GS2017-18

Quaternary stratigraphy and till sampling in the Kaskattama highland region, northeastern Manitoba (parts of NTS 53N, O, 54B, C): year two

by T.J. Hodder

In Brief:

- Follow-up to prospective KIM and till geochemistry results from 2016
- Collection of new till samples and stratigraphic data
- Clast fabrics conducted to help reconstruct the paleo-ice flow history

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Summary

The 2017 field season in the Kaskattama highland region follows up on intriguing results from 2016 fieldwork in the area, including elevated kimberlite-indicator-mineral (KIM) concentrations, elevated till-matrix geochemistry values in multiple commodities and an elevated clast-lithology signature of undifferentiated greenstone and greywacke clasts. The goals of the 2017 field season were to collect additional surficial till samples to tighten the sampling grid, sample additional stratigraphic sections and gather accompanying ice-flow information. All of the above work will assist with drift prospecting and ice-flow reconstruction in the area.

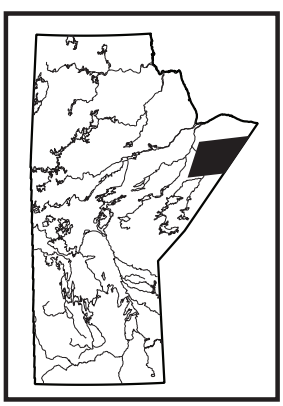
Sixty-two till samples collected in 2017 will be processed for till-matrix (<63 µm size-fraction) geochemistry and clast-lithology (2–30 mm size-fraction) analysis. At 34 till sample sites, an additional 11.4 L of till was collected, which will be analyzed for kimberlite-indicator minerals. Clast-fabric measurements were conducted at 17 stratigraphic till-sample sites to determine the ice-flow direction during deposition of the till. In addition to fieldwork, 15 till samples were collected from an archived drillcore, from a hole drilled on the Kaskattama highland, and these samples will also be processed for till-matrix (<63 µm size-fraction) geochemistry and clast-lithology (2–30 mm size-fraction) analysis.

Introduction

In July 2017, the Manitoba Geological Survey (MGS) conducted Quaternary fieldwork in the Kaskattama highland region of northeastern Manitoba (parts of NTS 53N, O, 54B, C; Figure GS2017-18-1). This work builds upon observations and analytical results from the 2016 field season (Hodder and Kelley, 2016, 2017). The purpose of this study is to document the till composition and Quaternary stratigraphy in this remote region, as well as provide baseline values for drift exploration. This study is also part of a renewed evaluation of the Quaternary stratigraphy in the Hudson Bay Lowland region of Manitoba (Trommelen, 2013; Trommelen et al., 2014; Kelley et al., 2015).

The goals and rationale of the 2017 field season were to

- conduct additional kimberlite-indicator-mineral (KIM) sampling to follow up on elevated KIM results from the 2016 till samples; the highest single sample-count recovered in 2016 was 17 KIMs (Hodder and Kelley, 2017), and average recovery from 2016 samples was more than double the mean amount of KIMs recovered in the prospective Knee Lake area (approximately 250 km southwest of the study area; Anderson, 2017);
- follow-up on unexpected elevated till-matrix geochemistry values of Au, Cu, Fe, Ni, Zn and Cr returned in 2016 samples, including a gold grain recovered from a KIM sample;
- document the sediments present at Quaternary sections, sample till and conduct clast-fabric measurements to determine the ice-flow direction during deposition of sampled till, which in turn guides drift exploration studies; and
- conduct additional surficial till sampling to establish compositional variations observed between streamlined-landform flowsets in the study area, including following up on elevated concentrations of undifferentiated greenstone and greywacke clasts identified in some 2016 till samples (Hodder et al., 2017b).



Previous work

The Kaskattama highland region is largely unexplored, primarily due to remoteness. Diamond exploration within the study area has taken place primarily through airborne geophysical surveys. A single drillhole was completed on the northwest side of the highland, the drillhole is Foran Mining Kaskattama Kimberlite No. 1 and referred to as KK1 (Figure GS2017-18-1; Nicolas and Armstrong, GS2017-12, this volume; Assessment File 74223, Manitoba Growth, Enterprise and Trade,

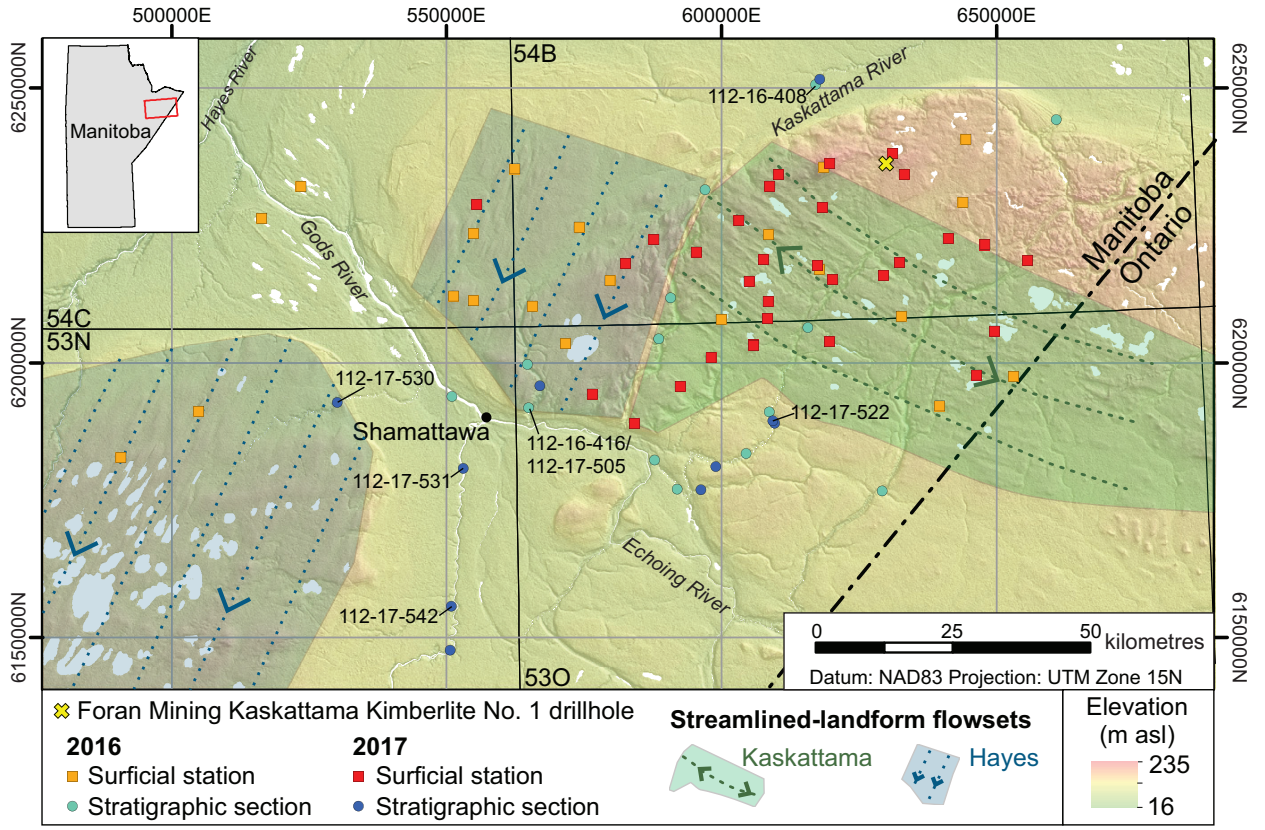


Figure GS2017-18-1: *Stations visited during the 2016 and 2017 field seasons, Kaskattama highland region, northeastern Manitoba. Sections discussed within the text are noted. Background hillshade image was generated using Canadian Digital Surface Model (Natural Resources Canada, 2012).*

Winnipeg). This drillhole intersected 223 m of inferred Quaternary sediments.

General knowledge of the Quaternary stratigraphy in northeastern Manitoba comes from descriptions of river-cut sections along the Hayes, Gods, Kaskattama and Echoing rivers, and the Nelson, Angling, Fox, Stupart and Pennycutaway rivers to the west of the study area (B.G. Craig, H. Gwyn and B.C. McDonald, unpublished notes, 1967; Netterville, 1974; Dredge and Nielsen, 1985; Dredge et al., 1990; Nielsen, 2002; Nielsen and Fedikow, 2002; Hodder et al., 2017a). Thick stratigraphic sections expose a long glacial history, including deposition from two or three different glacial and interglacial events (e.g., Dredge and McMartin, 2011). Observations of Quaternary stratigraphy in the Kaskattama highland region has been limited to reconnaissance-scale, mostly unpublished, observations from the Geological Survey of Canada's Operation Winisk (B.G. Craig, H. Gwyn and B.C. McDonald, unpublished notes, 1967), which included river traverses and helicopter-supported fieldwork across the Hudson Bay Lowland region in Quebec, Ontario and Manitoba (McDonald, 1968).

Greenstone, greywacke and the potential for a buried Precambrian inlier

In 2016, elevated concentrations of undifferentiated greenstone and greywacke clasts were identified in some till samples (Hodder et al., 2017b). The Kaskattama region is underlain by Paleozoic carbonate (Nicolas and Young, 2014), and hence the presence of these clast lithologies was unexpected. Additional geophysical surveys, sampling and drilling is required to confirm the suspicion that these undifferentiated greenstone and greywacke clasts are sourced locally, from a buried inlier of the Precambrian shield—much like the Sutton ridge in Ontario (Stott et al., 2010).

Regional setting

The Kaskattama highland in northeastern Manitoba, a prominent topographic high within the Hudson Platform, 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 northeastward into Hudson Bay. The Kaskattama River drains northeastward to Hudson Bay with the headwaters situated on the Kaskattama highland.

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 GS2017-18-1). Firstly, the curvilinear Kaskattama flowset overlies the Kaskattama highland. There is evidence for both northwest- and southeast-trending ice flow in the regional record, and the trend of this flowset is uncertain. Secondly, the Hayes flowset is a large, radiating, southwest-trending flowset, which starts in the study area and extends to the southwest. The Hayes flowset is part of the large deglacial Hayes lobe (Dredge and Cowan, 1989), which was approximately 320 km long and 270 km wide.

Bedrock geology

Regionally, the area is underlain by Paleozoic carbonate sedimentary rocks of the Hudson Bay Basin (Nicolas and Young, 2014), 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.

Methods

Helicopter-supported fieldwork was undertaken in July 2017. A total of 43 stations were visited to document both the Quaternary stratigraphy along natural sections and sediments present at surficial stations. Surficial till samples were collected from C-horizon material in mud boils (e.g., Figure GS2017-18-2a) or from hand-dug pits (e.g, Figure GS2017-18-2b). Mud boils are the preferred till-sampling sites, as these permafrost features bring unweathered till to the surface (McMartin and McClenaghan, 2001). Whenever possible, sample pits were dug in the crests of streamlined landforms (e.g., Figure GS2017-18-2c, d) to avoid postglacial sediments typically deposited at lower elevations around these landforms. Till encountered at natural exposures was sampled at 2–4 m intervals, depending on changes in stratigraphy and restrictions on the weight of samples being hauled out.

Sixty-two new till samples, each weighing 2–3 kg, were collected from C-horizon tills, bringing the total number of till samples to 119 for this study (Figure GS2017-18-3). The new till samples were split for archival purposes at the MGS Midland Sample and Core Library and then submitted for processing, till-matrix geochemistry (<63 µm size-fraction) and clast-lithology (2–30 mm size-fraction) analyses. At 34 till sample sites, an additional 11.4 L of till was collected for KIM analysis, which brings the total to 64 KIM samples for this study. Blind KIM 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 at a later date. The KIM results from the 2016 field season have been released (Hodder and Kelley, 2017b) and the sample locations are depicted on Figure GS2017-18-3.

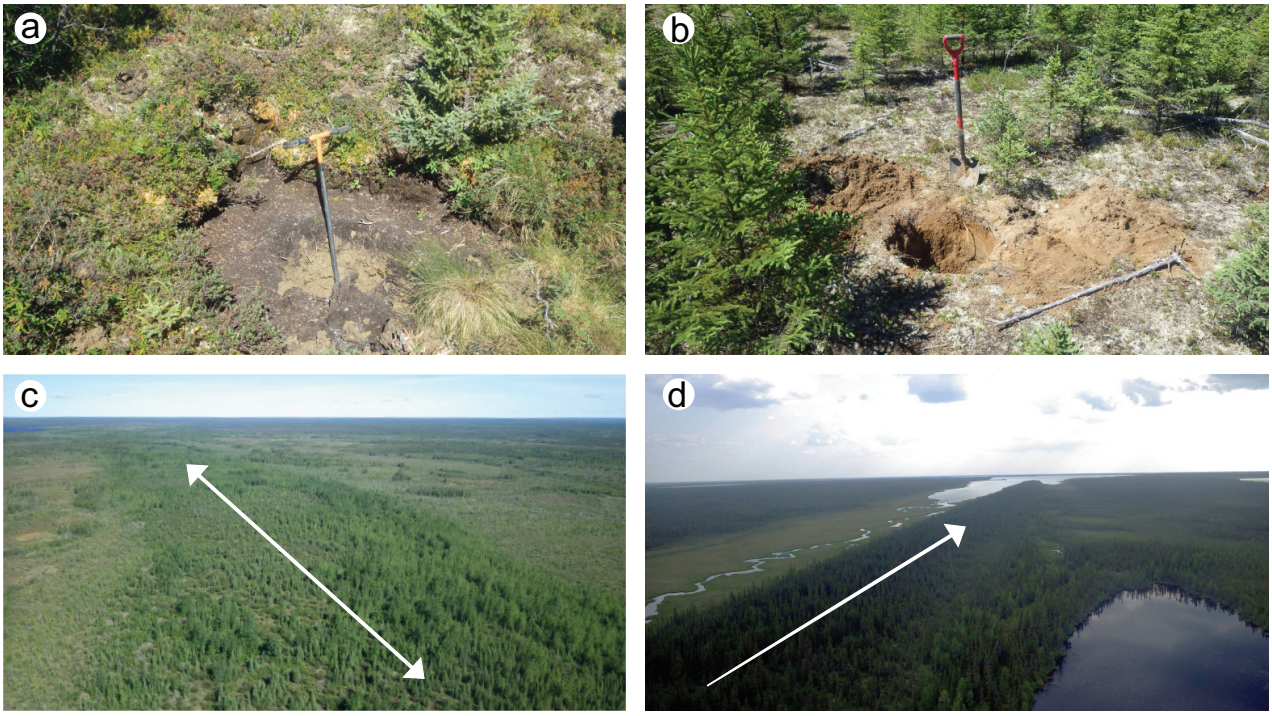


Figure GS2017-18-2: *Geomorphic expressions of till sampled in the study area:* ***a)*** *example of a vegetated, inactive, permafrost mud boil, which provides easy access to unweathered surficial till;* ***b)*** *example of a hand-dug pit used to sample surficial till where mud boils don't occur;* ***c)*** *northwest-southeast–oriented drumlin within the Kaskattama flowset;* ***d)*** *southwest-trending drumlin within the Hayes flowset.*

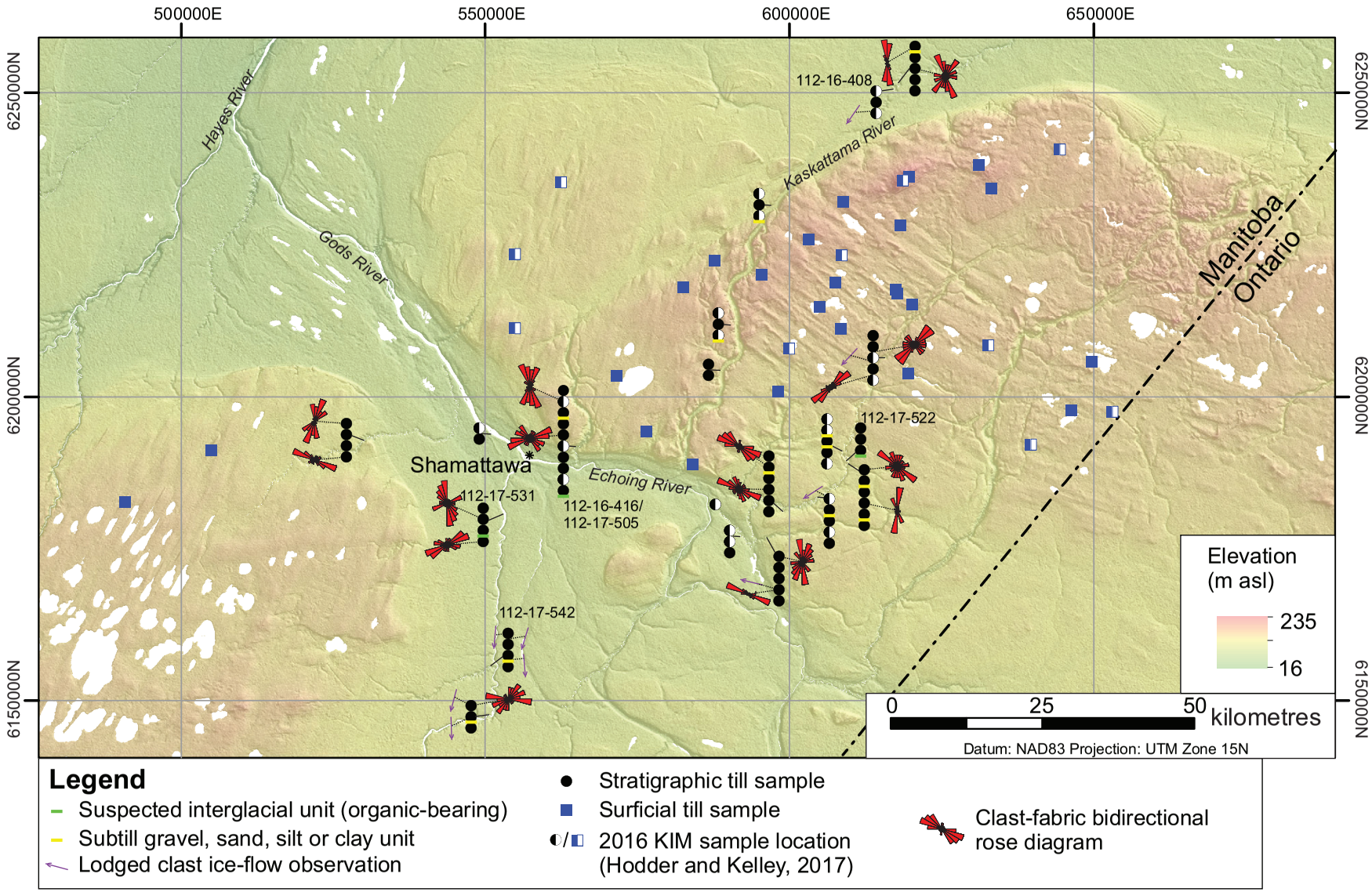


Figure GS2017-18-3: *Sites of surface and subsurface till samples collected in the Kaskattama highland region, northeastern Manitoba. Stratigraphic bidirectional ice-flow data, determined by measurements of clast fabrics and/or lodged striated clasts, are depicted. The 2016 kimberlite-indicator-mineral (KIM) sample sites are displayed. Background hillshade image was generated using Canadian Digital Surface Model (Natural Resources Canada, 2012).*

Ice-flow data was obtained from studied sections by measuring the long-axes orientation, or fabric, of clasts within till. It has been proven that certain shapes of clasts, defined as a particular arrangement of the a-axis (longest), b-axis (middle) and c-axis (shortest), will deposit parallel to the direction of stress that the overriding glacier puts on the till (Holmes, 1941). Clast fabric measurements were conducted at 17 sample sites. Sites were chosen based on uniformity of till and the absence of sand lenses or discontinuous bedding. At each site, a horizontal step was excavated at least 20 cm into the section face. Clasts were then carefully excavated and measured from within a 'box' consisting of three vertical faces of different orientations, over a maximum distance of 30 by 30 by 30 cm. Measurements were taken of the length of all axes, the a-axis orientation and the dip of the a-axis. At each site, the orientations of 30 rod, tabular-rectangle or wedge-shaped, elongate (a:b ratio of ≥1.5) clasts were recorded. Lodged clasts with parallel striae on their upper surface—considered to be a good indicator of ice flow—were observed at nine stratigraphic depths (Figure GS2017-18-3) and examples are presented in Figure GS2017-18-4.

In addition to fieldwork conducted, the KK1 drillcore (Figure GS2017-18-1) was pulled from the MGS archive and re-examined. The till that was present from 82–167 m depth was split and sampled at 5–8 m intervals, resulting in 15 till samples. These till samples will be processed for till-matrix (<63 µm size-fraction) geochemistry and clast-lithology (2–30 mm size-fraction) analysis.

Preliminary results

Ice flow

In 2017, clast fabric measurements were conducted at seven new sections and two sections initially visited in 2016 (Figure GS2017-18-3). When interpreting clast fabrics, it is commonly assumed that ice-flow direction was the opposite direction of that to which the clasts dip/plunge (Mark, 1974; Kjaer and Kruger, 1998). However, several studies, including MGS unpublished studies within the Hudson Bay Lowland, have since noted that only 40 to 60% of till fabrics dip up-ice, whereas the remainder dip down-ice (Andrews and Smith, 1970; Saarnisto and Peltoniemi, 1984; Larsen and Piotrowski, 2003). Additionally, till fabrics can have low dips, meaning that a preferred dip direction is not specified (Drake, 1974; Catto, 1998). As such, preliminary fabric data is displayed on bidirectional rose diagrams in Figure GS2017-18-3. Regional ice-flow interpretations give no indication that ice has flowed to the north, northeast or east, and hence an orientation of flow could be assigned to those clast fabrics that trend south, southwest or west. The regional ice-flow history neither precludes nor prefers ice flow to the northwest or southeast and thus assigning a trend to these clast fabrics is difficult. The data and further results, such as Schmidt equal-area stereonets and eigenvalue and eigenvector statistics, will be published in a forthcoming paper. Interpretations may be somewhat revised once till-composition data has been analyzed.

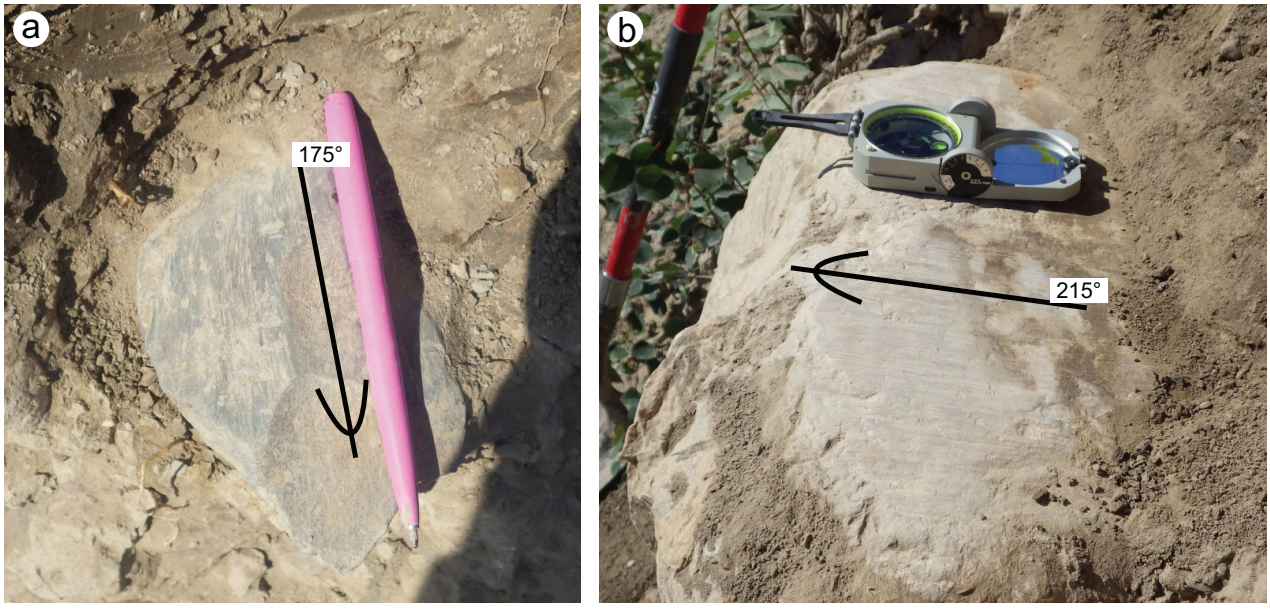


Figure GS2017-18-4: *Examples of lodged striated clasts that can be used to interpret ice-flow direction:* ***a)*** *lodged bullet-shaped cobble with parallel striae on its upper surface indicating ice flow toward 175° at a depth of 14.6 m at section 112-17-542;* ***b)*** *lodged boulder with parallel striae on its upper surface indicating ice flow toward 215° at a depth of 11.0 m at section 112-16-408.*

Regional ice-flow interpretations, including along portions of the Gods and Hayes rivers (depicted on Figure GS2017-18-3), can be found in Hodder et al. (2017a). That study releases data collected in 2001 and 2002, and also provides an analyses of the till composition.

The Hayes and Kaskattama flowsets do not overlap and therefore relative ages cannot be directly inferred from cross-cutting relationships of streamlined landforms. However, based on regional reconstructions it is anticipated that the Kaskattama flowset preceded the Hayes flowset, which is suspected to have been the last major ice-flow phase in this region (Dredge and Cowan, 1989).

Quaternary stratigraphy

The Quaternary stratigraphy was documented at nine sections along active river-cuts during the 2017 field season.

Section 112-17-542 (Figure GS2017-18-5) is an example of a section described during the 2017 field season. Section 112-17-542 is located 36.5 km south of Shamattawa along the Gods River (Figure GS2017-18-1) and exposes three diamict units recognizable in the field. The upper diamict is soft and olive brown (Munsell colour 2.5Y 4/3; Munsell Color–X-Rite, Incorporated, 2015), and is separated from the middle diamict by a boulder pavement (Figure GS2017-18-5c). The middle diamict is dense, blocky, dark greyish–brown (Munsell colour 2.5Y 4/2), and has a sharp, undulating lower contact with a 0.3 m thick, partially cemented sand and sandy gravel unit (Figure GS2017-18-5d). The lower diamict is greyish brown (Munsell colour 2.5Y 5/2) and is noticeably denser than the upper and middle diamicts. All three diamicts are interpreted as tills, because they are massive and contain striated clasts of various lithologies.

A striated clast within the upper till at 7.5 m depth indicates deposition by south-trending (185°) ice flow. A striated clast at the boulder pavement indicates deposition by south-southwest–trending (197°) ice flow. Collectively, these observations suggest deposition by ice flowing to the south. Near the lower contact of the middle till, a clast with parallel striation on its upper surface (Figure GS2017-18-4a) indicates ice flow toward 175°. Till-composition data is needed to confirm whether the upper and middle tills have the same composition, and hence were both deposited during southerly ice flow. If the composition is different, it would indicate slightly different (south-southwest versus south-southeast) ice-flow direction during deposition of the till units.

Suspected interglacial sediments

Subsurface organic-bearing sequences have been noted in the study area by previous workers, and interpreted to be of interglacial age (Dredge and Nielsen, 1985). Although organic-bearing sequences are rare, they are often correlated with the more abundant oxidized sand and gravel found below or between till units in exposed sections (Dredge et al., 1990; Dredge and Nixon, 1992; Dredge and McMartin, 2011). Deposits found in Manitoba, such as the Nelson River sediments (Nielsen et al., 1986; Nielsen and Fedikow, 2002) and the Gods River sediments (Netterville, 1974), may be correlative to the better studied Missinaibi Formation found in Ontario and Quebec (Wyatt, 1990; Thorleifson et al., 1993; Dalton et al., 2016).

Subsurface organic-bearing sequences are rare, and were observed at only three sections (Figures GS2017-18-3, 6). These subsurface units can consist of multiple beds (Figure GS2017-18-6a, b) or a single, laterally discontinuous bed (Figure GS2017-18-6c). There may be scattered pieces of wood and/or shell fragments, or organic-rich lenses within a sediment unit (Figure GS2017-18-6). One of these sections, section 112-17-522, is known as the “Echoing River” section (Dredge and Nielsen, 1985; Dredge et al., 1990; Dredge and McMartin, 2011) despite its location on an unnamed tributary. At this site, Dredge and McMartin (2011) suggested that the lower black clay is possibly marine, as it contains foraminifera in addition to elevated quantities of boron and vanadium. The upper sediments of this sequence are interpreted as having been deposited within terrestrial or shallow freshwater environments, as they consist of silt, marl and peat with infinite ^{14}C-age gastropods and spruce twigs (samples GSC-892 and GSC-4444HP, Dredge et al., 1990). The ages of all of these subtill organic-bearing units are unknown. However, they are currently being further characterized from a paleoenvironmental perspective using isotopic and deoxyribose nucleic acid (DNA) methods undertaken at the University of Colorado (Boulder, Colorado) and University at Buffalo (Buffalo, New York).

Inorganic subsurface beds of sorted sediments, situated below or within till units and termed ‘subtill sorted units’, were encountered at 50% (10 out of 20) of the sections where till outcrops (Figure GS2017-18-3). These include massive to bedded layers of sand, sand and gravel, silt and/or clay, devoid of organics, that typically have sharp upper and lower contacts. Subtill sorted units vary from 0.1 to >3.0 m thick. These inorganic subtill sorted units may have been deposited during an interglacial or interstadial period. Alternatively, they may be subglacial units that record decoupling at the ice-bed interface or the presence of subglacial lakes.

Future work

Future work will continue to focus on interpreting till-matrix geochemistry, clast-lithology and KIM analytical results. Ice-flow data and stratigraphic observations will be combined with till-composition results to provide a more thorough understanding of the Quaternary history of the study area and to assist drift prospecting practises in the region.

This work, in conjunction with studies conducted on the Nelson River and reinterpretation of earlier work along the Hayes and Gods rivers, will be used to aid ongoing efforts to reconstruct the glacial stratigraphy of the Hudson Bay Lowland. Additional characterization of subtill organic-bearing sediments is being conducted by S. Crump (University of Colorado) and E. Thomas (University at Buffalo).

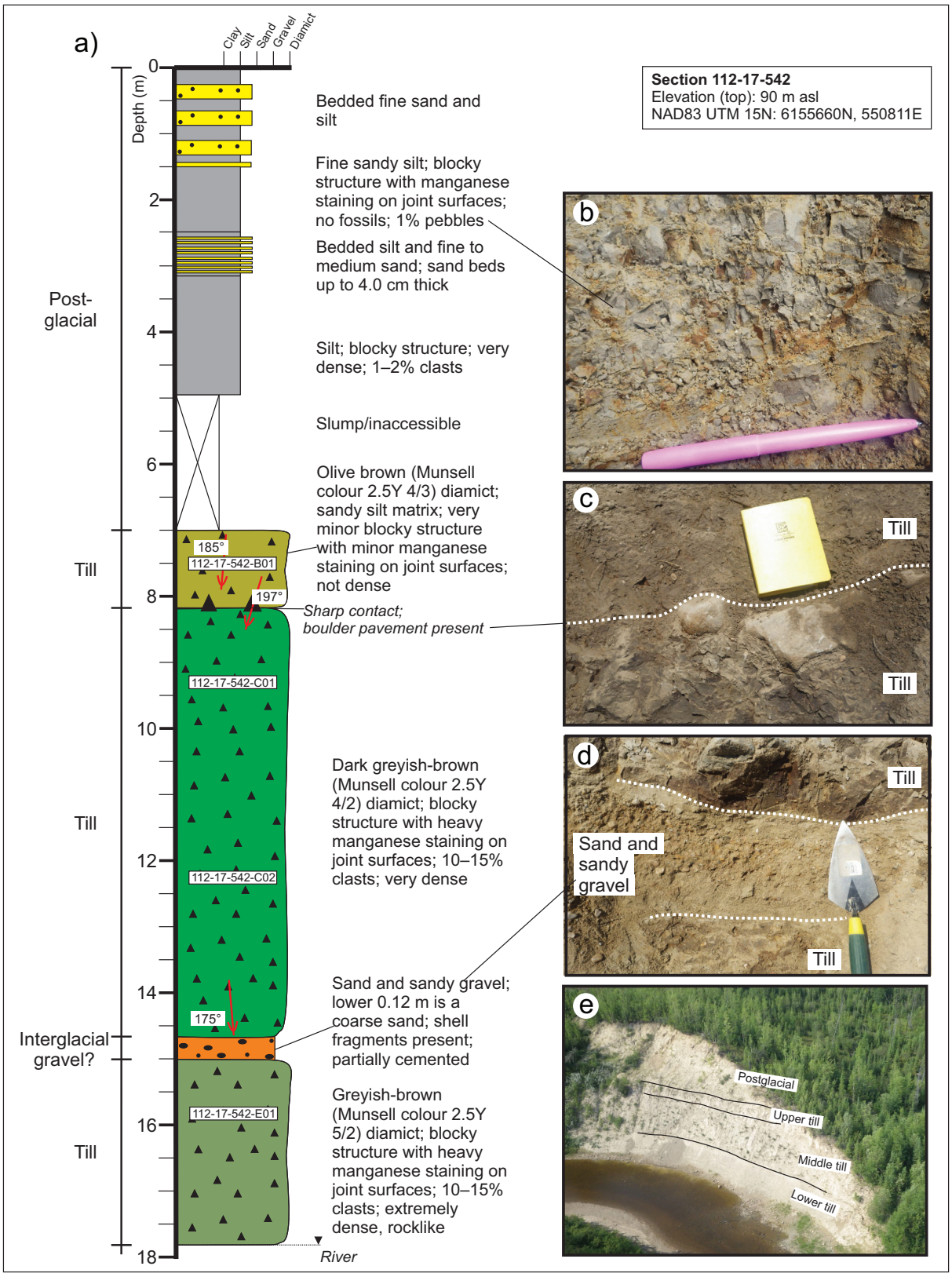


Figure GS2017-18-5: *Example of a stratigraphic section described and sampled during the 2017 field season.* ***a)*** *Stratigraphy at section 112-17-542. Till-sample numbers are labelled within the white boxes. Munsell colour was determined using Munsell Color–X-Rite, Incorporated (2015). Locations of lodged, striated clasts are indicated by red arrows and azimuths measured are indicated.* ***b)*** *Blocky, postglacial, fine sandy silt.* ***c)*** *Boulder pavement contact between the upper and middle till.* ***d)*** *Upper and lower contact of the subtill sand and sandy gravel unit.* ***e)*** *Oblique aerial view of section 112-17-542.*

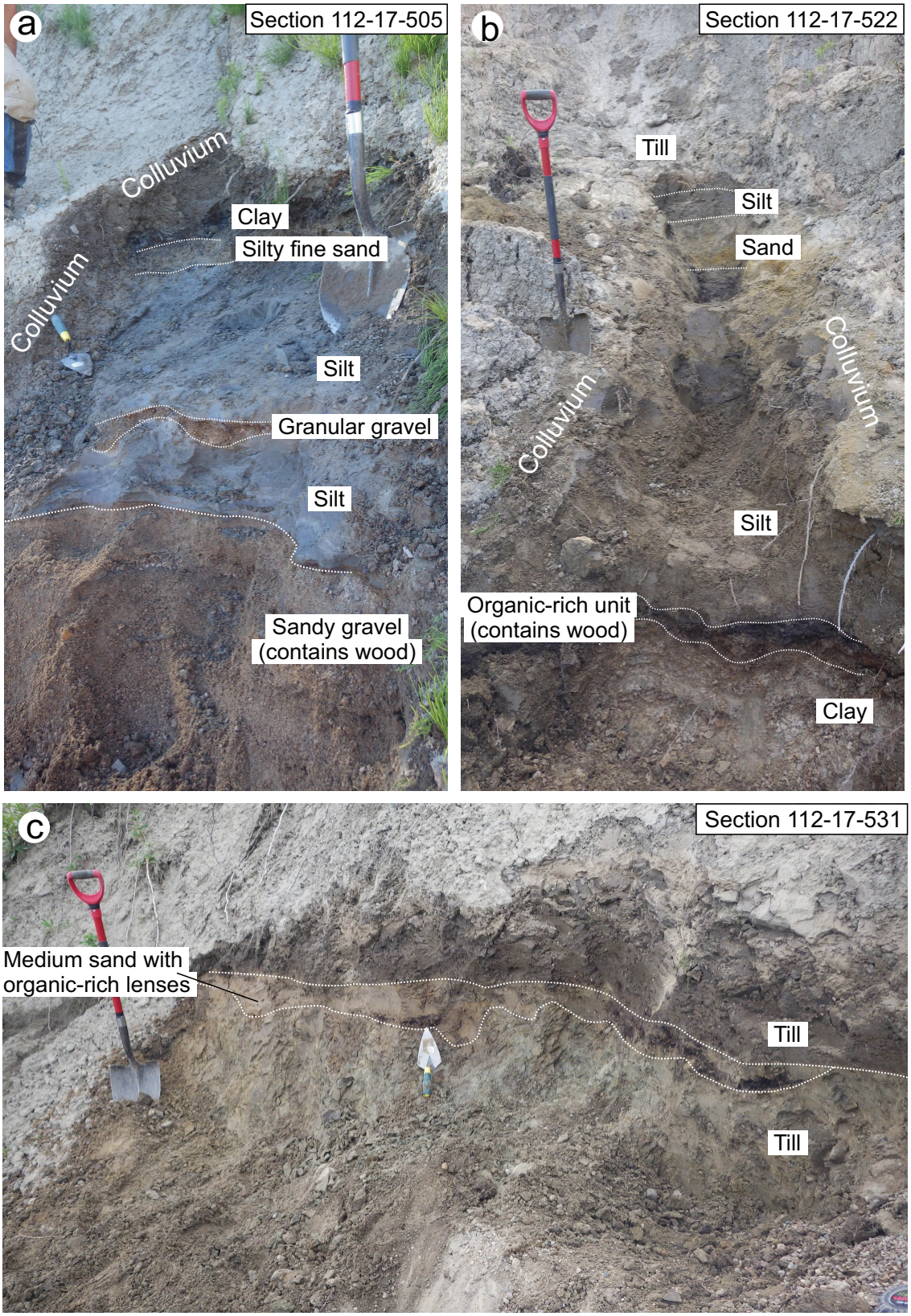


Figure GS2017-18-6: *Examples of subsurface organic-bearing sediments observed in the Kaskattama highland region:* ***a)*** *subtill inorganic- and organic-bearing sediments at 31.0–31.2 m depth at section 112-17-505;* ***b)*** *subtill inorganic- and organic-bearing sediments at 6.0–8.5 m depth at section 112-17-522;* ***c)*** *laterally discontinuous bed of thin subtill organic-bearing sediments at 11.8 m depth at section 112-17-531.*

Economic considerations

The Kaskattama highland region is a largely unexplored region of northeastern Manitoba. This study, started in 2016, is documenting the Quaternary stratigraphy and till composition in the region. The KIM grains recovered during the 2016 field season have hinted at the diamond potential of the region, and 2017 results will provide additional data. Elevated till-matrix geochemistry values in elements of economic interest have been documented and additional sampling conducted during the 2017 field season followed-up on these areas. Till-composition data coupled with ice-flow data will provide insight into potential glacial dispersal patterns in the Kaskattama highland area.

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