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Late Quaternary Mollusks from Glacial Lake Algonquin, Nipissing, and Transitional Sediments from Southwestern Ontario, Canada

B. B. MILLER,* P. F. KARROW,† AND L. L. KALAS‡

*Department of Geology, Kent State University, Kent, Ohio, 44242; †Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, Canada; and ‡Department of Environment, Canada Centre for Inland Waters, Burlington, Ontario, Canada

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Mollusks were studied from six sites in Lake Algonquin deposits (12,000–10,000 yr B.P.), five transitional (Lake Stanley low stage; 10,000–6000 yr B.P.), and six Nipissing stage sites (6000–4000 yr B.P.) east of Lake Huron in southwestern Ontario. The sites represent a variety of near-shore, lagoonal, estuarine, and fluvial environments. Eighteen species were limited to occurrences in Algonquin stage deposits; 8 were found only in the transitional age sites; and 14 species were restricted to Nipissing stage localities. With the possible exception of *Goniobasis livescens* which occurred at five of the six Nipissing stage sites, the remaining stratigraphically limited species were usually restricted to one or two localities and probably cannot be used as zone fossils. Some cold-tolerant species (e.g., *Anodonta grandis simpsoniana*) were very early migrants into the study area, while others arrived later, apparently from eastern, southern, and western sources. Mollusks proved useful in paleoenvironmental reconstructions and to a lesser extent in biostratigraphic zonation.

INTRODUCTION

Until very recently, little attention has been paid to the fossils, particularly the mollusks, which occur in deposits associated with the North American glacial Great Lakes. Early work by Baker on the Michigan Basin and his review of other occurrences (1920) was followed by several decades of general neglect, with minimal mention of fossils in scattered papers and reports dealing with areal geology, regional geomorphology, and glacial history.

In the last 20 years interest has increased as more detailed study of lake history and lake deposits has revealed the widespread occurrence of fossil remains, particularly associated with the later lake stages. Thus mollusks have been described from Lake Iroquois in the Ontario basin (Karrow *et al.*, 1972), mollusks and other fossils from Lake Algonquin in the Huron and Georgian Bay basins (Karrow *et al.*, 1975; Ashworth, 1977), mollusks from various stages of the Superior basin (Zoltai and Herrington, 1966), and mollusks (Tuthill, 1967b; Zoltai, 1969) and a variety of other fossil groups (Ashworth *et al.*, 1972) from the Agassiz basin of the eastern Prairies.

PURPOSE

The present study is an extension of previous work on Lake Algonquin and has two purposes: a long-range objective is to document the presence of various molluscan species in lakes of various ages and deduce therefrom the timing and patterns of migration of mollusks as climate and paleogeography changed. A more specific objective is to provide a basis for additional biostratigraphic zonation of the lake deposits based on molluscan assemblages.

The deposits of Lake Algonquin and Lake Nipissing hold promise of a good test case for molluscan biostratigraphic zonation since the former was an ice-margined lake that existed 12,000 to 10,000 yr ago, while the latter was a lake created by isostatic uplift during a time referred to by some as the Climatic Optimum, 6000 to 4000 yr ago, when temperatures were apparently higher than at present. At many sites we can form a good impression of the environment

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from the paleogeography, sediments, and contained pollen assemblages. The mollusks then add to this picture, and their interpretation can be evaluated in terms of the other evidence.

Along the east shore of Lake Huron, study of Lake Algonquin and Nipissing deposits is difficult in that subsequent shore erosion has removed the Algonquin and Nipissing lake terraces between Clark Point and Grand Bend (Fig. 1). Through that zone and beyond, however, most stream valleys have well-developed terraces apparently graded to former lake levels (Fig. 2). In some sites direct correlation of the valley terraces and lake levels is possible, while in others this geomorphic correlation is uncertain to varying degrees. Correlation has been aided by radiocarbon dating of some sites, supplemented by age estimates based on established palynological zonation (Karrow *et al.*, 1975).

LAKE HISTORY

The sites reported here are classified as Lake Algonquin, Lake Nipissing, and transitional on the basis of geomorphology, radiocarbon dating (Table 1), and palynology. Lake Algonquin formed as a glacial lake as the ice margin retreated northeast-

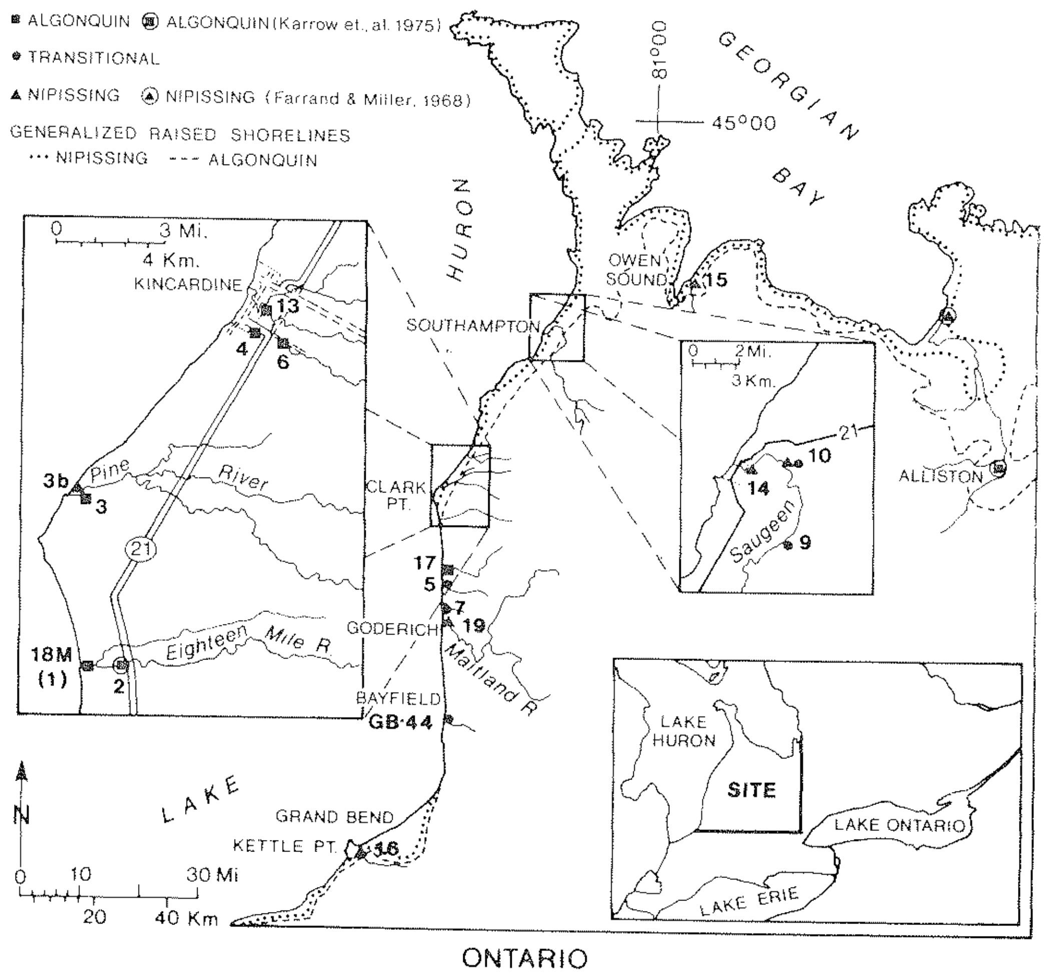

FIG. 1. Locality map showing the distribution of Algonquin, transitional and Nipissing sites in the Lake Huron–Georgian Bay region of Ontario.

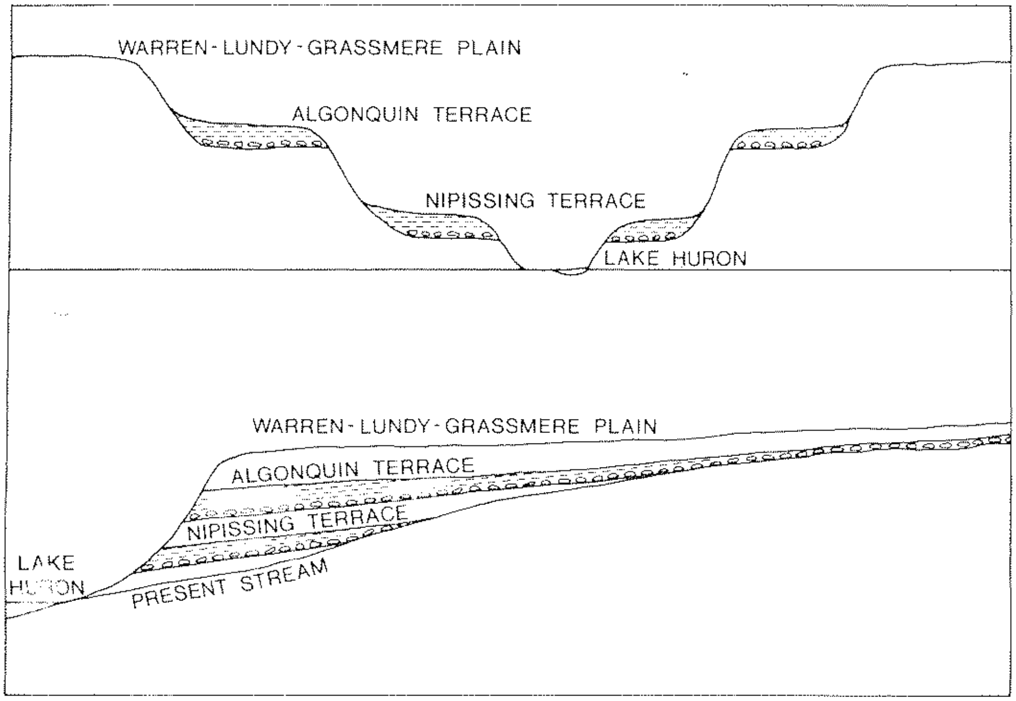

FIG. 2. Sketch (not to scale) showing relationship of transgressive estuarine terraces in stream valley east of Lake Huron.

ward. Early and Late (Main) Lake Algonquin were separated by a low water stage when the Kirkfield outlet was open to the Ontario basin (Fig. 3). All Lake Algonquin sites discussed here belong to the Late Algonquin stage, when the ice margin apparently was retreating across the rough terrain east of Georgian Bay. Near North Bay much lower outlets opened and Lake Algonquin drained down several hundred feet to the low Lake Stanley stage. Slow isostatic uplift of the North Bay area raised the water level in the Michigan and Huron basins back to the Port Huron outlet, which had been one of the Algonquin outlets, creating Lake Nipissing. During the low-water stage, valley terraces graded to the Algonquin level began to be incised by streams. Upstream from the knickpoints, reworking of terrace sediments took place, creating the transitional sites. In Nipissing time new terraces formed lower in the val-

TABLE 1

SUMMARY OF RADIOCARBON DATES REFERRED TO IN APPENDIX

Date	Locality	Depth (m)	Source
920 ± 130 (GSC-1134)	16	0.3–0.9	(Lewis, 1969)
4250 ± 130 (GSC-1122)	16	1.8–2.1	(Lewis, 1969)
5230 ± 100 (GSC-2046)	10	0.0–1.8	Shell
5770 ± 100 (GSC-2190)	16	1.8–2.1	*Thuja occidentalis*
6270 ± 250 (GSC-1620)	10	1.8–2.1	Charcoal
7660 ± 140 (GSC-2049)	GB-44	1.8–2.4	*Abies balsamea*
10,800 ± 110 (GSC-1904)	6	5.5	*Picea* wood and *Picea mariana* cone
11,300 ± 140 (GSC-1842)	13	2.7–3.4	*Picea* or *Larix* wood

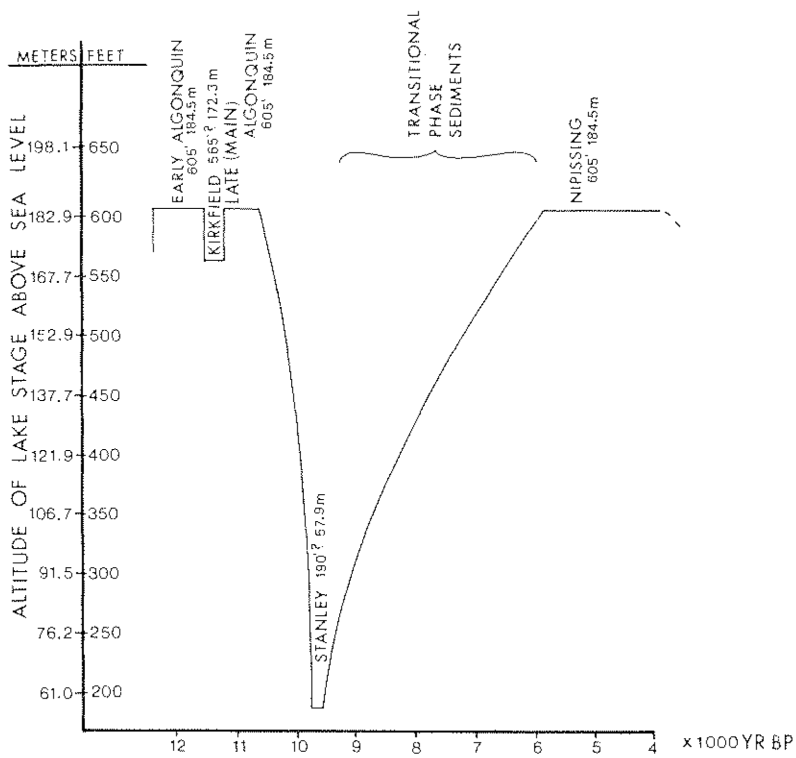

FIG. 3. Sequence of main water levels in southern Huron Basin between Early Lake Algonquin and Lake Nipissing time (modified from Hough, 1963).

leys, inset in the Stanley–Nipissing entrenchments. Lake Nipissing was brought to an end by downcutting of the outlet at Port Huron, bringing into existence present Lake Huron and Lake Michigan.

FIELD WORK

The discovery of the first sites along Eighteen Mile River has been described previously (Karrow *et al.*, 1975). Examination of air photos and field search in the valleys from northeast of Owen Sound to south of Bayfield yielded additional fossil localities in several of the valleys. Where practical, bulk sediment samples were collected. In many cases, however, where only surface picking was carried out, attempts were made to collect species in a manner that roughly reflected their correct proportions. Because of the nature of the distrubution of exposures, it has not been possible to achieve full parallelism of settings of collecting sites for each lake stage and this has to be considered in the resulting interpretations. Nevertheless, we believe that there are now a sufficient number of fossiliferous localities to allow us to reach some preliminary conclusions and to serve as a basis for further work.

STRATIGRAPHIC DISTRIBUTION OF THE MOLLUSKS

Previous collections made from near Lake Huron and Lake Simcoe (Karrow *et al.*, 1975), together with materials from six new sites (Fig. 1), have expanded the molluscan faunal list from Lake Algonquin deposits to include 18 terrestrial and 34 aquatic taxa (Tables 2 and 3). The new sites have added records of two aquatic species, *Sphaerium partumeium* and *Amnicola integra*, and four terrestrial species, *Pupilla muscorum*, *Vallonia albula*, *Vitrina limpida* and cf. *Zoogenetes harpa*. Five terrestrial species and 13 aquatic species appear to be restricted to Algonquin stage sites in the study area (Table 3).

Molluscan assemblages from six Nipissing and five transitional-age sites include 17 terrestrial and 33 aquatic (Nipissing), and 27 terrestrial and 25 aquatic species and subspecies, respectively. Six aquatic species, *Ferrissia fragilis*, *Gyraulus circumstriatus*, *Sphaerium* cf. *rhomboideum*, *Physa* cf. *gyrina*, *Lampsilis radiata radiata*, and *Marstonia decepta* and 12 terrestrial species, *Carychium exiguum*, *Helicodiscus parallelus*, cf. *Oxyloma retusa*, *Strobilops aenea*, *S. labyrinthica*, *Gastrocopta armifera*, *G. contracta*, *G. tappaniana*, *Punctum minutissimum*, *Striatura milium*, *Vertigo gouldi*, and *Hawaiia minuscula*, first appear in the study area in sediments associated with transitional-age sites 10,000 to 6000 years B.P.

Deposits from sites associated with glacial Lake Nipissing (6000–4000 yr B.P.) contain nine aquatic and three terrestrial species not present in Algonquin or transitional-age sites. These include *Pisidium* cf. *dubium*, cf. *Amblema plicata*, *Goniobasis livescens*, *Laevapex fuscus*, *Ferrissia parallela*, *Promenetus exacuous exacuous*, *Lymnaea obrussa*, *L.* cf. *dalli*, and *Armiger crista* (aquatic species), and *Zonitoides nitidus*, *Vertigo ovata*, and *V. morsei* (terrestrial species).

The limited temporal occurrences of many of the mollusks suggest that they may be locally useful in the zonation of Algonquin, transitional and Nipissing sediments. Fourteen of the 18 species restricted to Algonquin stage sediments (Table 4) are only known from localities within the Alliston Embayment. Only two species, *Pisidium nitidum* cf. *pauperculum* and *P. lilljeborgi*, however, are sufficiently widespread to be potentially useful in identifying Algonquin stage deposits in the Alliston area.

Table 5 shows the stratigraphic distribution of mollusks limited to post-Algonquin deposits in the study area. Many of these species are clearly restricted in their stratigraphic range. Unfortunately occurrences of most of the stratigraphically restricted species are confined to only one or two localities. Only *Goniobasis livescens* now appears to be sufficiently widespread and abundant to be considered a "zone" fossil for Nipissing stage deposits; this species is often the most abundant on the modern Lake Huron beach. Study of mollusks from many more sites will be necessary to test the general applicability of gastropods and small pelecypods for zoning these sediments.

As yet, collecting has yielded only very few large unionid clams. They normally do not occur in the abundance the smaller clams and snails do, and easily break up during weathering and transportation after death. If this group was fully represented in the collections they would probably add substantially to the distinctive species to be found in the Algonquin and younger deposits. At present only one species (*Anodonta grandis simpsoniana*) is known from Algonquin deposits and it has not been found in the younger deposits. On the other hand, *Amblema plicata* and *Lampsilis*

TABLE 4

MOLLUSKS RESTRICTED TO ALGONQUIN STAGE DEPOSITS

Sphaerium partumeium 1[a]	Pisidium nitidum cf. pauperculum 4[b]
Sphaerium lacustre?	Pisidium walkeri cf. mainense 1[b]
Physa cf. heterostropha 1[b]	Pisidium ventricosum 1[b]
Lymnaea modicella 1[b]	Pisidium millium?1
Lymnaea humilis 1[b]	Pisidium lilljeborgi 5[b]
Vallonia costata 1[b]	Anodonta grandis simpsoniana 1[b]
Columella edentula 1[b]	Pisidium conventus 2[b]
Vallonia pulchella 1[b]	Gyraulus sp. (articus)? 1[b]
Euconulus chersinus 1[b]	Zoogenetes harpa 1

[a] The integer following each name indicates the number of sites at which the taxon occurs.

[b] Restricted to localities in Alliston Embayment area.

TABLE 2

TERRESTRIAL SPECIES

Species	Karrow *et al.* (1975)	Algonquin 13	4	6	3	18M	17	Transitional Upper 10	9	5	7	GB-44	15	Nipissing Lower 10	14	3b	19	16
Carychium exiguum (Say)	—	—	—	—	—	—	—	—	—	2	—	36	1	—	5	—	—	—
cf. *Catinella* "*avara*" (Say)	x	—	—	—	—	9	—	7	6	—	34	5	—	—	—	—	—	—
Cionella lubrica (Muller)	x	—	—	—	—	1	—	—	—	1	—	14	—	—	—	—	—	—
Columella alticola (Ingersoll)	x	—	—	—	—	1	—	2	—	—	—	—	—	—	—	—	—	—
C. edentula (Draparnaud)	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Discus cronkhitei (Newcomb)	x	—	—	—	1	8	4	2	4	1	29	22	1	1	1	—	—	1
Euconulus chersinus (Say)	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E. fulvus (Muller)	cf	—	—	—	—	2	cf. 3	4	—	—	8	5	—	—	—	—	—	—
Gastrocopta armifera (Say)	—	—	—	—	—	—	—	—	—	—	4	1	—	1	—	—	—	3
G. contracta (Say)	—	—	—	—	—	—	—	—	—	—	—	19	—	4	1	—	—	2
G. tappaniana (Adams)	—	—	—	—	—	—	—	1	—	3	4	42	1	1	1	—	—	6
Hawaiia minuscula (Binney)	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
Helicodiscus parallelus (Say)	—	—	—	—	—	—	—	—	—	—	—	19	2	1	3	—	—	2
Nesovitrea electrina (Gould)	x	—	—	—	—	—	1	1	1	1	20	12	—	—	—	—	—	7
cf. *Oxyloma retusa* (Lea)	—	—	—	—	—	—	—	—	—	6	—	—	—	—	—	—	—	—
Punctum minutissimum (Lea)	—	—	—	—	—	—	—	—	—	—	18	13	—	—	—	—	—	—

TABLE 2—*continued*

Species	Karrow *et al.* (1975)	Algonquin 13	Algonquin 4	Algonquin 6	Algonquin 3	Algonquin 18M	Algonquin 17	Transitional Upper 10	Transitional 9	Transitional 5	Transitional 7	Transitional GB-44	Transitional 15	Nipissing Lower 10	Nipissing 14	Nipissing 3b	Nipissing 19	Nipissing 16
Pupilla muscorum (Linne)	—	—	—	—	—	1	—	—	—	—	—	8	—	—	—	—	—	—
Pupoides albilabris (Adams)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	2
Striatura milium (Morse)	—	—	—	—	—	—	—	—	—	—	—	16	—	—	—	—	—	—
Strobilops aenea Pilsbry	—	—	—	—	—	—	—	—	—	—	—	26	—	—	—	—	—	3
S. labyrinthica (Say)	—	—	—	—	—	—	—	—	—	—	—	17	cf. 1	—	4	—	—	cf. 2
S. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
cf. *Succinea* Draparnaud	x	—	—	—	—	—	—	—	—	—	—	6	—	—	—	—	—	9
Vallonia albula Sterki	—	—	—	—	—	—	1	6	1	2	22	6	—	—	1	—	—	cf. 1
V. costata (Muller)	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
V. pulchella (Muller)	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vertigo elatior Sterki	x	—	—	—	—	—	—	—	—	—	35	19	—	—	—	—	—	1
V. gouldi (Binney)	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—
V. g. cf. *hannai* Pilsbry	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
V. g. cf. *paradoxa* Sterki	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—
V. modesta (Say)	x	—	—	—	—	—	2	—	—	—	7	—	—	—	—	—	—	—
V. morsei Sterki	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9
V. ovata Say	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14
Vitrina limpida Gould	—	—	—	—	—	—	2	—	—	—	7	—	—	—	—	—	—	—
cf. *Zoogenetes harpa* (Say)	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Zonitoides arboreus (Say)	x	—	—	—	—	—	—	1	—	—	—	6	—	—	3	—	—	6
Z. nitidus (Muller)	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—
Total species	13	0	0	1	1	6	6	9	4	7	12	18	5	6	9	0	0	14

TABLE 3

AQUATIC SPECIES

Species	Karrow *et al.* (1975)	Algonquin						Transitional						Nipissing					
		13	4	6	3	18M	17	Upper 10	9	5	7	GB-44	15	Lower 10	14	3b	19	16
cf. *Amblema plicata* (Say)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7/2
Amnicola integra (Say)	—	—	—	—	1	—	—	—	—	—	—	—	6	—	6	—	—	—
Amnicola limosa (Say)	x	2	—	88	20	—	3	—	1	11	—	7	13	54	24	—	31	60
Anodonta grandis simpsoniana Lea	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Armiger crista (Linne)	—	—	—	—	—	—	—	—	—	—	—	—	—	6	1	—	—	—
Ferrissia fragilis (Tryon)	—	—	—	—	—	—	—	—	—	—	1	31	—	3	—	—	—	—
F. parallela (Haldeman)	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—
Gyraulus circumstriatus (Tryon)	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
G. deflectus (Say)	x	—	—	—	—	—	—	—	—	—	5	—	—	19	—	—	—	—
G. parvus (Say)	x	11	—	43	57	5	30	76	150+	51	38	50	7	16	16	—	24	12
G. sp. (*arcticus*?) (Beck)	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Goniobasis livescens (Menke)	—	—	—	—	—	—	—	—	—	—	—	—	15	—	17+	31	13	123+
Helisoma anceps (Menke)	x	5	—	12	36	1	4	15	29	8	37	23	3	10	3	—	21	—
H. campanulatum (Say)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	—
Laevapex fuscus (C. B. Adams)	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—
Lampsilis radiata radiata (Gmelin)	—	—	—	—	—	—	—	—	—	1/2	—	—	—	—	—	—	—	11/2
Lymnaea catascopium Say	x	—	—	—	—	—	—	—	—	—	—	cf. 2	cf. 6	—	3	—	—	13
L. cf. *dalli* Baker	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16
L. decampi (Streng)	x	13	1	10	8	19	cf. 20	65	14	6	72	17	—	10	9	—	—	19
L. elodes (Say)	x	—	—	cf. 1	cf. 2	—	cf. 1	11	—	—	17	—	—	—	—	—	—	—
L. humilis Say	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
L. modicella Say	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
L. obrussa Say	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	cf. 3	26
L. stagnalis (Linne)	x	4	—	—	—	—	—	3	8	—	—	—	—	—	—	—	—	cf. 1
Marstonia decepta (Baker)	—	—	—	—	—	—	—	—	—	1	—	—	—	16	21	—	14	—
cf. *Campeloma* Rafinesque	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—

TABLE 3—continued

Species	Karrow *et al.* (1975)	Algonquin 13	4	6	3	18M	17	Transitional Upper 10	9	5	7	GB-44	15	Nipissing Lower 10	14	3b	19	16
Physa cf. *gyrina* Say	—	—	—	—	—	—	—	—	13	—	—	—	—	4	—	—	13	10
P. cf. *heterostropha* Say	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
P. sp. Draparnaud	—	1	—	—	1	—	2	2	2	—	3	10	1	—	11	—	—	6
Pisidium casertanum (Poli)	x	9/2	1/2	6/2	11/2	9/2	1/2	61/2	27/2	20/2	25/2	70/2	10/2	92/2	7/2	—	2/2	67/2
P. compressum Prime	x	40/2	—	154/2	43/2	—	19/2	39/2	9/2	57+ 62/2	32/2	40/2	37/2	4/2	10/2	—	—	25/2
P. conventus Clessin	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
P. cf. *dubium* (Say)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1/2
P. ferrugineum Prime	x	—	—	—	—	—	—	4/2	—	—	—	—	—	—	—	—	—	—
P. lilljeborgi Clessin	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
P. milium Held?	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
P. nitidum Jenyns	x	—	—	—	—	—	—	4/2	—	2/2	—	7/2	14/2	—	—	—	—	6/2
P. nitidum cf. *pauperculum* Sterki	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
P. subtruncatum Malm	x	—	—	—	—	—	—	—	—	2/2	—	—	—	—	—	—	—	—
P. variabile Prime	x	—	—	—	—	3/2	—	—	—	3/2	4/2	250/2	210/2	—	—	—	—	364/2
P. ventricosum Prime	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
P. walkeri cf. *mainense* Sterki	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Probythinella lacustris (Baker)	x	—	4	3	—	14	—	22	5	—	—	—	—	—	11	—	—	—
Promenetus exacuous exacuous (Say)	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—	—
Sphaerium lacustre (Muller)	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S. partumeium (Say)	—	1+3/2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S. cf. *rhomboideum* (Say)	—	—	—	—	—	—	—	—	1/2	—	—	—	—	—	—	—	—	—
S. simile (Say)	x	—	—	—	—	—	—	—	—	—	—	cf. 2/2	—	—	—	—	cf. 1/2	14/2
S. striatinum (Lamarck)	x	—	55/2	26/2	—	—	1/2	28/2	23/2	—	23/2	30/2	2/2	—	—	—	—	—
Unionid fragments	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—
Valvata sincera helicoidea Dall	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	6
V. s. sincera Say	x	9	13	13	22	—	—	63	49	—	24	6	—	—	6	—	—	—
V. tricarinata Say	x	27	4	68	50+	15	18	87	150+	—	—	26	15	26	16	—	56	10
Total species	31	10	6	11	10	7	9	13	13	12	12	14	12	16	14	1	11	19

TABLE 5

MOLLUSKS RESTRICTED TO POST-ALGONQUIN DEPOSITS

Hawaiia minuscula 2[a]	cf. *Amblema plicata* 1[c]
Carychium exiguum 4	*Helisoma campanulatum* 1[c]
Helicodiscus parallelus 5	*Pisidium* cf. *dubium* 1[c]
Vertigo gouldi 1[b]	*Laevapex fuscus* 1[c]
V. g. cf. *hannai* 1[b]	*Goniobasis livescens* 5[c]
V. g. cf. *paradoxa* 1[b]	*Promenetus exacuous* 1[c]
Strobilops labyrinthica 4	*Ferrissia parallela* 1[c]
S. aenea 2	*Lymnaea obrussa* 2[c]
Gastrocopta contracta 4	*Gyraulus circumstriatus* 1[b]
G. armifera 4	*Ferrissia fragilis* 3
G. tappaniana 8	*Marstonia decepta* 4
Vertigo morsei 1[c]	*Armiger crista* 2[c]
V. ovata 1[c]	*Sphaerium* cf. *rhomboideum* 1[b]
cf. *Oxyloma retusa* 1[b]	*Physa* cf. *gyrina* 4
Zonitoides nitidus 1[c]	*Lymnaea* cf. *dalli* 1[c]
Punctum minutissimum 2[b]	*Lampsilis radiata radiata* 2
Striatura milium 1[b]	
Pupoides albilabris 2[c]	

[a] The integer following each name indicates the number of sites at which the taxon occurs.
[b] Restricted to transitional-age sites 10,000–6000 yr B.P.
[c] Restricted to Nipissing stage deposits 6000–4000 yr B.P.

radiata radiata have been found in younger deposits but not in Algonquin deposits.

CLIMATIC SIGNIFICANCE OF THE MOLLUSKS

Although most of the fossil mollusks belong to species which can now be found living in this area of Ontario (Robertson, 1915; Rawson, 1930; Bell, 1861; Herrington, 1968; Oughton, 1948), changes in the fauna have occurred within the past 12,000 years that appear to be related to climatic change and migration. The presence of *Pisidium conventus* in estuarine and near-shore sediments associated with glacial Lake Algonquin (Karrow *et al.*, 1975) implies cold water temperatures even in the shallower parts of the lake. This species is an oligothermal glacial relict, which in the Great Lakes is now rarely found in water shallower than 50 ft (15 m) (Henson, 1966; Henson and Herrington, 1965; Burch, 1975).

Cooler summer temperatures are indicated by the occurrence of *Columella alticola* and *Vertigo modesta* in Algonquin and transitional-age deposits. These species now reach the southern limits of their range in Ontario (Fig. 4) well to the north of the study area (Oughton, 1948). A modest range expansion during the Climatic Optimum between 6000 to 4000 yr B.P. is suggested by the presence of *Vertigo morsei* and *Pupoides albilabris* in sediments associated with glacial Lake Nipissing. Distribution data from Oughton (1948) indicate that these terrestrial species are now restricted in Ontario to counties bordering the lower Great Lakes (Fig. 5).

Although the unionids are poorly represented, the presence of *Anodonta grandis simpsoniana* in the Algonquin deposits only is noteworthy. Clarke (1973, p. 89) has commented on this occurrence:

> . . . one would expect that the first immigrants to a newly deglaciated area would be cold tolerant, and by its present distribution

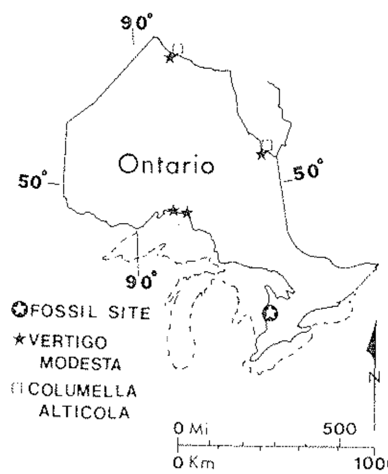

FIG. 4. Distribution map of *Vertigo modesta* and *Columella alticola* in Ontario (after Oughton, 1948).

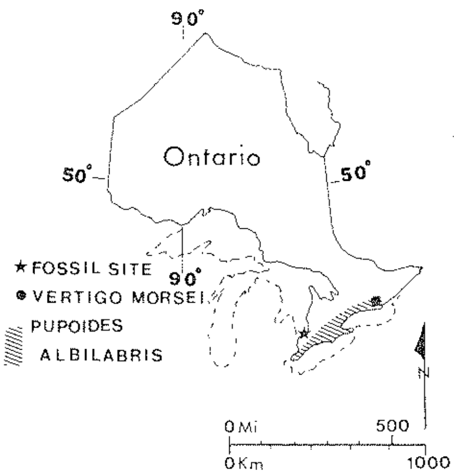

FIG. 5. Distribution map of *Vertigo morsei* and *Pupoides albilabris* in Ontario (after Oughton, 1948).

> in Canada *Anodonta grandis simpsoniana* is obviously cold tolerant to a remarkable degree.

The northern (colder) affinities of *A. grandis simpsoniana* and the southern (warmer) affinities of *Amblema plicata* and *Lampsilis radiata radiata* correspond well with the expected climates prevalent during Algonquin and later time respectively (Clarke, 1973).

MIGRATION AND DISTRIBUTION PATTERNS OF THE MOLLUSKS

Dated molluscan assemblages from the Great Lakes and peripheral regions provide insight into the timing and direction followed by some of the aquatic mollusks that entered the study area between 12,000 to 4000 yr B.P. The geographic distribution and sources for these data are shown in Fig. 6. The paucity of terrestrial species in these assemblages necessitates limiting the discussion that follows to aquatic forms.

Between 12,000 to 10,400 yr B.P. one group of species which includes *Gyraulus parvus*, *Valvata tricarinata*, *Amnicola limosa*, and *Helisoma anceps* was already established over a broad area extending

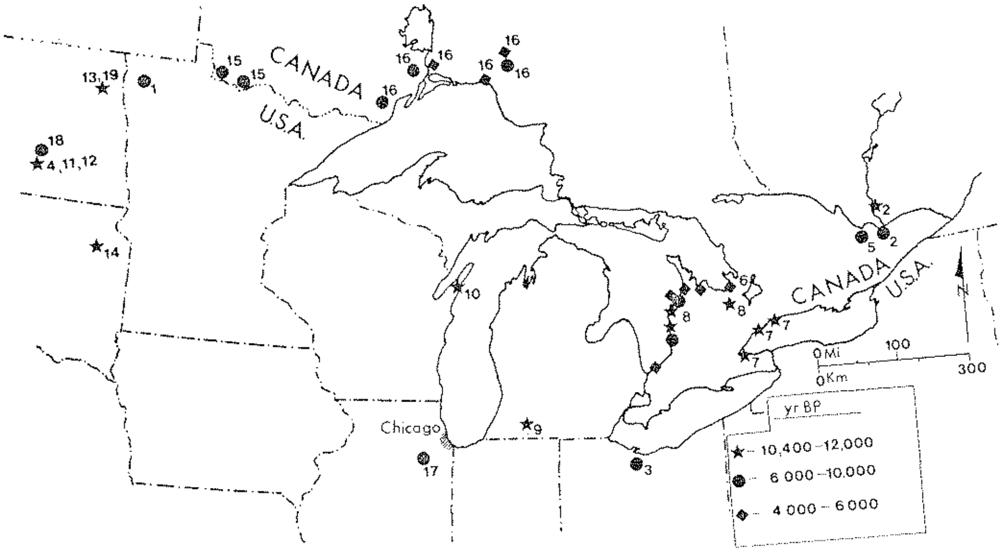

FIG. 6. Map of molluskan faunal sites used in construction of Figs. 7–10. The stars represent sites 12,000 to 10,4000 yr B.P.; circles represent sites 10,000 to 6000 yr B.P.; and diamonds represent sites 6000 to 4000 yr B.P. The number(s) following each site refer to the literature citations used in the compilation of the faunal lists or age data. (1) Ashworth *et al.*, 1972; (2) Bickel, 1970; (3) Clark, 1961; (4) Clayton, 1962; (5) Clowers, 1966; (6) Farrand and Miller, 1968; (7) Karrow *et al.*, 1972; (8) Karrow *et al.*, 1975; (9) Semken *et al.*, 1964; (10) Thwaites and Bertrand, 1957; (11) Tuthill, 1961; (12) Tuthill, 1967a; (13) Tuthill *et al.*, 1964; (14) Watts and Bright, 1968; (15) Zoltai, 1969; (16) Zoltai and Herrington, 1966; (17) Leonard, 1974; (18) McAndrews *et al.*, 1967; (19) Elson, 1967. Data from unnumbered localities are from this report.

from the Gatineau River Valley on the east to the eastern Dakotas on the west (Fig. 7). The early widespread occurrence, together with the general abundance of this group of species in Algonquin stage sediments of the study area (Table 3), suggests that they were perhaps already living in these areas on the ice margin before deglaciation. That they could indeed live in superglacial habitats is indicated by the occurrence of three species in this group from ice-contact deposits in the Missouri Coteau (Clayton, 1961).

Lymnaea stagnalis, *L. decampi*, *Pisidium variabile*, and *Probythinella lacustris* display a different distribution pattern. Between 12,000 and 10,400 yr B.P. these species were present in the study area and at sites to the east (Fig. 8). *P. lacustris* occurs in deposits from the Lake Nipigon and Rainy River District by 9580 to 9380 yr B.P. (Zoltai and Herrington, 1966; Zoltai, 1964) and *P. casertanum* was reported in Stutsman County, North Dakota (McAndrew *et al.*, 1967), from sediments estimated to be between 10,000 and 9000 yr B.P. suggesting a general migration from east to west (Fig. 9).

A third pattern involves *Lymnaea dalli*, *L. obrussa*, *Armiger crista*, and *Promenetus exacuous*. These species first appear in the study area in Nipissing stage sediments, but were already established at sites to the east and west of the study area by 11,000 yr B.P. (Fig. 10).

ECOLOGICAL IMPLICATIONS OF THE MOLLUSKS

Algonquin Stage Sites

Localities 13, 6, and 3 are dominated by six aquatic species, *Amnicola limosa*, *Helisoma anceps*, *Lymnaea decampi*, *Gyraulus parvus*, *Valvata tricarinata*, and *V. sincera sincera*, which comprise 83, 99, and 99% of the individuals at these respective sites. This association of species is typical of sheltered littoral lacustrine communities (Watts and Bright, 1968; Bickel, 1970). The molluscs at 13, 6, and 3 indicate a quiet, cool, silt-free, well-oxygenated shallow embayment of a lake, with areas of abundant macroscopic vegetation. The absence of terrestrial species at 13 and 4 and the solitary occurrence of one apical whorl from *Discus cronkhitei* at 3 suggest deposition away from shore.

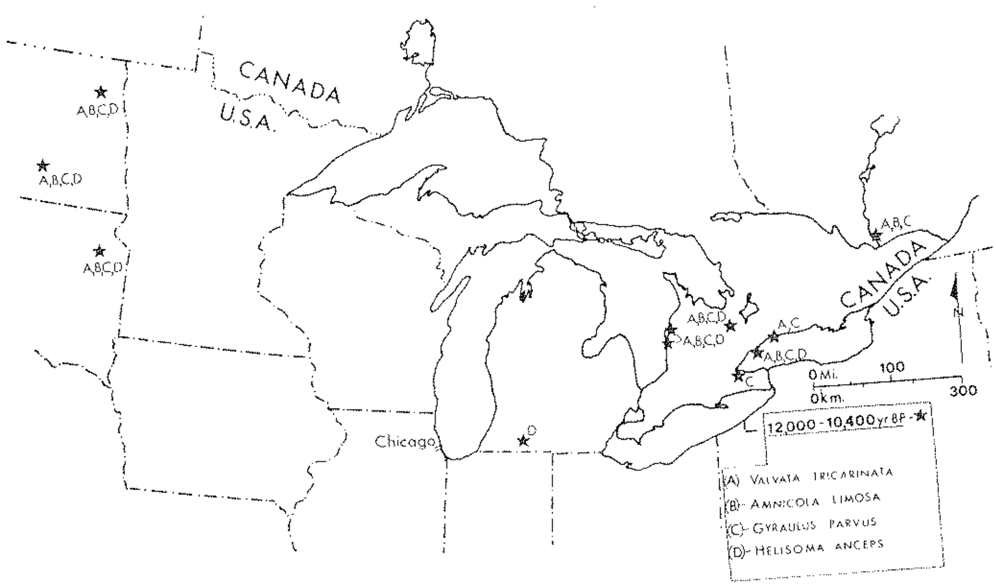

FIG. 7. Distribution map of molluskan species that were widespread in Great Lakes and peripheral areas between 12,000 and 10,400 yr B.P.

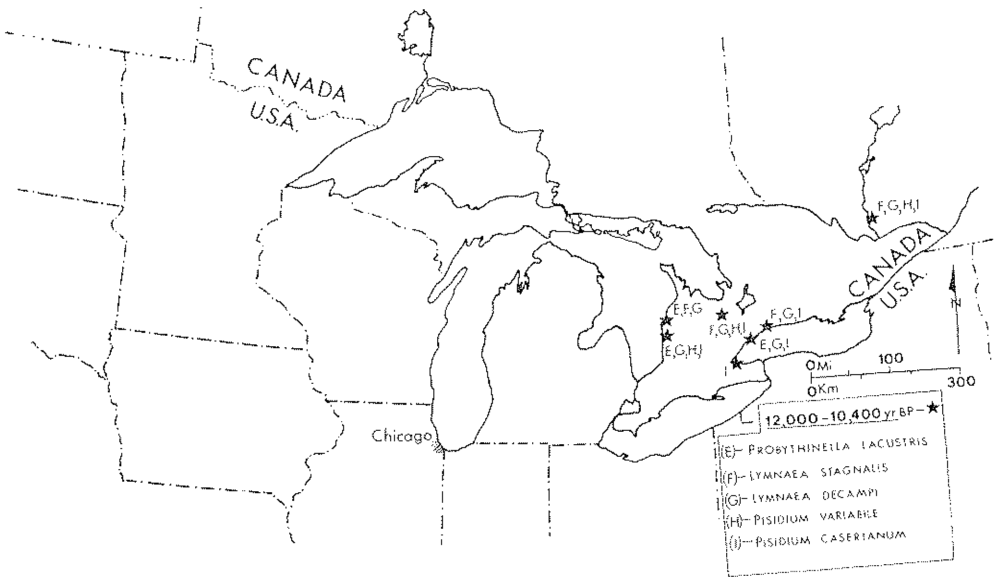

FIG. 8. Distribution map of molluskan species restricted to study area and localities to the east between 12,000 and 10,400 yr B.P.

Locality 4 probably also represents a lacustrine environment. The absence of terrestrial species, together with the small number and low diversity of aquatic species, suggests that deposition at this site may have been on the open lake side of an off-shore bar. The aquatic mollusks from localities 18M and 17 suggest that these

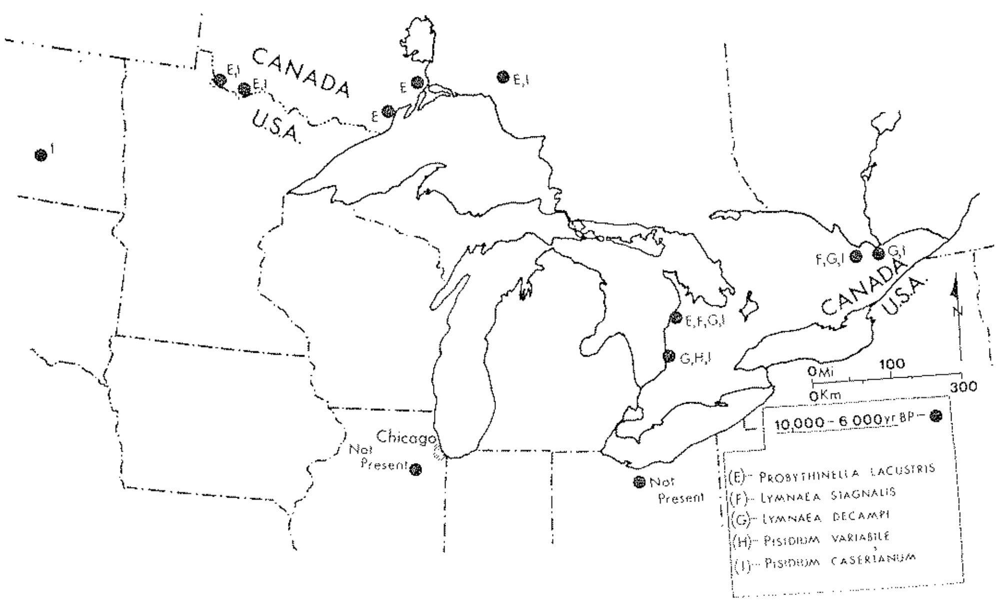

FIG. 9. Distribution map of same species group shown in Fig. 8 for time interval between 10,000 and 6000 yr B.P. No species from this group were present at the Castalia, Ohio (Clark, 1961), or Strawn Bog, Illinois (Leonard, 1974), localities.

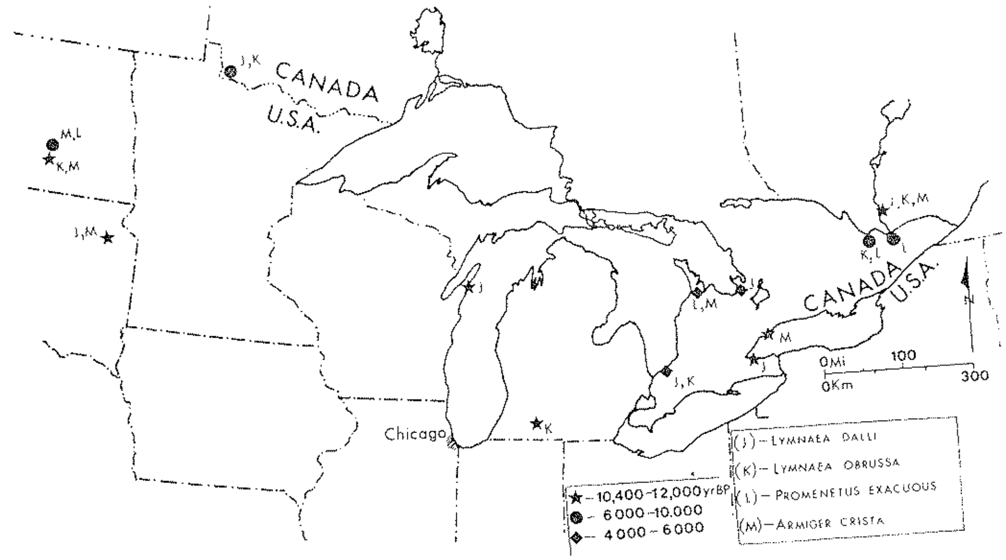

FIG. 10. Distribution map of species group that were present at sites east and west of the study area betwee 12,000 and 6000 yr B.P. (circles and stars). These species first appear in the study area between 6000 and 4000 B.P. (squares).

sites were probably part of a small stream that flowed into the same lake represented at localities 13, 4, 6, and 3.

Transitional Stage Sites

Localities 10 (upper), 9, 5, 7, and GB-44 include sediments intermediate in age between Algonquin and Nipissing stage deposits. Ninety three and 90% of the individuals at localities 10 and 9, respectively, belong to species associated with sheltered littoral lacustrine habitats. This assemblage, together with the abundance of *V. tricarinata*, *V. s. sincera*, *G. parvus*, and *Probythinella lacustris*, imply a permanent, cool, well-oxygenated, silt-free, lentic water situation, with areas of moderate to dense submerged aquatic vegetation. The terrestrial species indicate a swamp–woods area near the lake margin characterized by vegetation such as *Larix*, *Cornus*, and *Vaccinium*.

The absence of many of the typical littoral lake species such as *V. tricarinata*, *V. s. sincera*, and *P. lacustris*, together with the generally low diversity of aquatic species, suggests that locality 5 was probably the site of a small, slow-moving stream or small pond. The terrestrial species prob ably lived nearby in a marshy area, covere with scattered tall grasses and shrubs.

Locality 7 is the only site at which th individual abundance of terrestrial specie exceeded that of aquatic taxa. The associa tion of terrestrial species is characteristic o wet habitats which might be found alon margins of ponds, streams, and marshe (Oughton, 1948, p. 95). The mollusks indi cate that the depositional site was a mars marginal to a lake or slowly moving stream During high water aquatic species such a *Sphaerium striatinum*, *V. s. sincera*, *H. an ceps*, and *L. decampi* either migrated o were washed into the marsh.

The great species diversity and individu abundance of terrestrial species indicate that the depositional environment at local ity GB-44 was probably a swamp margina to a river or lake. The relative paucity o species characteristic of the sheltered lit toral lacustrine communtiy (only 37% of th individuals representing aquatic taxa be long to this assemblage), suggests that th body of water was probably a cool, slow flowing river, rather than a lake. Re marks on some of the *G. parvus*, *Physa* sp.

and *H. anceps*, which represent interruption in growth, taken together with the type of shell distortion found in some of the *Ferrissia fragilis* (Basch, 1963), suggest fluctuating water levels in the swamp. The shells of *V. tricarinata*, *V. s. sincera*, and *Amnicola limosa* show no rest marks, suggesting that they were probably washed into the swamp during seasonal floods from the perennial river in which they lived.

Nipissing Stage Sites

Nipissing stage sites include localities 15, 10 (lower), 14, 3b, 19, and 16. The dominance at locality 15 of prosobranch gastropods suggests a well-oxygenated, permanent body of water, probably a lake. The almost total absence of terrestrial species, together with the generally fragmental condition of the few that are present, imply that the sediments may have been deposited in open water away from shore.

The aquatic mollusks at locality 10 (lower) represent two different habitats. *Marstonia decepta*, *Amnicola limosa*, *V. tricarinata*, *L. decampi*, and *H. anceps* indicate a large to medium lake or very slow-moving river with areas of dense, submerged aquatic vegetation. A small body of water, perhaps an embayment within the lake, or a slough along the river, are indicated by *Armiger crista*, *G. parvus*, *Promenetus exacuous*, *Ferrissia parallela*, *F. fragilis*, and *Laevapex fuscus*. The terrestrial species are probably from a swamp near the lake or river margin, where they lived among tall grass and shrubs.

The *Valvata*, *Probythinella*, *Goniobasis* association suggests a large lake or slow-moving river at locality 14. The terrestrial gastropods imply a marsh–open woodland not very distant from the site of deposition.

The depositional site at locality 16 was probably a swamp or pond on the floodplain of a river. This interpretation is based on the relative abundance of *Lymnaea* cf. *L. dalli* and *L. obrussa*, species that frequently occur in marginal aquatic habitats (Hibbard and Taylor, 1960); the fragmental and abraded condition of the shells in many of the *Goniobasis livescens* from this site, which implies transportation through a high energy environment; and the numerical predominance of *Pisidium variabile*, a species that prefers quiet water where soft sediments accumulate (Clarke, 1973). This combination of factors can be explained by assuming that *G. livescens* and other river-dwelling species (e.g., *Sphaerium striatinum*) and the few terrestrial species present at this site were washed in during seasonal flooding.

The aquatic assemblage, together with the total absence of terrestrial species, suggests that deposition at locality 19 was probably in a lake well away from shore.

The small number of individuals and extremely low species diversity at locality 3b are probably an artifact of inadequate sampling and therefore no environmental interpretation appears justified.

CONCLUSIONS

Modern studies of molluscan faunules from deposits associated with the glacial Great Lakes have barely started. However, even at this early stage the potential utility of this group of organisms is starting to emerge. Mollusks frequently provide the only or the most abundant organic remains from many of these deposits. Fossil mollusks identified from collections made near Lake Huron and Lake Simcoe include 18 terrestrial and 34 aquatic taxa from Algonquin stage sites; 27 terrestrial and 25 aquatic species from transitional-age deposits; and 17 terrestrial and 33 aquatic forms from deposits associated with glacial Lake Nipissing.

Many of the mollusks appear to be stratigraphically limited, suggesting their potential use in the zonation of Algonquin, Nipissing, and transitional-age deposits. This study indicates that *Pisidium lilljeborgi* and *P. nitidum* cf. *pauperculum* may be useful in identifying Algonquin stage sediments in the Alliston Embayment area, and that *Goniobasis livescens* appears to be a "zone" fossil for Nipissing stage deposits. Unfortunately, most of the remaining restricted species are often not abundant and are frequently limited to only one or two localities. Study of mollusks from many more sites will be necessary to test the general applicability of mollusks for zoning these sediments.

Differences between the temporally distinct molluscan faunas of the area during the past 12,000 years reflect climatic changes, which altered geography and local habitats, and permitted migration of some species into the area. Among the first mollusks to migrate into the area after deglaciation were widespread aquatic species that apparently could live in pro-and supraglacial habitats. Published molluscan fauna lists from deposits 12,000 to 4000 yr B.P. within the Great Lakes and peripheral region suggest that *Lymnaea stagnalis*, *L. decampi*, *Pisidium variabile*, *P. casertanum*, and *Probythinella lacustris* may have migrated northwestward via Lake Ontario and the St. Lawrence River. The effect of climatic change on some of the terrestrial species can be seen in the local extirpation of *Columella alticola*, *Vertigo modesta*, *V. morsei*, and *Pupoides albilabris*.

The majority of the molluscan assemblages represent species associations characteristic of lacustrine habitats although several of the sites (e.g., GB-44, 7, and 16) suggest slow-moving river environments that were bordered by swamp or marsh.

In future collecting, special care should be taken to improve the records of unionid clams. When they become fully recorded, a much-enriched picture of paleoenvironments and migrations should result.

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4.6–5.8 m Buff silt with shell fragments in sandy stringers.

5.8–6.7 m Orange over buff angular gravel with chert.

6.7–14 m Silty clayey till, low in pebbles. Poorly exposed to river.

K-3b. About 100 m downstream (west) from K-3 a small exposure on the north bank exposes:

0–3 m Stratified fine to medium well rounded sand and gravel, probably beach gravel. Basal lag on till includes boulders. Sparse, usually well worn, shells. Springs at base.

3–6 m Gray silty clay till to below river level—forms bed of river.

South of Pine River old slumped excavations nearby show scattered shells on both terrace levels—*Gyraulus* (?), *Pisidium*, *Valvata*, and *Helisoma* noted on higher (Algonquin) terrace, and *Goniobasis* on lower (Nipissing) level.

K-4. Roadcut north side of Highway 21 (Kincardine Avenue), southeast edge of Kincardine. Lot 4, Concession C, Kincardine Township, Bruce County, Ontario. Cut now destroyed by landscaping. Cut in lagoonal plain behind Algonquin bar.

0–0.9 m Covered.

0.9–2.1 m Laminated buff silt and clay with shells. Visible plant fragments near base.

Augered below base of cut:

2.1–2.7 m Same as above.

2.7–3.5 m Stratified silt and fine sand with shells and plant fragments.

3.5–3.7 m Brown medium sand and fine gravel.

K-5. North bank of Boundary Creek, 1.6 km east of Lake Huron and about 100 m east of Highway 21. Lot 1, Concession I West, Ashfield Township, Huron County, Ontario. Section in river terrace graded to Algonquin level. Elevation top of terrace 200.1 m.

0–0.9 m Buff weathered silt, sa[illegible] at base. Shells near bas[illegible]

0.9–1.5 m Subangular, fine to coa[illegible] gravel with chert. So[illegible] boulders.

1.5–4 m Gray clayey silt till, low[illegible] pebbles, to creek level.

K-6. Cut on south side of township ro[illegible] on extension of Kincardine Avenue sou[illegible] east of Kincardine and east of Highway [illegible] Lot 1, Concession III South, Kincard[illegible] Township, Bruce County, Ontario. Cut [illegible] river terrace graded to Algonquin lag[illegible] plain. Elevation top of terrace 197.3 m.

0–3.7 m Stratified buff, clayey s[illegible] and silt with shells.

Test pit and auger holes:

3.7–4.6 m Buff silt with shells.

4.6–5.5 m Gray silt with shells a[illegible] plant fragments. *Pic*[illegible] wood and *Picea maria*[illegible] cone at 5.5 m dated 10,80[illegible] 100 (GSC – 1904).

5.5–7 m Wet fine to medium sa[illegible] some silt bands, with sh[illegible] and plant fragmen[illegible] Stopped by gravel at ba[illegible]

K-7. Point Farms Provincial Park. Tw[illegible] exposures on south bank of unnamed cre[illegible] west of Highway 21, near small sto[illegible] bridge in park, and 6.4 km north of Ma[illegible] land River mouth. Lot 11, Front Conc[illegible] sion, Colborne Township, Huron Count[illegible] Ontario. Section in river terrace graded [illegible] Algonquin level. Elevation top of terra[illegible] 202.5 m.

0–1.2 m Soil over stratified sil[illegible] medium sand with shells [illegible] base.

1.2–1.5 m Poorly sorted gravel wi[illegible] chert.

1.5–4.3 m Gray clayey silt till, low [illegible] pebbles.

K-9. East bank of Saugeen River, 4.8 k[illegible] northeast of Port Elgin, south of Sauge[illegible] Road to Paisley. Lot 37, Range east [illegible] Saugeen Road. Section in river terra[illegible] cut below Algonquin plain.

and wooded; shells recovered from hole dug near top of bank. Elevation top of terrace 187 m.

K-16. North edge of Shashawandah Creek, south edge of Kettle Point Indian Reservation. Locality described by Lewis (1969). About 100 m west of Nipissing bluff where cut by creek valley.

0–0.3 m	Soil.
0.3–0.9 m	Weathered clayey sediment. Date 920 ± 130 (GSC – 1134; Lewis, 1969).
0.9–1.2 m	Stratified medium sand with plant layers and shells.
1.2–1.8 m	Nearly barren medium sand.
1.8–2.1 m	Gray and buff medium sand. Basal gravel. Shells, including unionid clams, and plant debris, including wood. Dated 4250 ± 130 (GSC – 1122; Lewis, 1969) and 5770 ± 100 (GSC – 2190), the latter on *Thuja occidentalis*.
2.1–2.7 m	Gray, shale-rich silty till to creek level.

K-17. South bank Nine Mile River (Lucknow River) at Port Albert, downstream from old mill dam. Section in river terrace graded to Algonquin level.

0–2.7 m	Gray and buff silt with shells.
2.7–4.9 m	Subangular to subrounded medium gravel.
4.9–10.9 m	Mostly covered gray clayey till to river.

K-19. South of Maitland River, Goderich, Ontario. West-facing abandoned terrace scarp, separating lower and higher level terraces, is just west of Maitland Country Club clubhouse extension. Although exposures northeast along the same scarp reveal only barren gravels, here groundhog hole spoil piles are quite fossiliferous. No shells occur above about 1.3 m below top of scarp (higher terrace surface). Modern terrestrial snails occur on the surface in the patchy woods and were excluded from the collection, but spoil heaps show abundant aquatic mollusks.

A levelling survey showed the higher terrace to be almost certainly at the Nipissing level.

GB-44. North bank unnamed creek 5.6 km north of Drysdale. Lot 13, Lake Road Concession, Stanley Township, Huron County, Ontario. Section in river terrace graded to Algonquin level. (Cowan *et al.*, 1975). Elevation top of terrace 191.3 m.

0–1.8 m	Soil over brown silty clay.
1.8–2.4 m	Sand and fine to medium gravel with shells and wood. Dated 7660 ± 140 (GSC – 2049) on *Abies balsamea*.
2.4–7 m	Blocky clay till, low in pebbles, to creek.