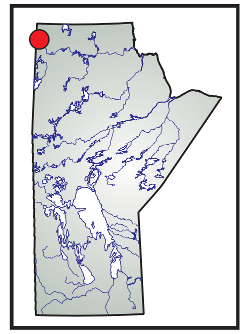
GS-2 Far North Geomapping Initiative: Quaternary geology of the Snyder–Grevstad lakes area, far northwestern Manitoba (parts of NTS 64N5)

by M.S. Trommelen



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Summary

Quaternary geological investigations were undertaken in the Snyder–Grevstad lakes area, situated in the far northwestern corner of Manitoba, as part of the Manitoba Far North Geomapping Initiative. In conjunction with detailed bedrock mapping (Kremer et al., GS-1, this volume), this work provides a modern geoscience knowledge base tailored towards current and future mineral exploration and/or infrastructure development. This report presents a summary of fieldwork activities related to a month-long detailed survey in July 2011. Geological observations, sampling of glacial sediments (till) and/or measurements of ice-flow indicators were recorded at 131 stations within a 577 km^2 area along the shores of Snyder and Grevstad lakes. Preliminary findings of this mapping (1:50 000 scale, Trommelen, 2011) are presented herein, and include the description of a bedrock regolith site that may have been preserved under a patch of locally cold-based ice. Dominant glacial landforms include hummocky stagnant ice moraine, streamlined landforms, ground moraine and eroded moraine within subglacial meltwater corridors.

The Quaternary geology survey focused on collection of ice-flow indicator data and till samples for dispersal-train analysis. Once analysis and interpretations are completed, knowledge of dispersal orientation and transport distance will be used to update drift-prospecting methodology for mineral (uranium and rare earth element) exploration in northwestern Manitoba. New ice-flow indicators were found that delimit ice flow to the east and east-southeast, in addition to known ice-flow indicators trending towards the southeast, south, southwest and west-southwest. These new ice-flow indicators are commonly rare and protected features indicative of old, relict ice-flow orientations. The ice-flow indicator record around Grevstad Lake is quite sparse, and most interpretations were made on indicators from the Snyder Lake area.

Introduction

An in-depth Quaternary geology study was conducted in the Snyder and Grevstad lakes area, far northwestern Manitoba, in July 2011 (Figure GS-2-1), as part of the Manitoba Far North Geomapping Initiative. This report presents a summary of fieldwork activities that included surficial geology mapping at 1:50 000 scale (Trommelen, 2011), regional ice-flow indicator analysis and till sample collection for geochemical and lithological analysis. This work was completed in conjunction with bedrock mapping (Kremer et al., GS-1, this volume) in the same area.

Objectives

The main objectives of the surficial geology component of the Manitoba Far North Geomapping Initiative are to better understand the glacial geology and geomorphology of the study area, and to generate geoscience data and maps that aid mineral exploration. The specific goals of the detailed surveys are to

- document micro- and meso-scale ice-flow indicators (e.g., glacial striae, roches moutonnées),
- improve understanding of regional ice-flow phases, and
- sample glacial sediments (till) to investigate compositional patterns (dispersal trains) and provenance.

Study area

The region (NTS 64N5) is part of the extensive discontinuous permafrost zone (Sladen, 2011), and permafrost was encountered beneath organic deposits. Elevation varies mainly from 380 to 430 m asl. Local relief is generally 10 to 30 m, but reaches up to 60 m at several large crag-and-tail landforms (tadpole-shaped landforms developed by glacial erosion of rocks of unequal resistance and/or by infill of a lee-side cavity). Numerous lakes and wetlands are present throughout the hummocky bouldery terrain, interspersed with swaths of streamlined terrain. The drift cover is generally thick and bedrock outcrops are rare. Where present, the regional southwest-trend of bedrock ridges typically coincides with the main ice-flow orientation, which has enhanced the bedrock ridges and eroded linear lake basins. Two main southwest-trending esker channel systems are present across the area.

The underlying bedrock consists predominately of Archean granitic gneiss, Paleoproterozoic psammite, pelite and calcsilicate of the Wollaston Supergroup, and subordinate granitic intrusive rocks (Kremer et al., GS-1, this volume).

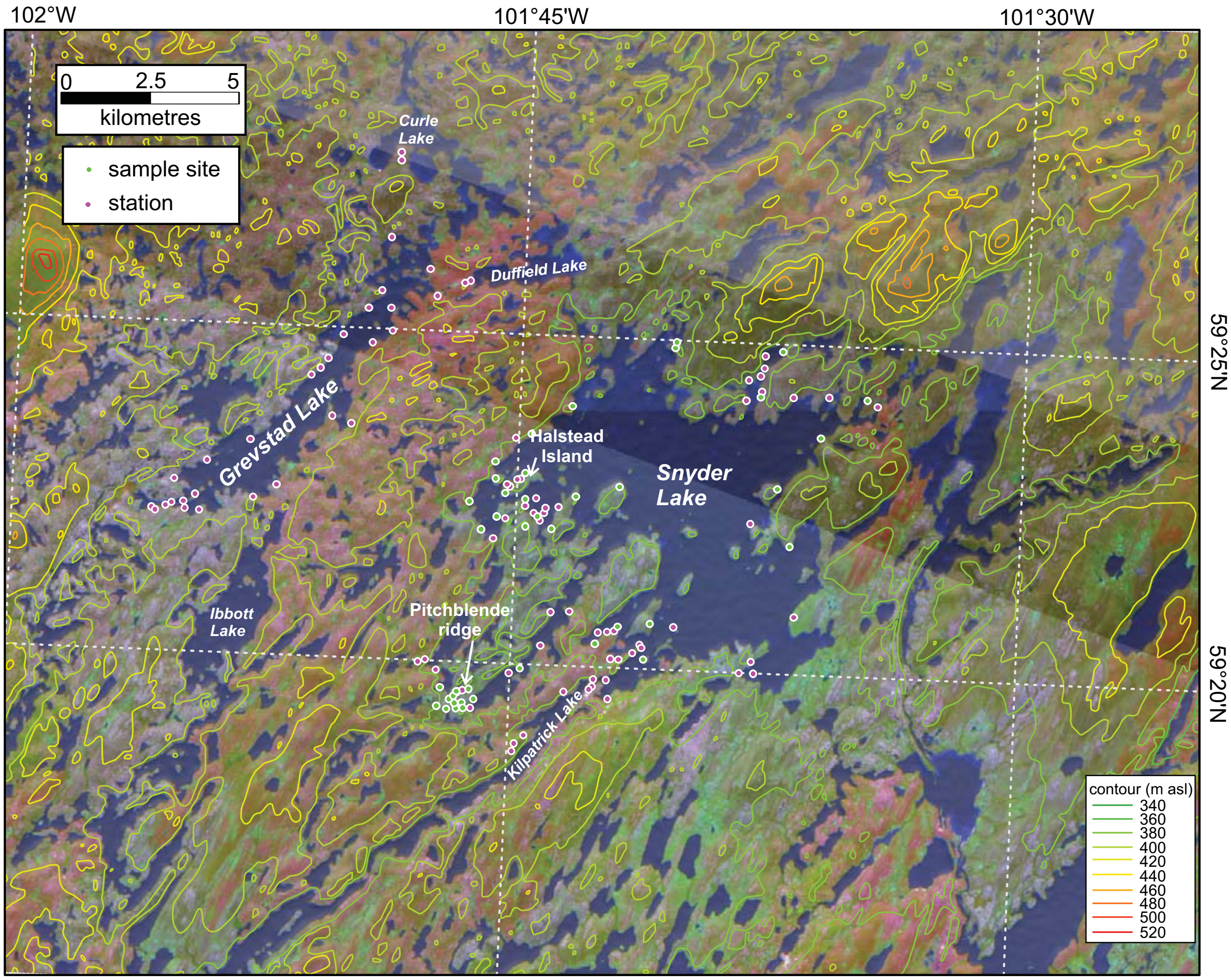

Figure GS-2-1: *Study area in far northwestern Manitoba with fieldwork based out of camps on Snyder and Grevstad lakes. Sample sites and mapping stations are shown. Background image was generated by draping SPOT 4 imagery over a Shutter Radar Topography Mission (SRTM) digital elevation model (United States Geological Survey, 2004).*

Regional glacial history

The study area was repeatedly glaciated by the Laurentide Ice Sheet (LIS) during the Quaternary period. In the pre-late Wisconsinan, ice flowed to the southwest (230 to 250°; Dredge et al., 1986; Campbell, 2001, 2002a; Smith, 2006; Smith and Kaczowka, 2007; Avery, 2010). In the late Wisconsinan, the main ice-flow orientation was south-southwest (205 to 215°). Early ice flow between 180 and 200°, and late ice flow between 232 and 258° have also been identified from striae and boulder dispersal trains (Dredge et al., 1986; Campbell, 2001, 2002a; Smith, 2006; Smith and Kaczowka, 2007; Avery, 2010). Rare nondirectional ice-flow indicators trending 295 to 115°, 336 to 156° and 270 to 90° have been documented nearby in northeastern Saskatchewan (Campbell, 2002a; Smith, 2006; Smith and Kaczowka, 2007). Trommelen and Ross (2010) provides a regional geomorphological context for the area.

The region was likely ice-free around 8.5 Ka C^{14} BP (Dyke, 2004), and was not transgressed by postglacial Lake Agassiz (Klassen, 1983).

Methods

In order to provide a better delineation of the complex geomorphology and surficial geology in the region, the study area was mapped in detail (Trommelen, 2011). The far northwest of Manitoba was first mapped in the early 1980s (Dredge et al., 1982) at 1:250 000 scale, and later recompiled as 1:500 000 scale maps (Dredge et al., 1985, 2007) along with a comprehensive report (Dredge et al., 1986). This extensive body of research provides a regional framework, which enabled the author to further refine the surficial geology and glacial dynamics at a detailed scale for the study area. Prior to fieldwork, 1:60 000 scale black-and-white aerial photographs were pre-mapped using a stereoscope. Mapping of the project area was finalized during August and September, and digitized in October.

Boat-supported fieldwork was undertaken during a four-week period in July 2011, based out of a main camp at Snyder Lake and a fly camp at Grevstad Lake. A total of 131 field sites were visited to ground-truth the surficial geology mapping, collect till samples and identify ice-flow indicators (Figure GS-2-1). Field sites were situated predominately near the lake shorelines, with the exception of inland sites, which were accessed by foot traverses. Forty-one samples, each weighing around 2 kg, were collected from C-horizon till in hand-dug pits at an average depth of 50 cm throughout the area for geochemical analysis (Figure GS-2-1). These sites included regional till sampling, as well as dense, local scale (<500 m) and regional scale (<2.5 km) surveys situated around known uranium– and rare earth element–bearing bedrock outcrops at Pitchblende ridge and Halstead Island (location of the Synder Island occurrence [Avery, 2010]; Figure GS-2-1; Kremer et al, GS-1, this volume). All till samples will be submitted for trace-element geochemical (<63 µm fraction) and pebble lithology (2 to 80 mm fraction) analysis. Identification of a boulder dispersal train encountered near Pitchblende ridge was carried out using a portable spectrometer (A. Chan, undergraduate assistant, University of Manitoba). The orientation of striations, grooves, chattermarks and roches moutonnées were measured at 53 sites (Data Repository Item DRI2011002[1]). Most ice-flow indicator sites, with the exception of outcrops cleaned of overburden by CanAlaska Uranium Ltd., are badly weathered bedrock outcrops with only the deep, larger, ice-flow indicators preserved. As such, the ice-flow indicator record discussed herein is skewed towards the older or more intensive ice-flow events and younger/weaker events may have been missed.

Results

Surficial geology

Keewatin till

Till cover is ubiquitous in the Snyder Lake area (Figure GS-2-2). There are two different facies of till, distinguished by clast concentration and matrix texture. The most common till is massive, moderately compact and matrix supported (fine to coarse sand) with 25 to 40% clasts. This till is designated bouldery till, as 30 to 40% of the surface consists of subrounded to subangular boulders. The second, less common till is massive, moderately compact and matrix supported, but with a sandy silt to silty sand matrix and only 10 to 20% subangular to subrounded clasts within the till and at surface. The percentage of surface boulders, and type of till, varies by glacial landform. Hummocks, drumlins and ribbed moraine contain higher concentrations of boulders and sandier till. Till veneers and blankets contain lower concentrations of boulders and siltier till. In both till types, the clast content is variable and generally decreases with depth. No sections were encountered though, so these observations are limited to the uppermost metre below surface. In depressions or in areas eroded by postglacial water, where peat is not present, the till is typically washed out and/or modified by frost heaving, leading to the development of extensive boulder fields (Figure GS-2-2b) consisting of subrounded to rounded clasts and mixed lithologies. In some areas, no till is present and instead perched erratics drape the bedrock (Figure GS-2-2c).

Eroded Keewatin till

Till situated either within a meltwater corridor (see Esker systems and meltwater corridors section below) or that was subsequently overrun by meltwater (sheet flooding) is termed eroded till (cf. Rampton, 2000; Campbell, 2001, 2002a). These areas have been uniformly eroded, leaving large steep-sided uplands (erosional scarps) and isolated islands of unmodified till. Eroded till consists of a 20 to 40 cm thick veneer of clast-rich material in a coarse to fine sand matrix. The percentage of fines (silt and clay) increases downwards as the intensity of erosion decreases.

Glaciofluvial

Glaciofluvial ice-contact deposits occur interspersed in hummocky and ridged landforms, which suggests abundant meltwater was present in the subglacial environment during deposition or modification of these landforms. Glaciofluvial landforms consist of massive to stratified fine to coarse sand with 5 to 20% subrounded to rounded clasts.

Organic

Organic bog deposits are common in very poorly drained surfaces in the study area, and are usually underlain by permafrost. Small streams that link the numerous lakes are usually bordered by fens. Organic cover is commonly thin (20 to 40 cm) where it overlies till plains, and thicker in low-lying areas between drumlins, hummocks or ridges. In a few areas along the shores of Snyder Lake, the peat is at least 4 m thick. Rare till mud boils are present within some of the widespread thin organic areas.

Regolith

Regolith, in-situ weathered bedrock (Figure GS-2-2d), was found at the three southernmost sites on Kilpatrick Lake (Figure GS-2-1). In this area, outcrops of both semipelite and calcsilicate bedrock consist of tilted, broken angular blocks in a weathered matrix of sandy silt (semipelite only). The character of these

[1] MGS Data Repository Item DRI2011002, containing the data or other information sources used to compile this report, is available online to download free of charge at http://www2.gov.mb.ca/itm-cat/web/freedownloads.html, or on request from minesinfo@gov.mb.ca or Mineral Resources Library, Manitoba Innovation, Energy and Mines, 360–1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada.

Figure GS-2-2: *Field photographs from the Snyder Lake area. **a)** and **b)** Till is the predominant surficial material in the region, and occurs as veneers and blankets (Tb), drumlin fields (white dashed lines, Tst) and hummocky terrain. Where water has removed the fine fractions, till is modified by frost-heave leading to the development of boulder fields (BF). Organic (O) peat is locally present in some very poorly drained areas. **c)** Rock drumlin draped by angular erratics of decreasing size. **d)** Regolith outcrop in the vicinity of Kilpatrick Lake. The semipelitic bedrock is strongly weathered and crumbly, with no evidence of glacial erosion. **e)** Felsenmeer (frost-shattered and -heaved bedrock) outcrops near Pitchblende ridge. **f)** On top of a drumlin, looking across the water to another drumlin.*

outcrop relics suggests significant chemical weathering occurred here. Typically, in glaciated terrains, chemically and mechanically weathered bedrock is removed by, and re-entrained within, overriding glaciers. These regolith outcrops at Kilpatrick Lake may be unique in Manitoba, and provide an example of what the bedrock elsewhere in the region may have looked like prior to glaciation. The regolith outcrops also have a significant influence on the paleoglaciological interpretation for the area, as they may have been preserved beneath the LIS by locally cold-based ice (cf. Hattestrand and Stroeven, 2002).

Felsenmeer

In-situ frost-shattered and -heaved bedrock (Figure GS-2-2e), composed mainly of angular monolithic blocks of local bedrock, occurs in several outcrop areas where till cover is thin or absent.

Geomorphology

The subglacial geomorphology of the Snyder Lake area is quite varied, and includes streamlined terrain (crag-and-tail features, drumlins and flutings), hummocky terrain and ribbed moraine (Figure GS-2-3). New SPOT 4 imagery has allowed for more detailed mapping of subglacial landforms than depicted in Trommelen and Ross (2010). The glacial landscape is quite chaotic and somewhat palimpsest. Difficulties still occur in deciphering precisely what type of landform occurs where and what the relationship is between different landforms.

Matile (2006) suggested that most glacial landforms in northwestern Manitoba are the result of turbulent meltwater flow. Whereas the role of subglacial meltwater in the dynamics of glaciers and the formation of subglacial landforms is widely recognized (van der Meer et al., 2003; Eyles, 2006; Piotrowski et al., 2006; Meriano and Eyles, 2009; Clark, 2010), there is limited evidence that meltwater formed glacial landforms in the study area. Boulders at surface and weathered outcrops as described by Matile (2006) can be alternatively explained as common boulder till subjected to localized erosion by meltwater and removal of till cover during or after glaciation. High velocities of turbulent meltwater flow

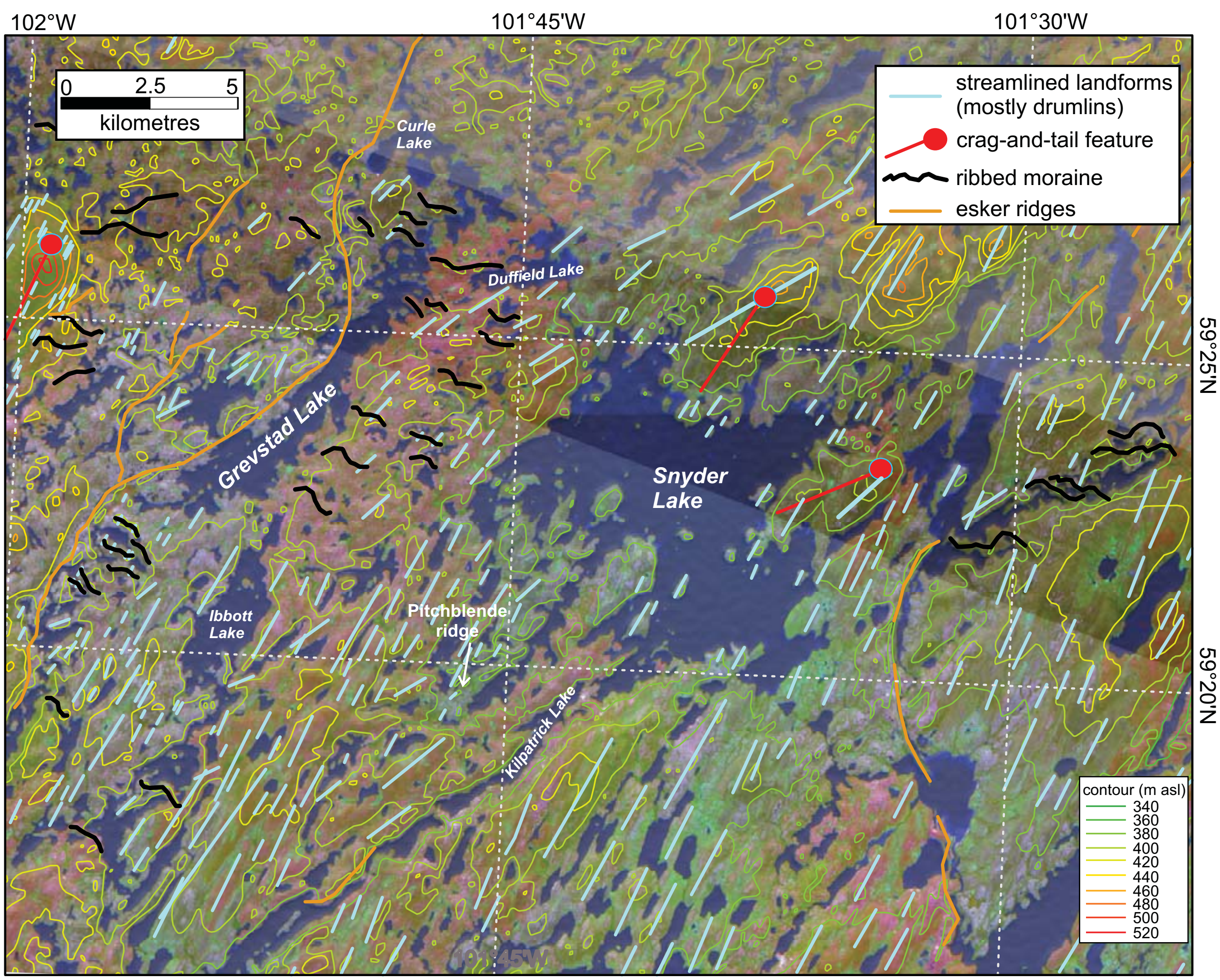

__Figure GS-2-3:__ Subglacial landforms in the study area, including streamlined landforms (drumlins, drumlinoid ridges and crag-and-tail features), ribbed moraine and eskers.

would be required to erode landforms at the scale of large drumlins present in the study area, and would not result in the short detritus transport distances observed. Instead, it is more likely that most subglacial landforms in far northwestern Manitoba were generated by a combination of subglacial deformation, basal sliding and/or glacial erosion at the ice-bed interface (cf. Evans et al., 2006). Contrastingly, landforms within meltwater corridors associated with eroded till may indeed have been formed or modified by significant amounts of meltwater.

Streamlined landforms

Two main sets of streamlined landforms occur in the study area (Figure GS-2-3). One rare set, consisting predominately of long (1.5 to 2.8 km) crag-and-tail landforms or drumlinoid ridges, trends toward 240°. The second, dominant set consists of drumlinoid ridges and spindle- or barchan-shaped drumlins (0.2 to 3.0 km long with a mean of 1 km) that trend between 200 and 210°. Streamlined landforms are widespread across the study area, except where partially to completely eroded and/or modified by meltwater within corridors. Within some large corridors, islands of non-eroded streamlined terrain remain.

Hummocky terrain

Hummocky terrain (Figure GS-2-4c, d), consisting of hillocks and hollows with multidirectional slopes dominantly between 15 and 35° and local relief greater than 1 m, is interspersed throughout the Snyder Lake area (Trommelen, 2011). In some cases, hummocky terrain appears to overlie streamlined landforms and/or ribbed moraine. All hummocky terrain consists of bouldery till.

Ribbed moraine

Scattered throughout the study area are sinuous bouldery till ridges, with long axes oriented east-southeast, broadly transverse to ice-flow (ribbed moraine, Figure GS-2-3). These ridges could be classified as lumpy, hummocky and poorly developed ribbed moraine ridges (Dunlop and Clark, 2006). They occur as scattered ridges, with nonuniform morphologies, and as such are unlike the pristine Rogen moraine fields in northeastern Manitoba (Trommelen and Ross, 2010; Trommelen et al., 2010). The relationship between the ribbed moraines and other subglacial landforms in the Snyder Lake area is difficult to understand with the resolution of imagery currently available, except to say that these ribbed moraine ridges appear to have been somewhat modified from their original form.

Esker systems and meltwater corridors

Esker ridges are the dominant glaciofluvial landform in the Snyder Lake area. The two main esker systems consist of large (3 to 10 m high), long (10 to 30 km) and regularly spaced (18 to 25 km) esker segments, with smaller (1 to 5 m high) and shorter (0.5 to 10 km) esker ridges between the large ridges (Trommelen, 2011). The orientation of the esker segments appears to have been partially influenced by the existing landscape and bedrock structure.

Eskers in the Snyder Lake area are part of a larger, regional meltwater channel network consisting of minor and major meltwater channels and corridors (Trommelen, 2011). The 0.1 to 2 km wide meltwater corridors (Figure GS-2-4a, b), also documented in the nearby Phelps Lake (Campbell, 2001, 2002a, b) and Wollaston Lake (Smith, 2006; Smith and Kaczowka, 2007) areas in northeastern Saskatchewan, consist of eroded and/or dissected till plains with boulder lags and patches of scoured bedrock, constrained by scarps at the boundary with non-eroded till. The corridors likely served as late deglacial pathways for significant amounts of glacial meltwater, during stagnation and downwasting of the LIS.

Ice flow

New ice-flow measurements were obtained from striations, grooves, chattermarks, crescentic gouges and fractures, rock drumlins (Figure GS-2-2c) and roches moutonnées, at 53 field sites in the Snyder Lake area (Figure GS-2-5). Most larger-scale features, such as rock drumlins and roches moutonnées, document an early, well-preserved widespread southwest-trending (220 to 250°) flow direction. This ice-flow phase is regionally extensive (Dredge et al., 1986; Campbell, 2001, 2002a; Smith, 2006; Smith and Kaczowka, 2007; Avery, 2010) and correlated to an 'older' ice-flow phase. The next ice-flow phase, preserved predominantly as chattermarks in two areas along the shores of Snyder Lake, is to the east-southeast (85 to 110° and 125 to 140°). Regionally, rare east- to east-southeast-trending ice-flow indicators have been documented in Saskatchewan (Campbell, 2002b; Smith, 2006; Smith and Kaczowka, 2007) and northern Manitoba (59°45'N and 102°W, Dredge et al., 1985), but an age has not been assigned. Based on crosscutting relationships in the Snyder Lake area, chattermarks are interpreted as the second regional ice-flow phase. It is possible that these striations indicate ice flow from an ice divide centred farther west in the south-central part of the District of Mackenzie (Dredge et al., 1986). Thirdly, ice flowed southeasterly across the region, documented by scattered chattermarks, gouges, striae and grooves oriented between 138 and 160°. Next, most field sites indicate a shift in ice flow over time, from southeast to southwest. At multiple field sites, ice-flow indicators with a southerly trend (175 to 195°) are crosscut by dominant ice-flow indicators trending south-southwest (200 to 212°), parallel to most drumlins in the region. These observations are consistent with published reconstructions suggesting major shifts of the Keewatin Ice Divide

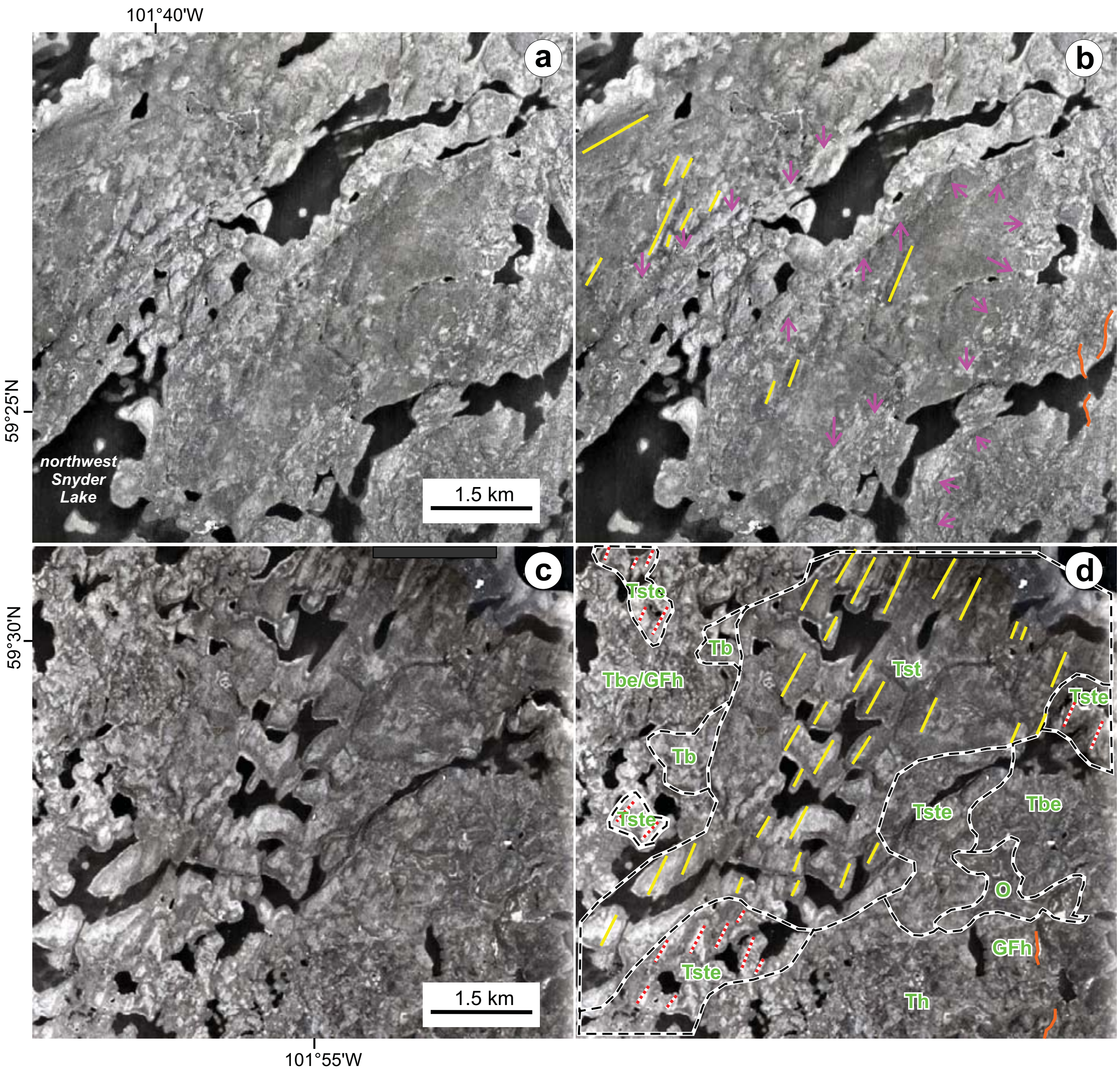

***Figure GS-2-4:** Meltwater features in the Snyder Lake area, as seen on aerial photographs. **a)** and **b)** Two meltwater corridors with eroded till at the base, and erosional side scarps (arrows). Streamlined landforms (yellow lines) and a till blanket are present on the plateau surface, between corridors. Esker segments are delineated in orange. **c)** and **d)** Transition from streamlined terrain (Tst) through eroded streamlined terrain (red and white lines, Tste) and eroded till blankets (Tbe) to interspersed hummocky till (Th) and glaciofluvial hummocky terrain (GFh). Organic terrain (O) is also present.*

eastward (e.g., McMartin and Henderson, 2004). Lastly, young southwest to west-southwest ice flow is evidenced by rare, fine striae (220 to 240°) preserved on outcrop surfaces that were recently cleaned of overburden.

Pitchblende ridge

Pitchblende ridge, southwest of Snyder Lake, is a crag-and-tail landform that trends toward 230° (Figure GS-2-6). The crag is a strongly metasomatized calcsilicate outcrop with uranium and rare earth element mineralization, whereas the tail consists of silty sand to sandy silt till with uraninite-bearing cobbles and boulders at surface. A second outcrop of mineralized calcsilicate felsenmeer occurs 65 m to the west of Pitchblende ridge (Figure GS-2-2e).

Preliminary boulder dispersal analysis suggests that boulders derived from Pitchblende ridge extend up to 335 m to the southwest, where boulder measurements dropped off to zero at the edges of the depicted boulder train (Figure GS-2-6). The first mineralized boulders (based on scintillometer readings of >0 counts per second [cps]) occur at surface 33 m southwest of the Pitchblende

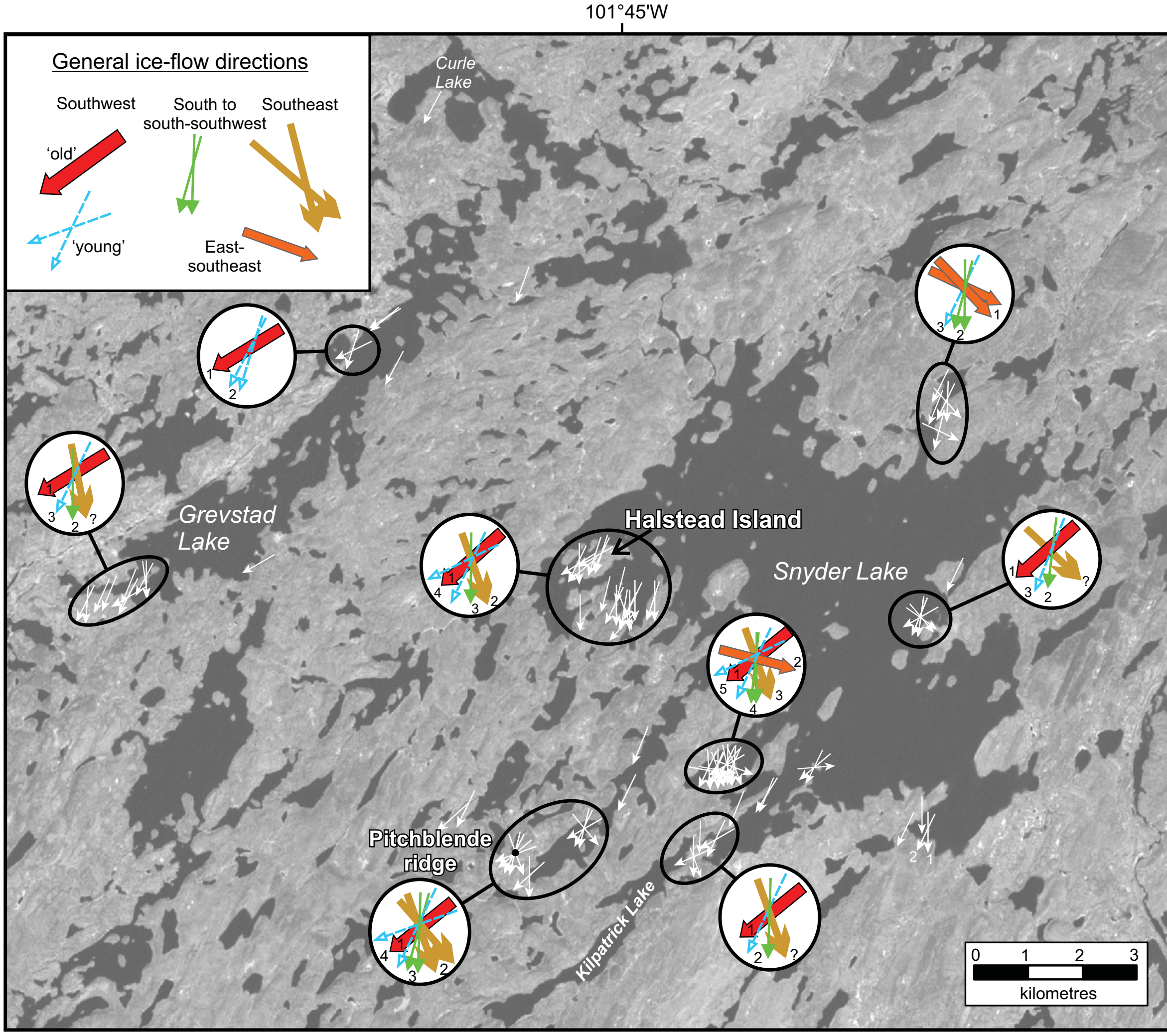

Figure GS-2-5: *Field-based ice-flow indicators in the Snyder Lake area. Larger circle insets are complied summaries of the relative ages (1 = oldest) and trends of ice-flow indicators for areas outlined in black. No absolute dates have been assigned.*

crag. The southern end of the dispersal fan is more diffuse, suggesting either minor re-entrainment and secondary dispersal in a different orientation, or a remnant of a first dispersal orientation (palimpsest dispersal, cf., Parent et al., 1996). Most highly mineralized boulders (>2000 cps) seem to have been transported from the felsenmeer outcrop rather than the Pitchblende crag.

Forthcoming trace-element geochemistry of the till matrix, and counts of pebble (2 to 80 mm) lithologies, will be complied with boulder dispersal results to provide a detailed case study of uranium dispersal at Pitchblende ridge. Preliminary results suggest the boulder dispersal train consists of a strong dispersal component toward 220° (ice-flow phase 5), with remnants of earlier dispersal components toward 140°, and 180 to 195° (ice-flow phases 4 and 3, respectively). The strong dispersal trend toward 220° may actually be a combination of dispersal produced during phases 1 and 5.

Future work

Ongoing surficial geological analysis focuses on tracing lithological indicators from known bedrock source areas, using pebble counts and the major- and trace-element geochemical composition of the till samples. Results of these analyses will

- establish compositional till characteristics and aid investigation of subglacial transport processes and distances;
- guide the mapping of glacial dispersal trains from mineralized outcrops, such as the uranium– and rare earth element–bearing Pitchblende ridge and Halstead Island outcrops; and
- provide information that can further delimit how the complex ice-flow record affected the strength of sediment erosion/transportation/deposition in the area; knowledge of which is required for mineral exploration that uses till to trace source areas.

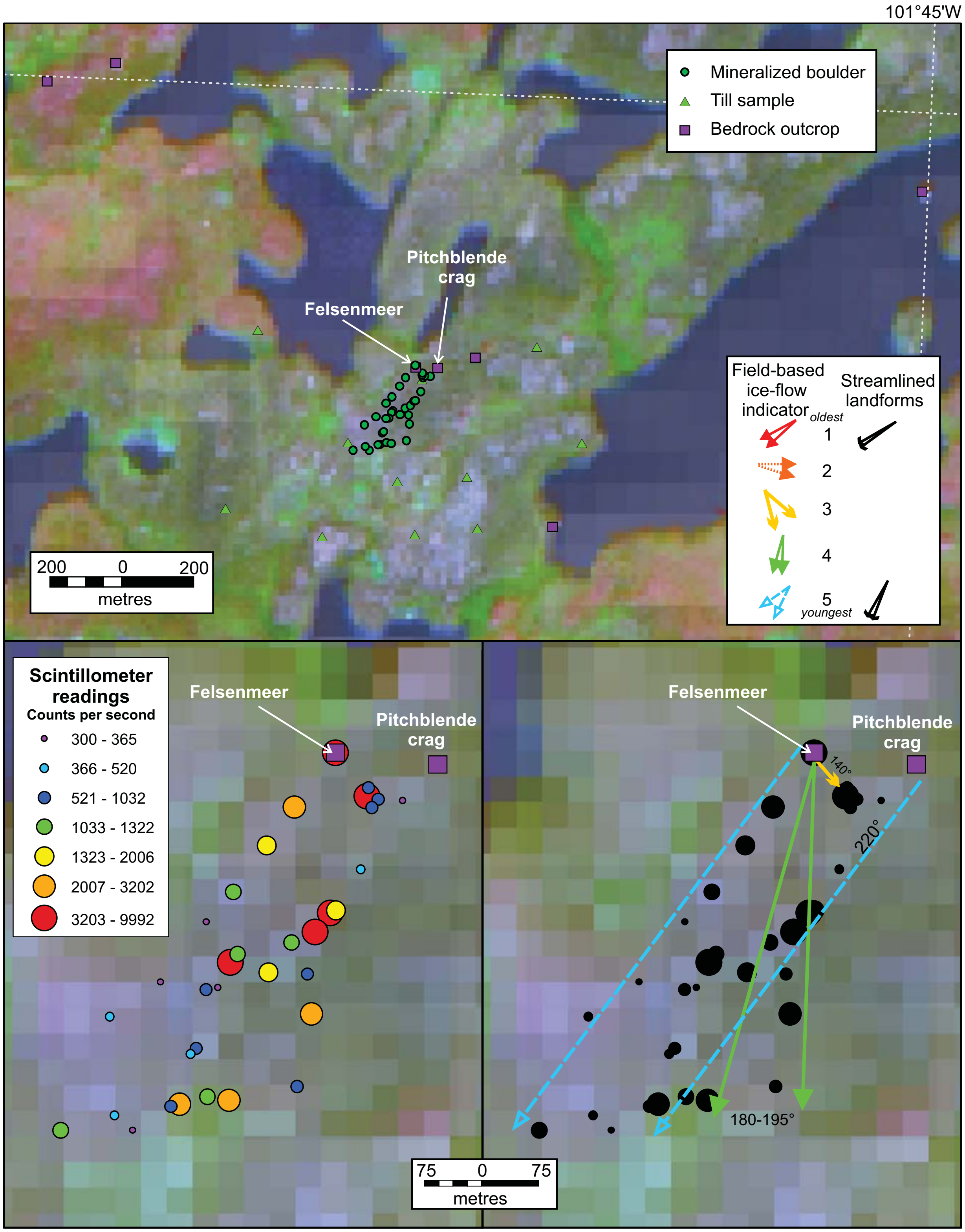

Figure GS-2-6: *Location of till samples and mineralized boulders associated with a crag-and-tail landform at Pitchblende ridge, southwest of Snyder Lake. Two mineralized calcsilicate outcrops (crag and felsenmeer) are the known sources for dispersal of calcsilicate boulders and sediment containing uraninite. Ice-flow phases for the region (field-based scale and landform scale) are also depicted. Field scintillometer readings (counts per second) suggest the concentration of uranium varies throughout the boulder train (lower left). Higher counts (higher uranium) are likely sourced from the felsenmeer outcrop. Comparing the dispersal train with measured ice-flow orientations (lower right), the dispersal train is likely palimpsest and formed by at least three ice-flow orientations.*

Economic considerations

As bedrock outcrops are rare in predominantly drift-covered northern regions, a thorough understanding of surficial geology is essential for drift prospecting in Manitoba's north. The Snyder–Grevstad lakes area hosts known showings and boulder trains with enriched uranium and/or rare earth elements (Avery, 2010). Till geochemistry is commonly used in drift-covered regions to help determine the source area for boulder trains, but is more difficult to interpret in palimpsest terrains such as the Snyder Lake area, which have been modified by more than one ice advance and transport direction. Whereas the scope of till sampling was limited by lakeshore access, ongoing surficial geological studies aim to provide a detailed framework for the directions, timing and nature (e.g., erosive or depositional) of major and minor ice-flow events in the region. Local, detailed boulder and till surveys based on known mineralized outcrops (e.g., uranium and rare earth elements at Pitchblende ridge and Halstead Island) can provide dispersal train patterns, which can be used to measure ice-transport distances and directions that can be applied to drift exploration in this region.

Acknowledgments

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