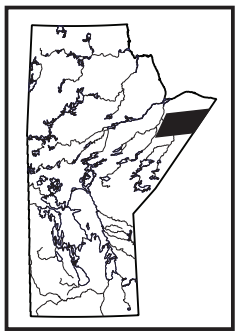
GS-19 Quaternary stratigraphy and till sampling in the Kaskattama highland region, northeastern Manitoba (parts of NTS 53N, O, 54B, C)

by T.J. Hodder and S.E. Kelley[1]



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Summary

This paper presents a summary of eight days of helicopter-supported fieldwork conducted in the Kaskattama highland region of northeastern Manitoba. Fieldwork consisted of logging exposures of Quaternary sediments along natural rivercuts and sampling the surficial till present in the study area. Exposures, up to 35 m thick, of Quaternary sediments are present in the study area and 14 new stratigraphic sections were logged during the 2016 field season. Shells were collected from postglacial sediments when encountered and resulted in 14 radiocarbon samples, which will be dated to investigate the postglacial history of the region. A total of 14 till samples were collected from surficial stations and 43 till samples were collected from stratigraphic sections during the 2016 field season. At the stratigraphic sections, till samples were taken at 2–4 m intervals yielding representative sample sets. Surficial till sampling focused on collecting a representative sample set from the Kaskattama highland to document the composition of the northwest- or southeast-trending streamlined landscape. West of the highland, comparable samples were collected from the southwest-trending streamlined landscape, to compare the composition of each streamlined landscape. To investigate the regional-scale diamond potential in the study area, an additional 30 till samples (9.5 L each) were collected for kimberlite-indicator-mineral analyses. Sediment with woody fragments was collected from a previously undescribed subtill organic-bearing unit and will be analyzed for paleoenvironmental reconstruction.

Introduction

In August 2016, the Manitoba Geological Survey (MGS) conducted Quaternary fieldwork in the Kaskattama highland region of northeastern Manitoba (Figure GS-19-1). This paper presents a summary of eight days of helicopter-supported fieldwork activity, which included documenting and sampling the Quaternary sediments at exposed sections and surficial stations. This project is a continuation of recent collaborative efforts between the MGS and University of Waterloo to document both the Quaternary stratigraphy of the Hudson Bay Lowland region and the composition of surficial sediments in northeastern Manitoba (Trommelen, 2013; Trommelen et al., 2014; Kelley et al., 2015).

Physiography

The Kaskattama highland is dissected by numerous north-northeast–trending drainages, the most prominent being the Kaskattama River, which flows north-northeast to Hudson Bay. The region is covered by a mixture of spruce and deciduous forest, with spruce bogs especially common below 137–146 m asl (marine limit). The highland is bounded to the south by the northwest-flowing Gods River, which is the largest river in the study area. Large (≥30 m) bluffs of Quaternary sediments are actively being eroded along its banks. Elevation in the study area varies from 30 m asl near the confluence of the Hayes and Gods rivers to 235 m asl on the Kaskattama highland. Relief on the north side of the highland is 50–70 m and gradually decreases southward from 235 to 95 m asl along the Echoing River.

The postglacial Tyrrell Sea inundated the area up to an elevation of 146 m asl along the northern Kaskattama highland, and around 137 m asl in the western margin of the field area near the Gods River (Dredge and Nixon, 1992). Below marine limit, the area is flat and featureless, though streamlined landforms are present southeast of the confluence between the Hayes and Gods rivers (Figure GS-19-1). Above marine limit, dominant landscape features include elongate till ridges, hummocky moraine and underfit valleys. Regionally, the area is underlain by Paleozoic sedimentary rocks of the Hudson Bay Lowland, with Archean and Proterozoic crystalline rocks mapped in the extreme southwestern portion of the field area (Manitoba Department of Mines, Natural Resources and Environment, 1979). Paleozoic bedrock outcrops in the study area were only observed along the bottom of the Gods River, northwest of the First Nation community of Shamattawa.

Previous work

Knowledge of the Quaternary stratigraphy in northeastern Manitoba comes from descriptions of rivercut exposures along the Hayes, Gods and Echoing rivers, and the Nelson and Pennycutaway rivers to the west of the

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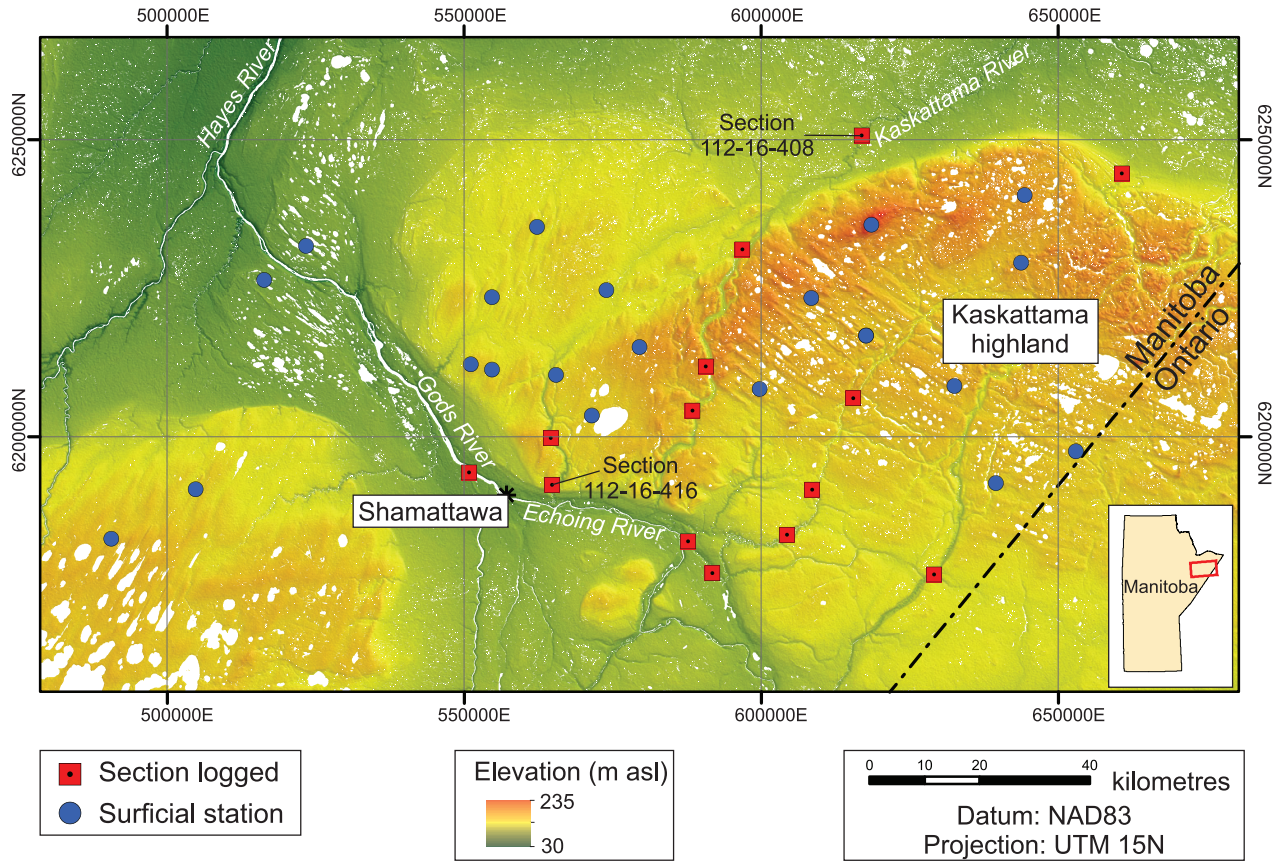

Figure GS-19-1: *Locations of surficial stations and Quaternary sections logged during the 2016 field season, Kaskattama highland region. Background hillshade image was generated using Canadian digital surface model (Natural Resources Canada, 2015).*

study area (McDonald, 1968; Netterville, 1974; Dredge and Nielsen, 1985; Nielsen, 2002; Nielsen and Fedikow, 2002). Thick stratigraphic sections expose a long glacial history, including deposition from two or three different glacial and interglacial events.

The Kaskattama highland region is largely unexplored, primarily due to its inaccessibility. It was investigated during Operation Winisk, a program initiated by the Geological Survey of Canada (GSC) in 1967. Work conducted during Operation Winisk included river traverses and helicopter-supported fieldwork across the Hudson Bay Lowland region in Quebec, Ontario and Manitoba (McDonald, 1968). Unpublished field notes from Operation Winisk (B.G. Craig, unpublished notes, 1967) were obtained prior to fieldwork, and were used to target Quaternary exposures and surficial stations in the study area.

Diamond exploration within the study area has taken place primarily through airborne geophysical surveys. These surveys resulted in the completion of a single drillhole: Foran Mining Kaskattama Kimberlite No. 1 (Assessment File 74223, Manitoba Growth, Enterprise and Trade, Winnipeg; location shown in Nicolas, Figure GS-13-1, this volume). This drillhole intersected 233 m of inferred Quaternary sediments suggesting the highland is composed of an exceptionally thick sequence of Quaternary sediments. Similar thick successions of sediments overlying Paleozoic rocks in the Hudson Bay Lowland have been described in the Attawapiskat region of northern Ontario (~600 km to the southeast), most of which have been interpreted as Pliocene in age (Gao et al., 2012). In the Attawapiskat area, exploration, including stream sediment sampling, led to the discovery of the Attawapiskat kimberlite field and subsequent development of the Victor mine (Kong et al., 1998).

Methods

Helicopter-supported fieldwork was undertaken in August 2016 in the Kaskattama highland region of northeastern Manitoba (parts of NTS 53N, O, 54B, C). A total of 36 stations were visited over eight days, to document the Quaternary stratigraphy along natural exposures and sediments present at surficial stations. Surficial till samples were collected from C-horizon material in hand-dug pits or from mudboils. Mudboils were the preferred sampling sites, as these permafrost features bring unweathered till to the surface (McMartin and McClenaghan,

2001). Till encountered at natural exposures was sampled at 2–4 m intervals.

A total of 57 till samples, each weighing 2–3 kg, were collected from C-horizon tills. These till samples were initially split for archival purposes at the MGS Midland Sample and Core Library, and then submitted for textural, till-matrix geochemistry (<63 µm size-fraction) and clast-lithology (2–30 mm size-fraction) analyses. An additional 30 till samples (9.5 L each) were collected for kimberlite-indicator-mineral (KIM) analysis. These 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) is publicly released at a later date.

Postglacial sequences were described in detail and shell samples were collected for radiocarbon dating where encountered. One previously undescribed subtill organic-bearing sequence was encountered and sampled in detail. These samples will be analyzed for paleoenvironmental reconstruction and potentially for regional correlation of intratill units.

Preliminary results

Geomorphology and the relation to ice-flow history

The ice-flow history of the Kaskattama highland area is unknown. There are no erosional ice-flow indicators because bedrock is buried by thick Quaternary sediments. It is possible, however, to obtain information about ice-flow orientation from areas where the glacier streamlined the substrate and formed a series of landforms parallel to paleo–ice flow. Three streamlined-landform flowsets, defined as a discrete assemblage of subglacial streamlined landforms based on their similar pattern and the degree of internal consistency, are present in the geomorphic record of the study area (Figure GS-19-2). On the Kaskattama highland, the landscape is dominated by northwest- or

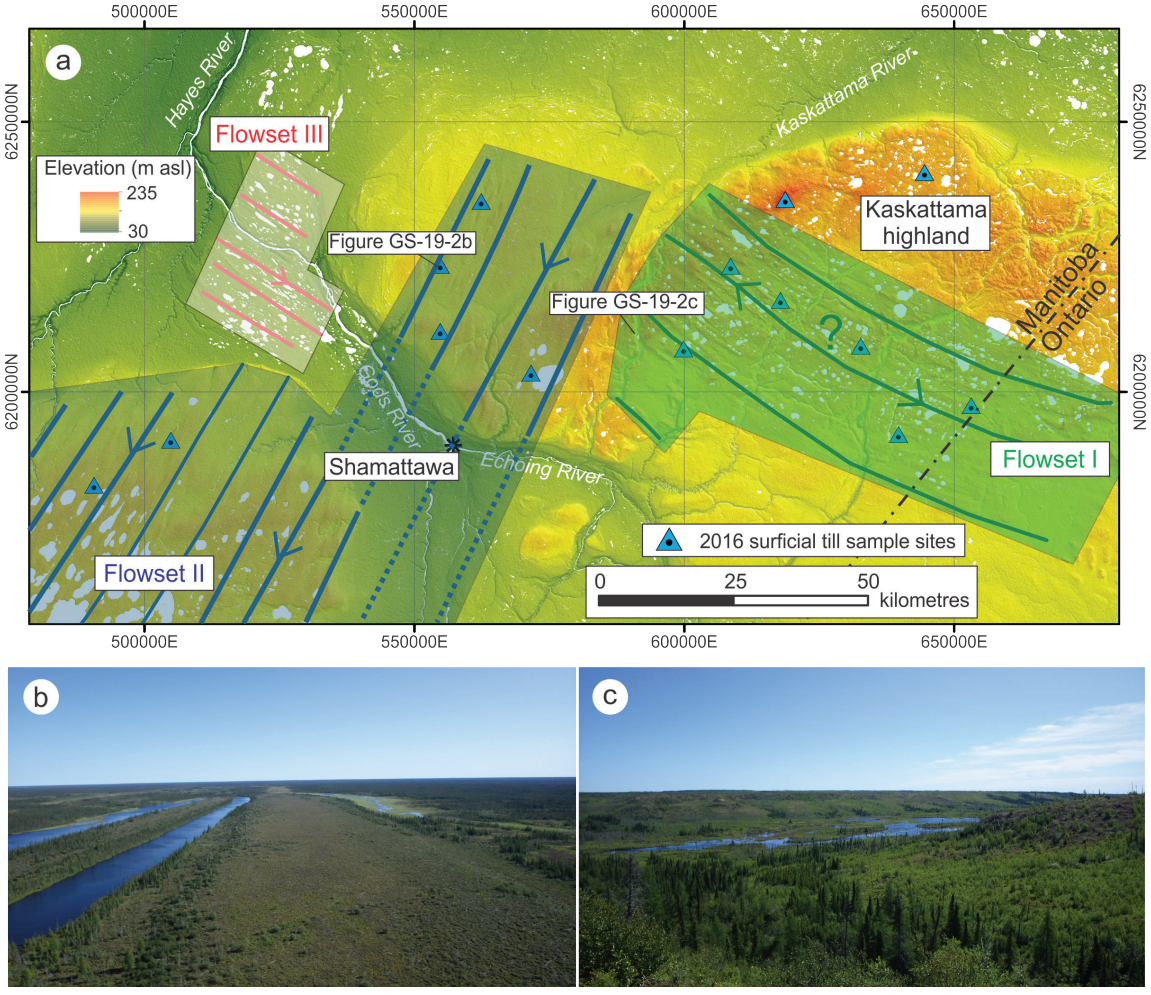

Figure GS-19-2: *Geomorphology setting of Kaskattama highland region:* ***a)*** *streamlined landform flowsets within the Kaskattama highland region;* ***b)*** *example of a streamlined landform within flowset II; and* ***c)*** *ground view of the underfit valley near the confluence of flowsets I and II. Background hillshade image was generated using Canadian digital surface model (Natural Resources Canada, 2015).*

southeast-trending streamlined landforms of flowset I. Since limited fieldwork has been done in this terrain, it is uncertain whether ice flowed to the southeast or northwest during formation of these landforms. Evidence of northwest-trending paleo–ice flow in the sedimentary record of the Hudson Bay Lowland has been recognized as the Rocksand till (Thorleifson et al., 1993) of northern Ontario and as the Amery till (Nielsen et al., 1986) of the Nelson River area of Manitoba. Northwest paleo–ice flow predates the last glacial maximum and is potentially early Wisconsinan or Illinoian in age (Dredge and McMartin, 2011). For flowset I to correlate with this old paleo–ice-flow event, it would have been necessary for the landscape to have been preserved over an extended period of glaciation. Alternatively, flowset I could be a result of an undocumented late-glacial northwest or southeast ice flow. The relative timing and direction of flowset I remain uncertain, but have significant implications for the glacial history of the region and drift prospecting efforts in the study area. A second flowset (flowset II) is found in the middle of the study area. Flowset II is southwest-trending and is part of the large deglacial Hayes lobe (e.g., Trommelen, 2015). Flowset III is oriented southeast, and is situated on the lowland to the west of flowsets I and II. It is preliminarily interpreted to be a result of late-glacial southeast-trending ice flow, based on an increase in the granitoid clast content of the upper till (Hodder et al., 2015).

Surficial till sampling

The surficial sediments at 22 stations were documented, and 14 surficial till samples were collected (Figure GS-19-2). The surficial till is typically a light brown to yellow-brown, calcareous diamict (Figure GS-19-3). A total of six surficial till samples were collected from

Figure GS-19-3: *Examples of till sampled within the Kaskattama highland region:* ***a)*** *example of mudboil sample site;* ***b)*** *yellow-brown clayey sandy-silt diamict representative of the surficial till on the Kaskattama highland;* ***c)*** *blocky grey-brown diamict;* ***d)*** *dark grey diamict logged along the Gods River downstream of the First Nation community of Shamattawa; and* ***e, f)*** *example of a two-till stratigraphy logged at section 112-16-430, an oxidized sand and gravel unit separates the two till units.*

flowset I and six surficial till samples from flowset II (Figure GS-19-2). Two surficial till samples were collected from the region north of flowset I (Figure GS-19-2), to investigate any compositional variances outside of the streamlined landscape. The surficial till sampled across the study area will be further characterized through geochemical and clast-lithology analyses.

Quaternary stratigraphy

The stratigraphy at 14 natural exposures, primarily along rivercuts, was logged during the 2016 field season. Glacial sediments (till) were sampled where encountered and a total of 43 till samples were collected from stratigraphic exposures. A total of 14 radiocarbon samples were collected from stratigraphic sections to document the postglacial history of the area and select samples will be submitted for identification and radiocarbon dating. Subtill organic-rich sediment and wood was collected at one station to reconstruct the paleoenvironment of a potentially new interglacial exposure.

Section 112-16-408 is an example of a Quaternary exposure logged during the 2016 field season. This exposure is located along the Kaskattama River, 8 km north of the Kaskattama highland (Figure GS-19-1). Section 112-16-408 exposes of 2.6 m of postglacial sand and gravel overlying more than 9.2 m of blocky, dark greyish-brown diamict (Figure GS-19-4). Near the base of the section, at 11.0 m below ground surface, a large (>0.5 m) boulder was observed protruding from the section. The top surface of this boulder was well polished and striated. The striations were parallel and indicated an ice-flow trajectory of 215°. This is in close agreement with the ice-flow trajectory of flowset II depicted in Figure GS-19-2a.

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 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 (e.g., Nielsen and Fedikow, 2002) and the Gods River sediments (Netterville, 1974), may be correlative to the well studied Missinaibi Formation found in Ontario and Quebec (Thorleifson et al., 1993).

Section 112-16-416, located 8 km east of the First Nation community of Shamattawa (Figure GS-19-1), contains more than 2 m of subtill organic-bearing sediments (Figure GS-19-5). This is a new exposure of subtill organic material in the Gods River area. At section 112-16-416, a thin (1–2 m) sequence of fine-grained postglacial sediments overlies 29 m of till. An upper 5 m thick, dense, blocky, brown (Munsell colour 10YR 4/3; Munsell Color–X-Rite, Incorporated [2015]) till overlies 24 m of blocky, dense, dark greyish-brown (Munsell colour 2.5Y 4/2) to olive brown (Munsell colour 2.5Y 4/3) diamict (Figure GS-19-3c). Till samples were collected at 2–4 m intervals to characterize the till composition and provide information regarding provenance. At the base of this sequence, from 31 to 32.88 m depth, is an exposure of sand, silt and gravel, which is interpreted to be nonglacial in origin (Figure GS-19-5). The stratigraphy of the subtill unit comprises alternating sand and silt from 31 to 31.4 m, below which is an oxidized gravel unit approximate 15 cm in thickness. Below the oxidized gravel lies a coarsening-upward sequence with organic material becoming more prevalent with depth. Woody fragments up to 3 cm in diameter were found in silt at the base of the sequence (Figure GS-19-5c). Below this is a fine sand unit with fine organic material as well as preserved plant stems. This overlies a second oxidized gravel unit and alternating sand and silt units. Five samples were collected from organic-bearing sections of the exposure for chronology and paleoenvironmental reconstructions.

Erratics

The Omarolluk Formation of the Belcher Group in southeastern Hudson Bay consists of greywacke with distinctive hemispherical calcareous concretions (Prest et al., 2000). These erratics, commonly referred to as Omars (Prest et al., 2000), were transported westward by the Quebec–Labrador sector of the Laurentide Ice Sheet. These rocks have been noted across Manitoba, and were commonly encountered during the 2016 field season (Figure GS-19-6a).

Distinctive oolitic jasper clasts, suspected to be derived from the Kipalu Formation of eastern Hudson Bay (Prest et al., 2000), were also encountered (Figure GS-19-6b). Till-derived gravel bars exhibited a significantly higher proportion of these erratics in the Kaskattama highland region relative to the Nelson River area, attesting to a stronger influence from the Quebec–Labrador sector. Variations in concentration across the study area will be interpreted alongside till clast-lithology counts to investigate the provenance of the till across the study area.

Future work

Future work will primarily focus on interpreting till geochemistry, clast-lithology and kimberlite-indicator-mineral analytical results. Further characterization of the sampled subtill sediments is being conducted by S.E. Kelley. 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, and will provide a framework for regional drift prospecting campaigns.

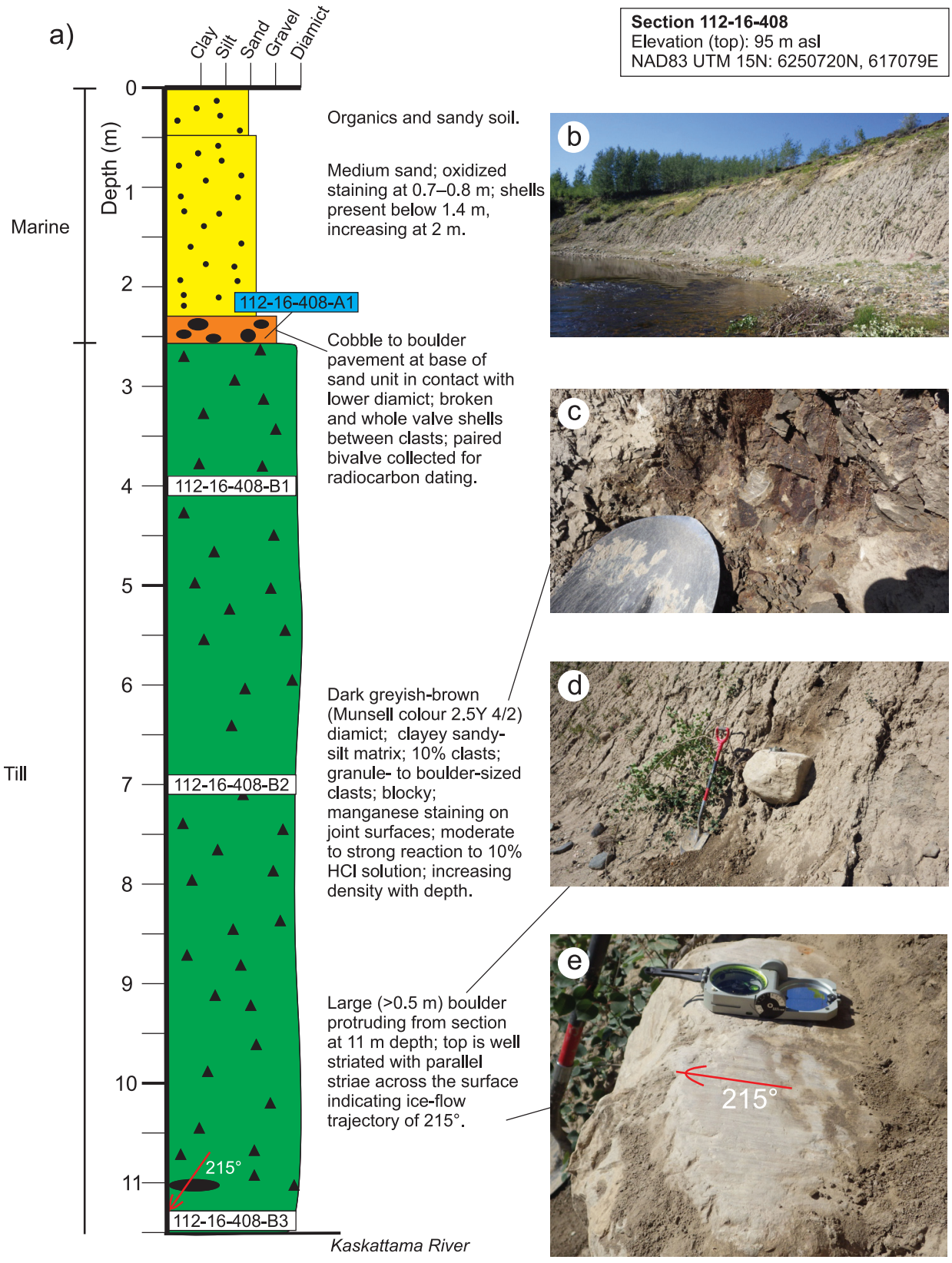

Figure GS-19-4: *Quaternary stratigraphy present at section 112-16-408.* ***a)*** *Stratigraphic log of section 112-16-408. Till sample numbers are in white boxes; radiocarbon sample number is in blue box. Munsell colour from Munsell Color–X-Rite, Incorporated (2015).* ***b)*** *View from river level of the exposed Quaternary sediments. The postglacial cover is recognized by its lighter colour.* ***c)*** *Dark greyish-brown diamict logged at the section.* ***d, e)*** *Lodged in situ boulder with parallel striae on its top surface. Ice-flow trajectory indicated is 215°.*

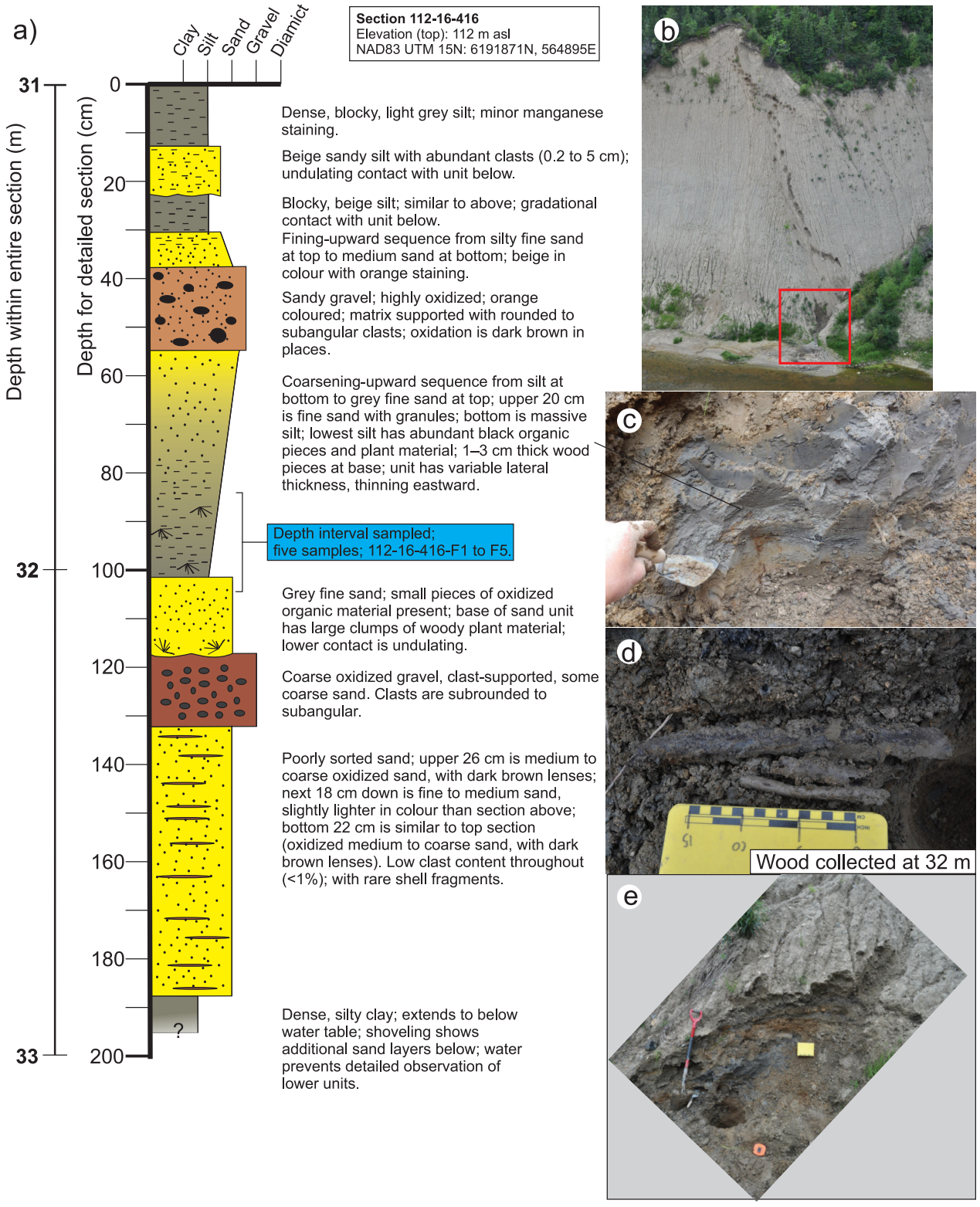

Figure GS-19-5: *Subtill organic-bearing stratigraphy observed at section 112-16-416.* ***a)*** *Detailed stratigraphic log of subtill sediments found in section 112-16-416.* ***b)*** *Oblique aerial view of the exposed Quaternary sediments, with red box outlining the position of exposed interglacial sediments.* ***c)*** *Organic-bearing silt present at 31.2–32.0 m depth.* ***d)*** *Wood material collected for sample 112-16-416-F3.* ***e)*** *Photograph of interglacial sediment exposure.*

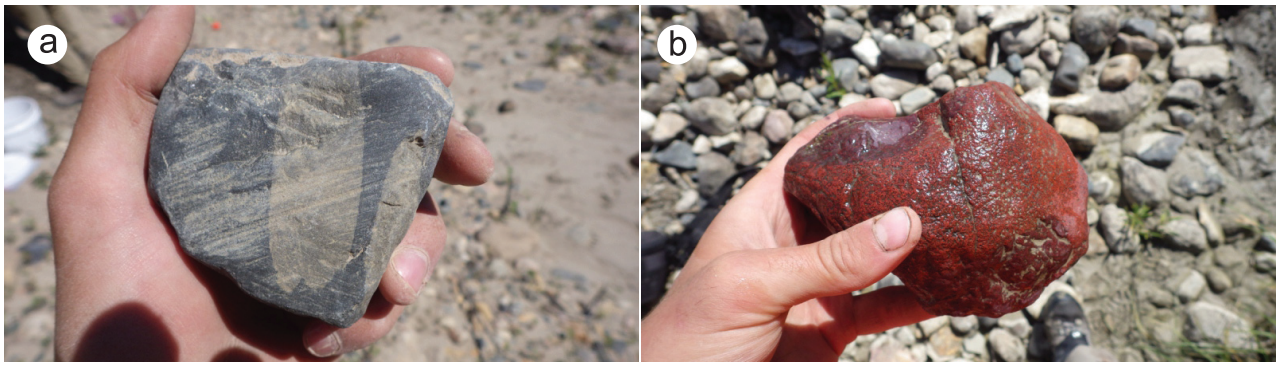

Figure GS-19-6: *Example of distinctive erratics of eastern Hudson Bay origin encountered in the Kaskattama highland region:* ***a)*** *Omarolluk Formation; and* ***b)*** *clast suspected to be derived from Kipalu Formation.*

Economic considerations

The Kaskattama highland region of northeastern Manitoba is a largely unexplored region of northern Manitoba. This study will provide the first documentation of till stratigraphy and surficial till properties in the region. This is a necessary step to assist any drift prospecting efforts in this region of exceptionally thick drift. Results from the kimberlite-indicator-mineral analysis will provide the first reconnaissance-scale insight into the diamond potential of the region.

Acknowledgments

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References

Manitoba Department of Mines, Natural Resources and Environment 1979: Geological map of Manitoba; Manitoba Department of Mines, Natural Resources and Environment, Mineral Resources Division, Geological Report 79-2, scale 1:1 000 000.

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

Dredge, L.A. and Nielsen, E. 1985: Glacial and interglacial deposits in the Hudson Bay Lowlands: a summary of sites in Manitoba; *in* Current Research, Geological Survey of Canada, Paper 85-1A, p. 247–257.

Dredge, L.A. and Nixon, F.M. 1992: Glacial and environmental geology of northeastern Manitoba; Geological Survey of Canada, Memoir 432, 80 p.

Dredge, L.A., Morgan, A.V. and Nielsen, E. 1990: Sangamon and pre-Sangamon interglaciations in the Hudson Bay Lowlands of Manitoba; Géographie physique et Quaternaire, v. 44, no. 3, p. 319–336.

Gao, C., McAndrews, J.H., Wang, X., Menzies, J., Turton, C.L., Wood, B.D., Pei, J. and Kodors, C. 2012: Glaciation of North America in the James Bay Lowland, Canada, 3.5 Ma; Geology, v. 40, no. 11, p. 975–978.

Hodder, T.J., Trommelen, M.S., Kelley, S.E., Wang, Y. and Ross, M. 2015: Revisiting the till stratigraphy in the Hudson Bay lowland region of Manitoba; CANQUA 2015, St. John's, Newfoundland, August 16–19, 2015, Program with Abstracts, p. 49–50.

Kelley, S.E., Hodder, T.J., Wang, Y., Trommelen, M.S. and Ross, M. 2015: Preliminary Quaternary geology in the Gillam area, northeastern Manitoba - year 3 (parts of NTS 54D5–9, 11, 54C12); *in* Report of Activities 2015, Manitoba Mineral Resources, Manitoba Geological Survey, p. 131–139.

Kong, J.M., Boucher, D.R. and Scott-Smith, B.H. 1998: Exploration of the Attawapiskat kimberlites, James Bay Lowland, northern Ontario, Canada; Seventh International Kimberlite Conference, Capetown, South Africa, April 1998, Extended Abstracts, p. 446–448.

McDonald, B.C. 1968: Glacial and interglacial stratigraphy, Hudson Bay Lowland; *in* Earth Science Symposium, Geological Survey of Canada, Paper 68-53, P.J. Hood (ed.), p. 78–99.

McMartin, I. and McClenaghan, M.B. 2001: Till geochemistry and sampling techniques in glaciated shield terrain: a review; *in* Drift Exploration in Glaciated Terrain, M.B. McClenaghan, P.T. Bobrowsky, G.E.M. Hall and S.J. Cook (ed.), Geological Society, Special Publication, no. 185, p. 19–43.

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

Natural Resources Canada 2015: Canadian digital surface model; Natural Resources Canada, URL <http://geogratis.gc.ca/api/en/nrcan-rncan/ess-sst/34f13db8-434b-4a37-ae38-03643433fbbb.html> [September 2015].

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

Nielsen, E. 2002: Quaternary stratigraphy and ice-flow history along the lower Nelson, Hayes, Gods and Pennycutaway rivers and implications for diamond exploration in northeastern Manitoba; *in* Report of Activities 2002, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 209–215.

Nielsen, E. and Fedikow, M.A.F. 2002: Kimberlite indicator-mineral surveys, lower Hayes River; Manitoba Industry, Trade and Mines, Manitoba Geological Survey, Geological Paper GP2002-1, 39 p.

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.

Prest, V.K., Donaldson, J.A. and Mooers, H.D. 2000: The Omar story: the role of Omars in assessing glacial history of west-central North America; Géographie physique et Quaternaire, v. 54, no. 3, p. 257–270.

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. 2013: Preliminary Quaternary geology in the Gillam area, northeastern Manitoba (parts of NTS 54D5-9, 11, 54C12); *in* Report of Activities 2013, Manitoba Mineral Resources, Manitoba Geological Survey, p. 169–182.

Trommelen, M.S. 2015: Glacial history and till composition, Knee Lake area, northeastern Manitoba (NTS 53L14, 15, 53M1, 2); Manitoba Mineral Resources, Manitoba Geological Survey, Geoscientific Paper GP2013-3, 30 p.

Trommelen, M.S., Wang, Y. and Ross, M. 2014: Preliminary Quaternary geology in the Gillam area, northeastern Manitoba (parts of NTS 54D5–11, 54C12) – year two; *in* Report of Activities 2014, Manitoba Mineral Resources, Manitoba Geological Survey, p. 187–195.