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QUATERNARY STRATIGRAPHY IN NORTHWESTERN MAINE: A PROGRESS REPORT

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ABSTRACT A preliminary Quaternary stratigraphy for northwestern Maine can be assembled from interpretation of ice-flow indicators (dispersal and erosional), exposed sections, and drill-hole logs. Evidence from the ice-flow indicators delineates at least four regions each with different ice-flow histories. The distribution of these regions may result from an eastward invasion of Laurentide source ice during the early portion of the late Wisconsinan and subsequent development of a local ice dome during the closing portion of the Late Wisconsinan substage. Exposed sections contribute the following probable sequence of events to the stratigraphy: 1) deposition of alluvial fans, 2) deposition of a gray compact till beneath eastward flowing (Laurentide) ice, 3) deposition of a brown till beneath northward flowing local ice, 4) deglaciation by a southward retreating ice margin. These events appear continuous and have all been provisionally assigned a Late Wisconsinan age. Drill-hole logs confirm the sequence derived from the exposed sections and allow extension of the Quaternary stratigraphy. The drill-log data show three associated groups of sediments that may in turn result from at least three separate ice margin advances and recessions. The uppermost group of sediments is correlated with those found in exposed sections. The position of the drill-hole logs in an over-deepened basin suggest erosion by at least one even earlier glaciation.

RÉSUMÉ *La stratigraphie du nord du Maine au Wisconsinien: état de la question.* À partir de l'interprétation des indicateurs de l'écoulement glaciaire (de dispersion et d'érosion), des coupes naturelles et des résultats des forages, on a tenté d'établir la stratigraphie préliminaire du Quaternaire pour le nord du Maine. Les renseignements tirés des indicateurs de l'écoulement glaciaire ont permis de circonscrire au moins quatre régions, chacune d'elles présentant un processus différent d'écoulement glaciaire. La répartition des régions est probablement le résultat de la progression vers l'est des glaces laurentidiennes au début du Wisconsinien supérieur et de la formation subséquente d'un dôme local à la fin du Wisconsinien supérieur. Les coupes naturelles ont permis de reconstituer la séquence d'événements suivante: 1) formation de cônes de déjection; 2) dépôt d'un till gris compact sous une des glaces laurentidiennes s'écoulant vers l'est; 3) dépôt d'un till brun sous les glaces locales s'écoulant vers le nord; 4) déglaciation résultant du retrait de la marge glaciaire vers le sud. Ces événements semblent s'être déroulés de façon continue; on les attribue du moins provisoirement au Wisconsinien supérieur. Les résultats des forages confirment la séquence reconstituée grâce aux coupes naturelles et permettent même de prolonger la stratigraphie du Quaternaire. Les données de forage démontrent la présence de trois groupes associés de sédiments qui, à leur tour, sont le résultat d'au moins trois récurrences et trois récessions de la marge glaciaire. Le groupe supérieur correspond aux sédiments observés dans les coupes. Les résultats de forage dans un bassin surcreusé laissent croire qu'au moins une glaciation antérieure y a laissé des traces d'érosion.

ZUSAMMENFASSUNG *Stratigraphie von Nord-West Maine im Quaternär: ein Verlaufs-Bericht.* Eine vorläufige Stratigraphie für Nord-West Maine im Quaternär kann durch Interpretation der Eis-Fluß Indikatoren (Dispersion und Erosion), der natürlichen Schnitte und der Bohrergebnisse erstellt werden. Durch die Eis-Fluß Indikatoren ergeben sich mindestens vier Gebiete mit jeweils unterschiedlicher Eis-Fluß Vergangenheit. Die Verteilung dieser Gebiete hat wohl ihren Ursprung im Eindringen von Laurentischem Quell-Eis in östlicher Richtung während des Beginns des späten Wisconsin und der darauf folgenden Entwicklung eines lokalen Eis-Doms während der Abschlußphase des späten Wisconsin. Die natürlichen Schnitte ergeben die folgende mögliche Abfolge der Ereignisse für die Stratigraphie; 1) Ablagerung von Alluvialkegeln, 2) Ablagerung eines grauen kompakten Tills unter ostwärts fließendem (Laurentischem) Eis, 3) Ablagerung eines braunen Tills unter nordwärts fließendem lokalem Eis, 4) Enteisung durch die südwärts zurückweichende Eisgrenze. Diese Ereignisse scheinen kontinuierlich abgelaufen zu sein und sind alle vorläufig dem späten Wisconsin zugeschrieben worden. Die Bohrergebnisse bestätigen die aus den natürlichen Schnitten gewonnene Abfolge und erlauben eine Ausdehnung der Stratigraphie des Quaternär. Die Bohrdaten zeigen drei Gruppen von Sedimenten, die ihrerseits ihren Ursprung in mindestens drei unterschiedlichen Vorstoß- und Rückzugs-Phasen der Eisgrenze haben. Die oberste Gruppe der Sedimente steht in Wechselbeziehung mit den in den natürlichen Schnitten gefundenen Sedimenten. Bohrergebnisse in einem übertieften Becken lassen vermuten, daß zumindest eine frühre Vereisung Erosionsspuren hinterlassen hat.

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INTRODUCTION

Much of the existing information on the chronology of ice-marginal fluctuations along the southeast margin of the Laurentide Ice Sheet has been obtained from stratigraphic studies in the St. Lawrence Valley (OCCHIETTI, 1982; LASALLE, 1984). Ongoing work there has continued to refine our knowledge of Quaternary events. A second area of particular stratigraphic wealth occurs on Long Island (SIRKIN and STUCKENRATH, 1980) and a third in Nova Scotia (GRANT and KING, 1984). Between these areas various factors so far have prevented the definition of a detailed Quaternary glacial record. This paper presents a preliminary report on Quaternary events that occurred east of the St. Lawrence River area in northwestern Maine.

One of the events that links southern Québec, northwestern Maine and northwestern New Brunswick is the northward directed ice flow that occurred during the last glaciation. Several models have been put forth to explain this phenomenon. GRANT (1977) suggested that it was the result of an independent ice mass over northern Maine, New Brunswick, and the Gaspé Peninsula. However, LASALLE *et al.* (1977) presented a model whereby calving of Laurentide ice migrated up the St. Lawrence Lowland. In this model the northward flow began about the same time as the marine waters invaded the lowland. CHAUVIN *et al.* (1985) refined this concept to develop a deglaciation model for the lower St. Lawrence region. DENTON and HUGHES (1981) suggest that flow reversal and downdraw were active for longer periods of time than the other models cited above do. In any case, the widespread evidence of northward flowing ice requires that portions of two provinces and one state must be considered together to develop a regional deglaciation history.

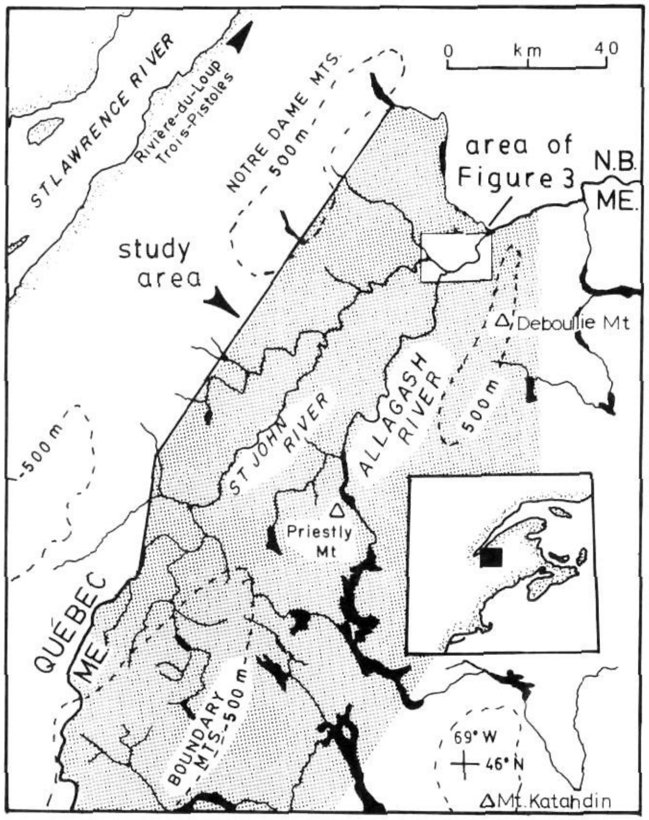

FIGURE 1. Northwestern Maine and surrounding areas. Shaded area covered by surficial mapping and glacial erosion studies.

Carte du nord-ouest du Maine et des régions avoisinantes. La cartographie des formations superficielles et les études d'érosion glaciaire ont été faites dans la zone en gris.

Our study in the area of northwestern Maine utilized various means, including: 1) reconnaissance mapping of surficial deposits; 2) documentation of striations and lithologic indicators; and, 3) preliminary studies of stratigraphic sequences. The mapping and erosional studies have been conducted over an extensive area (Fig. 1); however, the distribution of and availability of subsurface information has forced us to focus the stratigraphic studies on an area near the confluence of the Allagash and St. John rivers (Fig. 1, 3). Mapping for this project was carried out in 1979, and 1981-1984 whereas the stratigraphic work received most attention in 1979 and 1981. Preliminary data and discussion have been published elsewhere (BECKER *et al.*, 1981; LOWELL *et al.*, 1983).

Only four published works suggest that events prior to the Late Wisconsinan occurred in northern Maine. PRESCOTT (1973) relied on well-log data to invoke three advances or pulsations of glacial ice over the St. John River area. Radiocarbon dating of wood from one well yielded an age of > 38,000 yr. BP (W-2572) but its stratigraphic association is unknown. HOLLAND and BRAGDON (1981) reported the occurrence of cold water diatom assemblages from lacustrine sediments encountered in drill holes below a silt-rich diamicton some 30 km south of Deboullie Mountain (Fig. 1). These two reports provide the only concrete evidence of Quaternary sediments in the study area prior to the last glacial advance in northern Maine.

From their studies at the Golden Rapids section along the St. John River GENES *et al.* (1981) and NEWMAN *et al.* (1985) described a weathered zone that they considered to separate two diamicton units. They concluded that the lowest diamicton exposed was probably deposited by an Early Wisconsinan ice advance of either local or Laurentide source. GENES *et al.* (1981) concluded that the upper diamicton was emplaced by Laurentide ice after the formation of the St. Antonin-Highland Front Moraine complex. This interpretation has been challenged (LOWELL *et al.*, 1983). Although GENES *et al.* (1981) suggested formal stratigraphic names for some of the surficial units in northern Maine, no type localities were designated for these units and the names will not be used in this paper. Much additional work is required before formal stratigraphic names can be applied to lithostratigraphic units in this region of sparse exposure.

ICE-FLOW INDICATORS AND THE GLACIAL SEQUENCE

Glacial dispersion on both regional and local scales, and small-scale glacial erosional features have been used extensively as ice-flow indicators in this study. The generally thin nature of deposits in northwestern Maine required that we use these lines of evidence to help build our preliminary stratigraphy.

HALTER *et al.* (1984) and HALTER (1985) studied the local dispersion around two small granodiorite-diorite plutons in the areas of Priestly Mountain and Deboullie Mountain (Fig. 1). Both areas showed strong transport (amounts from 25 to 40%) of the igneous pebbles and boulders to the east-southeast (approximately 15 km); also, igneous material is mixed into the surface diamictons in this direction. A second weak dispersion (4 to 5%) was recorded over an area extending 6 km to the northwest of the plutons. However, soil pit studies in the area of the northwest trending boulder fans, revealed no incorporation of the igneous material. In northwestern New Brunswick MARTINEAU (1979) reported similar dispersions in both northwestward and southeastward directions.

On a regional scale, rounded granite and granite gneiss stones in the drift of northwestern Maine are used to suggest long-range glacial transport directions to the east or southeast. These stones have a source identified as the Grenville Province of the Canadian Shield, and stand apart from the locally derived clasts which consist of drab slate and graywacke. These erratics are rare and systematic boulder counts in northwestern Maine showed only 160 of these out of 36,361 boulders (0.44%) in all types of drift. All were found at elevations above the marine limit.

Striations and associated small-scale erosional features make-up the largest data set (> 2,500 observations) that indicate ice-flow history in northwestern Maine. Only the pertinent points of that study are included here as a more complete description of the methods, data, and interpretation are being prepared for publication separately. More than 50% of the outcrops studied have provided information on the direction of ice flow. This comes from criteria such as stoss and lee forms or rattail striations. Many striations displayed cross-cutting relationships that clarify the relative sequence of changing ice-flow directions. LOWELL (1984) suggested that northwestern Maine can be divided into four regions, each of which displays a different ice-flow history as outlined below. Region 1 (Fig. 2) erosional features indicate that an early ice flow to the east-southeast was succeeded by ice which moved to the north and northwest. In region 2 there is a belt in which varied flow indicators and varied age relationships predominate (Fig. 2). KITE *et al.* (1982) termed this area the "zone of confusion". The indicators of east-southeast flow again lie below northward flow indicators here; however, at several locations evidence of another northwestward flow event are preserved below the east-southeast event. The preservation of many outcrops with two or more sets of striations in region 2 sugests that the later ice flows produced only weak erosion.

In region 3, exposures observed show only the east-southeast indicators. All outcrops within this region are strongly imprinted with evidence of this one ice-flow direction. Region 4 (Fig. 2) like region 2 showed evidence of the first movement to the east-southeast, but the flows that succeeded this were directed to the southeast and subsequently to the south at some places. Localized variations of these general directions are sometimes found within this zone. Boundaries between these four regions are transitional over distances of 5 to 10 km.

We consider the characteristics of these regions to have resulted from the interplay of Laurentide and local ice masses. The ubiquitous evidence of the east-southeast ice flow probably represents a regional flow from the Laurentide highlands that

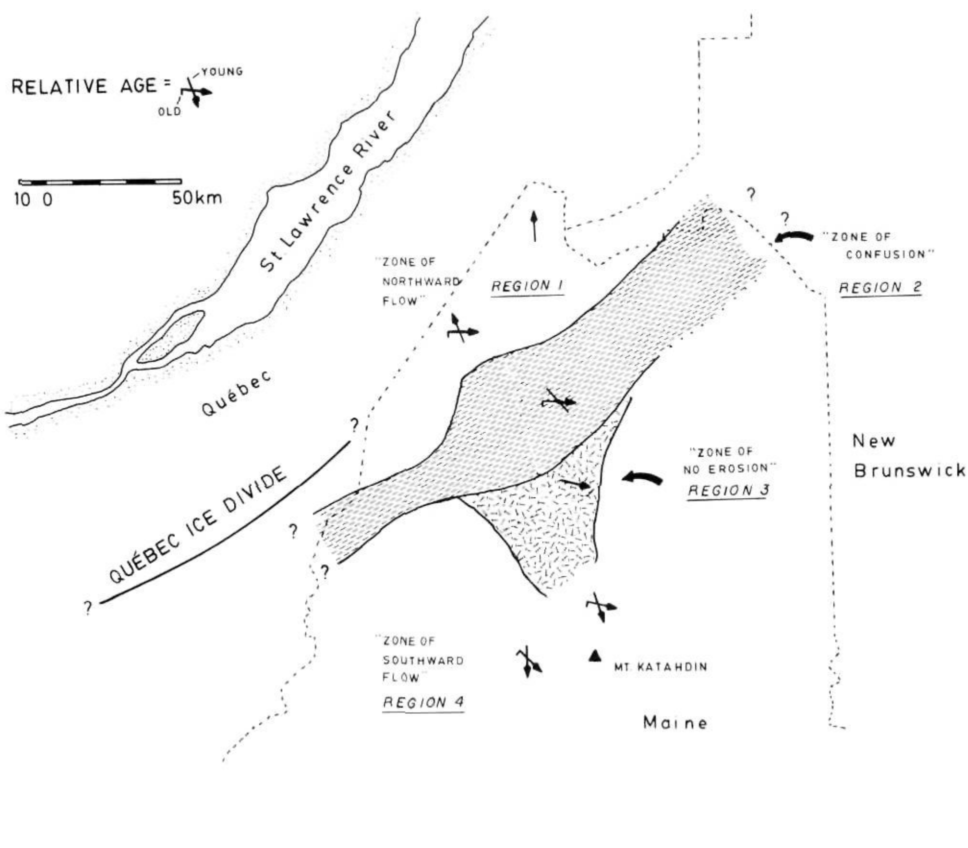

FIGURE 2. Ice-flow zones after LOWELL (1984). Position of Québec Ice Divide after SHILTS (1981). Arrows represent simplified ice-flow directions. Lack of arrowheads in region 2 indicates that the ice flow is weak in that area.

Les quatre régions d'écoulement glaciaire selon LOWELL (1984). Localisation de la ligne de partage des glaces du Québec selon SHILTS (1981). Les flèches montrent les directions de l'écoulement glaciaire. Dans la région n° 2, la direction de l'écoulement glaciaire n'est pas nette.

crossed all of northwestern Maine, perhaps bringing with it the granite and granite gneiss erratics. This flow also transported erratics from the local plutons to the east-southeast (HALTER *et al.*, 1984; HALTER, 1985). We provisionally have assigned the age of this flow to the beginning of Late Wisconsinan time for reasons outlined below. Data in the northern portions of the study area (regions 1 and 2) indicate a glacial ice-flow reversal subsequent to that event. The effects of this reversed flow appear to weaken with distance south of the St. Lawrence River as evidenced by the short northward transport of local erratics and the general decrease in the strength of the striated outcrops. It is our view that the second (lower) set of northward flow indicators present in region 2 represent activity prior to Late Wisconsinan times.

Region 3 may have been a window where the Laurentide source ice eroded the bedrock but if there was subsequent glacier flow in directions other than east-southeastward, it made no erosional impact. We correlate the shift, in region 4, to a southerly flow direction, to the flow reversal noted from region 1. We suggest that as the ice over northern Maine became independent of its Laurentide source, the ice over southern Maine would have also adjusted to the changing positions of ice divides.

The relative relationship between the two movements in region 1 (northward over east-southeastward) is a major mainstay of our working stratigraphy for northwestern Maine. We argue that the change in glacier flow direction occurred without retreat of glacier ice from northwesternmost Maine (region 1) for the following reasons: 1) we have never observed any weathering or staining between any of the striation sets; 2) lobation of an ice margin either during deglaciation or during a subsequent readvance might be expected to produce evidence of intermediate flow directions in this region; none have been found.

RELATIONSHIPS BETWEEN LITHOSTRATIGRAPHIC UNITS

LITHOSTRATIGRAPHIC UNITS PRESENT IN EXPOSED SECTIONS

The drift in northern Maine is generally very thin and on the higher bedrock ridges it often occurs only as a veneer. Over 75% of the surface area has been mapped as till (LOWELL, 1980a), which is calcareous, gray (5Y 5/2) to dark gray (5B 5/1) in the unaltered state. Near the surface, however, it is leached and oxidized to brown hues (for example, 2.5Y 5/2). Similar surface till has been described and mapped in New Brunswick (LEE, 1953), in Québec (LASALLE *et al.*, 1976; MARTINEAU, 1977; CHAUVIN, 1979), and in northeastern Maine (NEWMAN *et al.*, 1985).

Poorly sorted, stratified sand and gravel was concentrated in lowlands and fluvial valleys during deglaciation. A few of the deltaic deposits in the larger valleys may reach 30 m in thickness; however, most of the stratified deposits are less than 5 m thick. Several lowland regions of northern Maine display a slightly hummocky drift mantle which is comprised of interbedded sorted and unsorted materials. Such mantles have been mapped as stagnation moraine (LOWELL, 1985) and resulted from slow dissipation of separated ice masses. Subsequent to deglaciation the St. John River underwent a complex alluvial history during which the sediments in the lower portions of the valley were reorganized (KITE, 1983) and glacial and late-glacial sediments were exposed. Alluvial units have complex spatial and temporal relationships, but lie at the top of the stratigraphic sequence discussed below. LEE (1953, 1955), and KITE (1983) describe a similar relationship downstream on the St. John River.

The best-exposed stratigraphic sections through the Late Quaternary sediments in northwestern Maine occur down the St. John River from the town of Allagash (Fig. 3). These are at three sites where northward flowing tributaries join the St. John River and are named, from west to east, Wesley Brook, Golden Rapids, and McLean Brook. GENES *et al.* (1981) as well as NEWMAN *et al.* (1985) described and interpreted the Golden Rapids section (Fig. 4) whereas BECKER (1982) studied all three sections. Discussion centers here on the Golden Rapids section because it has been the subject of some controversy (LOWELL *et al.*, 1983; GENES and NEWMAN, 1983) and because it has units apparently representative of the other two sections. The reader may wish to consult GENES *et al.* (1981) and NEWMAN *et al.* (1985) for other descriptions and interpretations of this section.

The Golden Rapids section (Fig. 4) consists of two exposures, separated by Wiggins Brook and State Route 161. These are represented by columnar logs in the Appendix. The lower exposure, A, extends 240 m downstream from the mouth of Wiggins Brook and lies north of the highway; the upper exposure, B, extends 150 m upstream (St. John River) from the brook and lies south of Route 161. Correlation of units between the two sections allows us to build the following sequence. Slate of the Devonian Seboomook Formation forms the local bedrock and is exposed at the base of the section. The lowest unconsolidated sediments (unit 1) here consist of well-stratified and sorted sand and gravel beds. These are slightly indurated and locally contorted with collapse features present in one area. Cross-bedding within the unit suggests deposition by water flow eastward parallel to the modern St. John River or northward, into the river valley. Unit 2 above is a dark gray, compact diamicton with a sandy silt matrix. Pebble and larger-sized clasts comprise 25% of the unit and predominantly include the underlying Seboomook Formation with about one percent gneisses and granites (BECKER, 1982). The clast fabric indicates a strong alignment toward 100 to 110° with the clast dip to the west. Unit 2, in the B subsection, displays laminations and flow structures throughout the southwest part of the exposure but they are limited to the base of the unit in the northeast part of the subsection. In the A subsection, a 15 to 60 cm-thick massive sand layer at the base of unit 3 separates unit 2 from the main part of unit 3. The sand thickness has the same amount of variation in the other exposures (Appendix).

Unit 3 at Golden Rapids is a oxidized compact diamicton with a silty sand matrix and 15 to 20% stones. These stones display a maximum orientation in a north-south alignment with three of the four analyses showing a clast dip to the south

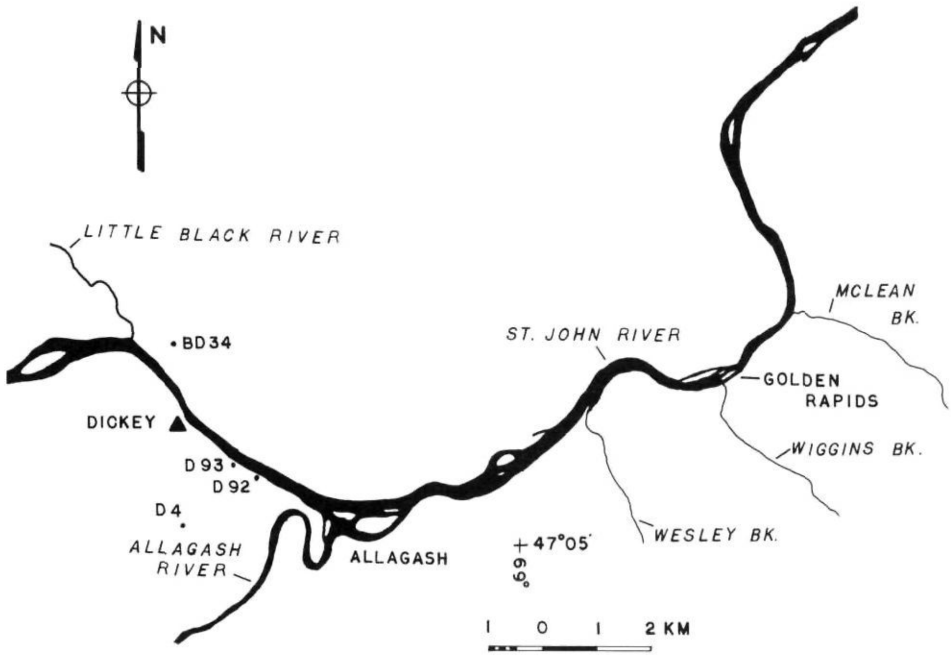

FIGURE 3. The St. John River near Allagash, Maine. Location of drill sites shown.

Le cours du Saint-Jean, près d'Allagash, dans le Maine. Localisation des sites de forage.

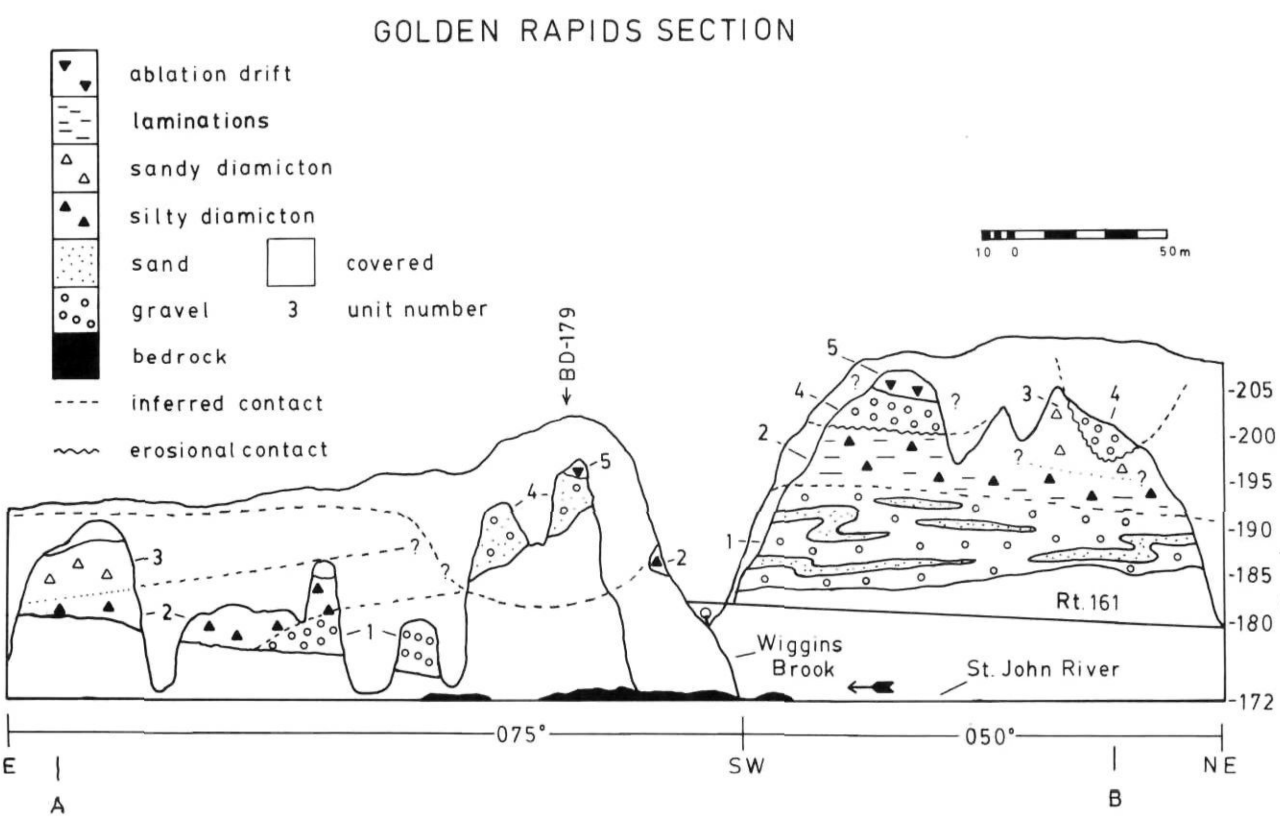

FIGURE 4. The Golden Rapids exposure. View looking to the south. Location of subsections described in the Appendix is indicated by letters A. and B. Units are numbered. Modified from BECKER *et al.* (1981).

La coupe de Golden Rapids (vue vers le sud). La localisation des sous-sections décrites en appendice est identifiée par les lettres A et B. Les unités sont identifiées par des numéros. Modifié de BECKER et al. *(1981).*

(Appendix). Pebble samples from units 2 and 3 show very similar pebbles lithologies and shapes. A greater variation exists between the same units in different sections than between units 2 and 3 in the same section (Fig. 5).

Lenses of poorly stratified sand and gravel (unit 4) overlie unit 3 at several locations. At two points these lie below a oxidized diamicton (unit 5) with a loose sand matrix and 10 to 15% clasts. Units 4 and 5 may have a intercalated relationship.

Units 1 through 5 display nearly identical characteristics between subsections A and B at Golden Rapids. McLean Brook (Appendix) downstream from this site also records this sequence. In addition, shallow borings from the Golden Rapids area, discussed in the following section, reveal a very similar sequence of strata. Thus we suggest that this sequence is representative of the near-surface stratigraphy. We find no evidence for the interpretation of GENES *et al.* (1981) that the sands and gravels exposed at the base of the B section lie stratigraphically above any of the units found in the A section.

Our studies at Golden Rapids and adjacent exposures have suggested the following sequence of events. Ice contact/outwash sediments (unit 1) built into the St. John River valley from the Wiggins Brook valley prior to or associated with the eastward advance of an ice margin. The deposits and advancing ice combined to pond water into which the laminated portion of the unit 2 diamicton was deposited. The remainder of unit 2 was deposited beneath the overriding eastward flowing ice mass. The massive thin sand at the base of unit 3 may be deposited from basal melting of relatively inactive ice.

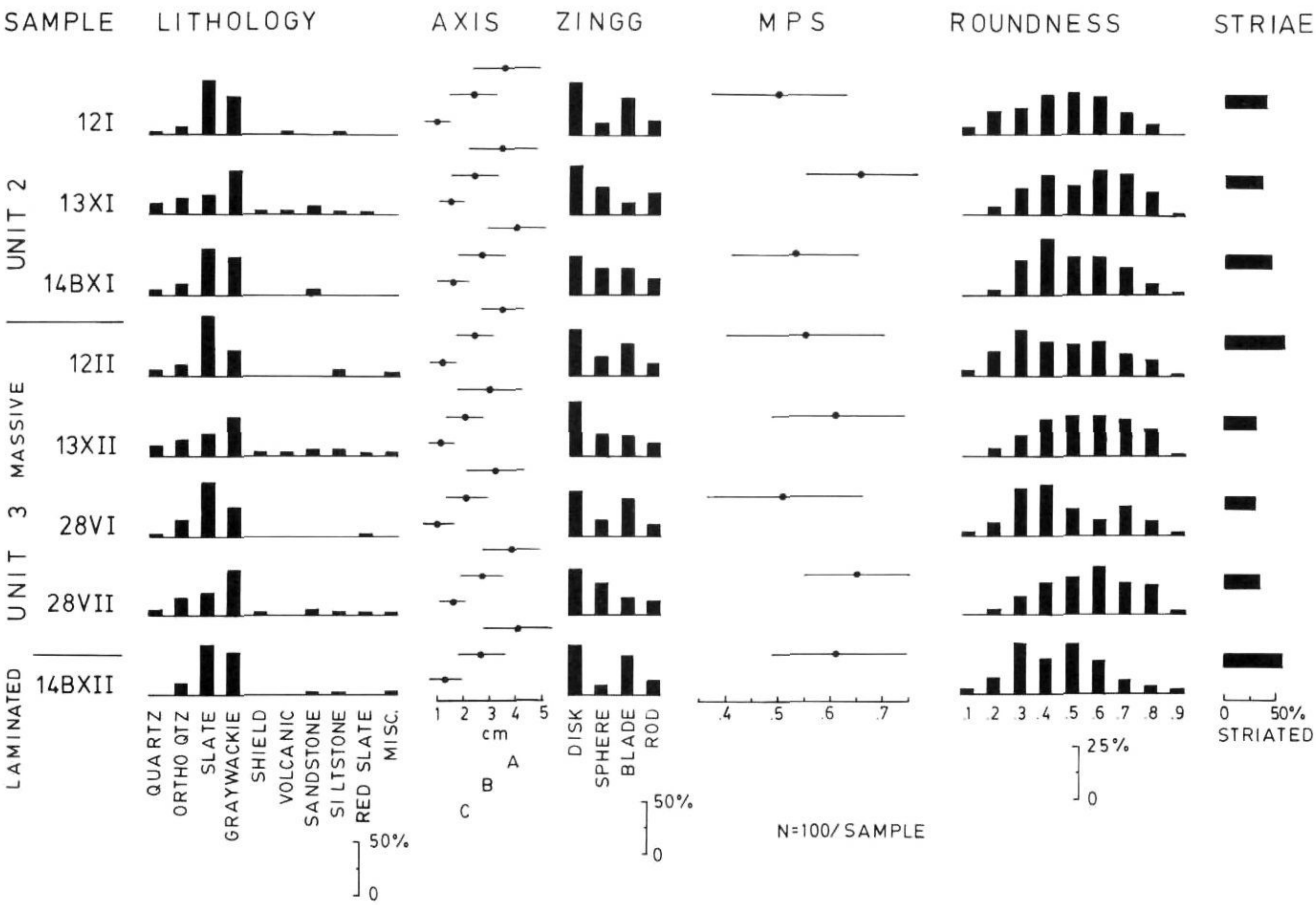

FIGURE 5. Pebble analysis from the exposed diamictons (units 2 and 3). The sample numbers are keyed to the sections (12 = McLean Brook, 13 = Golden Rapids A, 14 = Golden Rapids B, 28 = Wesley Brook). Under lithology, "shield" refers to clasts believed to have been derived from the Grenville Province northwest of the St. Lawrence River. Axis mean (dot) is for long (A), intermediate (B), and short (C). Bar represents the standard deviation. Zingg refers to the percent of each class on the Zingg diagram. MPS is the maximum projection sphericity of SNEED and FOLK (1958). Roundness scale after POWERS (1953). Striae indicates the percent of clasts that are striated.

Analyse des cailloux à la surface des diamictons (unités nos 2 et 3). Le numéro des échantillons se rapporte à un secteur (12 = McLean Brook; 13 = Golden Rapids A; 14 = Golden Rapids B; 28 = Wesley Brook). Sous la rubrique "lithology", le terme "shield" se rapporte aux constituants qu'on croit être de la province de Grenville, au nord-ouest du Saint-Laurent. La moyenne (point) s'applique aux axes longs (A), intermédiaires (B) et courts (C). Le trait horizontal représente l'écart type. Le terme "Zingg" se rapporte au pourcentage de chacune des classes du diagramme. "MPS" représente la projection maximale de sphéricité selon SNEED et FOLK (1958). L'indice d'émoussé est celui de POWERS (1953). "Striae" donne le pourcentage de fragments striés.

Because units 2 and 3 showed considerably different fabrics (Appendix) but similar lithology and shapes of the clasts we suggest the change in clast direction resulted from a change in ice-flow direction. The fabrics suggest that unit 3 was deposited below northward flowing ice. No evidence present in the sections requires a deglaciation event between deposition of the two diamictons.

We consider that units 4 and 5 were deposited during deglaciation. These sediments, in part, were derived from outwash that flowed northward, parallel to Wiggins Brook, into the St. John River valley and interacted with detached ice blocks laying in the valley floor (LOWELL, 1985).

LITHOSTRATIGRAPHIC UNITS PRESENT IN DRILL HOLES

Another rich source of stratigraphic data exists in the St. John River valley in the form of numerous drill-hole logs. The U.S. Army Corps of Engineers proposed a two-dam complex on the St. John River near Allagash (Fig. 3) for flood control and electricity generation. Drilling was undertaken to obtain foundation data and to make materials inventories (CORPS OF ENGINEERS, 1978). Two sets of these drilling logs are discussed below. The first set comes from the Golden Rapids area and supports the sequence developed from the surface exposures; the second set is from from the village of Dickey (Fig. 3) and give an example of the complex stratigraphy present at greater depth within the valley (Fig. 6).

Interpretation of all of these drill logs was based on the driller's descriptions, blow-count data, and textural analysis of the sediments (CORPS OF ENGINEERS, 1978). These interpretations have allowed identification of seven types of sediments (for example, layered silt) which we feel represent six different depositional environments (lacustrine) (Fig. 6). The alluvial deposits consist of stratified sands and gravels that are identical in description to those of outwash sediments. Separation of alluvium from outwash has been made in the upper part of Figure 6 on the basis of surficial mapping (LOWELL, 1985). However, this information is not available at depth, thus all the sand and gravel sediments have been grouped together. Stratified sediments of sand to clay sized material which constitute thick (> 5 m) sequences are interpreted to be of lacustrine origin.

Differentiation between the diamicton designated as sandy matrix and that designated as silty matrix comes from: 1) the log description of the sandy diamicton which was typically "brown, loose to compact, gravely silty clayey sand" whereas the silty diamicton was described in the drill logs as "gray compact to very compact, gravely sandy silt with occasional clays"; 2) the blow counts required by a 160 kg weight on the drill rig to penetrate 0.3 m of sediment. The sandy diamicton required from 50 to 250 blows whereas 250 to 650 blows were necessary to penetrate the same thickness of the silty diamicton. In some cases dynamite was necessary to loosen the silty matrix unit. The wide textural range of these diamictons, which were all described as till in the original logs (CORPS OF ENGINEERS, 1978), can be seen in Figure 7. The units shown in Figure 6 have been simplified somewhat from the original logs due to scale considerations and thus represent the simplest interpretation of these sediments.

The first set of logs come from near the Golden Rapids section and allow correlation of the subsurface and surface stratigraphy. The notation BD-179 on Figure 4 indicates the position of one of these drill holes; thirteen additional drill holes lie within a 5 km radius of Golden Rapids (BECKER, 1982). These holes are mostly less than 20 m deep because drilling here was undertaken to assess surface gravel resources. The upper portions of these logs show a wide range of stratified sands and gravels overlaying diamictons. We believe that these sands and gravels represent deglaciation units equivalent to units 4 and 5 above. Two different diamicton units appeared in several logs. The upper of these two was generally coarse grained (25 to 30 % < 4.0 phi), brown, and compact; it required 50 to 200 blows to penetrate 0.3 m. The lower diamicton unit was generally fine grained (45% < 4.0 phi) gray and very compact. The latter unit occurred at the base of most of the logs and generally required 200 to 600 blows to advance the coring device 0.3 m.

These cores displayed the same general sediment sequence as the exposures at Golden Rapids and McLean Brook, that is, stratified sands and gravels over a sandy matrix diamicton which in turn overlies a silty matrix diamicton. Thus the sequence seen at the surface can be traced to the subsurface in the same area.

The second set of logs consists of four deep drill logs upstream on the St. John River near Dickey (Fig. 3). These revealed information on the stratigraphy below that exposed on the surface (Fig. 6). In these logs, either thick silt sequences or sand and gravel units, or a combination of both separated units of diamictons. This relationship allowed tentative assignment of the units into groups based on a simple model of ice advance and recession. The simplest interpretation of the logs has four groups as outlined below.

	Sediment type	Genetic origin
Group 4	sands and gravels	alluvium
	layered silts	lacustrine
	gravels/loose diamicton	outwash/ ablation
	sandy matrix diamicton	sandy basal till
	silty matrix diamicton	silty basal till
Group 3	layered silts	lacustrine
	sands and gravels	alluvium/ outwash
	silty matrix diamicton	silty basal till
Group 2	gravels	alluvium/outwash
	sandy matrix diamicton	sandy basal till
Group 1	slate	bedrock (weathered ?)

Group 1 lies at the base of all four cores and consists of slate bedrock belonging to the Seboomook Formation. In all cores except D-4 (Fig. 6) the lowest portion of the log contains descriptions of shale fragments just above the bedrock. In logs D-93 and BD-34 the upper portion of the bedrock is described as "weathered rock". The fractured nature of the rock in these holes may represent either subaerial weathering of the rock surface or possibly oxidation and degradation by ground water movement. Thus we use the expression "weathered?" to point out the altered nature of the rock surface in three of the cores. All of these cores encountered bedrock at elevations below exposed bedrock thresholds on the present river.

Group 2 consists of a sandy matrix diamicton and the overlaying sands and gravels. It is present only in cores D-93 and BD-34 (Fig. 6). Group 3 units include a silty matrix diamicton and overlaying sands and gravels with the addition of a uppermost unit of silts and clays. The silts and clays reported in core BD-34 (Fig. 6) lie at elevations considerably above any known base level control from the last deglaciation.

Group 4 contains units similar to those exposed on the surface. Two diamictons, the lower one with a silt matrix and the upper with a sandy matrix, lie at the base of the group.

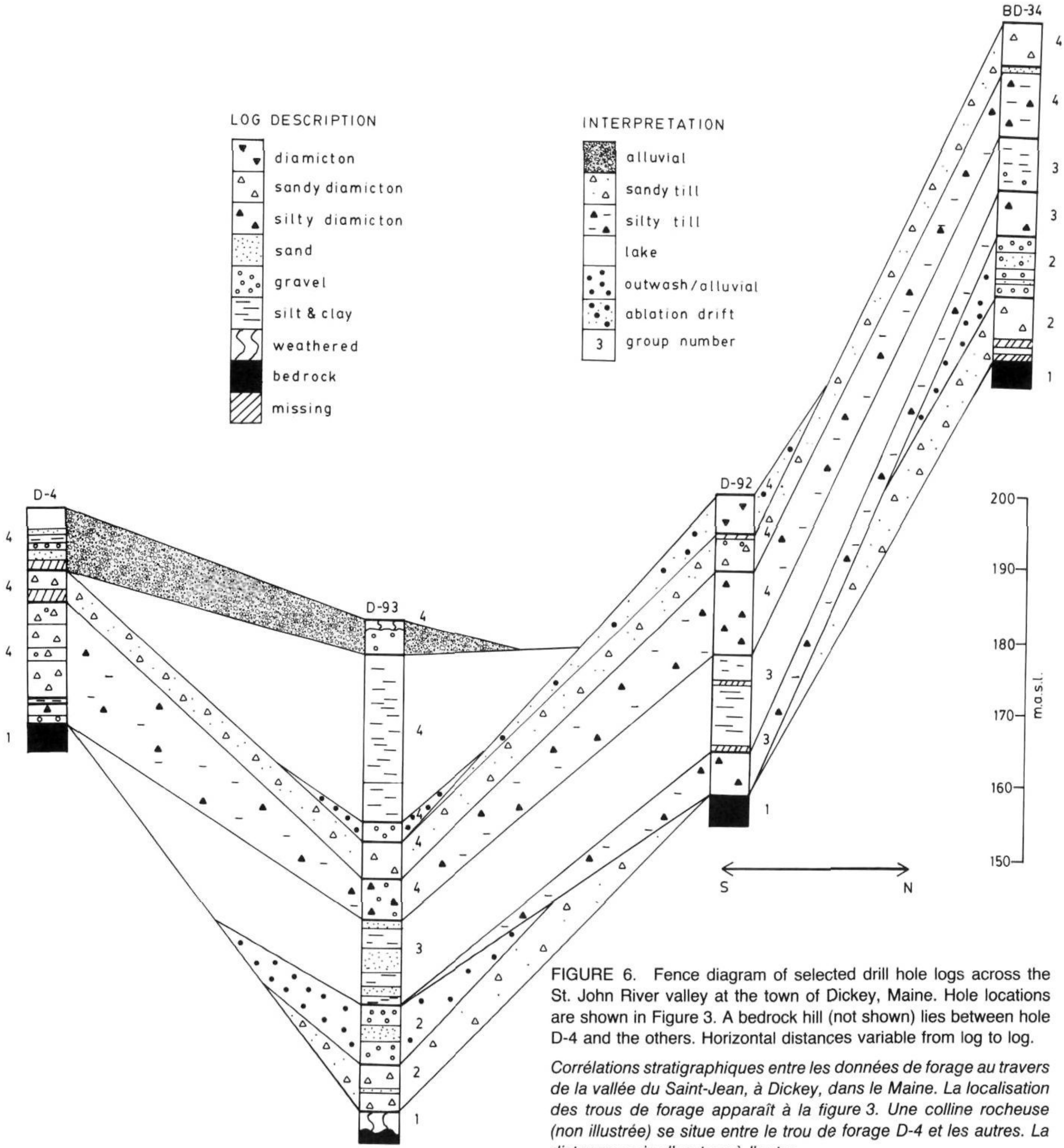

FIGURE 6. Fence diagram of selected drill hole logs across the St. John River valley at the town of Dickey, Maine. Hole locations are shown in Figure 3. A bedrock hill (not shown) lies between hole D-4 and the others. Horizontal distances variable from log to log.

Corrélations stratigraphiques entre les données de forage au travers de la vallée du Saint-Jean, à Dickey, dans le Maine. La localisation des trous de forage apparaît à la figure 3. Une colline rocheuse (non illustrée) se situe entre le trou de forage D-4 et les autres. La distance varie d'un trou à l'autre.

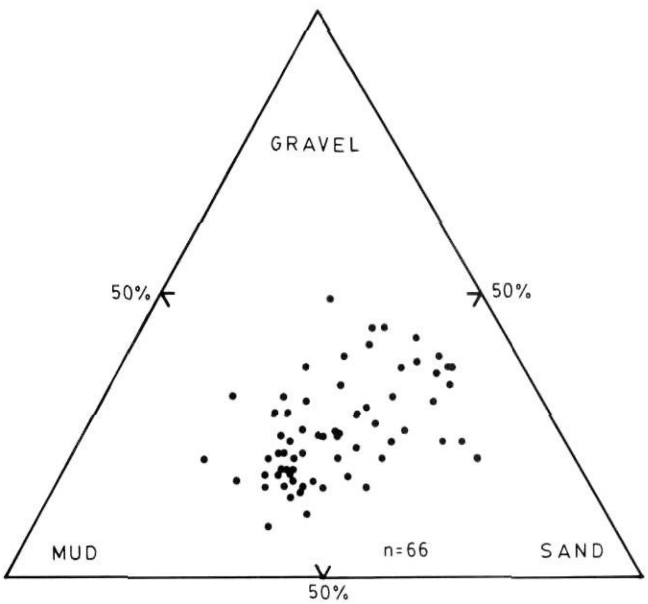

FIGURE 7. Textural diagram of samples from diamicton units in Corps of Engineer drill holes. Gravel percent low due to small sample size.

Diagramme triangulaire des échantillons prélevés dans les trous de forage. Le faible pourcentage des graviers est attribuable à un petit échantillonnage.

Above these in core D-92 (Fig. 6) is a unique unit of poorly sorted sediment (diamicton) considered to be related to deglaciation. In the lower elevation cores (D-93), the lacustrine silts and clays capped by alluvial sediments completes the group. We tie group 4 sediments directly to the sediments found in the short cores in the Golden Rapids area and hence to the sediments exposed at the surface. Therefore we have a continuous sequence from the surface through alluvium, lacustrine, and glacial deposits to bedrock at depth which represent several Quaternary events.

DISCUSSION

A relative sequence of Late Quaternary events can be suggested for northwestern Maine (Fig. 8) on the basis of the data presented above. However, there is an almost complete lack of radiometric age control. Thus we make no attempt to correlate this whole sequence with other, more established stratigraphies in the St. Lawrence Valley, on Long Island or in Nova Scotia.

The sequence begins with glacial overdeepening of the preexisting valley. This is indicated by the base of the cores at Dickey (Fig. 6), which lies lower than rock thresholds downstream on the present river. Following this, there may have been alteration of bedrock in the valley floor. The first depositional event involved formation of a sandy matrix diamicton (till, group 2, Fig. 6) resulting from an ice-margin advance over the St. John River area. The limited distribution of this till suggests that subsequent fluvial erosion has removed most of it. Deposition of outwash or alluvial gravels in the lower portions of the St. John River valley completes the deposition of group 2.

A subsequent ice margin advance across the St. John River valley produced a silty diamicton (till, group 3, BD-34, Fig. 6) and recession left fluvial gravels. Deposition of lacustrine silts put in group 3 may have also accompanied ice recession.

The lowest stratified sediments at the Golden Rapids exposure are interpreted to be ice contact or outwash sediments deposited prior to or just before the last regional ice margin advance across the St. John River valley. These gravels contain stones derived from the Canadian Shield which suggests that a Laurentide source ice moved into northwestern Maine at least once prior to deposition of these gravels.

The silty diamicton (till) overlaying the gravels at Golden Rapids represents a regional ice advance. It contains Laurentide source erratics and a strong west-northwest to east-southeast alignment of stones that parallels the most persistent and widespread but older of two major sets of striations present in northern Maine (Region 1, Fig. 2). The flow pattern suggested here by the till fabrics and the erosional indicators can be traced across all of northwestern Maine and back into adjacent Québec (CHAUVIN *et al.*, 1985). This supports the concept of Laurentide source for this east-southeastward flow. The presence of numerous striated outcrops, and a waterlain till facies directly on top of gravel sediments at the base of unit 2 suggest that this ice marginal advance involved temperate ice.

The sandy till of the sections and subsurface borings near Golden Rapids, unit 3, is considered here, based on the fabric data, to result from deposition beneath a northward flowing ice movement. We interpret the deposition of units 2 and 3 as resulting from the same ice cover, but one which changed flow direction. Support for this view comes from three points. First, the nature of the contact between the two tills. Observations along this contact reveal no location where surface weathering of the lower till unit (2) can be seen. Second, the nature of the massive sand layer between the two tills. Preservation of only a thin, uniform, unoxidized sand layer, that crops out at various elevations, seems fortuitous if the events which separated units 2 and 3 were separate glaciations. Other nonglacial units between the two or truncation of the sand layer might be expected if deglaciation events separated the two units. The third point relates to the fabrics within the the upper till units and the two regional striation sets which correspond precisely to them in orientation and relative age. The striations representing these movements are always fresh and show no evidence of a time hiatus between them. Thus a continuous ice cover that shifted source seems best to explain the relationship between units 2 and 3.

We feel that the upper till (unit 3) represents the closing portions of the Late Wisconsinan Substage when ice moved northward toward the St. Lawrence from northern Maine. The exact process responsible for this has been debated (for example LASALLE *et al.*, 1977; MARTINEAU, 1977, 1979; CHAUVIN *et al.*, 1985). We favor the hypothesis in which accelerated flow in the St. Lawrence Valley caused downdraw, increased calving, and eventual separation of ice between

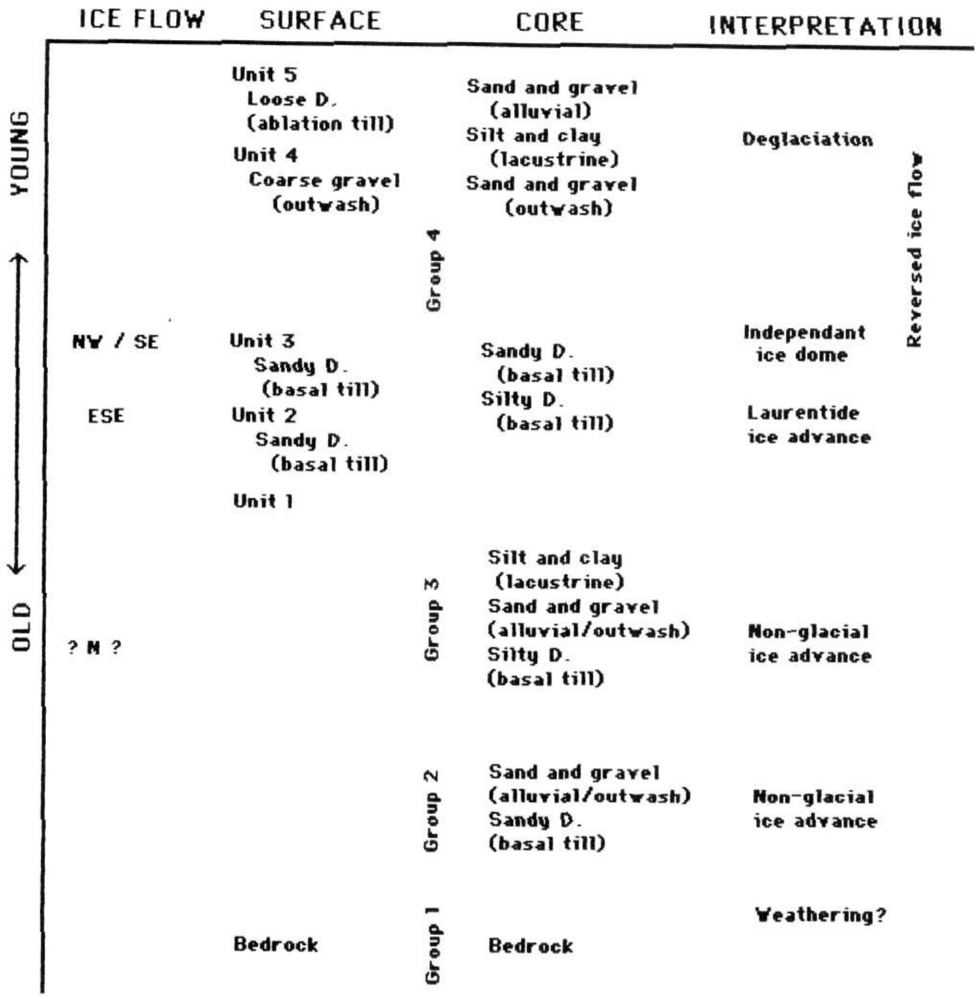

FIGURE 8. Summary of events recorded from various sources for northwestern Maine. For the Surface and Core columns the depositional environment is in () beside the sediment type. D. indicates diamicton.

Résumé des événements survenus dans le nord du Maine selon les différentes sources de renseignements. Sous les rubriques "Surface" et "Core", le milieu de dépôt a été mis entre parenthèses. D = diamicton.

Maine and the Appalachian uplands (LOWELL, 1980b; DENTON and HUGHES, 1981). Given that the lower till (unit 2) was also deposited under the same ice cover, the simplest age assignment of it would be an early portion of the Late Wisconsinan Substage.

The relative timing of these two ice movements is important to various models of glaciation for the northern New England-Atlantic Provinces region. GRANT (1977, 1982 [personal communication]) suggested that the northward movement of ice in the region during the Late Wisconsinan relates to independent ice masses that were active in this region throughout this whole time interval. Another possibility is that the eastward moving ice invaded the region prior to the Late Wisconsinan and the ice cover remained continuous, but inactive in the area until Late Wisconsinan time when it reactivated with movement to the north. However, the short northward transport of erratics (6 km) from the local plutons (HALTER *et al.*, 1984; HALTER, 1985) suggests that the northward flow event was of very limited duration; probably restricted to the very last part of the Late Wisconsinan. LORTIE (1976) also suggested a short duration for the northward flow event in southern Québec.

The influx of Laurentide ice from the west may correspond with the regional southeast movement recorded during the first half of the Late Wisconsinan in the Eastern Townships of Québec. (McDONALD and SHILTS, 1971; SHILTS, 1981). If so, advancing glacial ice would have moved across the northern portions of Maine in a eastward direction, across the central portions of Maine in a east-southeastward direction, and across southern Maine and most of southern New England in a southeastward direction. One implication of this model requires a eastward movement into New Brunswick; RAMPTON *et al.* (1984) have reported such a flow, but attributed it to a Middle Wisconsinan aged invasion.

A complex assemblage of stratified drift and ponded sediments represents the final deglaciation of northwestern Maine. The outwash (unit 5) present in the upper portions of the Golden Rapids and McLean Brook sections formed as meltwater flowed northward into the St. John River valley. The landforms associated with these sediments can be traced up either tributary valley to an ice contact head. Remnant terraces in the Allagash River and portions of the St. John River valley suggest that the immediate postglacial surface has been eroded considerably by subsequent fluvial activity. Details on deglaciation and Holocene activity are discussed in LOWELL (1985) and KITE (1983).

ACKNOWLEDGEMENTS

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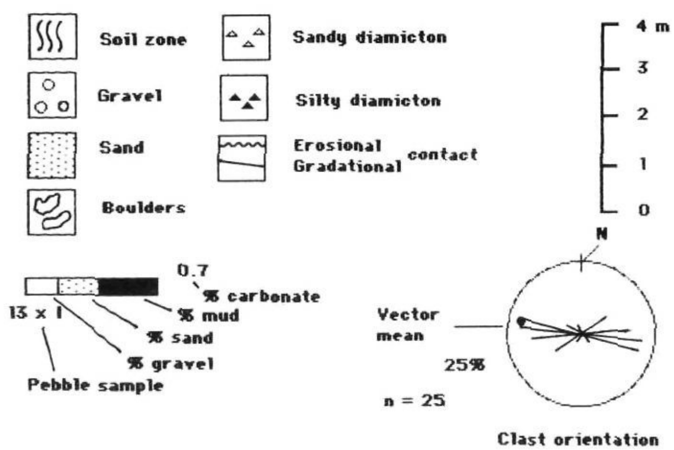
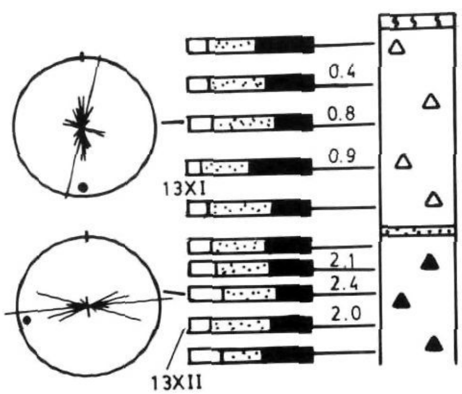
APPENDIX
SECTION DESCRIPTIONS

LEGEND



GOLDEN RAPIDS A

Location: St. Francis, ME USGS 15' quadrangle. On the St. John River, south bank 200 m downstream from the confluence of Wiggins Brook. UTM 5042E 52173N. Elevation 187 m.a.s.l. Described in July 1981.



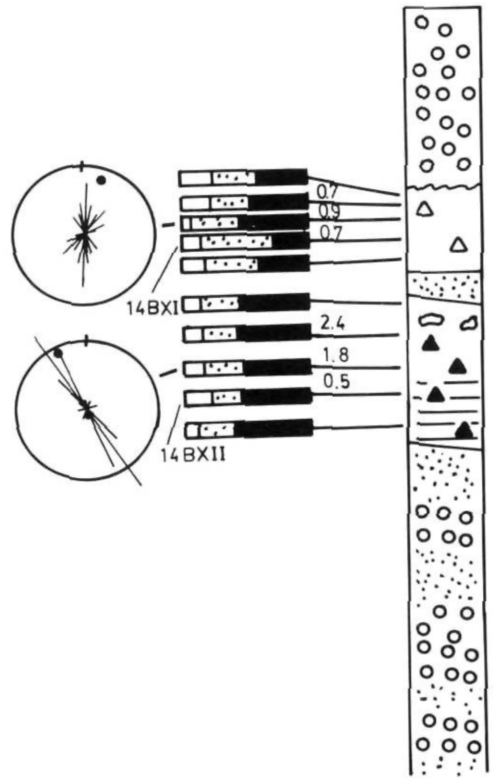
Diamicton, brown (5Y 5/4), silty sand, 20% stones, compact-very compact oxidation of matrix and clasts *slightly calcareous* — unit 2

Sand layer, coarse-grained, well sorted

Diamicton, gray (2.5Y 4/0), silty sand, silt increases toward bottom, 25% stones, calcareous, sharp upper contact, mottling at top — unit 1

GOLDEN RAPIDS B

Location: St. Francis, ME USGS 15' quadrangle. On road cut above the south bank of the St. John River, 75 m upstream from the confluence of Wiggins Brook. UTM 5037E 52170N. Elevation 202 m.a.s.l. Described in July 1981



Gravel, pebble-cobble, moderately sorted, imbrication at 340 azimuth, whole deposit is V-shaped indicating a channel deposit, erosional lower contact — unit 4

Diamicton, brown (5Y 5/4), *silty* sand, moderately compact, weathering of matrix and clasts, gradational lower contact with sand stringers — unit 3

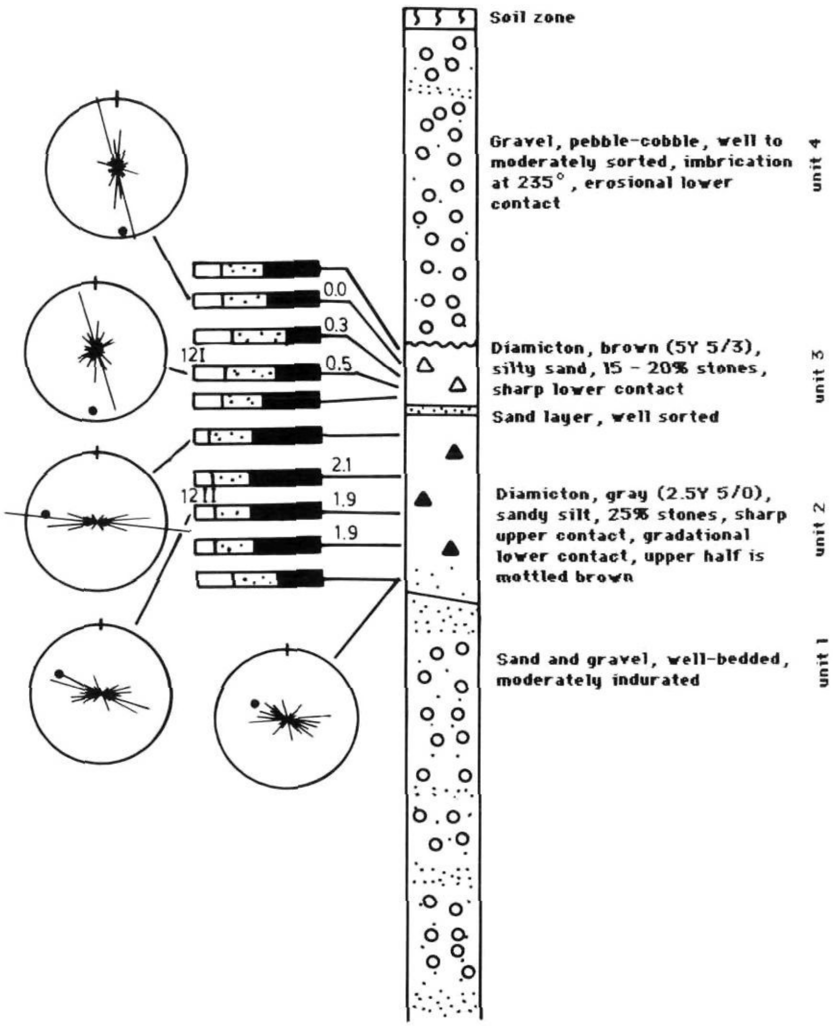
Sand layer, well sorted, medium grained

Diamicton, gray (5Y 4/1) mottled with brown, 25% stones, boulders near top, sandy silt, calcareous, lower portion becomes laminated — unit 2

Sand and gravel, pebble-cobble, moderately to well-bedded, folded and contorded layers and lenses — unit 1

McLEAN BROOK

Location: St. Francis, ME USGS 15' quadrangle. On road cut above the west bank of the St. John River, 75 m upstream from the confluence with McLean Brook. UTM 5052E 52183N. Elevation 207 m.a.s.l. Described in July 1981.



WESLEY BROOK

Location: St. Francis, ME USGS 15' quadrangle. On the St. John River, 100 m downstream from the confluence of Wesley Brook. UTM 5014E 52167N. Elevation 203 m.a.s.l. Described in July 1981.