Current Research (2009) Newfoundland and Labrador Department of Natural Resources
Geological Survey, Report 09-1, pages 339-356

RED INDIAN LAKE PROJECT: A REVIEW OF QUATERNARY INVESTIGATIONS SOUTHEAST OF RED INDIAN LAKE, NEWFOUNDLAND

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ABSTRACT

The second year of a multi-year, till-geochemistry and regional surficial mapping program in the central volcanic belt, Newfoundland, focused on the south side of Red Indian Lake from Harbour Round east to Tally Pond, and from Millertown south to Snowshoe Pond. Field work in 2008 included mapping of ice-flow indicators and till sampling.

The mapping of ice-flow striations in the Red Indian Lake basin indicated that the ice flowed in three directions during the late Wisconsinan. The earliest ice flow was southeastward throughout the field area, likely from an ice centre on the Topsails Plateau. This was followed by northeastward flow in the northeastern part of the study area and southwestward flow in the western and southwestern part of the field area. The data suggest that there was a paleo ice-divide located between Costigan Lake and Harbour Round Pond.

The field area is covered by varying amounts of thick till and organics, as well as thin till veneer, glaciofluvial deposits and rare glaciolacustrine sediments. Regional till sampling was conducted at a spacing of 1 sample per 1 km^2 along woods roads to 1 sample per 4 km^2 where helicopter-support was required.

Future work will focus on completing the surficial mapping, determining the Quaternary stratigraphy of the Red Indian Lake basin, relating the stratigraphy to the ice-flow history, refining the ice-flow chronology and determining the extent of glacial lake Shanadithit and other proglacial lakes in the area.

INTRODUCTION

A field program comprising till-geochemistry and regional surficial mapping was completed during the summer of 2008 in the southeastern part of Red Indian Lake basin (RILB), central Newfoundland. This is the continuation of a multi-year program that began in 2007 in response to increased mineral exploration activity in the Tulks Volcanic Belt (TVB) in the southern part of RILB (Batterson and Taylor, 2008). The area has a long history of mineral exploration with the discovery of the Cu–Pb–Zn deposit in the Buchans area in the early 1900s, and more recently the opening of the Cu–Zn mine at Duck Pond in 2007. Recent exploration has focused on the volcanogenic massive sulphide mineralization found in the TVB of the Victoria Lake supergroup (VLSG) on the south side of Red Indian Lake (Hinchey, 2008). Mineralized boulders found in thick glacial drift, have created a demand for a better understanding of the paleo ice-flow history to aid in the exploration, and possible discovery, of new resources. While it is believed this program adds to the geological knowledge base for the area, it will also provide support to the current exploration efforts and may also stimulate mineral exploration activity in more inaccessible parts of the area. Support for this project was provided, in part, through the Government of Canada's Targeted Geoscience Initiative (TGI3) Program.

This paper presents the preliminary results of the 2008 field season along with a review of Quaternary work completed in the RILB including Grant (1975), Klassen (1994), Klassen and Murton (1996), Klassen and Henderson (1992), Mihychuk (1985), Sparkes (1984, 1985), Taylor (1994) and Vanderveer and Sparkes (1982). The purpose of the review is not only to provide background information but to identify gaps in the data as well as determine the objectives for 2009 field season; all of which are useful to mineral exploration and gaining a clearer understanding of the stratigraphy and ice-flow chronology within the RILB.

LOCATION, ACCESS AND PHYSIOGRAPHY

The study area lies in the interior of the Island of Newfoundland, and includes all of NTS map area 12A/10 and

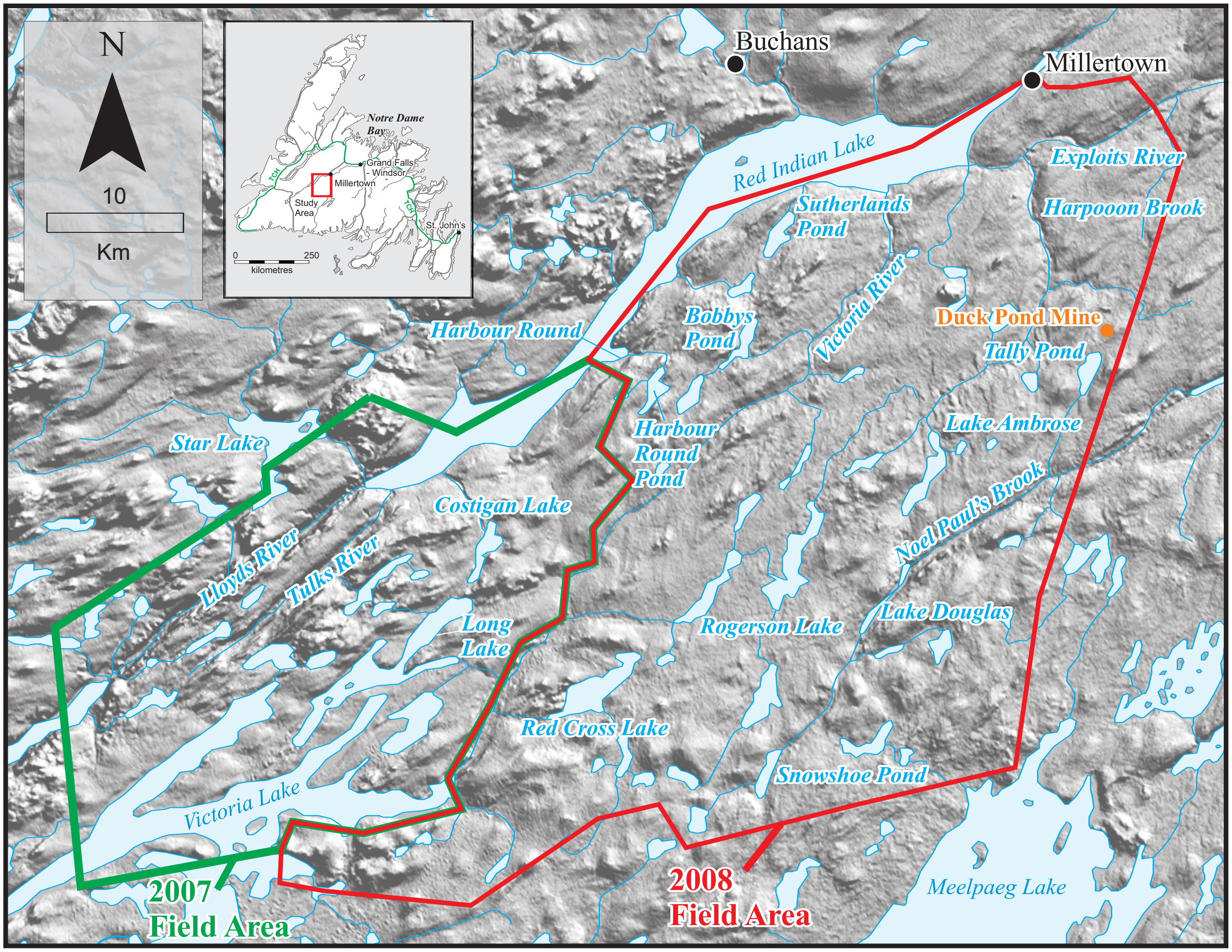


Figure 1. *Location of Red Indian Lake in central Newfoundland. Map identifies the location of the 2007 (green polygon, Batterson and Taylor, 2008) and 2008 field areas (red polygon). Note: Tulks River is also known as Tulks Brook.*

parts of NTS map areas12A/6, 7 and 15, covering an area of 1913 km^2 (Figure 1). It extends from the eastern boundary of the 2007 field area at Harbour Round, southeast to Victoria Lake and extends west to Tally Pond. The northern to southern boundaries extend from Millertown to Snowshoe Pond.

Located to the south of Buchans and Millertown, the field area may be accessed by Route 370 off the Trans-Canada Highway or by the woods road that extends south of the Exploits River from Grand Falls-Windsor. Being within 100 km of a recently active pulp and paper mill, the RILB has an extensive road network and has been an active logging area for the last 100 years; remote sampling sites were accessed by helicopter.

The RILB lies to the south of the Topsails Plateau and is part of the High Central Plateau as defined by Twenhofel and MacClintock (1940). The RILB lowland stretches from the southern end of Red Indian Lake to Notre Dame Bay and is drained by the Exploits River, the Lloyds and Victoria rivers and many streams flow into Red Indian Lake. Larger lakes within the field area include Harbour Round Pond, Sutherlands Pond, Bobbys Pond, Lake Ambrose and Rogerson Lake (Figure 1). Red Indian Lake, along with Victoria Lake and Meelpaeg Lake, are dammed for hydro-electrical power generation at Grand Falls and Bay d'Espoir.

PREVIOUS WORK

BEDROCK GEOLOGY

The Red Indian Lake area lies within the Dunnage Zone of the Newfoundland Appalachians (Figure 2). Sedimentary and volcanic rocks within this zone are the remnants of continental and intra-oceanic areas, back-arcs and ophiolites (Evans and Kean, 2002; Hinchey, 2008). Geochronology

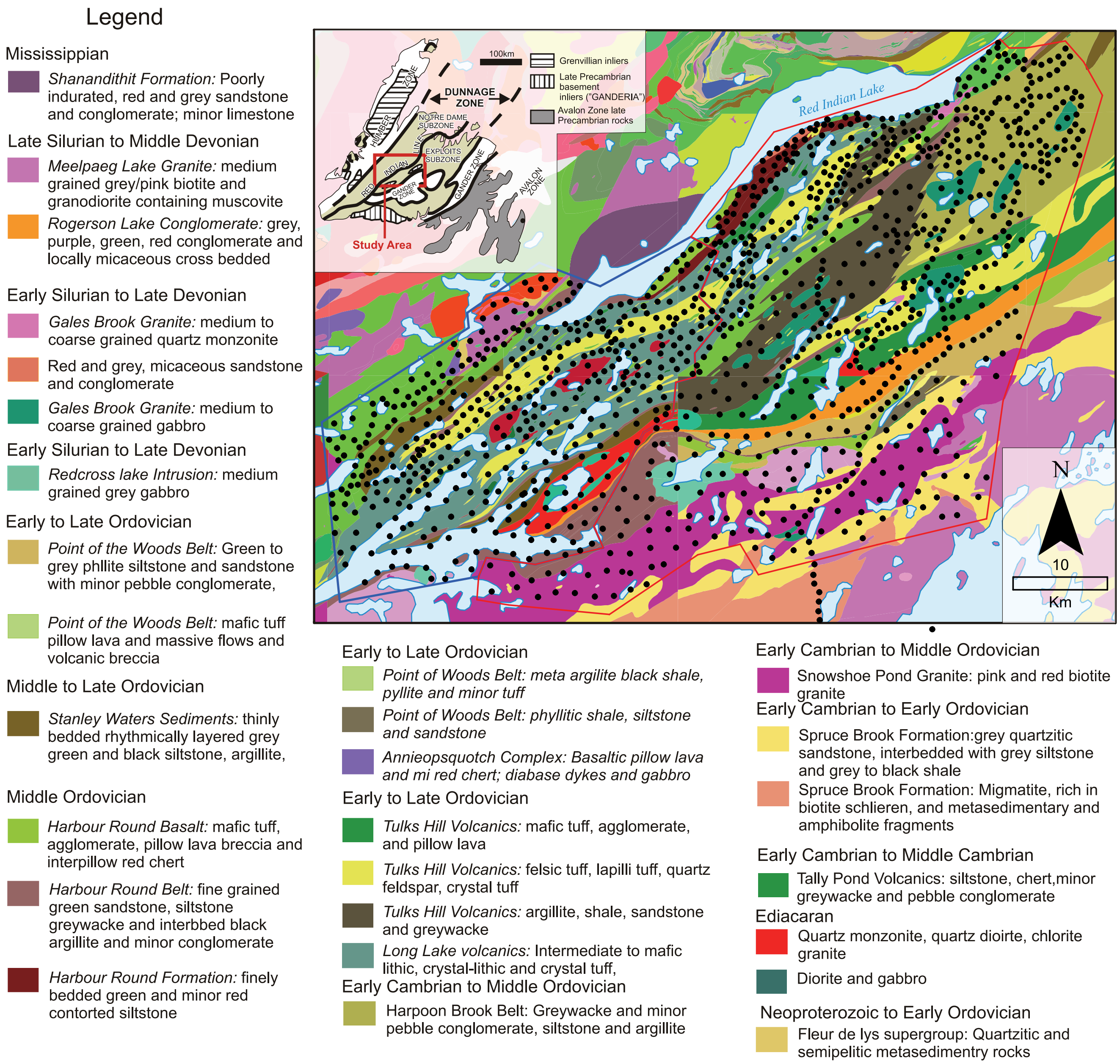


Figure 2. *Bedrock geology of the Red Indian Lake study area (taken from Colman-Sadd and Crisby-Whittle, 2005). Black dots show location of samples collected within the 2007 (blue polygon) and 2008 (red polygon) field areas.*

indicates these rocks were deposited within the Iapetus Ocean during the Cambro-Ordovician (Evans and Kean, 2002; Hinchey, 2008). The Red Indian Line, which lies along the south shore of Red Indian Lake, separates the rocks of the Red Indian Lake Group and Buchans Group of the Notre Dame Subzone from the VLSG of the Exploits Subzone. These subzones formed on the North American continent side and the Gondwanan side of Iapetus, respectively.

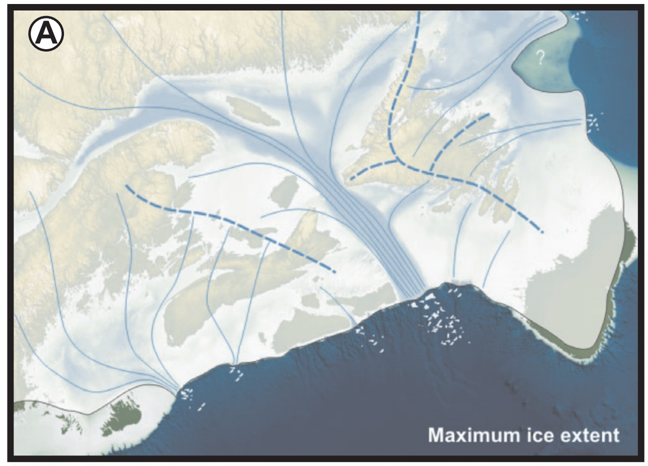
Most of the field area lies within VLSG and a detailed description of the geology of the area is given in Evans and Kean (2002) and in Hinchey (2007). A brief summary is given here.

The VLSG is bounded by the Red Indian Lake fault system to the north and Noel Paul's Brook to the south. The VLSG is subdivided into the Tulks Volcanic Belt, Long Lake Volcanics and Tally Pond volcanics. Rocks within the VLSG represent four different tectonic settings; active-arc, arc-rift, back-arc and mature-arc (Evans and Kean, 2002; Hinchey 2007). The rocks found in the TVB include: light grey to white quartz ± feldspar porphyritic pyroclastic rocks, felsic ash tuffs through to tuffs, and lapilli tuffs, breccias and local subvolcanic porphyries. Mafic volcanic rocks have also been identified and include tuffs, lapilli tuffs, breccias and local pillow lavas (Evans and Kean, 2002). These felsic volcanic rocks host several significant VMS deposits and showings. Mineral exploration within these rocks first started in 1905 with the discovery of the Victoria mine, a high-grade chalcopyrite–pyrite deposit. Between the 1960s and 1980s, the Tulks Hill deposit, Tulks Hill east prospect and Jacks Pond deposit, were discovered (Hinchey 2008). Recently in 2004, Messina Minerals discovered the Boomerang VMS deposit, as well as the Domino and Hurricane deposits in 2006 (Hinchey, 2007).

QUATERNARY GEOLOGY

The Quaternary geology of the Red Indian Lake area was first described by Coleman (1926), who noted the presence of boulder clay that contained many striated clasts. He also suggested that ice advanced from the northwest during the Wisconsinan glaciation. The first detailed report on determining direction of glacier ice motion in central Newfoundland was completed by Murray (1955). Quaternary investigations in the area surrounding Buchans began in the late 1970s and continued through the mid 1990s with the work of Grant (1975, 1976), Grant and Tucker (1976), Vanderveer and Sparkes (1982), Sparkes (1985) and Mihychuk (1985). Klassen (1994) and Klassen and Murton (1996) continued the detailed work and focused on refining the ice-flow history within the area. Regional interpretations of the glacial and Quaternary history of central Newfoundland are described in Grant (1989), Klassen (1994) and Shaw *et al.* (2006).

The Island of Newfoundland was covered by ice during the late Wisconsinan glacial maximum, by a series of coalescent ice caps known as the Newfoundland Ice Cap (Grant, 1989; Shaw *et al.*, 2006). Ice divides extended down the Long Range Mountains through central Newfoundland and eastward to the Avalon Peninsula (Figure 3a). This configuration likely remained stable throughout much of the late Wisconsinan (Shaw *et al.*, 2006). The configuration of the ice divides changed after 13 ka as deglaciation became land-based, leading to the disintegration of the Newfoundland Ice Cap into a number of small isolated ice caps (Figure 3b), one of which lay over Red Indian Lake (Grant, 1974; Figure 4). The central region of Newfoundland was likely the last place to become ice free, sometime after 10 ka (Shaw *et al.*, 2006). The complex ice-flow history recorded by many researchers in central Newfoundland (Vanderveer and Sparkes, 1982; Sparkes, 1985; Klassen and Murton, 1986; Klassen, 1994) reflects the shifting divides and local variations during the collapse of the Newfoundland Ice Cap. Central Newfoundland has also been suggested as one of the few places where a complete late Wisconsinan stratigraphy may exist (Klassen and Murton, 1996).



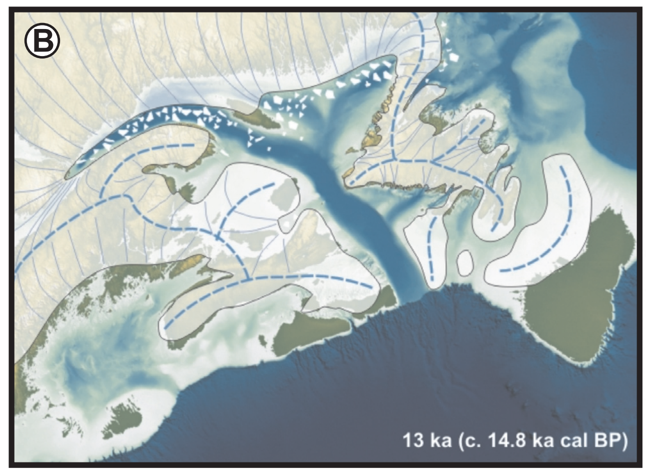


Figure 3. *Pattern of glaciation on the Island of Newfoundland. A) Shows the maximum ice extent of the Newfoundland Ice Cap. Note the ice divide extends down the Northern Peninsula and east to the Avalon Peninsula. B) Shows the retreat of ice on to land and change in the location of ice divides at 13 ka.*

ICE-FLOW HISTORY

Despite being the subject of numerous studies (Coleman, 1926; Murray, 1955; Grant, 1975, 1976; Grant and Tucker, 1976; Vanderveer and Sparkes, 1982; Sparkes, 1985; Klassen and Henderson, 1992; Klassen, 1994; Klassen and Murton, 1996; Batterson and Taylor, 2008) the ice-flow history and the chronology of ice-flow events is complex and remains poorly understood.

Grant and Tucker (1976) identified an early southwest ice flow, which was succeeded by a flow either to the northwest or southeast; however the timing of the latter two is unknown. Vanderveer and Sparkes (1982) and Sparkes (1984, 1985), suggested that the RILB was influenced by a southward flow (160–190º) that radiated from a centre on

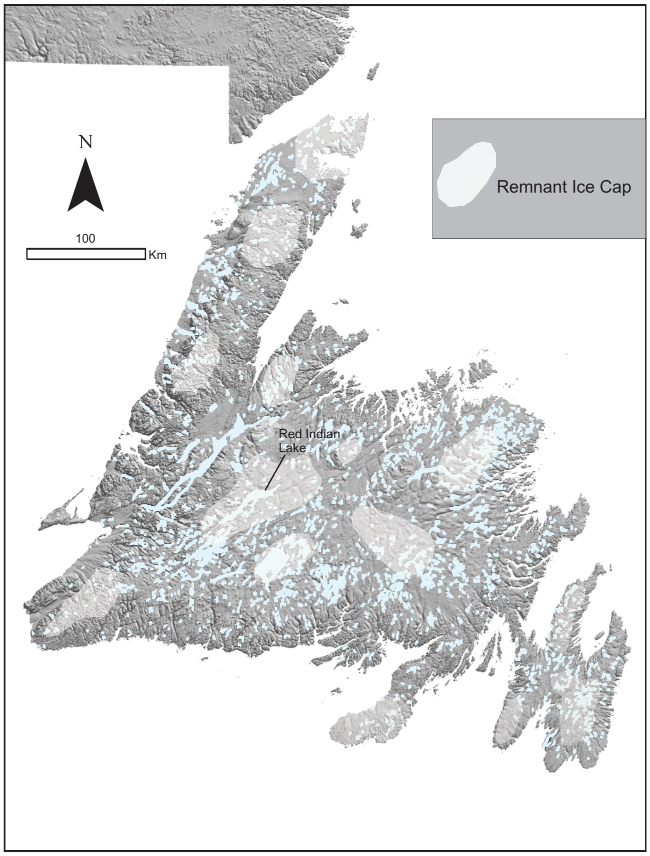


Figure 4. *Map of Newfoundland showing the approximate location of remnant ice caps as the Newfoundland ice cap disintegrated (modified after Grant, 1974).*

the Topsails Plateau, northwest of Red Indian Lake (Figure 5). The southward flow was followed by a southwest flow to the west of Lake Ambrose and a northeast flow to the northeast of Lake Ambrose (Vanderveer and Sparkes, 1982; Sparkes, 1984, 1985). Sparkes (1984) suggested that this divergent flow resulted from ice accumulation between Victoria Lake and Lake Ambrose. The ice-flow model of Batterson and Taylor (2008; Figure 6) shows flows similar to that described by Vanderveer and Sparkes (1982) and Sparkes (1984, 1985), but suggested the divergent northeast-southwest flow is from a paleo ice-divide located between Costigan Lake and Harbour Round Pond.

Klassen's (1994) ice-flow history suggests four ice-flow events affected the RILB and is the most complex model proposed to date (Figure 7). The evidence for the oldest flow is found in the Lake Ambrose area where the ice-flow was to the south and southeast (Event Ia; Klassen and Henderson, 1992; Klassen, 1994). Klassen (1994) indicates a more southward shift in ice flow occurred during Event Ib, but does not provide the details associated with this event. Klassen (1994) also suggested that the dispersal centre associated with this flow was located on, or north of, the Topsails Plateau, but there is no evidence to the north, in Buchans and Dawe's Pond, for this flow (Figure 7). This southward to southeastward flow (Events Ia, b, Klassen, 1994) is consistent with the oldest flow identified by Vanderveer and Sparkes (1982) and Batterson and Taylor (2008). Striations indicating a northeast-flowing ice are the most prominent and widespread; these represent Klassen's (1994) Event IIa. The northeastward flow is also suggested by the dispersal of red micaceous sandstone tens of kilometres from sources at the southern margin of the Topsails Plateau and underlying Red Indian Lake. Northeast-trending striations were also found in the Lake Ambrose area, and were reported as fresh and unweathered in comparison to the southern Event I striations identified at one location south of Red Indian Lake (Klassen, 1994). Also associated with Event IIa is a single striation site that records a southwest flow. This is the only evidence that relates to a southwest-orientated dispersal train of zinc in till described by James and Perkins (1981) in the Buchans area. Klassen (1994) interpreted this as a local reversal in ice flow and indicates that it is not well understood. Event IIb records a northward shift in ice flow within the Dawes Pond map area. Klassen (1994) attributes this to late glacial drawdown toward major bays on the northern coast. Event III (Klassen 1994) involves a southward flow across Red Indian Lake, which is younger than Event II and distinguished from Event I, by crosscutting relationships (Klassen, 1994). Klassen (1994) suggested this was a local ice flow that originated from the Topsails Plateau. Northward flow into Hinds Lake was also observed through striations and ice-marginal landforms (Figure 7). An ice divide separating the north-south flow is suggested to lie between Buchans and Hinds Lake (Klassen, 1994). The last phase of ice flow identified by Klassen (1994; Event IV) originated from a dispersal centre situated in the centre of Red Indian Lake and was oriented northeast–southwest. Evidence for this flow includes both striations and p-forms that are located along shoreline outcrops indicating that glaciofluvial erosion took place at the base of the ice (Klassen, 1994).

SURFICIAL GEOLOGY AND STRATIGRAPHY

Surficial deposits within the RILB are generally thick, exceeding 50 m in the Buchans area, but are thin adjacent to rock exposures (Klassen and Murton, 1996). The surficial units include till, glaciofluvial sands and gravels, glaciolacustrine silt and clay and organics. The morphology of these units varies considerably. Glacial deposits may be organized into drumlins, flutes and streamlined forms, ribbed moraine, or occur as thin veneers over bedrock (Vanderveer and Sparkes, 1982; Sparkes, 1984, 1985; Mihychuk, 1985; Klassen, 1994; Klassen and Murton, 1996).

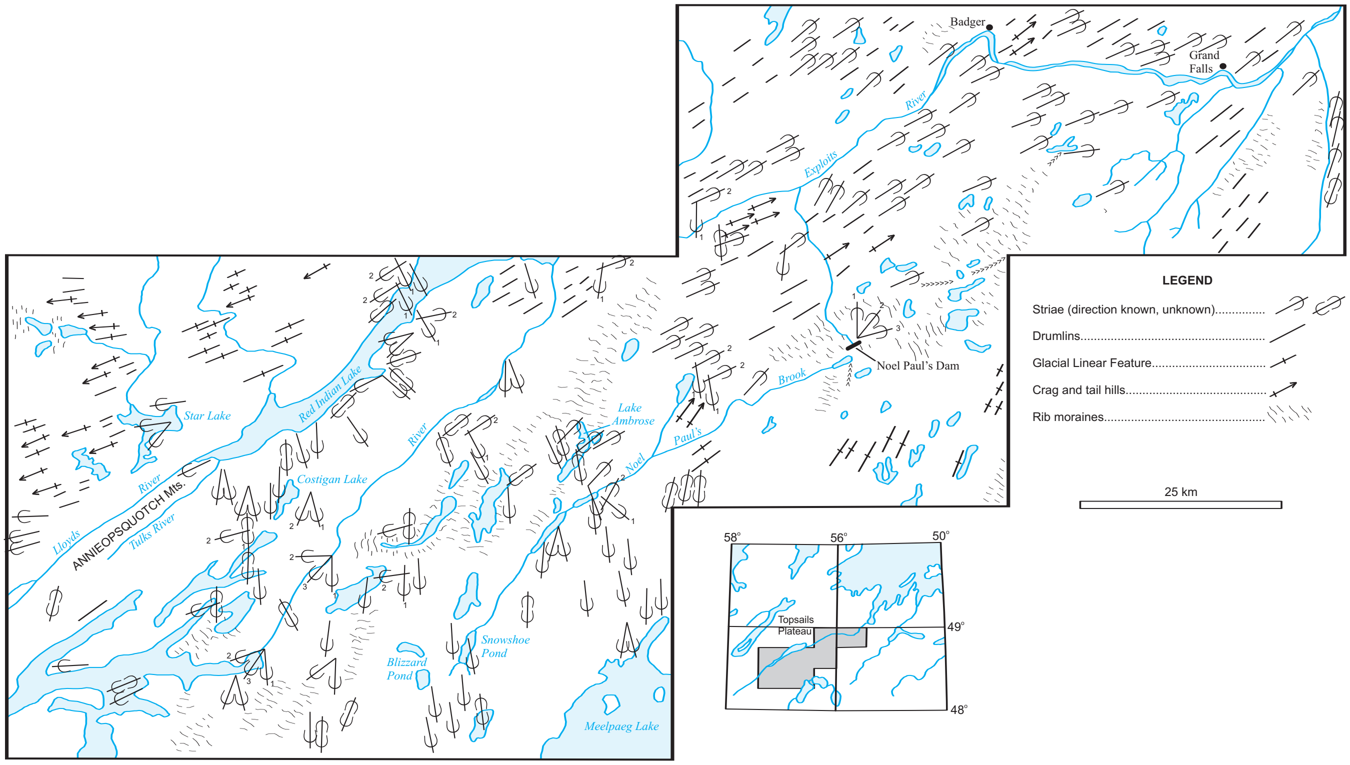


Figure 5. *Map showing the ice-flow chronology of Vanderveer and Sparkes (1982).*

Glacial stratigraphy of the RILB has been described by Vanderveer and Sparkes (1982), Mihychuk (1985), and Klassen and Murton (1996). However, each paper described the stratigraphy with reference to a different location within the basin (Figure 8).

The glacial stratigraphy identified by Vanderveer and Sparkes (1982) and Sparkes (1984, 1985) was described from the southwest end of Red Indian Lake in the Lloyds River, Tulks River and Costigan Brook valleys. In the Lloyds River valley, five succesive units are identified by Vanderveer and Sparkes (1982); a grey till, a sand–gravel, a silt–clay rhythmites, a silty till and a sand–gravel. However, the associated descriptions are poor and the units do not coordinate with the stratigraphic sections shown (Figure 9a), or with the later publications of Sparkes (1984, 1985). For the purpose of this paper, the description of three units given by Sparkes (1984, 1985) will be used, as they are represented in sites noted on Figure 9a. Rhythmites identified in this valley are termed the Lloyds River Rhythmites and are the lowest unit described by Sparkes (1985). These silty rhythmites are thinly stratified, graded and are commonly distorted or folded where overlain by till (Sparkes, 1984, 1985). The overlying till is sandy, poorly compacted and contains clasts of local origin (Site 33, Figure 9a). Sand and gravel commonly overlie this upper sandy till unit (Sparkes, 1984, 1985).

A reddish brown to grey basal till is identified in the Tulks River valley (Site 315). It is a sandy, compact, fissile till composed of locally derived Victoria Lake Group Volcanics (Vanderveer and Sparkes, 1982; Sparkes, 1984, 1985), which they called the Tulks River Till. It is overlain by distorted and folded, silty-clay rhythmites, which in turn is overlain by a thin loose, sandy brown-grey till.

In Costigan Brook, Vanderveer and Sparkes (1982) identified a stony compact till containing gabbroic clasts derived from a source to the north. Later, Vanderveer and Sparkes (1982) and Sparkes (1984, 1985) correlated this till with the Tulks River Till. The till identified at Costigan Brook is overlain by a thin, red silty till, which in turn is overlain by a sand and silt or a pebble gravel (sites 301 and 302, Figure 9a). At Site 301, the sand and silt is overlain by a red brown fissile till (Figure 9a; Vanderveer and Sparkes, 1982; Sparkes, 1984, 1985). Although Vanderveer and Sparkes (1982) and Sparkes (1984, 1985) provide little detail for the units described above, they do suggest a chronology for their deposition. The Tulks River Till (lowermost) and the lowermost Costigan Lake till were deposited during the earliest southward ice flow, as they both contain gabbroic clasts derived from a source to the north (Sparkes, 1984). The Lloyds River silt and clay rhythmites were deposited in a dammed proglacial lake (possibly glacial lake Shananditхit; Mihychuk 1985, *see* below) synchro-

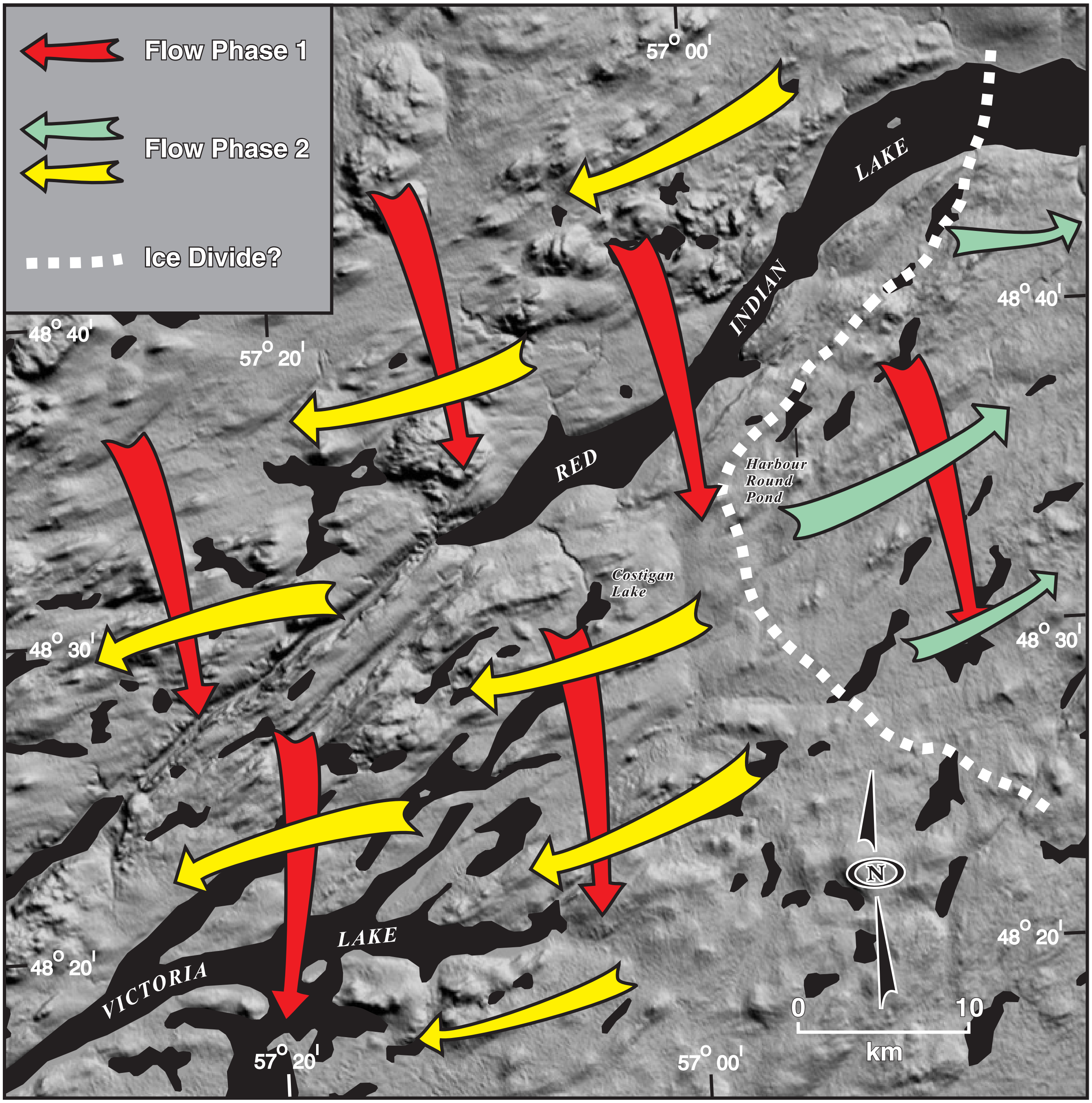


Figure 6. *Map showing Batterson and Talyor's (2008) ice-flow model.*

nous with the separation of the southward glacial flow into smaller local ice centeres (Sparkes, 1985). Once the rhythmites were deposited and the lake drained, the area was reglaciated by a smaller ice centre situated between Victoria Lake and Lake Ambrose; from this centre, ice flowed northeast and southwest. Simultaneously, ice flowed from a centre at Hinds Lake and occupied RILB including the Lloyds and Tulk River valleys, depositing till on top of the rhythmites at these locations (Figure 7; Sparkes, 1985).

Mihychuk (1985) identified three till units in the Victoria study area (Figure 9b). The lowest till is a silty light-grey till containing subround to subangular clasts. It is moderately over-consolidated and exhibits a well-developed fissility (Mihychuk, 1985). The presence of granites from the Topsails Plateau suggests it was deposited by southward-flowing ice. Mihychuk (1985) interpreted this unit as lodgement till (granitic lodgement till facies; Figure 9b). The overlying unit is a clast-rich, brownish-red till that has a sandy silty

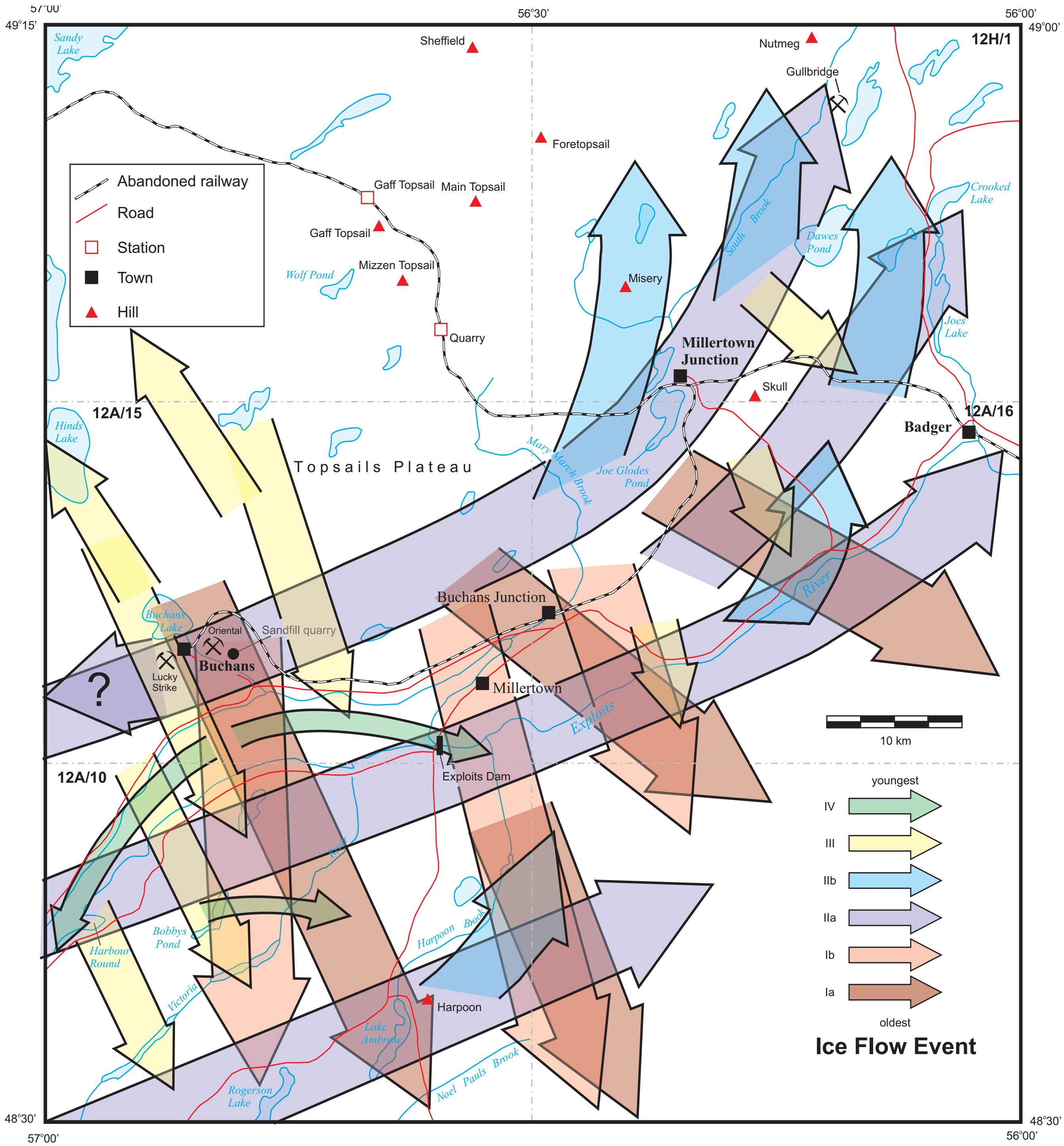


Figure 7. *Map showing Klassen's (1994) ice-flow model.*

matrix. Clasts are very angular and are from a local source. This till was also interpreted as a lodgement till (volcanic lodgement till facies; Figure 9b). Overlying the volcanic lodgement till facies is an under-consolidated sandy, tan-brown, stony till. It contains sparsely distributed sand lenses and the unit has no apparent fissility. Mihychuk (1982) interpreted this unit as a melt-out-till facies, which was deposited during the final phases of the last ice flow. Both medium-grained sand and well-rounded pebble cobble gravel have been found to overlie the uppermost till unit. The sediments are located at 212 m asl, 60 m above the modern level of Red Indian Lake, and were interpreted to be related to strandlines of a proglacial lake, informally named 'glacial lake Shanandithit' (Mihychuk, 1985).

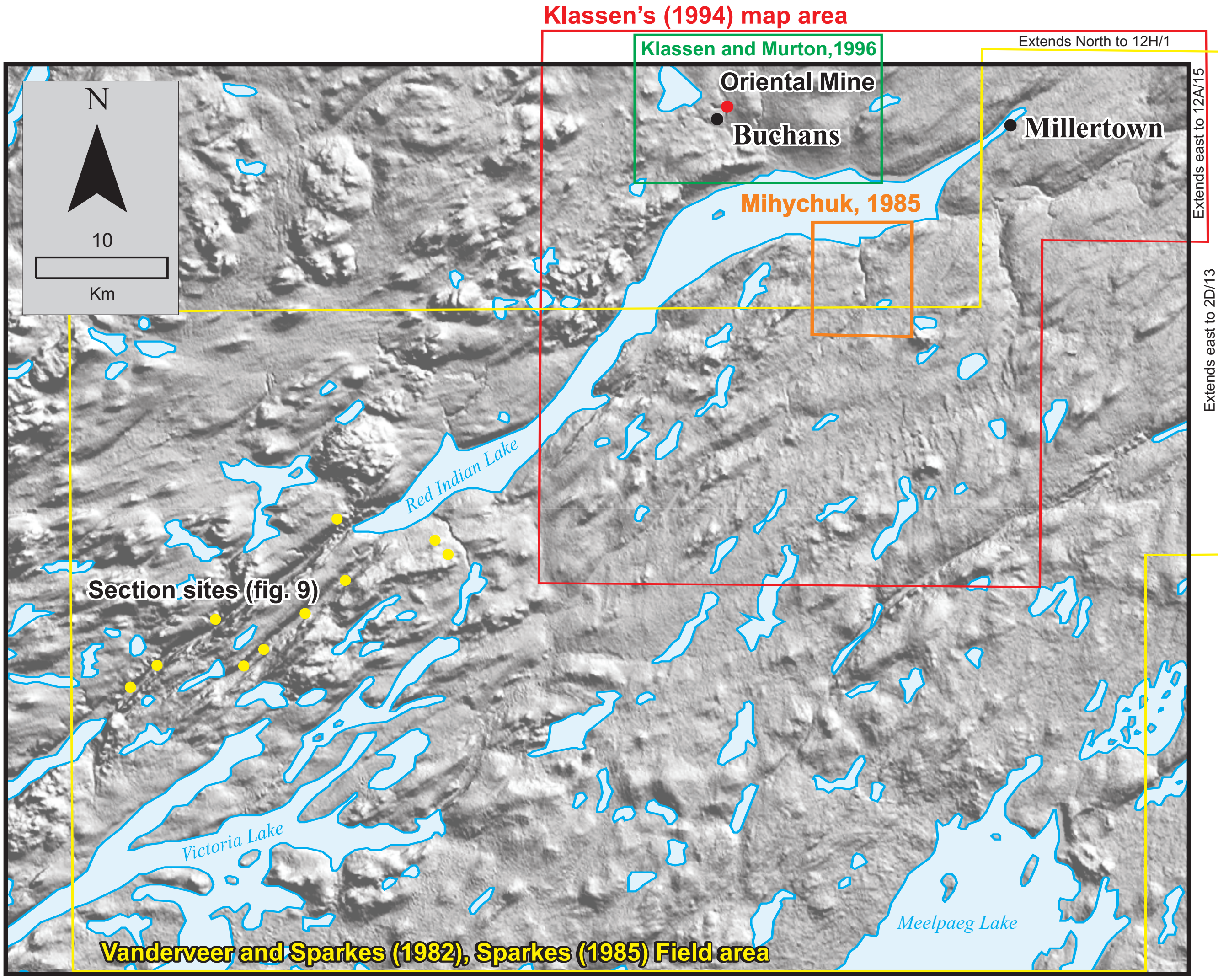


Figure 8. Location of stratigraphic investigations conducted by Vanderveer and Sparkes (1982), Mihychuk (1985), Sparkes (1985), Klassen (1994) and Klassen and Murton (1996).

Klassen and Murton (1996) studied 7 sections from the Buchans area. The Oriental Mine section was divided into five units (Figure 10). The depositional environments identified for these five units are similar to what was identified in the other sections. These units for the Oriental Mine section are briefly summarized here and are shown in stratigraphic context in Figure 10. Unit 1 is composed of a grey, compact, massive diamicton containing an irregular body of silt and clay, which exhibits horizontal and discontinuous laminae. The compact and massive diamicton, interpreted as a lodgement till based on its clast fabric, is locally clast-supported. Unit 2 is a loose, dark-grey sandy diamicton, which is matrix-supported and massive to poorly stratified. It contains inclusions of compact diamicton and red, silty sand. The origin of this unit is not clear, but it is likely a meltout till. Pink-grey, poorly laminated silt and clay comprises Unit 3. It has an undulating lower contact and contains lenses of fine to medium sand, granules and pebbles. Klassen and Murton (1996) suggest that these are deformed glaciolacustrine sediments as suggested by texture and poor laminae preservation. A silty sand diamicton containing sandy inclusions of fine to coarse sand comprises Unit 4. It is matrix-supported, loosely compacted and massive to poorly stratified and interpreted to have been deposited by debris-flow re-sedimentation, on the basis of textural heterogeneity, inclusions of sand and rhythmites, and disorganized to weak clast fabric. Brown sandy gravel having a medium to coarse sand matrix is defined as Unit 5. It is generally massive, clast-supported and contains rounded to subangular pebbles and cobbles. Klassen and Murton (1996) suggest that the clasts are of glaciofluvial origin but it is inconclusive whether the unit is an *in situ* glaciofluvial deposit or if it has been redeposited.

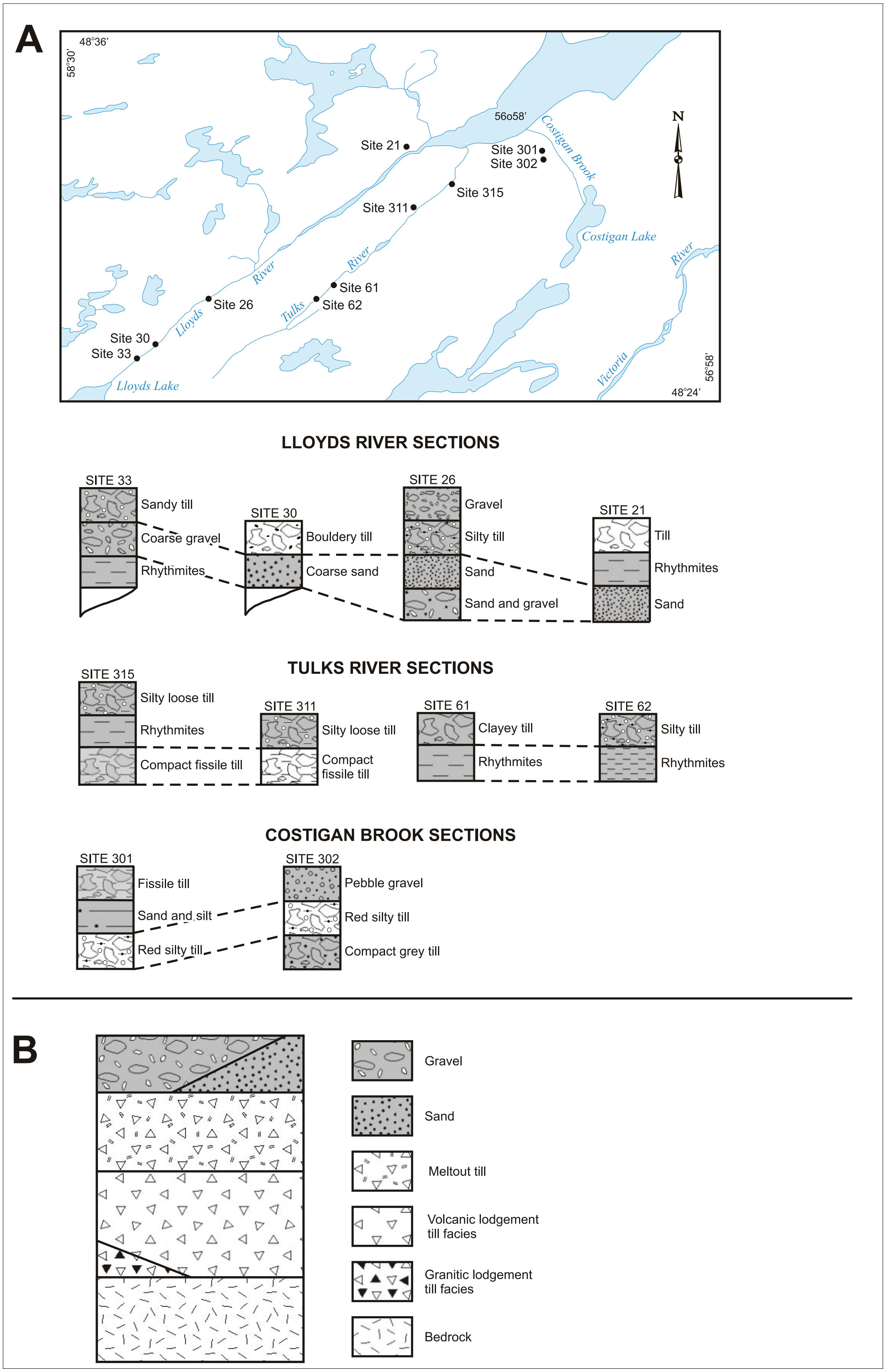


Figure 9. *Stratigraphic sections as developed by, A) Vanderveer and Sparkes (1982) and B) Mihychuk (1985).*

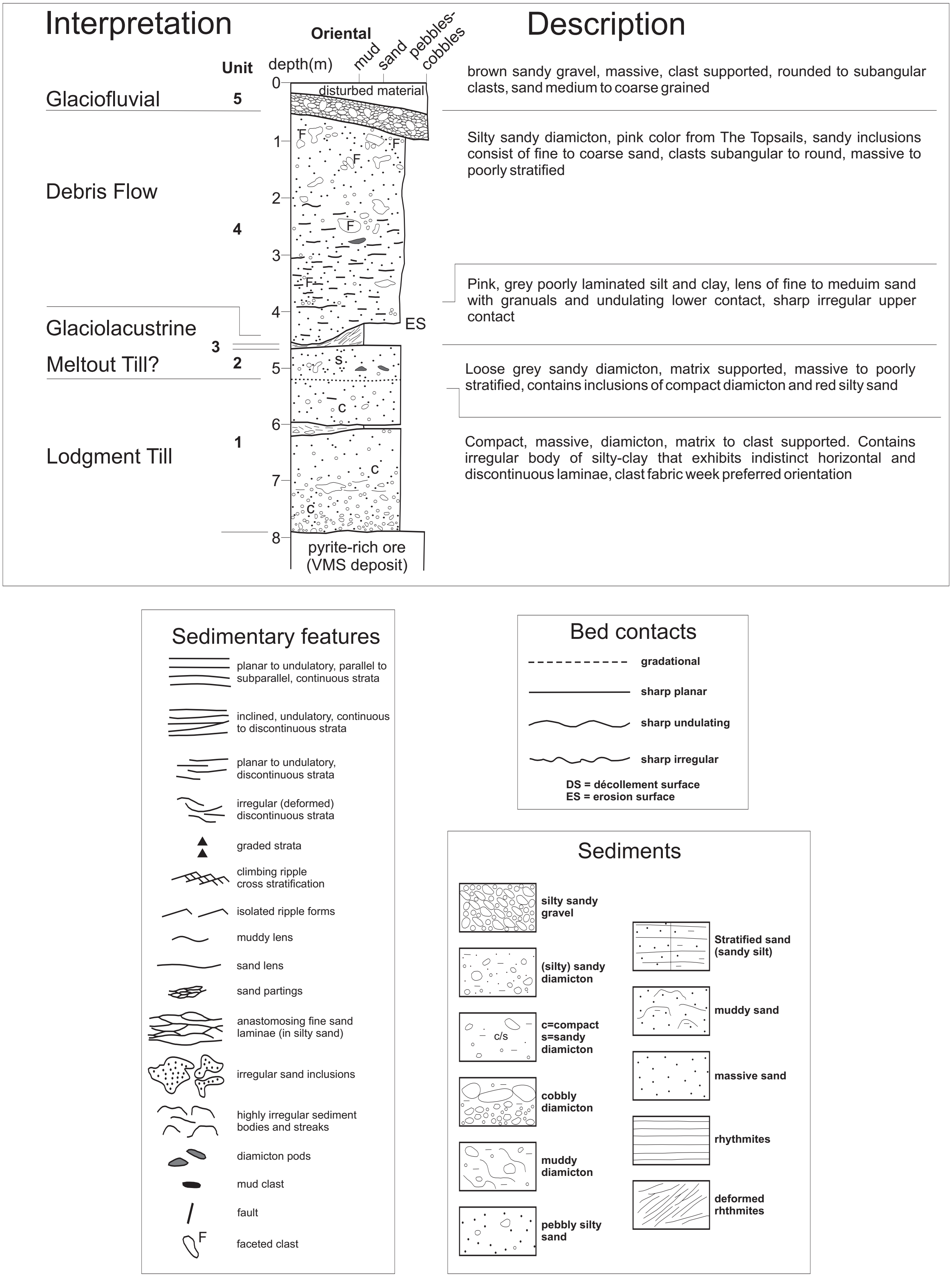


Figure 10. *Stratigraphic section from Oriental Mine as developed by Klassen and Murton (1996).*

Based on correlating the stratigraphy to the ice-flow record, Klassen and Murton (1996) suggest that the stratigraphic framework records two distinct glacial events separated by an ice-free period (Klassen and Henderson, 1992). All events are assumed to be Wisconsinan due to the lack of buried organic material. However, iron-stained southward-oriented striations identified south of Red Indian Lake, may suggest an ice-free period between glacial events. Therefore, Klassen and Murton (1996) suggest the southward to south-eastward flow of Events Ia and b (*see* Figure 7) could be pre-Wisconsinan. The oldest glacial deposits are represented by the grey compact till identified in Unit 1 in the Oriental Mine section (Klassen and Murton, 1996). Clast fabrics and provenance indicated that this till was deposited by the northeast-flowing ice during Event IIa (Klassen and Henderson 1992). Following this, the Buchans area was inundated by an ice-contact lake, in which the rhythmically bedded silts and clays at Oriental Mine section (Unit 3) were deposited. Glaciolacustrine deposits and sill elevations at Hinds Lake suggest that maximum lake surface elevation was 300-310 m asl. The ice-free event between Events II and III is inferred from the silty, sandy diamicton that overlies and incorporates glaciolacustrine sediment. A local ice advance during Event III deformed the glaciolacustrine sediment, and as a result granite-rich debris derived from the Topsails Plateau extends into the Buchans area (Klassen and Murton, 1996). This was followed by debris-flow re-sedimentation of the silty sand diamicton comprising Unit 4 at Oriental Mine section. Klassen and Murton (1996) indicate that the clasts within Unit 5 appear to be of a glaciofluvial origin, but were unsure how Unit 5 was emplaced.

RESULTS – FIELD SEASON 2008

REGIONAL TILL-GEOCHEMISTRY

Field work in 2008 focused on the continuation of a soil-sampling program that was started in 2007 (Batterson and Taylor, 2008) at the southwest end of Red Indian Lake (Figure 2). From the C- and BC-horizons of hand-dug pits and roadcuts, 772 samples were collected and placed in 1 kg bags. Depths in the hand-dug pits averaged 45 cm, whereas sampling depths in roadcuts ranged from 40 to 100 cm. The spacing between samples varied depending on the mode of transportation. Along woods roads a sample was collected every 1 km^2, and in more remote areas, where helicopter support was required, samples were collected every 4 km^2. Every 20 samples, a duplicate sample was collected to check for field reproducibility of elemental concentrations as part of the quality assurance – quality control (QA/QC) process. Samples were submitted to the Geological Survey laboratory for geochemical analysis that included ICP-ES, to evaluate a suite of elements. Samples will be sent to an external laboratory to assess for other elements including gold, using INAA techniques. Data release is anticipated by summer 2009.

ICE-FLOW HISTORY

Over 180 striations were recorded from 88 sites during the 2008 field season. Erosional ice-flow indicators suggest that ice flow ranged from north-northeast (20º) to north-northwest (344º) producing an almost complete radial pattern (Figure 11). Multidirectional sites were observed at 29 sampling stations. Relative age relationships were determined at 22 of these sites using crosscutting relationships and lee-side preservation of older ice flows.

Most of the striation data were collected along woods roads where outcrops were plainly visible, whereas 7 striation records were collected at remote sample sites where bedrock was present. All striations identified were fresh and unweathered, and are, therefore, tentatively interpreted as late Wisconsinan. Multiple ice-flow directions as seen from the data collected indicate that this area's ice-flow history is complex (Figure 11).

The ice-flow directions identified from data collected this past summer include:

- A southeastward ice-flow direction that was found throughout the central part of the field area between Red Indian Lake and Meelpaeg Lake.
- An east-northeast ice-flow direction that was found north of Noel Paul's Brook, in the central part of the field area, and along the northern edge of the field area.
- West-southwest and a north-northwest ice-flow direction were also common in the Red Indian Lake area. The west-southwest flow was identified south of Harbour Round Pond and northeast of Bobbys Pond, as well as at two localities south of Red Cross Lake. The north-northwest flow was identified around Harbour Round Pond, northeast of Bobbys Pond and along the road at Lake Douglas.

The age relationship data indicate the southeastward flow is older than the east-northeast flow. This relationship was recognized at 11 of 14 multidirectional sites containing these ice-flow directions. At the remaining 3 of 14 multidirectional sites, the opposite age relationship was noted. At one site along the western boundary of the study area, the southward flow was followed by a southwestward flow. This ice-flow pattern was also identified farther west during the 2007 field area (Batterson and Taylor, 2008).

Combining the data collected in the 2008 field season with data collected by Batterson and Taylor (2008), a tenta-

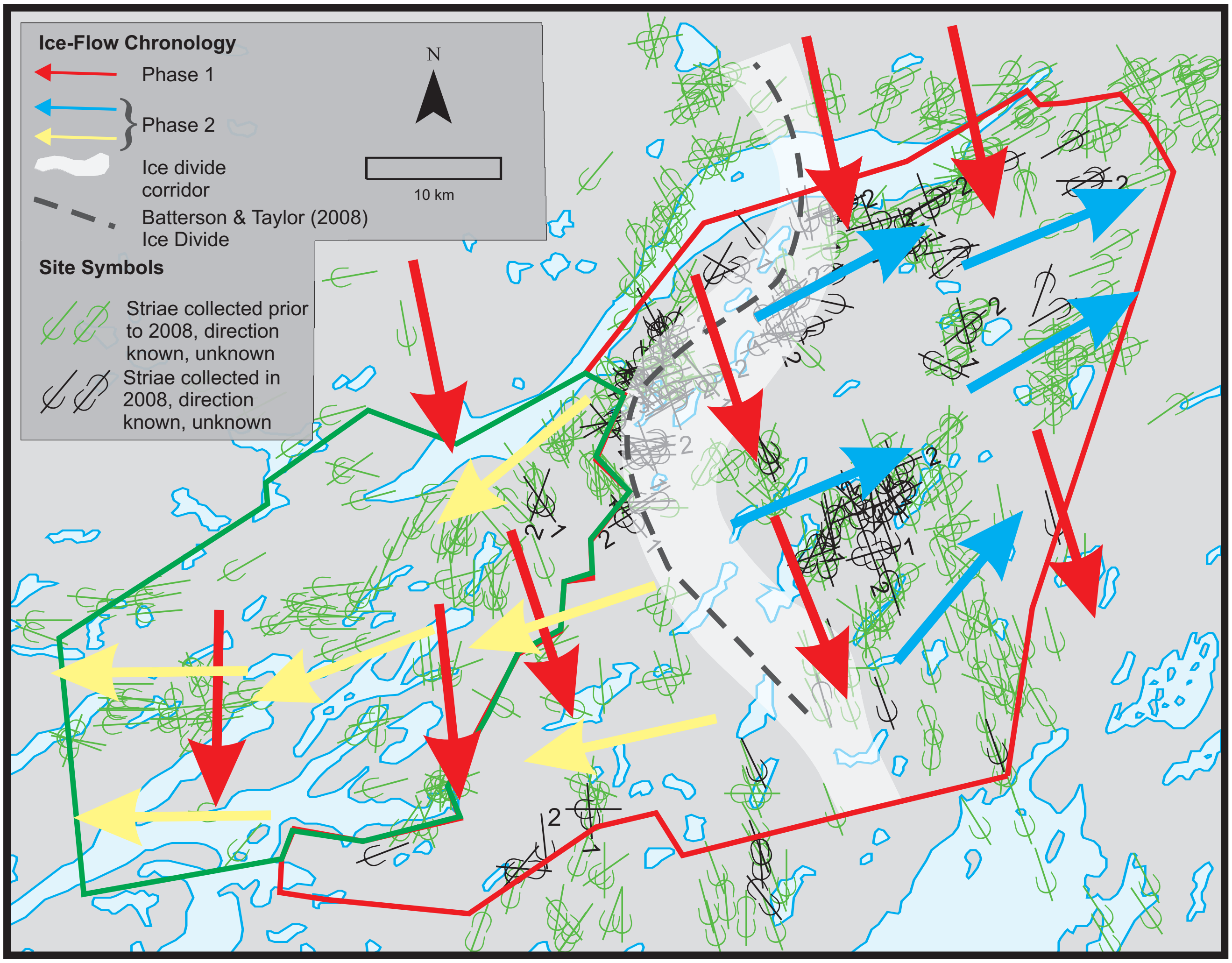


Figure 11. *Map showing the ice-flow data collected within the RILB. Green striations represent data compiled by previous researchers including Batterson and Taylor (2008), whereas black striations are those collected during the 2008 field season. Large arrows indicate the tentative ice-flow history for this area.*

tive ice-flow chronology can be constructed (Figure 11). The earliest ice flow recorded is a south to southeast flow (Figure 11, Phase 1, red arrows). In the southwest of the field area, the Phase 1 ice flow is more southward and in the northeast part of the study area it is more southeastward. This was followed by the development of a proposed ice divide between Harbour Round Pond and Costigan Lake where ice flowed toward the northeast and southwest (Figure 11, Phase 2, blue arrows and yellow arrows, respectively; Batterson and Taylor, 2008).

In comparing this chronology to that of Sparkes (1984, 1985), Vanderveer and Sparkes (1982), Klassen and Henderson (1992), Klassen (1994), Taylor (1994), Klassen and Murton (1996) and Batterson and Taylor (2008), there are a number of similarities, differences and uncertainties. All agree the oldest and earliest flow was the south to southeastward flow (Vanderveer and Sparkes, 1982; Sparkes, 1984, 1985; Klassen, 1994; Klassen and Murton, 1996; and Batterson and Taylor, 2008). Results of data collected in 2008 concur with the previous interpretations, but indicate the southward flow appears to be slightly more south-southeast in the eastern part of the field area. This corresponds to Event Ia of Klassen (1994) who suggested the flow was derived from an ice centre on the Topsail Plateau. The succeeding northeast flow (blue arrows, Figure 11) is consistent with Event IIa (Klassen, 1994). Sparkes (1985) also interprets a northeast flow, however he found that there was a southwest flow (yellow arrows, Figure 11) from an ice centre between Victoria Lake and Lake Ambrose. Batterson and Taylor (2008) agree with Sparkes' (1985) ice-flow interpretation, but propose the ice divide was east of Costigan Lake. The current model supports Batterson and Taylor (2008) and indicates that the ice divide likely occupied the area between Costigan Lake and Harbour Round Pond. However, more work is required to refine the location of the divide and to determine if it extends across Red Indian Lake. If this proposed ice divide extended to the north side of the lake, where there is some evidence for northeast-southwest flow, it may account for the southwest dispersal pattern from Buchans, as described by James and Perkins (1981). Klassen (1994) classified this southwest flow seen at Buchans under Event IIa and argued it was a local reversal of the northeastward flow, recognizing that the mechanism for this is not well understood. Klassen's (1994) Event III is a younger southern flow that is distinct from Event I, by crosscutting relationships. Although three sites identified this summer show the same relationship, further field work will be required to document and confirm the analogies. Rare north-northwest striations are also identified south of Red Indian Lake, and age relationship data suggest that these are older than the northeast flow. It is not known how this north-northwest flow relates to the southward flow. It appears that this north-northwest flow is older than Klassen's (1994) Event III, in which striations and landforms show a northern flow north of Buchans.

Klassen's (1994) Event IV suggests there was northeast and southwest flow from a dispersal centre in Red Indian Lake. Although southwest and northeast striations were identified, it is unknown if they represent Klassen's (1994) Event IV.

SURFICIAL GEOLOGY

The surficial geology of the Red Indian Lake area is dominated by till and organic deposits as well as rarer deposits of glaciofluvial and glaciolacustrine material.

Till

Till is generally thick (2-10 m) and is composed of locally derived diamicton that commonly forms blankets and areas of hummocky and ridged terrain (Plates 1a, b). Thin till veneer deposits are less common and are associated with exposed outcrop (Plate 1c). The lack of natural sections, lead to a single identifiable stratigraphic unit of diamicton (Plate 1d). The texture and colour of the diamicton ranged considerably throughout the field area and are likely the result of up-ice changes in bedrock geology. Although the textural analysis is not yet completed, subjective textural field observations suggest that the majority of the diamicton has a silty sand matrix with some areas being composed of either sandier material with little silt or sandy silt. The colour of the diamicton is variable, ranging from a reddish brown (5YR5/4) along the south side of Red Indian Lake, to the more common colours dark yellow-brown (10YR4/4) and light olive-brown (2.5Y4/4) seen throughout the rest of the field area.

Clast percentages have a wide range, but are generally moderate; clast sizes average 2 to 3 cm, but on the surface range from 0.2 - 3 m. Generally, clasts reflect local geology, but peralkaline granites from the Topsails Plateau were identified (M. Batterson, personal communication, 2008). Red siltstone and sandstone clasts, likely derived from Carboniferous bedrock exposed on the north side of Red Indian Lake, are common on the south side of the lake. The abundance of these clasts decreases with increased distances from the lake. More detailed clast provenance study will be conducted during future field work.

Detailed aerial-photograph interpretation has yet to be completed. Observations from the air and use of the Shuttle Radar Topography Mission (SRTM) data were used to identify glacial landforms and surface morphology. Most of the till unit is a thick blanket (Figure 12) and is characterized by smooth textures, whereas hummocky terrane, which commonly has a high boulder concentration on its surface, has a more irregular surface on the SRTM (Figure 12 and Plate 1a). A series of subdued till ridges north of Lake Ambrose, originally mapped by Sparkes (1985), is identified on the SRTM image. In addition, more ridged moraine was identified from the air on the west side of Rogerson's Lake (Plate 1b), although they are not clear on the SRTM.

Organics

Organics are common within the field area, and are generally found in poorly drained areas, or in depressions associated with hummocky or ribbed moraine (Plate 1b). Organic accumulations are commonly thin (<1 m), although thicker deposits occur locally.

Glaciofluvial

Glaciofluvial deposits are found adjacent to the Exploits River, Victoria River and near Harpoon Brook. These deposits are typically interbedded, well-sorted, coarse-grained sand to granule gravel. Near Harpoon Brook, 10 m of glaciofluvial sediment is composed of a lower unit of trough crossbedded medium- to coarse-sand and a upper unit of stratified coarse-sand to granule-gravel interbedded with clast-supported pebble beds that are 20 cm thick (Plate 2). Beds in both units appear to be dipping east, and are consistent with flow parallel to the modern-day fluvial system. Although this deposit has not been studied in any detail, the exposure indicates a change in energy flow regimes between the lower and upper units. This deposit is actively being quarried for road maintenance material.

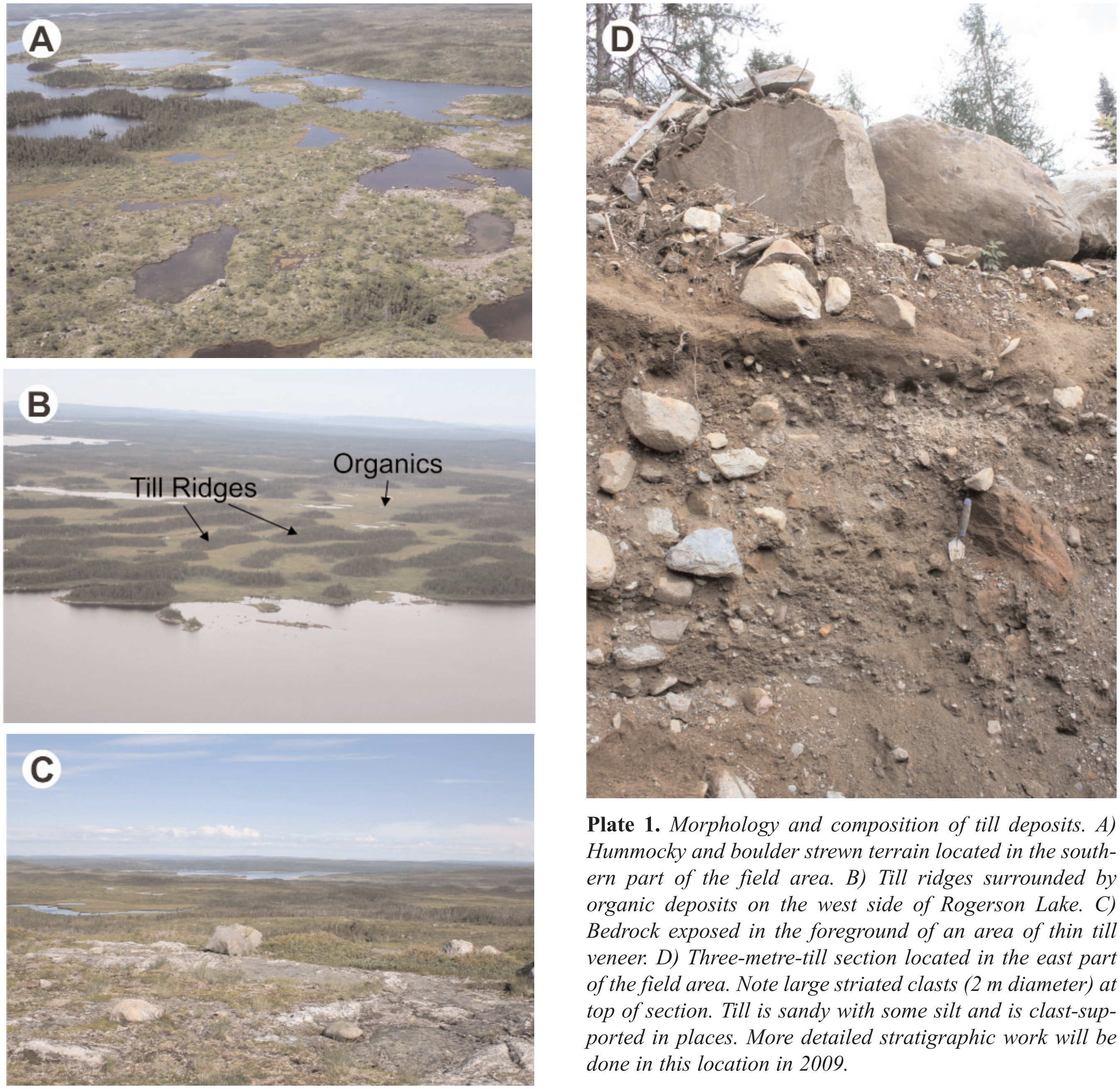


Plate 1. *Morphology and composition of till deposits. A) Hummocky and boulder strewn terrain located in the southern part of the field area. B) Till ridges surrounded by organic deposits on the west side of Rogerson Lake. C) Bedrock exposed in the foreground of an area of thin till veneer. D) Three-metre-till section located in the east part of the field area. Note large striated clasts (2 m diameter) at top of section. Till is sandy with some silt and is clast-supported in places. More detailed stratigraphic work will be done in this location in 2009.*

Glaciolacustrine

Fine-grained glaciolacustrine sediment was noted in the Red Indian Lake area from a single hand-dug pit. The geographical extent and thickness of this deposit is unresolved. The site is 14 km south of Red Indian Lake at an elevation of 336 m. The site is far-removed from Red Indian Lake and similarly, the elevation indicates it was unlikely to have been deposited in glacial lake Shananditit, and is proposed to be the result of localized ponding.

Mihychuk (1985) noted raised beaches in the Victoria River area at an elevation of 212 m asl, or 60 m above current lake levels. These features were not obvious while conducting sampling and can be easily missed where the terrane is tree covered. An examination of the SRTM at the southern end of Red Indian Lake shows possible raised beaches (Figure 12). These will be investigated during subsequent field work.

FUTURE WORK

A number of issues need to be addressed that arise out of the literature review and preliminary field work. These are:

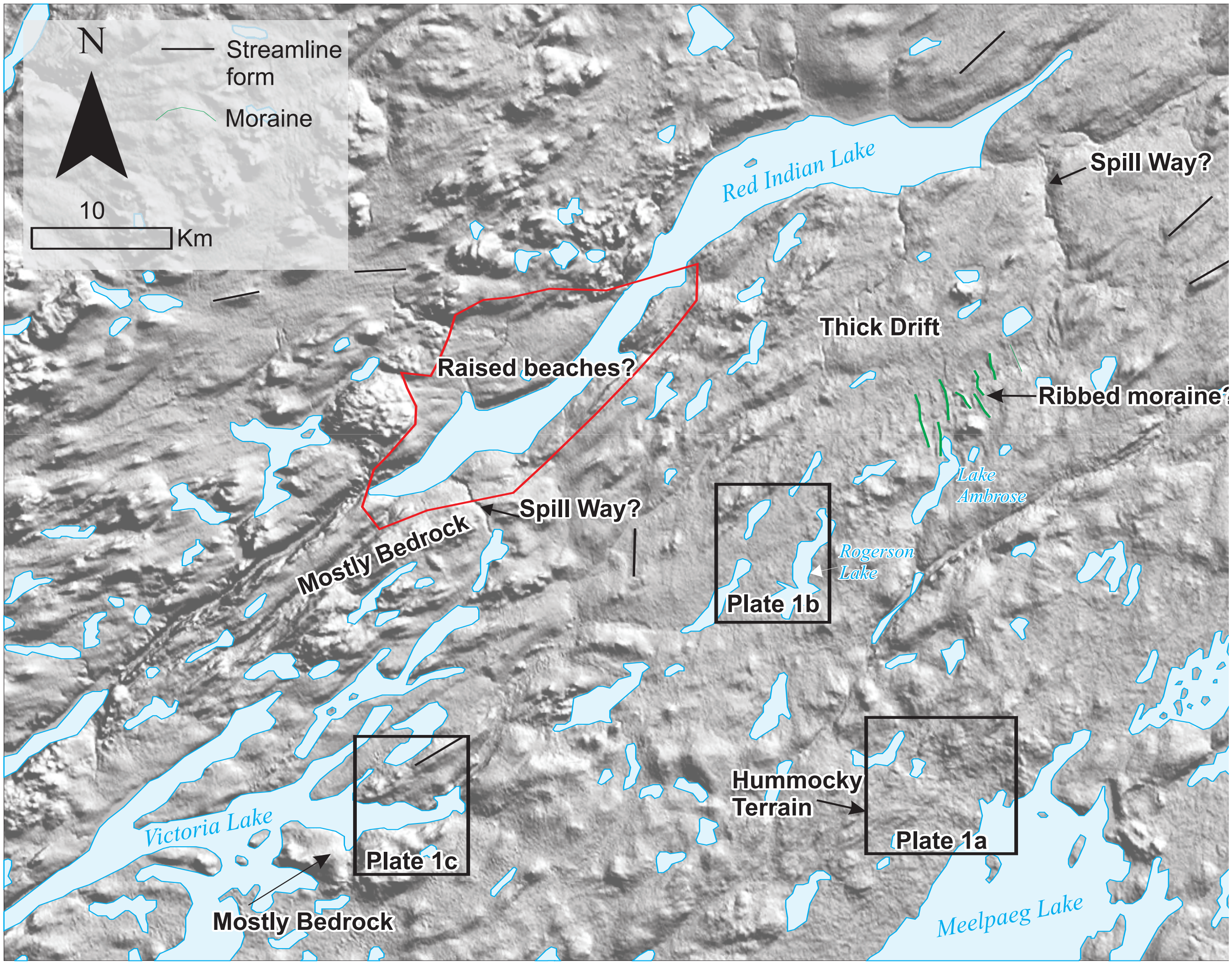


Figure 12. *Location of glacial landforms as interpreted from the SRTM image (modified from an unpublished map by D. Liverman, GSNL, 2009). Thick drift is characterized by smooth textures, as can be seen in the area north of Lake Ambrose. Hummocky terrain, is identified by an irregular stippled surface, northwest of Meelpaeg Lake (Box 1a refers to Plate 1a). Ridged moraine observed on the west side of Rogerson Lake is not easily seen on the SRTM but is easily distinguishable from the surrounding organic deposits when viewed from the air (Box 1b refers to Plate 1b). Thin drift is represented in areas where the underlying bedrock ridges show relief (Box 1c refers to Plate 1c).*

1. Based on the spatial distribution of previous field studies (Klassen, 1994; Sparkes 1984, 1985; Vanderveer and Sparkes, 1982; Mihychuk, 1985) it is difficult to delineate a regional stratigraphic framework. As a result, sections described in previous field studies will be examined during the upcoming field season, to determine if surficial units can be correlated to form a stratigraphic sequence for the RILB. New exposures as a result of mineral exploration and logging will be examined throughout the Red Indian Lake basin.

2. With the exception of work completed by Klassen and Murton (1996), no work has been done to relate the documented ice-flow events to the stratigraphy. Clast provenance and mapping the distribution of indicator clasts, such as peralkaline granites from the Topsails Plateau and red micacous sandstone from the southern margin of the of Topsails Plateau and underlying Red Indian Lake, would likely provide the information needed to link the ice-flow events to the stratigraphy. This will be an objective for the 2009 field season.

3. Refining the ice-flow history within the Red Indian Lake basin and further restricting the location and determining the timing of the ice divide mapped in the Costigan Lake area.

Plate 2. *Trough crossbed in the lower 2 m of a 10 m section on the west side of Harpoon Brook. Material ranges from medium to coarse sand and an upper unit of stratified coarse to granule gravel interbedded with thicker clast-supported pebble beds.*

4. Strandlines identified by Mihychuk (1985) from the Victoria River area will be traced to determine the extent of 'glacial lake Shanadithit', and other proglacial lakes in the RILB. Determining the extent of glacial lakes is important as these areas may contain modified glacial sediment or sediment that has been deposited by glaciofluvial or glaciolacustrine processes; these are less favourable sediments for mineral exploration.

5. Completion of detailed surficial mapping of NTS map areas 12 A/10 and parts of 12A/6, /7, /11 and /15 at 1:50 000 scale, including a thorough aerial-photograph interpretation.

6. Development of exploration models for correlating mineralized boulders or geochemical anomalies with the bedrock from which they were derived.

ACKNOWLEDGMENTS

The author thanks Gerry Hickey and Barry Wheaton for their continued logistical support. Nicole Devereaux provided capable, enthusiastic and entertaining field assistance. Dave Taylor provided much appreciated guidance and support while conducting helicopter sampling. Neil Stapleton is also thanked for his digging capabilities. Derek Newhook from Canadian Helicopters is thanked for his piloting skills. Barb and Terry Sheppard of the Lakeview Inn are thanked very much for their great hospitality and friendship. Martin Batterson is thanked for his support during the duration of this project as well as his critical review. Lori Cook and Melissa Putt are also thanked for their critical reviews.

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