GEOLOGICAL SETTING AND QUATERNARY DEPOSITS OF THE OTTAWA REGION

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Physiography and bedrock geology are the dominant factors that control both the patterns of glaciation and the nature and distribution of Quaternary sediments of the Ottawa region. The distribution of highlands and lowlands determined the patterns of ice flow during glacier advance, and the pattern of flow and location of residual ice blocks during retreat. Texture and composition of glacial sediments are controlled by the composition of bedrock from which they were derived, and the distribution of fine grained waterlain sediments is controlled by location of topographic basins.

PHYSIOGRAPHY AND BEDROCK GEOLOGY

Laurentian Highlands (Bostock, 1970; Fig. 2) rise abruptly to elevations of 400 m along the Eardley Fault escarpment on the north side of Ottawa River valley (Fig. 3) and from there northward consist of rolling hills that gradually rise to elevations of at least 600 m in the vicinity of Maniwaki and Mont-Laurier (Fig. 1). The difference in elevation between the lowland and the area immediately north of the Eardley escarpment is almost 300 m and relief within the highlands in places approaches 200 m.

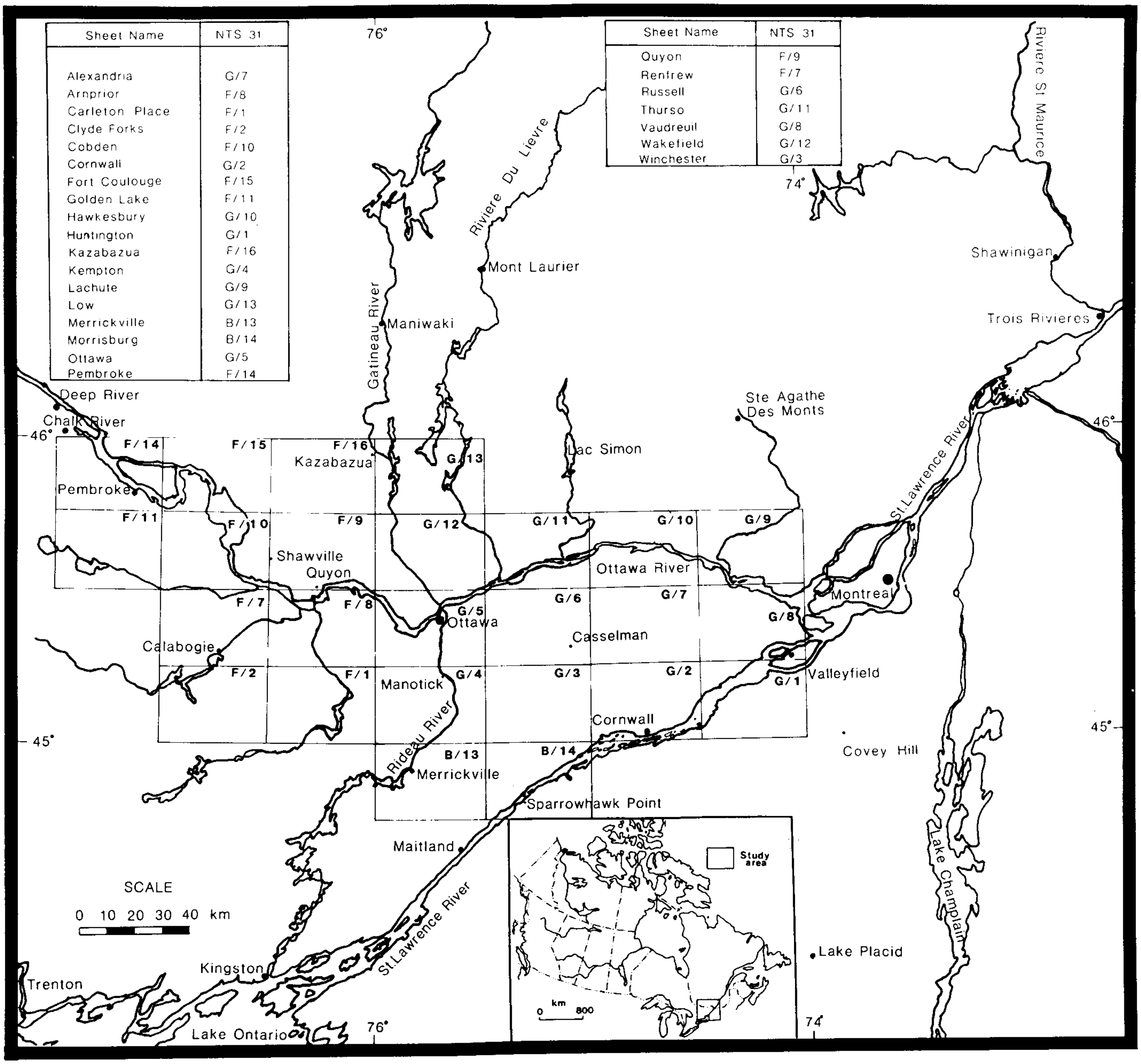

Figure 1. Location map showing the boundaries and names of NTS 1:50 000 scale map areas.

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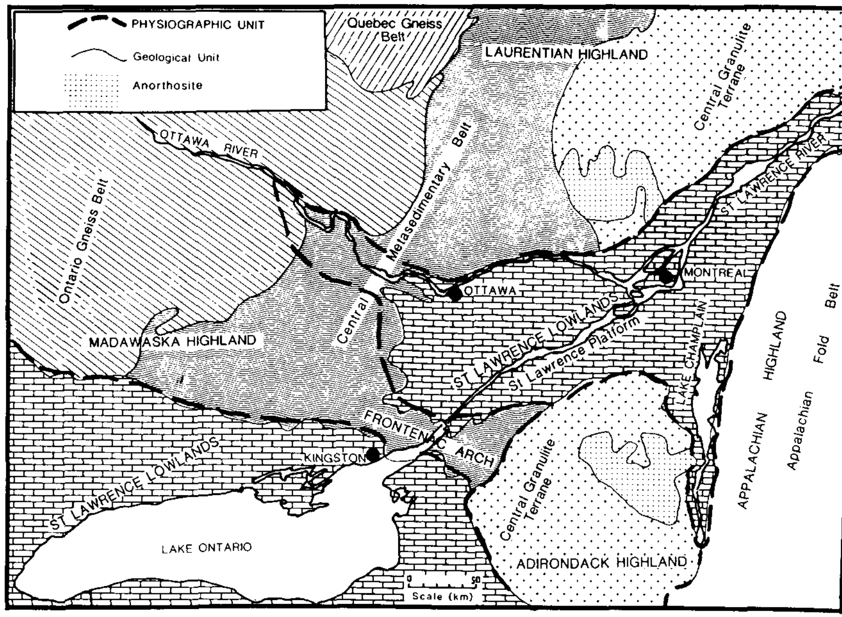

Figure 2

Physiographic and bedrock map of the Ottawa region. Physiographic subdivisions after Bostock (1970); bedrock geology after Sanford et al. (1979).

In the western sector of the area another part of the Laurentian Highlands, known as the Madawaska Highland, is separated from the lowland by major fault systems trending northwesterly (St. Patrick Fault scarp) and southerly (Fernleigh-Clyde Fault) from the vicinity of Calabogie (Fig. 1, 3). Elevations attain 300 m (in some places 450 m) along the St. Patrick Fault scarp and decline southward towards the St. Lawrence Lowlands where Precambrian rocks are overlain, in a minor scarp, by Paleozoic rocks dipping gently towards Lake Ontario (Kay, 1942; Fig. 2). South of St. Lawrence River in New York State, the Adirondack Mountains rise in graduated steps of moderate relief to elevations in excess of 1200 m in the High Peaks area, near Lake Placid (Fig. 1). Bridging the area between Madawaska Highland and the Adirondacks is a low arch of Precambrian rocks, the Frontenac Arch (Fig. 2). This low ridge constitutes the sill at the outlet of Lake Ontario where it is represented by the Thousand Islands in St. Lawrence River. All other areas of the region are underlain by relatively flat lying sedimentary rocks of the St. Lawrence Lowlands characterized by surface elevations which do not exceed 150 m a.s.l. and relief which is generally less than 30 m.

The main structural feature of the region is the Ottawa-Bonnechere Graben system (Kay, 1942; Kumarapeli and Saull, 1966; Kumarapeli, 1985). Upstream from Ottawa, the graben is defined by the Eardley Fault (north) and the St. Patrick Fault (south) that parallel the portion of Ottawa River between Ottawa and Pembroke (Fig. 3). This graben system and related less prominent faults control the location of a preglacial valley in the Ottawa-St. Lawrence system which connects with the "Laurentian Channel" of the Gulf of St. Lawrence. Other related features in the vicinity of Ottawa are the prominent cuesta on the right bank of Ottawa River just east of Ottawa and waterfalls on the Rideau and Ottawa rivers.

Precambrian bedrock in the Gatineau Valley region of the Laurentian Highlands, in the eastern part of the Madawaska Highland, and along the Frontenac Arch are described by Baer et al. (1977) as belonging to the Central Metasedimentary Belt (Fig. 2) which consists of "marble, quartzite, aluminous gneiss and metavolcanics" whose metamorphic grade "ranges from upper greenschist to granulite but is mainly amphibolite". West of Gatineau Valley and in the western Madawaska Highland, highland rocks belong to the Ontario Gneiss Belt (Fig. 2) which includes gneisses that "are dominantly quartzo-feldspathic, pink or grey, well-layered, and mainly at amphibolite, rarely granulite grade of metamorphism". East of the Central Metasedimentary Belt and in the Adirondacks the rocks are described (Baer et al., 1977) as Central Granulite Terrane (Fig. 2) whose rocks are "leucocratic to melanocratic para- and orthogneisses of unknown age". Metasedimentary rocks in these terranes are early Proterozoic (1600-2500 Ma) and Archean (older than 2500 Ma) and the latest phase of metamorphism and mountain building was related to the Grenville Orogeny ca. 1000 Ma.

The St. Lawrence Lowlands, in most of this region, are underlain by sedimentary rocks of the St. Lawrence Platform that lie unconformably on the Precambrian crystalline basement. Baer et al. (1977) described the St. Lawrence Platform rocks as: "Basal, northwesterly transgressive Cambro-Ordovician orthoquartzite....grades upward into Lower Ordovician carbonates. Disconformably overlying Middle Ordovician carbonates are succeeded by southerly thickening black shale and siltstone and the Upper Ordovician Queenston deltaic redbeds....". No younger pre-Quaternary rocks are present in the area. The sedimentary rocks of the St. Lawrence Platform are cut by northwest and northeast trending faults of the Bonnechere graben system which supposedly formed during opening of the Atlantic Ocean in Cretaceous time but which follows a similar, late Precambrian system which is associated with minor intrusives, such as carbonatites.

QUATERNARY DEPOSITS AND HISTORY

Pleistocene deposits consist almost exclusively of glacial and related deposits. One exception is at Pointe-Fortune, on Ottawa River 100 km east of Ottawa, where 10 m of nonglacial sediments occur between two tills (Veillette and Nixon, 1984). These deposits could relate to an Early Wisconsinan Interstade or might even be older.

Wisconsinan glaciation

Wisconsinan glaciation began with early ice accumulation in the highlands of Nouveau-Quebec (Occhietti, 1982). The ice sheet expanded progressively westward and southward, occupied the central St. Lawrence Lowland and Lake Champlain area, and extended into the Ottawa region. In the Laurentian Highlands (Gatineau Hills) north of Ottawa River, a major ice stream in the Gatineau and adjacent subparallel valleys produced an ice lobe that

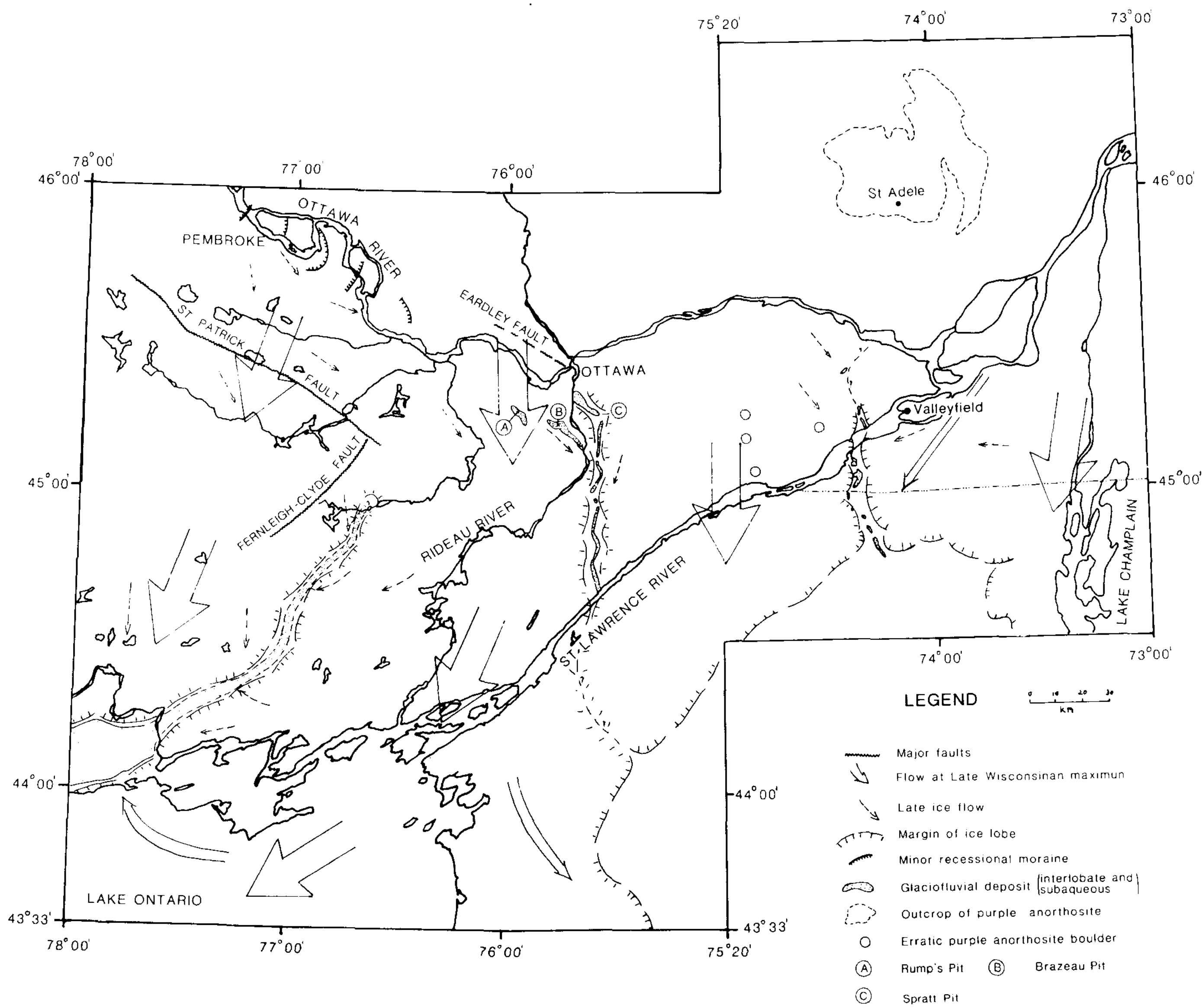

Figure 3. Main pattern of Late Wisconsinan ice lobation and flow

flowed south across Ottawa River valley and swung southwestwards and westward across the Frontenac Arch to flow into Lake Ontario basin. Most authors refer to the southern part of this lobe as the Ontario or Lake Ontario Lobe and Gadd (1980a) referred to it as the Ottawa-Lake Ontario Lobe in order to emphasize its Laurentide origin. Ice flow in Ottawa Valley upstream from Ottawa was initially southeastward, but as the ice sheet thickened it overtopped the fault scarp barrier on the south side of Ottawa Valley. At that time ice flow was southward across the valley and the Madawaska Highland. This movement produced the Madawaska Highland Lobe that extended south towards the Ontario basin.

Ice flowing across Ottawa Valley east of Ottawa moved mainly southward towards the Adirondacks but was deflected southwestward by that highland and by the Lake Champlain Lobe which already occupied the Lake Champlain basin. Some of this southwestward deflected flow apparently carried distinctive mauve to maroon coloured anorthosite from the Sainte-Agathe area north of Montreal to the area north of Cornwall (Fig. 1) and on through the Lake Ontario basin to Buffalo, New York (Gadd, 1981).

Gadd (1980a,b) used north trending interlobate ice contact and glaciofluvial deposits and the convergence towards these linear features of fine striations and other ice flow direction indicators as evidence that the retreating Late Wisconsinan ice margin in these areas had several lobations. The main ice lobe positions are delineated by interlobate deposits trending southerly from Rigaud Mountain to and beyond St. Lawrence River, extending from Ottawa to and beyond St. Lawrence River, and trend southwest from the vicinity of the Fernleigh-Clyde Fault (near Calabogie) to the eastern tip of Oak Ridges Moraine at Trenton, north of Lake Ontario (Fig. 3). The existence of these lobes suggests that the retreating ice margin was not the relatively straight, roughly east-west line extending between the eastern end of Oak Ridges Moraine and Covey Hill as proposed by Prest (1970), Karrow et al. (1961), and Dreimanis (1977).

At the time of deglaciation the St. Lawrence Lowlands were isostatically depressed below sea level. Proglacial lakes developed as ice masses shrank in the Lake Ontario basin to the west and in Lake Champlain basin to the south. As the ice was removed from lower St. Lawrence Valley to the east, marine waters invaded the area and the Champlain Sea developed (Elson, 1969a). There are two different ideas on submergence of the Ottawa area. Those who visualize a straight ice margin (see above) contend that St. Lawrence Valley between Montreal and Lake Ontario opened early so that glacial lakes in the Lake Ontario and Lake Champlain basins joined and extended into the Ottawa area. Retreat of ice near Quebec City then permitted the Champlain Sea to invade the area. This does not, however, explain why radiocarbon dates on marine shells from beach deposits near marine limit in upper St. Lawrence Valley are consistently several hundred radiocarbon years younger than those of the Ottawa and Gatineau valleys. Karrow (1981) and Hillaire-Marcel (1981) suggested that the discrepancy results from the northern shells containing old carbonate originating from glacial meltwater. As an alternative, Gadd (1980a) suggested opening of Ottawa Valley in early Champlain Sea time by a calving bay mechanism. He proposed that a calving bay would have extended along the Laurentian Channel and entered the deeper Ottawa Valley rather than penetrating the shallow upper St. Lawrence Valley. He referred to calculations by Thomas (1977) to support this hypothesis. A corollary of this proposal is that residual ice would have remained in upper St. Lawrence Valley south of the calving bay keeping marine waters from entering that area until some time later. Under this hypothesis, a proglacial lake could not have formed in the Ottawa area prior to arrival of marine waters, and Lake Iroquois in the Lake Ontario basin could have remained behind the residual ice at the time the Champlain Sea occupied the Ottawa area. The calving bay hypothesis provides a means of explaining the age discrepancy between marine shells in the Ottawa area and those in upper St. Lawrence Valley, but several other lines of evidence are in conflict with this proposal (for further discussion see Fulton and Richard, 1987).

Quaternary deposits

Glacial deposits in the area closely reflect the regional bedrock geology. Glacial and glacially derived sediments eroded from Precambrian rocks generally have sandy to gravelly textures and are either noncalcareous or variably calcareous depending on the local abundance of Precambrian marbles and their position in relation to flow from areas of Paleozoic carbonates. In the St. Lawrence Lowlands area, equivalent sediments are highly calcareous. The general distribution of tills of this region is shown in Figure 4 and they are discussed in more detail by Kettles and Shilts (1987).

Glaciofluvial sediments are common deposits in the Ottawa region. The most studied glaciofluvial deposits occupy ridges which rise above or are buried by marine deposits within the Champlain Sea basin. These are interpreted as having been deposited where meltwater conduits debouched from the ice into deep marine waters (Rust, 1977). These features were heavily reworked during regression and are capped by fossiliferous marine sediments (see Rust, 1987). In western parts of the basin, ridges and isolated bodies of glaciofluvial deposits occur in arcuate patterns. These isolated deltas and ice-contact fan complexes were deposited at the margin of an ice tongue retreating westward in Ottawa Valley.

Small eskers, and various types of outwash including kettle and kame terraces occur above marine limit in the Madawaska Highland. Most such deposits are small in extent but they occur in most of the valleys and lake basins of the area. Extensive glaciofluvial deposits lie near and north of marine limit but few details are available on their the nature and distribution; they consist of a variety of stratified sediments ranging from bouldery gravel to fine grained sand. In most places local units are well sorted, washed, and stratified but are deformed, are juxtaposed with contrasting units, are cut by closed depressions, and occur as hummocks and irregular benches. One major area of glaciofluvial sediment lies within the northern limits of the Champlain Sea north of Quyon and Shawville (Fig. 4). Along its southern margin it has been completely buried by Champlain Sea sediments but farther north it occurs as hummocks separated by hollows partly filled by marine sediments. Outwash terraces occupy many valleys north of this area and outwash fans are common at the edge of Ottawa Valley. Apparently this was an area where abundant glaciofluvial sediments were deposited on and at the margin of stagnant ice sitting in the Ottawa Valley.

Isolated bodies of glaciofluvial sediments occur in segments of north shore valleys lying below marine limit. Generally these are attached to one or both valley walls and apparently formed at locations where englacial or supraglacial debris, which was being flushed through these valleys, was trapped. Above marine limit, especially in the area adjacent to Gatineau Valley, glaciofluvial sediments line the bottoms of most valleys; these occur either as ridges and kame terraces, which apparently formed in valleys that were largely filled with ice at the time of sediment deposition, or terraces and kettled terraces, which formed in valleys that were largely ice free at the time of outwash deposition. It may be noted that the outwash terraces and fans in this area appear to have been constructed in short segments, each segment beginning at a lake and ending a few kilometres downvalley. One particularly large area of outwash lies in the northwest corner of the Kazabazua map area (Fig. 1, 4). It has been suggested that this might be related in some way to the glacial activity that to the east constructed the St. Narcisse Moraine (LaSalle and Elson, 1975; Fig. 5).

Preliminary maps showing the limit of the Champlain Sea were presented by Fransham et al. (1976), but the limit on these is based primarily on the elevation and distribution of fine grained sediments. Figure 5 is a summary of current knowledge of marine limit in the western basin of the Champlain Sea. It is taken largely from unpublished data by J-S. Vincent (Geological Survey of Canada) and Occhietti (in press) and is based on location of deltas and beach features in addition to the distribution of fine grained sediments. Of particular note is the area in Gatineau Valley which supposedly was contiguous with the Champlain Sea but was occupied by freshwater. Vincent (in press) explained that the former presence of a large water body in this area is based on the work of Dadswell (1974) and that the interpretation that this was freshwater is based on a lack of evidence that would prove the rhythmites, which are present in this area, are of marine origin.

Late Pleistocene and postglacial fine grained sediments as thick as 100 m occur in the Ottawa basin. The thickest deposits of these materials occur in deeper parts of the bedrock valley and adjacent to the north shore of the basin. Deposits on the south side of the divide between Ottawa and upper St. Lawrence Valley are generally thin and discontinuous. This suggests that the great bulk of sediments entered the basin during deglaciation of the north shore of Ottawa Valley and currents were such that most sediments were trapped in basins adjacent to the present position of Ottawa River. The limited thickness of fine grained marine sediments in upper St. Lawrence Valley might also be used as evidence that this area was occupied by stagnant ice during degaciation of the area to the north so it did not receive as much sediment as the Ottawa basin.

The fine grained marine sediments occur in several lithofacies which are best observed in deep borings. Cores up to 100 m in length are described briefly by Gadd (1977) and in more detail by Gadd (1986b). In stratigraphic order the suite consists of: varve-like rhythmites, massive clays and silty clays, laminated silty clays (red and grey banded) with some

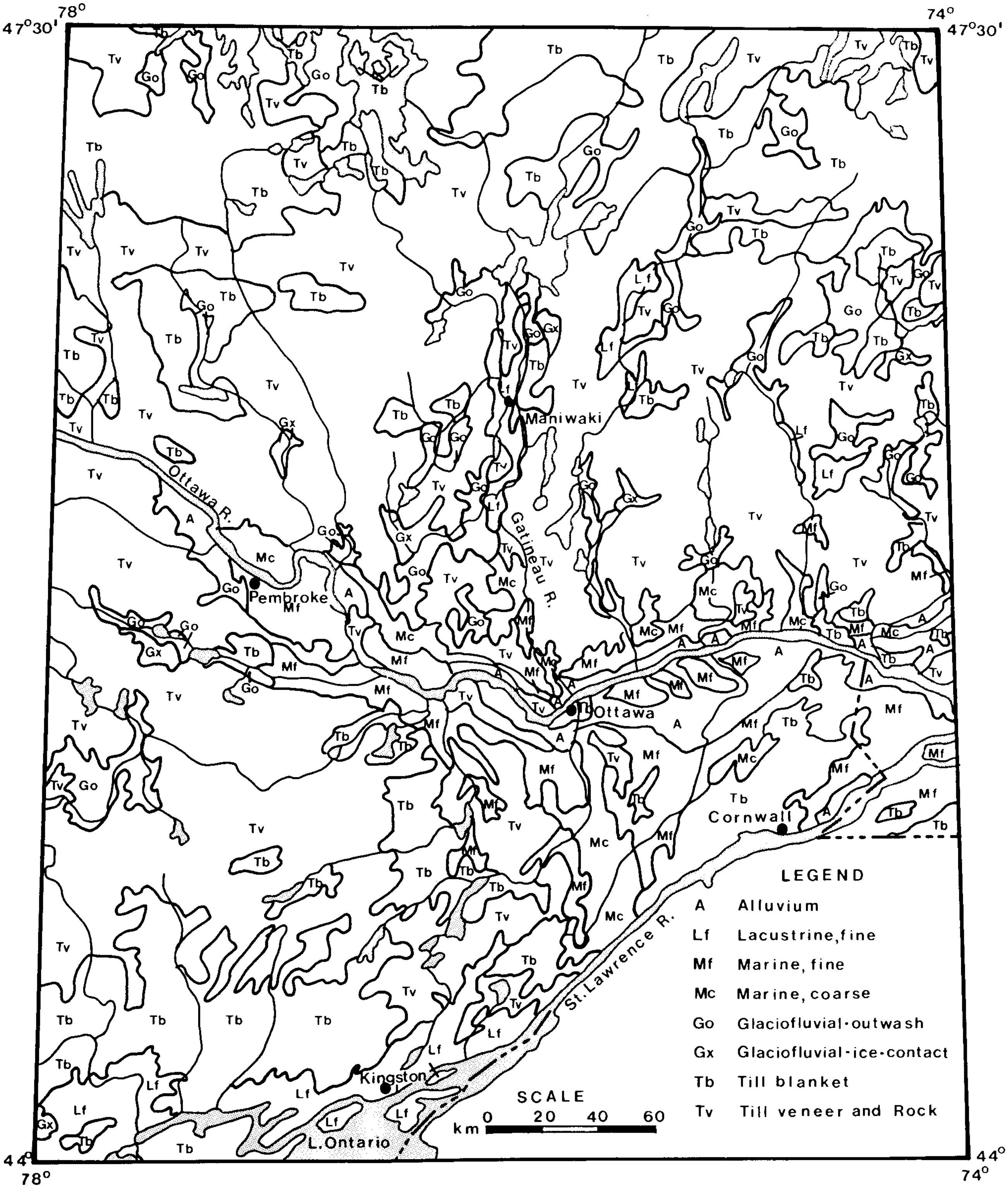

Figure 4. Surficial materials of the Ottawa area; geology compiled at a scale of 1:1 M by N.R. Gadd and J.J. Veillette, Geological Survey of Canada

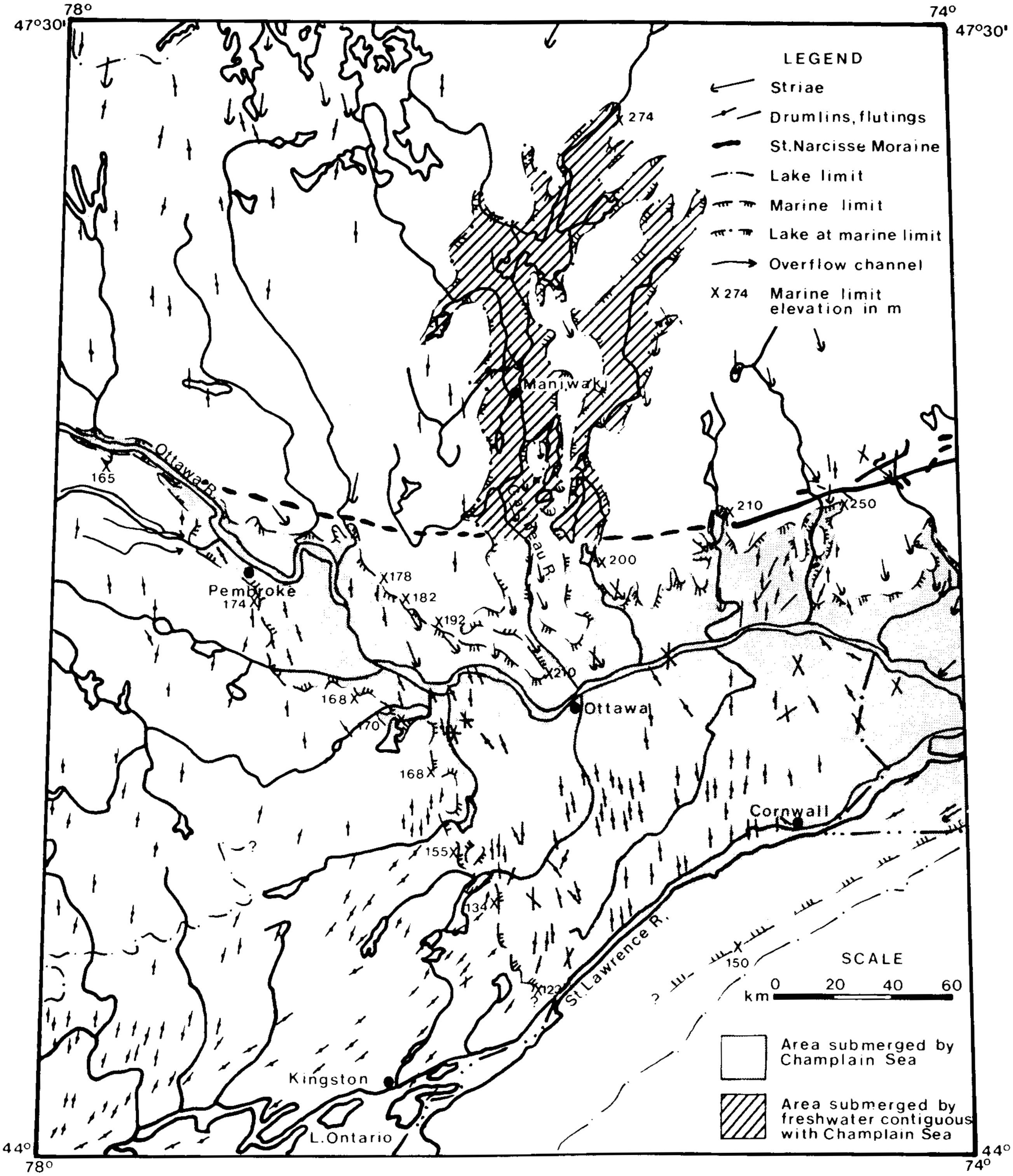

Figure 5. Marine limit in the western basin of the Champlain Sea, glacial flow features, and miscellaneous late glacial features of the Ottawa Region. Limit of Champlain Sea is from an unpublished compilation by J-S. Vincent, Geological Survey of Canada.

sand, and silty sand and sand with abundant channel structures. All contacts within the suite are gradational, suggesting sedimentation without significant erosional breaks. The lower laminated deposits are quiet water sediments derived from a nearby glacial source and deposited in freshwater. The massive clays and silty clays were similarly derived from a glacial source but were deposited in a marine environment. The upper sediments are largely the product of a delta migrating through the area as isostatic uplift drained the Champlain Sea.

The similarity of the older rhythmites to glacial lake varves was noted by earlier workers (Johnston, 1917; Antevs, 1925) and the sediments have been attributed to a glacial lake named glacial Lake Frontenac (Leverett and Taylor, 1915) or glacial Lake St. Lawrence (Goldthwait, 1971). According to Prest (1970) and Clark and Karrow (1984), this lake was part of a single lake that extended via upper St. Lawrence Valley from the Lake Ontario basin to the Lake Champlain Valley. If Gadd (1980a) is correct and a calving bay extended up Ottawa Valley, there would have been no opportunity for a glacial lake to precede the Champlain Sea in the area and the varve-like sediments would have to be related to an area of freshwater in a zone of maximum meltwater influx at the head of the calving bay.

The massive grey clays and silty clays were deposited in parts of the basin subject to high sediment influx at the time of deglaciation and in deeper parts of the basin following deglaciation. The younger laminated silty clays and silty sands can be related to the fluvial system that operated following deglaciation. Gadd (1986b) concluded that a major delta system developed in Ottawa Valley near Chalk River and another in Gatineau Valley near Kazabazua. These deltas prograded seaward as offlap of Champlain Sea took place and thus the several delta facies were stacked or superposed in a more or less continuous series. These delta facies included laminated red and grey silty clays with sand lenses and some turbidite beds, and silty sand and sand displaying channel structures. As the delta tops emerged, the modern drainage system was incised and two new facies of sediment were produced, a sandy facies in channels and a silty clay overbank facies in slack water areas.

The legacy of these proto-fluvial systems is a series of channels and cut terraces that largely parallel the present river channels (included in unit A of Fig. 4). In some parts of the area the terraces and channels are underlain by marine clay, locally with a thin cover of fluvial sand. In places the incising river uncovered buried glaciofluvial deposits or exposed till or rock ridges; bars of sand and gravel were deposited downstream from these sites. Rock areas that were exposed were swept free of sediment and bouldery lag was left on top of exhumed glaciofluvial deposits and till. Many large landslide scars indicate that during channel cutting the saturated clays that made up the channel walls were unstable. In some places landslide deposits lying on the channel floor indicate that failure occurred after the channels were abandoned. In many places, however, landslide debris has been removed from the toe of the scars suggesting that many of the slides occurred at a time when flow in the channels was sufficient to remove the slide debris. Slope failures are still occurring in the area but these are largely induced by human activities or occur in areas where rivers or streams are actively undercutting clay banks.

Eolian processes were active in the area immediately following deglaciation. This is shown by the presence of stabilized dunes in most areas underlain by sand. In addition a cap of loessal sediment several centimetres thick is present in most parts of the region and a blanket of silty cover sand, up to 50 cm thick, occurs in areas of abundant glaciofluvial, marine, and fluvial sand. Peat bogs have developed in poorly drained areas such as abandoned river channels; Mer Bleue on the eastern outskirts of Ottawa is a good example of a large peat bog that has developed in such a feature.

The chronology of late Quaternary events in the Ottawa region is discussed by Fulton and Richard (1987) but is mentioned briefly here for completeness. There is no information on the timing of the beginning or maximum phases of the last glaciation. Ice is known to have begun to retreat from its maximum position in New Jersey by 18.5 ka (Cotter et al., 1985). The Ottawa basin apparently was undergoing deglaciation by 12 ka when the Champlain Sea entered the area.[1] By 10 ka the water remaining in the basin was sufficiently fresh to support **Lampsilis** (Rodrigues, this publication) and by 8 ka many of the early proto-Ottawa River channels were abandoned and had become the sites of peat bogs.

[1] A date of 12 700 ± 100 BP (GSC-2151; Richard, 1978) at Clayton west of Ottawa is controversial. Some consider it to be too far out of line with other dates in the area to be reliable (see Fulton and Richard, 1987); others accept it at face value.