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PLEISTOCENE NON-MARINE MOLLUSCA OF THE GATINEAU VALLEY AND OTTAWA AREAS OF QUEBEC AND ONTARIO, CANADA[1]

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ABSTRACT

Fifty-five species and forms of land and freshwater mollusks were recovered from seven Late Wisconsin marl deposits in the Gatineau and Ottawa Valleys of Quebec and Ontario. Vertical samples were taken through marl beds and associated lacustrine sediments at four deposits, three in the Gatineau Valley and one in the city of Ottawa, and vertical changes in the relative abundance of mollusk species are reported. Two deposits in the Gatineau Valley and one in the Ottawa area are represented by single grab samples.

The history and paleoecology of each deposit are discussed. Most vertical changes in the molluscan assemblages are related to changing conditions within the littoral zone of each basin that were associated with development of littoral vegetation, falling water level, and shoreline retreat. The mollusk assemblages are composed of species still living in southern Quebec and Ontario, and there seems to be no reliable record, recognizable at present, of post-glacial climatic fluctuations in the faunal sequences. Different lacustrine habitats are represented in the deposits by four molluscan associations and their enclosing sediments. Units referable to a sheltered littoral habitat are composed of poorly sorted marl and aquatic plant detritus, and contain the greatest variety of aquatic mollusks. An open littoral habitat is represented by generally fine-textured pure marls that have fewer molluscan species. The shoreline habitat occurs in the tops of marl beds and portions of overlying peat and clastic units. These intervals contain fossils of mollusks that inhabit very shallow water or wet areas on shore, along with apparent seasonal inhabitants and allochthones from deeper water and land. A fourth habitat includes surface layers that contain land gastropod assemblages.

Elevations of radiocarbon-dated marine mollusks in the Upper St. Lawrence Valley indicate that sea level dropped below the basins described in this report about 11,000-10,800 yrs. BP. These basins were submerged only by the early, high-water phase of the Champlain Sea, and deposition was continuous during the transition from marine to freshwater conditions. A diverse molluscan fauna from the Great Lakes and Mississippi River drainages was established on highlands immediately north and south of the Ottawa River during the low-water stage of the Champlain Sea interval and before the opening of the Great Lakes outlets at North Bay, Ontario. The latter event was apparently a minor factor in the migration of lacustrine Mollusca into the Gatineau and Ottawa Valleys. Two deposits studied in the Ottawa area are correlated with stages of the Ottawa River and are probably less than 7600 years old.

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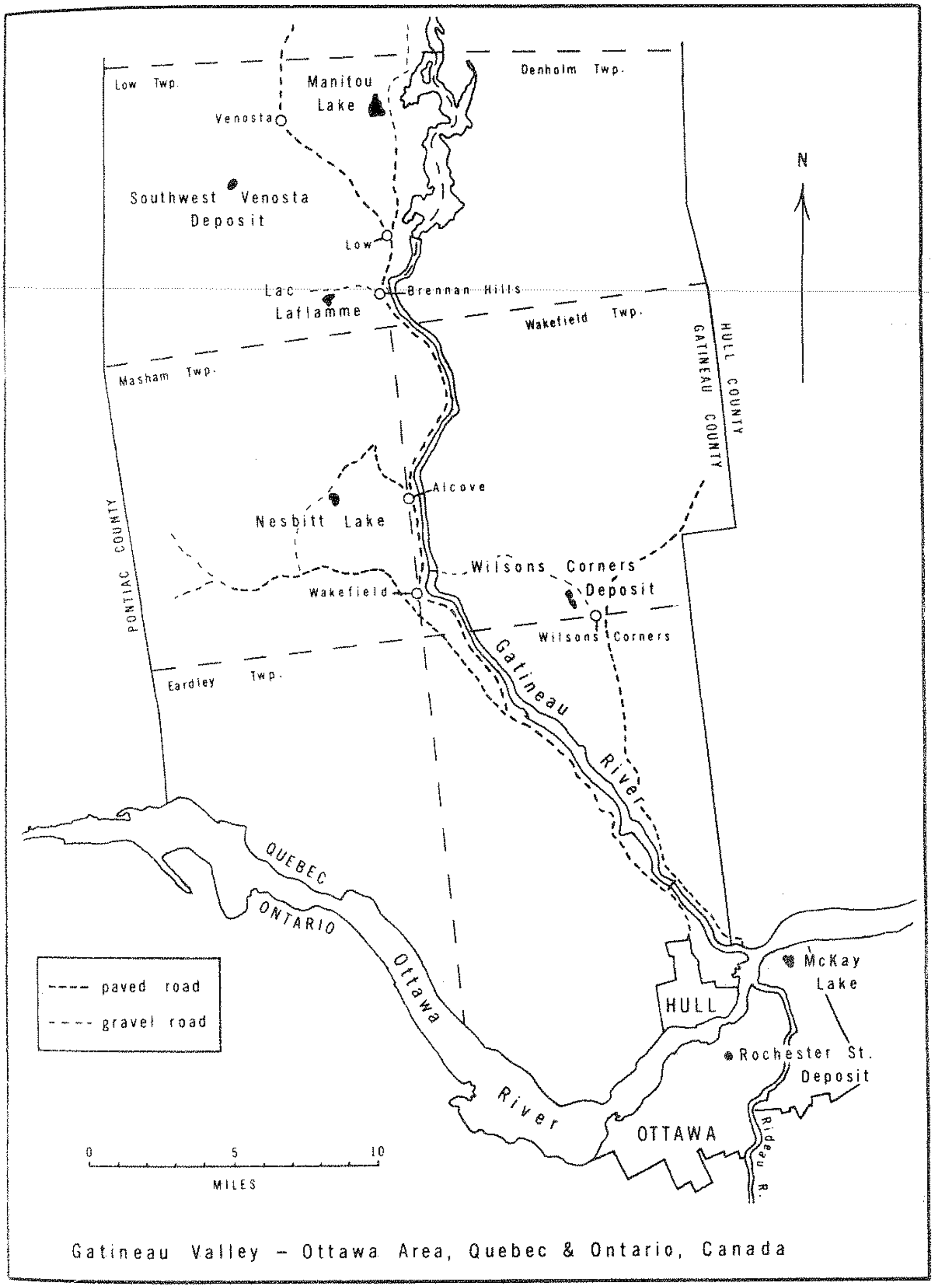


FIGURE 1. SKETCH MAP SHOWING LOCATIONS OF DEPOSITS SAMPLED IN THE LOWER GATINEAU VALLEY, QUEBEC AND THE OTTAWA AREA, ONTARIO, CANADA.

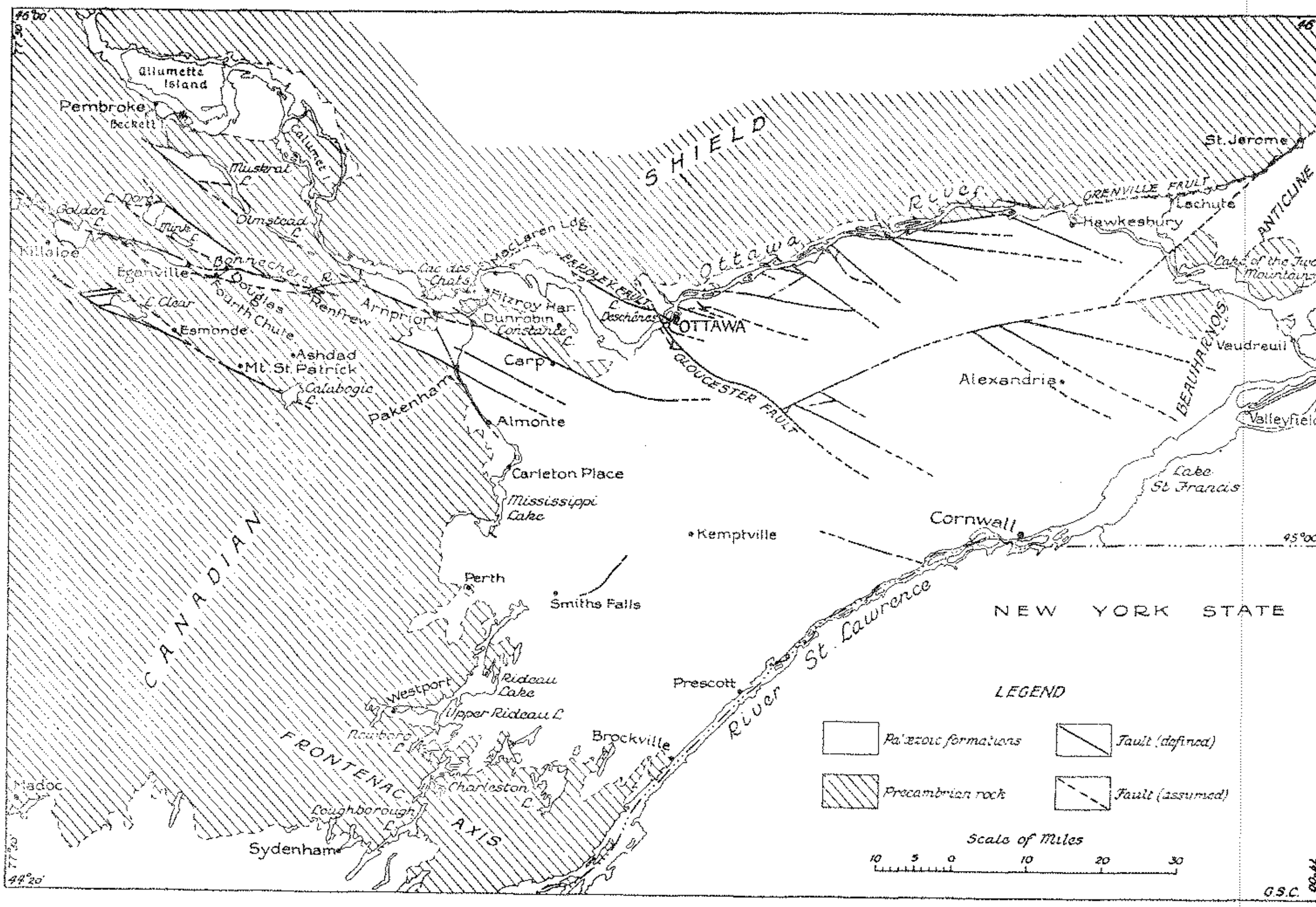


FIGURE 2. MAP SHOWING DISTRIBUTION OF BEDROCK AND FAULTS IN THE OTTAWA-ST. LAWRENCE LOWLAND OF CANADA

(from Wilson, 1946, Fig. 3)

INTRODUCTION

Purpose of investigation

The Gatineau Valley of Quebec and the area at its mouth, around the city of Ottawa, Ontario occupy an interesting geographic position relative to post-glacial events in the western St. Lawrence Valley. The Ottawa area includes the northern margin of a Late Wisconsin glacio-lacustrine body that pre-dates marine inundation, as well as abundant evidence of the Champlain Sea interval. The Gatineau Valley and the Ottawa Valley west of Ottawa were inland arms on the far northwest extent of marine water. The probable influence of geologic events on Quaternary molluscan faunas in this portion of the St. Lawrence Valley can be inferred from the fossil record in the Gatineau and Ottawa Valleys. From the standpoint of paleoecology, the region allows study of molluscan habitats represented in lacustrine deposits on the Canadian Shield and comparison of these with Pleistocene lake deposits elsewhere in eastern North America.

The purpose of this investigation is to give a systematic and quantitative account of non-marine mollusk assemblages in seven Late Wisconsin deposits in the Gatineau Valley and nearby Ottawa area, and to interpret changes in the mollusk assemblage and environment at each locality. Previous workers have examined the Pleistocene non-marine Mollusca from several sites west and south of the present study, and their results are important contributions to conclusions reached in this report. Correlations can be made between the lake basins and major geologic events in the region that have been dated by radiocarbon methods. From such data, a generalized description of molluscan habitats will be developed, and a pattern of molluscan repopulation in the area will be inferred.

Location of deposits

Three of the marl deposits sampled during this investigation are from shorelines of fairly large, named lakes in the Gatineau Valley. (See Fig. 1). Manitou Lake is located 3.2 miles east of Venosta and 4.8 miles north of Low in Low Township, Gatineau County, Quebec (45° 52' 50" N. Lat., 75° 53' 30" W. Long.). The shoreline is owned by several individuals. A road that leads to the town of Low passes east of the lake, and the north and south shores can be reached on farm roads. Lac Laflamme is 2 miles east of Brennan Hills in Low Township, Gatineau County, Quebec (45° 46' 54" N. Lat., 75° 59' 32" W. Long.). The property is owned by Mr. A. M. Jotoff of Ottawa. A gravel road running west from Brennan Hills passes along the north shore of the lake. Nesbitt Lake is situated 2.8 miles west of Alcove and 0.5 mile south of Rupert in Masham Township, Gatineau County, Quebec (45° 40' 58" N. Lat., 75° 59' 16" W. Long.). Mr. Keith Nesbitt, who owns and farms the property, operates a camping ground on the south shore of the lake.

Two of the sampled deposits are on small, unnamed lakes. The Southwest Venosta deposit is a bed of marl on the most northern of two small lakes in the southwest portion of the Venosta Creek drainage. The marl lake is 0.7 mile west of Carson Lake and 2.8 miles southwest of the town of Venosta, Low Township, Gatineau County, Quebec (45° 50' 24" N. Lat., 76° 03' 45" W. Long.). The lake is near the property line between two uninhabited farms and ownership was not determined. The Wilsons Corners deposit occurs between two small, connected lakes about 1.3 miles northwest of Wilsons Corners and 5.1 miles east of Wakefield in Wakefield Township, Gatineau County, Quebec (45° 37' 55" N. Lat., 75° 45' 34" W. Long.).

Samples from two marl beds in the Ottawa area were examined. McKay Lake, with its extensive marl deposit, is located 1.4 miles northeast of the mouth of the Rideau River in Rockcliffe, a suburb of Ottawa, Carleton County, Ontario (45° 27' 42" N. Lat., 75° 45' 39" W. Long.). A well established residential area surrounds the lake and sampling of the marl is usually limited to excavations for housing construction or utilities maintenance. Samples from the Rochester Street deposit were taken from an excavation for the High School of Commerce Building on Rochester Street in the city of Ottawa, Carleton County, Ontario (45° 24' 12" N. Lat., 75° 42' 37" W. Long.). The material was collected for the Geological Survey of Canada in 1966 by R. L. Christie (Moot and Camfield, 1969, p. 5) and this part of the section is no longer accessible for study.

Methods of investigation

Lakes and depressions that seemed to be likely sites for fossiliferous deposits were located initially on topographic maps at a scale of 1:50,000 distributed by the Department of Energy, Mines, and Resources of Canada. These localities and others were then examined during the summer of 1968. Waddington (1950, III) lists four marl deposits in the Gatineau Valley area. Of these localities, only the beds at Lac Laflamme and Wilsons Corners were above water and accessible for sampling. The other localities sampled in this study were found through field reconnaissance. Some likely sites in wooded areas far from roads were not investigated because available time and the need to transport large samples made examination of such areas impractical. Favorable locations were probed with a soil auger and the sediment type and general stratigraphy were noted. When a marl bed was found, the presence of fossil mollusks, approximate depth, and general characteristics of the deposit were determined.

Detailed study of individual deposits began with plotting the boundary of marl beds on sketch maps at scales of one inch to 100 or 200 feet. The position of auger holes and other features was determined by means of compass bearings and paced distances. The section observed in each auger hole was described and a marl sample was collected from most holes. The sketch maps accompanying this report were traced from aerial photographs and data from the field maps were transferred to these figures.

After mapping was completed, a representative site was chosen for quantitative sampling and a 4 foot by 6 foot pit was excavated to facilitate description and vertical sampling of the section. A column of sediment was removed from one wall of the excavation in 2-inch vertical units that measured 12 X 12 X 2 inches. A sheet-metal pan with the above dimensions and one open side was used to cut individual samples from the wall. Samples were labeled and stored in plastic bags.

In the laboratory, 2000 cubic centimeters of each sample were soaked in water for about 24 hours and washed through a series of U. S. Standard soil sieves. Sieves of 10, 20, 30, and 60 mesh sizes were used. Sieve contents, consisting primarily of plant material, mollusk shells, and rock fragments were dried and stored in labeled cardboard cartons. Most samples contained far more shells than were needed to constitute an adequate sample. These samples were thoroughly mixed and repeatedly divided with a sample splitter into quantities that would yield about 1000 mollusks. In most cases, the shells were separated from only 1/16 or 1/32 of the original square-foot sample. Specimens were picked from samples with a moist brush and stored in labeled cardboard cigarette boxes. The shells were later sorted to species, counted, and stored with labels in gelatin capsules. The abundance of species in individual samples is presented in table form. Vertical changes in the relative abundance of most species are also shown graphically.

The Rochester Street section was collected as a continuous vertical column from a building excavation site in the city of Ottawa. The sample was intended for pollen analysis and after small portions were removed for this purpose the rest of the material was stored in 4 to 7 inch segments. The individual segments dried and shrank during storage. The position of the segments in an accurately measured section was known, so they were subdivided into 2 inch units and referred to the appropriate depth intervals. The resulting samples which averaged about 50 cubic centimeters, were sieded and sorted in the manner outlined above. Decomposed peat from the top unit in the section had completely hardened, and could not be broken down by either water or organic solvents. The total number of mollusks recovered from individual samples ranged from 39 to 1043. The data, although not strictly comparable, are presented in the same manner as those from the other deposits.

Grab samples from the Southwest Venosta, Wilsons Corners, and McKay Lake deposits were treated in a similar manner. Sieve residues from 2000 cubic centimeters of sediment were dried and divided into quantities that yielded about 1000 specimens. In addition, all the washed material was examined for species that may not have appeared in the picked portion.

Illustrations of specimens were traced from photographs mounted on a light table. Specimens are stored in the collection of Pleistocene Mollusca in the Department of Geology, The Ohio State University.

Acknowledgments

I am most appreciative of the valuable guidance and assistance Professor Aurèle La Rocque has given to this work and my other academic endeavors at The Ohio State University. My wife, Barbara Sue, deserves special recognition for many hours of skillful help in the field and laboratory.

I wish to thank John G. Fyles and R. J. Mott of the Geological Survey of Canada who generously made available samples and data gathered in conjunction with Dr. Mott's research. Figure 3 from Geological Survey of Canada Memoir 241 is reproduced as Fig. 2 of this paper by permission of the Geological Survey of Canada.

Financial assistance for field work was provided by National Science Foundation Grant GB-818. I am grateful to the Friends of Orton Hall Fund for helping defray the cost of reproducing the illustrations.

Finally, I wish to dedicate this dissertation to four teachers who have inspired and directed my scientific training, Professors Daniel F. Jackson, James E. Conkin, Joe K. Neel, and Aurèle La Rocque.

GEOLOGY OF THE GATINEAU VALLEY AND OTTAWA LOWLAND

General Statement

The rocks of the Gatineau Valley and Ottawa Lowland include Precambrian igneous and metamorphic bodies, lower Paleozoic sediments, and late Pleistocene deposits. Most of the Precambrian rock is exposed north of the Ottawa River, whereas Paleozoic sediments are largely confined to areas south of the river. The older materials are discontinuously overlain by glacial drift, late-glacial marine clastics and freshwater lacustrine and fluvial sediments.

Geographic setting

The Grenville and St. Lawrence provinces and their respective physiographic subdivisions, the Laurentian Highlands and East St. Lawrence Lowlands, are represented in the Gatineau Valley and Ottawa areas (Bostock, 1964, map). The Laurentian Highlands are a broad plateau of Precambrian shield rock that rises more or less abruptly above the lowlands to a maximum elevation of about 1300 feet above sea level in the Ottawa district. Rivers, such as the Gatineau, gather volume on the hummocky interior and drop rapidly in wide, dissected valleys on the margin. Deep dissection has formed rugged topography along this margin of the Canadian Shield, with elevation ranges of over 1000 feet. The East St. Lawrence Lowland, more suitably termed the Ottawa-St. Lawrence Lowland (Wilson, 1946, p. 1) rises gently in a series of low steps from 70 feet above sea level near the mouth of the Ottawa River to 500 feet at its western extreme about 20 miles west of Ottawa.

Dresser and Denis (1944, p. 166 subdivide topography on the Laurentian Highlands north of Ottawa into rocky uplands and lowland flats and terraces. Rugged uplands and isolated knobs of Precambrian rock lie generally above 600 feet. These areas are covered by a very thin, discontinuous veneer of soil formed on glacial drift. Unconsolidated material has accumulated to produce small flatlands in bedrock depressions and along major stream drainages.

The lower Gatineau River begins at an impoundment, Baskatong Reservoir, about 100 miles north of Ottawa. Its drainage basin is bordered on the west by the Coulonge River basin and on the east by the Lièvre River drainage. Several small streams empty directly into the Ottawa River between these drainages. Larger tributaries of the Gatineau are the La Pêche, Kazabazua, Picanoc, and Eagle Rivers, all of which enter from the western part of the basin. The area drained east of the river is smaller, 5 to 15 miles wide, compared with the west side of the drainage basin, which is 20 to 30 miles wide.

The Ottawa - St. Lawrence Lowland around the city of Ottawa is flat and poorly drained. The Rideau and Nation Rivers drain most of this area. The Rideau begins at a series of lakes on the eastern edge of the Frontenac Axis and flows northeast to Ottawa. Abandoned channels of the Ottawa and Rideau Rivers have left wide, shallow depressions in the vicinity of Ottawa, and marshes now occupy many of these channel cuts. The Ottawa River flows on irregular bedrock topography at the faulted northern margin of the lowland. Its channel follows fault lines, or flows on or around displaced blocks in a series of lake-like pools that are joined by narrow reaches of fast water and rapids.

Most inhabitants of the Gatineau Valley are descendants of settlers from the British Isles and France. Agriculture is mainly limited to dairy and cattle farming, although field crops are raised in the southern third of the valley. Farms generally operate at a subsistence level and farm income is commonly supplemented by cutting poplar and spruce lumber. Logs are floated down the river or trucked to paper mills at the mouth of the Gatineau. Several small saw-mills are located in the area. Many residents operate small businesses that cater to a thriving recreation and tourist trade, since paved roads have made the area easily accessible to vacationers and sportsmen from Ottawa and Montreal.

Precambrian Geology

Highly deformed and intruded metasediments of the Grenville Series constitute bedrock over most of the region north of the Ottawa River. Typically, these are alternating layers of marble, sillimanite-garnet gneiss, and quartzite that strike roughly parallel to the north-northwest regional structural trend. Sillimanite-garnet gneiss is the most common rock and in many places is interbedded with massive quartzite (Dresser and Denis, 1944, p. 169).

Masses composed mainly of marble occur as elongate exposures that parallel the regional trend. This facies is more common in the Gatineau Valley than in adjacent areas. Dresser and Denis (1944, p. 170) summarize chemical analyses of Grenville limestone from six localities along the length of the Gatineau Valley. The samples were relatively pure calcium carbonate (83 - 86 percent); magnesium carbonate and silica were the most abundant minor constituents (each about 2 percent). In samples from Low and south of Brennan Hills magnesium carbonate content rose to 12.24 and 6.56 percent respectively.

Syenite, diorite, gabbro, and anorthosite intrusives are closely associated with the Grenville Series. These occur in the Grenville rocks as dikes, sills, stocks, or larger plutons and are termed the Buckingham Series. Age relationships between the different bodies are uncertain.

Larger plutons, stocks, and dikes of porphyritic syenite, granite, aplite-granite, or granite gneiss intrude rocks of the Grenville and Buckingham Series. Orthoclase, microcline, or quartz pegmatite also occur as large masses and dikes in Grenville and Buckingham rocks. These are apparently associated with the larger granite plutons, but all pegmatites in the region are not of the same age. Fluid emanations, presumably from these later intrusions, altered surrounding carbonates to form pyroxenite. The only Precambrian rocks in the area that have not been metamorphosed are east-west trending diabase dikes that cross the Gatineau Valley region. (Dresser and Denis, 1944, p. 180).

Isolated exposures of Precambrian rocks occur in several places along the eastern edge of the Frontenac Axis. Large inliers are also exposed on the eastern part of the Ottawa Lowland near the confluence of the Ottawa and St. Lawrence Rivers (Fig. 2).

Paleozoic Geology

The northern part of the Paleozoic basin, along the Ottawa River, is rather heavily faulted, whereas to the south it is undisturbed. The faults mark the border between the Ottawa-St. Lawrence Lowland and the Canadian Shield. Faults trend northwest and occur within the Paleozoic rocks east of Ottawa. Northwest of the city, the Paleozoic basin ends abruptly at the Eardley fault scarp, where Precambrian rocks rise several hundred feet above the lowland (Wilson, 1946, p. 5).

The western half of the Ottawa-Hull area is underlain by Ordovician (Champlainian) carbonates and shales, the Ottawa, St. Martin, and Rockcliffe Formations. The Ottawa Formation is composed chiefly of limestone and dolomite but lower units contain shale and sandstone. The Rockcliffe Formation is shale with sandstone lenses. It underlies the Ottawa Formation but the two are separated by a thin sequence of clastics and impure carbonates, the St. Martin Formation. Lower Ordovician (Canadian) limestone and dolomite, the Oxford Formation, covers much of the St. Lawrence Lowland south of Ottawa. A downfaulted block extends from the east half of Ottawa to some 20 miles southeast of the city. The wedge-shaped structure is bounded on the southwest by the Gloucester Fault and just east of Ottawa by two west-northwest trending faults (Fig. 2). A thick sequence of Ordovician sediments is preserved in the trough, and Upper Ordovician shales (Billings and Carlsbad Formations) constitute bedrock in this area. Along the north shore of the Ottawa River and east of Ottawa, the Oxford, Rockcliffe, and Ottawa Formations are at the surface (Wilson, 1946, map 852A).

Pleistocene Geology

Gadd (1962, p. 1) found evidence of only one glaciation in the vicinity of Ottawa. The resulting till reflects bedrock composition in the area. Till toward the north is made up largely of siliceous, granitic materials, but near local bodies of crystalline limestone in the Precambrian rocks it is calcareous. South of Ottawa, till is highly calcareous because of extensive limestone exposures.

The ice lobe that occupied the Ottawa and Gatineau Valleys built two northeast trending moraines south of Ottawa during its northward retreat. These are located at Stittsville, about 12 miles southwest of the city, and at Bells Corners and South Gloucester, just south of Ottawa. Still closer to Ottawa, a short segment of a third moraine trends east-west at Gloucester. Gravels and sands deposited by meltwater are interbedded with the till. Superposition of till and sorted material probably resulted from slumping and flowage of semi-fluid till and minor readvances over outwash material (Gadd, 1962, p. 1).

After ice retreat and before the lowlands were invaded by the Champlain Sea, glacial lakes occupied the St. Lawrence Lowland west of Quebec City. Lacustrine deposits are exposed at various localities in the Ottawa Lowland (Antevs, 1925, p. 64; Gadd, 1962, p. 2). Lake sediments were deposited on the lowland just before marine waters inundated the Ottawa area (Gadd, 1962, p. 2).

The continental ice sheet depressed the crust of the earth under its weight. As ice retreated, the crust rebounded slowly as compared with the rate of deglaciation, and low areas remained depressed below sea level for several thousand years after they were free of ice. Unlike the eastern part of the St. Lawrence Valley and low areas along the Atlantic Coast, the St. Lawrence Valley west of Quebec City was protected from marine inundation by ice remaining in the valley near that city.

Mott (1968, p. 322) reviews C-14 dates from the Upper St. Lawrence and Ottawa Valleys that indicate an age of 11,800 to 10,200 years BP. for the Champlain Sea. The Champlain Sea interval began when ice retreated from the Appalachian Highland near Quebec City. Sea water then intermixed with fresh water that stood west of the ice block. Gadd (1967, p. 161) suggests that this glacial lake reached to the present elevation of 600 feet, with no significant change in water level occurring at the onset of marine conditions. The high-water phase, when sea level stood above 500 feet in the Ottawa Valley, apparently began about 11,800 years BP. and lasted until 10,800 years BP. (Elson, 1969, p. 367). Radiocarbon dates from shallow-water marine mollusks collected above about 350 feet fall within this range, with the oldest dates occurring at higher elevations. Elson (1969, p. 371) notes that relative sea level dropped to a low level about 10,800 years ago (Valders time) but may have risen slightly before the end of marine conditions. Below 350 feet some younger dates occur at elevations above older dates; however, the evidence for a resurgence during the low-water phase is not conclusive. About 10,200 years BP. salinity decreased in what water remained in the embayment and marine conditions ended. Elson (1969, p. 368) found that the high-water phase was a subarctic body characterized by abundant specimens of the bivalve, ***Hiatella***. The low-water level was a warmer, boreal stage with a molluscan fauna characterized by *Mya arenaria*.

The first phase of the marine invasion reached present elevations of about 675 feet near Ottawa. The sea deposited fossiliferous beach sediments between 325 and 675 feet and fossiliferous marine clay at lower elevations (Gadd, 1962, p. 3). The Champlain Sea extended at least 60 miles west of Ottawa beyond Fort Coulonge and up the Gatineau Valley at least to Venosta.

In the Ottawa area, the gray marine clay is commonly overlain by oxidized, non-calcareous clay. The oxidized unit was apparently deposited when the water level dropped in response to regional uplift (Gadd, 1962, p. 3). Gadd (1962, p. 3) interprets the lower clay as Champlain Sea sediment and the upper clay as material laid down in a broad, sluggish, freshwater drainageway that was to become the Ottawa River as uplift progressed. Antevs (1939, p. 174) interprets the upper clay as sediment from a second marine invasion. The upper clay is seemingly unfossiliferous except for reworked specimens and there is no evidence of two transgressions elsewhere in the St. Lawrence Valley. The section at Brennan Hills given by Antevs (1939, p. 714) shows two clays separated by a gravel unit and erosional break. Antevs assigns the clays to separate invasions but it seems that this section could have been produced by minor fluctuations within the same water body. La Salle (1966, p. 102) and Elson (1969, p. 370) have cited fossil evidence and radiometric dates that suggest a drop in sea level followed by a slight rise about 11,800 to 10,200 years BP.

Details of Pleistocene events on the Laurentian Highlands north of Ottawa are largely unknown. Various workers have considered the area in reference to particular problems such as varve chronology, palynological studies, and the Champlain Sea, but always in general terms. Mapping programs under auspices of the Quebec Department of Natural Resources have been concerned with bedrock geology, and most reports overlook Pleistocene geology or include a few paragraphs about Quaternary deposits.

In the Gatineau Valley, coarse-textured till occurs at the surface as a thin veneer over parts of the upland above about

600 feet. Steep slopes are usually blanketed with material that has been reworked by erosion, and gentle slopes are commonly surfaced with boulder, cobble, or coarse sand concentrates where erosion has removed finer particles. Eskers and a lateral moraine are reported from the Maniwaki area, over 60 miles to the north of Ottawa (de la Rue, 1953, p. 24). Glaciofluvial sand and gravel occur with till on the uplands, but these deposits are thicker and more extensive in low areas.

Bedded sand and gravel deposited by the Champlain Sea occur in the southern part of the valley and are difficult to distinguish from glaciofluvial material. Antevs (1939, p. 715) reports marine shells at an elevation of 570 feet near Venosta and glaciofluvial deltas at 600 feet at Kazabazua, 8 miles farther north. Marine clay is common in low areas of the Gatineau Valley. The clay facies reaches higher elevations here than on the Ottawa Lowland. Antevs (1939, p. 714) mentions fossiliferous clay at 380 feet near Brennan Hills. The writer found calcareous bluish-gray clay with tests of Foraminifera (*Elphidium subarctatum* and Miliolidae) between [illegible]0 and 525 feet at Manitou Lake, Lac Laflamme, and Nesbitt Lake. Clay is exposed in stream and road cuts and on slopes where overlying material has been eroded away. The deposits in most places are overlain by marine sand and gravel units of varying thickness or by lacustrine and fluvial sediment. A sand deposit that is thick and extensive enough to sustain a large quarry operation overlies the clay at Wilsons Corners, Quebec.

Marl deposits

General Statement

Bedrock depressions on the Laurentian Highlands are generally elongate and trend roughly in a north-south direction. Orientation of the basins is probably due to a combination of less resistant rock exposures following the north-south regional trend and abrasion by ice moving southward.

Most of the lakes in low areas of the Gatineau Valley to about 40 miles north of Ottawa rest on Champlain Sea clay and sand. Lakes above the elevation of marine sediments, and in the northern part of the valley rest on glaciofluvial clastics and till. In general, rock basins control the shape and orientation of lakes. In a few localities, thick sand and gravel deposits have covered the bedrock terrain, and other features such as kettle holes, old stream channels, and surface irregularities determine the form of small lake basins. Of the 88 lakes examined during this study, about three-fourths were filling with sand and mud. Twelve of the basins are filling mostly with organic material and only eight of the lakes are accumulating marl in varying degrees of thickness and purity.

In the Gatineau Valley, marl generally occurs as shoreline deposits in lakes of medium size. Small shallow depressions like those that accumulate marl deposits in regions of calcareous till in the eastern United States are generally filled with sand and organic material. It is likely that early in the post-glacial history of the valley, marine and continental erosion rapidly transported great quantities of sand into low depressions from the blanket of glacial drift on surrounding slopes.

Marl formation on this part of the Canadian Shield seems to require 1) a basin large and deep enough to have survived filling by glacial, marine, and initial freshwater deposition, 2) local exposures of carbonate metasediments from which glacial abrasion has produced unconsolidated calcareous material and 3) moderately sloping terrain near the water body to hold sediments in position for efficient leaching and transport of carbonates by circulating groundwater. Stauffer and Thiel (1933, p. 101) recognized a possible relationship between increased hydrostatic head on slopes and the transport of dissolved carbonates to lake basins.

Unlike the numerous marl deposits on the Gaspé Peninsula, freshwater carbonate deposits in the Gatineau Valley region have been almost unused economically. Farmland near these deposits seldom needs lime treatment and commercially produced lime from a plant near Hull is a more convenient and economical source of lime fertilizer than marl. Of the many Gatineau Valley residents questioned, only one was familiar with the practice of using marl as a source of lime. Another landowner in the Venosta area recalled that marl from the Southwest Venosta deposit was used many years ago for the manufacture of plaster. Whittaker (1918, p. 14) notes that marl from McKay Lake was formerly used for making brick and cement.

Manitou Lake deposit

Manitou Lake (Fig. 3) is situated less than one mile from the west shore of the Gatineau River (Fig. 1) and has a present lake level of about 520 feet above sea level. The lake receives discharge from four very small ponds to the south and its outlet stream empties into the Gatineau. Steep slopes border the west shoreline and an isolated knob of bedrock is present on the northeast shore. Marble is abundant in the surrounding bedrock and exposures are common on the west shore. Coarse carbonate rhombs are a major constituent of a sandy beach that extends along the south shore. Marine clay is exposed at the surface along the east and north shores.

Four separate marl beds occur in the vicinity. Two shoreline deposits, 15 and 56 inches thick, are located on the south shore, and calcareous mud is still accumulating offshore from the sandy beach. A small water-saturated marl deposit more than 15 feet thick is located on the southeast shore. This bed extends about 50 feet inland and over 100 feet into the lake as a narrow shelf, with a maximum thickness of about 5 feet.

The submerged portion of this northern deposit is washed by gentle wave action and is uncovered except for sparse aquatic vegetation. Its surface is made up mainly of coarse shell fragments and is firm enough to be walked on to about 70 feet from shore. The quantity of fine particles gradually increases away from shore and in 3 feet of water the bottom is loose calcareous mud. At its edge, the carbonate shelf breaks into a steeper slope. On shore the marl is overlain by 10-12 inches of black humic soil. The west end of the deposit grades abruptly into a bed of peat and gyttja. The other beds are also overlain by thin peat and grade into organic accumulations shoreward. All of the freshwater sediments observed at Manitou Lake rest directly on bedrock or fossiliferous marine clay. An excavation for detailed study was made on the north shore near the center of the marl bed.

Stratigraphic section

Unit	Description	Thickness (inches)
1	Black, humic soil; fine, granular texture; living roots abundant. Samples 1 - 3 and half of 4.	7
2	White and gray marl; distinctly banded, gray bands with higher clay and organic content. Samples 4 (part) and 5-7.	7
3	Black gyttja; contacts sharp, smooth. Sample 8 (part)	1
4	White and gray marl; indistinctly banded; fossil plant stems, more or less intact, oriented vertically through the unit. Samples 8 (part) and 9-20 (part) . . .	25
5	Brownish-gray marl; plant fibers and vertical stems abundant; highly fossiliferous. Samples 20 (part), 21, 22, and 23 (part).	5
6	Grayish-brown, impure marl, plant fibers and vertical plantstems abundant; clay content increases near base; lower contact gradational. Samples 23 (part) and 24-27 (part).	8
Base	Bluish-gray marine clay; plastic; foraminiferal tests common; fresh-	

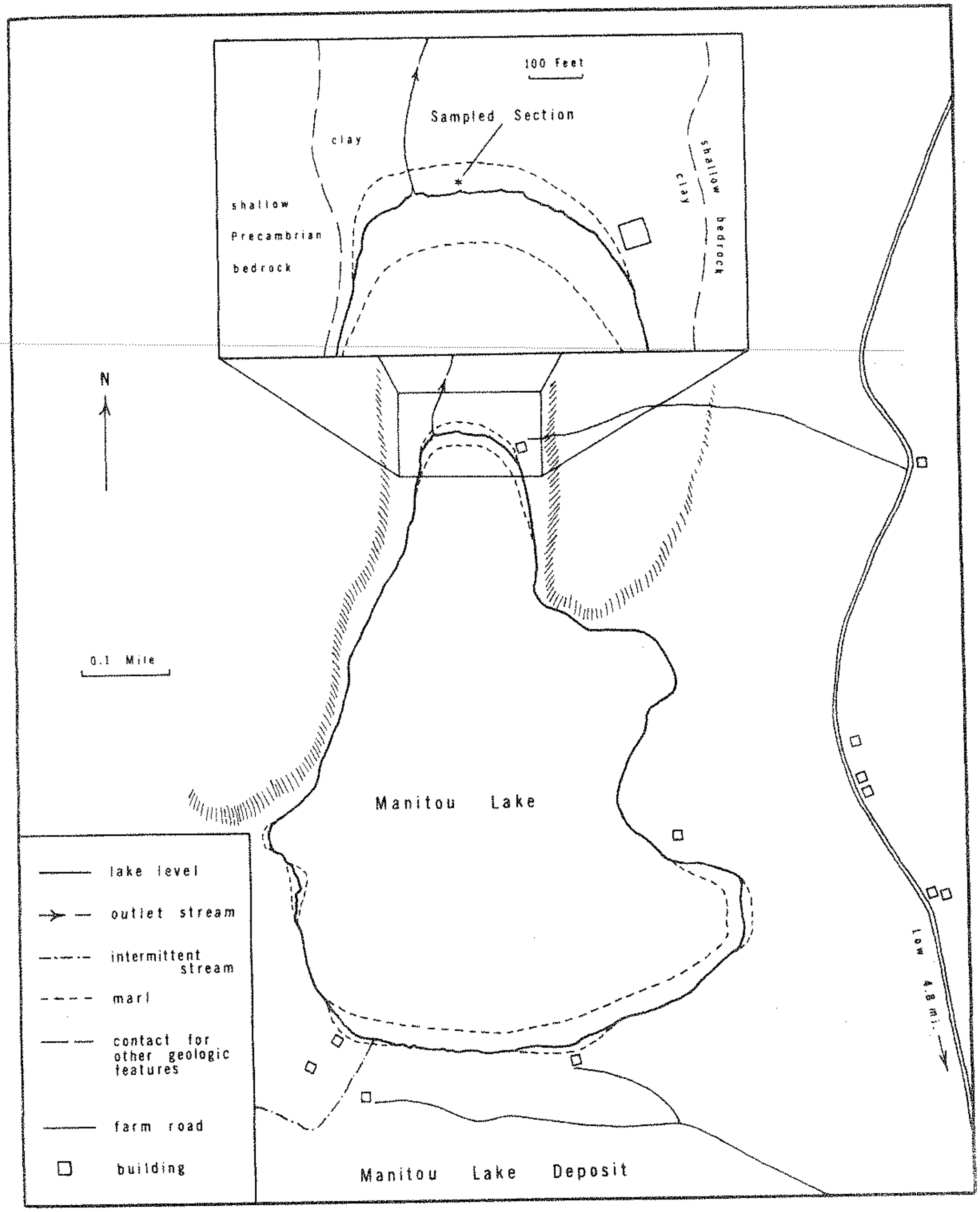


FIGURE 3. SKETCH MAP OF MANITOU LAKE, LOW TOWNSHIP, GATINEAU COUNTY, QUEBEC.

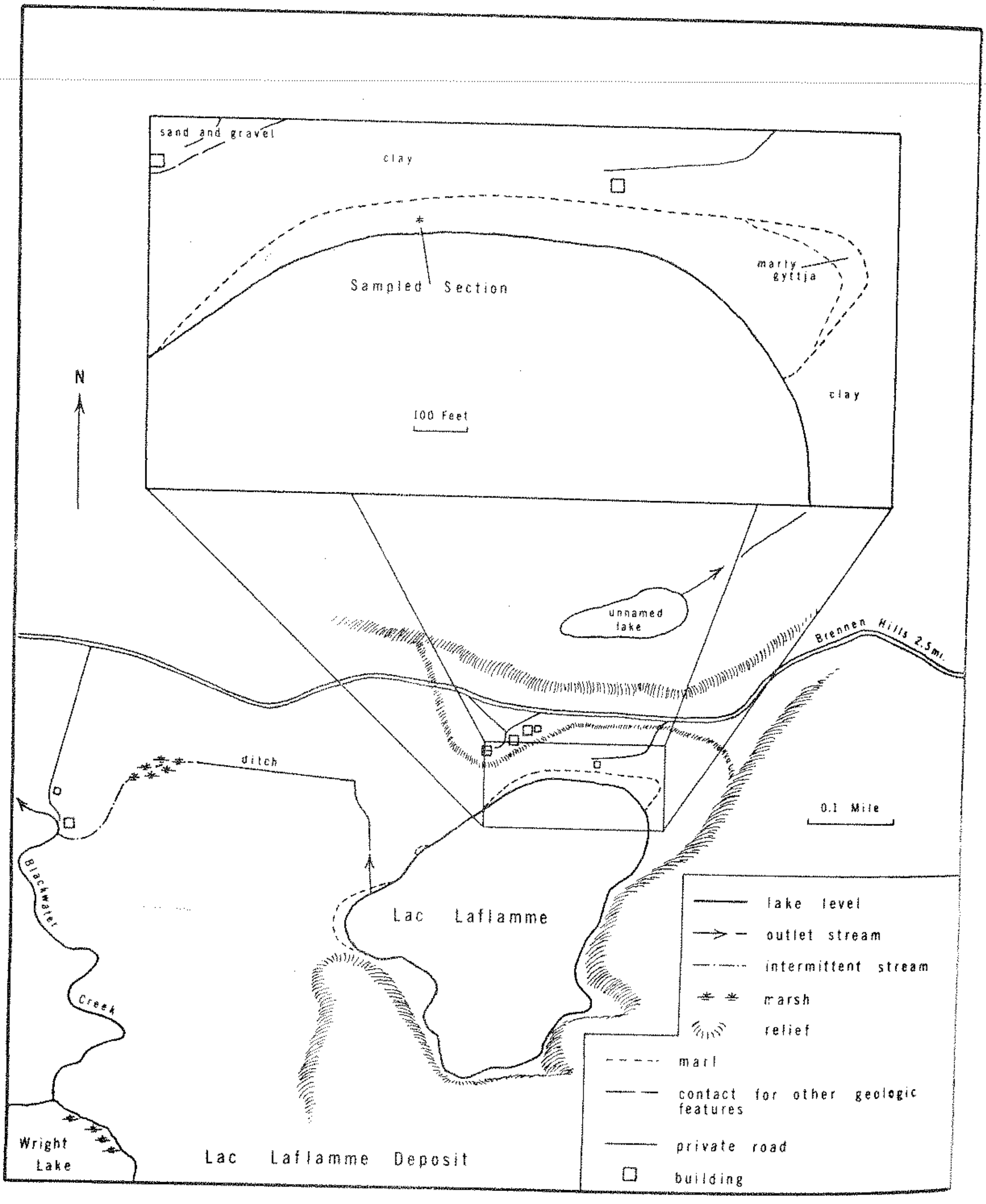


FIGURE 4. SKETCH MAP OF LAC LAFLAMME, LOW TOWNSHIP, GATINEAU COUNTY, QUEBEC.

	water mollusk shells, plant roots, and organic material in upper few inches, pure below contact. Sample included 27 (part).	---
	Total	53

Lac Laflamme deposit

Lac Laflamme (Figs. 1, 4) is one of several closely connected lakes, Lac Bernard being the largest, that drain north by Blackwater Creek and then east to the Gatineau River. Present lake level stands about 511 feet above sea level. Steep slopes with shallow or exposed Precambrian bedrock form the east and south shorelines. The north shore is moderately sloping but becomes steeper a short distance north of the water. A low, flat area extends west from the lake. Marine clay blankets the lower slope on the north shore to 13.5 feet above present lake level and the low area on the west shore. About 300 feet north of the lake, coarsely bedded sand and gravel over stony till were exposed in fresh excavations adjacent to the farm buildings. Soil auger probes taken through the clay near its margin showed that the clay was deposited on top of similar material.

Two features interpreted as former shorelines extend along the north shore. The first is a ridge standing 14 feet above present water level and visible as a fairly distinct break in slope along the north shore. It is composed mostly of fine- to medium-sized sand with some larger particles, and its outer margin rests on and grades into clay. A small break in the clay covered slope occurs at 5 feet above present lake level. This feature is not different in composition from the rest of the slope and appears to be a low bench cut into the clay during a period of higher lake level.

The occurrence of thick marl beds on the north and west shores of Lac Laflamme was first noted by Waddington (1950, p. 32). The maximum thickness of both deposits is greater than 15 feet and Waddington (1950, p. 32) reports a maximum thickness of 20 feet for the north bed. The west bed pinches out in peat on its southwest margin. The northern deposit grades into marly gyttja along its eastern edge, which in turn grades into fine peat landward. The marl is covered with thin clay-rich soil or peat. All of the deposits are underlain by Champlain Sea clay. A site on the north marl bed 13 feet wbove present lake level was chosen for excavation and detailed study.

Stratigraphic Section

Unit	Description	Thickness (inches)
1	Gray clay loam soil; calcareous; fine granular structure; grading into calcareous clay, sub-angular blocky structure. Samples 1-7	14
2	White and grayish white marl; banded; gyttja layers at 31 and 34 inches; fossil plant stems oriented vertically throughout. Samples 8 - 21 (part).	27
3	Brownish-gray impure marl; medium to fine plant material abundant; coarse clay blocks and sand abundant. Samples 21 (part) 22, and 23 (part). .	4
4	Brownish-gray marl, clay, and wood; large to medium sized wood fragments and beaver cuttings abundant (diameter ½ to 2½ inches, length over 1 foot); charred wood fragments common. Samples 23 (part) - 31.	17
5	Buff marl; occasional clay blocks; isolated clay fragments increase toward base; lower contact transitional. Samples 32-37.	14
Base	Bluish-gray clay; foraminiferal tests abundant; no freshwater shells; fine plant fibers in upper few inches.	--
	Total	76

Nesbitt Lake deposit

Nesbitt Lake (Fig. 5) is situated about 3 miles west of the Gatineau River (Fig. 1). It is fairly isolated since no tributaries enter the lake from other basins and the outlet stream flows directly into a tributary of the Gatineau. Present lake level stands about 520 feet above sea level. A ridge of bedrock extends along the east shore but the rest of the lake is surrounded by low, gently sloping flats. These low areas are blanketed with marine clay.

The freshwater sediments overlie Champlain Sea clay, except for a small segment of the east shoreline where marl rests directly on bedrock. Marl is continuous along much of the shoreline, but a steep slope that intersects the east shore and an elevated clay bank on the southwest shore are free of marl. Clay exposed along the southwest shore is highly calcareous and in places freshwater mollusk shells and bits of marl can be found at the surface. Apparently a thin accumulation of marl covered this area but was stripped off by erosion when lake level dropped below the clay shelf. Maximum thickness of the marl exceeds 15 feet along most of the shoreline. On the west and south shores, marl grades into thick accumulations of gyttja and peat. Two thick organic deposits were found landward of marl on the north shore. The marl is covered by 3 to 12 inches of impure, weathered marl or humic material. A pit was excavated on the east shore for sampling and description of the section.

Stratigraphic Section

Unit	Description	Thickness (inches)
1	Brown mixture of fine organic material and marl; granular texture; small to medium-sized roots abundant. Samples 1-3 . .	6
2	Buff marl; mottled around living roots; fossil plant parts vertically oriented near base. Samples 4-8 (part) . . .	9
3	Light brown marl; banded with brownish-black gyttja layers. Samples 8 (part) - 13 (part) .	10
4	Brownish - gray marl; very lightly banded; vertical plant parts abundant. Samples 13 (part) to 19 (part).	12
5	Yellowish-buff marl; coarse granular texture; calcareous casts of charophyte parts are the major constituent; stem and elongate leaf fragments from aquatic plants abundant in lowest 6 inches; lower contact smooth, distinct, sloping westward. Samples 19 (part) - 27.	17
Base	Bluish-gray clay; massive; plant roots penetrating upper 6 inches; Foraminifera abundant; occasional boulders or cobbles of crystalline rock.	--
	Total	54

Southwest Venosta deposit

This deposit (Fig. 1) is located on the north shore of a small lake that connects with four other lakes that drain eastward to the Gatineau. It and another small lake occur at about 560 feet in a low marshy basin that is enclosed on three sides by steep bedrock slopes (Fig. 8). The northern lake drains northeast through an outlet stream that crosses a low divide and empties into a series of intermittent drainageways. These run into nearby lakes, the largest of which is Venosta Lake. Marl with a maximum thickness of less than 2 feet occurs on the low, flat north shore and is flanked by extensive bog deposits. The marl and organic material rests on sand, which covers most of the basin floor. The water table is near the top of, or covers most of, the marl.

The high water table prevented excavation of a pit for sampling and detailed description of a section. A channel sample was taken through the marl at its deepest part with a posthole spade.

Stratigraphic section

Unit	Description	Thickness (inches)
1	Black peaty muck; very loosely compacted; saturated.	4
2	Light gray marl; fine texture; relatively pure; top few inches slightly darkened with organic material.	22
Base	Gray sand; siliceous; medium to coarse texture.	--
	Total	26

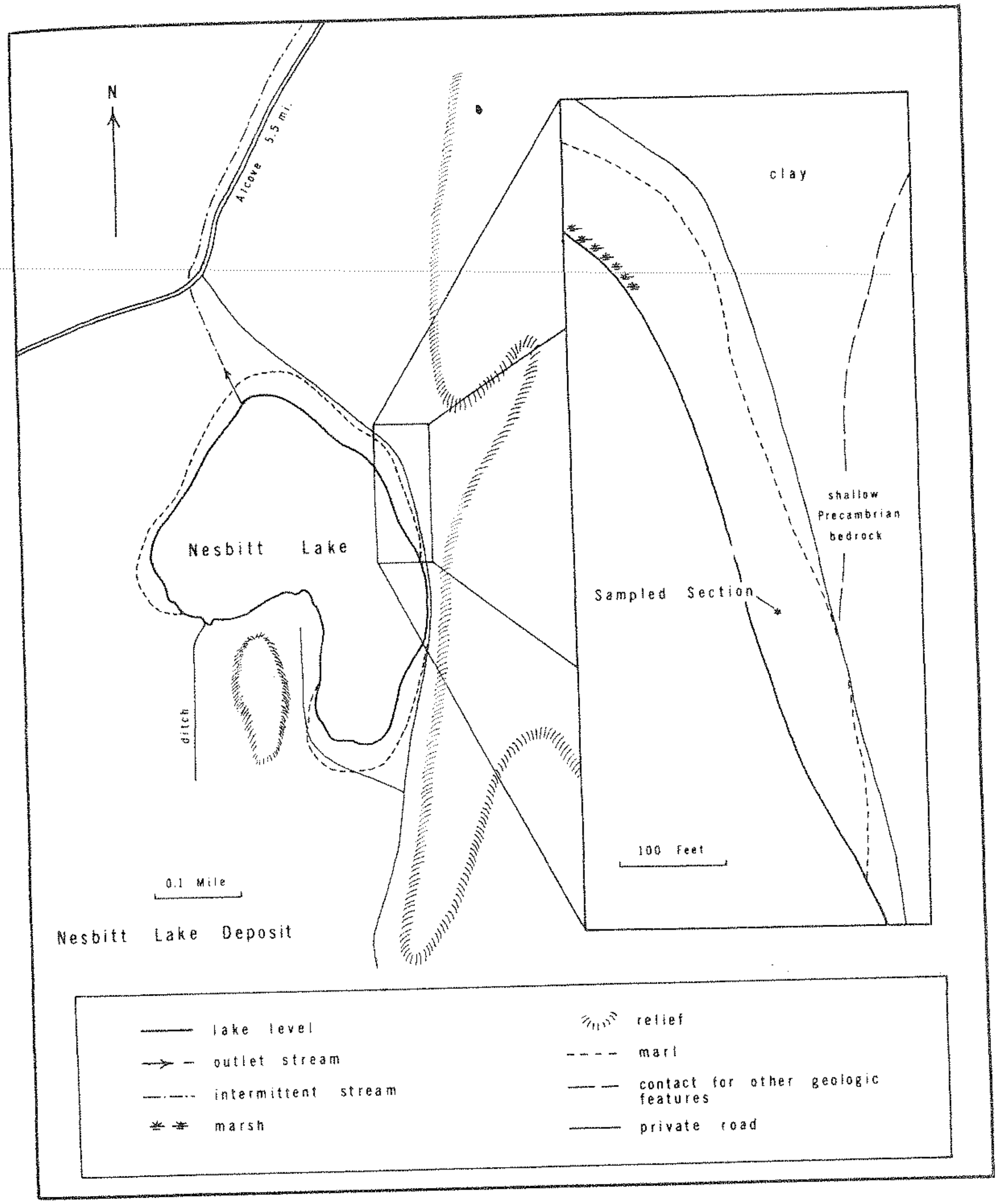


FIGURE 5. SKETCH MAP OF NESBITT LAKE, MASHAM TOWNSHIP, GATINEAU COUNTY, QUEBEC.

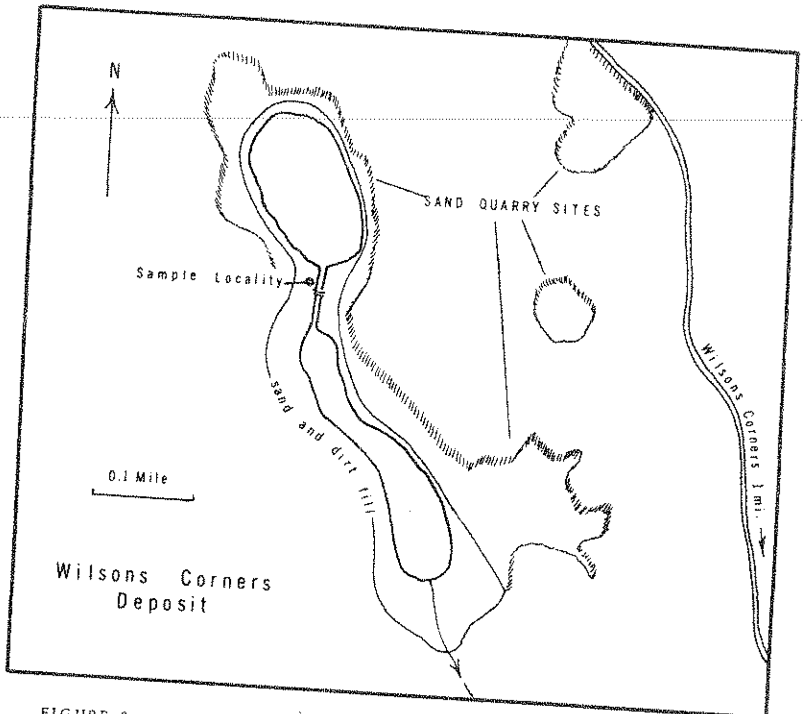


FIGURE 6. SKETCH MAP OF WILSONS CORNERS DEPOSIT, WAKEFIELD TOWNSHIP, GATINEAU COUNTY, QUEBEC.

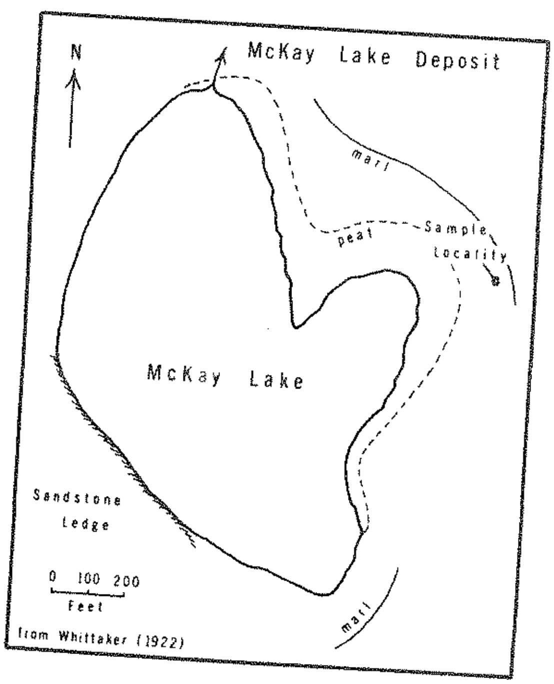


FIGURE 7. SKETCH MAP OF McKAY LAKE, ROCKCLIFFE, ONTARIO.

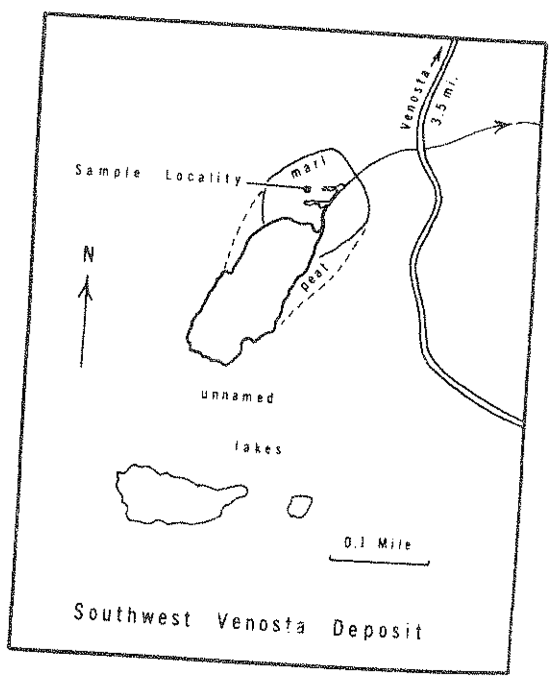


FIGURE 8. SKETCH MAP OF SOUTHWEST VENOSTA DEPOSIT, LOW TWP., GATINEAU CO., QUEBEC.

Wilsons Corners deposit

Waddington (1950, p. 56) reports the occurrence of marl in a marsh that joins two small lakes near Wilsons Corners in Wakefield Township, Quebec. (Fig. 6). The lakes are at an elevation of about 620 feet. The locality was visited in 1968 and found to be greatly altered by earth moving and quarry operations. The landowner had filled the marsh and low shorelines on the north lake. The south lake and adjoining marsh are filling in rapidly with waste material from a sand and gravel washing operation on the east shore. Sand and gravel are being removed from the shoreline of both lakes. The thick sand body that covers much of the area is underlain by massive bluish-gray clay, and was probably deposited during the marine invasion.

Large quantities of marl had been bulldozed into the marsh, along with sand and clay, to form a platform several feet above lake level. Careful search and auger probes did not reveal any marl in place. Apparently most of the deposit was incorporated in fill and the rest is buried under fill.

A large grab sample was taken from the displaced marl. Waddington (1950, p. 56) states that the marl was underlain by sand and covered by a 'bed of turf' over much of its area.

Rochester Street deposit

The Rochester Street deposit in the city of Ottawa accumulated at an elevation of 220 feet in an abandoned channel cut by an earlier stage of the Ottawa or Rideau Rivers (Fig. 1). The deposit occupies the same depression as Dows Lake Bog and is situated about 0.25 mile north of Dows Lake (Mott and Camfield, 1969, p. 5). A radiocarbon date of 8830 ± 190 yrs BP. (GSC-546) was obtained at the base of the marl, but Mott and Camfield (1969 p. 12) note that pollen stratigraphy indicates a younger age, closer to 7600 yrs. BP. It is quite possible that contamination by Paleozoic carbonate produced an older C-14 date. A sample of the silty clay was examined and found to be void of Foraminifera. A description of the section prepared by R. J. Mott is given below with some modification.

Stratigraphic Section

Unit	Description	Thickness (inches)
1	Disturbed peat and fill.	5
2	Well decomposed woody peat.	17
3	Buff marl; banded; fossiliferous; some gyttja layers. Samples 1-13.	31
4	Gray silty clay, stiff.	3
5	Coarse sand.	3
Base	Paleozoic bedrock	--
	Total	59

McKay Lake deposit

Published records of marl at McKay Lake date from 1845 (Whittaker, 1918, p. 14), and the deposit was studied extensively by E. J. Whittaker during the first quarter of this century. McKay Lake (Fig. 7) empties into the Ottawa River, which flows about 0.5 mile to the north (Fig. 1). Present lake level is 15 feet above the river. Except for an outcrop of Rockcliffe shale and sandstone on the west shoreline, the lake rests on post-Champlain Sea sands and clays (Gadd, 1962, map). Surrounding slopes, excluding the bedrock ledge, are gentle and in former times most of the shoreline was quite marshy (Whittaker, 1918, p. 14). Marl beds that vary in thickness from 3 to 5 feet occur along the east and south slopes, at an elevation of slightly less than 175 feet, about 18 to 20 feet above present lake level. The highly fossiliferous marl is fine textured and white to yellowish-white. Thin soil and organic material cover the deposits, and organic deposits occur along most of the present shoreline. (Whittaker, 1922, p. 141).

McKay Lake is now surrounded by a residential area, and the marl beds are covered by buildings and landscaped. A grab sample examined in this study was collected for A. La Rocque from the east beds by the Geological Survey of Canada.

SYSTEMATIC PALEONTOLOGY

General Statement

A systematic account is given of the taxonomy, rphology, ecology, and distribution of each species encountered in fossil collections made during this study. The statements are for the most part brief summaries of information contained in monographs and reviews dealing with various mollusk groups. In some cases these data are supplemented with observations made during this investigation. The synonymy includes citations of the original description and of a reference that gives a complete synonymy agreeable to the writer. All taxonomic or nomenclatorial changes are explained and supported by additional citations.

Free use has been made of La Rocque's *Pleistocene Mollusca of Ohio* (1966, 1967, 1968, and in press). It served as a framework for this discussion.

PHYLUM MOLLUSCA

Class BIVALVIA

Order TELEODESMACEA

Family SPHAERIIDAE

Genus *Sphaerium* Scopoli, 1777

Sphaerium lacustre (Müller) 1774

(Plate I, Figure 1)

Tellina lacustris Müller, 1774, Verm. Terr. et Fluv., p. 204.
Sphaerium lacustre (Müller), Herrington, 1962, Revis. Sphaeriidae N. Amer., p. 19.

ECOLOGY. The species seems to prefer mud bottoms. *S. lacustre* has been collected from a great variety and size range of lacustrine and fluvial bodies, and from very shallow water to depths of 8 meters. (La Rocque, 1967, p. 295).

Ontario, Quebec, and Nova Scotia south to California, Louisiana, Georgia, and Florida; from the Atlantic to the Pacific (Herrington, 1962, p. 20). *Sphaerium lacustre* was found living at Lac Laflamme, Nesbitt Lake, and at Wilsons Corners in the Gatineau Valley. Pleistocene distribution, this study: Lac Laflamme, Manitou Lake, and Nesbitt Lake deposits, Quebec. The species has been reported from the Richardson Lake deposit, Quebec (Gibson, 1967, p. 6); Box Marsh deposit, Ont. (Clowers, 1966 p. 36); and the Atkins Lake deposit, Ont. (Ouellet, 1968, p. 19).

GEOLOGIC RANGE. Early Pliocene to Recent for *S. lacustre* form *ryckholti* (Herrington, 1962, p. 21); Pleistocene, Late Nebraskan to present for typical *S. lacustre* (Herrington and Taylor, 1958, p. 9).

Sphaerium rhomboideum (Say) 1822

Cyclas rhomboidea Say, 1822, Acad. Nat. Sci. Philadelphia, Jour., v. 2, p. 380.
Sphaerium rhomboideum (Say), Herrington, 1962, Revis. Sphaer. N. Amer. p. 25.

ECOLOGY. *Sphaerium rhomboideum* occurs in creeks, rivers, and ponds and seems to prefer a muddy bottom with aquatic plants and algae (Herrington, 1962, p. 25). Baker (1928, p. 346) found it on mud in 0.6 to 2 meters of water, but also on gravel and coarse sand in shallow areas.

DISTRIBUTION. James Bay and Maine south to Pennsylvania and Ohio, west to Montana and Idaho (Herrington, 1962, p. 25). La Rocque (1962, p. 28) gives records for Leamy's Lake in Hull and Meach Lake northwest of Hull. Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec.

GEOLOGIC RANGE. Pleistocene, Sangamon to the present (La Rocque, 1967, p. 302).

Cyclas similis Say, 1816, Nicholson's Encycl., v. 2, pl. 1, fig 9.
Sphaerium sulcatum (Lamarck), Herrington, 1962, Revis. Sphaer. N. Amer., p. 28.

ECOLOGY. *Sphaerium simile* inhabits soft bottoms in fairly still water, along shores of lakes or in eddies of creeks and rivers (Taylor, 1960, p. 46). Herrington (1962, p. 29) states that it is never found in swamps or ponds.

DISTRIBUTION. Alberta, Saskatchewan, Manitoba Ontario, and Quebec south to Montana, Wyoming, Iowa, Illinois, Ohio, and Virginia. Apparently it does not occur south of the glacial boundary (Herrington, 1962, p. 29). La Rocque (1962, p. 28) lists the following Gatineau Valley localities: Meach Lake, Gauvreau Lake, McGoey's Lake near Chelsea. The writer found *Sphaerium simile* living at Manitou Lake, Lac Laflamme, and Nesbitt Lake. Whittaker (1918 p. 15) reports the species living in McKay Lake, Ontario. Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec. It has been reported as *S. sulcatum* from newrby fossil localities at Richardson Lake, Que. (Gibson, 1967, p. 10); Box Marsh and White Lake, Ont. (Clowers, 1966, p. 37, 55); and at Atkins Lake, Ont. (Ouellet, 1967, n. p.).

GEOLOGIC RANGE. Pliocene?; Pleistocene, Nebraskan to present (La Rocque, 1967, p. 303).

REMARKS. Herrington (1950, p. 117) interpreted Say's use of 'breadth' to mean height rather than length and rejected *S. simile* (Say) 1816 as the name for this species in favor of *S. sulcatum* (Lamarck) 1818. Herrington (1965, p. 44), after realizing that 'breadth' was commonly used by nineteenth century naturalists to describe the anterior-posterior dimension of clam shells, returned to using the older name. The synonymy of these names has never been seriously doubted. Temple Prime (1865, p. 35) considered them identical, but used *S. sulcatum* only because he assumed that this name had priority over *S. simile*. Stansbery (1961, p. 11) reviews the terms that have been used for pelecypod shell dimensions.

Genus *Pisidium* C. Pfeiffer, 1821

Pisidium adamsi Prime, 1851

(Plate I, Figure 4)

Pisidium adamsi Prime, Stimpson, 1851, Moll. New England, p. 16.
Pisidium adamsi Prime, La Rocque, 1967, Pleist. Moll. Ohio, pt. 2, p. 316.

ECOLOGY. The species prefers areas where muck and decaying plant material are accumulating in lakes, rivers, and rarely, creeks (Herrington, 1962, p. 31).

DISTRIBUTION. New Brunswick to Saskatchewan and the eastern United States south to Florida, west to Missouri and Montana (Herrington, 1962, p. 31). La Rocque (1962, p. 27) cites a record of this species in the Ottawa River near Ottawa. Live specimens were collected at Manitou Lake and at the site of the Southwest Venosta deposit in the Gatineau Valley. Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec. Ouellet (1967, n. p.) reports it from the marl at Atkins Lake, Ontario.

GEOLOGIC RANGE. Pleistocene, late Wisconsin to the present (La Rocque, 1967, p. 316).

Pisidium casertanum (Poli) 1791

(Plate I, Figure 5)

Cardium casertanum Poli, 1791, Test. utr. Sicil., p. 65, pl. 16, fig. 1.
Pisidium casertanum (Poli), Herrington, Revis. Sphaer. N. Amer., p. 33.

ECOLOGY. *Pisidium casertanum* occurs in a wide range of habitats from temporary pools to large lakes. It is found in situations where the water is shallow enough to expose the animals to seasonal desiccation, but also at depths up to 40 meters. The optimum depth range is probably from 0.5 to 3 meters. The species is also common in fluvial habitats, including streams with a considerable amount of current. It occurs on most bottom types. (La Rocque, 1967, p. 342-343). 'This is by far the most common *Pisidium*. (Herrington, 1962, p. 34).

DISTRIBUTION. All of North America, probably much of Central and South America, (Herrington, 1962, p. 34). New Quebec records are Nesbitt Lake and the lake at Wilsons Corners. Whittaker (1918, p. 15) found the species alive in McKay Lake, Ontario. Pleistocene distribution, this study: present in all the deposits sampled in this investigation, except the Wilsons Corners deposit. Other Pleistocene records for the area include: Richardson Lake deposit (Gibson, 1967, p. 10), Box Marsh deposit, White Lake deposit (Clowers, 1966, p. 38, 55), and the deposit at Atkins Lake (Ouellet, 1967, n. p.).

GEOLOGIC RANGE. Middle Pliocene to Recent (Herrington, 1962, p. 35).

Pisidium compressum Prime, 1851

(Plate I, Figure 6)

Pisidium compressum Prime, 1851, Boston Soc. Nat. Hist. Proc., v. 4,
Pisidium compressum Prime, Herrington, 1962, Revis. Sphaeriidae N. Amer., p. 35.

ECOLOGY. Inhabits creeks, rivers, and lakes. In streams, the species prefers sandy bottoms and a current. In a lacustrine habitat, the animal occurs on clay, sand, and mud sediment from very shallow water to a reported depth of 16 meters. It lives in permanent water bodies only where some current action is present; never in bodies of stagnant water (La Rocque, 1967, p. 331).

DISTRIBUTION. Northwest Territories (Great Slave Lake) east to Prince Edward Island, south to California, Mexico, and Georgia (Herrington, 1962, p. 35). Living populations occur at Lac Laflamme, Nesbitt Lake, and the lake at Wilsons Corners, Quebec. Pleistocene distribution, this study: Manitou Lake Lac Laflamme, Nesbitt Lake, and Wilsons Corners deposits, Quebec. Other fossil localities in the region include: Richardson Lake deposit (Gibson, 1967, p. 11), Box Marsh deposit, White Lake deposit (Clowers, 1966, p. 37, 55), and the Atkins Lake deposit (Ouellet, 1967, n.p.).

GEOLOGIC RANGE. Middle Pliocene to the present (Herrington, 1962, p. 35); very common in Pleistocene sediments (La Rocque, 1967, p. 331).

Pisidium ferrugineum Prime, 1851

(Plate I, Figure 7)

Pisidium ferrugineum Prime, 1851, Boston Soc. Nat. Hist. Proc., v. 4, p. 162.
Pisidium ferrugineum Prime, Herrington, 1962, Revis. Sphaer. N. Amer., p. 39.

ECOLOGY. *Pisidium ferrugineum* is found in lakes of various sizes, creeks, and rivers on sand, mud, clay, and marl bottoms. Specimens from lakes filling with marl or muck tend to have smoother surfaces, greater diameters, and less prominent beaks; whereas those from sand substrates have prominent striae and more or less tubercular beaks. The species seems to prefer cool conditions and a depth range of 1 to 3 meters. (Herrington, 1962, p. 40; La Rocque 1967, p. 340).

DISTRIBUTION. British Columbia and Northwest Territories east to Newfoundland and New Brunswick, south to California, Utah, Illinois, Indiana, Ohio, and New York. Pleistocene distribution, this study: All the sampled localities, except the Wilsons Corners deposit. It has been reported from the following nearby Pleistocene localities in Ontario: Box Marsh deposit, White Lake deposit (Clowers, 1966, p. 37, 55), and Atkins Lake deposit (Ouellet, 1968, p. 18).

GEOLOGIC RANGE. Pleistocene, Wisconsin to present (La Rocque, 1967, p. 340). *Pisidium ferrugineum* is widespread and abundant in late Wisconsin deposits of the Gatineau Valley and southern Ontario.

Pisidium lilljeborgi Clessin, 1886

(Plate I, Figure 8)

Pisidium lilljeborgi Clessin, 1886, *in* Esmark and Hoyer, Malak. Blätt., n. s., v. 8 p. 119.
Pisidium lilljeborgi Clessin, La Rocque, 1967, Pleist. Moll. Ohio, pt. 2, p. 350.

ECOLOGY. The species generally inhabits lakes although it occurs in streams as well. It has been collected on substrates varying from clay to boulders, and from very shallow water to depths of over 17 meters (La Rocque, 1967, p. 352). Its optimum habitat is probably a mud or sand bottom in about 0.5 to 3 meters of water.

DISTRIBUTION. Quebec, Ontario, Saskatchewan, Alberta, Northwest Territories to Great Bear Lake, and Alaska, south to California, Utah Colorado, Wisconsin, Indiana, and New York. Pleistocene distribution, this study: Lac Laflamme (7 valves). Nesbitt Lake (2 valves) deposits, Quebec; Rochester Street (1 valve) and Mc Kay Lake (2 valves) deposits, Ontario. The paucity of living and fossil records suggests that the species seldom develops large populations.

GEOLOGIC RANGE. Pleistocene, Wisconsin to Recent (La Rocque, 1967, p. 352).

Pisidium nitidum Jenyns, 1832

(Plate I, Figure 9)

Pisidium nitidum Jenyns, 1832, Cambridge Philos. Soc. Trans., v. 4, p. 304.
Pisidium nitidum Jenyns, Herrington, 1962, Revis. Sphaeriidae N. Amer., p. 45.

ECOLOGY. The species is found on loose sand and clay bottoms of lakes and streams. It has been reported from depths up to 25 meters, but seems to prefer clear, shallow water with aquatic plants. There are several records for very small bodies of water, although it seems to be rare in marshes (La Rocque, 1967, p. 334).

DISTRIBUTION. North America from Mexico to Northwest Territories and Hudson Bay, from the Atlantic to the Pacific, except for southeastern United States (La Rocque, 1967, p. 334). *Pisidium nitidum* was found alive at Manitou Lake, Quebec. Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, Nesbitt Lake, and Southwest Venosta deposits, Quebec; Rochester Street deposit, Ontario. It was common at all the localities and very abundant in the Nesbitt Lake and Southwest Venosta deposits. Ouellet (1968, p. 18) reports the species from the Atkins Lake deposit, Ontario.

GEOLOGIC RANGE. Early Pliocene to the present, common throughout the Pleistocene (La Rocque, 1967, p. 334).

REMARKS. The short, heavy form, *Pisidium nitidum* f. *pauperculum*, and the elongate form, *P. nitidum* f. *contortum*, occurred in all the fossil populations. These intergraded with typical *P. nitidum* and no attempt was made to separate the forms. Distinct examples of form *contortum* were rare, but 42 valves with this striking variation in outline were recovered from the Manitou Lake deposit.

Pisidium variabile Prime, 1851

(Plate I, Fig. 10)

Pisidium variabile Prime, 1851, Boston Soc. Nat. Hist. Proc., v. 4, p. 163.
Pisidium variabile Prime, Herrington, 1962, Revis. Sphaeriidae N. Amer., p. 50.

ECOLOGY. *Pisidium variabile* usually occurs on soft sediments in still water of creeks, rivers, and lakes (Herrington, 1962, p. 50). Data reviewed by La Rocque (1967, p. 338) suggest that it prefers shallow to moderately deep water, about 0.5 to 12 meters.

DISTRIBUTION. New Brunswick west to British Columbia south to California, Utah, Colorado, Alabama, Tennessee, and Virginia (Herrington, 1962, p. 50). Recent specimens were collected at Manitou Lake, Quebec. Pleistocene distribution, this study: all deposits sampled, except the Wilsons Corners deposit, Quebec. Ouellet (1967, n.p.) reports *P. variabile* from the deposits at Atkins Lake, Ontario.

GEOLOGIC RANGE. Pleistocene, Yarmouth to the present (La Rocque, 1967, p. 339).

Pisidium ventricosum Prime, 1851

(Plate I, Figure 12)

Pisidium ventricosum Prime, 1851, Boston Soc. Nat. Hist. Proc., v. 4, p. 68.
Pisidium obtusale Herrington, 1962, Revis. Sphaeriidae N. Amer., p. 46 (not *P. obtusale* Pfeiffer, 1821).
Pisidium ventricosum Prime, Herrington, 1965, Nautilus, v. 79, p. 44.

ECOLOGY. *Pisidium ventricosum* form *rotundatum* occurs in sheltered parts of lakes, creeks, and rivers, but is most common in ponds and lagoons. It commonly lives among dead tree leaves in shallow water. Form *ventricosum* inhabits lakes and large rivers. (Herrington, 1962, p. 47).

DISTRIBUTION. Northwest Territories south to California and Mexico, east to Quebec, Maine, New Jersey, Ohio, and Illinois (La Rocque, 1967, p. 346). La Rocque (1962, p. 27) lists a record for Hull, Quebec (form *rotundatum*). Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec. Ouellet (1967, n.p.) found it in the marl deposit at Atkins Lake, Ontario.

GEOLOGIC RANGE. Pleistocene, Illinoian to present (La Rocque, 1967, p. 347).

REMARKS. Both forms were present in the fossil populations discovered during this study and no attempt was made to separate them. The form *rotundatum* was more common in the Manitou Lake and Lac Laflamme deposits, whereas form *ventricosum* was more common in the Nesbitt Lake deposit. There were intermediate specimens in all the samples.

Pisidium walkeri Sterki, 1895

(Plate I, Figure 13)

Pisidium walkeri Sterki, 1895, Nautilus, v. 9, p. 75.

Pisidium walkeri Sterki, La Rocque, 1967, Pleist. Moll. Ohio, pt. 2, p. 343.

ECOLOGY. *Pisidium walkeri* inhabits creeks, rivers, and small lakes but is usually not abundant at any one place. A smaller, more rounded form, *P. walkeri* f. *mainense*, is usually found on the soft bottoms of small lakes and ponds. It occurs in fewer places than the typical form but is often abundant in marl lakes (Herrington, 1962, p. 51).

DISTRIBUTION. Northwest Territories east to Maine, south to Virginia, Ohio, Missouri, South Dakota, and Arizona (Herrington, 1962, p. 51). Pleistocene distribution, this study: Manitou Lake and Nesbitt Lake deposits, Quebec. Ouellet (1967, n. p.) reports the form *mainense* from the Atkins Lake deposit, Ontario.

REMARKS. A single specimen of *Pisidium walkeri* f. *mainense* was recovered from the Manitou Lake deposit and 23 valves of this form were found in the Nesbitt Lake samples. Only two valves, from the Nesbitt Lake deposit, were typical *P. walkeri*.

ORDER PRIONODESMACEA

FAMILY UNIONIDAE

Shell fragments, clearly of freshwater mussels, were collected during the excavation of sampling pits at Lac Laflamme and Nesbitt Lake. Two specimens, one at a depth of 56 inches and another from an unknown depth, were found in the marl at Lac Laflamme, but none was recovered from the quantitative samples. Two fragments occurred at the base (Unit 27) and near the top (Unit 2) of the Nesbitt Lake deposit, and another specimen was found during excavation. The shells were very friable, and crumbled when the soft, wet marl was slightly disturbed. The specimens seemed to be rather complete in place. Fragments in the quantitative samples were too small for generic identification. Glochidia occurred throughout the marl in sections at Lac Laflamme, Nesbitt Lake Manitou Lake, and Rochester Street.

CLASS GASTROPODA

ORDER CTENOBRANCHIATA

FAMILY VIVIPARIDAE

Genus *Campeloma* Rafinesque, 1819

Campeloma decisum (Say) 1817

(Plate I, Figure 14)

Limnaea decisa Say, 1817, Nicholson's Encycl., 1st ed., n.p., pl. 3, fig. 6.
Campeloma decisum (Say), Clench, 1962, Occ. Pap. Moll. Mus. Comp. Zool., v. 2, p. 277-279.

ECOLOGY. *Campeloma* is usually found in lakes and shallow parts of slow streams. The animal is practically restricted to bottoms of loose sediment into which it burrows and moves about partially buried. All species have a very large blanket-like foot that seems to give the animal considerable support and control of body movements on unstable substrates. At Roddick Lake in the Gatineau Valley, *Campeloma decisum* was found along shore on a loose sand and gravel bottom under 4 to 6 inches of water. Bovbjerg (1952, p. 176) finds that *Campeloma decisum* moves up-current in streams. This rheotactic response produces aggregations below physical barriers such as logs, bedrock steps, and riffles. In quiet, shallow water the partly buried animals plow slowly through the soft sediment. However, they leave their furrows and move about quite actively on top of the substrate in response to changing water levels.

DISTRIBUTION. Eastern North America from Nova Scotia to Saskatchewan, south to Tennessee, Virginia, and the Rio Grande (La Rocque 1968, p. 374). La Rocque (1962, p. 34) lists several records from western Quebec, including the Gatineau River at Alcove. The species is abundant at Roddick Lake on the east shore of Gatineau River, east of Bouchette, Que.; and in a stream joining Henry Lake and Lac à la Vase northwest of Kazabazua. Pleistocene distribution, this study: Lac Laflamme deposit, Quebec. Eight specimens were recovered, seven juveniles and one fragment of an adult body whorl.

GEOLOGIC RANGE. Pleistocene, Sangamon to Recent (La Rocque 1968, p. 375).

FAMILY VALVATIDAE

Genus *Valvata* Müller, 1774

Valvata lewisi Currier, 1868

(Plate I, Figure 15)

Valvata lewisi Currier 1868, Kent Sci. Inst. Misc. Publ. 1, p. 9.

Valvata lewisi Currier, La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 360.

ECOLOGY. *V. lewisi* inhabits rather shallow water on aquatic plants or sand or mud bottoms among plant beds (La Rocque, 1968, p. 360).

DISTRIBUTION. Mackenzie River south to Illinois and Ohio, east to the Atlantic (La Rocque, 1968, p. 360). La Rocque (1962, p. 35) records the species from the Ottawa River at Ottawa. Pleistocene distribution, this study: Manitou Lake Southwest Venosta, and Nesbitt Lake deposits, Quebec; Rochester Street deposit, Ontario. Gibson (1967, p. 12) reports it from the Richardson Lake deposit, Quebec.

GEOLOGIC RANGE. Pleistocene, late Kansan to the present (La Rocque, 1968, p. 360).

Valvata tricarinata (Say) 1817

(Plate I, Figure 16)

Cyclostoma tricarinata Say, 1817, Acad. Nat. Sci. Phila. Jour., v. 1, p. 13.
Valvata tricarinata (Say), La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 367-368.

ECOLOGY. The species inhabits lakes and streams from along shore to depths exceeding 9 meters. It lives on aquatic plants, submerged objects or bottoms that vary in texture from clay to boulders. In the Gatineau Valley, the writer found these animals in such diverse situations as on *Chara* in 1 meter of water (Lac Laflamme), on loose sand and filamentous algae in a few inches of water (Wilsons Corners), and on the sides of boulders in about 1 meter of water (Wolf Lake, Quebec).

DISTRIBUTION. Great Slave Lake and the Mackenzie River east to New England, south to Virginia; common in southern Ontario and Quebec. *Valvata tricarinata* was collected alive at Lac Laflamme, Nesbitt Lake, the lake at Wilsons Corners, and Wolf Lake in Auldfield Township, Quebec. Pleistocene distribution, this study: present and rather abundant in all deposits sampled. The species is listed in all published late Wisconsin faunas from the Ottawa region known to the writer.

GEOLOGIC RANGE. Pleistocene, Nebraskan to Recent (Taylor, 1960, p. 32).

REMARKS. No attempt was made to separate *V. tricarinata* into the named varieties that are based on variation in the number of carinae present (see La Rocque, 1968, p. 368). The common forms, in order of decreasing abundance, are 111, 101, and 100. In the Nesbitt Lake deposit, distinctly tricarinate specimens occur low in the section and bicarinate and unicarinate shells appear about half way in the section (Unit 14). Weakly carinate forms become more abundant toward the top of the deposit and the smooth form, *V. tricarinata* f. *simplex* (000), is common near the top. A similar sequence was found in the section at Atkins Lake by Ouellet (1968 p. 18).

FAMILY AMNICOLIDAE

Genus *Amnicola* Gould and Haldeman, 1841

Amnicola limosa (Say) 1817

(Plate I, Figure 17)

Paludina limosa Say, 1817, Acad. Nat. Sci., Phila., Jour., v. 1, p. 125.
Amnicola winkleyi leightoni F. C. Baker, 1920, Nautilus, v. 33, p. 125.
Amnicola limosa (Say), Berry, 1943, Amnicolidae of Michigan, p. 23.

ECOLOGY. *Amnicola limosa* is found in a great variety of habitats, including creeks, rivers, freshwater and brackish-water lakes. It is most common on rooted aquatic plants such as *Chara*, *Potamogeton*, *Vallisneria*, and *Elodea* where these occur in dense stands. The animals feed on diatoms and probably other periphyton attached to the plants. (Berry, 1943, p. 26).

DISTRIBUTION. New England and New Jersey west to Utah, Manitoba south to Texas. Living populations were found at Lac Laflamme, Nesbitt Lake, and Wilsons Corners in the Gatineau Valley. More rigorous collection would probably have produced specimens from other localities since the species is fairly common in Ontario and Quebec. Whittaker (1918, p. 15) reports living *Amnicola limosa*, under the synonym *A. porata*, from McKay Lake. Pleistocene distribution, this study: all fossil localities except the Southwest Venosta deposit. Other Pleistocene records for the area include the marl deposits at Richardson Lake, Que. (Gibson, 1967, p. 13); Box Marsh, Ont.; White Lake, Ont. (Clowers, 1966, p. 41, 55); and Atkins Lake, Ont. (Ouellet, 1968, p. 18).

GEOLOGIC RANGE. Pleistocene, Yarmouth to Recent (La Rocque, 1968, p. 385).

REMARKS. F. C. Baker (1920, p. 125) originally described *A. leightoni* as a subspecies of *A. winkleyi* Pilsbry on the basis of Pleistocene material collected by M.M. Leighton from the marl beds at Rush Lake, Logan County, Ohio. He gave the following description:

> Shell differing from *A. winkleyi* in being larger, heavier, wider in proportion to its height, the body whorl being more globose than in the typical form; there are 4½ whorls, the upper part of which is somewhat flat-sided just below the suture; this is especially marked on the last whorl of some individuals; the first whorl is flatter than in *winkleyi;* the umbilicus is wider and deeper and the aperture is wider in proportion to its height than in *winkleyi*. (F.C. Baker, 1920, p. 125).

Pilsbry (1912, p. 1) in the original description of *A. winkleyi* states that the radula of this species is like that of *A. lustrica* and unlike the radula of *A. limosa,* and the nuclear whorl projects upward instead of being planispiral as in *A. limosa.* Baker (1921, p. 23) later studied Pleistocene material from Illinois that showed greater variation in spire height and obesity than specimens from the type locality. He elevated the form to species rank after concluding that it was distinct from *A. winkleyi*. In his monumental work on the freshwater Mollusca of Wisconsin, Baker (1928 p. 119) considers *A. leightoni* an extinct species that constitutes a separate group in the genus *Amnicola*.

Topotypes of *A. leightoni* in the Orton Geological Museum, Ohio State University (OSU 14720) were examined and compared with specimens identified as *Amnicola limosa* and *A. leightoni* from Pleistocene marl deposits in Ohio, Wisconsin, Ontario, and Quebec. All lots show variation in size, spire height, and globosity. Spire height and globosity vary in these specimens to produce *A. porata* (globose adult whorls, short spire), *A. limosa* (spire short to one-half total height less globose), and *A. leightoni* (spire one-half or more of total height, globosity variable). There are gradations between the forms and all have the characteristic planispiral nuclear whorl of *A. limosa*. Differences

PLATE I. PLEISTOCENE MOLLUSCA FROM QUEBEC AND ONTARIO

Fig. 1. *Sphaerium lacustre*, Nesbitt Lake deposit, X 5
Fig. 2. *Sphaerium rhomboideum*, Nesbitt Lake deposit, X 4
Fig. 3. *Sphaerium simile*, Nesbitt Lake deposit, X 2.5
Fig. 4. *Pisidium adamsi*, Lac Laflamme deposit, X 6
Fig. 5. *Pisidium casertanum*, Manitou Lake deposit, X 10
Fig. 6. *Pisidium compressum*, Lac Laflamme deposit, X 10.5
Fig. 7. *Pisidium ferrugineum*, Nesbitt Lake deposit, X 10
Fig. 8. *Pisidium lilljeborgi*, Lac Laflamme deposit, X 10.5
Fig. 9. *Pisidium nitidum*, Lac Laflamme deposit, X 10.5
Fig. 10. *Pisidium nitidum* form *contortum*, Manitou Lake deposit, X 10.5
Fig. 11. *Pisidium variabile*, Manitou Lake deposit, X 10
Fig. 12. *Pisidium ventricosum*, Manitou Lake deposit, X 10
Fig. 13. *Pisidium walkeri*, Nesbitt Lake deposit, X 10.5
Fig. 14. *Campeloma decisum*, juvenile, Lac Laflamme deposit, X 4.5
Fig. 15. *Valvata lewisi*, Manitou Lake deposit, X 10
Fig. 16. *Valvata tricarinata*, Manitou Lake deposit, X 10.5
Fig. 17. *Amnicola limosa*, Nesbitt Lake deposit, X 10
Fig. 18. *Amnicola lustrica*, Rochester Street deposit, X 10
Fig. 19. *Lymnaea dalli*, Nesbitt Lake deposit, X 11
Fig. 20. *Lymnaea decampi*, Nesbitt Lake deposit, X 4
Fig. 21. *Lymnaea haldemani*, spire fragment, Manitou Lake deposit, X 10
Fig. 22. *Lymnaea haldemani*, aperture fragment, Manitou Lake deposit, X 3.5
Fig. 23. *Lymnaea megasoma*, Manitou Lake deposit, X 1
Fig. 24. *Lymnaea obrussa*, Lac Laflamme deposit, X 4.5

(Drawn by Barbara Sue Bickel)

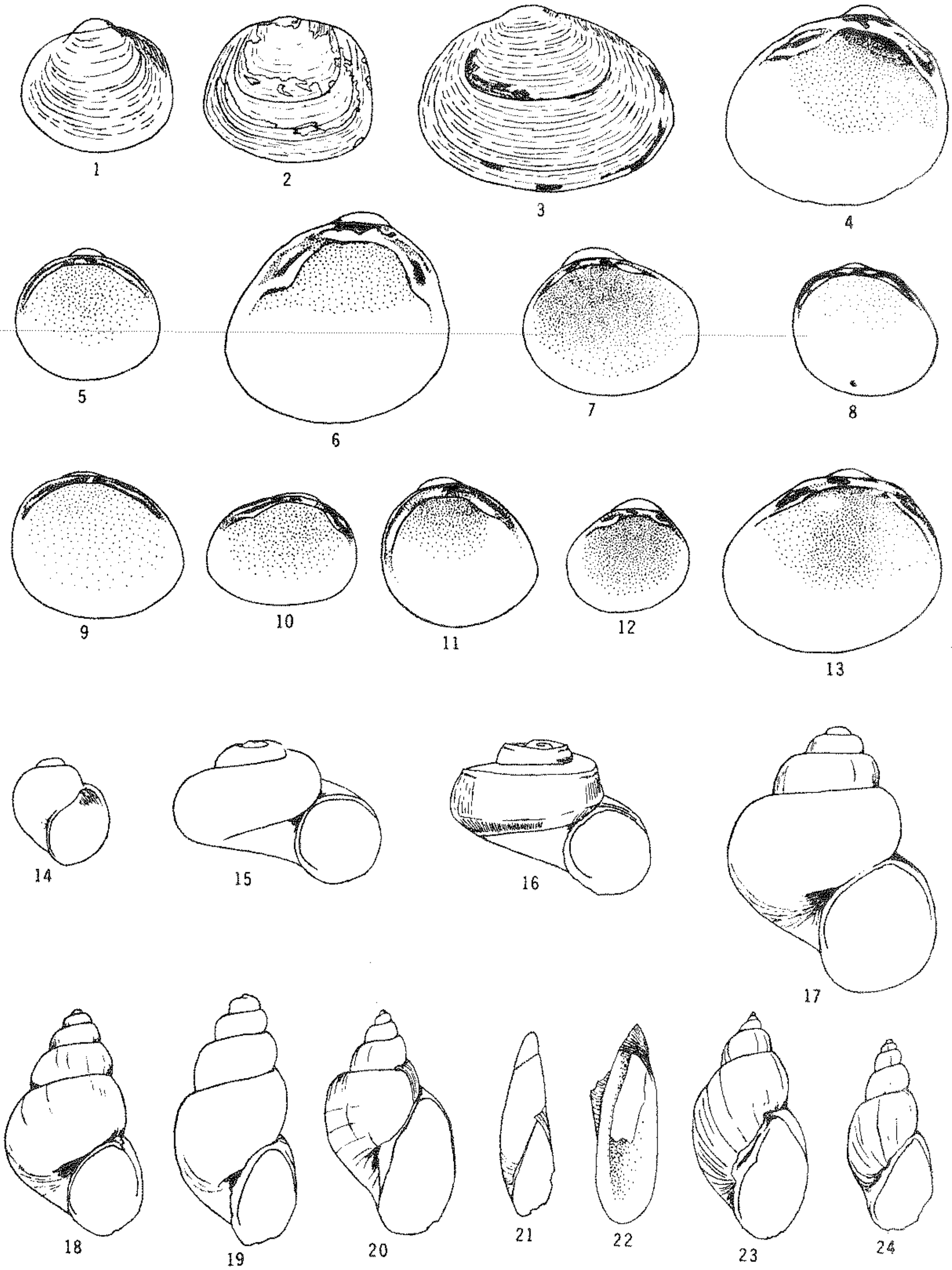


PLATE I. PLEISTOCENE MOLLUSCA FROM QUEBEC AND ONTARIO.

in aperture shape and diameter of apical whorls, cited by Baker (1928, p. 92) to separate forms *porata* and *leightoni*, overlap and the primary distinction (Baker, 1928 p. 121) is the difference in spire height. Specimens from living populations in Lac Laflamme, Nesbitt Lake, and the lake at Wilsons Corners, Quebec show this range of variation.

Amnicola leightoni seems to be an ecological form of *A. limosa* that is characteristic of alkaline lakes. Detailed examination of radulae and genitalia in living populations from the northeastern United States and Canada is needed to clarify relationships between typical *A. limosa* and this form.

Amnicola lustrica Pilsbry, 1890

(Plate I, Figure 18)

Amnicola lustrica Pilsbry, 1890, Nautilus, v. 4, p. 53.
Amnicola lustrica Pilsbry, La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 388.

ECOLOGY. *Amnicola lustrica* occurs in rivers and lakes on stones, on rooted aquatic plants such as *Vallisneria, Potamogeton,* and *Chara*; and on filamentous algae. It is often associated with *Amnicola limosa*.

DISTRIBUTION. Gaspé Peninsula to Minnesota, southern Ontario south to Illinois, Indiana, and Ohio. La Rocque (1962, p. 34) found no published record of the species for Quebec. A single shell of *A. lustrica* from the Lac Blanc deposit, Matapedia County, Quebec is in the Pleistocene Mollusca Collection at Ohio State University (Lot no. 263). The specimen, first identified as *A. limosa* (Shallom, 1965, p. 46), extends the post-glacial range of *A. lustrica* to the Gaspé Peninsula. Pleistocene distribution, this study: Rochester Street deposit, Ontario. Clowers (1966, p. 41, 55) reports the species from the Box Marsh and White Lake deposits, west of Ottawa. Ouellet (1968, p. 18) records it from the deposit at Atkins Lake, Ontario.

GEOLOGIC RANGE. Pleistocene, late Wisconsin to Recent (La Rocque, 1968, p. 390).

ORDER PULMONATA

FAMILY LYMNAEIDAE

Genus *Lymnaea* Lamarck, 1799

Systematics of the family Lymnaeidae are in a state of flux. Walter (1968, p. 19; 1969 p. 5) rejects the several genera established by F. C. Baker (1911, p. 125; 1928, p. 196) and places all members of the family in the genus *Lymnaea*. His detailed anatomical studies show that intraspecific relationships often cross these generic boundaries and that differences are not great enough to warrant formation of genera. Burch and Lindsay (1968, p. 22) state that the species groups *Lymnaea, Bulimnea, Fossaria, Pseudosuccinea, Radix,* and *Stagnicola* have distinct immunological characteristics. These authors feel that generic lumping obscures important relationships within the family. In the present study, all lymnaeid snails are grouped in the genus *Lymnaea*.

Lymnaea stagnalis (Linnaeus) 1758

(Plate II, Figure 2)

Helix stagnalis Linnaeus, 1758. Syst. Nat., 10th ed., p. 774.
Lymnaea jugularis Say, 1817, Conchology, *in* Nicholson's Encycl., 1st ed., n. p.
Lymneus appressus Say, 1818, Acad. Nat. Sci. Phila., Jour., v. 2, p. 168.

ECOLOGY. Inhabits quiet bodies of water with shallow areas and fairly dense vegetation such as shallow areas of ponds and lakes, river backwaters, and stagnant areas of sluggish streams. Living populations in the Gatineau Valley were commonly found (in July and August) near shore in less than two feet of water in stands of emergent aquatic vegetation, commonly cattails *(Typha)* and water lilies *(Nuphar)*. These habitats usually had thick accumulations of organic debris on the bottom. The animals moved over this mat and on the plant stems. The species feeds on microscopic plants and animals but also ingests decaying organic material (La Rocque, 1968 p. 436). Baker (1911, p. 147) states that *Lymnaea stagnalis* will attack small fish when both are kept in aquaria.

DISTRIBUTION. The species is apparently circumboreal. It ranges in North America from about the 37th parallel (western United States) and 41st parallel of north latitude to the Arctic Ocean (La Rocque, 1968, p. 436). The form *Lymnaea stagnalis appressa* is common in the Gatineau and Ottawa Valleys, often with dense populations where the habitat is suitable. Pleistocene distribution, this study: Lac Laflamme, Manitou Lake, Nesbitt Lake deposits, Quebec. It has also been reported from nearby Pleistocene deposits at Richardson Lake, Quebec and Box Marsh, Ontario (Gibson, 1967, p. 13; Clowers, 1966, p. 42).

GEOLOGIC RANGE. Pleistocene to the present. The species ranges from the Illinoian, and possibly late Kansan, of Kansas to the present (Hibbard and Taylor, 1960, p. 85).

Lymnaea dalli F. C. Baker, 1906

(Plate I, Figure 19)

Lymnaea dalli F. C. Baker 1906, Illinois Lab. Nat. Hist., Bull., v. 7, p. 104.
Fossaria dalli (F. C. Baker), La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 466.

ECOLOGY. *L. dalli* lives on submerged surfaces and debris in very shallow water along the margins of small bodies of water, or near water on moist surfaces. Its ecology is probably quite similar to that of *Lymnaea obrussa*. Leonard (1959, p. 56) found populations among sedges and grasses on marshy ground around ponds, and in association with *Lymnaea parva*.

DISTRIBUTION. New York to northern Michigan, northwest to Alberta, south to Arizona, Texas, Illinois, and Ohio. Pleistocene distribution, this study: Lac Laflamme and Nesbitt Lake deposits, Quebec. This is the first record of *L. dalli* in Quebec.

GEOLOGIC RANGE. Early Pliocene to Recent (Hibbard and Taylor, 1960, p. 93); relatively common in late Wisconsin deposits.

REMARKS. This species can be confused with *L. parva*, an equally small shell. The shouldered whorls, narrower aperture, smaller umbilicus, coarser growth lines, and more slender outline of *L. dalli* best separate it from *L. parva* in fossil material.

Lymnaea decampi Streng, 1906

(Plate I, Figure 20)

Limnaea desidiosa var. *decampi* Streng, 1906, Nautilus, v. 9, p. 123.
Fossaria obrussa decampi (Streng), F. C. Baker, 1928, Freshwater Moll. Wisconsin, pt. 1, p. 299.
Fossaria decampi (Streng) Clarke, 1968, Amer. Malacol. Union Ann. Rept. 1967, p. 21.

marl deposits indicates a tolerance for slightly deeper water than that inhabited by *L. obrussa*. *L. obrussa* is found in very shallow water near shore, and on mud flats. *L. decampi* occurs in this habitat, but its abundance at the base of marl sections also indicates habitation of near shore areas, possibly to depths of a few meters.

DISTRIBUTION. Maine west to Wisconsin, northern Michigan south to northern Illinois (La Rocque, 1968, p. 476). Pleistocene distribution, this study: it occurs in every deposit sampled, and is the most abundant lymnaeid. The species is equally common in nearby late Wisconsin deposits at Richardson Lake, Quebec (Gibson, 1967, p. 14); Box Marsh and White Lake, Ont. (Clowers, 1966, p. 43, 55); and Atkins Lake, Ontario (Ouellet, 1967, n.p.).

GEOLOGIC RANGE. Late Wisconsin to the present (La Rocque, 1968, p. 476). *Lymnaea decampi* is one of the most common gastropods in late-glacial and post-glacial marl deposits in eastern North America.

REMARKS. Clarke (1968, p. 21) first recognized this form as a species distinct from *Lymnaea obrussa*. *L. decampi* can be distinguished from *L. obrussa* by having convex to flat-sided, more strongly shouldered whorls than on *L. obrussa*; a narrow, elongate aperture; fine growth lines; and a fairly thick shell. In fossil material, *L. decampi* appears thick, heavy, and opaque, and *L. obrussa* is generally thinner, more translucent, and buff colored. Coarse growth lines and variations in shell thickness at rest periods seem to be more distinct on *L. obrussa*, and the species usually shows more surface ornamentation than *L. decampi*. Clowers (1966, p. 43) noted the difference in distribution of these species in marl deposits, and the ecological implication of this pattern needs verification in living populations.

Lymnaea haldemani Binney, 1867

(Plate I, Figures 21, 22)

Limnaea haldemani Deshayes, Binney, 1867, Jour. Conchyl., v. 15, p. 428.
Acella haldemani ('Deshayes' Binney), La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 455.

ECOLOGY. The species occurs in sheltered areas of larger lakes in water from 0.3

tus). Adult specimens are found only in the fall. (Baker, 1928, p. 270).

DISTRIBUTION. Lakes Huron and Ontario; Lake Simcoe; Lake Champlain; Quebec, Ontario, Vermont, and New York west to Illinois, Michigan, Minnesota, Wisconsin, and possibly southern Manitoba, south to Ohio, and Indiana (La Rocque, 1968, p. 456). La Rocque (1938, p. 111; 1962, p. 29) gives no records for *Lymnaea haldemani* in Quebec, but later (La Rocque, 1968, p. 456) includes the province in its range on the strength of the Lake Champlain record. F. C. Baker (1911, p. 197) lists a record for Ottawa, Ontario but this record is based on juveniles of *Lymnaea stagnalis* (La Rocque, personal communication). Pleistocene distribution, this study: Manitou Lake deposit, Quebec. I know of no additional records for Quebec.

GEOLOGIC RANGE. Late Wisconsin deposits in Ohio and Indiana (La Rocque 1968, p. 456). The poor fossil record of this species is probably due to its preference for a large lake habitat and its very fragile shell.

REMARKS. Like most fossil occurrences, specimens of *Lymnaea haldemani* from the Manitou Lwke deposit are shell fragments. These include three complete juvenile portions and one body whorl segment with a complete aperture (Fig. 22).

Lymnaea megasoma Say, 1824
(Plate I, Figure 23)

Lymneus megasomus Say, 1824, Rept. Long's Exped., v. 2, p. 263.
Bulimnea megasoma (Say), La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 463.

ECOLOGY. *L. megasoma* is found in quiet, shallow parts of lakes and sluggish streams. At the site of the Southwest Venosta deposit, the animals occur along the lake shore on a muck bottom with abundant submerged teigs and limbs. The snails seem to prefer slight embayments that are shaded by shore vegetation or lily pads; however, all of the shoreline is open to deeper water. Brightly lit areas and small sloughs that have poor connections with the lake proper are avoided. The animals crawl slowly over organic debris on the bottom and on plant stems or wood fragments rising above the bottom. La Rocque (1968, p. 464). states that the species has sluggish movements and tends to drop to the bottom when alarmed. It seems that the animals also maintain a high degree of buoyancy which helps support their body weight on very soft bottoms and on light submerged objects. When disturbed, the snails made no attempt to remain attached but drifted about on gentle currents generated by a hand reaching slowly into the water. The species feeds on microscopic organisms on the surface of plant debris and aquatic vegetation. La Rocque (1968, p. 464) reports finding *Lymnaea megasoma* on clay bottom of a small stream where vegetation was sparse.

DISTRIBUTION. New England west to Minnesota and Iowa, north to Manitoba, and south to Ohio and Indiana. La Rocque (1962, p. 29) lists records from Blue Sea Lake, Meach Lake, and near Chelsea in the Gatineau Valley. La Rocque (1968 p. 464) observes that the species has disappeared from many lakes in Ontario and Quebec during this century. He suggests that the animal is very sensitive to human interference with itshabitat. The writer found a living population only at the small lake, previously mentioned, southwest of Venosta, Quebec. Pleistocene distribution, this study: Manitou Lake deposit and Nesbitt Lake deposit, Quebec. Only one specimen was recovered from the marl at each lake and these were found while excavating the pits. None occurred in the quantitative samples.

GEOLOGIC RANGE. Pleistocene, Nebraskan to Recent. Taylor (1960, p. 56) reports it from Nebraskan localities in Nebraska. The species has been found in two late Wisconsin deposits in Ohio.

Lymnaea obrussa Say, 1825
(Plate I, Figure 24)

Lymneus obrussus Say, 1825, Acad. Nat. Sci. Phila., Jour., v. 5, p. 123.
Fossaria obrussa (Say), La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 473.

ECOLOGY. Generally found on submerged objects, mud bottoms, and exposed mud flats in shallow areas of creeks, ponds, sloughs, bays, and marshy spots along river banks. F. C. Baker (1911, p. 281) lists its occurrence in a dredge haul from 8-15 fathoms in Lake Superior. If valid, this record is certainly atypical. Leonard (1959, p. 52) found the species in shallow water on a mud substrate scarcely covered with water, and on exposed mud flats. He reports that the animal lays elongate, cylindrical egg masses on the undersurfaces of submerged objects in water a few centimeters deep. The habitat of living *Lymnaea obrussa* populations in the Gatineau Valley, Quebec fits this description.

DISTRIBUTION. Across North America from the Atlantic to Pacific Coasts, north to the Mackenzie District, Canada, and south to Arizona and northern Mexico (La Rocque, 1968, p. 475. Live specimens were collected at Wilsons Corners, Quebec. Pleistocene distribution, this study: Lac Laflamme, Manitou Lake, Nesbitt Lake, and Southwest Venosta deposits, Quebec; McKay Lake deposit, Ontario. *L. obrussa* is also known from the Box Marsh deposit, Ontario (Clowers, 1966, p. 43).

GEOLOGIC RANGE. Early Pliocene to present. (Hibbard and Taylor, 1960, p. 94).

Lymnaea palustris (Müller) 1774

(Plate II, Figure 1)

Buccinum palustre Müller, 1774, Verm. Terr. et Fluv. Hist., p. 131.
Stagnicola palustris (Müller), La Rocque, 1968. Pleist. Moll. Ohio, pt. 3, p. 443.

ECOLOGY. *Lymnaea palustris* inhabits quiet bodies of water with mud bottom and vegetation. It is found both in fairly clear areas and in stagnant areas with heavy organic accumulation. Absence of water motion seems to be the main criterion for suitable habitat. The species is omnivorous, feeding on living or dead plant and animal material. Baker (1928 p. 216) found the animals to be most abundant in 0.3 meter of water on a mud bottom.

DISTRIBUTION. Circumboreal; northern Asia and Europe, across North America, south to New Mexico in the western United States, north-central and northeastern United States (La Rocque, 1968, p. 445). Pleistocene distribution, this study: Nesbitt Lake deposit, Quebec. A possible Pleistocene record exists for the Richardson Lake deposit, Quebec (Gibson, 1967, p. 14).

GEOLOGIC RANGE. Pleistocene, Aftonian to Recent (La Rocque, 1968, p. 446). *Lymnaea palustris* seems to be fairly rare in late Wisconsin deposits of the Ottawa region. It is one of the more common gastropods in Pleistocene deposits of Ohio (La Rocque 1968, p. 445).

REMARKS. Apparently, convergence of shell morphology has occurred in several lymnaeid species and *L. palustris*, as defined by shell characters, is a form species (Burch 1968, p. 25; Walter, 1969, p. 5).

FAMILY PLANORBIDAE

Genus *Gyraulus* Charpentier, 1937

Gyraulus deflectus (Say) 1824

(Plate II, Figure 4)

Planorbis deflectus Say, 1824, Long's Exped., v. 2, p. 261.
Gyraulus deflectus (Say), La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 485.

ECOLOGY. The species generally occurs on mud or sand bottoms of protected nearshore areas from depths of 1 to 16 feet (La Rocque, 1968, p. 485). In the Gatineau Valley, it was found on sand among aquatic plants along the shore of a small lake, and on boulders in 2 to 3 feet of water on the protected shoreline of a large lake.

DISTRIBUTION. New England to Alaska south to Maryland. *Gyraulus deflectus* is easily confused with other species in the genus and its exact range cannot be reliably determined from records in the literature (La Rocque, 1968, p. 485). La Rocque (1962, p. 30) cites a record from Gauvreau Lake in the Gatineau Valley and Whittaker (1918, p. 15; 1921, p. 74) reports the species from McKay Lake and Colton Lake, Ontario. During this study, it was collected alive at Wolf Lake, Frazer Lake, and Wilsons Corners, Quebec. Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec; Rochester Street deposit, Ontario.

GEOLOGIC RANGE. Pleistocene, Yarmouth to the present (La Rocque, 1968, p. 486).

REMARKS. Specimens encountered in this study have moderately sharp to subrounded keels but fall in the range of variation described for *G. deflectus* by F. C. Baker (1928 p. 371) rather than the form, *G. deflectus obliquus*, with rounded peripheries. The peripheral keel is characteristic of adult shells and its degree of development can only be determined on mature shells. It is likely that the relationship of *G. deflectus* to its form, *obliquus*, is similar to that between *G. parvus* and its form, *altissimus*, described by Clowers (1966, p. 44).

Gyraulus parvus (Say) 1817
(Plate II, Figure 5)

Planorbis parvus Say, 1817, Nicholson's Encycl., 1st ed., v. 2, n.p., pl. 1, fig. 5.
Gyraulus parvus (Say), La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 491.

ECOLOGY. The optimum habitat for the species seems to be on or among vegetation in protected, shallow areas of lakes. La Rocque (1968, p. 491) states that it usually occurs in small bodies of water on mud, sand, gravel, boulders, logs, and vegetation at depths of 1 to 4 feet. Leonard (1959 p. 61) found *G. parvus* in association with aquatic plants or submerged grass blades and tree leaves. In larger lakes, he found the animals on driftwood along shore. Egg capsules, formed of 6 to 9 eggs in a single layer, are laid on the stems and leaves of living and dead submerged vegetation (Leonard, 1959, p. 61).

DISTRIBUTION. Eastern North America east of the Rocky Mountains from Florida to Alaska and northern Canada (La Rocque, 1968, p. 491). La Rocque (1962, p. 30) reports the species from Meach Lake Quebec and Whittaker (1918 p. 15) found it living in McKay Lake Ontario. *G. parvus* is very common in the Gatineau Valley; recent specimens were collected at all the sites sampled for Pleistocene mollusks. Pleistocene distribution, this study: present and generally abundant in all deposits sampled. It is present, and apparently equally abundant, in all previously studied deposits of the region. This species seems to be the most abundant planorbid snail in late Wisconsin marl deposits.

GEOLOGIC RANGE. Middle Pliocene to the present (Hibbard and Taylor, 1960, p. 100).

REMARKS. Specimens in this study demonstrate the relationship observed by Clowers (1966, p. 44) between *G. parvus* and its form, *altissimus*, with angulate body whorls. Immature shells are typical *G. parvus* and mature shells show a transition from distinctly angulate to rounded body whorls.

Genus *Armiger* Hartmann, 1840

Armiger crista (Linnaeus) 1758

(Plate II, Figure 3)

Nautilus crista Linnaeus 1758, Syst. Nat., 10th ed., p. 709.
Armiger crista (Linnaeus), La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 496.

ECOLOGY. *Armiger crista* inhabits small shallow lakes in areas with quiet water, mud or silt bottoms, and abundant vegetation. It occurs in intermittent bodies of water and has been reported from a stream in Maine, probably from a site with light current, similar to its lacustrine habitat (La Rocque, 1968, p. 497). Apparently the species rarely develops large populations.

DISTRIBUTION. Europe, Asia; North America from Maine west to Alberta, south to California, Utah, Illinois, Indiana, and Ohio (La Rocque, 1968, p. 497). A single dead specimen, apparently from a living population, was collected at Manitou Lake, Quebec. Pleistocene distribution, this study: Manitou Lake and Nesbitt Lake deposits, Quebec. Gibson (1967, p. 15) reports it from the Richardson Lake deposit, Quebec; and Ouellet (1967, n. p.) found it in the deposit at Atkins Lake, Ontario.

GEOLOGIC RANGE. Late Pliocene to Recent (La Rocque, 1968, p. 498).

Genus *Helisoma* Swainson, 1840

Helisoma anceps (Menke) 1830

(Plate II, Figure 6)

Planorbis anceps Menke, 1830, Syn. Meth., p. 36.
Helisoma anceps (Menke), La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 498.

ECOLOGY. Typical *H. anceps* is generally found in rivers or creeks, whereas *H. anceps striatum* is an inhabitant of shallow, hard-water lakes with abundant vegetation (La Rocque, 1968, p. 500, 501).

DISTRIBUTION. Typical *Helisoma anceps* occurs from the latitude of Hudson Bay south to Mexico and from the Rockies east to the Atlantic coast (La Rocque, 1968, p. 500). *Helisoma anceps striatum* has been reported living in Minnesota and Wisconsin but fossil records (largely late Wisconsin) indicate a range from northeastern United States and southern Canada west to the Dakotas and Alberta (La Rocque, 1968, p. 501-502). Pleistocene distribution, this study: all deposits sampled. It has been reported from deposits at Richardson Lake, Quebec (Gibson, 1967, p. 16); Box Marsh, White Lake (Clowers, 1966, p. 44); and Atkins Lake, Ontario (Ouellet, 1968, p. 19).

GEOLOGIC RANGE. Pleistocene to Recent. Its range in the Pleistocene is not precisely known (La Rocque, 1968, p. 501).

REMARKS. The fossil populations sampled in this study are composed of shells that correspond primarily to *Helisoma anceps striatum* and *H. anceps unicarinatum*. It is unclear whether or not these forms represent a geographic race that merits subspecific rank. However, they are characteristic of cool, hard water lakes and deserve recognition as ecophenotypes. Rigorous collecting of cool marl lakes may uncover more living populations.

Helisoma campanulatum (Say) 1821

(Plate II, Figure 7)

Planorbis campanulatus Say, 1821, Acad. Nat. Sci. Phila., Jour., v. 2, p. 166.
Helisoma campanulatum (Say), La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 504.

ECOLOGY. The species typically inhabits lakes but is also found in quiet reaches of rivers and smaller streams. Lacustrine habitats described by F. C. Baker (1928, p. 348) indicate that it occurs on a variety of bottom types but prefers 9.3 to 1 meter deep with vegetation.

DISTRIBUTION. Vermont west to North Dakota, south to Ohio and Illinois, north to the Mackenzie River drainage (La Rocque, 1968, p. 505). La Rocque (1962, p. 30) reports the form from Gauvreau and Mahon Lakes in the Gatineau Valley and Whittaker (1918, p. 15) reports it from McKay Lake, Ontario. The species is common in the Gatineau Valley. Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, Nesbitt Lake deposits Quebec; Rochester Street and McKay Lake deposits, Ontario. Pleistocene records for the area include Richardson Lake deposit, Quebec (Gibson, 1967, p. 17), Box Marsh, White Lake (Clowers, 1966, p. 44, 55), and Atkins Lake, Ontario (Ouellet 1968, p. 19).

GEOLOGIC RANGE. Pleistocene, late Wisconsin to the present (La Rocque, 1968, p. 505).

Helisoma trivolvis (Say) 1817

(Plate II, Figure 8)

Planorbis trivolvis Say, 1817, Nicholson's Encycl., Amer. ed., v. 2, n. p., pl. 2, fig. 2.
Helisoma trivolvis (Say), La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 501.

ECOLOGY. *H. trivolvis* is found in lakes, sluggish parts of rivers, ponds, creeks, ditches, and intermittent woodland pools. It seems to prefer stagnant water and abundant vegetation (La Rocque, 1968, p. 503). The species is often quite abundant in very shallow water, less than one foot deep, on aquatic plant stems and plant debris along shores of lakes and areas of streams with gentle current or standing water.

DISTRIBUTION. Atlantic coast drainage and Mississippi River system, north to the Arctic coast of Canada and Alaska, south to Tennessee and Missouri (La Rocque, 1968, p. 503). La Rocque (1962, p. 31) gives records for the Ottawa River, Meach Lake, Mahon Lake, Quebec. Whittaker (1918 p. 15) lists it in the living fauna of McKay Lake. *Helisoma trivolvis* is now common in lakes and small sluggish streams of the Gatineau Valley and seems to be more abundant and widespread than earlier in post-Wisconsin time. Pleistocene distribution, this study: Manitou Lake (1 specimen), Nesbitt Lake (2 specimens), and Southwest Venosta (1 specimen) deposits, Quebec. Specimens occurred in the upper third of the sections. There are no other Pleistocene records for the region.

GEOLOGIC RANGE. Pleistocene, Nebraskan or Aftonian to present (La Rocque 1968, p. 503).

Genus *Promenetus* F.C. Baker, 1935

(Plate II, Figure 9)

Planorbis exacuous Say, 1821, Acad. Nat. Sci. Philadelphia, Jour., v. 2, p. 168.
Promenetus exacuous (Say), La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 510.

ECOLOGY. The species occurs in quiet, shallow areas of lakes and streams on soft mud bottoms (La Rocque, 1968, p. 510).

DISTRIBUTION. Northern United States east to the Rockies, Canada south to New Mexico (La Rocque, 1968, p. 510). Gatineau Valley localities for the species are Manitou Lake and Nesbitt Lake. Whittaker (1918, p. 15) found it living at McKay Lake, Ontario. Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec; Rochester Street deposit, Ontario. It also occurs in the Richardson Lake marl (Gibson, 1967, p. 17) and the Box Marsh deposit (Clowers, 1966, p. 45).

GEOLOGIC RANGE. Pleistocene, Sangamon to Recent (Hibbard and Taylor, 1960, p. 107).

FAMILY ANCYLIDAE

Genus *Ferrissia* Walker, 1903

Ferrissia parallela (Haldeman) 1841

(Plate II, Figure 10)

Ancylus parallelus Haldeman, 1841, Monogr. Limniades N. America, pt. 2, p. 3 of cover.

Ferrissia parallela (Haldeman), Basch, 1963, Rev. freshwater limpet snails N. America, p. 440.

ECOLOGY. The species occurs on leaves and stems of aquatic vegetation, particularly *Scirpus* and *Typha*, in shallow lakes. It seems to prefer clean water but has been collected in muddy, turbid water in shallow swamps. Shell proportions which are somewhat variable, may be greatly influenced by the size and shape of stems and leaves inhabited by the animals (Basch, 1963, p. 440).

DISTRIBUTION. Northern United States and Canada from the Atlantic coast westward, abundant in smaller lakes of the Great Lakes region (Basch 1963, p. 440). La Rocque (1962, p. 29) cites a record for the Ottawa River. Living material was collected only at Manitou Lake during this study. Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec; Rochester Street deposit, Ontario. Other nearby records include the Richardson Lake deposit (Gibson, 1967, p. 18) and Box Marsh deposit, Ontario (Clowers, 1966, p. 46).

GEOLOGIC RANGE. Pliocene to Recent (Taylor, 1960, p. 61).

Ferrissia walkeri (Pilsbry and Ferriss) 1906

(Plate II, Figure 11)

Ancylus walkeri Pilsbry and Ferriss, 1906, Acad. Nat. Sci. Philadelphia, Proc., p. 564.

Ferrissia walkeri (Pilsbry and Ferriss), Basch, 1963, Rev. freshwater limpet snails N. America, p. 433.

ECOLOGY. *F. walkeri* is found on large flat surfaces, such as lily pads, in larger bodies of clean standing water (Basch, 1963, p. 434).

DISTRIBUTION. Actual range unknown: authenticated specimens from Arkansas, Michigan, and California (Basch, 1963, p. 434). A single recent specimen was collected at Nesbitt Lake, Quebec. Pleistocene distribution, this study: Lac Laflamme and Nesbitt Lake deposits, Quebec. I know of no additional records for the region, or Canada.

GEOLOGIC RANGE. Pleistocene, late Wisconsin to the present.

FAMILY PHYSIDAE

Genus *Physa* Draparnaud, 1801

Physa gyrina Say, 1821

(Plate II, Figure 12)

Physa gyrina Say, 1821, Acad. Nat. Sci. Philadelphia, Jour., v. 2, p. 171.

Physa gyrina Say, La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 541.

ECOLOGY. *Physa gyrina* is characteristic of shallow, slow moving or standing water. It generally occurs on a mud bottom, on coarser materials covered with a layer of mud or loose debris, and on or among aquatic vegetation. Dawson (1911, p. 2-44) describes in great detail the habitats of *Physa* and De Witt (1955, p. 40) discusses the life history and ecology of *Physa gyrina*.

DISTRIBUTION. North America from Alaska and the Canadian Arctic to the southern United States, west to Texas and California (La Rocque, 1968, p. 543). *Physa gyrina* is widespread in the Gatineau Valley and was collected live at the following sites of Pleistocene deposits: Manitou Lake, Lac Laflamme, Nesbitt Lake, and Southwest Venosta deposit. All Quebec records of *Physa* accumulated by La Rocque (1962, p. 31 - 32) are reported as species other than *P. gyrina*. Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec. *P. gyrina* has been reported from the Richardson Lake deposit, Quebec (Gibson, 1967, p. 18); Box Marsh, White Lake Ontario (Clowers, 1966, p. 46, 55); and Atkins Lake deposit Ontario (Ouellet, 1967, n. p.).

GEOLOGIC RANGE. Pleistocene, Aftonian to the present (La Rocque, 1968, p. 542).

Physa heterostropha (Say) 1817

(Plate II, Figure 13)

Limnea heterostropha Say, 1817, Nicholson's Encycl., Amer. ed., n. p., pl. 1, fig. 6.
Physa heterostropha (Say) La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 545.
Physa sayii Tappan, La Rocque, 1968, Pleist. Moll. Ohio, pt. 3, p. 548. (discussed separately but considered a synonym of *Physa heterostropha*).

ECOLOGY. Typical *P. heterostropha* is found on mud in ditches, small brooks, and small rivers. *Physa sayii*, placed in the synonymy of *Physa heterostropha* by Wurtz (1949, p. 31), is the form characteristic of small lakes. La Rocque (1968, p. 551) notes that this form also occurs in the Great Lakes, with the possible exception of Lake Superior.

DISTRIBUTION. Eastern United States and Canada, west to Texas, Utah, Wyoming, and western Canada (La Rocque, 1968, p. 546, 550). La Rocque (1962, p. 32) lists records for La Pêche River, Que.; near Hull; and Johnston Lake, Masham Co., Quebec. Whittaker (1918, p. 15) reports it from McKay Lake, Ontario. The species was collected by the writer at Nesbitt Lake, Quebec. Pleistocene distribution, this study: Lac Laflamme deposit, Quebec; Rochester Street and McKay Lake deposits, Ontario.

GEOLOGIC RANGE. Pleistocene, Aftonian? to the present (La Rocque, 1968, p. 550).

REMARKS. The recent and fossil material encountered in these collections is the lake form, *Physa sayii*.

FAMILY CARYCHIIDAE

Genus *Carychium* Müller, 1774

Carychium exiguum (Say) 1822
(Plate II, Figure 14)

Pupa exigua Say, 1822, Acad. Nat. Sci. Philadelphia, Jour., v. 2, p. 375.
Carychium exiguum (Say), Pilsbry, 1948, Land Moll. N. America v. 2, pt. 2, p. 1052.

ECOLOGY. The species occurs in moist or sometimes very wet areas among leaf mold, plant debris, grass, or under logs. La Rocque (in press) adds floodplains, swamps, marshy areas, stream and lake margins.

PLATE II. PLEISTOCENE MOLLUSCA FROM QUEBEC AND ONTARIO

Fig. 1. *Lymnaea palustris*, Nesbitt Lake deposit, X 3
Fig. 2. *Lymnaea stagnalis*, Nesbitt Lake deposit, X 1
Fig. 3. *Armiger crista*, Manitou Lake deposit, X 16
Fig. 4. *Gyraulus deflectus*, Nesbitt Lake deposit, X 7.5
Fig. 5. *Gyraulus parvus*, Manitou Lake deposit, X 11
Fig. 6. *Helisoma anceps*, Manitou Lake deposit, X 3.5
Fig. 7. *Helisoma campanulatum*, Nesbitt Lake deposit, X 2
Fig. 8. *Helisoma trivolvis*, Nesbitt Lake deposit, X 1.1
Fig. 9. *Promenetus exacuous*, Nesbitt Lake deposit, X 10.5
Fig. 10. *Ferrissia parallela*, Manitou Lake deposit, X 7
Fig. 11. *Ferrissia walkeri*, Lac Laflamme deposit, X 12
Fig. 12. *Physa gyrina*, Nesbitt Lake deposit, X 3
Fig. 13. *Physa heterostropha*, Rochester Street deposit, X 3
Fig. 14. *Carychium exiguum*, Lac Laflamme deposit, X 14.5
Fig. 15. *Paravitrea multidentata*, apical view, Nesbitt Lake deposit, X 6.5
Fig. 16. *Paravitrea multidentata*, basal view, Nesbitt Lake deposit, X 6.5
Fig. 17. *Euconulus fulvus*, Manitou Lake deposit, X 9
Fig. 18. *Nesovitrea binneyana*, Nesbitt Lake deposit, X 11

(Drawn by Barbara Sue Bickel)

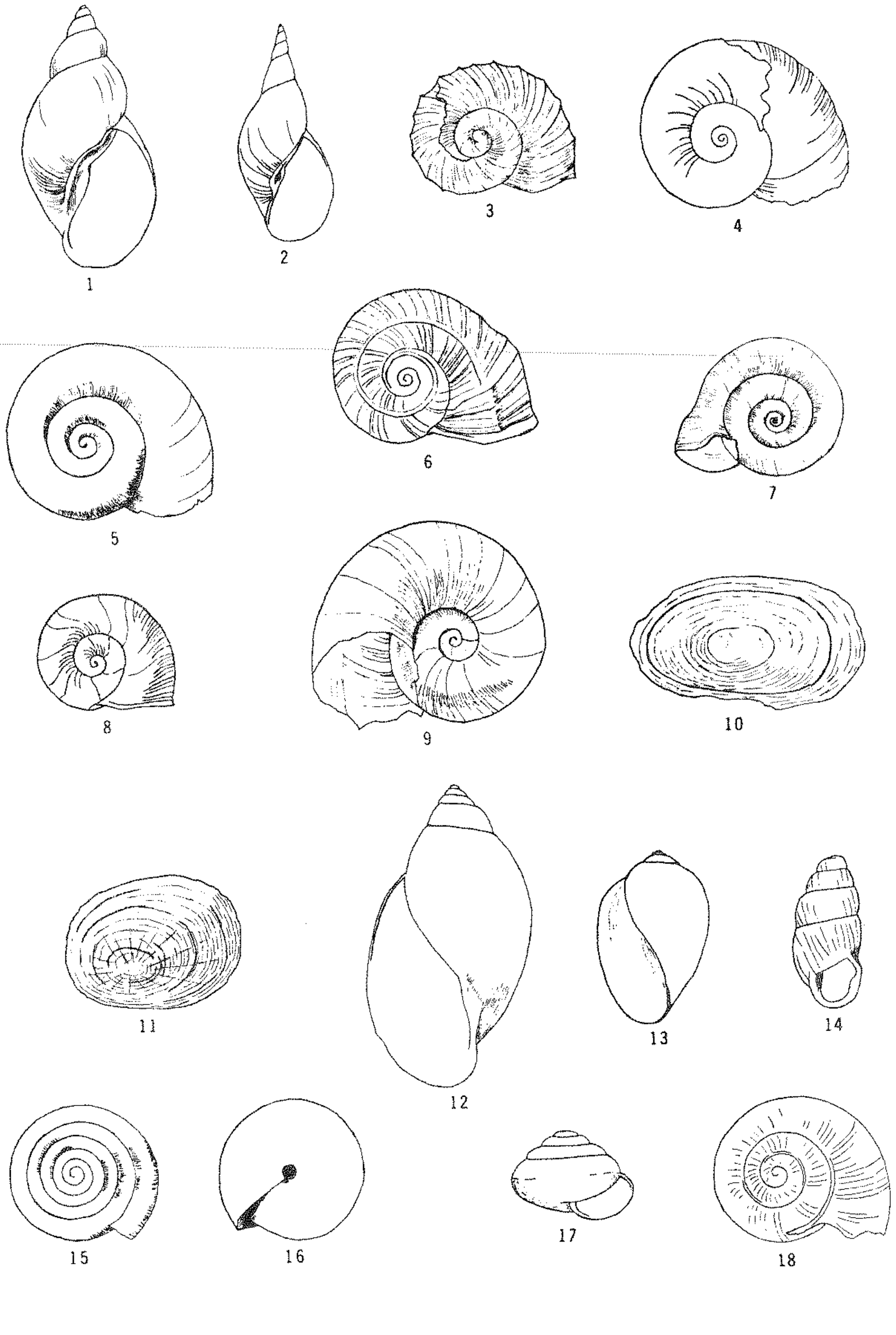


PLATE II. PLEISTOCENE MOLLUSCA FROM QUEBEC AND ONTARIO.

DISTRIBUTION. Newfoundland west to British Columbia and New Mexico, south to Florida (La Rocque, in press). It has been reported from the Ottawa area (La Rocque, 1962, p. 36). Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec.

GEOLOGIC RANGE. Pleistocene, Aftonian to the present (Baker, 1920, p. 388).

REMARKS. Harry (1952, p. 5-7) concluded that *C. exiguum* and *C. exile* Lea, 1842 are not distinct species.

FAMILY ZONITIDAE

Genus *Paravitrea* Pilsbry, 1898

Paravitrea multidentata (Binney) 1840

(Plate II Figures 15, 16)

Helix multidentata Binney, 1840, Boston Soc. Nat. Hist. Jour., v. 3, p. 425.
Paravitrea multidentata (Binney), Pilsbry, 1946, Land Moll. N. America, v. 2, pt. 1, p. 352.

ECOLOGY. 'Found under rotting logs and leaves.' (Robertson and Blakeslee, 1948, p. 27).

DISTRIBUTION. Maine, Quebec, and Ontario south to North Carolina, Alabama, and Arkansas, west to Michigan (Pilsbry, 1946, p. 354). Two specimens were recovered from the top (Unit 2) of the Nesbitt Lake section.

GEOLOGIC RANGE. Unknown.

Genus *Euconulus* Reinhardt, 1883

Euconulus fulvus (Müller) 1774

(Plate II, Figure 17)

Helix fulva Müller, 1774 (in part), Verm. Terr. et Fluv., v. 2, p. 56.
Euconulus fulvus (Müller), Pilsbry, 1946, Land Moll. N. America, v. 2, pt. 1, p. 235.

ECOLOGY. *Euconulus fulvus* commonly occurs in damp leaf litter or under stones, in wooded and well shaded spots. It is common on floodplains and lake margins and its shells are often found in stream drift (La Rocque, in press).

DISTRIBUTION. Holarctic, widespread; absent from the southeastern United States from Texas to North Carolina (Pilsbry, 1946, p. 236). La Rocque (1962, p. 37) lists a record for Hull, Quebec. Pleistocene distribution, this study: Manitou Lake and Lac Laflamme deposits, Quebec. Gibson (1967, p. 21) found four specimens at the top of the Richardson Lake deposit, Quebec.

GEOLOGIC RANGE. Middle Pliocene, France, to the present (Pilsbry, 1946, p. 236). Kansan to present in North America (Hibbard and Taylor, 1960, p. 147).

Genus *Nesovitrea* Cooke, 1921

Nesovitrea binneyana (Morse) 1864

(Plate II, Figure 18)

Hyalina binneyana Morse, 1864, Portland Soc. Nat. Hist. Jour., v. 1, p. 13.
Retinella binneyana (Morse), Pilsbry, 1946, Land Moll. N. America, v. 2, pt. 1, p. 259.

ECOLOGY. *Nesovitrea binneyana* lives in damp woodland habitats, especially among deciduous trees. Occasionally it is found in *Sphagnum* bogs (Oughton, 1948, p. 94). It has been found mainly under logs or near old stumps (La Rocque, in press).

DISTRIBUTION. Maine, Quebec and western Ontario south to Michigan, Ohio, Pennsylvania, and New York (La Rocque, in press). Records exist for Hull and the lower Lièvre River Valley, Quebec (La Rocque, 1962, p. 39). Pleistocene distribution, this study: Lac Laflamme deposit, Quebec.

GEOLOGIC RANGE. Pleistocene, late Wisconsin to present.

Nesovitrea electrina (Gould) 1841

(Plate III, Figure 1)

Helix electrina Gould, 1841, Invertebr. Mass., p. 183.
Retinella electrina (Gould), Pilsbry, 1946, Land Moll. N. America, v. 2, pt. 1, p. 256.

ECOLOGY. In Illinois, the species is commonly found under logs and loose bark (F.C. Baker, 1939, p. 70). Oughton (1948, p. 127) states that *Nesovitrea electrina* is restricted to lake and river margins, or marshy places. Leonard (1959, p. 112) found it both in wooded uplands and along stream margins. *Nesovitrea electrina* inhabits woodlands and occurs in plant debris, decaying leaves, and in or around old stumps and logs. It is commonly found in swamps or marshy areas on stream flats or margins of standing water, although it also occurs in drier habitats (La Rocque, in press).

DISTRIBUTION. Maritime Provinces and Ontario west to Alaska and Washington, south to Arizona, New Mexico, Kansas Missouri, Indiana, Ohio, Virginia, and New Jersey (La Rocque, in press). The species has been collected in the Ottawa area (La Rocque, 1962, p. 39). Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec.

GEOLOGIC RANGE. Late Pliocene to present (Hibbard and Taylor, 1960, p. 147).

FAMILY LIMACIDAE

Genus *Deroceras* Rafinesque, 1820

Deroceras sp.

(Plate III, Figure 2)

Deroceras Rafinesque, 1820, Ann. Nature, v. 1, p. 10.
Deroceras Rafinesque, Pilsbry 1948, Land Moll. N. Amer., v. 2, pt. 2, p. 532.

ECOLOGY. Slugs of the genus *Deroceras* occur in a wide variety of moist habitats, from woodlands to open places and in towns as well as wilderness areas. They are common garden pests. (Pilsbry, 1948, p. 533).

DISTRIBUTION. The genus is represented throughout the Palearctic realm and the western hemisphere. Several species are confined to western North America and two species, *D. laeve* and *D. reticulatum*, are widespread over North America. *D. laeve* is recorded from the Ottawa district, but both species occur there (La Rocque, personal communication). Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec. Gibson (1967, p. 22) reports *D. laeve* from the Richardson Lake deposit, Quebec.

GEOLOGIC RANGE. Upper Pliocene to Recent (Hibbard and Taylor, 1960, p. 20).

REMARKS. These are most likely shells of *D. laeve*.

FAMILY ENDODONTIDAE

Genus *Anguispira* Morse, 1864

Anguispira alternata (Say) 1816

(Plate III, Figure 3)

Helix alternata Say, 1816, Nicholson's Encycl., n. p., pl. 1, fig. 2.
Anguispira alternata (Say), Pilsbry, 1948, Land Moll. N. Amer., v. 2, pt. 2, p. 568.

ECOLOGY. *Anguispira alternata* is common and widespread. It is found under loose bark, dead wood, in stone piles, and under logs and stones. F. C. Baker (1939 p. 84) notes that the species is characteristic of the loose bark habitat. It seems to prefer somewhat open woodlands, such as clearings in old stands or open second growth, generally with plenty of cover such as dense undergrowth, forest debris, or litter. Populations occur on the moist soil of floodplains in debris piles (La Rocque, in press).

DISTRIBUTION. Nova Scotia west to Ontario, Michigan, Minnesota, South Dakota, Nebraska, Kansas, and Oklahoma, south to Texas, Louisiana, Mississippi, Alabama, and Florida (La Rocque, in press). La Rocque (1962, p. 35) lists records for Ottawa. Pleistocene distribution, this study: Lac Laflamme, Quebec. Whittaker (1921, p. 66) reports the species from the marl at McKay Lake, Ontario.

GEOLOGIC RANGE. Pleistocene, Aftonian to present (Baker 1920, p. 389).

Genus *Discus* Fitzinger, 1833

Discus cronkhitei catskillensis (Pilsbry) 1898

(Plate III, Figure 4)

Pyramidula striatella catskillensis Pilsbry, 1898, Nautilus, v. 12, p. 86.
Discus cronkhitei catskillensis (Pilsbry), Pilsbry, 1948, Land Moll. N. Amer., v. 2, pt. 2, p. 605.

ECOLOGY. Pilsbry (1948, p. 606) states that the form is found on rotten logs and among leaves in hilly or mountainous country, generally at higher elevations and in drier conditions than typical *D. cronkhitei*. Ecological data reviewed by La Rocque (in press) indicate that *D. cronkhitei catskillensis* lives in hardwood forests under stones, logs, and leaf litter. It occurs both in dry areas and moist situations such as along the margins of lakes.

DISTRIBUTION. Maine and the Adirondacks to Pennsylvania, west to the Upper Peninsula of Michigan, Minnesota, and South Dakota. Typical *D. cronkhitei* occurs across North America except for southern United States. (Pilsbry, 1948, p. 602, 605). La Rocque (1962, p. 36) cites records of *D. cronkhitei* for the Ottawa district.

GEOLOGIC RANGE. Middle Pliocene to the present for *D. cronkhitei* (Hibbard and Taylor, 1960, p. 143).

Genus *Helicodiscus* Morse, 1864

Helicodiscus parallelus (Say) 1821

(Plate III, Figure 5)

Planorbis arallelus Say, 1821, Acad. Nat. Sci. Philadelphia, Jour., v. 2, p. 164, 407. Typographic error on p. 164, intended spelling on p. 407.
Helicodiscus parallelus (Say), Pilsbry, 1948, Land Moll. N. Amer., v. 2, pt. 2, p. 625.

ECOLOGY. The species lives on decaying wood and damp leaves in shady or humid places (Pilsbry. 1948, p. 627). F. C. Baker (1939, p. 89) observes that *Helicodiscus parallelus* is a woodland species that rarely occurs in open places. The species prefers to live in moist woodlands under logs, forest litter, stones, and brush. It occurs near lakes and in bogs and swampy areas. Grimm (1959, p. 125) found it in a variety of habitats other than woodlands, including quarries, debris near railroad tracks, and the ruins of an old building.

DISTRIBUTION. Newfoundland, Prince Edward Island, New Brunswick, and Maine west to Manitoba, south to Georgia, Alabama, Arkansas, and Oklahoma (La Rocque, in press). La Rocque (1962, p. 37) lists a record for the Ottawa district. Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec. Whittaker (1921, p. 66) found it in deposits at McKay and Colton Lakes, Ontario.

GEOLOGIC RANGE. Pleistocene, Nebraskan to Recent (Hibbard and Taylor, 1960 p. 144).

FAMILY SUCCINEIDAE

Genus *Oxyloma* Westerlund, 1885

Oxyloma retusa (Lea) 1834

(Plate III, Figure 6)

Succinea retusa Lea, 1834, Amer. Philos. Soc. Trans., v. 5, p. 117.
Oxyloma retusa (Lea), Pilsbry, 1948, Land Moll. N. Amer., v. 2, pt. 2, p. 785.

ECOLOGY. The species occurs in wet situations such as along the margins of ponds, lakes, ditches, and streams, or in marshy or seasonally flooded areas. It lives on wet plant debris, wood fragments, stems of hydrophilic plants, or on wet mud and muck among vegetation.

DISTRIBUTION. Labrador and Maine west to Montana, possibly British Columbia and the Yukon; south to Illinois, Ohio, Minnesota, Iowa, North Dakota, and Montana (La Rocque, in press). La Rocque (1962, p. 38) gives a record for Hull, Quebec. Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, Quebec. Clowers (1966, p.) found *Oxyloma retusa* in the Box Marsh deposit, Ontario.

GEOLOGIC RANGE. Early Pleistocene to Recent (Hibbard and Taylor, 1960, p. 141).

Genus *Succinea* Draparnaud, 1801

Succinea ovalis Say, 1817

(Plate III, Figure 7)

Succinea ovalis Say, 1817, Acad. Nat. Sci. Philadelphia, Jour., v. 1, p. 15.
Succinea ovalis Say, Pilsbry 1948, Land Moll. N. Amer., v. 2, pt. 2, p. 801.

ECOLOGY. *Succinea ovalis* inhabits low areas adjacent to bodies of water, often on vegetation a foot or so off the ground. It has been found several feet from the ground on trees, and in both moist and dry woodlands, under stones and leaves (Pilsbry, 1948, p. 804; Oughton, 1948, p. 94).

DISTRIBUTION. Newfoundland and James Bay west to North Dakota and Nebraska, south to Alabama (Pilsbry, 1948, p. 803). La Rocque (1962, p. 40) lists published records for the Ottawa district and Hull, Quebec. Pleistocene distribution, this study: Manitou Lake, Lac Laflamme, Nesbitt Lake, and Southwest Venosta deposits, Quebec. Whittaker (1921, p. 67) reports it from the McKay Lake deposit, and Gibson (1967, p. 19) found it in the Richardson Lake deposit, Quebec.

GEOLOGIC RANGE. Pleistocene, Yarmouth to present (Leonard, 1950, p. 24).

FAMILY STROBILOPSIDAE

Genus *Strobilops* Pilsbry, 1893

Strobilops labyrinthica (Say) 1817

(Plate III, Figure 9)

Helix labyrinthica Say, 1817, Acad. Nat. Sci. Philadelphia, Jour., v. 1, p. 124.
Strobilops labyrinthica (Say), Pilsbry, 1948, Land Moll. N. America, v. 2, pt. 2, p. 854.

ECOLOGY. The species generally occurs on uplands, in damp deciduous forests under loose bark or debris. It also occurs in floodplain valleys. Baker (1939, p. 114) notes that it inhabits old woods and recently cleared spots where logs and decaying wood have accumulated.

DISTRIBUTION. 'Southern Ontario and Massachusetts to Michigan, Illinois, and Arkansas, south to southern Florida and Louisiana.' (Pilsbry, 1948, p. 863). Pleistocene distribution, this study: Lac Laflamme and Nesbitt Lake deposits, Quebec.

GEOLOGIC RANGE. Pleistocene, late Wisconsin to present.

FAMILY PUPILLIDAE

Genus *Gastrocopta* Wollaston, 1878

Gastrocopta contracta (Say) 1822

(Plate III, Figure 10)

Pupa contracta Say, 1822, Acad. Nat. Sci. Philadelphia, Jour., v. 2, p. 374.
Gastrocopta contracta (Say), Pilsbry, 1948, Land Moll. N. Amer., v. 2, pt. 2, p. 880.

ECOLOGY. *Gastrocopta contracta* is a woodland species but occurs in a wide range of habitats including moist, forested floodplains, wooded hillslopes, limestone bluffs, and less commonly, dry railway embankments. It is common in isolated deciduous woodlots. (F. C. Baker, 1939, p. 97). Information summarized by La Rocque (in press) indicates a preference for hardwood forests although the species also occurs in open areas where grasses, shrubs, and brush provide cover.

DISTRIBUTION. Eastern United States and Canada from Maine, Quebec, and Ontario west to Manitoba, south to Florida and Vera Cruz, Mexico; Cuba and Jamaica, probably through introduction by man (Pilsbry, 1948, p. 881). La Rocque (1962, p. 37) notes a report of this species in the Ottawa district. Pleistocene distribution,

PLATE III. PLEISTOCENE MOLLUSCA FROM QUEBEC AND ONTARIO

Fig. 1. *Nesovitrea electrina*, Lac Laflamme deposit, X 6
Fig. 2. *Deroceras* sp., internal shell, Lac Laflamme deposit, X 10
Fig. 3. *Anguispira alternata*, Lac Laflamme deposit, X 17
Fig. 4. *Discus cronkhitei catskillensis*, Lac Laflamme deposit, X 10.5
Fig. 5. *Helicodiscus parallelus*, Lac Laflamme deposit, X 10.5
Fig. 6. *Oxyloma retusa*, Lac Laflamme deposit, X 2.5
Fig. 7. *Succinea ovalis*, Manitou Lake deposit, X 4.5
Fig. 8. *Strobilops aenea*, Nesbitt Lake deposit, X 11
Fig. 9. *Strobilops labyrinthica*, Lac Laflamme deposit, X 14.5
Fig. 10. *Gastrocopta contracta*, Lac Laflamme deposit, X 14.5
Fig. 11. *Gastrocopta tappaniana*, Lac Laflamme deposit, X 14.5
Fig. 12. *Vertigo bollesiana*, Lac Laflamme deposit, X 14.5
Fig. 13. *Vertigo morsei*, Lac Laflamme deposit, X 14.5
Fig. 14. *Vertigo ovata*, Manitou Lake deposit, X 14.5
Fig. 15. *Vallonia pulchella*, Lac Laflamme deposit, X 10.5

(Drawn by Barbara Sue Bickel)

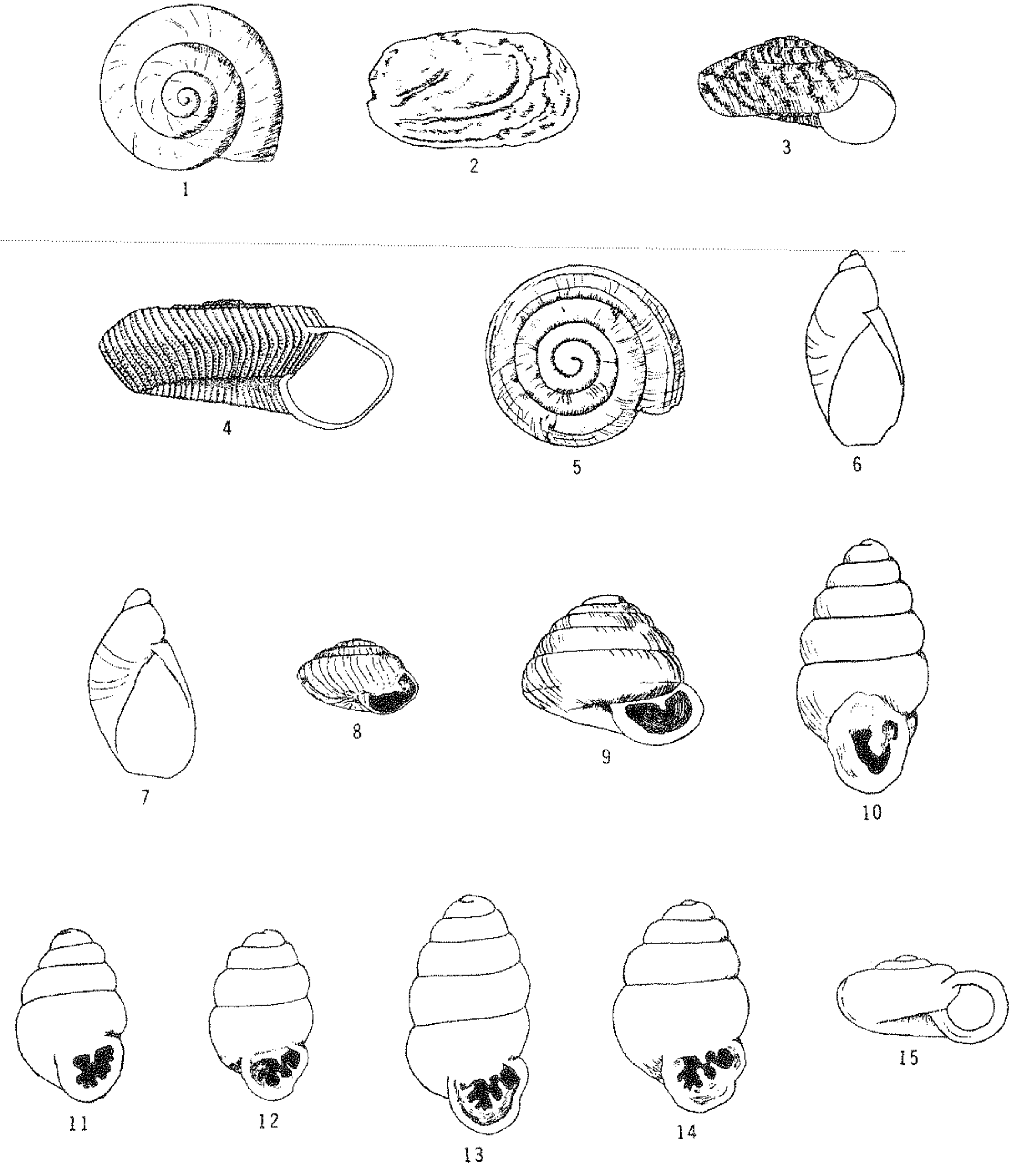


PLATE III. PLEISTOCENE MOLLUSCA FROM QUEBEC AND ONTARIO.

this study: Manitou Lake and Lac Laflamme deposits, Quebec. It occurs in the Richardson Lake deposit, Quebec (Gibson, 1967, p. 20).

GEOLOGIC RANGE. Early Pliocene to present (Hibbard and Taylor, 1960, p. 126).

Gastrocopta tappaniana (C. B. Adams) 1842

(Plate III, Figure 11)

Pupa tappaniana 'Ward' C. B. Adams, 1842, Thompson's Hist. Vermont, p. 158.
Gastrocopta tappaniana (C.B. Adams). Pilsbry, 1948, Land Moll. N. Amer., v. 2, pt. 2, p. 889.

ECOLOGY. The species lives in wet habitats such as floodplains, moist woodlands, and swamps and stream margins on pieces of wood, logs, stones, and damp litter. It occurs in wetter situations than *Gastrocopta pentodon*. (F. C. Baker, 1939, p. 101; La Rocque, in press).

DISTRIBUTION. Ontario and Maine south to Virginia and Alabama, west to South Dakota, Kansas, and Arizona; apparently absent from the southeastern Atlantic States (Pilsbry, 1948, p. 889; La Rocque, in press). Pleistocene distribution, this study: Manitou Lake and Lac Laflamme deposits, Quebec.

GEOLOGIC RANGE. Late Pliocene to the present (Hibbard and Taylor. 1960, p. 127).

Genus *Vertigo* Müller, 1774

Vertigo bollesiana (Morse) 1865

(Plate III, Figure 12)

Isthmia bollesiana Morse, 1865, Ann. Lyceum Nat. Hist. New York, v. 8, p. 209.
Vertigo bollesiana (Morse), Pilsbry, 1948, Land Moll. N. Amer., v. 2, pt. 2, p. 981.

ECOLOGY. The species has been found in hardwood groves on bark and in leaf litter (Pilsbry, 1948, p. 981). Oughton (1948, p. 94) reports *V. bollesiana* from dry woodlands and fields as well as damp forest areas.

DISTRIBUTION. Southern Ontario north to Lake Temagami; Maine, Massachusetts, New Hampshire, and New York; also reported from Indiana, Michigan, Virginia, and Tennessee not verified by Pilsbry (Pilsbry, 1948, p. 981). La Rocque (1962, p. 41) lists records from north of Hull (hills near Ironsides) and the Abitibi region of Quebec. Pleistocene distribution, this study: Manitou Lake and Lac Laflamme deposits, Quebec.

GEOLOGIC RANGE. Pleistocene, Yarmouth to present (F. C. Baker, 1920, p. 282).

Vertigo morsei Sterki, 1894

(Plate III, Figure 13)

Vertigo morsei Sterki, 1894, Nautilus, v. 8, p. 89.

ECOLOGY. *Vertigo morsei* occurs most commonly near lake shores (F. C. Baker, 1939, p. 104) and possibly the floodplains of creeks and rivers (Oughton, 1948, p. 94).

DISTRIBUTION. Ontario, Quebec, and New York west to Michigan, Indiana, and Illinois. Pleistocene distribution, this study: Manitou Lake and Lac Laflamme deposits, Quebec. Apparently these are the first Quebec records of this species.

GEOLOGIC RANGE. Pleistocene, late Wisconsin to the present.

Vertigo ovata Say, 1822

(Plate III, Figure 14)

Vertigo ovata Say, 1822, Acad. Nat. Sci. Philadelphia, Jour., v. 2, p. 375.
Vertigo ovata Say, Pilsbry, 1948, Land Moll. N. America, v. 2, pt. 2, p. 952).

ECOLOGY. *V. ovata* inhabits leaf litter, plant debris, bark, grass, and undersides of logs in moist situations, not far from water. It occurs on floodplains and margins of bodies of standing water, where it is often abundant among grasses or hydrophilic plants (La Rocque, in press).

DISTRIBUTION. Prince Edward Island and Ungava Bay, Labrador west to Alaska, British Columbia, Puget Sound, Utah, and Arizona; south to the Florida Keys, Texas, Mexico, and the West Indies (La Rocque, in press). A record for Hull, Quebec is mentioned by La Rocque (1962, p. 41). Pleistocene distribution, this study: Manitou Lake, Lac Laflamme and Nesbitt Lake deposits, Quebec. Gibson (1967, p. 20) reports it from the Richardson Lake deposit, Quebec; and Clowers (1966, p. 47) found it in the Box Marsh deposit, Ontario.

GEOLOGIC RANGE. Early Pliocene to present (Hibbard and Taylor, 1960, p. 135).

FAMILY VALLONIIDAE

Genus *Vallonia* Risso, 1826

Vallonia pulchella (Müller) 1774
(Plate III, Figure 15)

Helix pulchella Müller, 1774, Verm. Terr. et Fluv., v. 2, p. 30.
Vallonia pulchella (Müller), Pilsbry, 1948, Land Moll. N. America, v. 2, pt. 2, p. 1023.

ECOLOGY. According to F. C. Baker (1039, p. 118), *V. pulchella* occurs in a variety of habitats including wooded areas along streams, railroad embankments, and among grass and bushes. It has been collected from rather dry or open situations such as fields and around old foundations (La Rocque, in press). The species is often quite abundant in lawns and gardens when shade and cover are present (Pilsbry, 1948, p. 1024).

DISTRIBUTION. Eurasia, North Africa; North America east of the Rocky Mountains, south to Missouri and Kentucky; local populations introduced in many places (Pilsbry, 1948, p. 1024). La Rocque (1962, p. 41) lists records for the Ottawa district. Pleistocene distribution, this study: Manitou Lake and Lac Laflamme deposits, Quebec.

GEOLOGIC RANGE. Pleistocene, Nebraskan to the present (Taylor, 1960, p. 76).

Several species, not encountered in this study, have been reported from Pleistocene deposits in the Ottawa Valley by other workers. These records are listed here with localities and references. Additional fossil localities can be found for several species through examination of the references cited by La Rocque (1953, p. 347).

SPHAERIUM NITIDUM Clessin, 1876. Box Marsh and Colton Lake deposits, Ont. (Clowers, 1966, p. 35, 55), and Richardson Lake deposit, Que. (Gibson, 1967, p. 9). Doubtful. Lots from Box Marsh (OSU 155) are *Pisidium spp.*; sphaeriid material from the Richardson Lake deposit is not in the Pleistocene Mollusca collection at Ohio State University.

VALVATA SINCERA Say, 1824. Box Marsh and White Lake deposits, Ont. (Clowers 1966, p. 40, 55).

PSEUDOSUCCINEA COLUMELLA (Say) 1817. Box Marsh deposit, Ont. (Clowers, 1966, p. 42)

SUCCINEA GROSVENORI Lea, 1864. Richardson Lake deposit, Que. (Gibson, 1967, p. 19).

GLYPHYALINIA INDENTATA (Say) 1822. Richardson Lake deposit, Que. (Gibson, 1967, p. 21).

GLYPHYALINIA RHOADSI (Pilsbry) 1899 Richardson Lake deposit, Que. (Gibson 1967, p. 21).

ZONITOIDES NITIDUS (Müller) 1774. Richardson Lake, Que. at top of section and probably from a living population (Gibson 1967, p. 22).

TRIODOPSIS ALBOLABRIS (Say) 1816. McKay Lake deposit, Ont. (Whittaker, 1921, pl 6).

STENOTREMA FRATERNUM (Say) 1816. McKay Lake deposit, Ont. (Whittaker, 1921 p 65).

PALEOECOLOGY

General Statement

Freshwater marl with abundant mollusk, ostracode, and plant fossils generally accumulates in the littoral zone of lakes. Marls also form in the profundal zone or deep portion of lakes below the depth of effective light penetration, but these deposits seem to be largely composed of carbonate derived from shallow areas (Swain, 1956, p. 642). Marl alone is not indicative of a littoral environment. Remains of planktonic arthropods, chironomid larvae, and diatoms are the common fossils in deep-water marls. A thick marl deposit reaches depths of over 11 meters below the surface in Cedar Creek Bog, Minnesota. Lindeman (1941, p. 109) describes the deep portions of this bed as very minute, compacted carbonate grains, and the upper region as coarse flakes with abundant snail shells and pondweed seeds. Swain (1956 p. 632) finds that mollusks occur infrequently in hypolimnetic sediments, and Whittaker (1922, p. 153) and Dexter (1950, p. 20) found no mollusks below depths of 9 and 12 feet during their studies of living populations in basic lakes.

Swain (1956, p. 649) notes that in Minnesota there is a direct relationship between the soluble salt content of surrounding bedrock and unconsolidated material, and biotic productivity in lakes. The abundance of soluble salts, total precipitation, and the ratio of runoff to evaporation control the rate of change from

TABLE 1 Vertical distribution of species in the Manitou Lake deposit, Quebec, Canada

Samples	Sphaerium lacustre	Sphaerium rhomboideum	Sphaerium simile	Pisidium adamsi	Pisidium casertanum	Pisidium compressum	Pisidium ferrugineum	Pisidium nitidum	Pisidium variabile	Pisidium ventricosum	Pisidium walkeri	Valvata lewisi	Valvata tricarinata	Amnicola limosa	Lymnaea decampi	Lymnaea haldemani	Lymnaea obrussa	Lymnaea stagnalis	Gyraulus deflectus	Gyraulus parvus	Armiger crista
1	-	-	-	2	14	4	1	-	-	-	-	-	34	2	1	-	-	-	-	60	-
2	-	-	-	-	10	5	3	6	-	-	-	-	35	-	-	-	1	-	-	27	-
3	-	-	-	3	28	2	3	11	-	-	-	-	64	-	-	-	1	-	-	67	-
4	-	-	2	24	75	56	29	34	5	-	-	-	316	-	-	-	12	-	5	396	-
5	-	7	5	18	53	42	72	79	-	-	-	-	379	-	-	-	32	-	-	493	-
6	2	26	16	33	35	29	20	57	11	-	-	-	313	-	10	-	20	1	1	505	-
7	-	-	6	7	105	35	90	136	-	-	-	-	189	-	95	-	9	2	5	422	-
8	-	-	-	1	71	10	256	190	12	-	-	-	139	-	68	-	-	-	6	185	-
9	1	-	-	8	104	21	164	227	57	-	-	-	238	-	150	-	-	3	5	450	-
10	-	-	-	5	68	7	124	149	23	1	-	2	180	-	174	-	-	3	-	348	-
11	-	-	-	7	98	4	113	152	9	2	-	2	171	-	107	-	-	5	-	346	-
12	-	-	-	2	84	-	517	409	3	5	-	-	309	-	98	-	-	3	-	369	-
13	-	-	-	-	24	-	450	256	-	2	-	-	251	-	96	-	-	4	1	308	-
14	-	-	-	-	20	-	475	259	3	1	-	-	179	-	34	-	-	1	-	223	-
15	-	-	-	-	42	15	464	159	75	1	-	-	354	-	165	-	-	3	-	282	-
16	-	-	-	-	32	29	160	253	158	22	-	3	313	-	214	-	-	8	-	228	-
17	-	-	-	-	11	3	384	319	18	9	-	-	147	-	52	-	-	2	2	211	-
18	-	-	-	-	24	-	721	285	6	32	-	2	185	-	38	-	-	1	-	230	-
19	-	-	-	-	12	8	622	404	63	50	-	-	179	-	128	-	-	1	-	147	-
20	-	-	5	-	180	37	38	19	296	10	-	1	218	-	88	-	-	2	9	432	-
21	-	-	-	-	21	42	2	18	348	2	1	4	276	-	75	-	-	-	16	663	-
22	1	-	1	-	14	13	2	1	245	-	-	13	232	-	69	3	-	-	25	578	2
23	1	-	-	4	14	15	-	15	268	-	-	70	4	-	81	2	-	-	21	699	4
24	16	-	-	-	-	21	6	112	126	-	-	198	8	-	75	-	-	-	1	650	5
25	13	-	-	-	-	21	26	155	75	-	-	252	7	-	47	-	-	-	-	511	6
26	6	-	-	-	-	13	1	147	45	-	-	416	2	-	39	-	-	-	-	749	18
27	-	-	-	-	-	6	-	14	11	-	-	43	1	-	38	-	-	-	-	155	-

Sample	Helisoma anceps	Helisoma campanulatum	Helisoma trivolvis	Promenetus exacuous	Ferrissia parallela	Physa gyrina	Carychium exiguum	Euconulus fulvus	Nesovitrea electrina	Deroceras	Helicodiscus parallelus	Oxyloma retusa	Succinea ovalis	Strobilops labyrinthica	Gastrocopta contracta	Gastrocopta tappaniana	Vertigo bollesiana	Vertigo morsei	Vertigo ovata	Vallonia pulchella	Total Specimens
1	1	-	-	-	-	-	17	3	6	1	-	-	1	-	23	28	-	-	15	116	329
2	-	-	-	1	-	-	15	-	-	2	-	-	-	-	-	-	-	-	-	-	105
3	-	-	-	3	1	-	4	-	-	-	-	-	-	-	-	3	-	-	-	4	194
4	9	-	-	8	5	-	-	3	-	-	1	-	5	-	2	16	-	-	13	45	1061
5	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1192
6	24	10	-	4	12	8	1	-	-	-	-	-	8	-	-	-	-	-	-	-	1146
7	67	9	-	17	15	12	2	-	4	-	-	-	21	3	-	1	-	-	2	-	1254
8	40	10	1	16	7	8	1	-	-	-	-	-	9	-	-	-	8	-	1	-	1041
9	39	17	-	5	8	12	-	2	2	-	-	-	8	-	-	-	-	-	5	-	1546
10	51	17	-	9	3	26	-	1	-	-	-	-	8	-	-	-	-	2	-	-	1201
11	55	10	-	-	2	18	-	1	-	-	-	-	1	-	-	-	-	2	-	-	1105
12	2	9	-	-	-	12	-	-	-	-	-	-	1	-	-	1	-	-	-	-	1818
13	10	43	-	1	3	48	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1498
14	5	37	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1253
15	23	17	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1603
16	48	13	-	-	-	8	-	-	-	-	-	1	-	-	-	-	-	-	1	-	1491
17	6	23	-	-	2	3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1193
18	1	22	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1555
19	55	22	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1698
20	96	6	-	1	4	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1442
21	70	2	-	-	7	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1549
22	27	3	-	-	10	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1241
23	6	2	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1212
24	6	1	-	-	1	4	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1231
25	4	8	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1134
26	6	4	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1452
27	8	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	272

TABLE 2. Vertical distribution of species in the Lac Laflamme deposit, Quebec, Canada

Sample	Sphaerium lacustre	Sphaerium rhomboideum	Sphaerium simile	Pisidium adamsi	Pisidium casertanum	Pisidium compressum	Pisidium ferrugineum	Pisidium lilljeborgi	Pisidium nitidum	Pisidium variabile	Pisidium ventricosum	Pisidium ventricosum	Campeloma decisum	Valvata tricarinata	Amnicola limosa	Lymnaea dalli	Lymnaea decampi	Lymnaea obrussa	Lymnaea stagnalis	Gyraulus deflectus	Gyraulus parvus	Helisoma anceps	Helisoma campanulatum
1	-	-	-	-	-	-	-	-	-	6	-	-	-	4	2	-	1	-	-	-	4	-	-
2	-	-	-	-	12	7	-	-	-	15	-	-	-	8	8	-	5	-	1	-	38	1	-
3	-	-	-	-	19	16	-	-	-	26	-	-	-	28	26	-	3	-	-	-	73	1	-
4	-	-	-	-	15	10	-	-	-	8	-	-	-	6	6	-	2	-	-	-	32	1	-
5	-	-	-	-	20	5	-	-	3	16	-	-	-	27	26	-	6	-	-	1	23	7	-
6	-	-	-	1	75	49	5	-	9	134	1	1	-	125	154	-	52	10	2	12	205	64	-
7	-	-	1	6	34	63	9	1	14	185	1	1	-	122	188	-	38	6	4	7	223	43	2
8	1	-	2	2	24	60	61	-	95	164	-	-	-	89	256	1	42	19	8	15	292	92	5
9	-	-	-	-	14	38	56	1	37	116	-	-	-	96	195	1	44	12	11	17	292	109	2
10	-	-	-	1	13	28	73	2	47	148	-	-	-	116	281	-	31	9	3	4	237	100	3
11	-	-	2	2	11	39	75	1	33	124	1	1	-	107	317	1	54	13	6	-	199	86	6
12	-	-	-	3	18	55	22	2	41	119	3	3	4	100	304	-	120	11	9	-	150	114	6
13	1	-	4	5	40	51	52	-	68	145	2	2	3	180	319	1	90	6	2	1	255	101	23
14	1	-	-	-	24	25	50	-	69	62	-	-	-	95	205	1	63	11	12	-	180	62	18
15	2	-	-	-	15	20	93	-	82	64	1	1	-	76	309	-	75	16	11	-	211	65	19
16	2	1	2	-	29	6	124	-	88	32	-	-	-	93	285	-	56	2	15	-	194	48	13
17	-	3	-	2	33	10	133	-	115	46	1	1	-	100	363	-	66	-	16	1	306	63	16
18	1	-	-	-	73	29	102	-	49	48	-	-	1	105	279	-	71	-	6	1	174	69	7
19	-	-	2	-	26	12	86	-	36	63	-	-	-	90	136	-	57	-	5	1	101	42	3
20	-	-	4	4	32	52	121	-	59	45	4	4	-	227	224	-	52	-	7	3	267	83	17
21	-	-	-	6	109	25	99	-	74	89	6	6	-	205	163	-	50	-	1	3	339	55	5
22	-	-	5	21	70	67	37	-	45	99	9	9	-	246	177	-	31	-	6	3	221	46	-
23	4	-	1	14	53	43	71	-	48	129	10	10	-	206	167	-	39	-	4	6	270	36	1
24	-	2	4	21	41	31	50	-	52	104	9	9	-	205	174	-	38	-	-	7	227	29	1
25	-	-	5	12	68	44	126	-	141	117	10	10	-	205	177	-	31	-	6	2	260	52	2
26	3	-	6	16	23	39	158	-	148	91	10	10	-	198	240	-	41	-	10	5	255	51	5
27	4	-	8	5	24	32	133	-	124	103	3	3	-	124	198	-	30	-	10	4	145	35	9
28	1	-	6	10	33	43	133	-	98	150	3	3	-	305	344	-	44	-	9	6	311	106	6
29	1	-	6	19	43	52	35	-	36	176	1	1	-	218	282	-	18	-	2	1	174	104	4
30	-	-	9	11	47	41	3	-	25	123	-	-	-	226	285	1	15	-	-	3	216	100	9
31	-	-	3	6	36	59	6	-	22	146	-	-	-	239	314	-	15	-	-	3	244	116	8
32	-	-	13	3	41	35	4	-	47	153	-	-	-	217	309	-	6	-	-	-	197	110	10
33	-	-	9	4	49	64	9	-	56	119	-	-	-	231	289	1	8	-	-	-	216	120	6
34	-	-	7	1	6	24	2	-	38	85	-	-	-	274	290	-	3	-	-	-	207	103	4
35	-	-	3	2	14	18	10	-	71	48	-	-	-	334	247	-	3	-	-	-	212	72	7
36	2	-	3	2	65	27	4	-	19	96	-	-	-	227	263	-	17	-	-	-	179	111	6
37	-	-	1	2	7	72	25	-	36	160	5	5	-	259	376	-	27	-	-	-	248	136	5

Sample	Promenetus exacuous	Ferrissia parallela	Ferrissia walkeri	Physa gyrina	Physa heterostropha	Carychium exiguum	Euconulus fulvus	Nesovitrea binneyana	Nesovitrea electrina	Deroceras	Anguispira alternata	Discus cronkhitei	Helicodiscus parallelus	Oxyloma retusa	Succinea ovalis	Strobilops labyrinthica	Strobilops aenea	Gastrocopta contracta	Gastrocopta tappaniana	Vertigo bollesiana	Vertigo morsei	Vertigo ovata	Vallonia pulchella	Total Specimens
1	-	-	-	-	-	3	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	117	140
2	-	-	-	-	-	8	-	-	1	1	-	-	-	-	-	-	-	-	1	-	-	-	235	341
3	-	-	-	-	-	15	-	-	5	-	-	-	-	2	-	-	-	1	1	-	-	1	255	473
4	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-	-	2	2	-	-	-	77	167
5	-	-	-	-	-	19	-	-	4	-	-	-	-	2	-	-	-	1	5	-	-	-	39	204
6	1	-	-	-	-	21	-	-	7	-	-	-	2	6	-	3	-	1	4	-	-	2	-	945
7	4	-	-	-	-	10	1	-	5	-	-	-	-	-	3	7	-	1	4	2	-	1	-	985
8	7	-	-	4	-	7	-	-	-	-	-	-	-	5	1	3	-	1	3	-	-	-	-	1259
9	5	-	-	7	-	-	-	-	1	-	-	-	-	3	5	1	-	-	-	-	-	2	1	1066
10	3	-	-	5	-	-	-	-	-	-	-	-	-	4	-	3	-	-	-	1	-	-	-	1112
11	5	-	-	6	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	1	-	1092
12	3	-	-	5	-	-	-	-	-	-	-	-	-	-	4	1	-	1	-	2	-	-	-	1097
13	13	-	-	24	-	-	-	1	-	-	-	-	-	-	9	1	-	-	1	-	-	-	-	1398
14	10	-	-	10	-	-	2	1	-	-	-	-	-	-	3	-	-	-	-	-	1	-	-	905
15	7	-	-	6	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1074
16	9	-	-	21	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	1022
17	13	-	-	15	-	1	-	-	1	1	1	-	-	1	-	1	-	-	-	2	-	-	-	1310
18	9	-	-	8	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1033
19	3	-	-	2	1	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	668
20	7	1	-	3	-	-	-	-	1	-	1	1	-	-	1	-	-	2	1	-	-	1	-	1220
21	7	-	-	6	-	-	-	-	-	-	-	-	1	-	3	-	2	1	-	2	-	2	-	1249
22	17	-	-	5	-	2	-	-	5	-	-	-	-	-	2	-	1	2	2	-	-	5	-	1124
23	18	-	-	5	-	-	-	-	-	-	-	-	-	-	4	-	-	1	-	-	-	-	-	1130
24	11	-	-	7	-	1	-	-	-	-	-	1	-	2	2	2	-	-	1	-	-	1	-	1023
25	15	-	-	4	-	-	2	-	1	-	1	1	1	-	6	2	-	4	1	2	1	1	-	1300
26	14	-	-	4	-	-	-	-	-	-	2	-	-	-	3	-	-	1	2	-	-	-	-	1325
27	6	-	-	6	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	1006
28	19	-	-	10	-	-	-	-	-	-	1	-	-	-	2	3	-	1	2	1	-	-	-	1648
29	6	-	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	1	-	1183
30	14	-	-	9	-	-	-	-	-	1	1	-	-	-	2	1	-	-	3	1	-	1	-	1147
31	21	-	-	19	-	-	-	-	1	-	-	1	-	-	1	3	-	-	1	-	-	-	-	1264
32	16	-	1	25	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1193
33	12	1	-	23	-	-	-	-	-	-	-	-	-	-	3	1	-	-	-	-	-	2	-	1223
34	12	-	-	52	-	-	-	1	-	-	-	-	-	-	2	-	1	-	1	-	-	2	-	1115
35	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

oligotrophy to eutrophy in a new lake. Swain (1956, p. 651) concludes that the stage of lake trophication, degree of thermal stratification, and basin morphometry strongly influence the coarse fraction of lake sediments. Depth of effective light penetration, or the depth to which infiltrating light enables photosynthesis to equal or exceed respiration, also influences lake sediments. Light penetration determines the depth range of aquatic plants and is a greater factor than thermal stratification in differentiating littoral and deep basin sediments in eutrophic lakes. The following summary of sedimentation in hard-water lakes is based largely on his discussion.

Both the littoral and profundal zones of a lake are characterized by low biotic productivity at the inception of lacustrine conditions. Sediments are predominantly clastic material with coarser fractions settling in near-shore areas and finer particles settling from quieter water in offshore portions of the lake. This pattern is maintained while the lake remains in a state of low biotic productivity and is altered mainly by changes in type, size range, and size frequency of sediment transported into the basin. As nutrients build up in the lake and productivity increases, littoral zone sediments contain increasing percentages of biogenic material including mollusk shells, ostracode valves, insect exoskeletons, plant detritus, and marl. Marl beds are produced if there is an abundance of carbonate ion. If carbonate precipitation proceeds at a slow rate or not at all, shallow water deposits are characteristically peaty and sapropelic clastics. In deep water, there is a corresponding increase in organic sediment consisting of fine phytogenic material, cladoceran exoskeletons, chironomid exoskeletons, annelid worm parts, diatoms, pollen, and other microfossils. In addition, carbonate grains and shallow-water fossils may be washed in from littoral areas. The profundal sediment is generally a mixture of copropelic or sapropelic material and fine clastics. Diatomaceous marls can develop in deeper parts of marl lakes during later stages when phytoplankton productivity is high and thermal stratification is minimized by filling in of deep areas. Continued filling of deep areas eliminates the hypolimnion and raises most of the bottom into the zone of effective light penetration. At this point, thermal stratification ceases and the littoral zone covers all or most of the bottom. Sediments deposited during the last stages of filling are dominated by plant material. Bog peat occurs in low shoreline areas and lake peat accumulates in surviving pools of open water.

Littoral sediments contain the most complete and prolific record of Pleistocene Mollusca in lake deposits. These beds may extend across most of the deposit in basins that are nearly or completely filled. In larger basins or shallow depressions in an early stage of filling, littoral deposits are situated on marginal shelves around all or part of the shoreline, depending on basin morphometry.

In this study, the Pleistocene Mollusca and their enclosing sediment are interpreted with reference to this generalized sedimentary sequence. Analyses are based on faunal composition and the relative abundance of species (Plates IV-XI and Tables 1-5). Observations on stratigraphy, sediment type and distribution, and basin morphometry have been used along with these data to make paleoecological inferences.

Manitou Lake Deposit

At some stage in the Champlain Sea invasion Manitou Lake basin was submerged under an inlet of the marine arm that extended up the Gatineau Valley. When the present elevation of 550 feet emerged, the basin was isolated from the main water body except for a low valley north of the lake now occupied by the outlet stream. During the last stages of marine recession, the sand-gravel facies was limited to higher areas, whereas clay continued to be deposited in low, submerged depressions until the end of marine conditions.

The gray marine clay deposited by the Champlain Sea at low elevations in the Gatineau Valley contains numerous Foraminifera, mostly *Elphidium* spp. and rarely, Miliolidae. Data summarized by Phleger (1960, fig. 29, 31) indicate that *Elphidium* is characteristic of shallow nearshore areas and generally a sandy bottom with depths of 15 to 90 meters. A water plane standing at least 45 to 60 feet above the present level of ManitouLake would have had an open connection with the main valley.

The water body changed from a shallow, semi-isolated marine inlet to a eutrophic freshwater lake in a relatively short period of time. Most Foraminifera tests at the clay-marl contact are not fresh and were possibly derived from sediment exposed during successive drops in water level. This period of falling water level apparently included decreases in salinity that eliminated the marine fauna but had not reached levels suitable for freshwater organisms. A high baselevel established by water standing in the main valley probably controlled lake level at its earliest stage. As baselevel dropped, the outlet stream cut through unconsolidated material until bedrock topography controlled the course and gradient of the outlet and lake level.

The marine clay grades into highly fossiliferous marl or lake peat in a span of two inches on low shelf areas of Manitou Lake. The base of the marl on the north shore ranges from about 4 feet below to 3 feet above present lake level, and water most likely stood from 5 to 10 feet above present level at the beginning of marl deposition.

Of the 28 freshwater mollusk species found in the deposit, nine occur at the base of the marl in the sampled section (Sample 27). *Gyraulus parvus*, *Valvata lewisi*, *Pisidium nitidum*, and *Lymnaea decampi* are most abundant (Plates IV, V). *Pisidium variabile*, *P. compressum*, and *Helisoma anceps striatum* are present in smaller numbers. Single specimens of *Valvata tricarinata* and *Ferrissia parallela* were recovered from the sample. This assemblage is characteristic of a littoral zone with fairly abundant aquatic vegetation. The abundance of *Valvata lewisi* and *Lymnaea decampi*, and the absence of near-shore dwellers and land snails suggests a deeper offshore position, possibly in 6 to 12 feet of water. The basal 8 inches of marl (Unit 6) contains an abundance of detrital plant fragments and long, intact, vertically oriented plant parts. Most of the aquatic mollusks first appear in this unit and several species, *Pisidium variabile*, *Valvata lewisi*, *Sphaerium lacustre*, *Armiger crista*, and *Gyraulus parvus*, reach their maximum relative abundance.

AT a depth of 40 to 45 inches in the section (Unit 5) there is a decline in coarse plant detritus and the marl becomes progressively lighter colored, and eventually white with indistinct gray bands. The decrease in plant fibers does not reflect a decline in littoral vegetation, since the sediment still contains vertically oriented plant parts, abundant charophyte oogonia, and carbonate casts of charophyte stems. The change may represent vegetational changes on the shelf, floral changes on the lake margin, increased rate of carbonate deposition, or any combination of these factors. A drop in lake level or a decrease in turbidity would increase the depth of effective light penetration and enable denser stands of aquatic plants, especially *Chara*, to thrive on the shelf. Denser vegetation would increase pH and the rate of marl deposition through photosynthetic activity.

A distinct change in faunal composition occurs in the vicinity of units 6 and 5. *Pisidium variabile*, *Valvata lewisi*, *Sphaerium lacustre*, and *Armiger crista* gradually disappear or become far less abundant in higher units. The decline of *Gyraulus parvus* in the middle portion of the section may be in part a statistical artifact produced by greater representation of other species in the assemblage. *Pisidium variabile* reached its maximum abundance in this unit, and *Valvata tricarinata* increased rapidly, replacing *V. lewisi* as a major faunal element in the upper three-fourths of the section. Unit 5 marks a transition to warmer, shallower water and more dense vegetation than prevailed during deposition of the lowest unit. The faunal change may have been affected by changes in any of the interrelated factors of depth, type or density of vegetation, light intensity, temperature, or pH.

Near the transition from brownish-gray marl to white marl (Samples 19 to 21), *Pisidium ferrugineum*, *P. nitidum*, *P. ventricosum*, and *Helisoma campanulatum* increase. The most abundant species in the white, banded marl (Unit 4) are *P. ferrugineum*, *P. nitidum*, *Valvata tricarinata*, and *Gyraulus parvus*. *Lymnaea decampi* *Pisidium casertanum*, and *P. variabile* are less abundant here than in the preceding unit. *Pisidium ventricosum*, *Lymnaea stagnalis*, *Helisoma campanulatum*, and *Physa gyrina* attain their maximum abundances in this unit but all are minor elements in the assemblage. The common species occur in more nearly equal numbers than in Unit 5, where *Gyraulus parvus* accounted for 40 to 55 percent of the specimens.

Pisidium ferrugineum, *P. nitidum*, *P. ventricosum*, and *Helisoma campanulatum* are characteristic of a depth range of about 3 to 9 feet. Accumulation of about 2 feet of sediment on the shelf and downcutting of the outlet decreased the water depth about 4 feet in this area. The relatively thick sequence of marl with intact charophyte stem incrustations and vascular plant stems buried in place indicates a period when this part of the bottom was relatively free from current action and major fluctuations in water level. A dense stand of *Chara* evidently blanketed the bottom. In terms of faunal diversity, the quiet, rather shallow water and dense *Chara* bed provided the most favorable molluscan habitat.

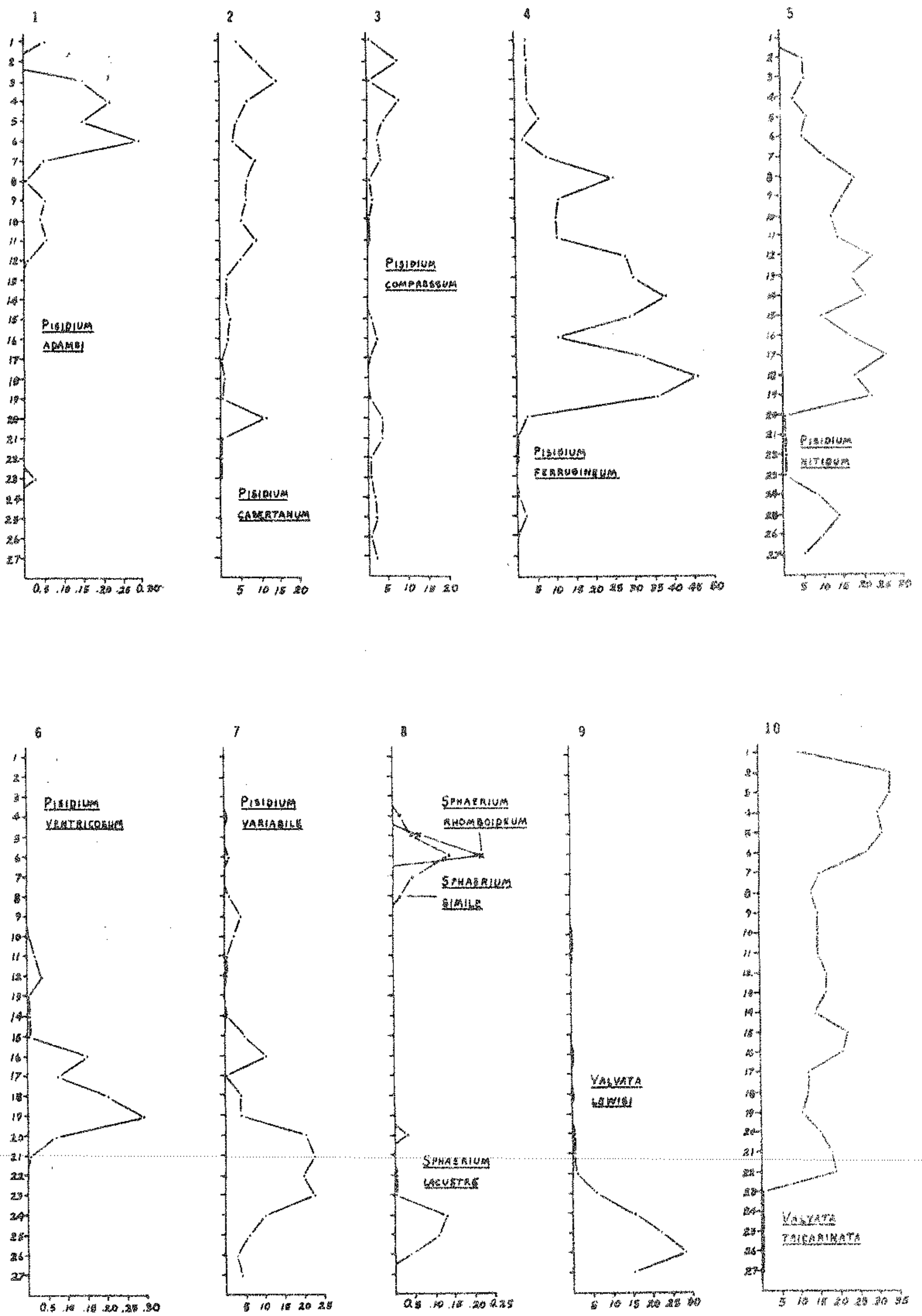


PLATE IV. VERTICAL CHANGES IN RELATIVE ABUNDANCE OF MOLLUSK SPECIES IN THE MANITOU LAKE DEPOSIT.

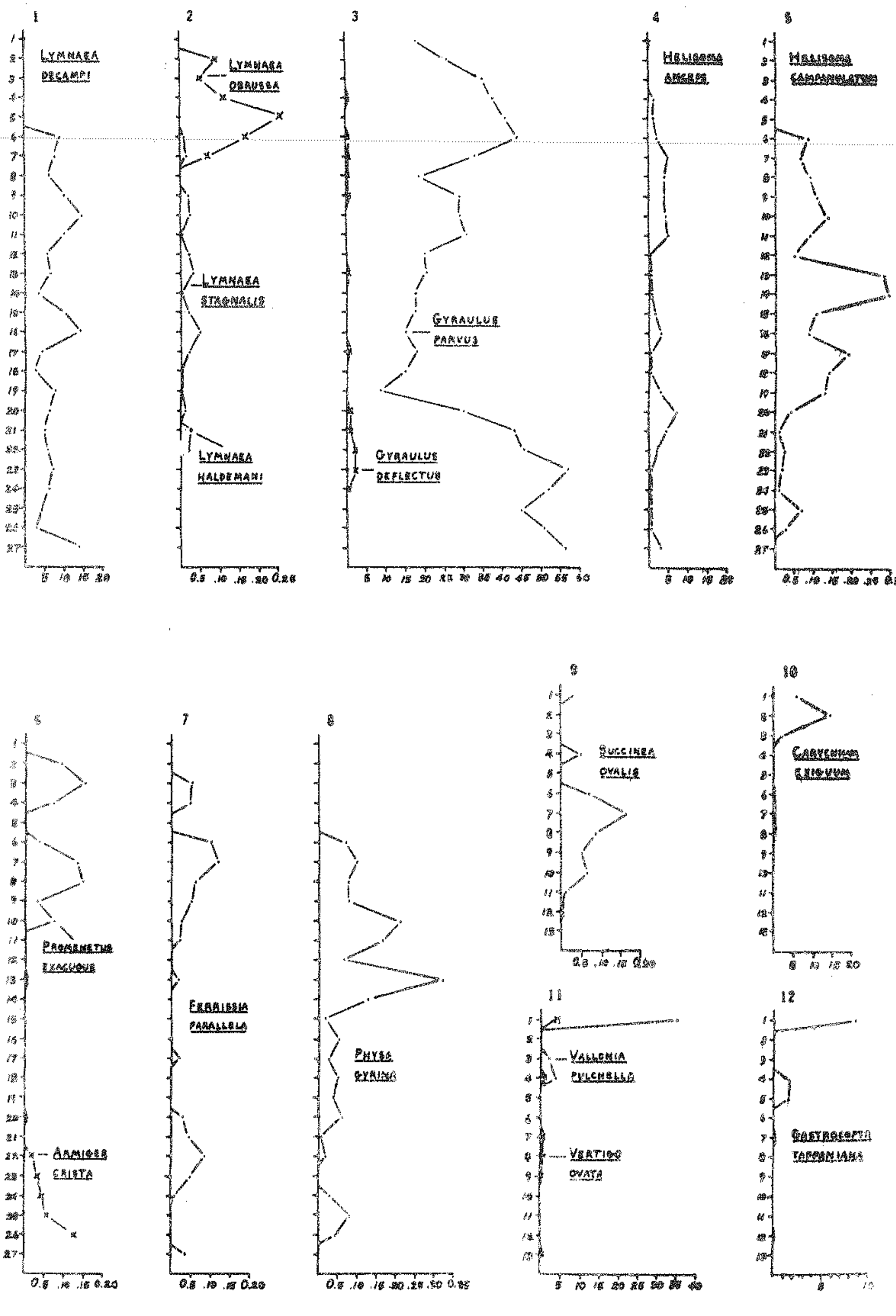


PLATE V. VERTICAL CHANGES IN RELATIVE ABUNDANCE OF MOLLUSK SPECIES IN THE MANITOU LAKE DEPOSIT.

The numbers of *Pisidium adamsi*, *P. casertanum*, *Sphaerium simile*, *Promenetus*, and *Ferrissia parallela* increase toward the top of Unit 4, and land snails begin to appear more frequently in samples. A one-inch band of fine black gyttja (Unit 3) occurs at a depth of 14 inches in the section but no particular change in the fauna is associated with the bed.

Banding is more distinct in the topmost unit of marl (Unit 2). The bands are composed of gray clay, generally medium to coarse fragments, and fine plant detritus as well as marl. Coarse plant fragments are uncommon. *Gyraulus parvus* and *Valvata tricarinata* are the dominant species and together they represent two-thirds of all specimens in the interval. Common, but less abundant species include *Pisidium casertanum*, *P. compressum*, and *P. ferrugineum*. *P. adamsi*, *Sphaerium rhomboideum*, *S. simile*, *Lymnaea obrussa*, and *Promenetus exacuous* are minor elements that reach their greatest numbers in this unit.

The appearance or increase of shallow-water and near-shore forms indicates water depth of less than 3 feet and closer proximity to the emerging shoreline. Sphaeriids represent a smaller percentage of the total mollusks, and species such as *Pisidium ferrugineum* and *P. nitidum* that inhabit moderate depths and cool water are far less abundant. The clams that maintain or increase their numbers are those that prefer light current, a substrate of organic detritus, or that tolerate a wide range of conditions. The change to shallow, near-shore conditions altered the habitat of bottom dwelling organisms in two ways. The canopy of vegetation, mostly *Chara*, thinned and the bottom was more exposed to gentle currents and solar radiation than before. Secondly, greater quantities of allochthonous material were laid down on the shelf.

The shallow-water assemblage of aquatic mollusks continues into the peat layer (Unit 1). At this stage of filling the bottom was composed predominantly of medium to coarse plant fragments, and emergent vascular plants along with occasional pieces of wood provided habitable surfaces projecting above the bottom. Similar conditions occur in extant lakes in less than 2 feet of water and in areas exposed to annual fluctuations of water level.

Land gastropods that occur with increasing frequency in the upper half of the section were washed in from a low wooded shoreline. Living specimens and shells of recently dead animals are abundant in the surface sample along with weathered fossil shells of aquatic mollusks. The most abundant land snails, *Vallonia pulchella*, *Gastrocopta tappaniana*, *Carychium exiguum*, and *Vertigo ovata*, still inhabit the open wooded and grassy area now established on this portion of the deposit.

The marl deposit on the north shore of Manitou Lake is 150 feet wide and formed on a shallow shelf. As sediment accumulated on the platform and lake level dropped, the shoreline portion was filled, invaded by emergent aquatic plants, and finally grown over by shore vegetation. The larger, lakeward part of the deposit was gradually exposed to wave action that became more intense as the lake level continued to fall. Wave action has cut a distinct bank, left a lag of coarse carbonate fragments on the bottom, and inhibited the development of littoral vegetation. Small clumps of *Chara*, sparse mats of aquatic moss, and a few emergent aquatic plants are scattered over the otherwise bare bottom. A bed of sedges grows offshore from a small peat bed on the west edge of the marl.

Little is precisely known about the chemical preferences and tolerance limits of freshwater mollusks, but pH ranges (Morrison, 1932, p. 389-396) associated with several species that occur in this deposit indicate a p& of 7.0-8.4 from Units 6 to 2. *Valvata lewisi* and *Sphaerium lacustre* suggest a pH of 7.1 to 7.7 for Unit 6, and the known values for *Pisidium adamsi* imply similar or lower values for the top of the section. Except for *P. ventricosum*, the species in Unit 3 are characteristic of more basic conditions. Any pH increase in Unit 3 that can be inferred from the mollusks was probably a microenvironmental difference produced by a local increase in photosynthetic activity and poor circulation rather than a change in water chemistry that occurred throughout the greater part of the lake. Within bog vegetation on the shore margin (Unit 1) pH probably dropped below neutrality. A pH range of 5 to 7 can be inferred from data presented by Dexter (1950, p. 22-25) for the margins of an alkaline bog in Ohio.

Three zones of aquatic mollusks occur in the Manitou Lake section. A lower zone that extends from the base of the marl to the base of Unit 3 is characterized by *Valvata lewisi* and *Sphaerium lacustre*, but *Gyraulus parvus*, *V. lewisi*, and *Pisidium variabile* are the most abundant species. The assemblage inhabited the deep outer margin of the littoral area. A middle zone, largely concurrent with Unit 3, contains *Pisidium ferrugineum*, *P. nitidum*, and *Valvata tricarinata* as the characteristic and most abundant species. Several other species reach their peak abundances in this zone. An upper zone of near-shore and shallow-water species begins near the top of Unit 3 and is marked by increases in *Pisidium adamsi, Lymnaea obrussa, Valvata tricarinata, Gyraulus parvus,* and allochthonous land snails. This assemblage continued into the overlying peat but was succeeded by land gastropods when filling and shoreline emergence were complete.

Lac Laflamme deposit

The early history of Lac Laflamme is similar to that of Manitou Lake. Both lakes occur at about the same elevation and the stages and time of marine recession were probably the same in both basins.

Across low terrain on its west shore, Lac Laflamme connects with Lac Bernard, a much larger body of water to the south. During the last stages of marine conditions and its earliest freshwater phase, Lac Laflamme was part of a continuous water body that included Lac Bernard and several smaller lakes. When the 14-foot beach along the north shore was constructed, these basins were isolated from the main valley except for narrow connections through low valleys east of Lac Bernard and along the northern path of present drainage.

There is no sedimentary evidence of a long transition period between marine and freshwater conditions. Marine clay at the graded contact with freshwater sediments contains both fresh and weathered tests of Foraminifera. At least part of this material was reworked during the period of transition from brackish to fresh water. Salinity levels tolerable by a few species of near-shore Foraminifera may have persisted for some time after the depression was more or less isolated from open water in the Gatineau Valley arm of the Champlain Sea.

In the sampled section, the first undoubted freshwater sediment is marl intermixed with clay and clay fragments (Unit 5). The base of this unit (Sample 37) contains 17 of the 27 freshwater mollusk species found in the deposit. The graphs of relative abundance of mollusks (Plates VI, VII, and VIII) show an uncharacteristic degree of uniformity throughout the section. Species that generally exhibit long vertical ranges and pronounced fluctuations in abundance in other deposits maintain rather constant numbers throughout the section. Near-shore aquatic species and land snails occur unusually low in the section. Eight species of land gastropods were recovered from the lowest marl unit. The steep slope of the submerged shelf and shoreline slope enabled material f-er shore and adjacent wooded slopes to be transported into offshore areas by gentle currents and surface runoff. The most abundant mollusks, *Amnicola limosa, Valvata tricarinata,* and *Gyraulus parvus,* are inhabitants of plant beds; plant detritus, charophyte oogonia, and carbonate casts of *Chara* stems are abundant in the sediment. Vascular plants and charophytes were well established at the beginning of marl deposition. Freshwater mussel glochidia are common near the base and indicate that the lake was colonized by unionid clams and their fish hosts early in its history.

The mollusks in Unit 5 are inhabitants of the littoral zone of lakes, generally at depths of less than 12 feet. Marl occurs about 3 feet above present lake level and water level apparently stood at or near the 5 foot terrace during the early stages of marl deposition. The sample was under about 12 feet of water and initial deposition began in over 20 feet of water on the lakeward margin where up to 15 feet of marl accumulated.

The trend toward increasing purity of the marl that occurs upward through Unit 5 stops at an overlying bed of interspersed fossiliferous marl, clay and clay fragments, coarse plant material, and wood (Unit 4). The wood layer, mostly small trunks and branches of birch, extends along the north shore and was dense enough to block an earlier attempt to excavate a pit 75 feet west of the sampled site. Many of the wood fragments are clearly charred and several of the larger pieces are pointed and bear distinct beaver incisor marks. The more abundant aquatic mollusks show few changes in the unit except for slight increases in *Pisidium ferrugineum, P. nitidum,* and *P. ventricosum.* The number of *P. adamsi* increases sharply. The abundance of *P. adamsi* and *P. ventricosum* seems to reflect the heavy accumulation of plant debris. These species usually appear near the top of sections where woody plant debris begins to accumulate in very shallow areas next to shore. These species must be used cautiously as depth indicators. *Lymnaea stagnalis* and *Gyraulus deflectus* first appear in this unit, probably as new arrivals to the lake. The number and variety of land snails increased and specimens representing 15 of the 18 species found at Lac Laflamme were recovered from this interval.

Unit 4 was laid down during a rapid influx of wood debris, driftwood, and eroded material. One or more forest fires generated wood debris and accelerated erosion on shoreline slopes by disrupting vegeta-

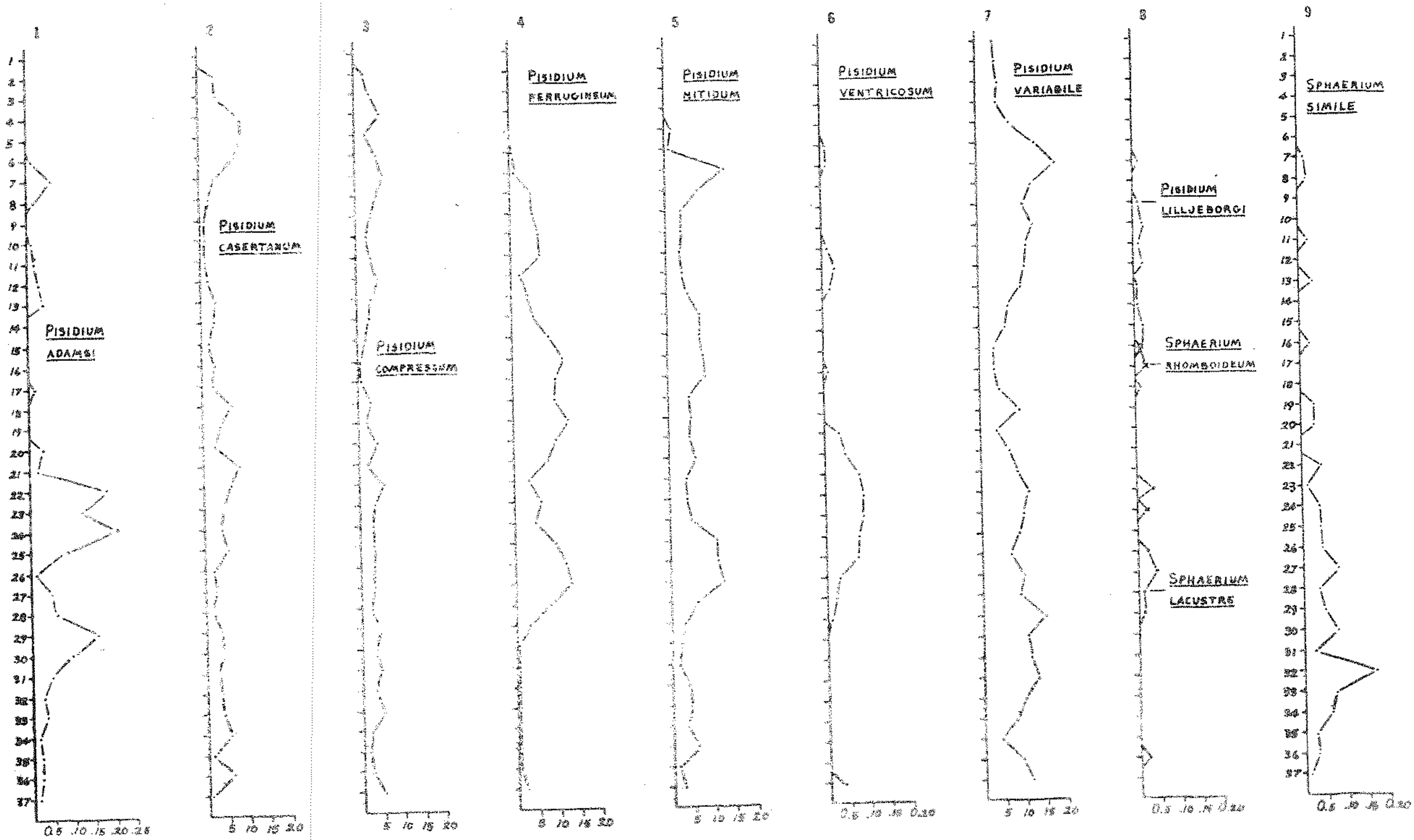


PLATE VI. VERTICAL CHANGES IN RELATIVE ABUNDANCE OF MOLLUSK SPECIES IN THE LAC LAFLAMME DEPOSIT.

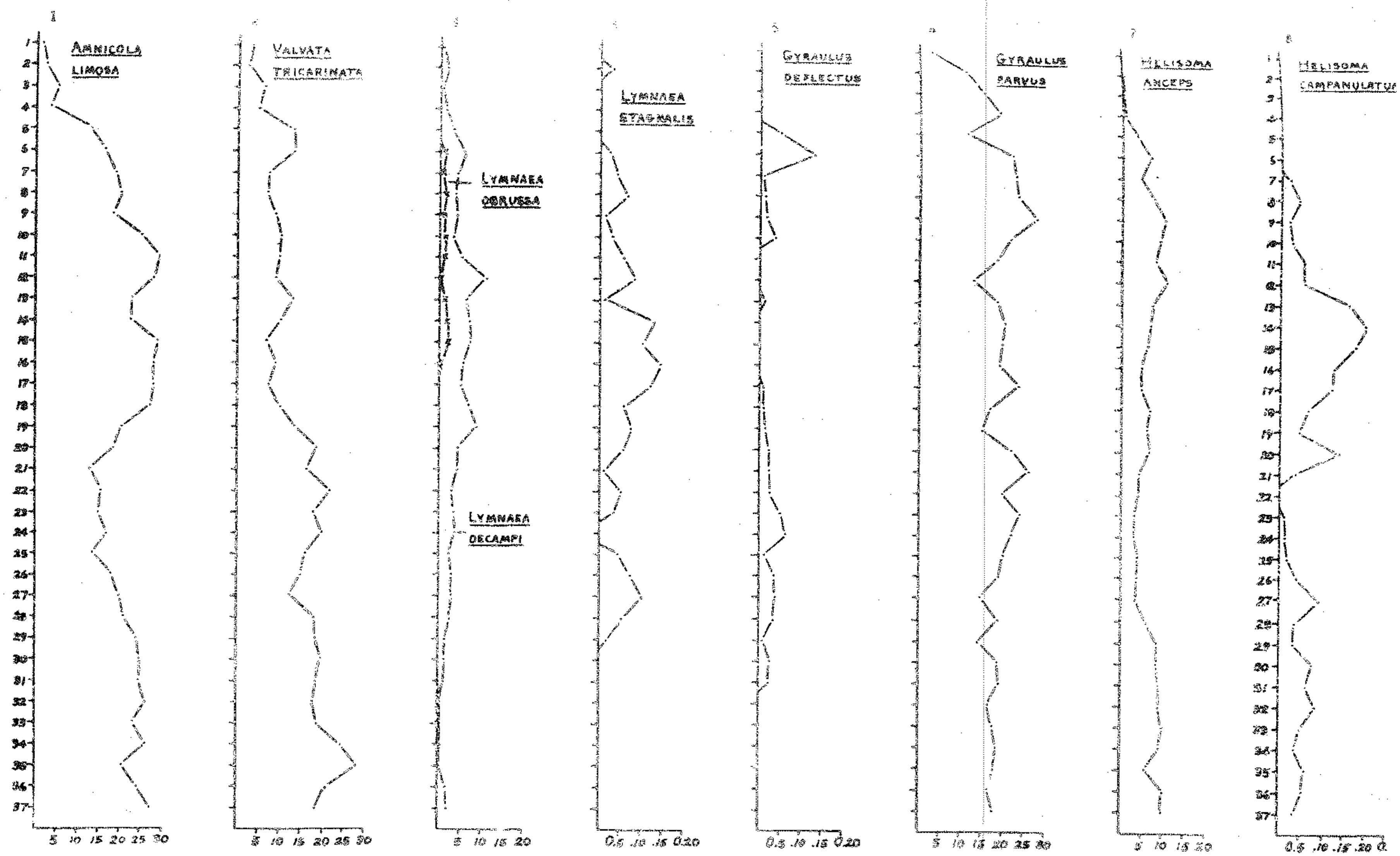


PLATE VII. VERTICAL CHANGES IN RELATIVE ABUNDANCE OF MOLLUSK SPECIES IN THE LAC LAFLAMME DEPOSIT.

ducing wood into the lake. Much of the wood probably accumulated as floating drift along this shore before becoming waterlogged and sinking. Surface runoff periodically dumped sand, clay, clay clumps, and fire debris into the littoral zone of the lake, and autochthonous sediment was also redistributed on the shelf by increased turbulence during these periods. The number of land snails and near-shore aquatic mollusks washed into deeper water increased. This episode of rapid sedimentation seemed to have little discernible effect on the aquatic mollusk assemblage, although it must have altered the bottom and aquatic plant beds for a short period of time. Slight declines in the numbers of *Amnicola limosa, Helisoma campanulatum,* and *H. anceps* may be partly due to disturbance of aquatic vegetation.

The wood layer is overlain by 4 inches of impure marl (Unit 3) that in turn grades into an overlying bed of relatively pure marl (Unit 2). Unit 2 is a white banded marl with vertically oriented plant parts. *Amnicola limosa, Gyraulus parvus, Pisidium variabile,* and *Valvata tricarinata* are the most abundant species. The first three of these reach their maximum abundances, whereas *V. tricarinata* continues a gradual decline that began near the base of the section. Species that live among vegetation in quiet water such as *Helisoma campanulatum, Lymnaea stagnalis,* and *L. decampi* are slightly more abundant. *Pisidium adamsi* and *P. ventricosum* whose maximum densities are reached along shore or in shallow water among detritus occur less frequently.

The most abundant species in Unit 2 are inhabitants of dense aquatic plant beds, generally in water less than 4 to 5 feet deep. Water stood between 2 and 3 feet above present level. Biogenic material produced in the littoral zone rather than allochthonous material dominates the sediment in this unit, but the continued occurrence of numerous land snails indicates that runoff still carried shore materials onto the shelf. The interval represents quieter and more stable littoral conditions than existed during the previous unit. *Lymnaea obrussa, Pisidium lilljeborgi,* and *Campeloma decisum* apparently invaded the lake at this time.

Mollusks that normally inhabit shallow areas wander into or occasionally inhabit deeper areas, but most of the specimens that are preserved as fossils in units deposited in deeper water are transported there by water currents or floating vegetation. Reduced current action in Unit 2 lessened the number of shallow water inhabitants being washed into deeper areas in the littoral zone. In deposits where only gentle currents prevailed and very little mixing of near-shore and offshore elements took place, the sudden appearance of a species may reflect the transition to near-shore conditions as filling progressed, as well as colonization. Most likely, a few specimens of *Lymnaea decampi* and *Campeloma decisum* would have appeared as allochthones in Unit 4 had populations been established in shallow areas near shore during deposition of this interval. *Campeloma decisum* was an early inhabitant of the Gatineau River drainage that managed to reach and establish populations in several of the larger lakes. Since it relies on upstream migration for dispersal, physical stream barriers evidently prevent its entry into many lakes. After reaching Lac Laflamme and giving birth to one and probably more generations, the population died off. The species requires a substrate of loose, fine sediment and the absence of extensive areas of suitable bottom type may have been a factor in its disappearance.

There is a sharp decline in the number of aquatic species in the top 14 inches of the section (Unit 1), and only two, *Pisidium casertanum* and *P. compressum* increase in number of individuals. The relative number of land snails increases appreciably, particularly *Vallonia pulchella, Gastrocopta tappaniana,* and *Carychium exiguum.* Calcareous clay at the base of the unit grades into a clay loam toward the top. Good drainage along this segment of the shoreline prevented peat accumulation during the final phases of filling. Peat beds overlie marl on the east end of this deposit, and the marl bed on the west shore where shoreline slopes are gentle and drainage is poor. Changes in the mollusk assemblage that are usually associated with heavy accumulation of plant detritus, such as increases in the number of *Gyraulus parvus* and *Pisidium adamsi,* do not occur at the top of this section. Reworked clastic sediment and organic detritus from shore and debris from stands of aquatic plants filled in the area after marl deposition ceased.

The land snail assemblage in the middle part of Unit 1 is characteristic of a moist woodland with abundant leaf litter of wood debris. The common species, *Gastrocopta tappaniana, Carychium exiguum, Nesovitrea electrina,* and *Oxyloma retusa* are inhabitants of lowland woods, usually near bodies of water. *Vallonia pulchella* dominates the top two samples and is a common species in the open pastureland habitat that now covers most of the south shore of Lac Laflamme.

The molluscan fauna indicates a pH range of 7.0 to 8.4. Values in the lower part of this range are suggested for Units 3 and 4 by the increases in *Pisidium adamsi* and *P. ventricosum*.

Many of the aquatic mollusks range throughout the section with only minor fluctuations in relative abundance. Several slight changes are associated with Units 3 and 4, but no distinct subdivision of the littoral assemblage is evident. An upper zone, coinciding with Unit 1, is distinguished by an increase in land snails and a decline in the number of freshwater mollusks.

Nesbitt Lake deposit

Nesbitt Lake, like the basins of Lac Laflamme and Manitou Lake, is underlain by Champlain Sea clay containing shallow-water Foraminifera, and the basin apparently had a similar history of transition from marine to freshwater conditions. There is a higher proportion of fresh tests of Foraminifera in the upper few inches of clay here than in the other deposits.

During the waning stages of the Champlain Sea invasion, Nesbitt Lake basin remained connected with Lac Gauvreau to the south and to a shallow portion of the Gatineau Valley arm that stood in lower valleys to the north and northeast. Several other small lakes, including Johnston Lake and Fairburn Lake, are associated with this area and drain across it to the Gatineau along with Nesbitt Lake.

On the southwest shore of Nesbitt Lake, weathered freshwater shells and scattered patches of marl and calcareous clay indicate that littoral sediments accumulated at least 2.5 feet above present lake level on this shore. Marl extends to about 3 feet above present lake level on the east shore. The marl beds on the whole contain more plant debris than the other deposits examined during this study. The freshwater unit that overlies marine clay (Unit 5) in the sampled section is a 17-inch interval of granular marl. Fragmented charophyte stem incrustations are the major constituents and account for the arenaceous texture.

Twenty of the 31 aquatic mollusks found in the deposit are present at the base of the marl (Sample 27). *Valvata tricarinata*, *Gyraulus parvus*, and *Pisidium nitidum* are the dominant species at the base and throughout the marl (Plates IX, X). *Amnicola limosa*, *Pisidium ferrugineum*, *Physa gyrina*, *Valvata lewisi*, and *Promenetus exacuous* are common in Unit 5, although each generally represents less than 10 percent of a total sample. *Gyraulus deflectus* appears about mid-way in the unit (Sample 23) and is present in all overlying samples. Several other less common species appear first near the top of Unit 5. *Pisidium nitidum*, *P. compressum*, *Amnicola limosa*, *Lymnaea decampi*, *L. palustris*, *Helisoma campanulatum*, and *Physa gyrina* reached their maximum relative abundances in this part of the section. Fragments of freshwater mussel shell and glochidium valves at the base of the marl are evidence of established mussel populations during the earliest freshwater phases of the basin.

The molluscan assemblage in this unit and the lower half of the section are characteristic of a moderately shallow littoral area, probably within a depth range of 5 to 10 feet. Most of the species, including *Gyraulus parvus*, *Pisidium nitidum*, and *Amnicola limosa* are abundant on or among rooted aquatic plants. Coarse plant fragments in the upper few inches of clay and lower few inches of marl are largely from narrow-leaved vascular plants. Deep-water vascular plants, possibly *Myriophyllum*, *Vallisneria*, and certain members of the Potamogetonaceae, were common at the beginning of freshwater conditions but were soon replaced by dense beds of *Chara* along this shore. Relatively stable littoral conditions and high biotic productivity were reached very soon after establishment of a freshwater environment. The lake was quickly colonized by aquatic mollusks. Very little material was washed onto the submerged shelf from shore, and a single specimen of *Oxyloma retusa* was the only land gastropod recovered from this interval.

The overlying marl units (Units 2-4) are generally similar to one another but represent a decrease in coarse plant detritus. Vertically oriented plant parts and abundant charophyte fossils occur in these intervals and there is no evidence of less aquatic plant growth. The decline in plant detritus apparently reflects a greater dominance of the alga, *Chara*, over vascular plants, or less plant material being carried into the lake. *Pisidium nitidum*, *Valvata tricarinata*, and *Gyraulus parvus* continue to be the most abundant species. *Pisidium ferrugineum*, *Sphaerium rhomboideum*, *S. simile*, *P. ventricosum*, and *Lymnaea stagnalis* increase in numbers, and *V. lewisi*, *S. lacustre*, and *L. palustris* decline in this interval. The common spe-

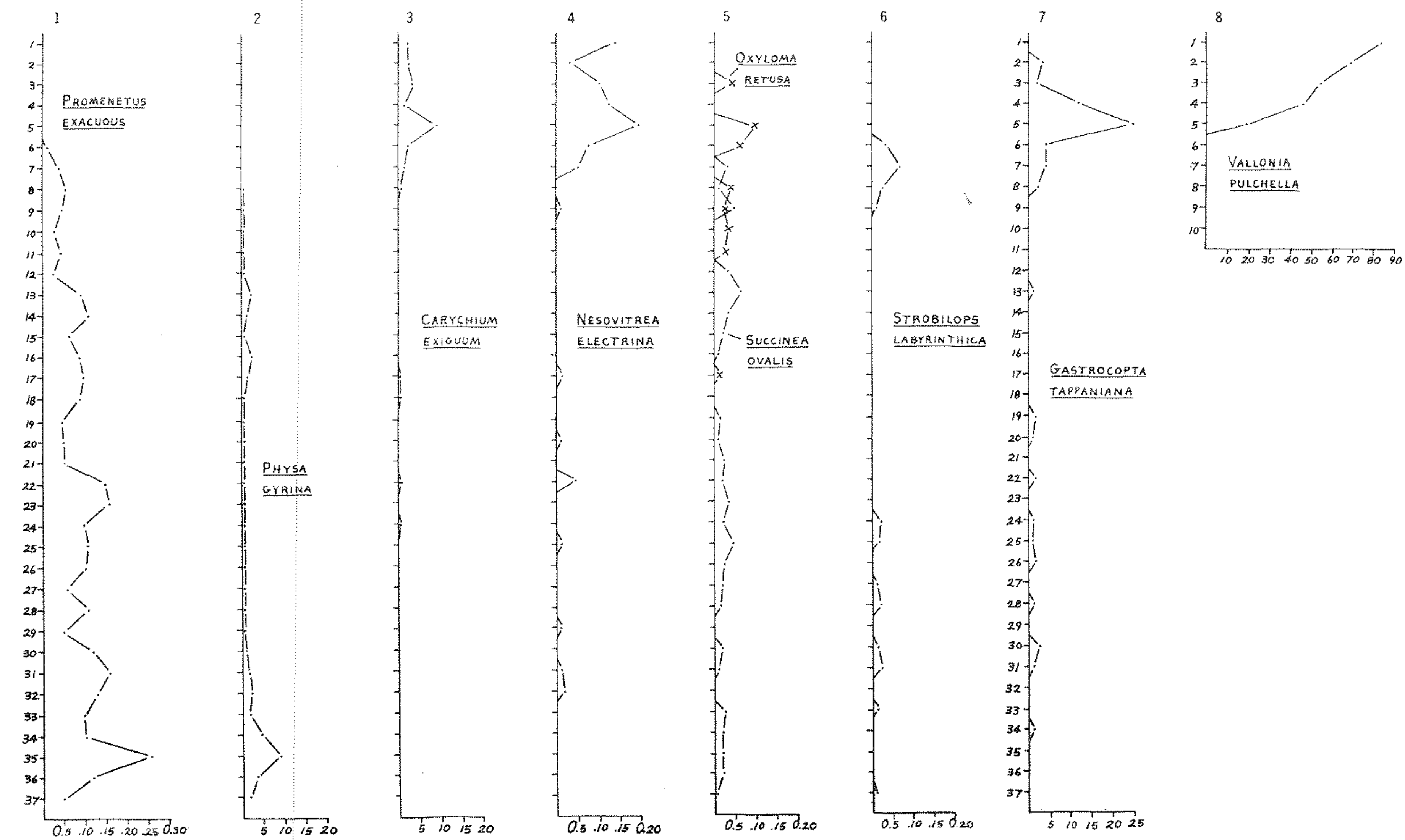
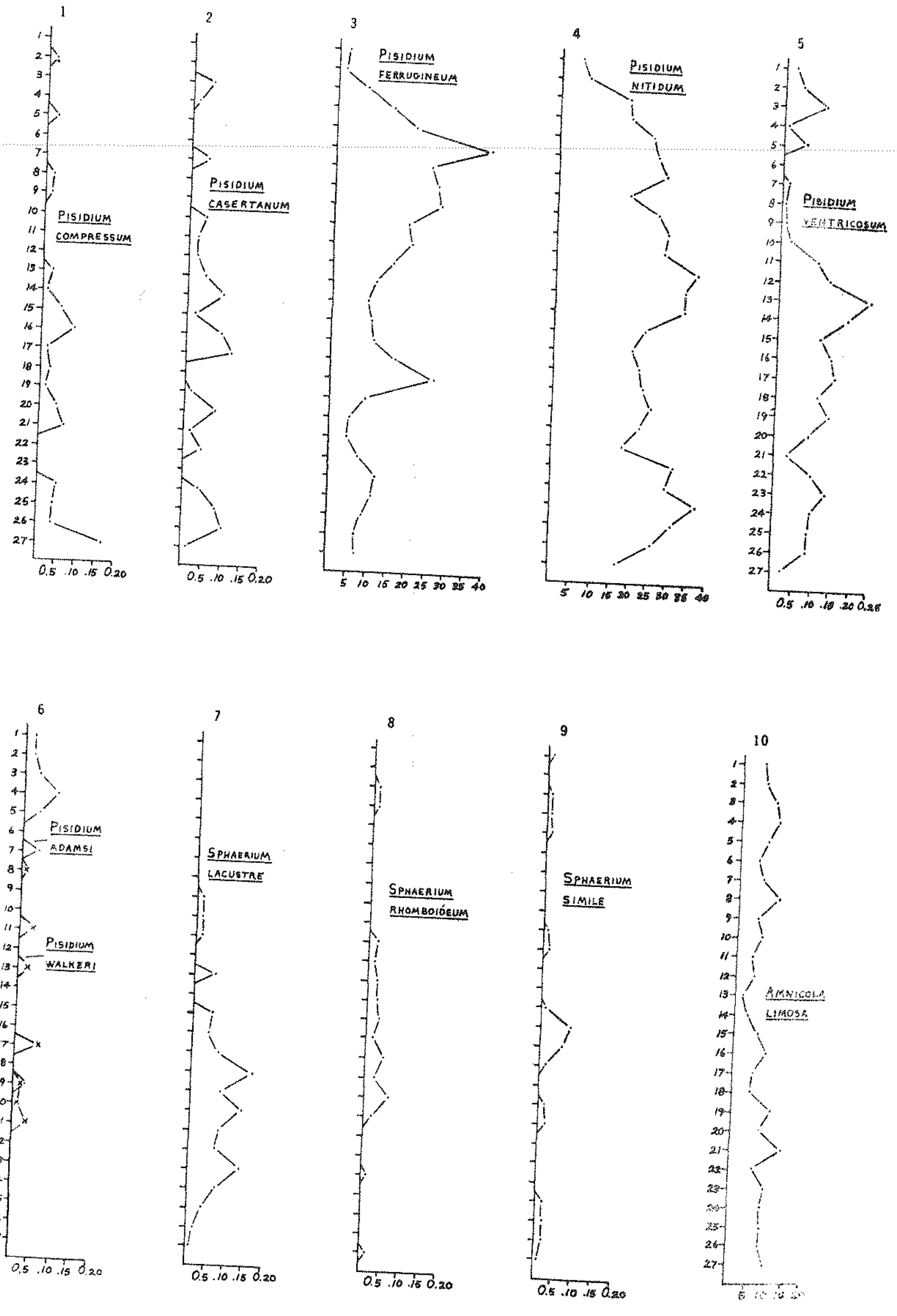


PLATE VIII. VERTICAL CHANGES IN RELATIVE ABUNDANCE OF MOLLUSK SPECIES IN THE LAC LAFLAMME DEPOSIT.



1
Pisidium compressum
0.5 .10 .15 0.20
2
Pisidium casertanum
0.5 .10 .15 0.20
3
Pisidium ferrugineum
5 10 15 20 25 30 35 40
4
Pisidium nitidum
5 10 15 20 25 30 35 40
5
Pisidium ventricosum
0.5 .10 .15 .20 0.25
6
Pisidium adamsi
Pisidium walkeri
0.5 .10 .15 0.20
7
Sphaerium lacustre
0.5 .10 .15 0.20
8
Sphaerium rhomboideum
0.5 .10 .15 0.20
9
Sphaerium simile
0.5 .10 .15 0.20
10
Amnicola limosa

cies and those reaching their maximum numbers are indicative of moderately shallow water (3 to 6 feet) and abundant vegetation. *V. lewisi* and *S. lacustre* occur in the lower parts and decline toward the top of the sections at Manitou Lake (Plate X) and Richardson Lake (Gibson, 1967, p. 7, 8). These species are characteristic of deeper littoral areas in marl lakes. The occurrence of *L. palustris* at the base of the section and its almost complete disappearance in higher units demonstrates a preference for deeper littoral areas that is contrary to published accounts of its shallow water habitat. The confused systematics of these animals cast doubt on conclusions drawn from the literature concerning their biology. Changes in the relative abundance of most species are slight or occur gradually, suggesting rather uniform conditions throughout the marl units.

Inhabitants of shallow-water plant debris close to shore increase near the contact between marl and the overlying unit of peat and marl (Unit 1). *Valvata tricarinata* and *Gyraulus parvus* are the dominant species and their relative abundance shows a resurgence in this interval that is a typical occurrence among shoreline vegetation and plant detritus. *Pisidium ferrugineum* and *P. nitidum* declined sharply in this unit but remained the most abundant sphaeriids. *Pisidium adamsi* and *P. ventricosum* increased when greater quantities of plant debris accumulated on the bottom. However, many species that were common in the marl also occurred in the top 2 inches of the section. Much of the organic detritus deposited in the late phase of filling has been lost during subsequent erosion. A drop in lake level apparently interrupted the bog stage of filling and exposed this area of the shore to erosion.

The land snail assemblage is characteristic of a moist woodland habitat and close proximity to water. The fauna is poor in species and numbers in comparison to those of Manitou Lake and Lac Laflamme.

Mollusks and lithology indicate a pH range and vertical sequence of change in temperature and pH similar to that inferred for Manitou Lake. Vertical changes in the Mollusca are more gradual in the Nesbitt Lake section than in the Manitou Lake deposit, and variation in environmental conditions may have been equally gradual.

Three molluscan zones are evident in the Nesbitt Lake section. A lower zone that includes Unit 5 and part of Unit 4 is dominated by *Pisidium nitidum*, *Valvata tricarinata*, and *Gyraulus parvus*. *Sphaerium lacustre*, *Valvata lewisi*, and *Lymnaea palustris* distinguish the assemblage as one occurring in a deeper portion of the littoral environment. The middle zone represents a transition from offshore to shallow, marginal conditions. *Pisidium nitidum*, *P. ferrugineum*, *Valvata tricarinata*, and *Gyraulus parvus* are the most abundant species. *Lymnaea stagnalis*, *Sphaerium rhomboideum*, *S. simile*, and *Ferrissia parallela* increase in the lower part, and *Lymnaea obrussa* and *Pisidium adamsi* occur in the upper portion. Intermingling of near-shore and offshore elements occurred in the interval. The assemblage changes near the contact of Units 1 and 2 where material from shoreline vegetation increases in the sediment. Samples are composed mostly of *Gyraulus parvus* and *Valvata tricarinata*, most other aquatic mollusks decrease in number, and land gastropods become more frequent.

Southwest Venosta deposit

The basin of the Southwest Venosta deposit is smaller and shallower than those of the other extant lakes sampled in this study. Although the lake appears to have an extensive zone of open water, observations from shore and aerial photographs reveal shallow beds of submerged aquatic plants across the northern half of the lake and far from shore in the southern half. A profundal zone, if present, is restricted to a small area in the southern half of the lake. The basin is in a later stage of filling than the other Gatineau Valley sites and mostly peat is being deposited at present. Bog peat is accumulating on the northern margin and lake peat covers the shallow bottom, at least in areas that could be observed from shore.

The marl deposit extends to 6 inches above present water level on the north shore. It is exposed or covered by a few inches of peaty material and scattered clumps of grasses where above water. Seasonal increases in water level inundate much of this marl meadow and bog area. Many fresh shells of *Helisoma trivolvis*, *Lymnaea stagnalis*, and *Oxyloma retusa* lie on the surface along with fossil specimens of other species eroded from the marl.

The marl has a fine texture and light gray color. Coarse plant fibers are present but there is very little fine plant detritus interspersed with the carbonate.

No fossils were recovered from the sand that underlies peat and marl beds in this deposit and the material may be of marine or post-marine freshwater origin. During freshwater marl deposition, water level probably stood about 2 feet higher than the present level in order to produce relatively pure marl on the outer margins of the deposit. Most of this increase in lake area involved the north shore within the areas of marl and peat in Figure 8. Other parts of the shoreline are rather steeply banked and a 2 foot rise in water level would only slightly increase the submerged area.

The molluscan assemblage (Table 5) includes fewer species than are present in the Manitou Lake, Lac Laflamme, and Nesbitt Lake deposits, and several factors may be responsible for the lack of variety. The basin is somewhat isolated about 50 feet above the larger and more closely connected lakes to the northeast, and the early stage of marl deposition may have been too short to allow colonization by a great number of species, especially those that disperse along waterway connections. The absence of freshwater mussels or their glochidia supports this possibility. Also, the fine textured marl and worn fragments of charophyte casts suggest that the shelf was exposed to current agitation strong enough to break and abrade delicate incrustations into fine particles but not strong enough to disturb aquatic vegetation greatly. A maximum depth of about 3.5 feet decreasing to less than 18 inches in the last stages of marl deposition restricted vegetation to rather short plants that offer a minimum of protection and habitable surface area. These conditions may have been unsuitable for certain species.

Gyraulus parvus and *Pisidium variabile* were the most abundant species in the sample, whereas *Valvata tricarinata* accounted for only 2 percent of the total specimens. The mollusks are inhabitants of shallow and well vegetated littoral areas where marl is accumulating. The large number of *Pisidium variabile* in a habitat where *P. nitidum* and *P. ferrugineum* are usually the most common bottom dwellers, apparently reflects the unstable bottom conditions that existed during marl deposition. The unusually low number of *Valvata tricarinata* might be related to the presence of current action.

The fossil assemblage is quite different from the living fauna sampled along the present shore, and from stranded specimens on the bog meadow. *Helisoma trivolvis* is very abundant, and *Lymnaea stagnalis* and *L. megasoma* are fairly common at present in the lake. No specimens of these lymnaeids and only one specimen of *H. trivolvis* were recovered as fossils from the marl or peat beds. *Valvata tricarinata* and *Helisoma anceps* were not found alive but collecting offshore might have produced specimens. *L. megasoma* apparently colonized the lake after the early stage of marl deposition.

Wilsons Corners deposit

Waddington (1950, p. 16) states that marl overlies sand and is overlain by peaty material in a marsh between two lakes at Wilsons Corners (Fig. 6). The grab sample examined in this study came from freshly exposed marl that had been bulldozed over the present lake shoreline as fill. It was impossible to determine if the marl was moved in from a landward position or dredged from below water level and redistributed as fill.

The mollusks were studied primarily to gain distribution records, since the value of most paleoecological conclusions is limited by the absence of detailed information concerning field relationships of samples. Although the marl is quite fossiliferous, it contains the smallest number of species of any deposit sampled in this study. *Valvata tricarinata, Gyraulus parvus*, and *Pisidium compressum* together account for 95 percent of the specimens (Table 5). *Amnicola limosa, Helisoma anceps striatum, Lymnaea decampi*, and a single specimen of *Vertigo* sp. make up the rest of the assemblage. The species are common inhabitants of shallow and well vegetated littoral zones of marl lakes. The presence of charophyte beds is verified by abundant stem casts and oögonia. Fragments of narrow-leaved vascular plants and occasional pieces of moss are also present. The numerical dominance of *V. tricarinata, Gyraulus parvus*, and a species of *Pisidium* tolerant of near-shore conditions suggests that the sample accumulated in a shallow (2-4 feet) portion of a littoral marl bed during the waning stage of marl deposition.

Rochester Street deposit

A depression cut by a former stage of the Ottawa or Rideau Rivers remained as a shallow ponded body after the stream abandoned this channel for a lower course. The sequence of coarse sand overlain by silty clay at the base of the section was deposited during the last phase of fluvial activity or an initial stage of lacustrine sedimentation. No mollusks, ostracodes, or plant macrofossils were found in these

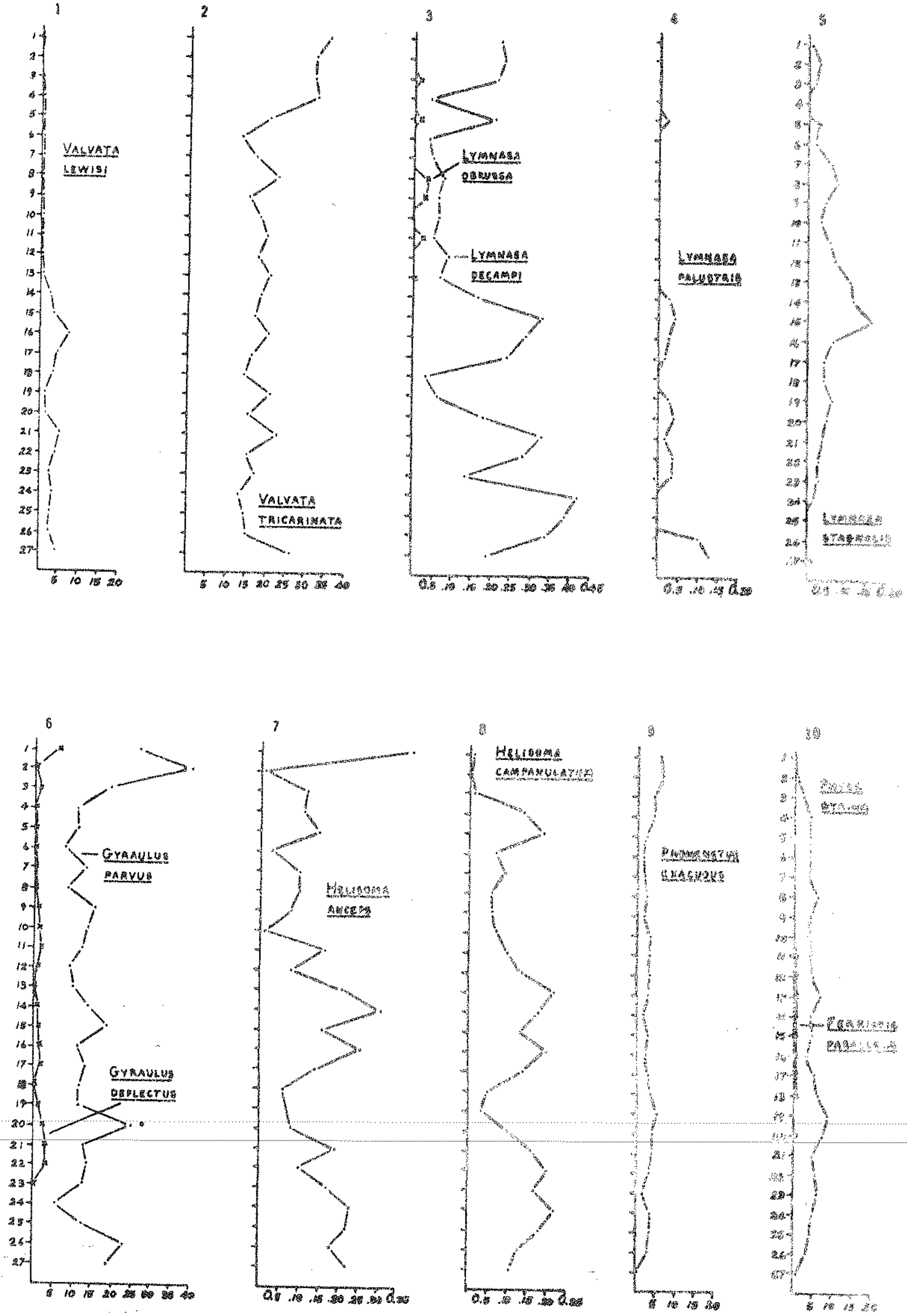


PLATE X. VERTICAL CHANGES IN RELATIVE ABUNDANCE OF MOLLUSK SPECIES IN THE NESBITT LAKE DEPOSIT.

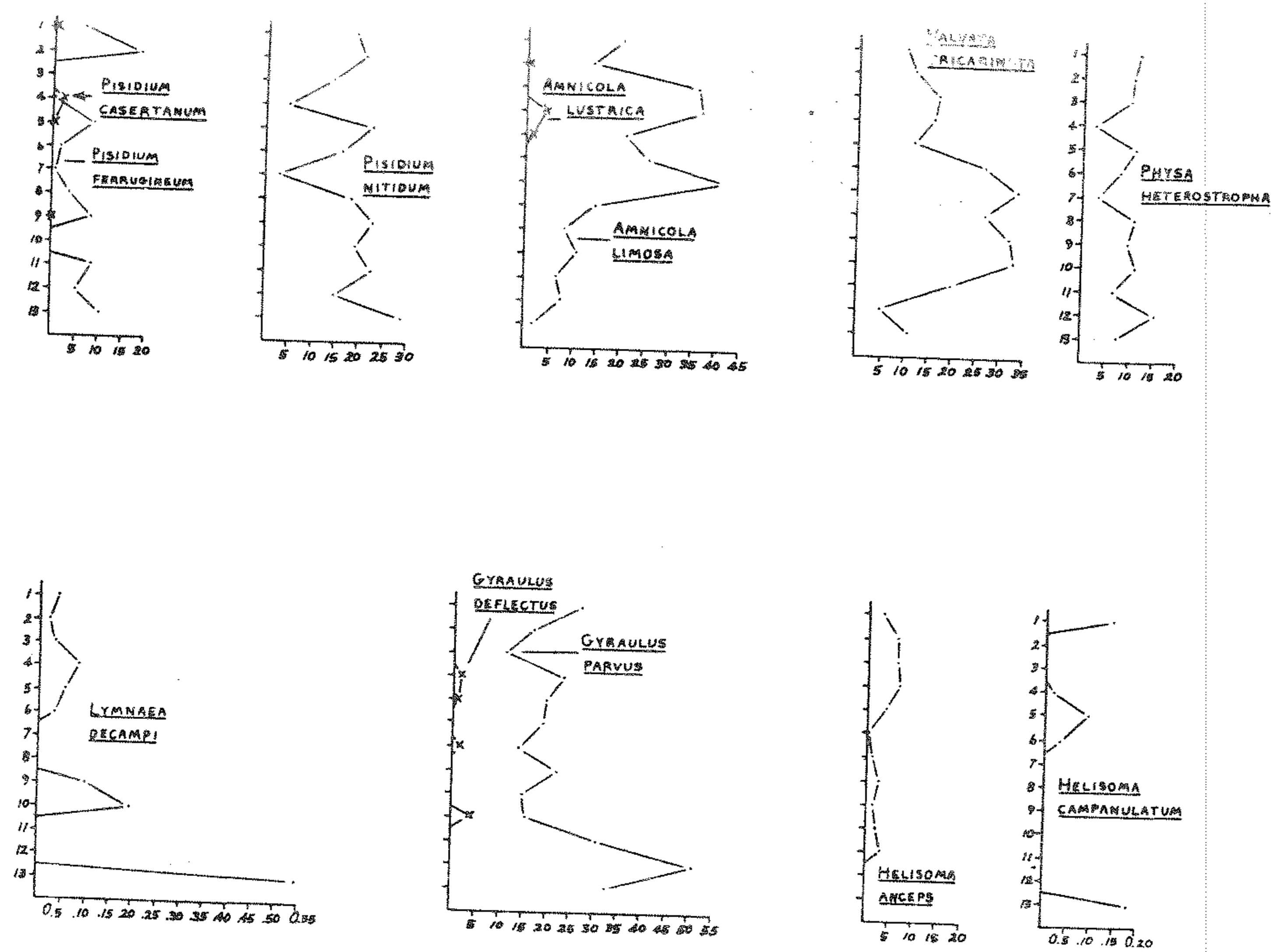


PLATE XI. VERTICAL CHANGES IN RELATIVE ABUNDANCE OF MOLLUSK SPECIES IN THE ROCHESTER STREET DEPOSIT.

clastic units. Pollen stratigraphy indicates that marl deposition began about 7000 years BP. but a C-14 date suggests a greater age.

Mollusks in the marl unit (Plate XI) are characteristic of a moderately shallow littoral habitat with water depths of less than 8 or 9 feet. The Mollusca indicate a pH range of 7.0-8.2. The abundant species are all inhabitants of plant beds. At least seven thin bands of plant detritus occur in the unit and lighter colored marl layers contain abundant charophyte stems, oögonia, and vascular plant detritus. Increase in *Amnicola limosa* and *Helisoma anceps* upward through the unit may have been in response to increases in plant density. *Gyraulus parvus*, but not *Valvata tricarinata*, increases at the top of the marl. Any complete molluscan transition to bog conditions occurred during deposition of overlying peat units. The somewhat erratic fluctuations in the relative abundance of *Lymnaea decampi* and *Helisoma campanulatum* are probably a function of sample size. A small quantity of sediment will not adequately sample populations of larger sized or less common molluscan species.

Marl production halted as the depression filled with marl and plant debris, and marsh vegetation constricted the area of open water. About 2 feet of plant detritus accumulated during the last stage of filling when a bog habitat prevailed.

McKay Lake deposit

Marl beds at McKay Lake are situated on the east and south shorelines about 15 to 20 feet above present lake level. The lake outlet empties into the Ottawa River and has cut a valley 25 to 40 feet deep into Champlain Sea and post-marine clays (Whittaker, 1922, p. 143). Present lake level is about 15 feet above the Ottawa River. The beds were deposited during a higher water level, probably at a late stage of post-Champlain Sea fluvial deposition in the Ottawa Lowland when the Ottawa River stood at a slightly higher level than at present. Whittaker (1922, p. 142) states that these sediments formed during the last stages of marine invasion but assumed that the drop in lake level was due wholly to headwater downcutting of the outlet stream. More likely, this early stand was maintained by a higher stage of the Ottawa River and a higher water table in the lowland, at a time when the regional uplift was not yet complete. When the Ottawa River assumed a lower level, the drop in baselevel enabled the discharge from McKay Lake to deepen the outlet channel and lower lake level.

Whittaker (1918, p. 15 and 1922, p. 153) studied the Pleistocene Mollusca of McKay Lake in detail. A marl sample was examined to verify his results and to evaluate his paleoecological interpretations. My list adds only *Pisidium ferrugineum*, *P. variabile*, *P. lilljeborgi*, *Lymnaea decampi*, and *Oxyloma retusa* to the fauna. These minor additions may have been lumped into *P. casertanum*, *L. obrussa*, and *Succinea ovalis* by Whittaker. Whittaker (1921, p. 65) reported several land gastropods from the deposit but only one terrestrial species occurred in my sample.

Gyraulus parvus, *Valvata tricarinata*, and *Amnicola limosa* are the most abundant species but *Lymnaea decampi*, *Helisoma anceps striatum*, *Physa heterostropha*, and *Pisidium casertanum* are common, although less abundant (Table 5). *P. casertanum* occurs in a wide range of habitats [illegible] an optimum depth range of less th[illegible] 3 meters, and *Physa heterostropha* also lives in a variety of lacustrine habitats. The other species are usually associated with abundant aquatic vegetation in shallow water. A pH range of 7 to 8 is indicated by the mollusks. Similar values were reported from the present water body by Kindle (1927, p. 5).

Charophyte oögonia and vascular plant detritus are abundant, but only a few Chara stem casts can be seen in the compact material. The fine-grained and relatively pure marl is similar in appearance to that of the Southwest Venosta deposit. The south and east shorelines of McKay Lake were apparently exposed to wave action during the higher water level. Present lake level is much lower in the basin and the water surface is more protected from wind turbulence. Whittaker (1918, p. 17) notes that fossils of some species, especially *Valvata tricarinata* and *Helisoma campanulatum*, were smaller than living specimens at McKay Lake and concludes that the fine-textured marl produced an unsuitable molluscan habitat. The great abundance of fossils in the deposit contradicts this conclusion. Whittaker (1921, p. 146-155) also described existing molluscan habitats in McKay Lake. He notes an absence of pronounced wave or current action, a large proportion of organic deposits, absence of marl production, and the occurrence of most mollusks along the shore where emergent aquatic plants are absent and the bottom is a soft, black mud. This habitat is different from that represented in the marl deposit and many altered factors such as nutrients, wave and current action, type of submerged surfaces, interspecific competition, as well as bottom type can account for size differences. The littoral environment that exists today in McKay Lake is more similar to that represented in peat beds overlying marl units. However, the small number of species in this marl deposit as compared with other deposits may be a function of current and wave action making the shallow littoral zone a less suitable habitat for certain species that require quiet bottom conditions. The exact position of the sample in the section is unknown but the abundance of aquatic plant inhabitants and the rarity of land snails suggests a position in the lower or middle third of the marl bed.

CONCLUSIONS

Paleoecology

Regional aspects

Eutrophic lakes formed in several of the deeper basins in the Gatineau Valley very soon after they emerged from the Champlain Sea. Water in the depressions changed from marine to fresh in a relatively short period of time. Some early stages in the transition from oligotrophy to eutrophy such as transport of soluble nutrients into the basins and initial influxes of sediment from freshly exposed watersheds apparently took place during the marine episode or its waning stages.

Lake levels have fallen in the Gatineau Valley since the beginning of freshwater deposition. High stands during the early history of the basins were controlled by water remaining at sea level in the main valley. As regional uplift continued, basins became more isolated and outlet downcutting controlled lake levels. The Rochester Street and McKay Lake deposits both reflect lowering of the Ottawa River and a general lowering of the water table in the Ottawa Lowland. Freshwater bodies were in all likelihood more numerous and more closely connected than at present on uplands surrounding the high stand of the Champlain Sea, and freshwater organisms were able to disperse throughout this system of surface water quite rapidly. Nonmarine Mollusca that migrate along watercourses, such as Naiades, were able to colonize basins early in their freshwater history. The more ubiquitous freshwater forms that disperse by passive means undoubtedly moved quickly into new areas under these conditions.

The Late Wisconsin molluscan fauna is similar to that now inhabiting southern Ontario and Quebec. Except for possible minor fluctuations in temperature and precipitation, the assemblage existed in lacustrine environments not too different from those now characteristic of the region. There is no reliable indication in the fossil Mollusca of post-glacial climatic fluctuations recorded in the pollen stratigraphy. Climatic variations were possibly not severe enough to affect lacustrine mollusk assemblages. It is difficult to differentiate between complex microenvironmental conditions in lakes and minor fluctuations in regional climate; therefore, utmost care should be used in drawing climatic inferences from aquatic organisms under these circumstances. In southern deposits, for instance in Ohio, the occurrence of *Helisoma anceps striatum*, *Pisidium ferrugineum*, *Promenetus exacuous*, and other northern species in littoral sediments is a valid indication of cooler temperatures than at present. When temperature variation seems to be the best explanation for changes in fossil populations of stenothermal mollusks from within their present geographic range, temperature variation within the water body should be considered before any past variation in regional climate is assumed.

Molluscan habitats

Four molluscan habitats are represented in the lacustrine sequences examined in this study. Watts and Bright (1968, p. 860) named and described several habitats of living mollusks in conjunction with a study of Pickerel Lake, South Dakota and two of their terms are adopted here.

The sheltered lacustrine habitat of Watts and Bright (1968, p. 860) includes shallow areas generally less than 10 feet deep, where the bottom is soft marl and gyttja. Rooted aquatic vegetation is dense, with scattered open areas, and very little wave or current action disturbs the water. It is represented in the lake deposits of this report by impure, poorly sorted marl and marly gyttja with a conspicuous coarse-carbonate fraction of plant encrustations. Fine to coarse organic plant detritus is common and larger fragments of plant parts

TABLE 3. Vertical distribution of species in the Nesbitt Lake deposit, Quebec, Canada

Sample	Sphaerium lacustre	Sphaerium rhomboideum	Sphaerium simile	Pisidium adamsi	Pisidium casertanum	Pisidium compressum	Pisidium ferrugineum	Pisidium lilljeborgi	Pisidium nitidum	Pisidium variabile	Pisidium ventricosum	Pisidium walkeri	Naiade fragments	Valvata lewisi	Valvata tricarinata	Amnicola limosa	Lymnaea dalli	Lymnaea decampi	Lymnaea obrussa	Lymnaea palustris	Lymnaea stagnalis
1	-	-	1	2	-	-	20	-	39	-	2	-	-	2	284	64	-	17	-	-	1
2	-	-	-	3	-	2	15	-	83	-	5	-	1	-	365	68	-	26	-	-	3
3	-	1	1	4	5	-	74	-	173	-	11	-	-	3	319	93	-	21	1	-	2
4	-	1	1	10	2	-	169	-	216	-	1	-	-	2	382	112	-	5	-	-	-
5	-	-	2	5	-	3	262	-	312	-	8	-	-	19	273	95	-	28	2	2	5
6	-	-	-	-	-	-	518	-	333	-	-	-	-	2	174	68	-	5	-	-	3
7	-	-	-	6	6	-	343	-	385	-	2	-	-	4	244	87	-	7	-	-	9
8	-	-	-	-	-	2	301	1	203	-	1	1	-	5	265	117	-	9	4	-	9
9	2	-	-	-	-	2	374	-	355	-	1	-	-	9	214	70	-	9	4	-	[illegible]
10	2	-	1	-	6	-	267	-	394	-	3	-	-	7	259	87	-	9	-	-	5
11	2	3	2	-	3	-	263	-	362	-	13	4	-	2	271	56	-	7	3	-	8
12	-	2	-	-	3	-	206	-	493	-	18	-	-	3	249	64	-	12	-	-	10
13	14	3	-	-	6	3	143	-	438	-	32	3	-	8	279	26	-	9	1	-	15
14	-	3	1	-	12	1	113	-	425	-	24	-	-	33	345	40	-	21	-	3	15
15	5	3	8	-	2	5	102	-	241	-	12	-	-	39	183	62	-	35	-	4	17
16	5	2	7	-	11	10	130	-	240	-	17	-	-	89	252	101	1	35	-	3	8
17	9	6	2	-	15	2	207	-	280	-	20	8	-	58	229	65	-	31	-	1	5
18	19	3	-	-	-	3	304	-	263	-	13	-	-	40	159	52	-	4	-	-	5
19	10	8	2	3	2	2	114	-	322	-	18	2	-	16	275	135	-	8	-	3	8
20	14	2	2	-	8	4	53	-	230	2	9	1	-	15	162	78	-	19	-	4	5
21	9	-	-	-	2	8	55	-	214	-	4	4	-	64	232	164	-	40	-	2	4
22	8	-	-	-	5	-	85	-	363	-	11	-	-	49	180	68	-	33	-	4	3
23	17	1	-	-	-	-	148	1	368	-	17	-	-	32	216	115	-	17	-	4	3
24	8	-	2	-	4	5	115	-	394	-	10	-	-	31	143	92	-	44	-	-	1
25	4	-	2	-	8	4	87	-	315	-	9	-	-	26	147	85	-	39	-	-	-
26	2	-	2	-	11	4	75	-	272	-	9	-	-	25	160	88	-	35	-	11	-
27	1	2	1	-	17	22	90	-	212	-	3	-	1	53	328	122	-	24	-	16	1

Sample	Gyraulus deflectus	Gyraulus parvus	Armiger crista	Helisoma anceps	Helisoma campanulatum	Helisoma trivolvis	Promenetus exacuous	Ferrissia parallela	Ferrissia walkeri	Physa gyrina	Carychium exiguum	Paravitrea multidentata	Nesovitrea electrina	Deroceras	Helicodiscus parallelus	Oxyloma retusa	Succinea ovalis	Strobilops labyrinthica	Strobilops aenea	Vertigo ovata	Total Specimens
1	5	210	-	3	1	-	46	-	-	1	2	-	6	-	2	-	-	6	2	-	784
2	3	452	-	6	1	-	74	-	-	7	-	2	3	-	-	-	-	1	-	-	1120
3	8	194	-	12	1	-	42	-	-	23	-	-	-	-	-	-	-	1	-	-	989
4	3	126	-	13	16	1	50	-	-	48	-	-	-	-	-	-	-	-	-	1	1159
5	3	148	-	20	25	-	33	-	-	49	-	-	-	-	-	-	-	-	-	-	1295
6	7	106	-	4	10	-	22	-	-	50	-	-	6	-	-	-	-	-	-	-	1303
7	3	190	-	15	9	1	26	-	-	54	-	-	-	1	-	-	-	-	-	-	1392
8	5	104	-	12	7	-	26	-	-	65	-	-	-	-	-	-	-	-	-	-	1137
9	10	210	-	12	9	-	25	-	-	58	-	-	-	-	-	-	1	-	-	-	1372
10	22	193	-	18	11	-	50	-	-	48	-	-	-	-	-	2	1	-	-	-	1385
11	25	166	-	23	14	-	43	1	-	52	-	-	2	-	-	-	-	-	-	-	1324
12	12	132	1	11	20	-	47	3	1	67	-	-	-	-	-	-	-	-	-	-	1354
13	6	139	-	28	29	-	38	1	1	94	-	-	-	-	-	-	-	-	-	1	1317
14	10	187	-	39	24	-	23	2	-	57	-	-	-	-	-	-	-	-	-	-	1278
15	14	196	-	17	14	-	31	1	-	50	-	-	-	-	-	-	1	-	-	-	1042
16	21	144	-	31	24	-	32	2	1	40	-	-	-	-	-	-	1	-	-	-	1207
17	22	173	-	19	18	-	42	2	-	68	-	-	-	-	-	-	1	-	-	-	1283
18	4	139	-	7	6	-	42	3	-	74	-	-	-	-	-	-	-	-	-	-	1150
19	13	150	-	9	4	-	62	-	-	115	-	-	-	-	-	-	-	-	-	-	1281
20	25	260	1	9	11	-	40	3	-	78	-	-	-	-	-	-	-	-	-	-	1036
21	38	159	-	23	20	-	47	-	-	59	-	-	-	-	-	-	-	-	-	-	1199
22	38	161	-	12	23	-	41	-	-	68	-	-	-	-	-	-	-	-	-	-	1152
23	2	165	-	22	22	-	23	-	-	78	-	-	-	-	-	-	-	-	-	-	1252
24	-	62	-	25	24	-	38	-	-	58	-	-	-	-	-	-	-	-	-	-	1055
25	-	127	-	22	18	-	34	-	-	45	-	-	-	-	-	-	-	-	-	-	1001
26	-	242	-	19	14	-	34	-	-	36	-	-	-	-	-	-	-	-	-	-	1039
27	-	236	-	28	14	-	33	-	-	35	-	-	-	-	-	-	-	-	-	-	1240

TABLE 4. Vertical distribution of species in the Rochester Street deposit, Ontario, Canada

Sample	Pisidium casertanum	Pisidium ferrugineum	Pisidium lilljeborgi	Pisidium nitidum	Pisidium variabile	Valvata lewisi	Valvata tricarinata	Amnicola limosa	Amnicola lustrica	Lymnaea decampi	Gyraulus deflectus	Gyraulus parvus	Helisoma anceps	Helisoma campanulatum	Promenetus exacuous	Ferrissia parallela	Physa heterostropha	Total Specimens
1	1	66	1	199	-	-	108	217	-	4	-	278	32	15	-	1	121	1043
2	-	90	-	103	-	-	59	72	1	1	-	83	30	-	1	-	52	492
3	-	-	-	30	2	-	36	76	-	6	-	25	13	-	-	1	21	210
4	9	1	-	38	-	-	124	272	30	6	10	174	48	1	-	-	18	731
5	4	49	-	127	-	-	69	118	7	3	5	110	21	5	-	-	62	559
6	-	6	-	53	-	-	88	83	-	1	-	62	2	1	-	-	25	321
7	-	1	-	6	-	-	67	83	-	-	3	28	2	-	-	-	6	196
8	-	3	-	15	-	-	22	12	-	-	-	18	2	-	-	-	9	81
9	2	26	-	68	-	-	98	25	-	3	-	45	4	-	--	-	29	301
10	-	-	-	10	-	-	17	6	-	1	2	8	1	-	-	-	6	51
11	-	5	-	13	-	1	12	4	-	-	-	18	2	-	-	-	4	59
12	-	2	-	6	-	-	2	3	-	-	-	20	-		-	-	6	39
13	-	6	-	16	-	-	6	1	-	3	-	18	-	1	-	-	4	55

TABLE 5. Number of specimens in samples from the Wilsons Corners, Southwest Venosta, and McKay Lake Deposits, Ontario and Quebec, Canada

Deposit Sampled	Sphaerium lacustre	Pisidium casertanum	Pisidium compressum	Pisidium ferrugineum	Pisidium lilljeborgi	Pisidium nitidum	Pisidium variabile	Valvata tricarinata	Amnicola limosa	Lymnaea decampi
Wilsons Corners	-	-	367	-	-	-	-	735	43	7
Southwest Venosta	4	19	-	6	-	66	496	27	-	46
McKay Lake	-	60	-	8	4	-	6	216	156	80

Deposit Sampled	Lymnaea obrussa	Gyraulus deflectus	Gyraulus parvus	Helisoma anceps	Helisoma campanulatum	Helisoma trivolvis	Physa heterostropha	Succinea ovalis	Total Specimens
Wilsons Corners	-	-	434	29	-	-	-	-	1615
Southwest Venosta	6	20	750	4	-	1	-	2	1447
McKay Lake	2	-	300	48	30	-	70	-	980

are often preserved in place. The living mollusk community found in this habitat by Watts and Bright (1968, p. 861) consisted of 21 forms; the most diverse assemblage they encountered. In my Pleistocene samples, the greatest number of species occurred in units referable to this habitat. *Pisidium nitidum, P. ferrugineum, Gyraulus parvus, Valvata tricarinata, V. lewisi, Helisoma anceps, H, campanulatum, Lymnaea decampi, Promenetus exacuous, Physa gyrina, Sphaerium rhomboideum,* and *S. simile* are common species in units apparently deposited in the sheltered littoral areas of Pleistocene lakes in the Gatineau and Ottawa Valleys. This habitat can extend from water only a few feet deep to the outer portions of the shelf, and species that generally inhabit deeper and cooler parts of the littoral zone such as *Valvata lewisi* and *Sphaerium lacustre* also dwell in these surroundings. The conditions described above prevailed during marl deposition in the Manitou Lake section, Units 2 and 5 in the Lac Laflamme section, during marl deposition in the Nesbitt Lake section, and in Unit 3 of the Rochester Street deposit.

The open lacustrine habitat of Watts and Bright (1968, p.860) refers to parts of the littoral zone affected by moderate currents and periodic wave action. Such areas occur in less than 12 feet of water and have marly silt and sand bottoms. Vegetation is generally less dense than in sheltered areas and large spots without rooted plants are common. Watts and Bright (1968, p. 860) found only *Pisidium casertanum, Lampsilis radiata siliquoidea, Amnicola limosa, Gyraulus parvus, Helisoma anceps, Valvata tricarinata,* and *V. lewisi* living in this habitat. The present north shoreline of Manitou Lake is an example of exposure to strong wave action whereas the Southwest Venosta deposit and the deposit at McKay Lake were produced under conditions of less extreme exposure. These beds are composed of relatively pure and fine-textured marl with less fine plant debris than is generally present in the other deposits examined. Apparently they were exposed to gentle but persistent oscillatory wave action that kept plant bodies and loose bottom sediment exposed to periodic motion. The agitation prevented formation of thick encrustations on plant parts, and fragmented most carbonate casts into fine material. The mollusk specimens from these deposits show no signs of unusual abrasion. *Gyraulus parvus, Valvata tricarinata, Amnicola limosa, Lymnaea decampi, Helisoma anceps,* and a few species of *Pisidium* constitute most of the freshwater assemblage in the Southwest Venosta and McKay Lake deposits. Species of *Pisidium* that occur in quiet areas and the larger lymnaeid and planorbid snails are absent or poorly represented. Few species make up the assemblage.

The shoreline habitat, termed a littoral habitat by Watts and Bright (1968, p. 861), includes the very shallow margin along shore where plant debris and clastic material form the bottom and dense stands of emergent plants such as cattails or rushes are common. It also encompasses submerged or wet portions of the encroaching mat of hydrophilic mosses and higher plants, as well as mud flats, shoreline pools, and small inlets. This part of the lacustrine environment is more affected than others by seasonal changes in water level, storms, and diurnal or seasonal temperature changes. Outer margins of the area are inhabited by many of the mollusks that occur in deeper water, but *Lymnaea obrussa* and *L. dalli* are the common bottom dwellers along shore, with species of *Oxyloma* and *Succinea* often occurring on wet areas of the shoreline. The plant dwellers, *Gyraulus parvus* and *Valvata tricarinata,* and some sphaeriids live among plant debris or the bog mat. During seasonal periods of high water, inhabitants of shallow offshore areas invade the marsh habitat. Dexter (1950, p. 21) found that an 8 to 10 inch rise in lake level enabled most species of aquatic Mollusca temporarily to invade marginal areas of a bog lake.

The peat and fine clastic beds that overlie marl deposits in the Gatineau Valley were produced by the shoreline marsh environment. The characteristic aquatic species in these units are *Gyraulus parvus, Valvata tricarinata, Pisidium casertanum, P. compressum, P. adamsi,* and *Lymnaea obrussa.* Other species also extend into the peat layer but in decreasing numbers toward the tops of sections. These were probably regular inhabitants of the emergent plant zone but seasonal invaders of the shoreline bog during times of high water. Likewise, many of the land snails preserved in peat layers were likely seasonal inhabitants of the bog mat as well as allochthones.

The top 4 to 6 inches of sections in the Gatineau Valley include living animals and modern shells of land gastropods. These represent a wooded lowland habitat. The most common species, *Carychium exiguum, Nesovitrea electrina, Vertigo ovata, Gastrocopta tappaniana,* and *Vallonia pulchella* normally occur in moist, wooded areas usually adjacent to bodies of water.

Role of plants

Rooted aquatic plants are well known as primary producers, inhabitable surfaces, and sheltering structures in the aquatic ecosystem. Vegetated shallow areas harbor species and individuals of consumer organisms in large numbers. The common freshwater mollusks in marl beds in the Gatineau Valley region and elsewhere in eastern North America are species whose living representatives thrive in this complex littoral community. In addition to influencing faunal composition, aquatic vegetation seems to be the primary agent forming the marl deposits encountered in this study. Algae, particularly a few species of bluegreen algae and *Chara*, are quite efficient at marl accumulation. The marl deposits discussed in this report were laid down amid more or less dense beds of *Chara*, and marl is still accumulating at Lac Laflamme and Manitou Lake on and among *Chara* plants. Few vascular plants are present in the vicinity of marl deposition and most of the carbonate is being laid down in the zone of submerged vegetation. Davis (1900, p. 494; 1901, p. 506) concluded that charophytes are largely responsible for the accumulation of lake marl and its textural properties. Some slight variation in molluscan assemblages may be associated with establishment of almost pure charophyte stands, or stonewort meadows, and the presence of fossil charophytes should be noted in conjunction with studies of non-marine mollusks from carbonate deposits. Unlike vascular plants, stoneworts produce very little organic debris, and a succession of decreasing plant detritus in a section can be misinterpreted as a decline in vegetation if charophyte fossils are overlooked.

Origin of the fauna

Most of the Pleistocene Mollusca found in the Ottawa-St. Lawrence Lowland and adjacent areas are common species whose ranges extend over the greater part of eastern North America and beyond. Such organisms contribute little to determining the origins of an assemblage in a small regional unit such as the Ottawa and Gatineau Valleys. Eleven of the species have more restricted ranges and they are: *Lymnaea dalli*, *L. decampi*, *L. haldemani*, *L. megasoma*, *Helisoma campanulatum*, *Ferrissia parallela*, *Nesovitrea binneyana*, *Discus cronkhitei catskillensis*, *Gastrocopta tappaniana*, *Vertigo bollesiana*, and *V. morsei*. Together, the present range of these forms includes the Great Lakes - St. Lawrence drainage system and adjacent portions of the Upper Mississippi River system, coastal drainage in New England, and northern parts of the Ohio River system. *L. dalli* extends into the southwestern United States and *F. parallela* has an uncertain range but is most abundant in the Great Lakes region.

Mollusca apparently followed retreating ice into the Great Lakes region from unglaciated areas in the Mississippi Valley, and it is likely that this advance followed deglaciation northeastward into the eastern Great Lakes and St. Lawrence Valley. Gadd (1962, p. 2) describes varved glacial lake clay overlain by marine sediment in the Rideau Valley south of Uplands Airport. This section and others in the Ottawa Valley seem to mark the northern extent of Lake Frontenac, a pre-marine glacial lake. The deglaciated southern portion of the Ottawa Lowland was open to molluscan colonization prior to inundation by marine water; however, there are no records of Late Wisconsin mollusks in postglacial beds overlain by marine sediment known to the writer. Marine water extended to between Pembroke and Deep River, Ontario and into the Gatineau Valley during the maximum advance of the Champlain Sea. Emergent parts of the Frontenac Axis such as the Algonquin Park-Renfrew County area and unglaciated uplands in Pontiac County, Quebec north of Ottawa River were still available for non-marine molluscan habitation. Segments of populations that became established in lakes at higher elevations before the marine invasion probably survived the Champlain Sea interval in these bodies of fresh water. A corridor for eastward dispersal of non-marine organisms onto the Laurentian Upland probably existed between ice standing somewhere south of Mattawa and extensive areas of marine water in the Ottawa Valley north of Pembroke.

The Gatineau Valley deposits described in this report and deposits at Richardson Lake, Quebec; Box Marsh, Ontario; and Atkins Lake, Ontario were all exposed during recession of the early, high-water phase of the Champlain Sea. The first molluscan pioneers of these lakes probably came from populations already established on nearby highland areas. Deglaciation at North Bay, Ontario and the shift of Great Lakes discharge to the Fossmill and Mattawa-Ottawa channels opened a major route for molluscan entry into the St. Lawrence Valley during the waning stages and at the end of the Champlain Sea interval but this event apparently post-dates the beginning of marl deposition at many sites in the Gatineau and Ottawa Valleys. Although the outlets provided an important route into the Ottawa Valley for some organisms, a diverse molluscan assemblage was already established in the Ottawa and Gatineau Valleys prior to their inception. The large marine embayment in the St. Lawrence Valley and Ontario basin probably inhibited but not necessarily halted non-marine mollusk dispersal from source populations south and east of the Ottawa region.

Roy (1964, p. 71) found that *Lymnaea stagnalis, L, megasoma, L. haldemani*, and *Helisoma trivolvis* were apparently late arrivals into northeastern Wisconsin lake sections. He concluded that these species were unable to invade northern areas until the post-glacial climate became more moderate. While climate seems to be responsible for extinction of these elements along the southern part of their Late Wisconsin range, other factors apparently exert a strong influence on their post-glacial fossil record in northern areas. *Lymnaea stagnalis, L. megasoma,* and *Helisoma trivolvis* are certainly among the later inhabitants of marl lakes in the Gatineau Valley. These animals are also inhabitants of quiet, shallow water where emergent vegetation and its debris are abundant. Thus, a water body is a likely habitat for large populations of these species only after emergent plant zones and shoreline beds of organic detritus become well developed, rather than during the earliest stages of lake filling. *Lymnaea stagnalis* and *Helisoma trivolvis* are confined to the middle and upper portions of lake sections. They are rare or absent from the Southwest Venosta, McKay Lake, and Box Marsh deposits, but are living today in marshy areas and among emergent plant beds at these localities. McKay Lake is several thousand years younger than the other basins in which these species often occur as fossils. The late appearance of *Lymnaea stagnalis, L. megasoma,* and *Helisoma trivolvis* in Quaternary lake sediments may be more a function of habitat development in individual bodies of water than a second wave of faunal migration reaching the region. However, if these gastropods are dispersed through passive transport over short distances between shallow, heavily vegetated pools, their Late Wisconsin migration into northern areas may have been delayed until such habitats became established along waterway connections in freshly deglaciated areas.

Age and correlation

Marine shells at 450 feet near Pembroke, Ontario have been dated at 10,870 ± 130 yrs. BP. (GSC-90, Dyck and Fyles, 1963, p. 44). If this date is consistent with others for the Champlain Sea, down-warping may have enabled marine water to reach higher present elevations in the Gatineau Valley than in the Ottawa Valley to the south as Antevs (1939, p. 714) suggests. Isobases on raised beaches west of Ottawa show that tilting was toward true north, at least when beaches were being constructed between 250 and 300 feet (Gadd, 1961, p. 3). The Champlain Sea water plane was apparently confined to present elevations of 450-500 feet in the Gatineau Valley about 10,800 years ago, since the dated site at Pembroke occurs at approximately the same latitude as Brennan Hills, Quebec. Within this elevation range, sea level was confined to a narrow strip along the main channel of the Gatineau River, and the basins discussed in this report rose above sea level before about 10,800 years ago. The Gatineau Valley lacustrine deposits all occur above 500 feet. Sections at Manitou Lake, Lac Laflamme, and Nesbitt Lake indicate a rapid transition from marine to freshwater conditions that took place in years or decades rather than time intervals of greater magnitude. If the time between 11,800 and 10,800 yrs. BP. is taken as an age range for the recession of marine water from higher elevations in the Gatineau Valley, the onset of lacustrine deposition should have similar ages.

Marine sediments occurring at high elevations in the Gatineau Valley were deposited during the early post-glacial subarctic phase of the Champlain Sea. Freshwater sediments began accumulating in depressions from which the sea had receded near or after the time of transition from a subarctic to boreal molluscan fauna in the main marine body remaining at lower elevations.

Msrl deposits formed at Richardson Lake, Quebec, and Box Marsh, Ontario soon after marine conditions ended in these areas (Gibson, 1967, p. 32; Clowers 1966, p. 56). Clowers and Gibson chose as a maximum age for freshwater sedimentation in these lakes the minimum age of 9,500 yrs. BP. proposed by Terasmae (1965, p. 36) for the end of the Champlain Sea interval. Box Marsh and Richardson Lake are both situated between 500 and 600 feet and it is likely that they were inundated only by the early, high phase of the Champlain Sea. These basins evidently rose above sea level around 11,000 years ago and began accumulating freshwater marl about the same time as, or probably before, the Gatineau Valley lakes.

Pleistocene Mollusca at Atkins Lake northwest of Brockville, Ontario were studied by Ouellet (1967, n.p.; 1968, p. 18) and the base of the freshwater beds was dated at 11,100 ± 270 yrs. BP. This age is probably contemporaneous with or slightly older than the beginning of marl deposition at the Gatineau Valley localities and at Box Marsh and Richardson Lake.

Terasmae and Hughes (1960, p. 1444) determined an age of about 10,000 yrs. BP. for entry of Great Lakes discharge into the Ottawa River through outlets at North Bay, Ontario. Subsequent C-14 dates support this age (Dyck and Fyles, 1963, p. 44; Lowdon and Blake, 1968, p. 215) and Gadd (1962, p. 3) suggests that the influx of fresh water was an important factor in lowering salinity in the Ottawa area during the final Champlain Sea stage.

The Rochester Street and McKay Lake deposits are associated with early stages of the Ottawa River and are considerably younger than the lakes previously discussed and the Champlain Sea episode. The Rochester Street deposit is dated at 8830 ± 190 yrs. BP. (GSC-546, Lowdon, *et al.*, 1967, p. 161), but R. J. Mott (personal communication) believes the date to be about 1800 years too old. Other dated beds in abandoned channels of the Ottawa River at elevations of 200 to 235 feet indicate that the river left courses through the city of Ottawa and Mer Bleue Bog to the east between 8200 and 6700 years ago (Lowdon, *et al.*, 1967, p. 160-162; Lowdon and Blake, 1968, p. 213). The McKay Lake marl beds occur below 175 feet and the east side of the basin is underlain by fluvial sediment (Gadd, 1962, map). Marl deposits apparently formed on the east and south shores after the Ottawa River cut below the higher channels south of McKay Lake and reached its present channel north of the lake. The McKay Lake marl deposit can only be dated as much younger than 6700 yrs. BP., because little is known about the ages of late Ottawa River stages. McKay Lake occupies a deep depression that probably had a long history of fluvial and lacustrine sedimentation before the exposed marl beds formed.

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