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GLACIAL SPILLWAY DEPOSITS IN THE GANDER LAKE–GAMBO AREA

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ABSTRACT

Thick, gravelly deposits are found between the eastern end of Gander Lake and Freshwater Bay, near Gambo. Exposures in gravel pits were logged, and four geomorphic units were identified by air-photo interpretation. A ground-penetrating radar profile was also acquired near Gambo, in an area of limited sediment exposure.

This area is considered to have once been a meltwater spillway draining a glacier that retreated toward Gander Lake, during deglaciation. Eskers in the Butts Pond area are the oldest deposits, as glacier ice must have been present for such features to form. All other deposits are subaerial, and formed after the glacier retreated to the northwest; it is not known if the deposits are coeval or time-transgressive.

Hummocky deposits near Gander Lake formed in an ice-contact proglacial environment. Localized ponds and small meltwater rivers deposited fine- and coarse-grained sediment in this area, commonly on top of ice. Farther from the ice front, meltwater deposited gravelly and bouldery sediment in a braided river environment. It is unusual that eskers in the Butts Pond area were not completely eroded away by the braided river, which at times experienced very high flow velocities. It is hypothesized that widening of the spillway valley at Butts Pond allowed river flow velocity to decrease significantly, so that the largest eskers were preserved. The braided river may have also flowed over stagnant ice in this area, which may have played a role in esker preservation. Butts Pond likely formed when the stagnant ice melted.

In the Gambo area, two deltas are preserved. One formed when sea level was 43 m above present, and the other when sea level was at 30 m above present. Some incision of the upper delta occurred when sea level fell.

INTRODUCTION

This paper explores the sedimentary deposits and glacial history of the area between Gander Lake and Gambo. Thick, gravelly deposits are present in this area, indicating that it was a zone of deposition during the last glaciation or the following deglacial period. The Gander Lake area is interesting, in that the Gander Lake valley is a very deep basin, which likely affected glaciation and ice-flow directions. However, little is known about the details of glacial history in this area.

Gander Lake has a depth of at least 277 m (A. Aksu, personal communication, 2005). Ice is known to have covered the entire Gander area during the last glaciation (Batterson and Vatcher, 1991), but it is unlikely that ice was grounded within such a deep trough as Gander Lake. Ice-flow directions were to the east and northeast (Batterson and Vatcher, 1991), and thus ice likely retreated westward along the Gander Lake valley (or it may have stagnated). A major spillway representing meltwater flow eastward away from such a westward-retreating glacier was investigated during reconnaissance work in the summer of 2005. The spillway extends from the eastern end of Gander Lake to the town of Gambo, on the west side of Freshwater Bay (Figure 1). Several gravel pits in this area expose different parts of the spillway zone, providing clues to the environments of deposition that existed just before and during deglaciation.

Gander Lake currently drains northward from its western end through Gander River. The drainage outlet is between the towns of Glenwood and Appleton. The spillway is found at the southeastern end of the lake, but it is no longer a drainage outlet, as the deposits are thick, and rise well above the lake. Fossil evidence (*this study*) suggests that Gander Lake once may have been open to the sea. The marine clam *Hiatella arctica* was found in silty clay near the shore of Gander River, about 15 km northeast of the northern outlet.

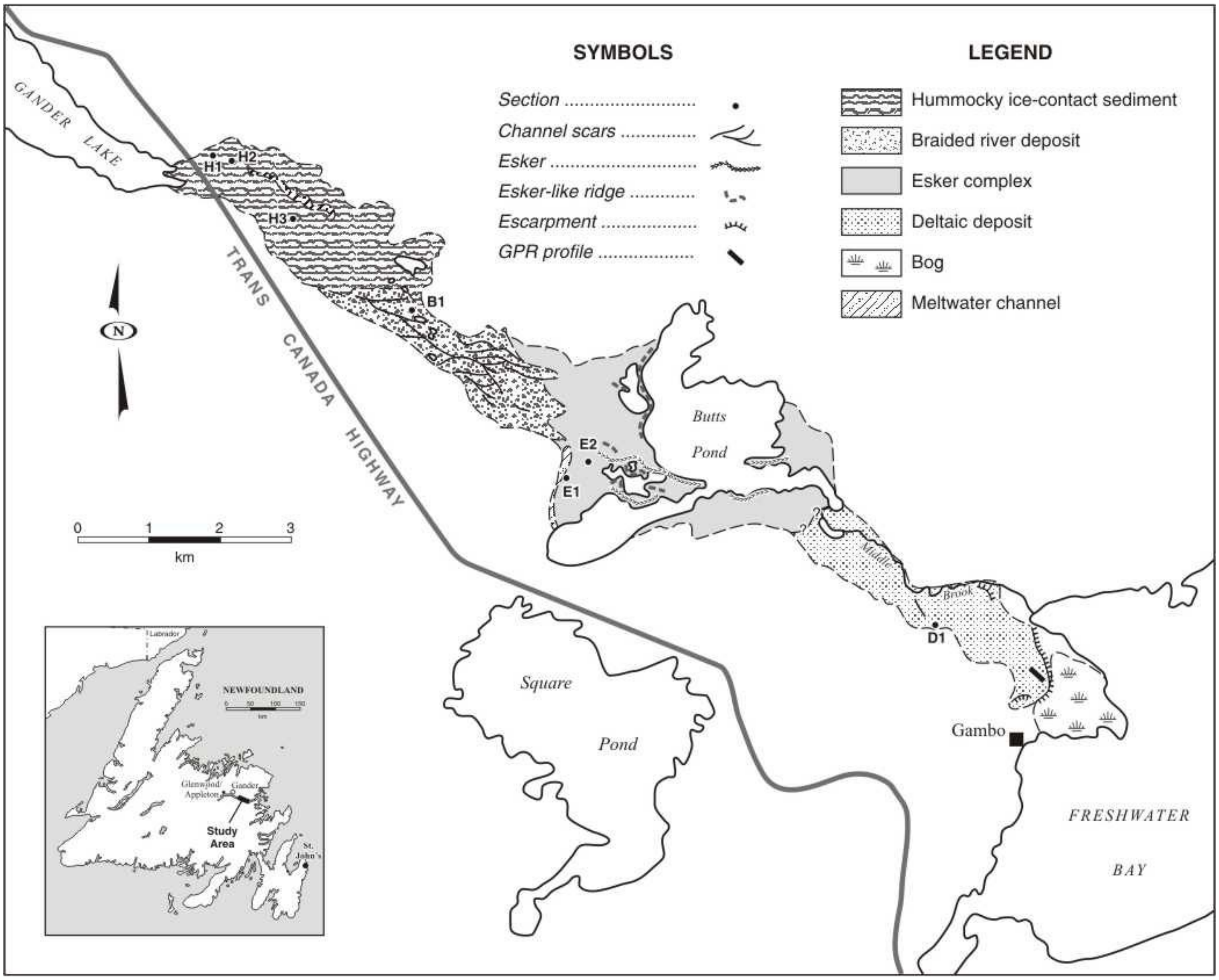

Figure 1. *Glacial deposits in the Gander Lake–Gambo area, and locations of section logs and the ground-penetrating radar profile. Study area indicated on index map.*

PREVIOUS WORK

There were two major late Wisconsinan ice-flow directions in the area. The first was eastward (Batterson and Vatcher, 1991; Vanderveer, 1985; Vanderveer and Taylor, 1987) and the second was to the north-northeast, although some valley-parallel flow was found in the eastern part of Grand Lake (Batterson and Vatcher, 1991; Vanderveer and Taylor, 1987).

Thick sediments between Butts Pond and Gambo were first identified by Vanderveer (1985), who interpreted them as ice-contact outwash deposits indicating drainage to the east during deglaciation. Two sedimentologically distinct tills, stratified sand/gravel and possible glaciomarine rhythmites were also identified west of Gambo. The rhythmites suggest a possible marine limit of 30 m (Vanderveer and Taylor, 1987). At the western end of Gander Lake, ripple marks, interpreted as possible marine beach sediments, may indicate that marine limit was as high as 64 m asl in that area (Batterson and Vatcher, 1991).

METHODS

Aerial photographs were examined and geomorphological features and boundaries were identified. Marine fossils were collected on the shore of Gander River at an elevation of about 24 m asl, and were placed in plastic bags; these were later submitted for radiocarbon dating. Selected elevational data was determined from 1:50 000 topographic maps and elevation accuracy may be limited as a result. Gravel pit sections and other exposures were logged using standard methods.

Ground-penetrating radar (GPR) was used in the Gambo area to obtain subsurface information where exposures were lacking. The 50 MHz antennae used had a 2 m separation, and traces were collected every metre. Topographic correction was unnecessary as the surface was reasonably flat. Processing parameters included the following: background removal, direct current removal, subtract mean trace, lower bandpass of 40 MHz and upper bandpass of 70 MHz, and time varying gain (linear gain of 25 and exponential gain of 8). An arbitrary velocity of 120 m/ns was used, as it was not possible to do a common midpoint survey due to equipment difficulties; depth determinations are thus only approximate. The chosen velocity was found to be a common velocity in similar glaciofluvial deposits in British Columbia (McCuaig, 2000).

GEOMORPHOLOGY

The sediments are located between the eastern end of Gander Lake and Freshwater Bay, including the Gambo area (Figure 1). They are flanked by bedrock, till and bogs and the margins of the possible spillway zone are well defined.

Within the spillway zone, air-photo interpretation revealed four major geomorphic units that reflect, to some extent, deposit genesis (Figure 1). Bogs fill scattered kettles and depressions in all of the units. At the northwestern end, near Gander Lake, a hummocky zone of glaciofluvial deposits is present, which contains an abandoned meltwater channel. Hummocky glaciofluvial sediments commonly form when buried ice blocks melt after deposition of clastic sediments, implying an ice-contact or ice-proximal depositional environment. The hummocky zone increases in elevation away from Gander Lake, and is highest at its southeastern margin (about 35 m asl). As the surface of Gander Lake sits at about 26 m asl, drainage from the lake no longer occurs to the southeast (there are no meltwater channels present that incise the deposits to a level below 26 m asl). A more planar deposit whose surface is dissected by channel scars is located southeast of the hummocky zone. The scars are clearly visible on aerial photographs and are typical of a braided river system. In the vicinity of Butts Pond, a zone containing a series of sinuous features appears to be an esker complex, which represents several tunnels of a subglacial river system. However, many of the sinuous features are not prominent ridges - they are of considerably lower relief than some of the others. Two large, sharp-crested ridges that jut into Butts Pond are interpreted as eskers. The other flatter sinuous features could be eskers as well. Hummocky, boggy deposits are found in the rest of this geomorphic zone. A planar to undulating deposit, containing only one channel scar, extends from Butts Pond to Gambo. Escarpments are found at the southeastern end of the unit, and a trench has been carved along Middle Brook by a late glacial meltwater river. Parts of this trench are now bog-filled. A large bog adjacent to Freshwater Bay has formed just below a sizable escarpment at the edge of this unit, possibly on top of sediments slumped into the ocean from the unconsolidated cliff. A spit protects the northern side of the bog from wave erosion. It is difficult to assign a genetic origin to this zone based on geomorphic evidence.

STRATIGRAPHY

The following exposures were logged in active and inactive gravel pits within the four geomorphic zones. The first three sections are found within the hummocky ice-contact sediment zone.

SECTION H1

This section is 10 m high, but the lower 6.5 m is slumped (Figure 2). The upper part was logged and is made up of beds of granule, pebble and cobble gravel, both matrix- and clast-supported. Clasts are subround to subangular or angular and the matrix is granule to pebble gravel. The lower two beds strike 78° and dip 13°. A few 1- to 3-cm-thick interbeds of silt, fine sand and medium sand containing mica grains are also present. These beds are very well sorted, and contain a few lenses of less well-sorted silt to medium sand. The lower contact of the finer beds is draped on the underlying gravel beds (at 170 cm). A few beds of overlying matrix-supported pebble gravel and medium sand (120 to 150 cm) are in turn overlain by gravelly silt to medium sand. The gravelly component includes subround to angular pebbles and a few cobbles. The section is capped by 50 cm of subangular to angular boulder gravel, set in a medium sand to granule gravel matrix.

This deposit is interpreted as fluvial, with varying flow volumes and paleoflow to the south-southeast. The variable flow volumes, range between clast and matrix support and pebble roundness suggest that it is glaciofluvial.

SECTION H2

A small gravel pit to the east of section H1 contains two exposures. On the northern side of the pit (Section H2a, Figure 2), fine-grained sediments are slumped into a lower unit of pebble and cobble gravel; silt, sand and gravel of various sizes are all present. The basal pebble and cobble gravels (188 to 278 cm) are weakly bedded and the former are clast or matrix supported, whereas the cobble gravels are clast supported. Beds are undulating and locally imbricate (clasts dip toward 290°). The upper, fine-grained beds (15 to 188 cm) are well to very well sorted, 2 to 10 cm thick, and display crossbedding, ripple crosslamination, erosive and draped contacts and high-angle reverse faults; crossbedding

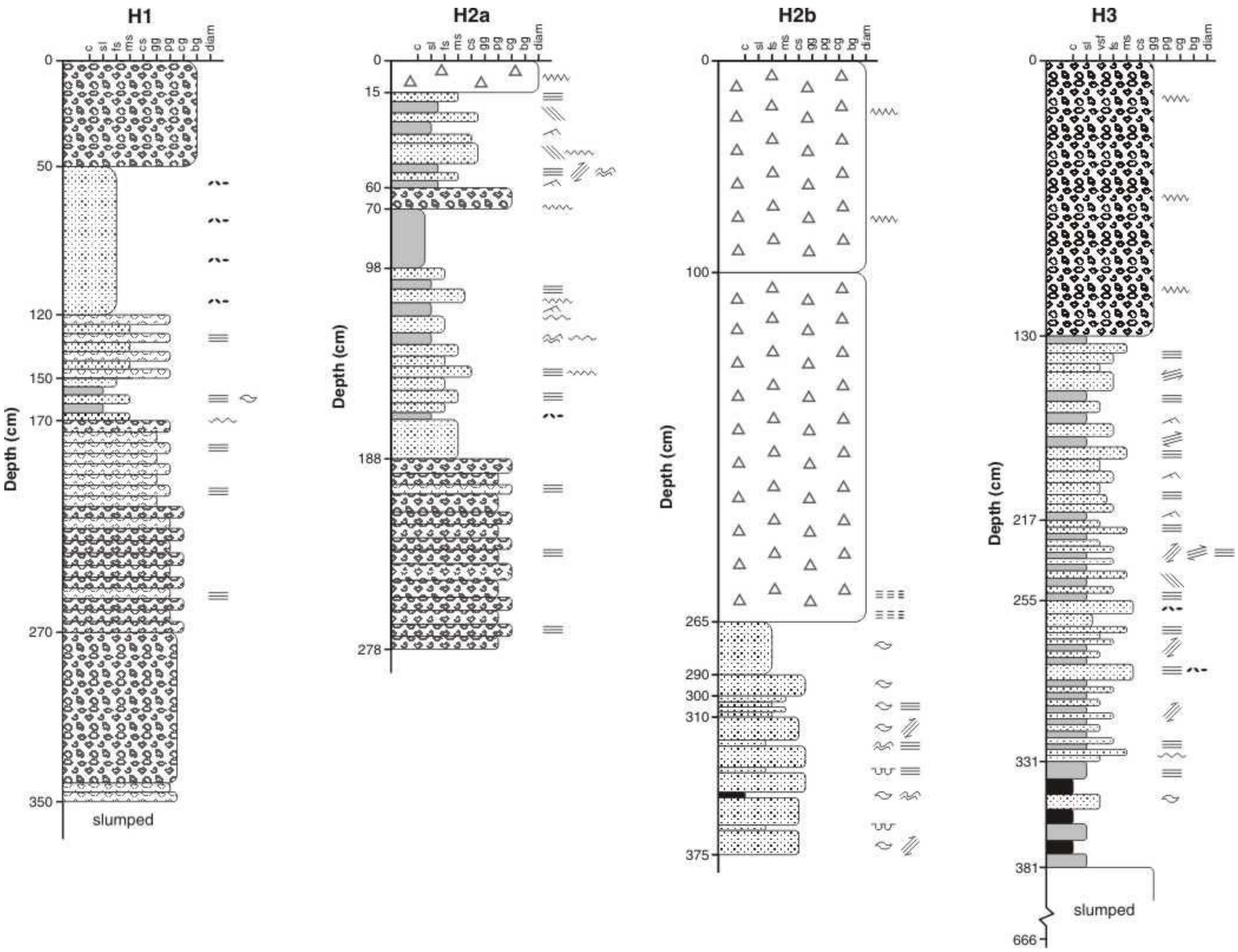

Figure 2. *Exposures in the hummocky ice-contact sediment zone.* See *Figure 3 for legend.*

in the sand and gravel beds strikes 90° and dips 43°. Ripple crosslamination in the finer beds appears to indicate flow in the opposite direction. One bed has dispersed pebble-sized clasts that impact the beds beneath them and a few beds are deformed. The upper 15 cm is a diamicton that has been pushed into place by bulldozing during gravel-pit operations.

The finer upper units are slumped into the lower beds in a V-shape (Plate 1), which is probably why there are beds that dip at an angle beyond the angle of repose, which is 35°. The large-scale slumping, along with the high-angle reverse faults, indicates ice melt below this location. This type of post-depositional deformation is common in ice-contact settings, which leads to the interpretation that the ice front must have been in close proximity when these deposits formed. High-angle reverse faults are particularly indicative of loss of support from below due to ice melt and are commonly associated with normal faults (McDonald and Shilts, 1975).

Plate 1. *Fine-grained sediments (above dashed line) slumped into underlying gravel, Section H2.*

The clasts within the sand beds are interpreted as dropstones, which may have fallen from small icebergs into backwater ponds in a meltwater river system that was locally deposited over ice, or they could have rolled into a pond from the ice front itself. Imbrication of clasts indicates eastward flow, crossbedding implies southward flow, and ripple cross-stratification suggests northward flow. Such variable paleoflow directions represent a meltwater river that was constantly changing direction due to either high sediment influx or changes in geomorphology brought about by ice melt, or both.

The southern side of the pit is somewhat different – it exposes sand overlain by a matrix-supported diamicton (H2b, Figure 2). The basal sand beds contain many lenses, laminations and beds of sand of variable grain size, and some minor silt and granules. Load structures, soft sediment deformation and high-angle reverse faults are present. The undisturbed diamicton from 100 to 265 cm has a silt to medium sand matrix. It contains clasts ranging from subround to angular and from 2 to 60 cm in size, that make up about 40 percent of the diamicton. It is poorly sorted, and weakly laminated at the base. The top 100 cm of the section consists of slumped or anthropogenically disturbed material. None of these sediments are laterally continuous – section H2a, less than 50 m away, is a good illustration of this.

The diamicton may be a debris-flow deposit, as evidenced by weak lamination at its base (Postma, 1986). The ice margin would have been nearby, and till melting out from it may have become saturated, flowing downhill and coming to rest on top of other ice-contact sediments. The lower contact is undulating, and the diamicton appears to be slumped into the underlying deformed sediments. It is possible that ice re-advanced, causing the underlying deformation, which implies that the diamicton is a till, but there are no overturned folds or other features indicating glaciotectonism. The debris-flow interpretation is thus favoured.

The lower beds contain erosive contacts, lenses, pinching out beds, load structures, high-angle reverse faults and soft sediment deformation, indicating a very dynamic and laterally variable proglacial environment, where rapid deposition was occurring over local ice bodies. The lack of coarse gravels indicates that this area was likely an area of ponding or lower flow regime fluvial flow. The coarse gravels at site H2a show that rapid meltwater river flow occurred less than 50 m away, however.

SECTION H3

This exposure is within a gravel pit to the southeast of the last two sections, but still within the ice-contact hummocky zone identified from air-photo interpretation (Figures 1 and 2). All the sediments exposed in this pit are laterally discontinuous. Fine-grained, undeformed sediment is exposed on the south side of the pit and is described below, as it is rather uncommon in this geomorphic zone.

Massive clay, silt and minor rusty lenses of fine sand are found below 331 cm. The sediments from 130 to 331 cm consist of well- to very well-sorted, horizontal to slightly undulating beds of silt, fine sand, very fine sand, medium sand and medium to very coarse sand. Finer sediments are laminated and sand beds are up to 2 cm thick. Large normal faults and high-angle reverse faults within this unit are offset 1 to 5 cm; low-angle reverse faults that become high-angle reverse faults at depth are displaced about 1 cm (Plate 2). Ripple crosslaminated beds up to 7 cm thick and minor crossbeds that pinch out are also present. Pebbles are present locally within the coarser beds; some are aligned with bedding. The top 130 cm of the logged section consists of slumped material, which may have been disturbed by quarry operations.

Plate 2. *Reverse faults in silt and sand, Section H3. The fault on the left is a high-angle fault at depth, but flattens upward to a low-angle one.*

Deformed beds and lenses of pebble gravel, cobble gravel, sand and silt, displaying some crossbedding and ripple lamination are found on the north side of the same pit. On the south side, just east of the logged location, there is a channel cut into clast-supported pebble gravel. Medium to coarse sand beds fill the base of the channel and contain climbing current ripples and granule gravel. Pebble and cobble beds overlie these and infill the upper part of the channel.

The deformed bedding on the north side of the pit suggests an ice-contact environment, whereas the pebble/cobble gravel and channel cut indicate fluvial deposition. Fine sed-

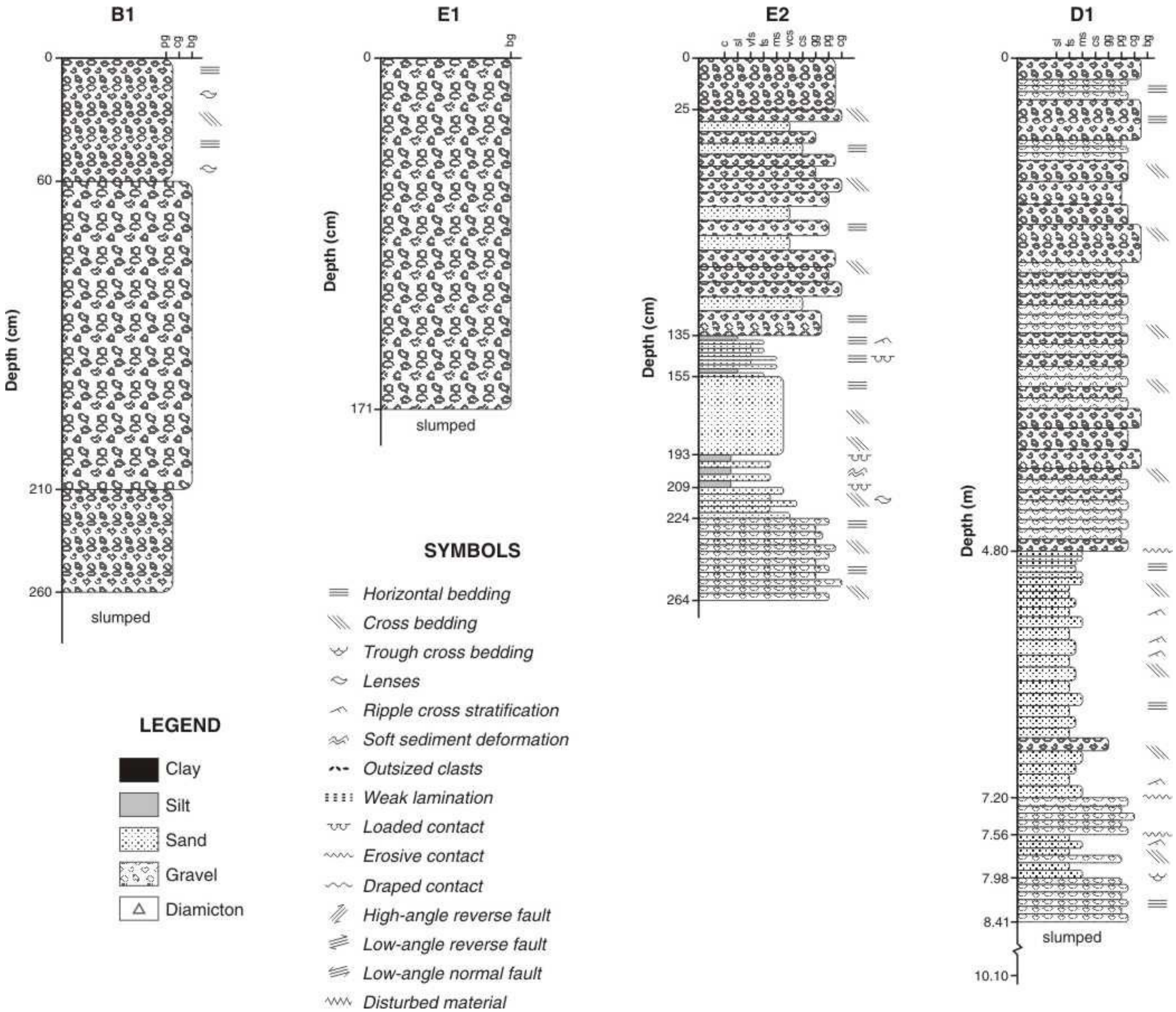

Figure 3. *Exposures in the braided river, esker complex and deltaic zones.*

iment in the logged section suggests a lacustrine origin. Such a complex environment must have formed near the ice front, with a meltwater river, ponds and buried ice present at the same time. The fine sediments were probably deposited in a localized pond fed by a meltwater river.

Reverse and normal faults, and especially reverse faults that flatten upward, suggest that ice blocks melted around and beneath these deposits (McDonald and Shilts, 1975), and is consistent with an ice-proximal interpretation.

SECTION B1

This is the only section from the braided river geomorphic zone (Figures 1 and 3). At this site, gravel beds are interfingered with large boulder beds, and only the top of the 5 m section could be logged due to collapse of the bouldery debris. The top and bottom of the section is made up of beds and lenses of clast- and matrix-supported pebble to cobble gravel that have a very coarse sand matrix. Beds are moderately sorted and clasts are mainly subround; many are discoid. Some vague crossbeds indicating approximately eastward flow are visible, but there is no clast imbrication. The central unit is a thick bed of poorly sorted boulder gravel that pinches out laterally and forms a channel cut boulder lag at the northern end of the section. Boulders are large (25 to 150 cm in diameter) and range from subangular to rounded, but are mainly subrounded. They are predominantly coarse-grained granite of local provenance.

Plate 3. *Exposure of large, subrounded boulders at Section E1.*

These sediments are interpreted to be the product of high-energy fluvial flow to the east, as suggested by boulder size, rounding, vague crossbedding, the channel cut and the boulder lag (Rust, 1978). This is in agreement with the braided river depositional environment surmized from air-photo interpretation.

SECTION E1

This section is found near Butts Pond, in the esker complex zone near a meltwater channel, but not within an esker ridge. Only the upper 171 cm could be logged, as the rest of the exposure consists of large piles of boulders apparently slumped off the section (Figure 3); however, the section appears to be about 4 to 6 m high. The deposit consists mainly of poorly sorted, large, subrounded boulders of local granite and minor rhyolite (averaging 50 cm in diameter, ranging from 25 to 150 cm; Plate 3). Some clasts are subangular and no imbrication was seen. The boulders are set in a poorly sorted fine sand to cobble gravel matrix and are matrix-supported.

The size and rounding of the boulders suggests a fluvial origin (Rust, 1978) and very high velocity flow. The local provenance of the boulders indicates a short transport distance (about 3 km). Similar bouldery beds are found within the braided river section of the spillway at section B1. Preservation of eskers in an area that saw high-velocity meltwater river flow after the ice melted is highly unusual. There is no evidence (fluvial features or deposits) of meltwater flow into Square Pond, rather, that area is till-dominated, with crag and tail features indicating east-northeast ice flow. One hypothesis for the preservation of the eskers is that flow velocity dropped dramatically due to valley widening in the Butts Pond area, reducing the river's capacity to erode the largest eskers. Butts Pond would have infilled with fluvial gravel in this case and there would be no pond. A large block of stagnant ice must have been present, and the meltwater river must have flowed over it. A lack of marginal gravelly deposits north and south of Butts Pond implies that meltwater did not flow around it. Melting of the stagnant ice formed the lake and may have isolated some parts of the braidplain, forming sinuous, flat features that resemble eskers except for the lack of a crested ridge. A second option is that the esker-like ridges may be eskers that were planed off by river flow over top of them while they were still encased in ice. The high-velocity flow evidenced at Section E1 may have occurred just before flow slowed, as it is found at the western boundary of the esker complex zone near a meltwater channel. Alternatively, high-velocity flow may have occurred over top of stagnant ice in some areas, which would have caused localized rapid melting.

SECTION E2

This 2.6 m exposure is found within the esker complex zone (Figure 1). The basal unit (224 to 264 cm) comprises granule or pebble gravel beds and minor cobble gravel up to 3 cm thick. The pebble to cobble gravel is matrix supported and has a granule gravel matrix. Both horizontal beds and crossbeds are present, but there is no clast imbrication. From 135 to 224 cm, horizontal bedding and lamination, cross-bedding, climbing ripple crosslamination (some ripples have a silt drape) and loaded contacts are found in well- to very well-sorted sand and silt. One of the lower contacts is strongly loaded (relief is about 10 cm), and is infilled with undeformed crossbeds (Plate 4). Other load casts show the normal deformation of overlying sands into underlying finer sand and silt. The upper beds (0 to 135 cm) consist of interbedded coarse sand and clast- or matrix-supported granule to cobble gravel with some tangential crossbeds. Clasts are subangular to subround, and beds are 2 to 10 cm thick, dipping to the southwest.

Plate 4. *Gravel and sand beds at Section E2. The large load casts in the centre of the photo are infilled with undeformed crossbedded medium sand. Trowel handle is about 12 cm long.*

Plate 5. *Laterally continuous rippled and crossbedded sand overlain by horizontally bedded and crossbedded gravel, eastern half of Section D1.*

This site is considered to be a fluvial deposit. The sediments are interpreted as having been deposited under variable flow conditions, ranging from lower flow regimes (ripples in sand) to higher flow regimes (gravel beds). However, the higher volume flows were much less powerful than those at site E1, as they were only able to move up to cobble-sized clasts. The large-scale load features infilled with crossbedded sand rather than deformed sand suggest that the original sand that caused the loading was eroded away before the crossbeds were deposited. Alternatively, these large relief features may be flutes carved on a bedding plane; however, they are more irregular in shape than typical fluvial flutes. This type of sedimentation is unusual - it may record erosion and infill during waning stages of flow.

Plate 6. *Beds of fine sand to medium sand, 2 to 13 cm thick, showing ripple crosslamination. Sand unit is 2.4 m thick.*

SECTION D1

A 10-m-high, curving gravel-pit exposure is found just northwest of Gambo, in the easternmost geomorphic zone (Figure 1, Plate 5). The bottom 1.7 m is concealed by slumped material. Above is a 221-cm-thick unit of moderately to poorly sorted pebble or pebble to cobble gravel having a medium sand to granule gravel matrix, and interbedded with sand. It contains both clast- and matrix-supported beds, and the c-axis of clasts averages 4 cm, but ranges up to 15 cm. Clasts are mainly subangular to subround. A thick unit of laterally continuous, horizontally bedded and laminated sand is found between 4.8 and 7.2 m. Crosslamination, current ripples, climbing ripples, draped lamination and low-angle crossbeds 10 to 15 cm thick are present. Ripple wavelengths are 11 to 13 cm, amplitudes are 1.5 to 2 cm and ripple beds are 2 to 13 cm thick, giving an apparent south-southeastward paleoflow direction (Plate 6). There are a few granule gravel beds on the lee face of prograding bars, a few reactivation surfaces and some erosive contacts, some of which cut through ripples. The upper 100 to 120 cm of this sandy unit is less mica-rich than the lower portion and the beds thin upward. The upper 4.8 m of the section consists of moderately to poorly sorted beds of pebble, cobble and minor boulder gravel. Beds alternate between clast and matrix support, and have a sand and minor granule gravel matrix. Flat-lying beds are 10 to 100 cm thick and undulate slightly in the eastern part of the exposure, becoming more undulating in the southern part. Large-scale crossbeds dip to the east in the south part of the pit, whereas they dip to the south on the east side of the pit, suggesting overall south-eastward flow. Clasts are mainly subround, with a range of round to subangular and an average size of 6 cm; however, boulders can be up to 40 cm in diameter. The lower contact of this unit is erosive.

The lateral continuity of the sand beds suggests that this is not a fluvial deposit. The fine-grained sediments contain-

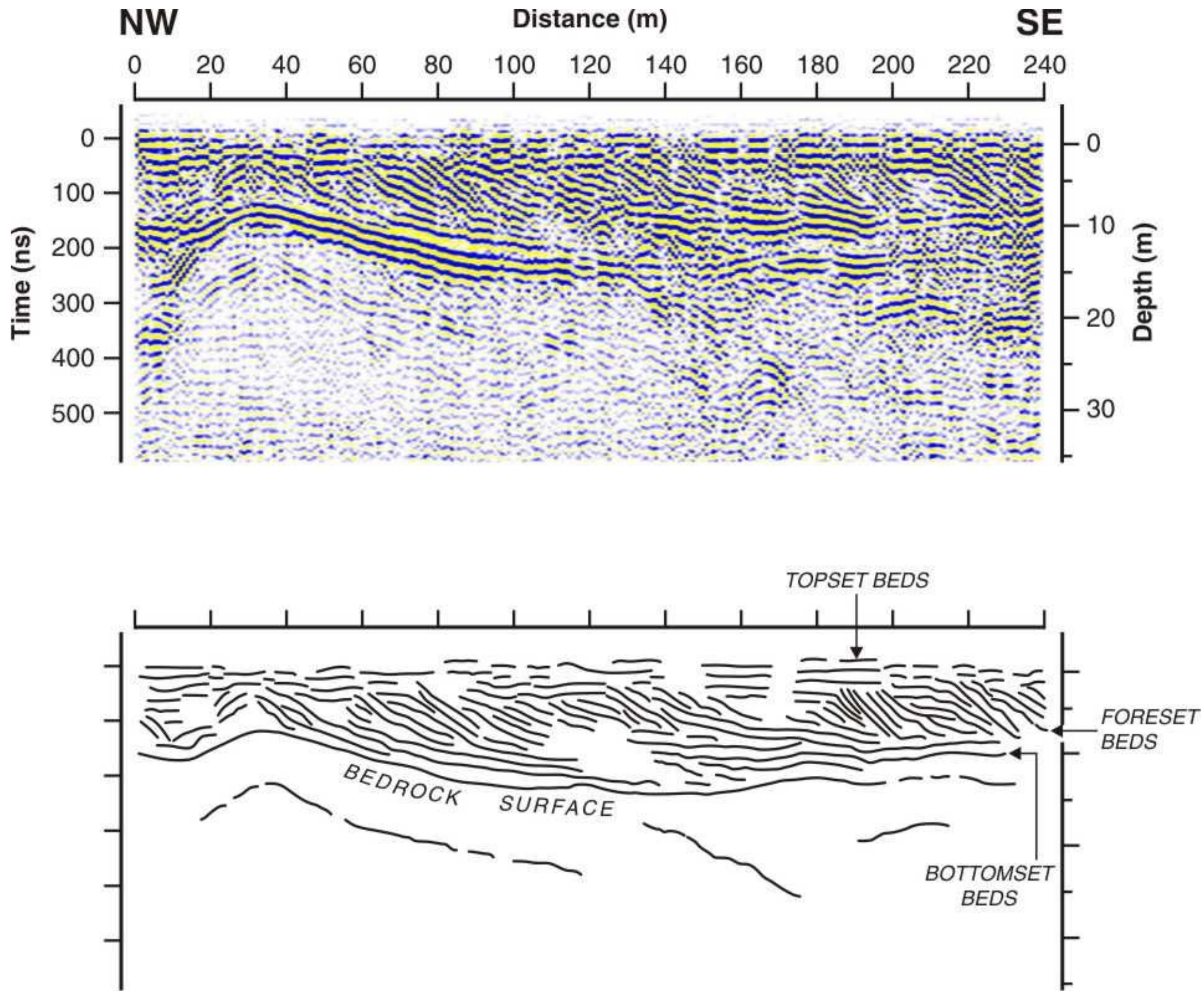

Figure 4. *Ground-penetrating radar profile from the Gambo area; an interpretation of the reflections is shown below the profile.*

ing current ripple marks indicate the lower flow regime: flow velocity was 15 to 50 cm/s (Ashley *et al*., 1982). The sand beds are, therefore, interpreted as the bottomset beds of a delta with a southeastward direction of progradation (as indicated by paleoflow direction). The overlying gravels containing large-scale crossbeds dipping southeast are considered to be foreset beds. Horizontal gravel beds, which are interpreted as topsets, cap the gravel unit and support a deltaic interpretation. However, some of the upper gravels form undulating, discontinuous horizontal beds (right half of Plate 5). The upper gravels thus may include some fluvial beds formed by a river that incised the deltaic sediments.

GROUND-PENETRATING RADAR

Seaward of site D1, there are no exposures suitable for logging. However, there are some flat areas above the escarpment where it is possible to collect ground-penetrating radar data. A 240-m-long GPR profile was acquired in this area using 50 MHz antennae (Figures 1 and 4). An interpreted version of the profile is shown below the uninterpreted one in Figure 4.

The strong reflection at 10 to 15 m depth is interpreted as the surface of bedrock. Other weaker reflections at depth are suggested to be bedrock discontinuities.

Above the bedrock reflector are a series of tangential off-lapping reflections suggestive of the foreset beds of a Gilbert-type delta. A few large, lower angle reflections are interpreted as reactivation surfaces. Horizontal reflectors underlying the dipping ones in the southeastern half of the profile are interpreted to be bottomset beds. Despite the removal of the mean trace, discontinuous, horizontal reflections are visible at the top of the profile. These are interpreted as topset beds.

The deposit is interpreted as a delta, which appears to have prograded over its bottomset beds. Two GPR lines that run perpendicular to the main profile are not shown, but indicate that the progradation direction of the 'Gambo Delta' is to the east at the beginning the radar profile and more east-southeast near the end. This is probably due to the changing location of surface distributary channels during delta progradation. The elevation of the delta at this location is approximately 30 m asl.

DISCUSSION AND CONCLUSIONS

A series of sediment exposures, coupled with air-photo interpretation and ground-penetrating radar data, allow a history of deglacial events to be suggested for this area.

The oldest deposit consists of eskers in the Butts Pond area, which formed as subglacial drainage tunnels in a southeastward-flowing glacier that likely extended to Freshwater Bay. Ice retreat in a northwestward direction revealed the land surface and meltwater drainage became subaerial. The Gambo Delta formed in Freshwater Bay where a subaerial meltwater river flowed into the sea. The delta appears to have begun to develop at 43 m asl (the elevation of topset beds at site D1), and then became incised when sea level fell and formed another delta at 30 m asl (the elevation of the GPR profile). This would mean that some of the upper gravels at section D1 are likely fluvial. Deltaic deposition followed by cannibalization and re-deposition of deltaic sediments is typical of a forced regression (Posamentier and Morris, 2000) or a falling stage systems tract (Plint and Nummedal, 2000). Forced regression is caused by sea-level fall, which appears to have occurred in this area during deglaciation. Marine limit is tentatively set at 43 m asl, the elevation of topset beds at site D1.

As ice retreated farther inland, a braided river formed, draining meltwater from the glacier to the ocean. The river did not, however, manage to erode the previously formed eskers. Flow velocity may have dropped considerably upon entering the Butts Pond area, which allowed the river to flow around the eskers and over top of stagnant ice. This ice later melted, forming Butts Pond and small kettle lakes, and possibly several sinuous gravelly features resembling eskers. Alternatively, the river may have flowed over debris-rich ice, missing some eskers completely and planing off the tops of others that were still encased in ice. The same meltwater river may have deposited both levels of the Gambo Delta. However, a lack of radiocarbon dates in this area means that an interpretation of coeval vs. time-transgressive deposition cannot be made.

The ice margin had retreated almost to Gander Lake when the hummocky sediments were deposited; meltwater drainage and localized ponding both occurred in the proglacial environment. Although no datable organics were found, it is highly probable that the complex ice-contact system graded distally to the braided river system. Current flow directions are variable in the hummocky ice-contact zone, whereas they are clearly east to southeast in the deltaic zone.

Once ice retreated to Gander Lake, sedimentation in the spillway would have ceased, and deposition in Gander Lake would have begun. Lake drainage must have switched to the northern outlet sometime thereafter. An age of 12 220 ± 90 radiocarbon years BP (11 595 to 11 240 BC) on the shells from Gander River (TO-12570) shows that ice had retreated from the area near the northern lake outlet and that marine water was present in the Gander River area at that time. The lack of dateable material from Freshwater Bay makes a discussion of the timing of deglaciation problematic. The shells may be related to the proposed marine limit of 64 m asl at the western end of Gander Lake. However, they could be related to a lower sea-level stand. The northwestward isostatic tilt from the western end of Gander Lake to Gambo means that the Gambo Delta could be equivalent in age to the proposed marine sediments at the west end of Gander Lake. These relationships will remain unresolved until further dating control is achieved.

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