GS2022-12

Quaternary stratigraphic investigations near the confluence of the Hayes and Gods rivers, northeastern Manitoba (part of NTS 54C7)

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

Summary

The occurrence of a relatively elevated concentration of kimberlite-indicator-mineral (KIM) grains, identified during a previous survey, at a site near the confluence of the Hayes and Gods rivers has led to a further investigation of the kimberlite potential in the region. Previous work interpreted the Quaternary stratigraphy at this site as a single till that was deposited by south- to southeast-trending ice flow. This site was revisited and a reinterpretation identified two tills that were deposited by separate ice-flow events; both were likely deposited by northwest-trending ice flow. Two additional nearby sites were described and sampled to 1) further assess the KIM potential in the region and 2) help establish the Quaternary stratigraphy and till provenance.

In Brief:

- Investigation of the Quaternary stratigraphy and till provenance near previous KIM high

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Introduction

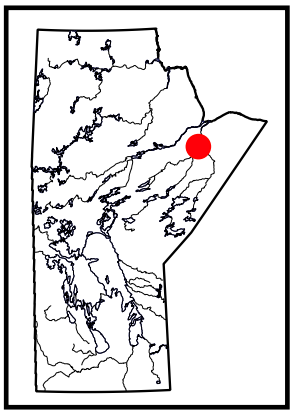
The Manitoba Geological Survey (MGS) conducted an investigation of the Quaternary stratigraphy exposed along three river sections near the confluence of the Hayes and Gods rivers in northeastern Manitoba (Figure GS2022-12-1). This helicopter-supported work was completed over a half day in 2019 and two days in 2022. The purpose of this study is to gather additional observations of the Quaternary stratigraphy in the area, and collect indicator mineral samples to assess the kimberlite potential in the region.

Previous work

The MGS conducted a reconnaissance-scale glacial sediments (till) KIM survey in the Hudson Bay Lowland (HBL) in 2001 and 2002 (Nielsen, 2001, 2002). Results from this survey indicated that the KIM distribution across the region was not uniform; there was a relatively elevated concentration of KIMs at a site on the north shore of the Hayes River near the confluence with the Gods River (Syme et al., 2004; Hodder et al., 2017).

Sediments exposed at this site were previously described in three separate studies (Figure GS2022-12-1; Operation Winisk [B.G. Craig, H. Gwyn and B.C. McDonald, unpublished notes, 1967; McDonald, 1969]; Klassen, 1986; Nielsen, 2002). The Quaternary stratigraphy comprises postglacial sorted sediments overlying two till beds, which are separated by 1.5–2.4 m of sorted intertill sediments (Figure GS2022-12-1). Two of the studies reported that the river bank exposed between 17.9 and 21.3 m of sediments (Operation Winisk [B.G. Craig, H. Gwyn and B.C. McDonald, unpublished notes, 1967; McDonald, 1969]; Klassen, 1986; Figure GS2022-12-1), whereas Nielsen (2002) indicated that 38 m of sediments were exposed; nearly twice as thick as previous studies.

Nielsen (2002) interpreted both diamicton beds as till, and correlated them to the Long Spruce till (Nielsen et al., 1986). The Long Spruce till was originally defined in the Gillam area as light olive grey with a blocky appearance and light oxidation rind on joint surfaces. Initial studies indicated large variations in the concentration of undifferentiated greenstone and greywacke within this 'one' named till (Nielsen et al., 1986). Till-fabric measurements from the Long Spruce till were interpreted to indicate deposition by west- and west-southwest-trending ice flow (Nielsen et al., 1986). Additional work in the lower Hayes River area expanded the mapped extent of the Long Spruce till (Nielsen, 2001; Nielsen and Fedikow, 2002). Till-fabric measurements from the Long Spruce till were now interpreted to indicate deposition by southwest-trending ice flow (~195–215°; Nielsen and Fedikow, 2002). Additional work in 2002 led to mapping of the Long Spruce Till at every section investigated, primarily based on stratigraphic position relative to nonglacial sediments (Nielsen, 2002). On the basis of 30 till fabrics, it was then interpreted that the lower part of the Long Spruce till was deposited by southwest-trending ice flow and the upper part was deposited by south- to southeast-trending ice flow (Nielsen, 2002). These studies have shown that there is significant variability in the characteristics of the named Long Spruce till, including the direction of ice flow that deposited the sediment.



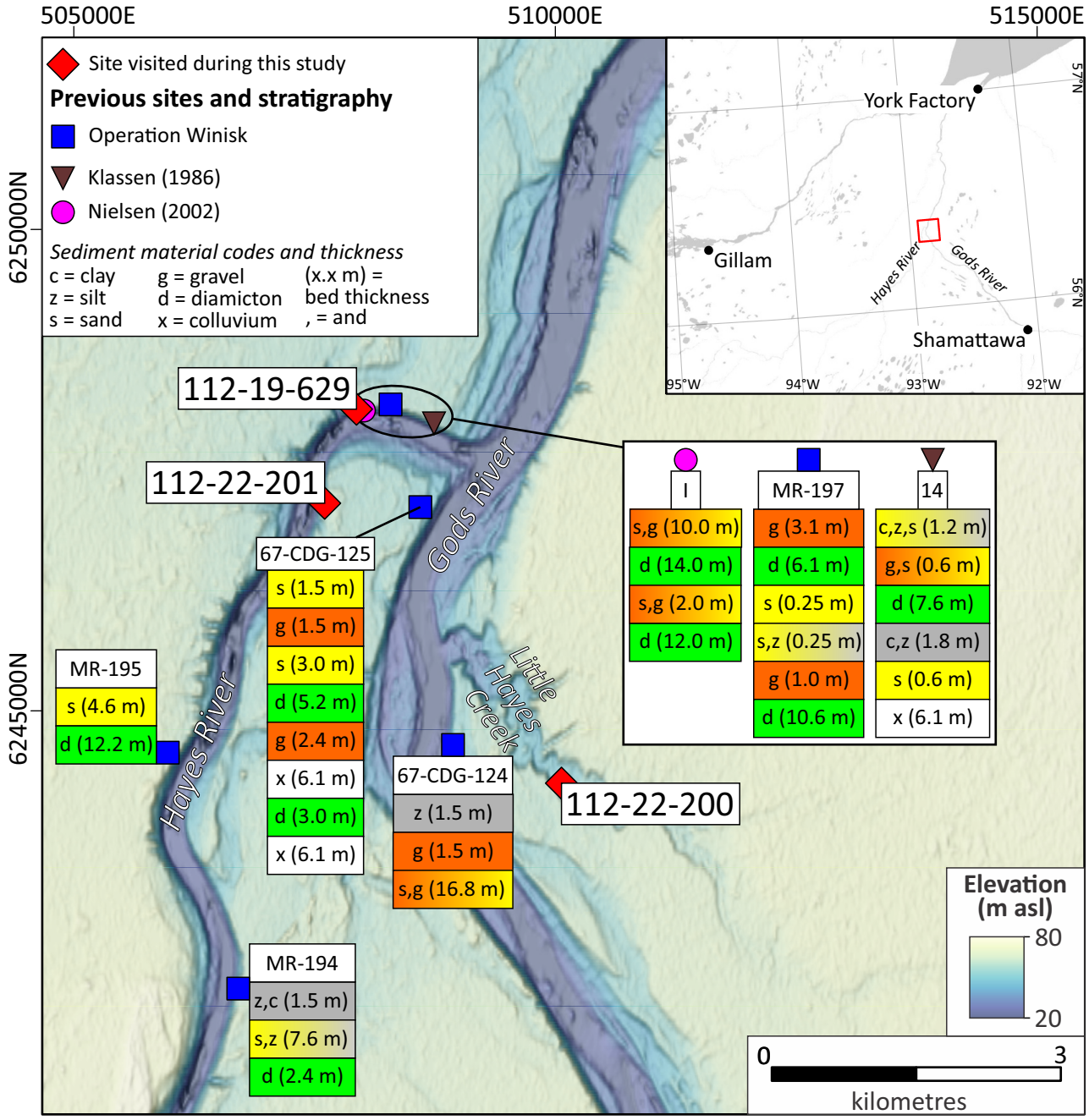


Figure GS2022-12-1: *Location of the study area (red square on inset) near the confluence of the Hayes and Gods rivers, northeastern Manitoba. Previous sites investigated, and the stratigraphy at each site, are shown alongside the three sites investigated as part of this study. Operation Winisk data from B.G. Craig, H. Gwyn and B.C. McDonald (unpublished notes, 1967) and McDonald (1969). Background digital surface model is provided by Earth Observation Research Center and Japanese Aerospace Exploration Agency (2022).*

The understanding of Quaternary stratigraphy records has continued to evolve since these initial investigations. Whereas geologists once strived to correlate these stratigraphic records over great distances, assuming rather continuous deposition during ice-flow events (e.g., Thorleifson et al., 1993), there is now a better appreciation for the fragmented nature of continental glacial records (e.g., Trommelen et al., 2013; Lee, 2018; Gauthier et al., 2019, 2022). Fragmentation needs to be considered when conducting Quaternary stratigraphic investigations in complex glacial terrains, such as northeastern Manitoba, where stratigraphic ice-flow indicators range from northwest-trending (310°) to east-southeast-trending (105°) over at least three glacial cycles (Gauthier et al., 2019). A recent stratigraphic study of 83 sections in the Gillam area suggests that the terms Long Spruce till and Sky Pilot till (overlying unit; Nielsen et al., 1986; Dredge and McMartin, 2011) be retired, and instead be recognized as one 'upper' till unit that overlies nonglacial sediments (Gauthier et al., 2022). This new upper till is interpreted as a cumulative record of erosion, deposition and deformation over at least one glacial cycle. Importantly, careful interpretations of

till texture, density and fabrics suggest that the upper till consists of fragmented patches of sediment belonging to two separate glaciations (occurring where nonglacial sediments are missing between the two chronologically different tills [Gauthier et al., 2022]). Current MGS work in the HBL attempts to better understand the patchy stratigraphic record (Gauthier et al., 2021) and decipher these shifts in ice-flow directions through multiple glaciations.

Current work

River and creek sections in the study area expose 10–24 m of Quaternary sediments. The Quaternary stratigraphy was documented at two new locations and one previously investigated section (Figure GS2022-12-1). Sediment exposures were first cleared of slumped detritus, exposing a continuous section with no gap, and then described in detail. A total of 10 till samples (two in 2019 and eight in 2022) were collected, each weighing 2–3 kg. The till samples were split for archival purposes at the MGS Midland Sample and Core Library (Winnipeg, Manitoba) and then analyzed for grain size, matrix geochemistry (<63 µm size fraction) and clast lithology. An additional 11.4 L till sample was collected at seven till sample sites for indicator mineral analysis. Indicator mineral samples were submitted for analyses to Overburden Drilling Management Limited (Ottawa, Ontario) in collaboration with the Geological Survey of Canada.

Ice-flow data was obtained from studied sections by measuring the long-axes orientation, or fabric, of clasts within till. 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). A minimum of 30 elongated clasts were measured at each of the nine clast-fabric sites to ensure a statistically valid result.

Section 112-19-629

The north shore of the Hayes River near the confluence with the Gods River was revisited to verify the stratigraphy and thickness of the Quaternary sediments exposed here. Five different stratigraphic beds (SB; SB A–E) were denoted within the upper 24 m of the investigated section. These beds were underlain by ~12 m of colluvium to the river level in 2022. The thicknesses of the two till beds reported here are proportional to the thicknesses reported in Nielsen (2002), but at a ratio of ~0.5:1. For example, Nielsen (2002) reported that the upper SB B till is 14.0 m thick, whereas it has been reported to be 6.1–7.8 m thick across three other studies (including this one). This needs to be considered when revisiting sections reported in Nielsen (2002), since this pattern of overestimating sediment bed thicknesses is not limited to this site.

The uppermost SB A consists of bedded sand and gravel with minor clay (Figure GS2022-12-2). Shell fragments were observed throughout the upper sediments and some beds contain paired whole valves of *Hiatella arctica*, which are indicative of deposition within a marine environment. The bedded sequence and grain-size variations of SB A are interpreted to represent postglacial marine transgression at this site.

A 7.8 m thick layer of brown (Munsell colour 10YR 4/3; Munsell Color–X-Rite, Incorporated, 2015), massive, matrix-supported diamicton (SB B; Figure GS2022-12-3a) sharply underlies SB A. The diamicton contains 10–15% clasts and has a sandy-silt matrix. The diamicton has a crumbly appearance with minor oxidation rind developed on joint surfaces.

A 0.6 m thick layer of matrix-supported, massive, sandy gravel (SB C) underlies SB B. The gravel is poorly sorted and contains 40% clasts that are granule- to large pebble-sized. The lower 0.2 m of this gravel contains rip-up clasts of diamicton. This gravel is interpreted as a glaciofluvial or fluvial deposit based on the poorly sorted nature of the sediments.

A 1.6 m thick layer of well sorted, bedded, very fine sand and medium- to coarse-grained sand (SB D) underlies SB C gravel. Shell fragments were observed in the upper 0.1 m of the bedded sands. The sands are interpreted to have been deposited in a marine environment, based on the rhythmic bedding, the elevation (41 m asl), the position beneath postglacial Tyrrell Sea sediments and the proximity to the modern shoreline (~90 km).

More than 6.0 m of dark greyish-brown (Munsell colour 2.5Y 4/2), massive, matrix-supported diamicton (SB E; Figure GS2022-12-3a) sharply underlies SB D sand. The diamicton contains 15% clasts and has a clayey sandy-silt matrix. The diamicton has a blocky structure with oxidation rind on the joint surfaces, and is relatively denser compared to the upper diamicton (Figure GS2022-12-3a). Both SB B and E diamicton are interpreted as till based on their massive structure, their texture, the glaciogenic shape of the clasts (bullet shaped, faceted and striated), the modality and strength of the clast fabrics, and the lateral continuity.

Ice-flow data, till composition and sediment provenance interpretation

Ice-flow data for both tills (SB B, E) were measured during this study and by Nielsen (2002). The complete dataset is published in Hodder and Gauthier (2022)[1]. To allow a comparison of data from the two studies, the depth of Nielsen (2002) till-fabric measurements were scaled to fit the stratigraphic observations obtained in this study. Two till-fabric analyses were completed in SB B at a similar depth. For this study, the till-fabric measurements were conducted 0.5 m above the lower contact of the till, and were interpreted to indicate deposition by northwest- or southeast-

[1] MGS Data Repository Item DRI2022011, containing the data or other information sources used to compile this report, is available online to download free of charge at https://manitoba.ca/iem/info/library/downloads/index.html, or on request from minesinfo@gov.mb.ca, or by contacting the Resource Centre, Manitoba Natural Resources and Northern Development, 360-1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada.

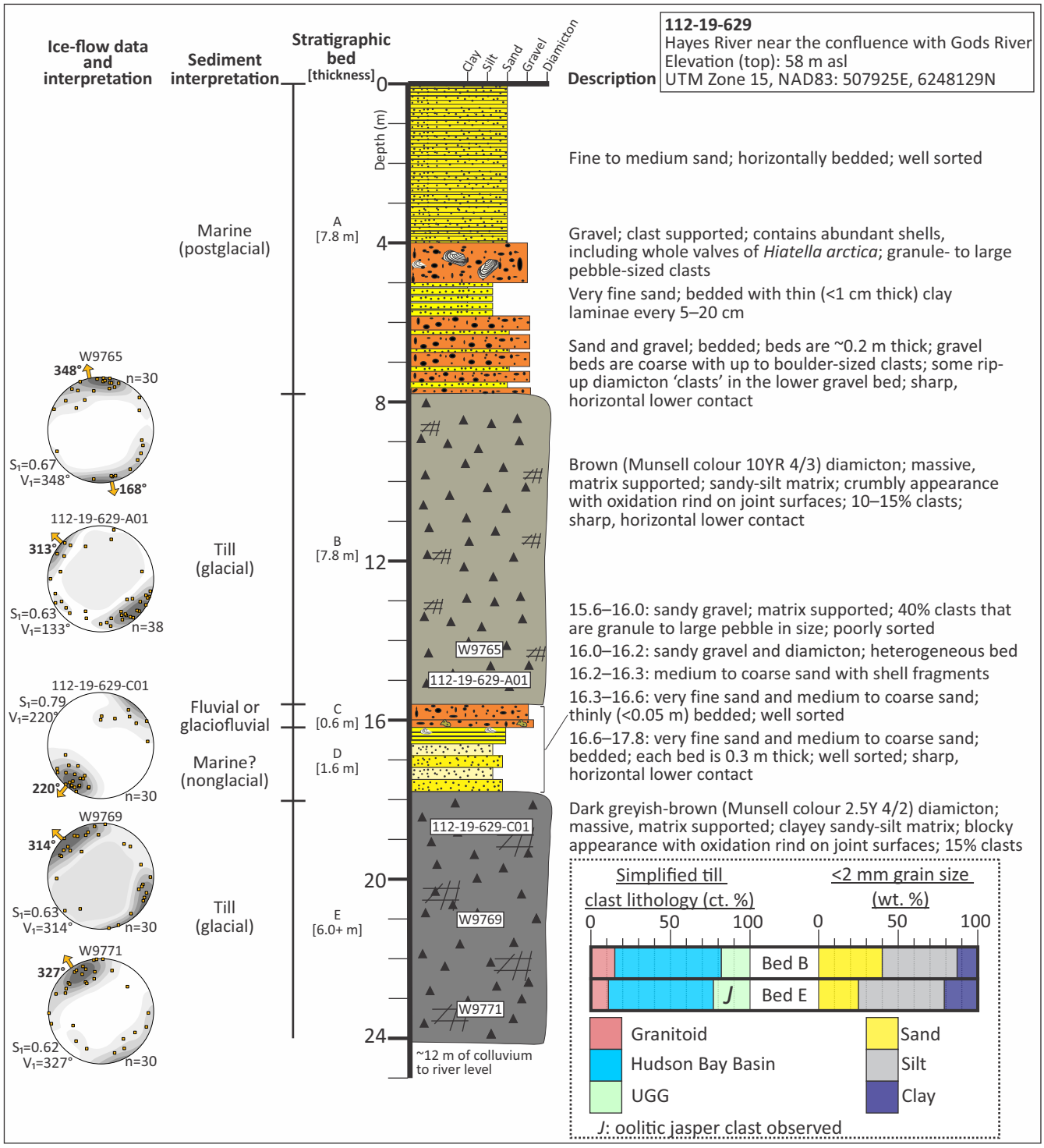


Figure GS2022-12-2: *Quaternary stratigraphy on the north shore of the Hayes River near the confluence with the Gods River (section 112-19-629). Till sample numbers and till-fabric sites are labelled within the white boxes. Till-fabric data is plotted on equal area, lower hemisphere projection stereonets. The value of the principal eigenvalue (S_1) and direction of the principal eigenvector (V_1) are provided and an interpretation of the ice-flow direction is indicated (orange arrow). Diamicton colour from Munsell Color–X-Rite, Incorporated (2015).*

oriented ice flow (site 112-19-629-A01; Figure GS2022-12-2). The second till fabric indicates deposition by north-northwest- or south-southeast-oriented ice flow (site W9765; Figure GS2022-12-2). The SB B till contains 18 ct. % undifferentiated greenstone and greywacke (UGG) clasts in the 2–8 mm size fraction (see Figure GS2022-12-3b for 2–4 mm size fraction). This is in agreement with counts on the 4–8 mm fraction from three other samples from this till bed, which ranged from 12.8 to 19.0 wt. % and increased in concentration with depth (Hodder et al., 2017). Three till-fabric analyses were completed in SB E. The two lower fabrics indicate deposition by northwest- or southeast-oriented ice flow and the uppermost fabric indicates deposition by south-

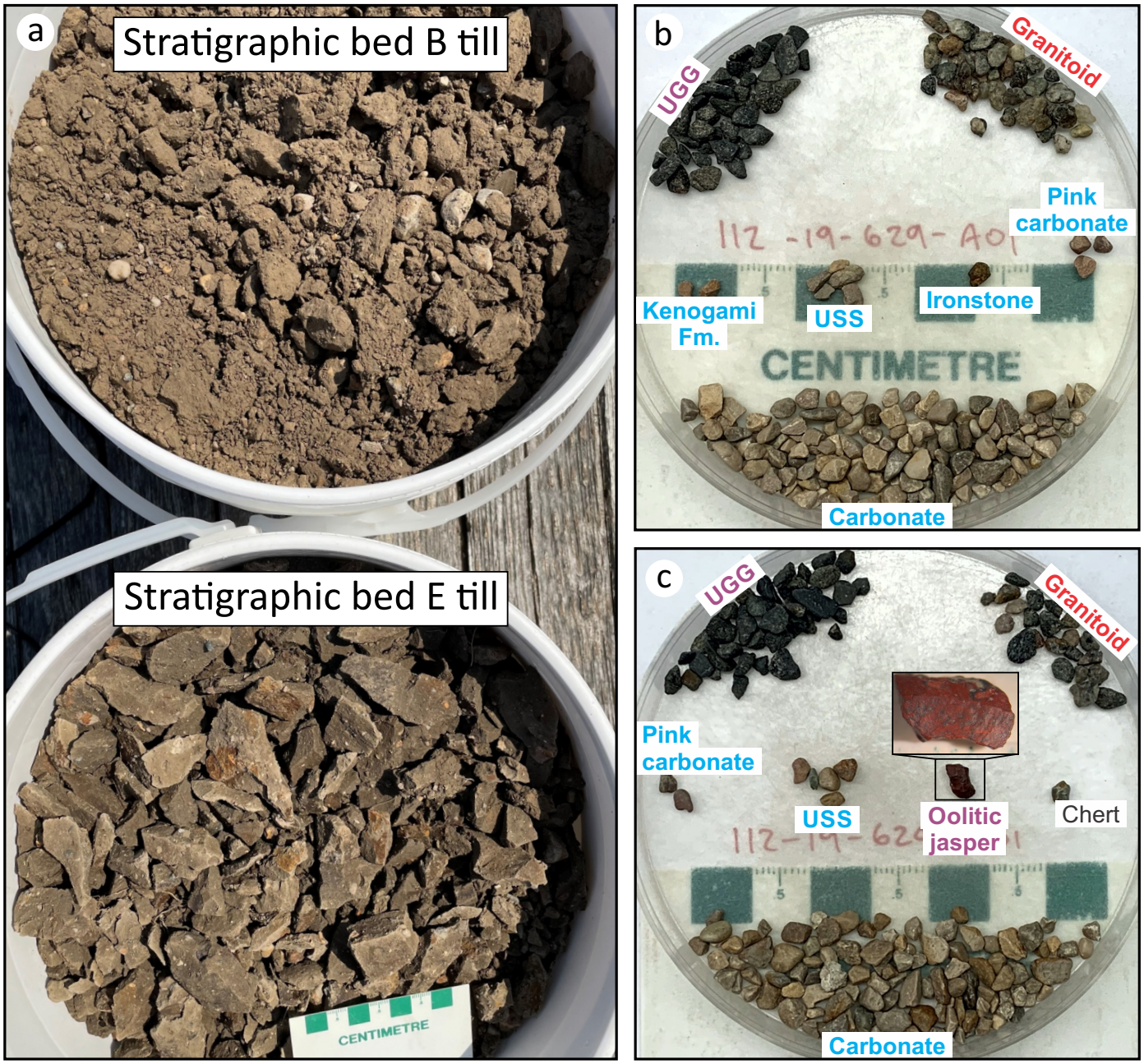


Figure GS2022-12-3: *Glacial sediment and clast count examples for section 112-19-629 on the Hayes River near the confluence with the Gods River:* ***a)*** *comparison of the upper crumbly till (stratigraphic bed [SB] B) and lower blocky till (SB E);* ***b)*** *sorted 2–4 mm granules from SB B till;* ***c)*** *sorted 2–4 mm granules from SB E till. Abbreviations: Fm., Formation; UGG, undifferentiated greenstone and greywacke; USS, undifferentiated sandstone and siltstone.*

west- or northeast-oriented ice flow (sites W9769, W9771, 112-19-629-C01; Figure GS2022-12-2). The lower till contains 23 ct. % UGG clasts at 18.7 m depth (Figure GS2022-12-3c). This is in agreement with counts on the 4–8 mm fraction from seven other samples from this till bed, which ranged from 17–25 wt. % (Hodder et al., 2017). An oolitic jasper clast from the Proterozoic Kipalu Formation, which has an eastern provenance (Hodder and Kelly, 2018), was observed in the 2–4 mm size fraction of the till sample counted during this study (Figure GS2022-12-3c).

The largest bedrock source by aerial extent for UGG clasts recovered in the Hudson Bay Basin is interpreted to be the Belcher Group and Sutton Inlier to the east and southeast (Shilts, 1980; Hodder and Kelley, 2018). Scattered greenstone belts throughout the Canadian Shield are also potential source rocks for these indiscriminate dark grey erratics. The UGG concentrations of SB B and E tills are consistent with till interpreted to have an eastern provenance based on a regional-scale study over the Kaskattama highland area (~80 km to the east; Hodder and Kelley, 2018) and ongoing provenance work in this area. This is further supported by the recovery of an oolitic jasper from SB E till. Thus, it is interpreted that both tills at section 112-19-629 have an east to southeast provenance. The lower (SB E) till was depos-

ited by northwest-trending ice flow and was overprinted by a later southwest-trending ice flow, but this did not change the till composition. The upper (SB B) till was deposited by northwest- to north-northwest-trending ice flow.

Qualitatively, the lower till is significantly denser than the upper till and there is a difference in the ice-flow direction indicated above and below the intertill sorted sediments. These changes suggest that the tills were deposited during separate ice-flow events and the intertill sediments were deposited during an ice-free period following retreat of the ice that deposited the lower till. A sample of the sand (SB D) was collected for optically stimulated luminescence dating, which should help to confirm the chronology at this site.

Section 112-22-200

Section 112-22-200 on the Little Hayes Creek exposes 10.4 m of Quaternary sediments (Figure GS2022-12-4). The uppermost sediments consist of texturally bedded silt and fine sand (SB A; Figure GS2022-12-5a). These postglacial sediments are in sharp horizontal contact with an underlying 15 cm thick diamicton (SB B). The SB B diamicton is massive, matrix supported, contains 5% clasts and is sharply separated from the underlying 0.4 m thick

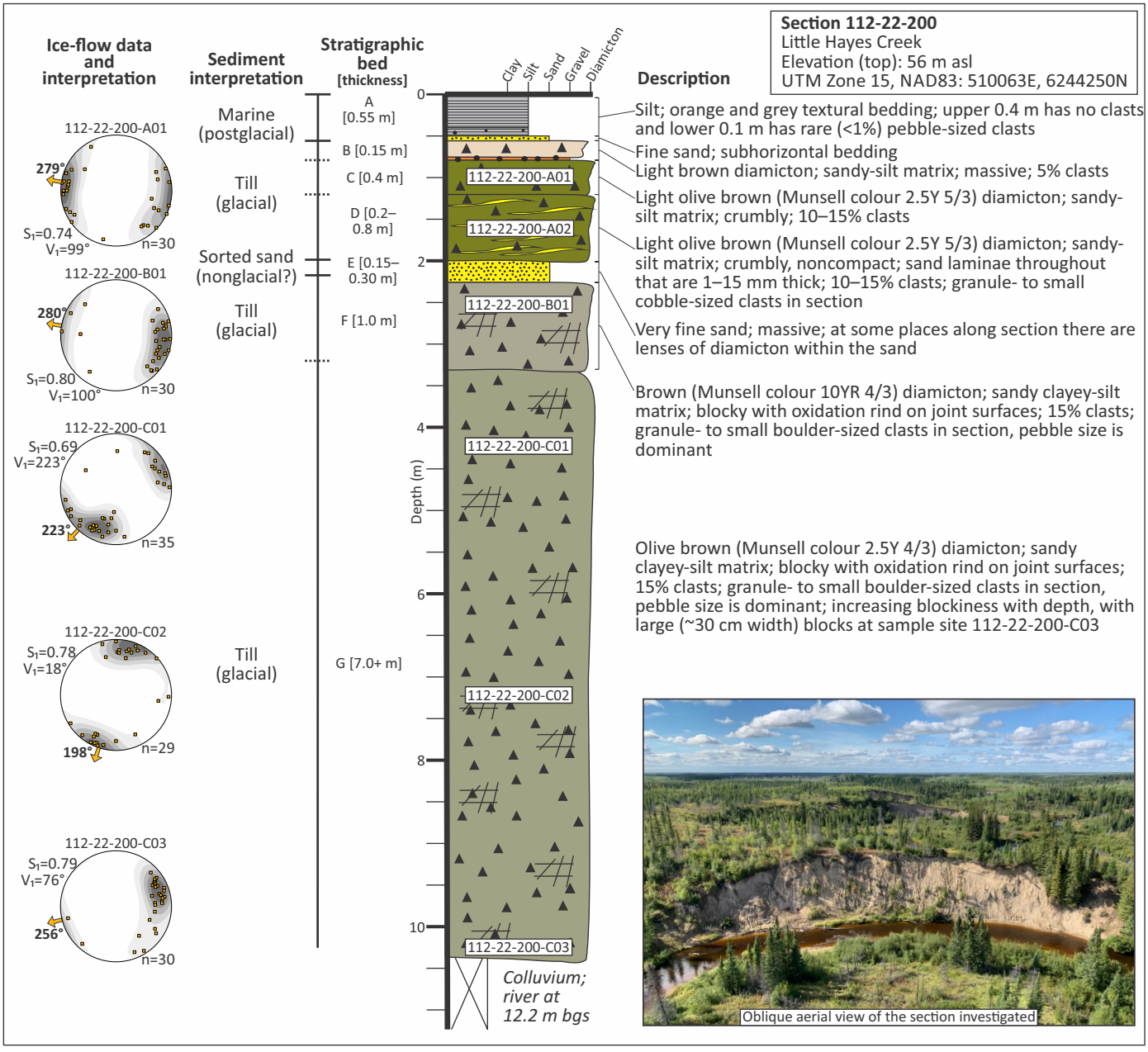


Figure GS2022-12-4: *Quaternary stratigraphy exposed at section 112-22-200 on the Little Hayes Creek. Till sample numbers and till-fabric sites are labelled within the white boxes. Till-fabric data is plotted on equal area, lower hemisphere projection stereonets. The value of the principal eigenvalue (S_1) and direction of the principal eigenvector (V_1) are provided and an interpretation of the ice-flow direction is indicated (orange arrow). Diamicton colour from Munsell Color–X-Rite, Incorporated (2015). Abbreviation: bgs, below ground surface.*

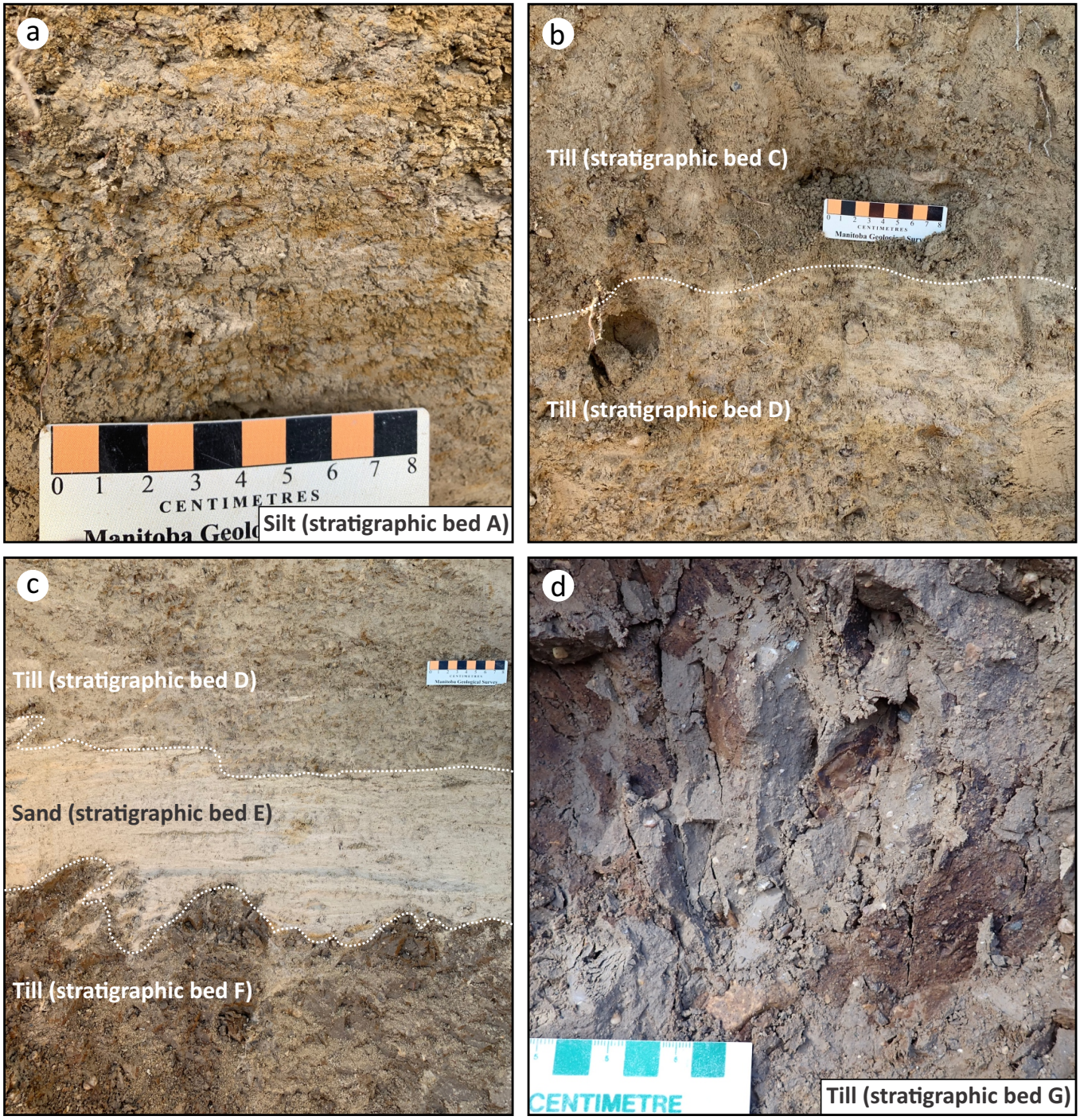


Figure GS2022-12-5: *Sediments exposed at section 112-22-200 on the Little Hayes Creek:* ***a)*** *stratigraphic bed (SB) A texturally bedded silt;* ***b)*** *SB C and D tills highlighting the sharp subhorizontal contact separating the two tills;* ***c)*** *SB D and F tills separated by very fine sand (intertill);* ***d)*** *dense blocky till of SB G.*

diamicton (SB C). Stratigraphic bed C is a light olive brown (Munsell colour 2.5Y 5/3) diamicton that is massive, matrix supported and contains 10–15% clasts (Figure GS2022-12-5b). The SB C diamicton has a sharp subhorizontal contact with an underlying 0.2–0.8 m thick diamicton (SB D; Figure GS2022-12-5b). Stratigraphic bed D is a light olive brown (Munsell colour 2.5Y 5/3) diamicton that contains sand laminae that are 1–15 mm thick throughout the sediment (Figure GS2022-12-5b). The diamicton is matrix supported and contains 10–15% clasts. The SB D diamicton has a sharp undulatory lower contact with a 15–30 cm thick sand (SB E; Figure GS2022-12-5c). Stratigraphic bed E consists of well sorted, very fine sand, though laterally this unit becomes heterogeneous and contains lenses of diamicton. The lower contact of SB E is sharp and undulatory with the underlying 1 m thick diamicton (SB F; Figure GS2022-12-5c). Stratigraphic bed F is a brown (Munsell colour 10YR 4/3) diamicton that is massive, matrix supported and contains 15% clasts. The diamicton has a blocky appearance with oxidation rind on joint surfaces. There is

a gradational contact between SB F and the underlying diamicton (SB G); the diamicton beds are qualitatively very similar except for their colour. The SB G diamicton is olive brown (Munsell colour 2.5Y 4/5), massive, matrix supported and contains 15% clasts (Figure GS2022-12-5d). The diamicton has a blocky appearance with oxidation rind on joint surfaces. Density increases with depth in SB G, and large (~20 by 30 cm) blocks are broken off at sample site 112-22-200-C03. The SB B, C, D, F and G diamictons are interpreted as tills, based on their massive structure, their texture, the glaciogenic shape of the clasts (bullet shaped, faceted and striated), the modality and strength of the clast fabrics, and the lateral continuity of beds.

Till fabrics were measured for five sample sites at section 112-22-200. A till fabric measured in SB C is interpreted to show deposition by west-trending (279°) ice flow, as is a till fabric conducted in SB F (280°; Figure GS2022-12-4). Though the ice-flow direction indicated for these two beds is identical, they are interpreted to have been deposited during separate ice-flow events based on qualitative differences, including density of the tills and presence of sorted sediments separating the beds. Next, three till fabrics were measured in SB G. The upper and middle fabrics indicate deposition by southwest-trending (198°, 223°) ice flow. The lower fabric is interpreted to show deposition by west-southwest-trending (256°) ice flow, indicating a transition in ice flow up unit from west-southwest- to southwest-trending. Future work on the composition of the till will aid in understanding this transition as it relates to this change in ice-flow orientation.

Section 112-22-201

Section 112-22-201 on the Hayes River exposes 21.1 m of Quaternary sediments (Figure GS2022-12-6). The uppermost sediments are 10 m of bedded sand and gravel with minor silt (SB A). The uppermost gravel bed contains whole valves of *Hiatella arctica,* indicating deposition within a marine environment. The bedded sand and gravel underlying this gravel contains shell fragments that are presumably of marine origin. Stratigraphic bed A is interpreted to represent a cycle of postglacial marine transgression and regression.

Postglacial sediments of SB A are in sharp horizontal contact with 2.2 m of diamicton (SB B; Figure GS2022-12-7a). The SB B diamicton is very dark greyish-brown (Munsell colour 2.5Y 3/2), massive, matrix supported and contains 15% clasts. The diamicton has a blocky appearance with oxidation rind on joint surfaces and sharply overlies a 1.2 m thick diamicton (SB C; Figure GS2022-12-7b). Stratigraphic bed C is olive brown (Munsell colour 2.5Y 4/3) diamicton that is massive, matrix supported and contains 15% clasts. Within this diamicton there is a laterally discontinuous pod of gravel that is ~1.1 m wide by 0.2 m high (Figure GS2022-12-7c). Both the SB C and D diamictons are interpreted as tills based on their massive structure, their texture, the glaciogenic shape of the clasts (bullet shaped, faceted and striated), the modality and strength of the clast fabrics, and the lateral continuity of the beds.

Stratigraphic bed C is in sharp contact with more than 7.7 m of the underlying bedded sand and diamicton (SB D). Individual beds range from 0.1 to 0.8 m in thickness and there are two distinctly different diamicton beds within SB D. The diamicton beds are either silty dark greyish-brown or sandy light brown (Figure GS2022-12-7d). The sand and diamicton beds are horizontal from 13.4 to 18.4 m below ground surface (bgs) and disturbed beyond 18.4 m bgs, with vertical contacts and convoluted bedding. Stratigraphic bed D is interpreted to have been deposited in a proglacial subaqueous setting with significant glacial input.

Till fabrics were measured in SB B and C, and both indicate deposition by northwest- or southeast-trending ice flow (Figure GS2022-12-6). Till composition data will be assessed to determine which of the ice-flow orientations deposited these beds, and if there is any variation in composition between the two beds.

Implications for diamond exploration

The two till beds at section 112-19-629 have previously been interpreted to be deposited by the same ice-flow event (Long Spruce till) and by south- to southeast-trending ice flow (Syme et al., 2004). This study, however, has determined that both tills likely have an east to southeast provenance, based on their clast-lithology composition and ice-flow data, indicating that both tills were deposited by northwest-trending ice flow. The lowermost till was later modified by southwest-trending ice flow, but this ice-flow direction change did not change the clast-lithology composition (Hodder et al., 2017). This ice-flow directional change does add an additional parameter to consider for drift prospecting since this could create complex palimpsest dispersal patterns (McClenaghan et al., 2020). Furthermore, it is suggested that the two tills were deposited by separate ice-flow events, and that there was an ice-free period between these two glacial events that deposited nonglacial sorted sediments. This new interpretation recognizes that the upper and lower tills are different in colour, texture, density and till fabrics, in addition to their separation by 2.2 m of sorted sediments.

The eastern to southeastern till provenance interpreted here implies a similar provenance for the KIM grains recovered from these tills. The recovery of relatively elevated KIM counts from samples deposited by west- to northwest-trending ice flow has emerged as a trend across two additional surveys that are situated to the east and northeast of this study area in the HBL (Hodder and Kelley, 2018; Hodder and Gauthier, 2021).

Economic considerations

Manitoba's far northeast is a remote and largely unexplored frontier area with thick drift covering much of the bedrock in the region. Results from this study continue to document the Quaternary stratigraphy, glacial history and indicator-mineral patterns

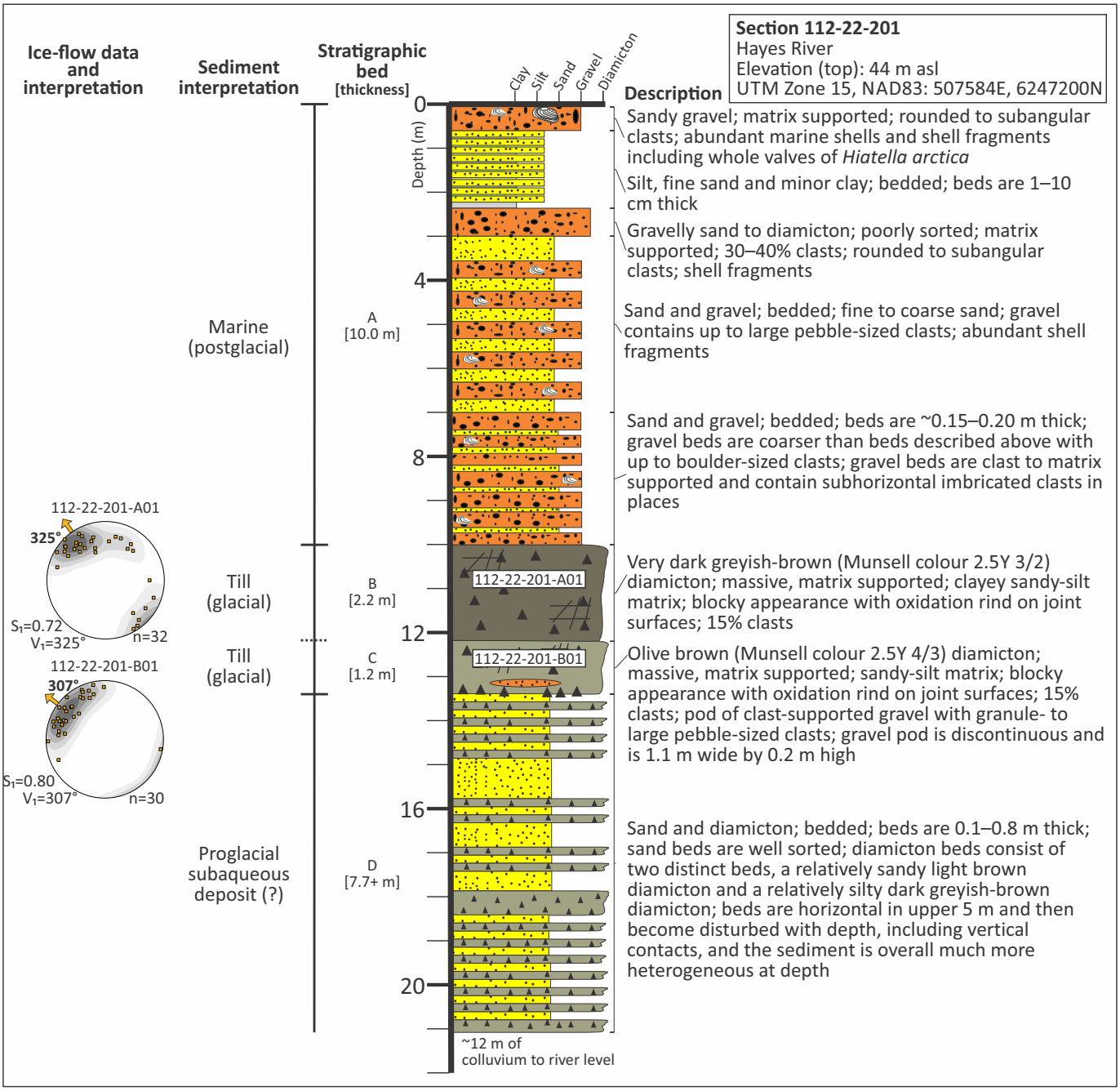


Figure GS2022-12-6: *Quaternary stratigraphy exposed at section 112-22-201 on the Hayes River. Till sample numbers and till-fabric sites are labelled within the white boxes. Till-fabric data is plotted on equal area, lower hemisphere projection stereonets. The value of the principal eigenvalue (S_1) and direction of the principal eigenvector (V_1) are provided and an interpretation of the ice-flow direction is indicated (orange arrow). Diamicton colour from Munsell Color–X-Rite, Incorporated (2015).*

in the study area. This is necessary to support drift prospecting efforts in this region of thick drift, which contains a depositional record spanning multiple glaciations.

Acknowledgments

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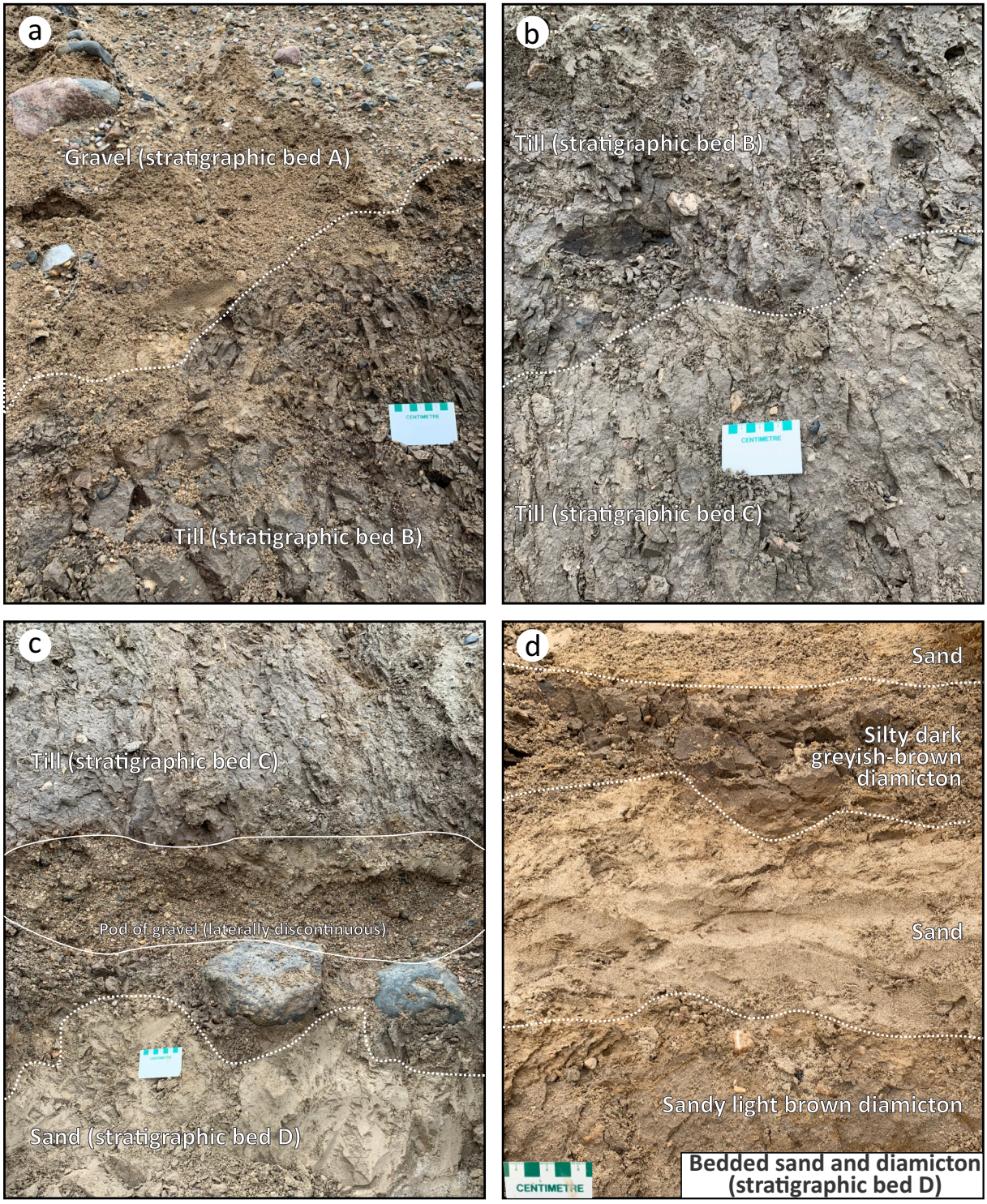

Figure GS2022-12-7: *Sediments exposed at section 112-22-201 on the Hayes River:* ***a)*** *stratigraphic bed (SB) A gravel in sharp contact with SB till;* ***b)*** *sharp contact between SB B and C tills;* ***c)*** *pod of gravel within SB C till and view of the sharp undulatory contact between SB C and D;* ***d)*** *horizontally bedded sand and diamicton of SB D.*

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