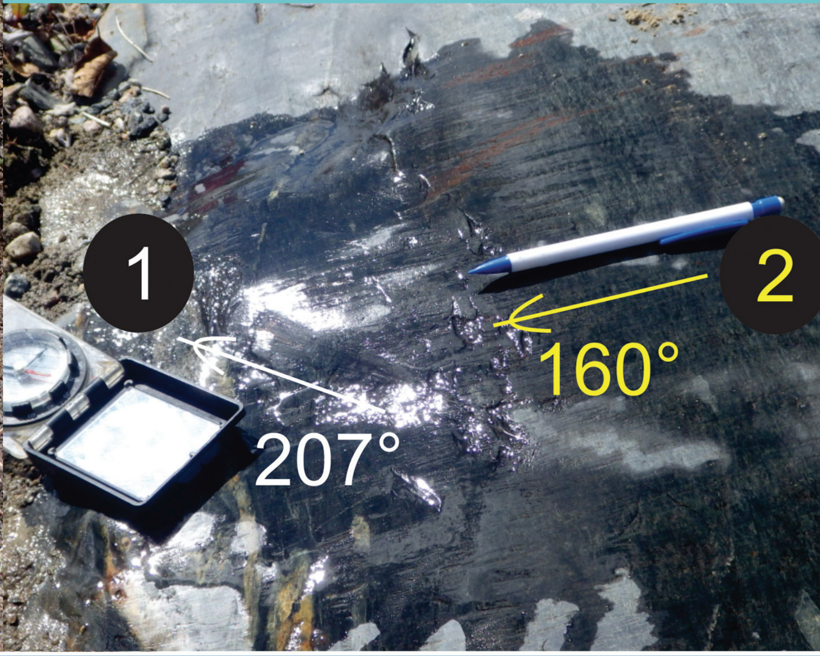
TILL COMPOSITION OF A SAMPLING TRANSECT IN THE LYNN LAKE AREA, NORTHWEST MANITOBA (parts of NTS 64B12, 64C9, 11, 12, 14–16, 64F3, 4)

Manitoba Geological Survey



Manitoba

Open File OF2018-3

Till composition of a sampling transect in the Lynn Lake area, northwest Manitoba (parts of NTS 64B12, 64C9, 11, 12, 14–16, 64F3, 4)

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Manitoba Geological Survey
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Cover illustrations:

Left: Geological assistant N. Clark collects a kimberlite-indicator mineral sample from the C-horizon of till in the Lynn Lake area.

Right: Bedrock ice-flow indicators where two generations of ice-flow are preserved indicating a SSW (207°) ice-flow event was followed by a SSE (160°) ice-flow event.

Abstract

A till sampling transect was completed from the Manitoba-Saskatchewan border to the town of Leaf Rapids in the summer of 2017. A total of 48 samples were processed for till-matrix geochemistry and kimberlite-indicator mineral (KIM) analysis. Till-matrix geochemistry identified an elevated Cu concentration in till southeast of Dunphy Lakes and elevated Zn and Pb concentrations in till southeast of Adams Lake. Till compositional studies in the Lynn Lake area have demonstrated the presence of short (100–2000 m) till geochemistry dispersal trains from volcanogenic massive sulphide and orogenic gold deposits. Considering this factor, elevated geochemical signatures of economic interest should be followed up with a tight sampling grid in the up-ice direction(s). Ten samples from this study contained KIM grains. In this area, KIM recovery is correlated to till-matrix carbonate content, which suggests an east to northeast provenance for the KIMs recovered. This survey has highlighted the KIM potential in the Southern Indian Lake area to the northeast, where significantly higher concentrations of KIMs were recovered from till samples.

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Introduction

Quaternary geology fieldwork using local road access was undertaken by the Manitoba Geological Survey (MGS) from the Saskatchewan-Manitoba border to Leaf Rapids during the 2017 field season. The purpose of this study was to 1) conduct regional scale till sampling (one sample every 2.5–4.0 km) for kimberlite-indicator mineral (KIM) recovery and till-matrix geochemistry along a transect roughly perpendicular to the regional ice-flow orientation; 2) conduct paleo–ice-flow mapping at road-side bedrock outcrops to assist with reconstructions of the glacial dynamics of this region; 3) compile and digitize all existing till geochemistry data.

Detailed description of the surficial geology in the study area can be found in Gauthier and Hodder (2017a). This report releases the KIM, till-matrix geochemistry, till-matrix texture and till clast-lithology data.

Previous till compositional studies

Drift prospecting within the Lynn Lake area has had a long history, which includes the initial discovery of the greenstone belt through boulder tracing efforts by J. Barrington in 1927 (Brown, 1947). Since this early work, government studies have been completed at a regional-scale (Figure 1; Table 1; Kaszycki, 1989; Lenton and Kaszycki, 2005) and at local- to property-scales (Figure 1; Table 1; Nielsen and Graham, 1985; Nielsen and Fedikow, 1986, 1987; Nielsen and Conley, 1991). This includes orientation surveys over and down-ice of the MacLellan mine (Au-Ag; Nielsen and Fedikow, 1987) and the Lar volcanogenic massive sulphide (VMS) deposit (Cu-Zn; Nielsen and Conley, 1991).

Till compositional data in the study area was recently digitized and compiled as part of a Geological Survey of Canada (GSC) initiative (McMartin et al., 2012). In addition to the McMartin et al. (2012) data compilation, this study digitized absent sample coordinates for the property-scale dispersal studies (Nielsen and Graham, 1985; Nielsen and Fedikow, 1986, 1987; Nielsen and Conley, 1991) which are provided along with the digitized geochemistry data from McMartin et al. (2012) in Appendix 2. Despite the breadth of previous till sampling in the Lynn Lake area, this study is the first to provide a public regional-scale KIM dataset.

Ice-flow history

New ice-flow measurements were obtained from striations, grooves, chattermarks, crescentic gouges and fractures, and roches moutonnées at 22 field sites in the study area (Gauthier and Hodder, 2017a, b), and were combined with measurements from previous mapping in the area (Figure 2).

Ice-flow measurements yielded at least six phases of ice flow in the study area. Northwest-, southwest- and southeast-trending ice-flow indicators are rare and probably old. Old southwesterly ice flow is regionally extensive (Dredge et al., 1986; Campbell, 2001, 2002; Smith, 2006; Smith and Kaczowka, 2007; Trommelen, 2011, 2013, 2015a; Campbell et al., 2012) and is correlated to the pre-Late Wisconsinan. Old east-southeast ice flow is also regionally extensive (Dredge et al., 1986; Campbell, 2001, 2002; Smith, 2006; Smith and Kaczowka, 2007; Trommelen, 2011, 2015a, b; Campbell et al., 2012), though an age has not been assigned. Old northwesterly ice flow (270–300°) has been mapped in the Southern Indian Lake area (Hodder, 2018), approximately 145 km northeast of Leaf Rapids, as well as in parts of northeastern Manitoba (Campbell et al., 2012; Trommelen, 2015a). No relationships were documented in the field area between old southwesterly, southeasterly or northwesterly ice-flow indicators. Fieldwork within the Southern Indian Lake area (Hodder, 2018; Trommelen, 2015b), suggests that southeasterly ice flow is older than southwesterly ice flow. The relationships with old northwesterly ice flow remain uncertain, mainly because these ice-flow indicators are rare.

Dominant ice flow in the Lynn Lake area was to the south, between 170 and 214°. Southerly ice flow is regionally extensive across northern Manitoba, and is likely Wisconsinan in age. Most streamlined landforms in the region were also formed during this major southerly ice-flow phase. Young southeasterly ice flow (158–172°) crosscuts the southerly flows between Wetkoeekan and Adam lakes, and may relate to deposition of the Adam Lake esker ridge during late deglaciation (Figure 2). Young southwesterly ice flow (257°) crosscuts the southerly flows just east of Leaf Rapids, and is also documented further east along the road to South Indian Lake and at Karsakuwigamak Lake (Kaszycki and Way Nee, 1989). This young southwest- to northwest-trending (260–280°) ice flow was also mapped near Thompson and Split Lake (McClenaghan et al., 2009; McMartin et al., 2010; Trommelen, 2013), where it is correlated with late deglacial ice flow related to ice flowing from Hudson Bay.

Glacial dispersal

Glacial dispersal of bedrock detritus can be mapped at varying scales from continental (100 to 1000s of kilometres) to local scale (1 to 100s of metres; McClenaghan and Paulen, 2017). Factors that influence glacial dispersal include deposit characteristics (e.g., morphology, size and erodibility of outcrop, pre-glacial metal rich gossan presence or absence), glacial dynamics of the area, depth to bedrock and geochemical contrasts between the deposit and surrounding rocks (McClenaghan and Paulen, 2017). Dispersal distances will also be affected by robustness of the indicator. For example, KIM grains are more resistant to glacial comminution and their associated dispersal trains are commonly recognizable greater than 50 km from source (McClenaghan and Kjarsgaard, 2007). Contrastingly, a review of till-matrix geochemistry dispersal trains from VMS deposits across Canada indicates that dispersal distances typically range from a few hundred metres to a few kilometres (McClenaghan and Peter, 2016).

Nielsen and Conley (1991) conducted a till geochemistry orientation survey around the Lar Cu-Zn VMS deposit near Laurie Lake (Figure 1). Cu, Pb and Zn values indicate a recognizable glacial dispersal train of 400 m in the clay-sized (<2 µm) fraction of till and 100 m in the silt- and clay-sized (<63 µm) fraction (Nielsen and Conley, 1991; McClenaghan and Peter, 2013). Based on these observations, regional-scale elevated till-matrix geochemistry signatures of interest should be followed up with a dense till sampling program, keeping in mind that the

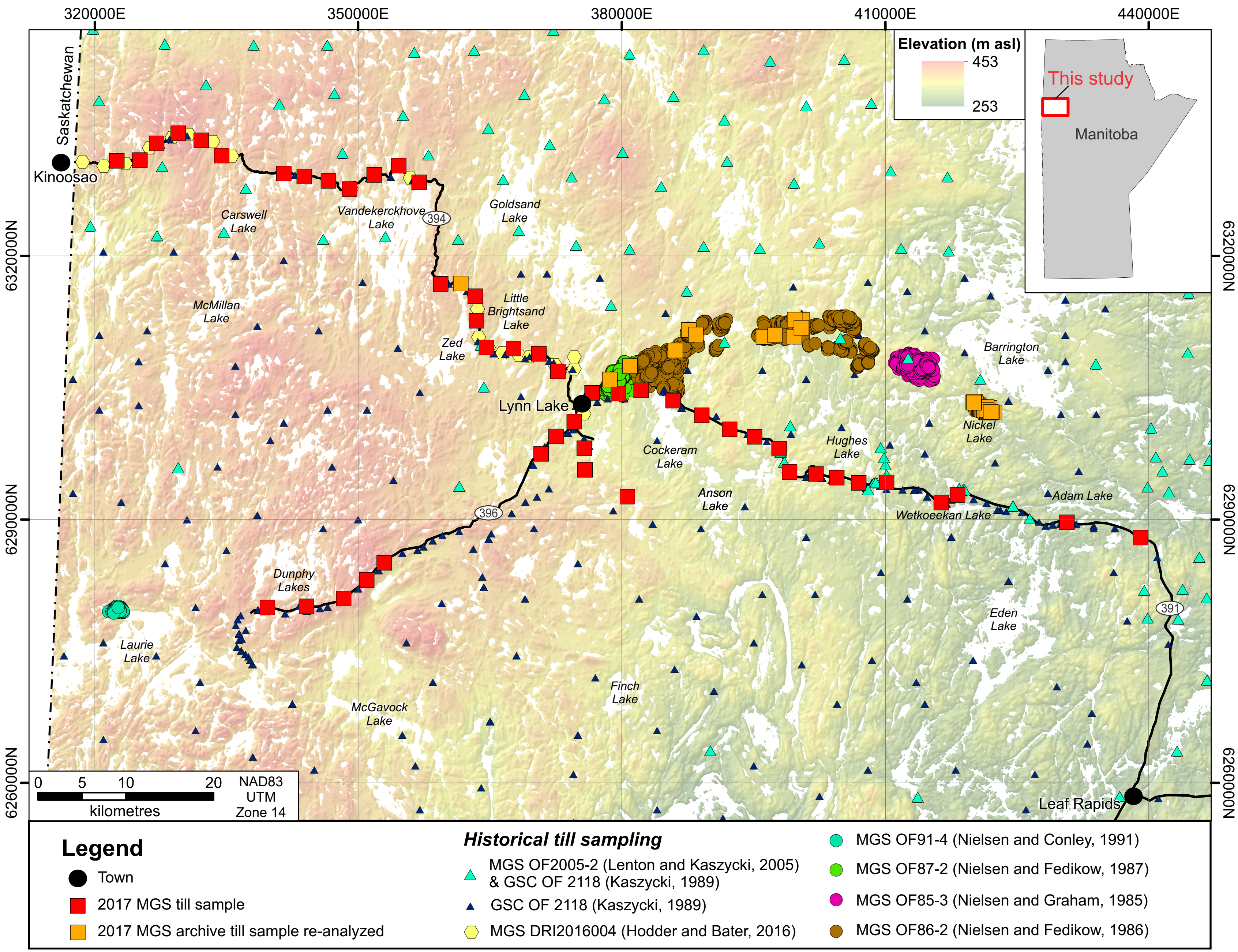

Figure 1: *Till sample sites in the Lynn Lake area. Background hillshade was generated using a Canadian Digital Surface Model (Natural Resources Canada, 2015). Abbreviations: DRI, Data Repository Item; GSC, Geological Survey of Canada; MGS, Manitoba Geological Survey; OF, open file.*

Table 1: Summary of till compositional data in the Lynn Lake area. Abbreviations: AA, atomic absorption spectroscopy; FA, fire assay; ICP-MS, inductively coupled plasma–mass spectrometry; INAA, instrumental neutron activation analysis; KIM, kimberlite-indicator mineral; NM-HMC, non-magnetic heavy mineral concentrate; PD, partial digestion; TD, total digestion.

Publication	Reference	Geographic Area	Size-fraction and analyses	Data Source
MGS OF85-3	Nielsen and Graham (1985)	Farley Lake NTS 64C16	<2 µm AAS, As; <2 mm NM-HMC AAS, Au (count, FA)	This study, Appendix 2
MGS OF86-2	Nielsen and Fedikow (1986)	Minton Lake to Nickel Lake NTS 64C15, C16	<2 µm AAS, As; <2 mm NM-HMC AAS, Au (count, FA)	This study, Appendix 2
MGS OF87-2	Nielsen and Fedikow (1987)	Dot Lake-MacLellan mine area NTS64C15	<2 µm AAS, As; <2 mm NM-HMC AAS, Au (count, FA)	This study, Appendix 2
MGS OF91-4	Nielsen and Conley (1991)	Laurie Lake NTS 64C12	<2 µm AAS, As; <63 µm INAA	This study, Appendix 2
GSC OF 2118	Kaszycki (1989)	NTS 63N, 64B, C, F, G	<2 µm AAS, As, U; <63 µm INAA, Au (FA), $CaCO_3$ (LECO) <2 mm NM-HMC Au (count, FA)	Kaszycki (1989); McMartin et al. (2012)
MGS OF2005-2	Lenton and Kaszycki (2005)	NTS 63N, 64B, C, F, G	<177 µm TD ICP-MS, INAA	McMartin et al. (2012); Lenton and Kaszycki (2005)
DRI2016004	Hodder and Bater (2016)	Parts of NTS 62P, 64C14, 64F3, 4, 64F14, 64K3, 6, 11, 64G8, 9	<177 µm TD ICP-MS, INAA	Hodder and Bater (2016)
This study	--	Parts of NTS 64B12, 64C9, 11, 12, 14–16, 64F3, 4	<63 µm TD ICP-MS, PD ICP-MS, Ca/Mg; 0.3–0.5 mm KIM	This study, Appendices 3–6

distance to source could be very short (100 m). The source of KIM grains can be significantly further and follow-up sampling should keep this parameter in mind.

Bedrock geology

The Lynn Lake greenstone belt consists of two east-west trending belts that contain a variety of metavolcanic and metasedimentary rocks, separated by various granitoid plutons (Figure 3). The southern and northern belts are marked by structural transposition and imbrication during multiple stage of deformation, and show variations in geology, age and geochemistry that might be due to regional differences in tectonic settings (Syme, 1985; Zwanzig et al., 1999). Included in the northern belt is the Agassiz metallotect, a relatively narrow, stratigraphically and structurally distinct unit composed of ultramafic, banded iron formation and epiclastic rocks (Beaumont-Smith et al., 2001). This unit has been the target of mineral exploration and previous Quaternary studies (Nielsen and Graham, 1985; Nielsen and Fedikow, 1986, 1987). For more information regarding the bedrock geology of the Lynn Lake area the reader is referred to reports and maps by the MGS and references therein (e.g., Gilbert et al., 1980, Gilbert, 1993, Zwanzig et al., 1999; Beaumont-Smith and Böhm, 2004; Yang and Beaumont-Smith, 2017).

Methods

Field data collection

Field work was conducted based out of the town of Lynn Lake in late June of 2017. A total of 109 sites were visited to ground truth pre-existing surficial geology maps, collect till samples and/or observe bedrock ice-flow indicators. At each site, the sediments present, as well as, geomorphic and terrain characteristics were noted. Station and till sample observations are presented in Appendix 1.

Till sampling

A till sampling survey was conducted using the local road access between the Manitoba-Saskatchewan border and Leaf Rapids (Provincial Road (PR) 394 and 391) and between Lynn Lake and the Fox Lake mine (PR 396). Till samples were collected every 2.5–4.0 km if suitable sample medium was present. At each sample site, a pit was hand-dug and C-horizon material was targeted as a sample medium. At the majority of sample sites, C-horizon material was present (e.g., Figure 4) and sampled (n=31/48 sample sites). At some sample sites, C-horizon material could not be obtained for various reason, including 1) thin till overlying bedrock, with no C-horizon material present; 2) frozen ground conditions encountered, which only allowed sampling of the unfrozen B-horizon; and 3) poorly drained areas where the soil was gleyed. In these cases, B-horizon material was collected (n=7/48 sample sites) or a mix of B- and C-horizon material was collected (n=10/48 sample sites).

Two samples were collected at each station. A 22.7 L till sample was collected and processed for KIM and clast-lithology counts. A 3 kg sample was collected and processed for till-matrix (<63 µm size-fraction) geochemistry and texture analysis.

Archived samples

Till samples collected in 1985 around the Nickel Lake area were initially split, with one quarter of the sample archived

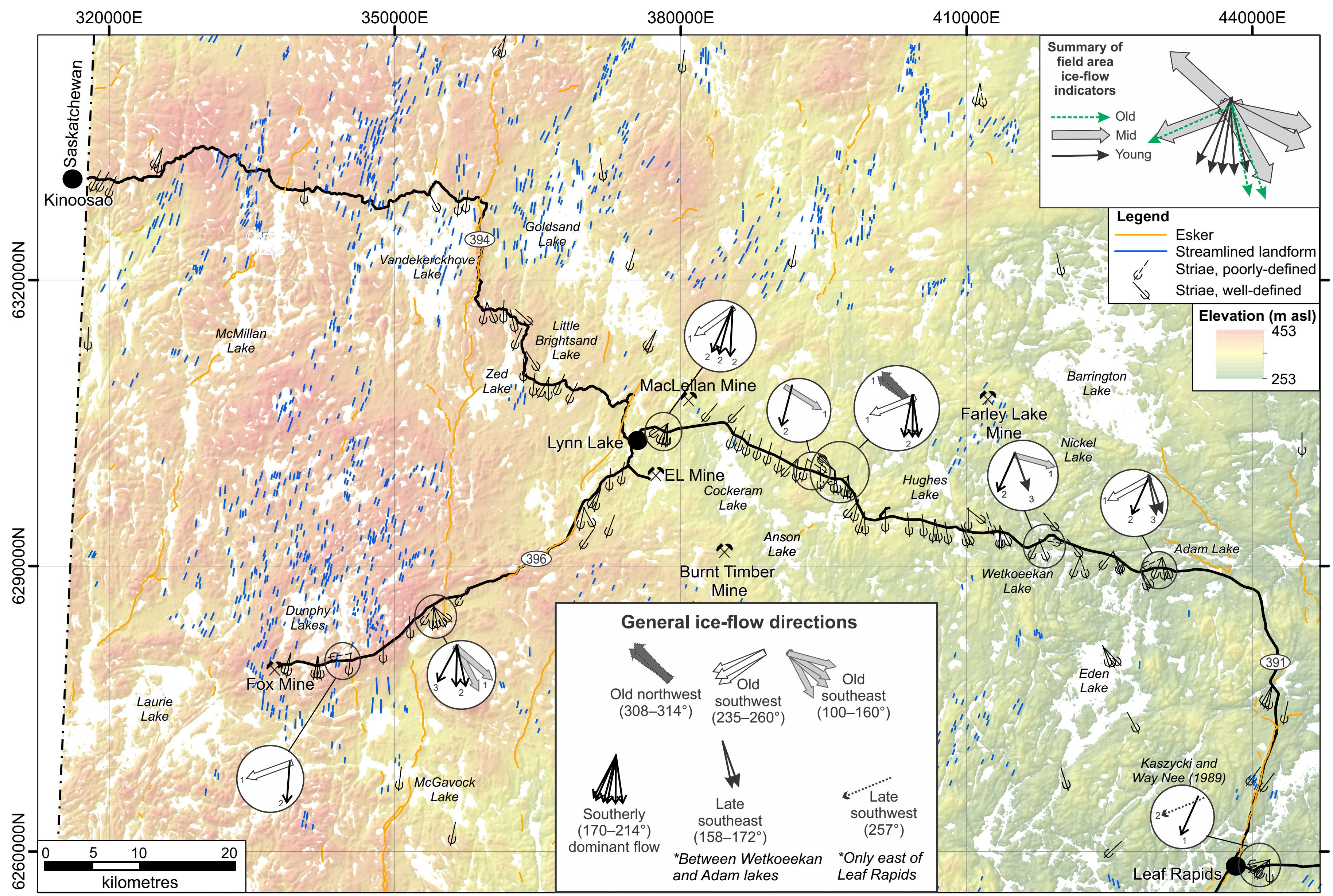

Figure 2: *Historical and recent field-based ice-flow–indicator data in the study area. Larger circles are a summary of the relative ages (1=oldest) and trends of ice-flow indicators for a single site or sites in close proximity to each other. The generalized ice-flow directions provide a key for differentiating between old and young ice flows of similar orientation. Background hillshade was generated using a Canadian Digital Surface Model (Natural Resources Canada, 2015).*

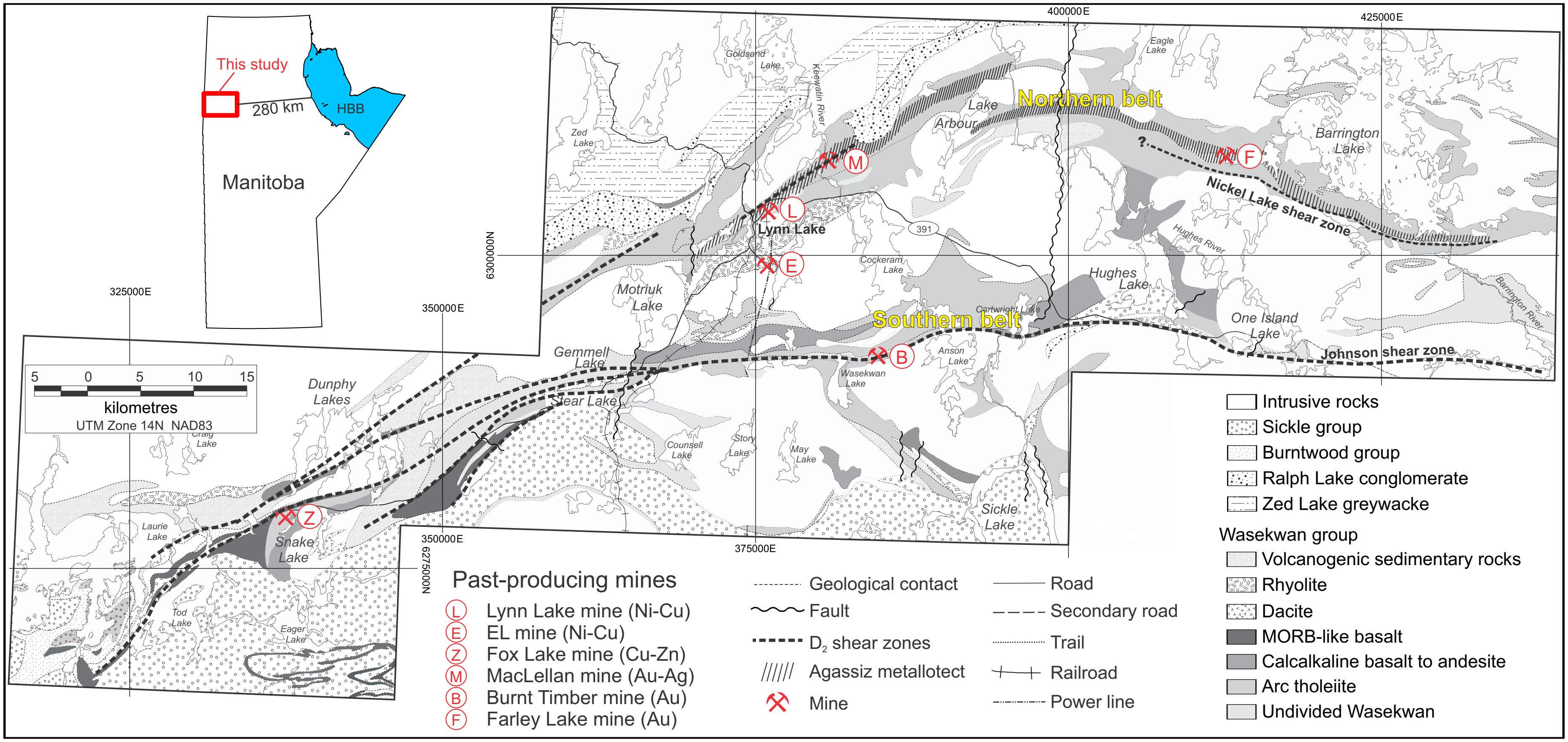

Figure 3: *Bedrock geology of the Lynn Lake area (modified from Yang and Beaumont-Smith, 2017). Inset shows the location of this study in context to the Hudson Bay Basin, the closest known source of carbonate rocks. Abbreviation: HBB, Hudson Bay Basin.*

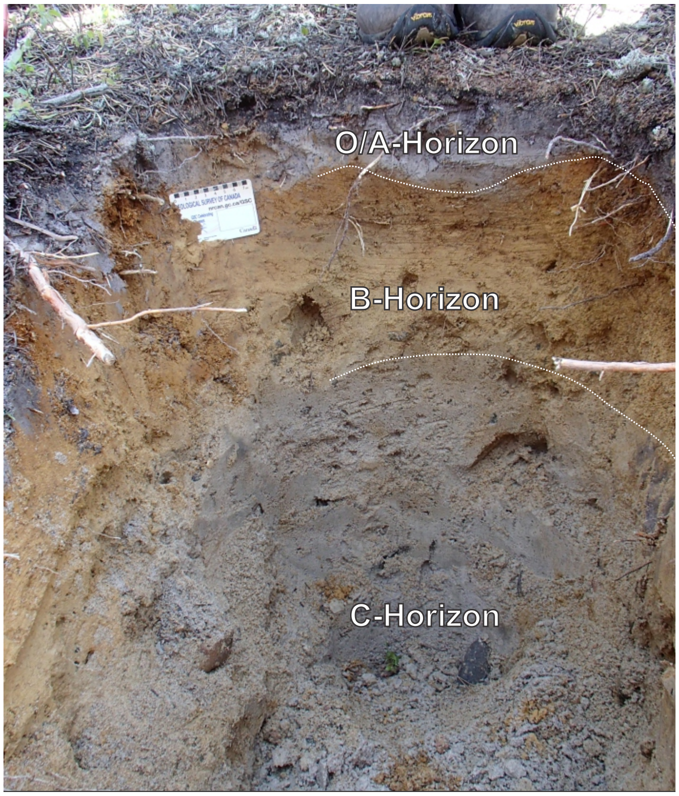

Figure 4: *Typical soil horizon developed in the Lynn Lake area (station 112-17-093).*

(Nielsen and Fedikow, 1986). As part of this study, 48 out of the 50 original till samples were located in archives and pulled for re-analysis using standard analytical methods. In addition, 13 samples northeast of Lynn Lake overlying the northern belt were pulled from archive (Figure 1). The archival till samples were submitted along with till samples collected in the field in 2017 and analytical results are provided in Appendix 2.

Kimberlite-indicator mineral processing and classification

The De Beers Group of Companies processed the KIM samples through in-kind support. Sample locations were withheld from the company to allow equal opportunity for follow-up by all interested parties when data is released as part of this study (Appendix 3). Till heavy mineral concentrate from the <0.5 mm size-fraction was passed over a 0.3 mm aperture sieve and the <0.3 mm size-fraction was discarded, leaving only the 0.3–0.5 mm size fraction. Suspected KIM grains were then selected visually, and subsequently analyzed by electron microprobe. These KIM grains were initially classified using electron microprobe results according to the method outlined by Thorleifson et al. (1994). Garnet grains were further classified according to the method outlined by Grütter et al. (2004; Figure 5a). Mg-Ilmenite grains were confirmed using the compositional field defined by Wyatt et al. (2004; Figure 5b). Diamond-inclusion spinel grains were classified according to a modified discriminate diagrams of Fipke et al. (1995; Figure 5c, d). Although, caution should be exercised when relying on the TiO_2 vs. Cr_2O_3 discriminant plot, since chromite grains from chromite deposits in the McFaulds Lake ("Ring of Fire") area of northern Ontario can plot within this diamond inclusion and intergrowth field (Gao and Crabtree, 2016).

Till-matrix geochemistry

Collected till samples were analyzed for clast-lithology, grain-size (<2 mm size-fraction) and till-matrix geochemistry (carbonate content, partial digestion and near total digestion of the <63 µm size-fraction) analysis. Archived till samples were processed for till-matrix (<63 µm size-fraction) partial digestion geochemistry and a select group were also processed for near-total digestion geochemistry. Clast-lithology counts were conducted by A. Hutchins at the MGS Midland Sample and Core Library. Till-matrix texture (<2 mm size-fraction) and till-matrix geochemistry (<63 µm size-fraction) analysis was conducted at Activation Laboratories Ltd (Actlabs). Results for re-analysis of archived till samples is presented in Appendix 2 and 2017 till sample results are presented in Appendices 4–8.

Ca and Mg method for carbonate content

The results for till carbonate content, expressed as weight percent, are provided in Appendix 4. An aliquot of the till-matrix (<63 µm size-fraction) was digested using HCl and analyzed for Ca and Mg by inductively coupled plasma-optical emission spectroscopy (ICP-OES). The proportion of calcite and dolomite were then calculated (wt. %).

Partial digestion till-matrix geochemistry

An aliquot of the <63 µm size-fraction was digested in a aqua regia (1:3 HNO_3:HCl) mixture. Following digestion, samples were analyzed by inductively coupled plasma-mass spectrometry (ICP-MS) and by inductively coupled plasma-optical emission spectrometry (ICP-OES) techniques for 63 elements at Actlabs. The analytical results are presented in Appendix 5, together with analytical data for control reference standards, analytical and field duplicates, and blanks.

Near-total digestion till-matrix geochemistry

An aliquot of the <63 µm size-fraction was digested in a four-acid (HF:HNO_3:$HClO_4$:HCl) mixture. Following digestion, samples were analyzed by ICP-MS and ICP-OES techniques for 58 elements at Actlabs. The analytical results are presented in Appendix 6, together with analytical data for control reference standards, analytical and field duplicates, and blanks.

Till clast-lithology counts

Simplified clast-lithology counts were conducted on the 4–8 mm size-fraction. An average of 207 clasts were counted, ranging from 147–245 per sample, and were separated into four simplified rock categories relevant for the area: granitoid, metavolcanic, metasedimentary and quartz (e.g., Figure 6). The purpose of this simplification is to quantify the proportion of greenstone and granitoid detritus present within till samples. During clast counts, carbonate pebbles were not observed in any samples. Clast count results are presented in Appendix 7.

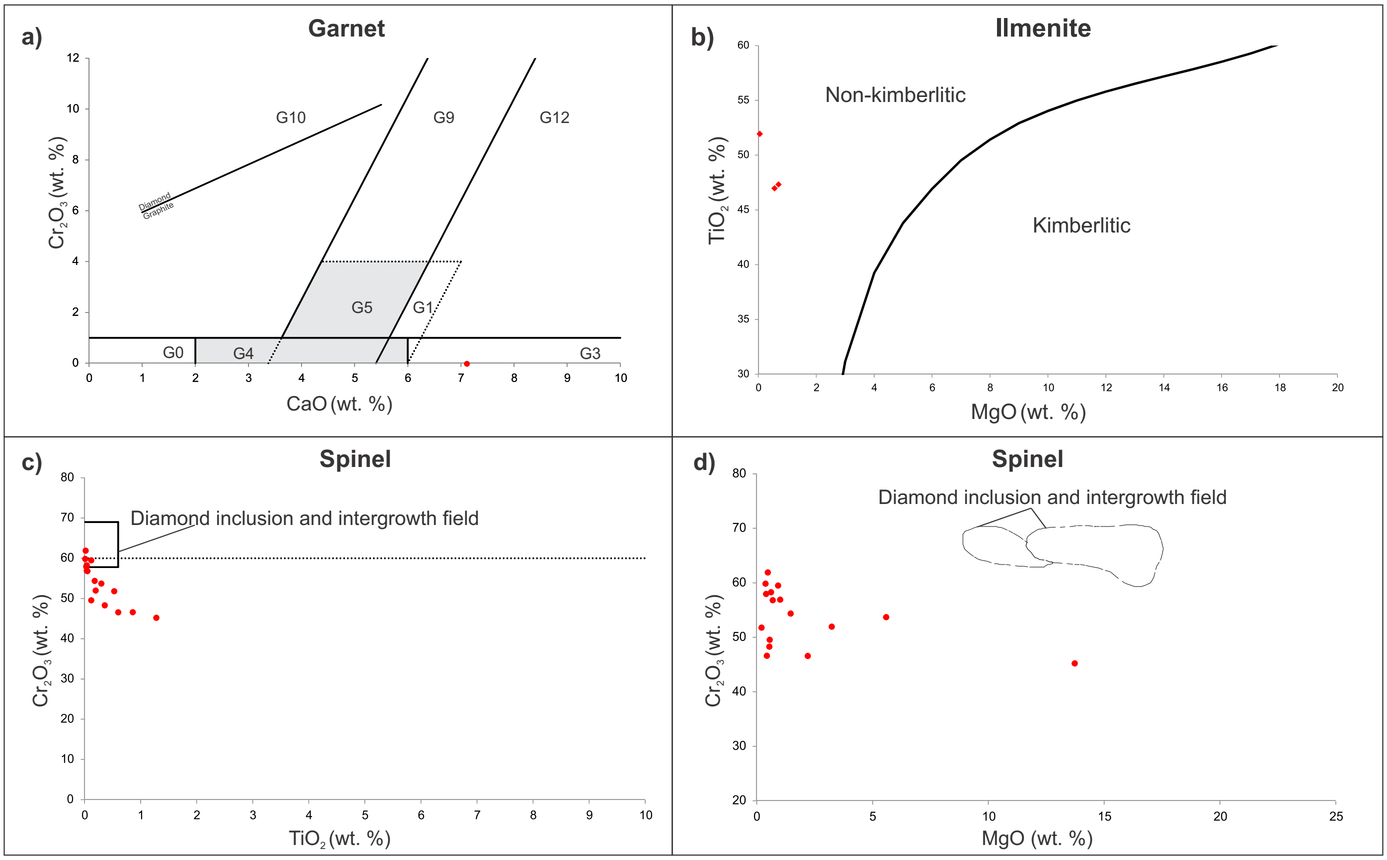

***Figure 5:** Discriminant diagrams for kimberlite-indicator minerals: **a)** Cr_2O_3 vs. CaO diagram for garnet grains after Grütter et al. (2004). The G5 and G4 classifications indicated by the light grey fill pattern are distinguished by Mg-number. The stippled G1 group does not overlap G4, G5, G9 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; **b)** TiO_2 vs. MgO diagram for ilmenite grains after Wyatt et al. (2004); **c)** Cr_2O_3 versus TiO_2 and **d)** Cr_2O_3 vs. MgO diagram for Cr-spinel grains modified after Fipke (1995). A dashed line representing 60 wt. % Cr_2O_3 is shown for visual reference.*

Till-matrix texture

An aliquot of each till sample was initially sieved into >2 and <2 mm size-fractions. The <2 mm size-fractions was further sieved to determine the weight proportion of silt/clay (<63 µm size-fraction) and sand (63–2000 µm size-fraction). The <63 µm size-fraction was analysed using a laser particle size analyzer at Actlabs to determine the proportion of silt and clay. Till-matrix textural results for all till samples are expressed in weight percent and provided in Appendix 8.

Results

Kimberlite-indicator minerals

A total of 17 KIM grains were recovered from 10 samples during this study. No gold grains were observed in any samples during KIM recovery (0.3–0.5 mm size-fraction). The visual identification, chemistry and total-KIM counts are presented in Appendix 3. The spatial distribution of total-KIM counts per sample does exhibit variation (Figure 7): no KIM grains were recovered from till samples northwest of Little Brightsand Lake along PR 394; the majority of KIM grains (9/17) were recovered from till samples along PR 391 between Hughes and Adams lakes.

The majority of the KIMs are Cr-spinels (16/17). Four Cr-spinels have low TiO_2 and high Cr_2O_3 content and plot in the diamond inclusion and intergrowth field (Figure 5c). One G3 garnet was recovered southeast of Hughes Lake (Figure 7).

Till-matrix geochemistry

Till geochemistry data is useful to reconcile glacial dispersal patterns, establish background geochemical variation within different geological settings and highlight elevated economic signatures against background.

Carbonate content

The carbonate content of till in the study area can be used as a proxy for the proportion of far-travelled detritus within the glacial sediment. The carbonate content of till-matrix (<63 µm size-fraction) samples ranges from 0.57 to 7.20 wt. % (Figure 8). No carbonate pebbles were observed in the 4–8 mm size-fraction of till. Carbonate-bearing till in the Lynn Lake area is part of the tail end of a continental-scale dispersal train originating in the Hudson Bay Basin 280–420 km to the east/northeast (Figure 3). The highest concentration of carbonate in till-matrix

Figure 6: *Examples of sorted 4–8 mm size-fraction lithologies from till samples in the Lynn Lake area:* ***a)*** *example of a metavolcanic-rich till;* ***b)*** *and* ***d)*** *examples of granitoid-rich tills;* ***c)*** *example of a metasedimentary-rich till.*

is near Hughes Lake (Figure 8). The ratio of Ca+Mg to Na is another useful geochemical proxy for the proportion of carbonate detritus present in till (McMartin et al., 2016) and these two proxies correlate well in the Lynn Lake dataset (Figure 9).

Elemental concentrations of economic interest

In addition, till-matrix geochemistry can guide drift exploration efforts by establishing background and elevated concentrations for elements of economic interest or pathfinder elements. The spatial distribution of Pb, Cr and Ni classified based on percentiles is provided in Appendix 5 and Cu (Figure 10) and Zn (Figure 11) are provided herein for discussion purposes.

Cu

Till-matrix Cu values range from 1.24–118.00 ppm within samples collected as part of this study (Figure 10). As evident from the probability plot (Figure 10), several samples are elevated above the background signature within this dataset. The highest Cu value (118.00 ppm) return was from a till sample located 11 km east of the Fox Lake Mine, a past producing Cu-Zn deposit.

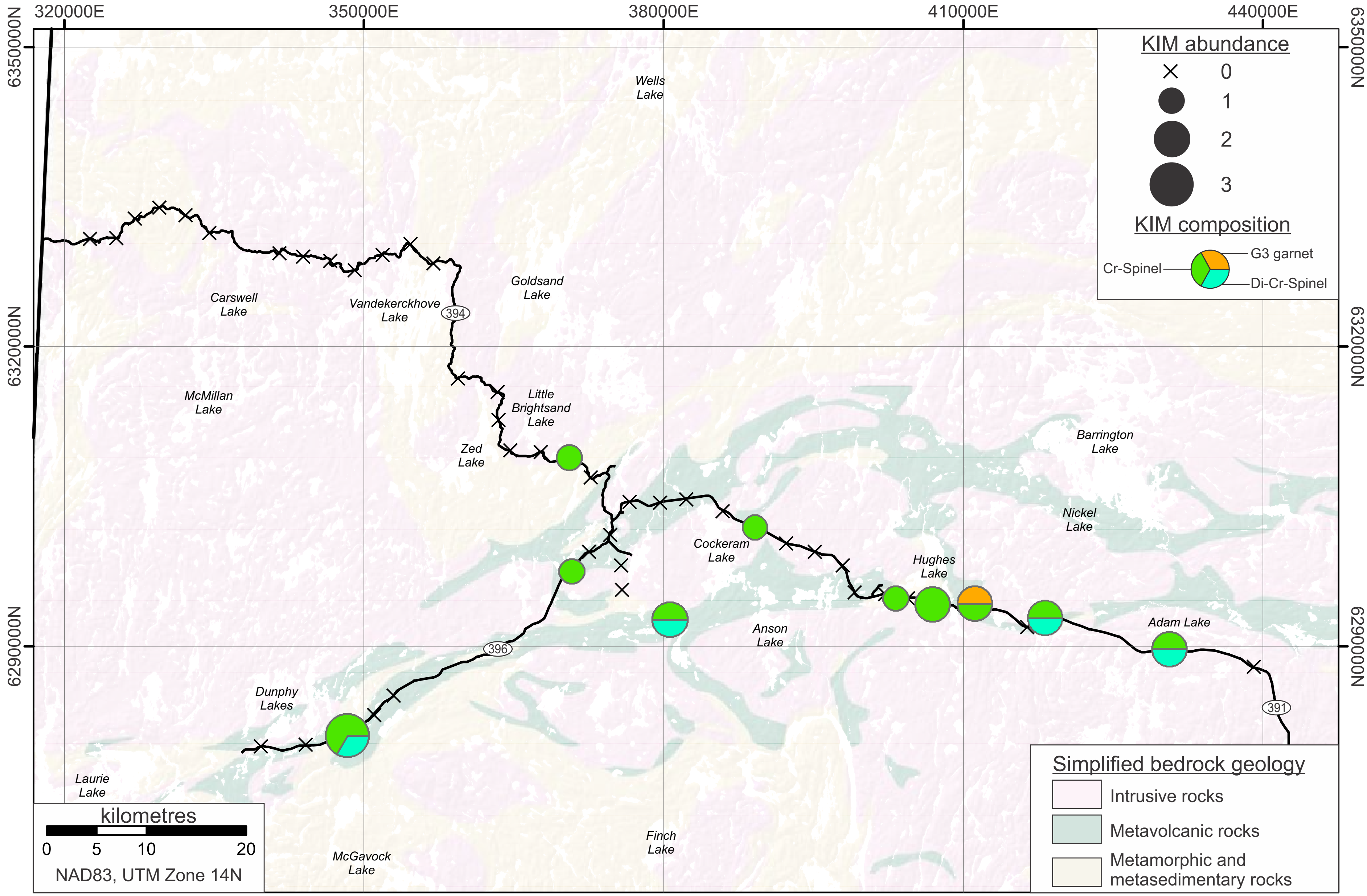

Figure 7: *Data for KIM results displayed as proportional-sized compositional pie charts.*

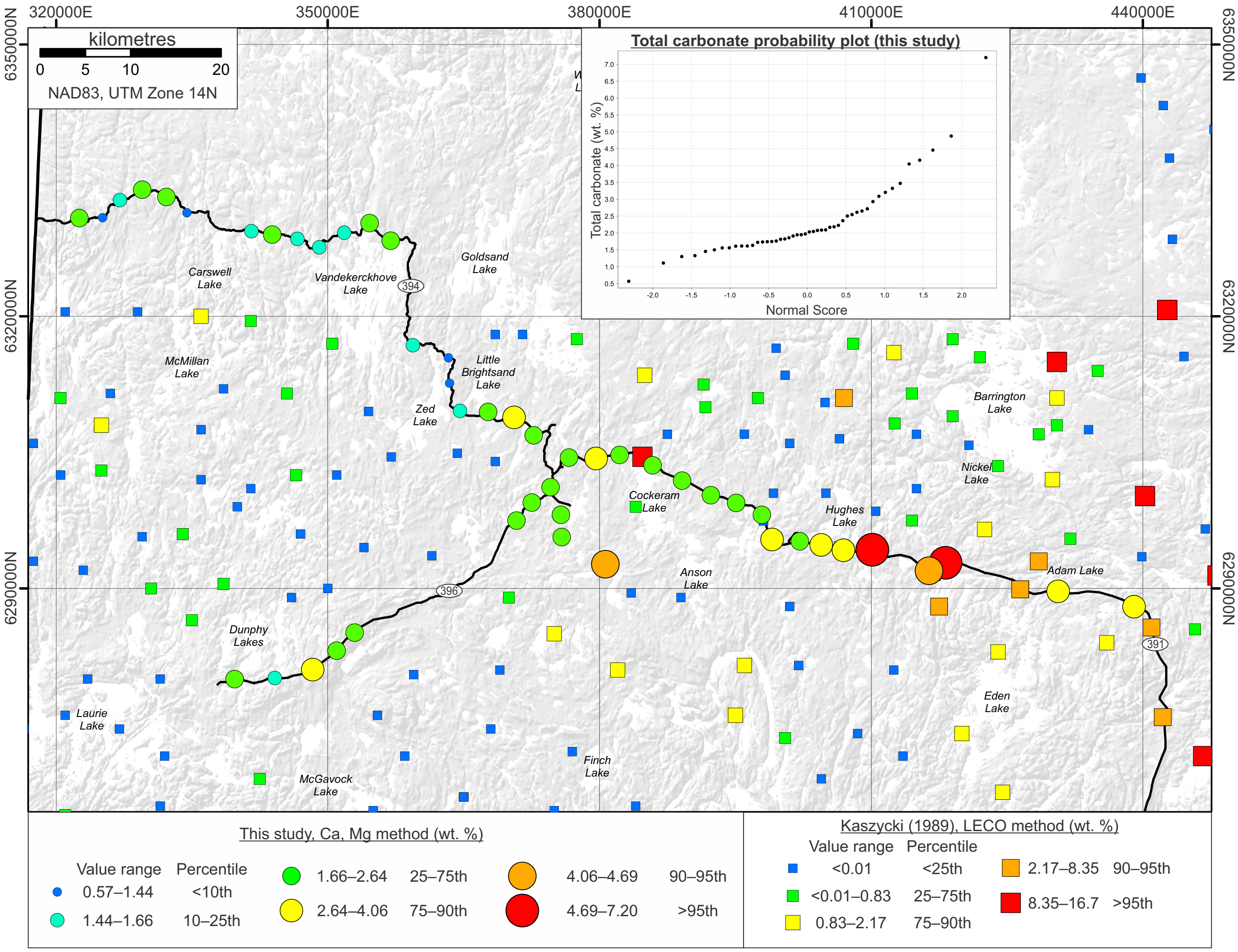

Figure 8: *Till-matrix (<63 µm size-fraction) total carbonate content. The 2017 samples were analyzed at Actlabs using the Ca-Mg method, whereas the Kaszycki (1989) samples were analyzed at the Geological Survey of Canada laboratory using LECO.*

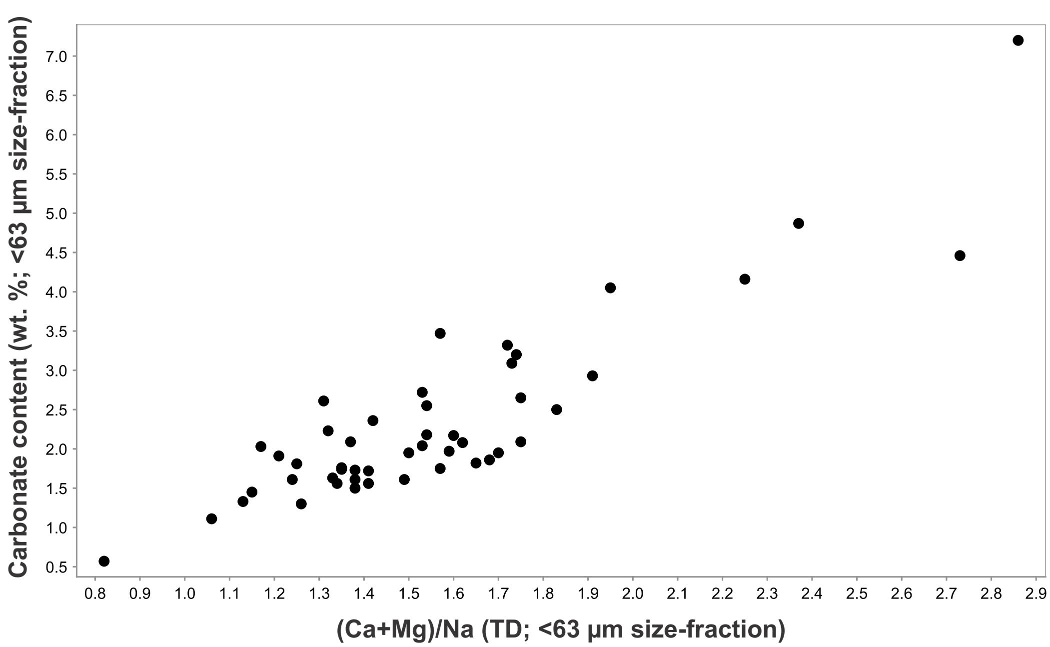

Figure 9: *Till-matrix (<63 µm size-fraction) total carbonate content vs. (Ca+Mg) / Na. Abbreviation: TD, near-total digestion analysis.*

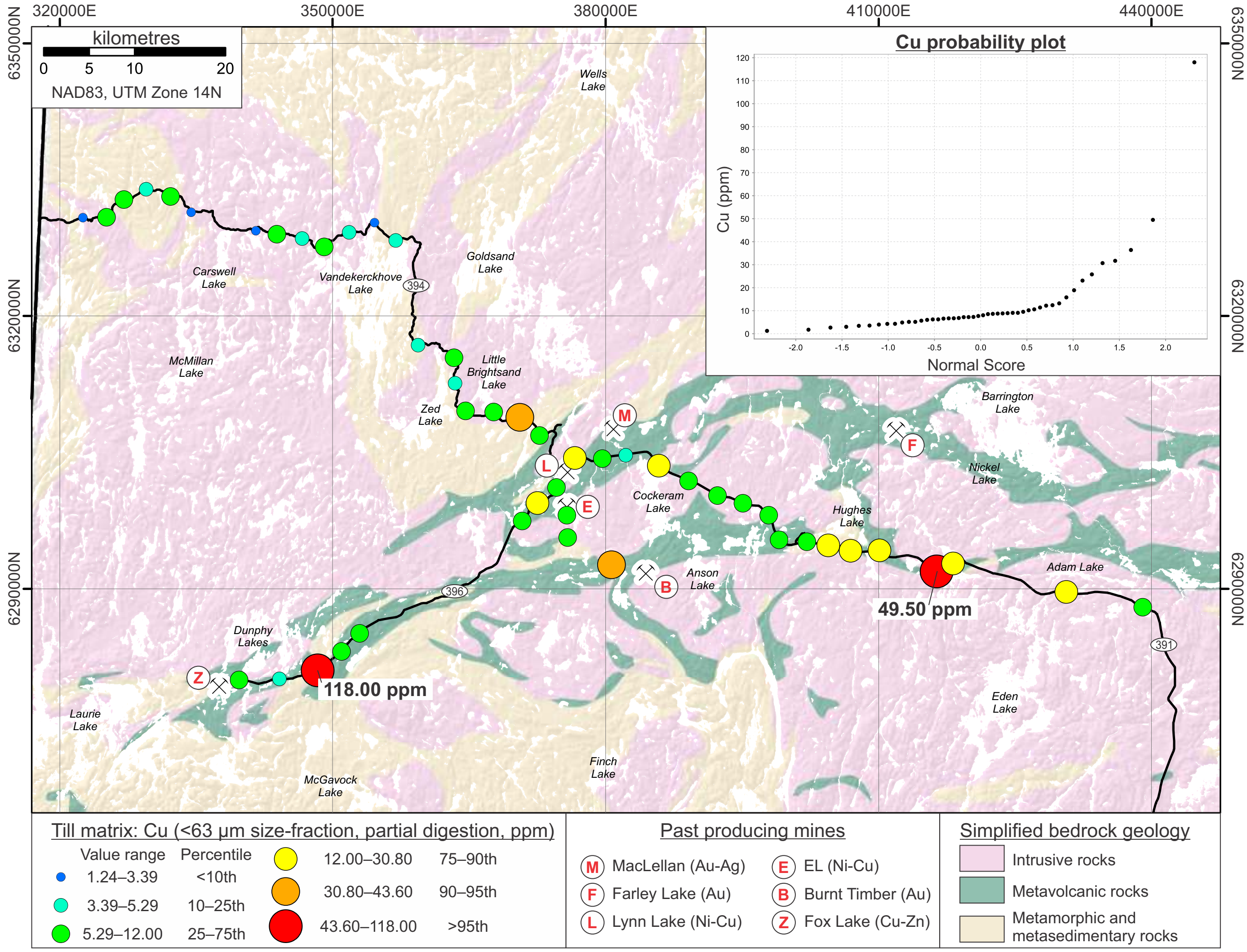

Figure 10: *Till-matrix (<63 µm size-fraction) partial digestion Cu values.*

Zn

Till-matrix Zn values range from 3.5–70.5 ppm within samples collected as part of this study (Figure 11). Zn values in the dataset are correlated to the carbonate content of till (c.f., Figure 8); however, one sample is elevated above the background signature (70.5 ppm) within this dataset—and does not have an above average carbonate content (3.47 wt. %)—is located southeast of Adam Lake along PR 391 (Figure 11). Interestingly, this elevated till sample is located 18 km south of the MacBride VMS deposit. This site also has an elevated Pb signature (>95th percentile; Figure 25, Appendix 5).

Au

Gold concentration in till-matrix (<63 µm size-fraction) sampled as part of this study was below detection in 29/48 till samples and ranged from 0.5–10.6 ppb in samples above detection.

Extensive local-scale sampling was conducted in the northern belt during the 1980s and heavy mineral concentrate (HMC) gold content from these studies was compiled and plotted in Figure 12 (Nielsen and Graham, 1985; Nielsen and Fedikow, 1986, 1987). The MacLellan mine area stands out within the dataset, but there are many additional elevated gold signatures across the northern belt (Figure 12a). Several notable examples highlighted on Figure 12a are:

1 Farley Lake area: a sample with 1030 ppb Au located ~950 m northeast (up-ice) of the Farley Lake Mine;

2 Eagle Lake area: Two elevated (97–99th percentile) samples with 480 and 630 ppb Au with visible Au grain counts of 7 and 1, respectively. These samples are located 1.4 km southeast of Eagle Lake and are 500 m apart from one each other;

3 Arbour Lake area: A sample with 585 ppb Au and 2 visible Au grains located 150 m west of Arbour Lake. Three samples within 500 m to the southwest of this sample all recovered 1 visible Au grain;

4 Arbor Lake area west: A sample with 605 ppb Au and 1 visible gold located 2 km west of Arbour Lake. There are two samples with elevated (>95th percentile) concentrations of 240 and 125 ppb Au that are 150–190 m down-ice, one site also recovered 1 visible Au grain;

5 Minton and Dot lakes area: A sample with 1220 ppb Au located 540 m SE of Minton Lake and another sample with 610 ppb located 550 m NW of dot lake.

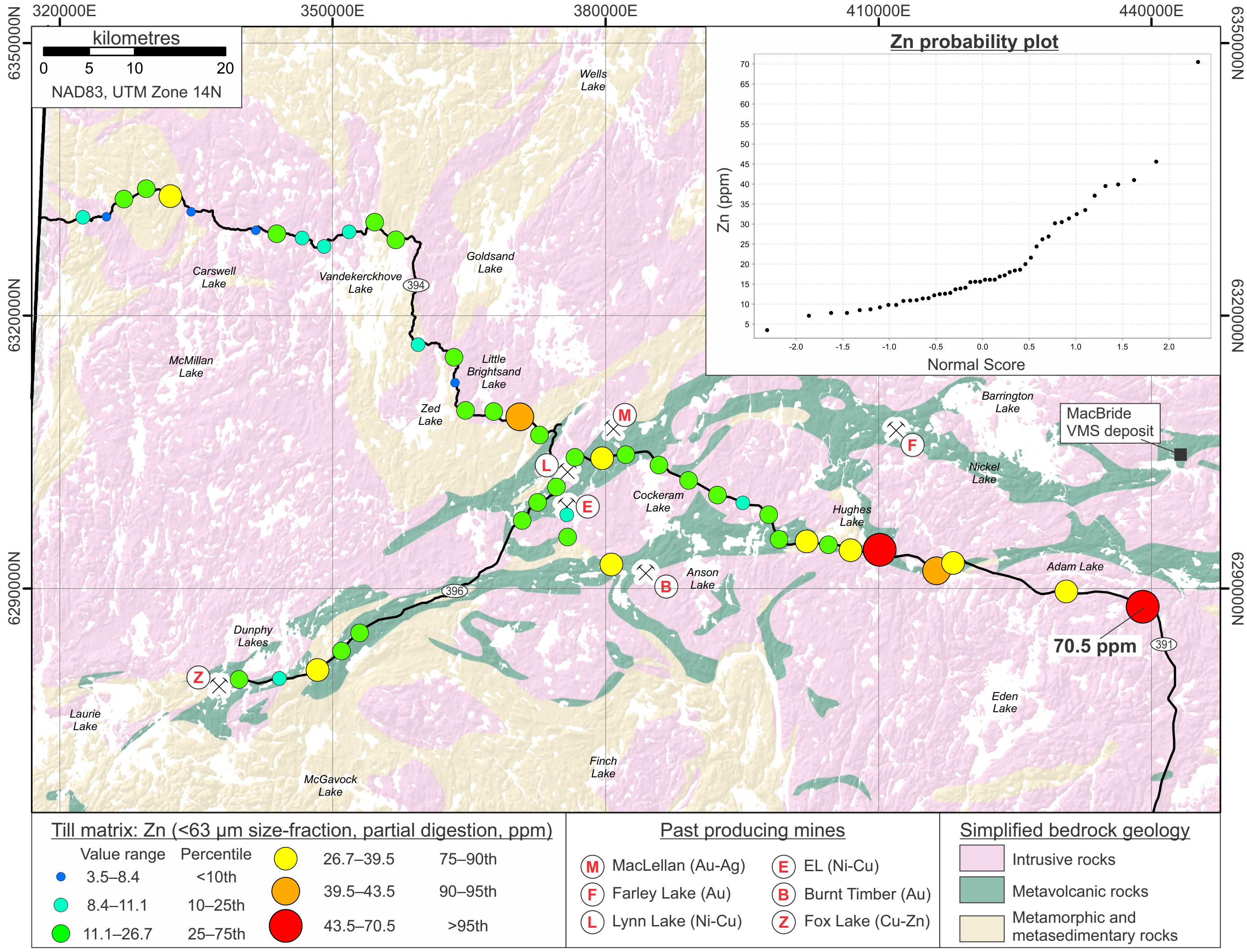

Figure 11: *Till-matrix (<63 µm size-fraction) partial digestion Zn values.*

Near the MacLellan mine, till sampling was conducted down-ice of known mineral occurrences at surface (Nielsen and Fedikow, 1987). Nielsen and Fedikow (1987) recognized two distinct dispersal trains (Figure 13). Dispersal associated with the MacLellan deposit is detectable at least 150–200 m down-ice. Extensive black spruce bog in the area inhibited further sampling down-ice, but, till gold concentrations were <10 ppb 450 m down ice of the deposit providing a maximum dispersal distance. Along the western extension of the MacLellan mineralization, dispersal is detectable up to 1.5 km from mineralized outcrop (Figure 13). Nielsen and Fedikow (1987) attributed the difference in dispersal from each of these outcrop sources to the local topography, since the western extension is on relatively flat ground and the MacLellan mineralization is on the lee-side of a hill.

Till clast counts

In the northwest region of the study area, from Zed Lake to the Saskatchewan border, the concentration of metavolcanic and metasedimentary rocks does not exceed 3.4 ct. % and till contains high proportions of granitoid bedrock. The highest concentration (33.7 ct. %) of metasedimentary clasts is from a sample overlying metasedimentary bedrock east of Zed Lake (Figure 14). The concentration of metavolcanic clasts in till generally follows the distribution of the local metavolcanic bedrock units in the study area (Figure 14).

Till-matrix texture

Till in the study area contains 72 to 94% sand, 4 to 24% silt and 1 to 6% clay and all samples would be considered sandy till. The distribution of samples with relatively elevated silt and clay content does not appear to follow any spatial pattern (Figure 15). Till sampled between Zed and Little Brightsand lakes is the only area where there are multiple samples with high silt and clay content in till-matrix (2.4–5.5 wt. % clay, 13.3–20.0 wt. % silt, 18.3–23.9 wt. % silt and clay).

Legacy data re-analysis

<2 and <63 µm comparisons

Plots comparing the <2 and <63 µm size-fraction geochemistry results for elements Cu, Ni, Cr, Fe and Zn are provided in Appendix 2 and the plot of Cu values is reproduced in Figure 16 for discussion purposes. Interested parties are encouraged

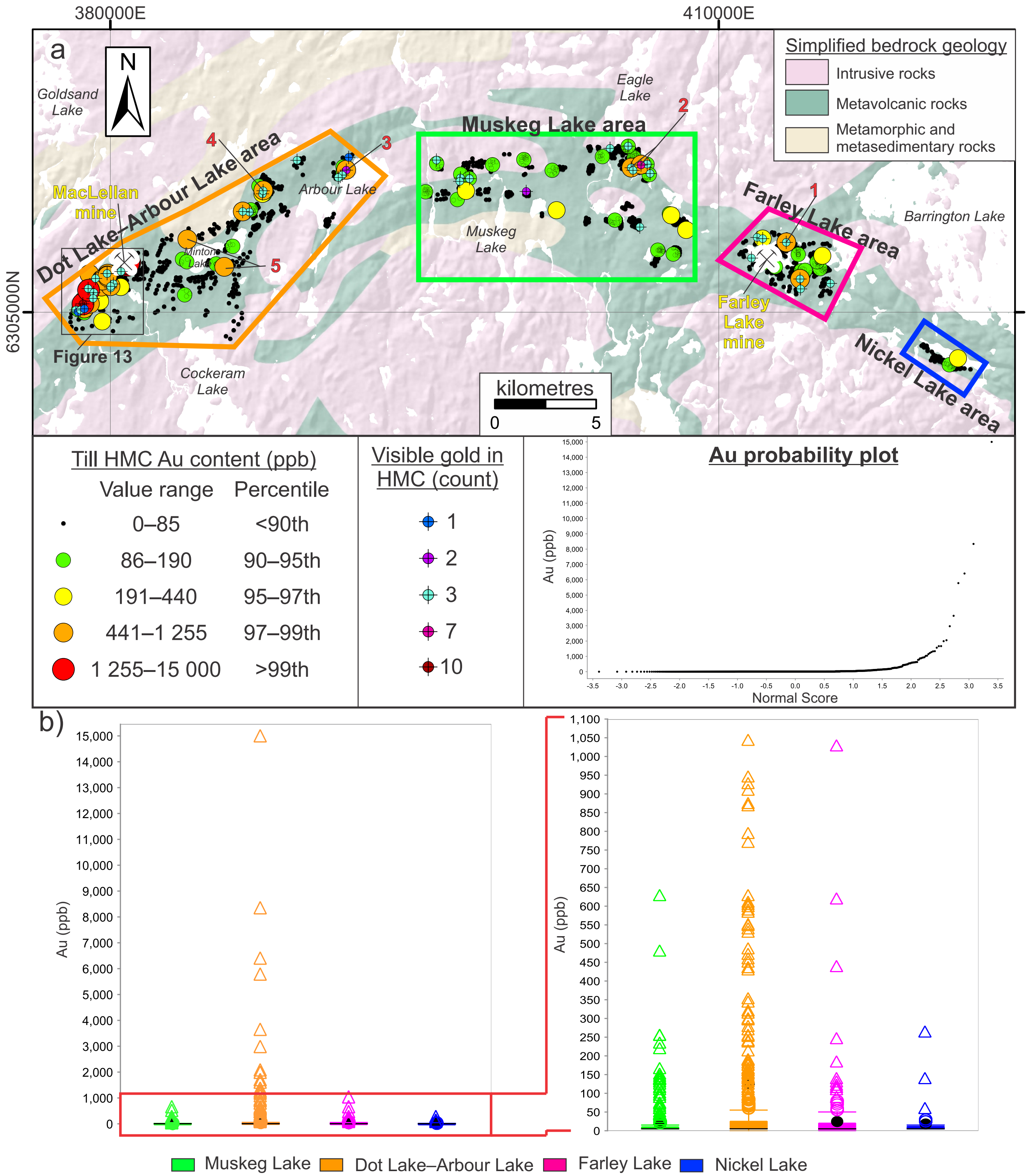

Figure 12: *Gold concentration in the non-magnetic HMC of till matrix (fine-sand fraction) across the northern greenstone belt:* ***a)*** *spatial distribution and probability plot of data compiled from Nielsen and Graham (1985) and Nielsen and Fedikow (1986, 1987). Numbered regions are discussed within the text;* ***b)*** *box plot of gold concentrations classified according to each region designated in a). Abbreviation: HMC, heavy mineral concentrate.*

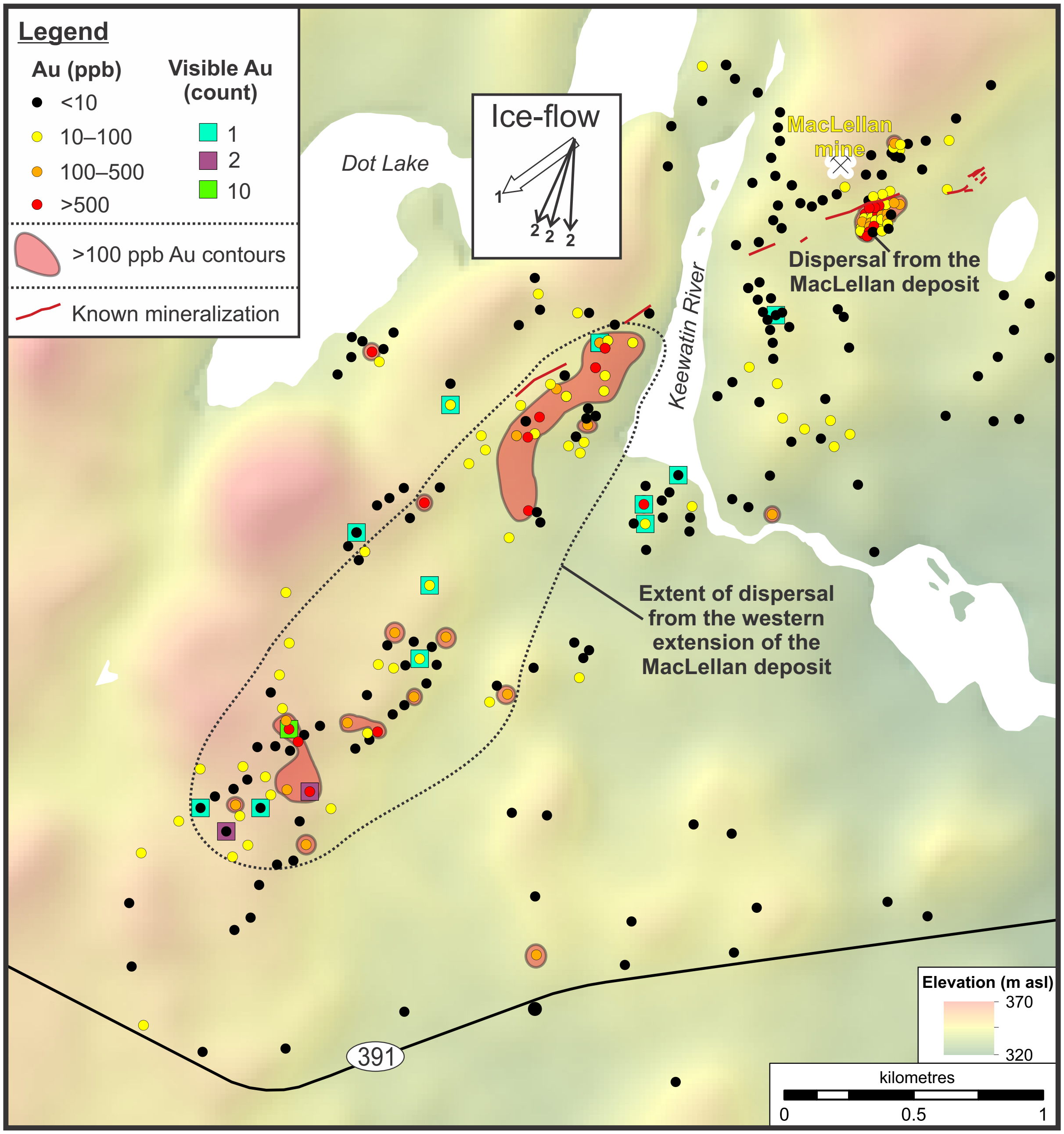

Figure 13: *Gold concentration in the non-magnetic HMC of till matrix (fine-sand fraction) in the MacLellan mine area. Modified from Nielsen and Fedikow (1987). Ice flow history in the MacLellan mine area is from Figure 2. Location of this dispersal train is shown on Figure 12.*

to explore this new dataset and the legacy datasets that are provided as complementary materials to this publication.

Here, one observation is highlighted pertaining to the distribution of Cu in the dataset. Previous till sampling in the Nickel Lake area demonstrated that this area has regionally elevated Cu concentrations (Figure 16c, d). Re-analysis of the <63 µm size-fraction reinforces this observation and shows adequate correlation between the <2 and <63 µm size-fractions (Figure 16e).

Since no Cu values were obtained from previous studies on the <63 µm size-fraction of till, the re-analyses of historic till samples carried out during this study was fundamental for regional context interpretation. For example, the elevated till Cu value (118 ppm) along PR 396 southeast of Dunphy Lakes (Figure 10) from the <63 µm size-fraction would roughly correlate to ~500 ppm Cu in the <2 µm size-fraction (see scatted plot in Figure 16e), which would rank this particular sample among the highest Cu values recovered from till in the Lynn Lake area (c.f., Figure 16d).

Discussion

Northwest Manitoba kimberlite-indicator mineral trends

Comparing till KIM recovery (Figure 7) and the carbonate content of the till-matrix from the studied area (Figure 8) sug-

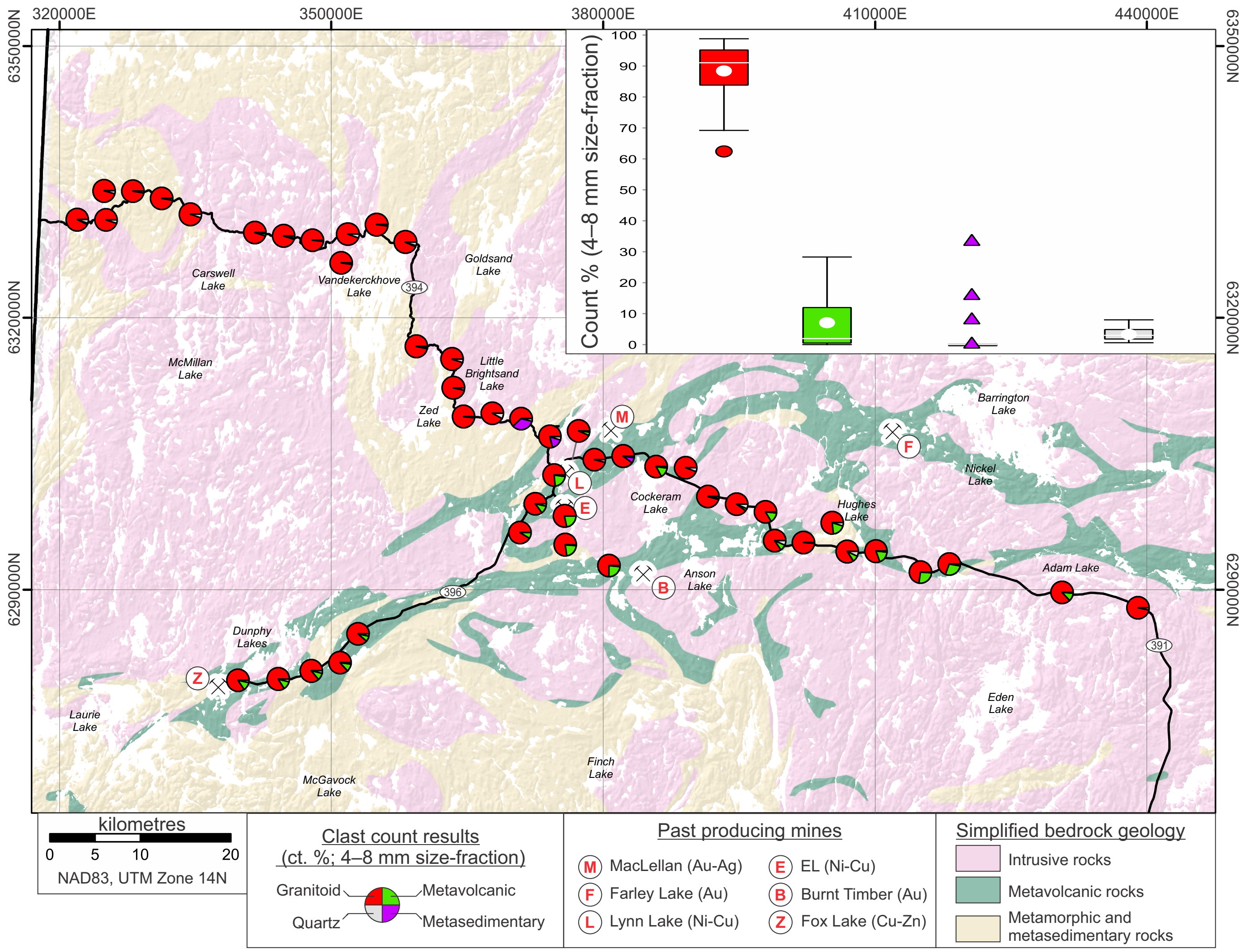

Figure 14: *Clast count results displayed spatially as pie charts and summarized with a box plot.*

gests a correlation. This correlation is highlighted by plotting samples classified according to KIM recovery on probability plots of total carbonate content and Ca+Mg/Na (Figure 17) where it is evident that samples with high carbonate content also have the highest number of KIMs recovered. This observation suggests that the majority of the KIMs recovered in the Lynn Lake area during this survey were glacially transported by an ice-flow event that also dispersed carbonate detritus into the study area. Alternatively they could have been derived from the reworking of a pre-existing carbonate-bearing till. The provenance of carbonate detritus is interpreted to be the Hudson Bay Basin, which is located 280–420 km to the east of the study area. It is important to note that this correlation does not signify that these KIMs are derived from the basin, but, instead that they are potentially sourced from a region along this ice-flow path(s) and suggests an initial east to northeast provenance.

The high carbonate-KIM recovery relationship has reinforced the diamond prospectivity of the Southern Indian Lake area, which is located 80–120 km northeast of the Lynn Lake area (Figure 18). Shoreline KIM sampling of till in the central area of the Southern Indian Lake recovered 106 KIM grains, ranging from 1–13 per sample, from nineteen samples (Hodder, 2017). Till-matrix carbonate content of till sampled for KIM analysis from the Southern Indian Lake area ranges from 25.77–34.82 %.

The objective of KIM sampling surveys at Southern Indian Lake and Lynn Lake areas was to provide a reconnaissance- to regional-scale insight into the diamond potential of this northern location of Manitoba. As such, the delineation of individual dispersal trains is not possible at this scale of sampling and the potential for missed dispersal trains is possible. Considering the relationship of carbonate content and KIM recovery in the Lynn Lake area and the KIM abundance in the Southern Indian Lake area, it is highly recommended that further sampling is conducted in the Southern Indian Lake area and to the east and northeast of there, since the dominant ice-flow mapped in the area was 210–244° (Hodder, 2018). As was demonstrated during the Southern Indian Lake study (Hodder, 2018) using the bedrock ice-flow indicators and carbonate content, earlier ice-flow phases have an important impact on till composition and cannot be ignored, which can result in complex palimpsest dispersal trains. Additional sampling will be needed to thoroughly understand KIM dispersal trends in this area of Manitoba. These MGS surveys have started to build-up this necessary base knowledge and provide regional-scale insights to be followed-up by more local-scale reconnaissance work.

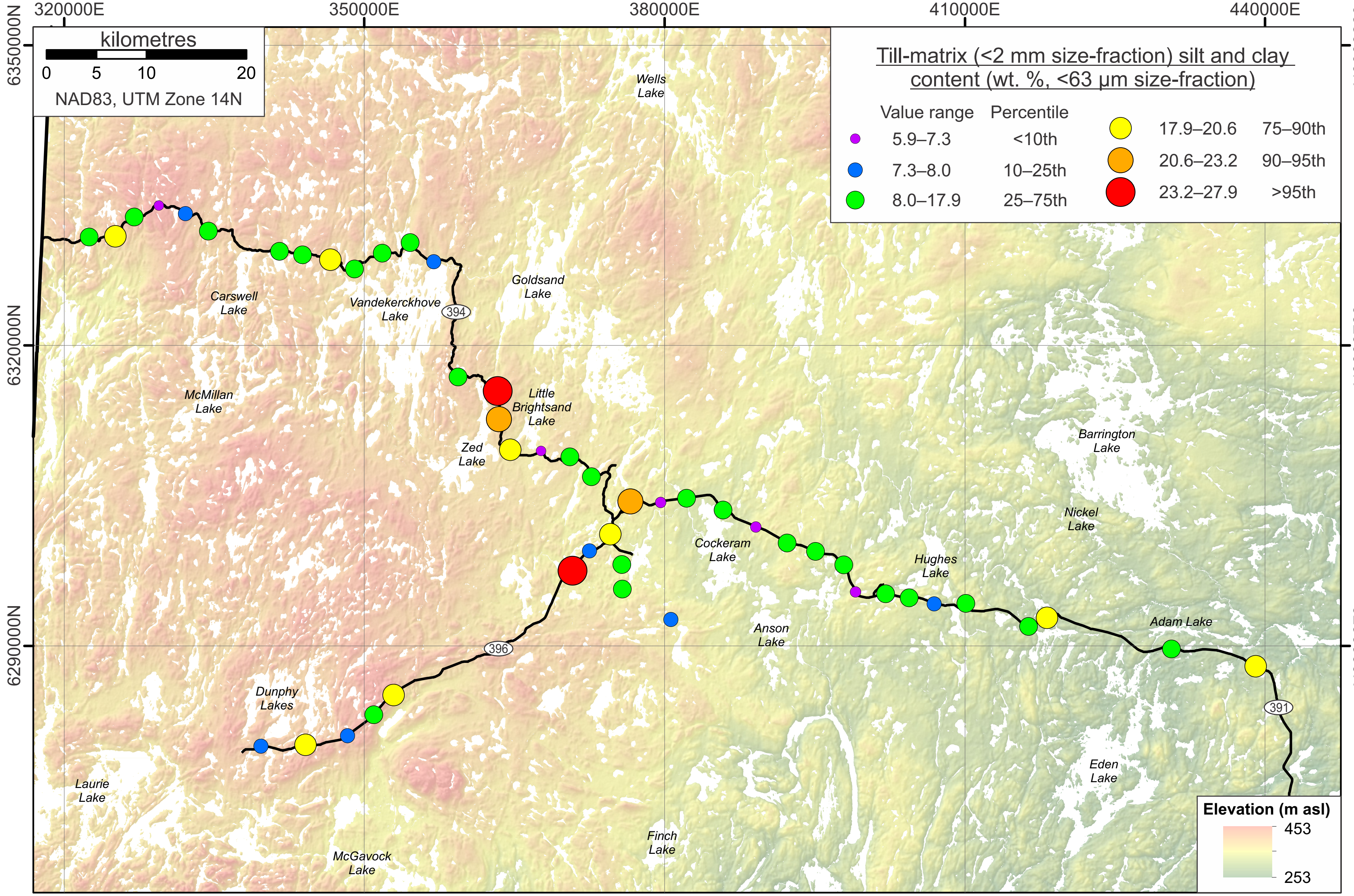

Figure 15: *Till-matrix (<2 mm size-fraction) silt and clay content (<63 µm size-fraction).*

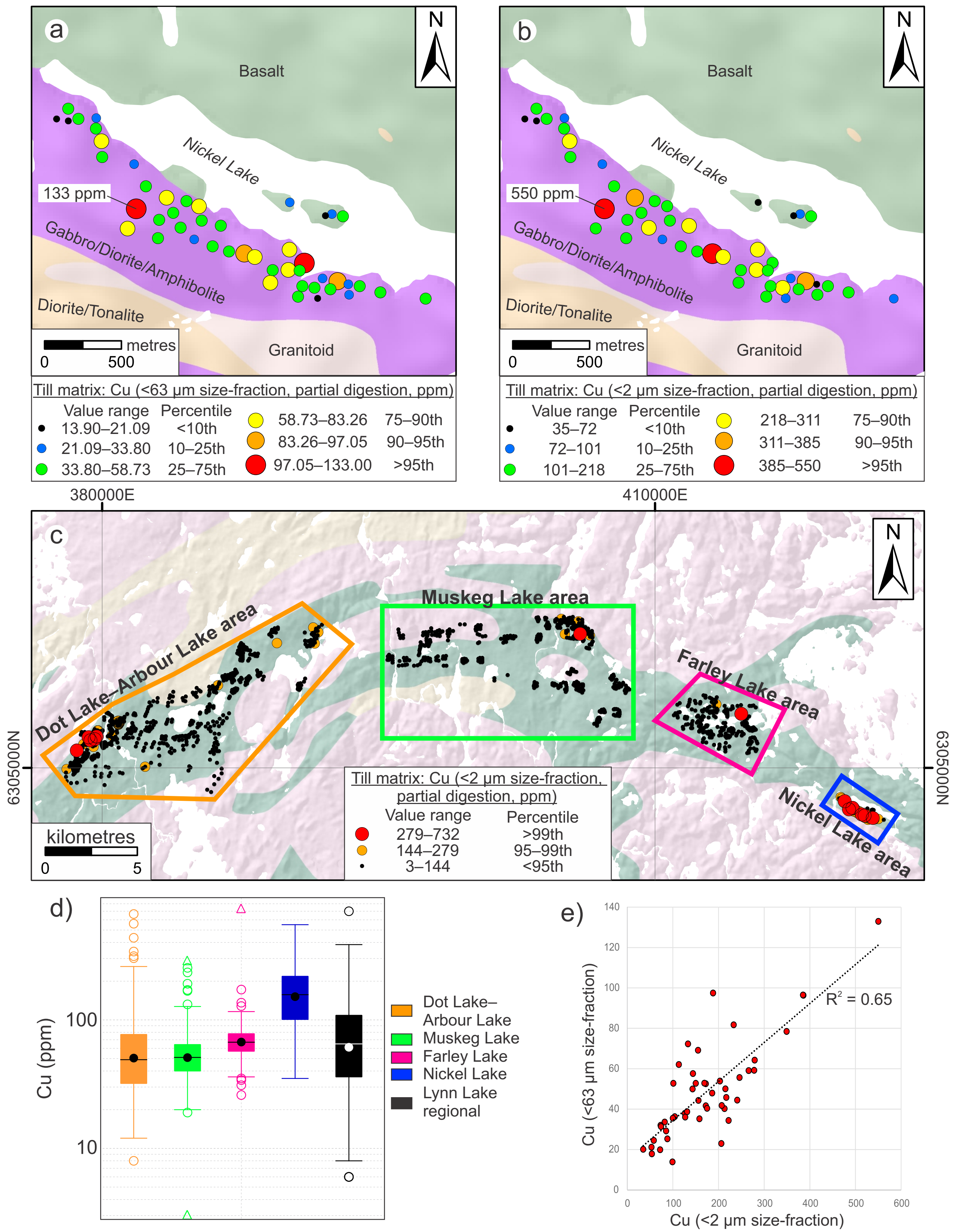

***Figure 16:** Till-matrix (<2 and <63 µm size-fraction) Cu values, Nickel Lake and surrounding area. **a)** Till-matrix (<63 µm size-fraction) Cu concentrations; **b)** Till-matrix (<2 µm size-fraction) of till Cu distribution; **c)** Till-matrix (<2 µm size-fraction) Cu values from the Agassiz metallotect; **d)** Box plot of Cu values for each region identified in c); **e)** Scatter plot comparison between the <63 µm size-fraction and <2 µm size-fraction Cu values for the Nickel Lake area.*

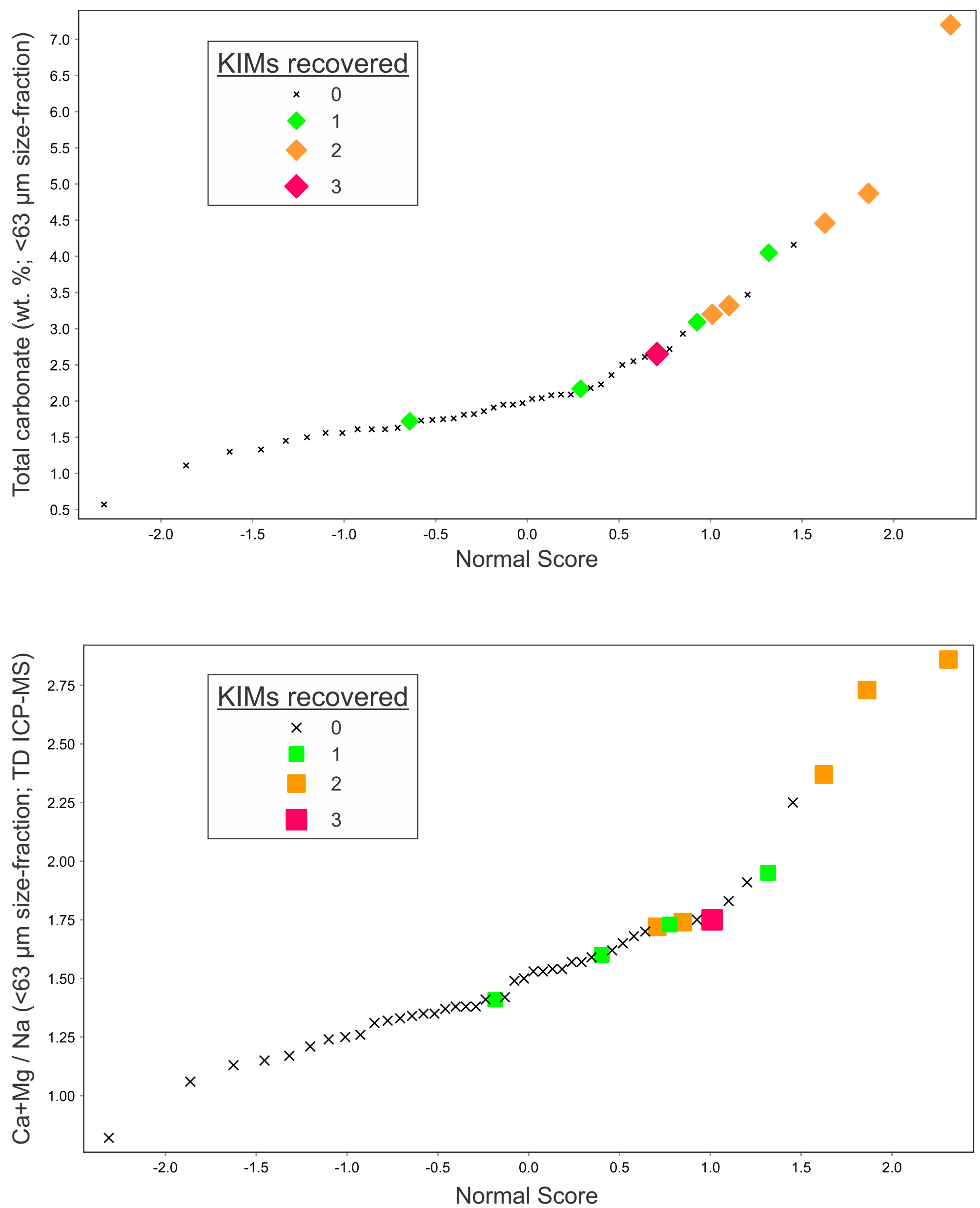

Figure 17: *Total carbonate content of till matrix (<63 µm size-fraction) probability plot with each sample classified according to the amount of KIMs recovered. Abbreviations: TD ICP-MS, near-total digestion inductively coupled plasma-mass spectrometry.*

Conclusions and recommendations

This publication compiles previous till-matrix geochemistry data and provides associated spatial data that is needed for database incorporation. New till-matrix geochemistry data collected during this study has highlighted several elevated signatures in elements of economic interest. The most significant is an elevated Cu value 11 km east of the past-producing Cu-Zn Fox Lake mine in a region without extensive previous till sampling. Considering the short (few hundred metres to a few kilometres) dispersal trains typically associated with VMS deposits (McClenaghan and Peter, 2016) and with deposits in this study area (Lar Cu-Zn deposit, Nielsen and Conley, 1991; MacLellan Au-Ag deposit, Nielsen and Fedikow, 1987) follow-up sampling of any till-matrix geochemistry signature of economic interest should be conducted in close proximity, considering the source could be within a few 100 metres.

A correlation between KIM grain recovery and carbonate till composition was demonstrated during this study. This indicates that KIM provenance may be to the east or northeast of the study area. This is reinforced by elevated numbers of KIM grains from till samples in the Southern Indian Lake area. These observations together indicate further KIM sampling should be conducted in the Southern Indian Lake area as well as to the east and northeast of that region.

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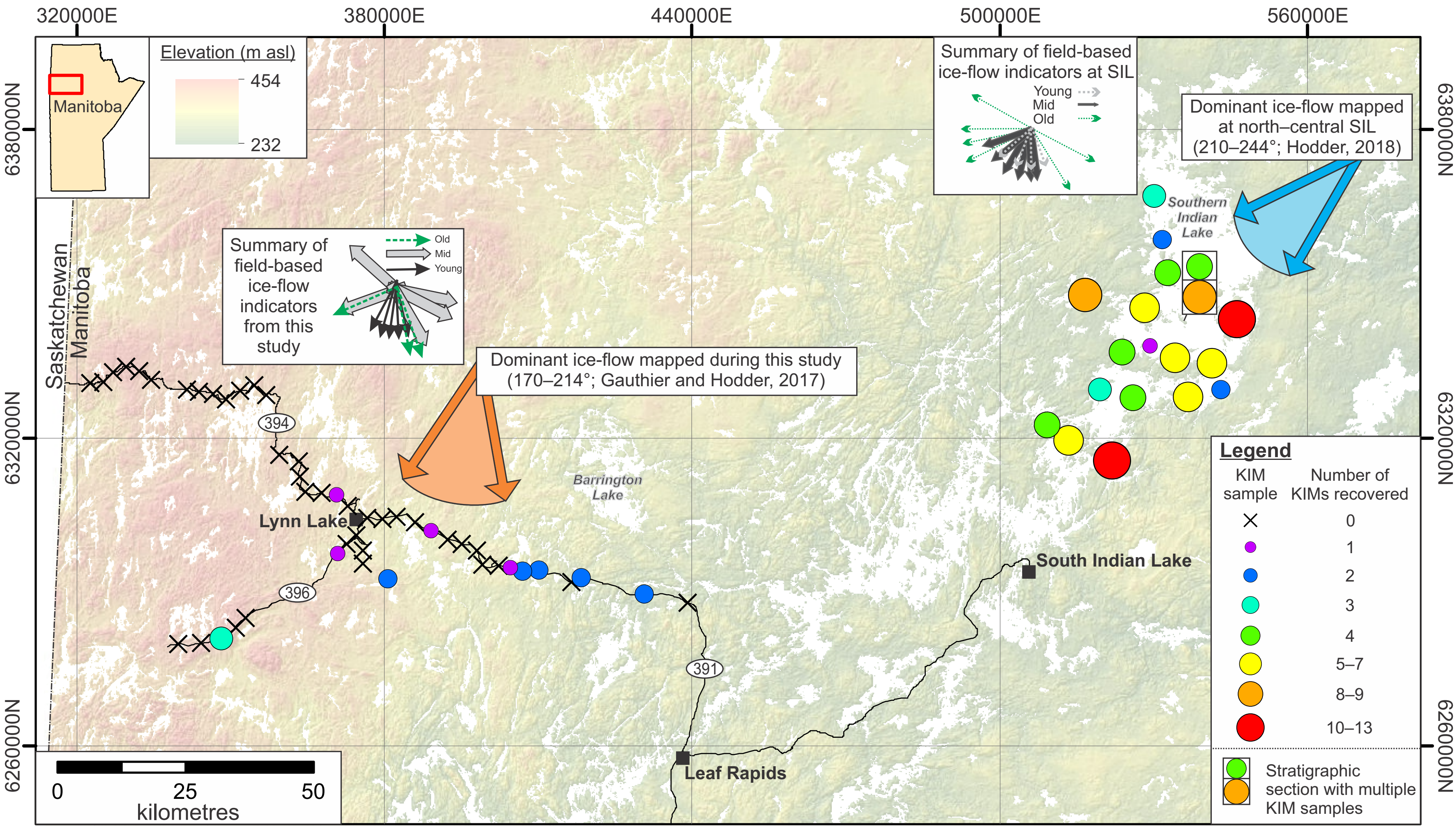

Figure 18: *Till KIM recovery in the Lynn Lake (this study) and Southern Indian Lake (Hodder, 2017, 2018) areas. Abbreviation: SIL, Southern Indian Lake.*

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