THE UNIVERSITY OF MANITOBA

A PALEOECOLOGICAL INVESTIGATION INTO THE POST-GLACIAL HISTORY OF DELTA MARSH, MANITOBA

by

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ABSTRACT

The project provides information on the ecological history of the Delta Marsh as part of an ongoing study of the marsh ecosystem at the University of Manitoba.

Three cores were taken from neighbouring sites in Cadham Bay, a large central bay in marsh complex. Their lengths were: Core B, 2.19 m; Core A, 3.85 m; and Core C, 8.3 m. Core A was analyzed for sediment, pollen, seeds and selected invertebrate macrofossils, Core B for sediment and pollen, and Core C only for stratigraphy. Sediment type was analyzed to provide information to elucidate trends indicated by the distribution of seeds, selected invertebrate macrofossils and pollen. Fossils were well represented in the upper portion of the cores, but their paucity below the 1 m depth suggests that marsh conditions did not exist when the sediments below this level were being deposited.

The cores were divided into six zones based upon seed composition and density. The calcareous silty clay of zone 1 (385-115 cm in Core A) contains a few Bryozoa and scattered ostracods and molluscs, suggesting that relatively deep water conditions prevailed during its deposition.

Macrofossils of aquatic plants became abundant at the

base of zone 2 (115-95 cm) indicating the onset of marsh conditions. A radiocarbon date of 2,400 plus or minus 230 years provides an approximate date for the 102-106 cm depth.

Shallow water is indicated by seeds of submerged (*Zannichellia palustris*), floating (*Lemna* sp.) and emergent aquatics (*Eleocharis compressa*-type). The rise in seeds of the pioneer species *Chenopodium rubrum* near the top of zone 2 suggests that water levels had continued to decline. In zone 3 (95-80 cm) macrofossils are rare implying that either sedimentation rates increased sharply or water depths became unfavourable for aquatic organisms.

In zone 4 (80-50 cm) the reappearance of *Z. palustris*, *E. compressa*-type and *Scirpus* spp. suggests a return to the water levels prevalent in zone 2. Like zone 3, zone 5 (50-15 cm) contained few macrofossils although the pollen diagram contains *Potamogeton* and Cyperaceae which may have grown locally. A thick sand lens within this zone was probably derived from erosion of the ridge to the north. The replacement of *Zannichellia palustris* by *Potamogeton pectinatus* in zone 6 (15 cm to the surface) as the dominant submerged aquatic suggests that the water depth is now shallower than previously. Succession however, has been slow in the marsh, probably because of periodic flooding and the lack of inwashed mineral sediments.

The twice repeated alternating fossil composition of the zones (2 and 4, 3 and 5) may reflect two cycles of marsh development over the past 2,400 years. This supports the idea that flooding is necessary for the rejunivation of the marsh. It is suggested that prior to 2,400 years ago, a river, or rivers, flowed into Lake Manitoba via Delta Marsh.

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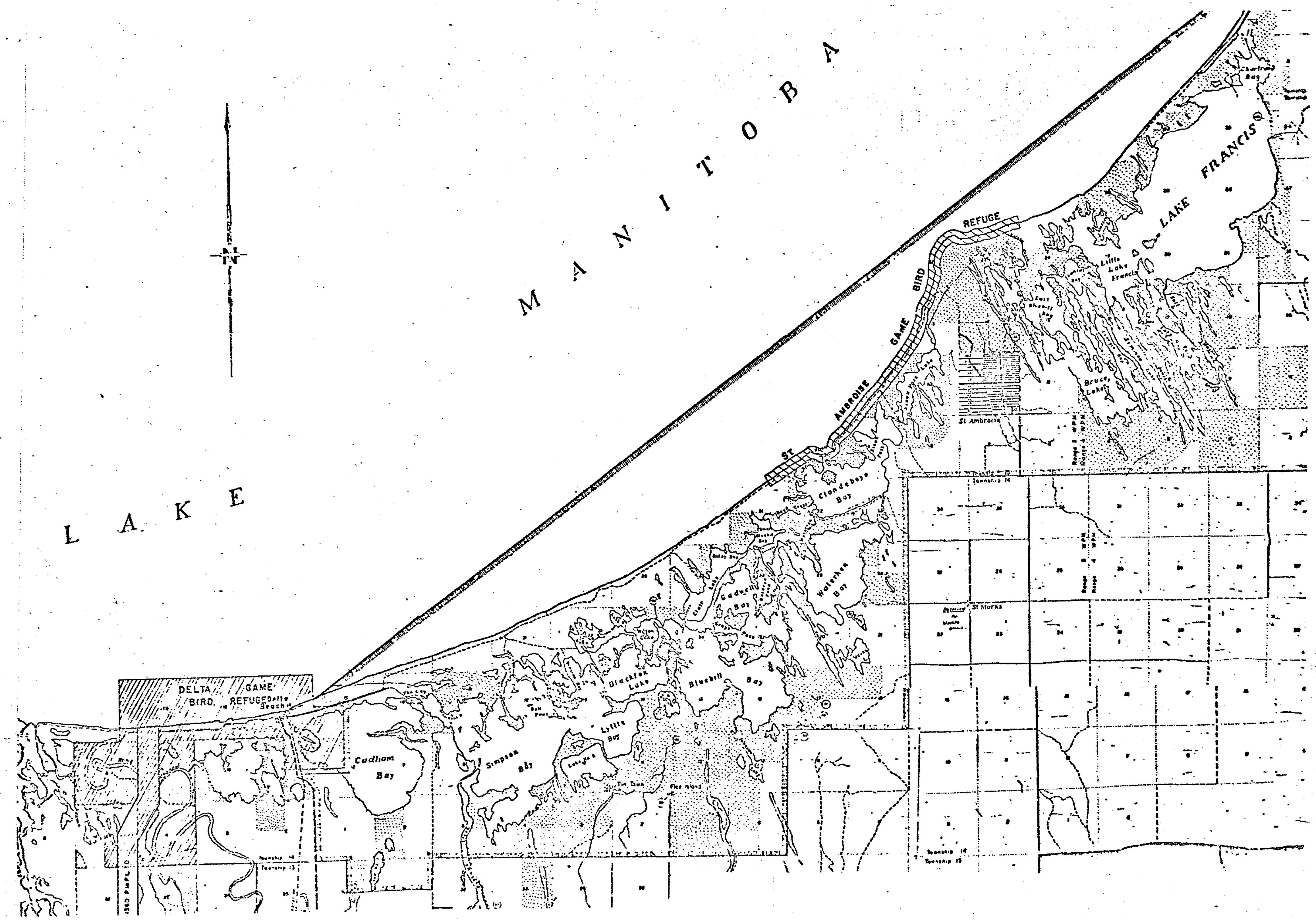

LAKE MANITOBA
DELTA GAME BIRD REFUGE
Delta Beach
ST AMBROISE GAME BIRD REFUGE
LAKE FRANCIS
Little Lake Francis
Bruce Lake
St Ambroise
Clandeboye Bay
Waterhen Bay
Cadwell Bay
Blackfox Lake
Bluebill Bay
Little Bay
Simpson Bay
Cadham Bay
St Marks
Township 14
Township 13

INTRODUCTION

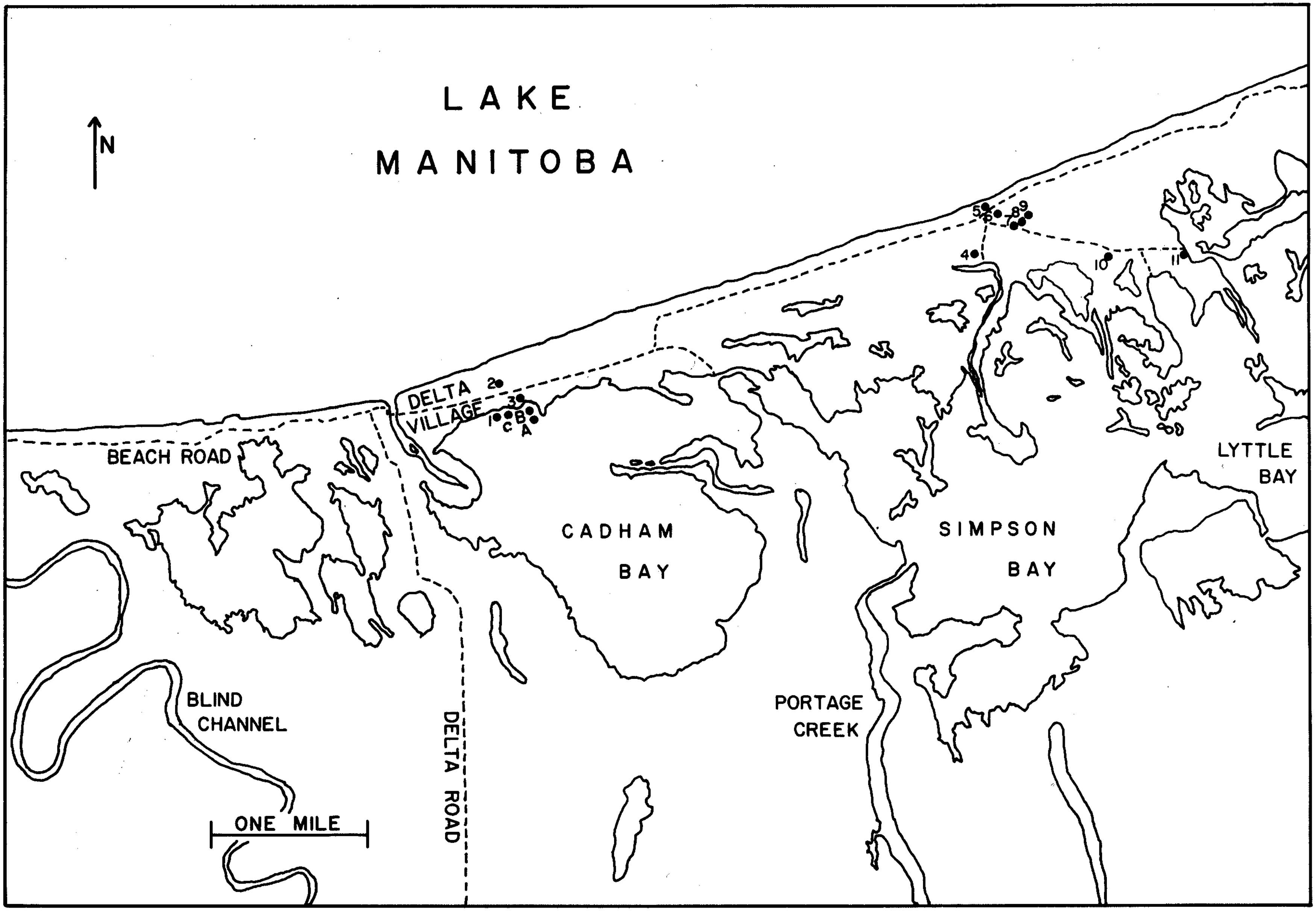
The Delta Marsh is one of the best known waterfowl marshes in North America. It borders the southern shore of Lake Manitoba, (Fig. 1), and covers approximately 15,000 ha, (Hochbaum, 1944). Hochbaum (1968), states that there are fewer ducks nesting, or migratory waterfowl at Delta than in the earlier part of the century. This reduction in waterfowl numbers coupled with a decrease in the amount of vegetation suitable as food and cover for waterfowl has indicated that some form of management plan may have to be devised for the marsh.

A knowledge of the history of the marsh would, it was hoped, show whether presently declining water levels are a permanent trend or part of a periodic cycle.

In addition to aiding management of the marsh as a waterfowl area, information provided by this study should also prove useful to the University of Manitoba, which has initiated an intensive study of the marsh ecosystem on 410 ha leased from the Provincial Goverment in 1965.

Within the confines of this study it was impossible to sample and analyse material from more than one part in the marsh, accordingly it was decided to concentrate on the

FIGURE 2. Map of the Cadham Bay region of Delta Marsh, showing location of sampling sites (Mines and Technical Surveys, 1955-58)


N
LAKE
MANITOBA
DELTA
VILLAGE
BEACH ROAD
CADHAM
BAY
SIMPSON
BAY
LYTTLE
BAY
BLIND
CHANNEL
DELTA ROAD
PORTAGE
CREEK
ONE MILE
1
2
3
4
5
6
7
8
9
10
11
A
B
C

Cadham Bay area, (Fig. 2.), which forms a discrete unit within it. It was presumed that its development and history was representative of other parts of the marsh.

The investigation consisted of an analysis of macro-fossils (seeds and selected invertebrates), and pollen, present at different depths of sediment. Because of their greater size, macrofossils are unlikely to contain species which have been carried by the wind from a considerable distance, (Watts & Winter, 1966). They may therefore be expected to yield information on the history of purely local vegetation, (Watts & Winter, 1966). Pollen diagrams on the other hand contain species whose pollen has been wind-carried from a considerable distance. Their greatest value is therefore as an indicator of regional vegetation (Faegri & Iversen, 1964) and even some aspects of local vegetation (Watts & Bright, 1968). Accordingly the present investigation is centred around an analysis of seeds substantiated by information from selected invertebrate fossils and correlated with regional conditions as interpreted from a pollen diagram prepared from the same sediment. In addition to the macro-fossil and pollen analyses, a particle size analysis was carried out on the sediment to provide further information on the prevailing conditions and relative water depths

(Thompson, 1960).

It was felt that the Delta Marsh would prove particularly suitable for this type of macrofossil investigation, since the present day vegetation of the marsh had been studied by Love & Love (1954) and Walker (1959, 1965). Plant fossils present in the surface sediments of an area may be taken to be representative of the plant communities growing there. A knowledge of the vegetation therefore provided valuable information for the interpretation of the fossil diagram, and allowed the present project to commence without first inventorying the vegetation of the marsh.

Financial support for the project came from the University of Manitoba, Faculty of Graduate Studies and the Delta Waterfowl Research Station.

CHAPTER II

LITERATURE REVIEW

Paleoecological studies

Reference will be made to studies in the Lake Agassiz basin utilising different types of fossil evidence. Most studies of the history of the region have taken the form of palynological investigations. Those relevant to the present project include Jannsen (1967 a, b.), McAndrews (1966), Ritchie (1964, 1967, 1969), Ritchie and De Vries (1964), Ritchie and Lichti-Federovich (1968) and Shay (1967). Integrated studies have been carried out by Watts and Winter in Kirchner Marsh, Minnesota, (1966) using pollen and seed analyses and by Watts and Bright at Pickerel Lake, South Dakota, (1968), using Molluscan fossils in conjunction with pollen and seed analyses.

Pollen diagrams are normally divided into zones, a zone being defined as "a body of sediment distinguished from adjacent sediment bodies by differences in kind and amount of its contained fossil pollen grains and spores", (Cushing, 1964). One zone common to all the Lake Agassiz studies mentioned above is that of a _Picea_ dominated forest in the immediate post glacial period, approximately 11,5000 to 10,000 years B.P. In the diagrams from Tiger Hills, Manitoba

(Ritchie & Lichti-Federovich, 1968), 100 km south-west of Delta and from Riding Mountain, Manitoba (Ritchie, 1969), 160 km north-west of Delta, the Picea dominated zone is succeeded by a zone of maximum herbaceous pollen suggesting prairie conditions and a warmer drier climate. From 2,500 years B.P. to the present a deteriorating climate had brought about a southward shift of the Boreal forest into the Riding Mountain area with the diagrams there being dominated by Picea, Pinus, Larix, Betula, Quercus and Alnus, (Ritchie, 1969). During the same period in the Tiger Hills an Oak-savannah type vegetation is suggested by an increased percentage of Quercus pollen.

The most important part of the present investigation is the analysis of seeds found in the sediments. Because of their greater size, seeds are less likely to be carried far from the parent plant and hence are more likely to be representative of local vegetation. However Watts and Winter (1966), caution against careless use of macrofossil evidence. They stress that "the stratigraphic position of finds should be accurately related to a pollen diagram." This provides a time scale into which the development of local vegetation can be fitted. They also state that "mention should be made of the actual numbers of fossils found in stated volumes of sediment." This enables others to assess the accuracy of interpretations made, since, the fewer the macrofossils, the less reliable the results are likely to be.

In the same paper they reported on pollen and seed analyses from a core in Kirchner Marsh, Minnesota, covering the entire Holocene period. Local conditions were interpreted from the seed diagram and correlated with the regional conditions indicated by the pollen diagram. In many instances, observations based on the abundance of certain species in the seed diagram, were directly confirmed by the abundance of the same species in the pollen diagram.

Molluscan fossils were used by Watts and Bright (1968), in conjunction with seed and pollen analyses. Working at Pickerel Lake, South Dakota, they interpreted the history of the local vegetation, basing their conclusions on the present day habitats of the plants and animals represented by the fossils. They related changes in molluscan shell frequency to changing $CaCO_3$ content of the sediment. Tuthill (1967), reviewed the work done on molluscan fossils in the Lake Agassiz basin, and the reliability of conclusions reached. He emphasized the importance of "permanence of data" as a means of removing operator bias from an investigation. In other words interpretations made in an investigation are insufficient in themselves and should be accompanied by a permanent record of the data used in the study.

Fossil cladocera, from a lake sediment in Wisconsin, were studied by Frey (1960). He compared them with present day cladoceran populations and found they resembled each other closely. Cladoceran ephippia were used in the present project as an indication of cladoceran populations.

Studies related to Delta Marsh

The vegetation of the marsh was studied by Love and Love (1954) and by Walker (1959, 1965). The former surveyed the vegetation and found a distinct zonation with water depth. When the level of the soil was above the water table, distribution appeared to be more or less random, apart from the ubiquity of *Phragmites communis*. They discussed the origin of the marsh and hypothesized that "the retreat of the lake had occurred in waves of drought interspersed by more stable, moist periods. A system of sand ridges on the Portage Plain support this assumption. Every time a dry period or some other cause lowered the surface of the lake permanently, the tree and shrub vegetation could invade the next sand ridge farther out. The gap between the new and the old shoreline then became a new piece of marsh, while the old marsh, now with a lower water table, was filled with meadow vegetation."

The first quantitative studies of the vegetation were by Walker (1959, 1965), who also emphasized zonation with water depth. Although she considered the effect of other environmental factors, she felt that competition and chance factors played an important role and cautioned against placing too much emphasis on the measurable environmental factors such as pH.

The geological history of the region was studied by Gilliland (1965). He traced four phases of alluvial activity all governed by Lake Manitoba or its ancient equivalent. He concluded from the presence of marsh vegetation at high elevations and the thickness of alluvium under Lake Manitoba that the level of the lake had in the past been approximately 20 feet higher than at present. He also studied the evidence of former river channels in the region, and suggested that the Assiniboine River at one time flowed down the Fort La Reine Channel, into Lake Manitoba. As the ice sheet retreated northwards the differential postglacial uplift of the land resulted in a relative lowering of the base level to the east. This led the river to cut the eastern channel in which it presently flows. While exact dates were not ascribed to these events he felt that the change was a relatively recent one, possibly in the last 2,000 to 3,000 years.

In the context of declining water levels it is interesting to note that Bupree (1927), wrote that in the late 1700's, the explorers, La Verendrye and his sons had little trouble taking their canoes from Portage la Prairie to Lake Manitoba, due to an almost continuous system of marshes. Their total portage from Fort la Reine on the Assiniboine River, to Lake Manitoba, was about three leagues or nine statute miles. Unfortunately no account could be found of conditions prior to, or after this, and the system of marshes could have been due to a temporary flood.

Investigations of other fresh water marshes

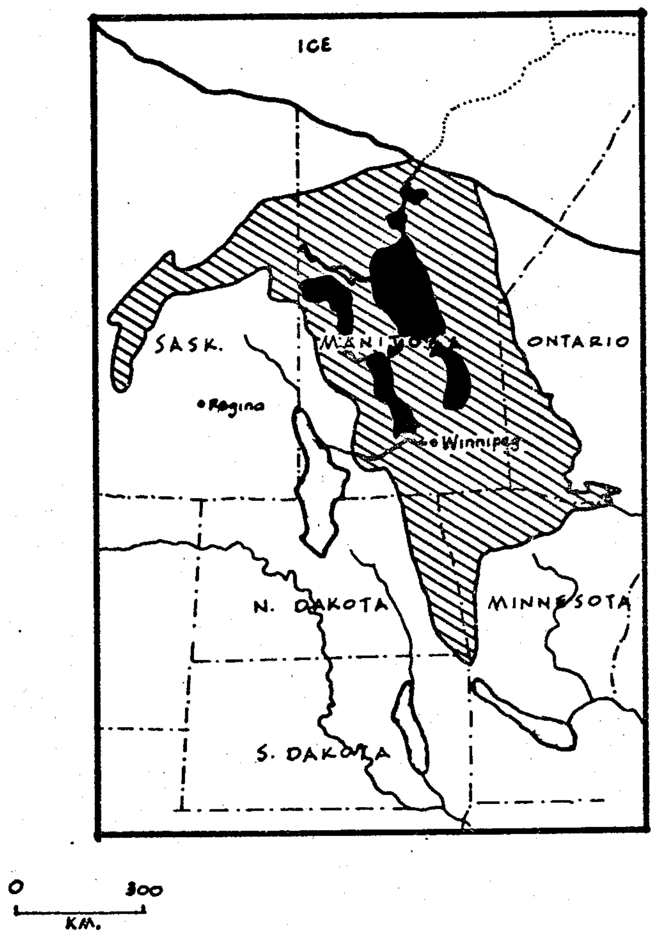
Investigations of marshes with similar vegetation to Delta Marsh include Kadlec (1960) and Harris and Marshall (1963). Both studies dealt with vegetational changes in relation to changing water levels.

Kadlec (1960) found in Michigan that the hardy perennating organs of emmergent aquatic species such as *Typha* and *Scirpus* enabled them to persist, even though changes in water level had rendered the habitat less suitable. Harris and Marshall (1963), worked out critical ranges of water depths for each of the major emergent aquatics, chiefly *Typha*, *Carex*, *Scirpus* and *Eleocharis* in a marsh in Minnesota. The critical depths were based on the response of these species to changing water levels over a period of five years. Perhaps the most valuable inference to be drawn from these investigations, is that water level is only one of a set of interacting environmental factors which influence the presence or absence of certain types of vegetation.

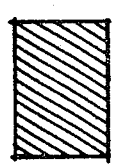
Studies of individual species

Several studies have been made on the ecology of the individual species used in this project. It was felt however, that rather than include them in the literature review, it would be better to make appropriate references in the results and discussion section.

FIGURE 3. Glacial Lake Agassiz.



Source: Elson, 1967.



Extent of Glacial
Lake Agassiz

DESCRIPTION OF THE AREA

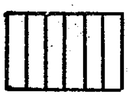
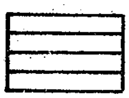
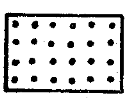
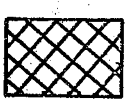
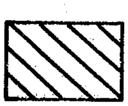
At its maximum extent, about 12,000 years ago, Lake Agassiz covered most of the province of Manitoba, and extended into Saskatchewan, Ontario, Minnesota and North Dakota, (Fig. 3). The lake began to drain southward, via the Lake Traverse outlet, approximately 10,000 years ago. Drainage from 9,000 to 7,500 years ago was through the eastern outlets and finally, about 7,500 years ago, northward into Hudson Bay. The glacial lake, had by this time, receded northward and eastward far enough to expose Lake Manitoba, (Elson, 1967). Today, lakes Manitoba and Winnipeg, Winnipegosis and some smaller Manitoba lakes, represent remnants of Glacial Lake Agassiz, (Elson, 1967). Lake Winnipegosis, elevation 253 m, drains southward via Waterhen Lake to Lake Manitoba, 247 m. Since 1961 drainage from Lake Manitoba through Lake St. Martin, 243 m, to Lake Winnipeg, 217 m, has been regulated by the Fairford Dam. Lake Winnipeg still drains into Hudson Bay via the Hudson River. In the prevailing continental climate, evaporation losses from these lakes are considerable. Lake Winnipegosis is nearly closed in drought years, i.e. evaporation losses are almost equal to incoming drainage water and Lake Manitoba is virtually closed, (Hochbaum, 1967).

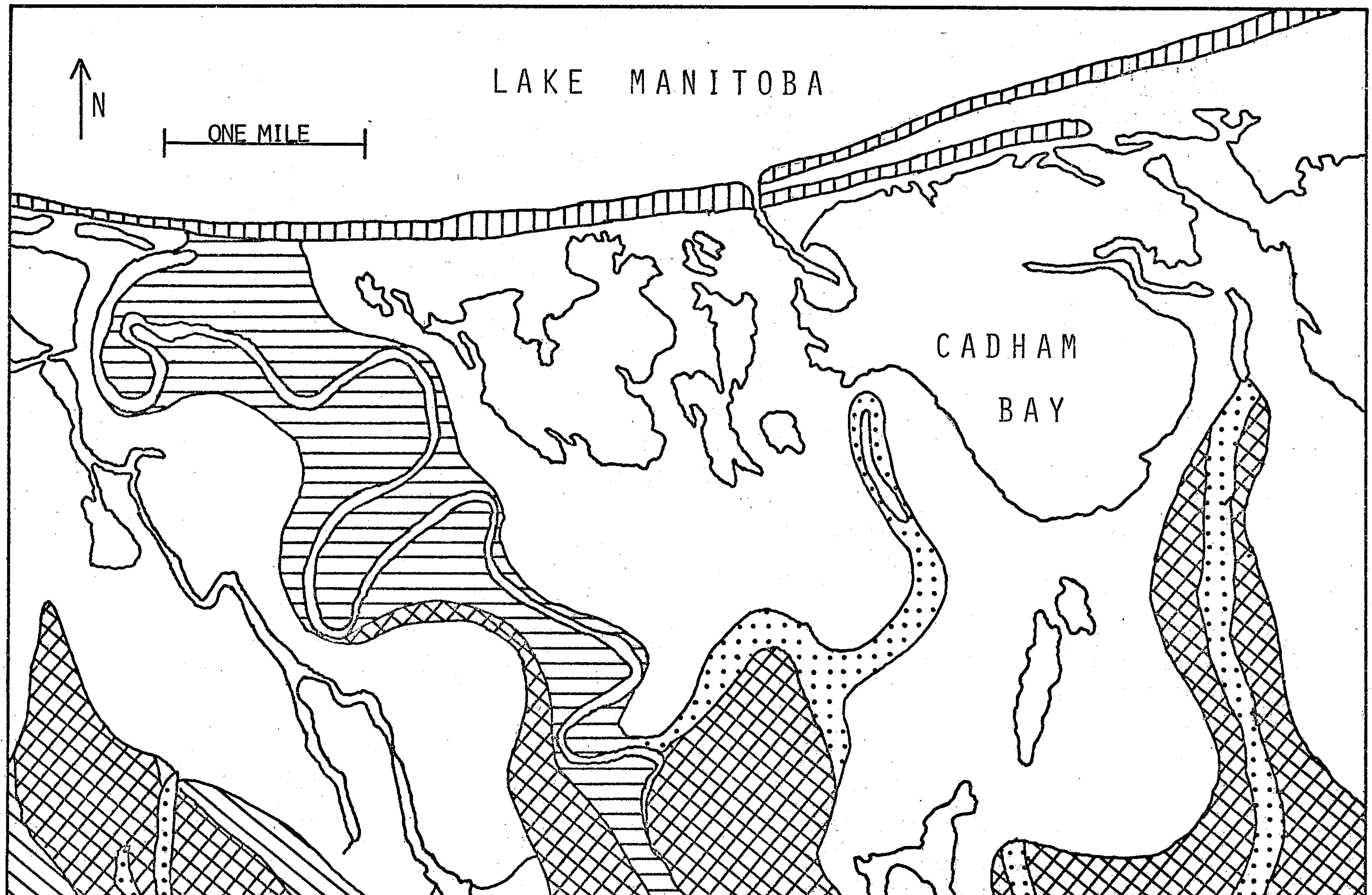
Mackay (1965) stated that "evaporation losses from Lake Manitoba are much larger than the run-off from the incremental drainage basin."

Lake Manitoba is a large shallow body of water, 248 m above sea level, approximately 180 km long and 52 km wide at the southern end, with an area of 465,000 ha. Its depth does not exceed 7.6 m (Hochbaum, 1944). Along its southern shore a ridge of sand and gravel has been built up by winter ice and by wind and wave action (Hochbaum, 1967). The average elevation of the ridge is 250 m above sea level, but several points are considerably lower than this (Walker, 1965).

The Delta Marsh lies south of the ridge (Fig. 1). For many years there was a free passage of water between the lake and the marsh at several points (Walker, 1965). By the 1930's however Clandeboye and Delta Channels were the only ones still in existence. The construction of a dam at Clandeboye in 1944, at an elevation of 240 m, meant that water could only flow into and out of the marsh when levels were higher than 240 m (Walker, 1965). During periods of high water in Lake Manitoba, low points in the ridge serve as channels to convey water from the lake to the marsh (Walker, 1965). At these times sediment may be transported from the lake and deposited in the marsh (Walker, 1965).

Figure 4 Geological map of Cadham Bay region, Delta Marsh.
(after Gilliland 1965)

	BEACH DEPOSITS	Sand and silty sand
		Later old river channels Brown sand facies
	ALLUVIAL	Earlier old river channels. Gray sand facies
		Clay and silt. No age differentiation
	LACUSTRINE	Dominantly clay.


N
ONE MILE
LAKE MANITOBA
CADHAM BAY

Since 1913 records of the water level in Lake Manitoba have been kept by Provincial Government of Manitoba in the Department of Mines and Natural Resources. They indicate five periods of high water. The most recent, from 1953 to 1958, reached a maximum of 249 m in 1955.

Today the marsh covers an area of approximately 15,000 ha stretching for 31 km from east to west, and 8 km from the lake ridge to the farm fields of the Portage Plain in the south (Hochbaum, 1944). It is a complex of bays, interconnected by creeks together with sloughs and potholes. The bays vary in size from 1 ha to approximately 400 ha. Their water depth averages one metre and is nowhere deeper than three meters (Hochbaum, 1944). Cadham Bay, which is 400 ha in area, has a maximum water depth of three meters, (Walker, 1965). When the water level in Lake Manitoba exceeds 248 m, the level of the Clandeboye Dam, there is a direct flow of water from the lake into the marsh, (Walker, 1965). Unlike the bays however, isolated sloughs and potholes depend entirely on precipitation, and local surface run-off for their water supply, except when the water level of the lake is high enough to inundate them, (Hochbaum, 1944). On the south side of the marsh there is evidence that drainage channels once flowed into it from the Portage Plain (Fig. 4). These are elongate meandering depressions between raised sandridges. Older residents of the area remember water flowing in some of these channels in the early 1900's (Simpson, pers. communication), but in recent years they have carried water only during spring run-off. This may possibly be a side-effect of extensive drainage schemes in the farmland which formerly supplied the run-off, (Report of the Association for Restoration of Water Levels, 1942).

The climate of the area is typically continental, characterized by high summer and low winter temperatures. The mean temperature in July is 20° C and in January -17° C. The mean annual precipitation is 500 mm, 70% of which falls as rain between April and October. From October to April the water in the marsh and in Lake Manitoba is frozen to a depth of 80 to 100 cm and the entire area is covered with snow, (Weir, 1960).

The geology of the area was studied by Gilliland (1965). He described a system of beach deposits forming the ridge between Lake Manitoba and the marsh, and alluvial deposits of different ages deposited in the sites of former river channels, (Fig. 4).

Soils of the marsh have been described by Ehrlich, Poyser and Pratt, (1957), as very poorly drained, undifferentiated muck and peat, overlying glacial drift, and more recently by Walker (1965) as a complex of Peaty Saline Rego Humic Gleysols and Organo and Saline Regosols, according to the classification system now in use by the Department of Agriculture, (Miller, Turk & Foth, 1966). Both soils and waters of the marsh are circumneutral or alkaline with a pH range of 6.4 to 8.5, (Walker, 1965).

The variation in soil types and alkaline conditions are reflected in the vegetation of the marsh. Love & Love (1954), described the dominant communities as Phragmition and Scolocloetum. These terms refer to plant associations the former dominated by *Phragmites communis*, the latter by *Scolochloa festucaceae*. Walker (1959, 1965) in quantitative studies in the marsh, reported *Phragmites communis* and *Scolochloa festucaceae* as the species covering the greatest area. In a cursory survey of the region by the author in the Summer of 1968, the dominant submerged aquatic was *Potamogeton pectinatus*; emergent aquatics included *Scirpus acutus*, *Scirpus validus* and *Typha latifolia*; on exposed shores *Atriplex patula*, *Chenopodium rubrum* and *Chenopodium glaucum* var. *salinum* were found, and where the soil was less water-logged *Phragmites communis* and *Scolochloa festucaceae*. The sand ridge between the lake and the marsh supports woody vegetation, chiefly *Acer negundo*, *Fraxinus pensylvanica*, *Populus deltoides*, *Salix* spp., *Quercus macrocarpa* and *Ulmus americana*, with an abundant undergrowth of *Prunus*, *Cornus* and *Sambucus*. Only in a few places is it devoid of vegetation.

As can be seen from the preceding list, different stages of the hydrosere are represented. Although the term Delta "Marsh" is loosely used to describe the area all stages of the hydrosere, from open water to shrub carr are present, (Walker, 1965).

CHAPTER III

METHODS

Field sampling

A reconnaissance of the marsh was made in November 1967 which involved sampling eleven localities in the central and eastern portions of the marsh, (Fig. 2). Five soil pits, (2, 3, 7, 8 and 9) were excavated by Backhoe digger. Four were dug by hand, no's 5, 6, 10 and 11, and no's 1 and 4 were sampled using a Hiller sampler. The Backhoe was effective only to a depth of about two metres because the entry of water made excavation at greater depths impossible.

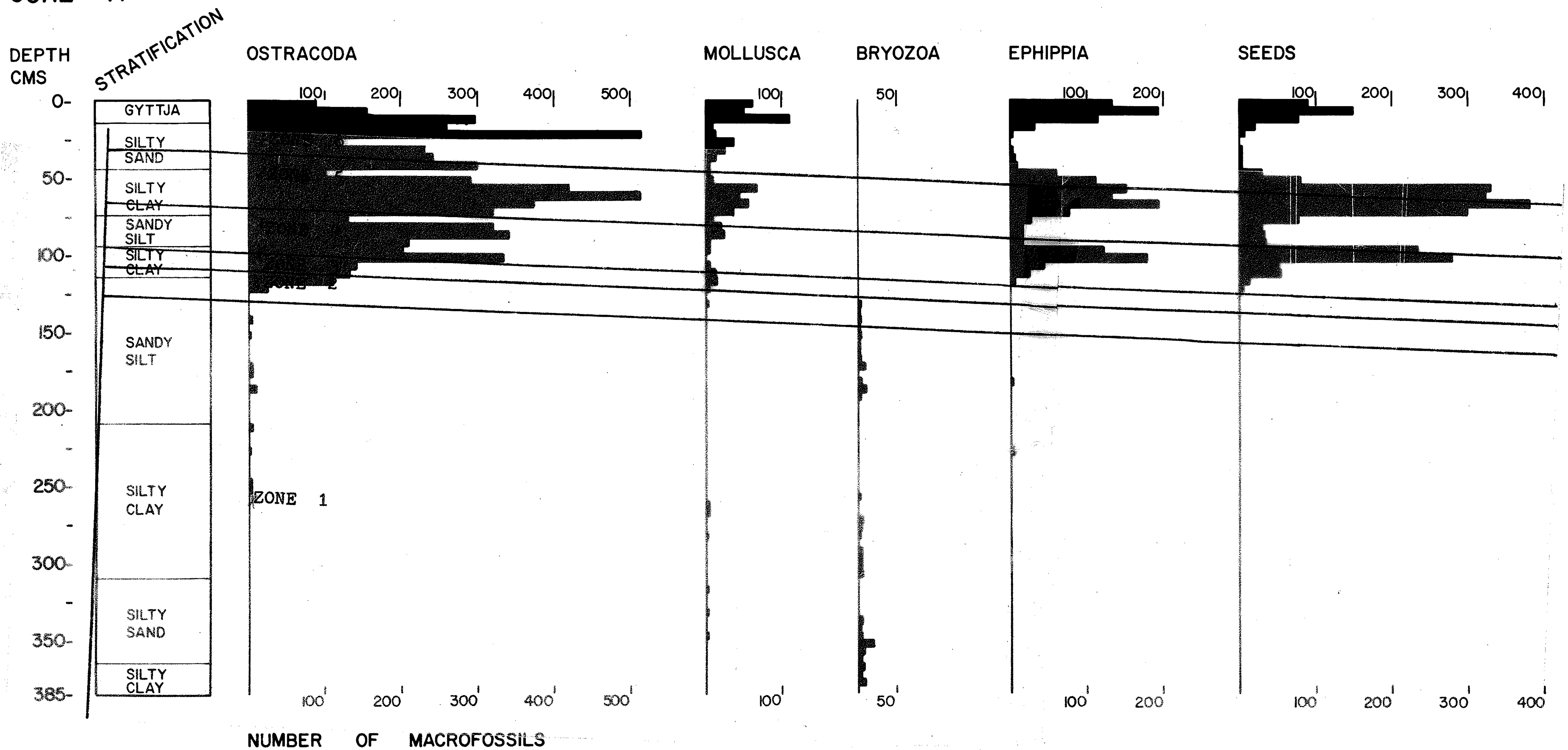
Two cores were taken in Cadham Bay in water 1 m deep in December 1967 and March 1968. Core B, (Fig. 2), was taken in December 1967, 80 m from the northern shore, using a Livingstone-Vallentyne piston sampler with a diameter of 3.8 cm (Wright, 1967). Penetration beyond 219 cm was impossible, due to the increasing compaction of the heavy clay sediment. Core A, (Fig. 2), was taken in March 1968, 150 m from the northern shore, using the same sampler together with a Swedish crank drill driver. A 385 cm core was obtained. Each section of core was wrapped in plastic and aluminum foil, labeled, transported to the laboratory and stored at 0^{o} C.

In order to determine the stratigraphy at greater

FIGURE 5. Macrofossils from core A.

MACROFOSSILS FROM CADHAM BAY, DELTA MARSH

CORE A



depths, an 830 cm core was obtained by a motor driven Atlas Copco soil auger, in August 1968 (core C, Fig. 2).

Laboratory procedure

Each 5 cm portion was scraped with a spatula to remove any contamination. Core A was halved longitudinally. Five cm portions of one half of core A, each approximately 50 cm^3 were examined for macrofossils. Because little organic matter was present hot water was sufficient to break up the sediment. The disaggregated sediment was washed through 18 mesh (1.0 mm) and 140 mesh (0.1 mm) sieves and the residue was examined in water, on a white tray, under 20X with a binocular microscope.

Four groups of invertebrate macrofossils, Byrozoa, Mollusca, Cladocera and Ostracoda were identified and enumerated (Fig. 5). Keys in Pennak (1953) and Ward and Whipple (1959) were used in the identification.

Seeds were identified by using a reference collection from Delta Marsh and seed keys by Martin (1951, 1954) and Martin and Barkley (1961). Where specific identification was not possible, the generic name is followed by sp., e.g. Lemna sp; where a specific name is followed by 'type', the specimen fits the description of more than one species in that genus. The species name was that of the most likely one from evidence of present day flora. Identification of Lemna sp. and Eleocharis compressa-type was verified by Dr. J. McAndrews, University of Toronto and by Dr. R. C. Bright of The University of Minnesota. Nomenclature throughout follows Scoggan (1957). Examples of all macrofossils identified were deposited in the Herbarium of the University of Manitoba.

Samples for pollen analysis were removed from inside the cores at regular intervals, each 10 cm in core A and 15 cm in core B. The samples were prepared for analysis by the method of Assarson and Granlund (1924). Samples were mounted in glycerine, stained with safranin and examined under compound binocular microscope. An oil immersion lens giving a total magnification of 1425 was used for detailed examination. Identification was aided by the use of a small reference collection and Erdtman (1943) and Faegri and Iversen (1964). The pollen sum averaging about 150 includes tree and anemophilous herb pollen.

Particle size analysis was carried out on both cores. Core A was analysed at 5 cm intervals from 0 to 120 cm and at 15 cm intervals from 120 to 385 cm; and core B at 5 cm intervals to a depth of 150 cm. Ten grams of sediment was used in each determination. The method followed was that of Kilmer and Alexander (1949). Sands were separated by sieving into medium (0.5-0.25 mm) and fine sand (0.25-0.1 mm). Silt and clay fractions were determined by rate of sedimentation following Stokes' Law. In a completely deflocculated soil solution the heavier silt particles settle out first, leaving the clay in suspension. By titration, evaporation and weighings the amount of clay and in turn the amount of silt can be calculated.

Loss of ignition, which approximates the amount of organic matter was determined for both cores: core A by 2 cm intervals to a depth of 120 cm, and core B to 150 cm by 5 cm intervals. Two-gram samples of oven-dried sediment were kept in a muffle furnace for two hours at a temperature of 430^{o} C. The loss in weight on ignition was expressed as a percentage of the weight of the oven-dry sample.

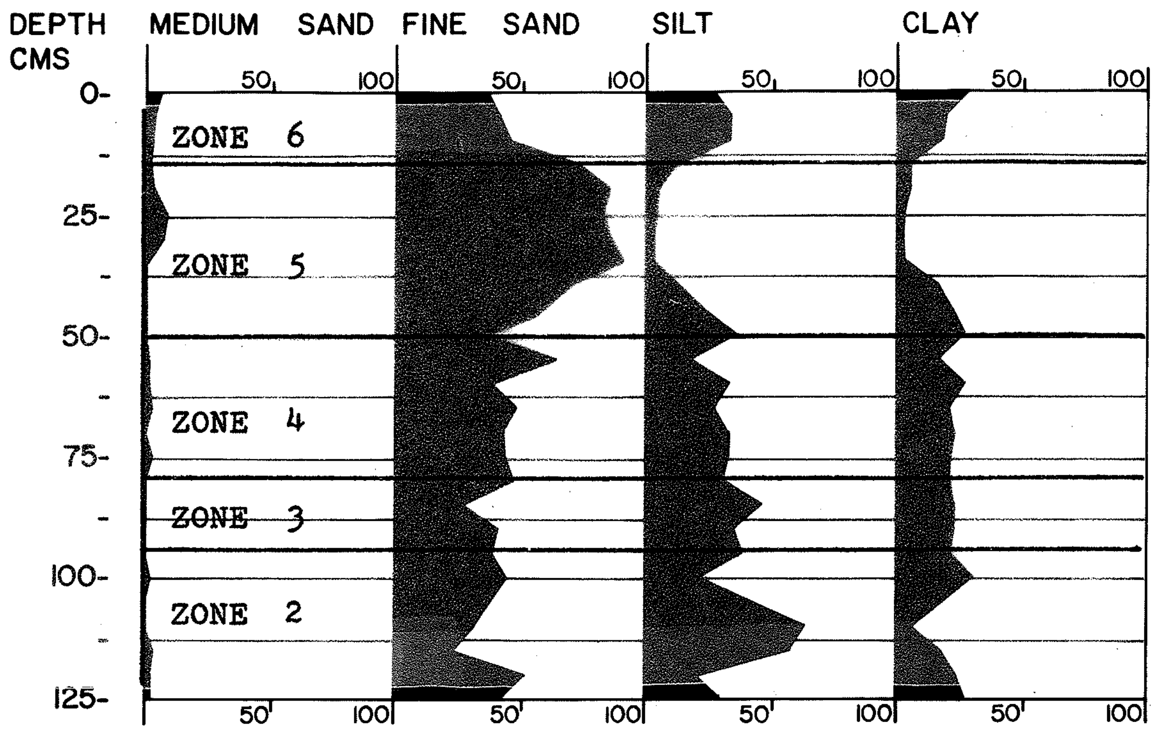
Approximately 45 cm^3 of sediment from 102 to 106 cm in core A was sent to the radiocarbon dating laboratory of Dr. K.J. McCallum at the University of Saskatchewan.

CHAPTER IV

FIGURE 6. Particle size analysis of
core A (0-125 cm) and
core B (0-150 cm).

PARTICLE SIZE ANALYSIS

CORE A



CORE B

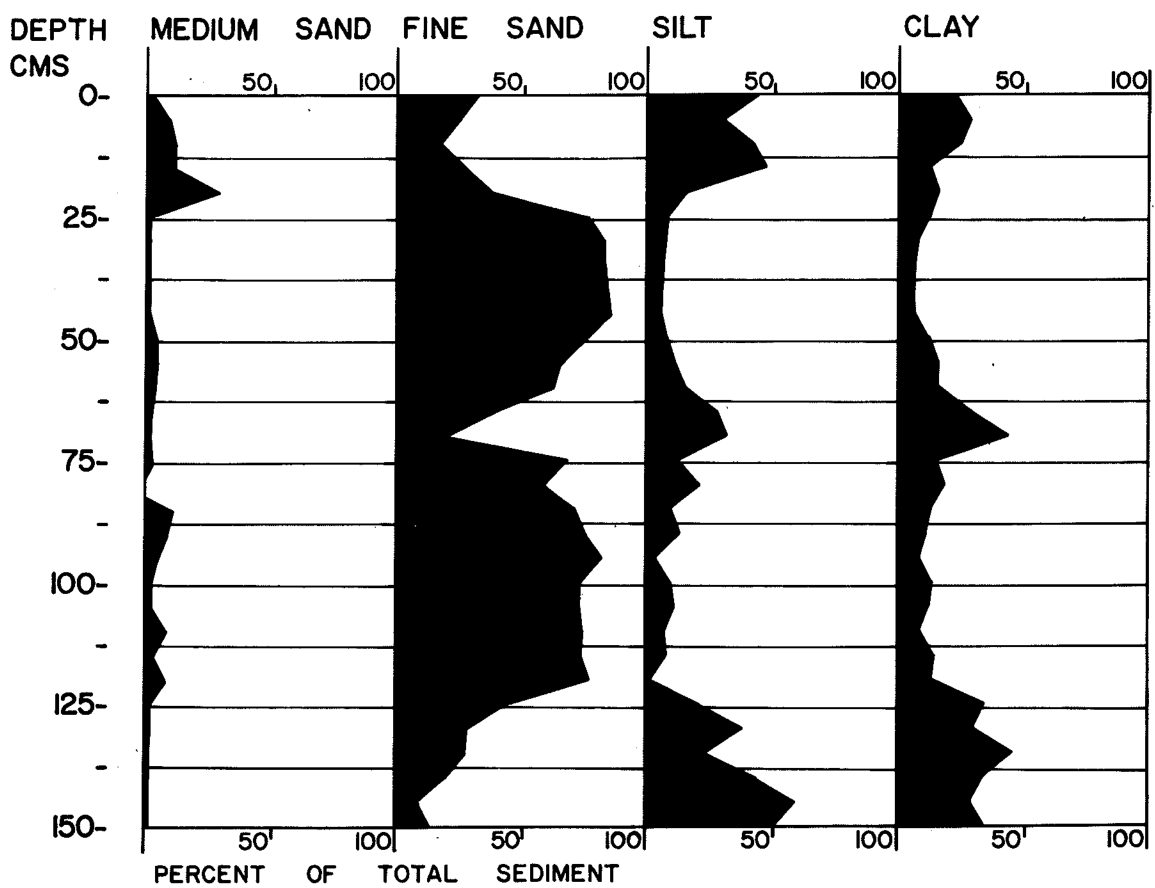


FIGURE 7. Pollen diagrams from core A and core B.

POLLEN DIAGRAMS FROM CADHAM BAY, DELTA MARSH.

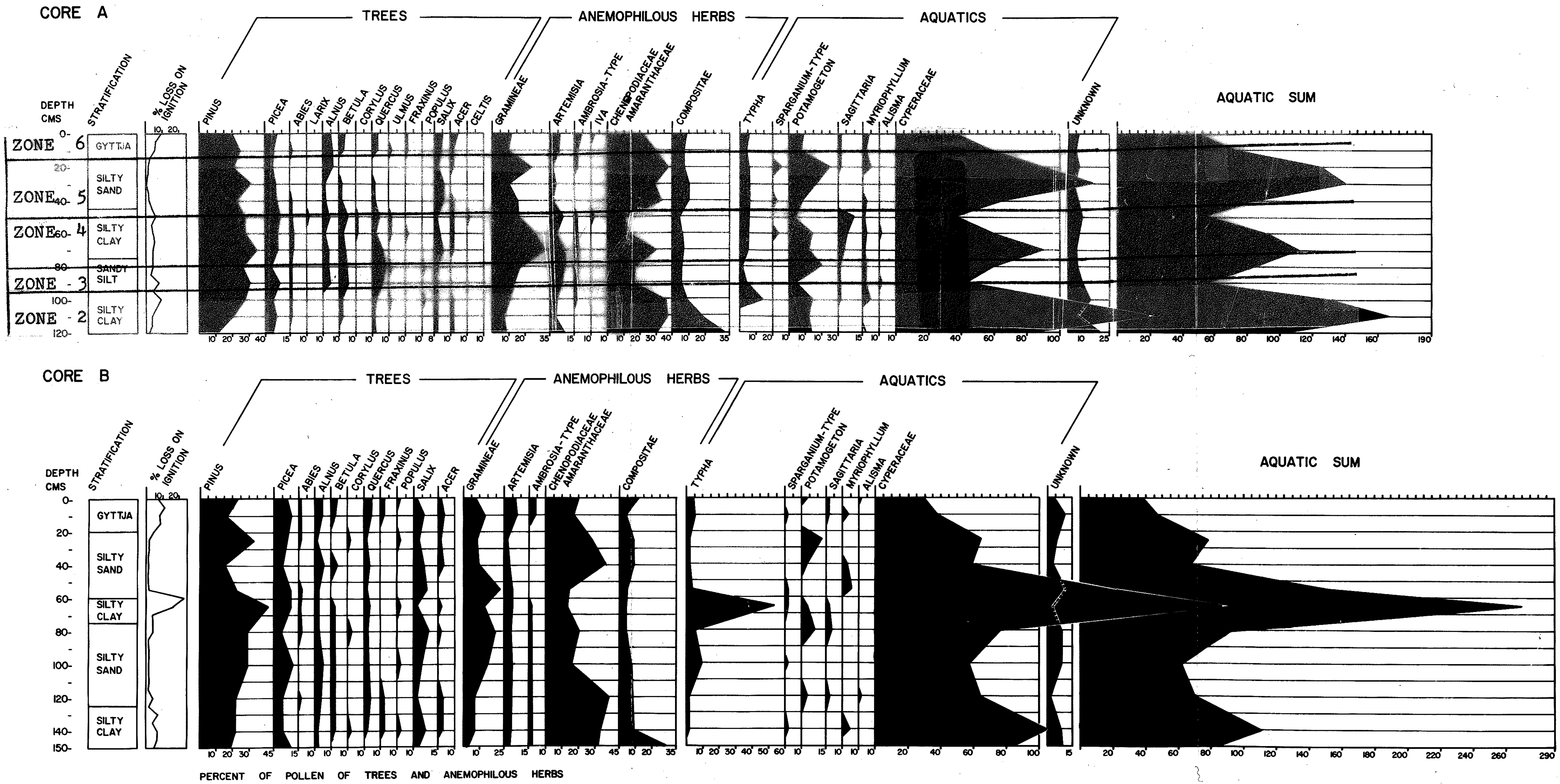
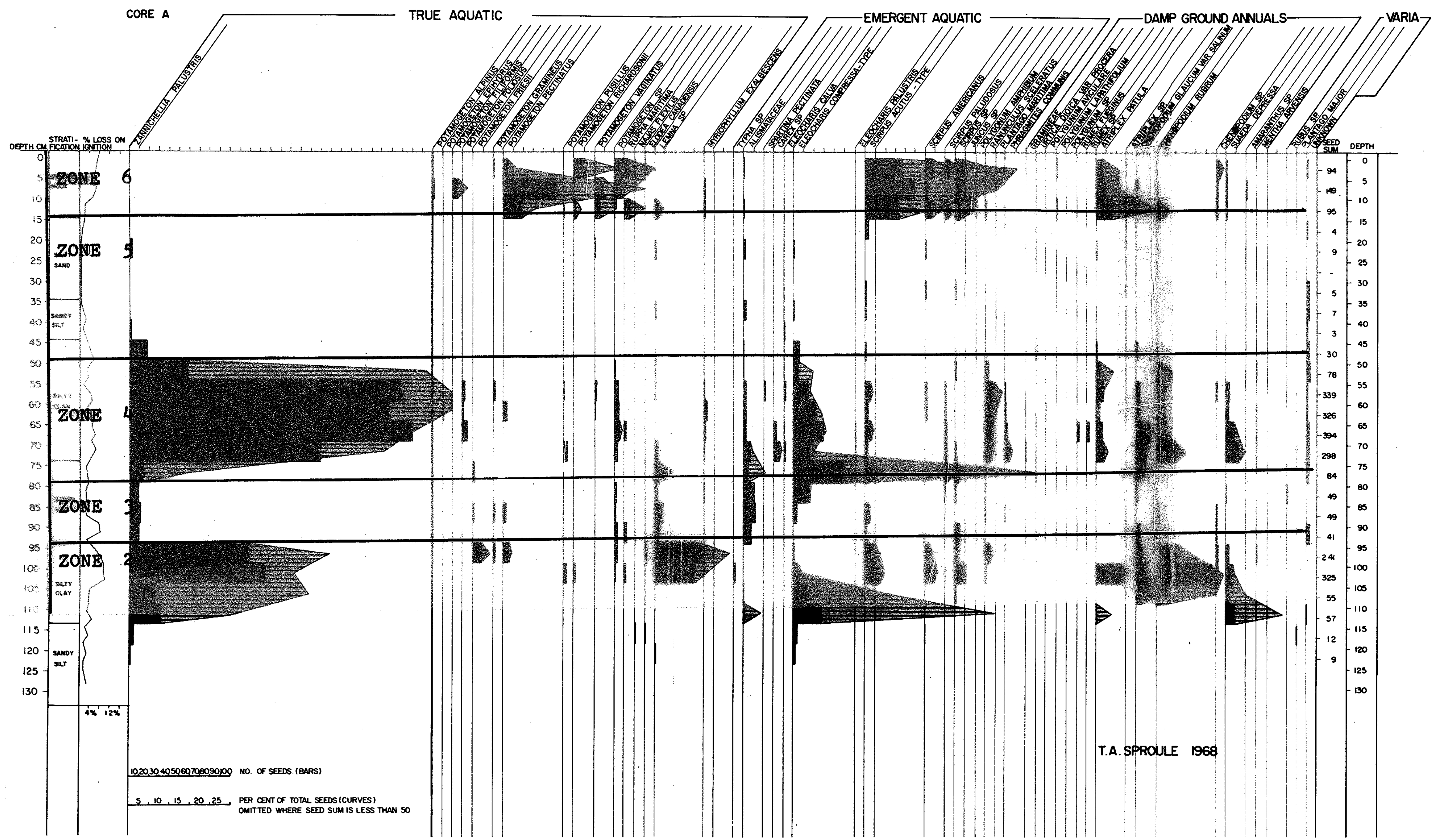


FIGURE 8. Seed diagram from core A.

SEED DIAGRAM FROM CADHAM BAY, DELTA MARSH.



RESULTS AND DISCUSSION

General

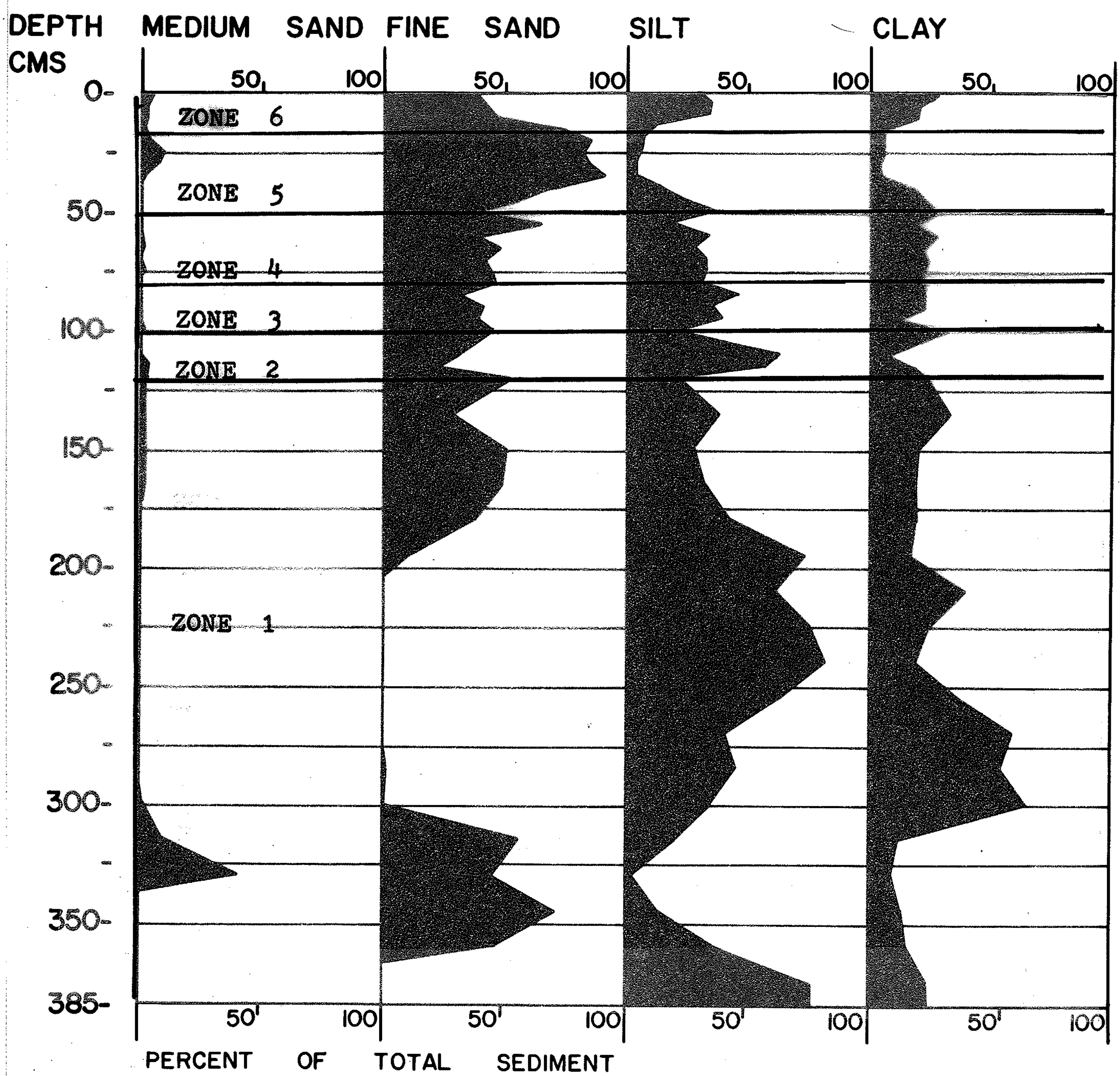
Results of the preliminary reconnaissance in November 1967, showed that the part of the marsh covered by sampling sites 4 to 11 (Fig. 2), was affected by flooding from Lake Manitoba, resulting in a confused stratigraphy. These sites were at a point in the ridge where flood water enters from the lake. In the sites a layer of mixed sand and gravel, 15-25 cm thick was found approximately 10 cm below the surface. The proportion of gravel in this layer decreased with increasing distance from the lakeshore indicating that the material had been transported from the lake. Flood-borne materials such as these were also described by Walker (1965). Cores from sites A and B by their stratigraphy (Fig. 6), appeared to have been deposited under relatively undisturbed conditions, and hence were suitable for fossil analysis.

It had been hoped to carry out a detailed analysis of pollen, seeds, macrofossils and sediment type on both cores but time did not allow for seed and macrofossil analysis of core B. Both cores were analysed for pollen (Fig. 7), and sediment type (Fig. 6). The maximum depth from which countable pollen could be recovered was 120 cm in core A and 150 cm in core B. Despite the fact that four different methods were used to prepare pollen samples, there was a very low recovery of pollen from the remainder of the cores, any grains that were present being so poorly preserved as to be unidentifiable. This may in part have been due to the high alkalinity of the sediment. Faegri and Iversen (1964), felt that the poor preservation of pollen in alkaline substrates was at least partly due to the action of bacteria and fungi. In the pollen diagrams (Fig. 7), the curve for each species represents the percentage which the pollen of that species forms of the pollen of trees and anemophilous herbs. In the present situation it is probable that some of the anemophilous pollen is of local origin, especially that of Chenopodiaceae-Amaranthaceae, Compositae and Gramineae. The pollen curves of cores A and B appear to follow a similar course, with pollen from aquatic plants showing three definite maxima in each diagram (Fig. 8). Equivalent time periods are probably covered by the top 10-15 cm in each core, with both showing a rapid rise in the curve for Ambrosia-type pollen. The bottom portion of each diagram also probably represents the same time period. This is borne out by the peak in aquatic pollen of both diagrams, and by the high percentage of

FIGURE 9. Particle size analysis
of core A.

PARTICLE SIZE ANALYSIS

CORE A



Compositae pollen.

Sediment type diagrams of the two cores (Fig. 6), are generally similar, but there is more fine and medium sand in core B, probably accounted for by the fact that B is nearer the lakeshore, and was subjected to more inwash from the north.

The similarity of the sediment-type and pollen diagrams from the two cores indicates that similar conditions must have existed over the sites during deposition of the sediment.

Zonation of the Fossil Diagram

Zonation was based on a combination of seed number and species composition, since both features reflect changes in the environment. For example in zones 3 and 5 (Fig. 7), decrease in seed number indicates either declining seed production or increased sedimentation rates or both. The seed number used as a standard in delimiting zones was 50 per 5 cm's. The zones established were also applied to the macrofossil, pollen and sedimentation diagrams (Figs. 5,6,7,9).

Core C

Core C was taken in August 1968 to a depth of 8.3 meters. A visual examination showed that no macroscopic plant of animal fossils were present in the lower portion of the core. The character of the core was consistent throughout its length, the sediment being a calcareous silty clay. This would suggest that stable, probably deep water conditions existed while the sediment was being deposited. A definite time period could not be assigned to core C, in the absence of organic material for radiocarbon dating, but from the consistency of the sediment would appear to be post-glacial.

Analysis of Core A

Zone 1 (385-115 cm)

The high percentage of silt and clay, together with the paucity of macrofossils in the zone are taken to indicate quiet relatively deep water conditions. Bryozoa are consistently present throughout the zone with scattered occurrences of Ostracoda and Mollusca.

Zone 2 (115-95 cm)

Continued high percentages of silt and clay throughout the zone (Fig. 9), suggest relatively stable water, although the macrofossils indicate the onset of marsh conditions.

Organic matter, which is absent in zone 1, reaches 10% at 104 cm in this zone (Fig. 8). About 45 cm^3 of sediment from 102 to 106 cm was dated at the University of Saskatchewan and yielded an age of 2,400 plus or minus 230 years B.P.

Thus the entire pollen diagram from core A (Fig. 7), lies within zones 1 and 2 from the Tiger Hills, Manitoba, (Ritchie, 1968), approximately 100 km south-west of Delta Marsh. Although the two sites are 100 km apart, some features of the regional pollen types are common to both diagrams, notably the large percentage of Pinus throughout, and consistent presence of Picea, Alnus and Betula.

The seed and pollen diagrams (Figs. 8 and 7), show the presence of four vegetation stages of the hydrosere in this zone. These are submerged, floating and emergent aquatic, and colonisers of exposed shores (damp ground annuals), as examplified respectively by Zannichellia palustris, Lemna sp., Eleocharis compressa-type and Atriplex patula. At the bottom of zone 2 Z. palustris and Eleocharis compressa-type are the most abundant species. There are few published references on the ecology of Z. palustris although Nelson (1954), working in Utah, found that a layer of silt, deposited in a shallow lake by a flood, resulted in good growth of this species. He also mentions it as occurring in dense stands, at depths of between 10 and 100 cm. Its present occurrence in the marsh is limited to Clandeboye Bay where it grows on a silty, detritus-covered bottom in approximately two metres of water (Walker, 1965). Z. palustris flowers underwater. It has a longer flowering season than most angiosperms and has been recorded in flower in November (Arber 1963). The length of the flowering season may mean that it is overrepresented in the seed diagram, especially since it belongs to the group of angiosperms whose food reserves are divided amongst many small seeds, rather than being concentrated in a few large ones (Salisbury 1942). Interestingly, Zannichellia is completely absent from the pollen diagram, undoubtedly because the thin exine of its pollen grain disintegrates soon after it is shed (Faegri and Iversen, 1964).

The most abundant species of Eleocharis presently growing in the marsh are the emergent aquatics Eleocharis palustris and Eleocharis acicularis, according to Love and Love (1954) and Walker (1959, 1965). It would seem probable that the Eleocharis compressa-type seeds found occupied a similar habitat in zone 2. Unfortunately, Cyperaceae pollen cannot be identified to genus and it can only be presumed that much of the abundant Cyperaceae pollen came from local emergent aquatics such as Eleocharis and Scirpus. Typha is also represented, although sparingly, in both seed and pollen diagrams.

The increased percentage of seeds of damp ground annuals in the upper part of the zone, and the appearance of

Scirpus spp., suggest a decline in water levels. Seeds of the *Scirpus* species in zone 2 are large and unlikely to be carried far by either wind or water (Salisbury, 1942). Hence *Scirpus* species may have been growing close to the sampling site during this period. Seed production in most *Scirpus* species is low (Stevens, 1932) and may be under-represented.

Damp ground annuals are chiefly represented by *Chenopodium rubrum*. Pioneer species such as this usually have large seed outputs. An average figure of 227,000 per plant was computed by Salisbury (1942) from 32 such species. *C. rubrum* alone may produce more than 250,000 seeds per plant (Salisbury, 1942). Because its seeds are small, abundantly produced and easily dispersed, *C. rubrum* may be over-represented in the diagram. Walker (1965) commented on the occurrence of *C. rubrum* in the marsh and noted that it quickly became abundant in new areas exposed by falling water levels, but if these became completely dry, its abundance diminished. Its presence in the top 15 cm of zone 2 suggests that suitable habitats were available for colonization during the period due to either steadily falling, or continually fluctuating water levels. Evidence from the pollen diagram supports the view that water levels had decreased. Although pollen from anemophilous herbs is usually treated as extra-local, in this situation much of the Chenopodiaceae-Amaranthaceae pollen and species of Compositae such as *Senecio* and *Aster* may have come from nearby exposed shores.

Possibly the most interesting seed type in this zone is *Lemna* sp. Lemna is represented by two species in Manitoba, *L. minor*, a floating aquatic, and *L. trisulca*, a submerged aquatic (Scoggan, 1957). The specimens found in this investigation could only be identified to the genus *Lemna* on the basis of seed morphology. The literature contains few references to seed production in *Lemna*, although Wilson (1935), noted flowering in *L. minor* as "not being an uncommon occurrence in Vilas County, Wisconsin" and Gilbert (1937) found both *L. minor* and *L. trisulca* in flower in a Minnesota pond. Daubs (1965), in his "Monograph of the Lemnaceae", states that most species flower quite infrequently. The significance of the presence of *Lemna* is that comparatively calm conditions are necessary for its growth. Conditions which would have existed had the site been sheltered either by dense stands of emergent species or physical barriers to wave action.

Ostracods, molluscs and cladoceran ephippia appear or become abundant in this zone while Bryozoa disappear (Fig. 5). Ostracods, aquatic molluscs and cladocera all live on or near aquatic plants, in relatively shallow water. Ephippia, the sexual eggs of cladocera, are produced in response to adverse conditions such as crowding caused by declining water levels (Pennak, 1953; Ward and Whipple, 1959).

The fact that a physical barrier may have sheltered the site from wave action during zone 2, provides evidence for the existence of a lakeshore ridge which would have allowed plant growth in the marsh during low water periods in zones 2, 4 and 6, but was insufficient protection against continued high water or storms during zones 3 and 5. Since zone 2 the ridge would have been eroded by high water and storm and stabilized by pioneer vegetation during calm low water periods, until eventually a long enough period of stability permitted the development of forest vegetation which provided protection against all but the most severe erosion.

Zone 3 (95-80 cm)

Conditions similar to those of zone 2 are suggested by the sediment type diagram (Fig. 9), with fine sand still comprising 40-50% of the sediment and silt and clay the remaining 50-60%.

Tree pollen percentages assume a pattern which they maintain, with minor variations, for the rest of the core, suggesting that regional conditions remained relatively unchanged.

Pinus, Picea, Alnus, Betula and Quercus are the most important types.

The seed diagram (Fig. 8), and pollen curves of aquatic and anemophilous herbs (Fig. 7) indicate that local environments changed between zones 2 and 3. Zannichellia palustris and Lemna sp. the most important true aquatic in zone 2 are still present but greatly reduced in number. The emergent aquatic Eleocharis compressa-type and Scirpus spp., and the damp ground annuals Chenopodium spp. and Suaeda depressa have virtually disappeared. The same pattern is present in the pollen diagram in which percentages of Cyperaceae, Potamogeton, Typha and Chenopodiaceae-Amaranthaceae have all been reduced. A newcomer to the seed diagram in zone 3 is the Alismataceae, presently represented in Manitoba by Alisma and Sagittaria (Scoggan, 1957). In this investigation only embryos were found and it was not possible to separate the genera on the basis of embryo morphology. Arber (1963), stated that members of the Alismataceae exhibit dimorphism, the submersed form of which is usually sterile (Fassett, 1940; Arber, 1963). The embryos in zone 3 are thus more likely to have come from Alismataceae growing in shallow water. Seed production in Alismataceae was investigated by Stevens (1932), he computed a figure of 21,000 seeds per plant. Salisbury (1942), found the average number of seeds produced annually by each plant, to be between 27,000 and 46,000. This figure is higher than in most emergent aquatics and Alismataceae may therefore be over-represented in the seed diagram.

A possible reason for the apparent decline in vegetation could have been a moderate increase in water depth, eliminating the weedy annuals of intermittent habitats and the emergent aquatics of shallow water. The increase however must have been minor because although it changed the vegetation it did not noticeably affect sediment type (Fig. 9), nor did it decrease the numbers of Ostracoda and Mollusca present in zone 3 (Fig. 5). The decrease in ephippia (Fig. 5) would have been a response to lessening of adverse conditions.

Zone 4 (80-50 cm)

Regional conditions, as interpreted from the pollen diagram (Fig. 7), remain unchanged, although an interesting feature of this zone is the occurrence of *Celtis* pollen. The only *Celtis* species presently growing in Manitoba is *C. occidentalis*, which grows on the forested ridge separating the marsh from Lake Manitoba (Scoggan, 1957). As only three grains were found it would be unwise to speculate on its distribution.

Sedimentation patterns also resemble that of zone 3 (Fig. 9) with fine sand comprising 50% of the sediment, the remainder being composed of clay and silt.

The seed diagram (Fig. 8) and the curves of anemophilous herb and aquatic pollen (Fig. 7) however resemble zone 2 rather than zone 3 suggesting a return to zone 2 conditions. Seeds of the aquatic species Zannichellia palustris, Eleocharis compressa-type and Scirpus spp. which were important in zone 2 are again well represented, while the Cyperaceae pollen curve probably includes emergent aquatics such as Scirpus spp. and Eleocharis spp. Submerged aquatics Potamogeton and Myriophyllum appear in the pollen diagram but are only sparingly represented in the seed diagram. The emergent aquatics which become important for the first time in this zone of the seed diagram are Ranunculus sceleratus and Phragmites communis. Salisbury (1942), referred to R. sceleratus as a species characteristic of drying mud flats but Arber (1963) classed it as being capable of living both on land and in water. Walker (1965), found that in the Delta Marsh it flourished in water up to 30 cm deep. It is one of the most prolific seed producers amongst the emergent aquatics, the average output being 26,500 achenes per plant (Salisbury, 1942). R. sceleratus is probably over-represented on the seed diagram.

Of the damp ground annuals, *Chenopodium* spp. and *Atriplex patula* are present in the seed diagram and in the pollen diagram as Chenopodiaceae-Amaranthaceae. Also in the pollen diagram a small percentage of *Ambrosia*-type is present throughout zone 4. This could have been *Ambrosia trifida*, which is restricted to moist habitats such as riverbanks and lakeshores (Bassett and Terasmae 1962).

Zone 4 therefore appears to have been a period of declining water levels allowing the re-establishment of aquatic vegetation and the exposure of shores on which the pioneer species *Chenopodium rubrum*, *Atriplex patula* and *Suaeda depressa* became established, with the change in water depth being insufficient to change the sedimentation pattern (Fig. 9). The macrofossil diagram (Fig. 5) also indicates a period of declining water levels with increased numbers of Mollusca, Ostracoda and ephippia.

Zone 5 (50-15 cm)

While regional conditions, as interpreted from tree pollen (Fig. 7) remained unchanged in zone 5 the remainder of the pollen diagram, the seed diagram (Fig. 8), particle size (Fig. 9) and macrofossil diagram (Fig. 5) present a confused picture.

The particle size analysis (Fig. 9) has up to 90% fine sand with some medium sand and only traces of silt and clay. Core B (Fig. 6) has a thicker sand horizon at approximately the same depth and because it lies about 70 metres north of core A (Fig. 2), the sand probably came in from a northerly direction, with more being deposited at B. If a sand ridge had been present to the north, a storm or series of storms could easily have transported sand from the ridge to the northern shores of Cadham Bay.

While the macrofossil diagram (Fig. 5) and the seed diagram (Fig. 8) suggest a drastic reduction in local plant and animal life during this period, no such indication can be found from the pollen diagram where the curves for Cyperaceae, *Potamogeton*, Chenopodiaceae-Amaranthaceae and Gramineae actually reach a peak during zone 5. Faced with such contradictory data it would be foolish to speculate on the nature of the environmental conditions which existed during zone 5.

Zone 6 (15 cm to surface)

Regional pollen from this zone is a modern assemblage. Of the broadleaved tree species in the diagram *Acer*, *Fraxinus*, *Quercus*, *Salix*, and *Ulmus* are today found on the lakeshore ridge and in stands immediately south of the marsh. A significant feature of the diagram is the sharp rise in the percentage of *Ambrosia*-type pollen, a feature common to many North American pollen diagrams. Three species, *Ambrosia trifida*, *A. artemisiifolia* and *A. coronopifolia* occur in southern Manitoba. All are agricultural weeds, although *A. trifida* also occurs along riverbanks and lakeshores (Bassett and Terasmae, 1962). The increase in *Ambrosia*-type pollen reflects the advent of modern agriculture in this region. Hence zone 6 probably covers a time period of 100 to 150 years.

From the local aspect the evidence suggests that a stable environment existed during zone 6. In the particle size analysis (Fig. 9) the fine sand percentage has fallen to approximately 40% with silt and clay making up 40% and 20% respectively. While from the macrofossil diagram (Fig. 5) increased numbers of Ostracoda, Mollusca and ephippia indicate conditions suitable for plant growth.

Potamogeton species, the most important being *P. pectinatus*, dominate the true aquatic vegetation of the seed diagram (Fig. 8) while Potamogeton is also important in the pollen diagram (Fig. 7). The replacement of *Zannichellia palustris* by *P. pectinatus* as the dominant submerged aquatic provides information on water depth in this zone. As mentioned in the discussion on zone 2, Zannichellia palustris is more frequently found in deeper water on a silty substrate (Nelson, 1954). Potamogeton pectinatus prefers shallower water with a more organic substrate. Robel (1962) in Utah found the best growth of P. pectinatus in 30 cm of water. In the Delta Marsh, Löve and Löve (1954) recorded P. pectinatus growing in rather shallow water near the shores of the bays. Walker (1965) found Z. palustris growing on a silty substrate in two metres of water in Clandeboye Bay while P. pectinatus occurred in the larger bays in water 0.6 to 1.5 metres deep where the bottom was soft. In a similar habitat in Ogden Bay Refuge, Utah, Nelson (1954), found Chara spp. in deep water, then Z. palustris, Ruppia maritima and P. pectinatus in progressively shallower water. These reports would suggest that water levels during deposition of zone 6 were shallower than during any previous zone.

Emergent aquatic seed species are dominated by the genus Scirpus with S. acutus the most important single species. In the pollen diagram these are probably contained in the Cyperaceae. As previously mentioned, Scirpus species are under-represented in the seed diagram due to their low seed production. The fact that the curve for Scirpus-type rises to 33% at 5 cm indicates the importance of emergent aquatics during this period. Damp ground annuals are scarce in this zone and almost solely represented by Atriplex patula in the seed diagram, with its counterpart Chenopodiaceae-Amaranthaceae in the pollen diagram.

A comparison of the important seed species of zone 6 (Fig. 8) with the species at present growing in the Cadham Bay area, as listed in the description of the area (page 15), shows that the composition of the vegetation has scarcely changed during zone 6, approximately 100-150 years. This is surprising since, in the conventionally depicted hydrosere, build up of sediment and succession, are most rapid when the stage of large emergent aquatics such as Scirpus spp. and Typha spp. is reached (Knight 1965). A possible explanation of the vegetational stability in the Delta Marsh is provided by Walker (1965). She concluded that periodic elimination of the emergent aquatic vegetation, by flooding from Lake Manitoba, played a considerable part in slowing down normal succession in the marsh. Another explanation is provided by Sculthorpe (1967). He stated that "rapid vegetational succession, as conventionally depicted in 'typical hydroseres', does not occur in the absence of inwashed inorganic sediments, even though the accumulation of plant debris may provide an organic substrate apparently favourable for succession".

This argument would appear to be applicable in the present situation. An examination of maps of the Cadham Bay area (Figs. 2 and 4) show that the most likely source of mineral sediment is by water erosion from the forested ridge or by flooding from Lake Manitoba. However, none of the characteristic mineral sediments deposited in the marsh during periods of inundation by the lake (Walker, 1965) were found in zone 6, although the marsh was inundated as recently as 1957. It would appear therefore, that the stability of vegetation in the marsh has been at least partly due to the slow accumulation of inorganic sediments.

CHAPTER V

SUMMARY

Two cores, A and B, (Fig. 3) were taken near the northern shore of Cadham Bay in Delta Marsh in water approximately one metre deep. Core A was taken to a depth of 385 cm and core B to 219 cm. Both were analysed for pollen and sediment type. The results (Figs. 6 and 7), were sufficiently similar to establish that conditions had been parallel over the two sites during deposition of the sediment.

A third core (core C, Fig. 3) was taken to a depth of 8.30 metres to determine whether marsh conditions had existed in the more distant past, but no macrofossils were found below about 1 metre.

Core A was further analysed for seeds and selected invertebrate macrofossils. It was subdivided into six zones based on seed composition and number. In zone 1 (385-115 cm) the scarcity of macrofossils and the high percentages of silt and clay suggest a stable deep water situation, with water levels gradually declining until at the bottom of zone 2, at 115 cm, animal fossils increase sharply and plant fossils appear in the sediment indicating that the water had become sufficiently shallow to permit the development of aquatic plants and animals. The important seed species were the

submerged aquatic *Zannichellia palustris*, *Lemna* sp., a floating aquatic and the emergent aquatic *Scirpus acutus*. The presence of seeds of *Lemna* sp. suggests that the site may have been sheltered from wave action either by stands of aquatic vegetation or by a barrier ridge. Increasing importance of *Chenopodium rubrum*, a pioneer species, indicates that the decline in water level continued to the top of zone 2 at 95 cm. Sediment from a depth of 102-106 cm yielded a radiocarbon date of 2,400 ± 230 years B.P. indicating that marsh conditions existed, although not continuously, since then. A decrease in seeds during zone 3, 95-80 cm, suggests a change in the local environment, either an increase in water depth, which inhibited plant growth, or an increased sedimentation rate. This was followed by another change during zone 4, 80-50 cm, evidenced by the development of damp ground annuals and emergent aquatics. As in zone 2 *Zannichellia palustris* and *Scirpus acutus* were the dominant species. In zone 5, 50-15 cm, seeds are again scarce although the pollen diagram contains *Potamogeton*, Cyperaceae, and Chenopodiaceae-Amaranthaceae, which may have grown locally. A 15 cm thick sand lens at this depth was probably washed in from a northerly direction. During deposition of zone 6, (15-0 cm), the fossil assemblage reflects present vegetation. The replacement of Zannichellia palustris by Potamogeton pectinatus as the dominant submerged aquatic and the abundance of Scirpus spp. suggests that water depths during this period were shallower than at any previous time. Evidence of the advent of modern agriculture in the area is provided by the rise of Ambrosia pollen. The information obtained from the seed and sediment type diagrams is summarized in Table 1, below.

Zone	Stratigraphy (from Fig. 9)	Dominant plants (from Fig. 8)	Inferred water level (approx.)
6 (0-15 cm)	Clayey silty sand	Potamogeton pectinatus Scirpus acutus	1 metre, stable
5 (15-50)	Fine sand and silt	Fossils very sparse	unknown
4 (50-80)	Clayey silty sand	Zannichellia palustris Eleocharis compressa-type	1-2 metres, stable
3 (80-95)	Clayey sandy silt	Zannichellia palustris Alismataceae (both scarce)	unknown
2 (95-115)	Clayey sandy silt	Zannichellia palustris Lemna sp. Eleocharis compressa-type	1-2 metres declining
1		absent	deep, declining
(190-115)	Clayey silty sand		
(190-260)	Clayey silt		
(260-315)	Silty clay		
(315-360)	sand		
(360-385)	Clayey silt		

TABLE 1. Summary of information from seed diagram (Fig. 8) and sediment-type diagram (Fig. 9).

The evidence from Table 1 indicates that water levels are as low or lower than at any time over the past 2,400 years. However succession in the marsh has apparently been slow. There are two possible reasons for this. Walker (1965), attributed it to periodic elimination of the emergent vegetation by flooding from Lake Manitoba. Another point of view was suggested by Sculthorpe (1967) who discussed hydroseres in general and concluded that rapid vegetational succession in hydroseres does not occur in the absence of inwashed inorganic sediments. Probably both of these phenomena have played a part in maintaining a slow rate of succession in the Delta Marsh. A possible reason for the slow build up of mineral sediment could be that there is no major drainage channel flowing into Lake Manitoba, although geological evidence suggests that such a drainage channel existed sometime prior to 2,400 years ago.

The recurring zones of marsh vegetation 2,4 and 6, interrupted by deep water zones 3 and 5, suggests that flooding may be necessary for the perpetuation of marsh conditions.

CHAPTER VI

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