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THE EVOLUTION OF GLACIAL LAKES BARLOW AND OJIBWAY, QUEBEC AND ONTARIO

J-S. Vincent
Léon Hardy

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Preface

Large areas of the Canadian Shield of northwestern Quebec and northeastern Ontario, commonly known as the Clay Belt, are covered by thick sequences of lacustrine clays which have had an impact on the economic development of the region. The extensive clay plains have made farming feasible in this northern area and they generally support commercial stands of trees to benefit the lumber industry. However, the clay masks bedrock, making mining exploration and exploitation more difficult and creating engineering problems for road building and construction.

During the retreat of the Laurentide Ice Sheet, water produced by the melting ice was commonly dammed at the ice margin, forming large glacial lakes in which thick accumulations of clay and other sediments were deposited. This report, which describes the evolution of glacial lakes Barlow and Ojibway, provides a framework for an understanding of the formation of landforms and deposits in the Clay Belt, as well as a description of the postglacial history of the region. The information provided in this report will be useful as the area undergoes further economic development.

D.J. McLaren
Director General
Geological Survey of Canada

Ottawa, February 1979

This is a revised, somewhat expanded version of "L'évolution et l'extension des lacs glaciaires Barlow et Ojibway en territoire québécois", originally published in Géographie physique et Quaternaire (v. XXXI, no. 3-4) and reproduced here with permission of the journal.

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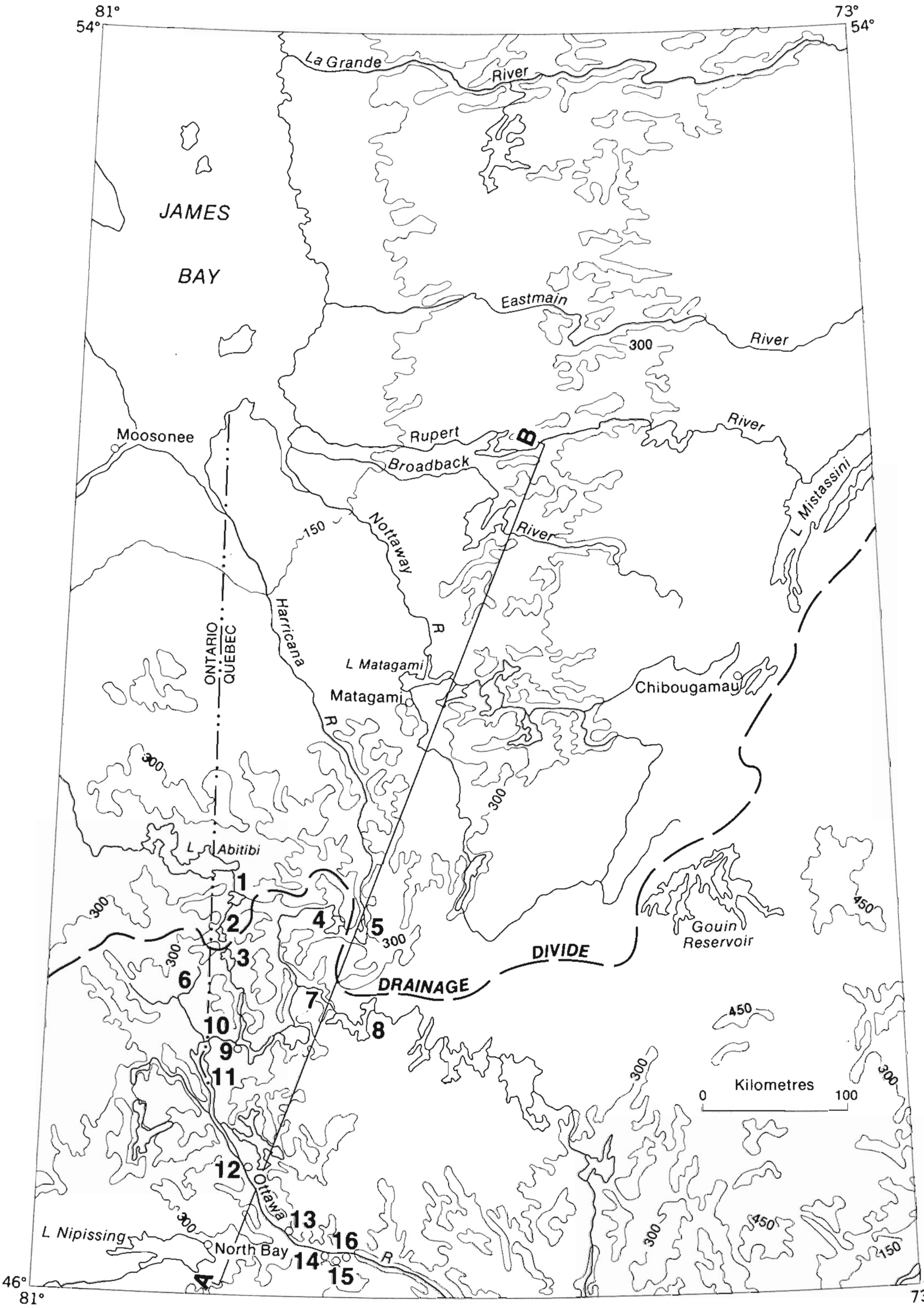


NUMBERED LOCALITIES

1. Lake Duparquet	5. Lake Malartic	9. Angliers	13. La Cave
2. Lake Dasserat	6. Larder River	10. Des Quinze River	14. Deux Rivières
3. Lake Opasatica	7. Kinojévis River	11. Lake Timiskaming	15. Aylen
4. Lake Preissac	8. Décelles Reservoir	12. Témiscaming	16. Bissett

Figure 1. Location map showing place names, the Hudson Bay-St. Lawrence River drainage divide, and the plane of projection for the shoreline distance diagram (see Fig. 2).

THE EVOLUTION OF GLACIAL LAKES BARLOW AND OJIBWAY, QUEBEC AND ONTARIO

Abstract

A new interpretation of the last phases of the post-Algonquin glacial lake and of the main phases in the evolution of glacial lakes Barlow and Ojibway is presented, based on a synthesis of data collected from upper Ottawa River and James Bay drainage basins in Quebec. These water bodies, which existed between 11 500 and 7 900 years B.P., were the penultimate lake phases in a series of proglacial lakes that followed the retreating Laurentide ice margin from its late Wisconsin maximum stand.

Shorelines associated with these lacustrine phases show that the maximum elevation of the water planes are tilted up towards the north-northeast and that differential uplift varies from 0.5 to 1.2 m/km. Lake levels were controlled by a series of outlets situated at slope inflections along Ottawa, Des Quinze, and Kinojévis river systems.

The plot of the deformed water-level planes compared to the long profiles of the present river valleys indicates that at the time of deglaciation the Hudson Bay – St. Lawrence River drainage divide was displaced far to the south by isostatic delevelling. It was this temporary deformation of the earth's surface that retained Lake Barlow waters. Differential isostatic uplift brought a slow shift of the drainage divide to its present location and a consequent progressive shifting of the outlets towards the north. The separation of lakes Barlow and Ojibway is arbitrarily set at the Angliers sill, on Des Quinze River, which represents the most important inflection of slope in the whole fluvial system. The emergence of this sill confined Lake Barlow to the Timiskaming basin and created Lake Ojibway, an independent lake that extended towards the north and northeast on the recently deglaciated terrain; later outlets of Lake Ojibway probably were situated along the present height of land. When Hudson and New Quebec masses of ice separated at the latitude of Hudson Bay, Lake Ojibway drained rapidly northward.

Résumé

Une nouvelle interprétation de l'évolution des dernières phases du lac glaciaire post-Algonquin et des phases des lacs glaciaires Barlow et Ojibway, à partir d'une synthèse des données recueillies dans le bassin de l'Outaouais supérieur et sur le versant québécois de la baie de James, est présentée. Ces nappes d'eau, qui existèrent entre environ 11 500 et 7 900 ans BP, furent les derniers d'une série continue de lacs qui suivirent la marge glaciaire laurentidienne depuis le début de la dernière déglaciation.

Les lignes de rivage associées à ces phases lacustres montrent que l'altitude maximale des plans d'eau se relève vers le nord-nord-est et que le relèvement différentiel varie entre 0.5 et 1.2 m/km. Le niveau des eaux était contrôlé par des séries d'exutoires localisés aux ruptures de pente le long de l'axe fluvial constitué par les vallées de l'Outaouais, de le rivière Des Quinze et du Kinojévis.

Le tracé des plans de déformation des niveaux lacustres comparé au profil longitudinal actuel de ces vallées montre, qu'au moment de la déglaciation, la ligne de partage des eaux fut déplacée loin vers le sud. C'est ce gauchissement temporaire de la surface qui a permis la rétention des eaux du Lac Barlow. Le relèvement isostatique différentiel a entraîné un lent retour de la ligne de partage des eaux jusqu' à sa position actuelle et par conséquent, un déplacement progressif des exutoires vers le nord. La coupure entre les lacs Barlow et Ojibway est fixée arbitrairement au seuil d'Angliers, sur la rivière Des Quinze, qui représente la rupture de pente la plus importante de tout l'axe fluvial. Son émersion a confiné les eaux du lac Barlow au bassin du Témiscamingue et a donné naissance à un autre lac indépendant, le lac Ojibway, qui s'est agrandi vers le nord et le nord-est sur le territoire nouvellement déglacié. Les derniers exutoires du lac Ojibway furent probablement situés le long de l'actuelle ligne de partage des eaux. Lorsque les glaciers d'Hudson et du Nouveau-Québec se sont séparés, à la latitude de la mer d'Hudson, le lac Ojibway s'est drainé rapidement vers le nord.

INTRODUCTION

During the deglaciation of the drainage basins of upper Ottawa River and James Bay (Fig. 1), vast lacustrine areas were produced as a result of the retention of water between the ice margin (receding northward) and the Hudson Bay – St. Lawrence River drainage divide (displaced far southward by the temporary warping of the land surface). As the Laurentide Ice Sheet retreated, the proglacial lakes expanded considerably in the newly deglaciated terrain, while the southern shoreline evolved under the influence of differential isostatic uplift, the emergence of a series of outlets, and fluvial downcutting of these outlets. The lacustrine episode ended suddenly with the northward drainage of water at a time when the New Quebec glacier had retreated as far as the Sakami ice front position and the ice of the Cochrane II surge still was at its maximum extent (Hardy, 1976).

This report relates the last phases of the post-Algonquin glacial lake in Ontario and the main phases in the evolution of glacial lake Barlow and Ojibway in Quebec and provides an overall interpretation of their development. This interpretation differs from those of earlier authors (Coleman, 1909, 1922; Wilson, 1918; Antevs, 1925; Prest, 1970) in that it considers lacustrine phases controlled by a series of outlets, whose successive emergence was the result of differential isostatic uplift. The study is based on a synthesis of the available geological, morphological, and biological data as well as recent unpublished information.

Acknowledgments

Appreciation is extended to J.E. Harrison, formerly of the Geological Survey of Canada, who presented us with the results of his research on the southern outlets of Lake Barlow, thus bolstering our efforts. We had fruitful discussions with D.R. Grant and V.K. Prest, also with the Geological Survey of Canada. The latter, along with J-C. Dionne, Department of Fisheries and Environment, gave us access to unpublished documents. We wish to thank J.A. Elson of McGill University, O.L. Hughes, and R.J. Fulton of the Geological Survey of Canada, and J-C. Dionne for their kind and valuable assistance in reading and commenting on the manuscript.

Previous Studies

In studying the distribution of varved clays and the altitudes of beaches and lake outlets, Coleman (1909) held that the glaciolacustrine sediments encountered south of the Hudson Bay – St. Lawrence River drainage divide had been deposited in a lake constituting a northeastward extension of Lake Algonquin. While admitting the possibility of a local extension of the lake into the drainage basin of James Bay, Coleman (1909) thought that the ice front remained stable for a long period while it was directly north of the drainage divide, thus preventing the expansion of Lake Algonquin. According to Coleman, following the deglaciation of Mattawa and Ottawa valleys, Lake Algonquin drained eastward. The lowering of the water to the Nipissing level then supposedly produced another lake located north of the Hudson Bay - St. Lawrence River drainage divide; Coleman (1909, p. 284) proposed calling this proglacial lake "Ojibway", after an Indian tribe that once had occupied the area. He (1909, p. 293) also situated the outlet for this lake at the heads of Duparquet and Opasatria lake basins at approximately 285 m altitude. According to our estimation, his figure is probably a few metres higher than the true altitude.

In a later study, Wilson (1918) showed that the glaciolacustrine sediments observed in the vicinity of Lake Timiskaming extended north beyond the present drainage divide between the basins of Hudson Bay and St. Lawrence River. He therefore concluded that they were deposited in a single lake, which was separated from Lake Algonquin for the greater part of its existence, and named it "Lake Barlow". To explain its formation above the present level of Lake Timiskaming (178 m), Wilson (1918) postulated the existence of an ice dam, which blocked the Timiskaming trench. Lake Barlow was said to have expanded northward as the glacier retreated, and melting of the ice dam was believed to be responsible for the drainage of the lake except for the portion located north of the present drainage divide.

Antevs (1925) accepted some of the conclusions reached by Wilson but considered that the ponded water was attributable to a morainic dam, which blocked the Timiskaming trench, and the more depressed nature of the terrain in the north as opposed to the south. According to Antevs (1925, p. 75) Lake Barlow expanded to the north and combined with Lake Ojibway to form a single body of water called "Lake Barlow-Ojibway". Boissonneau (1968, p. 105) agreed with the idea of a morainic dam, but suggested that it was the Lake McConnell Moraine, located 18 km north of Témiscaming, that acted as a barrier.

The location and characteristics of the outlets have received little attention since the work of Coleman (1909, p. 292-3) and Antevs (1925, p. 74-7). Hughes (1965, p. 557), advanced that a southern outlet of Lake Ojibway must have been blocked at one point to account for the sudden deepening of water, corresponding to varve year 1528. On the other hand, Prest (1970, p. 733) considered that the low water phase that preceded the deposition of varve 1528 could have been caused by a temporary flow westward into the basin of Lake Superior. Prest (1970, p. 733-4) also discussed the other outlets that could have controlled the altitude of the water planes throughout the glaciolacustrine episode. More recently, Harrison (1972) determined the location and the altitude of the outlets that controlled the post-Algonquin lakes in the vicinity of Mattawa and North Bay.

The expansion and maximum levels of the lakes have been studied by several authors, particularly Coleman (1909), Antevs (1925), Hume (1925), Hughes (1955), Lumbers (1963), Boissonneau (1966, 1968), MacDonald (1968), and Prest (1970) with respect to locations in Ontario; and Gill (1929), Cooke et al (1933), Norman (1938, 1939), Wilson (1938), Longley (1943), Shaw (1944), Ambrose (1941), Tremblay (1950), Hughes (1955), Ignatius (1958), Thomson (1960), Allard (1974), Tremblay (1974), Vincent (1975), and Hardy (1976) for locations in Quebec. To these may be added unpublished observations, related to strandlines, by J-C. Dionne, D.R. Grant, L. Hardy, V.K. Prest, and J-S. Vincent.

Norman (1939) and Shaw (1944) used De Geer moraines to determine the northeastward extension of Lake Barlow-Ojibway. Prest (1970) supplied a series of schematic maps showing the variable limits of the lake during the entire glaciolacustrine episode. Finally, Hardy (1976) determined the northward extension of the lacustrine area and the position of the ice margins in Quebec at the time of drainage of the glacial lake. Dadswell (1974) used the distribution of the crustaceans **Mysis relicta, Pontoporeia affinis, Limnocalanus macrurus,** and **Senecella calanoides,** and the fish **Myoxocephalus quadricornis** to define the southern and southeastern limits of the proglacial lake.

The chronostratigraphy of the lacustrine episode was determined by Antevs (1925, 1928) who measured 2027 varves. Some of these varves (1163 to 2027) were remeasured by Hughes (1965), who found an additional 60 varves that were deposited during the Cochrane readvance. In his study Hughes distinguished three deep water and shallow water phases, which he associated with possible outlet changes or temporary blockage of the same outlet. Vincent (1973, 1975) and Tremblay (1974) published radiocarbon dates for the emergence of the southern portion of the inundated area. Hardy (1976) determined, by counting varves, the duration of the lacustrine episode in the lowland section of James Bay.

Few authors have ventured to specify the final drainage location of the lake. Antevs (1931) thought that drainage had occurred near the ice margin in the vicinity of the mouths of Hayes and Nelson Rivers in Manitoba; this hypothesis was retained by Prest (1970, p. 734). Lee (1968) suggested that the marine invasion began on the east side of James Bay and Hudson Bay, which implies that the lake was drained on the Quebec side. Skinner (1973) thought that drainage could have occurred towards the north along a line passing through Cape Henrietta Maria. Hardy (1976) showed, from the characteristics of the drainage horizon, that the water must have drained northward between the margins of the Hudson and New Quebec glaciers.

All these authors, except for Antevs, believed that Lake Ojibway drained around 7700 to 7900 years ago. This minimum age is based on radiocarbon dates on shells from the Tyrrell Sea, which immediately succeeded the lacustrine episode.

EXTENSION OF THE PROGLACIAL LAKES

The area of expansion of the proglacial lakes can be deduced from the presence of shorelines, glaciolacustrine sediments, De Geer moraines, and by the distribution of biological indicators in modern lakes.

Strandlines

The various signs of shore activity, such as accumulations and reworking and washing of materials through the action of waves and drift ice, are considered evidence of strandline existence. The altitudes of strandlines observed in the study area are given in Table 1. These values commonly represent the upper lacustrine limit and thus make it possible to determine the total area of submerged terrain. From the same figures, the amount and direction of tilt of postglacial isostatic uplift also can be calculated; available data show that the average direction of tilt is N20°E for the southern half of the submerged area, and this progressively shifts to the northeast in the northern half. Observations on intermediate strandlines are too fragmentary to allow correlation of water planes and hence to determine their true deformation. Since the drainage of Lake Ojibway was synchronous for the entire area, however, it should be possible to use the lower limit of shore activity to determine the deformation of the Lake Ojibway water plane.

The altitudes of the upper strandlines recognized are between 293 m in the vicinity of Lake Timiskaming and a little more than 457 m near the northeastern end of the area submerged by Lake Ojibway. As shown in Table 1, the maximum altitude of the water planes varies considerably from one location to another, particularly south of the present Hudson Bay–St. Lawrence drainage divide. These variations are associated with the deglaciation of outlets located at different altitudes or with downcutting as a result of water overflow. North of the drainage divide, the maximum lacustrine levels follow a more constant north-northeasterly progression because of the northward migration of outlets corresponding to bedrock sills.

A comparison of the maximum altitudes of strandlines on both sides of the Harricana Interlobate Moraine (Hardy, 1976), or of its presumed southward extension, shows that for a given latitude the maximum water plane was approximately 25 m higher on the west side than on the east side. This difference in altitude is explained by the fact that the area west of the moraine was deglaciated before the area east of it, thus permitting an earlier lacustrine submergence to the west. Because uplift continued as the area to the east of the moraine was deglaciated, the maximum lacustrine level is lower on the east side for a given latitude.

Except for measurements reported by Tremblay (1950) and Ambrose (1941), all altitudes shown in Table 1 are perfectly in keeping with the lacustrine phases given below. The view that the highest beaches were created in small supraglacial or annular lakes around nunataks, as stated by Laverdière (1969, p. 235) and later by Allard (1974, p. 278) and Tremblay (1974, p. 57), has not been retained. These authors seem to have ignored the differential isostatic disequilibrium of the terrain at the time of the lacustrine inundation.

Varved Sediments and De Geer Moraines

Strandlines in the lowland section of James Bay could not be observed in the area of lacustrine inundation, because that section remained well below the maximum level of Lake Ojibway. The distribution of deep water sediments, however, shows that Lake Ojibway extended north of La Grande River and eastward as far as the Sakami Moraine (Hardy, 1976). The glaciolacustrine sediments consist mainly of varved clayey silts; north of 52°N, their distribution is sporadic and generally is limited to depressions.

Deposits of varved silts are exceptional east of the lowland above an altitude of 325 m. In this area the extent of Lake Ojibway as far as the Sakami Moraine is confirmed by the presence of De Geer moraines which normally are considered to be built at the margin of an ice sheet retreating in a water body. Based on various data (presence of De Geer moraines, varved clays) provided by his own work and that of Mawdsley (1936), Norman (1938), and Wilson (1938), Shaw (1944, p. 83), also surmised that the ice in the area in question retreated in a glacial lake. Since De Geer moraines are found at altitudes that vary between 300 and 400 m, and since marine limit of the Tyrrell Sea is situated at 290 m, it is evident that these landforms were built in a glacial lake rather than a marine contact area.

Biological Indicators

Recent work by Dadswell (1974) on the distribution of crustaceans such as **Mysis relicta** and the fish **Myoxocephalus quardricornis** in present lakes shows that these species became dispersed by migration into proglacial water bodies and that those lacustrine areas correspond to the present area of distribution for the species. This technique also was used to determine the extent of part of Lake Algonquin (Martin and Chapman, 1965) and of the lakes that were formed at the retreating southeastern margin of the Scandinavian Ice Sheet (Segerstråle, 1976).

In the region concerned, Dadswell (1974) surveyed just over 150 lakes for the presence of indicator species. His findings have been incorporated into this report. In general, the biological data are perfectly in keeping with the other evidence of the extent of glaciolacustrine water bodies. In certain areas where other evidence is lacking, however, Dadswell's findings are the principal indication of the extent of the proglacial lakes.

LAKE OUTLETS AND THE ASSOCIATED WATER PLANES

Outlets are rarely prominent in the landscape by their morphology because they are located along valleys where present-day river systems may be responsible for morphological changes or, theoretically, for incisions in unconsolidated materials. The locations of the outlets are deduced from morphological and topographic clues and also from such information as the extent of the various lacustrine phases, land deformation as presented by the plot of waterlevel planes, and the successive positions of the ice margin. It should be pointed out that the natural long profiles of many river systems now have been concealed by numerous hydroelectric works. Figure 2 shows the original long profiles of selected watercourses, along which discharge waters from glacial lakes were routed, based on hydrological surveys conducted prior to the hydroelectric developments.

The interpretation is obviously somewhat arbitrary with respect to the specific position of the outlets and their actual importance in the history of the proglacial lakes. To see this in perspective, however, we have only to recall the weakness of earlier interpretations: the ponding of proglacial lakes was explained by the presence of an ice dam in the Timiskaming trench (Wilson, 1918) or by the presence of morainic dams (Antevs, 1925; Boissonneau, 1968), of which no evidence has been found in Quebec. Hughes (1955, p. 154) suggested that control of drainage by differential isostatic uplift could explain the presence of strandlines 100 m above the present Hudson Bay–St. Lawrence River drainage divide and their terraced profile up to 422 m altitude on Plamondon

Table 1
Measured altitudes of strandlines of glacial lakes Barlow and Ojibway.

SITES (see Fig. 2,3)	LOCATION	REFERENCES	METHOD OF MEASUREMENT	INTERPRETATION OF PHENOMENA MEASURED[1]	ALTITUDES (m)
1	Lake Oxbow, South Lorrain Township, Ontario 47°10'N, 79°29'W	Hughes, 1955, Plate 8	photogrammetry	upper limit of wave wash	300
2	Maidens, South Lorrain Township, Ontario 47°13'N, 79°27'W	Hughes, 1955, Plate 8	photogrammetry	upper limit of wave wash	293
3	Hill east of Baie l'Africain, Fabre Township, Quebec 47°14'N, 79°23'W	Hughes, 1955, Plate 8	photogrammetry	upper limit of wave wash	301
		Prest and Vincent, 1976, unpublished	aneroid barometer	upper limit of wave wash	303
4	Mission Point, Lorrain Township, Ontario 47°17'N, 79°28'W	Hughes, 1955, Plate 8	photogrammetry	upper limit of wave wash	294
		Thomson, 1960, p. 24-5	aneroid barometer	upper limit of wave wash	296
5	Hill west of Miron, Duhamel Township, Quebec 47°17'N, 79°25'W	Vincent, 1975, p. 119	aneroid barometer	upper limit of wave wash	$\geq$305
6	Northwest of Haileybury, Bucke Township, Ontario 47°27'N, 79°40'W	Hume, 1925 p. 6-7	aneroid barometer	beach[2]	267
7	Hill south-southeast of Guigues, Guigues Township, Quebec 47°26'N, 79°25'W	Vincent, 1975, p. 119	aneroid barometer	upper limit of wave wash	313
8	West of New Liskeard, Dymond Township, Ontario 47°31'N, 79°44'W	Hume, 1925, p. 7	aneroid barometer	two beaches[2]	275, 274
9	East of Lake Hudfin, Lundy Township, Ontario 47°30'N, 79°54'W	Hughes, 1955, Plate 8	photogrammetry	upper limit of wave wash	312
10	Northwest of Milberta, Kearns Township, Ontario	V.K. Prest, pers. comm. in Hughes, 1955, Plate 8	aneroid barometer	ten beaches[2]	nine between 297 and 275, one at 259
11	North entrance of La Vérendrye Park, Villebon Township, Quebec 47°53'N, 77°21'W	V.K. Prest and J-S. Vincent, 1976, unpublished	aneroid barometer	wave washed summit of esker (near upper limit?)[2]	355
12	Southeast of Lake Villebon, Villebon Township, Quebec 47°54'N, 77°17'W	V.K. Prest and J-S. Vincent, 1976, unpublished	aneroid barometer	upper limit of wave wash	349
13	Southeast of Kearns, McGarry Township, Ontario 48°08'N, 79°33'W	V.K. Prest and J-S. Vincent, 1976, unpublished	aneroid barometer	upper limit of wave wash	349
14	North slope of Swinging Hills, Dasserat Township, Ontario 48°12'N, 79°24'W	Gill, 1929, p. 100	aneroid barometer	twelve beaches; beach at 366 m interpreted as being at upper limit	twelve between 366 and 305
15	Aldermac, Beauchastel Township, Quebec 48°13'N, 79°14'W	Cooke et al., 1933, p. 167	theodolite	three beaches; beach at 366 m interpreted as being at upper limit	366, 358, and 354
16	Amulet Mine, Dufresnay Township, Quebec 48°19'N, 79°52'W	Cooke et al., 1933, p. 168	theodolite	beach interpreted as being at upper limit	371
17	East of Lake Savard, Cléricy Township, Quebec 48°20'N, 78°52'W	Cooke et al., 1933, p. 168	topographic map	beach[2]	365
18	West of Nissing Hills, Chazel Township, Quebec 48°55'N, 78°52'W	Tremblay, 1974, p. 58	aneroid barometer	strandline on outwash[2]	376
19	Northeast of Adair Township, Ontario 49°08'N, 79°33'W	Lumbers, 1963, p. 30	aneroid barometer	six beaches[2]	six between 379 and 369
20	Plamondon Hill, Céloron Township, Quebec 49°08'N, 78°33'W	Wilson, 1938, p. 56-8	aneroid barometer	upper limit of wave wash	457[4]
		G. Mizerovsky for J-S. Vincent, 1976	photogrammetry	upper limit of wave wash	422[4]
21	Esker south of Amos Airport, Figuery Township, Quebec	Tremblay, 1974 p. 57	topographic map?	shorelines on esker[2]	366, 363, 360

SITES (see Fig. 2,3)	LOCATION	REFERENCES	METHOD OF MEASUREMENT	INTERPRETATION OF PHENOMENA MEASURED[1]	ALTITUDES (m)
22	Esker west of Lake Charpentier, Courville Township, Quebec 48°25'N, 77°27'W	Tremblay, 1974, p. 58	topographic map?	shorelines on esker (near upper limit?)[2]	~366
23	On Harricana Interlobate Moraine, northeast of Landrienne Township, Quebec 48°32'N, 77°49'W	Tremblay, 1974, p. 58	topographic map?	shorelines on Harricana Interlobate Moraine (near upper limit?)[2]	~366
		Allard, 1974, p. 277-8	topographic map	shorelines on Harricana Interlobate Moraine (near upper limit?)[2]	≤366
24	North of Senneterre, Montgay Township, Quebec 48°26'N, 77°13'W	V.K. Prest and J-S. Vincent, 1976, unpublished	aneroid barometer	upper limit of wave wash	364
25	North of Mégiscane, Dallard Township, Quebec 48°23'N, 77°06'W	V.K. Prest and J-S. Vincent, 1976, unpublished	aneroid barometer	upper limit of wave wash	377
26	East of Fish Lake, Tiblemont Township, Quebec 48°11'N, 77°12'W	V.K. Prest and J-S. Vincent, 1976, unpublished	aneroid barometer	upper limit of wave wash	396
27	South slope of Mont Laurier, Lozeau Township, Quebec 49°48'N, 77°32'W	Longley, 1943, p. 23		beach[2]	336
		Hardy, 1976, p. 155	topographic map, contour interval 20 feet	strandlines, 395 m interpreted as upper limit	between 383 and 395
28	Southwest of Lake Sébastien, Brochant Township, Quebec 49°36'N, 74°52'W	Ignatius, 1958, p. 30	topographic map?	beach near upper limit[2]	~427
29	Hills in the vicinity of Lake Opémisca, Quebec	Norman, 1938, p. 70		beaches interpreted as being at upper limit	438
		Shaw, 1944, p. 43		beaches[2]	>427
30	South-southeast of Lake Amisquioumisca, Quebec 50°19'N, 76°07'W	J-C. Dionne, pers. comm., 1975 in Hardy, 1976, p. 157	altimeter	beach at upper limit	438
31	West of Lake Duchat, Paulariès Township, Quebec 48°35'N, 78°57'W	V.K. Prest and D.R. Grant, pers. comm., 1976	aneroid barometer	upper limit of wave wash	389
32	Nissing Hills, Disson Township, Quebec 48°54'N, 78°51'W	V.K. Prest and D.R. Grant, pers. comm., 1976	topographic map, contour interval 10 feet	upper limit of wave wash	405
33	Hill west of Lake Father, Du Guesclin Township, Quebec 49°21'N, 75°28'W	L. Hardy, 1976, unpublished	topographic map, contour interval 10 feet	upper limit of wave wash	415
34	East of Lake Tésécau, Quebec 51°02'N, 75°45'W	L. Hardy, 1976, unpublished	topographic map, contour interval 10 feet	upper limit of wave wash lower limit of wave wash	>442 418
35	North of Lake Weakwaten, Quebec 51°10'N, 75°46'W	L. Hardy, 1976, unpublished	topographic map, contour interval 10 feet	upper limit of wave wash lower limit of wave wash	>457 427
		REJECTED ALTITUDES[3]			
36	Northwest of Senneville Township, Quebec 48°17'N, 77°45'W	Tremblay, 1950, p. 65.		upper limit of wave wash	450
37	Abijevis Hill, Aiguebelle Township, Quebec	Ambrose, 1941, p. 4		beaches	457

1 In a few cases the synthesis of data led us to reconsider the interpretation of certain authors.

2 Strandlines associated with intermediate lacustrine levels

3 The altitudes reported by Tremblay (site 36) and Ambrose (site 37) were rejected because they seemed much too high. In the first case, Tremblay used the presence of "bare rock" to define the limit, which seems indeterminate; in the second case, Ambrose indicated that the altitude was only very approximate.

4 Wilson (1938, p. 56, 57) drew the well defined trimline around Plamondon Hill on an airphotograph and indicated that its altitude, measured by aneroid barometer, was 457 m. If Wilson's trimline is transferred on the recent 1:50 000 scale map sheet of the area (NTS 32 E/2), it is obvious that the trimline falls well below the 1500 foot contour line (457 m) and is situated close to the 1400 foot contour line (427 m). Photogrammetric measurements made on more recent aerial photographs (NAPL A22558-48, 49) using the same trimline confirmed this and indicated that the altitude of the trimline is situated at about 422 m.

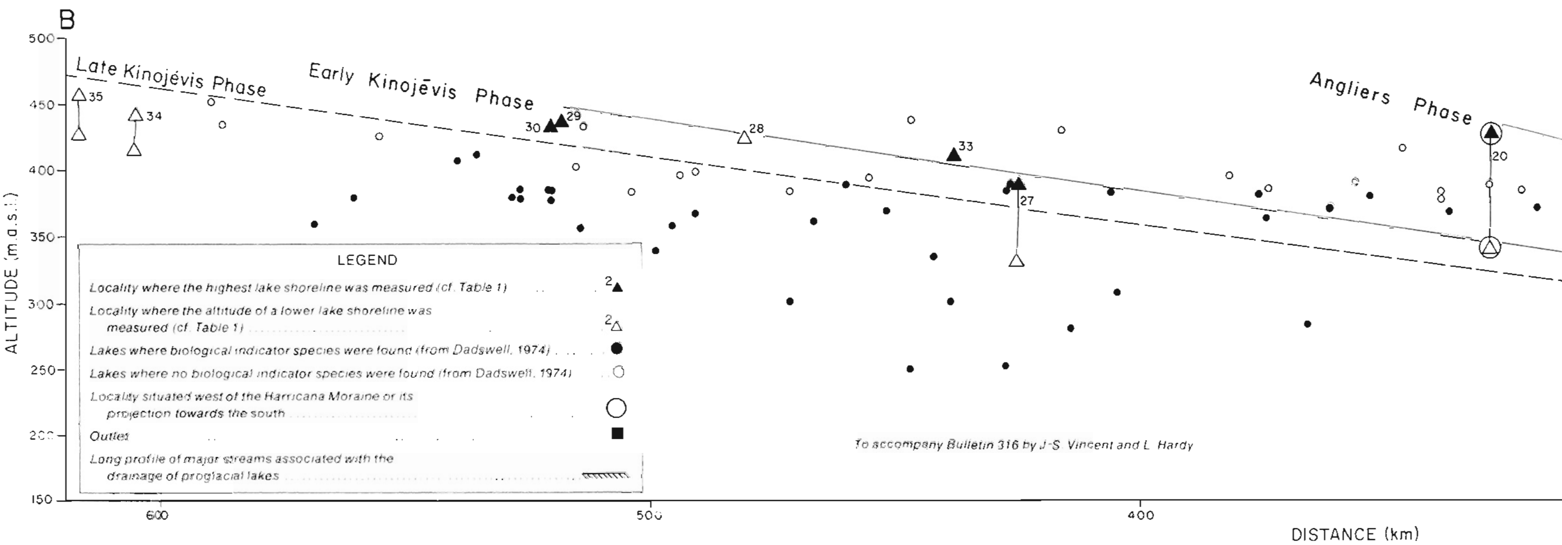
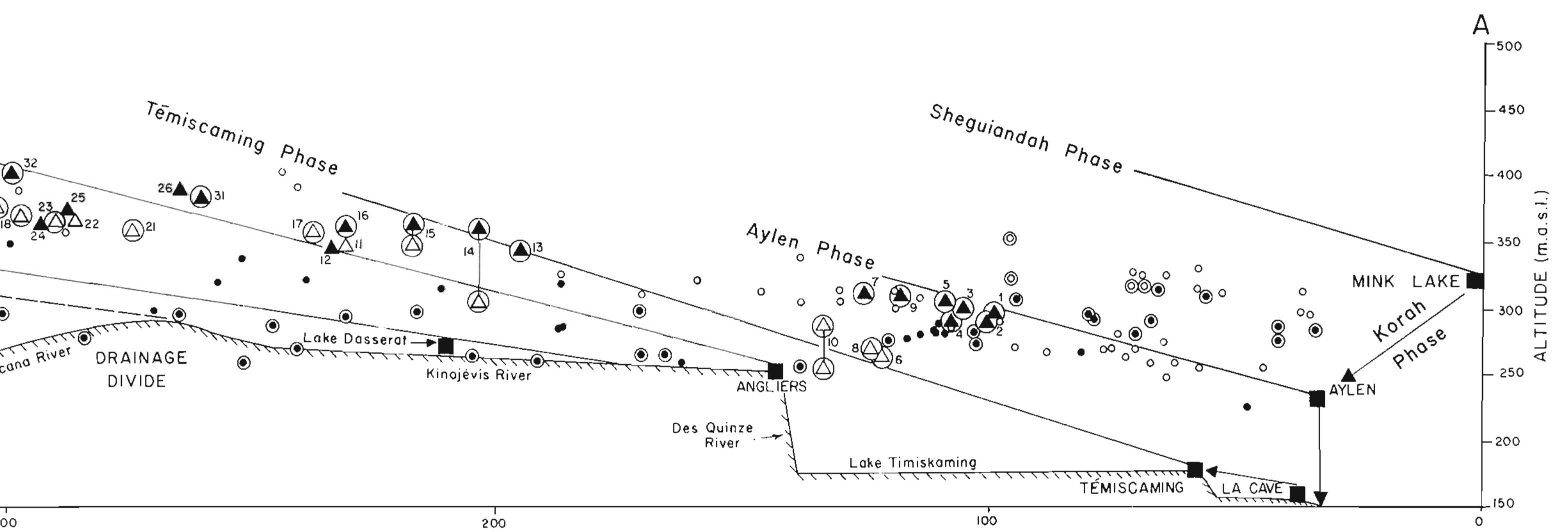


Figure 2. *Shoreline distance diagram, showing observed elevations of shoreline features and known and inferred outlets for post-Algonquin, Barlow and Ojibway glacial lakes in western Quebec and adjacent Ontario, from which several new hypothetical lake phases are proposed. Also shown are the projected locations of the modern lakes sampled by Dadswell (1974) for biological indicator species.*


A
Témiscaming Phase
Sheguiandah Phase
Aylen Phase
Korah Phase
MINK LAKE
AYLEN
LA CAVE
TÉMISCAMING
Lake Timiskaming
Des Quinze River
ANGLIERS
Kinojévis River
Lake Dasserat
DRAINAGE DIVIDE
cana River
ALTITUDE (m.a.s.l.)
500
450
400
350
300
250
200
150
200
100
0

Hill (see site 20, Table 1). In Hughes' reconstruction, the sill controlling drainage of Lake Barlow-Ojibway is situated at Témiscaming. His hypothesis does not take into account the strandlines that rise to 300 m on each side of Lake Timiskaming or the dispersal of biological indicators in lakes perched at 318 m altitude west of Lake Timiskaming. These values, for a water plane controlled by an outlet at Témiscaming, would imply a differential uplift of 3.6 m/km. Although differential uplift is undoubtedly the main explanation for the ponding, the location of the first dam (according to our analysis) that retained Lake Barlow waters has to be shifted southward from the Témiscaming sill as far as Aylen (42 km east of Mattawa).

The Aylen outlet is made up of a morainic accumulation around which the waters originally detoured on the south, carving a channel in the loose material between Deux-Rivières and Bissett (J.E. Harrison, pers. comm., 1976). The channel deepened until bedrock was reached at 225 m altitude (Fig. 2). Strandlines associated with this outlet are found mainly near the northern end of Lake Timiskaming and correspond to a water plane inclined 1 m/km to the south-southwest. Downcutting in the morainic material caused a shifting of the outlet and a lowering of the lake level by about 75 m. Following downcutting, the outlet probably migrated rapidly upstream to the site of rock sills, the altitude of which rise to 160 m in the vicinity of La Cave.

With differential uplift, the outlet shifted upstream and settled at the point of greatest slope inflection, immediately south of Témiscaming. In view of the low gradient of Ottawa River upstream from Témiscaming to the head of Lake Timiskaming (Fig. 2), this outlet must have been the southern limit of Lake Barlow for the remainder of the lake's existence. Associated strandlines are found as far north as the present Hudson Bay–St. Lawrence drainage divide, and their altitude implies a mean differential uplift of 1.2 m/km.

The rocky sill at Angliers on Des Quinze River, 20 km east of the northern end of Lake Timiskaming, constitutes the first major slope inflection after Témiscaming. Its emergence resulted in the formation of Lake Ojibway. The Angliers outlet is located at an altitude of 260 m, at the head of a series of rapids which drops a total of 81 m.

As a result of differential isostatic uplift, it is probable that the entire Kinojévis River system progressively emerged from south to north and served as an outlet for the waters of Lake Ojibway. The southern end of the Kinojévis system is at an altitude of 267 m and at its northern end the maximum altitude at Lake Preissac is 295 m. Middle and upper Kinojévis Valley is characterized by wide areas, where accumulations of clay with 30 m-deep incisions are localized, and by constrictions caused by the presence of rock hills. The Kinojévis outlet seems to have continued over the height of land between Lake Preissac and Lake Malartic, judging from the channels cut in the clay. In fact, deep channels cut in upper Harricana Valley, north of Lake Malartic, indicate that the drainage divide migrated farther north than its present position.

The clay plain in the area of the drainage divide is cut by numerous channels (e.g., Larder River, lake and river system south of Lake Opasatica), the dimensions of which can only be explained by temporary action of the overflow water immediately prior to the final emergence. These channels showing evidence of fluvial discharge have been observed on aerial photographs; they are especially common on the drainage divide in the region south of Lake Preissac. Coleman's (1909, p. 293) outlet, located at the drainage divide between Lake Dasserat (formerly called Lake Mattawagogig) and Lake Opasatica, shows the same characteristics. The altitude of the terrain along the line of equal uplift passing through this site and the Kinojévis outlet shows that upper Kinojévis Valley was still under water when the outlet discussed by Coleman emerged and that it would have served as the only possible logical route for overflow water. It is probable that Coleman's outlet, like several other outlets of equivalent altitude, was used only during the time immediately preceding the emergence of the drainage divide. The upper Kinojévis is the lowest and also the largest of the outlets observed. It is necessarily the one which was used for the evacuation of overflow waters for a long period preceding final drainage of Lake Ojibway.

The highest strandlines associated with the Angliers and Kinojévis system outlets are tangent to lines whose mean inclination along an axis lying N20°E varies from 0.5 to 0.9 m/km.

A shoreline distance diagram (Fig. 2) shows the distribution of all known measured strandlines and of the lakes sampled by Dadswell (1974) for biological indicator species in connection with the outlets that controlled the various water planes. The observation sites were projected on an axis running N20°E and passing through the outlets concerned. The slight distortions in the general uplift plane for Lake Barlow and Lake Ojibway produced a certain scattering of points, since the points commonly were projected over distances exceeding 200 km. The straight lines joining the points of maximum strandline altitude indicate that for a given lake phase the upper limit of the water body increases in almost linear fashion to the north-northeast at a rate varying from 0.5 to 1.2 m/km. These values are equivalent to the data obtained for other proglacial lakes associated with the Laurentide Ice Sheet (see Andrews and Barnett, 1972, their Table 1), and the connections proposed between the strandlines and their outlets appear credible.

The intersection of the long profile of the fluvial axes and of the straight lines, which represent mean differential uplift, means that certain outlets unquestionably were used (Fig. 2). Taking into account the actual deformation of the water planes over time, presumably represented by a series of exponential curves under the straight lines shown in Figure 2, and connecting them at the ends, it is obvious that the above mentioned outlets were used.

RECONSTRUCTION OF LACUSTRINE PHASES

Lakes Barlow and Ojibway were the penultimate lake phases in a series of glacial lakes that followed the retreating Laurentide ice margin during the last deglaciation. Their evolution is closely linked with the rate of retreat and the profile of the ice front and with the emergence of the outlets defined in the previous section.

The reconstruction of the lacustrine phases is illustrated in Figures 3A-I, which schematically depict the successive positions of the ice front, the locations of the outlets, and the extent and maximum altitude of the water planes. Although intermediate strandline levels have not been correlated, we have tried to ensure that the lines of equal altitude on a given water plane represent an exponential deformation. Because of the absence of data, the isolines shown in Figures 3A-I are probably somewhat different from true altitudes, except at the location of the outlet and near the ice front.

The formation of Lake Barlow was preceded by two post-Algonquin lacustrine phases that reached beyond Ottawa River into Ontario. Post-Algonquin Lake Sheguiandah, controlled by Mink Lake outlet at an altitude of 328 m, extended north of North Bay into a deep re-entrant of the ice sheet (Fig. 3A) (Harrison, 1972). Overflow water was routed down Petawawa and Ottawa valleys and finally emptied into Champlain Sea.

Figure 3

Schematic reconstruction of lake phases showing the successive positions of the ice front and the extent of the glacial lakes. Also shown are isolines giving the maximum altitude of water planes, locations of the observed shoreline features and outlets, and locations of modern lakes sampled by Dadswell (1974) for biological indicator species.

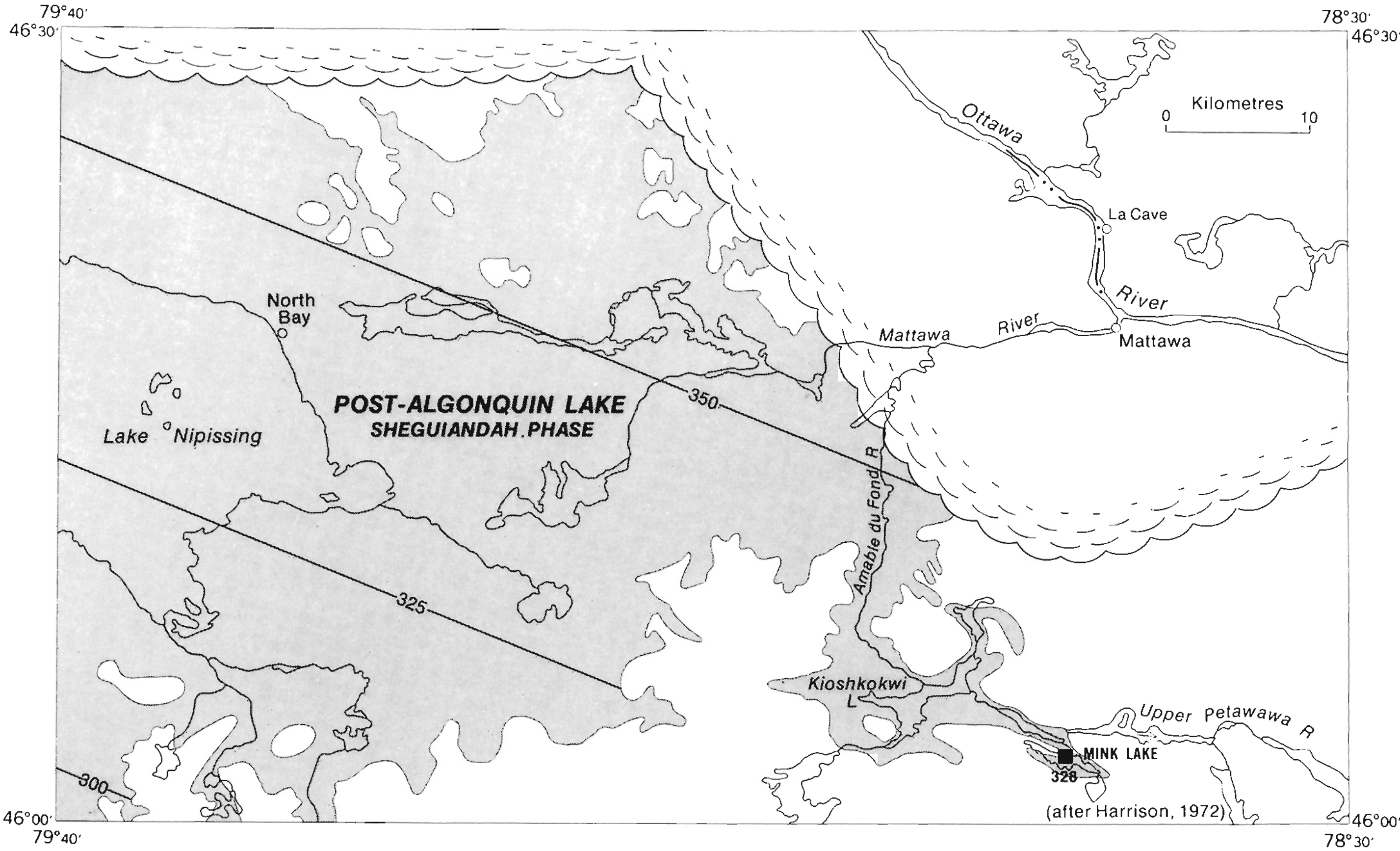


Figure 3A. Post-Algonquin lake – Sheguiandah phase.

Legend for Figures 3A to I.

Presumed location of ice margin

Area submerged by glacial lake

Isoline showing maximum altitude of a water plane .... —300—

End and interlobate moraines ....

Direction of lake drainage .... ⟶

Lakes where biological indicator species were found (from Dadswell, 1974) .... ●

Lakes where no biological indicator species were found (from Dadswell, 1974) .... ○

Outlet with altitude in metres .... 260 ■

Locality where highest lake shoreline was measured (cf. Table 1) .... 14 ▲

Locality where an intermediate lake shoreline was measured (cf. Table 1) .... 14 △

Evidence of fluvial discharge at low points .... ➞

The development of a re-entrant in the southern margin of the ice sheet is attributed to the fact that southeast of Mattawa the ice retreated from the Algonquin Highlands, while in the west its retreat was accelerated by calving into the waters of Algonquin and post-Algonquin lakes. This concavity remained and even deepened to the north as the Labrador section of the Laurentide Ice Sheet progressively separated into two distinct entities, namely, Hudson glacier and New Quebec glacier (Hardy, 1976).

North of Decelles reservoir (Ottawa River), the dividing line between the two glaciers was marked by the Harricana Interlobate Moraine (Fig. 3E). South of the reservoir, this dividing line has not been determined, although it must lie generally along an axis running northeast from North Bay to Decelles reservoir. An examination of the glacial flow indicators and ice contact deposits in this area could make it possible to determine the line more accurately.

The retreat of the ice front as far as the hills that border Ottawa River, south of Mattawa, enabled the overflow waters to spill eastward, between the ice sheet and the side of Ottawa Valley. During this lacustrine phase (known as the Korah phase) the level of the post-Algonquin lake was controlled by the position of the ice on the north side of the hills (Fig. 3B). As the glacier retreated downslope, lake level dropped progressively to the level of the Aylen outlet (Harrison, 1972). The position of the ice front to the

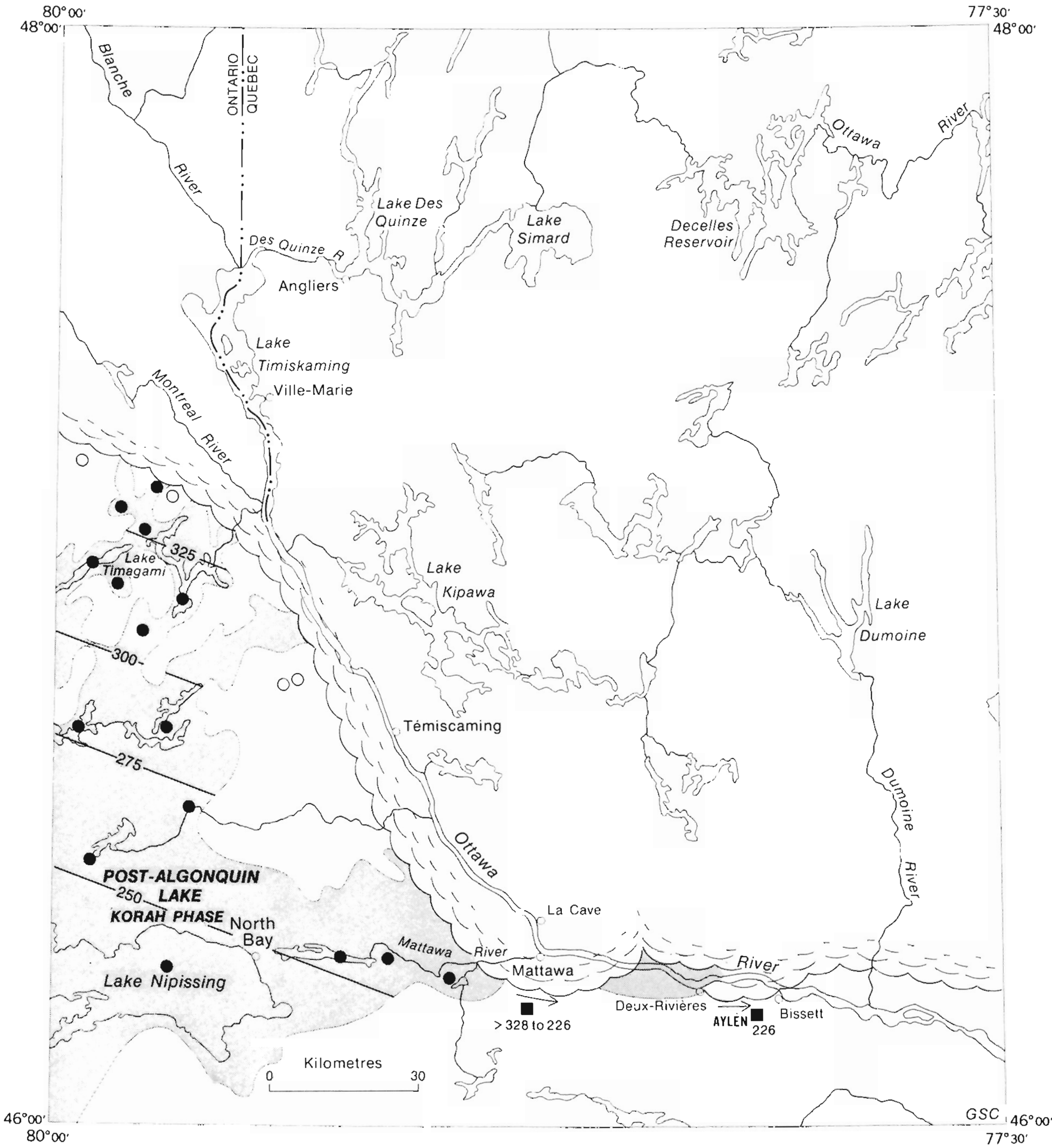


Figure 3B. Post-Algonquin lake – Korah phase.

northwest enabled the lacustrine water to extend as far as the basin of Lake Timiskaming and allowed biological indicator species to penetrate by this route into Timiskaming basin (Dadswell, 1974, p. 54). The distribution (or absence) of indicator species in modern lakes whose altitudes lie between the levels of the water planes controlled by the Mink Lake and Aylen outlets confirms that these organisms were dispersed during a phase when the water level was dropping. Figure 2 clearly indicates that if this were not the case, lakes containing indicator species would be found at much higher altitudes to the north and west.

The complete deglaciation of Ottawa Valley in the vicinity of Mattawa caused the water body to drop to the level of the Aylen outlet, which controlled the first phase of Lake Barlow (Fig. 3C). During the Aylen phase, the water plane extended into the basin of Lake Nipissing.

The Aylen outlet was used at least until the ice reached the northern part of Lake Timiskaming. Here the upper limit of the strandlines varies between 293 and 312 m altitude, for a mean uplift of 1 m/km to the north-northeast.

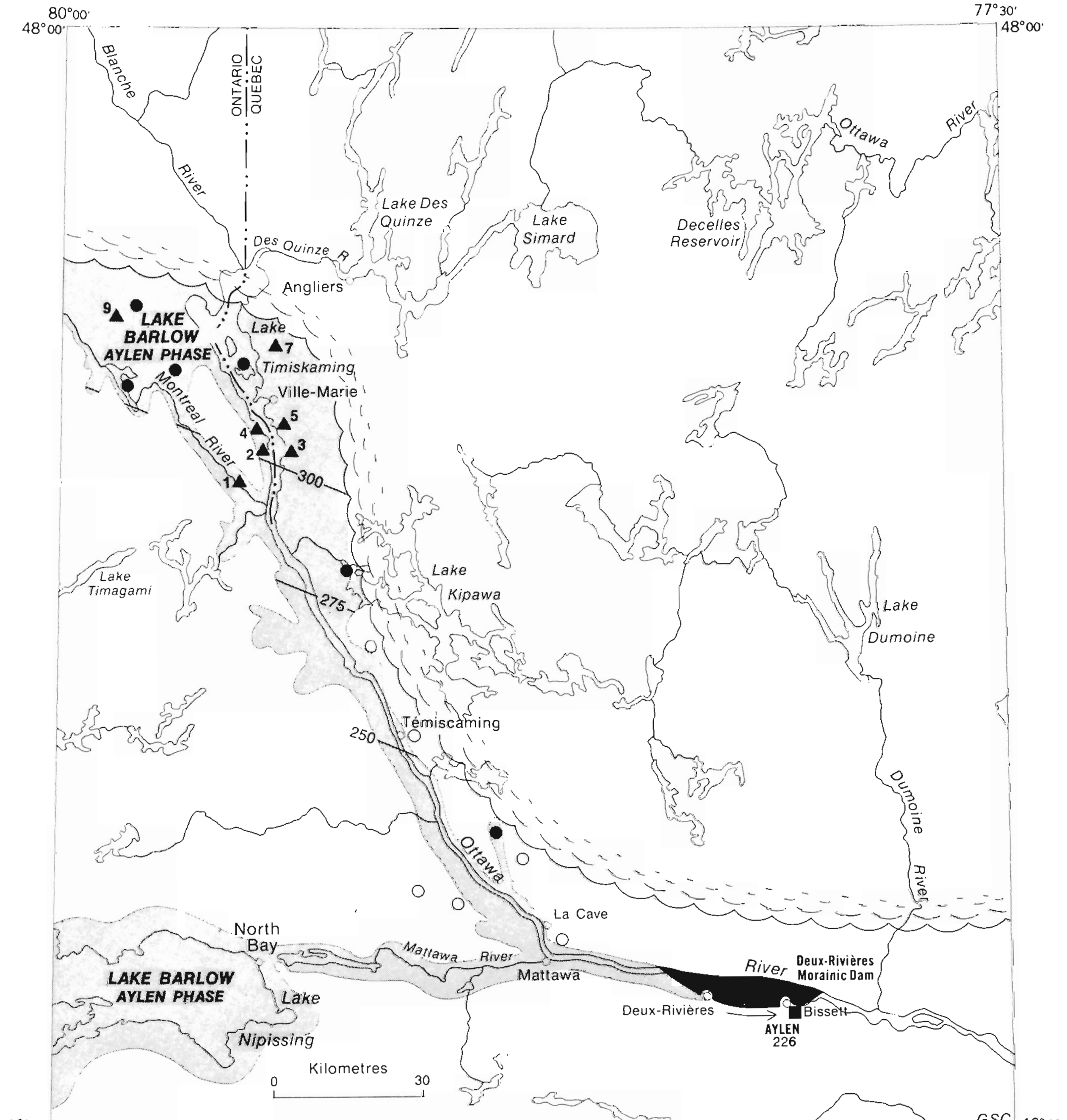


Figure 3C. Lake Barlow – Aylen phase.

Downcutting in the morainic material, which blocked Ottawa Valley between Deux-Rivières and Bissett, caused the outlet to drop by approximately 75 m to an altitude of 160 m. As a result, Ottawa basin and Lake Nipissing basin were separated; this terminated the Aylen phase (Fig. 3D).

With differential isostatic uplift, the Lake Barlow outlet migrated upstream to the head of a series of rapids at 178 m altitude at Témiscaming (Fig. 3E, 3F). The Témiscaming phase was marked by a period of transgression, during which Lake Barlow grew with the retreat of the ice front, and a period of regression, which began with the emergence of the Angliers outlet. The northward progression of Lake Barlow was controlled by the margin of the glacier, whose contour was marked by a frontal moraine (Prest et al., 1968) which is formally named here Roulier Moraine (Fig. 3E) after the name of the nearest locality. At the same latitude, the separation of the Hudson and New Quebec glaciers began to take shape; the place of this separation is marked by the Harricana Interlobate Moraine (Hardy, 1976).

Determining the position of the ice front or the maximum northward extent of Lake Barlow prior to the emergence of the Angliers outlet poses a problem. The youngest strandlines that could be associated with the Témiscaming outlet, based on a realistic deformation plane, are near the present Hudson Bay–St. Lawrence River drainage

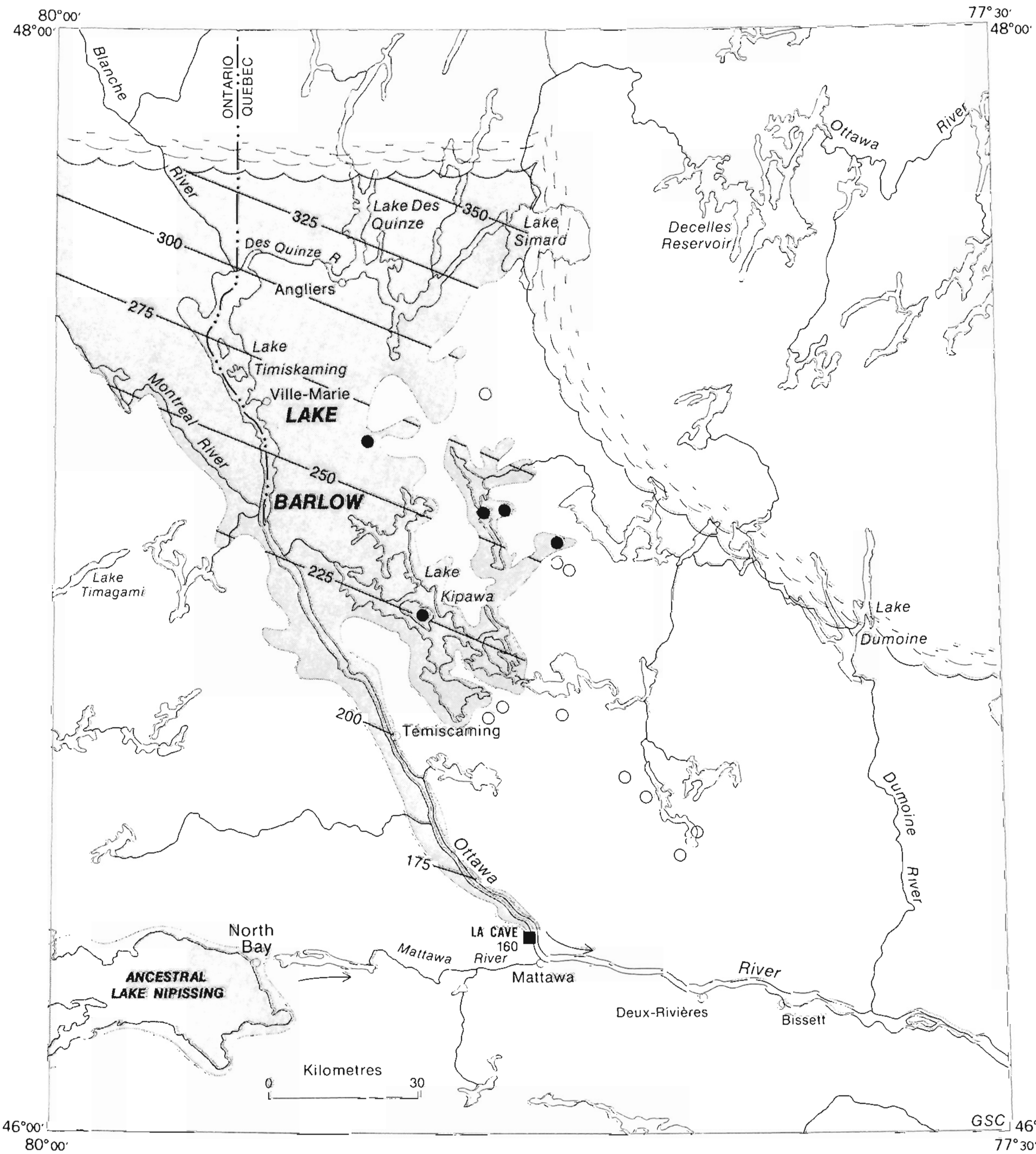


Figure 3D. Lake Barlow – transition from the Aylen phase to the Témiscaming phase.

divide, at altitudes varying between 349 and 371 m (localities 13 to 15, Table 1; Fig. 2, 3F). Farther north, most strandlines are associated with water planes controlled by the Angliers or Kinojévis outlets (Fig. 2). It is probable therefore that the present drainage divide represents the approximate limit of extent of Lake Barlow. West of the Harricana Moraine, the lake extended farther north because of the position of the ice front (Fig. 3F, 3G).

Towards the end of the transgression period of the Témiscaming phase, interfluves had emerged near the drainage divide, but a uniform water plane projected northward through the valleys. The emergence of the Angliers sill cut the water body in two (Fig. 3G). Lake Barlow, which had become a separate entity, was confined to the Timiskaming basin, the northern portion of which was still depressed more than the Témiscaming sill. The subsequent evolution of the lake was controlled by decreasing differential uplift.

The Angliers outlet controlled the first phase of Lake Ojibway. The limits of the lake therefore were south of those proposed by Coleman (1909) in his definition of Lake Ojibway. Valley profiles and the direction and values of differential uplift, however, show that the lake initially could not have been controlled by a single sill located at the present drainage divide, but by a series of sills in Kinojévis Valley, from Angliers to the drainage divide, that acted successively as outlets.

The Angliers phase, like the Kinojévis phase that followed it, was marked by a rapid transgression of Lake Ojibway to the north and northeast on newly deglaciated terrain and by a slow northerly shifting of outlets. This northward succession of outlets was due to the progressive isostatic emergence of different sills in Kinojévis Valley (Fig. 3H, 3J).

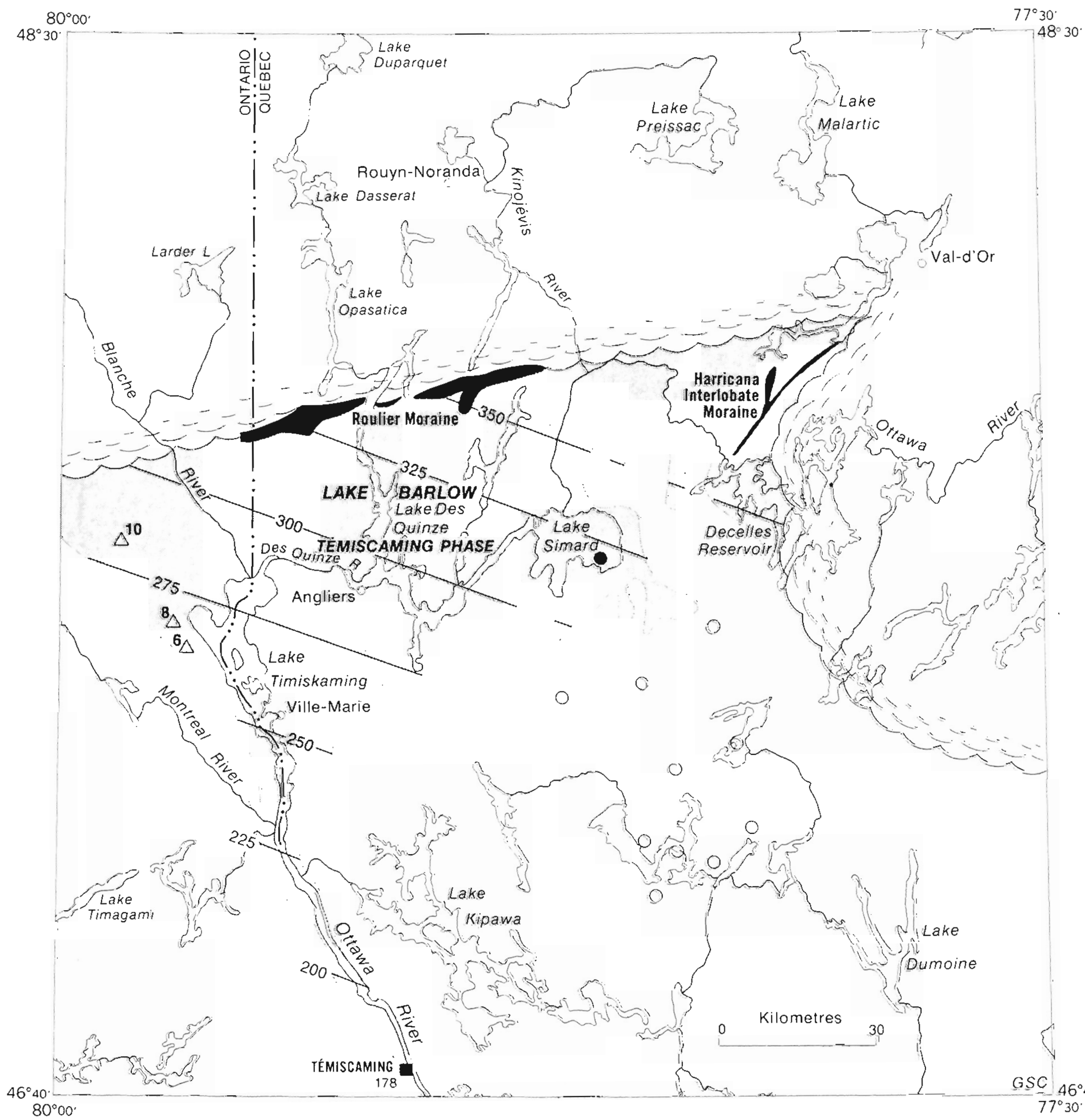


Figure 3E. Lake Barlow – Témiscaming phase.

Because of the continuous shifting of sill positions, it is improbable that there were rapid changes in the depth of water; water depth presumably was controlled by isostatic uplift and, to a lesser extent, by outlet downcutting. The early Kinojévis phase as illustrated in Figures 2 and 3H is an arbitrary level that was chosen to illustrate the trend of shorelines and the development of the lake basin and does not mark a position of stability. The positioning and timing of the two different Cochrane advances (I and II) shown in Figures 3H and 3I are based on detailed work by Hardy (1976, 1977) in the lowlands east of James Bay.

The last 600 years of the lacustrine episode are well documented in varved sequences on the shore of Lake Matagami. The continuity of the varves indicates that there was no intermediate drainage of the lake. In the southeastern portion of James Bay lowlands, progressive variations in varve thicknesses, as well as the abrupt intercalation of thick varves in the sequences, are accompanied by variations in grain size and carbonate content which definitely can be related to the various Cochrane readvances (Hardy, 1976, p. 166-180). Hughes (1965, p. 557-558) interpreted the same type of information as indicating a rapid fluctuation of lake level. The geomorphological and sedimentological data collected on the Quebec slope of James Bay allow a new interpretation of Hughes' (1955) conclusions that the Barlow-Ojibway lacustrine episode was marked by rapid fluctuations of water levels, based on observations of varve sequences (particularly the increase in varve thickness in varve year 1528) in the Cochrane area of Ontario. It is suggested that the sedimentological character of the varves, interpreted by Hughes (1955) as being the result of changes in water depth, instead could be due to rapid movement of the ice front caused by an ice readvance similar to the Cochrane.

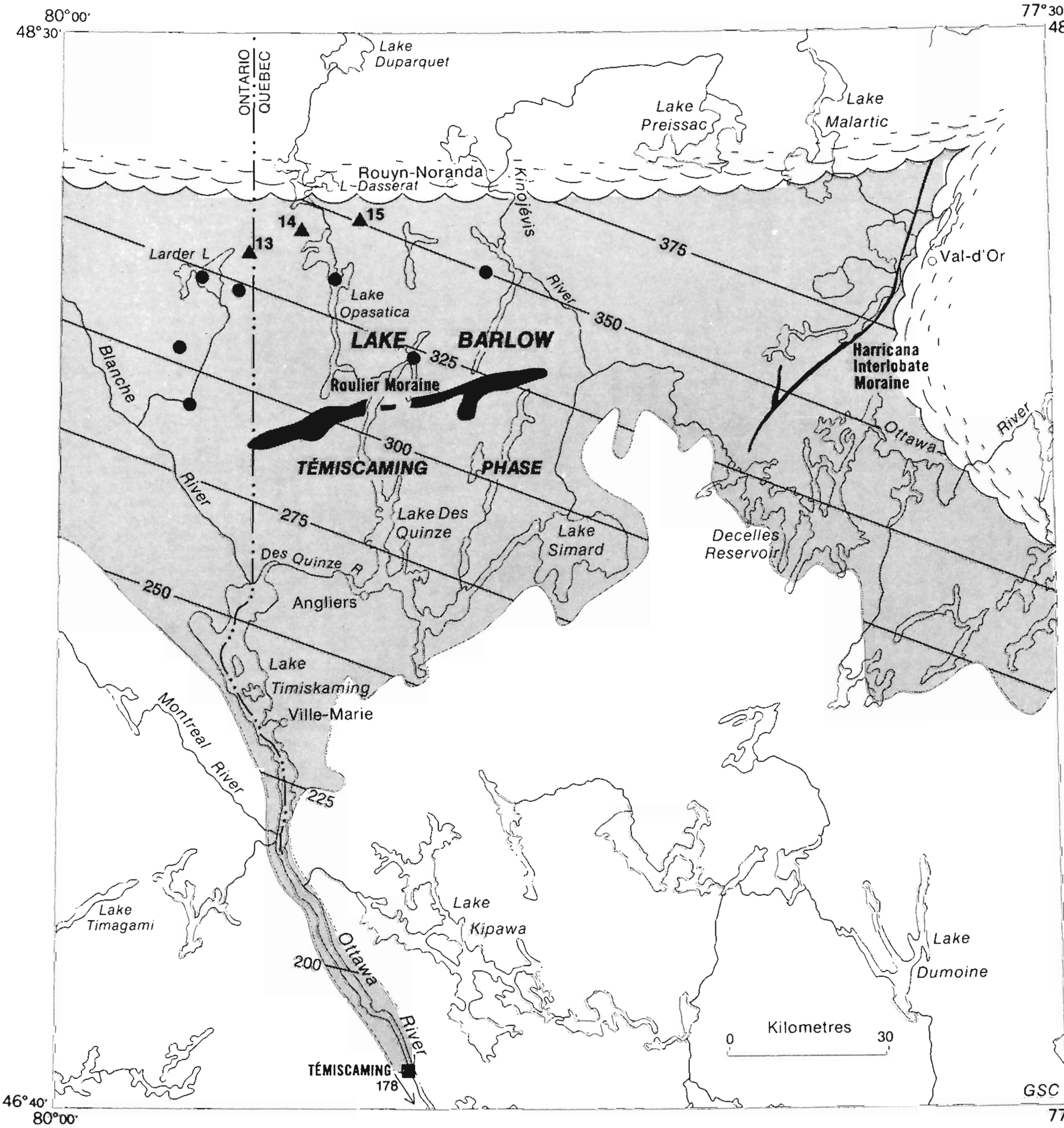


Figure 3F. Lake Barlow – Témiscaming phase.

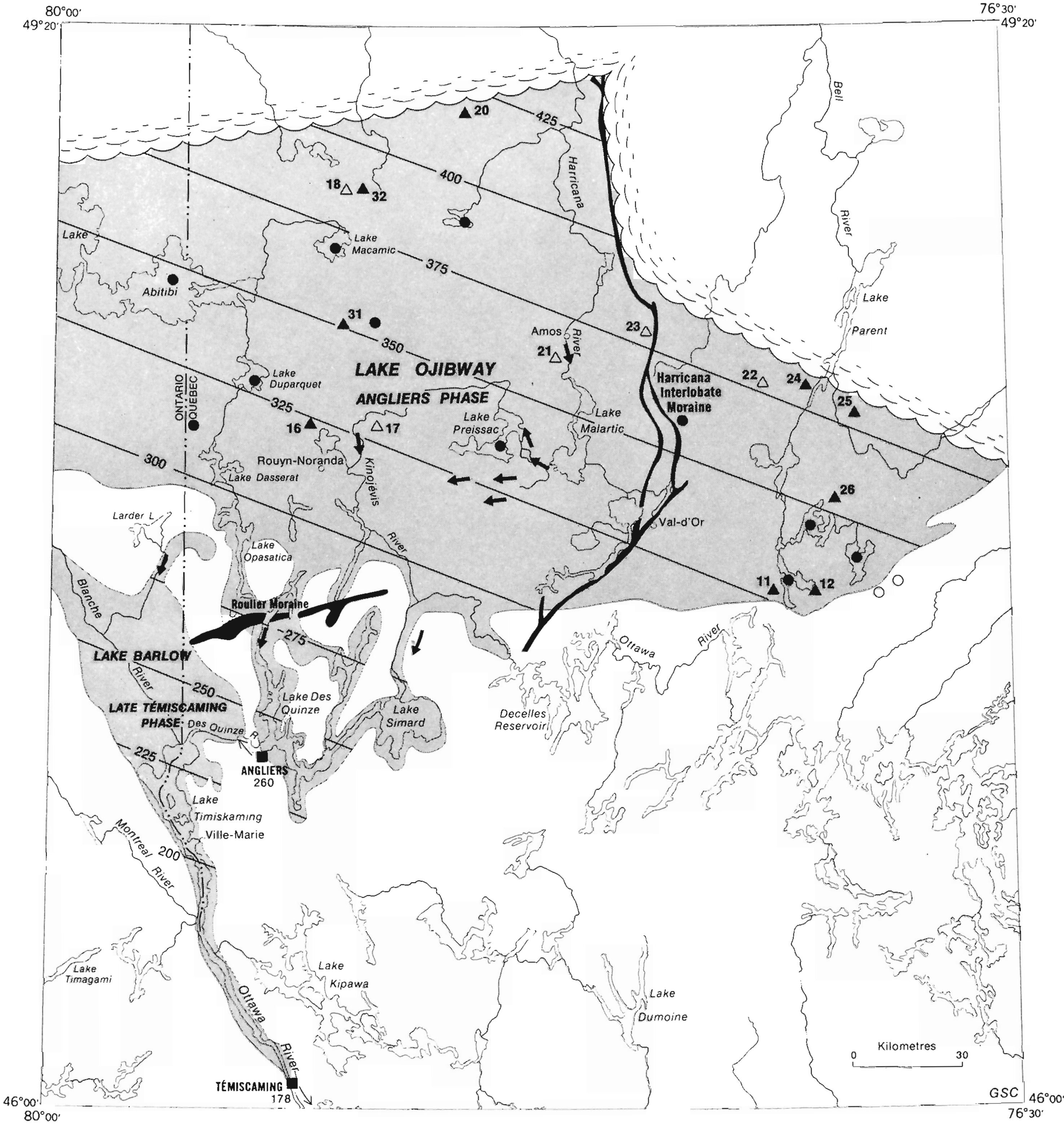


Figure 3G. Lake Ojibway – Angliers phase (Lake Barlow – late Témiscaming phase).

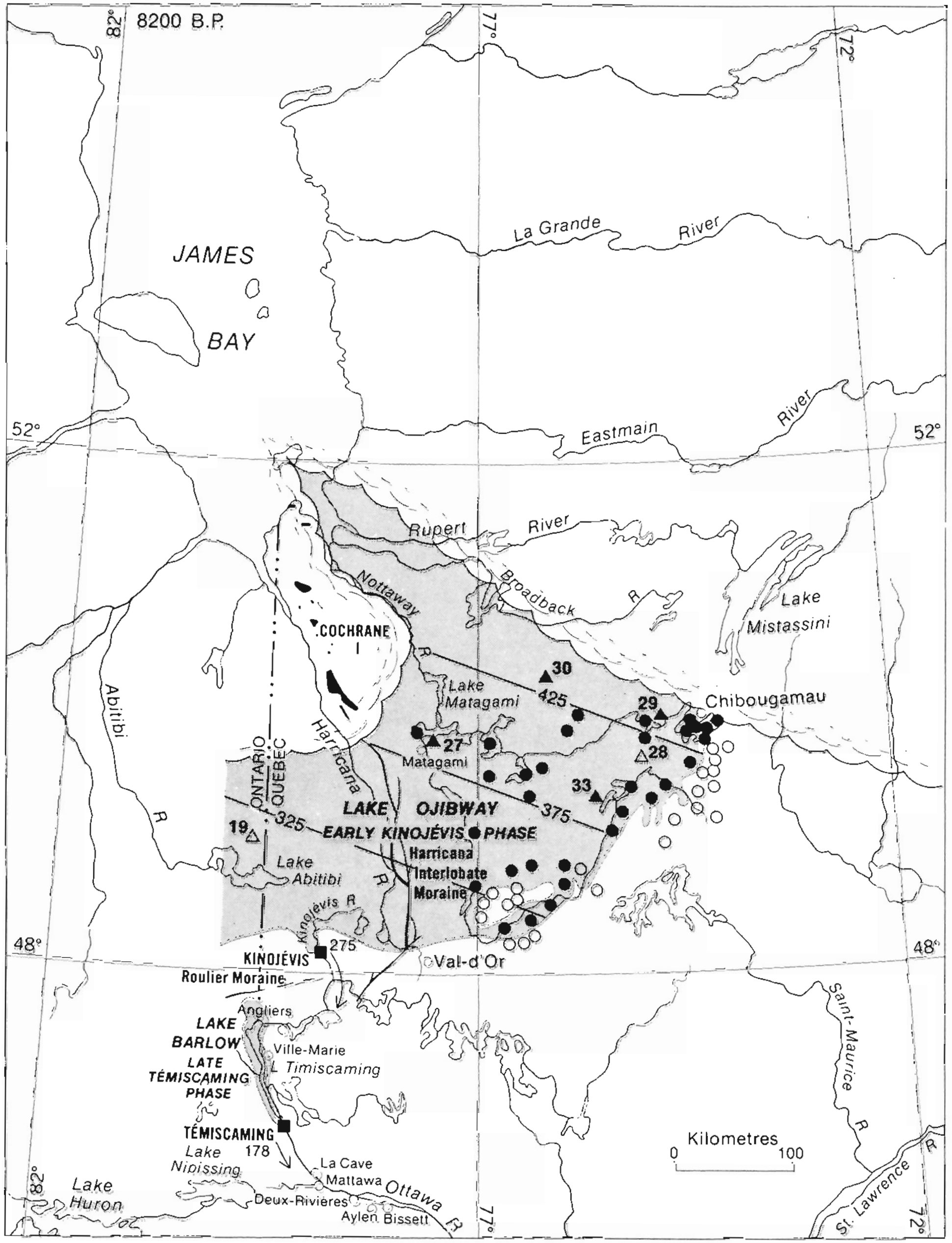


Figure 3H. Lake Ojibway – early Kinojévis phase
(Lake Barlow – late Témiscaming phase).

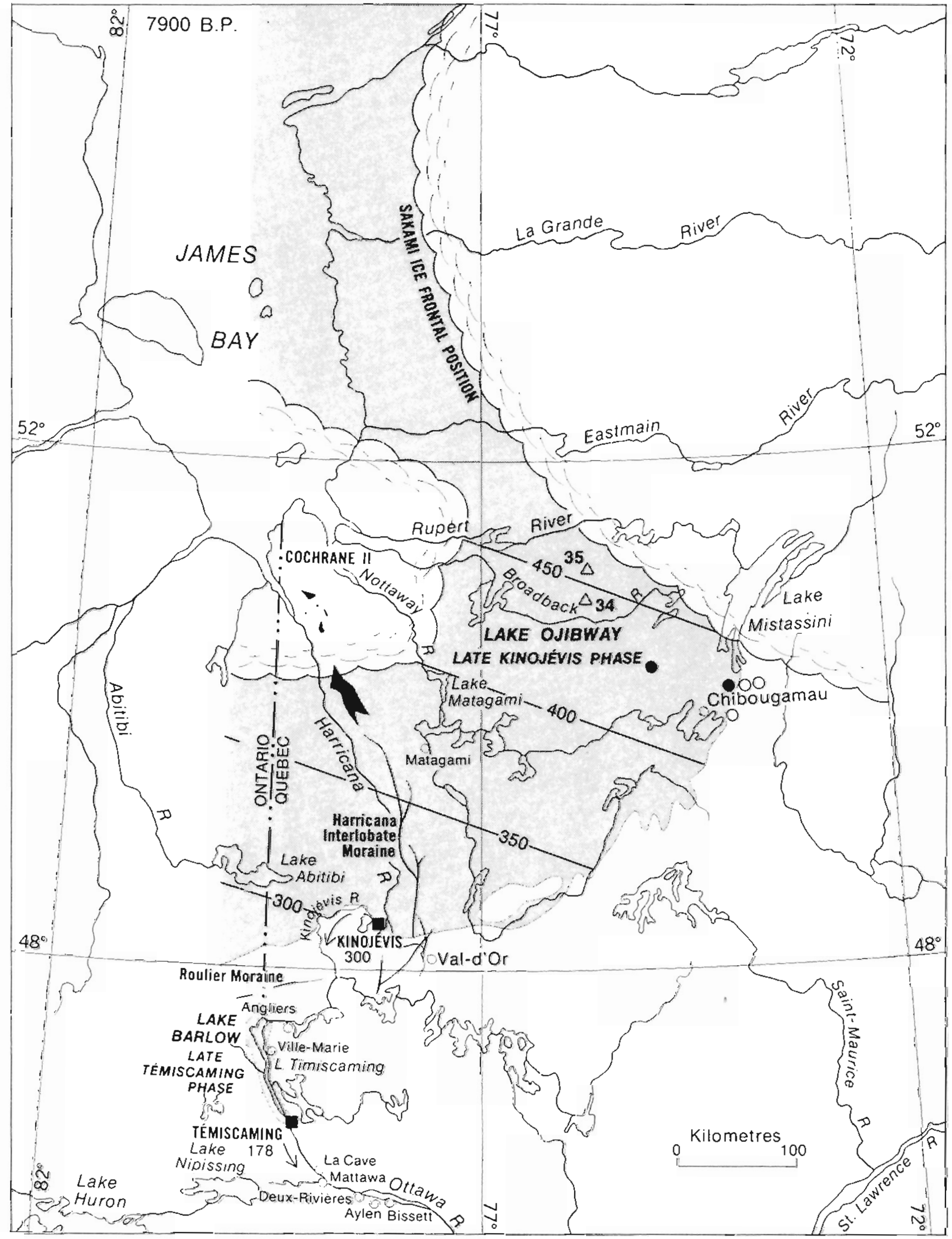


Figure 3I. Lake Ojibway – late Kinojévis phase
(Lake Barlow – late Témiscaming phase).

Lake Ojibway grew to the northeast and drained south via the Kinojévis outlet until the Hudson and New Quebec glaciers separated completely at the latitude of Hudson Bay, thus permitting a rapid discharge of the water to the north (Fig. 31). Drainage took place approximately 7900 years ago, at a time when the New Quebec glacier had retreated to the Sakami position and Cochrane II ice had maintained its maximum stand south of James Bay (Hardy, 1977).

The distribution of the crustacean **Mysis relicta** indicates that a proglacial lake survived in the basin of Lake Mistassini after the draining of Lake Ojibway. The altitude of the water plane in this post-Ojibway lake varied from approximately 395 m in the south to 410 m in the north. The lake drained toward Tyrrell Sea, first via Broadback River and then via Rupert and Eastmain rivers as new outlets became unglaciated.

CONCLUSION

The various data relating to the post-Algonquin lakes that submerged the area west of Ottawa River north of Mattawa and those parts of lakes Barlow and Ojibway lying in Quebec give rise to a new interpretation of the lacustrine phases. This interpretation is based on the fact that deformation of the terrain at the time of deglaciation had produced a southward shift of the Hudson Bay – St. Lawrence River drainage divide and that postglacial isostatic recovery produced a slow return of the divide northward to its present position.

The extent of the proglacial water bodies and the deformation of the terrain, superimposed on the present long profile of the valleys that logically served as a passage for overflow water, show that Lake Barlow first was retained by the Aylen outlet, where the threshold was formed by a morainic accumulation. The northward migration of the drainage divide took place in stages corresponding to the emergence of the main sills. Thus, after downcutting of the Aylen outlet, the southern limit of Lake Barlow migrated north as far as Témiscaming. The northern limit of the lake probably extended beyond the present drainage divide, but the emergence of the Angliers sill created a second lake and separated lake Barlow from the main glaciolacustrine basin. Since Lake Barlow survived for a long period of time in the Timiskaming trench, the independent water body retained between the Angliers sill and the ice margin here has been called Lake Ojibway.

During the Angliers and Kinojévis lacustrine phases, the northward migration of the drainage divide took place very gradually, given the much more regular profile of the river systems. The expansion of Lake Ojibway to the north and northeast continued until the separation of the Hudson and New Quebec glaciers permitted drainage of the lake into Hudson Bay to the north.

This interpretation does not take into account the hypothesis of morainic or ice dams in the Timiskaming trench and shows that differential isostatic uplift by itself is sufficient to explain the existence of lakes Barlow and Ojibway. Additional data on intermediate strandline levels should make it possible to correlate the water levels, determine the time of emergence of the outlets, and define their relative importance in the history of the proglacial lakes. It is improbable, however, that in the area inundated by Lake Barlow, such correlations can be performed given the narrowness of the depression and the poor development of strandlines.

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