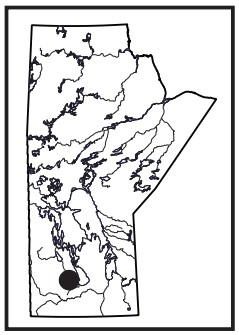
GS-10 Quaternary geology of the Arden NTS area (62J6), southwestern Manitoba

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



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Summary

Quaternary geology investigations were undertaken in the summer of 2015 in the Arden NTS area (62J6), southwestern Manitoba. Fieldwork focused on site characterization, including geomorphology, texture, thickness and stratigraphy, and the collection of till samples for composition analyses. Geological observations at 197 stations were made to support 1:50 000 scale surficial geology mapping. Field-site characterization identified several map units including alluvial, offshore lacustrine, beach and till deposits. Stratigraphic sections investigated suggest a multi-till stratigraphy in some areas, in accordance with multiple till units identified during surficial mapping observations. A total of 62 till samples were collected for clast-lithology and matrix-geochemistry analyses, which will establish background compositional till characteristics and aid in the investigation of regional till provenance for drift-exploration purposes. A further 20 till samples were collected for kimberlite-indicator-mineral analyses.

Introduction

In the summer of 2015, the Manitoba Geological Survey (MGS) conducted Quaternary geology fieldwork in the Arden NTS area (62J6). This report presents a summary of three weeks of fieldwork activity, which included surficial geology mapping, stratigraphic logging of Quaternary sections and till sampling for geochemical, lithological and kimberlite-indicator-mineral analyses.

Objectives

The current objectives of the Quaternary projects at the MGS are to better understand the glacial geology and geomorphology of Manitoba, and to generate 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 studies, subsurface mapping efforts, etc. The specific goals of this project are to

- document the geomorphology, stratigraphy and distribution of surficial materials;
- improve the understanding of regional ice-flow phases; and
- sample glacial sediments (till) to investigate compositional patterns (dispersal trains).

The Arden map area was chosen because there is no detailed, or digital, surficial geology map for the area.

Previous work

Previous surficial geology mapping within the study area was conducted by MGS (Mihychuk and Groom, 1979a) and Western Groundwater Consultants (Sinclair and Phimister, 1981). Mihychuk and Groom (1979a) mapped the western half of NTS 62J6 at a 1:50 000 scale and published a preliminary map (Mihychuk and Groom, 1979b). Field stations were primarily focused on aggregate resources. The original field notes for this work were archived by MGS, and data from field sites and backhoe stations (Figure GS-10-1a) were used during the 2015 project. Sample analyses data, however, were not published and these results have not been located. Sinclair and Phimister (1981) published an inventory of sand and gravel in the Westlake area based on 1:50 000 scale surficial mapping, including the 2015 study area. Mapping was primarily focused on delineating aggregate resources from airphoto interpretation and field observations. A reconnaissance-scale (1:250 000) surficial materials compilation map was produced by MGS (Matile and Keller, 2004). This map was derived from the existing soils maps for NTS 62J and aerial photographs of the area without field verification.

Soil maps have also been produced for the study area by the Manitoba Soil Survey. A reconnaissance map (1:126 720 scale; Ehrlich et al., 1958) covers the entire study area, whereas a detailed map exists for the Rural Municipality of Westbourne (1:20 000 scale; Langman, 1984). These maps are available digitally in GIS format and are accompanied by written reports (Ehrlich et al., 1958; Langman, 1984), which outline the legend and unit descriptions of the survey. Field-site locations were not included on any Manitoba soil maps, therefore, the extent of field verification completed for the reconnaissance map is uncertain. However, discussions with the Manitoba Soil Survey (L. Manaigre, pers. comm., 2015) have noted that 1:20 000 scale surveys require 25–30 field sites per section (2.6 km^2) of land. Thus, although the field sites have not been published, the detailed map is considered precise for 1:50 000 surficial geology mapping purposes.

Physiography

The study area is located in southwestern Manitoba. Elevation varies from 270 m above sea level (asl) in the northeast to 500 m asl in the west. Local relief is generally 5–10 m throughout the study area, except at the Manitoba escarpment, where relief can be up to 60 m. Drift cover is

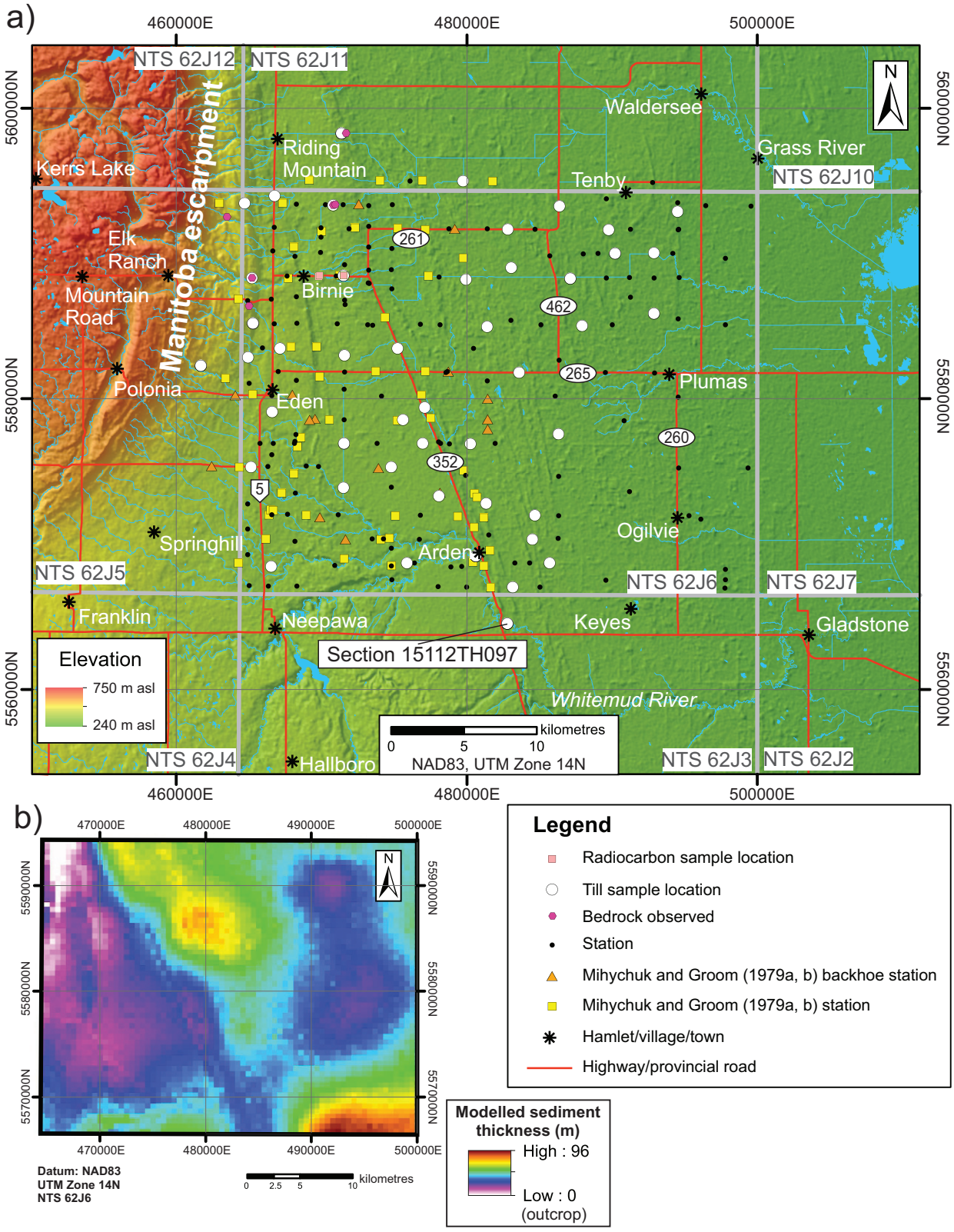

Figure GS-10-1: *Arden NTS area (62J6) and the surrounding region.* ***a)*** *Field stations visited during the 2015 field season and location of samples collected. Manitoba Geological Survey's (MGS) 1979 field stations (Mihychuk and Groom, 1979a) are also depicted. Background hillshade image was generated using Canadian digital surface model (Natural Resources Canada, 2012).* ***b)*** *Modelled sediment thickness of the Arden NTS area (62J6; 500 m horizontal resolution) was calculated using the Canadian digital surface model (Natural Resources Canada, 2012) and the current MGS bedrock surface model (Manitoba Mineral Resources, unpublished data, 2015).*

generally thick, with rare bedrock outcrops encountered along the beds of several streams in the northwest of the study area (Figure GS-10-1).

The estimated Quaternary sediment thickness for the study area (Figure GS-10-1b) suggests up to 96 m of Quaternary sediments are present in the study area. Sediment thickness was calculated using the Canadian digital surface model (20 m resolution; Natural Resources Canada, 2012) and subtracting the elevation of modelled bedrock surface (500 m resolution; Manitoba Mineral Resources, unpublished data, 2015), providing a sediment thickness map with a 500 m horizontal resolution.

The study area is underlain in the east by the Jurassic Upper Amaranth Member of the Amaranth Formation, which consists of gypsum and anhydrite (Nicolas, 2009; Nicolas et al., 2010; Figure GS-10-2). The Reston Formation is present in the central and east-central regions of the study area (Nicolas et al., 2010; Figure GS-10-2) and consists of shale and argillaceous limestone (Nicolas, 2009). The Melita Formation is present west of Arden and is composed primarily of shale, with some interbeds of sandstone (Nicolas, 2009; Nicolas et al., 2010; Figure GS-10-2). The Cretaceous Swan River Formation sandstone is present southwest and southeast of Arden (Nicolas et al., 2010; Figure GS-10-2). The west portion of the study area is underlain by the Cretaceous Ashville, Favel and Carlile formations and Pierre Shale (Nicolas et al., 2010; Figure GS-10-2). These bedrock units are shale-dominated with minor siltstone, limestone and bentonite (Nicolas, 2009).

Regional glacial history

The study area was repeatedly glaciated during the Quaternary and most recently by the Laurentide Ice Sheet (LIS) during the Wisconsinan glaciations (Klassen, 1979; Teller and Fenton, 1980; Clayton and Moran, 1982). The Quaternary stratigraphy within and surrounding the study area has not been extensively studied. Klassen (1979) documented Quaternary stratigraphy in the Riding Mountain and Duck Mountain areas, ~45 km west of the study area. Klassen (1979) identified four Wisconsinan tills based on texture, colour, carbonate content and stratigraphic relationships: the Minnedosa, Lenard, Zelena and Arran formations. Three pre-Wisconsinan tills were also recognized: the Largs, Shell and Tea Lakes formations. South of Lake Manitoba in the Portage la Prairie region (50 km east of the study area), Fenton (1970) identified three subsurface till units with stratified sediments situated above and below each unnamed till unit. Within the study area, the surface till has been assumed to be the Arran formation, and above the Manitoba escarpment the Zelena formation is at surface.

Paleo–ice-flow directions in southern Manitoba have varied from southwest to southeast, with late-glacial paleo-ice flow southward, part of the Red River lobe (Clayton and Moran, 1982). Following the initial retreat of the LIS, the area was inundated by glacial Lake Agassiz by at least 11.3 C^{14} ka (Clayton and Moran, 1982). Retreat was not steady, as several oscillations (readvances) of the LIS margin are evidenced by till overlying deltaic sediments south of Arden (Sinclair and Phimister, 1981) and buried forests in the northern United States (Clayton and Moran, 1982). It has also been suggested that the Arran formation was deposited by a readvance at 9.9 C^{14} ka, possibly associated (Thorleifson, 1996) with a buried moraine in the Portage la Prairie area (Fenton, 1970). Streamlined lineations northeast of Gladstone (Sinclair and Phimister, 1981) indicate that ice likely flowed to the southeast (155°) during this readvance and deposited the surface till. Beach development and offshore deposition occurred throughout the duration of glacial Lake Agassiz.

Alluvial deposition along the edge of the Manitoba escarpment is thought to have occurred mostly during the Holocene (McGinn and Zaniewski, 2003). Within the study area, large alluvial fans composed predominately of shale gravel are present (Ehrlich et al., 1958), the relationship, if any, between these fans and glacial Lake Agassiz is unknown.

Methods

Truck-based fieldwork was undertaken within the study area using local road access. The team was based in Neepawa, which is situated just southwest of the study area (Figure GS-10-1a). A total of 197 field sites were visited to provide site characterization for surficial mapping, document the Quaternary stratigraphy at rare sections, conduct till fabric analyses, and collect organic and till samples. Unpublished information from field sites visited by Mihychuk and Groom (1979a, b) are incorporated into the project, and were used to help plan field-site targets. Soil map polygons were also field checked, using real-time GPS and Nomad® Trimble® handheld computers with ArcPad software, to ascertain the feasibility of using the data for surficial geology mapping. The crew also benefitted from a field visit from soil scientist R. Wu of the Manitoba Soil Survey.

A total of 62 till samples, each weighing approximately 2–3 kg, was collected from C-horizon tills throughout the study area. The samples will be submitted for trace-element matrix-geochemistry (<63 µm size-fraction) and clast-lithology (2–30 mm size-fraction) analyses. In addition, 22 L pails of till were collected at 20 targeted sites and submitted to De Beers Group of Companies (De Beers) to be analyzed for kimberlite-indicator minerals (KIMs) through in-kind support. The purpose of this sampling was to follow-up on several KIM anomalies identified in the region during surveys conducted by the Geological Survey of Canada and MGS in the 1990s (Matile et al., 1996; Garrett et al., 2008; Figure GS-10-2). These older surveys documented 32 KIMs from nine

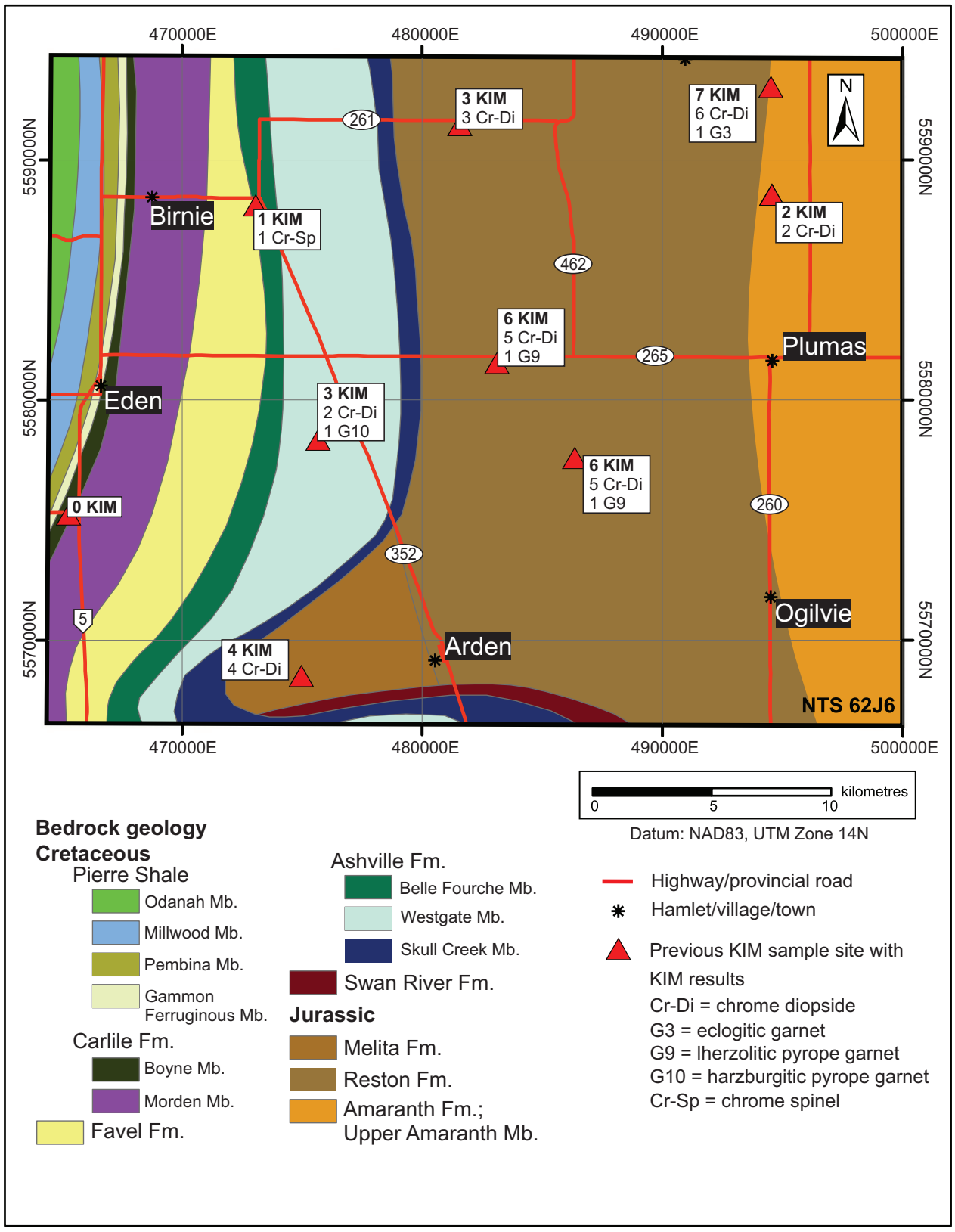

Figure GS-10-2: *Bedrock geology of the Arden NTS area (62J6; Nicolas et al., 2010). Previous kimberlite-indicator-mineral (KIM) sample sites and results are also depicted (Matile et al., 1996; Garrett et al., 2008). The KIM classification system used was Grütter et al. (2004) for garnets and Thorleifson and Garrett (1993) for nongarnet minerals.*

samples within the study area, including a slightly subcalcic G10 garnet and two G9 garnets (Figure GS-10-2). The KIM sample locations from this study were withheld from De Beers, to allow equal opportunity for follow-up by all interested parties when the data is released with sample locations at a later date.

Preliminary results

Surficial geology

Alluvial deposits

Alluvial deposits, consisting of silt, sand, gravel and organic material, are deposited within streams, rivers and as fans when water flows over wide-open expanses of land. These sediments are commonly exposed along the banks of modern streams, and also drape the surface of the landscape east of the Manitoba escarpment in the vicinity of the town of Birnie. For example, 1 km east of Birnie, thick (>2 m) alluvial sections have bedded, clast-supported, shale gravel and silty sand to silt (Figure GS-10-3a). Imbricated clasts within the lower shale gravel unit indicate deposition by fluvial flow toward the southeast (134°; n=4). The shale clasts are thought to have been derived from erosion of the Manitoba escarpment (McGinn and Zaniewski, 2003; Figure GS-10-1a). Approximately 2.3 km east of Birnie, >2.3 m thick alluvial deposits consist of massive, fine-sandy, clayey silt, with at least five buried paleosol horizons (four paleosols are indicated on Figure GS-10-3b). Each sediment–paleosol couplet was deposited during a period of flooding followed by a slowing of water and marsh/streambank conditions. Organic samples were collected from these two sites (Figure GS-10-1) and have been submitted for radiocarbon dating. At one site, shells were sampled from within silt and clay at 3 m depth below shale gravel and at another site, wood was sampled at 0.9 m depth from silty fine sand.

Lacustrine

Deltaic and offshore deposits

Deltaic and offshore glacial Lake Agassiz deposits, consisting of massive, brown, silty fine sand to fine sand (Figure-X04-3c), blanket the southeast study area. These deposits can be at least 3 m thick. Drilling by the Manitoba Soil Survey confirmed these deposits are laterally extensive, and overlie silty clay at 2 to >3 m depth (Langman, 1984).

Beach deposits

The most prominent geomorphic features in the study area are beaches associated with glacial Lake Agassiz (Mihychuk and Groom, 1979a; Sinclair and Phimister, 1981). These deposits typically consist of interbedded sand and gravel, of 1–12 m local relief. The prominent beaches near Arden are correlated with the upper and lower Campbell beaches (Mihychuk and Groom, 1979a). Several beaches are present at higher elevations than the Campbell beaches, and are correlated to the Herman beaches (Mihychuk and Groom, 1979a). Beaches at lower elevations than the Campbell beaches are smaller in amplitude. Beach deposits consist of bedded, clast-supported, sandy gravel and medium to coarse sand. Figure GS-10-3d provides an example, from an active gravel pit, of the sediments present in the lower Campbell beach and Figure GS-10-3e is from an active gravel pit in the upper Campbell beach.

Till

Till was documented at 103 stations, either at surface or below postglacial sediments. Tills in the study area display variations in colour, lithology and texture (Figure GS-10-4). The tills are primarily distinguished in the field by colour: variably yellow-brown (Figure GS-10-4a), grey-brown mottled (Figure GS-10-4b), light to dark brown (Figure GS-10-4c–e) and blue-grey (Figure GS-10-4f). Matrix texture varies from clay to silty sand and clast content varies from 5 to 20%.

The yellow-brown till is carbonate-rich and had a very strong reaction to HCl (10% dilution). In contrast to some of the other tills, the granitoid clasts within this till were typically chemically weathered and the diamict was soft. This till was generally found only east of the Campbell beaches. Grey-brown mottled till was found throughout the study area. Clasts were a mixture of carbonate and shield rock types. Brown till was found throughout the study area. Clasts were a mixture of carbonate, shield and shale/siltstone rock types, with shale/siltstone content increasing in proximity to the Manitoba escarpment.

Although variations in the till were noted in the field, it is uncertain if there are spatial and stratigraphic relationships. It is also uncertain how the study area tills would correlate to the named tills of Klassen (1979). To better differentiate the tills, all 2015 till samples are being analyzed for clast lithology, till-matrix geochemistry and till-matrix texture.

Quaternary sections

A total of eight sections were logged to investigate the regional stratigraphy. At these sections, 10 till fabric analyses were conducted to determine paleo–ice-flow trajectories. Section 15112TH097 (Figure GS-10-5) is an example from the Whitemud River (Figure GS-10-1), where 5 m of Quaternary sediments are exposed in a cliff, at the bridge on Manitoba Provincial Road 352 south of Arden. The lowest unit is a >3.4 m thick, dark grey-brown diamict with a clayey sandy-silt matrix and 15–20% clasts. A thin (0.03–0.10 m), massive, dark grey clay unit, with sharp, undulatory contacts, separates the underly-

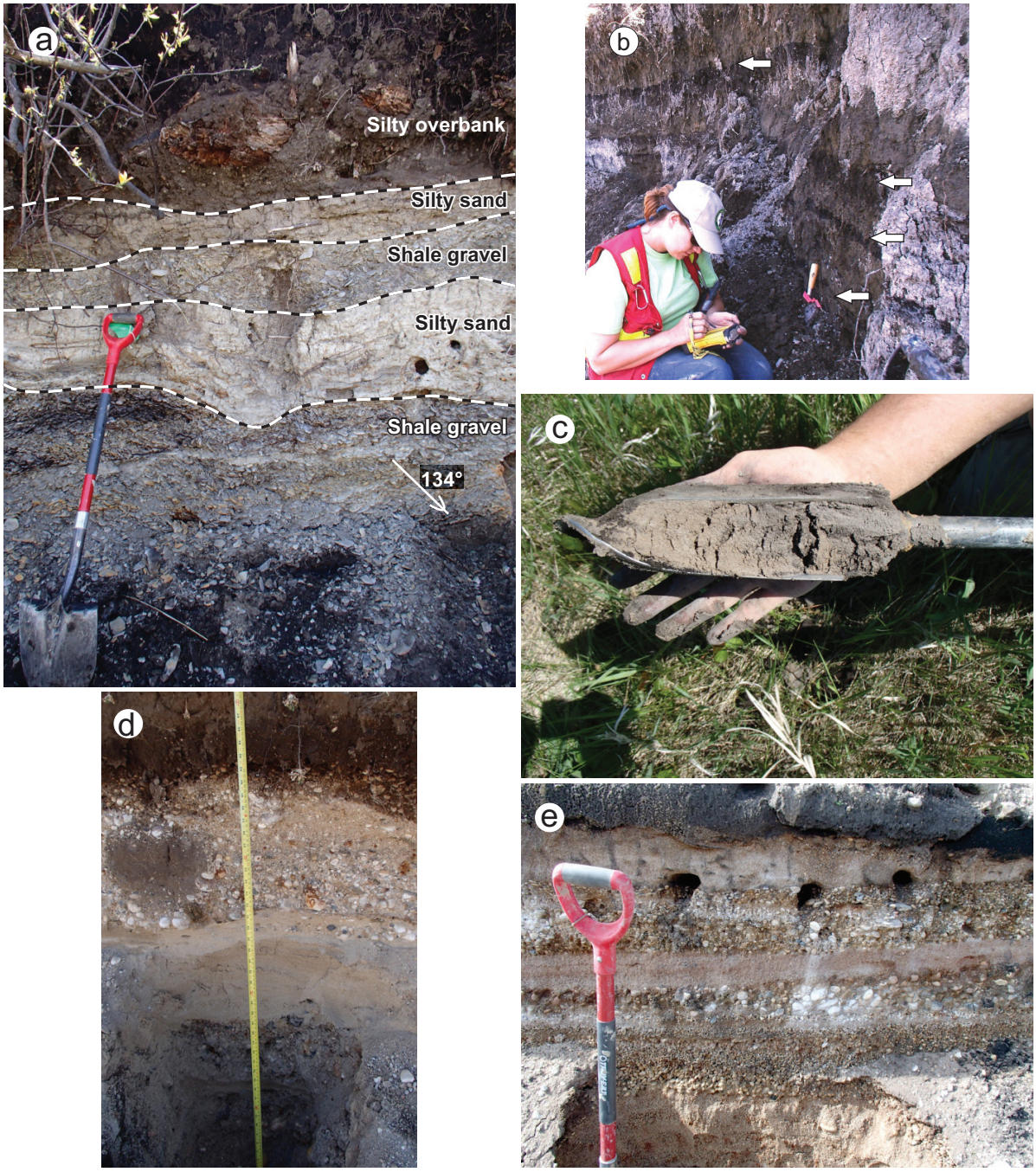

Figure GS-10-3: *Examples of alluvial, beach and offshore deposits.* ***a)*** *Alluvial deposit consisting of bedded shale gravel, silty sand and silt. Imbricated clast measurements indicate deposition by fluvial flow toward the southeast (134°).* ***b)*** *Alluvial deposit consisting of fine-sandy clayey silt. Buried paleosols are indicated by the white arrows.* ***c)*** *Offshore deposit of massive, light brown fine sand.* ***d)*** *Section within an active gravel pit in the lower Campbell beach, consisting of bedded sand and gravel.* ***e)*** *Section within an active gravel pit in the upper Campbell beach, consisting of bedded clast-supported sandy gravel and medium to coarse sand.*

ing diamict unit from the upper diamict unit. The upper diamict is 0.30 m thick, massive, and mottled grey and brown, with a clayey-silt matrix and 5% clasts. The upper 1.30 m is a postglacial sequence of silt coarsening upward to medium sand with cobbles. Till fabric analyses suggest south to southwest–flowing ice deposited the lower diamict unit, and south-southwest–flowing ice deposited the upper diamict. Clast analyses will help determine how different these till units actually are.

Future work

The tracing of lithological indicators in till, from known bedrock source areas using clast lithology counts

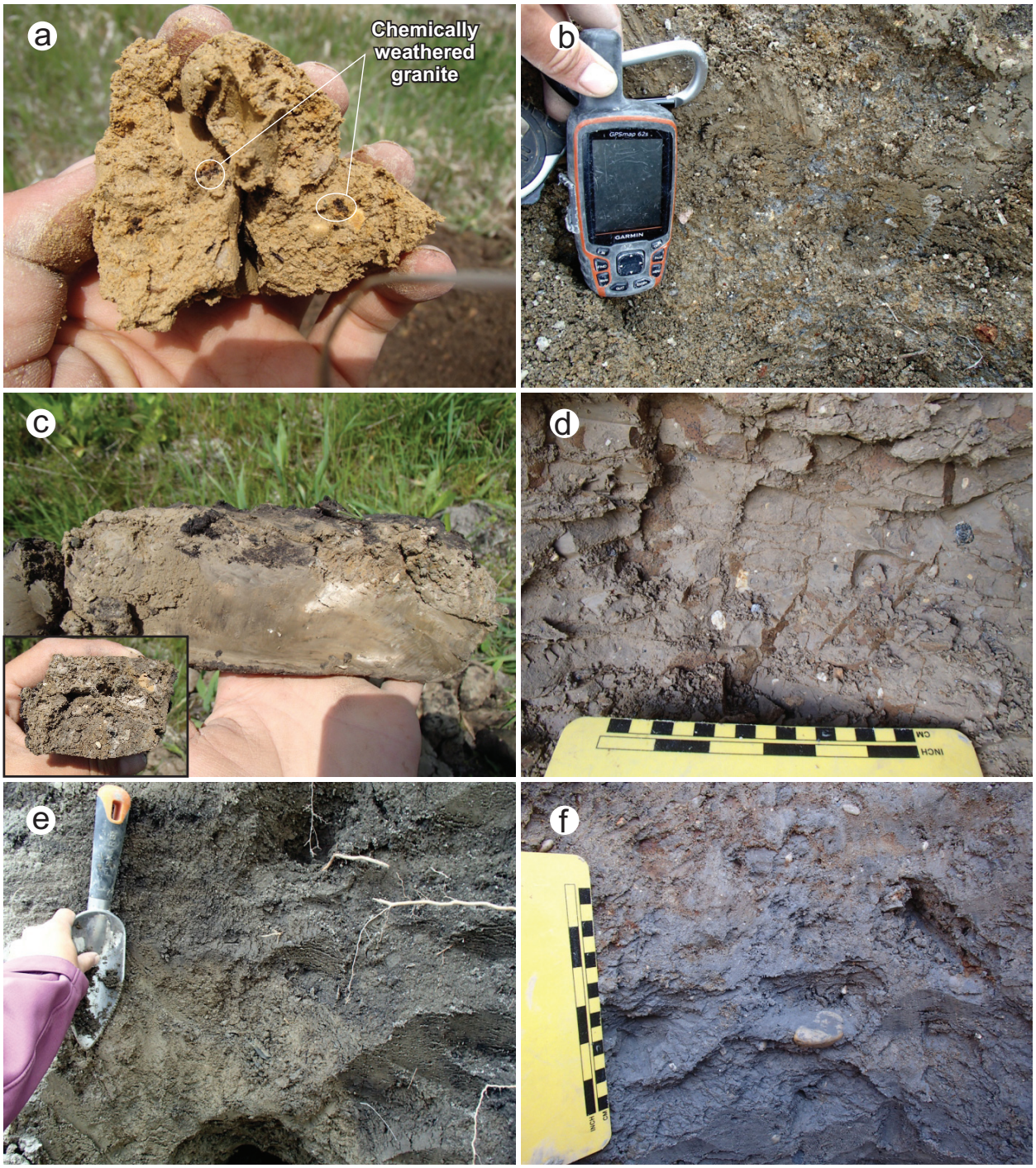

Figure GS-10-4: *Examples of tills in the study area:* ***a)*** *soft yellow-brown, carbonate-rich diamict, granitoid clasts are typically chemically weathered;* ***b)*** *mottled grey-brown diamict, mixed shield and carbonate clasts;* ***c)*** *stiff light brown diamict, carbonate-rich;* ***d)*** *blocky brown diamict, clasts of mixed rock types, manganese staining present along joint surfaces;* ***e)*** *light to dark brown diamict, shale-rich;* ***f)*** *stiff blue-grey diamict, carbonate-rich.*

and geochemical composition of the matrix will establish background compositional till characteristics and aid in the investigation of regional till provenance. Interpretation of aerial photographs of the NTS 62J6 area (captured directly into GIS format) will be combined with field observations to produce a 1:50 000 scale surficial geology map. An aggregate derivative map will also be produced.

Economic considerations

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 to encourage drift prospecting in regions where bedrock outcrops are rare; such as in southwest Manitoba. Detailed mapping of the surficial geology will

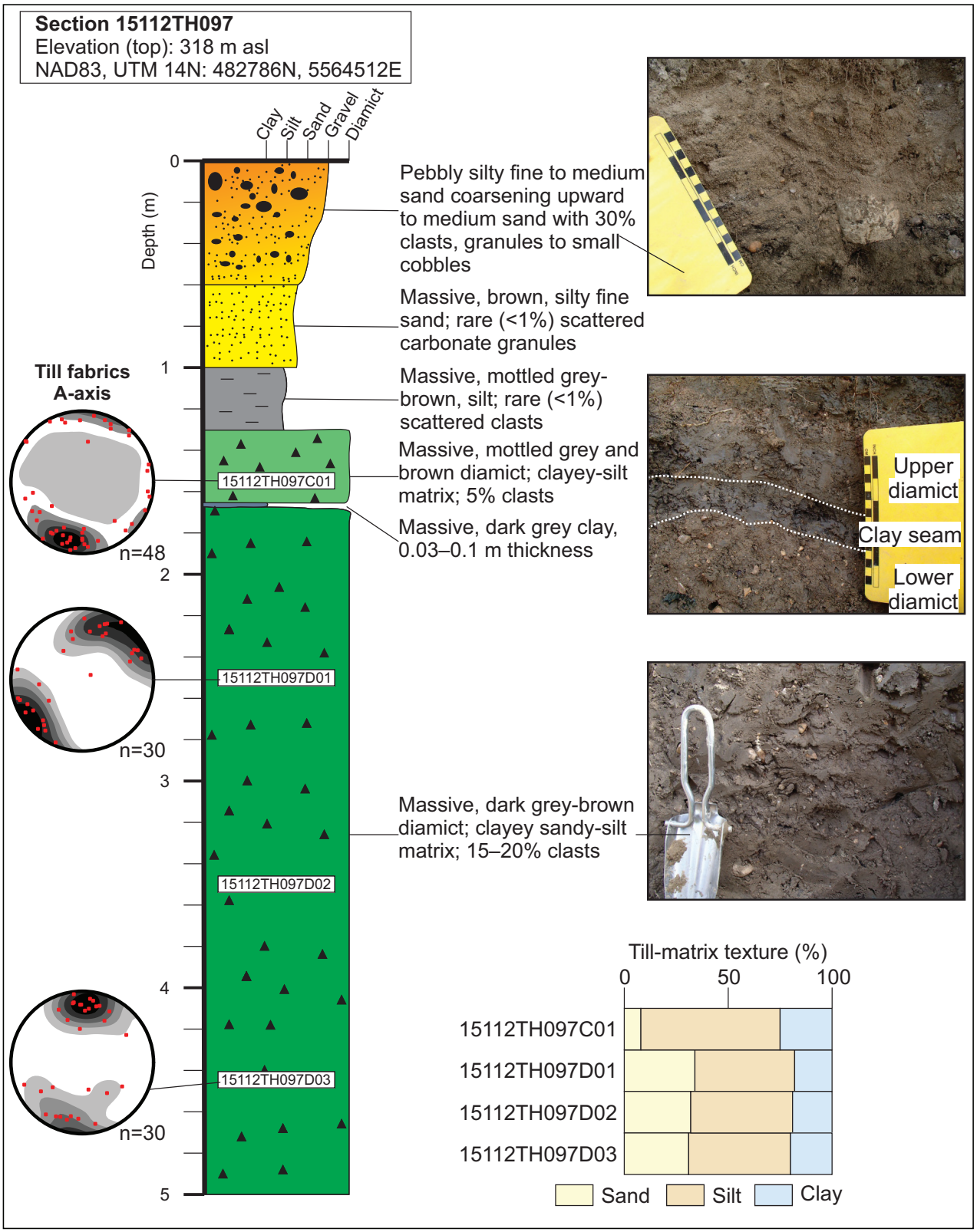

Figure GS-10-5: *Section 15112TH097 along the Whitemud River, south of Arden. Sample numbers 15112TH097C01, D01, D02 and D03 on the stratigraphic column refer to the location of till samples in their stratigraphic positions. Till-matrix texture results are presented for each sample. The a-axis till fabric results are presented on an equal-area, lower-hemisphere projection. See Figure GS-10-1 for section location.*

aid infrastructure and agricultural planning, highlight prospective regions for aggregate resources and provide a framework to understand the hydrogeology of the region. The Arden area is a large supplier of high-quality aggregate and understanding the Quaternary geology of the area will enhance future resource development.

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