

GS-12 Preliminary Quaternary geology in the Gillam area, northeastern Manitoba – year 3 (parts of NTS 54D5–9, 11, 54C12) by S.E. Kelley¹, T.J. Hodder, Y. Wang¹, M.S. Trommelen and M. Ross¹

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Summary

Two weeks of fieldwork were conducted in the summer of 2015, in the Stephens Lake area near the town of Gillam and along the Nelson River downstream from Gillam, in northeastern Manitoba. Fieldwork included collection of till samples for textural and geochemical analyses, as well as descriptions of surficial materials for mapping and stratigraphy. This work builds upon two previous Manitoba Geological Survey field seasons led by M.S. Trommelen in 2013 and 2014, and provides additional field data for an M.Sc. project at the University of Waterloo. During the previous field seasons, six ice-flow phases were identified in the landform (depositional) and bedrock (erosional) records. A goal of the 2015 field season was the collection of till samples and clast-fabric measurements to examine local till stratigraphy in the context of previously recognized ice-flow phases. The quantitative properties of till samples, such as grain size, geochemistry and clast lithology, will assist in the correlation of local till units. In total, 39 sites were visited and 44 till samples were collected. Ten new stratigraphic sections were documented along the Nelson River, bringing the total number of sections examined/re-examined to 42. These new data and observations will address questions raised in the previous field seasons, and add to our growing understanding of the complex glacial history of northeastern Manitoba.

Introduction

In 2015, the Manitoba Geological Survey (MGS) continued a Quaternary geology multiyear collaborative program with the University of Waterloo. The goal is to investigate the Quaternary stratigraphy of the Gillam area of northeastern Manitoba, with the aim of unravelling the glacial history in terms of surficial materials (mapping and aggregate-resource assessment) and till composition as it relates to drift exploration. Exposures of Quaternary sediments, typically up to tens of metres high, along the Nelson River record deposition from at least three glacial cycles (Dredge and McMartin, 2011). At many sites, the glacial and interglacial sediments are overlain by Holocene lacustrine and marine deposits, left as the Laurentide Ice Sheet (LIS) retreated. Findings from the first two years of the project have started to unravel the complex Quaternary geology of the Gillam area, but a number of

questions still need to be resolved (Trommelen 2013; Trommelen et al., 2014).

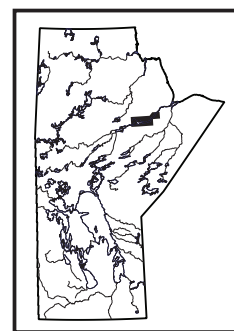
This report presents a synthesis of initial results from the August 2015 field season. Objectives for the field season included mapping additional field sites along the shores of Stephens Lake and the local road network, revisiting key stratigraphic sites to collect additional data and samples, and documenting ten new stratigraphic sections along the Nelson River below the Limestone dam (Figure GS-12-1). The 2015 fieldwork builds upon two previous field seasons (Trommelen, 2013; Trommelen et al., 2014), as well as earlier, primarily airphoto-based mapping (Klassen and Netterville, 1980) and numerous stratigraphic investigations (Klassen, 1972; Klassen and Netterville, 1973; Nielsen and Dredge, 1982; Dredge and Nielsen, 1985; Klassen, 1986; Nielsen et al., 1986; Roy, 1998; Nielsen, 2001, 2002; E. Nielsen, unpublished data [Pebble lithology of sections in the Hudson Bay Lowland], 2002). The volume of previous work highlights the geological interest in this area, while the contrast in interpretations within the publication record emphasizes complexities and outstanding questions with respect to ice-flow history and ice-sheet dynamics (Trommelen et al., 2014).

Physiography

The Gillam area has relatively low relief, with the exception of large (30–50 m) bluffs along the Nelson River (Figure GS-12-2). The Nelson River flows north-east and drains into Hudson Bay. There are three major hydroelectric dams in the area (Kettle, Long Spruce and Limestone), with attendant reservoirs upstream (Stephens Lake being the largest), as well as two hydroelectric projects currently under construction (Keeyask and Keewatinohk; Figure GS-12-1). The region is gently sloping, poorly to moderately drained and covered mainly by spruce bogs and forests. Shallow permafrost is common in most areas. Due to the thick drift cover, bedrock exposure is poor in the region and generally restricted to rare, low-lying outcrops.

Methods

Truck- and boat-accessible fieldwork was undertaken at 39 sites during a two-week period in August of 2015,



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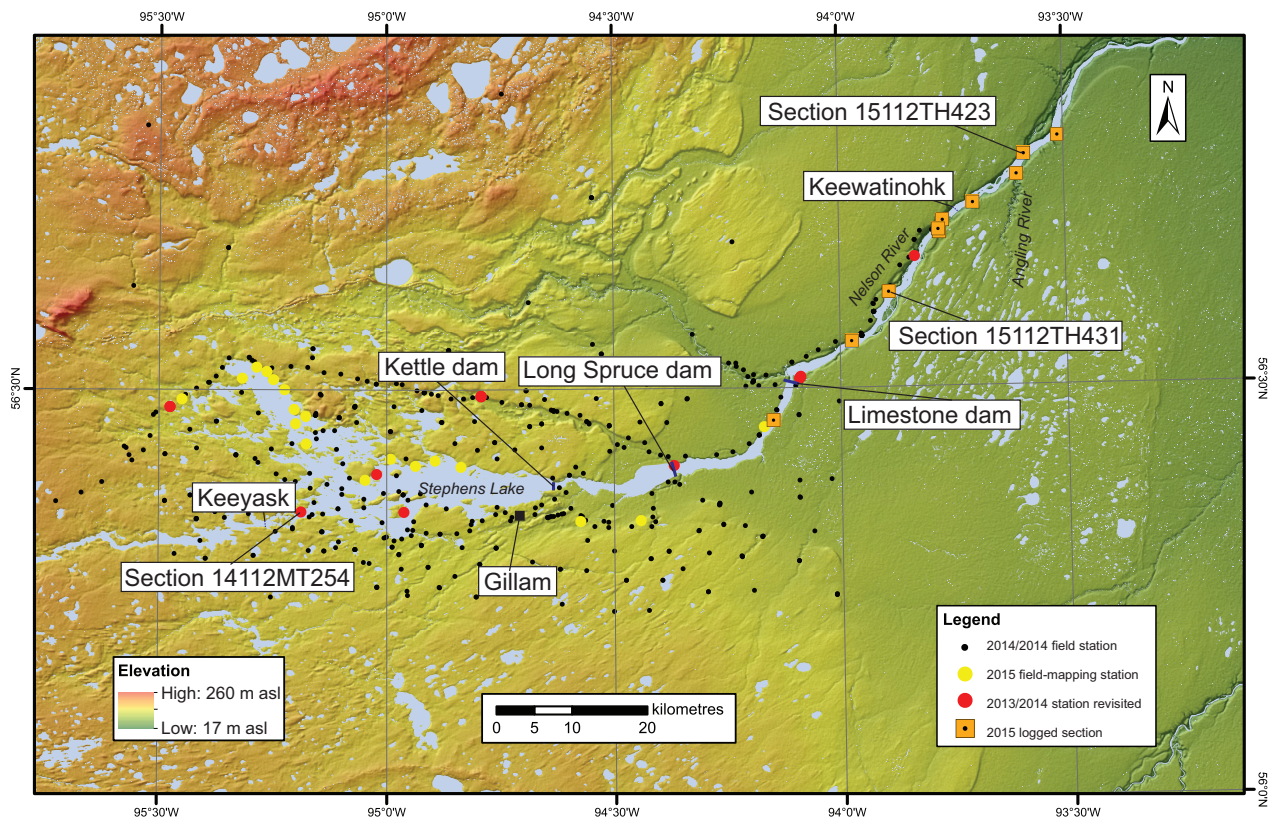


Figure GS-12-1: Study area and 2015 field sites in northeastern Manitoba, showing approximate locations of the Keewatinohk and Keeyask construction projects; background hillshaded image generated using the Canadian Digital Surface Model Mosaic (Natural Resources Canada, 2012).



Figure GS-12-2: Example of the thick Quaternary stratigraphy visible along the Nelson River (vertical relief ~50 m), looking from section 15112TH431 down river to the northeast; see Figure GS-12-1 for location.

based out of the town of Gillam. Investigations focused on two types of sites: 1) sections where multiple stratigraphic units are visible and relationships could be assessed; and 2) surficial-mapping sites where additional detail was needed to aid mapping from previous field seasons. Field observations at surficial-mapping sites included description of vegetation, local relief and surficial materials examined to a depth of ~1.2 m (reached with a Dutch auger or shovel). Additionally, the orientations of striations and grooves were measured when encountered. At

sections, each unit was described and distinguished based on texture (grain size), structure, colour and depth with relation to other units within the exposure.

Twenty-five shell and wood samples were collected for radiocarbon dating from silts, sands and gravels that are interpreted to be postglacial. Suspected interglacial sediments found between till units in two sections along the Nelson River were sampled for paleoenvironmental analyses. One site is new and one was previously described (Roy, 1998; Trommelen et al., 2014).

Forty-four till samples, each weighing approximately 2–3 kg, were collected from C-horizon tills throughout the study area and will be submitted for textural, geochemistry (<63 µm fraction) and clast lithology (2–30 mm fraction) analyses. Clast- and magnetic-fabric measurements (see below for more detail about fabric measurements) were conducted at stratigraphic sections in order to assess paleo-ice flow. Till samples collected in 2015 are all from new mapping and stratigraphic field sites. Results from these samples will be added to the regional database of till-sample analyses compiled over the last two years. Ongoing work strives to differentiate between till units within (time) and between (space) stratigraphic sections and field-mapping sites.

Clast- and magnetic-fabric measurements were conducted at 12 stratigraphic sections. Clast-fabric measurements were taken on elongate clasts (with an a:b ratio of 1.5:1 or greater) within excavations, measuring approximately 30 by 30 by 30 cm, into till exposures. Clasts touching other clasts within the till were not measured, nor were small clasts situated near much larger clasts. This was done to ensure that the clasts were matrix supported and would have been allowed to align to local stresses within the till matrix. Samples for magnetic-fabric measurements were also collected from similar 30 by 30 by 30 cm excavations into the till. From each excavated area, 25 individual 1 cm³ plastic geomagnetic sampling boxes were filled with sediment following the methods of Hopkins et al. (in press). To collect a sample, a pedestal was carved out of the till and an uncapped sampling box was fit over the pedestal. The dip of the box in three directions and the orientation of the z-axis (into the face) were measured before the sample was broken off the exposure for collection. The magnetic fabric of samples will be analyzed using an AGICO Kappabridge at the Western University paleomagnetism lab in the fall of 2015. When measured, each magnetic fabric will consist of compiled measurements for the 25 separate samples from the single, 30 by 30 by 30 cm sampling location.

Preliminary results

Stratigraphy

Sections were visited along lakes and rivers throughout the study area. Lake and river levels frequently vary due to local control by hydroelectric dams, resulting in frequent changes in the number, extent and quality of exposures. The 2015 fieldwork focused on documenting new exposures, obtaining additional fabric measurements (both clast and magnetic) and sampling of till units for textural, geochemical and clast-composition analyses.

Section 15112TH431

Figure GS-12-3 illustrates observations and data collected at a newly described section from this summer (section 15112TH431 on Figure GS-12-1). The site is located

on the Nelson River, approximately 20 km northeast of the Limestone dam. At section 15112TH431, 11 m of sands, silts and gravel overlie 22 m of diamict. The sands, silts and gravel are interpreted as postglacial sediments, which were deposited during changing environmental conditions during the local retreat of the LIS. The diamict is chocolate brown with 5–15% clasts and a sandy-clay matrix. It becomes increasingly blocky and stiff with depth, and manganese staining was observed from ~16 m depth downward, its prevalence increasing with depth. This diamict is interpreted as till, deposited during one or more glacial cycles. Due to its great thickness, it remains to be determined whether the till section is composed of one or multiple till units, possibly deposited over a long period of time and from multiple directions. Composition and fabric data will be used to resolve this question.

Section 15112TH423

Figure GS-12-4 is a second example of a newly described section, accessed by boat on the Nelson River (section 15112TH423 on Figure GS-12-1). In contrast to the previous section, almost 2 m of bedded sand overlies ~16 m of diamict that contains a thin silt and gravel unit at 7.75 m depth. The upper sand contains shell fragments and is probably marine in origin. The upper part of the brown diamict is blocky with 10% clasts and a clayey-sandy silt matrix. Manganese staining is present along joint surfaces and the diamict is increasingly more dense with depth. The silt and gravel unit, at 7.75–8.0 m depth, consists of massive silty clay with 10% clasts (7.75–7.85 m) in contact with finely laminated silty clay with no clasts (7.85–7.91 m), which then sharply overlies massive, oxidized gravelly sand (7.91–8.0 m). This unit then unconformably (sharp contact) overlies a brown, blocky diamict that contains 10% clasts and has a sandy-silt matrix. Manganese staining is present along joint surfaces throughout the lower diamict.

The lower silt and gravel unit may have been deposited beneath a glacier ('subglacial sediments') or during a nonglacial period. Based on the stratigraphic position of this unit, the authors suspect it may be nonglacial, deposited during an interglacial or interstadial time. To determine the age and genesis of this unit, samples were collected and will be submitted for detailed pollen and macrofossil analysis. Previous work in the region identified sub-till nonglacial sediment of uncertain age at several sections along the Nelson River (Nielsen et al., 1986).

If the silt and gravel unit is nonglacial, then the two diamict units could be interpreted as tills deposited during two separate glacial cycles. The field characteristics of both till units are similar, and only subtle colour and textural changes were observed. However, since these two characteristics are subjective, till samples were collected

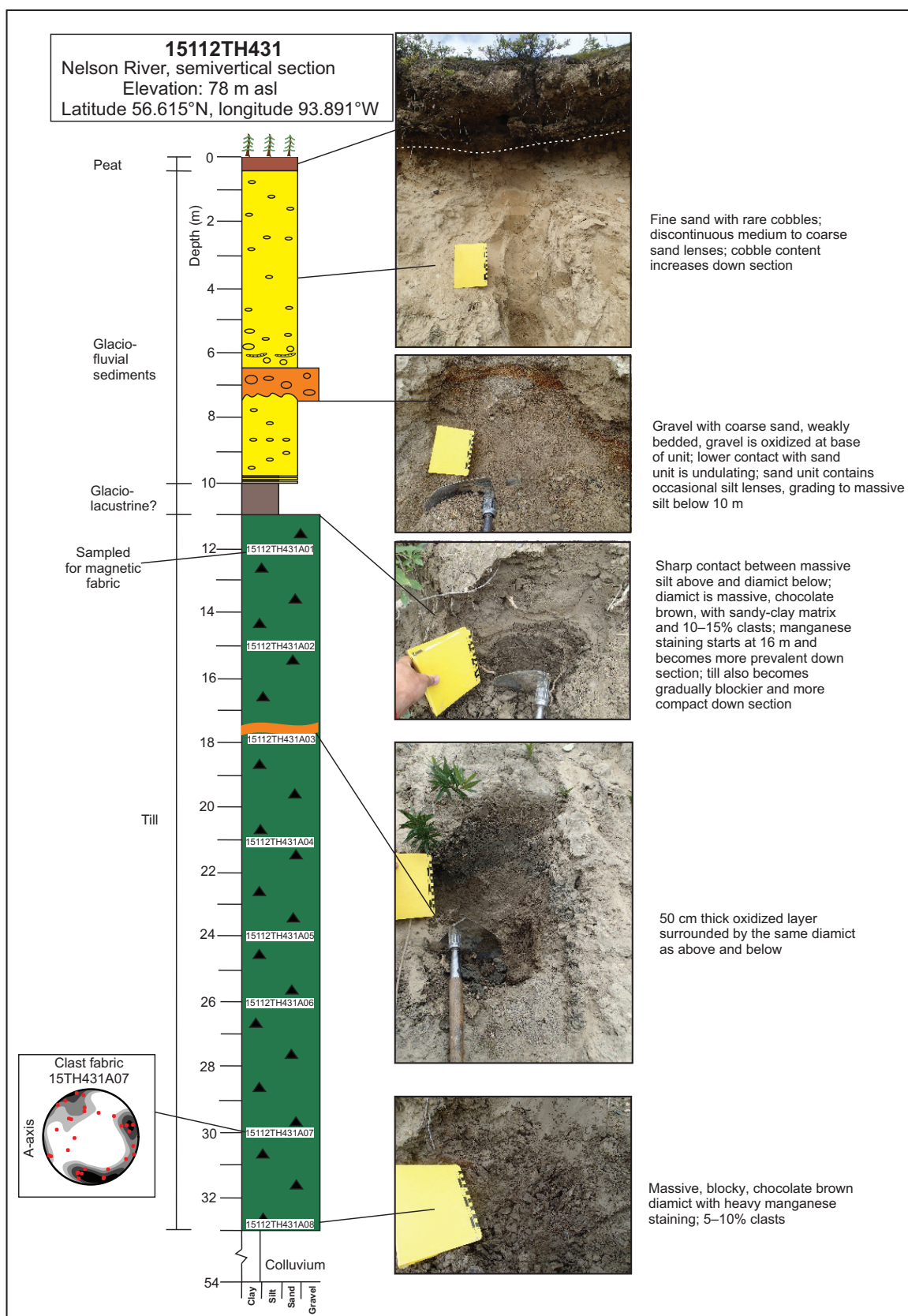


Figure GS-12-3: Stratigraphic section 15112TH431 on the Nelson River, downstream of the Limestone dam; numbers 15112THA01 to A08 in white boxes refer to collected till samples; a-axis clast-fabric results are presented on an equal-area, lower-hemisphere projection and Kamb contoured; see Figure GS-12-1 for section location.

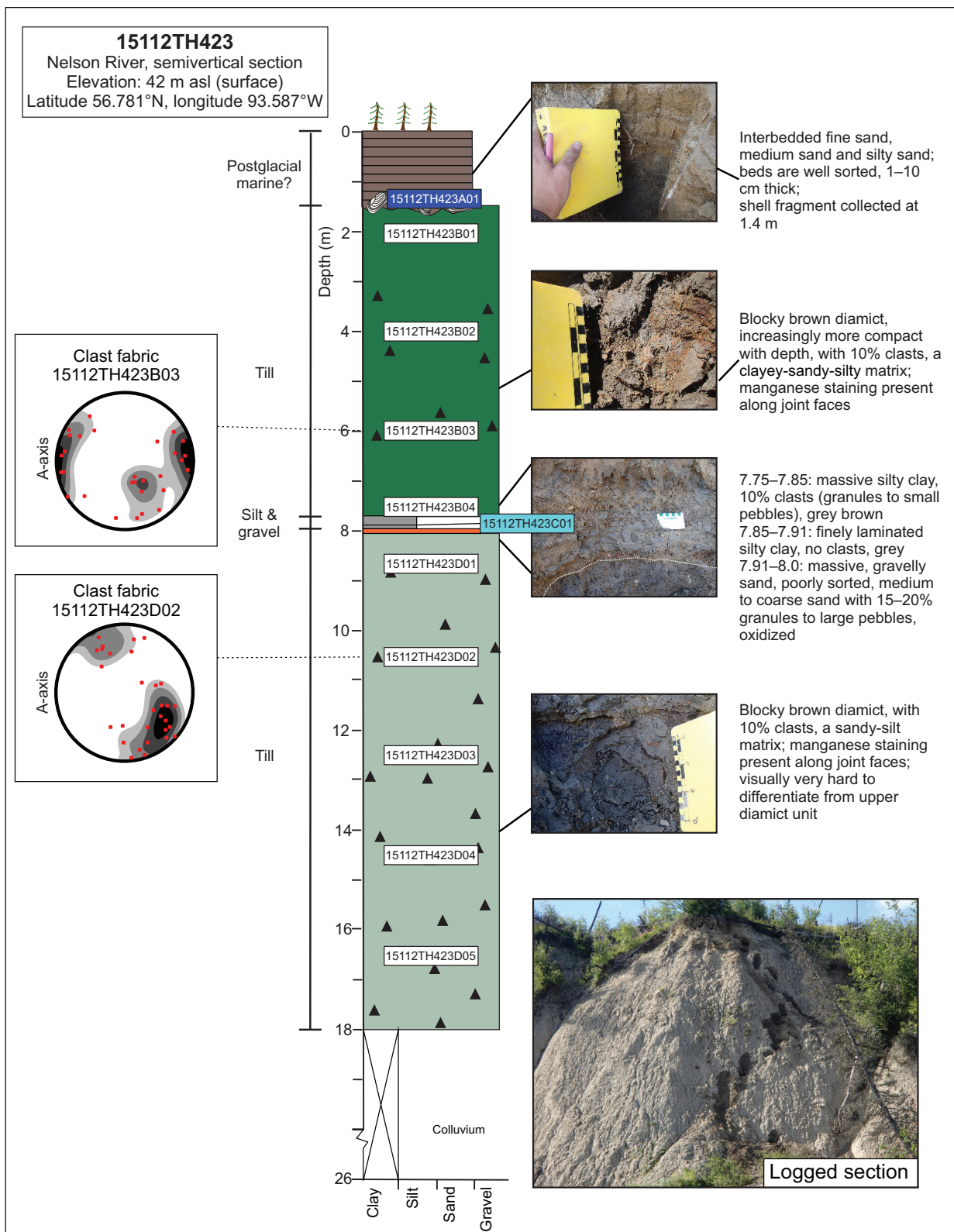


Figure GS-12-4: Stratigraphic section 15112TH423 on the Nelson River, downstream of Keewatinohk construction area; white boxes refer to till-sample sites, blue box refers to shell collection for radiocarbon analysis and teal box marks position of sediment collection for paleoenvironmental analysis; a-axis till-fabric results are presented on equal-area, lower-hemisphere projections and Kamb contoured; see Figure GS-12-1 for section location.

at 2 m intervals. Laboratory texture results, along with till-composition analyses (geochemistry and clast lithology), will aid in determining how different the two till units are. Clast-fabric measurements were also conducted within each till unit, and the results suggest different ice-flow directions (Figure GS-12-4).

Ice-flow reconstruction

Northern Manitoba, including the Gillam area, has undergone repeated glaciations during the Quaternary (Dredge and Thorleifson, 1987; Dyke and Dredge, 1989; Dredge et al., 1990; Dredge and Nixon, 1992). Ice-flow measurements obtained during the 2013 and 2014 field seasons documented numerous striations representing six ice-flow phases (Trommelen, 2013; Trommelen et al., 2014). The work reported herein has added to the ice-flow history of the region by providing 21 clast-fabric measurements from 12 stratigraphic sections. This information is enabling correlation of ice-flow phases with till units.

Section 14115MT254

Section 14115MT254 (Figure GS-12-5) is a section of thick till that overlies bedrock. The uppermost diamict, overlain by 0.3 m of clay, is stratified, loose and interpreted as water laid during retreat of the LIS. In contrast, the lowermost diamict is dense and cemented, and overlies oxidized sand that, in turn, overlies bedrock. One question that arose at this site was whether the abnormally thick till (for this part of Stephens Lake) was all one unit or could be split into different units. The changes in stratification and density suggest multiple till units, but the field characteristics did not enable differentiation of multiple tills. This section was revisited in 2015 to further investigate the character of the till—through collection of clast-fabric data.

Erosional indicators

Striation and groove measurements at the base of the section indicated three different ice-flow orientations (Figure GS-12-5b). Old ice flows toward 238° and 220° were found on facets that were protected from the youngest ice flow, which trends between 266° and 272° (Trommelen, 2014). The westerly ice-flow event(s) was strong, as it formed striations and grooves on most bedrock surfaces and also generated larger roches moutonnées with wrap-around grooves (Figure GS-12-5b).

Clast-fabric measurements

The a-axis clast-fabric measurements were conducted at three different depths in the section (Figure GS-12-5c), where till samples were also taken. Results from the lowermost clast fabric, in the cemented diamict, indicate flow to the west-southwest or east-northeast. Given the position of the study area within the LIS and the regional

ice-flow history (Trommelen et al., 2014), it is more likely that this old ice flow was toward the west-southwest. The middle clast fabric is interpreted to document a strong ice-flow phase toward the southwest (230°). Lastly, the uppermost clast fabric is interpreted to document a strong ice-flow phase toward the northwest (300°).

Preliminary interpretation

Preliminary interpretations at this section suggest a correlation between deposition of the lowermost diamict and the 238° or 270° ice-flow recorded in the erosional record. This implies that the bedrock was protected by till cover from further erosion by later ice flows (Veillette and Roy, 1995; Trommelen and Ross, 2011). Higher up in the section, the two clast-fabric analyses are correlated with ice-flow phases represented in the landform (depositional) record of the region (Figure GS-12-5d). The middle fabric is correlated with the Hayes lobe ice-flow phase (southwest) and the upper fabric with the younger Stephens Lake advance (west to northwest).

This section provides an excellent example of the need to incorporate information from the erosional and depositional record at varying scales to understand past glacial dynamics. It will be further investigated using till-sample geochemistry, clast lithology and till-matrix texture analyses to solidify the above interpretations.

Surficial geology mapping

Building on surficial mapping in the Gillam area (Trommelen, 2013; Trommelen et al., 2014), 18 field stations (4 truck, 16 boat) were added in 2015. Sites were targeted to fill gaps within the existing dataset, particularly along the north and northwest shores of Stephens Lake (Figure GS-12-1). Boat-mapping sites in northern Stephens Lake commonly consisted of thick sequences of brown clay that is interpreted as glaciolacustrine. Diamict was more common along the southern shore of Stephens Lake.

Future Work

Laboratory and data analyses of samples and observations collected during the 2015 field season are ongoing. A particular focus is the characterization of till(s) in stratigraphic sequences and at the surface. Results from the 2015 field season will be incorporated with outcomes from previous surficial-geology investigations in the area (e.g., Nielsen, 2001, 2002; E. Nielsen, unpublished data [Pebble lithology of sections in the Hudson Bay Lowland], 2002; Trommelen, 2013, Trommelen et al., 2014), with the principal objective of generating a new till classification. This work aims to improve upon previous work, where units were identified using qualitative methods in the field and correlated over long distances (Nielsen and Dredge, 1982; Nielsen et al., 1986; Roy, 1998). This updated classification, relying on quantitative rather than

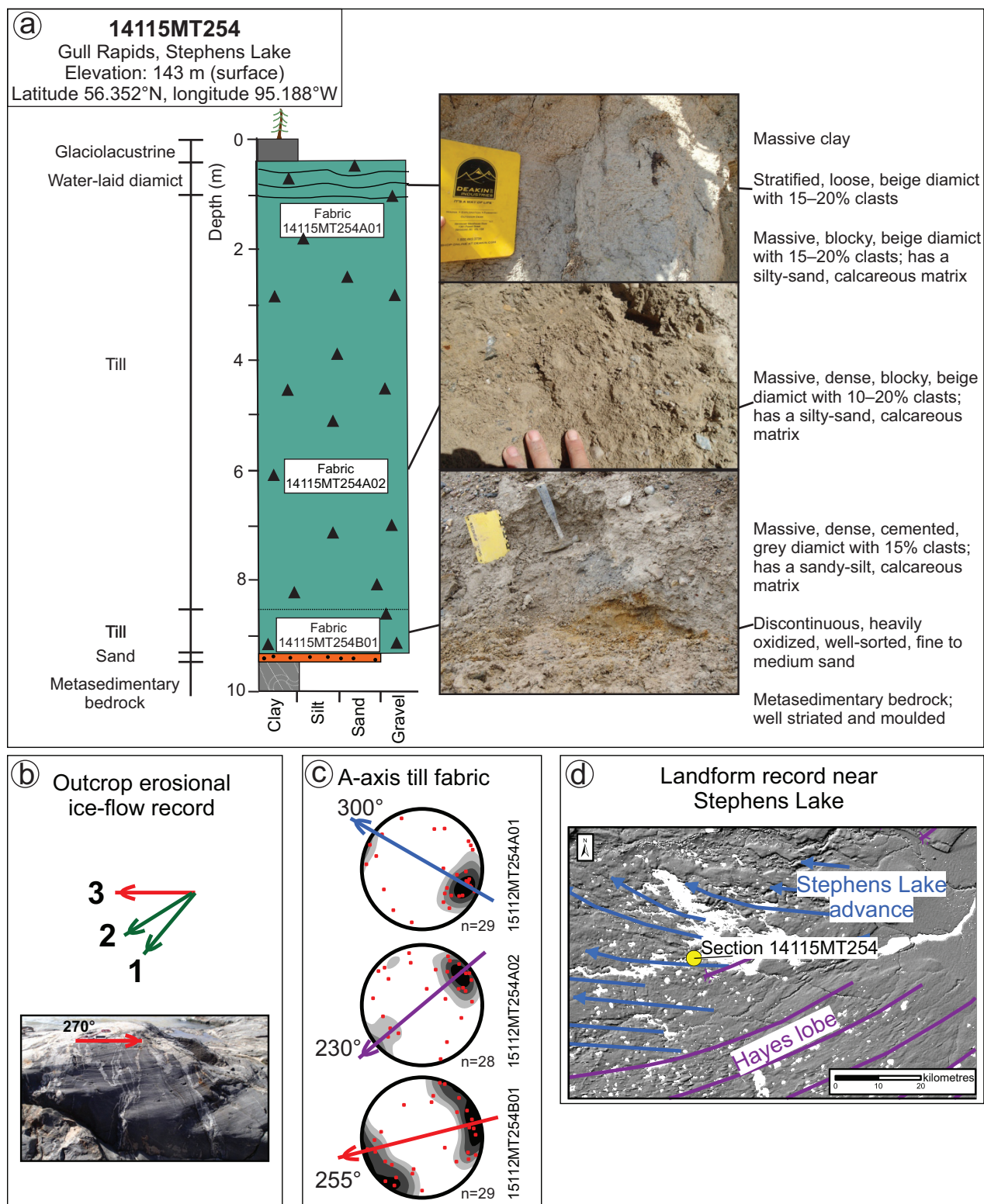


Figure GS-12-5: **a)** Stratigraphic log for section 14115MT254, with sites of clast-fabric measurement shown in the white boxes. **b)** Summary of the erosional paleo-ice-flow record on the bedrock at the section; an example of a roche moutonnée, trending 270°, with rat tails on the side is shown. **c)** The a-axis till-fabric measurements from the 14115MT254 section, presented in stratigraphic order from top to bottom, on equal-area, lower-hemisphere projections and Kamb contoured. **d)** Summary of the streamlined landform record near Stephens Lake, highlighting the Hayes lobe and Stephens Lake ice-flow phases.

qualitative methods to classify the local till stratigraphy, will allow integration of previous information of a qualitative nature.

Field observations from 2013–2015 are currently being incorporated with digital airphoto interpretation to produce surficial-geology maps for NTS areas 54D6–8 at 1:50 000 scale. These maps will aid infrastructure development, highlight areas of potential aggregate resources and provide a framework for mineral exploration in this remote region of northeastern Manitoba.

Economic considerations

This project will provide maps that delineate aggregate deposits, a valuable resource for the ongoing hydroelectric projects in the region. Additionally, as bedrock outcrops are limited, resource exploration in glaciated regions relies largely on till geochemistry and drift prospecting to determine the source for anomalies. The outcome of this project is geared toward providing mineral-exploration geologists with a modern Quaternary knowledge base of ice-flow directions and related till-production phases, which give important insights into the broader ice-sheet configuration at different times. It will also provide more systematic and comprehensive facies descriptions of subsurface units, which is an essential tool for more accurate prospecting in Manitoba's drift-covered areas.

Acknowledgments

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