GS2021-9

Kimberlite-indicator-mineral results from till sampled in the Machichi–Kettle rivers area, far northeastern Manitoba (parts of NTS 54A–C)

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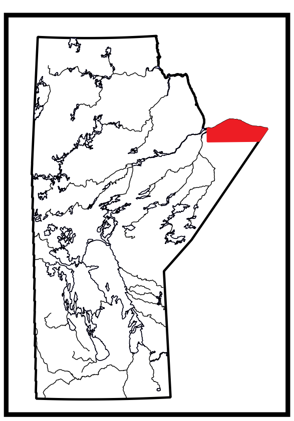
In Brief:

- Results of a kimberlite-indicator-mineral survey in far northeastern Manitoba
- Highest KIM yields deposited by till interpreted to be deposited by NW-trending ice-flow

Citation:
Hodder, T.J. and Gauthier, M.S. 2021: Kimberlite-indicator-mineral results from till sampled in the Machichi–Kettle rivers area, far northeastern Manitoba (parts of NTS 54A–C); *in* Report of Activities 2021, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 77–83.



Summary

This report presents the results of a kimberlite-indicator-mineral (KIM) survey in a remote region of northeastern Manitoba. Natural exposures along waterways in the region were used to describe the stratigraphy of Quaternary sediments and sample till for KIM analysis. Stratigraphic observations, including paleo–ice-flow data, allowed for an interpretation of the provenance of KIM minerals recovered from the till. The highest KIM recovery was from the southern extent of the survey on the Kaskattama River. At sites investigated in this region, the upper till had the highest proportion of KIMs and is interpreted to have been deposited by northwest-trending ice flow, indicating a possible source to the southeast. This interpretation is being tested using additional till-provenance parameters.

Introduction

The Manitoba Geological Survey (MGS) conducted Quaternary geology fieldwork in the Machichi–Kettle rivers area of far northeastern Manitoba during the summer of 2019 (Hodder and Gauthier, 2019; Figure GS2021-9-1). This remote region of northeastern Manitoba is covered by thick Quaternary sediments with numerous till units. Kimberlite-indicator-mineral (KIM) counts from till samples by Hodder and Gauthier (2021a[1]) provide the first public assessment of the region's diamond potential. These results are being released before the comprehensive data report, to provide the mineral exploration industry timely updates on new geological knowledge.

These results build on an aeromagnetic survey in the Kaskattama–Kettle rivers region of this study area (Assessment File 93361, Manitoba Agriculture and Resource Development, Winnipeg) and a 2002 alluvial and beach KIM sampling program along the Kaskattama River (Assessment File 74009). Regionally, KIM sampling has taken place along the Nelson, Pennycutaway, Hayes and Gods rivers to the west and south of this study area (Nielsen and Fedikow, 2002; Hodder et al., 2017) and the Kaskattama highland area to the south of this study area (Hodder and Kelley, 2018).

Methods

Field collection

The MGS collected a total of 63 subsurface samples from sections exposed along the Kettle, Mistikokan, Machichi and Kaskattama rivers. Each sample was 11.4 L and weighed between 13.9 and 19.6 kg. Till geochemistry samples were also taken and analytical results were released within Hodder and Gauthier (2021b).

Kimberlite-indicator-mineral processing and classification

The KIM till samples were submitted to the De Beers Group of Companies (De Beers; Sudbury, Ontario) 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. 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. Sus-

[1] MGS Data Repository Item DRI2021018, 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 Agriculture and Resource Development, 360–1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada.

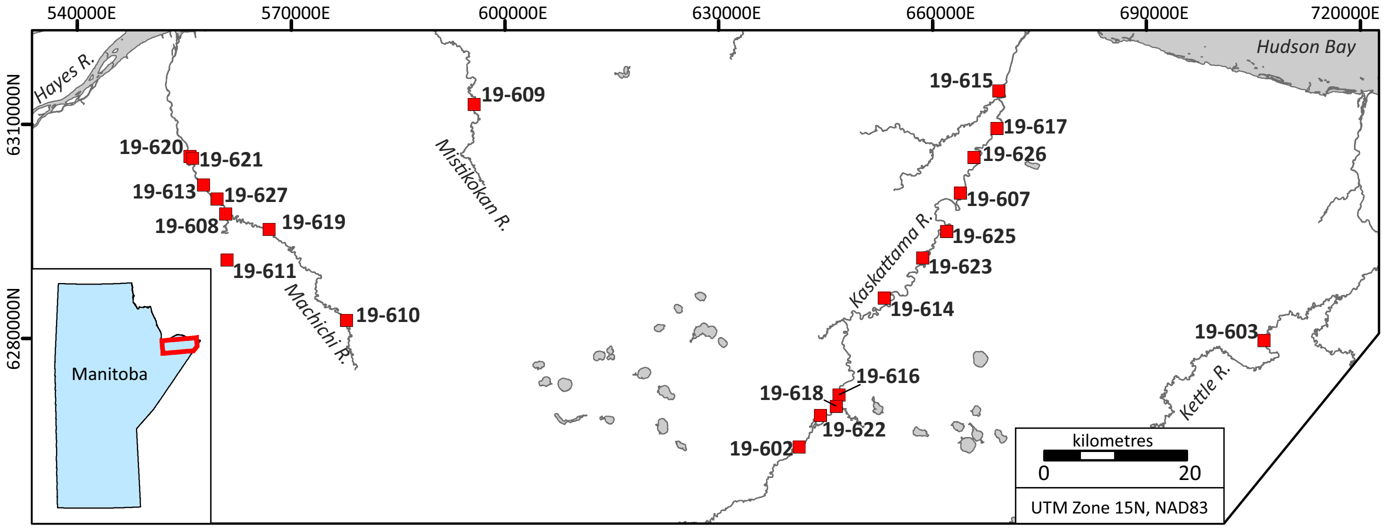


***Figure GS2021-9-1:** Location of sections sampled in 2019 for kimberlite-indicator-mineral counts in Machichi–Kettle rivers study area, far north-eastern Manitoba. Section labels have been abbreviated (e.g., 112-19-602 to 19-602) relative to those found in the accompanying data repository item (DRI2021018; Hodder and Gauthier, 2021a).*

pected KIM grains were then visually selected, and analyzed by electron microprobe. The resultant KIM grains were initially classified using electron microprobe results, following the methodology outlined by Thorleifson et al. (1994). The visually identified Mg-ilmenite grains were confirmed using the compositional field defined by Wyatt et al. (2004; Figure GS2021-9-2a). Garnet grains were classified according to the method outlined by Grütter et al. (2004; Figure GS2021-9-2b). The Cr-spinel grains identified were plotted on modified discriminate diagrams to verify whether any grains were within the diamond inclusion and intergrowth fields (Figure GS2021-9-2c, d). The Cr-diopside grains were confirmed using the Cr_2O_3 versus Al_2O_3 plot defined by Nimis (2002; Figure GS2021-9-2e).

Results

Kimberlite-indicator-mineral recovery

A total of 107 KIM grains were recovered, averaging 1.1 KIM recovered per 10 kg of till processed. The visual identification, chemistry and total grain counts are presented in Hodder and Gauthier (2021a).

The majority of the KIMs recovered are chromite and Cr-spinel grains (77%; n=82). Of these grains 57% (n=47 of 82) are Cr-spinel (>45 wt. % Cr_2O_3; >10 wt. % MgO) and 43% (n=35 of 82) are chromite (>25 wt. % Cr_2O_3). Chromite and Cr-spinel were collectively grouped as Cr-spinel herein and in Hodder and Gauthier (2021a), in accordance with the terminology established in the MGS KIM database (Keller, 2019). None of these Cr-spinel grains fall within the diamond inclusion and intergrowth compositional fields (Figure GS2021-9-2c, d).

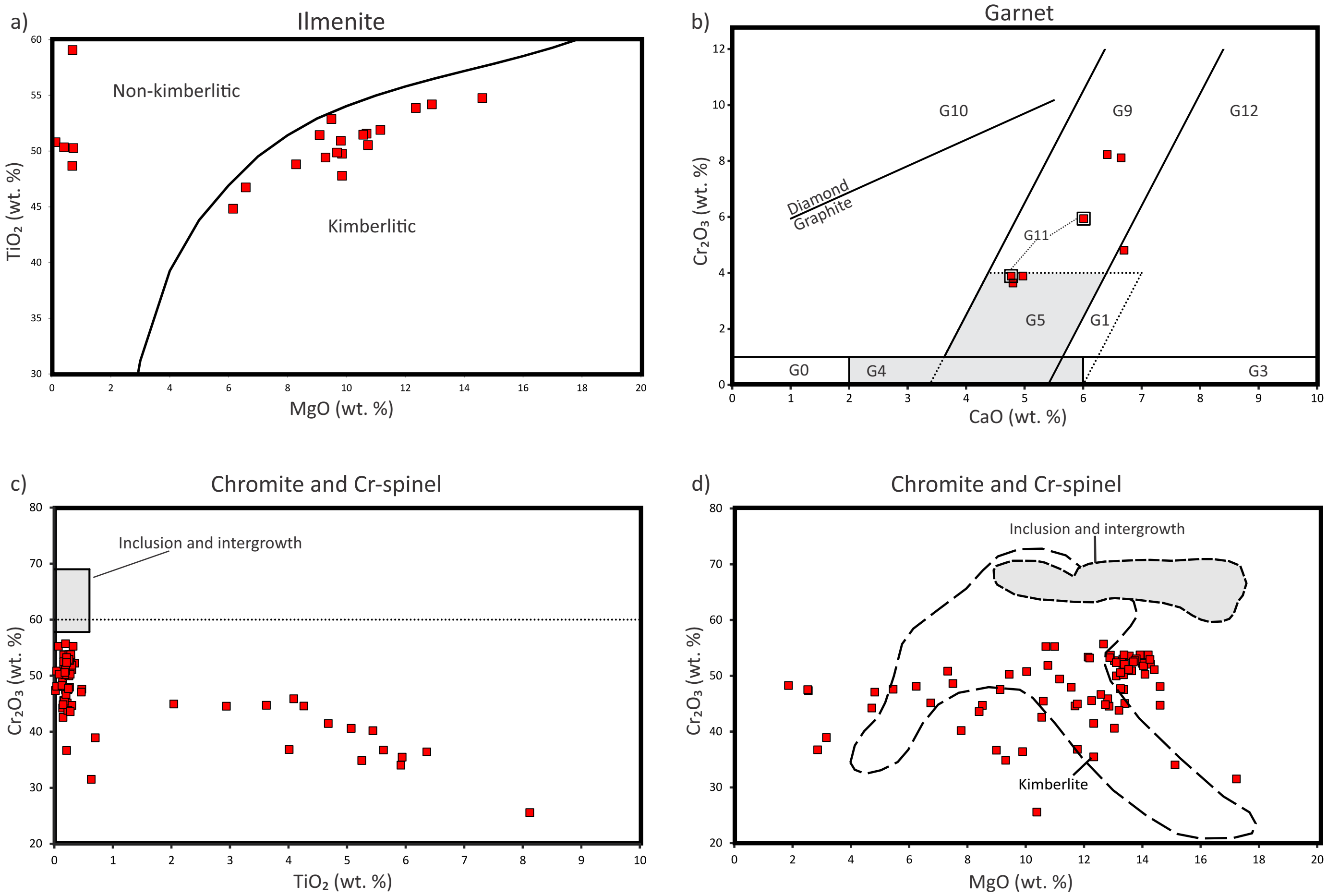
Other recovered KIMs include seventeen kimberlitic Mg-ilmenite grains, seven garnet grains and one Cr-diopside grain. The Cr-diopside composition is near the border of the diamond inclusion and intergrowth field defined by Nimis (2002; Figure GS2021-9-2e). Of the garnet KIMs, four are G9 garnets, two are G11 garnets and one is a G12 garnet.

Kimberlite-indicator-mineral trends

The KIM distribution is plotted spatially as pie charts scaled to the proportion of KIMs recovered per 10 kg of till processed (Figure GS2021-9-3). Overall, there is a higher concentration of KIMs within the eastern half of the study area (Table GS2021-9-1). The highest KIM recovery occurred along the southern extent of the survey on the Kaskattama River (Figure GS2021-9-3).

Link to till units

Figure GS2021-9-4a depicts the Quaternary stratigraphy exposed at the southern extent of the Kaskattama River (sections 19-602, 19-622 and 19-618; Figure GS2021-9-3). In this region, there are two tills documented in the subsurface, referred to as till-1 (lower) and till-2 (upper), herein. Till-2 either sharply overlies till-1 or is separated by intertill sand containing shell fragments. Till-1 is a dark greyish-brown (Munsell colour 10YR 4/2; Munsell Color–X-Rite, Incorporated, 2015) to brown (10YR 4/3) diamicton that has a silty sand to clayey sandy silt matrix. The till is compact with a blocky appearance and a massive structure (e.g., Figure GS2021-9-4b, c). Till-1 was deposited by ice flow ranging from south- to southwest-trending (183–243°). In contrast, till-2 is a brown (7.5YR 4/2; 7.5YR 4/3; 10YR 4/3) diamicton that has a sandy silt to sandy clayey silt matrix. Till-2 is less compact than the underlying till-1 at each section investigated. The till has a minor blocky appearance



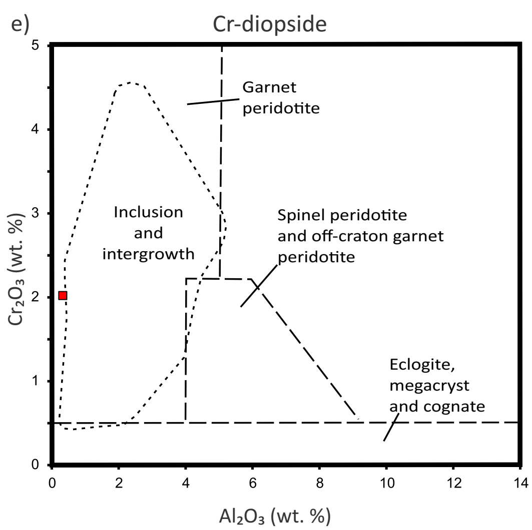


Figure GS2021-9-2: *Bivariate plots of compositional data for kimberlite-indicator minerals, Machichi–Kettle rivers study area:* ***a)*** *TiO_2 versus MgO discriminate for ilmenite grains; compositional field for kimberlite after Wyatt et al. (2004);* ***b)*** *Cr_2O_3 versus CaO for garnet grains; 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;* ***c)*** *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;* ***d)*** *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);* ***e)*** *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).*

and a massive or stratified structure (e.g., Figure GS2021-9-4c, d). Ice-flow data from all three sections indicate bidirectional northwest-southeast–oriented ice flow within till-2. At section 19-622, two clast fabrics were completed within till-2. The lower clast fabric has a strong northwest-southeast orientation (130–310°) whereas the upper fabric is bimodal but interpreted to have been deposited by a dominantly 170° ice-flow orientation. The change in till-fabric orientation up-unit could indicate that till-2 was later affected by a south-trending (170°) or southwest-trending (225°) ice flow.

Till-2 provided the two highest KIM recoveries in this survey (sections 19-602 and 19-622; Figures GS2021-9-3, -4a). Strong bidirectional northwest-southeast–oriented clast fabrics were measured at both of these sample locations (Figure GS2021-9-4a). Because a unidirectional up-ice source area is needed for drift exploration, the clast lithology of till-2 was first examined. The resultant unpublished data shows elevated undifferentiated greenstone and greywacke (UGG) concentrations relative to the entire dataset (Figure GS2021-9-5a). The largest source for UGG rocks in

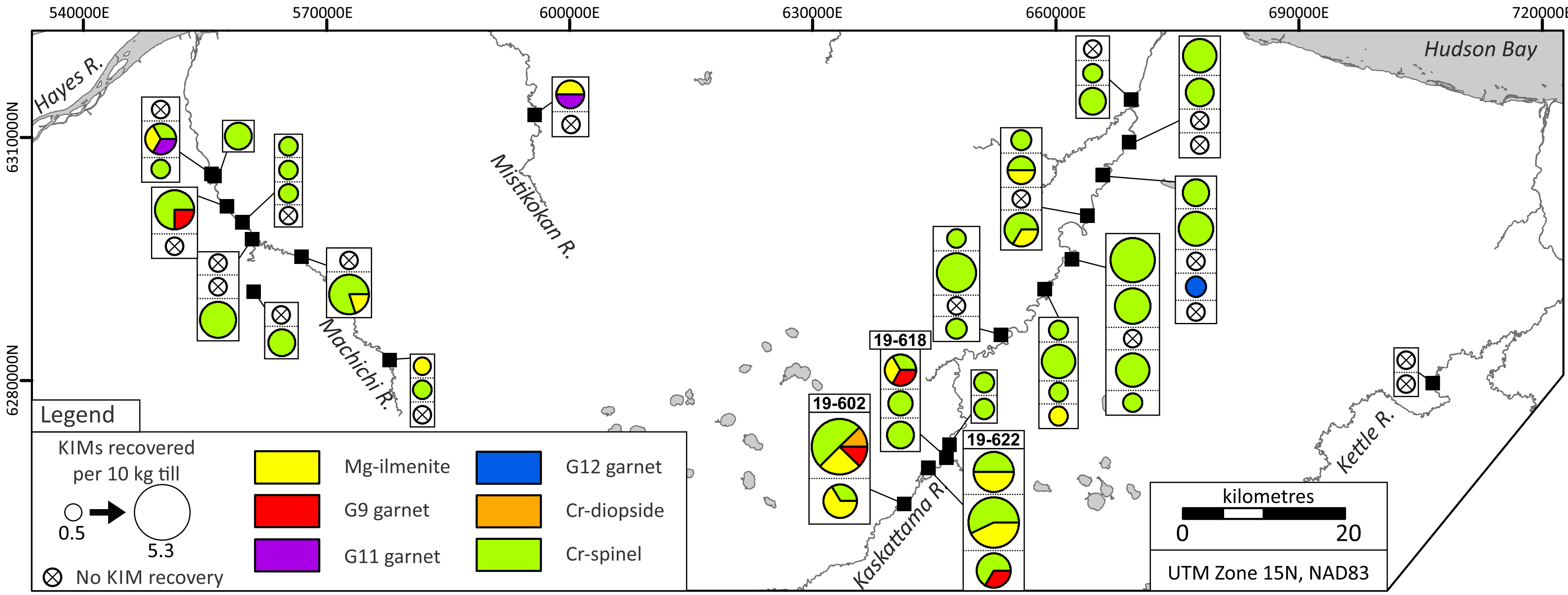


Figure GS2021-9-3: *Kimberlite-indicator-mineral (KIM) results displayed spatially as proportional-sized compositional pie charts, Machichi–Kettle rivers study area. Black squares refer to the site location and stacked boxes are multiple till samples at that site, arranged from top to bottom by increasing sample depth. Section labels have been abbreviated (e.g., 112-19-602 to 19-602) relative to those found in the accompanying data repository item (DRI2021018; Hodder and Gauthier, 2021a).*

Table GS2021-9-1: Kimberlite-indicator-mineral (KIM) data from sections in the western half (Machichi–Mistikokan rivers) and the eastern half (Kaskattama–Kettle rivers) of this study area. Abbreviations: Cr-diop, chrome diopside; Cr-sp, chrome spinel; G9, G9 garnet; G11, G11 garnet; G12, G12 garnet; KIM, kimberlite-indicator mineral; Mg-ilm, Mg-ilmenite.

Region	n	KIMs recovered	Recovery / 10 kg till	Cr-sp	Cr-diop	Mg-ilm	G9	G11	G12
Machichi–Mistikokan rivers	22	28	0.8	21	0	4	1	2	0
Kaskattama–Kettle rivers	41	79	1.2	61	1	13	3	0	1
Total	**63**	**107**	**1.1**	**82**	**1**	**17**	**4**	**2**	**1**

the region is the Circum-Superior belt (Figure GS2021-9-5b), which includes the Belcher Group and Sutton inlier to the east and southeast, and the Fox River belt to the south and southwest. There are also UGG rocks within the supracrustal greenstone belts in the surrounding Precambrian shield (Wheeler et al., 1996). Given the elevated UGG concentrations in till-2 and large source regions to the east and southeast, it is suspected that till-2 was deposited by northwest-trending ice flow.

This preliminary interpretation is being tested by determining the age of detrital hornblende within till using $^{40}Ar/^{39}Ar$ dating methods, and comparing these results with the unique metamorphic ages of geological provinces of the Precambrian shield (Figure GS2021-9-5b). The application of detrital hornblende $^{40}Ar/^{39}Ar$ age determination to assist with differentiating sediment provenance has proven to be a valuable tool in glacial sediment studies (Hemming and Hajdas, 2003; Roy et al., 2007, 2009).

Future work

The stratigraphic and till compositional data (clast-lithology and till-matrix geochemistry) from the Machichi–Kettle rivers area are currently being analyzed to assess till provenance, till stratigraphy and the ice-flow history for the region. Pending detrital hornblende $^{40}Ar/^{39}Ar$ age results from till samples will help resolve the northwest versus southeast provenance for till. Till provenance data will be synthesized with stratigraphic observations to provide a stratigraphic framework for the Kaskattama and Machichi rivers area. This data and subsequent interpretations will be combined with similar studies in the Kaskattama highland region (Hodder and Kelley, 2018) to provide an updated drift prospecting framework for northeastern Manitoba.

Economic considerations

The Machichi–Kettle rivers area of far northeastern Manitoba is a remote, thick drift covered and largely unexplored frontier area of northern Manitoba. Till sampled in this region yielded KIMs and has elucidated the diamond potential of the region. On-going till composition and stratigraphic studies will help to constrain till provenance and provide a framework for drift prospecting in the region.

References

Dalton, A.S., Margold, M., Stokes, C.R., Tarasov, L., Dyke, A.S., Adams, R.S., Allard, S., Arends, H.E., Atkinson, N., Attig, J.W., Barnett, P.J., Barnett, R.L., Batterson, M., Bernatchez, P., Borns, H.W., Jr., Breckenridge, A., Briner, J.P., Brouard, E., Campbell, J.E., Carlson, A.E. et al. 2020: An updated radiocarbon-based ice margin chronology for the last deglaciation of the North American Ice Sheet Complex; Quaternary Science Reviews, v. 234, p. 106223.

Fipke, C.E., Gurney, J.J. and Moore, R.O. 1995: Diamond exploration techniques emphasising indicator mineral geochemistry and Canadian examples; Geological Survey of Canada, Bulletin 423, 96 p.

Grütter, H.S., Gurney, J.J., Menzies, A.H. and Winter, F. 2004: An updated classification scheme for mantle-derived garnet, for use by diamond explorers; Lithos, v. 77, p. 841–857.

Hemming, S.R. and Hajdas, I. 2003: Ice-rafted detritus evidence from $^{40}Ar/^{39}Ar$ ages of individual hornblende grains for evolution of the eastern margin of the Laurentide ice sheet since 43 ^{14}C ka; Quaternary International, v. 99–100, p. 29–43.

Hodder, T.J. and Gauthier, M.S. 2019: Quaternary stratigraphy and till sampling in the Machichi–Kettle rivers area, far northeastern Manitoba (parts of NTS 54A–C); *in* Report of Activites 2019, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 83–89, URL <https://www.manitoba.ca/iem/geo/field/roa19pdfs/GS2019-9.pdf> [October 2021].

Hodder, T.J. and Gauthier, M.S. 2021a: Kimberlite-indicator-mineral data derived from glacial sediments (till) in the Machichi–Kettle rivers area, far northeastern Manitoba (parts of NTS 54A–C); Manitoba Agriculture and Resource Development, Manitoba Geological Survey, Data Repository Item DRI2021018, Microsoft® Excel® file, URL <https://www.manitoba.ca/iem/info/libmin/DRI2021018.xlsx> [November 2021].

Hodder, T.J. and Gauthier, M.S. 2021b: Till-matrix geochemistry data, Machichi–Kettle rivers area, far northeastern Manitoba (parts of NTS 54A–C); Manitoba Agriculture and Resource Development, Manitoba Geological Survey, Data Repository Item DRI2021007, Microsoft® Excel® file, URL <https://www.manitoba.ca/iem/info/libmin/DRI2021007.xlsx> [October 2021].

Hodder, T.J. and Kelley, S.E. 2018: Kimberlite-indicator minerals and clast-lithology composition of till, Kaskattama highland region, northeastern Manitoba (parts of NTS 53N, O, 54B, C); *in* Report of Activities 2018, Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, p. 150–156, URL <https://www.manitoba.ca/iem/geo/field/roa18pdfs/GS2018-13.pdf>[October 2021].

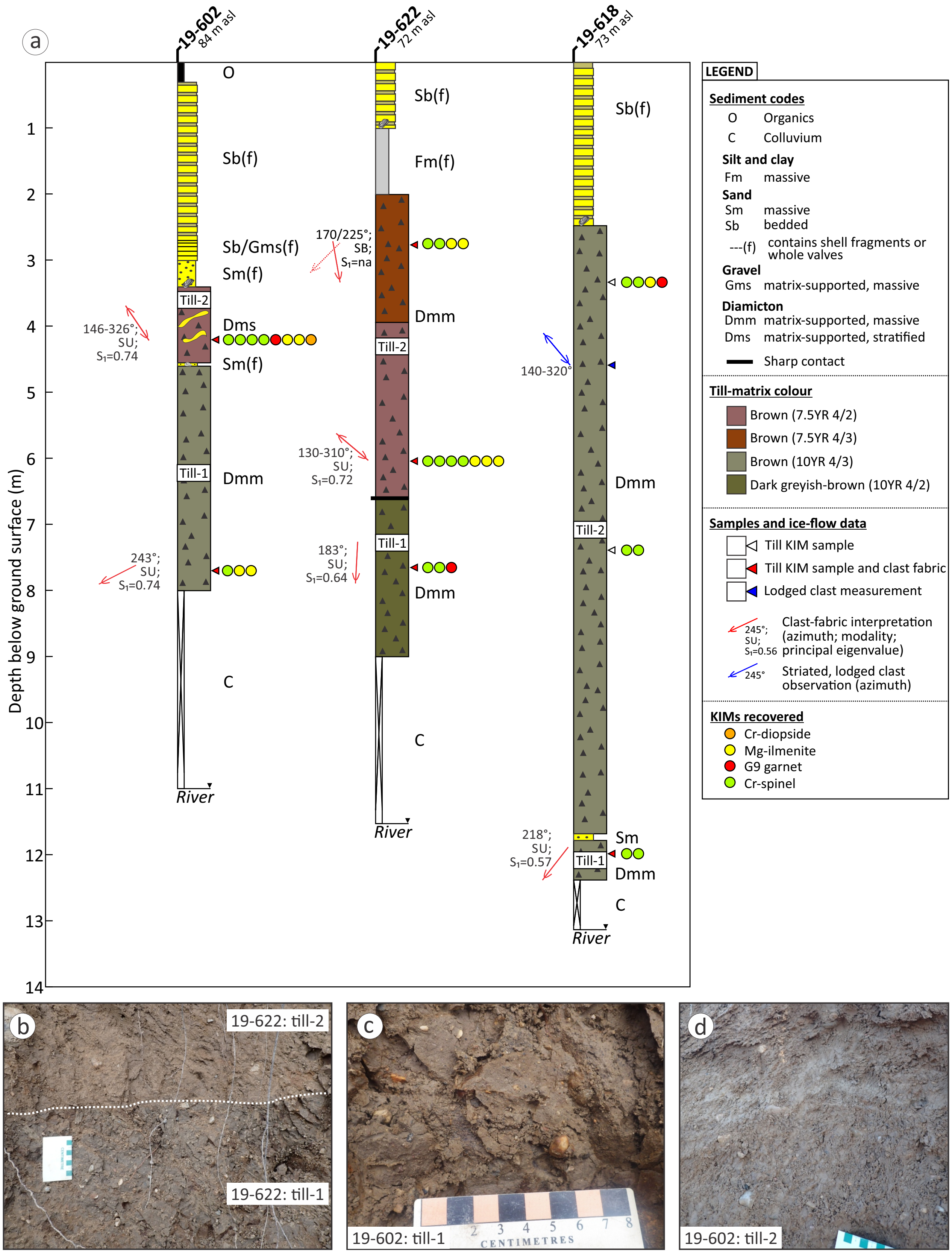


Figure GS2021-9-4: a) *Simplified Quaternary stratigraphy and kimberlite-indicator-mineral (KIM) sample results at sections 19-602, 19-618 and 19-622 on the Kaskattama River;* ***b)*** *contact between till-1 and till-2 at section 19-622;* ***c)*** *till-1 at section 19-602;* ***d)*** *till-2 at section 19-602. Section labels have been abbreviated (e.g., 112-19-602 to 19-602) relative to those found in the accompanying data repository item (DRI2021018; Hodder and Gauthier, 2021a). Till-matrix colour from Munsell Color–X-Rite, Incorporated (2015). Abbreviations: SB, spread bimodal modality; SU, spread unimodal modality.*

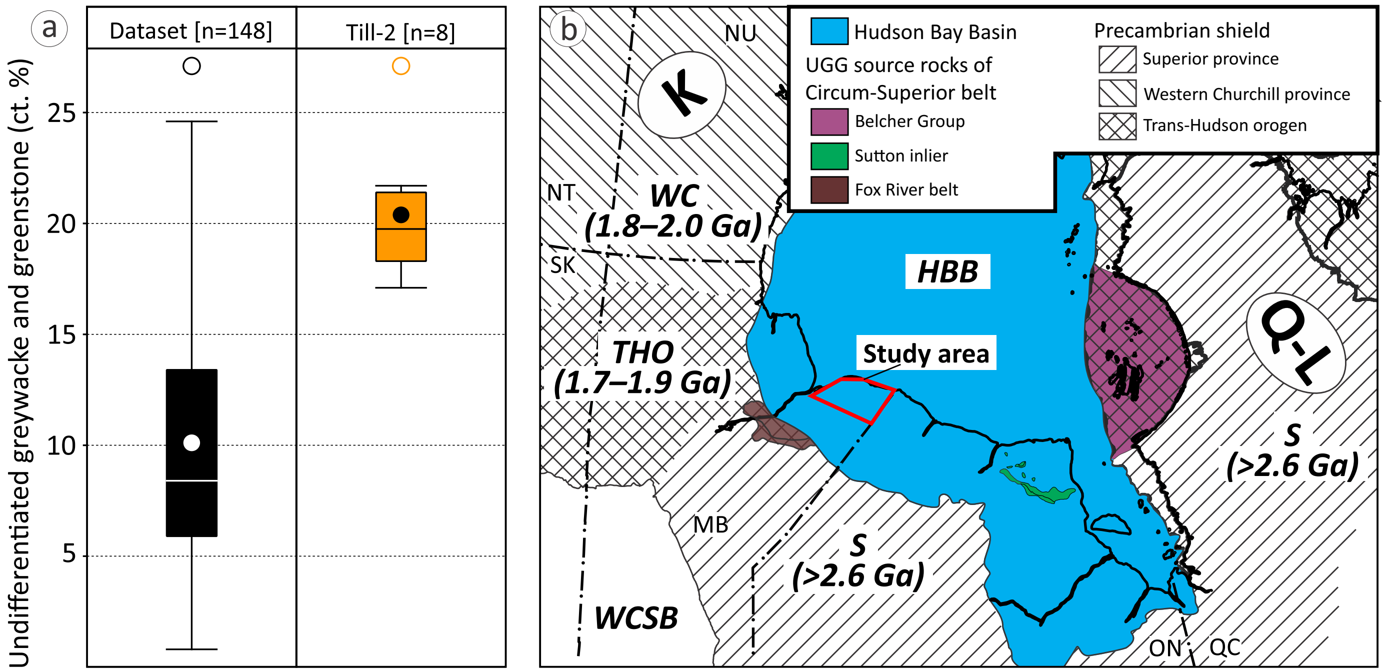


Figure GS2021-9-5: *Concentrations and source regions of undifferentiated greenstone and greywacke (UGG) rocks:* ***a)*** *Tukey box plots showing the distribution of UGG rocks in till-2 compared to the entire dataset (Machichi–Kettle rivers study area);* ***b)*** *regional bedrock geology of central Canada (modified from Wheeler et al., 1996) and the tectonic age of geological provinces (derived from Roy et al., 2007). The location of Keewatin (K) and Quebec-Labrador (Q-L) domes of the Laurentide Ice Sheet during deglaciation are from Dalton et al. (2020). Abbreviations: HBB, Hudson Bay Basin; S, Superior province; THO, Trans-Hudson orogen; WC, western Churchill province; WCSB, Western Canada Sedimentary Basin.*

Hodder, T.J., Gauthier, M.S. and Nielsen, E. 2017: Quaternary stratigraphy and till composition along the Hayes, Gods, Nelson, Fox, Stupart, Yakaw, Angling and Pennycutaway rivers, northeast Manitoba (parts of NTS 53N, 54C, 54D, 54F); Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, Open File OF2017-4, 20 p., URL <https://www.manitoba.ca/iem/info/libmin/OF2017-4.zip> [October 2021].

Keller, G.R. 2019: Manitoba Kimberlite Indicator Mineral Database (version 3.2); Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, zipped Microsoft® Access® 2016 database, URL <https://www.manitoba.ca/iem/geo/diamonds/MBKIMDB_32.zip> [October 2021].

Munsell Color–X-Rite, Incorporated 2015: Munsell Soil Color Book; Pantone LLC, Carlstadt, New Jersey, 42 p.

Nielsen, E. and Fedikow, M.A.F. 2002: Kimberlite indicator-mineral surveys, lower Hayes River; Manitoba Industry, Trade and Mines, Manitoba Geological Survey, Geological Paper GP2002-1, 39 p., URL <https://www.manitoba.ca/iem/info/libmin/GP2002-1.zip> [October 2021].

Nimis, P. 2002: The pressures and temperatures of formation of diamond based on thermobarometry of chromian diopside inclusions; The Canadian Mineralogist, v. 40, p. 871–884.

Nowicki, T.E., Moore, R.O., Gurney, J.J. and Baumgartner, M.C. 2007: Diamonds and associated heavy minerals in kimberlite: a review of key concepts and applications; Developments in Sedimentology, v. 58, p. 1235–1267.

Ramsay, R.R. and Tompkins, L.A. 1994: The geology, heavy mineral concentrate mineralogy, and diamond prospectivity of the Boa Esperança and Cana Verde pipes, Corrego D'anta, Minas Gerais, Brazil; *in* Kimberlites, Related Rocks and Mantle Xenoliths, H.O.A. Meyer and O.H. Leonardos (ed.), Proceedings of the 5th International Kimberlite Conference, Araxá, Brazil, Companhia de Pesquisa de Recursos Minerais (CRPM), Special Publication, v. 2, p. 329–345.

Roy, M., Hemmings, S. and Parent, M. 2009: Sediment sources of northern Quebec and Labrador glacial deposits and the northeastern sector of the Laurentide Ice Sheet during ice-rafting events of the last glacial cycle; Quaternary Science Reviews, v. 28, p. 3236–3245.

Roy, M., Clark, P.U., Duncan, R.A. and Hemming, S.R. 2007: Insights into the late Cenozoic configuration of the Laurentide Ice Sheet from $^{40}Ar/^{39}Ar$ dating of glacially transported minerals in midcontinent tills; Geochemistry, Geophysics, Geosystems, v. 8, no. 9, p. 12.

Thorleifson, L.H., Garrett, R.G. and Matile, G. 1994: Prairie kimberlite study - indicator mineral geochemistry; Geological Survey of Canada, Open File 2875, 15 p.

Wheeler, J.O., Hoffman, P.F., Card, K.D., Davidson, A., Sanford, B.V., Okulitch, A.V. and Roest, W.R. 1996: Geological map of Canada; Geological Survey of Canada, Map 1860A, scale 1:5 000 000.

Wyatt, B.A., Baumgartner, M., Anckar, E. and Grütter, H.S. 2004: Compositional classification of 'kimberlitic' and 'non-kimberlitic' ilmenite; Lithos, v. 77, p. 841–857.