SURFICIAL MATERIALS OF NORTHERN NEW BRUNSWICK (north of 47°N)

by

R.C. Gauthier

Navacel Enterprises Limited
365 Bloor Street East, Suite 1208
Toronto, Ontario
M4W 3L4

INTERPRETATION OF QUARTERNARY HISTORY

Preglacial drainage

Pre-quarternary morphological evolution is almost entirely responsible for the state of the present landscape. Major river courses are deeply entrenched in bedrock and their positions have been largely unaffected by glaciers. Such is the case of the upper Nepisiquit River, the Restigouche, the Upsalquitch and Tobique Rivers. However, the Rivière Verte, the Madawaska and the St. John River systems have been partially modified by the glaciers. The course of the Northwest Miramichi was redirected towards the Main Miramichi system, forming a "U" shaped detour covering more than 25 kilometres of its course. The central segment of the Tetagouche, Nigadoo and Millstream Rivers, whose positions were determined by a set of parallel faults were also affected by glaciers, which forced the course of the rivers to migrate laterally within the group of fractures.

The characteristics of minor river systems and the upper portion of the larger systems in the Maritime Plain have been affected by the glaciers. The positions of these rivers have been modified by the accumulation of disintegration drift. Lower courses of larger rivers are well entrenched in the sandstone and have re-established their original pre-glacial course.

Overfit valleys reflect the variable water regime at the time of deglaciation. The Tonogonops, Little Tobique and Mamozekel Rivers illustrate this situation; their courses were enlarged by glaciers and remain today disproportionate to the present river regime.

Preglacial Sedimentation and weathering

Limited of information was gathered about Quarternary preglacial events. Three types of observations about Quaternary activity are described; granite weathering, alteration of bedrock and accumulation of gravel in valleys.

Weathering of granite has occured in most of the granitic terrain of the Miramichi Anticlinorium zone. The grus has been described by Wang (1981), Gauthier (1980), Needham (1979) and Anderson (1962). Grus mantles the surface of granitic terrain in areas of low relief; it had often been reworked by glacier and was included in the till and glacio-fluvial sediments. The grus consists of a mixture of granule and sand-size angular rock crystals. The geochemical characteristics of the grus and of the fresh rock are similar; the index of chemical weathering (K, Na, Si) (Figure ______) for fresh and altered samples indicates a minimum amount of variability.

Figure ____ shows the mineralogical variability of the grains within different size fractions in the grus. More chemically susceptible grains (plagioclase and micas) become less abundant in the smaller grain size fractions. Grain count on thin section of fresh, solid granite samples provide a reference value for the mineralogical variability of the grus.

Physical and chemical alteration of bedrock is quite common in the New Brunswick Highlands. The abundance of sulphide minerals in the rocks make them susceptible to rapid weathering. It is not always possible to attribute this type of weathering to a pre-glacial origin, even if the exposed rock is covered by till. Post-glacial ground water infiltration and frost-heave together may have weathered the bedrock alone. The weathering observed in the Highlands on rock types other than granite may well be combined effect of the preglacial and post-glacial influence.

The weathering of the sandstone in the Maritime Plain is interpreted as evidence of pre-glacial alteration of the bedrock surface. The weathered material has generally been preserved from glacial erosion and has become integrated into the lower portion of the till, in a transitional sequence to be solid bedrock. No paleosol was observed. Thin beds of lignite and precipitated manganese oxyde are commonly mixed with this unit.

Pre-glacial gravel is found in the Maritime plain in several areas around the Tracadie Region. The gravel is located near the present valleys, and indicates a partial filling-up of the valleys. The abandoned segments were probably completely filled in and were not re-opened by post-glacial streams. There are other sites of gravel over-ridden by till which are not part of the stream systems. The pre-till gravel is predominantly composed of rounded pebbles and cobbles of distal origin. It contains large quantities of granite. Local sandstone represents less than 30% of the combined lithologies. Sorting is fair, and the material is commonly stratified. No paleoflow direction has been measured.

Ice Flow Directions

Ice flow indicators are unevenly distributed throughout the study area. They consist largely of striae, crag and tails and nail heads on polished bedrock and whale backs. On a small scale, information has been obtained from the orientation of fluting lineaments, morainic ridges and eskers about the directions of the last ice flow, which direction helps close gaps in areas where striations were not observed. Together, the flow indicators provide information about the direction of retreat of the last ice fronts, as well as information about the direction of last glacier progression and enough isolated examples to reconstruct former ice flow directions and to establish their relative chronology.

An effort was made during the field operations to note the ice-flow directional indicators. Striae are the most common source of information. A large number of outcrop observations allows a complete cross-check of the information as well as a good reconstruction of the regional ice flow phases. Minor late flows, because of their weak nature, left only a minimum amount of polished bedrock over the previous glacial flow striae. As presented on the maps, the striation sites recorded are a synthesis of several independent outcrops with one or several readings and reflect orientations that are consistant and which can be corroborated. Sense of flow was not recorded when no convincing observations colud be made from the outcrops. The density of the striation sites observed is largely determined by two factors: the bedrock type and drift thickness.

The bedrock type is the chief element determining the amount of striations. A fine grained isotropic rock surface is well polished and striated. The volcanics of the Miramichi Anticlinorium exhibit a dense system of striated outcrops. A coarser rock, such as granite, tends to shatter and the rock surface is easily grooved, and it may also form micro-striae on large mineral grains. A non-homogeneous rock, when influenced by bedding, foliation and fracturation is more likely to lose its glacial polish. Susceptibility to weathering is another element determining the amount of striated surfaces. The foliated shales and sandstones of the Matapedia Anticlinorium and the Gaspé Synclinorium and the sandstones of the New Brunswick Platform are hightly susceptible to physical weathering when exposed to the elements quickly lose all glacial polishing.

The other element determining the amount of striae is the thickness of the drift, on a regional basis. Frequency of outcrops in any given area is a highly variable element which reflects drift thickness and the morphology of the underlying bedrock. An irregular topography tends to make a thick drift blanket accumulate in the lower areas and leave rock summits barren and exposed to weathering. A flat topography favors an even deposition of a protective drift layer that tends to preserve events prior to the last flow direction. An undulating terrain favors an optimal situation to alternate cycles of erosion/deposition and allows the greatest concentration of glacial polished sites. The eastern half of the Miramichi Anticlinorium has such characteristics and exhibits the greatest abundance of flow indicators in the study area. Valleys, by channelling the ice flow, are also elements that affect the concentration of striated outcrops. The valley floor in the Kedgwick River, for example, is all heavily striated, unlike the barren interfluves.

An effort was made in the field to determine the direction and the sense of striations and to gather any information revealing the relative chronology of different systems. The determination of relative chronology includes the use of the following characteristics: cross-cutting relationship of two systems (large, older grooves with the stoss side of the depression striated by the younger system); striated crag and tail; orientation of two or three stoss rock facets eroding one another, with development of inter-penetrating edges.

The following types of features are used to determine the sense fo flow: crag and tail features (resistant nodule of rock or grain, creating a shadow of protected rock behind - scale: few mm to few metres); nail heads (small groove, increasing in width and depth, terminated by an abrupt assymetrical fracture at the down-ice end - scale: 1 to 3 cm); whalebacks (elongated outcrops with stoss end polished and striated, and lee end plucked or unpolished - scale 3 to 5 metres). Less common features also include: concentric and lunate fractures (mostly granitic rocks).

Observations collected in the study area allowed a partial reconstruction of the ice flow directions during deglaciation to be made, at time when ice-contact and glacial melt-out features were formed and sedimentation related to melt-water damming and glacio-fluvial activity were taking place. The compilation of ice-flow indicators provides the basis for the interpretation of the deglaciation history. Figure _____ is the synthesis of all ice-flow indicator for the last deglaciation and also contains some information about ice flow direction prior to the last deglaciation. Supplementary information supplied by Chalmers (1898) and Alcock (1932) are included in the compilation.

The Dispersion of Erratics

The dispersion of erratics is another element used to determine the ice flow directions. Different rock types have been used to establish an overall picture of transport. It is however impossible to establish a definite chronology on that basis. Erratics can be transported in reverse directions by different glaciers. Therefore, unless a dispersion trend can be identified, individual observations must be examined carefully. In order to be used effectively, a rock type source must have a position and a shape from which a dispersion pattern of a glacial transport could have developed. The rock type also has to be unique, so that it can be effectively differentiated on the field.

The sources used are the Caraquet dyke, the Pennsylvanian sandstone of the Maritime Plain, the Bathurst granite batholith, the Nigadoo granite stock, the Big Bald/Grand Lake granite batholith and the Mississipian red sandstone of the Tobique Valley.

The Caraquet dyke is defined by Hamilton and Gupta (1972) as parallel series of mafic dykes of Late Triassic age, varying in width up to 60 metres, cutting across the Pennsylvanian sandstone. The linear feature oriented 050° extend discontinuously throughout the study area from Caraquet through Waterton, in the Miramichi area, as traced from aeromagnetic anomalies. Known exposures used in the dispersion study are located in the Paquetville and Val Ducet area. The rock is typically dark grey to black, dense, fine-grained diabase. Chilled margins are locally present, in contact with the sandstone.

Erratics of diabase are found on both sides of the dyke in the surface till. Two kilometres west of the closest occurence of the dyke in the Val Doucet area, pebbles of the chilled contact zone were found in the till. The frequency of the diabase in the till on both sides of the dyke is too low to establish a meaninful dispersion trend. Nevertheless, the erratics indicate that there definitely were two opposite directions of glacial transport in the lowlands.

In areas where unconsolidated red beds of shale locally outcrop at the surface in the New Brunswick Platform, the reddish colour of the till derived from the shale is observed to the east and the west of the outcrop for a few kilometres. This situation has frequently been observed in the Allainville area and confirms that there were two opposite directions of glacial transport.

The greenish and reddish Pennsylvanian sandstone of the Maritime Plain is a unique lithologic group. No comparable sandstone is present to the west of its boundaries. No westward dispersal trend was observed in the till west of the boundaries between the New Brunswick Platform and the Miramichi Anticlinorium. Abundant volcanic and parasedimentary rock fragments from the Miramichi Anticlinorium are present in the till of the western New Brunswick Platform area. This observation confirms the predominantly eastward nature of the glacial flow in the area of contact between the New Brunswick Platform and the Miramichi Anticlinorium zones.

Erratic content in the till of the New Brunswick Platform is greater than 30%. The erratics represent a diversity of lithologies of a western provenance. Among these erratics, Chalmers (1887, 17M) refers to the inexplicable high content of a ubiquitous kind of granite, in the middle of a Carboniferous district, east of Bathurst. This comment does not seem justified in the light of the following factors: the presence of a large batholith up-ice, in the Bathurst area; the mechanical resistance of the granite to glacial abrasion; the presence of a variety of other up-ice lithologic types in the till and the contrast in hardness between the local friable sandstone and the distal lithologies. The granite clasts of pebble size generally represent less than 10% of the total pebble content. Other foreign lithologies account for another 20% of the erratic content of the pebble size. Their source area is the New Brunswick Highlands. No rapid decrease of erratic content is observed in an eastward direction, away from the highlands.

The Big Bald/Grand Lake region (maps 21-0/1 and 2) is occupied by a Devonian granite batholith. Striations recorded in the area indicate an eastward glacial flow affecting the entire area. Dispersion of granite blocks, cobbles and pebbles in till and at the surface confirms the eastward glacial flow direction. In the Long Lake area of contact between the granite and the phyllite, no granite erratics were found west of the boundary of the batholith. Transport is exclusively to the east? west: phyllite fragments are common in the till on granitic terrain, near the contact. East of the Big Bald area, up to 5% of the till content was granite pebbles, 25 kilometres from their source. This type of dispersion indicates a regional eastward glacial flow covering the entire area occupied by the Big Bald batholith.

The Mississipian red sandstone of the Tobique Valley is an enclave of distinctive clastic, friable rock preserved in a large depression of the Chaleur Bay Synclinorium. The till west of the contact of the red sandstone exhibited no trace of red sandstone. Past the boundary between the sandstone and the Devonian sedimentary rock to the east, the till is in a deep red colour, and sandstone clasts become a predominant component of the till. East of the sandstone enclave contact, the till continues to have a reddish colour over a distance of more than 15 kilometres. The eastward glacial flow helped establish a strong eastward glacial transport over the red sandstone of the Tobique Valley

Deglaciation

From the information gathered from the study area, glacial history can only be reconstructed with certainty for the period of the last glaciation. Stratigraphic in the St. John Valley is indicative of several glacial events, and may be related to the stratigraphic framework defined by Genes and Newman (1981) on the American side of the St. John River. Stratigraphic information about the St.John Valley has been presented by Lee (1955, 1959a, 1959b) and reviewed by Rampton and Paradis (1981b). The observations made by the author in the St.John Valley are presented in the stratigraphic section of this report and no new interpretation is suggested, due to the isolated nature and the scarcity of the sections described.

Deglaciation Framework

Glacial events in Northern New Brunswick have been divided in to one main glacial period and three deglaciation phases, in order to interpret the field observations made in the study area. Each phase of deglaciation is characterized by its own flow patterns and ice-contact systems. Phase 3 is subdivided into four periods, based to the lowering of a dammed glacial lake in the Upsalquitch Valley. Most of the information regarding the glacial history of the region is based on the last glaciation. Only a few observations can be attributed to earlier glaciations. They are mostly older flow directors as recorded by isolated striation sites in the New Brunswick Highlands (southward and westward flows) and till stratigraphy observed along the St. John Valley region.

The main glacial period recorded in the area is part of the activity of the Laurentide Ice Sheet during the Late Wisconson~~i~~an time. The main glacial period is synonymous with the Caledonian Phase as defined by Rampton and Paradis (1981b), although these authors thought that the event occurred in the Early or Middle Wisconsin~~i~~an age. During subsequent deglaciation phases, local centers of accumulation controlled the directions of flow; interlobate accumulations developed in several areas as a response to conflicting flow directions. Large areas revealed by accumulation of a disintegration moraine blanket, reflecting regional ice stagnation in the later stages of deglaciation.

Main glacial period

The definition of the late Wisconsin~~i~~an glacial period is based on the dispersal pattern of erratics throughout the study area, both from distal and proximal lithologies and on the collection of eastern striations recorded in many areas of Northern New Brunswick.

The most useful lithology is the Precambrian gneiss of the Canadian Shield. Although Central New Brunswick Devonian granite and isolated areas of gneiss provide a source of local granitic material, Precambrian erratics have been positively identified in all the St. John Valley region (up to 5% of the clasts content in till). Prest (1980, personnal communication) has obtained an average age of 1,090 $\pm$ 35 m.y. on granite cobbles of the St. John Valley from three Potassium-Argon age determination analyses (GSC, K-AR 3100, 3100A and 3137). The central New Brunswick Region is devoid of Precambrian clasts. Clasts of the Val-Brillant Formation, a white, hematite-pigmented quartzite, were observed in the Restigouche Valley, in the Kedgwick area. This unique rock type has a specific source: it forms a narrow band of rock in the Appalachian Mountains of the Notre Dame Mountain Regions. Its presence in the Restigouche Valley area is supportive of the concept of ice crossing the Appalachian barrier to reach New Brunswick.

All indications suggest the glacier covered the entire study area during the main glacial period. Although there is a discrepancy in the time framework, this phase is what Rampton-Paradis called the Caledonian Phase (1981a). Three characteristic types of ice behaviour in the region can be defined during this phase:

1. The eastern portion of the New Brunswick Highlands and the entire Maritime Plain were affected by an eastward flow.

2. The central part of the study area, forming a broad triangle pointing to

the east, was not touched by glacial erosion. Englacial transport dispersed a certain amount of local erratics. Most summits in the area exhibit evidence of physical weathering, with rock breakage determined by joint systems. In granitic terrains, chemical and physical weathering are present; the Big Bald area may be used to illustrate the typical development of tors at the summits of hills and accumulation of grus in lowlands. Lower areas, where ice thickness was greater, were covered by till deposition.

3. The St. John Valley region channeled the ice to the south-east, creating a divergent ice-stream directed to the central region of New Brunswick and the St. John Valley. A similar icestream developed in the Baie des Chaleurs, directing ice into the Gulf of St. Lawrence. Both ice flows were directly controlled by the activity of the Laurentide glacier. The two ice streams have their sources in lower passes across the Appalachian Mountains. They contribute to the sluggishness of the ice in the central portion of the study area.

Deglaciation, Phase 1.

The beginning of the deglaciation history is characterized by a drastic change in the ice flow pattern in the New Brunswick Lowlands. An independent ice-cap centered in the Gulf of St. Lawrence and Northern P.E.I., the Escouminac Ice Centre, (Rampton & Paradis, 1981a; Prest, 1967) prompted an ice-flow reversal in the eastern half of the Maritime Plain. As a result, ice previously flowing eastward in the rest of the Plain and in the Highland was diverted to the north-north-east and was forced to flow into the Baie des Chaleurs. In order to be effective, this flow pattern implies that the ice front in Baie des Chaleurs had retreated up to the Bathurst Bay area at least. This pattern of diversion has left abundant evidences of flow indicators in the region of the contact between the Maritime Plain and the New Brunswick Highlands: a well-developped fluted morphology, abundant directional striae, discontinuous esker segments and frontal morainic ridges. These directional elements are the result of a north-north-east flow diverted from the New Brunswick Highlands. The flow pattern is defined as the Nepisiguit flow pattern. Previous interpretations by Gauthier (1977, 1978) atttributing this pattern to an isolated lobe of ice have been rejected, as no distinctive boundaries to the east and to the west existed during this phase. To the west, the eastern flow of Highland ice was gradually diverted to the north. To the east, an unstable zone of interlobate interplay developed between the northern flow and the ice centered on the Guld of St. Lawrence. After reaching the Chaleur Bay, the interlobate system retreated to the south.

A till section, 1.5 km south of Bathurst reveals a superimposition of two tills reflecting the change in glacial flow direction. The lower till is greenish in colour and has a variety of clast types, reflecting the diversity of lithologies of the Tetagouche Group. Till fabric shows an eastward orientation of the elongated clasts, which indicates a glacial flow to the east during deposition. The upper till is reddish and contains granitic clasts from the Bathurst granite batholith, located to the south. Orientation of the long axis of clast confirms a north-south direction of glacial flow and relagates this till unit to Phase 1 of the deglaciation.

At 2.5 km south of Bathurst, an accumulation of ice-contact sediments, the Blue Mountain, is attributed to the retreat of the north-north-east ice-flow in the Nepisiquit region. It consists of 2 separate cores of material forming hills with more than 30 metres of relief. The cores consist of silty diamicton containing many angular cobbles and blocs. Granite of local origin is one of the dominant rock types. The flanks of the hills are covered with sorted and crudely stratified sediments that extend laterally into a thick accumulation of glacio-fluvial material in the area surrounding the hills. Accumulation is locally in excess of 30 metres (Finamore, 1978, seismic survey). To the east, the gravel is coarse and contains abundant granitic clasts. Paleocurrent measurements indicate an eastward flow. To the north and the north-east, the surface material is characteristically sandy and contains a mimimum amount of gravel. It is thought that the position of the textural contrast was determined by the maximum level of marine submergence in the area. Accumulation below sea-level was sorted during deposition. Above the 60-metre level, the material is coarse and sorting variable.

The Blue Mountain complex extends to the west and the south-west in a series of discontinuous ridges. To the south, a short esker ridge surrounds the Lake Papineau. A dense field of granite blocks is present at the surface for several square kilometres in the area. It is sufficiently dense to impede the development of the forest in certain sectors.

The retreat of the north-north-east flow has gradually opened the lower Nepisiquit River region. Isolated ice-contact ridges and segments of eskers were left behind during the retreat. When the ice-front retreated into the northern extension of the Northwest Miramichi divide, it dammed the water to form a glacial lake, in front of the glacier. The outlet of the lake established its course in the divide between the McKay and Gordon Rivers, at an elevation of 80 metres a.s.l.

During the retreat of the frontal system of the Nepisiguit flow pattern in the drainage basin of the Northwest Miramichi River, a glacial lake was dammed. A sequence of silt and clay described by Chalmer (1888) as marine and reinterpreted by Shaw (1936) as varves is exposed in the Sevogle River Valley, 2.8 km above its confluence with the Northwest Miramichi. The exposure of 4.3 metres show the presence of 370 couplets of silt and clay with a discordant sequence of gravel on top. The section extend below the river level to an unknown depth (Gauthier, 1978).

The varves are sedimented in a lake resulting from the damming of the Northwest Miramichi and Sevogle Rivers. Brinsmead (1978) referred to the presence of the glacial lake in the Sevogle and the Northwest Miramichi valleys as the Glacial Lake Sevogle.

The triangular region of confluence between the Sevogle and the Northwest Miramichi contains by a large accumulation of outwash and deltaic material. This sediment mass has been referred to by Brinsmead (1978) as the Glacial Lake Sevogle paleodelta. He differentiated two facies. A deltaic facies, at an elevation of 80 metres a.s.l., corresponds to the elevation of the McKay outlet in the Nepisiguit system. A facies of outwash material, with a channelized surface, developed from a reworking of previously deposited sediments, after the opening of the lake.

In the central and eastern portion of the Maritime Plain, a different glacier covered the area. Evidences of its presence includes the following: 1. Dispersion of local erratics towards the west (diabase of the Caraquet Dyke and red beds of shale); 2. Till fabrics with strong alignment and imbrication, indicating a westward ice flow (Paquetville area; Lamèque Island, coastal till sections); 3. Frontal morainic system, ice-contact ridges and outwash plain with paleocurrent directions indicating the proximal side of the complex to the southeast (Paquetville system); 4. Striation sites with an ice flow direction at 320° (Bartibog and Millstream Rivers area).

The Paquetville frontal morainic system marks the end of active frontal retreat. Stagnation south of the area has left a blanket of disintegration moraine which characterizes most of the region.

The zone of contact between the two divergent ice flow directions is represented by a large corridor of disintegration and waterlain material which is most developed in the region of Allardville. This corridor of desintegration is a zone of interplay between the two glacier flows, which developed a zone of interlobation and concentrated melt-water flow. To the south, in the upper Bartibog River area, the Nepisiquit flow pattern has left a succession of ribbed moraine oriented east-south-east; within the same area, striae showing a north-north-west ice flow direction are also present.

Two convergent flow directions in the Maritime Plain determined the type of deglaciation that affected the Maritime Plain. Rampton and Paradis (1981a) recognized the existence of both flow patterns in their study area, but attributed them to two distinctive deglaciation phases: the earlier Chinecto phase, (the NW flow in the Plain), centered to the west of P.E.I., and the Kent and Bantalor phases, which generated the Renous River flow pattern, the southern extension of the Nepisiguit flow pattern.

The two convergent ice flow directions have to be synchronous in order to exist. The cause of divergence of the central New Brunswick ice to the north in the Baie des Chaleurs is the existence of the Escuminac Ice Centre in the gulf. This late center of accumulation had grown enough to override the eastward ice flow from the central highlands and divert it towards the north. The New Brunswick ice was easily diverted because of its inactive center in the New Brunswick Highlands, resulting in a lack of glacial basal flow moving the ice into the lowlands.

In the area of the Bartibog River, the presence of ribbed moraines oriented north-north-west overlying the bedrock striated to the west indicates a gradual shift to the east of the interlobate contact zone of the two movements. This indicates that in spite of its earlier strength, enabling it to divert the New Brunswick ice, the Escuminac Ice Centre vanished more rapidly than the Central New Brunswick ice.

Deglaciation, Phase 2

The beginning of Phase 2 of deglaciation starts with the opening of the Northwest Miramichi River and the re-establishment of its post-glacial drainage. This event coincides with the disappearance of the Glacial Lake Sevogle. The Escuminac glacier retreated from the Miramichi estuary, allowing the present drainage of the Miramichi River system in the gulf. The beginning of Phase 2 is also characterized by the stagnation of the ice in the Grand Lake area, the end of the Renous River flow pattern and the beginning of the Tuadook flow pattern (Rampton & Paradis, 19~~7~~8 1a).

When the Northwest Miramichi River area had been deglaciated, ice in the highlands was still active. Striation chronology indicates that the western region affected by the Nepisiguit flow pattern was overridden by a later eastward re-advance of the ice from the highlands. In this narrow corridor of overlap, numerous field observations show bedrock surfaces with northward striations and superimposed, truncated rock faces of eastward striae. Although this fluctuation was minor and overrode less than 5 km of the area occupied by the previous Nepisiquit flow pattern, it indicates a reactivation of the highland ice. This re-advance did not leave any frontal ice-contact system, but its position is associated with the abrupt disappearance of the fluted morphology of the Nepisiquit flow pattern.

The event can be traced to the south, where a broad ice-contact position, the Millville/Dungarvon Phase, has been defined by Rampton and Paradis (1981b). The same system extends to the south of the St.John River, where Gadd (1973) traces an ice frontal system he called the "Canterbury Ice Margin". In Northern New Brunswick, a belt of ablation material has been attributed to the regional stagnation of the ice. The region of Serpentine and Long Lakes is characterized by the presence of a thick blanket of ablation material. Segmented eskers, systems of ribbed moraines, kames and kettles, and deranged drainage patterns, are among the common features observed in the area. The orientation of the features suggests a glacial flow direction at 110°, in accordance with the Tuadook flow pattern described by Rampton and Paradis (1981a).

In the Baie des Chaleurs area, observations suggest a reactivation of a lobe of ice in the Bay, fed by ice from the Matapedia Valley area. The Baie des Chaleurs ice flow and the glacier in the Central New Brunswick formed a discontinuous interlobate morainic system along the coast of the Baie des Chaleurs, stretching from Charlo up to Petit Rocher. This system was identified by Chalmers (1898) and Alcock (1923) as the Restigouche Kame System. Paleocurrent indicators show a systematic direction of the melt water flow at 120°, parallel to the orientation of the morainic ridges. Variability is locally observed (from 000° to 160°) and related to frontal segments of the system, and minor fluctuation of the Baie des Chaleurs lobe. Alcock (192__) observed sections of deformed varved clay overtopped by till in several area along the Baie des Chaleurs. This stratigraphic relationship suggests the lobe in the Baie des Chaleurs readvanced into the open sea and into isolated pondings along the glacier.

Two distinctive lithologies have been identified in the Restigouche Kame System which confirm its interlobate characteristics. Beds of the Bonaventure Formation outcrop along the coast in the Charlo and Dalhousie area. The rock is a distinctive friable, red clastic sediment, composed predominantly of sandstones and conglomerates. These beds occur exclusively to the north of the western extension of the Restigouche Kame System. The rocks form a small portion of the kame system in several localitions.

To the south, several intrusive granitic bodies are present. They are typically fine-grained, and are distinctive dark pink colour. These rocks are also found in the kame system.

No other rock types have a unique source that would allow them to be used as source indicators. Outcrops of the Bonaventure Formation are also found in the floor of the upper Tetagouche valley. Their topographic position and their distance from the kame system indicate that it is highly unlikely that these rocks were incorporated into the kame system. Moreover, ice flow direction does not favour such a direction of transport.

The Restigouche Kame system is interpreted as a time-transgressive feature. It extends over a distance of more than 60 kilometres, with some gaps. The eastern extension was formed on land, predominantly by the New Brunswick glacier. This segment consists of a sharp, well defined ridge of ice-contact material to the east of the Jacquet River, up to 35 metres high, gradually widening and decreasing in height towards the east. Numerous small fans of glacio-fluvial material have developed on the north side of the ridge. To the south, isolated damming between the ice and the ridge has resulted in the accumulation of isolated terraces of glacio-lacustrine material. This phenomenon is especially evident in the Jacquet River area, where the river had to breach the ice-contact ridge before it could re-establish its course.

The central area of the Restigouche Kame (between Dickie Cove and the Charlo River) was built under or at the level of marine water. The sediment indicates two types of occurrences: accumulation of silty diamicton with abundant blocks, and beds of sorted gravel and sand, gently dipping towards the east, with frequent glacio-tectonic deformations.

The seal-level at 60 metres a.s.l. has been responsible in some instances for the summit elevation of the kame. Under these conditions, the accumulation developed as a sub-surface ice-contact delta.

The western extension of the Restigouche Kame, in the area of Balmoral, was deposited at the edge of and outside the marine limits. The lower portion of the deposit has been wave-washed below 60 metres a.s.l., creating a distinctive break between the original kames and kettles morphology of the deposit and the smoothened, reworked marine surface.

After the inland ice had retreated from the Restigouche Kame System in the Charlo area, an extensive system of deltaic and outwash sediments was deposited completely masking the previous topograph of ice-contact sediments in the area. Up to 40 metres of outwash and deltaic sediments were accumulated in a broad plain, west of the Charlo River. As the sea-level lowered, the course of the Charlo River meandered over the area of accumulation. Marine benches were later eroded in the deltaic and fluvial terraces. The development of beaches and spits temporarily diverted the course of the Charlo River, thus eroding fluvial channels behind coastal barriers; such a channel is preserved south of the Charlo airport, and extends over 2 km in length, to a depth of 10 metres. North of the Charlo airport area, the marine facies changes: clay deposits form the lower portion of the sequence, covered by a thin cap of gravel and sand.

In the upper St.John Valley area, a drastic change of ice flow direction occurred during Phase 2 of deglaciation. An ice divide, situated to the west of the middle course of the Restigouche River, developed and caused the ice to flow towards the northwest. The region affected by this reversal show a strong pattern of uniform northern flow evidenced by abundant striation sites. To the south of the divide, the glacier flow was concentrated in the St. John Valley (Woodstock flow, Rampton & Paradis, 1981a). Northward glacial flow in the Edmunston area was not been recognized by Lee (1955) nor by Genes and Newman (1981); these authors interpreted the sens of the flow direction of striae in the opposite sense.

Deglaciation, Phase 3

Five broad positions or retreat of the ice front have been attributed to Phase 3 of deglaciation. Four of these positions have been defined on the basis of the water level variation of a glacial lake dammed in the Upsalquitch Valley and the presence of isolated ice-contact accumulations. The fifth position is based on the presence of ice-contact sediments in the Edmunston area.

The beginning of Phase 3 is characterized by the opening of the New Brunswick Highlands and the gradual retreat of the Baie des Chaleurs lobe. Two ice barriers were established, which caused the damming of two glacial lakes. One of them is a short-lived glacial lake at the head of the Mamozekel River in Nictau Lake. The glacial lake drained across the divide, in the Nepisiquit River, at an elevation of 312 metres a.s.l. Deltaic accumulations corroborate the existence of the divide at the same level in the Mountain Brook Valley, south of Nictau Lake. Accumulation of lacustrine fine sand is observed along the southwest area of Nictau Lake. Ice contact ridges are also present. One of them cut across the lake; others are segmented ridges observed on the lower valley slopes and in the lowlands between Lakes Nictou and Nepisiquit. The area of the divide, between the Nepisiquit and Nictou Lakes is covered with a thick accumulation of disintegration material, which was deposited in a structural depression, prior to the damming of the glacial lake of Nictau.

The second glacial lake developed in the Upsalquitch Valley. It is referred to as the "Glacial Lake Upsalquitch". Four successive phases have been defined, based on the position of successive lower outlets, opened during the retreat of the ice front.

Little information was obtained on shoreline deposits and erosion because of the dense forest coverage and the narrow fetch of the body of water, the short duration of each lake phase, and the low energy environment (mostly frozen lake surface) involved. Small deltaic terraces at the head of creeks and sorted gravel ridges (beach segments) formed during Phase 2 of the glacial lake were observed.

Sections of rhythmites are freshly exposed at several sites along the bank of the central portion of the Upsalquitch River. The rhythmites are topped by fluvial gravel. Maximum observed thickness of the exposed rhythmites is 2.5

metres; the deposit also extends below river level. Discordant fluvial gravel covers the rhythmites. Based on these observations, minimum deposit thickness is 4 metres. Pollen analysis made on nine samples from six locations submitted to Bob Mott (1981) (table __) indicates the presence of a barren environment. Pinus and Betula pollen are present; Herbaceous pollen types include Gramineae, Tubyliflorae and Artemisia. The low frequency of tree pollen suggests that forest coverage was absent during the sedimentation of the varves. Artemisia, Spagnum and some ferns existed near the body of water.

Position 1 of the Glacial Lake Upsalquitch occupied the upper course of the Upsalquitch River. The outlet used was the divide between the Nepisiquit the Upsalquitch drainage systems, though the Portage Brook Valley, at an elevation of 280 metres asl. More than 65 metres of sediment accumulated in the Portage Brook Valley, according to refraction seismic profiles made by Gauthier (1980) and Gagné (1981). Position 1 of the glacial lake is time-equivalent to the presence of the Glacial Lake Nictau.

Position 2 of the Glacial Lake Upsalquitch coincides with the opening of the Southwest Upsalquitch and Mamozekel Rivers. The opening of the Mamozekel River also marks the end of the Glacial Lake Nictau. During Pase 2, the Glacial Lake Upsalquitch established its outlet in the Southwest Upsalquitch and the Mamozekel Rivers divide, in the Oxford Brook, at an elevation of 220 metres a.s.l.

Position 3 of Glacial Lake Upsalquitch begins with the opening of the Eel River spillway, at 160 metres a.s.l. This outlet was used for a short period of time as the retreating ice in the Baie des Chaleurs was temporarily blocking several other lower outlets readily accessible. The outlet through the Eel River allowed a large amount of water to escape by this route. As a result, extensive deltaic material was deposited in the sea, in the Dundee area. The accumulation formed a succession of deltaic terraces that vary between 45 and 55 metres a.s.l.

The location of the ice front during Position 4 of the Glacial Lake Upsalquitch has been traced to the southwest through the Kedgwick-St-Quentin area, where a thin blanket of disintegration material and discontinuous ridges of ice-contact material are present. Numerous discontinuous ridges, kames, rillens and melt-water channels are present in the area. The same ice front, possibly at an earlier position, also extended into the Tobique-Plaster Rock area where ice-contact ridges are present (Rampton & Paradis, 1981b).

Position 4 of Glacial Lake Upsalquitch is characterized by the accumulation of an extensive sequence of deltaic material in the lower course of Christopher Brook. The lake level was established at 100 metres a.s.l. controlled by the divide of the Black Brook. Deltaic terraces were built up at 40 to 45 metres asl. During this phase, the lower course of the Restigouche Valley may have been included in the total extent of the glacial lake, although the fetch would have been very narrow. This possibility is based on the presence of isolated high terraces along the course of the Restigouche Valley.

Position 4 of the retreat has been extended into the St. John Valley, into the Grand Falls, Ste-Anne-de Madawaska and Rivière Verte areas, where successive isolated ice contact accumulations were observed (Lee, 1955; Thibault, 1981; Kite, 1981)

The gradual northern retreat of the ice front into the St. John Valley forced the ice divide established during Phase 2 of deglaciation to migrate to the north, which resulted in the development of an unstable glacier profile. It also forced the ice flow in the vicinity of the glacier margin to reverse its flow direction back to the south for the last deglaciation event. This reversal characterizes the type of retreat that took place during retreat position 5 of deglaciation Phase 3.

Valleys oriented parallel to the ice flow (Green River, Iroquois, Madawaska Rivers) were affected by lobe of ice progressing to the south-east. Kame terraces were built along the rivers, and area of ice disintegration developed in the central portion of the Green River and in the Iroquois River. Similar accumulations also developed in the Madawaska River, at St. Jacques and in the Baker Lake area.

This lobation event in the tributaries of the St. John caused a reversal of the paleo-current orientation of the glacio-fluvial sedimentary features recorded in the kames and the striation of bedrock in the valleys and the interfluves. With the exception of the floor of the Green River Valley, bedrock outcrops in all valleys and their interfluves are striated with crag and tails, nailheads and whalebacks indicating a westward glacial flow. Where bedrock under the kames is exposed, the westward flow is also observed on the bedrock surface. In direct contact with the bedrock, the ice-contact material exhibits paleo-current directions oriented to the opposite direction to the striae. This phenomenon is systematically observed in the Madawaska River, between St. Jacques and the New Brunswick border and the Iroquois Valley. The westward striations were formed during Phase 2 of deglaciation, at a time when an ice divide existed west of the Restigouche River. Rapid retreat of the southern edge of the glacier forced the ice divide to migrate to the north and, as a consequence, reverted the ice flow direction to the south. The southern ice-front had its activity concentrated in the valleys, as lobes developed and formed the kame terraces in the valleys. The floor of the Green River Valley is striated to the south. In this valley, the lobe produced enough activity to striate the rock. Outside the valley, on both interfluves, bedrock is striated to the west.

Direct proof of this relationship is provided at St. Jacques, on the south side of the Madawaska River. Bedrock exposed under an ice-contact complex that forms the kame terraces along the valley reveals a relative chronology of ice flows where a younger southward flow is superimposed on a northwestward flow. The southward striations are recorded on friable shale beds and on the stoss side of the large westward crag and tails. This site confirms the interpretations of a late minor reversal of ice flow, concentrated in the valleys.

Other areas of ice-contact accumulation are present to the west, in the St. John Valley. The major concentrations are found in the Saint Hilaire area and at Pelletier Mills. They are also associated with the northward retreating ice front, resulting from a previously westward oriented ice flow.