

## Quaternary stratigraphy and till sampling in the Machichi–Kettle rivers area, far northeastern Manitoba (parts of NTS 54A–C)

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

### In Brief:

- Documenting the Quaternary stratigraphy at exposed river sections
- Collection of till samples to determine provenance and investigate the regional diamond potential
- Collection of ice-flow data and geochronology samples to reconstruct the glacial history

### Citation:

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 Activities 2019, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 83–89.

### Summary

Quaternary geology fieldwork was conducted over 15 days in September 2019 in the Machichi–Kettle rivers area of far northeastern Manitoba. The objective of this study was to document the Quaternary stratigraphy at a regional scale. This was accomplished by documenting the sediments exposed along river cuts in the study area. Ice-flow data were collected from till and samples were collected to determine till provenance using geochemistry and clast-lithology analysis. Sediments underlying till units were examined in detail and samples were collected for geochronology analysis by radiocarbon and luminescence dating methods, if an appropriate sample medium was observed. Sixty-three till kimberlite-indicator mineral samples were collected to assess the regional diamond potential. Field data collected includes 121 till samples, 43 clast fabric analyses, 22 paleoenvironment samples, 19 optically stimulated luminescence samples and 14 radiocarbon samples.

### Introduction

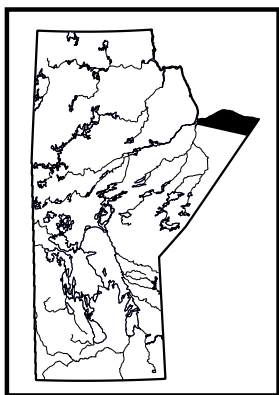
The Manitoba Geological Survey (MGS) conducted 15 days of helicopter-supported fieldwork in September of 2019 in the Machichi–Kettle rivers area of far northeastern Manitoba (parts of NTS 54A–C; Figure GS2019-9-1). This study provides the first reconnaissance-scale survey of the Quaternary geology in this remote area. The objectives of the 2019 field season were to

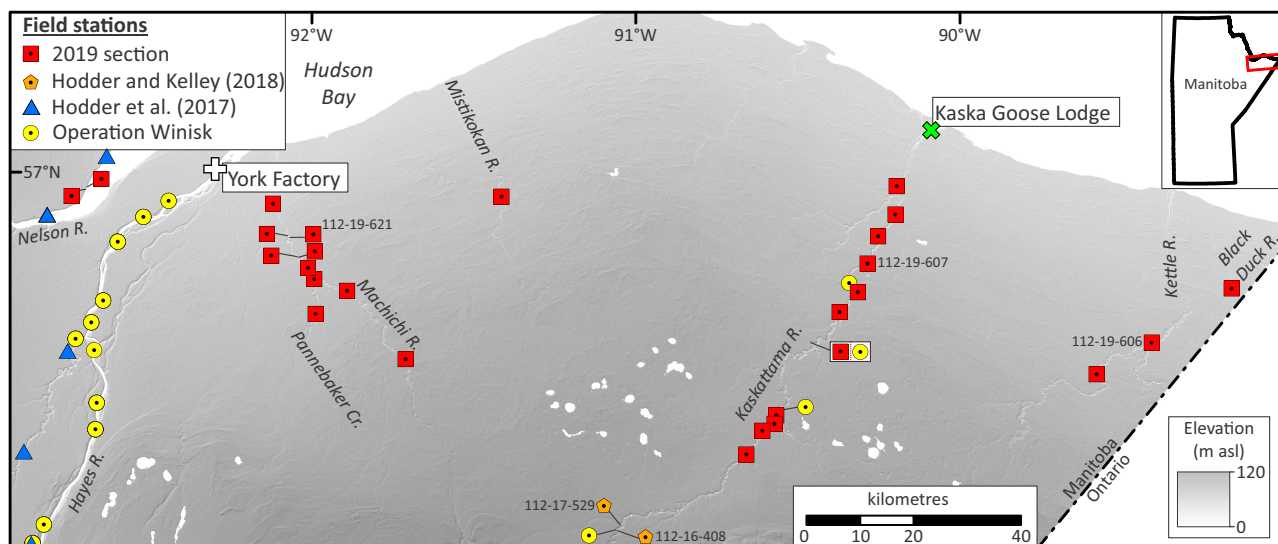
- document the sediments observed at Quaternary sections;
- sample till and conduct clast-fabric measurements to determine the ice-flow direction during till deposition;
- conduct kimberlite-indicator mineral (KIM) sampling to assess the diamond potential of the region; and
- collect geochronology and paleoenvironment samples to help establish stratigraphic correlations in the Hudson Bay Lowland (HBL).

### Previous work

The Machichi–Kettle rivers area has undergone little geological study. The first known accounts describing the Quaternary geology of this area are by Tyrrell (1913, 1916) who traversed up the Machichi River and noted “...cliffs of till up to 60 feet in height bound the valley, while the newer marine sands and clays are conspicuously scanty.” In 1967, the Geological Survey of Canada initiated Operation Winisk to better understand the geology of the HBL region of Quebec, Ontario and Manitoba (Craig, 1969; McDonald, 1969). Within the study area, Operation Winisk fieldwork provided helicopter-supported observations at four sections along the Kaskattama River, where it was noted that one or two tills were exposed at each of the sections (B.G. Craig, H. Gwyn and B.C. McDonald, unpublished notes, 1967). Additionally, the region was mapped at 1:250 000 scale in the late 1980s, though mapping was based mainly on airphoto interpretation and satellite imagery (Clarke, 1989).

The MGS has conducted Quaternary fieldwork in adjacent areas along the Hayes River (Hodder et al., 2017) and in the Kaskattama highland to the south (Hodder and Kelley, 2016, 2017, 2018; Hodder, 2017, 2018). Correlation between Quaternary sections is difficult, and additional fieldwork in the HBL is required to confirm the absolute ages of stratigraphic non-





**Figure GS2019-9-1:** Location of sections visited in the Machichi–Kettle rivers study area. Sections referred to within the text are labelled. Background hillshade image was generated using Canadian Digital Surface Model (Natural Resources Canada, 2015).

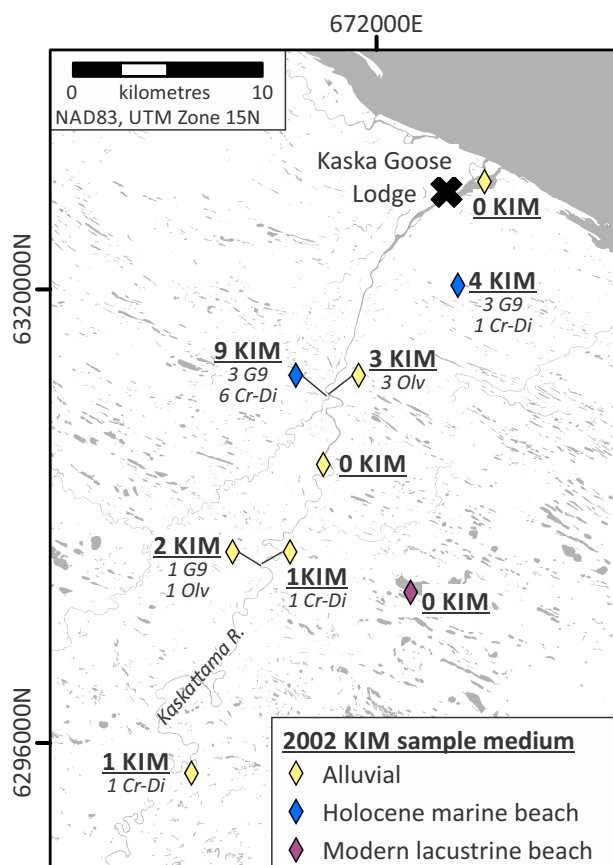
glacial units. This has been identified as a priority to better understand the stratigraphy of tills in this area (Gauthier et al., 2019).

### Mineral exploration

The study area is largely unexplored, primarily due to its remoteness. Previous exploration is limited to airborne geophysical surveys and scant KIM sampling for diamond exploration. An aeromagnetic survey was completed in the Kaskattama–Kettle rivers region of this study area (Assessment File 93361, Manitoba Agriculture and Resource Development, Winnipeg). The KIM sampling was undertaken in the northeastern Kaskattama River area, where KIMs were recovered from alluvial, modern lacustrine beach and Holocene marine beach sediments (Figure GS2019-9-2; Assessment File 74009). This previous sampling recovered seven G9 garnet, nine chrome-diopside and four olivine mineral grains. The KIM recovery was preferential within marine beach sediments as they generally have a higher quantity of the specific grain size (0.25–1.19 mm) picked for KIM analysis in this previous study (Assessment File 74009; Figure GS2019-9-2). Regionally, KIM sampling has taken place along the Nelson, Pennykutaway, 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).

### Quaternary stratigraphy

Far northeastern Manitoba was repeatedly glaciated by the Laurentide Ice Sheet, as evidenced by stratigraphic sequences of two nonglacial units and up to four tills



**Figure GS2019-9-2:** Previous kimberlite-indicator mineral (KIM) sample sites near the mouth of the Kaskattama River (Assessment File 74009). Microprobe data was classified according to the KIM database standardized classification (Keller, 2019) and shown here. Abbreviations: Cr-Di, chrome-diopside; G9, G9 garnet; Olv, olivine.

documented across the HBL (Netterville, 1974; Klassen, 1986; Nielsen et al., 1986; Dredge and McMartin, 2011; Hodder et al., 2017), but robust correlations between studies have proven difficult. During deglaciation, the study area was inundated by glacial Lake Agassiz (Klassen, 1983; Thorleifson, 1996) and by the Tyrrell Sea (Klassen, 1986).

The nature of interaction between ice from central mainland Nunavut and from Hudson Bay is uncertain, but a thick ice saddle was likely present over southern Hudson Bay late in deglaciation (Dyke and Prest, 1987; Thorleifson et al., 1993; Trommelen et al., 2012; Gauthier et al., 2019). The study area may have been within the zone of confluence between ice flowing from the north, the east and the saddle (Gauthier et al., 2019); the nature of till composition mixing is unknown. Two different tills were mapped at sections visited near the upper reaches of the Kaskattama River in 2016 and 2017 (Figure GS2019-9-1; Hodder and Kelley, 2018). At these sites, a clast fabric in the upper till indicated paleo-ice flow toward the south (176°), whereas a clast fabric in the lower till indicated paleo-ice flow toward the south-southwest (193°, 215°). Interestingly, there was 2.0 m of light brown, massive silt between the two tills at section 112-17-529 (Figure GS2019-9-1). This silt could indicate a nonglacial interval occurred between the deposition of the two till units, or, that this silt was deposited in a subglacial environment. Along the Gods River, at least four different tills have been mapped (Netterville, 1974). The two lowermost tills are separated by an organic-bearing unit referred to as the Gods River sediments (GRS), which is interpreted to have been deposited during the last interglacial period (Netterville, 1974). The upper three tills are separated by organic-barren sorted sediments, one of which has been named the Twin Creeks sediments (Netterville, 1974). Along the lower Hayes River, at least three tills have been mapped (Nielsen and Fedikow, 2002), with the lowermost Amery till separated from the middle Long Spruce till by the organic-bearing Nelson River sediments (NRS), which are interpreted to have been deposited during the last interglacial period.

Across the Manitoba-Ontario border (12.3 km east of section 112-19-606 on Figure GS2019-9-1), Dalton et al. (2016) investigated a section along the Black Duck River. At this section, a 1.2 m organic-rich unit was observed overlain by postglacial marine sediments and underlain by till. Four radiocarbon dates were obtained from wood within the organic-rich unit. Near the base of the unit, radiocarbon dating of two wood fragments yielded ages of 50 100 ±3300 and 49 600 ±950 <sup>14</sup>C yr. BP, and a third wood fragment yielded an infinite age (>48 000 <sup>14</sup>C yr. BP). Wood from the upper part of this unit was radiocarbon dated to 46 300 ±1750 cal. yr. BP. These dates have been used

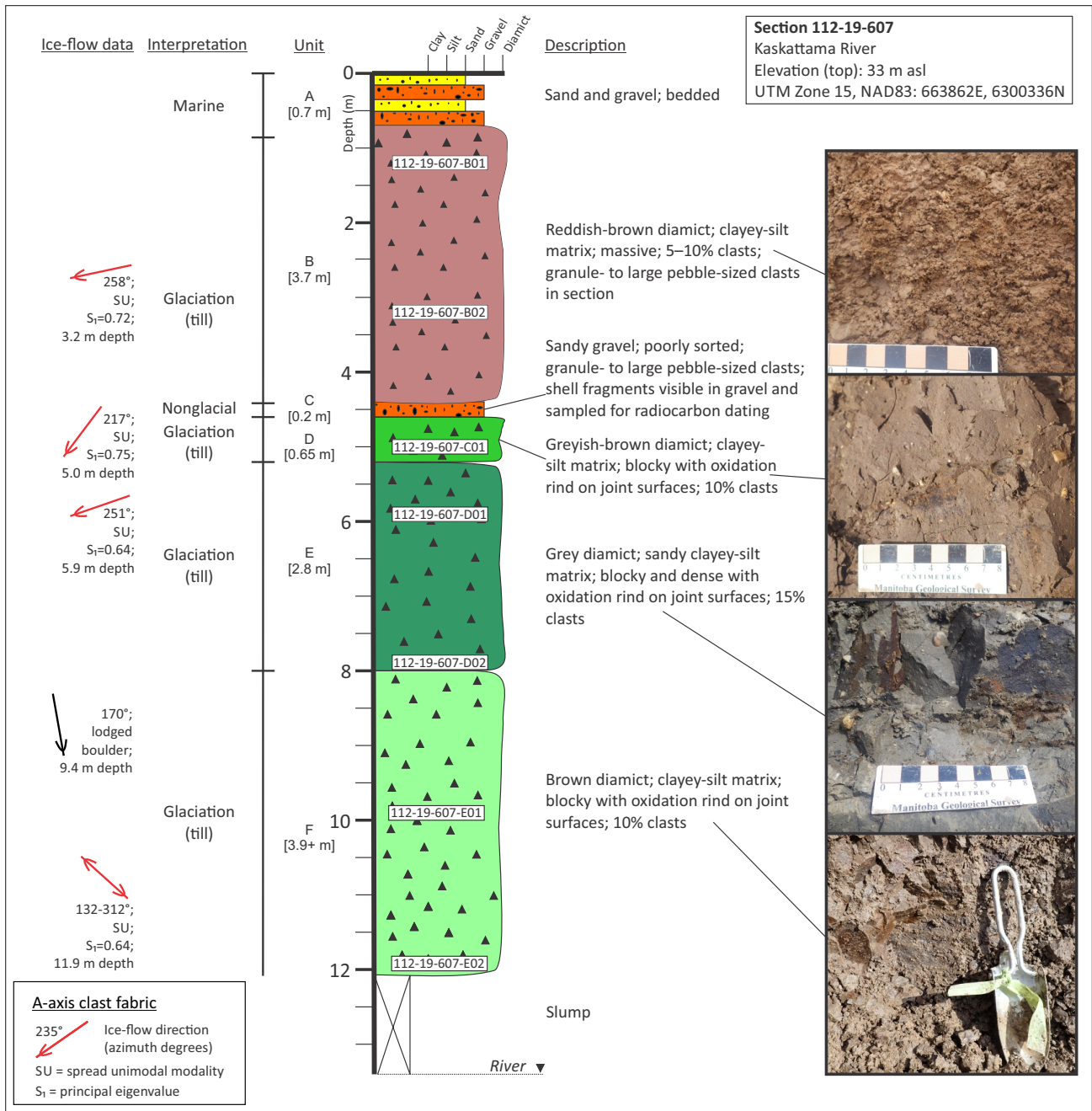
as one line of evidence to support the interpretation of an ice-free Hudson Bay during marine isotope stage (MIS) 3 (29–57 ka). This is important because organic-bearing units, e.g., GRS and NRS, have been correlated to the last interglacial period (MIS 5, 71–123 ka). Geochronology data derived from this project will help to resolve stratigraphic inconsistencies in the HBL.

## Data collected

The Quaternary stratigraphy exposed along natural river sections was documented at 27 stations (Figure GS2019-9-1). Sections were first cleared of slump, and then examined in detail (e.g., Figure GS2019-9-3). Where encountered, till was sampled at 2 m intervals; resulting in a total of 121 till samples, each weighing 2–3 kg. The new till samples will be split for archival purposes at the MGS Midland Sample and Core Library and then analyzed for grain-size, matrix geochemistry (<63 µm size-fraction) and clast lithology. An additional 11.4 L till sample was collected for KIM analysis at 63 till sample sites. The average KIM sample weight was 16.5 kg (range of 13.9–19.6 kg). The KIM samples were submitted to the De Beers Group (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) is publicly released at a later date.

Ice-flow data was obtained from studied sections by measuring the long-axes orientation, or fabric, of clasts within till (e.g., Figure GS2019-9-4a, b). Elongate clasts, defined by a minimum 1.5:1.0 ratio of the a-axis (longest) to the b-axis (middle), will rotate within the till matrix and orient parallel to the direction of stress that the overriding glacier exerts on the till (Holmes, 1941). Clast-fabric measurements were conducted at 43 till sample sites. Each clast-fabric site had a minimum of 30 elongated clasts measured. Lodged clasts with parallel striae on their upper surface—considered to be a good indicator of ice flow—were observed at nine stratigraphic depths (e.g., Figure GS2019-9-4c, d). This ice-flow data will be combined with the forthcoming till composition and geochronology data to understand the till provenance and glacial history of the study area, which will allow for more effective drift prospecting approaches.

Sorted sediments, underlying or between till units, were also of interest for this study. These potentially nonglacial or interglacial units were documented, described and examined for organic matter. Organic matter was collected for radiocarbon dating wherever encountered, resulting in a total of 14 shell and wood samples. Organic-bearing units were sampled for pollen and macrofossil



**Figure GS2019-9-3:** Example of a section described and sampled on the Kaskattama River during the 2019 field season. Till sample numbers are labelled within the white boxes.

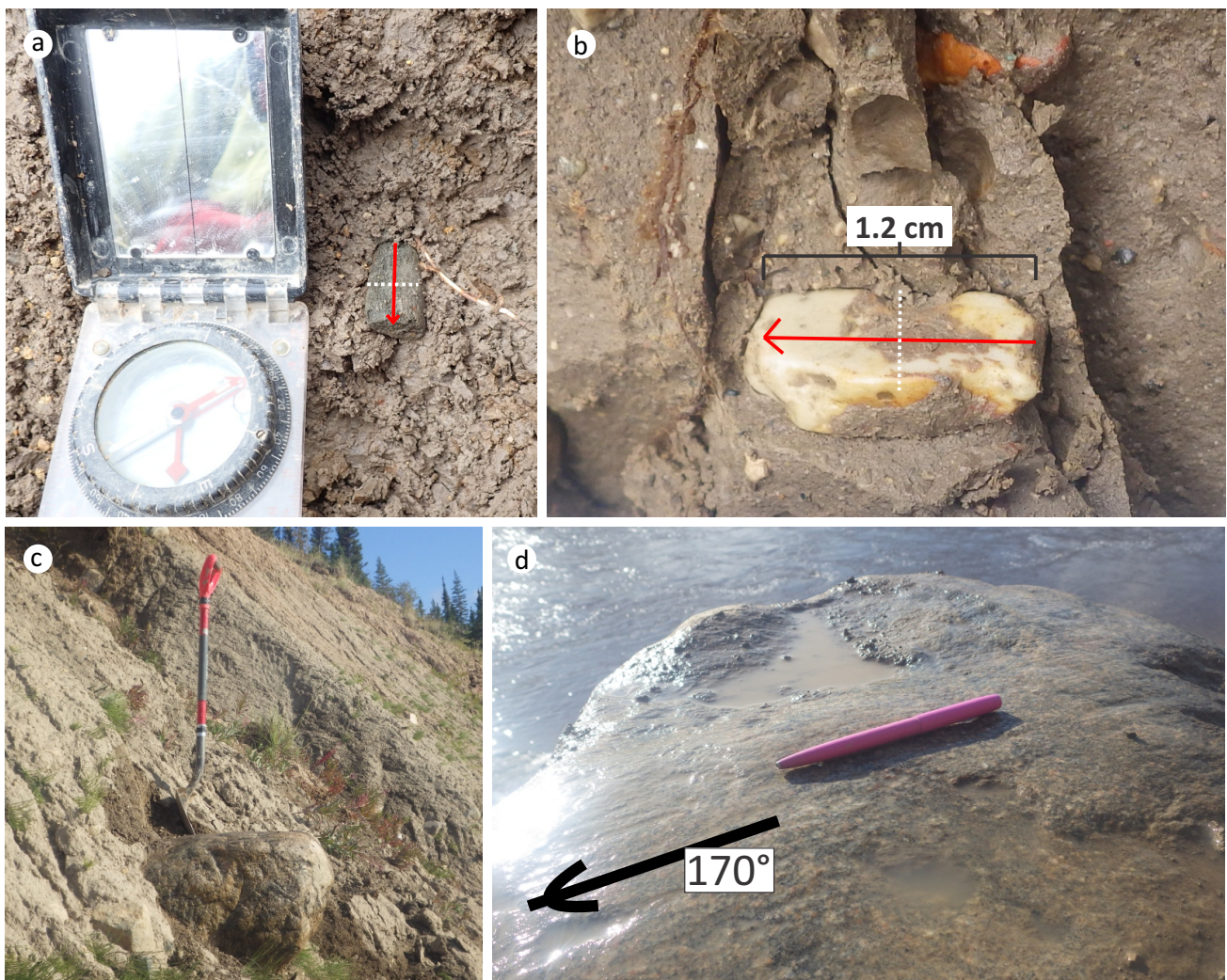
analysis at five sections, totalling twenty-two samples. In addition, because some sub/intertill units may be older than the limits of radiocarbon dating (~50 000 years), 19 sorted sand units were also sampled for optically stimulated luminescence (OSL) dating (e.g., Figure GS2019-9-5). These OSL techniques have been used to date a variety of sediments deposited within the last 500 000 years (Forman et al., 2000).

Future work will synthesize stratigraphic observations with forthcoming analytical results, including till-matrix

geochemistry, clast-lithology, geochronology and indicator mineral results. These results will provide insight into the economic potential and glacial history of far northeastern Manitoba.

**Economic considerations**

The far northeastern region of Manitoba is a remote and largely unexplored frontier area of northern Manitoba. This study will provide the first documentation of



**Figure GS2019-9-4:** Examples of ice-flow data collected: **a, b**) clasts measured during clast-fabric analysis, the *a*-axis and dip direction is highlighted by the red arrow and the *b*-axis is highlighted by the dashed white line; **c**) view of the lodged boulder within till at section 112-19-607; **d**) view of the flat, striated and grooved upper surface of the boulder shown in **c**).

the Quaternary stratigraphy and glacial history of the area. This is a necessary step to support any drift prospecting efforts in this region of thick drift. Results from the kimberlite-indicator mineral analysis will provide the first reconnaissance-scale insight into the diamond potential of the region.

### Acknowledgments

The De Beers Group is thanked for their continued analytical support for Quaternary initiatives at the Manitoba Geological Survey by providing kimberlite-indicator mineral processing. Prairie Helicopters Inc. and pilot H. Johnson are thanked for providing air support during the field season. Kaska Goose Lodge provided accommodations. Thanks to H. Thorleifson from the Minnesota Geological Survey for discussions regarding the Quaternary stratigraphy in the Hudson Bay Lowland region. The

authors thank E. Anderson and C. Epp from the Manitoba Geological Survey for logistical support throughout the field season. Also, K. Lapenskie and C. Böhm are thanked for their review of this publication.

### References

- Clarke, M.D. 1989: Surficial geology, Kaskattama River, Manitoba-Ontario; Geological Survey of Canada, Map 1696A, scale 1:250 000.
- Craig, B.G. 1969: Late glacial and post-glacial history of the Hudson Bay region; *in* Earth Science Symposium on Hudson Bay, P.J. Hood (ed.), Geological Survey of Canada, Paper 68-83, p. 63–77.
- Dalton, A.S., Finkelstein, S.A., Barnett, P.J. and Forman, S.L. 2016: Constraining the Late Pleistocene history of the Laurentide Ice Sheet by dating the Missinaibi Formation, Hudson Bay Lowlands, Canada; *Quaternary Science Reviews*, v. 146, p. 288–299.



**Figure GS2019-9-5:** Example of sub till medium sand at section 112-19-621. This sediment was sampled to determine its age using optically stimulated luminescence dating methods. Dashed white line denotes contact between sediments.

Dredge, L.A. and McMartin, I. 2011: Glacial stratigraphy of northern and central Manitoba; Geological Survey of Canada, Bulletin 600, 27 p.

Dyke, A.S. and Prest, V.K. 1987: Late Wisconsinan and Holocene Retreat of the Laurentide Ice Sheet; Geological Survey of Canada, Map 1702A, scale 1:5 000 000.

Forman, S.L., Pierson, J. and Lepper, K. 2000: Luminescence geochronology; in *Quaternary Geochronology: Methods and Applications*, J.S. Noller, J.M. Sowers and W.R. Lettis (ed.), American Geophysical Union, AGU Reference Shelf 4, p. 157–175.

Gauthier, M.S., Hodder, T.J., Ross, M., Kelley, S.E., Rochester, A. and McCausland, P. 2019: The subglacial mosaic of the Laurentide Ice Sheet; a study of the interior region of southwestern Hudson Bay; *Quaternary Science Reviews*, v. 214, p. 1–27.

Hodder, T.J. 2017: Quaternary stratigraphy and till sampling in the Kaskattama highland region, northeastern Manitoba (parts of NTS 53N, O, 54B, C): year two; in *Report of Activities 2017*, Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, p. 205–214.

Hodder, T.J. 2018: Till composition of the Kaskattama Kimberlite No. 1 drillcore, Kaskattama highland region, northeastern Manitoba (part of NTS 54B7); in *Report of Activities 2018*, Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, p. 166–174.

Hodder, T.J. and Kelley, S.E. 2016: Quaternary stratigraphy and till sampling in the Kaskattama highland region, northeastern Manitoba (parts of NTS 53N, O, 54B, C); in *Report of Activities 2016*, Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, p. 187–195.

Hodder, T.J. and Kelley, S.E. 2017: Kimberlite-indicator-mineral results derived from glacial sediments (till) in the Kaskattama highland area of northeast Manitoba (parts of NTS 53N, O, 54B, C); Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, Open File OF2017-1, 6 p.

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. 150–165.

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.

Holmes, C.D. 1941: Till fabric; *Bulletin of the Geological Society of America*, v. 52, p. 1299–1354.

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.gov.mb.ca/iem/geo/diamonds/MBKIMDB\\_32.zip](https://www.gov.mb.ca/iem/geo/diamonds/MBKIMDB_32.zip)> [June 2019].

Klassen, R.W. 1983: Lake Agassiz and the late glacial history of northern Manitoba; in *Glacial Lake Agassiz*, J.T. Teller and L. Clayton (ed.), Geological Association of Canada, Special Paper 26, p. 97–115.

Klassen, R.W. 1986: Surficial geology of north-central Manitoba; Geological Survey of Canada, Memoir 419, 57 p.

McDonald, B.C. 1969: Glacial and interglacial stratigraphy, Hudson Bay Lowland; in *Earth Science Symposium on Hudson Bay*, P.J. Hood (ed.), Geological Survey of Canada, Paper 68-83, p. 78–99.

Natural Resources Canada 2015: Canadian Digital Surface Model; Natural Resources Canada, URL <<https://open.canada.ca/data/en/dataset/768570f8-5761-498a-bd6a-315eb6cc023d>> [September 2015].

Netterville, J.A. 1974: Quaternary stratigraphy of the lower Gods River region, Hudson Bay Lowlands, Manitoba; M.Sc. thesis, University of Calgary, Calgary, Alberta, 79 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, 11 p.

- Nielsen, E., Morgan, A.V., Morgan, A., Mott, R.J., Rutter, N.W. and Causse, C. 1986: Stratigraphy, paleoecology and glacial history of the Gillam area, Manitoba; *Canadian Journal of Earth Sciences*, v. 23, p. 1641–1661.
- Thorleifson, L.H. 1996: Review of Lake Agassiz history; *in* *Sedimentology, Geomorphology and History of the Central Lake Agassiz Basin*, J.T. Teller, L.H. Thorleifson, G.L.D. Matile and W.C. Brisbin (ed.), Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Winnipeg, Manitoba, May 27–29, 1996, Field Trip Guidebook B2, p. 55–84.
- Thorleifson, L.H., Wyatt, P.H. and Warman, T.A. 1993: Quaternary stratigraphy of the Severn and Winisk drainage basins, northern Ontario; *Geological Survey of Canada, Bulletin* 442, 65 p.
- Trommelen, M.S., Ross, M. and Campbell, J.E. 2012: Glacial terrain zone analysis of a fragmented paleoglaciological record, southeast Keewatin sector of the Laurentide Ice Sheet; *Quaternary Science Reviews*, v. 40, p. 1–20.
- Tyrrell, J.B. 1913: Hudson Bay exploring expedition 1912; Ontario Bureau of Mines, 22 Annual Report, v. 22, pt. 1, 51 p.
- Tyrrell, J.B. 1916: Notes on the geology of Nelson and Hayes rivers; *Proceedings and Transactions of the Royal Society of Canada*, v. 10, sec. IV, p. 1–27.