GS2018-13

Kimberlite-indicator minerals and clast-lithology composition of till, Kaskattama highland region, northeastern Manitoba (parts of NTS 53N, O, 54B, C)

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In Brief:

- Till KIM counts are elevated compared to regional data
- The lowest KIM yields are associated with samples indicating a Hudson Bay Basin provenance, while the highest KIM yields are associated with till samples that have a relatively elevated greywacke/greenstone or granitoid provenance signature
- Till composition, ice-flow data and stratigraphy indicate the potential for multiple KIM sources

Citation:

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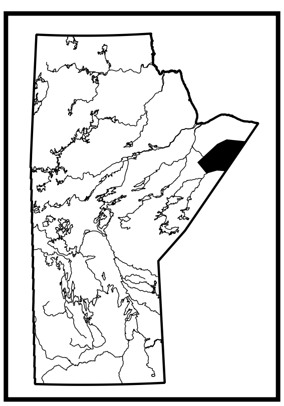

Summary

Quaternary geology fieldwork was conducted at a reconnaissance-scale in the Kaskattama highland area to document the Quaternary stratigraphy and till composition. The diamond potential of this region was investigated using kimberlite-indicator–mineral (KIM) counts from till samples. Indicator mineral results are the focus of this report and are combined with ice-flow and till-clast–lithology data to provide a context to interpret provenance.

Kimberlite-indicator minerals were recovered from glacial sediments (till) in the Kaskattama highland area and KIM counts are elevated relative to data from the surrounding area. The lowest KIM counts were from till with a high Hudson Bay Basin (carbonate-dominated) and low undifferentiated greenstone and greywacke (UGG) provenance signature. The highest KIM counts are associated with till samples that have a relatively elevated UGG or elevated granitoid provenance signature. Till samples with relatively elevated UGG concentration have an interpreted east or southeast provenance, which is supported by ice-flow data and the recovery of distinct east-sourced erratics. Till samples with a relatively elevated granitoid clast concentration have a correlation with the southwest-trending Hayes streamlined-landform flowset. Considering the likely provenance for granitoid clasts is to the northwest, the presence of relatively high concentrations of granitoid clasts in the Hayes flowset could be indicative of a higher inheritance from previous ice-flow events or a palimpsest dispersal pattern. Interpretation of till-composition and ice-flow data has indicated there are likely multiple sources for the KIMs recovered during this study. Detailed work is recommended to clarify local-scale dispersal patterns.

Introduction

The Manitoba Geological Survey (MGS) conducted Quaternary geology fieldwork in the Kaskattama highland region of northeastern Manitoba during the summers of 2016 and 2017 (parts of NTS 53N, O, 54B, C; Hodder and Kelley, 2016; Hodder, 2017). A key aspect of this project is documenting the till composition and Quaternary stratigraphy at a reconnaissance-scale in this remote region of northeastern Manitoba. As part of this project, the diamond potential of the region is being assessed through kimberlite-indicator–mineral (KIM) counts from till samples. The purpose of this study is to publish KIM data collected in 2017, along with previously released 2016 data (Hodder and Kelley, 2017), as a data repository item (Hodder, 2018b) and to provide the mineral exploration industry timely updates on new geological knowledge. This report provides insight into the relationships between KIM recovery and till composition, primarily clast-lithology counts, which when combined with ice-flow–indicator data provide an important context to interpret KIM provenance.

Regional setting

The Kaskattama highland in northeastern Manitoba, a prominent topographic high within the Hudson Bay Basin, rises 130 m above the flat-lying Hudson Bay Lowland terrain, reaching a maximum elevation of 235 m asl. The Gods River is the main drainage channel flowing northwestward toward a confluence with the Hayes River, which drains

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northeastward into Hudson Bay. The Kaskattama River drains northeastward to Hudson Bay with the headwaters situated on the Kaskattama highland. Access to the region is by air-support or by winter road into the First Nation community of Shamattawa.

Geomorphology

Two streamlined-landform flowsets, defined as discrete assemblages of subglacial streamlined landforms based on their similar direction and the degree of internal consistency (Kleman and Borgstrom, 1996; Clark et al., 2000; Greenwood and Clark, 2009), are present in the geomorphic record of the study area (Figure GS2018-13-1). The Hayes flowset is southwest-trending (204–207° in the study area) and is attributed to the large deglacial Hayes lobe (Dredge and Cowan, 1989). On the Kaskattama highland, the landscape is dominated by a curvilinear flowset of northwest-oriented streamlined landforms, referred herein as the Kaskattama flowset. The trend of this flowset is interpreted to be toward the northwest based on the surficial till composition discussed in this report. The boundary between the two flowsets is sharp, distinct and delineated by a northeast-oriented channel.

Bedrock geology

Regionally, the area is underlain by Paleozoic carbonate sedimentary rocks of the Hudson Bay Basin (Nicolas and Armstrong, 2017), with Precambrian crystalline rocks mapped in the southwestern portion of the study area (Manitoba Department of Mines, Natural Resources and Environment, 1979). Bedrock is hidden beneath thick Quaternary sediments throughout the study area. Outcrops of Paleozoic bedrock were only observed along the base of the Gods River, northwest and south of the First Nation community of Shamattawa.

Distinctive erratics

The lithology of clasts within till can assist with the delineation of glacial transport directions and distances (glacial dispersal), as well as potentially identifying buried unmapped bedrock units. Glacial dispersal can be mapped at varying scales from continental (hundreds of kilometres) to regional (tens of kilometres) to local (<10 km). In northern Manitoba, two groups of distinctive erratics are the result of continental-scale glacial dispersal from eastern and northern source areas.

Distinctive erratics of eastern provenance include clasts derived from the Omarolluk Formation and oolitic jasper clasts. The Omarolluk Formation, of the Belcher Group in southeastern Hudson Bay (Figure GS2018-13-2), is a distinctive greywacke with hemispherical calcareous concretions (Prest et al., 2000; Jackson, 2013). These erratics, commonly referred to as Omars (Prest et

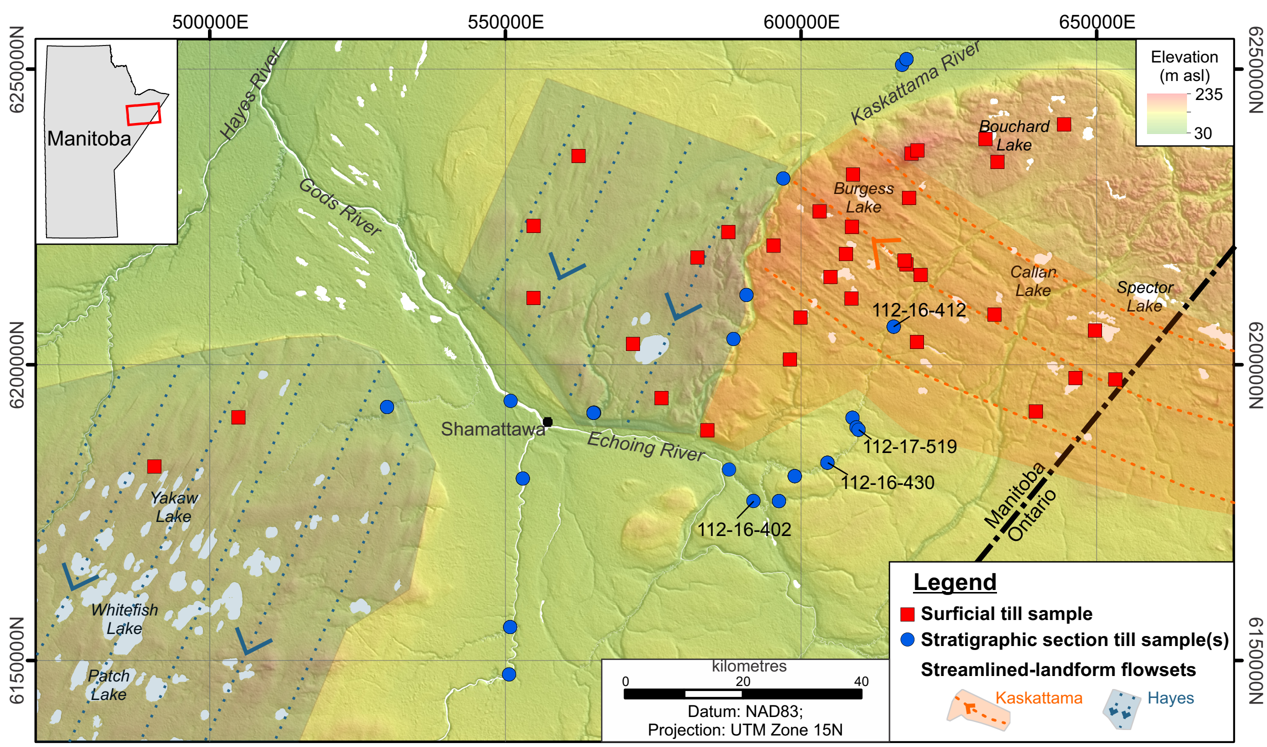

Figure GS2018-13-1: *Till sample sites and streamlined-landform flowsets in the Kaskattama highland region, northeastern Manitoba. Background hillshade image was generated using Canadian Digital Surface Model (Natural Resources Canada, 2015).*

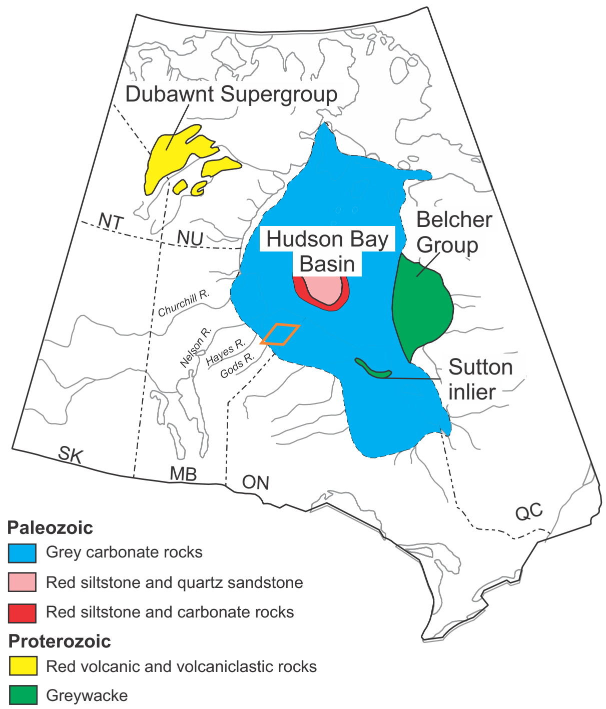

Figure GS2018-13-2: *Bedrock sources of distinctive continental-scale erratics observed in northeastern Manitoba and outline of the Hudson Bay Basin. The location of this study is depicted by the orange polygon. Figure is modified from Kaszycki et al. (2008).*

al., 2000), were transported westward by the Laurentide Ice Sheet (LIS) into the study area, a minimum of 650 km from known outcrops in southeastern Hudson Bay. As such, the presence of Omars within glacial sediments has been used to infer an eastern provenance (Prest et al., 2000; Nielsen and Fedikow, 2002; Trommelen et al., 2013). Omars are easily identified in the large pebble to boulder size-fractions, but in smaller size-fractions these erratics become more difficult to confidently identify. Metavolcanic and metasedimentary rocks that comprise greenstone belts in the Canadian Shield can often resemble the matrix of Omar clasts in small size-fractions. As such, Omar clasts without distinctive concretions and greenstone clasts are indistinguishable during clast-lithology counts. A second distinctive lithology of eastern origin, oolitic jasper, is easily recognized in clast-lithology counts. These clasts are interpreted to be derived from the Kipalu Formation of the Belcher Group (Jackson, 2013) or from iron formation rocks found at the Sutton inlier (Figure GS2018-13-2; Stott et al., 2010).

Distinctive erratics derived from the Dubawnt Supergroup of central mainland Nunavut are also found throughout northern Manitoba (Dredge and McMartin, 2011). These include reddish to pinkish sandstone and conglomerate of the Thelon Formation, and purple to mauve rhyolite with glassy quartz and chalky sanidine phenocrysts and volcaniclastic rocks with phlogopite phenocrysts of the Christopher Island Formation (Rainbird et al., 2003). These erratics were transported into northeastern Manitoba by ice flow(s) with a net glacial dispersal of over 800 km, by either the LIS and/or precursor ice sheets.

Methods

Field data collection

Helicopter-supported fieldwork was undertaken by the MGS during the 2016 and 2017 field seasons. A total of 116 till samples were collected from surficial sites and stratigraphic river section exposures (Figure GS2018-13-1; 34 surficial and 82 stratigraphic samples). At 64 till sample sites, an additional 11.4 L of till was collected for KIM analysis. Surficial till samples were collected from C-horizon material in hand-dug pits or with an auger. Sediments exposed at river sections were first cleared to remove any slump material and till samples were collected every 1–4 m depth depending on the stratigraphy observed at the section. Clast-fabric measurements were completed within till at selected sample sites to assess the paleo-ice flow during deposition and assist till provenance interpretations. Clast-fabric measurements taken included the trend and plunge of 30 clasts with an a:b axis ratio of >1.5. In situ, lodged, cobble- to boulder-sized clasts with parallel striae on their upper surface are considered good indicators of paleo–ice-flow direction (McMartin and Paulen, 2009) and the striae were measured where encountered in sections.

Clast-lithology counts

Clast-lithology counts were conducted for each till sample to aid in the determination of provenance. Clasts larger than 2 mm were initially sieved into 2–4, 4–8 and 8–30 mm size-fractions and counts conducted on each fraction with the assistance of an optical microscope. These size-fractions were then summed and expressed as a count percentage of the 2–30 mm size-fraction. Clasts were separated into 14 rock types during identification and simplified into three provenance classes for the purpose of this report: granitoid, Hudson Bay Basin (HBB) and undifferentiated greenstone and greywacke (UGG). To establish a clast-lithology composition-derived till classification, the three provenance classes were processed by k-means cluster analysis after a centred log ratio transformation. For a thorough review of k-means cluster analysis methods used in this study see Wang (2018). Data presented herein are to support KIM provenance interpretations, and a more thorough review of clast-lithology count data will be part of a forthcoming report.

Kimberlite-indicator mineral processing and classification

Blind KIM till samples were submitted to the De Beers Group of Companies (De Beers) to be analyzed through in-kind support. The KIM sample locations were withheld from De Beers, to allow equal opportunity for follow-up by all interested parties when the data (with sample locations) are publicly released along with this report. 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 only the 0.3–0.5 mm size-fraction. Suspected KIM grains were then selected visually, and analyzed by electron microprobe. The KIM grains were initially classified using electron microprobe results, following the methodology outlined by Thorleifson et al. (1994). The Mg-ilmenite grains were confirmed using the compositional field defined by Wyatt et al. (2004; Figure GS2018-13-3a). Diamond-inclusion Cr-spinel grains were identified according to modified discriminate diagrams after Fipke et al. (1995; Figure GS2018-13-3b, c). Although, caution should be exercised when relying on the TiO_2 versus Cr_2O_3 discriminate plot (Figure GS2018-13-3b), as 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). The Cr-diopside grains were confirmed using the Cr_20_3 versus Al_2O_3 plot defined by Nimis (2002; Figure GS2018-13-3d). Garnet grains were classified according to the method outlined by Grütter et al. (2004; Figure GS2018-13-3e).

Results

Till-clast–lithology composition

The lithology of clasts within till samples was determined to help identify major directions of glacial dispersal and hence till provenance. The k-means cluster analysis of simplified till-clast–lithology count data identified seven clusters, herein referred to as till types and displayed on a ternary diagram in Figure GS2018-13-4. The spatial distribution of till types separated into surficial and stratigraphic section samples is presented in Figure GS2018-13-5.

Till types 1 and 2 are characterized by elevated concentrations of UGG clasts. Till type 1 is separated from till type 2 based on a higher UGG content and/or lower granitoid content (Figure GS2018-13-4). Till types 3, 4 and 5 are characterized by high concentrations of HBB clasts. Till type 5 is distinguished from till types 3 and 4 based on its lower UGG content and higher granitoid content (Figure GS2018-13-4). Till type 3 is distinguished from till types 4 and 5 based on its higher UGG content (Figure GS2018-13-4). Till type 6 is characterized by average UGG and high granitoid concentrations. Till type 7 is unique and contains high UGG and granitoid concentrations and is only documented at two surficial sites (Figure GS2018-13-5).

Surficial till types

The surficial tills within the Hayes and Kaskattama flowsets are compositionally distinct from each other. The surficial till in the Kaskattama flowset contains till types 1 and 2 whereas the Hayes flowset contains till types 3 and 6 (Figure GS2018-13-5). One sample from each flowset belongs to till type 7, which has elevated UGG and granitoid concentrations, unique to the entire dataset (Figure GS2018-13-5b). The contrast in clast-lithology composition of these flowsets suggests a different till provenance for each flowset, as would be expected as these landscapes contain streamlined landforms suggestive of near perpendicular ice flow.

The Kaskattama flowset is characterized by a higher concentration of UGG clasts in the surficial till. The interpreted source of these clasts is the Belcher Group, with the nearest known exposures a minimum of 650 km to the east in the Belcher Islands, or the Sutton inlier, located 400 km to the southeast. Based on this observation, the Kaskattama flowset has been assigned a northwest trend. This interpretation is further supported by the presence of oolitic jasper clasts in four samples, and higher concentrations of oolitic jasper in till types 1 and 2 (Table GS2018-13-1), the source of which is to the east and/or southeast. Four out of the five surficial till samples that are north of the Kaskattama flowset are classified as till type 2 and two contain oolitic jasper clasts (Figure GS2018-13-6), which would suggest correlation with the same ice-flow event that deposited the surficial till associated with the Kaskattama flowset.

The southwest-trending (204–207°) Hayes flowset has relatively high concentrations (19.7–28.7 ct. %) of granitoid clasts in till type 6 samples. The closest known source of granitoid bedrock is to the southwest or northwest. The presence of Dubawnt erratics in three till samples from the Hayes flowset suggest an initial provenance to the northwest. The transport of these clasts into the study area does not correspond with the trend of the Hayes flowset (southwest) and could represent a palimpsest dispersal pattern or a region with a higher

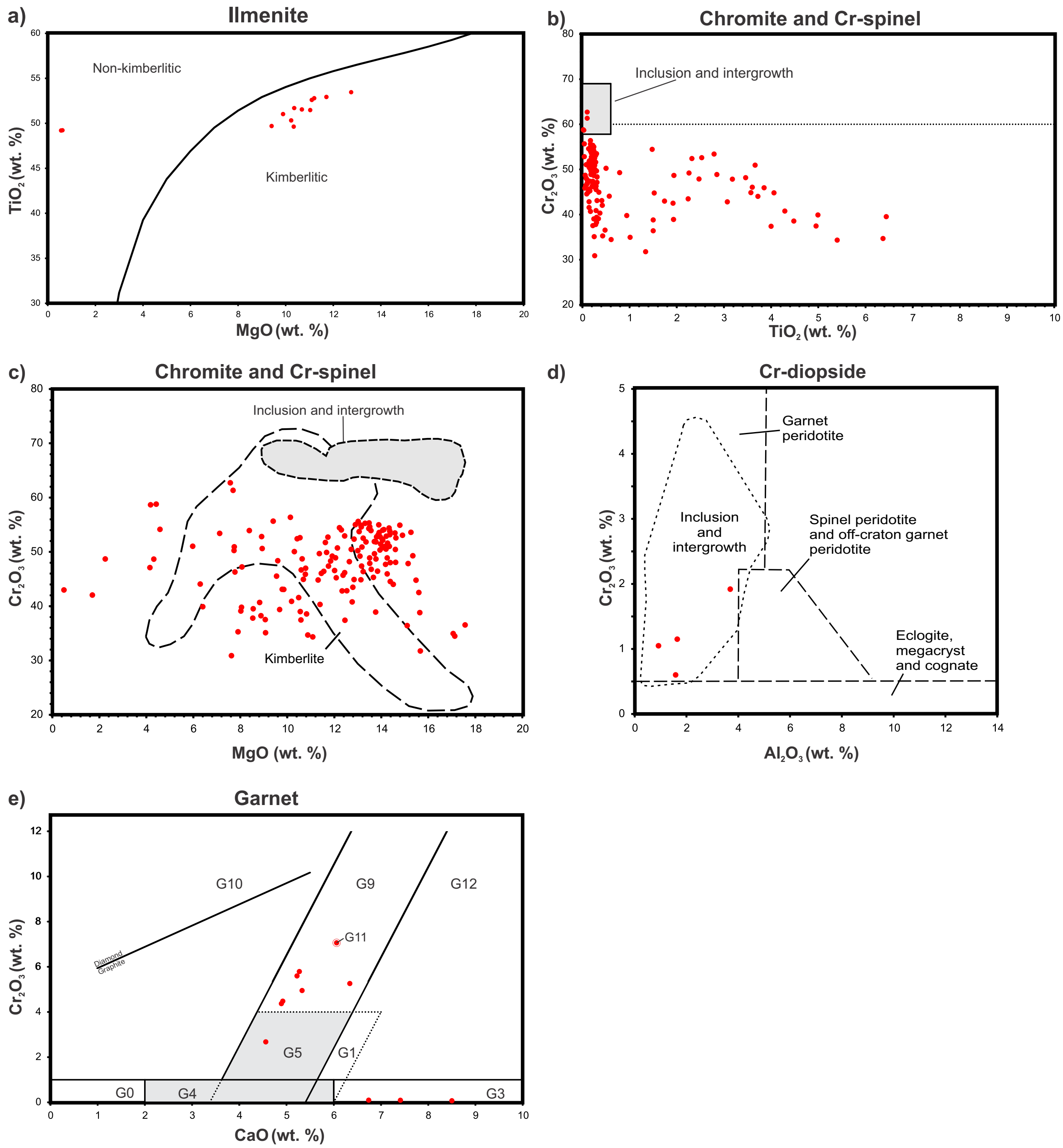

Figure GS2018-13-3: *Bivariate plots of compositional data for kimberlite-indicator minerals:* ***a)*** *TiO_2 versus MgO discriminate for ilmenite grains; compositional field for kimberlite after Wyatt et al. (2004);* ***b)*** *Cr_2O_3 versus TiO_2 for chromite and Cr-spinel grains; diamond inclusion and intergrowth field modified after Fipke et al. (1995); a dashed line representing 60 wt. % Cr_2O_3 is shown for visual reference;* ***c)*** *Cr_2O_3 versus MgO for chromite and Cr-spinel grains; compositional field for diamond inclusion and intergrowth after Fipke et al. (1995); compositional field for kimberlite from Nowicki et al. (2007);* ***d)*** *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);* ***e)*** *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 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; a G11 garnet classified from this study is highlighted.*

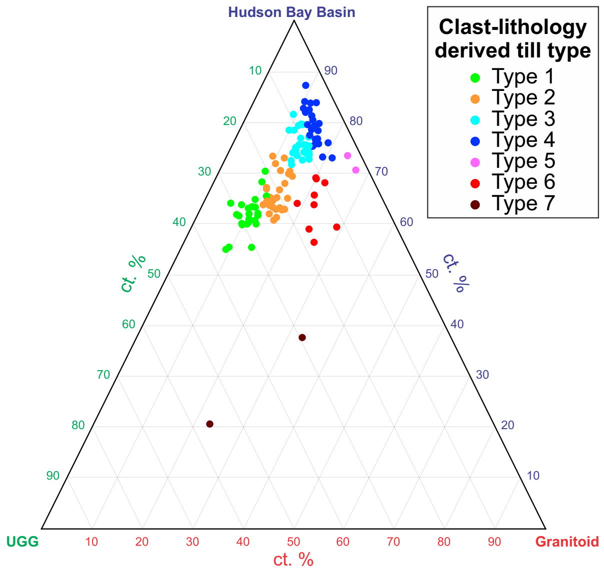

Figure GS2018-13-4: *Till types, derived from k-means cluster analysis, displayed on a ternary diagram. Abbreviation: UGG, undifferentiated greenstone and greywacke.*

compositional inheritance from a previous ice-flow event (e.g., Trommelen et al., 2013). Three till type 3 samples were sampled in the Hayes flowset northeast of Shamattawa and one was sampled near Yakaw Lake (Figure GS2018-13-5), and these samples all have elevated pink carbonate clast concentrations (>95th percentile), which suggests a central Hudson Bay provenance input (Figure GS2018-13-2). This observation would suggest at least some northeast-derived detritus was deposited in the Hayes flowset (by southwest-trending ice flow).

Stratigraphic ice-flow data and till type

Combining ice-flow data and corresponding till composition provides insight into sediment provenance. Clast-fabric data along with paleo–ice-flow directions from in situ, lodged and striated clasts are presented in Figure GS2018-13-7, separated according to the till type assigned to the interval where the ice-flow observation was recorded.

The majority (n=5 of 9) of ice-flow data associated with till types 1 and 2 indicate deposition by northwest-southeast–oriented ice flow. This is in agreement with the surficial till of the Kaskattama flowset (northwest-trending landforms) and suggests an eastern provenance. This interpretation is supported by the provenance of UGG clasts, which is interpreted to be from the Belcher Group located in eastern Hudson Bay or the Sutton inlier in northern Ontario, as discussed above. Particularly strong northwest-trending fabrics were observed within till types 1 and 2 along the Echoing River and its tributaries, east of Shamattawa. Three south- to southwest-trending ice-flow indicators are present in till types 1 and 2, which could be as a result of inheritance of this till type composition after a switch in ice-flow direction. Nearly all (n=8 of 9) of the ice-flow data obtained for till type 3 samples indicates deposition by south- or southwest-trending ice flow. All ice-flow data obtained from till type 4 samples indicate deposition by southwest- or south-trending ice flow, which is in agreement with the composition of this till type, high HBB clast concentrations and low UGG concentrations. Till type 6 ice-flow data yielded two strong indicators of south-trending ice flow and one scattered fabric indicating an east-west trend.

Distinctive erratic trends

Oolitic jasper clasts observed within till samples have a strong correlation to till types 1 and 2. This reinforces an eastern provenance for these till types (Table GS2018-13-1; Figure GS2018-13-6). Outside of the Kaskattama flowset and sections near the Echoing River, only one oolitic jasper clast was observed in a sample from 5 km west of the Hayes–Kaskattama flowsets boundary (Figure GS2018-13-6). Oolitic jasper clasts have been observed as far west as Southern Indian Lake (Hodder, 2018a) and as far south as Morden in Manitoba to date.

Shell fragments observed in till were sourced from marine sediments that were overridden by ice-sheet advances and integrated into the subglacial sediments. The extent of marine sediments deposited by earlier nonglacial seas (e.g., Bell Sea) is likely similar to the current distribution of marine sediments in northeastern Manitoba (Matile and Keller, 2007), the largest source of which was Hudson Bay. Therefore shell fragments in till in the Kaskattama highland area were sourced from the northwest through to the southeast, with the largest source to the northeast (Hudson Bay). Shell fragments observed in till-clast–lithology counts are strongly correlated to till types 3 and 4 (Table GS2018-13-1; Figure GS2018-13-6), which are distinguished by their elevated HBB clast count. This observation reinforces a local to Hudson Bay Basin provenance for these till types.

The distribution of Dubawnt erratics in the study area is more variable and likely a reflection of multiple episodes of deposition and re-entrainment by the LIS and earlier ice sheets. There is a slight correlation of Dubawnt erratics with till types 6 and 7. These types only represent 9.5% of till samples collected but account for three of the nine Dubawnt erratics observed. Till samples from the Hayes flowset recovered three of the nine Dubawnt erratics. The presence of Dubawnt erratics in till samples from the Kaskattama flowset and from sections to the

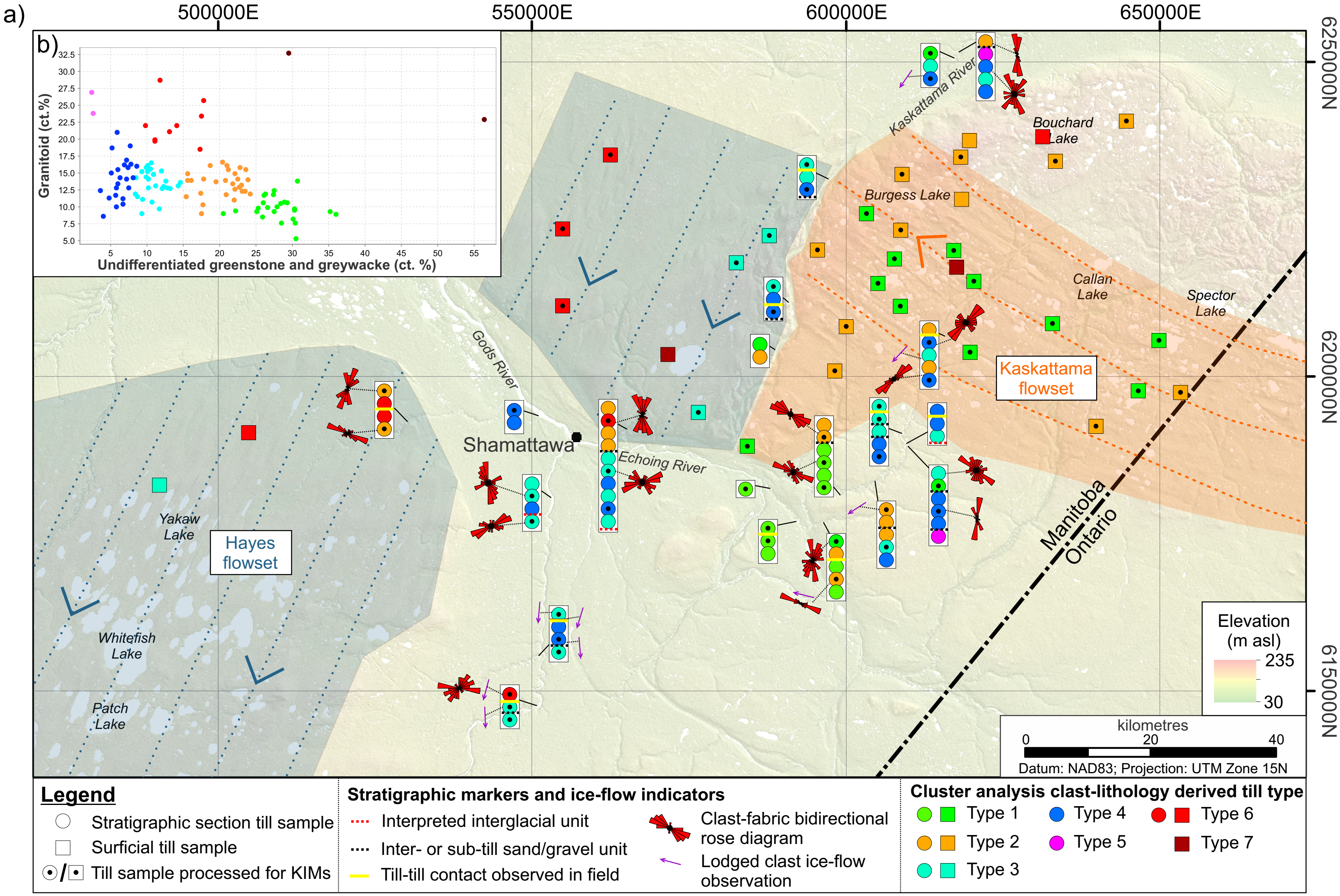

Figure GS2018-13-5: *Till types derived from k-means cluster analysis:* ***a)*** *till samples classified by till type; stratigraphic section till samples are displayed as stacked symbols; ice-flow data obtained at sections is displayed where measured as bidirectional rose diagrams or as the azimuth of the lodged clast; background hillshade image of the Kaskattama highland area was generated using Canadian Digital Surface Model (Natural Resources Canada, 2015);* ***b)*** *bivariate plot of granitoid versus undifferentiated greenstone and greywacke concentrations in till samples, classified according to designated till type. Abbreviation: KIM, kimberlite-indicator mineral.*

Table GS2018-13-1: Count of till samples containing distinct erratics. Samples were assigned to clast-lithology composition-derived till types, Kaskattama highland area.

Till type	Percentage of sample population	Oolitic jasper erratic	Shell fragment	Dubawnt Supergroup erratic
Type 1	21.6	7	2	2
Type 2	24.1	4	1	1
Type 3	23.3	1	9	3
Type 4	19.8	0	10	0
Type 5	1.7	0	0	0
Type 6	7.8	0	0	2
Type 7	1.7	0	0	1
Total		12	22	9

north and south indicate that these clasts have undergone multiple ice-flow transport events.

Omars were observed at the base of every section that was logged at an active rivercut/streamcut (Figure GS2018-13-6). Since the defining characteristics of Omars (greywacke with hemispherical calcareous concretions) are only obvious in the large pebble– to boulder-size range, identification in clast-lithology counts is inhibited by clast size, and thus they are not reported in clast-lithology counts. The pervasive presence of Omars at the described sections suggests a strong influence of the lithology of the source bedrock on the UGG content of till in the study area. Boulder-size Omars observed in the field can reach impressive sizes (Figure GS2018-13-8a, b), considering the nearest mapped source is 650 km to the east of this study area.

Kimberlite-indicator mineral results

A total of 181 KIM grains were recovered during this study. The visual identification, chemistry and total grain counts are presented in Data Repository Item DRI2018001[2] accompanying this report (Hodder, 2018b). The majority of the KIMs recovered are chromite and Cr-spinel grains (86%; n=155). Of these grains 58% (n=90 of 155) are considered Cr-spinel (>45 wt. % Cr_2O_3; >10 wt. % MgO) and 42% (n=65 of 155) are considered chromite (>30 wt. % Cr_2O_3). Chromite and Cr-spinel are collectively grouped as Cr-spinel herein and in DRI2018001, in accordance with the terminology established in the MGS KIM database (Keller et al., 2004). Four of these Cr-spinel grains are considered to fall within the diamond inclusion and intergrowth compositional field based on their elevated Cr_2O_3 (>58 wt. %) and low TiO_2 (<0.4 wt. %) contents. Eleven Mg-ilmenite grains were recovered. Four Cr-diopside grains were recovered, and all four plot within the diamond inclusion and intergrowth field defined by Nimis (2002; Figure GS2018-13-3d). Eleven garnet KIMs were recovered: seven G9-garnets, three G3-garnets and one G11-garnet. The spatial distribution of total KIM counts per sample (Figure GS2018-13-9) does not appear to show a well-defined dispersal pattern, which was not the goal of this reconnaissance-scale survey.

Kimberlite-indicator–mineral provenance trends

The relationship between KIM recovery and clast-lithology composition-derived till types is presented in Table GS2018-13-2. The average KIM recovery per sample in the dataset is 2.8 KIMs. The highest average KIM recovery was from till type 2 at 3.6 KIMs. Till types 1, 3 and 6 have a similar average KIM recovery. Till type 4 stands out because of the relatively low average KIM recovery (1.0 KIMs) associated with this till composition.

Only four samples of till type 6 were sampled for KIM analysis during this survey. These four samples (6.3% of sample population) contained four of the seven G9-garnets recovered, highlighted by three G9-garnets recovered at a surficial till sample site within the Hayes flowset (Figure GS2018-13-10). This is a relatively small dataset to confidently infer associations, but would preliminarily indicate either a correlation between till type 6 or the Hayes flowset with G9-garnet recovery. The three other G9-garnets were all recovered from surficial till samples in the Kaskattama flowset.

The recovery of Cr-diopside is spatially correlated, with three of the four Cr-diopside grains recovered in the southwestern region of the Kaskattama highland (Figure GS2018-13-10). Two of these samples correspond to till type 3, with one sample having a corresponding strong southwest-trending ice flow indicated, and one sample corresponds to till type 2 and is part of the Kaskattama

[2] MGS Data Repository Item DRI2018001 containing the data or other information sources used to compile this report is available online to download free of charge at https://www.gov.mb.ca/iem/info/library/downloads/index.html, or on request from minesinfo@gov.mb.ca, or by contacting the Resource Centre, Manitoba Growth, Enterprise and Trade, 360–1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada.

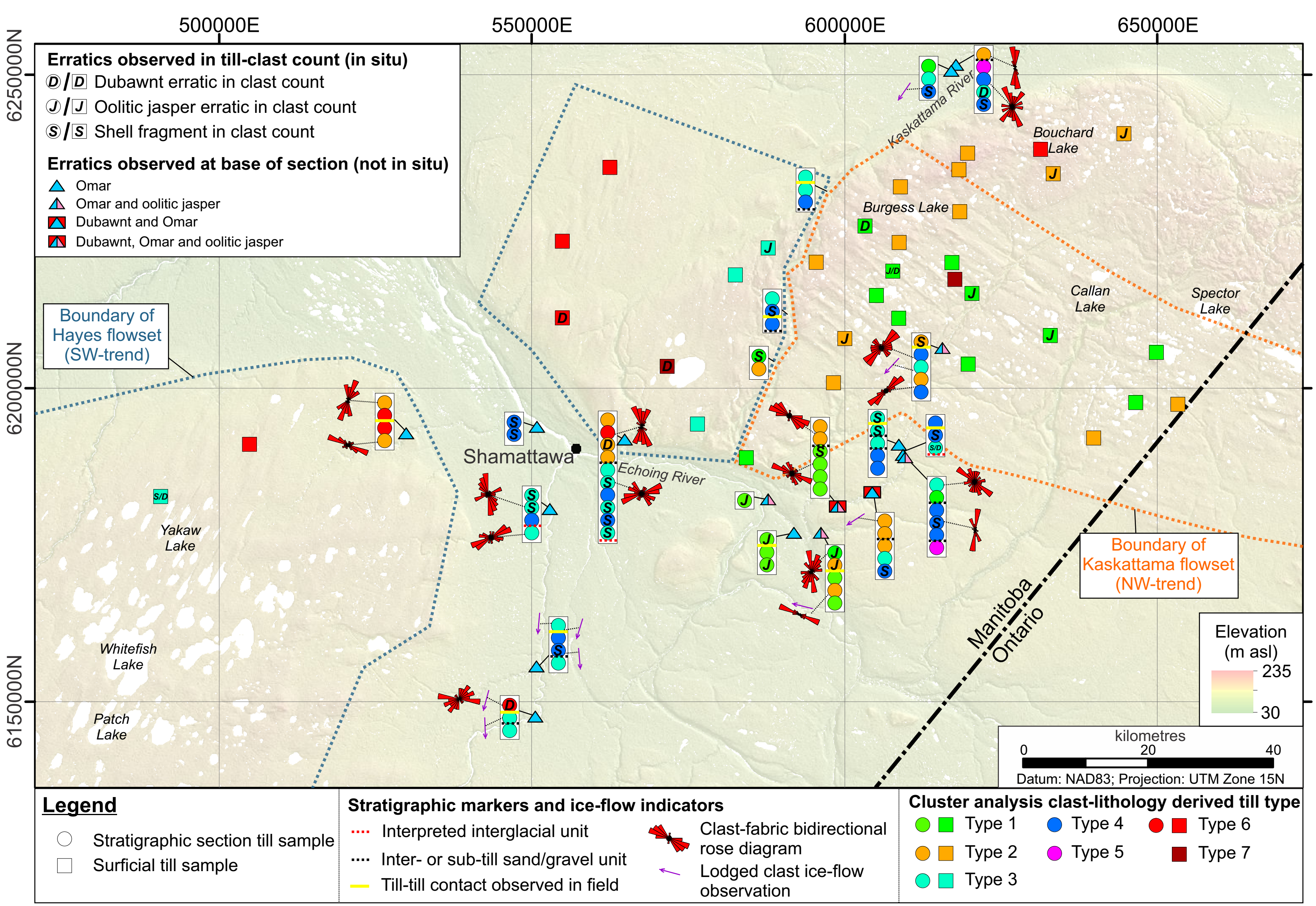

Figure GS2018-13-6: *Locations of exotic erratics observed during clast-lithology counts from till samples and in the field at the base of sections described in the Kaskattama highland area. Background hillshade image was generated using Canadian Digital Surface Model (Natural Resources Canada, 2015). Abbreviations: Dubawnt, Dubawnt Supergroup; NW, northwest; Omar, Omarolluk Formation erratic; SW, southwest.*

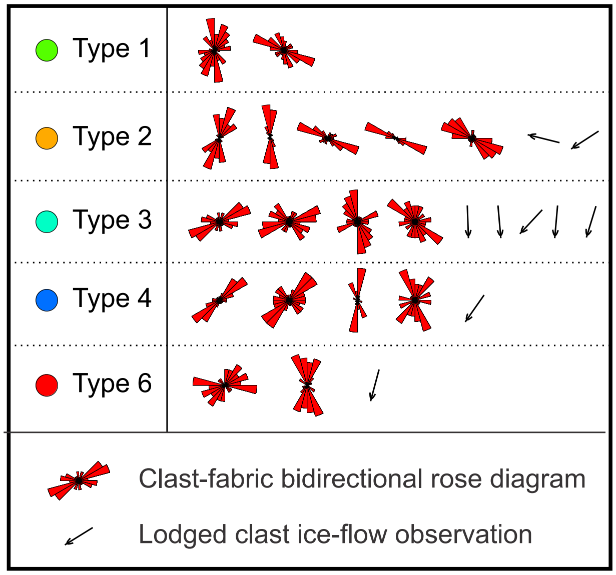

Figure GS2018-13-7: *Summary of ice-flow data associated with stratigraphic section till samples in the Kaskattama highland area. No ice-flow data was obtained for till type 5 or 7 samples.*

flowset (northwest-trending). Therefore, there appears to be a spatial correlation, but not a till composition correlation with Cr-diopside grains recovered in this area (Figure GS2018-13-10).

A cluster of samples located east of the Echoing River recovered the majority (n=6 of 11) of Mg-ilmenite grains during this study (Figure GS2018-13-10). These samples all have similar till composition and ice-flow indicators suggesting that the source of these KIMs is to the southeast and/or east.

Interestingly, KIM recovery from the Kaskattama and Hayes flowsets (Figure GS2018-13-9), and associated till types (Hayes flowset, till types 3 and 6; Kaskattama flowset, till types 1 and 2), have similar average KIM recovery. Given the compositional contrast of till associated with each streamlined-landform flowset, the simplest interpretation is that there are multiple sources for the KIMs recovered from each flowset, which is likely the case for the entire dataset. For example, the highest returns of 15 KIMs (11 km south of Shamattawa on Gods River) and 17 KIMs (15 km south of Spector Lake near the Ontario–Manitoba border) are on opposite sides of the study area, have near perpendicular ice-flow directions indicated and have a different till type. This highlights the prospectivity of the region for diamond exploration but also the need to collect additional data to define dispersal patterns.

Northeastern Manitoba regional KIM distribution

This study expanded on a regional KIM survey conducted in 2001 and 2002 by the MGS that sampled accessible Quaternary sections along the Nelson, Angling, Pennycutaway, Fox, Hayes, Yakaw and Gods rivers (Nielsen and Fedikow, 2002; Hodder et al., 2017), and these datasets are plotted in Figure GS2018-13-11, along with data from the MGS KIM database (Keller et al., 2004). Regionally, till samples from the Kaskattama highland area recovered the highest KIM counts, and also the highest proportion of samples that recovered KIMs.

The junction of the Hayes and Gods rivers has previously been highlighted as a region to conduct follow-up work based on previous work at section 15 (Figure GS2018-13-11; Syme et al., 2004; Hodder et al., 2017). Till sampled (n=7) from 16 to 28 m below ground surface at section 15, below a suspected intertill interglacial unit, had corresponding clast fabrics (n=2) indicating northwest-southeast–oriented ice flow (Hodder et al., 2017). The UGG (16.9–24.5 wt. %) and granitoid contents (7.4–12.4 wt. %) from this till interval would correspond to a till type 1 or 2 classification within this study (cf. Figure GS2018-13-5b). The KIM recovery from this interval ranged from 2 to 11 KIMs. These observations, based on results in this report, would indicate a likely east to southeast provenance for the till interval sampled at section 15. Deposition of this till could be related to one of the northwest-trending ice-flow events observed during this study in the Kaskattama highland or a previous west- to northwest-trending ice-flow event, since this ice-flow direction occurred multiple times in northeastern Manitoba, and has been mapped as far west as Lynn Lake in Manitoba (Gauthier and Hodder, 2017) and into Saskatchewan (Schreiner, 1984).

Conclusion

Kimberlite-indicator minerals were recovered from glacial sediments (till) in the Kaskattama highland area. Till composition, stratigraphic observations and ice-flow data obtained during this study has provided additional insight into KIM provenance to assist further drift exploration efforts in this remote region of Manitoba. Preliminary conclusions regarding till and KIM provenance include

- the sharp contact between the Kaskattama and Hayes flowsets is reflected in the contrasting till composition of each landscape, the Kaskattama flowset is interpreted to be northwest-trending and the Hayes flowset is southwest-trending;
- till type 1 (highest UGG content) is restricted to the Kaskattama highland (including section samples);
- oolitic jasper clast recovery in till is strongly correlated to till type 1 and 2 (elevated UGG content) and supports a southeast to east provenance indicated

Figure GS2018-13-8: *Examples of distinctive erratics observed at the base of stratigraphic sections in the Kaskattama highland area:* ***a)*** *boulder-size Omarolluk Formation erratic (Omar) at section 112-17-519, rock hammer for scale is 43 cm in length;* ***b)*** *boulder-size Omar at section 112-16-402, co-author for scale is 177 cm in height;* ***c)*** *oolitic jasper cobble at section 112-16-412, cobble shown is 19 cm long;* ***d)*** *Dubawnt Supergroup erratic at section 112-16-430, pebble shown is 5 cm in diameter. See Figure GS2018-13-1 for section locations.*

by the Kaskattama flowset and the majority of stratigraphic ice-flow data for these till types;

- samples with a strong Hudson Bay Basin and weak UGG provenance signature have the lowest average KIM recovery; and
- the recovery of KIM grains from different till compositions, flowsets and stratigraphic units indicates the potential for multiple KIM sources in the region.

Economic considerations

The Kaskattama highland region of northeastern Manitoba is a remote and largely unexplored frontier area of northern Manitoba. Till sampled in this region yielded above average KIMs and has elucidated the diamond potential of the region. Till-composition data coupled with ice-flow data has provided insight into potential dispersal patterns in the Kaskattama highland area. Till provenance data indicate that there are likely multiple sources for the recovered KIMs, requiring additional investigations to clarify local-scale dispersal patterns.

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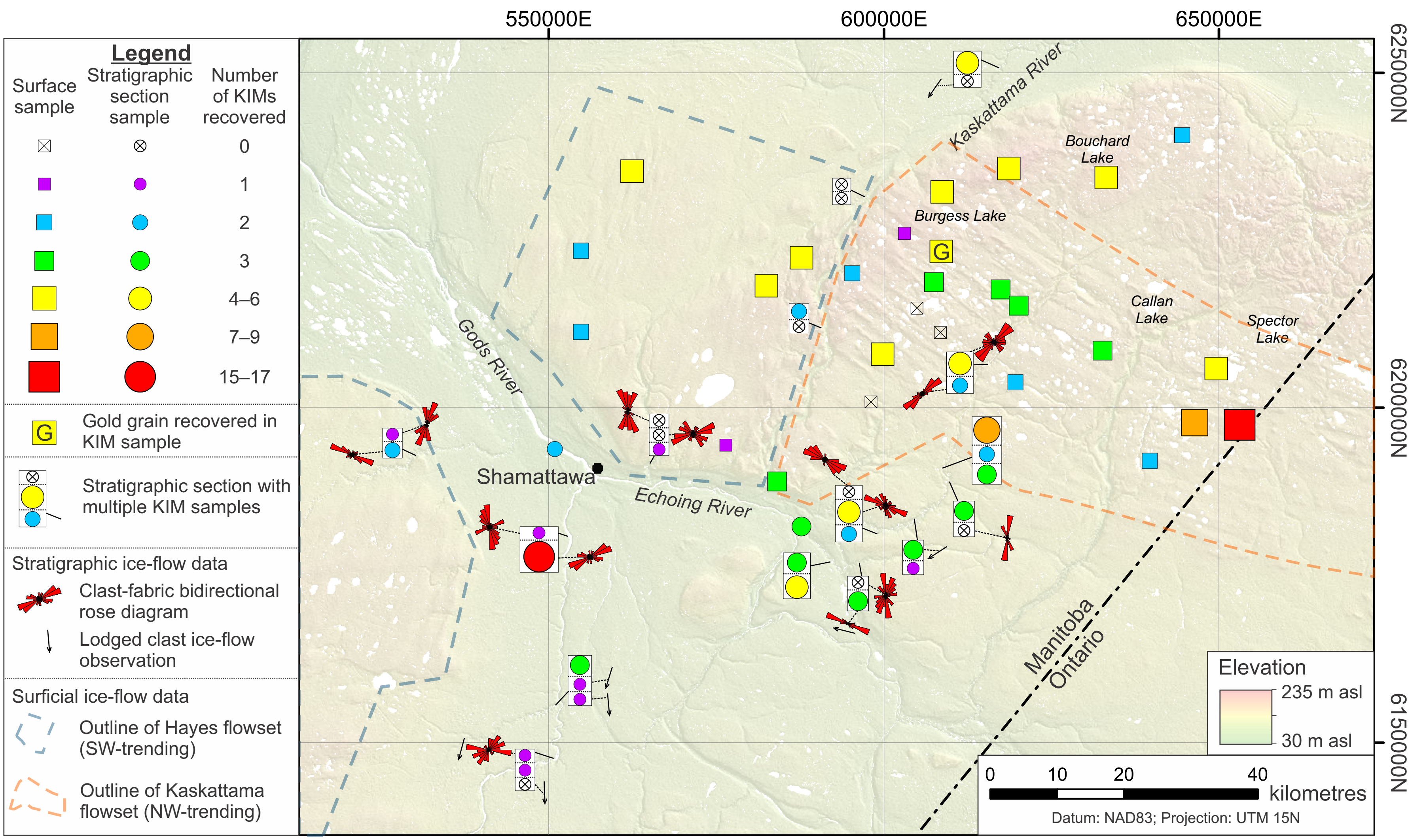

***Figure GS2018-13-9:** Kimberlite-indicator mineral (KIM) results displayed as proportional-sized symbols, Kaskattama highland area. Background hillshade image was generated using Canadian Digital Surface Model (Natural Resources Canada, 2015). Abbreviations: NW, northwest; SW, southwest.*

Table GS2018-13-2: Kimberlite-indicator mineral (KIM) recovery according to clast-lithology composition-derived till type, Kaskattama highland area.

Till type	No. of samples	Cr-diopside	Cr-spinel	DI Cr-spinel	Mg-ilmenite	G3-garnet	G9-garnet	G11-garnet	Total KIM	Average KIM recovery
Type 1	19	0	44	1	5	1	2	1	54	2.8
Type 2	16	1	52	1	3	0	1	0	58	3.6
Type 3	16	2	42	2	2	1	0	0	49	3.1
Type 4	9	0	8	0	0	1	0	0	9	1.0
Type 6	4	1	5	0	1	0	4	0	11	2.8
Total	64	4	151	4	11	3	7	1	181	2.8

Abbreviation: DI, diamond inclusion

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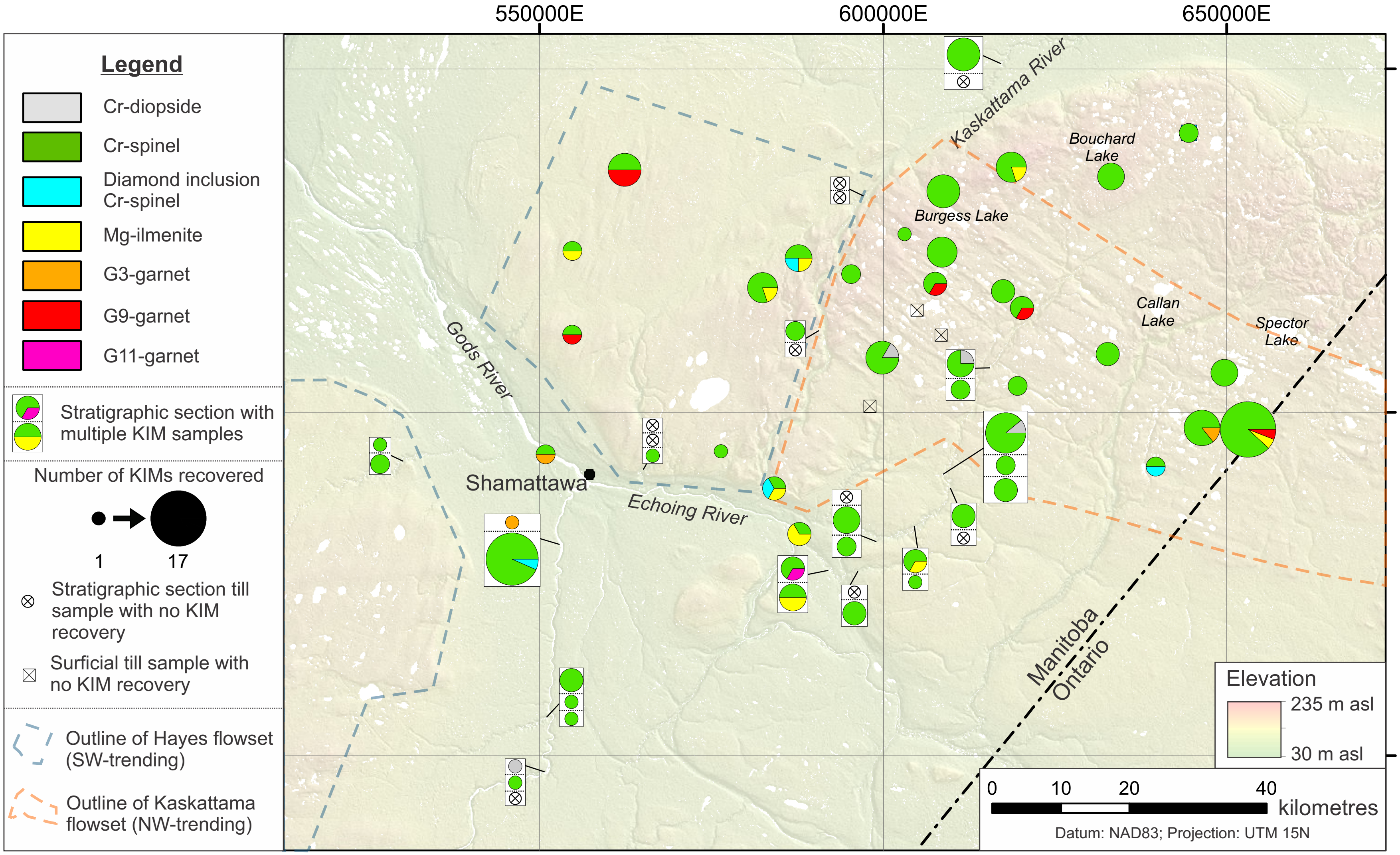

Figure GS2018-13-10: *Kimberlite-indicator mineral (KIM) results displayed as proportional-sized compositional pie charts, Kaskattama highland area. Background hillshade image was generated using Canadian Digital Surface Model (Natural Resources Canada, 2015). Abbreviations: NW, northwest; SW, southwest.*

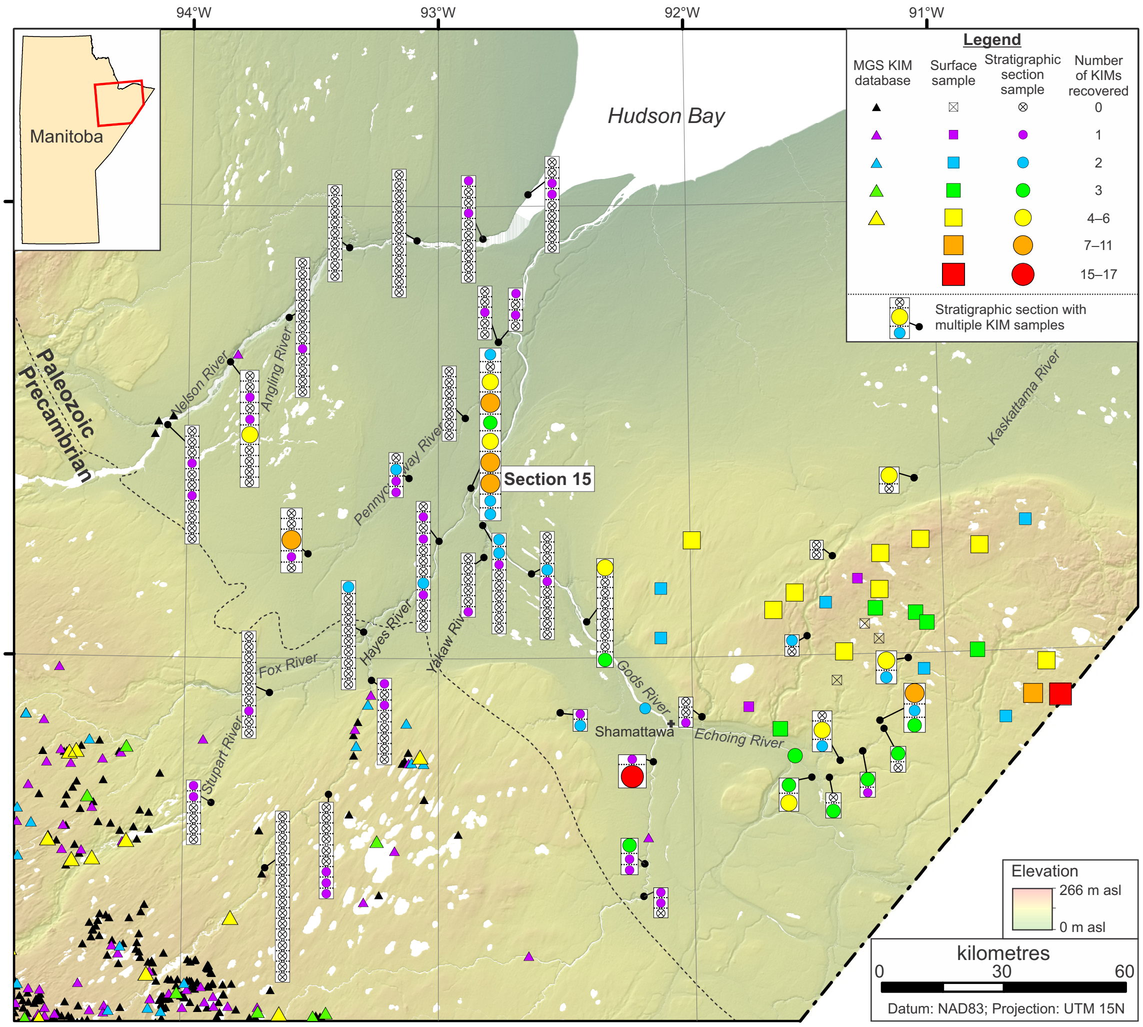

Figure GS2018-13-11: *Kimberlite-indicator mineral (KIM) results for MGS surveys conducted in northeastern Manitoba (this study; Nielsen and Fedikow, 2002; Hodder et al., 2017) and results from the MGS KIM database (Keller et al., 2004). Note, data from the KIM database is not separated into stratigraphic and surficial samples or separated by material sampled (e.g., beach versus till). Where multiple samples are present at the same location, the highest KIM count is shown. Background hillshade image was generated using Canadian Digital Surface Model (Natural Resources Canada, 2015).*

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