GS2021-8

Stratigraphic, paleoenvironmental and geochronological investigations of intertill nonglacial deposits in northeastern Manitoba (parts of NTS 54B–F, K, L, 64A, H, I)

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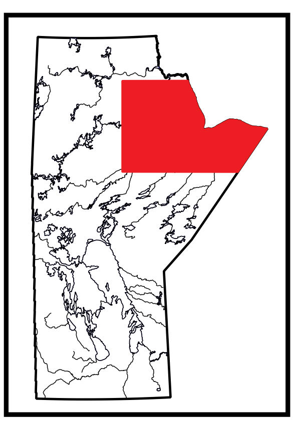
In Brief:

- New collaboration on the Quaternary stratigraphy in the Hudson Bay Lowland
- Field data will be enhanced by paleo-botantical data and optical dating

Citation:
Gauthier, M.S., Hodder, T.J., Lian, O.B., Finkelstein, S.A., Dalton, A.S. and Paulen, R.C. 2021: Stratigraphic, paleoenvironmental and geochronological investigations of intertill nonglacial deposits in northeastern Manitoba (parts of NTS 54B–F, K, L, 64A, H, I); *in* Report of Activities 2021, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 71–76.



Summary

The Manitoba Geological Survey has embarked on a new collaborative study to advance the Quaternary stratigraphic framework in the Hudson Bay Lowland, an area which is critical for understanding the patterns of North American glaciation. This study uses a multiproxy approach to facilitate correlations, two of which include the age and paleoenvironment of intertill nonglacial sediments. This work endeavours to establish a better understanding of the surface and subsurface geology throughout the Hudson Bay Lowland, and advance exploration methods in the study area and other similar regions draped by thick Quaternary sediments.

Introduction

The Quaternary landscape of the Hudson Bay Lowland (HBL) in Manitoba is complex. This area has unique access to numerous sections that expose multiple till sequences interbedded with nonglacial sediments (Figure GS2021-8-1). There are thick till sections (5 to 40 m) that are not easily differentiated into stratigraphic units. Fieldwork between 2013 and 2021 demonstrates that stratigraphic sections in the Manitoba HBL expose a patchy mosaic of sediments that is variable in both space (horizontal) and time (vertical up-section; Trommelen, 2013; Trommelen et al., 2014; Kelley et al., 2015; Hodder and Kelley, 2016; Hodder, 2017; Gauthier et al., 2019; Hodder and Gauthier, 2019). The patchy stratigraphic mosaic means that the development of a regional stratigraphic framework is difficult, since observations at one section may not correlate to those at an adjacent section in a traditional and continuous 'layer cake' model (Gauthier et al., 2016; Wang, 2018). It also means that drift exploration is more complex than previously thought. The objective of this study is to develop a robust stratigraphic framework, using a multiproxy approach to facilitate correlations. Two proxies include the age and paleoenvironment of intertill nonglacial sediments. Intertill nonglacial deposits are spatially restricted, but when combined with an extensive till dataset (provenance, ice-flow direction), these stratigraphic horizons are integral to facilitating stratigraphic correlations.

Background

Intertill nonglacial sediments

Nonglacial-sorted sediments in northeastern Manitoba have been separated from glacial sediments based on the presence of organic material. Organic-rich intertill sorted sediments were then assigned a relative age of deposition pertaining to either an interglacial or interstadial period (Netterville, 1974; Dredge et al., 1990; Dredge and McMartin, 2011). Interglacial refers to a prolonged period of mild climate between two glacial periods, when the HBL was ice free and likely vegetated similar to present day (e.g., Marine Isotope Stage [MIS] 5). In contrast, interstadial refers to a minor period of less cold climate during a glacial period, when the HBL was ice free but temperatures were cooler than present day (e.g., MIS 3). Problematically, previous researchers have ascribed contrasting interpretations of subtill glacial, interglacial or interstadial to the same sediments (Netterville, 1974; Dredge et al., 1990; Dredge and McMartin, 2011). These stratigraphic issues, compounded with issues in dating these nonglacial sediments, have made it extremely

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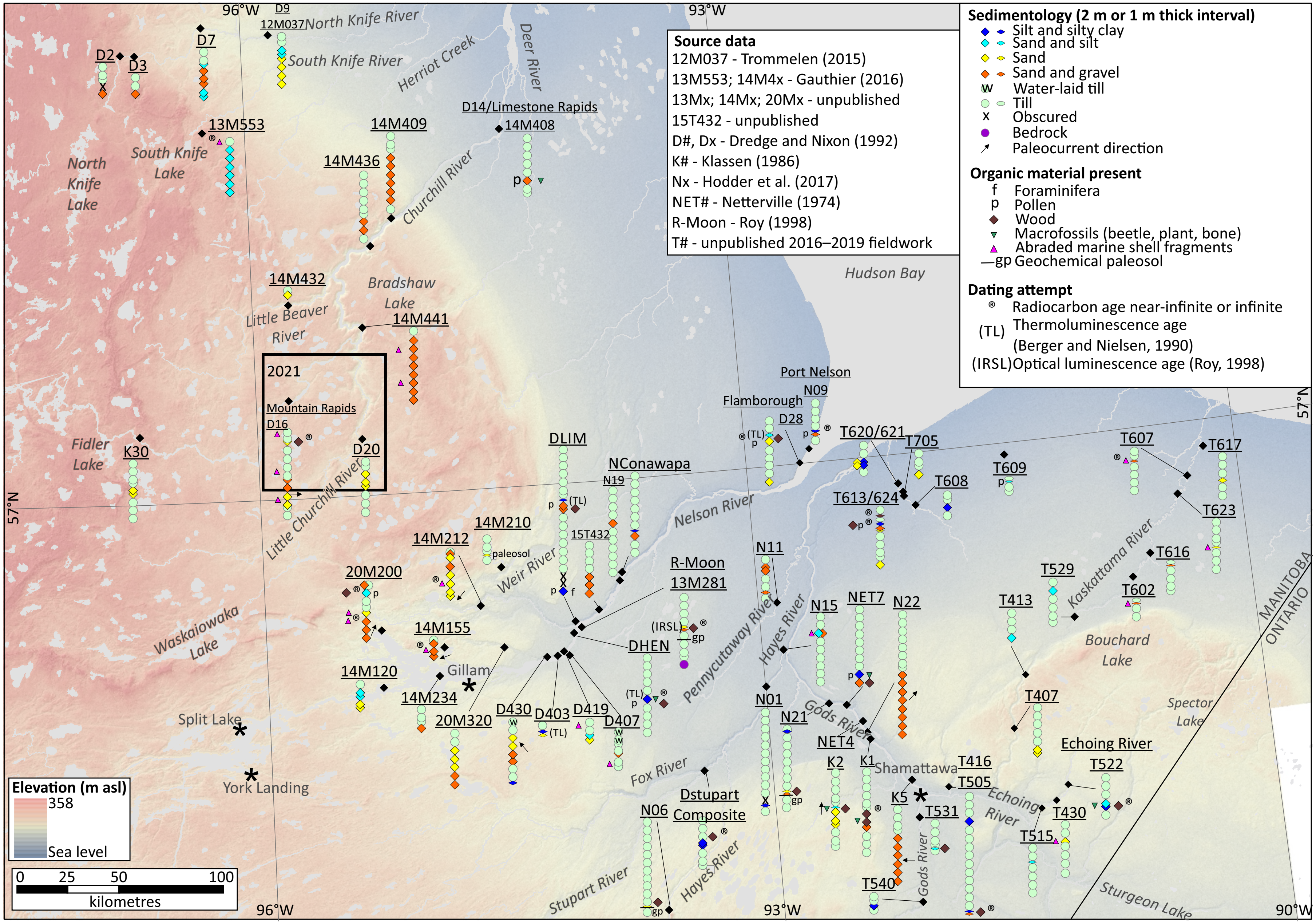
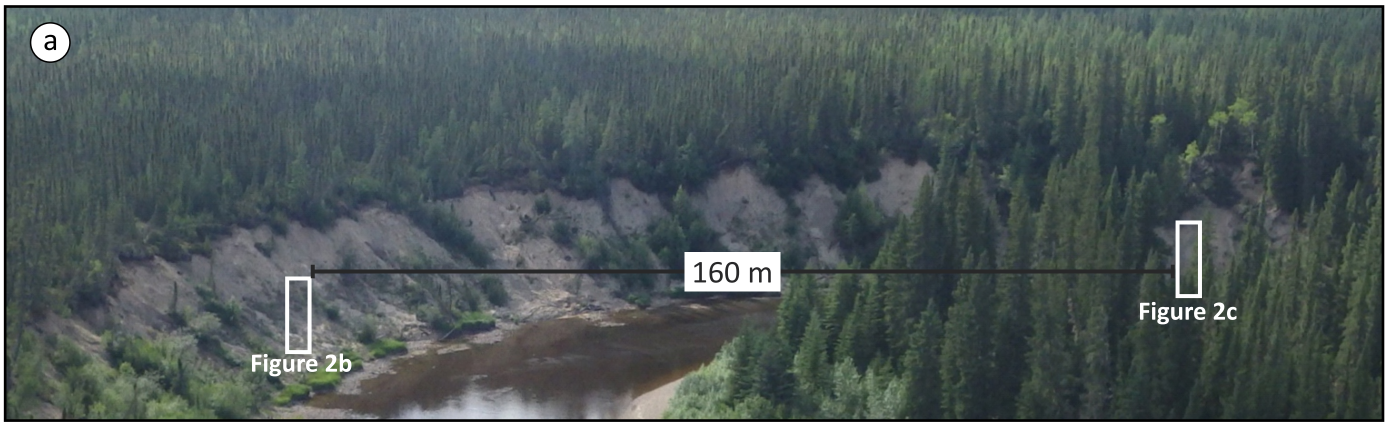


Figure GS2021-8-1: *Map of known sites with intertill nonglacial sediments in northeastern Manitoba, together with a summary of the different data from analyses of those sediments (Netterville, 1974; Klassen, 1986; Dredge and Nixon, 1992; Roy, 1998; Trommelen, 2015; Gauthier, 2016; Hodder and Gauthier, 2017; unpublished Manitoba Geological Survey [MGS] data). Area of MGS fieldwork in 2021 indicated by black outlined box (Hodder and Gauthier, 2021). Background hillshade image was generated using Canadian Digital Surface Model (Natural Resources Canada, 2015).*

difficult to establish a regional stratigraphic framework for the HBL. Hence, a better understanding of the depositional environment(s) of these deposits is essential to determine the chronology of the nonglacial periods within the stratigraphic record.

Within the study area, there are nonglacial-sorted sediments deposited within fluvial, lacustrine, terrestrial and marine environments (McDonald, 1968; Netterville, 1974; Nielsen et al., 1986; Dredge et al., 1990). Organics within these sediments have been dated as nonfinite using radiocarbon (>50 000 ^{14}C years; compiled within Gauthier, 2021). Unfortunately, organic-bearing units are not laterally extensive and can pinch-out to organic-barren units or disappear entirely (eroded or not deposited) within a single section, which makes correlation between multiple exposures difficult (Figure GS2021-8-2). Previously mapped nonglacial sediments are situated at different elevations and contain paleoecological evidence for different depositional environments (Nielsen et al., 1986; Dredge et al., 1990; Roy, 1998). Despite these differences, all 'upper' organic-bearing nonglacial sediments have been correlated as one unit, and termed the Nelson River sediments (Nielsen et al., 1986) or the Gods River sediments (Netterville, 1974; Klassen, 1986). To the east in Ontario, most nonglacial sediments were similarly lumped into the Missinaibi Formation (Terasmae and Hughes, 1960; Skinner, 1973; Dalton et al., 2016). A second deeper nonglacial unit, interpreted as older than MIS



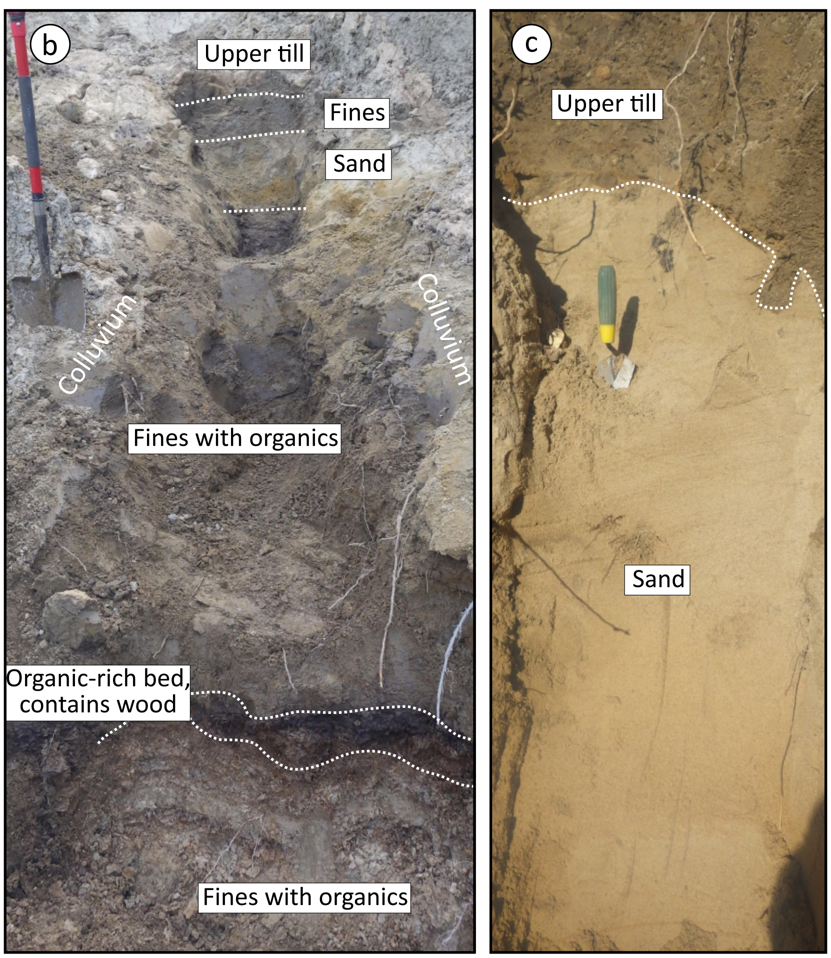


Figure GS2021-8-2: *An overview of the* ***a)*** *'Echoing River' section, northeastern Manitoba (T522 on Figure GS2021-8-1), shows the lateral transition from* ***b)*** *>3.5 m thick organic-bearing sediments to* ***c)*** *>1.5 m organic-barren cross-bedded sand in over just 160 m.*

5, was noted near Gillam along the Nelson River (section DLIM; Figure GS2021-8-1) and correlated to a paleosol developed on the lowermost till at a nearby section (Nielsen et al., 1986).

Confirming the presence of multiple different nonglacial units, Manitoba Geological Survey fieldwork in 2019 and 2021 identified additional stratigraphic sections with two subtill organic-bearing units (Figure GS2021-8-1; Hodder et al., 2020; Hodder and Gauthier, 2021). The danger of correlating nonglacial units based on stratigraphy at any one site is highlighted in eastern James Bay, Ontario, where nonglacial sediments beneath till from two different river sections were dated, using optically stimulated luminescence methods, to MIS 5e and MIS 7 (Dube-Loubert et al., 2013). Only one nonglacial unit was documented at any one section, and lumping would have erroneously assumed the units were both MIS 5e. Ongoing till-stratigraphy reconstructions support the separation of nonglacial units, as work along the Machichi and Nelson rivers has identified three or four different organic-bearing subtill units (Hodder et al., 2020).

Age determination of intertill nonglacial sediments is inherently difficult, since organic matter within these sediments is either at or beyond the ~<50 000 year limit of radiocarbon dating. Laboratory measurements near this limit need to be approached cautiously, because a small amount of contamination can have significant deleterious effects on the age determined (Reyes et al., 2020). For example, the amount of original radiocarbon used for age estimation in samples >40 ka is <1% of the initial total and is extremely sensitive to contamination during burial, sampling or laboratory processing (Pigati et al., 2007). Optical dating, in this case optically stimulated luminescence (OSL) dating, has a longer accepted age range. For quartz, ages from a few decades to about 100 ka can be achieved when the environmental dose rate is typical (approx. 1–3 grays per thousand years [Gy/ka]) and dose-response data are represented by a saturating exponential function, which is usually the case. In some cases, however, where environmental dose rates are low and/or the dose-response data are represented by an exponential plus linear function, samples as old as ~300 ka can be dated (e.g., see review by Wintle, 2008). The luminescence signal from K-feldspar (the other preferred mineral for optical dating) saturates at higher doses, which means that higher age values can be achieved. However, K-feldspar suffers from so-called anomalous fading, which results in age values that underestimate samples' true ages. For samples with linear dose responses, age values can be corrected for anomalous fading, but this usually restricts the use of K-feldspar to samples younger than ~50 ka (e.g., Lian and Roberts, 2006). It is possible to entirely, or at least partially, circumvent the malign effect of anomalous fading by using different luminescence signals from K-feldspar. Unfortunately, these signals have been found to bleach (reset) much more slowly than those traditionally used, which usually means they can only be applied to sediments that received extended exposure to direct sunlight before burial (e.g., Li et al., 2014). The two past attempts to date nonglacial Manitoban samples by luminescence have been only partly successful, as the accuracy of the Berger and Nielsen (1990) ages were questioned by Roy (1998) due to inappropriate pre-heat treatment and anomalous fading.

Methods

New data from the northeastern Manitoba intertill nonglacial beds (Figure GS2021-8-1) will help determine whether paleoenvironmental data and optical dating can be used to differentiate organic-bearing nonglacial units that were deposited during different interglacial or interstadial periods. Pollen, nonpollen palynomorphs and plant macroremains are often present, with varying degrees of preservation, in the organic-bearing sediments. These paleobotanical remains are being used to reconstruct paleoenvironments. Quantitative estimates of paleotemperature and paleoprecipitation derived from pollen assemblages can also contribute to discussions around age assignments (see Dalton et al., 2017). New optical dating of subtill sands will test the ability of this method to date these sediments.

Economic considerations

This work will help to reconcile the stratigraphy of glacial sediments, enabling better identification of exploration vectors of economic interest in the multitill, thick drift of the HBL and similar regions elsewhere.

Acknowledgments

This research is funded by the Manitoba Geological Survey and the Geological Survey of Canada's Geo-mapping for Energy and Minerals program (GEM-GeoNorth). O.B. Lian acknowledges funding support from Discovery grants and Research Tools and Instruments grants from the Natural Science and Engineering Research Council of Canada (NSERC). This report has benefited from internal reviews by C. Bohm, M. Nicholas and A. Plouffe.

Natural Resources Canada, Lands and Minerals Sector contribution 20210307

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