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THE PALEOGEOGRAPHY OF GLACIAL LAKE SHANADITHIT, RED INDIAN LAKE BASIN, NEWFOUNDLAND: IMPLICATIONS FOR DRIFT PROSPECTING

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ABSTRACT

Central Newfoundland has had ice-marginal lakes because of its topography and diachronous pattern of deglaciation. The spatial distribution and elevation of features such as deltas and shorelines, along with the presence of fine-grained sediment, enable the delineation of ice-marginal lakes, the largest of which was glacial Lake Shanadithit, which occupied over 116 km of the Red Indian Lake Basin at its greatest extent.

The location of topographic lows, along with the pattern of glacial retreat, suggests that glacial Lake Shanadithit experienced four phases of ice-marginal lake development. These were: the Lloyds River Phase 1 at 310–330 m asl; the Star Lake Phase 2 at 310 m asl; the Hinds Lake Phase 3 at 302 m asl, and the Joe Glodes Pond Phase 4 at 195 m asl.

De-levelled shoreline features and corresponding outlets indicate that the basin has undergone a minimum isostatic tilt of 0.22 m km^{-1}. This indicates that the Newfoundland Ice Cap influenced the amount of glacio-isostasy on the Island, and was not overshadowed by crustal depression associated with the Laurentide Ice Sheet, as previously suggested.

The development of ice-marginal lakes within the Red Indian Lake Basin suggests that drift-prospecting survey programs should pay close attention to the material being sampled, to ensure that it has not been deposited or washed in a glaciolacustrine environment. Similarly, the presence of mineralized boulders on till surfaces, found below the maximum elevation of the ice-marginal lake level, may be unrelated to ice flow, having been deposited by ice rafting.

INTRODUCTION

Radial retreat of the Newfoundland Ice Cap, coupled with the topography of central Newfoundland, creates a potential environment for the formation of ice-marginal lakes. Ice-marginal lakes are formed when meltwater from an actively retreating or down-wasting ice mass is prevented from draining naturally. Ice typically blocks water in a valley or against an adjacent hillside, blocking access to topographic lows that would normally act as natural drainage routes. The size and depth of ice-marginal lakes are influenced by topography, the direction of retreat in relation to topography, and the amount of meltwater being released from the ice mass. Documenting ice-marginal lakes is an important component of the glacial history of an area because ice-marginal lakes can affect local ice dynamics, and will affect the way drift-prospecting surveys are conducted.

Numerous ice-marginal lakes have been described in Newfoundland and Labrador (Henderson, 1959; Ives, 1960; Evans and Rogerson, 1986; Clark and Fitzhugh, 1990; Liverman and Vatcher, 1993; Geological Survey of Newfoundland and Labrador, 2011). However, on the Island, only glacial Lake Howley (Batterson, *et al.*, 1993; Batterson and Catto, 2001; Batterson, 2003) and glacial Lake Shanadithit have been described in any detail (Vanderveer and Sparkes, 1982; Mihychuk, 1985).

Significant changes to the ice dynamics may occur when meltwater collects at the ice margin. Water lubricates the base of glaciers and basal ice movement is improved, allowing calving and increased rates of retreat (Tsutaki *et al.*, 2011). Increased movement and retreat rates have been linked to reduced glacier thickness, as observed on the Tasman Glacier in New Zealand (Tsutaki *et al.*, 2011). When lake levels rise to 90% of the ice thickness, the ice margin will float (Tweed and Russell, 1999). Floating ice margins can be unstable and cause increased calving. Subglacial drainage may also take place if the ice has been raised from its bed (Tweed and Russell, 1999). In contrast, ice-marginal lakes, in which deltas have had the opportunity to develop, represent periods of stability along the ice margin.

Identifying areas that have been covered and influenced by ice-marginal lakes is important when conducting drift-prospecting studies because sediments within these areas are either reworked till, sediments deposited in ice-marginal lake settings that are deposited by water (*e.g.*, deltas, gravels, silts, fine sands), or modified by water (*e.g.*, shorelines). Mineralized boulders identified within the margins of ice-marginal lakes may have been deposited by ice rafting and unrelated to the till they are deposited on. It is important to be able to identify features and sediments associated with ice-marginal lake areas, and understand the implications for drift prospecting, so that modifications can be made to exploration methods.

OBJECTIVES

The objectives of this paper are to:

- Review the lines of evidence used to identify and map ice-marginal lakes, so that those conducting drift-prospecting surveys can recognize former ice-marginal lake environments,
- present new data on glaciolacustrine deposits and features from the Red Indian Lake Basin (RILB), and
- refine the history and paleogeography of glacial Lake Shanadithit.

DEGLACIATION AND ICE-MARGINAL LAKES IN NEWFOUNDLAND

At the late Wisconsinan glacial maximum, Newfoundland was covered by a series of coalescent ice caps that formed 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 1A; Shaw *et al*., 2006). This configuration remained stable throughout much of the late Wisconsinan, until deglaciation became terrestrially based sometime after 13 ka BP (Shaw *et al*., 2006). Once on land, the deglacial configuration was irregular and time-transgressive due to both ice thickness and topography. By 12 ka BP, ice remained over much of the interior of the Island; however, Grand Lake and the northeastern part of the Exploits River were deglaciated by this time (Figure 1B; Shaw *et al*. (2006). Farther retreat of the Newfoundland Ice Cap resulted in its disintegration into a series of isolated ice centres located on topographic highs (Grant, 1974; Shaw *et al*., 2006). The disintegration of ice in central Newfoundland blocked local drainage. This, coupled with topographic highs, such as the Long Range Mountains and The Topsails, suggests that central Newfoundland had potential for the formation of ice-marginal lakes.

The best documented example of an ice-marginal lake is glacial Lake Howley that formed within the Grand Lake

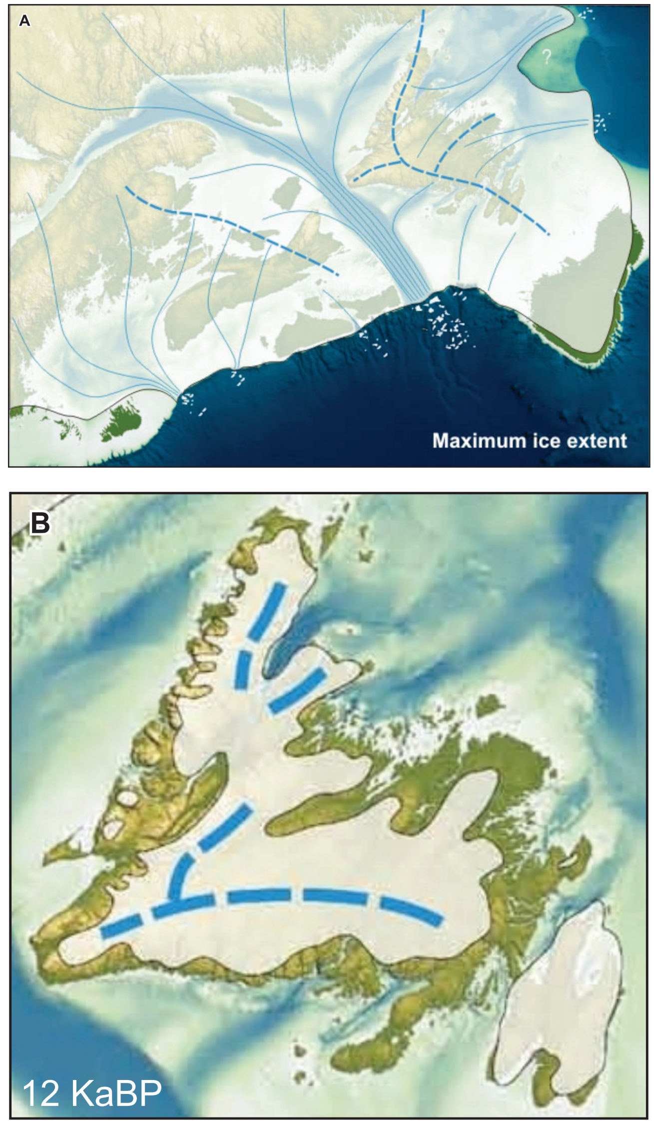


Figure 1. *Pattern of deglaciation for the Island of Newfoundland at: A) the last glacial maximum and B) 12 ka BP. Dashed lines indicate approximate location of ice divides (modified after Shaw* et al., *2006).*

Basin in west-central Newfoundland. Located east of Deer Lake, the Grand Lake Basin trends northeast–southwest. The interior (*i.e.*, of the basin) was deglaciated sometime after 12.6 ka BP, based on radiocarbon dating in the Stephenville area, where drainage from melting glaciers inland reached St. George's Bay (Batterson, 2003; Bell *et al.*, 2003; Shaw *et al.*, 2006). Glacial Lake Howley developed in front of a rapidly retreating ice margin in the Grand Lake Basin (Batterson and Catto, 2001). Impounded water formed a long, narrow lake, up to 135 km long and 10 km wide, having a surface area of 650 km^2 (Figure 2; Batterson and Catto, 2001; Batterson, 2003). The water level was controlled by the elevation of an outlet at the southwestern end

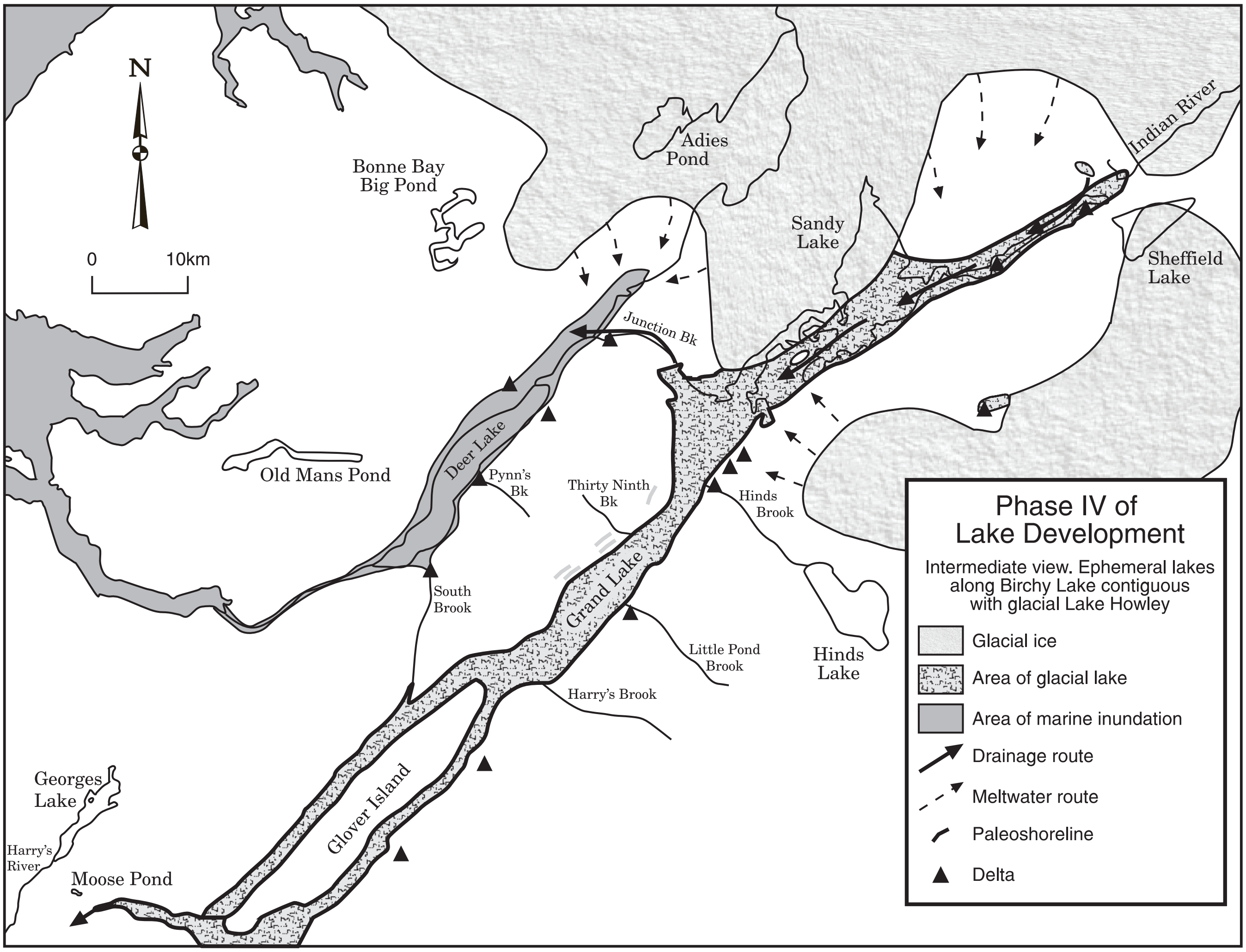


Figure 2. *Paleogeography of glacial Lake Howley (modified after Batterson, 2003).*

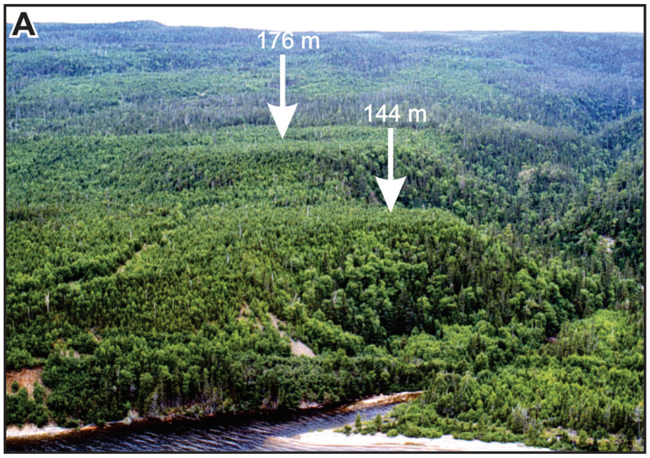
of Grand Lake. Subsequent lowering of the lake was controlled by the opening of topographically lower outlets as the ice retreated to the northeast. Final drainage of the lake was through a spillway (currently occupied by Junction Brook) in the northwest. The lake emptied about 12.3 ka BP, based on the elevation of deltas at the head of Deer Lake (Batterson, 2003).

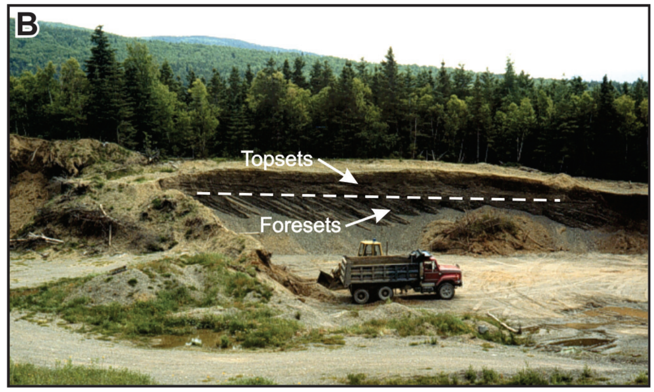
EVIDENCE FOR ICE-MARGINAL LAKES

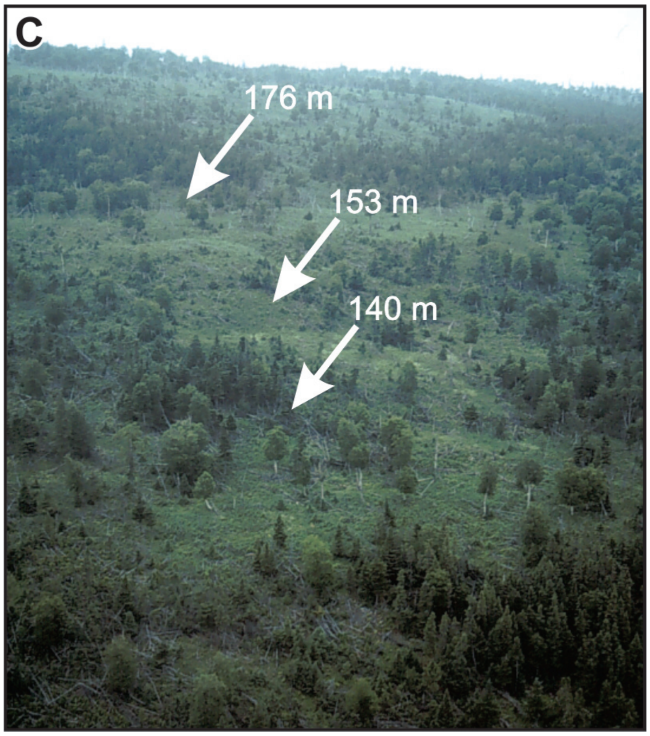
Depending on the longevity and the amount of sediment–meltwater influx, former ice-marginal lakes can be identified from shorelines, deltas, and fine-grained sediment (Batterson *et al.*, 1993; LaRocque *et al.*, 2003). It is important to be able to identify these features when conducting drift-prospecting surveys in an area that may have had an ice-marginal lake because these areas are likely to contain glaciolacustrine sediment and winnowed till that are not suitable for geochemical analysis, as well as, mineralized boulders that are unrelated to ice flow. These features, *i.e.*, deltas, shorelines, and sediments, are described below.

Deltas

The best evidence for the existence of ice-marginal lakes is the formation of deltas. Deltas are common in proglacial environments and form as meltwater from retreating ice flows into standing water. Deltas are often identified above current lake levels and have flat tops with a steep front and/or sides. During the life span of glacial Lake Howley in the Grand Lake Basin (Plate 1A; Batterson, 2003), ten deltas were formed between 128 and 141 m asl (the range being the result of isostatic rebound, discussed below). As meltwater enters standing water, sediment is deposited rapidly with the coarsest deposited first; the finer sediment (fine-grained sand, silt and clay) is carried, in suspension, into deeper water. The coarser material is deposited by a combination of fluvial aggradation forming horizontal beds







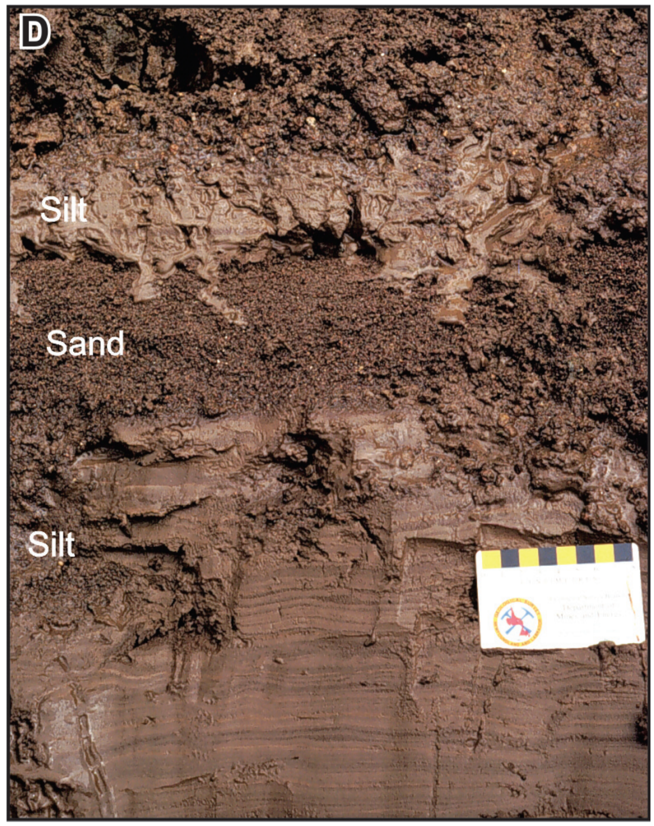


Plate 1. *Features and sediments indicative of ice-marginal lakes (from Batterson, 2003); glacial Lake Howley in the Grand Lake Basin. A) Oblique aerial view of two flat-topped deltas at the mouth of Harry's Brook on the east side of Grand Lake. B) Cross-section of deltaic sediments identified in a raised delta. C) Shorelines adjacent to Thirty-ninth Brook valley. D) Sand and silt rhythmites within the Little Pond Brook section. E) Dropstone within fine-grained glaciolacustrine sediment (Batterson, 2003).*

(topsets) above the water level, and progradation forming dipping beds (foresets) on the front edge of the delta (Benn and Evans, 1998; Plate 1B). The elevation at the topset–foreset transition represents the water level of the standing water. Deltas may be classified as ice contact or glacier fed. Ice-contact deltas are fed directly by glacier meltwater. The distance from the ice edge to the water edge is relatively short. In contrast, glacier-fed deltas may be some distance from the ice margin and at a lower elevation; these are formed by proglacial rivers (Benn and Evans, 1998).

Shorelines

Elongate beaches or shorelines identified above current lake levels are indicative of higher water levels. The relative amounts of sand and gravel in the shoreline will depend on the sediment availability. Once the elevation of one beach is identified, others may be located by searching at similar elevations around the basin, particularly in areas adjacent to sediment inflows. Batterson (2003) identified eight shorelines in the Grand Lake Basin up to 174 m asl, 86 m above current lake levels (88 m asl; Plate 1C).

Fine-grained Sediment

Fine-grained sediment are typically deposited within a distal and/or quiescent glaciolacustrine system. Rhythmically bedded sediment provides strong evidence of fine-grained deposition in a glacial lake. Twelve sections exposing rhythmites, comprising coarse-grained sand and very fine-grained sand to silt, were identified along the modern Grand Lake shoreline (Batterson, 2003; Plate 1D). These were interpreted to have formed in standing water by suspension settling from overflow and interflow (Batterson, 2003). Rare clasts found within these sediments may be dropstones, deposited by ice rafts (Plate 1E). Whereas fine-grained sediments are an indication of glaciolacustrine deposition, their associated elevation represents only a minimum estimate of the elevation of the surface of the water they were deposited in.

BUILDING A GLACIAL LAKE HISTORY

Ice-marginal lakes may have a number of phases that form as a result of uncovering progressively lower outlets. An outlet is a topographic low point (a present-day col) in the watershed that controls the maximum water level of an ice-marginal lake. For example, the water level in glacial Lake Howley was initially controlled by an outlet in the western end at Harry's River (Plate 2); however, as ice retreated, the South Brook Valley col was exposed and water levels fell to 145 m (Batterson, 2003). Farther to the northeast, ice retreat exposed the lowlands northeast of the South Brook valley that initiated the final drainage of glacial Lake Howley. The drainage formed the spillway in which Junction Brook now flows (Batterson, 2003). The drainage pattern and the paleogeography change each time a new outlet is uncovered, allowing deltas, shorelines, and fine-grained sediment to be deposited at lower levels. The number of ice-marginal lake phases, as well as their size and elevation, can be determined by assessing all of the site evidence in terms of elevation and spatial distribution. Multiple features identified at the same elevation, or multiple features at different elevations but in the same plane (as a result of isostatic rebound) over a large area, likely indicate a single lake or show a progressive change related to isostatic deformation (*e.g.*, Batterson, 2003). Isostatic deformation refers to the amount the Earth's crust moves in response to the weight of the overlying ice. As ice retreats, the Earth's crust rebounds, the amount of rebound is time-transgressive, hence features formed at the same time may show a progressive increase in elevation due to differential uplift. The elevations of deltas along Grand Lake increase from the southwest (128 m asl at the mouth of Lewaseechjeech Brook) to the northeast (145 m elevation from a delta north of Hinds Brook), suggesting

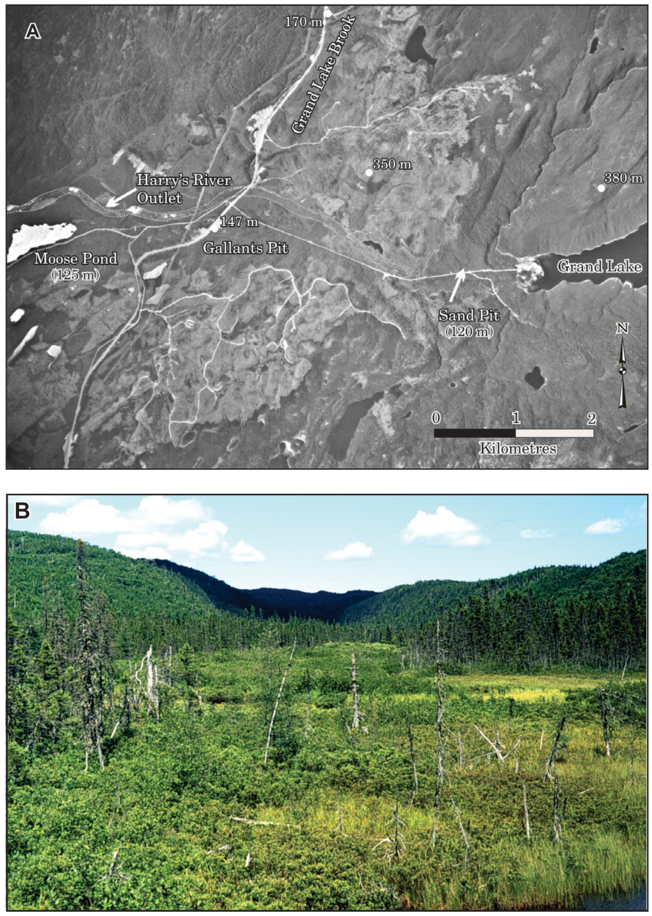


Plate 2. *A) Aerial photograph of part of the Harry's River outlet at the southwest end of Grand Lake. B) View of Harry's River outlet from near Moose Pond (from Batterson, 2003).*

an increase of 0.22 m km^{-1}, which may be due to progressively younger deltas forming to the northeast, or may be attributed to isostatic rebound (Batterson, 2003). The difference in elevation between shoreline features and outlets within the Grand Lake Basin indicates a de-levelled or tilted lake surface. For glacial Lake Howley to form, these features and the outlet would have been located at the same level. Subsequent differential isostatic rebound may explain the elevation difference between the features. Small, isolated ice-marginal lakes will have features that are identified over a range of elevations. Ice-dammed lakes are typically more difficult to map because they are generally short-lived and have less developed shoreline features (LaRocque *et al*., 2003).

RED INDIAN LAKE BASIN PROJECT

The Red Indian Lake Basin (RILB) project began in 2007 in response to an increase in mineral exploration in the southern part of the basin. The purpose of the project was to conduct sampling of the tills for geochemical analyses, and surficial mapping, to construct a drift-prospecting model to aid in mineral exploration. The focus during the 2007–2008 field seasons was on till sampling, measuring ice-flow indicators and surficial mapping, whereas field work from 2009–2011 focused on determining the stratigraphy of the RILB by completing detailed descriptions, including clast-fabric analysis and mapping of glacial lake sediments of naturally exposed sections and backhoe-dug pits.

PREVIOUS RESEARCH

The stratigraphy of the RILB was described by Vanderveer and Sparkes (1982), Sparkes (1984, 1985), Mihychuk (1985) and Klassen and Murton (1996). In the southwest part of Red Indian Lake, Vanderveer and Sparkes (1982) described the lowermost till in the Tulks River valley and near Costigan Lake as having been deposited during the earliest southward ice flow, based on the presence of gabbro clasts derived from a bedrock source to the north. Sparkes (1984) also described a repetitive sequence of sand and silt, which he termed the Lloyds River rhythmites. These were deposited in a proglacial lake whose formation was synchronous with the separation of the southward glacial flow into smaller ice centres. This area was covered by a local re-advance from an ice centre situated between Victoria Lake and Lake Ambrose, from which ice flowed northeast and southwest (Sparkes, 1985). Simultaneously, ice flowed from a centre at Hinds Lake and occupied the RILB, including the Lloyds and Tulks River valleys, depositing till on top of the rhythmites (Sparkes, 1985). Vanderveer and Sparkes (1982) suggested that the elevation of the proglacial lake was at least 59 m ± 5m above Red Indian Lake (*i.e.,* 216 m asl); however, no explanation was given for this elevation. Mihychuk (1985) described a well-developed raised shoreline at 212 m asl in the Victoria River area and suggested that it was related to the proglacial lake described by Vanderveer and Sparkes (1982). Mihychuk (1985) informally named this lake glacial Lake Shanadithit.

In the Buchans area, Klassen and Murton (1996) describe four ice-flow events along with the deposition of three diamictons and glaciolacustrine sediment, which were deposited during two glacial events with an intervening ice-free period; all events were presumed to be Wisconsinan (Klassen and Murton, 1996). Both Grant (1989) and Klassen and Murton (1996) indicate that differential staining of striated surfaces, identifying a southerly flow (Event 1 of the model proposed by Klassen and Murton, 1996), south of Red Indian Lake, could be pre-Wisconsinan.

The oldest glacial deposit is represented by a lodgment till that was deposited by northeast-flowing ice (Event II, Klassen and Murton, 1996). This is overlain by meltout till, glaciolacustrine sediment, gravity flows and glaciofluvial deposits. Sand and silty clay rhythmites were deposited by underflows in an ice-contact lake during the deglaciation of Event II. This ice-contact lake occupied the Buchans Saddle and the valley extending southwest of Buchans and was dammed by ice in Red Indian Lake (Klassen and Murton, 1996). The maximum surface elevation was between 300–310 m asl and was controlled by the outlet at Hinds Lake. Ice-free conditions between Events II and III (northeastward flow and southward flow) are suggested by the silty sandy diamicton that overlies the glaciolacustrine sediment. These sediments were deposited by debris flow, as suggested by the deformed glaciolacustrine sediments, and were associated with the final drainage of the lake (Klassen and Murton, 1996). The origin of the coarsening-upward sequence of glaciofluvial sediments is not fully understood (Klassen and Murton, 1996). The last phase of ice flow identified by Klassen and Murton (1996) was oriented northeast–southwest, and originated from a dispersal centre situated in the centre of Red Indian Lake.

PHYSIOGRAPHY AND ACCESS

The study area lies in the interior of the Island of Newfoundland, and can be reached from the east *via* Route 370, off the Trans-Canada Highway, or by the forest-resource road that extends south of the Exploits River from Grand Falls-Windsor (Figure 3). From the west, Route 480 (Burgeo Highway) provides access to the forest resource road that extends through the Lloyds River valley.

The RILB is flanked by The Topsails (maximum elevation 550 m asl) to the north, the Long Range Mountains (600 m asl) to the west and the Annieopsquotch Mountains (650

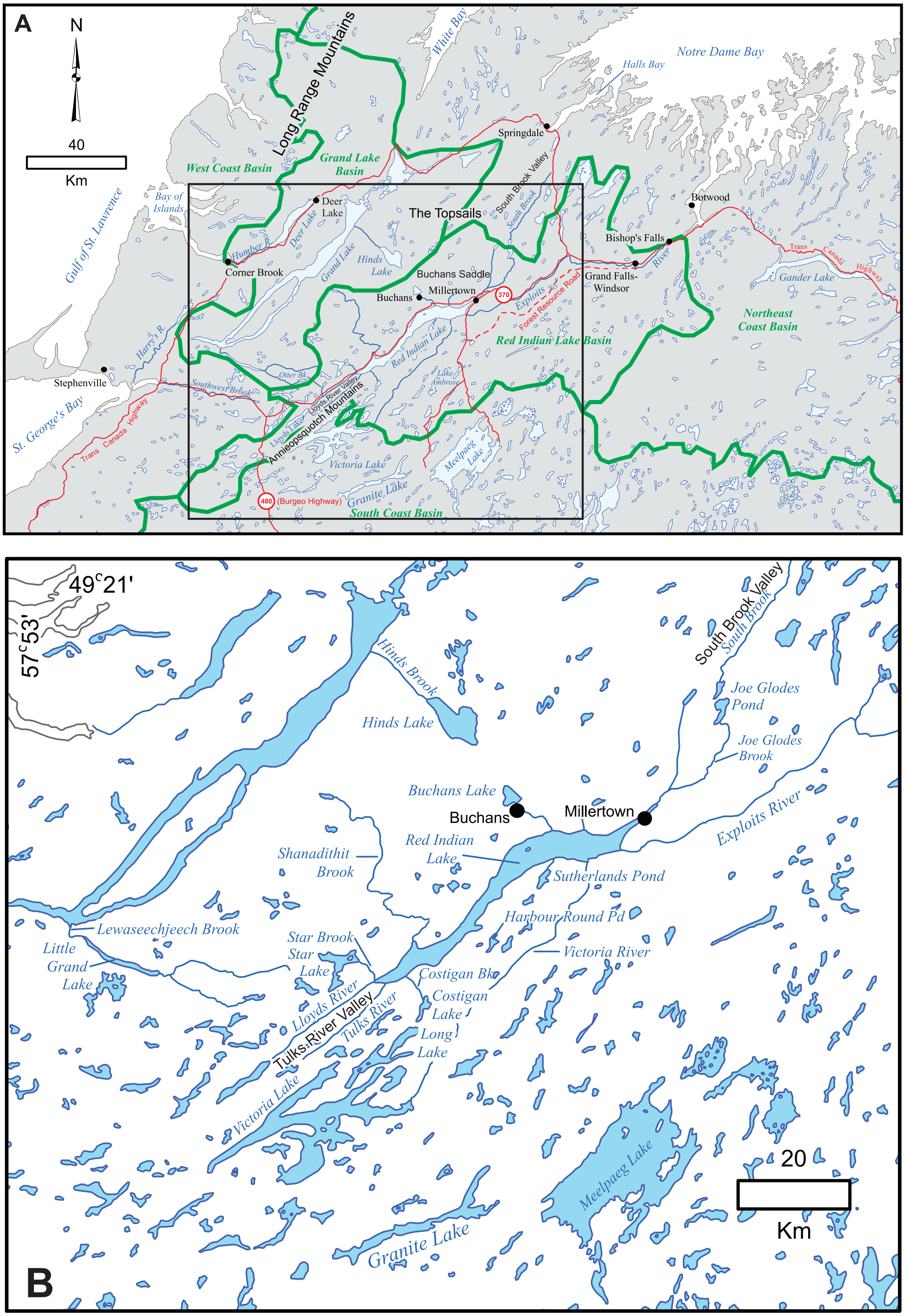


Figure 3. *A) Map identifying the location of the Red Indian Lake Basin and place names used in text. Box refers to location of map show in Figure 3B. B) Box represents detailed map of the Red Indian Lake Basin. Note: Tulks River is also known as Tulks Brook.*

m asl) to the southwest (Figure 3). East of Victoria River, with the exception of a few small hills, the elevation is less than 300 m and the land has an undulating surface. Surrounded by highlands on three sides, the RILB trends southwest–northeast, and extends from the Long Range Mountains to the Bay of Exploits. The Lloyds River flows from the Long Range Mountains, through a narrow valley into Red Indian Lake (surface elevation: 156 m asl). Although Red Indian Lake has many inflowing streams it has only one outlet, the Exploits River, which flows northeastward to the Bay of Exploits (Figure 3).

METHODS

The identification of glaciolacustrine features and sediments requires the close examination of sediment types in hand-dug holes, the identification of subtle breaks in slope that may indicate the presence of beaches, and the careful planning of backhoe sites, all of which can help delineate the aerial extent of glaciolacustrine sediments. Success in identifying glaciolacustrine sediments is linked to identifying the positions of inflows. As a part of the backhoe programs carried out in 2009, 2010 and 2011, sites were chosen where detailed observations on the thickness and physical characteristics of glaciolacustrine sediment could be made either in natural sections, or from hand-dug pits and/or sites, close to inflows (*e.g.*, Costigan Brook, Lloyds River, and Star Lake Brook).

Knowledge of the elevation of glaciolacustrine sediments and features is necessary to determine the height, and establish the size, of an ice-marginal lake. Prior to the summer of 2011, elevations were measured using a Garmin GPSMAP 76CSxGPS barometric altimeter that had an associated error of ± 20 m. In 2011, elevations of critical sites including deltas, fine-grained sediments, and coarse-grained sediments were measured using a Novalynx 230-m202 handheld digital barometer altimeter that has an associated error of ± 3 m.

EVIDENCE FOR ICE-MARGINAL LAKES IN RED INDIAN LAKE BASIN

Field work, conducted as part of the RILB project, provided many types of evidence (*e.g.*, deltas, as well as the presence of fine- and coarse-grained sediment) related to the development of glacial Lake Shanadithit. Examples of this evidence are described below, and their locations are shown in Figure 4.

Deltas

Three deltas have been identified at the southwest end of Red Indian Lake. Their existence suggests that the water level was stable during their formation. These deltas, two of which (Site 119, the Caribou Pit delta, Figure 5; and Site 400, the Costigan Brook delta, Figure 6) are described below, play a critical part in the development of the paleogeography of the RILB. The remaining delta at Costigan Brook (Site 201), identified at ~200 m asl was described in Smith (2010, Plate 2).

Caribou Pit Delta

Smith (2010) identified coarse-grained sediments on the north shore of Red Indian Lake between Shanadithit Brook and Star Lake at 300 m asl (Site 119 – Caribou Pit; Figure 4) that were interpreted as deltaic. This site was investigated further during the summer of 2011 using a backhoe and Novalynx 230-m202 handheld digital barometer altimeter (indicated a surface elevation of 295 m asl). A hole, 2 m deep, was dug upslope from the exposed wall of the pit, and revealed 0.5 m of silty sand diamicton overlying gravel. Clasts in the diamicton range from 3–65 cm in diameter, and are subangular to subround, with slightly larger boulders (<1 m diameter) on the surface. The existing pit was cleared to provide a 4.7-m-deep exposure oriented southeast–northwest (Figure 5A). The lower 2 m is composed of fine- to medium-grained sand, with very fine-grained sand–silt beds. Contacts between the beds are sharp. Some of the very fine-grained sand–silt beds are convolute and exhibit loading structures. In some places, these beds have been truncated and eroded by a fine- to medium-grained sand marked by sharp and irregular contacts (Figure 5B), and contain a 5–10-cm-thick bed of silty sand diamicton that thins toward the northwest (Figure 5C). The diamicton contains subangular to subrounded clasts that are 0.5–3 cm in diameter.

One metre of interbedded medium sand and pebble–gravel overlies the fine-grained material. The contact is erosional and irregular. The pebble–gravel is moderately well sorted and contains rare cobbles and boulders. Beds dip approximately 15º toward 047º. This unit is overlain by 1.7 m of weakly stratified clast-supported pebble–cobble gravel having a medium-grained sand matrix. Whereas horizontal bedding was reported in this unit by Smith (2010), it was not observed in 2011. It may not have been observed due to excavating past the farthest extent of the horizontal bedding.

The new observations do not contradict an earlier interpretation (page 212, Smith, 2010) that these sediments were formed in a delta. However, it is now interpreted as an ice-contact delta, because of the presence of diamicton within the fine-grained sediment. The diamicton is a debris flow, indicating that the ice margin is in close proximity to the ice-marginal lake. The 0.5-m-thick diamicton overlying the gravel is also indicative of the proximity of ice. The local

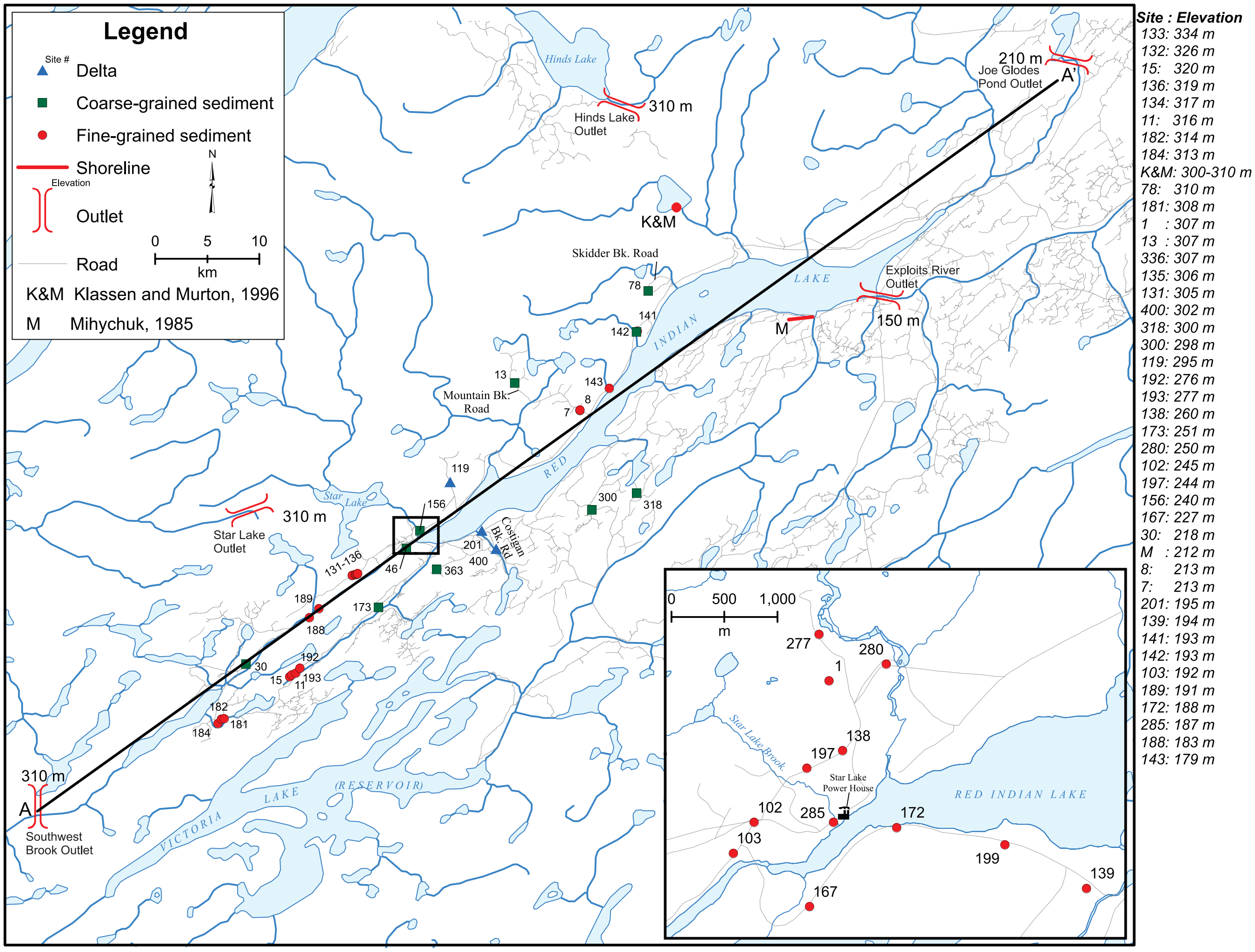


Figure 4. *Map showing the location of shoreline features, fine- and coarse-grained sediments and outlets within the Red Indian Lake Basin. A to A' represents the line onto which the sites identified in this figure are projected in Figure 8.*

topography suggests that the sediment-laden meltwater was derived from ice retreating to the northwest up the hillside. The current position of the diamicton was likely influenced by gravity flow as ice retreated up the hillside.

Costigan Brook Delta

Gravel was identified in the wall of a newly excavated pit, 2.6 km southeast of Red Indian Lake on Costigan Brook Road, adjacent to Costigan Brook, at an elevation of 303 m asl. The section is oriented southwest–northeast (250–070º), was cleared and dug to a depth of 600 cm by a backhoe (Figure 6). The lower 500 cm is composed of coarse sand to granule gravel interbedded with 10–20-cm-thick beds of pebble–cobble gravel that are locally clast-supported. Clasts range from angular to subround and are 0.5–20 cm in diameter. Pebble–cobble gravel beds within this unit dip 26–31º toward 290º. There is a sharp contact with the overlying 100 cm of moderately to well-sorted coarse-grained sand to granule gravel. This uppermost unit contains three, 10-cm-thick beds of horizontally bedded clast-supported pebble gravel.

The horizontal and dipping beds observed at this site are interpreted as topset and foreset sedimentation, typical of classic Gilbert-type deltas (Benn and Evans, 1998). Such deltas develop when sediment-laden streams or meltwater enter standing water, resulting in deposition of the carried load (LaRocque *et al*., 2003). The topset/foreset transition represents the standing water elevation into which the delta prograded. Therefore, the water elevation for this delta is 302 m asl.

Other Coarse-grained Deposits

The identification of deltas at between 295 and 302 m asl suggests that others may be identified at similar elevations. Careful examination of elevations between 290 and

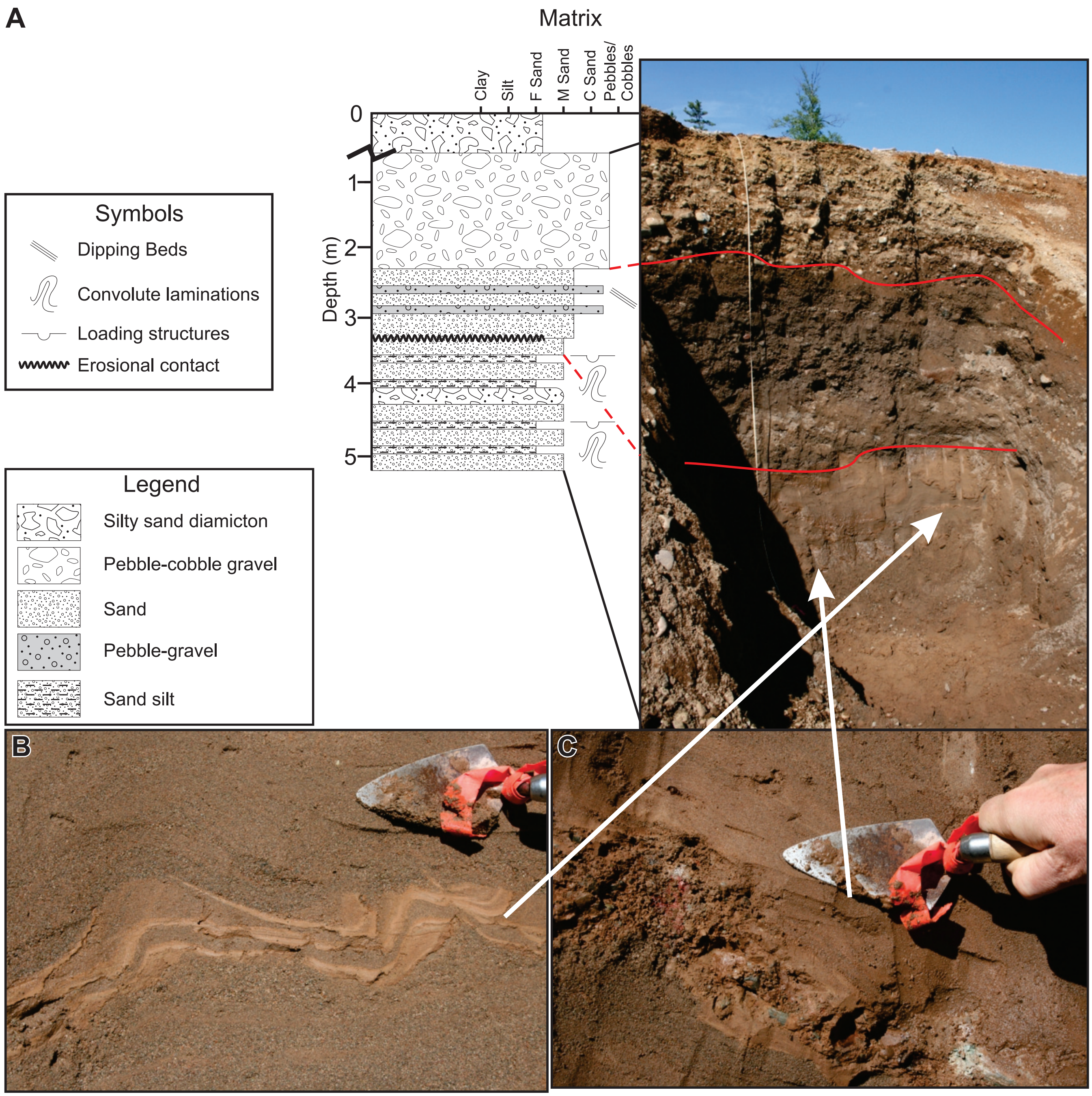


Figure 5. *A) Stratigraphic column for Site 119. Inset shows picture of 4.7 m section. B) Truncation of silt laminations by fine- to medium-grained sand. C) Silty sand diamicton that thins to the northwest (right).*

310 m asl, in areas adjacent to stream inflows, failed to identify any flat-topped features resembling a delta; five coarse-grained sediment sites were identified in the basin between 290 and 310 m asl. Identified on Figure 4, these are found at the mouth of Tulks River (Site 363), northeast of Costigan Brook (Site 300), south of Harbour Round Pond (Site 318) and two sites on the north side of Red Indian Lake, one on Mountain Brook Road (Site 13) and the other on Skidder Brook Road (Site 78). All are composed of fine-grained sand to pebble gravel that is locally clast supported. Steeply dipping beds were identified in the gravel northeast of Costigan Brook (Site 300). However, no internal structures were identified at the remaining sites. Whereas there is not enough information to confirm how these sediments were deposited (*e.g.,* delta, kame) it is interesting to speculate that they may correspond to the water level that formed the deltaic surfaces identified (Sites 119 and 400).

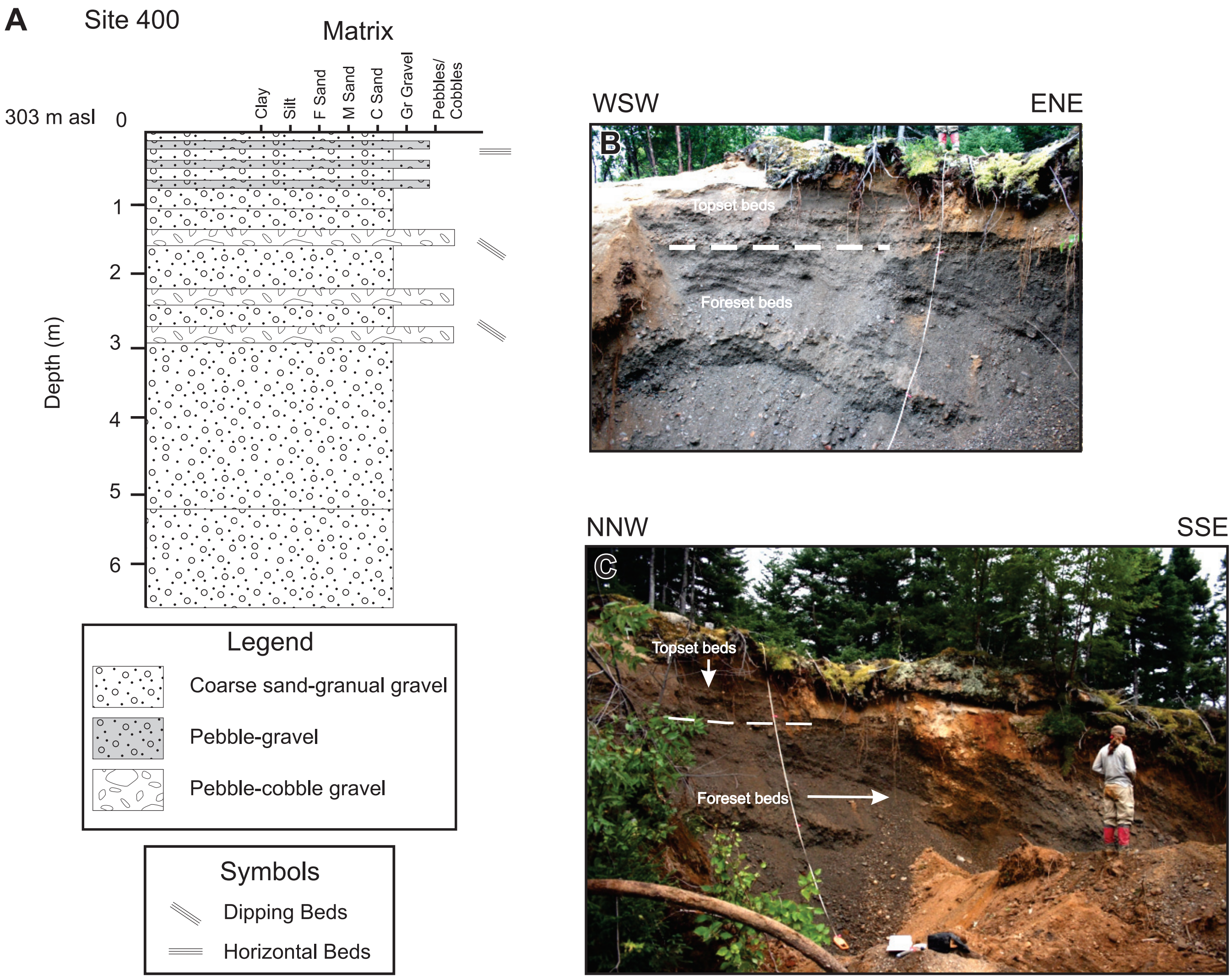


Figure 6. *A) Stratigraphic column Site 400 (Costigan Brook delta) at 303 m asl. B) Section oriented west-southwest–east-northeast showing topset and foreset beds. C) Section oriented north-northwest–south-southeast showing topset beds and steeply dipping foreset beds.*

Fine-grained Deposits

Thirty-one fine-grained sediment sites have been identified by the author in the past four field seasons (Figure 4); two of which have been described in Smith (2010, Sites 141 and 103 on page 210). The following describes Sites 138 and 285 in the Star Lake Brook area of the RILB.

Site 138 - West of Star Lake Brook

Very fine-grained sand having silt laminations is identified in a 420-cm-deep section (surface elevation, 260 m asl), on the north side of Red Indian Lake, east of Star Lake Brook (Site 138; Figure 4). The lower 265 cm consists of silty to very fine-grained sand with 0.5 cm pink silt–clay laminations (Figure 7). The laminations are spaced 5–15 cm apart, and have sharp, slightly undulating upper and lower contacts. Some of the silt laminations are convolute in places. Rare clasts averaging 0.5 cm diameter were identified in the silty–clay. In the overlying 30 cm, the very fine-grained sand contains silt laminae up to 0.5 cm thick. Contacts with the silt are sharp and the laminae are convolute in places. The upper contact of this unit is sharp, undulating and overlain by 20 cm of silty sand diamicton. The diamicton contains 20% clasts ranging from 0.2–10 cm in diameter, which are subangular to subrounded. There is a sharp, erosive upper contact with an overlying metre thick unit of fine to coarse sand and pebble gravel.

Site 285 - Southwest of Power Plant

Site 285 (Plate 3) is a 15-m-deep section (surface elevation 187 m asl), on the north shore of Red Indian Lake, southwest of the power plant at Star Lake Brook (Site 285).

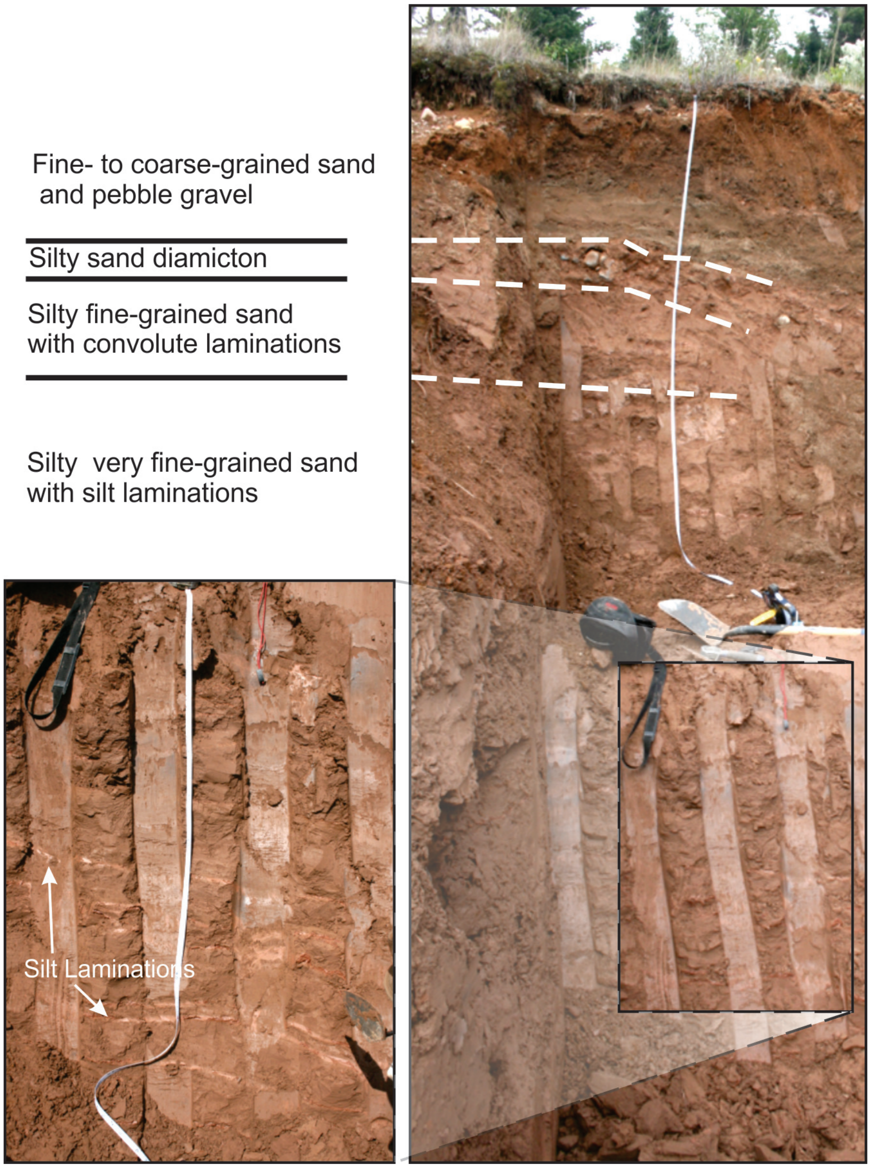


Figure 7. *Fine-grained sediments identified at 260 m asl (Site 138) approximately 1 km east of Star Lake Brook. Inset on left shows silt laminations within the very fine-grained sand.*

Only the upper 270 cm was logged because of slumping. The lowermost part of the section consists of 10 cm of medium to coarse sand containing scattered subangular to subround clasts, ranging from 0.5 to 7 cm in diameter. Overlying this unit is 180 cm of interbedded, normally graded, very well-sorted fine- to very fine-grained sand–silt. Lower contacts of the medium sand are sharp, undulating and erosional. Within this unit, there are two medium-grained sand beds that are 3 to 4 cm thick. Fine- and very fine-grained sand beds have thicknesses that range from 0.5 to 5 cm. Flame structures are present along the lower contact of the very fine-grained sand. Rare subround to subangular clasts, with a maximum diameter of 14 cm, are found within the fine-grained sand. The uppermost 80 cm is poorly sorted gravelly sand that has a fine-grained to granule-gravel matrix containing very little silt and contains 30% subangular to subround clasts ranging from 0.5 to 15 cm in diameter.

Interpretation of Sites 138 and 285

The fine-grained nature of the sediment identified at both sites indicates that deposition was distal in an ice-marginal lake. Convolute laminations and flame structures signify that these sediments were waterlain, whereas the sharp erosional contacts of the graded beds show that deposition occurred quickly, as turbulent underflow currents carried sediments to distal parts of the basin (Boggs, 1995; Benn and Evans, 1998). The silt laminations indicate suspension deposition, settling between underflow currents (Boggs, 1995; Benn and Evans, 1998). The normal graded bedding resulted from suspension settling, following the underflow currents (Boggs, 1995; Benn and Evans, 1998). The rare clasts identified in the graded bedded sequences and silty– clay laminations are interpreted as ice-rafted dropstones. The thin diamicton identified at Site 138 is a debris-flow deposit originating from a higher elevation. The sand and gravel are representative of increased flow velocities and deposition of sediment in standing water.

PALEOGEOGRAPHY

The paleogeography of the RILB was most likely time-transgressive and represented a continually evolving landscape and changing drainage patterns, in response to retreating ice. The deposition of glaciolacustrine sediments and features in the southwest part of Red Indian Lake, along with the topography of the basin, suggest that the ice blocked natural drainage patterns to the northeast, allowing an ice-marginal lake to form. The spatial distribution of glaciolacustrine sediments and features, along with the elevation of potential outlets, is considered to determine whether the evidence is indicative of a single large lake, which had phases of progressively lower altitude, or a series of small ice-marginal lakes (Figure 8). Multiple phases are indicated by progressively lower outlets that are uncovered as the ice retreats. Five potential outlets are identified in the RILB (Figure 4);

these include: Southwest Brook (310 m asl), Star Lake (310 m asl), Hinds Lake (310 m asl), Joe Glodes (210 m asl) and the Exploits River (150 m asl). It should be noted that while three of the outlets are identified at the same elevation, this is merely a coincidence, as each of these outlets would have been at lower elevations, immediately following ice retreat from the area and have undergone subsequent isostatic uplift since deglaciation. Therefore, these outlets represent four different delevelled lake surfaces, while the fifth represents the finial drainage.

The paleogeographic reconstruction model for glacial Lake Shanadithit contains four phases of a single ice-dammed lake. These are: Lloyds River Phase 1 at 310–330 m asl, Star Lake Phase 2 at 310 m asl, Hinds Lake Phase 3 at 302 m asl, and Joe Glodes Phase 4 at 200 m asl. The final drainage of glacial Lake Shanadithit is through the Exploits River outlet at 150 m asl.

Lloyds River Phase 1: 310–330 m asl

Retreat of ice within the Lloyds River valley allows for the formation of a 47-km-elongate ice-dammed lake covering 151 km^2 (Figure 9). This lake extends almost the entire length of the current Lloyds River. Minimum water level elevation of 330 m asl are shown by the elevation of fine-grained sediments identified on the edge of the Lloyds River valley, and supported by the presence and elevation of fine-grained sediments located south of Lloyds Lake (Figure 4, Sites 181, 182, 184). At the time of formation, the ice margin was close to the southwest end of Red Indian Lake, and ice blocking the Lloyds River valley; in addition, ice was also located on the highlands above the valley walls. The lowest outlet available to control the water level is the Southwest Brook outlet located in the Long Range Mountains, approximately 10 km southwest of Lloyds Lake, at 310 m asl. Drainage from this outlet is *via* Southwest Brook into St. George’s Bay. The lack of corresponding deltas and shoreline features suggests that this was a short-lived phase.

Plate 3. *A) Photograph of 15 m section described at Site 285. Inset shows graded beds and a dropstone between 1.7 m and 2.7 m. B) Photograph shows flame structures of very fine-grained sand extending into the overlying fine-grained sand.*

Star Lake Phase 2: 310 m asl

As ice retreat continued both northeastward and north of Lloyds River, glacial Lake Shanadithit expanded *via* Otter Brook and Star Lake Brook, filling Star Lake. The minimum lake extent for this phase is an ice margin located on the northeast side of Star Lake Brook (Figure 10A). The result was the formation of a 53-km-long lake that continued to fill the Lloyds River valley, having a maximum width of 1.6 km within the valley and 15 km at the northeast end (surface area of 179 km^2; Figure 10A). Fine-grained sediments at an elevation of 304 m above Star Lake Brook are indicative of minimum water-level elevations for this phase because no deltaic sediments were identified that could potentially be associated with this phase. The deglaciation of the southwest end of Red Indian Lake and Star Lake opened the Star Lake outlet at 310 m asl. Due to glacial isostasy, this outlet was at a lower level than the Southwest

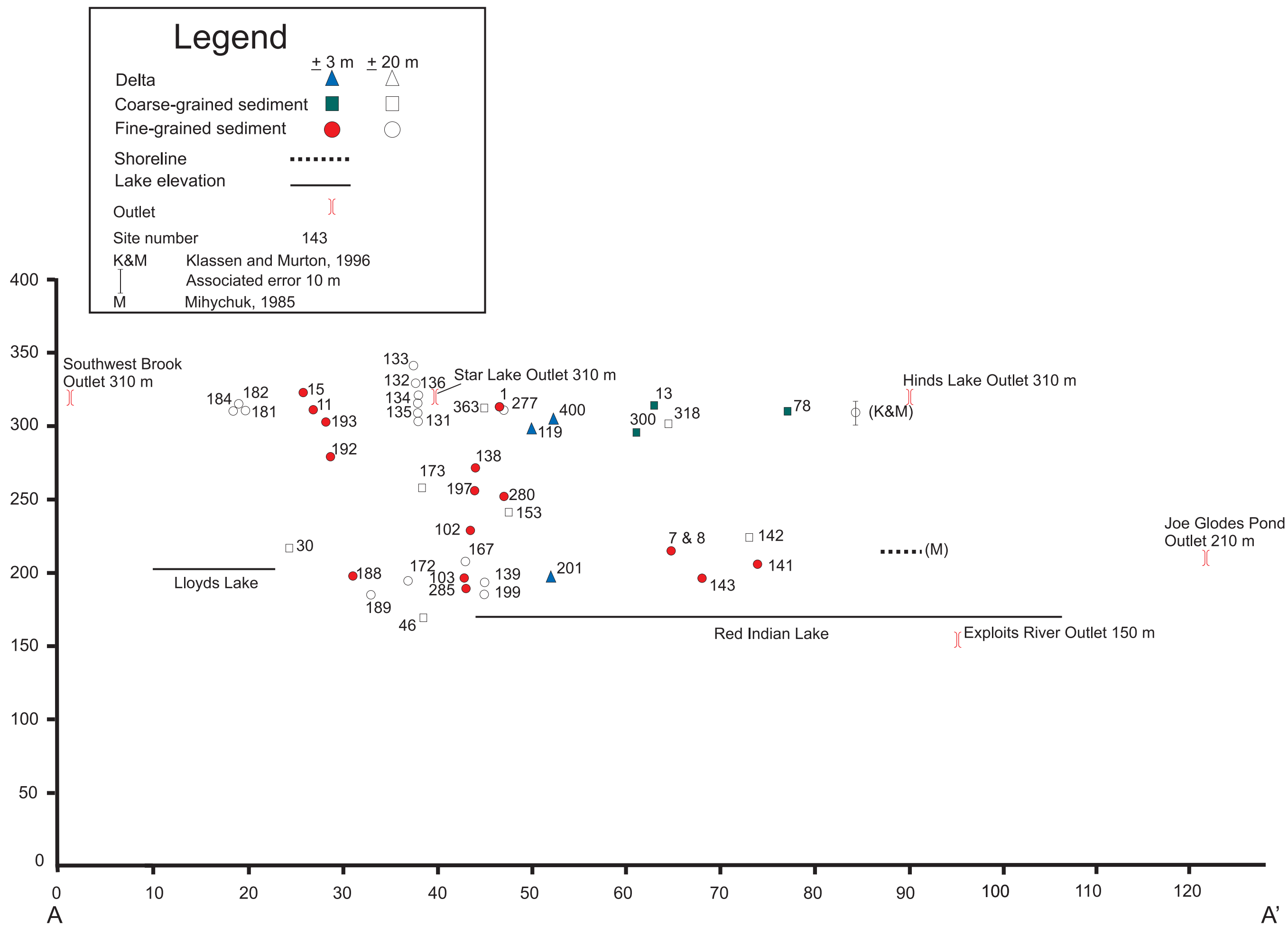


Figure 8. *Elevation of glaciolacustrine sediment, and shoreline features against distance along the Red Indian Lake Basin. The difference in elevation error associated with the sites is due to the type of digital altimeter used. Outlet elevations were interpolated from a topographic map. The elevation associated with the fine-grained sediments described by Klassen and Murton (1996) ranges from 300-310 m. The elevation error associated with Mihychuk's (1985) raised beach is unknown. The line in which the sites are projected onto is shown in Figure 4.*

Brook outlet, causing the drainage pattern to shift to this new outlet at the west end of Star Lake. Drainage from the Star Lake outlet was routed into Grand Lake *via* Little Grand Lake and Lewaseechjeech Brook. The development of the Star Lake Phase 2 likely happened very quickly, with only 10 km of northeast ice-marginal retreat from the ice margin proposed for the Lloyds River Phase 1. Rapid retreat of an unstable ice margin is also suggested between the minimum and maximum extents in this phase, as there are no deltas and shorelines recognized in the area. The maximum extent is suggested by coarse-grained sediments identified at 307 to 310 m asl (Figure 10B). A water level of 307 m asl shows the lake extending 85 km, from the southwest end of the Lloyds River valley to southwest of Buchans. The surface area of the maximum extent of the Star Lake Phase 2 is 569 km^2.

Hinds Lake Phase 3: 302 m asl

The water level for the Hinds Lake Phase 3 of glacial Lake Shanadithit is marked by the 302-m Gilbert-style delta identified at Costigan Brook (Figure 11). The water level was controlled by the outlet at Hinds Lake, at 310 m asl, where drainage entered Grand Lake *via* Hinds Brook. The ice margin extended from the highlands east of Hinds Lake southeast to Sutherlands Pond, thus maintaining glacier cover to the northeast (*i.e.*, Joe Glodes Pond and the modern Exploits River valley) and most of the southern shore of Red Indian Lake. This is the maximum eastern extent of the ice margin necessary to maintain a 302 m asl water-level elevation. The paleogeography of this lake phase covers a surface area of 727 km^2 and shows a lake that extends 90 km from the upper reaches of the Lloyds River valley to just east of

Buchans, and has a maximum width of 25 km. Ice occupied the highlands immediately northeast of Star Lake Brook and was the source of drainage for the formation of the ice-contact delta identified at Caribou Pit. The ice margin on the south side of the lake was south of Costigan Brook, allowing glacier-fed meltwater to build the Costigan Brook delta. Coarse-grained gravels identified at 300 m asl on the south side of the lake may also help to determine the approximate position of the shoreline of the Hinds Lake Phase 3 on the south side of the lake. The glaciolacustrine sediments identified by Klassen and Murton (1996) in the Buchans area have a maximum elevation of 300–310 m asl, and are interpreted to correspond to this phase of ice-marginal lake development.

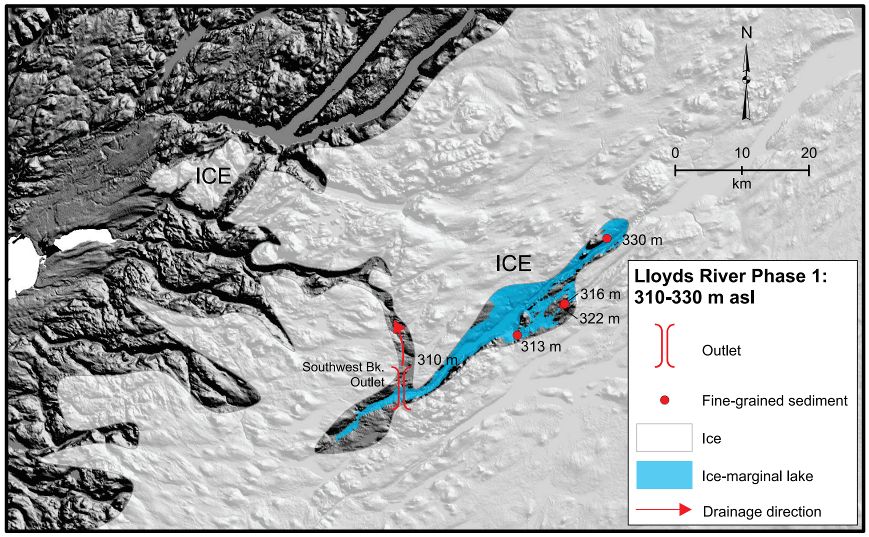


Figure 9. *Paleogeography of glacial Lake Shanadithit, Lloyds River Phase 1. The 310–330-m-asl lake surface forms a 47-km-long lake that is controlled by the Southwest Brook outlet. This represents a minimum elevation based on fine-grained sediments within the Lloyds River valley.*

Joe Glodes Pond Phase 4: 195 m asl

The Joe Glodes Pond Phase 4 of ice-dammed lake development is represented by the 195 m asl delta at Costigan Brook (Figure 12). The 212-m-asl shoreline identified by Mihychuk (1985) in the Victoria River area suggests that the ice margin was east of this location and blocking the Exploits River. The outlet controlling this phase of glacial lake development is located at Joe Glodes Pond (210 m asl). Drainage through this outlet was *via* South Brook into Halls Bay. During this phase, the lake extended 116 km from the southwest end of Lloyds Lake to Joe Glodes Pond, had a maximum width of 10 km and covered a surface area of 349 km^2. In addition to the ice margin lying over the northeast end of Red Indian Lake, smaller remnants of ice were located on the highlands east and west of Buchans.

Whereas the outlet at Joe Glodes Pond, at 210 m asl, controlled the water-surface level for the 195 m asl phase, the drainage route of the water released between the phases is uncertain. There are four hypotheses: 1) between the upland east of Buchans, and Joe Glodes Pond 2) at Joe Glodes Pond 3) subglacial drainage, or 4) a combination of the three. With such a large volume of water, meltwater channels along the hillside or an incised valley would be expected. No meltwater channels or incised valleys have been identified. If ice remained on the side of the upland, water may have been directed through Joe Glodes Pond at 210 m asl. However, aerial photographs of this area do not suggest that it hosted a large volume of water. The alternative hypothesis is subglacial drainage down the Exploits Valley. The erosive power of drainage of 6.69×10^{13} litres of water would have initiated the formation of the incised valley. The modern Exploits River valley is over 50 m deep and has a minimum width of 200 m. It forms the most extensive incised valley in the RILB. Whereas the hypothesis of subglacial drainage is preferred, it must also be recognized that the other hypotheses could also be responsible for the drainage.

Ice retreat to the north and south at the northeast end of Red Indian Lake opened the Exploits River outlet (150 m asl) and caused the final drainage of glacial Lake Shanadithit. Small ice remnants likely remained between the Exploits River and Joe Glodes Pond, south of the Exploits River and on the highlands east and west of Buchans.

GLACIO-ISOSTASY

The elevation difference between the water level and the outlets for each of the phases indicates that the lake surfaces have been de-levelled or tilted in response to isostatic rebound. The pattern of deglaciation toward the northeast may suggest a similar pattern for tilt of the de-levelled lake phase surfaces. The amount of tilt is estimated from the difference in elevation between the 302-m-asl water level identified by the Costigan Brook delta, and the 310 m Hinds Lake outlet. This represents an increase of 0.22 m km^{-1} to the northeast. This is a minimum estimation of the rate of tilt, as data to calculate a maximum rate are not available. A slightly lower rate of 0.20 m km^{-1} is identified for the 195-m-asl-delta surface and the Joe Glodes Pond outlet at 210 m asl. Minimum rates of tilt are not calculated for Lloyds River Phase 1 or Star Lake Phase 2 as water levels are minimum estimates only and are not defined by delta surfaces.

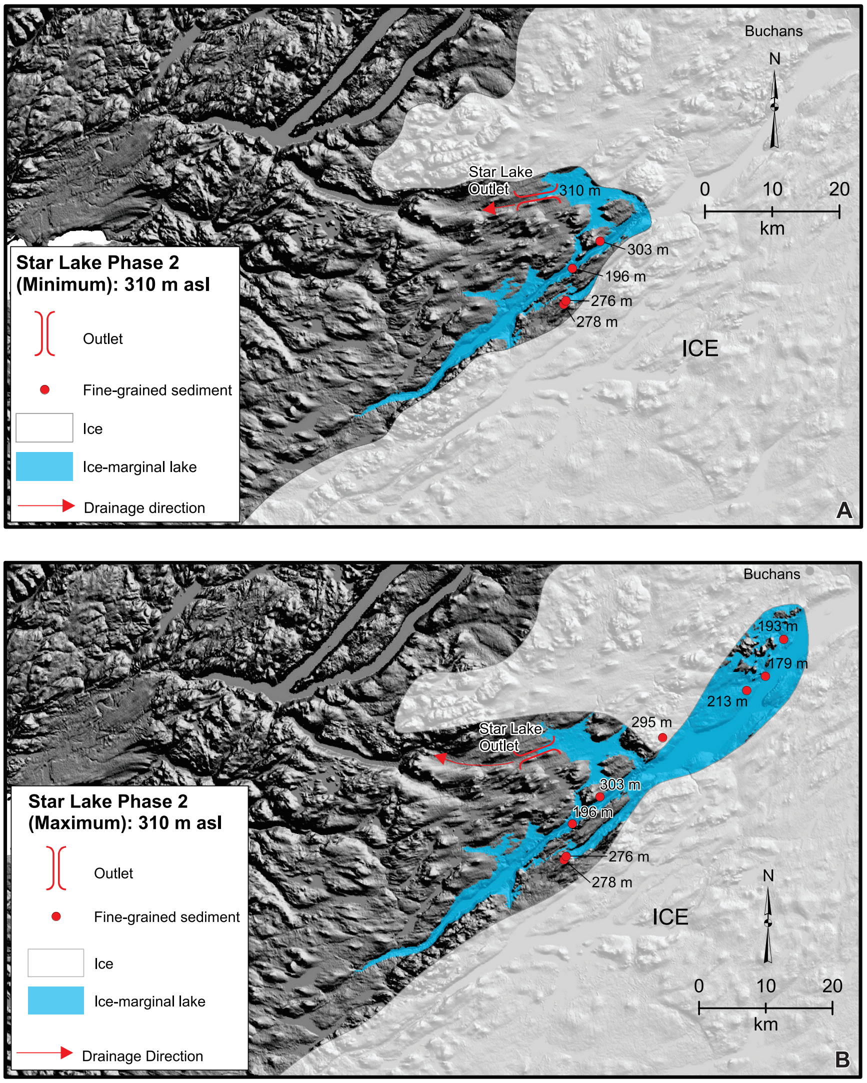


Figure 10. *Paleogeography of glacial Lake Shanadithit, Star Lake Phase 2. The 310-m-lake surface is controlled by the outlet at Star Lake for both the minimum and maximum extents. A) The minimum extent shows a 53 km lake with the ice margin located on the northeast side of Star Lake Brook. B) At the maximum extent the ice margin is west of Buchans forming an 85-km-long lake.*

DISCUSSION

The paleogeographic reconstruction model presented for glacial Lake Shanadithit is updated (based on new analyses), and has been modified from that presented by Vanderveer and Sparkes (1982) and Smith (2010). These modifications are discussed below.

The three phases identified by Smith (2010) correspond to the phases presented here. Phase 1 of Smith (2010) has been divided into two phases in the model presented above, the Lloyds River Phase 1 (310–330 m asl) and the Star Lake Phase 2 (310 m asl). Phase 2 and 3 of Smith (2010) correspond to the Hinds Lake Phase 3 (302 m asl) and Joe Glodes Pond Phase 4 (195 m asl), respectively.

The model presented above differs from previous models presented by Vanderveer and Sparkes (1982) and Smith (2010), in the direction in which the lake drained. The model of glacial Lake Shanadithit presented by Vanderveer and Sparkes (1982) identified a glacial lake at a minimum of 216 m asl, which drained through an outlet in the Long Range Mountains at the end of Lloyds Lake (*i.e.*, Southwest Brook; Sparkes, 1984). However, this is not possible as the lowest outlet identified in the Lloyds River valley is at 310 m asl. No maximum elevation or size is given for glacial Lake Shanadithit by Vanderveer and Sparkes (1982). A 216-m-asl lake surface fits within Phase 2 (300 m) of Smith's (2010) model (Hinds Lake Phase 3 of the present model). Smith's (2010) model does not describe the route by which the 300-m-asl water surface (Phase 2) drained.

RELATIONSHIP OF GLACIAL LAKE SHANADITHIT TO GLACIAL LAKE HOWLEY AND ICE CAP RETREAT DYNAMICS

The paleogeography of glacial lakes Howley and Shanadithit suggests that the lakes formed independently of one another. Drainage of glacial Lake Shanadithit through the outlets at Star Lake and Hinds Lake indicate that the Grand Lake Basin was free of ice during their formation. It is possible that the formation of the deltas at the end of Lewaseechjeech Brook and Hinds Brook, in glacial Lake Howley, is, in part, due to drainage from glacial Lake Shanadithit. However, there is no direct evidence to support this. Ice remnants located on the highlands, east and west of Buchans, likely provided meltwater to both lake systems.

TIMING OF GLACIAL LAKE SHANADITHIT

The formation of glacial Lake Shanadithit has not been constrained, due to the lack of radiocarbon dates in the RILB. However, relative chronologies have been suggested by Vanderveer and Sparkes (1982), Sparkes (1984), and Klassen and Murton (1996). Vanderveer and Sparkes (1982) and Sparkes (1984) suggest that an ice-marginal lake formed following the south-east–south ice flow, which was thought to be pre-late Wisconsinan. This was followed by ice flow to the southwest during the late Wisconsinan, which deposited till over the rhythmites identified in the south-west end of Red Indian Lake by Vanderveer and Sparkes (1982). The ice-flow history presented by Smith (2009) is late Wisconsinan, as are the Quaternary sediments described by Smith (2010). Clast fabrics measured from the diamicton overlying the Lloyd River rhythmites (the type locality for glaciolacustrine sediments described by Vanderveer and Sparkes, 1982), indicate the till was deposited as a result of sediment gravity flow. Smith (2010) suggested that glaciolacustrine sediments in the Lloyds River valley were deposited during the late Wisconsinan deglaciation. This concurs with the timing of deposition of glaciolacustrine sediments at Buchans, which Klassen and Murton (1996) suggest occurred after the last, northeast–southwestward flow, and thus to be a deglacial event.

The lack of strandlines and the few identified deltas suggest that the lake was short-lived, perhaps several hundred years; however, the exact timing of formation of glacial Lake Shanadithit is uncertain. The formation of deltas on the south shore of Grand Lake, along with the Star Lake outlet and Hinds Lake outlets, suggests that Grand Lake was ice free during the formation of glacial Lake Shanadithit. The formation of glacial Lake Howley occurred between 12.6 and 12.3 ka BP (Batterson, 2003). Thus drainage through Southwest Brook must have been into an ice-free St. George's Bay. The formation of glacial Lake Shanadithit therefore began sometime after 12.6 ka BP and may have formed and drained within a couple of hundred years of glacial Lake Howley.

REGIONAL ICE CAP RETREAT DYNAMICS

Regional ice-retreat patterns are identified by Grant (1974) and Shaw *et al.* (2002, 2006). The paleogeography described by Shaw *et al.* (2006) indicates

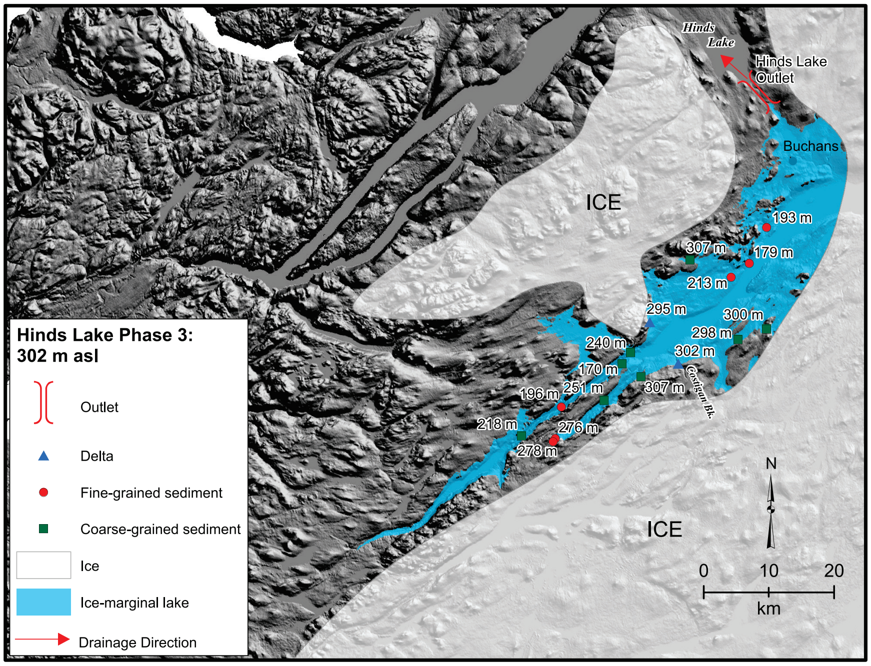


Figure 11. *Paleogeography of glacial Lake Shanadithit, Hinds Lake Phase 3. Once ice retreated east of Buchans, the Hinds Lake outlet opened creating a water-surface level at 302 m asl as indicated by Costigan Brook delta.*

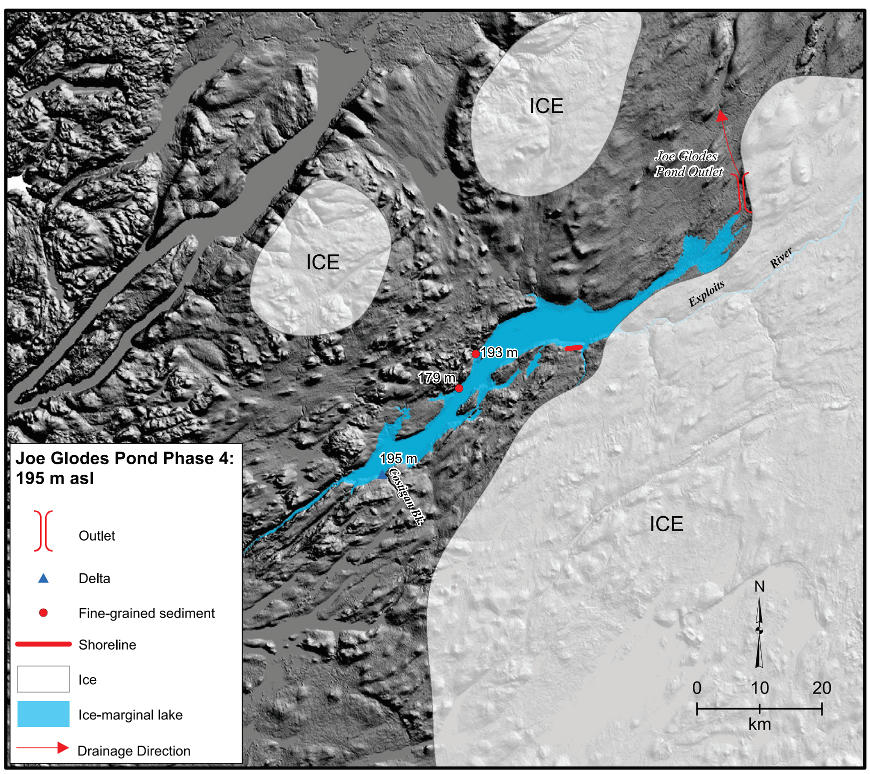


Figure 12. *Paleogeography of glacial Lake Shanadithit, Joe Glodes Pond Phase 4. The final phase of ice-marginal lake development was a 195-m-asl water level as identified by the delta at Costigan Brook. This level was controlled by the Joe Glodes Pond outlet. The opening of the Exploits River outlet caused the emptying of glacial Lake Shanadithit.*

that most of the interior of the Island was still covered with ice at 12 ka BP, with the exception of Grand Lake and some of the Exploits River valley. Grant's (1974) speculative late deglaciation pattern identifies large remnant ice caps over Red Indian and Meelpaeg lakes. The late deglacial paleogeography shown in Shaw *et al.* (2002) for 10 ka BP identifies a similar pattern to that of Grant (1974), with smaller ice remnants over northeast part of Red Indian Lake, Granite Lake and Meelpaeg Lake.

Whereas the proposed paleogeographic reconstruction model for glacial Lake Shanadithit agrees with the location of an ice cap over Meelpaeg Lake, it is not consistent with a large remnant ice cap over Red Indian Lake as suggested by Grant (1974). Prior to the Lloyds River Phase 1 of the proposed paleogeographic reconstruction model of glacial Lkae Shanadithit, the entire basin, as well as much of the interior, was covered by ice, similar to the Shaw *et al.* (2002) 12 ka BP model. The proposed paleogeographic reconstruction model indicates that active retreat, and the formation of glacial Lake Shanadithit, left isolated ice remnants on the highlands west of Buchans, and a larger ice remnant over the areas northeast and south of Red Indian Lake. An ice mass over the northeast part of Red Indian Lake was needed to block drainage and form glacial Lake Shanadithit. Upon the opening of the Exploits River, a small ice mass was left to the north, and a large ice mass existed south of the Exploits River. The large ice mass actively retreated south toward Meelpaeg Lake where the ice disintegrated *in situ* as suggested by the boulder-rich hummocky moraine in the area.

GLACIAL LAKE SHANADITHIT'S CONTRIBUTION TO REGIONAL GLACIO-ISOSTASY

There are conflicting views on the affect the Newfoundland Ice Cap had on isostatic rebound; however, the identification of tilted lake surfaces in the RILB indicates that central Newfoundland has been affected by glacio-isostasy. This is the first documentation of isostatic rebound in the interior of Newfoundland. A minimum rate of de-levelling for the RILB increases to the northeast by 0.22 m km^{-1}. This is the same direction and rate of isostatic tilt determined for glacial Lake Howley (Batterson, 2003), and is similar to a 0.20 m km^{-1} increase calculated from known paleo-sea level data between Stephenville and Springdale (Batterson, 2003). The similar rates of isostatic tilt determined for both glacial Lake Howley and glacial Lake Shanadithit are, perhaps, further evidence that these areas were deglaciated and formed ice-marginal lakes within a couple of hundred years of one another.

The presence of isostatic rebound in central Newfoundland indicates that the Newfoundland Ice Cap did have an influence on glacio-isostasy, as suggested by Grant (1989). This is in contrast to Quinlan and Beaumont (1982), who suggested the thickness of the Newfoundland Ice Cap would have little affect on the regional pattern of crustal depression due to its being overwhelmed by the influence of the Laurentide Ice Sheet. The identification of additional ice-marginal lakes containing de-levelled water levels in central Newfoundland along with related radiocarbon dated material will help to refine the glacio-isostasy of central Newfoundland. However, geophysical modelling of the crustal response to the retreat of Newfoundland Ice Cap using the present knowledge of ice-retreat dynamics and radiocarbon ages could provide a better understanding of the Island's glacio-isostasy.

IMPLICATIONS FOR DRIFT PROSPECTING

A complex glacial and deglacial history of the RILB makes drift prospecting within the area difficult. A better understanding of the glacial history and paleogeography of the RILB is needed for drift prospecting to be successful. Klassen's (1994) ice-flow model, along with that of Smith (2009), showed that ice flow in the RILB is complicated by shifting ice divides. This is made more complex by the pattern of retreat and the formation of glacial Lake Shanadithit. The formation and drainage of glacial Lake Shanadithit divided the retreating ice in the RILB into at least three smaller ice centres: the highlands west of Buchans, and northeast and south of Red Indian Lake. Topographic controls on ice flow are evident in this late stage of deglaciation (Klassen, 1994). This is a slightly different pattern of late deglaciation to that described earlier by Grant (1974, 1975). Special considerations need to be taken when conducting drift-prospecting surveys in areas with complex ice flow. For example, mineralization within a unit may form a ribbon dispersal pattern with one ice-flow direction. If a subsequent ice-flow direction affects this dispersal train, the result may form a fan-like dispersal train. A good example of this kind of dispersal train is documented by Klassen and Thompson (1989) in central Labrador, where indicator erratics from the Red Wine Complex, form a fan-shaped dispersal train resulting from transport and erosion during three ice flows.

The following should be taken into consideration prior to prospecting within the current study area:

1. Glaciolacustrine deposits are a small fraction of the surficial sediment in the RILB, recognition of these sediments is crucial because they were either deposited by water (*e.g.,* deltas, gravels, silts, fine sands) or modified by water (*e.g.,* shorelines). These sediments must be considered separately from tills when interpreting geochemical data because dispersal is unrelated to ice movement and there may have been selective sorting of heavy minerals within the glaciolacustrine environment.

2. It is important to consider the scale of mapping, when consulting surficial maps, as glaciolacustrine sediments may cover too small an area (<5% of a single map unit) to be represented on a 1: 50 000-scale surficial geology map. Therefore, it is important to keep in mind the elevation at which glaciolacustrine sediments are located.
3. Caution needs to be exercised when sampling in areas occupied by former glacial lakes as the upper parts of diamicton units may be washed or winnowed. When diamictons are washed or winnowed the finer fraction is removed, leaving remnant material that is unsuitable for till sampling, and thus it is important to conduct sampling below sediments that show evidence of washing to ensure that appropriate material (*i.e.,* unwinnowed till) is sampled.
4. Any isolated mineralized boulders found in areas previously occupied by glacial lakes, (*i.e.*, below the maximum lake surface) may have been ice-rafted and deposited as dropstones. They have no relationship to ice flow, which makes the tracing of such boulders to their bedrock source more difficult.

CONCLUSIONS

Evidence for ice-marginal lakes has been identified in the RILB during field investigations over the past four field seasons. This evidence has led to the development of the paleogeographic reconstruction model of glacial Lake Shanadithit in which four phases have been identified. These include: the Lloyds River Phase 1 at 310–330 m asl; the Star Lake Phase 2 at 310 m asl; the Hinds Lake Phase 3 at 302 m asl, and the Joe Glodes Pond Phase 4 at 195 m asl. Whereas no radiocarbon dates are present to constrain the timing of formation of glacial Lake Shanadithit, the relative chronology suggests that St. George's Bay and Grand Lake Basin would have to be ice free in order for drainage to occur *via* Southwest Brook outlet into St. George's Bay. Therefore, the formation of glacial Lake Shanadithit began sometime after 12.6 ka BP and may have formed and drained within a couple hundred years of glacial Lake Howley.

The proposed paleogeographic reconstruction model has important implications for both glacio-isostasy and for regional ice-retreat dynamics, which differ to previous glacio-istoasy and ice-retreat models.

De-levelled shoreline features and corresponding outlets indicate that the basin has undergone a minimum isostatic tilt of 0.22 m km^{-1}. This is the first evidence of iostatic tilt within the interior of Newfoundland and indicates that the Newfoundland Ice Cap influenced the amount of glacio-isostacy on the Island and was not over shadowed by the Laurentide Ice Sheet, as previously thought.

The active retreat and formation of glacial Lake Shanadithit within the RILB as indicated by the proposed paleogeographic reconstruction model indicates the regional ice-retreat pattern left isolated ice remnants on the highlands west of Buchans, and a larger ice remnant over the areas northeast and south of Red Indian Lake. This is in contrast to Grant's (1974) model with a large ice mass situated over all of Red Indian Lake.

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