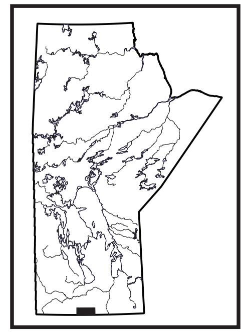
GS-21 Quaternary geology of the Morden and Pilot Mound NTS areas (62G1, 2), south-central Manitoba

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



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Summary

Quaternary geology investigations were undertaken in 2016 in the Pilot Mound and Morden NTS areas (62G1, 2), south-central Manitoba. Fieldwork focused on site characterization, including geomorphology, texture, thickness and stratigraphy, and the collection of till samples for composition analyses. Geological observations at 353 stations were made to support 1:50 000 scale surficial geology mapping. A total of 90 till samples were collected for clast-lithology and matrix-geochemistry analyses, which will establish background compositional till characteristics and aid in the interpretation of glacial history for the area.

Dominant glacial landforms include the Darlingford moraine, the Pembina spillway, glaciotectonic hill-hole pairs and glacial Lake Agassiz trimlines and beaches east of the Manitoba escarpment. Stratigraphic sections investigated suggest a multi-till stratigraphy in some areas, in accordance with multiple till units identified during surficial mapping observations.

Introduction

In 2016, the Manitoba Geological Survey (MGS) conducted Quaternary geology fieldwork in the Morden (NTS 62G1) and Pilot Mound (NTS 62G2) NTS areas (Figure GS-21-1). The study area encompasses parts of three rural municipalities (RM): Pembina, Louise and Stanley. This paper presents a summary of four weeks of fieldwork activity conducted during the spring and late summer of 2016. The purpose of the fieldwork was to conduct surficial geology mapping, log Quaternary stratigraphic sections and collect till samples.

Objectives

The current objectives of Quaternary projects at the MGS are to better understand the glacial geology and geomorphology of Manitoba, and to generate updated geoscience data and maps. These products aid a widespread spectrum of stakeholders by providing information on mineral exploration, aggregate resources, infrastructure development, soil studies, environmental assessments, wetland initiatives, terrain hazards, subsurface mapping efforts, etc. The specific goals of this project are to

- document the geomorphology, stratigraphy and distribution of surficial materials;
- produce aggregate potential and depth to bedrock derivate maps; and
- sample glacial sediments (till) to investigate compositional patterns; and
- interpret the glacial history of the area.

Previous work

Previous surficial geology mapping in the study area has been conducted by the Geological Survey of Canada (Elson, 1960) and MGS (Ringrose and Mihychuk, 1978a). Elson (1960) mapped the Brandon area (NTS 62G) at a scale of 1:250 000. The MGS published a preliminary black and white map of the Morden area (NTS 62G1) at a scale of 1:50 000 (Ringrose and Mihychuk, 1978b). Soil survey maps in the study area have been published on a RM basis at a 1:50 000 scale (Michalyna et al., 1988; Podolsky, 1993, 1998). These previous publications were used as background information and to help guide field targets.

Physiography

The study area is located in south-central Manitoba. Elevation varies from 272 to 505 m above sea level (asl). Relief is generally subdued (0–20 m), except at the Manitoba escarpment and the Pembina spillway where relief can be up to 75 and 130 m, respectively.

The Pembina spillway is the most prominent feature in the landscape of the study area (Figure GS-21-2a, c). The spillway has a width of 1.6 km near the community of La Rivière and southwest of the community of Brown. Interestingly, it widens northeast of the communities of Snowflake and Mowbray, reaching a maximum width of up to 6.3 km (Figure GS-21-2a, c). Several prominent terraces are developed within the wider area of the spillway.

The Manitoba escarpment (Figure GS-21-2a) is a laterally extensive preglacial feature, composed of Cretaceous rocks, that forms part of the erosional edge of the Western Canada Sedimentary Basin.

The Darlingford moraine is a prominent feature in the Morden map area, situated above the escarpment (Figure GS-21-2a, b). The moraine was formed at the southwestern edge of the Red River ice lobe, as it abutted the escarpment.

The Campbell beach or strandline (Figure GS-21-2a) is a significant wave-cut shoreline at ~320 m asl and is

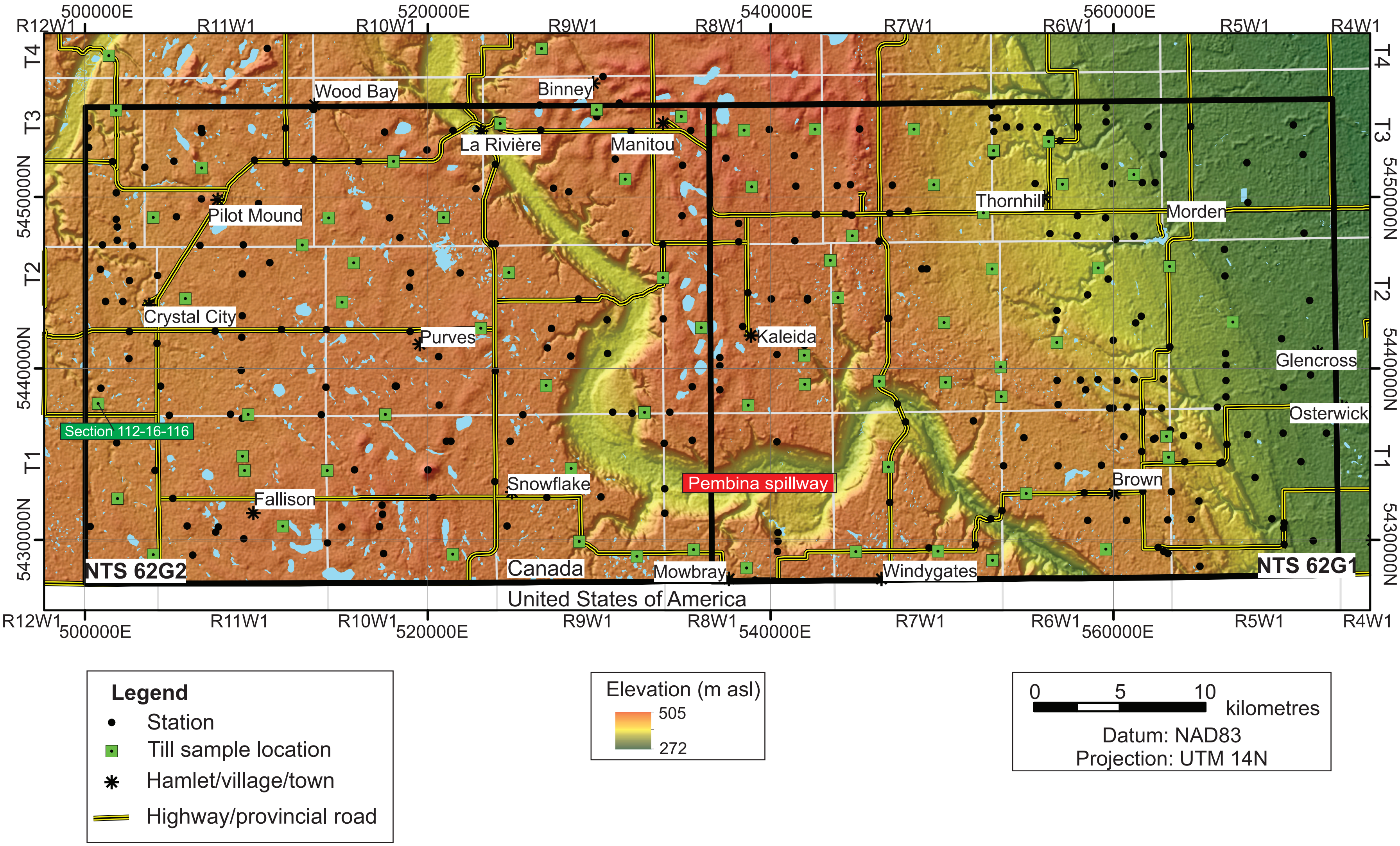

Figure GS-21-1: *Surficial mapping stations and till sample locations in the Morden (NTS 62G1) and Pilot Mound (NTS 62G2) NTS areas, 2016 field season. Elevation varies from 272 to 505 m asl. Background hillshade image was generated using Canadian digital surface model (Natural Resources Canada, 2015).*

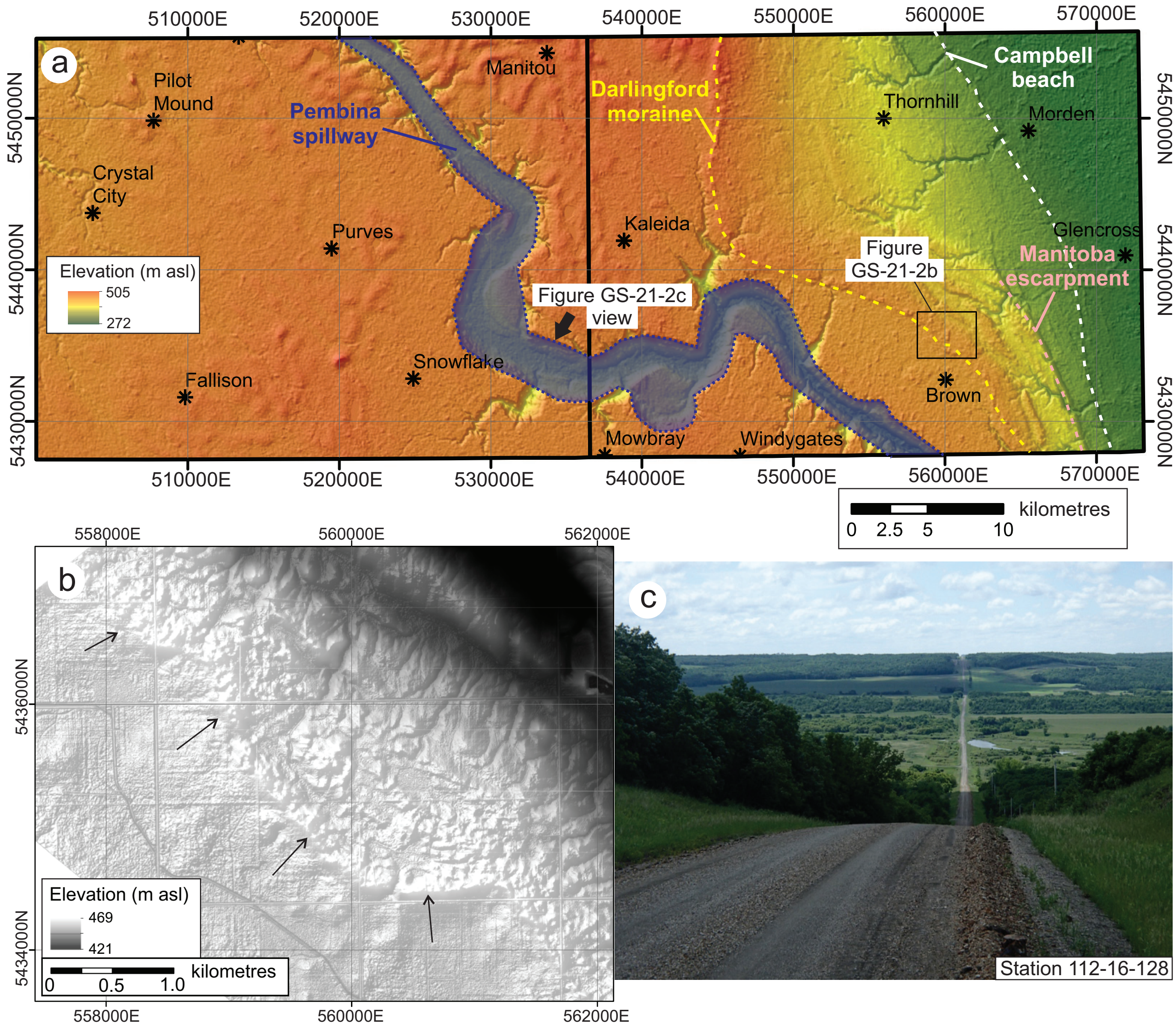

Figure GS-21-2: ***a)*** *Regional geomorphology features in the study area include the Manitoba escarpment, Campbell beach, Darlingford moraine and Pembina spillway. Background hillshade image was generated using Canadian digital surface model (Natural Resources Canada, 2015).* ***b)*** *Hillshaded light detection and ranging (LiDAR) image of the Darlingford moraine (image from LiDAR Services International, 2006). Arrows depict the edge of the moraine.* ***c)*** *View of the Pembina spillway looking toward the southwest.*

locally 15–20 m high. It was formed within glacial Lake Agassiz, an immense ice-dammed lake that covered most of Manitoba during the last deglaciation (Thorleifson, 1996).

Methods

Truck-based fieldwork was undertaken during the 2016 field season in the Pilot Mound (NTS 62G2) and Morden (NTS 62G1) areas. A total of 353 field stations were visited to characterize the Quaternary sediments present, document stratigraphy, sample till and conduct till-fabric measurements. At each field station a Dutch auger hole, soil probe core or hand-dug pit was used to log the sediments present in the upper 1–2 m. Natural exposures of Quaternary sediments were logged where encountered.

A total of 90 till samples, each weighing 2–3 kg, were collected from C-horizon tills at a spacing of roughly one sample per 5 km^2. Samples were split for archival purposes, with one half submitted for till-matrix geochemistry (<63 µm size-fraction) and clast-lithology (2–30 mm size-fraction) analyses and the other half archived with the MGS.

The long-axes orientation, or fabric, of clasts within till is often used as a proxy for ice-flow direction. This is because particles can develop specific fabric arrangements as a response to bulk sediment strain driven by effective stress at the bed of a glacier. This methodology is particularly useful in areas where no other ice-flow indicators are present, such as streamlined landforms or striations. Clast-fabric analyses were conducted at five till sampling sites. For each clast, the trend and plunge of the long a-axis and the intermediate b-axis were measured, as well as the length of each axis. The data were plotted on equal-area stereonets and contoured using RockWare® StereoStat v. 1.6.1 software.

Preliminary results

Surficial geology mapping

Till

Till is an unsorted to poorly sorted diamicton that has been deposited in subglacial or ice-marginal environments. Till was documented at 63% of field sites, either at surface or below postglacial sediments. Tills in the study area display variations in colour, lithology, texture and matrix carbonate content. The tills preliminarily identified in the field include two main tills. The first is a moderately to strongly calcareous till that has 5–15% clasts. The clasts within this first till include carbonate, dolomite, shale, granitoid and greenstone rock types (Figure GS-21-3a, b). The second is a weakly calcareous till that has 5–15% clasts. The clasts within the second till are dominantly shale (Figure GS-21-3c), with some carbonate and dolomite and rare granitoid and greenstone rock types. In regions of thin till over bedrock, the till is locally enriched in the Cretaceous bedrock forming a shaly diamict with no other clast types. An old, subsurface pale brown till (Figure GS-21-3d), with dominantly calcareous clasts, was also encountered at four field sites.

The presence of multiple till types was identified in exposed sections, but also within auger holes (maximum 1.2 m depth) throughout the study area. Representative till samples were collected along a rough spatial grid in the study area, but also from areas where different tills were encountered in stratigraphic sections. All till samples will be submitted for further analyses, which will include till-matrix geochemistry and textural analyses and clast-lithology counts. This data should help determine the provenance (source area) of tills and the ice-flow history of the area.

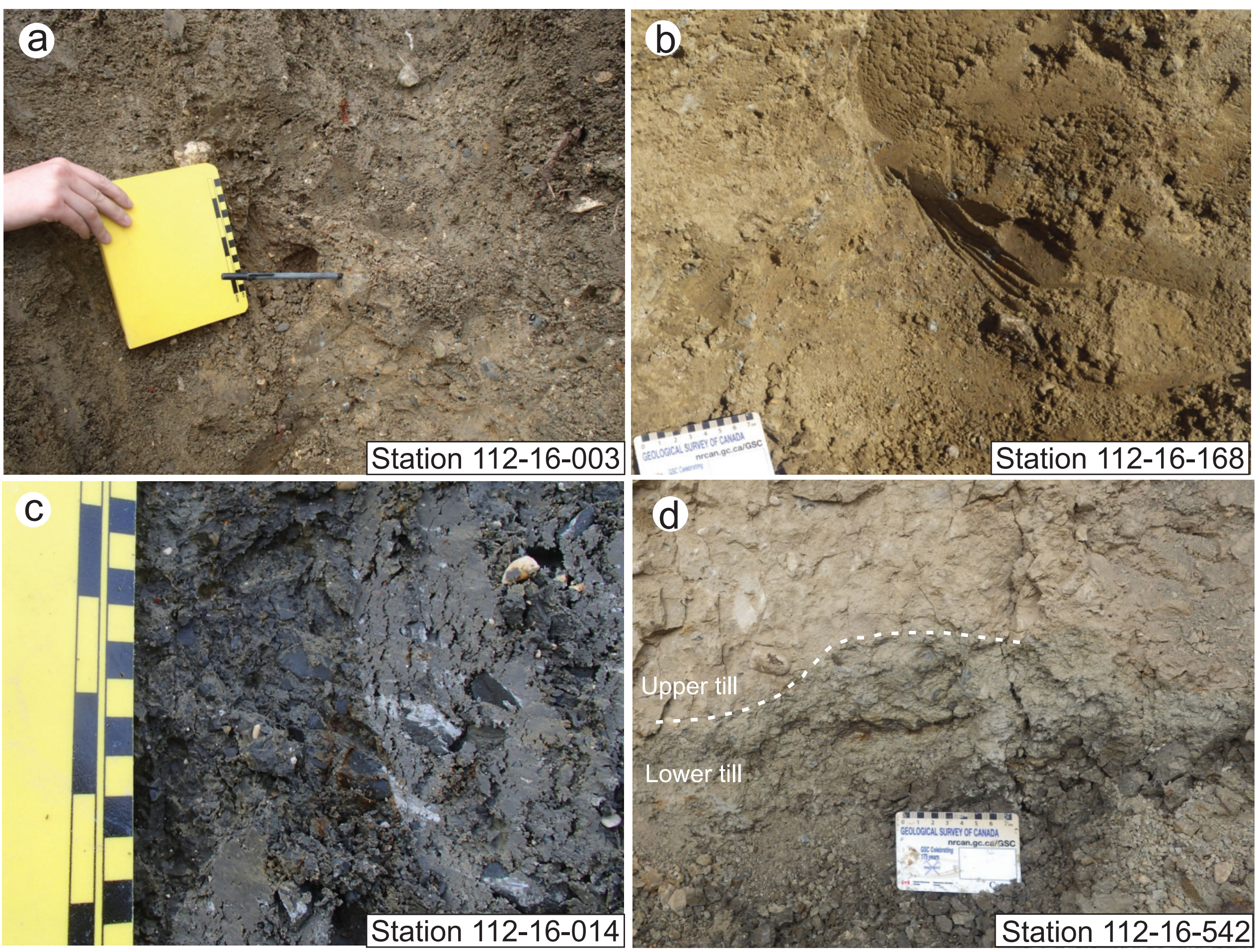

Figure GS-21-3: *Diamict sediments observed in study area:* ***a)*** *olive brown clayey-sandy–silt diamict;* ***b)*** *dark greyish-brown sandy-silt diamict;* ***c)*** *dark grey shale-rich diamict that overlies bedrock; and* ***d)*** *pale brown silty diamict that sharply overlies a very dark grey-brown diamict.*

Section 112-16-116

Section 112-16-116 along Cypress Creek, southwest of the village of Crystal City (Figure GS-21-1), is an example of a two-till stratigraphy exposure logged in the Pilot Mound map area (Figure GS-21-4a). At this section, a lower dark grey diamict, which contains abundant shale, is overlain by a light olive brown diamict, which contains abundant carbonate clasts and some granitoid clasts.

A sharp contact was observed with a distinctive boulder pavement that separates the two till units (Figure GS-21-4d). The top surface of one large (0.6 m) boulder exhibited parallel striations oriented 310-130° (Figure GS-21-4e). Additional ice-flow information was obtained by clast-fabric analysis at this site. The a-axis clast-fabric measurements at sample site 112-16-116-C1 indicate ice flow toward 162°. Lastly, the surficial till in the vicinity of the section is streamlined toward 140°. Thus, based on surface geomorphology, the subsurface till fabric and the striated boulder pavement from the base of the unit, it appears that the upper till unit at section 112-16-116 was deposited as a result of paleo–ice flow from the northwest toward the southeast. Analyses data from the upper and lower till samples should help confirm if the two tills are related to the same ice-flow event and source area, or whether there were multiple ice-flow events recorded in the sedimentary record.

Sand and gravel deposits

Sand and gravel deposits are of interest to aggregate producers in the region. Because of the paucity of

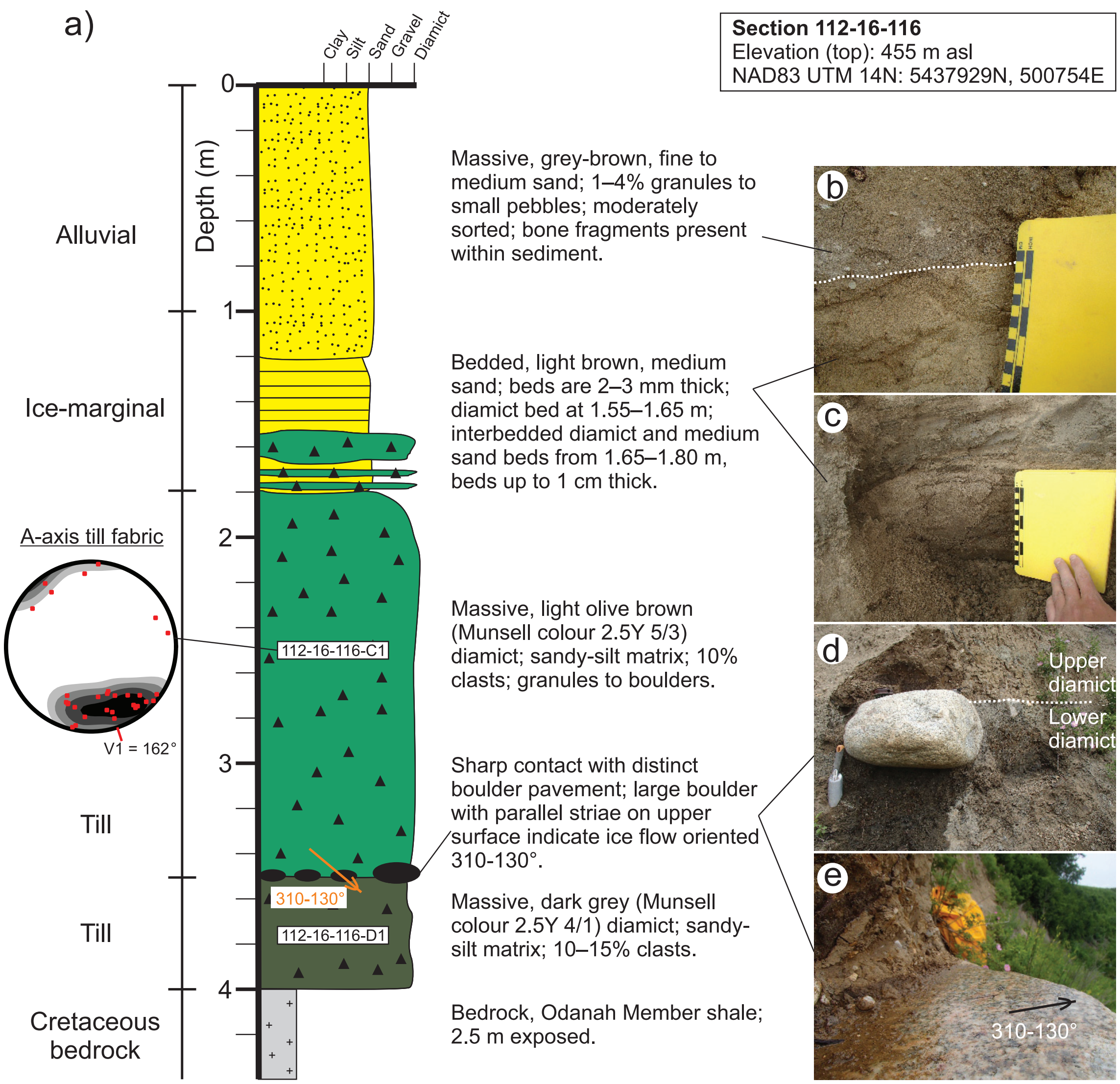

***Figure GS-21-4:** Quaternary stratigraphy of section 112-16-116: **a)** stratigraphic column of section 112-16-116 (Munsell colour from Munsell Color–X-Rite, Incorporated [2015]); **b)** contact between alluvial sand and bedded sand; **c)** interbedded diamict and medium sand; **d)** contact between upper light olive brown and lower dark grey diamict, a distinct boulder pavement separates the two till units; and **e)** large lodged boulder exhibits parallel striae on its upper surface indicating that a 310–130° trajectory ice flow deposited the till directly above the boulder.*

deposits, shale bedrock quarries are common. Aggregate resource inventories, including information about specific deposits in the study area, have been published on a RM basis at a 1:50 000 scale (Young, 1989, 1991, 1993).

Sand and gravel deposits were visited during the course of field mapping. These deposits included terraces of gravel with imbricated shale clasts within the Pembina spillway (Figure GS-21-5a) and small esker ridges of sandy shale-rich gravel (Figure GS-21-5b). Eskers within the study area have previously been recognized (Elson, 1960; Michalyna et al., 1988; Podolsky, 1993, 1998) and are easily mapped on airphotos. Within the study area, these landforms are subtle topographic features, typically rising 2–10 m above the surrounding landscape. These landforms are typically composed of shale-rich sandy gravel to gravelly sand.

Along the Manitoba escarpment in the Morden NTS area (62G2), numerous glacial Lake Agassiz shorelines are present. These may consist of beach deposits—where numerous gravel pits are active—or erosional scarps (trimlines) developed into till. An example of a boulder lag developed on such an erosional scarp, along the Campbell beach, 2 km northwest of the community of Morden, is presented in Figure GS-21-5c.

Buried gravel exists in the southeast region of the Morden NTS area, above the escarpment. Here, 1–3 m of diamict sharply overlies more than 3–5 m of sand and gravel. This gravel is exposed in two major aggregate pits (Figure GS-21-5d), but also within some auger holes. At station 112-16-242, crossbeds indicate paleo-flow toward the south (180–200°). These deposits were mapped as outwash terraces by Young (1993). As these deposits are buried by till, however, it suggests that these are glacial-advance outwash gravel deposits that were overridden during an ice-flow event. As such, the extent of these buried gravel deposits is unknown.

Glaciotectonic landforms

Glaciotectonism of Cretaceous bedrock has been widely identified throughout the interior plains of North America (Moran et al., 1980; Bluemle and Clayton, 1984). Within the study area, deformation of the underlying bedrock by subglacial processes is evident. Two main types of features are observed, hill-hole pairs and large transverse bedrock ridges. Contorted or dipping bedding at the till-bedrock contact was observed at four different bedrock quarries. At another site, a large 2.5 m thick bedrock slab (20 m long) had been rafted and completely encased within the till.

Hill-hole pairs

The town of Pilot Mound owes its name to a streamlined landform. Just to the northwest of this streamlined landform is a lake with similar dimensions and sharp northeast and southwest margins (Figure GS-21-6a, b). The lake together with the mound is a classic example of a hill-hole pair (cf., Bluemle and Clayton, 1984; Aber et al., 1989), where ice scooped/plucked bedrock from the current lake area, and thrust it down-ice. The mound is situated on private land and the composition of the landform could not be verified; however, Elson (1955) states that the feature is a "drumlin with a bedrock knob and that it is primarily composed of crushed shale."

Another hill-hole pair is situated 5 km west of the community of Snowflake. The informally named Star Mound is the highest topographic feature in the Pilot Mound map area at 502 m asl. An auger hole on the top of the feature indicated that 0.4 m of sandy-silt diamict overlies shale bedrock. In the up-ice direction (northwest), a large wetland is present and likely represents a partially in-filled source depression for the landform. Both the Pilot Mound and Star Mound hill-hole pairs indicate ice-flow toward 140°, which is in close agreement with ice-flow direction indicated by eskers, streamlined landforms, striated boulder pavements and till fabrics in the Pilot Mound map area (Figure GS-21-6a).

Large transverse bedrock ridges

In the central region of the study area, west of the Darlingford moraine (Figure GS-21-2a), large subarcuate transverse landforms are present (Figure GS-21-6c, d). The landforms have a relief of 12–16 m (e.g., Figure GS-21-6c) and are up to 8 km in length. These landforms were investigated during the field season to gain insight into their composition. A quarry exposed a variable thickness (0.5–2.0 m) of sandy-silt diamict over shale bedrock and auger holes typically encountered a veneer (<1 m) of sandy-silt diamict overlying bedrock. Auger holes in the inter-ridge lows typically encountered silt to clayey silt overlying a sandy-silt diamict. These observations indicate that these landforms are primarily composed of shale bedrock, with an overlying veneer of till. Similar transverse landforms have been described in North Dakota and have been interpreted to be formed as a result of glacial thrusting of the underlying bedrock (Bluemle and Clayton, 1984).

Future work

Field observations will be combined with airphoto interpretation to produce 1:50 000 scale surficial geology maps of the Pilot Mound and Morden NTS areas (62G1, 2). Aggregate potential maps will be updated, based on orthophotos, field data and mapping, to guide future aggregate development. Depth to bedrock maps will be derived from the current 3D model of the area, field data and digital elevation models.

Till samples will be analyzed for till-matrix geochemistry and clast lithology. A further understanding of till composition will aid in the interpretation of sediment-landform assemblages in the Pembina Valley region and

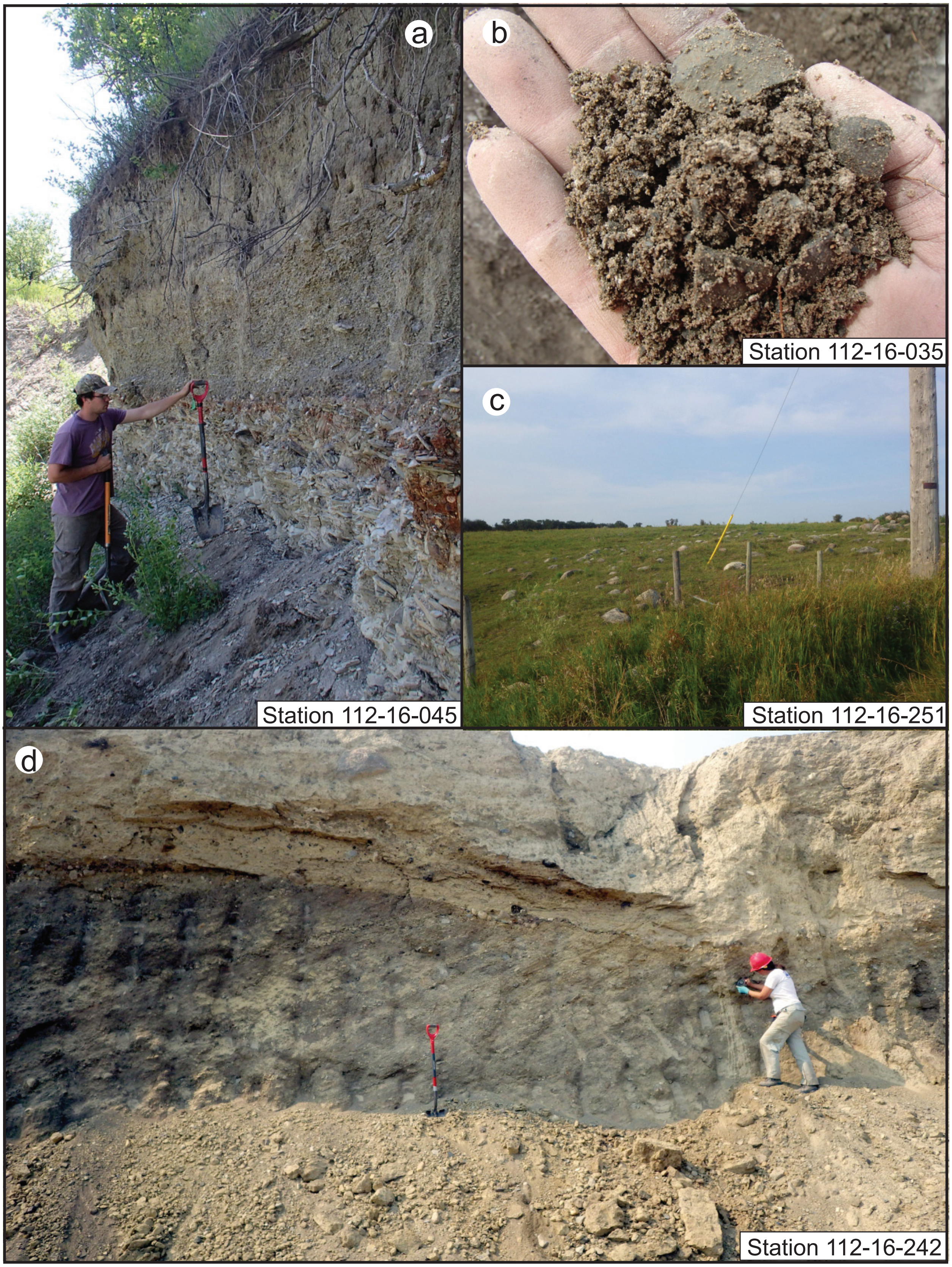

Figure GS-21-5: *Sand and gravel sediments observed in the study area:* ***a)*** *terrace gravel deposit within the Pembina spillway;* ***b)*** *shale-rich sandy gravel from an esker;* ***c)*** *boulder lag developed on an erosional scarp of the Campbell beach; and* ***d)*** *interpreted glaciofluvial gravel overlain by diamict.*

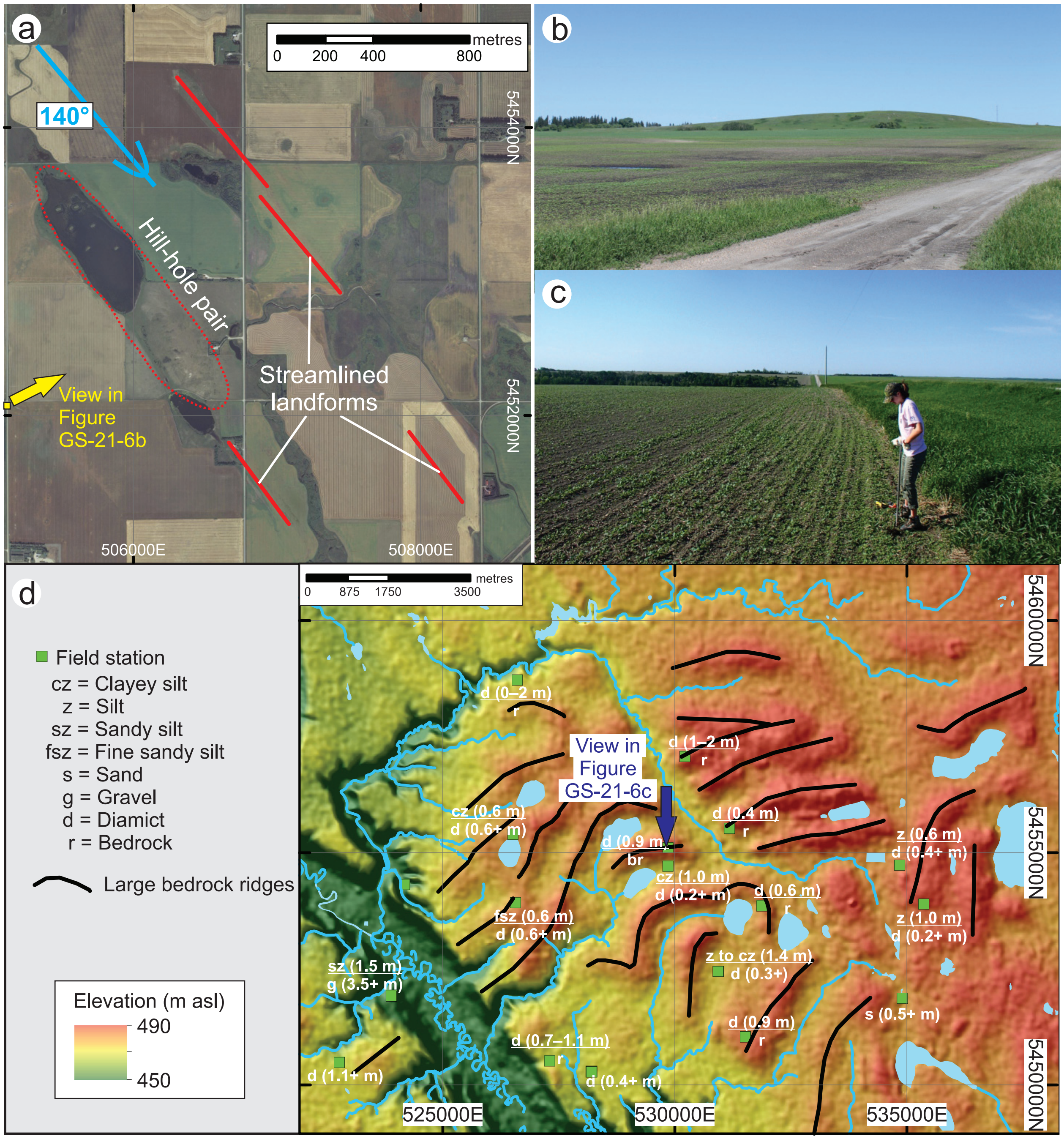

***Figure GS-21-6:** Example of glaciotectonic landforms: **a)** hill-hole pair near Pilot Mound; **b)** view of the hill-hole pair from the ground; **c)** view from a transverse ridge looking south toward a separate transverse ridge; and **d)** large transverse bedrock ridges near Manitou. Field station locations are plotted with the observed surficial materials. Background hill-shade image was generated using Canadian digital surface model (Natural Resources Canada, 2015).*

contribute to understanding the glacial history of the region. This work will be summarized in an open file report.

Economic considerations

Detailed mapping of the surficial geology will aid infrastructure and agricultural planning, highlight prospective regions for aggregate resources and provide a framework to understand the hydrogeology of the region. Although the main aggregate resources have already been delineated, the extent of a major buried deposit may be larger than previously identified. Additionally, detailed mapping serves to demarcate where aggregate is not present. It may be counterintuitive, but knowing where not to explore for resources also saves money.

Ongoing surficial geological studies aim to provide a detailed framework for direction, timing and nature of major and minor ice-flow events in the region. This is a necessary task, as an understanding of depositional environments helps predict aggregate resource potential.

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