Report on fossiliferous glacial marine localities in the Passamaquoddy Bay area and sediment cores from ponds in eastern Maine

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Methods

Selection Criteria for Sites in the Field Area

The objective in selecting field sites in the Passamaquoddy Bay area was to develop a chronology of when the southeastern margin of the Laurentide Ice Sheet (LIS) receded through eastern Maine. This study was part of a larger project to map the changes in glacier thickness and areal extent through time as the LIS receded northward of 45° N latitude. To do this, it was necessary to develop a chronology that closely dated the time of deposition of ice-contact deposits. The 40 km wide end moraine belt of eastern Maine was selected. The method of King and Fader (1986) and King (1996) was adapted. In their work, seismic data revealed interbedded glaciomarine mud and till tongues comprising the distal flanks of individual moraines that were part of a broad morainal complex on the Scotian Shelf. Piston cores were located to penetrate these interbedded units. AMS $^{14}C$ dates were then obtained from various levels in the cores to bracket the time of deposition of the till tongues and hence the moraines. This method of dating the ice-contact deposits, and thus the ice terminus, by sampling marine invertebrates that lived in the marine mud interbedded with ice-contact sediment was the foundation for the chronology developed in the present study.

To supplement natural exposures in ice-contact deposits, a regional program of lake coring inland from the coast was carried out. Lake basins were sediment focusing centers that began collecting clastic and organic material during or immediately after ice recession. There were hundreds of lake basins in close proximity to morphological features such as end moraines, eskers, deltas, and subaqueous fans. While basal ages on ponds did not directly date the age of a landform, they yielded bracketing ages if one cored ponds inboard and outboard of the landform in question.

Eastern Maine was chosen because of the extensive emergent marine deposits that extended up to 100 km inland from the present coast in the St. Croix valley. The extent of the maximum marine inundation was traced onto 7.5' quadrangles using the elevations of topset -
foreset contacts in Thompson et al. (1989). Coastal sites were selected on the basis of fresh exposures in wave cut bluffs. Lakes were chosen by their position along an approximate northwest/southeast transect and their relationship to major ice marginal deposits.

$^{14}$C Age Analyses

Radiocarbon samples fall into two groups: carbonate samples, including mollusc valves and microfauna such as foraminifera and ostracodes, and organic materials, such as seaweed, mollusc periostracum, and aquatic or terrestrial vegetation. Carbonate samples were prepared for analysis by acid hydrolysis and organic samples by organic combustion. The CO$_2$ gas evolved was then split into 3 subsamples. The first subsample was dedicated to $\delta^{13}$C analysis on a VG ISOTECH PRISM (organic samples) and a VG PRISM ISOCARB (carbonate samples) with a precision of $\pm$ 0.01 $^{\circ}$/oo. The second subsample proceeds to the graphite target preparation process. The third subsample is archived.

Graphitization occurs by reaction of the CO$_2$ gas with an Fe/H$_2$ catalyst. Graphite targets are then loaded into a 59 slot carousel in the ion source where AMS processing begins. Further technical details of the AMS direct counting method are found in Schneider et al. (1994) and von Reden et al. (1994).

Radiocarbon ages are reported without reservoir corrections or calibration to a calendar year chronology and follow the reporting guidelines outlined in Stuiver and Polach (1977) and Stuiver (1980). A half-life of 5568 years is used and all sample ages are normalized to a $\delta^{13}$C$_{VPDB}$ value of -25$^{\circ}$/oo.

It was crucial to analyze $\delta^{13}$C values of shell carbonate. Any dissolution or reprecipitation in the presence of modern groundwater would dramatically shift shell $\delta^{13}$C, indicating the unsuitability of that sample for analysis.
Analyses of mollusc and foraminiferan δ¹⁸O provided additional paleoenvironmental data. A secondary objective of the analyses was to check for reprecipitation by modern groundwater of the aragonitic shell to calcite during the last 12,000 to 14,000 ¹⁴C years of burial. Most of the analyses were performed by Kreutz (1994) in a collaborative effort on this research project in eastern Maine. Unless specified, all analyses were on whole shell carbonate. The periostracum was removed by gentle grinding followed by mechanical crushing with an agate mortar and pestle. The resulting powder was homogenized and samples were loaded into stainless steel boats with methanol. Reaction with 100% H₃PO₄ in an automated carousel occurred in the University of Maine’s Stable Isotope Lab using a VG Prism Series mass spectrometer. Sample results are reported relative to PDB-1 (Chicago). Additional systematics can be found in Kreutz (1994).

Loss on Ignition

Loss on ignition (LOI) was carried out to determine two objectives: 1.) The variability in organic percent of the sediment that accumulated in the marine basins during late glacial time, and, 2.) The percentage of carbonate precipitated authigenically or diagenetically in each basin. Samples of 6 cm³ for LOI analyses were removed from cores, weighed, and dried at 100° C for 48 hours, weighed, and then burned for 120 minutes at 550° C to determine organic percent. A final burn at 925° C combusted any carbonate in the sediment. All procedures and calculations follow the conventions of Bengtsson and Enell (1986).

Close sampling intervals in the cores allowed for high temporal resolution to show the variability in organic percent. This directly reflects the inputs of clastic sediment relative to organic lacustrine (gyttja) deposition. Marker horizons, such as the Younger Dryas climatic reversal, were clearly seen in the organic percent record. The LOI graph was then combined with the each lake’s core log to correlate stratigraphic units among the sites. ¹⁴C dating of material in relevant units then demonstrated whether the events seen as sedimentologic changes in the cores
were chronologically equivalent or time transgressive.

The second objective of the LOI analyses served as an indicator of carbonate and bicarbonate influence on the lake sediment by dissolution of the underlying Paleozoic bedrock, forming clayey marls in the lake sediment. Large apparent age differences, or hard water effects, of 3,500 ¹⁴C years, exist when dating carbonate material from alkaline lakes relative to acidic lakes in Maine (Dorion, 1995). This was crucial to the chronology developed for northern Maine because the late-glacial to post-glacial lake sediment is often composed of marl. To avoid the hard water effect, the marl was disaggregated with 2% KOH for 24 hours and the sediment was then sieved. Only terrestrial macrofossils were utilized for dating to avoid additional problems associated with aquatic vegetation which metabolizes dissolved CO₂ in the lake water which may have as its source the Paleozoic limestone bedrock.

Microfauna - Foraminifera and Ostracodes

Marine mud was collected in the field either from bluff sites at elevations described in stratigraphic sections or from precise depths in a core. Mud samples were sieved with tap water on 425 µm, 212 µm, and 125 µm screens. The sieved sediment was dried at 50 °C for 48 hours. Foraminifera and ostracodes were picked and counted on a tally box. Identification of foraminifera to the species level was under the guidance of D. Schnitker, University of Maine. Identification of ostracodes to the species level was under T. Cronin, U.S.G.S. in Reston, Virginia. Samples were then split and used by Kreutz (1994) for δ¹⁸O analysis at the University of Maine Stable Isotope Lab.

Macrofossils - vegetation

Similarly, the 3 sieved fractions from each lake core were examined for terrestrial and aquatic plant remains. The objective of this procedure was to identify the environment of deposition for a given level in the core. Regression of the De Geer Sea caused a transition in each marine basin to a brackish basin and ultimately to a fresh water lake in the Passamaquoddy Bay
area. In northern Maine, only late-glacial vegetation dominated by arctic shrubs and grasses was present. Whether the environment was marine or terrestrial, a distinctive floral assemblage served to identify if the sediment was of marine, intertidal, or a lacustrine environment.

**Molluscs and Seaweed**

Molluscs and seaweed were collected from detailed stratigraphic sections where their relationship to ice proximal deposits could be determined. Bluff faces were cleaned and material was sampled from *in situ* marine mud. Subareally exposed molluscs were avoided as repetitive exposure to meteoric water begins a dissolution and precipitation process by substituting modern calcite for original aragonite. Samples were washed of adhering sediment with tap water. Neither dispersants nor other deflocculents were used to avoid carbon contamination. Mollusc valves were then dried for 48 hours at 50°C. Seaweed or other organic materials were examined under a binocular microscope for rootlet or other modern contamination. Identification occurred while the sample was wet. The target material was then picked and dried for 48 hours at 50°C. Molluscs were identified after drying and examined under a binocular microscope for evidence of dissolution/calcification.

**Logging Sections**

Coastal bluff and artificial (gravel pit) exposures were logged using a modified version of Folk (1974), Reinick and Singh (1980), Eyles *et al.* (1983), and Boggs (1987), Figure 1. Elevation measurements were estimated from the mean high water mark with a tape measure hung vertically down the bluff face. Exposures were scraped clean and in some cases trenches were dug to expose slumped units.

**Lake Coring**

Lakes were cored with a 5 cm diameter square rod piston corer modeled after the design of Wright (1967). Practical refusal was reached when 250 kg of mass could not drive the corer any
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Facies Code</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Dmm]</td>
<td>Dmm: Diamicton, matrix supported</td>
<td>Lodgement till, Ablation till</td>
</tr>
<tr>
<td>![Dmm (r)]</td>
<td>Dmm (r): (resedimented)</td>
<td>Flowtill, Debris flow</td>
</tr>
<tr>
<td>![Dmm (c)]</td>
<td>Dmm (c): (current reworked)</td>
<td>Current winnowed till</td>
</tr>
<tr>
<td>![Dmm (s)]</td>
<td>Dmm (s): (sheared)</td>
<td>Glacially tectonized till</td>
</tr>
<tr>
<td>![Gms]</td>
<td>Gms: Gravel conglomerate, matrix supported.</td>
<td>High energy, low current velocity.</td>
</tr>
<tr>
<td>![Gm]</td>
<td>Gm: Gravel, clast supported.</td>
<td>Sediment gravity flows, Surf zone deposits.</td>
</tr>
<tr>
<td>![St]</td>
<td>St: Sand, trough crossbedded, curved bounding surface.</td>
<td>Scour and fill channels, Point bar deposits, Megaripples.</td>
</tr>
<tr>
<td>![Sm]</td>
<td>Sm: planar crossbedded, planar bounding surface.</td>
<td>Scour and fill channels, Point bar deposits, Megaripples.</td>
</tr>
<tr>
<td>![Sr]</td>
<td>Sr: ripples (all types)</td>
<td>Lower flow regime.</td>
</tr>
<tr>
<td>![Fl]</td>
<td>Fl: Rhythmically laminated mud/sand</td>
<td>Distal glacial marine, Nearshore deposits.</td>
</tr>
<tr>
<td>![Fl (d)]</td>
<td>Fl (d): (with dropstones)</td>
<td>Distal glacial marine with ice rafted detritus.</td>
</tr>
<tr>
<td>![Fm]</td>
<td>Fm: Fines, massive, fossiliferous</td>
<td>Bioturbated or resedimented Fl.</td>
</tr>
<tr>
<td>![Fm (d)]</td>
<td>Fm (d): (with dropstones)</td>
<td>Bioturbated or resedimented Fl with ice rafted detritus.</td>
</tr>
<tr>
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<td>Conformable</td>
<td></td>
</tr>
<tr>
<td>![Loaded]</td>
<td>Loaded</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1.** Lithofacies coding for marine environments, modified after Folk (1974), Reineck and Singh (1980), Eyles et al. (1983), and Boggs (1987). Facies and interpretations describe glacial marine to purely marine environments.
deeper. Cores were extruded in the field, cleaned, logged, photographed, wrapped, and then transported back to 4°C coolers at the UMO Palynology Lab for later analyses. In most lakes, multiply overlapping cores were obtained 1 m apart.

**Passamaquoddy Bay**

The landscape of eastern Maine preserved an excellent record of the response of the southern terminus of the Laurentide Ice Sheet (LIS) to regional cooling and warming during the time period 14,000 to 12,000 14C yrs. B.P. The overall purpose of this study was to examine the effects of a rapidly changing climate in the northern hemisphere on a sector of the southeastern margin of the LIS. This was accomplished by developing a high resolution 14C based chronology documenting the recession of the margin of the LIS along a transect from eastern coastal Maine to the marine limit 125 km inland near Princeton, Figure 2.

Specifically, the first objective of this project was to locate, describe, and recover fossiliferous glacial marine sediment from the Passamaquoddy Bay area of eastern Maine. Unlike past studies which examined marine sediment deposited during the waning phase of the De Geer Sea, the objective was to locate glacial marine sediment deposited within 100 to 200 m of the terminus of the southeast margin of the LIS as it receded northward across the study area. During deglaciation, the Gulf of Maine encompassed waters from Georges Bank to Millinocket and was termed the De Geer Sea probably by R. J. Lougee in the 1930s or 1940s. The study area, although formerly submerged by the De Geer Sea, is now emergent due to the effects of isostatic rebound in post-glacial time.

Glacial marine sediment was classified by its intimate association with ice-proximal environments. The margin of the LIS terminated in sea water up to 60 m depth as a vertical sea cliff, probably 200 m in height. Its contact with the sea floor was defined as the grounding line. It was in the grounding line environment that ice-proximal sediment was deposited.
The ice-proximal sediment consisted of 3 units based on textural classifications: 1.) Diamictons, 2.) Sand and gravel, and, 3.) Fine grained silt and clay. These 3 groups were often found interbedded with one another suggesting a very dynamic environment. The diamictons ranged from pure lodgement till deposited subglacially to remobilized, resedimented tills (flowtill) deposited subaqueously near the grounding line. The sand and gravel deposits were the result of glacial meltwater winnowing diamictons under high current velocities. The fine grained silt and clay were deposited more distally to the grounding line by suspension settling through the water column and were termed the Presumpscot Formation by Bloom (1960). This last unit was the focus of this project because it contained the well-preserved remains of molluscs, seaweed, and microfauna such as foraminifera and ostracodes. These marine invertebrates living in the marine mud in the ice-proximal environment were used for $^{14}$C dating and served as the foundation for the chronology developed in the present study.

To find this environment in eastern Maine required two methods of attack. The first was a thorough reconnaissance of natural shoreline exposures from West Quoddy Head north to the head of the Ste. Croix estuary, including the New Brunswick side of the bay. The optimal stratigraphic setting consisted of glacially striated bedrock directly overlain by sandy, gravelly subaqueous outwash. This unit was in turn overlain by fine grained silt and clay that was coarsely bedded at the bottom and graded into a more massive structure at the top. In some cases the marine mud was interbedded or directly overlay sand and gravel deposits or had been incorporated into a diamicton during a short readvance of the grounding line. In summary, the ice-proximal environment was characterized by a rapid fining-up sequence of stratigraphic units or abrupt lateral and vertical facies changes in an ice-marginal landform such as a fan or moraine complex.

The second method of attack was used inland from the coast where natural exposures were rare or nonexistent. This involved piston coring of lakes from inland ponds. The ponds were former depositional basins in the De Geer Sea. Isostatic rebound lifted the basins above sea level in post-glacial time and the marine sediment was preserved in the anoxic conditions beneath freshwater lakes. Piston coring through the accumulated Holocene lacustrine gyttjas into the ice-
proximal marine sediment retrieved long sedimentologic, faunal, and chronologic records that
recorded a slowly receding ice margin depositing sediment in an arctic to sub-arctic, open marine
environment. The piston corer was able to penetrate into the underlying lodgement till or
subaqueous outwash; thus, a complete record of ice-proximal to ice-distal deposition could be
recovered virtually anywhere in eastern Washington County.

Report on Shoreline Exposures

Lewis Cove, North Perry

Lewis Cove was located on the Robbinston 7.5' quadrangle in the town of Perry. The
landowner is George Fatula, Rt. 1, Box 258, Robbinston, ME 04671 853-2952 and he should
be contacted for access. Extensive δ¹⁸O analyses on the molluscs at the site is found in Kreutz
(1994). The 8.5 m high bluff exposure was composed of ice-distal marine mud with reworked
shallow water shells such as Mytilus edulis. These younger, intertidal shells were incorporated
with older shells that inhabited deeper water environments. This probably occurred as sediment in
the nearshore was washed down from higher ground surrounding Lewis Cove. The age of
12,900 ± 50 ¹⁴C yrs. B.P. was a minimum age for deglaciation of the area. The bluff was actively
eroding due to strong wave fetch across the bay and should be periodically visited because bedrock
of the Perry Formation outcropped 50 m east of the site. It would be at this location that ice-
proximal sediment and associated shells could be recovered. Lodgement till overlying the
bedrock was eroding but the marine mud was slumped directly above. The striae recorded ice flow
to the east/southeast at 102°.

Sand Point, New Brunswick

Located on the Robbinston 7.5' quadrangle. This site was briefly described by Gadd
(1973) and more extensively by Dorion (1996). The site was owned by Donny McLaren, phone #:
(506) 529-3572. It was in the process of being reclaimed for a housing development. It was a
large ice-contact, coalescing, subaqueous fan complex. The complex was being mined for sand from the mid-fan facies which consisted of gently dipping, tabular beds of medium to coarse grained sand. Collapse of the central portion of a fan lobe was interpreted as either ice-shove or a large scale mass movement. In the collapsed area, marine mud filled a wedge between fan lobes. An age of 13,700 ± 70 14C yrs. B.P. was obtained on *Nucula tenuis expansa* valves. Distal fan facies of laminites of fine sand and mud comprised a large segment of the complex and were barren of fauna. An erosional unconformity truncated the landform 1 to 2 m below the surface and was interpreted as a regressional beach formed after 13,000 14C yrs. B.P.

**Hinton Point (Lambs Bluff), Robbinston**

Approximately 15 m of the bluff is composed of marine mud. However, the bluff was entirely slumped during the summers of 1993 and 1994. This site should be periodically checked for fresh exposure.

**Summary of Shoreline Exposures**

These were the only 3 sites along both the U.S. and Canadian shores of Passamaquoddy Bay with any exposures of marine mud. Generally the shoreline was composed of bedrock outcrop with a thin mantle of till. Overall, the marine mud and till formed a thin and discontinuous cover over bedrock.

**Gravel Pit Exposures**

*Wayne Dennison Pit, Cutler*

This gravel pit is located on the proximal flank of Pond Ridge moraine, approximately 5 km east of the town of Cutler, behind the old town dump (now reclaimed). Although fossiliferous marine mud was not present, it lies directly below the lowest lift in the gravel pit operation. This site is significant not as an indicator of ice-proximal conditions but rather as a sea level indicator for
falling sea level. The gravel being removed on the proximal flank is derived from extensive washover fans dipping to the north/northwest. These were deposited as wave base began reworking the original moraine crest sometime after 13,000 $^{14}$C yrs. B.P. A similar stratigraphy is present along most of the proximal flank of Pond Ridge moraine, especially in areas where wave fetch across the Gulf of Maine could attack the moraine when sea level was $+55$ m. The reworking of the moraine was time transgressive because the moraine was originally deposited at elevations ranging as high as 60 masl down to 30 mbsl under Machias Bay. Thus, a sea level curve for eastern Maine could be developed by retrieving fossiliferous intertidal marine mud from beneath the washover fans along the length of Pond Ridge moraine. This would be the focus of a separate study from the present one.

**Passamaquoddy Nation Lands**

A south trending esker-fan system, located in the south-central section of the Waite 7.5' quadrangle, contained an extensive gravel pit operation. The pits are listed on the quadrangle as Waite 1 through Waite 6. Although no fossiliferous marine mud was observed, the esker system was unusual in that it was overlain by 1 to 2 m of diamicton. This stratigraphy is common in the Princeton area and the diamicton is referred to as "overburden" by gravel pit operators.

I have drawn the marine limit in the area at an elevation of 280 fasl. I believe this to be accurate because the esker terminated periodically in small fans with foreset beds dipping to the south, necessitating a water body to the south. The top surface of the fans lay at 260 fasl. The regional physiography consisted of a gently sloping, low-relief landscape with no evidence or possibilities of glacial lakes. Thus, in all likelihood the fans were deposited into the sea, requiring a minimum synglacial sea level in excess of 260 fasl.

**Pembroke Moraine-Esker**

A crudely shaped and discontinuous esker system trended SE down the Pennamaquan River valley. Six pits were visited; all but one were composed of poorly sorted stony diamicton
and resedimented diamicton (flowtill) and with very shallow depths to bedrock.

The Sawyer pit, labeled Pembroke 4 on the Pembroke 7.5' quadrangle, contained 1.5 m of bluish gray marine mud overlain by 1.5 m of horizontally and massively bedded sand overlain by diamicton. The marine mud contained broken fragments of unidentifiable molluscs. The microfauna was dominated by the foraminiferan \textit{Elphidium excavatum} \textit{f. clavatum} (80%) and \textit{E. excavatum} \textit{f. excavatum} (20%).

This site should be revisited periodically as it contains a clear ice-contact association between the marine mud and ice-proximal sediment.

Approximately 80 active or abandoned gravel pits were also examined but did not expose marine mud. In some cases, such as the De Geer esker system that runs under Route 191, marine mud was exposed but did not contain the ice-proximal facies. Thus, these sites were not utilized in this study.

**Pond Cores**

\textit{Lily Lake, Long Pond, Marks Lake, Patrick Lake, Pocomoonshine Lake}

Lily Lake, Long Pond, Marks Lake, Patrick Lake, and Pocomoonshine Lake were the 5 lakes chosen along the transect in eastern Maine. The cores all penetrated at the surface thick Holocene gyttjas. As the coring proceeded downward, the late-glacial record was recovered and the Younger Dryas climatic oscillation was present in Lily, Long, and Marks Lakes although it was only dated in Lily Lake as this was not a priority of the program. However, the cores are archived in the University of Maine pollen lab coolers and should remain viable for several more years. Beneath the late-glacial sediment was the zone of FeS precipitates which was indicative of meromixis, or salinity stratification of the lake basin. This occurred as the former basin in the ocean was lifted above highest high tide approximately 13,000 \textsuperscript{14}C yrs. B.P. Below this zone was generally 2 to 3 m of bluish gray marine sediment containing the well preserved remains of arctic to sub-arctic molluscs, foraminifera, ostracodes, and sea weed. The lowest fossils in the marine sediment were used for \textsuperscript{14}C dating. The marine sediment graded down into sandy subaqueous
outwash which directly overlay lodgement till.

The Marks Lake core was unusual in that a 3 m interval of marine diamicton separated overlying and underlying horizontally laminated marine mud units. The upper unit was late Wisconsinan in age while the lower unit, beneath the marine diamicton, was most likely middle Wisconsinan in age, similar to the stratigraphy at Gould Pond, Anderson *et al.* (1992) and Dorion (1996). Only the upper marine unit was dated for this project.

In summary, virtually any suitable lake basin can be cored to refusal using this method. Applicable $^{14}$C, $\delta^{13}$C, $\delta^{18}$O analyses, and site attributes are found in Table 1.

Stratigraphic sections of each of the 5 cores are found in Appendix I, Core Logs from Ponds in Eastern Maine Below the Inland Marine Limit.

**Northern Maine**

**Pond Cores**

A total of 22 ponds were cored to refusal in northern Maine as the second phase of this project. The coring took place in 1993 and 1994. All the ponds lay elevationally above the inland marine limit. This method was the only practical technique for recovering late-glacial organic material from northern Maine that was deposited in close proximity to the receding ice margin.

The ponds were chosen along a theoretical transect approximating geomorphic features deposited by the receding LIS. North of the marine limit in eastern Maine, the last glacial striae generally trend southeast whereas north of Houlton the trend is more southerly. In addition, the Mars Hill moraine complex is composed of numerous east-west trending ridges presumably deposited by a northward receding ice margin.

Several ponds were cored that lay beneath the remnant ice mass of northern Maine defined spatially by Lowell (1990). The objective was to determine the time of dissipation of this ice mass
<table>
<thead>
<tr>
<th>Site, Township</th>
<th>Quadrangle</th>
<th>Status</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Pond Core Elevation (m.a.s.l.)</th>
<th>Depth in core (cm)</th>
<th>Significance</th>
<th>Accession #</th>
<th>C-14 age</th>
<th>Material</th>
<th>13 C</th>
<th>18 O</th>
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<tbody>
<tr>
<td>Black Lake, Fort</td>
<td>Dalglies</td>
<td>Complete</td>
<td>47 12 45 N</td>
<td>68 28 03 W</td>
<td>234</td>
<td>1025-1020 [A] Ice proximal</td>
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<td>46 48 38 N</td>
<td>68 03 59 W</td>
<td>166</td>
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<td>OS-5993</td>
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<td>46 48 38 N</td>
<td>68 03 59 W</td>
<td>166</td>
<td>488-484 [C] Y-D onset</td>
<td>OS-6146</td>
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<td>68 03 59 W</td>
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<td>468-465 [C] Y-D termin.</td>
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<td>67 58 52 W</td>
<td>200</td>
<td>733-729 [A&amp;B] Ice proximal</td>
<td>OS-4845</td>
<td>16,100 +/- 55</td>
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<td>46 36 55 N</td>
<td>68 00 17 W</td>
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<td>1024-1027 [A&amp;B] Ice proximal</td>
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<td>68 00 17 W</td>
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<td>1042-1022 [A&amp;B] Calibration</td>
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<td>OS-4844</td>
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<td>Nuculana sp. -2.34</td>
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<td>Middle Unknown</td>
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<td>67 06 27 W</td>
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<td>Ice proximal</td>
<td>OS-2659</td>
<td>12,900 +/- 50</td>
<td>Nuculana sp. -2.34</td>
<td>4.5</td>
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<td>12,900 +/- 50</td>
<td>Nuculana sp. -2.34</td>
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**Table 1.** 14C, δ13C, δ18O analyses, and site attributes for Passamaquoddy Bay and northern Maine.
and whether it persisted or reactivated in Younger Dryas time, similar to the scenario proposed by Stea and Mott (1989) in Nova Scotia. These ponds were:

- Black Lake, Fort Kent
- First Pelletier Brook Lake, T16 R9
- Isie (Icy) Lake, Eagle Lake
- Island Pond (T14 R8)

These cores did not show a Younger Dryas oscillation and thus it was proposed that the basins did not deglaciate until relatively late in post-glacial time. Ponds outside the area of the remnant ice mass generally showed a strong Younger Dryas oscillation but without any evidence of a readvance into the basin. Thus, the sequence of deglaciation, warming, Younger Dryas cooling, and a resumption of warming into the Holocene was proposed.

Ponds showing a strong Younger Dryas oscillation are listed below:

- Caribou Lake, Washburn
- Dipper Pond, Carroll Plantation
- Echo Lake, Presque Isle
- Green Lake, T35 MD
- Middle Unknown Pond, T4 ND
- Tote Road Pond, Moro Plantation
- Youngs Lake, Westfield

Caribou Lake was cored by Deevey (1951) and the Younger Dryas oscillation was identified as a return to ice-proximal sediment accumulation conditions. The cause of this dramatic change in the watersheds of ponds is unresolved at this point. Stea and Mott (1988) proposed reactivation of small ice masses and perennial snow fields in addition to increased frost action and solifluction processes. The cause of this climatic oscillation can be further elucidated by work around the periphery of the extensive post-glacial ice masses of northern Maine.

Three ponds contained middle Wisconsinan age organic materials unconformably truncated by late Wisconsinan deglacial age sediments, Isie (Icy) Lake, Jo Mary Pond, and Number 9 Lake.
The ponds were protected from the erosive action of glacial overriding by hills that lay to the west or northwest at each site. The ages from the paleosols at Isie Lake and Jo Mary Pond showed that the LIS advanced through northern Maine approximately 24,000 $^{14}$C yrs. B.P. The lower 2 meters of the core from Number 9 Lake was composed of sand that contained abraded wood fragments which probably represented a deglaciated landscape 43,000 $^{14}$C yrs. B.P.

Three ponds failed to yield sediment of late-glacial age. Both Hunter Pond (Linneus) and Trout Pond (Soldiertown) were located on the flanks of eskers. It appeared that substantial lake level lowering occurred, exposing the bottoms of the ponds to subaerial processes. This probably occurred during the mid-Holocene and led to soil development that created a hiatus in the sediment record, destroying older organic material and creating an impenetrable barrier to piston coring. Butterfield Lake in Caswell was found to be artificially dammed by beavers sometime in the middle to late Holocene and thus was not utilized for this study.

The AMS sample from Island Pond, T14 R8 and Black Lake, Daigle, were lost during the sample preparation and pretreatment stage at the AMS lab. A second sample was prepared for Black Lake and successfully dated. Unfortunately, there was insufficient organic material from Island Pond to submit a second sample. In the summer of 1996, Island Pond was recored as it was strategically located under the ice divide of the remnant ice mass of northern Maine and will provide crucial age control on the ice mass.

It was found that the large lakes did not closely date the actual time of deglaciation. From the style of sediment deposition in the cores, it was proposed that high wind stress on the lake surface in late- and post-glacial time created a deeper wave base which continually reworked bottom sediment. Also, leaves, twigs, seeds, and fruits falling near shore would not drift out to the deepest part of a large lake basin where coring took place. Lastly, changes in a large lake's watershed, such as increased frost action, solifluction, or overland sediment transport, would not be seen in the middle of the lake basin but rather only in the nearshore areas.

Applicable $^{14}$C, $^{13}$C, $^{18}$O analyses, and site attributes for northern Maine ponds are found in Table 1.
Stratigraphic sections of the lake cores are found in Appendix II, Core Logs from Ponds in Northern Maine.

**Topographic Maps**

The following 7.5' quadrangles were used in the Passamaquoddy Bay area:

- Devil's Head
- Eastport
- Meddybemps Lake East
- Pembroke
- Red Beach
- Robbinston
- Waite

They are enclosed with this report with fossiliferous localities noted. Exact latitude and longitudes of sites are listed in Table 1. Extensive mapping of glacial landforms was not performed as reconnaissance level mapping had already been done in this area.

**U.S.G.S. Test Borings**

On July 18 and 20 I accompanied the U.S.G.S. on Silsby Plain during their test boring work. The objective was to sample by split spoons the marine mud that composed the bottom set beds of glacial marine deltas and sieve it for datable material. No fine grained material was found under Silsby Plain. It appeared to be substantially reworked by the Middle Branch of the Union River during post-glacial time as base level (sea level) fell rapidly. The delta "disemboweled" itself down to bedrock, winnowing the fine grained, bottom set mud which was carried farther offshore. This process left the sand size sediment from later stream aggradation unconformably resting on bedrock. The deep channels that "gutted" the delta are interpreted as river channels carved during incision by the Middle Branch Union river and not meltwater channels cut by meltwater emanating directly from the ice margin.

On July 28, 29, and 30 I accompanied the drilling group on "The Prairie", north of Brownville Junction, with the objective of recovering fossiliferous marine mud from beneath
glacial outwash. It was inferred that the extensive sand plain, or sandur, was built as sediment-laden glacial meltwater debouched into the regressing sea. The prograding sandur would cover nearshore muds with coarser sediment as the plain built to progressively lower sea levels. Thus, marine mud would be preserved beneath the cover sands. Indeed, this proposed stratigraphy was repeatedly found in eastern Maine during U.S.G.S. test borings, Weddle et al. (1988).

Unfortunately, the sand at "The Prairie" directly overlay lodgement till which overlay bedrock in all test borings. It was inferred that the Pleasant River reworked substantial portions of the valley, winnowing the fine grained marine mud and moving it down-valley. Subsequently, as the ice margin receded above the inland marine limit, continued sediment discharge aggraded in the valley to form "The Prairie" surface present today.

Although no fossiliferous marine muds existed below the Silsby Plain delta or The Prairie sandur, marine mud occurs extensively in bottom set beds of deltas and sandurs below the marine limit in coastal Maine. Future test borings should be monitored so that a direct date of an ice-contact landform can be obtained.
References Cited


APPENDIX I

Core Logs for Ponds in Eastern Maine Below the Inland Marine Limit
Black Lake, Daigle, Maine

Depth (cm)

900

Lithofacies

GY

Fl, marl

Fl, weak organic

Fl

Fm

Sm, Gmm

Dmm

Loss on Ignition

10,600 ± 30
OS-4383
-28.82 o/oo

Ericaceae, Rosaceae
Betula, Silene, Carex
wood stems and bracts

CO₂ %

Organic %

Christopher C. Dorion, 1995
Core Log
Quaternary Paleocology & Paleohydrology

Site: BUTTERFIELD LAKE  Date cored: 7/22/94  Crew: ML5
Segment:  Date described: 11/15/94  Analyst: DURON

150

WATER

288

Shark contact

274

67, gray/yellow  MACRO- RICH

Diam. 67.4 cm

241

Diam. 57.4 cm

LATEAL 2.32 cm

373 cm

Notes and color notes: 3.3 cm
- all records are notes and color notes

THE END

Massive muddy 67, tan

Demolished sand

2.5 to 7/2 light gray
Caribou Lake

Description/Correlation After Deevey (1951)

% Carbonate

Depth

350
400
450
500
550

10,500 ± 45 OS-6149
Insect parts

10,600 ± 50 OS-6146
Insect parts
Fl-marl

11,000 ± 160 OS-5993
Terrestrial vegetation
Fl-clastic

Gmm

Younger Dryas (L3)
Late Glacial (L2)
Ice Contact Stratified Drift (L1)

C. C. Dorion 10/96
<table>
<thead>
<tr>
<th>Date cored:</th>
<th>Crew:</th>
</tr>
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<tbody>
<tr>
<td>Date described:</td>
<td>Analyst:</td>
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AMS 9

Sieved 710 - 733

Macros present

Fibrous aquatic algae
### Core Log

**Quaternary Paleoecology & Paleohydrology**

**Site:** DIPPER POND  
**Segment:** 700 - 750 cm  
**Date cored:** 7/11/94  
**Date described:** 9/28/94  
**Crew:** MCS  
**Analyst:** ALEXA

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<tr>
<td>750</td>
<td>Mottled mud, dark gray 5Y 4/1</td>
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<tr>
<td>700</td>
<td>Sandy gravel, no mud or matrix</td>
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<tr>
<td>725</td>
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675 - 695 = nothing but collection 2 very brown, mostly clay

684 - 688 = 2

690 - 882 = AaS > Y-D [+6]

810 - 2.5/2.51 |

890 - 2.57 to 2.51 (Ocher)  
| |

895 - 5Y 3/1 (very dark gray) laminated organic rich mud |

Fibers visible |

Mottled mud, dark gray (N4/1) |

Sandy gravel, no mud or matrix |

725 - 750 = very high density of mussels, echinoid algae
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<th>Core Description</th>
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<tbody>
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<td>1000</td>
<td>F1, gray mud and U.F.S. 57.511 mm + shell</td>
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<tr>
<td>1000</td>
<td>F1, dark grayish grey laminated, slightly calcareous</td>
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<tr>
<td>1000</td>
<td>F1, with black Fe²⁺ laminated, mm + shell</td>
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<tr>
<td>1000</td>
<td>F1, mm. scale grey (5Y 5/1) mud and U.F.S. 64% of fauna, tube crinoid</td>
</tr>
<tr>
<td>1000</td>
<td>F1, mm. scale grey and U.F.S. 65% of fauna, tube crinoid</td>
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**Site:** Puck Lake  
**Date cored:** 13 July 1994  
**Crew:** DeJong / EDS  
**Date described:** 24 July 1994  
**Analyst:** DeJong
Core Log

Quaternary Paleoecology & Paleohydrology

Site: DUCK LAKE  Date cored: 13 JULY 1994  Crew: POLAN
Segment: 1200-1237cm  Date described: 29 JULY 1994  Analyst: POLAN

1200cm

1211

1219

1237

Gunge

Laminated (mm - scale) made laminated separated by VFS.
Sand - fell out bottom on way up hole.

bunched up again.
Quaternary Paleoecology and Paleohydrology
Core Log

Site: **FISHER LAKE**  Date cored: **7/23/94**  Crew: **Mc**
Segment: **1007-1100cm**  Date described: **11/15/94**  Analyst: **Doren**

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**Description:**
- 1007-25 cm: Mud laminas (weak; n x/cm)
- 1007-25 cm: Water termination
- 1023 cm: Laminas (y)
- 1023 cm: Organics terminate w/ Sg
- 1048 cm: Organics terminate with mud deposition!
- 1049 cm: Sg; S; Sg; S date grade from V. T. to mud
- 1049 cm: Organics = sharp bottom contact color change
- 1050 cm: Sg
- 1052 cm: Sg
- 1053 cm: Sg
- 1057 cm: Sg
- 1063 cm: Sg
- 1065 cm: Sg
- 1070 cm: Sg
- 1072 cm: Sg
- 1077 cm: Sg
- 1082 cm: Sg
- 1085 cm: Sg
- 1089 cm: Sg
- 1099 cm: Sg
- 1104 cm: Sg
- 1124 cm: Sg
- 1129 cm: Sg
- 1137 cm: Sg

AMS 1052
Quaternary Paleoecology and Paleohydrology
Core Log

Site FISCHER LAKE  Date cored  Crew

Segment  Date described  Analyst

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<td>intercalated gray mud/organicannce</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1051</td>
<td></td>
<td>brown orgainc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1057</td>
<td></td>
<td>gray/brown mottled</td>
<td>1058</td>
<td></td>
</tr>
<tr>
<td>1074</td>
<td></td>
<td>F1, gray</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1078</td>
<td></td>
<td>F1, yellow/grey/green</td>
<td>1084</td>
<td></td>
</tr>
</tbody>
</table>

CAUTION:
- Hole: 4: 920-926 mottled mud, 926-929 brown organinc
- Hole: C: 759-767 mottled mud, 767-771 squeezing transition, 771-775 brown organinc, 775-779 yellow mud
- 1007-1045 intercalated gray mud/organicannce, 1045-1051 brown organinc, 1051-1057 gray/brown mottled, 1057-1078 F1, gray, 1078-1084 F1, yellow/grey/green
Site: FISCHER LAKE
Segment: Quaternary Paleoecology & Paleohydrology
Detection: Crew: Date cored: Date described: Analyst:

- 700
  - 701: Blue brown GY
- 721: Dominated mud
- 752: Dominated GY
- 774: Transition
- 800: Dominated mud
- 828: Brown organic
- 848: Yellow mud
- 852: Yellow and brown organic
- 890: Wetted mud
Site: FIS-HER LAKE
Segment: A
Date cored:
Date described: 1970
Crew:
Analyst:

Layer 500
Laminated silt and clay
Dark brown C4

Layer 600
Laminated silt and clay

Layer 500
Orange brown C4

Layer 600
Laminated silt and clay

Layer 700
Mud
Orange brown C4
Site: FISCHER LAKE
Segment: 
Date cored: 
Date described: 
Crew: 
Analyst: 

Laminated silt and sand from GY
### Core Log

**Site:** Fischer Lake  
**Segment:** A

<table>
<thead>
<tr>
<th>Depth</th>
<th>Water</th>
<th>Notes</th>
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**Date cored:**

**Date described:**

**Crew:**

**Analyst:**

**Number of samples:** A, B, C
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<th>Description</th>
<th>Depth</th>
<th>Hole:</th>
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<tbody>
<tr>
<td>300</td>
<td>0</td>
<td>WATER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>312</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>0</td>
<td>line/green GY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>0</td>
<td>laminated GY, grey/green</td>
<td></td>
<td></td>
</tr>
<tr>
<td>700</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
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Quaternary Paleoecology and Paleohydrology
Core Log

<table>
<thead>
<tr>
<th>Site</th>
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<th>Crew</th>
</tr>
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<tbody>
<tr>
<td>First Fellet Creek Lake</td>
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<table>
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<th>Segment</th>
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<th>Analyst</th>
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<th>Description</th>
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<tbody>
<tr>
<td>765</td>
<td>A</td>
<td>Laminated G7, organic clay to light brown silt clay</td>
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<tr>
<td>767</td>
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<td>Laminated G7</td>
</tr>
<tr>
<td>774</td>
<td></td>
<td>Laminated G7</td>
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<tr>
<td>779</td>
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<td>Laminated G7</td>
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<tr>
<td>800</td>
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<td>Laminated G7</td>
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<tr>
<td>812</td>
<td></td>
<td>Pink zone @ 812 cm</td>
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<tr>
<td>817</td>
<td></td>
<td>Laminated G7</td>
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<tr>
<td>840</td>
<td></td>
<td>AMS: Fine, grey</td>
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<tr>
<td>850</td>
<td></td>
<td>Smudged zone</td>
</tr>
<tr>
<td>857</td>
<td></td>
<td>Fine, grey</td>
</tr>
<tr>
<td>877</td>
<td></td>
<td>Loamy silt clay</td>
</tr>
<tr>
<td>892</td>
<td></td>
<td>Grading transition</td>
</tr>
<tr>
<td>900</td>
<td></td>
<td>5 cm, 56</td>
</tr>
<tr>
<td>905</td>
<td></td>
<td>L.C.Fusal @ 894 cm</td>
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Date cored: __________
Date described: __________
Analyst: __________
Quaternary Paleoecology and Paleohydrology

Core Log

Site: SLICE LAKE
Date cored: 8/29/94
Crew: MES/DF-JN

Segment: __________
Date described: 4/15/95
Analyst: DOLTON

Depth
Hole: (A)
Description

55

SPEARS - ABUNDANT, FRESH WOOD FRAGMENTS ROLLING
STEMS - S. REPENS SP. ABUNDANT
STEM LEAVES OF S. REPENS
INSECT PARTS
SEEDS
OSMITACES - 3 SPECIES; ABUNDANT

SPRAYS - Some are a higher plant, like Myriophyllum?
Rime - leaf bases
Double Otsa - same moss line

OSTRACODS
First Lemn - 2 mid species present

CARACAL
INSECT PARTS
THRU MIDDLE PL. VEGETABLE
STEMS
(SOIL CASE)
ROOTS - thin and thin
pods - chetia? (chekia?)

Seeds - some chetia?

COCONUTS
INSECT PARTS
OSMITACES

LEAVES OF S. REPENS SP
STEMS
GEOCHEMICAL PARTS
OSTRACODS

SPRAYS
INSECT CASES, PARTS
SEEDS - LEAF FRAGMENTS, S. REPENS SP.
WOODY STEM
BROKEN OSTRACODE VALVES (NOT PICKED)

Depth
Hole: (B)

055

510

15

20

524

5 cm

405

MOSSES ABUNDANT
Quaternary Paleoecology and Paleohydrology
Core Log

<table>
<thead>
<tr>
<th>Site</th>
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<th>Crew</th>
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<td>IS1E LAKE</td>
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<thead>
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<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td>700</td>
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<table>
<thead>
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<td></td>
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</tr>
<tr>
<td>866</td>
<td></td>
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</tr>
<tr>
<td>FINAL</td>
<td>866 cm</td>
</tr>
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</table>

- 823 grading transition
- sharp contact
- F1, tan/musty
- F1, gray
- 866 cm
- F1, gray
- 802
- 700 cm
Quaternary Paleoecology and Paleohydrology
Core Log

<table>
<thead>
<tr>
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<th>Description</th>
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<td>650</td>
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<td></td>
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<tr>
<td>620</td>
<td>F1 gray,</td>
<td></td>
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<tr>
<td></td>
<td>well mixed</td>
<td></td>
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<td>50</td>
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<tr>
<td>0</td>
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</tbody>
</table>
Quaternary Paleoecology and Paleohydrology
Core Log

Site 151E LA 102
Date cored
Crew
Segment
Date described
Analyst

Depth Hole: [A]
Description

Depth Hole:

300
400
500
Black sand
Black sand
Remineralized G.7, 7/8/84.
<table>
<thead>
<tr>
<th>Depth</th>
<th>Hole:</th>
<th>Description</th>
<th>Depth</th>
<th>Hole:</th>
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<tbody>
<tr>
<td>100</td>
<td>A</td>
<td></td>
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<td></td>
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<td></td>
<td>WATER</td>
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</tr>
<tr>
<td>200</td>
<td>X</td>
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<td>300</td>
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<tr>
<td>500</td>
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</tbody>
</table>

**Site**: LAKES

**Date cored**: 

**Date described**: 

**Crew**: 

**Analyst**: 

---

Quaternary Paleoecology and Paleohydrology

Core Log
Core Log

Quaternary Paleoecology & Paleohydrology

Site:

Segment:

Date cored: Crew:

Date described: Analyst:

- Organic zone
- Silt, silt-mud, silty sand, sand, and gravel
- Water source: lacustrine
- Marine layer
Core Log

Quaternary Paleoecology & Paleohydrology

Site: [Blank]
Segment: [Blank]
Date cored: [Date]
Date described: [Date]
Crew: [Name]
Analyst: [Name]

[Blank Page]
TROUT POND

A

GI, SY 3/2, dark olive gray
mottled sand

1000

1014

1020

rock mottling decreasing upwards

lightly muddy GI
Dark FS zone

5, 2/2, 2/3

1032

1033

1040

1034, 2/3

both cores
drilled up from bottom
to 1050 cm minus within

dark FS zone; fossils to top

meeting up to muddy GI
from as A except F1
unit missing on top of Dm

B

solid log crud though

1003

1072

1076

1070

1093

1095

1103

5G, 2/1, dark greenish gray

1051

muddy GI

1065

massive greenish gray mud

5G, 2/1

1060

1065, stiff 5mm mud lamina

1068

complete silt/sand
mixture, from 0.5 mm to 5 mm;
5G 2/1 greenish gray

1077

weathered contact

very firm, mottled muddy sand;
56, 2/1 greenish gray

1070

very stiff

56, 2/1 dark greenish gray

1090

56, 2/1 dark greenish gray

1093

very well preserved
APPENDIX II

Core Logs for Ponds in Northern Maine
Core log, loss on ignition, and δ¹⁸O analyses of molluscs and foraminifera from Lily Lake, West Lubec, Maine. Modified after Dorion et al. (in preparation).

C. C. Dorion 8/96
Figure ???. Core log and loss on ignition from Long Pond, T10 SD, Maine.
14C chronology

Depth in core (cm) below lake surface

Lithofacies

Organic %

13,300 ± 65
OS-3161
Nucula tenuis expansa

Figure 2? Core log, loss on ignition, macrofossils, and foraminifera observed in the Marks Lake Core, Marshfield, Maine.
13,400 ± 95
OS-3465
Seaweed

Figure 1. Core log and loss on ignition for the Patrick Lake core, Marion, Maine.
Figure 7. Core log and loss on ignition for the 1993 Pocomoonshine Lake core.